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Chapter 14

CONTROL AND PROTECTION UNIT, ROTAX, TYPE U3708 AND VARIANTS

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LEADING PARTICULARS

Control and protection unit, Type U3708	*Ref. No.* 5UC/7012
Output voltage	200*V a.c.* ± 2½ *per cent*
Phases	3
Frequency	400 *c/s* ± 2 *per cent*
Load range	0–30 *kVA*
Power factor	*Unity to* 0·9 *lag*
Temperature range	−50 *deg. C. to* + 70 *deg. C.*
Altitude	60,000 *ft.*
Rating	*Continuous*
Cooling	*Blast air at* 2 *lb. per min. (in flight)*
Length (over handle)	11·6875 *in.*
Width	9·125 *in.*
Height	8·375 *in.*
Weight	22 *lb.*

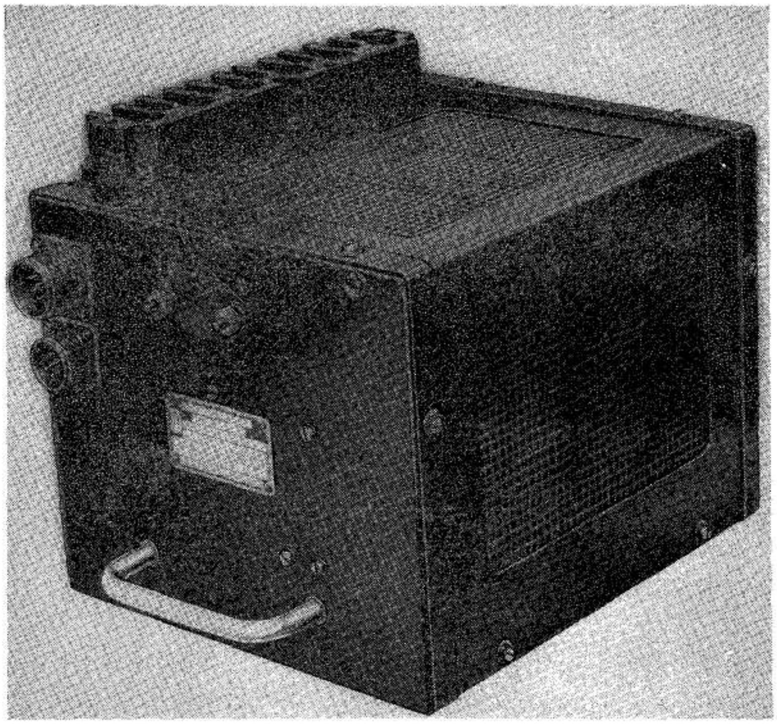


Fig. 1. Control and protection unit, Type U3708

Introduction

1. The Type U3708 control and protection unit (*fig.* 1) is designed to control and protect the 30 kVA a.c. generator, Type N0313, in the turbo-alternator set, Type TGA.30, Mk. 1.

DESCRIPTION

2. The components are housed within an alloy box, the cover of which has perforated panels to provide ventilation.

3. Two chassis, one fixed and the other hinged, are used for mounting the components; by turning the hinged chassis about the hinge pin, access is gained to all components. The components are identified by code symbols which are directly related to the circuit diagram (*fig.* 5).

4. Figures 2, 3 and 4 show the physical layout of the components in the unit.

OPERATION

5. Operation of the U3708 unit is based on the use of magnetic amplifiers, by which means accurate control of the output voltage and effective protection arrangements are achieved.

6. Minor adjustments of the controlled voltage level can be made with the voltage trimmer potentiometer (1RV3) which is located behind the swing cover plate on the front of the unit, above the data plate; adjustments can be made in steps of approximately 1V to ± 9V without the necessity of disturbing the unit cover.

7. Control of the busbar voltage is obtained by a system of operation which is based on the use of magnetic amplifiers. The average of the three line voltages is maintained at 200V r.m.s. ± 2½ per cent. The alternator drive is of constant speed, and thus frequency is held constant at 400 c/s. ± 2 per cent. at a load range of 0–30 kVA.

8. Protection is provided against over-voltage and feeder faults, up to the busbars. The protection circuits employ pilot relays, controlled by magnetic amplifiers, each pilot relay in turn operating an alternator field shorting relay.

9. A voltage pick-up relay, also controlled by a magnetic amplifier, is incorporated to provide a 28V d.c. (positive) supply to an external plug position when the line voltage rises above 185V r.m.s.

10. With the use of feedback windings, each magnetic amplifier is adjusted to develop an infinite gain characteristic thereby providing a 'trigger' action for control of the pilot relay. This produces stability against variations in temperature, frequency and voltage.

