PART 2

CHAPTER 5 — ELECTRICAL SYSTEM

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(Completely Revised by AL11)

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DESCRIPTION

General

1. The main electrical system is AC operated at 115/200 volt, 3-phase 400 Hz, power being supplied by four 40 kVA AC generators, one on each engine. The generators normally operate in parallel, No 1 and No 3 (System A) and No 2 and No 4 (System B) forming two independent AC systems. Both systems are connected together automatically, provided that the split system breaker (SSB) is at AUTO, should a generator fail or if an engine is shut down. Each generator system incorporates automatic circuits for the detection of faults and initiates automatic action to isolate a defective generator and, if necessary, to de-excite it. Other automatic circuits are provided to monitor distribution busbar conditions, and to isolate faulty busbars.

2. A 28-volt AC supply, obtained from the two main AC systems via two step-down transformers, provides a limited number of services, mainly lighting.

3. Two main and one standby transformer — rectifier units (TRU), rated at 28-volt/150 amperes, together with two 24-volt 25 ampere/hour batteries, provide power for two independent 28-volt DC systems. The standby TRU can be selected to supply either DC system.

4. An emergency 10 kW AC supply from a 115/200-volt, 3-phase 400 Hz ram air turbine driven generator (Elrat), can be used to provide power for certain essential services in an emergency. The Elrat can also be used to supply power to the standby TRU to maintain essential DC services.

5. The main controls for the electrical system are on panels B and C at the engineer's station. A warning lights test supply switch is on panel C. A fuse test holder and associated press-to-test light, supplied with 28-volt DC, are on panels C and P. To check a fuse, test the light by pressing the lamp holder — the light should come on. Insert the suspect fuse into the socket, the light should come on if the fuse is serviceable.

Note: The fuse test holder does not have a cap fitted. The fuse to be tested is inserted with cap.

6. An external power supply plug is under the left-hand underside of the fuselage, below panel J. External power, on being supplied, supplies a Ground Power busbar which automatically supplies Domestic and 28-volt AC busbars, and may be selected to supply all generator busbars through a ground power circuit breaker (GPB).

7. An auxiliary power unit (APU), which drives a 40 kVA generator, is in the tail cone, aft of the pressure bulkhead. The 115/200-volt AC supply from the generator is connected to the Ground Power busbar, from which supply is made available to the aircraft in the same manner as for ground power from an external supply. Provision is made to prevent the APU generator and ground power from being connected to the Ground Power busbar simultaneously.

Location of Power Sources and Main Electrical Panels

8. All power sources are controlled by switches on the engineer's AC and DC power panels. Each panel has a line diagram of the associated system, to indicate diagrammatically the distribution of power sources to the various busbars. Magnetic indicators show continuity when the associated busbar contactors are closed.

9. The main power distribution busbars and associated control components are on panels in the electrical bay as follows:

a. The major control and distribution components for No 1 and No 3 generators are on panel J, and those for No 2 and No 4 generators are on panel K.

b. The major control and distribution components for the Elrat generator are on the emergency panel (panel P).

c. The No 1 and standby TRU are housed in panel J.

d. The No 2 TRU is housed in panel K.

e. The main control and distribution components for the No 1 DC system are on panel U.

f. The main control and distribution components for the No 2 DC system are on panel Z.

g. The No 1 and No 2 batteries are immediately at the rear of panels J and K respectively.

h. A spare battery stowage is located adjacent to the No 1 battery.

10. The external power supply plug is on the left underside of the fuselage at station 252.

11. The principal control and protection components for the APU generator are situated on the right of the forward freight hold bulkhead at station 379.

Alert Warning System

12. Two amber lights on the glare shield, one in front of each pilot, give flashing warning when failure or malfunction in one or more of the following services occur:

a. AC generator supplies (four).

b. CSD low oil pressure (four).

c. DC power supplies (two).

(The numbers in parentheses refer to the number of individual warning lights associated with each service.)

13. When the alert lights are flashing, the signal to both alert lights can be cancelled by pressing either light, thus leaving them available to indicate any further failure/malfunction, but the individual warning light for the failed service, will remain on until the fault is cleared. The right-hand alert warning light is a 'push to cancel/pull to isolate' type. Pulling the right-hand lamp housing isolates both alert warning lights.

Note: If one alert light filament fails during operation, the other light remains on steady.

AC SUPPLIES

General

14. Each generator provides AC power at 115/200-volts 400 Hz. A main control panel (MCP) associated with each generator provides control and protection for the individual generators.

15. Each generator is driven by its appropriate engine via a hydro-mechanical constant speed drive (CSD) unit which operates in conjunction with a load controller to maintain the generator speed at 6000 RPM and thus the generator output frequency at 400 Hz with varying engine speeds and generator load conditions. A disconnect facility, controlled from the engineer's panel, is provided, to permit the CSD unit to be disconnected from the engine in case of malfunction. Each generator output voltage is controlled by its individual voltage regulator.

16. In-flight cooling for each generator and oil in its associated CSD is by ram air which is exhausted overboard. On the ground an airflow is induced through the ram system by jet pumps in the exhaust outlet. The jet pumps use pressure-reduced air from the engines.

17. The output of each generator is fed to its busbar via its generator circuit breaker (GCB). Each generator busbar comprises a set of three distribution busbars — one for each phase. The generators are normally coupled in pairs through bus-tie breakers (BTB) and synchronising busbars to form two separate paralleled generating systems. No 1 and No 3 form System A and No 2 and No 4 form System B. If a failure occurs or an engine is shut down, the two systems are automatically connected via a split system circuit breaker (SSB). Automatic monitoring circuits ensure that the systems can only be interconnected when acceptable conditions exist. The provision for automatic coupling may be overridden for take-off and landing conditions by the use of a MANUAL SPLIT switch.

18. When two generators, or more, are connected in parallel, kW load sharing (distribution of real power between the generators) is maintained by load controllers which trim the constant speed drives (CSD) by making fine adjustments to their basic governors to synchronise them so that their outputs are in phase. KVAR load sharing is controlled by automatic adjustment of the voltage regulators which modifies the field current of the generators, thereby ensuring that the reactive load is equally distributed between paralleled generators. The out-of-balance loads should not exceed 2 kW (real) and 4·0 kVAR (reactive).

Distribution Busbars

19. Each AC system comprises the following busbars:

a. Generator busbars, 115/200 volt.

b. Generator Sub busbars, 115/200 volt.

c. Generator Ground Cut-off busbars, 115/200 volt.

d. Domestic supplies Sub busbars, 115/200 volt.

e. A 28-volt AC busbar (28 volts derived from 115 volts via step-down transformer).

20. The Domestic supplies Sub busbars and 28-volt AC busbars are normally supplied from the generator busbars but whenever the Ground Power busbar is energised changeover relays are automatically operated to connect them to the Ground Power busbar.

21. The Elrat generator can be used to automatically feed a 115/200-volt AC Emergency busbar which is isolated during normal operating conditions.

22. A 115/200-volt Auxiliary AC busbar is supplied by No 3 Generator busbar under normal operating conditions but when the Elrat is operating it is supplied by the Emergency busbar.

23. The 115/200-volt Ground Power busbar is live when 115/200-volt power is coupled to the ground power supply socket or whenever the APU generator is in operation.

24. The Ground Cut-off busbars are isolated whenever the Ground Power busbar is live and the GROUND/FLIGHT switch on panel C is at GROUND.

25. *Generator Controls and Indicators.* (See **Table 1**).

Table 1 — Generator Controls and Indicators

The following generator controls and indicators are on the AC power panel:

Item	*Marking/Indication*
Generator drives (four)	DRIVE-NORMAL/DISCONNECT (guarded)
CSD oil low pressure warning lights (four) ...	OIL LP (red)
CSD oil outlet/generator stator temperature gauges (four)	Minus 60°C to +160°C
Generator control relay switches (four)	GCR — NORMAL/TRIP
Elrat light	Comes on when EMERGENCY BUSBAR is energised (green)
kW/kVAR meters (four)	KW/KVAR
Generator failure lights (four)	GEN FAIL (red)
Generator circuit breaker (GCB) indicators (four)	Magnetic indicators: in-line; cross-line
Generator control switches (four)	GEN CONTROL — CLOSE/TRIP spring-loaded to centre off
Frequency control rheostats (four)	FREQ — DEC/INC
CSD oil outlet/generator stator changeover switch	TEMP — CSD OIL OUTLET/GEN STATOR
kW/kVAR changeover switch	KW/KVAR
Bus-tie breaker (BTB) indicators (four)	Magnetic indicators: in-line; cross-line
SSB control switch	AUTO/MANUAL SPLIT
Split system (SSB) indicator	Magnetic indicator: SPLIT SYSTEM BREAKER: in-line; cross-line
Frequency and volt selector switch	GRD POWER/GEN 1, 2, 3, 4,/ELRAT BUS
Auxiliary busbar indicator	Magnetic indicator: Straight in-line — No 3 busbar continuity with Auxiliary busbar. Right-angle line — Emergency busbar continuity with Auxiliary busbar
Frequency meter	CYCLES — 330 to 450
AC voltmeter	VOLTS AC — 0 to 130

26. The following AC switches are on the DC control panel:

GALLEY LOAD — ON/OFF	GLY 2/GEN 1
	GLY 3/GEN 2
	GLY 4/GEN 3
	GLY 1/GEN 4

27. Four GEN BUS FAIL — 1, 2, 3, 4 warning lights associated with the four main generator load busbars are on the 1st pilot's panel and are duplicated at the bottom of the engineer's panel. The appropriate warning lights come on when power is lost on phase A of the associated generator busbar.

