Chapter 13 A.C. POWER SUPPLIES

(completely revised)

LIST OF CONTENTS

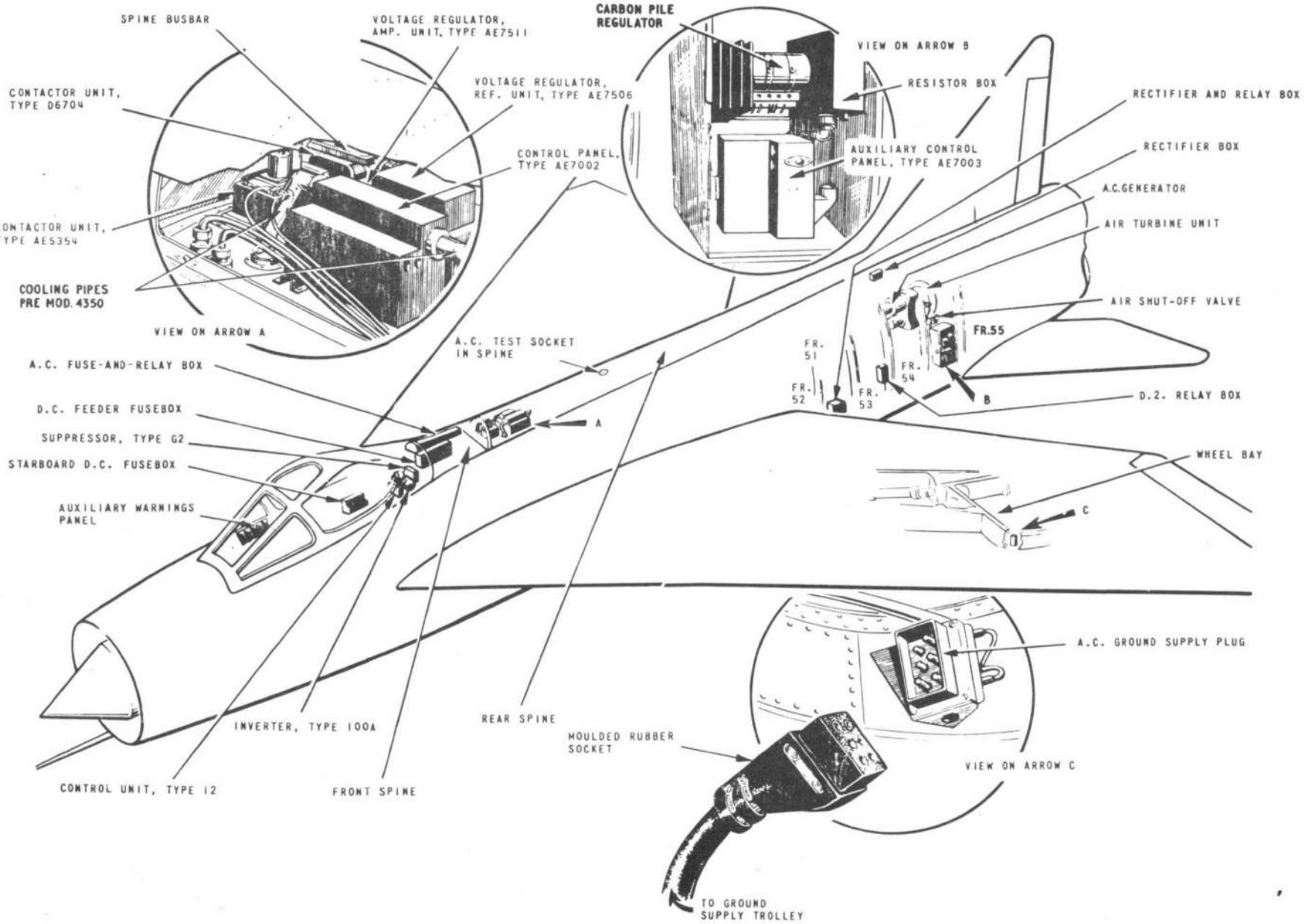

FIG.I. A.C. SUPPLY EQUIPMENT

IA-9152-1

◀ *Minor alterations* ▶

DESCRIPTION

Introduction

1. Power for all the a.c. operated equipment is normally supplied by a 3-phase a.c. generator driven by the air-turbine unit. In the event of failure of the a.c. generator system, a stand-by inverter is provided to maintain supplies to the flight instruments and other essential equipment. The installation provides for the connection of an external supply to the a.c. distribution system whilst ground servicing and testing.

General information

2. The a.c. generator supply system comprises the following main items:-

A.C. generator, Type 162

Magnetic amplifier voltage regulator. This unit incorporates a voltage regulator reference unit, Type AE 7506 or AE 7525 and a magnetic amplifier unit, Type AE 7511, Mk.3 (pre Mod.4349) or AE 7511, Mk.4 (post Mod. 4349).

Rectifier unit

Carbon pile regulator, Type 118

Control panel, Type AE 7002

Auxiliary control panel Type AE 7003

Resistor box, Type AE 7701

Main contactor, Type 5354, Mk.3

The associated circuit also includes a number of automatic switches and relays which operate in conjunction with the main items, to control and protect the system.

A.C. generator

3. The Type 162 a.c. generator, fitted to and driven by the air-turbine unit, is located between frames 53 and 54 (access panel 77P) in the rear fuselage. The a.c. generator is a 200-volt, 400 Hz, 3-phase machine of conventional design, having a nominal output rating of 20 kVA. Its short-circuit current is rated at two and a half times the full load value; thus providing for the clearance of faults on the distribution system cables without damage to the machine. The stator windings are star-connected and the rotor is energized by a built-in exciter fitted with shunt and bias field windings. The a.c. generator speed, hence its output frequency, is maintained at a constant value by the turbine governor system. Blast cooling is employed, this being described in A.P.101B-1001-1A, Sect.3. A full description of the a.c. generator is given in A.P.4343A, Vol.1, Sect.2, Chap.16.

Magnetic amplifier voltage regulator

4. The a.c. generator voltage is normally controlled at 200 volts by a magnetic amplifier regulator located in the spine. It is energized by the a.c. generator output supply, and automatically takes over control of the voltage as the turbine attains its normal speed. Further information is given in A.P. 4343B, Vol.1, Sect.2.

Rectifier unit

5. Output signals from the magnetic amplifier regulator are fed to the shunt field of the a.c. generator exciter, via a rectifier unit fitted above the turbine unit in the cooling air duct from the fin. The rectifier block contains twelve Type IN 347 rectifiers.

Carbon-pile voltage regulator

6. The Type 118 voltage regulator, located behind access panel 81P (frame 54-55) functions as an emergency voltage control unit. If the normal voltage control unit fails, the regulator is automatically switched into circuit to provide coarse regulation of the a.c. generator voltage at 200-volt a.c. ± 4 per cent. A description of the Type 118 regulator is given in A.P.4343B, Vol.1, Book 1, Sect.2, Chap.5.

Control panel, Type AE 7002

7. This control panel, located in the spine, provides a 28-volt d.c. supply to the a.c. generator bias field, the interlocking of the circuit being such that the a.c. generator and the ground supply cannot be connected to the load at the same time. Protection against over- and undervoltage and reverse phase sequence is incorporated, and in each event (in conjunction with the AE 7003 auxiliary control panel) control of the a.c. generator voltage is transferred from the magnetic amplifier voltage regulator, to the carbon-pile regulator, at the same time as the a.c. generator is disconnected from the busbars. Further details of the Type AE 7002 control panel can be found in A.P.4343B, Vol.1, Book 2, Sect.8, Chap.12.

Control panel, Type AE 7003

8. Known as the auxiliary control panel, it is located below the Type 118 carbon-pile regulator behind access panel 81P. It operates in conjunction with the Type AE 7002 control panel, to transfer control of the a.c. generator from the magnetic amplifier regulator to the carbon-pile regulator, and vice-versa. The unit is fully described in A.P.4343B, Vol.1, Book 2, Sect.8, Chap.13.

Resistor box

9. A number of trimming and ballast resistors are housed in a Type AE 7701 resistor box assembly which is fitted above the auxiliary control panel.

Main contactor

10. The 3-phase a.c. supply circuit from the a.c. generator output terminals to the distribution system is controlled by a Type AE 5354, Mk.3 contactor unit installed in the rear fuselage spine. The contactor has two solenoids, one to close it, the other to trip it. Having closed, the contactor is magnetically held in this condition as long as the close coil remains energized.

Regulator circuits

11. Each shunt field winding and associated resistor are connected across the exciter armature via a Type S3 relay, the carbon-pile and a Type AE 7704 compensating resistor which offsets the effect of the short field leads. The control solenoid of the carbon-pile regulator is energized from the a.c. generator output circuit via the transformer and bridge rectifier in the auxiliary control panel. A variable ballast resistor, which sets the control datum of the regulator, is connected in series with the control solenoid. When the magnetic amplifier regulator is controlling the a.c. generator voltage, its rectified output voltage is applied to the exciter field circuit at the junction points between the shunt windings and the field resistors. Any variation of a.c. generator voltage is reflected at the amplifier output, and the current through both shunt windings is varied by an inversely proportionate amount to restore the a.c. generator voltage to the normal value.

Turbine switches

12. Three turbine-operated switches are employed in the a.c. generator control system viz. the underspeed switch, the overspeed switch and the stall warning switch. The underspeed switch is centrifugally operated and has three sets of contacts but only one set is used, contacts 2 and 3 are closed when the turbine is at rest and will remain so until the turbine attains 90 per cent of its normal speed. The overspeed switch, also centrifugally operated, has one pair of contacts which close at 17.5 per cent above normal speed. The stall warning switch is operated by the turbine governor mechanism and closes when the supply of air from the engine compressors becomes insufficient to maintain normal turbine speed.

OPERATION

Note...

Reference to the a.c. supply circuit diagram is necessary whilst reading the following para.13-22 inclusive.

Starting

13. To ensure that the a.c. generator voltage builds up satisfactorily, a field tickling supply is fed from the d.c. distribution system, via a Type 10B relay and a ballast resistor in the resistor box, to the bias winding of the exciter. When either engine is started, the air turbine runs up to speed, and as the a.c. generator output voltage increases, the rectified supply from the auxiliary control panel energizes the control solenoid of the carbon-pile regulator. At this stage, part of the variable ballast resistor in the regulator is short-circuited by No.1 transfer relay, and this sets the control datum of the carbon-pile to 200 volts. The a.c. generator output supply is also connected to the magnetic amplifier regulator, and to the power transformer and rectifiers, on the main control panel. The control supply, derived from the relevant group of rectifiers, is connected to the solenoid of No.1 transfer relay, via the overvoltage relay, circuit VA52, contacts 2 and 3 of the underspeed switch, circuit VA28, and the test switch. Operation of No.1 transfer relay connects the rectified output of the magnetic amplifier to the exciter field circuit, removes the short-circuit from the ballast resistor in the carbon-pile regulator to raise the control datum of the regulator to 220 volts, and energizes No.2 transfer relay via circuit VA52 and the test switch. Closing of the second transfer relay connects the control supply via contacts 1 and 2 of the undervoltage phase sequence unit on the control panel and circuit VA29 to the solenoid of No.1 transfer relay,

reduces the value of the ballast resistance in the exciter bias field circuit, and interrupts the supply from the d.c. distribution system to the trip solenoid of the main contactor by breaking the connection between circuits VA1 and VA15. Since the transfer relays are now energized from circuits VA29 and VA52, they will remain closed when the turbine underspeed switch opens at 90 per cent governed speed. The a.c. generator output voltage is now controlled at 200 volts by the magnetic amplifier regulator and, as the control datum of the carbon-pile regulator has been raised to 220 volts, the pile opens fully and has no further effect on the regulation system except to provide continuity of the exciter shunt field circuit. When the ground supply is switched off, the hold-off relay and the ground contactor open, the trip solenoid of the main contactor is de-energized, and the closing solenoid energized. The main contactor then closes and, in consequence, the a.c. generator output supply is connected to the a.c. distribution system and the Type 10B relay becomes energized. This action de-energizes the a.c. generator failure warning circuit *(Chap.12)*, and transfers the exciter bias field circuit from the distribution supply circuit VA1, to the control supply circuit VA21A.