11. The unit is equipped with reset/kill and protection facilities.

Voltage control

12. Accurate regulation of the busbar voltage is obtained by closed loop control of the alternator excitation. Two factors affecting this control are (1) the load current delivered by the alternator, and (2) the error between the desired line voltage and the actual line voltage.

13. Field excitation current, proportional to the load current, is derived from the current compounding transformer 1TR1 and rectifier 1MR1. This source of excitation is linear and the alternator characteristic is not; therefore the balance of excitation must be provided by the voltage regulator. A similar condition exists between the alternator excitation requirement, which varies with the power factor of the load, and the output of the transformer 1TR1, which remains stable. Again the balance of excitation is provided by the voltage regulator.

14. Components of the voltage regulator include:—

(1) A voltage sensitive network, comprising two circuits, one containing resistors 1R5,

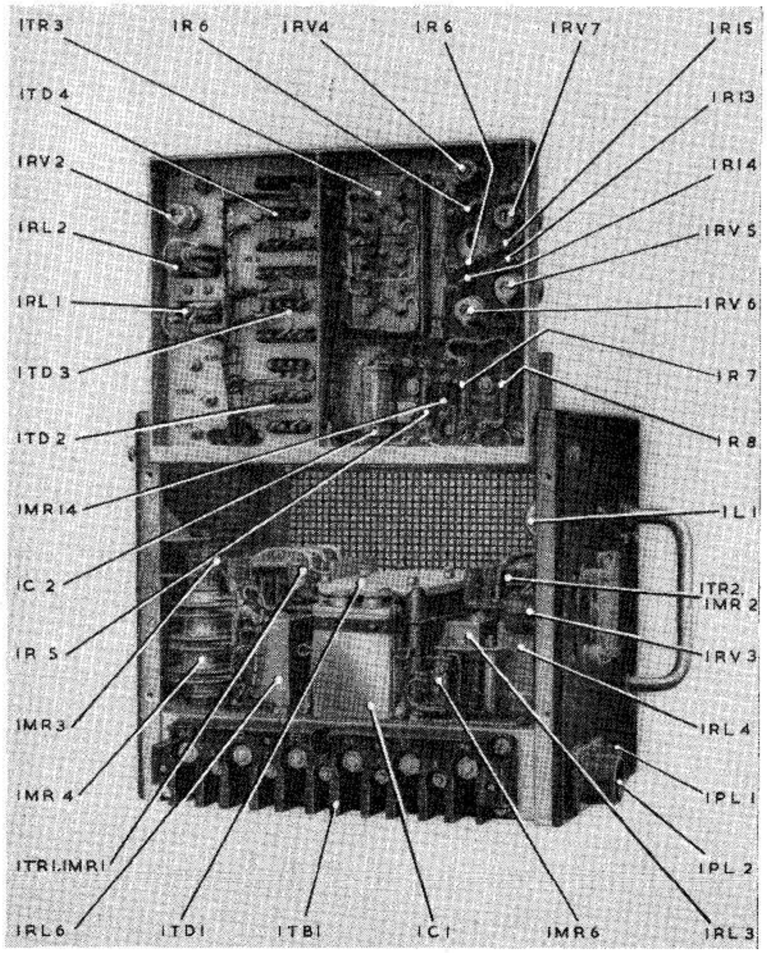


Fig. 2. Layout of components (1)