Generators

28. The generators are 8-pole brushless machines nominally rated at 115/200 volts 3-phase, 400 Hz. Permanent magnets are installed in an exciter stator to ensure excitation build-up under all conditions. The generator consists basically of an exciter and main generator. The output winding is star-wound with earthed centre point. The brushless arrangement is made possible by feeding the AC output from the rotor of the exciter directly into the rotary field system of the generator via a rectifier consisting of six silicon diodes located in the centre of the hollow drive shaft. Cooling air is directed through the drive shaft to achieve diode cooling.

Voltage Regulators

29. Voltage regulation is achieved by controlling each generator exciter field current by means of magnetic amplifier voltage regulators. Each voltage regulator senses its generator output voltage, compares it against a reference bridge and produces an output signal which after amplification becomes the generator field current. Each regulator draws its supply from its own generator and, to ensure that the

output voltage is maintained during fault conditions long enough for the protective circuits to operate, three boost-transformers are fitted to give additional output during these fault conditions. Interconnected stability windings in the generator and its associated voltage regulator provide damping action during changing load conditions. During parallel operation a reactive load sharing loop circuit causes changes to be made to the generator exciter field currents to ensure that reactive load is shared. The reactive load loop circuit is shorted out during single generator operation, ie when the generator GCB or its associated BTB is tripped. The excitation current output from the voltage regulator to the generator exciter field is fed via the generator control relay (GCR); with this relay tripped the generator is de-excited.

Constant Speed Drive Units

30. Constant speed drive units are used to drive the generators at a constant speed of 6000 RPM in spite of varying engine speeds and also to synchronise them so that their outputs are in phase. Each CSD is driven via a disconnect unit and a universal joint by gearing from the HP compressors. Each CSD is mounted under the LP compressor casing on the left-hand side of its engine and the generator is bolted to its front face.

31. The drive is transmitted through a hydraulic pump and a hydraulic motor, each of the wobble plate type. The 'input' from the engine drives the pump, and the 'output' to the generator is from the motor. A servo-piston can vary the delivery of the pump by altering the angle of the wobble plate; this in turn varies the RPM of the motor relative to the RPM of the pump. If the pump wobble plate angle is increased, the delivery of the pumps is increased and the output RPM increases relative to input RPM, and vice versa.

32. A centrifugal governor called the basic speed governor controls the position of the servo-piston and therefore the output RPM. It works in the same way as a 'constant speed unit' used with oil-operated propellers. Generators operating in parallel have a natural tendency to remain in phase. However, if the load on individual generators varies, they tend to move out of phase. A magnetic trim system keeps the generators in phase and therefore their real loads equal. The magnetic trim is an electro-magnet which can be made to attract or repel the flyweights in the basic speed governor which are themselves permanent magnets. It can therefore bias the setting of the governor and cause the output RPM to change. If the generator does move out-of-phase, a signal is sent, from its associated load controller, to the magnetic trim to slightly speed up or slow down the generator and bring it back into synchronisation.

33. Also incorporated in each CSD is a further governor called a limit governor which operates in extreme underspeed and overspeed conditions to minimise the CSD load on the engine during starting and prevents excessive overspeed if the basic speed governor system fails. Associated with each limit governor is a speed switch which provides underspeed and overspeed protection as described in para 67.

34. Oil for the operation of the CSD and its lubrication is supplied from a tank on the port lower forward side of the engine. The CSD has two pressure pumps and one scavenge pump. The circulation is directed back to the tank via an oil cooler which uses ram air in flight and airflow induced by jet pumps on the ground. Jet pump air supply is from the appropriate engine P_3 source. The oil system is self-contained and though using oil of the same specification as the engine has no connection with it. The oil tank and the CSD are both pressurised with P_2 air tapped from the associated engine and passed through a pressure-reducing valve to prevent aeration and pump cavitation.

Current Transformer Packages

35. Associated with each generator is a current transformer package which is across the generator output lines between the generator and its GCB. Each package contains 7 coils as follows:

a. Reactive load sharing loop coil — voltage regulator control (C phase).

b. Three boost transformer coils — voltage regulator (A, B and C phase).

c. Reactive load protection loop coil — generator main control panel (A phase).

d. Real load sharing loop coil — load controller (C phase).

e. Metering loop — kW/kVAR Meter (B phase).

Load Controllers

36. Each generator has an associated load controller. In parallel-operation the real load coils in the current transformer packages are connected in a loop circuit. Variations between generator kW loads, indicating that the generators have a phase difference, cause a circulating current in the loop. The loop current is sensed by the individual load controllers which provide a signal to the coils in the CSD basic speed governors to provide a magnetic trim of CSD speed, so the higher loaded generator is reduced and vice versa, the result being to bring the generators into phase.

37. When a GCB or its associated BTB trips the real load loop of that generator is shorted out and removed from the real load sharing circuit.

Generator Main Control Panels

38. A main control panel (MCP) provides control and protection of each generator. The two MCP for No 1 and No 3 generators (System A) are on the forward face of panel J and those for No 2 and No 4 generators (System B) are on the forward face of panel K. The following facilities are provided:

Generator field control (GCR)
Generator breaker control (GCB)
Bus-tie breaker control (BTB)
Over-and-under voltage protection
Differential fault protection
Over-and-under speed protection
Stability protection
Automatic paralleling
Time delay circuits
Disconnect switch circuit
Internal TRU to provide 28-volt DC for generator control bus power.

Auxiliary Control and Protection Panel

39. The auxiliary control and protection panel (ACP) provides certain system and ground power control and protection. The ACP is mounted on the forward face of panel K. The following facilities are provided:

Auto-parallel latching relays (APLR)
Bus-tie breaker latching relays (BTBLR)
Bus-tie breaker negative sequence control
Split system breaker control
Split system breaker auto-paralleling
Ground power phase sequence sensing.

Generator Control Relays

40. Each generator control relay (GCR) is mounted in its associated MCP. They are of the magnetic latch type and remain in the position to which they have been operated. Normally each GCR is closed and only trips under fault conditions; they are not tripped during normal engine shut-down.

41. When a generator control relay is closed, the generator field excitation circuit from the voltage regulator is completed. When tripped the generator is de-excited and GCR auxiliary contacts complete a circuit to trip the generator circuit breaker (GCB).

42. A relay closes, provided that no fault condition exists, when the GCR — NORMAL/TRIP switch is set to NORMAL and the GEN CONTROL — CLOSE/TRIP switch is set to CLOSE. A relay is tripped automatically if a fault condition arises or whenever the GCR — NORMAL/TRIP switch is set to TRIP.

Generator Circuit Breakers

43. Closing a generator circuit breaker (GCB) connects the generator feeder lines to the generator load busbar. Setting a GEN CONTROL — CLOSE/TRIP switch to CLOSE, provided that auto-paralleling conditions are satisfied and no fault exists, closes the GCB. The associated magnetic indicator then shows in-line, indicating that the generator circuit breaker is made. If this is the first generator to be brought on line ground power is disconnected from the generator busbars at the same time.

44. The GCB is tripped manually by setting the GEN CONTROL — CLOSE/TRIP switch to TRIP, or automatically by:

a. Tripping of the GCR.

b. Fault sensing circuits.

c. Setting the NORMAL/DISCONNECT switch to DISCONNECT.

45. The generator control switch requires only momentary operation to CLOSE or TRIP to connect or disconnect the generator. Its functions are to close the generator control relay, if tripped, and to complete the generator field circuit in the absence of aircraft power. It also ensures that a ground power source already supplying the aircraft busbars is disconnected before the generator is connected to them. An auto-paralleling latching relay (APLR) is also controlled by this switch.

46. The APLR holds on the GCR close demand for all generators. When a GEN CONTROL switch is selected to CLOSE the close coil of the APLR is energised. When auto-paralleling conditions are satisfied, the GCB close relay is closed and power via the APLR closes the GCB. This allows release of the GEN CONTROL switch while waiting for correct paralleling conditions to automatically close the GCB. The APLR is tripped when:

a. The GEN CONTROL switch is set to TRIP or the GCB trips automatically under fault conditions.

b. The NORMAL/DISCONNECT switch is set to DISCONNECT.

Generator Failure Warning Lights

47. A GEN FAIL red warning light comes on when the associated generator circuit breaker (GCB) is de-energised; the alert warning system operates at the same time.