Note...

The additional circuit (VA17 and VA18) controlled by the Type 10B relay is associated with the A.I.23 supply.

Normal regulation

14. Within the magnetic amplifier regulator, the a.c. generator output supply is rectified, smoothed, and applied to a voltage-sensing bridge consisting of two voltage reference tubes and two 15,000-ohm resistors. The voltage across the reference tubes is virtually constant at 85 volts, irrespective of the current through them. A rise in a.c. generator voltage will increase the current through the resistors and tubes, causing an increased voltage-drop across the resistors only. The increase in potential difference between the junction points of the bridge will cause more current to flow in the control winding of transductor No.1. Since the output of this transductor is connected to the control winding of transductor No.2, the rise in a.c. generator voltage will increase the output voltage of the power amplifier. This voltage, when rectified and applied to the exciter field circuit, will reduce the excitation to restore the a.c. generator voltage to the normal level. To minimize overshoot and suppress any tendency towards oscillation, a feed-back winding on transductor No.2 is connected to the secondary winding of a damping transformer which is energized on the primary side by the exciter output voltage (circuit VA42). A change in excitation will produce a transient output from the damping transformer, which will energize the feedback winding in such a direction that it will oppose the effect of the control winding. With the response of the transductor thus retarded, smooth and stable regulation is obtained.

Protective devices

Overvoltage

15. The output of the 230-volt rectifier on the control panel is connected to an overvoltage trip circuit consisting of a trigger tube, several resistors and capacitors, and an overvoltage relay. If the a.c. generator voltage rises due to faulty regulation, the trigger tube will strike between anode A1 and cathode C when the output voltage of the rectifier reaches approximately 248 volts. The precise striking voltage, which corresponds to an a.c. generator voltage of 215 volts, is adjusted by varying the voltage on the ionizing electrode I by means of resistor R7. As the anode A1 starts to conduct, anode A2 strikes, and the resulting current energizes the overvoltage relay which, on operating, interrupts the supply to the transfer relays. Both relays drop out, the main contactor is tripped, and the voltage control is transferred to the carbon-pile regulator. Additional contacts on the overvoltage relay complete the solenoid circuit via R5 and R6, so that the relay is maintained in the closed position when the trigger tube ceases to conduct. This condition will prevail until the turbine is shut down. Resistor R3 and the capacitors form a time-delay network which prevents tripping of the circuit by voltage transients.

Overfrequency

16. In the event of overspeeding and the resultant rise in frequency, a switch on the air turbine unit is set to operate at 17.5 per cent overspeed. The switch contacts will close to energize the air valve feeding the turbine, thereby shutting down the turbine. Owing to a mechanical self-locking feature the valve will remain in this closed condition until it is unlocked on the ground.

Underfrequency (stall warning)

17. If the supply of air to the turbine unit is reduced below a point sufficient to maintain normal speed, the governor loses control and contacts in the stall switch are closed, thus tripping the main contactor via circuit VA15A. The turbine stall switch also controls a warning lamp on the auxiliary warnings system *(Chap.12)*.

Earth faults

18. The neutral point of the a.c. genera-

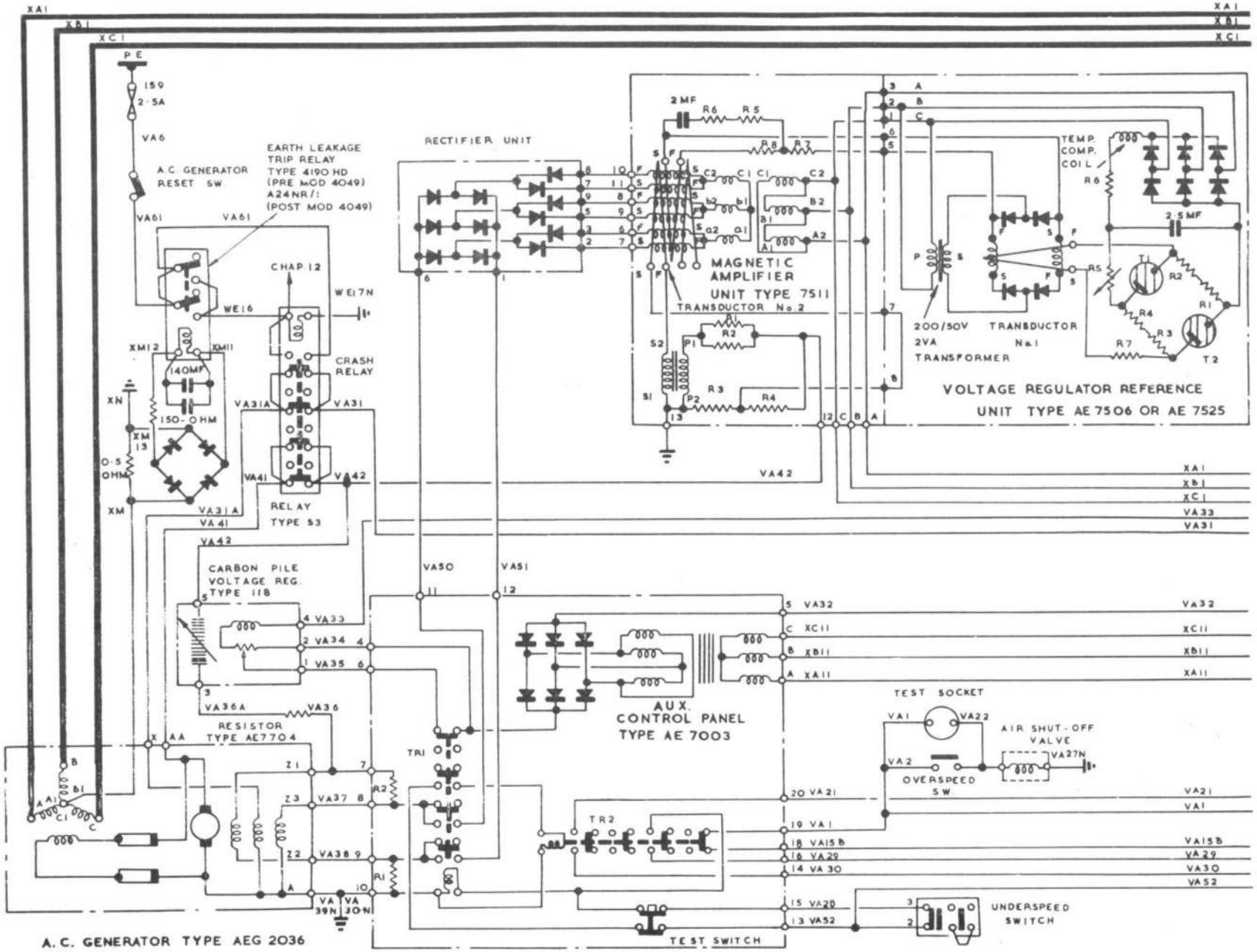

FIG.2. A.C. POWER SUPPLY SYSTEM

◀ Mod 4049 embodied ▶

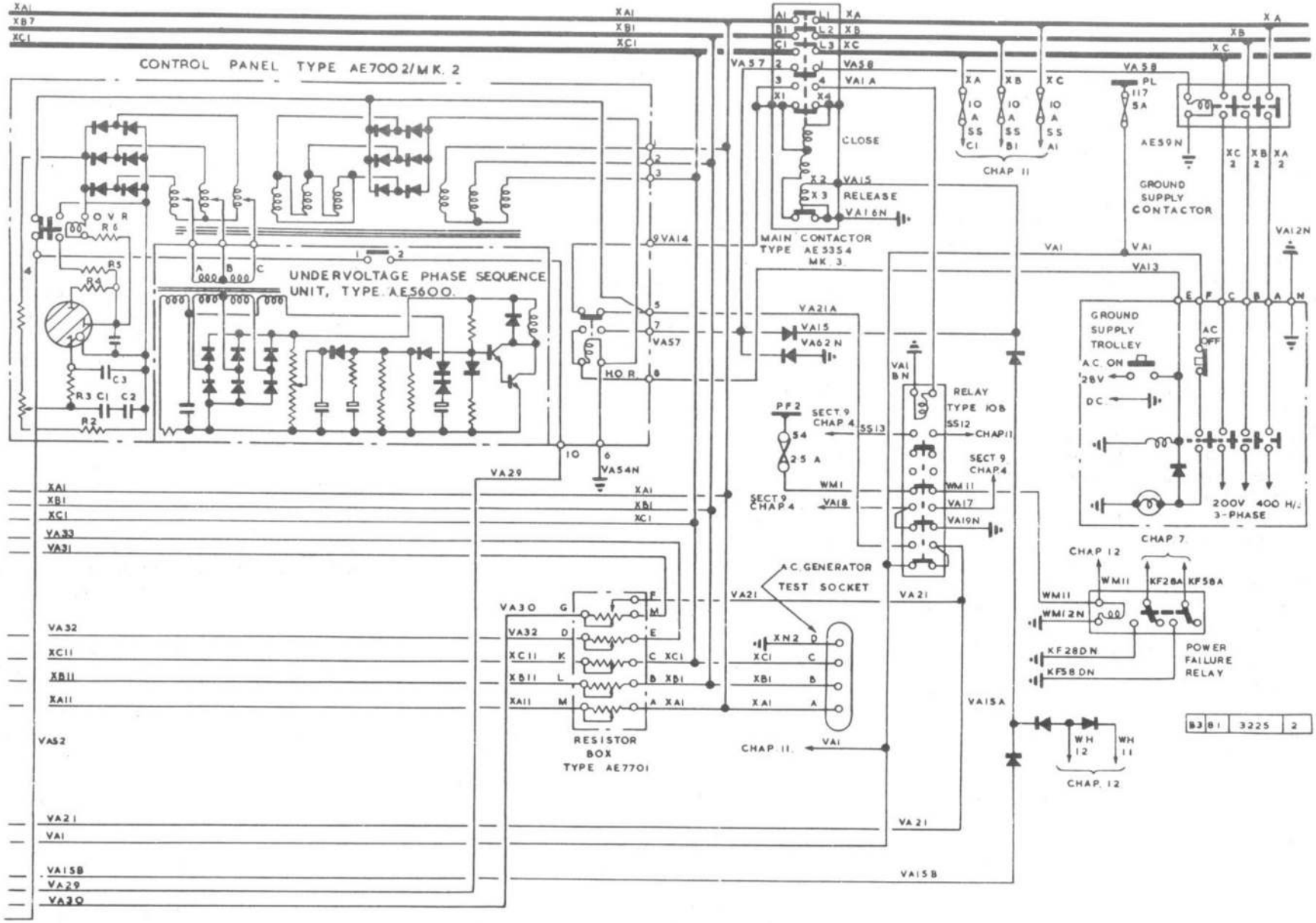

FIG.2A. A.C. POWER SUPPLY SYSTEM

tor stator is connected to earth via a 0.5-ohm, Type 5003 resistor, located adjacent to the a.c. generator. In the event of an earth fault between the a.c. generator and the distribution system, the fault current flows via the neutral connection, and a proportionate voltage drop occurs across the resistor. This voltage is applied to a bridge rectifier across which is connected the solenoid circuit of a Type 4190 HD (pre Mod. 4049) or A24NR/1 (post Mod. 4049) relay. If the earth current is greater than 20 amps, the relay closes and connects an emergency supply to a Type S3 relay which, on operating, interrupts the shunt and bias field circuits, causing the a.c. generator voltage to collapse. When this occurs, the earth fault trip relay will open again, but the Type S relay will be maintained in an energized condition by a supply fed through a reset switch in the d.c. feeder fusebox. When the cause of tripping has been determined and the fault cleared, the exciter field circuits can be restored by operating the reset switch. Since the largest fuse in the distribution system is of 10-amp rating, an earth fault beyond the a.c. fusebox will be isolated by the rupturing of the relevant fuse. To prevent operation of the relay by a heavy transient current before rupturing of the fuse occurs, a resistance-capacity network is included in the relay solenoid circuit. This consists of two 140 mF capacitors and a 150-ohm resistor. These components, together with four rectifiers and the relay, are contained in a box located between frames 51 and 52 on the port side of the rear fuselage.