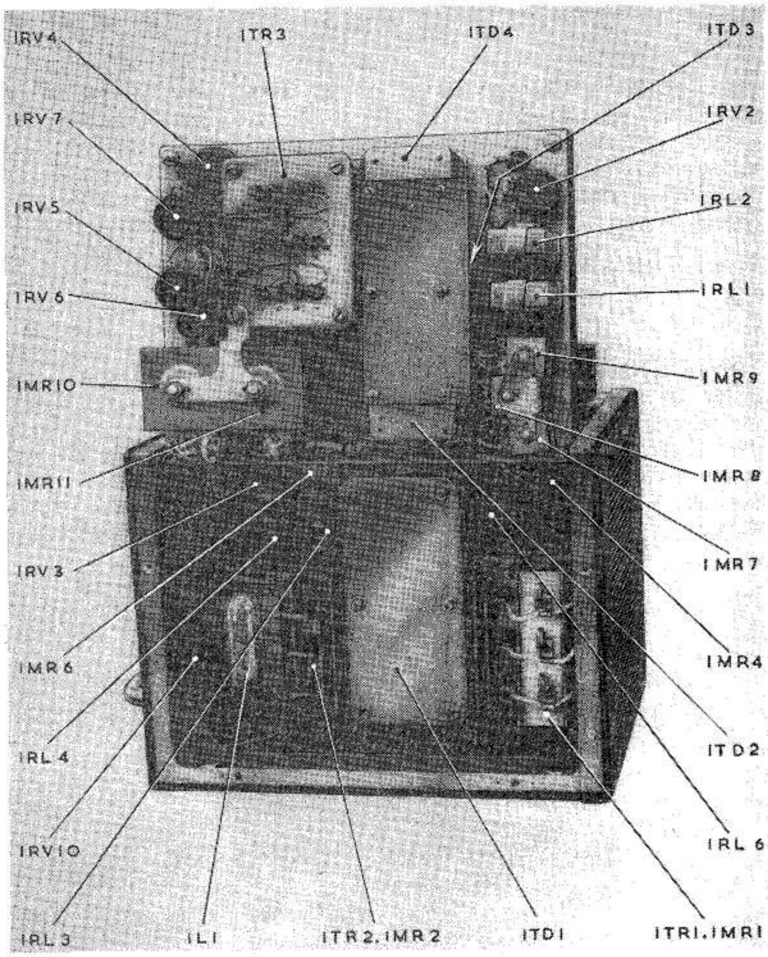


Fig. 3. Layout of components (2)

1R6, and potentiometers 1RV2 and 1RV3, and the other, barretter 1L1.

(2) An error magnetic amplifier containing transductor 1TD2 and rectifier 1MR7.

(3) A power magnetic amplifier comprising transductor 1TD1 and main auto-rectifier 1MR4.

15. The total excitation requirement of the alternator is provided by the combination of the amplified error and power magnetic signals which, in turn, combine with the current compounding output of 1TR1.

16. Sensing of the error between the desired line voltage and actual line voltage is dependent upon the comparison of the two resistive circuits. One circuit, containing 1RV2, 1RV3, 1R5 and 1R6 provides a linear voltage/current relationship whilst the other circuit, containing barretter 1L1, gives an almost constant current. The two signal currents are then fed in opposing senses to the control windings of the error amplifier 1TD2.

17. The resistor circuit is adjusted so that at the required busbar voltage its current is nominally equal to the current in the barretter circuit. In practice a slight unbalance of currents at the desired voltage level obviates the use of a bias winding on transductor 1TD2. Any change in the average of the three r.m.s. line voltages above or below the nominal level is detected by the voltage sensitive network. The error signal is then fed into the error amplifier 1TD2, the output of which is, in turn, fed as a negative control into the power magnetic amplifier (1TD1, 1MR4). The resultant output from 1TD1 and

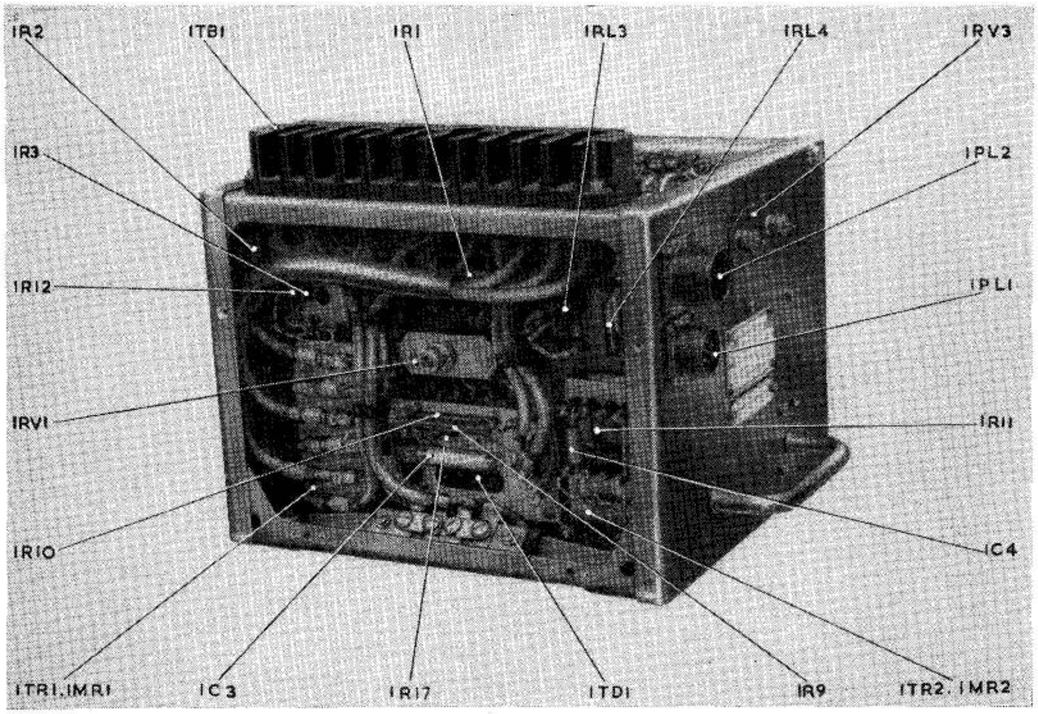


Fig. 4. Layout of components (3)