CSD Oil Outlet and Generator Stator Temperature Gauges

48. The oil temperature gauges indicate the associated CSD oil outlet or the generator stator temperatures, depending on the setting of the TEMP CSD OIL OUTLET/GEN STATOR changeover switch. Normal oil outlet temperatures, with 10 kW loading, should be 70°C to 85°C. The CSD oil outlet individual temperatures are not so important as the spread or balance across the four gauges. An increase of 15°C for any one gauge should be monitored.

CSD Oil Low Pressure Warning

49. A low pressure warning system, for each constant speed drive unit is interconnected with the alert warning system. An oil LP warning light for the associated CSD comes on and the alert warning system operates when the CSD oil pressure falls below 220 PSI.

Load Meters and Changeover Switch

50. KW/KVAR meters indicate the load conditions for each generator as selected by the KW/KVAR switch. The maximum difference between a pair of generators in one system should not exceed 2kW/4kVAR.

Frequency Control Potentiometers

51. A FREQ INC/DEC potentiometer is provided for each generator and permits manual trimming of the basic settings of each load controller and thus the CSD magnetic trim within ± 7 Hz approx, allowing generator frequencies to be set during system adjustment. The generators must not be in parallel operation when carrying out adjustments.

CSD Disconnect

52. Each CSD disconnect facility is controlled by an associated guarded DRIVE — NORMAL/DISCONNECT switch. When DISCONNECT is selected, a solenoid in the disconnect unit on the selected CSD causes the driving dogs to be disengaged, allowing in case of malfunction the CSD together with its generator to be disconnected from the engine; at the same time the associated generator circuit breaker (GCB) is tripped. The CSD can only be reconnected on the ground, requiring manual operation at the disconnect unit itself. After disconnecting a CSD, the solenoid must be de-energised by returning the disconnect switch to NORMAL.

Voltmeter and Frequency Meter

53. A single AC voltmeter indicates the voltage between phase B and neutral at any one of the engine driven generators, the Elrat generator or the power at the ground services busbar. The power source to be measured is selected by the operation of an adjacent 6-position rotary switch. The frequency of the power source selected by the rotary switch is simultaneously indicated by a frequency meter above the voltmeter.

Busbar Neon Indicators

54. Neon indicators are in the electrical bay for the following busbars:

All four generator busbars

Both domestic supply busbars

Auxiliary busbar

Ground services busbar

Bus-tie Breakers (BTB) and Magnetic Indicator

55. A BTB connects a generator to its synchronising busbar. Control of the BTB is automatic; the BTB is normally closed but trips open if a fault condition arises. If the fault also causes the GCB to trip then the BTB automatically closes again. Magnetic indicators on the line diagram give visual indication of the settings of each BTB.

Split System Breaker (SSB) and Magnetic Indicator

56. The SSB connects the synchronising busbars of Systems A and B and is normally open. Closure of the SSB is automatic when a GCB trips and paralleling conditions between the two Systems are satisfactory. *The SSB cannot close if both BTB in one system are tripped* (*fault condition*). The AUTO/MANUAL SPLIT switch, when set to MANUAL, disconnects the automatic closing circuit and holds the SSB open. A SPLIT SYSTEM BREAKER magnetic indicator adjacent to the switch is provided to indicate the setting of the split system circuit breaker (SSB).

Operation of the AC System

57. The main generation system is split into two completely isolated systems during normal operation. Wherever possible all control, protection and switching functions have been made automatic to prevent the possibility of incorrect operation.

58. During normal operation, No 1 and No 3 generators are paralleled on one system through the normally closed bus-tie breakers (BTB), and No 2 and No 4 generators are paralleled on the other system. Should a generator fail under normal

flight conditions, provided that the split system breaker (SSB) switch is at AUTO, the split system breaker closes automatically when any generator circuit breaker (GCB) opens, thus paralleling the systems. This maintains the power supply to all generator busbars and also prevents generator overloading.

59. Apart from the ground power control switch and the four GCR switches, there is only one switch per generator channel. This, the generator control switch, is used to reset the generator control relay, controlling the generator excitation and to initiate closure of the generator circuit breaker (GCB).

60. Operation of the split system breaker, which opens when all four generators are on line and closes when any single generator fails, is automatic under normal flight conditions. The split system isolating switch, when set to MANUAL SPLIT (for take-off and landing conditions), prevents automatic closure of the split system breaker.

61. Operation of the bus-tie breakers is also automatic—they open under fault conditions and close whenever the respective generator circuit breakers are open.

62. With no power on the aircraft, all generator circuit breakers are tripped and all bus-tie breakers are closed. The split system breaker will be either tripped or closed, depending on the setting of the AUTO/MANUAL SPLIT switch.

63. With ground power plugged in and switched on, and with the correct phase sequence, setting the ground power control switch on the engineer's panel to CLOSE initiates closure of the Ground Power breaker (GPB). (See para 80). With the split system breaker AUTO/MANUAL SPLIT switch at AUTO, ground power is available to all four generator busbars. The Ground Power breaker can be tripped manually by setting the ground power control switch to TRIP.

64. As engines are started, the generators build up to the correct voltage, supplying power to the live side of the generator circuit breakers, provided that the generator control relays are not tripped due to a previous fault. Setting a GEN. CONTROL switch to CLOSE trips the Ground Power breaker and closes the associated generator circuit breaker, thus supplying power to all generator busbars. The remaining three generator circuit breakers close when their respective GEN CONTROL switches are set to CLOSE. The last generator circuit breaker to close trips the split system breaker, thus splitting the system into two isolated systems.

Protective Circuits

65. *The Differential Protection Circuit* provides automatic protection against line-to-line or line-to-earth faults on the feeder lines to the generator load busbars. Current transformers sense the three line currents at the generator star point 'cold' and similar transformers sense the three line currents between the GCB and the load bus 'hot'. The 'hot' and 'cold' coils are series connected in phased pairs. A fault in the line between pairs of coils causing a differential current of 30 to 40 amperes causes the differential protection circuit in the MCP to trip the GCR and GCB, de-exciting the generator and leaving the load busbar supplied by the synchronising busbar.

66. *The Negative Sequence Protection Circuit* provides automatic protection against line-to-line or line-to-earth faults on the synchronising busbars. Two negative sequence sensing units in the ACP monitor the two synchronising busbars (System A and B). A fault sensed by a unit will trip both BTB of its associated system via the BTB latching relays (BTBLR). If operating on ground power, the operation of any one of the four BTB latching relays opens the Ground Power breaker (GPB) thus covering negative sequence faults with ground power unit or the APU generator in use.

67. *Underspeed — Overspeed Protection.* An oil-pressure operated switch in the CSD closes its contacts if the output falls below 4875 RPM (325 Hz) approximately, or rises to 7125 RPM (475 Hz) approximately. The signal, via an 0·4 to 1·0 second time delay, trips the GCB and also blocks the under-voltage and under-excitation protection circuits to prevent the associated GCR and BTB from tripping during normal engine shut-down.

68. *CSD Drive Disconnect.* Operation of the CSD drive disconnect switch to DISCONNECT, disconnects the CSD input drive and also trips the GCB. The switch must be returned to NORMAL to remove the power from the disconnect solenoid which is not rated for continuous use.

69. *Over-voltage Protection.* This circuit protects against control faults which would cause an unparalleled generator's voltage to exceed a safe value. When the line-to-neutral voltage reaches 130 volts, a signal via an inverse time delay trips the GCR.

70. *Under-voltage Protection.* This circuit causes the GCR to trip if an unparalleled generator's line-to-neutral voltage falls to 100 volts or below for a period of 7 ± 2 seconds (Time Delay No 1).

71. *Excitation Protection.* In single channel operation, the generator feeder line voltages are monitored in the associated MCP. In parallel operation it is not possible to sense individual generator voltage, so the reactive load component is used. An

over-excited generator assumes more reactive load and vice versa. The reactive load is sensed by a reactive load protection coil in each current transformer package which forms a loop with a transformer in the MCP. The individual loops are connected to form an equalising loop. The individual loops are shorted-out and thus removed from the equalising loop when the BTB or GCB of that generator are tripped. In parallel operation with balanced reactive loads no current flows in the equalising loop, but when load variations occur a circulating current is produced. The resulting transformer output is fed to the over- and under-excitation protection circuit cards in the MCP as follows:

a. Over-excitation is a state whereby the exciter field current supplied to a paralleled generator is in excess of normal requirements. This may occur as a result of a defective load-sharing circuit or may be caused by a faulty voltage regulator. If over-excitation occurs a signal via an inverse time delay trips the BTB of the over-excited generator. This action may isolate the fault because, when the bus-tie breaker is tripped the generator is no longer operating paralleled. If the generator still receives excitation current in excess of normal requirements, the result is an over-voltage condition (para 69).

b. Under-excitation is a condition whereby the exciter field current supplied to a paralleled generator is below the normal requirement. The cause of under-excitation may be a defective load-sharing circuit, a defective generator, or a defective voltage regulator. Should under-excitation occur, a signal starts the operation of two time delays; time delay No 1 (7 ± 2 seconds) and time delay no 2 (3 ± 1 seconds). If under-excitation persists for 3 ± 1 seconds a signal trips the BTB. If tripping the BTB isolates the fault, time delay No 1 becomes de-activated. If the generator still receives excitation current below normal requirements time delay No 1 continues from the resulting under-voltage condition. After expiration of time delay No 1 a signal is supplied to trip the GCR.