Crash landing

19. The Type S3 relay which is associated with the earth fault trip circuit, can also be energized via the crash relay in the inertia switch circuit *(Chap. 12)*. In the event of a crash landing, the shunt and bias fields are isolated automatically, causing the a.c. generator voltage to collapse.

A.C. generator failure warning

20. Whenever the main contactor is in the tripped condition, the Type 20B relay is de-energized and completes a circuit WM1 – WM11 to the a.c. generator failure warning lamps on the auxiliary warnings panel *(Chap. 12)*. The supply also energizes a Type 4190 HD (pre Mod. 4049), or A24NR/1 (post Mod. 4049), relay associated with the engine reheat system. When closed the relay connects circuits KF28A and KF58A to earth, rendering both reheat circuits inoperative *(Chap. 7)*.

Test socket

21. A test socket is provided to facilitate voltage and frequency measurement when testing the a.c. supply system. It is located on a bracket in the rear fuselage spine, and connected across the input terminals of the magnetic amplifier regulator.

External supply

22. An external supply may be fed to the a.c. distribution system via a ground supply plug located in the port wheel well. The three large pins of this 6-pole plug carry the 3-phase supply, whilst the remaining pins connect a d.c. circuit which effects automatic isolation of the a.c. generator and ensures that an external supply cannot be connected to the a.c. distribution system unless the main contactor is open. This protective interlock is provided by the hold-off relay in the a.c. generator control panel. The relay becomes energized when the ground supply trolley is switched on, and its function is to trip the main contactor if it is not already open, and to connect an energizing supply via the main contactor, to the Type D 6704 ground supply contactor which, on closing, connects the external supply to the a.c. busbars. The trolley contactor and the hold-off relay are initially energized by pressing the A.C. ON push-switch and are subsequently maintained in this condition by a supply from the d.c. busbar, returned via the ground supply connector. This supply also illuminates the trolley indicator lamp. When the A.C. OFF push-switch is pressed, or the ground supply disconnected, the trolley contactor, hold-off relay and ground supply contactor are de-energized, the trolley indicator lamp will go out, and the control circuit of the main contactor is reset.

SERVICING

WARNING

The relevant safety precautions detailed on the LETHAL WARNING marker card must always be observed before entering the cockpit or performing any operations upon the aircraft.

General

23. All equipment units, cables, and connectors, associated with the main a.c. supply and instrument supply systems, should be examined periodically for signs of damage, insecurity, and over-heating.

Functional tests

24. In addition to the normal operational and continuity checks, the following tests should be made at the intervals laid down in Vol. 4 of this publication, or whenever any major component of the system has been repaired or renewed.

A.C. generator

Equipment

25.

A.C. tong test ammeter (0-100 amp)
Test lamp (28-volt)
400 Hz test set

Procedure

26.

Note...

When running the aircraft engines, an a.c. ground supply must be connected and switched on until the a.c. generator supply has been checked for correct phase sequence.

(1) Connect a test lamp between terminals 18 and 10 of the Type AE 7003 auxiliary control panel in the port aft equipment compartment.

(2) Connect the 400 Hz test set to terminals A, B, C and earth at the a.c. generator.

(3) Connect a.c. and d.c. ground supplies. The test lamp should light.

(4) Run one engine at 65 per cent rev/min and the other at any speed. The test lamp should go out.

(5) Press the push button on the auxiliary control panel. The test lamp should light.

(6) Check that the test set meter reads 200-205 volts; if necessary, adjust the external trimmer on the Type AE 7701 resistor box to obtain this reading.

(7) Switch the meter to read frequency. This should be 405-410 Hz at the start of engine running, falling during the engine run to 395-405 Hz. Immediately after a high-speed flight the frequency should be 390-400 Hz.

Note...

The meter indicates on the right-hand side only of the scale for the frequency test, therefore the calibrated dial should be turned until the meter pointer is at the mid-scale mark. The frequency is then shown on the calibrated dial.

(8) Switch the meter to phase rotation, and check that the phase sequence of the supply is correct.

(9) Disconnect the test set from the a.c. generator terminals, and connect it to the spine test socket. Set the meter to read 3-phase mean volts.

(10) Reduce the engine speed to ground idling, and then increase it again to 65 per cent rev/min. The test lamp should go out.

(11) Check that the test set meter reads 200 ± 0.25 volts; if necessary, adjust resistance on the Type AE 7506 first-stage amplifier to obtain the reading.

(12) Check that the phase rotation is correct.

(13) Check the line voltages, RED-WHITE, WHITE-BLUE, BLUE-RED. The line voltage in each case should be equal to the mean voltage ± 1 volt.

(14) Switch off the ground supply trolley, and ensure that the a.c. generator is delivering power by measuring the current in the heavy cables at the main contactor, using the a.c. tong test ammeter. Check that the lamps A.C. and TURB. on the auxiliary warnings panel are out.

(15) Press the push button on the auxiliary control panel. The main contactor should be tripped, and the test lamp should light. The TURB. lamp should stay off and the A.C. lamp come on.

(16) Reduce the engine speed to ground idling, TURB. lamp should come on. Increase to 65 per cent rev/min and the main contactor should close, the test lamp come on and both the TURB. and A.C. lamps go off.

(17) Insert the shorting plug in the air shut-off valve test socket. The turbine should shut down. Remove shorting plug and reset the shut-off valve.

(18) Shut down both engines and disconnect the ground supplies. Disconnect and remove all test equipment.

A.C. generator control system

Equipment

27.

A.C. generator test rig

A.C. system test box

Terminal strip assembly

Voltmeter (0-300 volts a.c.)

Ammeters (0-1, 0-5 and 0-10 amp)

ON/OFF switch

Procedure

28.

(1) Remove access panel 77P and disconnect the a.c. generator leads at the a.c. generator.

(2) Fit the terminal strip assembly into the securing holes of the access panel hatch, then connect the a.c. generator leads to the wiring of the

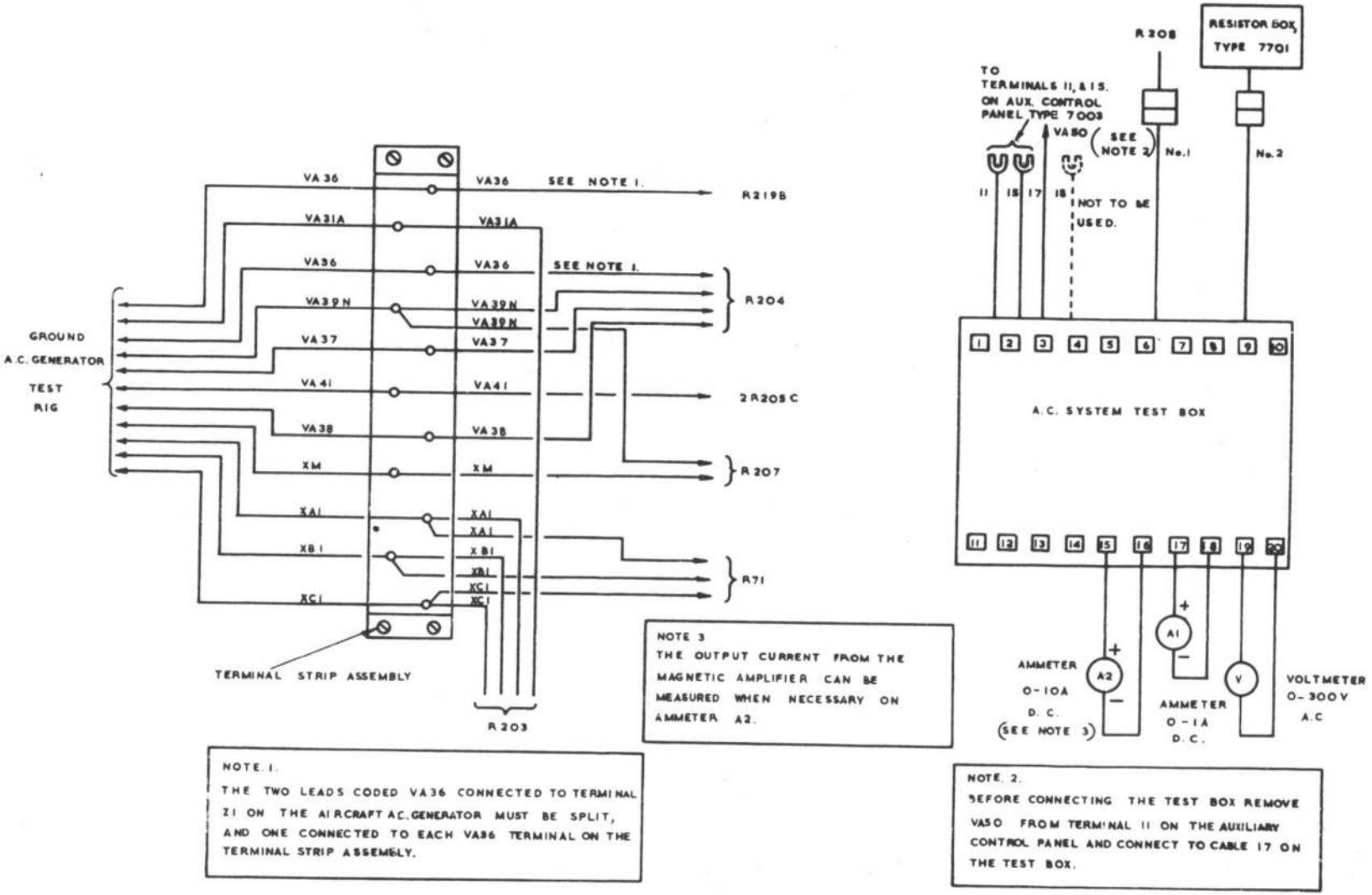

FIG.3. CONNECTIONS TO A.C. GENERATOR TEST RIG

a.c. generator test rig as detailed in fig.3.

(3) Disconnect cable R208 from the resistor box and connect the a.c. system test box to the circuit as detailed in fig.3.

Note...

No connection is to be made to terminal 18 of the auxiliary control panel.

(4) Disconnect the plug connection from the underspeed switch on the air turbine unit.

(5) Switch on the d.c. ground supply. The TURB and A.C. warning lamps should light.

WARNING

During the following tests it may be necessary to adjust the clips on the resistors in the resistor box. When making these adjustments the ground test a.c. generator must be OFF.

(6) Set the external trimmers on the resistance box, AE7701, and the voltage-sensing and first-stage amplifier, Type AE 7506, to mid-position.

(7) Remove fuse 117 (field tickling supply) and replace by the ammeter (0-5 amp).

(8) Close the underspeed switch on the test box. Ammeter A1 should read 0.4-0.6 amp (field tickling). The ammeter in place of fuse 117 should read in excess of ammeter A1.

(9) Run the ground a.c. generator. The voltage between any pair of lines should be 195-205 volts.

(10) Switch off the underspeed switch on the test box, and press the push button on the auxiliary control panel. The voltage should then be 180-220 volts.