1MR4 is supplied to the alternator field as the modified excitation contribution of the regulator, thereby correcting the voltage error.

18. The purpose of the error magnetic amplifier (1TD2, 1MR7) is to relieve the duty of the power magnetic amplifier. This improves stability with temperature variation and reduces the overall time constant of the regulator.

19. Bias and negative feedback loops are included to provide optimum operating conditions, e.g., a positive bias signal is applied to 1TD1 to compensate for the standing output of the error amplifier. Stabilization of the closed loop voltage regulating system is provided by transient negative feedback networks passed over each amplifier stage, e.g., a signal proportional to the output current of 1TD2 is derived across the coupling potentiometer 1RV7 and is fed to the control winding of 1TD2 via the network 1C3 and 1R17. Similarly, in the output stage a three-phase voltage, proportional to the field voltage, is applied via rectifier 1MR3 to the control winding of 1TD1 via the capacitor 1C1.

Over-voltage protection

20. Protection against an over-voltage condition is provided at a voltage level of 220 ± 2V r.m.s. The circuit arrangement basically is formed by the combination of transductor 1TD3 and rectifier 1MR8, the output of which is applied to the protection relay 1RL1 which in turn operates the field-shorting relay 1RL3. Positive feedback is applied to 1TD1, thereby providing an infinite gain characteristic resulting in a trigger action for operation of relay 1RL1. Resistor 1R11 is inserted in the circuit to lock the relay.

21. A voltage sensitive network similar to the one described for voltage control is incorporated in this protection arrangement, i.e., the voltage sensing is dependent upon the comparison of two resistive circuits which supply the respective control windings of 1TD3. One resistive circuit of the network, comprising 1R8, 1R13, 1R14 and 1RV6, provides the linear voltage/current relationship, whilst the other circuit, incorporating barretter 1L1, provides the constant current signal. Both the resistive circuits are fed from the output of rectifier 1MR11.

22. At the nominal supply voltage the circuit is adjusted so that 1RL1 is de-energized. If the line voltage rises above the required 220 $\pm$ 2V, transductor 1TD3 saturates, energizing 1RL1. This subsequently isolates the alternator from the busbars, and also de-energizes 1RL3, so restoring the field short and de-energizing the alternator. An inverse time characteristic is achieved by short-circuiting windings on 1TD3, to prevent inadvertent operation of the over-voltage protection circuit during load switching.

Feeder protection

23. Protection against line to line and line to neutral faults is provided by use of a modified Merz-Price system. Two three-phase, delta connected transformers are employed, one (2TR1) being situated adjacent to the alternator star point circulating current (in the alternator terminal block) and the other (3TR1) close to the busbars; the resultant output of these transformers is fed into the three-phase bridge rectifier 1MR6.

24. Under normal operating conditions a state of balance exists between the two transformers, and the output of 1MR6 is sensibly zero. A feeder fault up to the busbar increases the output of 2TR1 above that of 3TR1. A potential is then applied to rectifier 1MR6 and the output of 1MR6 is applied to the control windings of protection transductor 1TD3 and is interpreted as an over-voltage condition. Relay 1RL1 is energized and 1RL3 subsequently de-energized thereby short-circuiting the alternator field to switch off the alternator. Rectifier 1MR14 is included in the control circuit to prevent the protection system from accepting inappropriate (small) signals.

Reset/kill facility

25. Incorporated into the protection circuit is an electrical latching arrangement. If the pilot relay 1RL1 operates due to fault conditions, a circuit is completed by means of normally open contacts on the pilot relay, which feeds the relay coil from an external battery source. This prevents 1RL3 being re-energized and removing the field short, as the generated voltage falls.

26. A reset relay 1RL4 is provided to break the hold-on supply to the protection relay. The ends of the reset relay coil are brought out to pins C and H on plug 1PL2 and hence to a double pole switch in the external circuitry.