72. *Stability Protection.* Instability is said to exist when the output of a generator rapidly fluctuates. A fault of this nature may cause erratic operation of loads such as the autopilot and other navigation systems, as well as causing lights and voltage or power meter needles to flicker noticeably. Stability protection circuits monitor generator feeder line voltage in isolated operation and reactive line current in parallel operation. Instability of the voltage greater than 7%, or of the reactive load greater than 6 kVAR causes the protection system to operate. If instability persists for 3 ± 1 seconds the output of time delay No 2 operates to trip the BTB. When generators are paralleled busbar instability will affect all operating generators and the BTB of all paralleled generators may trip, each generator then supplying its own busbar. If a generator continues to be unstable after the BTB trips, time delay No 1 operates to trip the GCR. If all the BTB trip, the serviceable generator systems can be restored to parallel operation by momentarily setting the respective generator control switches to TRIP and then to CLOSE.

73. *Auto-Paralleling* provides protection against the paralleling of generators if a serious discrepancy in their output exists, in that a generator cannot be connected to a live 'bad' busbar, ie its GCB cannot close if:

Frequency difference exceeds 3 to 5 Hz

Phase angle difference exceeds 90°

Voltage difference exceeds 10 volts

74. A bus voltage and auto-parallel card (BV and APC), in each MCP, senses conditions across the contacts of its GCB and, if conditions are satisfied, allows the GCB to close.

75. The bus voltage circuit enables the first generator to be connected to the dead busbars without fulfilling the auto-parallel requirements.

76. With the first generator on line, the other busbars are fed via the BTB and the SSB and subsequent generators can only be connected to their busbars when the auto-parallel conditions are satisfied.

77. *SSB Paralleling.* A BV and APC card in the auxiliary control panel, identical to those for the generators, is used to monitor Systems A and B Synchronising busbars when an automatic closure of the SSB is demanded to connect the two systems, except that the SSB cannot close if one Synchronising busbar is dead due to both BTB on that system being tripped (a fault condition).

OTHER AC SUPPLIES

External Power Supply

78. An external power supply (ground power) plug is provided to connect an external 115/200-volt 3-phase power supply to the aircraft system. The six-pin external power supply plug is housed in a glass-fibre box recessed into the left underside of the fuselage (below panel J), about 3 feet aft of the left nosewheel door hinge line. The Ground Power breaker (GPB) is on panel J. The circuit is integrated with the main generating system.

79. *External Power Supply — Controls and Indicators.* The following ground power controls and indicators are on the AC power panel:

Item	*Marking/Indication*
Ground Power supply switch	CLOSE/TRIP
Ground Power breaker magnetic indicator	GROUND POWER BREAKER. In-line: cross-line
Ground Power warning light	Amber

On panel C there is:

Ground/Flight switch ...	GROUND/FLIGHT

80. When ground power is connected and switched on, the amber light on the AC power panel comes on, indicating that power is available at the Ground Power busbar to supply:

Four Domestic AC sub busbars

Two 28-volt AC busbars (via transformers).

These busbars provide a limited number of services, mainly lighting. The aircraft service lights and a number of power sockets are also automatically switched on.

81. Ground power is made available to the whole aircraft electrical system by connecting the Ground Power busbar to the main generator Synchronising busbars via a Ground Power breaker (GPB). When the ground power switch is set to CLOSE, provided certain conditions exist (para 82), the GPB closes to connect the Ground Power busbar to System A Synchronising busbar. System A Synchronising busbar is connected to System B Synchronising busbar via the split system breaker (SSB) when the SSB control switch is selected to AUTO. A magnetic indicator shows the position of the Ground Power breaker and completes a line diagram on the engineer's panel.

82. When the Ground Power control switch is set to CLOSE, the Ground Power breaker closes only if:

The phase sequence is correct

All generators are isolated from their busbars

The two battery isolation switches are at POWER ON.

Ground/Flight Control

83. To save unnecessary operation of certain items of equipment when on the ground, these items are supplied from two AC and two DC Ground Cut-Off busbars which are isolated from their parent busbars when the GROUND/FLIGHT switch on panel C is set to GROUND; also certain items supplied from the Auxiliary busbar via a Ground Cut-Off relay are isolated. The ground/flight switch control circuit is arranged so that Ground Cut-Off can only occur provided the Ground Power busbar is live thereby eliminating the possibility of isolation of services in flight. The GROUND/FLIGHT switch, when set to GROUND also transfers the operation of certain instruments on the flight deck to external servicing panels irrespective of the availability of power at the Ground Power busbar.

84. The following services can be isolated by use of the GROUND/FLIGHT switch:

Fuel flow amplifiers
Turn-and-slip indicators
Standby artificial horizon
Windscreen heating
Side screen heating
Rear periscope supplies
Waste water drains heating (115-volt AC only)
Ice detector motor
Stall warning

The following indications can be transferred from flight deck instruments to external servicing panel instruments:

Hydraulic contents (System A)
Fuel contents
Oxygen contents

Emergency AC Supply

85. The Elrat generator is in an unpressurised area on the underside of the fuselage, left of the centre line between stations 719 and 777. A ground lock is provided to prevent the uplock being released when the aircraft is on the ground.

86. When extended into the airstream, the generator is driven at 8000 RPM by a self-contained constant-speed air turbine. The output of the Elrat (rated at 115/200-volts 3-phase 400 Hz, 10 kW continuous or 20 kW for 30 seconds), is controlled by a voltage regulator (on panel P) and supplied to the Emergency busbar which also supplies the Auxiliary busbar. All Non-Essential busbars are isolated when the Elrat is in use.

87. The Elrat is extended into the airstream by setting the guarded selector lever on the centre console to EXTEND. With the lever at EXTEND, the battery control circuits are overridden; the batteries are retained on line, their control switches being ineffective. The Elrat cannot be retracted in flight.

88. A warning light on the AC power panel comes on when the Elrat generator is operating or when the test facility is used (para 89). A magnetic indicator on the line diagram shows a right-angled line when the Emergency busbar is connected to the Auxiliary busbar.

89. A TEST/NORMAL (spring-loaded to NORMAL) switch on panel EA, when held to TEST,

energises the Elrat test control relay (on panel PA) and connects No 3 Generator busbar to the Emergency busbar, thus enabling the services on the Emergency busbar to be tested. An indicator adjacent to the switch shows in-line when the Elrat generator is connected to the Emergency busbar.

WARNING: When TEST is selected, all PCU automatically start up. All personnel must be clear of the control surfaces before the test switch is operated.

Auxiliary Power Unit

90. The APU consists of a gas-turbine engine which drives a 40 kVA generator in the fuselage tail cone, aft of the rear pressure bulkhead. It provides a 115/200-volt AC supply for use on the ground when an external supply is not available and also a low pressure air supply for engine starting. Oleo-operated microswitches and relays render the APU inoperative in flight.

91. The APU generating system consists of the following equipment, which is identical with the equipment used in the main generator control systems:

Generator
Voltage regulator
Main control panel
Main current transformer unit
Differential protection circuits
Control circuit breaker.

Note: The APU generator cannot be brought on line until the APU is running at governed speed.

92. The generator is cooled by use of a jet-pump system. Cooling air enters the front of the generator from the plenum chamber. This air exhausts from the rear end of the generator casing and is discharged inboard on the right side of the aircraft. The jet-pump nozzles are fitted in the outlet and they derive their HP air from the P_2 tapping on the APU.

93. The APU generator supply is connected to the Ground Power busbar from which, by operation of the Ground Power breaker, power is made available to the main electrical system in the same manner as for ground power from an external supply.

94. The APU generator control is arranged so that the external supply breaker is automatically 'tripped' whenever the APU generator supply is selected. This ensures that the external supply, when connected, is always isolated from the APU generator.

95. With the main engines running, connecting a generator to its busbar automatically trips the Ground Power breaker, ensuring that the APU or external supply is isolated from the aircraft generated supplies.

96. The APU is started electrically, using a 28-volt DC supply direct from the No 1 battery or from an external supply.

97. A full description of the APU is given in Chapter 7, Engines and APU.

DC SYSTEM

General

98. Three transformer rectifier units (TRU), two Main and one Standby, together with two batteries, provide the Normal and Emergency power supplies for the two independent DC systems (No 1 and No 2 systems). One Main TRU and one battery supply the power for each system; the Standby TRU, which is normally inoperative, can be selected to replace either TRU should failure occur. The systems cannot be paralleled.

99. No 1 and No 2 TRU are fed from No 1 and No 4 generators, respectively, when the generators are on line, or from an external 115/200-volt ground power supply, when the Ground Power breaker is closed. The Standby TRU is fed from the Auxiliary AC busbar, which is normally connected to the No 3 generator, but is automatically fed from the Emergency busbar when the Elrat is on line.