(11) If the voltage is above 212 volts or below 188 volts, adjust the clips on the three resistors fitted with single tappings, and situated inside the resistor box, to obtain a voltage between 195 and 205 volts. When making this adjustment, both ends of each clip must first be slackened and then the clips must be adjusted uniformly.

(12) Trim the voltage to 200-205 volts by means of the external trimmer fitted to the resistance box.

(13) Close the underspeed switch on the test box and then re-open it. The a.c. generator should be controlled by the magnetic amplifier, and the voltage should be 195-205 volts. If in test (10) the overvoltage relay is tripped during change-over to carbon-pile control, it will first be necessary to stop the ground a.c. generator, and restart it with the underspeed switch closed.

(14) Adjust the trimmer on the voltage-sensing and first-stage amplifier to give between 200 and 204 volts.

(15) Remove fuse 95 (stall warning light). This will allow the main contactor to close, cutting off the field tickling supply, and causing a drop of 0.75 amp on the ammeter connected in place of fuse 117.

Note...

Fuse 95 must be replaced before stopping ground a.c. generator in order to trip the main contactor.

(16) Adjust the bias field current shown on ammeter A1 to 0.7-0.75 amp with the resistors cold. This is effected by means of the clip nearest the connected end of the resistor fitted with two tappings.

Note...

The bias field current may fall below the minimum value quoted if a d.c. supply has been switched on to the aircraft for any length of time. This is due to the field tickling current heating the resistor and the bias field winding. The bias field current should therefore be checked with these components as cool as possible.

WARNING

The ground trolley must be OFF before adjusting the above clip.

(17) Check the voltage after running for 10 minutes, and adjust the trimmer on the voltage-sensing and first-stage amplifier to obtain a voltage of 200-204 volts.

(18) Switch on an a.c. load and check that the load equipment operates.

(19) Press the test switch on the auxiliary warnings panel, and check that the load equipment continues to operate.

(20) Release the test switch.

(21) Remove the a.c. load.

(22) Press the push-button on the auxiliary control panel, and check that the main contactor opens.

(23) Replace fuse 95 and stop the ground a.c. generator.

(24) Switch off the d.c. ground supply.

(25) Remove the ammeter connected in place of fuse 117, and replace fuse 117.

(26) Remove the a.c. system test box, and reconnect cable R208 to the resistor box. Restore all connections on the auxiliary control panel to their original state. With the exception of the ground a.c. generator being connected in place of the aircraft a.c. generator, and cable R85A being disconnected from the air turbine underspeed switch, all other aircraft wiring connections should be as normal.

(27) Switch on the d.c. ground supply.

(28) Apply a short-circuit to pins D and E of plug R85A.

(29) Run the ground a.c. generator.

(30) Remove short-circuit from pins D and E, and check that the voltage is 200-204 volts at the test socket in the spine.

(31) Check that circuit VA18 is earthed.

(32) Remove fuse 95 (stall warning light).

(33) Earth should disappear from circuit VA18.

(34) Press the push button on the auxiliary control panel. The main contactor should trip and circuit VA18 should be earthed.

(35) Replace fuse 95.

(36) Stop the ground a.c. generator.

(37) Connect the ON/OFF switch in the supply circuit to terminal A on the power amplifier, Type 7511. Leave the switch in the closed position.

(38) Connect an earth to the 200-volt busbar XA1, on the a.c. generator side of the main contactor.

(39) Start the ground a.c. generator. The voltage should build up to approximately 10-20 volts, and then fall to zero as the earth leakage trip operates.

(40) Stop the a.c. generator, and remove the earth from busbar XA1.

(41) Restart the a.c. generator. The voltage should not build up, as the earth leakage relay is self-locking.

(42) Apply a short-circuit between pins D and E of plug R85A. Operate the a.c. generator reset switch in the d.c. feeder fusebox. The a.c. generator should build up to 200-204 volts.

(43) Remove the short-circuit from pins D and E of R85A.

(44) Check the voltage to earth on terminals 13 and 16 of the auxiliary control panel. This should be approximately 28 volts on each.

(45) Open the switch in the lead to terminal A of the power amplifier; then close it. The voltage on terminals 13 and 16 of the auxiliary control panel should fall to zero, thus showing that the overvoltage relay has tripped. The a.c. generator should be controlled at 200-205 volts by the carbon-pile regulator.

(46) Stop the ground a.c. generator. Remove the ON/OFF switch connected in the supply circuit to the power amplifier, and restore the supply lead to the normal condition.

(47) Short-circuit pins D and E of plug R85A. Start the ground a.c. generator and then remove the short circuit.

(48) Check the voltage on the A.I.23 supply leads, SSA1, SSB1, and SSC1, at the A.I. relay. This should be zero.

(49) Remove fuse 95. The voltage on SSA1, SSB1, and SSC1 should be 200 volts.

(50) Plug in the a.c. ground supply. The main contactor should be open, and the voltages on SSA1, SSB1, and SSC1, should be 200 volts. The a.c. generator failure warning lamps on the auxiliary warnings panel should light.

(51) Remove the a.c. ground supply. The main contactor should close. The voltages on SSA1, SSB1, and SSC1, should be 200 volts. The a.c. generator failure warning lamps should go out.

(52) Replace fuse 95. Stop the ground a.c. generator.

(53) Remove the ground test rig, and restore the a.c. generator system connections to normal.

FIG. 4. A.C. POWER SUPPLY SYSTEM

(illustration overleaf)