Protection test facility

27. Over-voltage conditions may be simulated for protection tests by short circuiting resistor 1R8 which is in the linear resistor arm of the protection transductor voltage sensing circuit. Both ends of the resistor are brought out to studs on the terminal block and subsequently to a spring loaded switch.

Voltage pick-up relay

28. The voltage pick-up relay 1RL2 operates in a manner similar to the over-voltage protection pilot relay 1RL1 (*para.* 20 *to* 22). The control signals of the magnetic amplifier (1TD4 and 1MR9) are adjusted so that 1RL2 operates when the line to line voltage rises to 185V and above. At this voltage, a 28V d.c. (positive) supply from an external source is fed from a pair of normally open contacts on 1RL2 to pin E of 1PL2. This 28V d.c. supply is used to control the a.c. feeds to the aircraft equipment.

29. The control signal is adjusted to be insensitive to transient voltages caused by load switching.

INSTALLATION

30. The unit must be mounted base downwards and secured by four 0·250 in. B.S.F. stiff anchor nuts located in the base of the unit.

31. Electrical connections are made via two plugs mounted on the front of the unit and a terminal block mounted on top of the unit.

SERVICING

32. Servicing of these units will normally be restricted to checking security of connections and that no damage is apparent. Where it is obvious that such components as transformers, rectifiers etc. are unserviceable, these components will need renewal. A list of components is given in Table 1.

Insulation resistance tests

33. Common together poles A, B, C, D, E, and F on a 7-pole socket for 1PL1 and poles A and G on a 10-pole socket for 1PL2. With flying leads and crocodile clips common together terminals A7, B7, C7, B9, and B10 on 1TR3 and terminals X, X1 and 1 on 1TB1. Bring out these connections as a common lead.

34. On the socket for 1PL2 common together poles C and H and bring out as a common lead and bring out SEPARATE leads from poles D, E, and F.

35. Common together terminals A1, B1, C1, on 1TB1 and terminals A1, B1, and C1 on 1TR2 and bring out the connections as a common lead.

36. Common together terminals A3, B3, C3, C9, and C10 on 1TR3 together with terminals 2 and 3 on 1TB1. Bring out the connection as a common lead.

37. Common together terminals A9 and A10 on 1TR3 and bring out the connection as a common lead.

38. Connect all but the first commoning lead (e.g. the lead denoted in para. 33) to a suitable point on the chassis and with a 250V insulation resistance tester check the insulation resistance between the first commoning lead and the chassis. The reading must not be less than 3 megohms.

39. With the same instrument, repeat the insulation resistance tests between each of the remaining commoning leads in turn, with the other leads connected to the chassis; the reading in each instance must not be less than 3 megohms.

Table 1
Circuit component details

Cir. Ref.	Description	Value		Rotax No.
1R1	Bias resistor	620 ohms	3W	
1R2	Feedback load resistor	10K	$4\frac{1}{2}$W	
1R3	Gain limiting resistor	390 ohms	$1\frac{1}{2}$W	
1R5	Signal resistor	100 ohms	3W	
1R6	Signal trim resistor	33 ohms	$1\frac{1}{2}$W	
1R7	Under voltage resistor	120 ohms	3W	
1R8	Over voltage resistor	150 ohms	3W	
1R9	Starting resistor	6·8 ohms	6W	
1R10	Starting resistor	6·8 ohms	6W	
1R11	Relay hold resistor	680 ohms	$1\frac{1}{2}$W	
1R12	Field short ballast resistor	1·2K	3W	
1R13	Over voltage trim resistor	22 ohms	$1\frac{1}{2}$W	
1R14	Over voltage trim resistor	22 ohms	$1\frac{1}{2}$W	
1R15	Under voltage trim resistor	22 ohms	$1\frac{1}{2}$W	
1R16	Under voltage trim resistor	22 ohms	$1\frac{1}{2}$W	
1R17	Current feedback resistor	1·5K	$1\frac{1}{2}$W	
1R19	Ballast resistor	680 ohms	$1\frac{1}{2}$W	
1RV1	Output bias control	350 ohms	$\frac{1}{2}$W	
1RV2	Signal control course	25 ohms	$\frac{1}{2}$W	
1RV3	Signal control fine	25 ohms	$\frac{1}{2}$W	
1RV4	Merz-Price trim	100 ohms	$\frac{1}{2}$W	
1RV5	Under voltage trim	25 ohms	$\frac{1}{2}$W	
1RV6	Over voltage trim	25 ohms	$\frac{1}{2}$W	
1RV7	Coupling control (208V)	450 ohms	$\frac{1}{2}$W	
1RV10	Relay operate control	650 ohms		