100. No 1 TRU and the Standby TRU are on panel J; No 2 TRU is on panel K.

101. *DC Controls and Indicators.* (*See* **Table 2**).

DC Busbars

102. Each DC system comprises the following DC busbars:

A Battery busbar. (No 1 on panel U: No 2 on panel Z)

An Essential busbar. (No 1 on panel U: No 2 on panel Z)

An Essential sub busbar. (No 1 and No 2 on panel C)

A Non-Essential busbar. (No 1 on panel U: No 2 on panel Z)

A Non-Essential sub busbar. (No 1 and No 2 on panel C)

A Ground Cut-Off busbar. (No 1 on panel U: No 2 on panel Z).

103. A Standby TRU control busbar (on panel U), fed from the Standby TRU, can be connected to the Essential busbars of either system.

Table 2 — DC Controls and Indicators

The following controls and indicators are on the DC power panel:

Item	*Marking/Indication*
TRU switches (two)	No 1 TRU — NORM/ISOL No 2 TRU — NORM/ISOL
Standby TRU switch	TRU SELECTOR — BUS 1/NORMAL/BUS 2
TRU power supply indicators (three)	Magnetic indicators: In-line; cross-line
Battery switches (two)	POWER ON/OFF/BATT ISOL
TRU ammeters (two)	TRU AMPS (0 to 200 amperes)
Standby TRU ammeter	TRU AMPS (0 to 200 amperes)
Standby TRU output indicators (two)	Magnetic indicators: In-line; cross-line
DC supply failure warning lights (two)	No 1 MAIN DC SUPPLY FAIL (red) No 2 MAIN DC SUPPLY FAIL (red)
Battery indicators (two)	Magnetic indicators: BATT BUS 1: In-line; cross-line BATT BUS 2: In-line; cross-line
Battery ammeters (two)	BATT AMPS (100 to 0 to 100 amperes)
Non-Essential busbar indicators (two)	Magnetic indicators: NON-ESSENTIAL BUS 1: In-line; cross-line NON-ESSENTIAL BUS 2: In-line; cross-line
DC voltmeter	DC VOLTS (0 to 32-volt)
DC voltmeter rotary selector switch	OFF/ESS BUS 1/BATT 1/BATT 2/ESS BUS 2

Batteries

104. Two 24-volt 25 ampere hour batteries, (on No 1 crate at the rear of panel J and No 2 crate at the rear of panel K), provide an emergency source of DC power for the two DC systems. Under normal operating conditions each battery is maintained in a charged condition by its associated TRU. The batteries are separately vented to atmosphere via flexible tubing connected to outlets in the fuselage skin beneath the batteries. Provision is made for the stowage of a spare battery adjacent to No 1 battery crate.

105. The batteries are controlled from two POWER ON/OFF BATT ISOL switches, one for each battery. A magnetic indicator adjacent to each battery switch shows in-line when the battery is connected to its associated Essential busbar and cross-line when the battery is isolated from that busbar.

106. When a switch is set to:

POWER ON

(1) The associated battery contactor is energised.

(2) The non-essential control relay is energised via the Elrat microswitches.

(3) Part of the circuit controlling the Ground Power breaker is completed.

(4) The DC supply failure, and under-voltage relay circuits are energised.

OFF

All contacts are broken.

BATT ISOL

(1) The Non-Essential control relay is energised via the Elrat microswitches.

(2) The DC supply failure, and under-voltage relay circuits are energised.

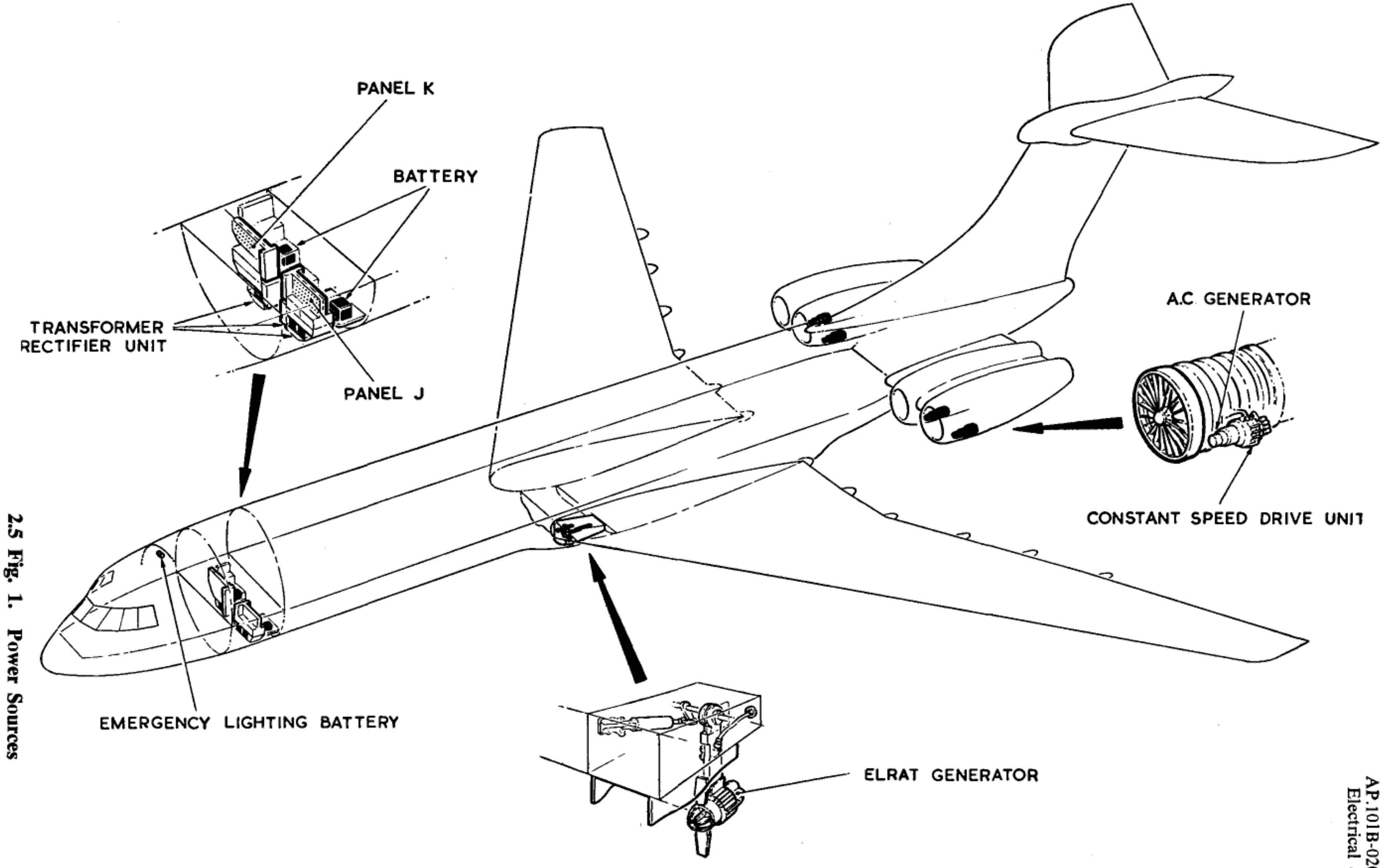
107. Two battery ammeters, one for each DC system, are above the battery switches. They indicate charge or discharge ratings for the associated battery. The ammeter shunts are located close to each battery.