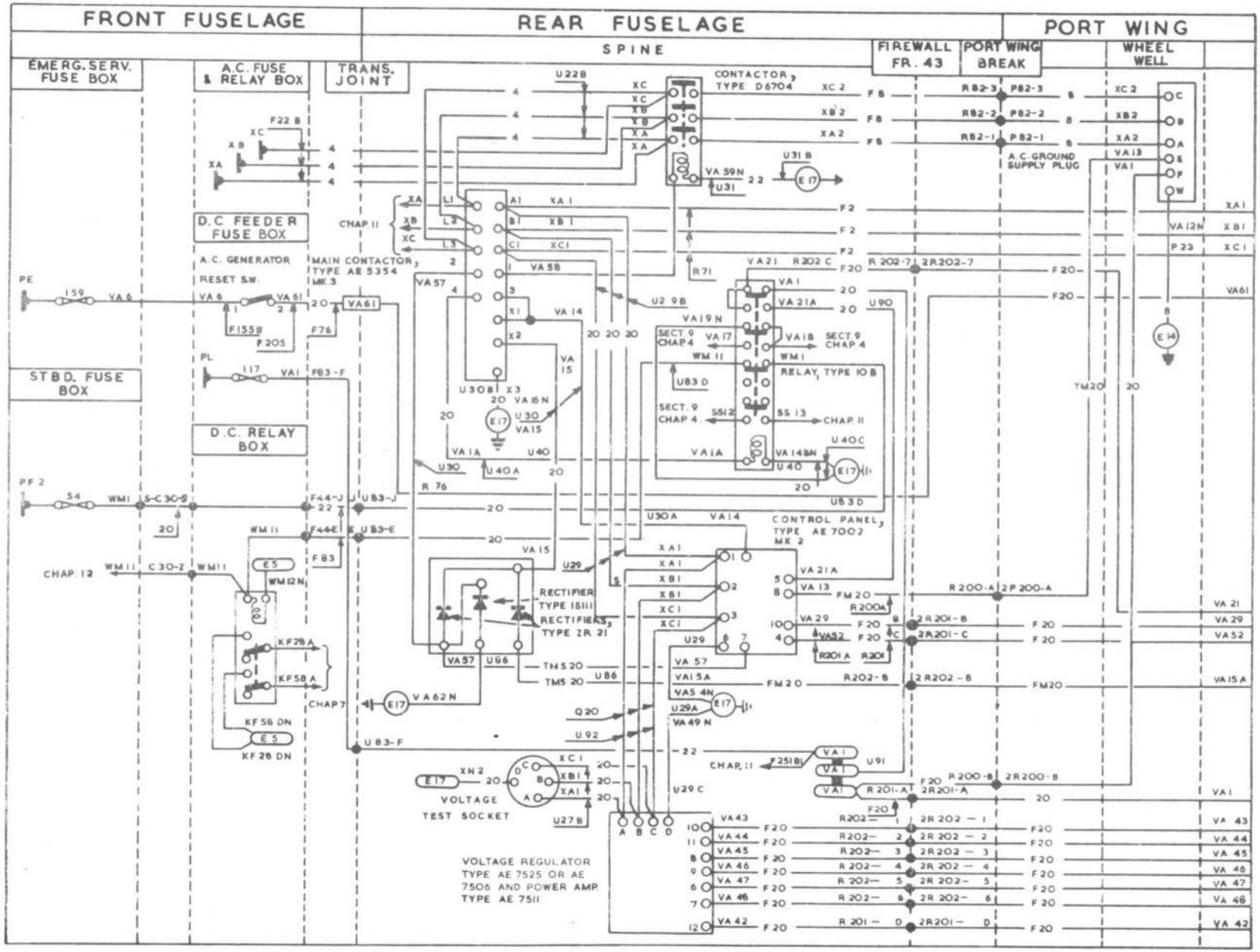

FIG.4. A.C. POWER SUPPLY SYSTEM

◀ Minor alterations ▶

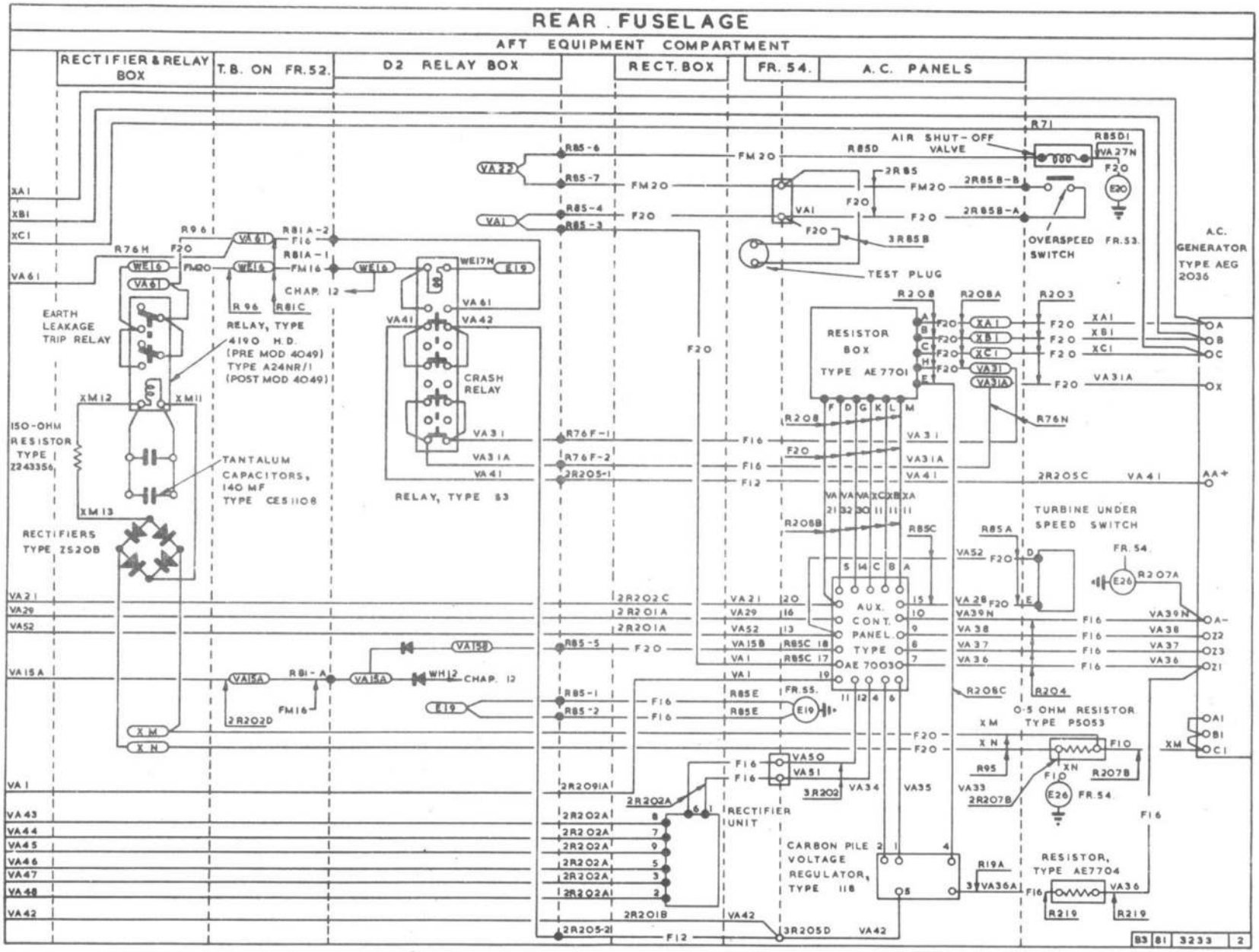

FIG.4A. A.C. POWER SUPPLY SYSTEM

◀ Mod.4049 embodied ▶

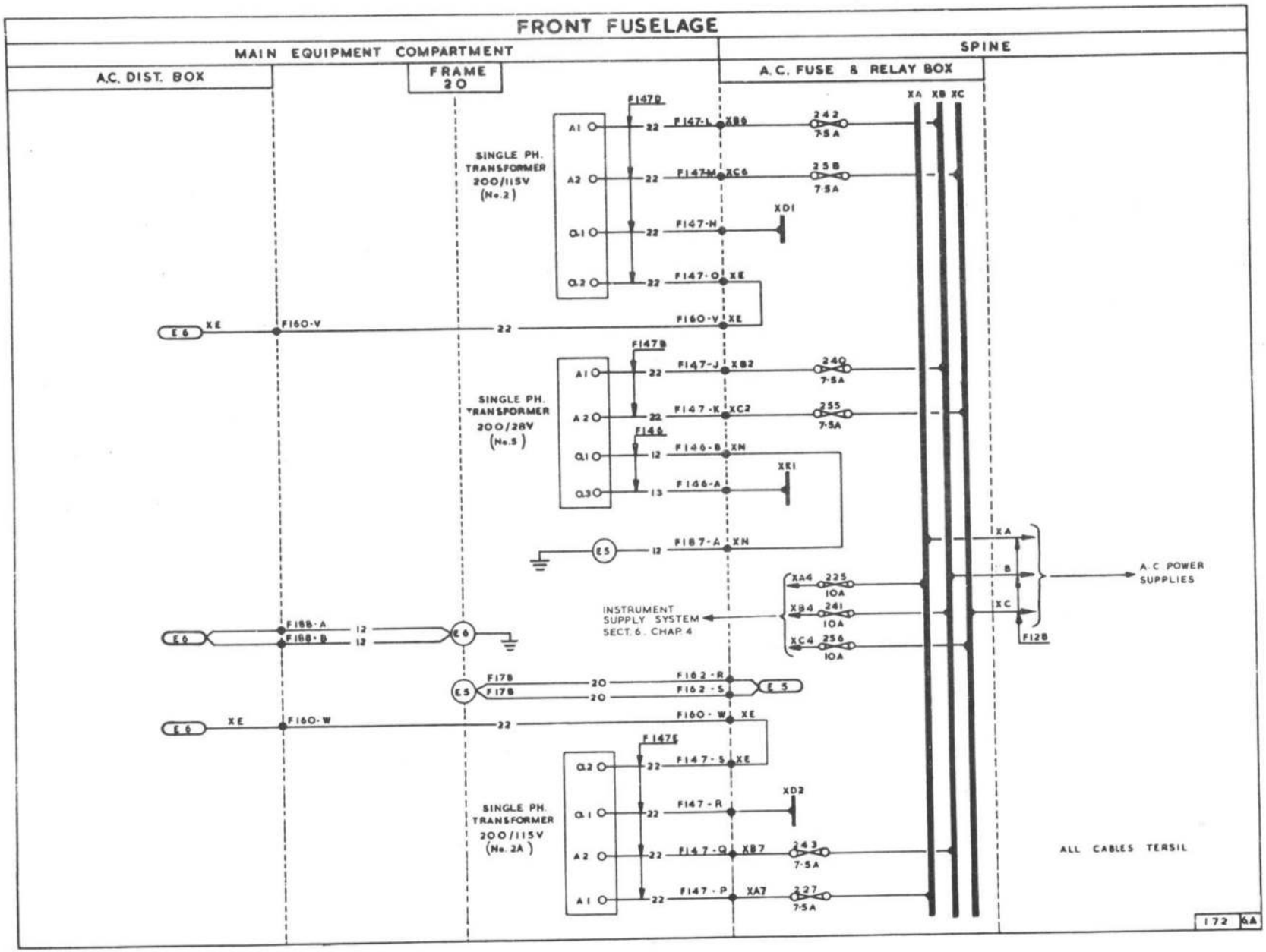

FIG.5. POWER DISTRIBUTION SYSTEM

Appendix I MODIFICATION 2160, 4092, 4160, 4240, 4551

LIST OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

DESCRIPTION

General

1. The main source of a.c. power in the aircraft is a 200-volt, 3-phase, 400 Hz brushless generator providing a rated output of 20/28 kVA. The generator is coupled to a gearbox which is driven by the speed-controlled air turbine unit which also drives the d.c. generator. Supplies for the a.c. operated instruments are derived from the main busbars as described in Chap.4. A description of the a.c. power supplies for the A.I.23 system will be found in Chap.11. Provision is made for connecting a ground supply, the circuit being so arranged by interlocking that the possibility of connecting both aircraft and ground supplies at the same time is avoided.

Generation system

2. The system comprises the following units interconnected as shown in the circuit diagram: -

Generator
Control panel
Voltage regulator
Main contactor
Undervoltage/phase sequence unit
Contactor
Generator field crash relay
Main contactor slave relay
Underspeed relay
Earth fault detector relay
Turbine stall warning switch
Reset switch
Lock-out relay
◄ Overfrequency warning indicator switch ►

Air turbine unit

3. The turbine unit, located in the rear fuselage, port side, runs at a speed of approximately 16,000 rev/min when supplied with compressed air from both engines. Non-return valves are fitted into each supply line as a protection in case of failure of one engine, or during engine runs when one engine is stopped or idling. The speed is controlled by guide vanes which are adjusted automatically by a governor embodied in the unit. The turbine drives the generator through a reduction gearbox at a speed of 12,000 rev/min. It also drives a fan to provide cooling air during ground running, taxying and take-off. In flight a simple flap valve by-passes the fan and cooling is by ram air. Further information regarding the air turbine unit and its installation can be found in A.P.101B-1004-1A and also in A.P.2204A.

A.C. generator

4. The generator, Type AE.2071, is a three-stage machine consisting of pilot exciter, main exciter, and main generator respectively. The rotor carries a permanent magnet, main exciter windings and rectifiers, and the main generator field windings. Wound on the stator are the pilot exciter and the main exciter field coils, and the output windings of the main generator.

5. When the generator is driven by the engines through the air turbine unit and gearbox, single phase a.c. is generated in the pilot exciter by means of a rotating permanent magnet, the supply being fed via the generator field relay to the voltage regulator. Here a thyrister bridge pulse-width modulator converts it into unidirectional pulses which are fed to the main exciter field. The main exciter is a three-phase star connected winding, the output of which is half-wave rectified by the rotating rectifiers to supply power to the output field coils.

Control panel

◄ 6. The Type AE.7014, Mk.2 control ► panel, located in the spine, incorporates a power transformer, a group of rectifiers, transistorized undervoltage/phase sequence and overvoltage units in the form of printed circuits, and an undervoltage slave relay. Under operating conditions, the transformer supplies 200 volts by separate windings to the printed circuit units and, via the rectifiers, a 28-volt d.c. supply for the control circuit. Full details of the control panel will be found in A.P. ◄ 113D-0735-16. ►

Voltage regulator

7. The automatic voltage regulator, Type AE.7311, receives single-phase a.c. from the pilot exciter stage of the generator and converts it into unidirectional pulses by means of a thyrister bridge pulse-width modulator which is controlled by an error-sensing circuit connected to the 3-phase, 200-volt output of the generator. These pulses are then fed to the field winding of the main exciter, and changes in their width provide control of the field current. The regulator is miniaturized, containing nine individual