Table 1—*continued*

Cir. Ref.	Description	Value	Rotax No.
1C1	Feedback capacitor	15μF 150V D.C.	
1C2	Isolating capacitor	1μF 150V D.C.	
1C3	Current feedback capacitor	40μF 12V D.C.	
1C4	Output transductor control winding capacitor	10μF 6V D.C.	
1MR1	Compounding rectifier	(see 1TR1)	
1MR2	Excitation rectifier	(see 1TR2)	
1MR3	Feedback rectifier		
1MR4	Main auto rectifier		
1MR6	Merz-Price rectifier		
1MR7	Pre-amp rectifier		
1MR8	Protection rectifier		
1MR9	Indication rectifier		
1MR10	Contactor supply rectifier		
1MR11	Signal rectifier		
1MR12	Blocking rectifier		
1MR14	Merz-Price shaping rectifier		
1RL1	Protection relay	2M 2B	
1RL2	Under voltage relay	1 c/o 1B	
1RL3	Field shorting relay	2M 2B	
1RL4	Lock-out relay	4B	
1RL6	Separate excitation relay	2M 2B	
1TR1	Compounding transformer		P7340
1TR2	Excitation transductor		P7405
1TR3	Supply and reference transformer		P7501
1TD1	Excitation transductor		P7103
1TD2	Pre-amp. transductor		P7201
1TD3	Protection transductor		P7002
1TD4	Indication transductor		P7003
1PL1	A.C. protection lines plug		
1PL2	D.C. control lines plug		
1TB1	Terminal block		
1L1	Barretter		
2ALT1	A.C. generator		N0313
2TR1	Merz-Price transformer		Part of N0313
3TR1	Merz-Price transformer		P6601