Voltmeter

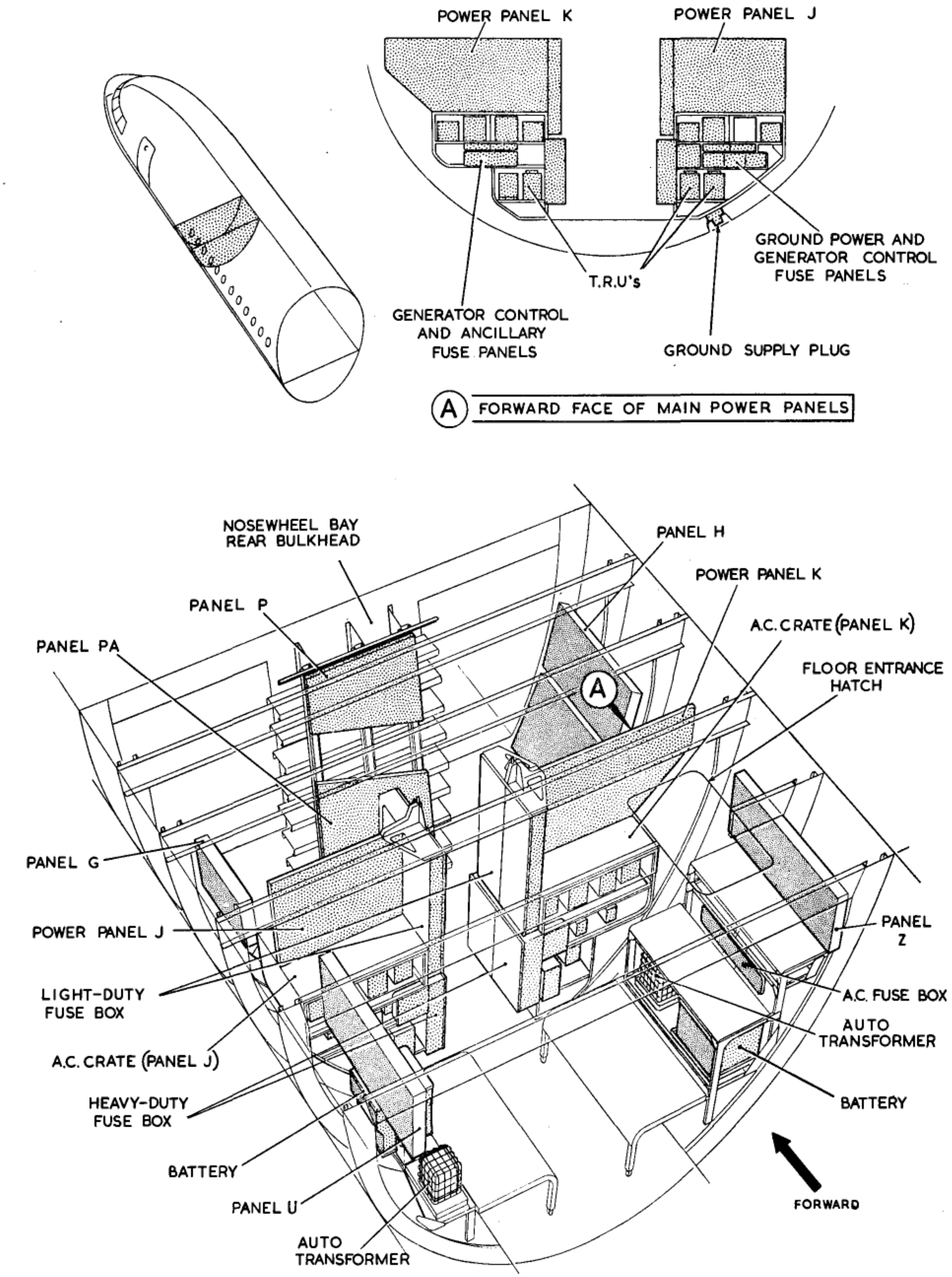
108. A voltmeter, together with a rotary selector switch, enables the voltage of the batteries and TRU to be checked. The selector switch, which provides five selections, one of which is OFF, connects the voltmeter to the following busbars:

No 1 Essential busbar
No 1 Battery busbar
No 2 Battery busbar
No 2 Essential busbar.

(*continued on page* 18)

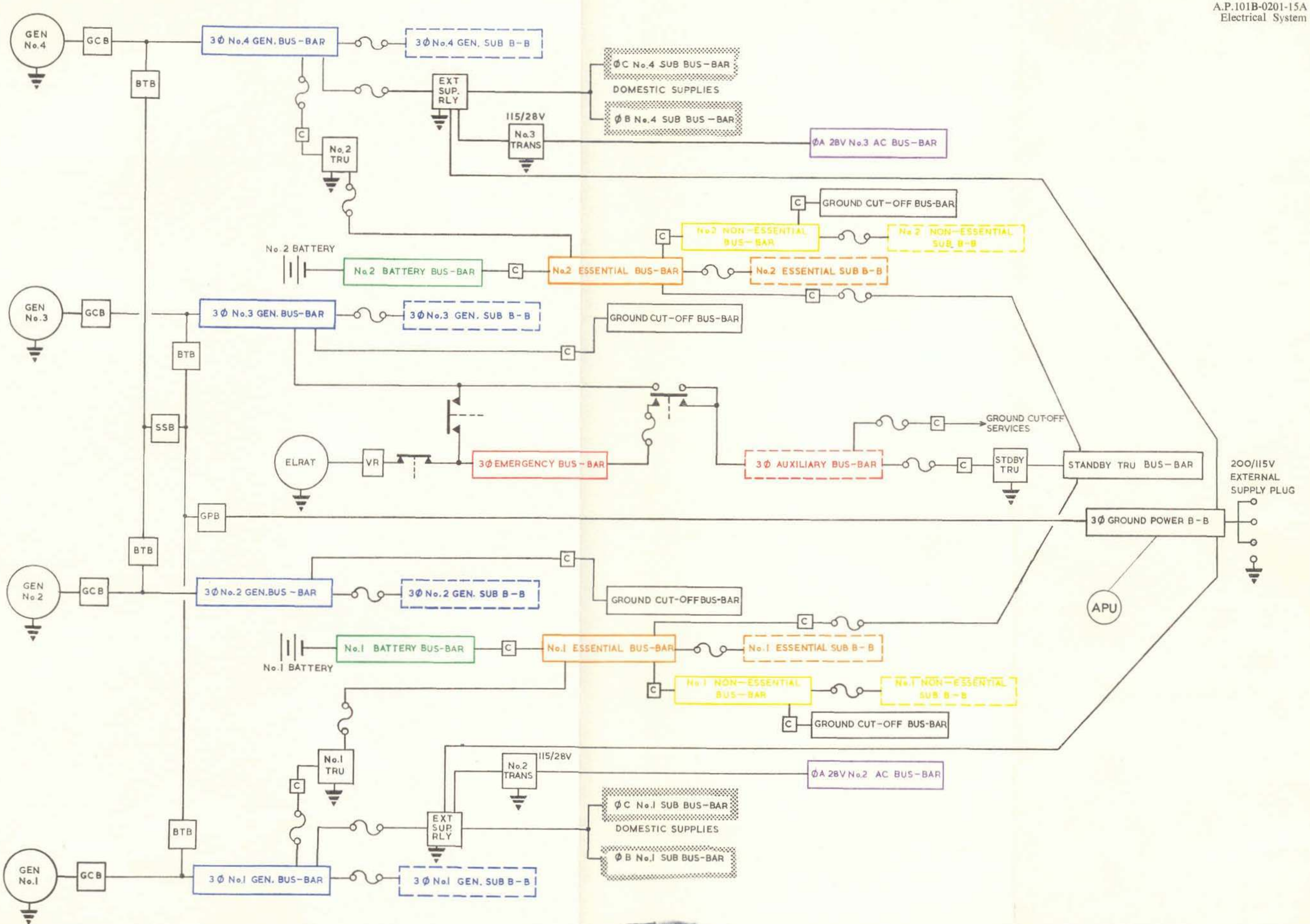


2.5 Fig. 1. Power Sources



2.5 Fig. 2. General Arrangement of Electrical Bay

[redacted]



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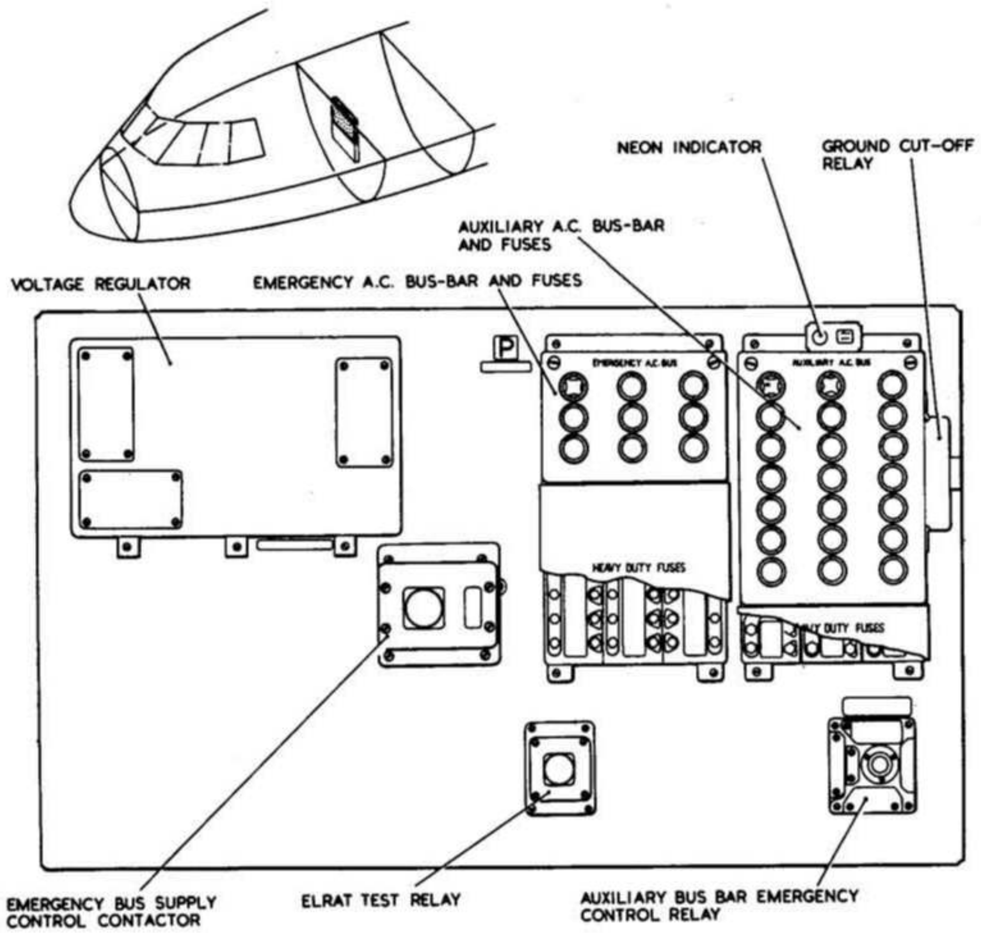
2.5 Fig. 3. Power Distribution — Simplified System