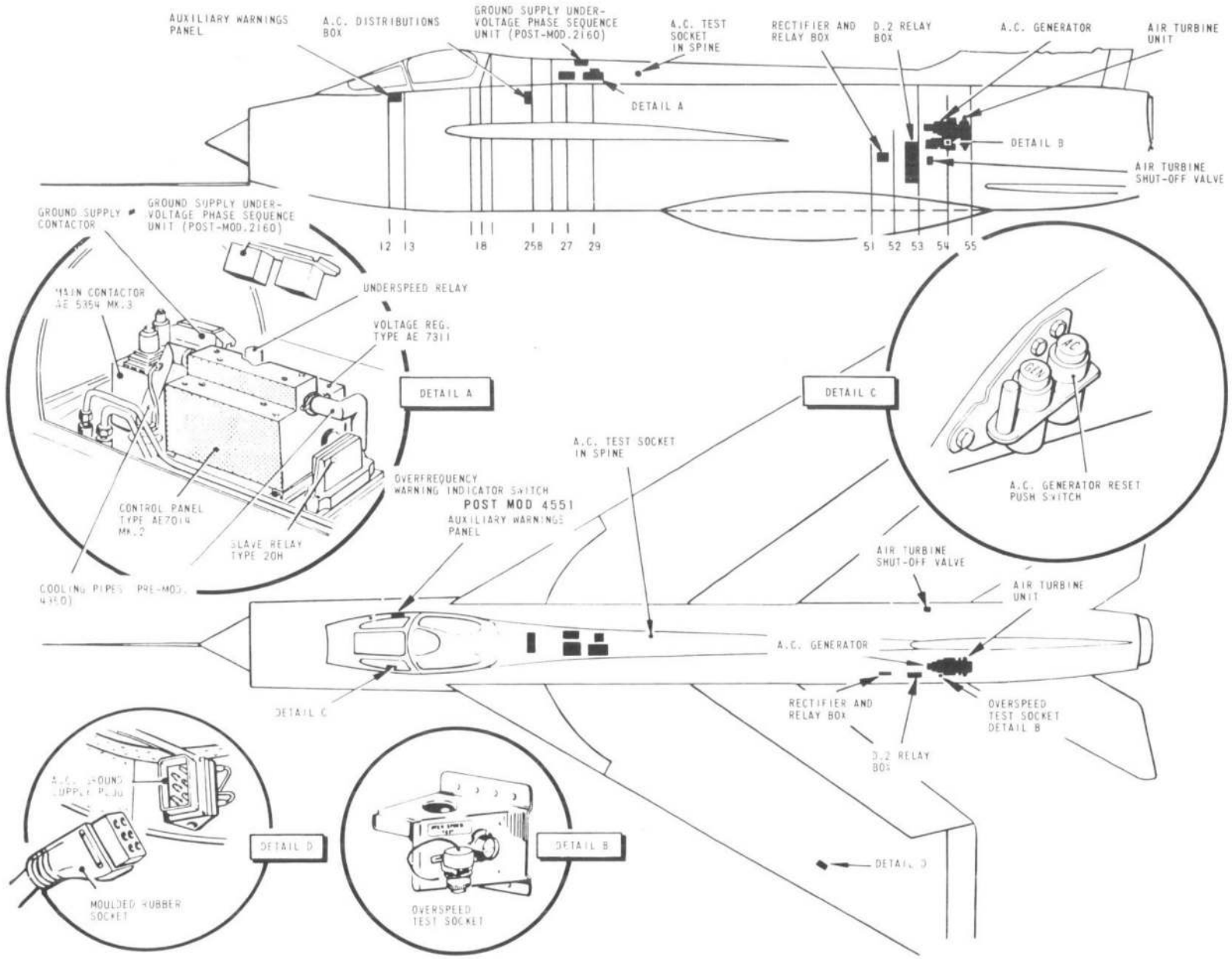

FIG. 1. A.C. POWER SUPPLY EQUIPMENT

◀ Mod. 2160, 4092, 4240, 4511 ▶

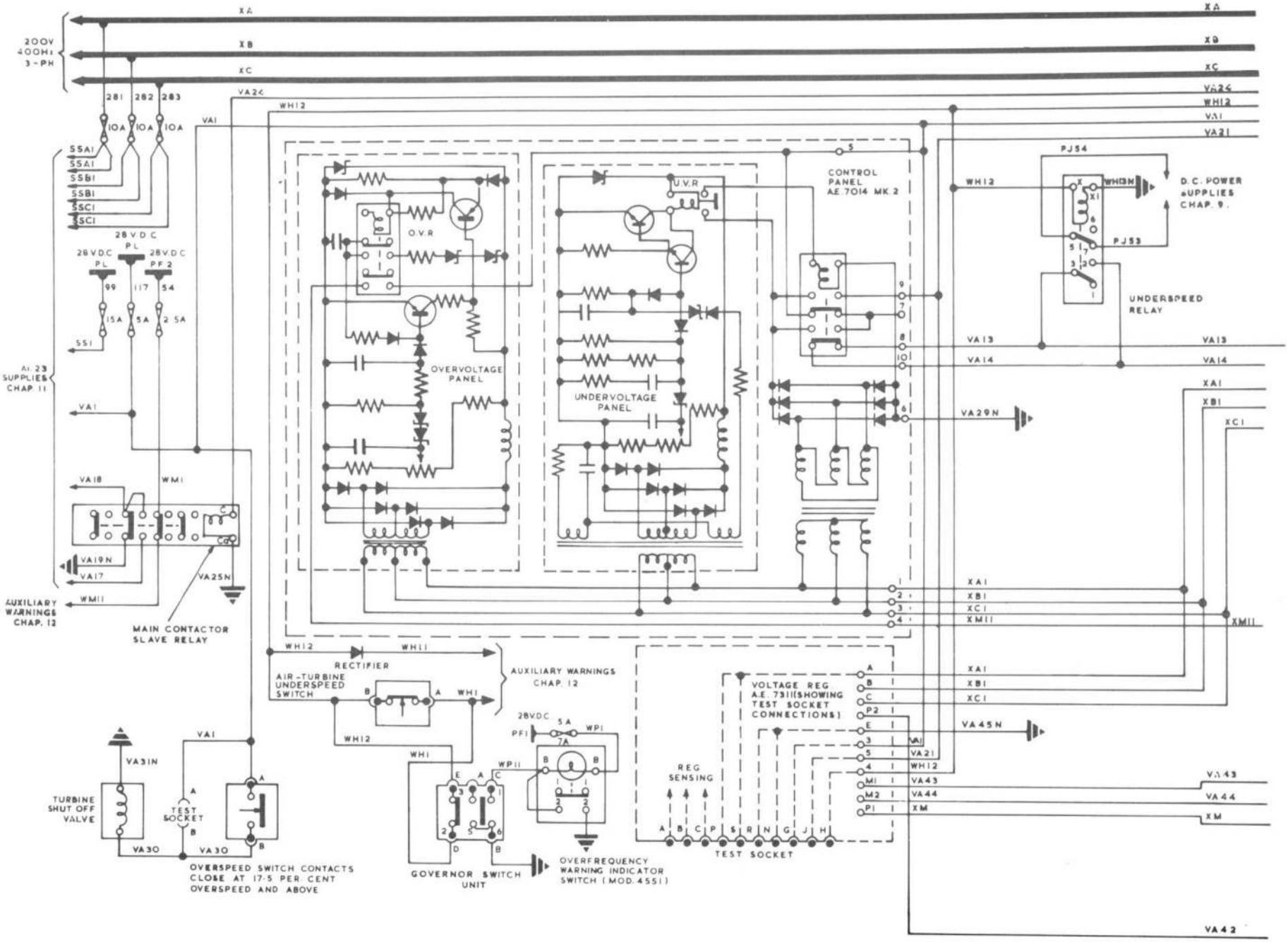

FIG. 2. A.C. POWER SUPPLY SYSTEM

◀ MOD. 2160, 4049, 4092, 4160, 4240, 4494, AND 4551 ▶

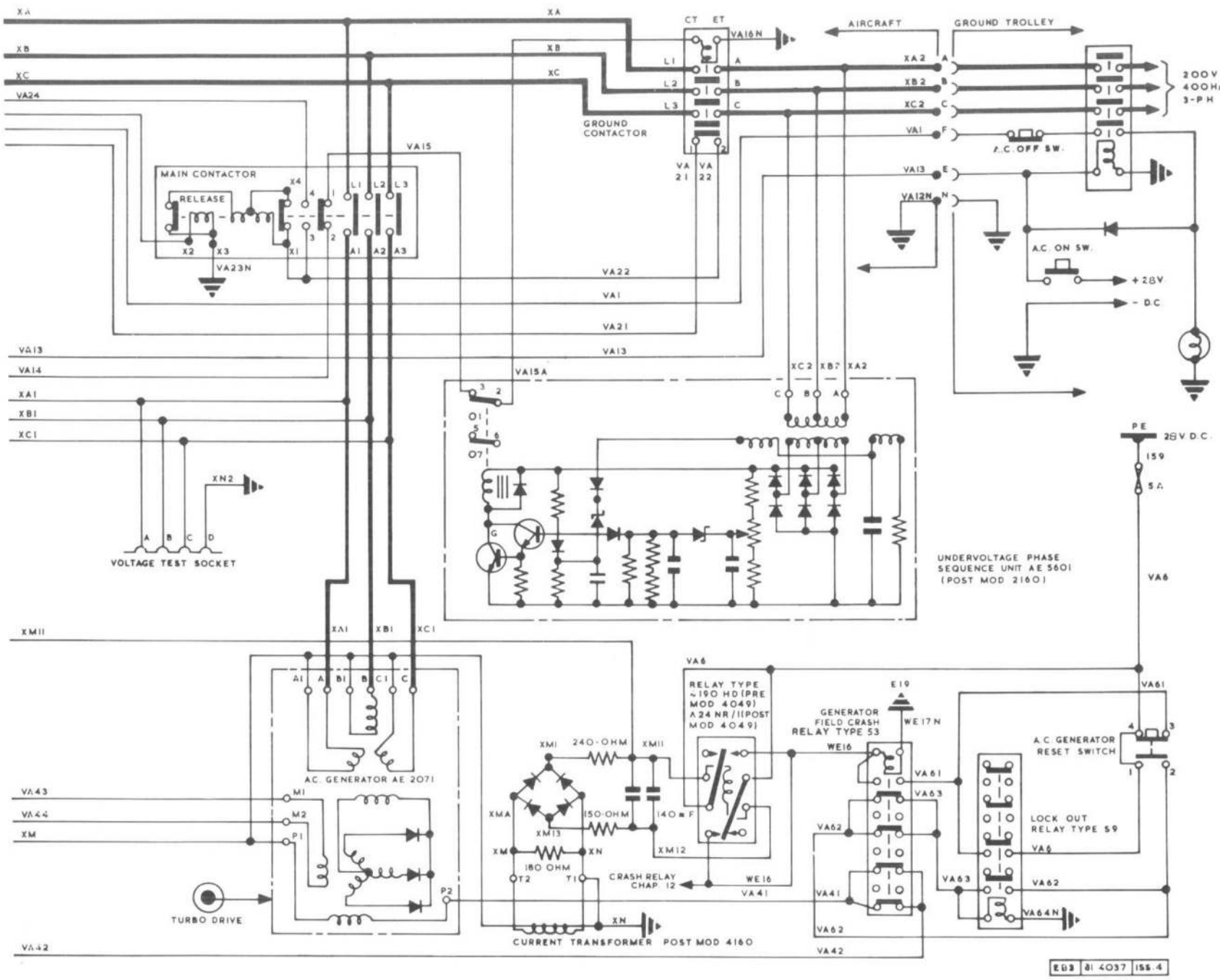

FIG. 2A. A.C. POWER SUPPLY SYSTEM

◀MOD. 2160, 4049, 4092, 4160, 4240, 4494 AND 4551▶

encapsulated modules covering the following stages of regulation.

Module 1	Voltage sensing and reference
Module 2	Power supplies
Module 3	Pulse injection and phase shift
Module 4	Differential amplifier (3 separate modules)
Module 5	S.C.R. gate firing (2 separate modules)
Module 6	Feedback circuits

Main contactor

8. The 3-phase a.c. supply circuit from the generator output terminals to the distribution system is controlled by a Type AE.5354, Mk.3 contactor unit located in the rear fuselage spine. The contactor is solenoid-operated and is fitted with an economy winding which is switched into circuit by a pair of auxiliary contacts. A separate release relay, built in as an integral part of the contactor will, when energized, override the closed coil. The operation of the contactor is electrically interlocked with the ground supply contactor to prevent the ground and aircraft supplies being paralleled.

Main contactor slave relay

9. Fitted in the rear fuselage spine, the slave relay controls part of the A.I.23 circuit and the a.c. failure warning lines. During normal operation with the generator on line, the relay is energized by a rectified a.c. voltage fed from the Type AE.7014, Mk.2 control panel. Failure of the a.c. de-energizes the relay, and its contacts complete circuit WM1–WM11, which lights the A.C. warning indicator on the auxiliary panel.

Ground supply contactor

10. This Type 6703/2 contactor is located in the rear fuselage spine and provides the link between the a.c. ground supplies and the main busbars XA, XB, XC.

Ground supply undervoltage phase-sequence unit (post Mod.2160)

11. A Type AE.5601 undervoltage phase-sequence unit is installed in the hinged cover above the a.c. control equipment in the spine. Its operation ensures that an a.c. ground supply cannot connect to the aircraft busbars unless the phase-sequence and voltage are correct.

12. The unit comprises an assembly of transistors, resistors and capacitors. The transformer primary is connected to the busbars between the ground supply plug and the ground supply contactor and, providing voltage and phase-sequence are correct, the relay will become energized, its contacts 1 and 2 closing to complete the coil circuit of the ground supply contactor. With low voltage or incorrect phase-sequence present, the relay will be de-energized, its contacts will open, and tripping of the ground supply contactor will occur.

Underspeed relay

13. The underspeed relay fitted adjacent to the voltage regulator in the rear fuselage spine prevents malfunction of the voltage regulator and the main contactor circuit during the period in which the generator is running up to full speed.

Overfrequency warning indicator switch (post Mod.4551)

14. The overfrequency warning indicator switch is fitted on the starboard instrument panel and connected to the air-turbine governed switch on the turbo-generator. With the turbo-generator running at 10 per cent overspeed and above, a warning is given by means of a lamp lighting in the indicator switch.

OPERATION

Ground supply operation

15. With a suitable ground supply trolley connected and running, a 24/28 volt d.c. supply available on the aircraft, and the engines stationary, pressing the trolley A.C.–ON switch button will supply 28 volt d.c. from the trolley to the coil of the trolley contactor and pin E of the ground supply plug.