P30591 553547/3934 12/60 2125 C & P Gp 375

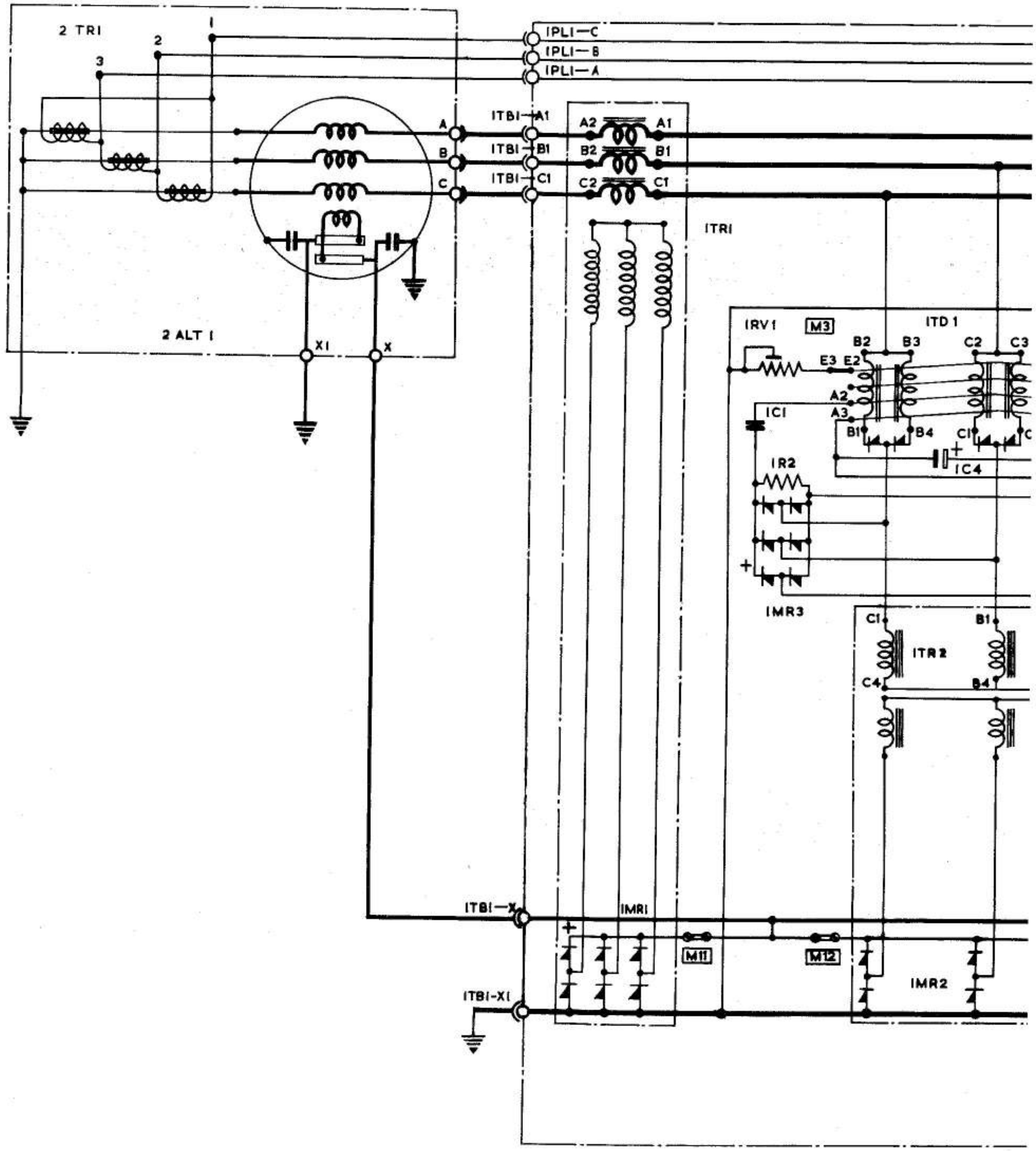
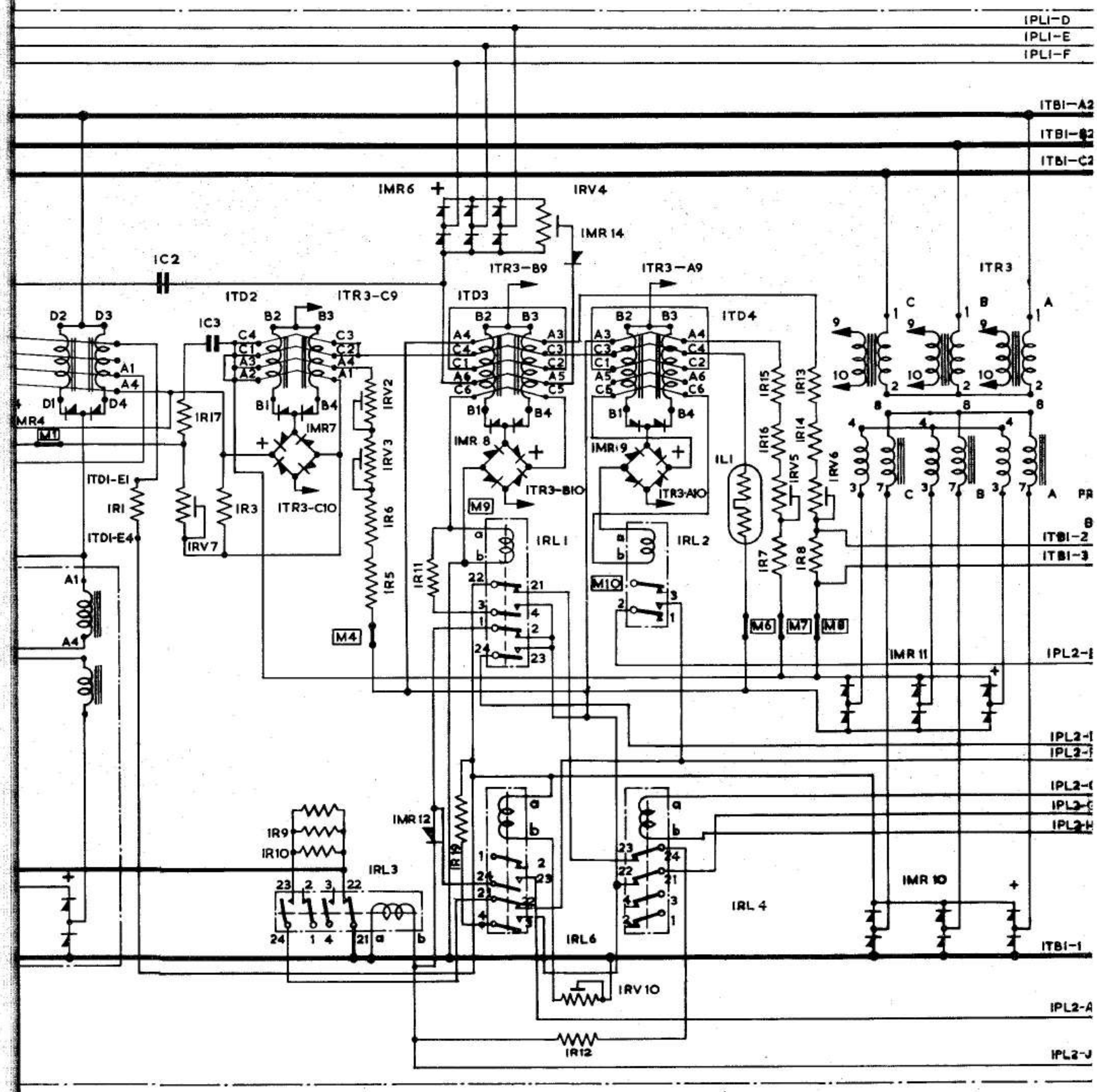