[redacted]



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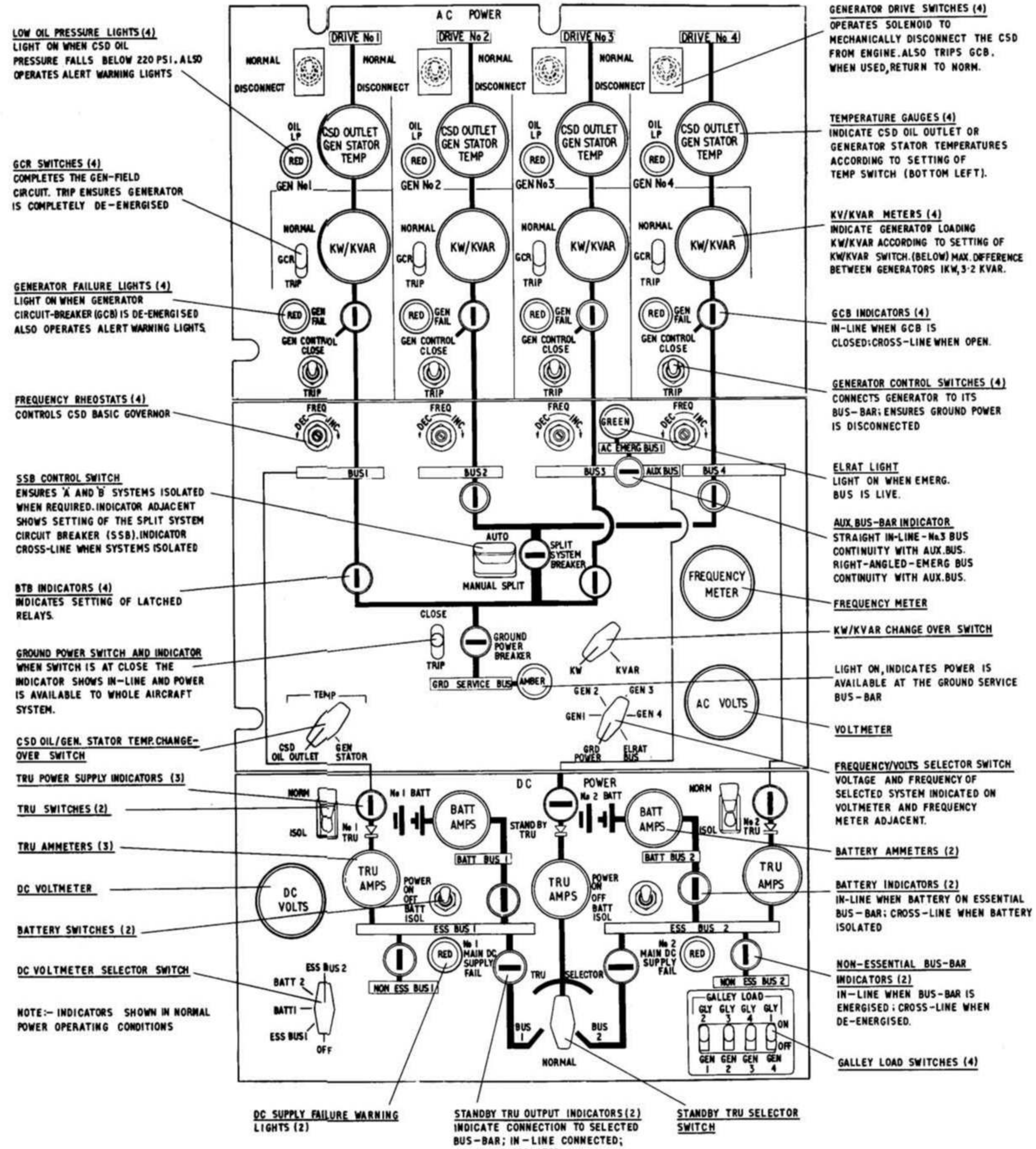
2.5 Fig. 5. Panel P



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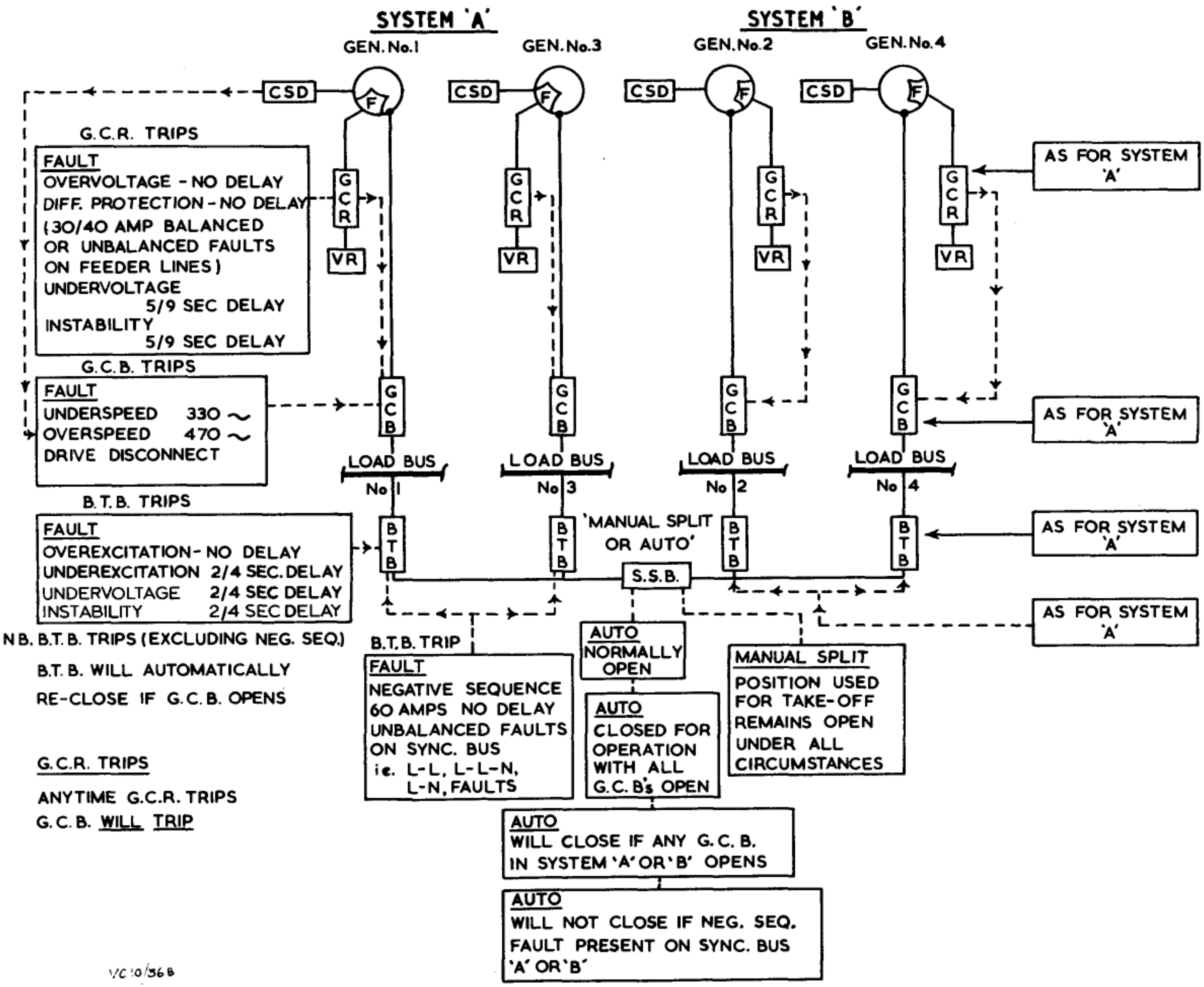
2.5 Fig. 4. DC and AC Power Panels