16. Operation of the trolley contactor completes the a.c. supplies to the ground supply plug, and a hold-on circuit to the coil of the contactor and pin E of the ground supply plug via fuse 117, in the d.c. feeder fuse panel, circuit VA1, pin F of the ground supply plug, the closed contacts of the A.C.–OFF switch and a rectifier. Simultaneously the hold-on circuit illuminates the trolley indicator lamp.

17. The pin E supply is used to energize the Type 6703 ground supply contactor

thus putting the ground supply on to the main distribution busbars XA, XB, XC. The operational circuit for this being from pin E, VA13, terminals 8–10 on the control panel or terminals 2–3 of the underspeed relay, VA14, the closed contacts 2–1 of the main contactor, VA15, closed contacts 1–2 of the ground undervoltage phase-sequence unit, VA15A to the coil of the ground supply contactor.

Note...

The relay in the undervoltage phase sequence unit will energize only if phase-sequence and voltage of the ground supply are correct.

18. Operation of the A.C.–OFF switch button on the ground trolley de-energizes both the trolley contactor and the aircraft ground supply contactor so that the ground supply is isolated. Under normal operating conditions the ground supply is automatically disconnected by the opening of the ground supply contactor whenever the main contactor closes.

Aircraft generator supply operation

19. As the turbine speed increases and the generator output builds up, supplies are fed to the control panel and the voltage regulator via lines XA1, XB1, XC1. At approximately 170 volts, provided phase rotation is correct, the contacts of the undervoltage phase sequence relay in the control panel will close. The rectified 28 volt output from the secondary winding of the transformer is then fed through the undervoltage phase sequence relay to energize the undervoltage slave relay coil.

20. As the undervoltage slave relay closes, the underspeed relay, the solenoid of which is energized via the governor switch (WH12), maintains a supply to the trip coil of the main contactor, preventing it from closing, and also maintains the ground supply contactor until the turbine attains its controlled speed.

21. When the governor switch contacts open, the underspeed relay opens, the main contactor trip coil is de-energized, and the ground contactor opens. The d.c. supply from the rectifiers is fed via the undervoltage slave relay, terminal 9, VA21, the auxiliary contacts of the ground supply contactor, VA22, and the 'close' coil of the main contactor which then closes to connect the generator voltage to the main busbar distribution system. At the same time VA22 is passed through the main contactor to VA24 and energizes the main contactor slave relay. This relay fulfils two functions, i.e. it operates in the A.I.23 circuit *(Sect.9, Chap.3)*, and breaks the WM1–WM11 line to the a.c. indicator on the auxiliary warnings panel. This warning and also the TURB warning will go out, indicating that the underspeed switch on the governor has broken and that the generator is on line.

Voltage regulation

22. The output voltage of the generator is controlled by the Type AE.7311 automatic regulator. Single phase a.c. produced by the pilot exciter stage of the generator is fed through the thyrister bridge pulse-width network of the regulator, where it is controlled and modulated by an error signal from a sensing circuit connected to the 3-phase, 200-volt lines of the generator. The resultant voltage appearing as unidirectional pulses of variable width depending on the excitation regulation, is fed to the field windings of the generator main exciter, thus controlling the output to the main distribution system at a nominal 200 volts.

Protective circuits

Undervoltage

23. When the input to the control panel drops to approximately 170 volts, the undervoltage phase sequence unit relay will open, dropping out the undervoltage slave relay, which in turn breaks the line VA21-VA22 to the 'close' coil of the main contactor which opens, thus isolating the generator lines from the main busbars.

Overvoltage

24. Should overvoltage conditions arise, the associated overvoltage unit in the control unit comes into operation causing its relay to close and lock-in via resistors. A delay network prevents inadvertent operation due to transient voltages. Operation of the overvoltage relay breaks the generator field circuit by energizing the earth fault detector relay through terminal 5 of the control unit, the closed contacts of the relay, terminal 4, and XM11. The action of the earth fault relay operates the generator relay and breaks the field circuit of the generator which comes off line. To prevent cycling of the generator the generator relay

remains energized by a d.c. voltage through the reset push switch.

Overfrequency

25. At 17.0 per cent overspeed, contacts A–B of the overspeed switch close and energize the air shut-off valve. This shuts down the turbine unit with the consequent loss of the generator supply. The turbine will remain in this condition owing to the shut-off valve being mechanically self-locking. The valve can only be manually reset on the ground.

Underfrequency

26. As the turbine unit slows down and the frequency drops, the nozzle guide vanes will open to the position where the turbine is about to run below its normal operating level. At this point the underspeed switch on the governor unit operates, tripping the main contactor via line WH1–WH12, and bringing on the TURB indicator on the auxiliary warnings panel. Tripping of the main contactor automatically trips the main contactor slave relay to complete the circuit to the a.c. failure warning indicator. The underspeed relay also receives a positive supply through the WH12 line to hold in the ground contactor as well as operating in the undervoltage circuit of the d.c. system *(Chap.9)*.

Earth faults (post Mod.4160)

27. To protect the generator against earth faults up to the circuit fuses the generator star point, A1, B1 and C1, is connected to earth via a current transformer, on frame 53 in the port aft equipment compartment, the output of which is connected to a rectifier and bridge circuit and the coil of the earth fault relay. An earth fault current greater than 65 amp will generate a voltage in the current transformer sufficient to upset the bridge circuit and energize the earth fault relay and, subsequently, the generator field relay which in operating, breaks the generator field circuit causing the generator output to collapse and the earth fault relay to de-energize.

A.C. generator reset

28. The generator can be brought back on line by operating the A.C. reset switch on the port shroud extension panel at the side of the cockpit. This action de-energizes the generator relay, and the P2 line is restored to the circuit. At the same time the lockout relay is energized and a hold-on circuit is completed via its contacts 1 and 1a. When the switch is released the circuit to the coil of the lockout relay is interrupted and the relay becomes de-energized. In the event of a fault condition persisting whilst the reset switch is held depressed, the above sequence of events takes place but, as the generator output builds up, the earth fault relay will again become energized completing the circuit to energize the generator field relay which will hold in through a pair of contacts of the lockout relay, thus preventing the system from cycling.

Test facilities

29. Test points for the system are brought out to a plug and socket connection on the voltage regulator. With a suitable test box connected, it is possible to simulate the under and over-voltage and earth fault conditions and prove the associated trip circuits are operating correctly.

◄ **Overfrequency warning indicator switch (post Mod.4551)**

30. When the turbo-generator is running at 10 per cent overspeed and above, contacts 1 and 6 on the air turbine governed switch close and the lamp in the over-frequency warning indicator switch will light. To test the lamp and the circuit supply, depress the cover on the switch/lamp holder. ►

SERVICING

WARNING

The relevant safety precautions detailed on the LETHAL WARNING marker card must always be observed before entering the cockpit or performing any operations upon the aircraft.

General

31. In addition to normal operational and continuity checks, a full functioning check of the a.c. generating system is given in the following text.

Check on a.c. generating system

Equipment required

32.

1. 400 Hz test set, Ref.No.5PQ/3198
2. A.C. generating system test box
3. A.C. voltmeter, 0–300 volts
4. Suitable a.c. ground supply

Note...

An a.c. test and meter box Type

6J11/820 may be used as a substitute for items 2 and 3.

Preparation

33.

(1) Fit a 10 amp test fuse in the a.c. generating system test box and connect the box to the test socket on the voltage regulator Type AE.7311.

(2) Select TRIP on the OV/UV selector switch; ensure that all other switches are in the OFF position and that the trimming potentiometer is turned fully clockwise.

(3) Connect the a.c. voltmeter to the terminals on the test box.

(4) Connect the 400 Hz test set to the voltage test socket in the rear fuselage spine.

(5) Connect the ground supply to the associated socket in the port wheel well.

Note...

If the a.c. test and meter box is used connect to the voltage socket in the rear fuselage spine and connect the 400 Hz test set to the a.c. test and meter box.

Procedure

34.

(1) Switch ON ground supplies, operate BATTERY MASTER switch and switch ON ENGINE MASTER switch.

(2) Check that the A.C., TURB and GEN warnings are illuminated.

(3) Start No.2 engine, run up and maintain speed at 65 per cent rev/min.

(4) Generator should build up to 200-volts -0 +2 per cent as measured on the 400 Hz test set.

(5) Switch the test set to phase rotation and check that it indicates correctly.

(6) Switch the test set to frequency. This should read 400-410 Hz.

(7) Select OV/UV selector switch on the a.c. generating system test box to OFF. Check that the A.C. and TURB warnings are extinguished, and the ground supply is not supplying load.

(8) Select the 400 Hz test set to read 3-phase mean volts. This should be within the limits 0 to +2 per cent.

(9) Switch the meter to read, in turn RED-WHITE, WHITE-BLUE, BLUE-RED. Each reading should be within the limits ± 1 per cent of that obtained in (8).

(10) Using the a.c. generating system test box, select OV TRIP. The generator voltage should build up and drop off as soon as the overvoltage trip system operates. The TURB and A.C. failure warning indications should both appear and the ground supply should come on line.

(11) Adjust potentiometer on test box until the generator trips on overvoltage. This should be at 218± 4 volts as indicated on the voltmeter. Return the potentiometer to the fully clockwise position.

(12) Depress and hold A.C. generator reset switch in cockpit. The generator voltage should again build up and then collapse as the overvoltage relay operates. No cycling of the overvoltage relay should occur.

(13) Release the reset switch, return the OV/UV selector switch on the a.c. generating system test box to OFF and select the 400 Hz test set to read 3-phase mean volts. The TURB warning should extinguish.

(14) The generator voltage may again build up and collapse when the A.C. reset switch is released, if so, momentarily depress the A.C. reset switch. The generator voltage should build up to 200-volts -0 +2 per cent and come on line and the A.C. failure warning should extinguish. Check that the ground supply rig is not supplying load.

(15) On the a.c. generating system test box, turn the potentiometer fully clockwise and select UV on the OV/UV selector switch. Reduce the generator voltage using the potentiometer.

(16) Main contactor should open at 173 ± 4 volts as indicated on the voltmeter. Indicator lamp on test box should extinguish A.C. failure warning lamp should illuminate and ground supply should come on load.

(17) Increase generator voltage using test box potentiometer until contactor

closes. This should be at 178 ± 6 volts and the A.C. failure warning lamp should extinguish. Check that the ground supply rig is not supplying load.

Note...

The difference between the contactor opening and closing voltages should not be less than 1 volt.

(18) Return the OV/UV selector switch to OFF. Generator voltage should increase to 200 volts − 0 + 2 per cent.

(19) Select TRIP on the selector switch and operate the earth switch. The earth leakage detection circuit should operate and shut down the generator.

(20) Depress the A.C. reset switch. The generator should build up and come 'on-line'.

(21) Check 10 amp fuse in test box by operating the fuse check switch. Fuse blown lamp should illuminate.

(22) Select FUSE on the test box and operate the earth switch. The 10 amp fuse should blow and the fuse blown lamp should illuminate. The generator should remain 'on-line'.

(23) Recheck the 3-phase mean voltage as in sub.para.(8). The reading should be within limits of 0 to +2 per cent.

(24) Recheck the line voltages as in para.9. The readings should be within 1 per cent of those obtained in sub. para.(23).

(25) Reduce the engine speed to ground idling. The A.C. failure and TURB warning lamps should illuminate.

REMOVAL AND ASSEMBLY

Generator

35. Removal and assembly of the a.c. brushless generator requires the use of a special handling arm, cradle and hoist. A description of these items, and the procedure adopted for their use, can be found in Sect.3, Chap.8A. Before removal of the generator, the electrical leads must be disconnected and safely stowed so that they are clear of the access panel and not liable to accidental damage during the generator removal and assembly operations.