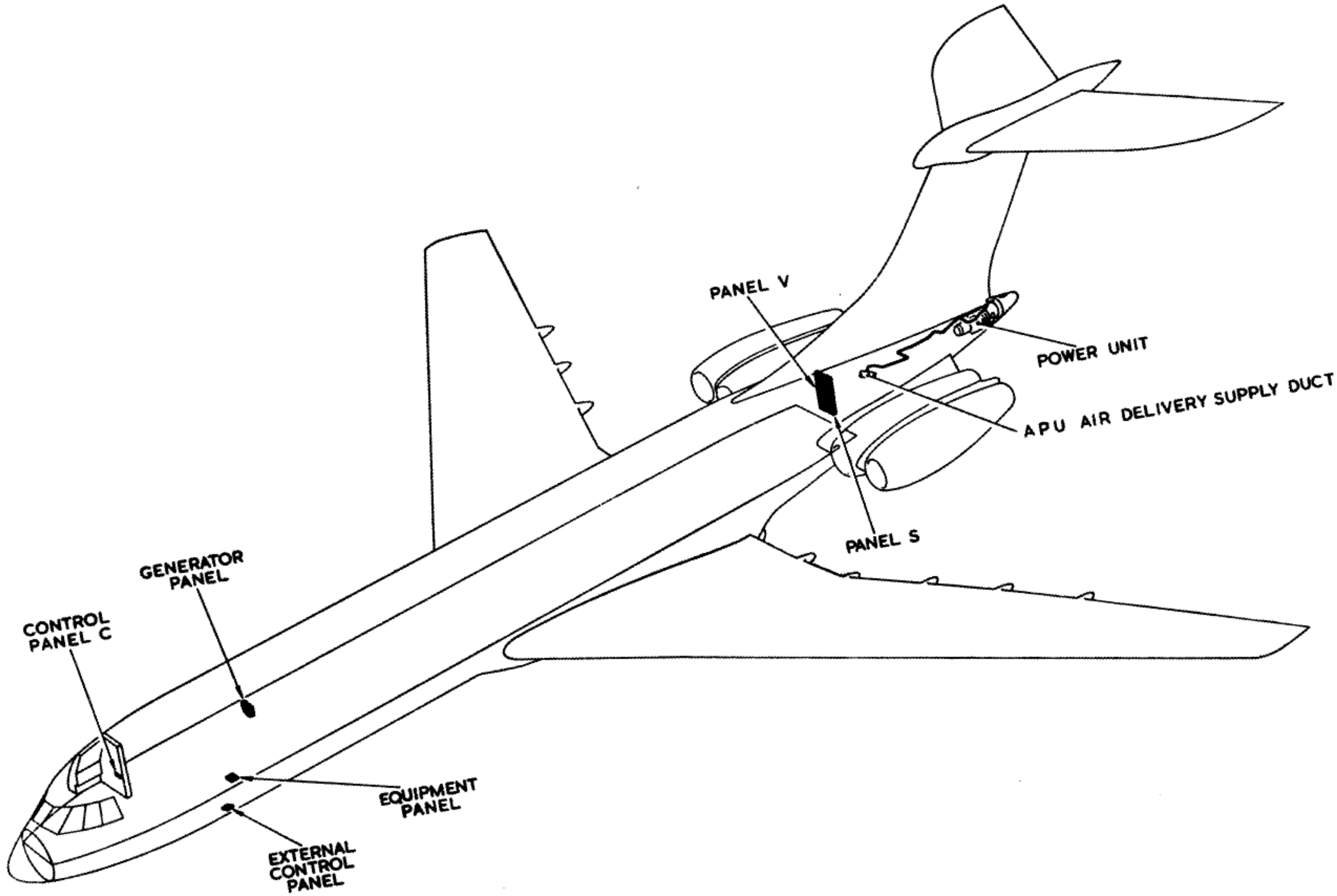
◀ *Fourth Galley Load Switch* ▶

2–5 Fig 6 Fault Diagnosis Diagram
◄(Minor Amendment)►

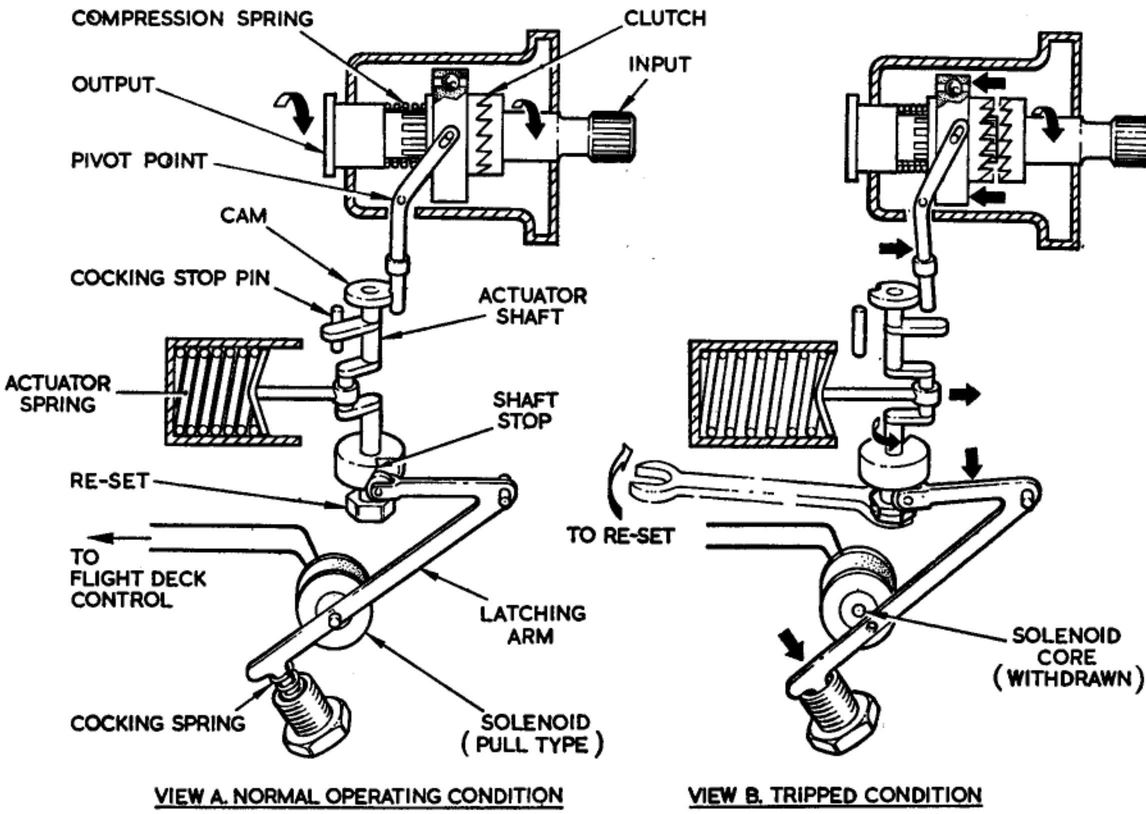


VC10/36B

VC10 POWER FAULT SCHEMATIC



2–5 Fig 7 APU Installation



VC10/38A

2—5 Fig 8 Generator Disconnect Facility

Operation of the DC System

109. Each TRU has an associated TRU relay to control the AC input to the TRU. The two main TRU relays are operated by the individual NORM/ISOL switches. No 1 and No 2 TRU relays are on panels J and K respectively.

110. The standby TRU relay is on panel P and is controlled by the STANDBY TRU SELECTOR switch, which also selects the associated STANDBY TRU output relay on panels U and Z, dependent upon standby selection.

111. The 3-position TRU SELECTOR-BUS 1/NORMAL/BUS 2 selector switch is normally set to NORMAL, and microswitches are operated in this setting to form part of No 1 and No 2 TRU control circuits.

112. Associated with each of the two DC systems is a Non-essential isolation relay, which isolates the Non-essential busbars until their associated TRU is selected and operating. The No 1 and No 2 Non-essential isolation relays are on panels U and Z respectively.

113. The magnetic indicators of the two DC systems and the standby system, form part of the line diagram of these systems on the DC panel. They show in-line when the associated item is in circuit and cross-line when the item is isolated.

114. A TRU, when operating, maintains power to its respective Essential and Non-essential busbars and, provided that the associated battery switch is set to POWER ON, also maintains the associated battery in a charged condition.

115. A DC supply failure warning light comes on when the voltage at the associated system Essential busbar falls to approximately 25 volts; it goes out when the voltage rises above approximately 26 volts. The DC failure warning lights are controlled by under-volt relays which also cause the alert warning lights to operate.

116. Failure of AC input to a TRU will:

a. Isolate the TRU.

b. Isolate the associated Non-essential busbars.

c. Cause the associated failure warning light to come on and the associated magnetic indicator to show cross-line.

117. When the standby TRU is selected, the associated Non-essential busbars are available, provided that the battery switch is at ON or BATT ISOL.

118. With the Elrat in operation, only the standby TRU and No 1 and No 2 batteries are available to supply DC power. The standby TRU can be connected to only one of the two DC systems at a time. By alternately supplying each DC system from the standby TRU at approximately 15 minute intervals, both DC systems remain operative and both batteries remain charged.

Effect of Elrat Selection

119. Under emergency conditions, setting the Elrat selector lever to EXTEND, operates two Elrat microswitches with the following results:

a. The battery switches are by-passed and the battery isolation relays are directly energised.

b. The No 1 and No 2 Non-essential control relays are de-energised.

Thus, use of Elrat removes control of the batteries from the engineer, and causes the Non-essential busbars and their sub busbars for both DC systems to be isolated.


MOVE STAND
DO NOT TOW