TABLE 1

Fuses, circuits and locations

Fuse No.	Rating (amp)	Circuit ident	Circuit	Location
◄ 7	5	PF1	Overfrequency warning indicator switch	Starboard instrument panel ►
54	2.5	WM1	A.C. warning circuit	Starboard fusebox
99	15	SS1	A.I.23	D.C. feeder fuse panel
117	5	VA1	Control circuit	D.C. feeder fuse panel
150	5	SS14	A.I.23	Spine
281	10	SSA1	A.I.23	Spine
282	10	SSB1	A.I.23	Spine
283	10	SSC1	A.I.23	Spine
159	5	VA6	A.C. generator reset switch	Emergency services fusebox

FIG. 3. A.C. POWER SUPPLY SYSTEM

(illustration overleaf)

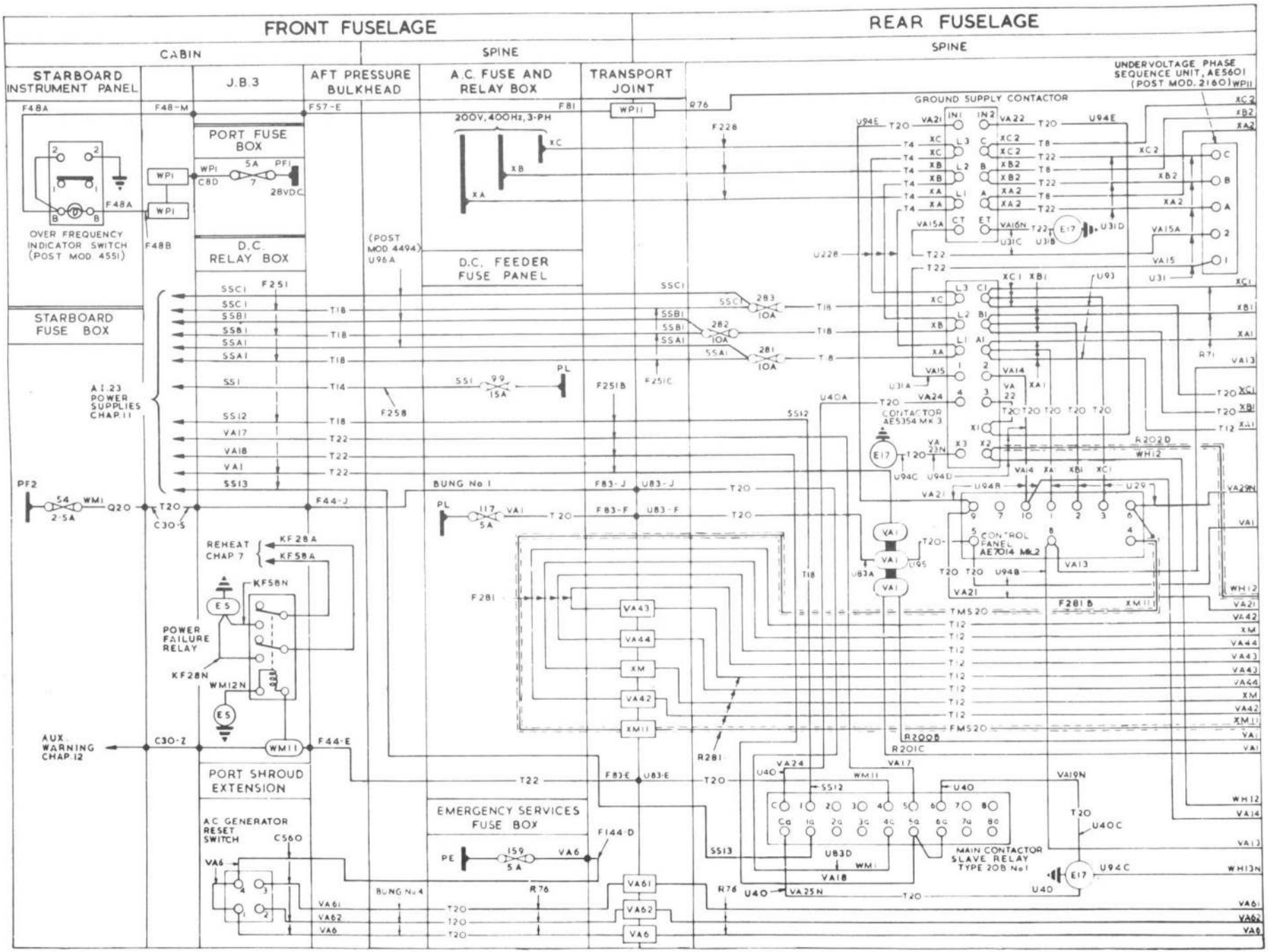

FIG.3. A.C. POWER SUPPLY SYSTEM

◀ MOD. 2160, 4092, 4160, 4240, 4494, 4551 ▶

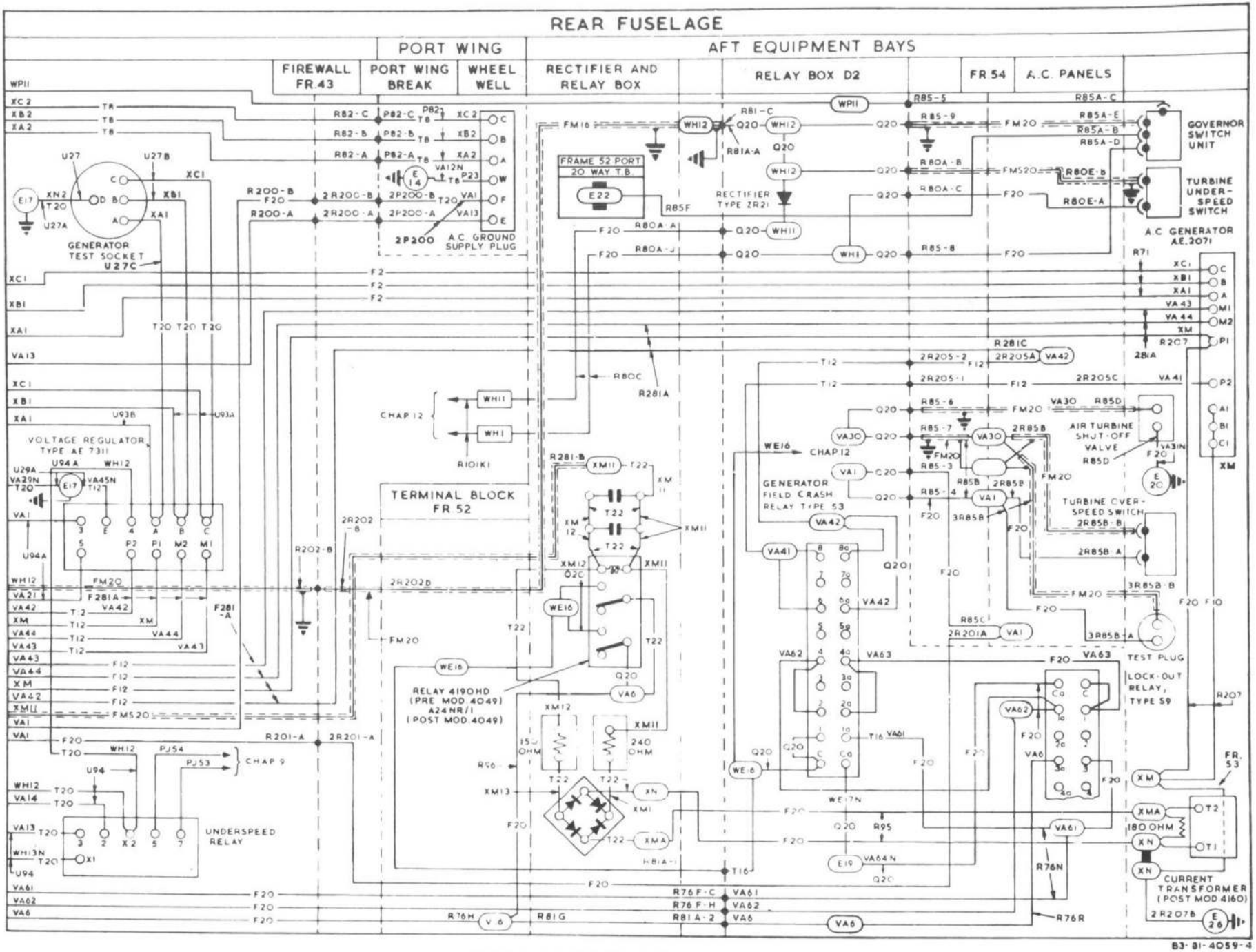

FIG.3A. A.C. POWER SUPPLY SYSTEM

◀ MOD. 4092, 4160, 4240, 4494, 4551 ▶

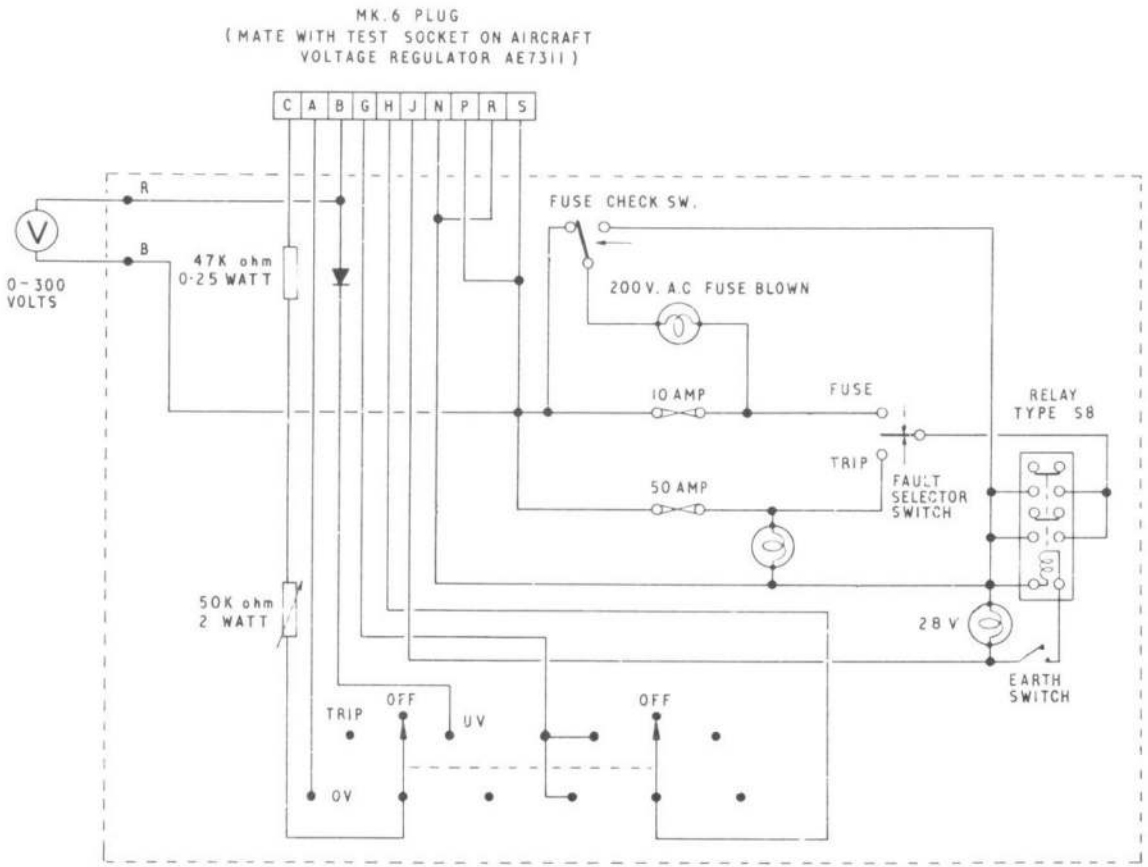

FIG.4. A.C. GENERATING SYSTEM TEST BOX