Fig. 5

PP9091 253066/2979 10/62 2256 C & P Gp. 924 (4)



Circuit diagram

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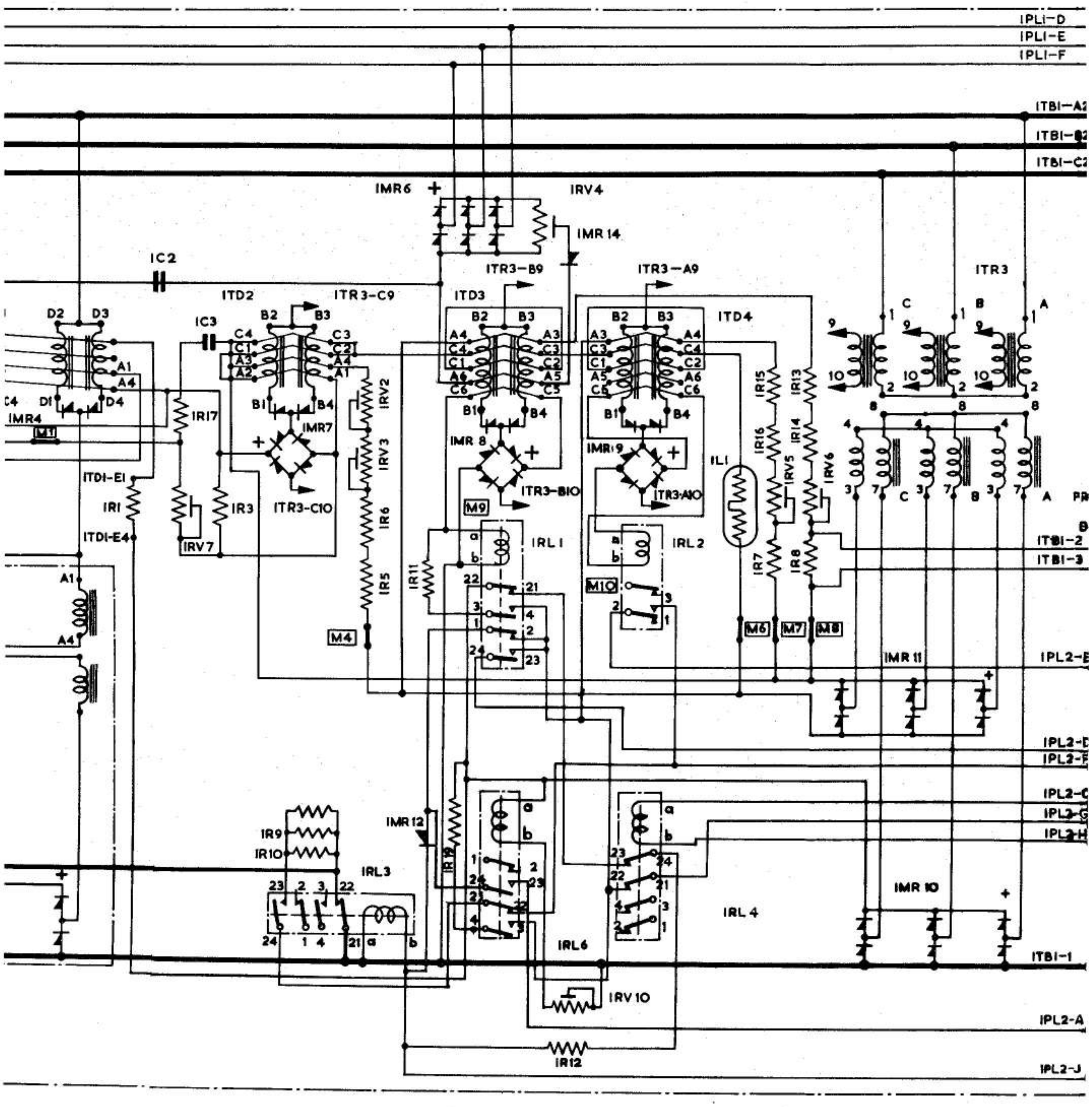

Circuit diagram

RESTRICTED

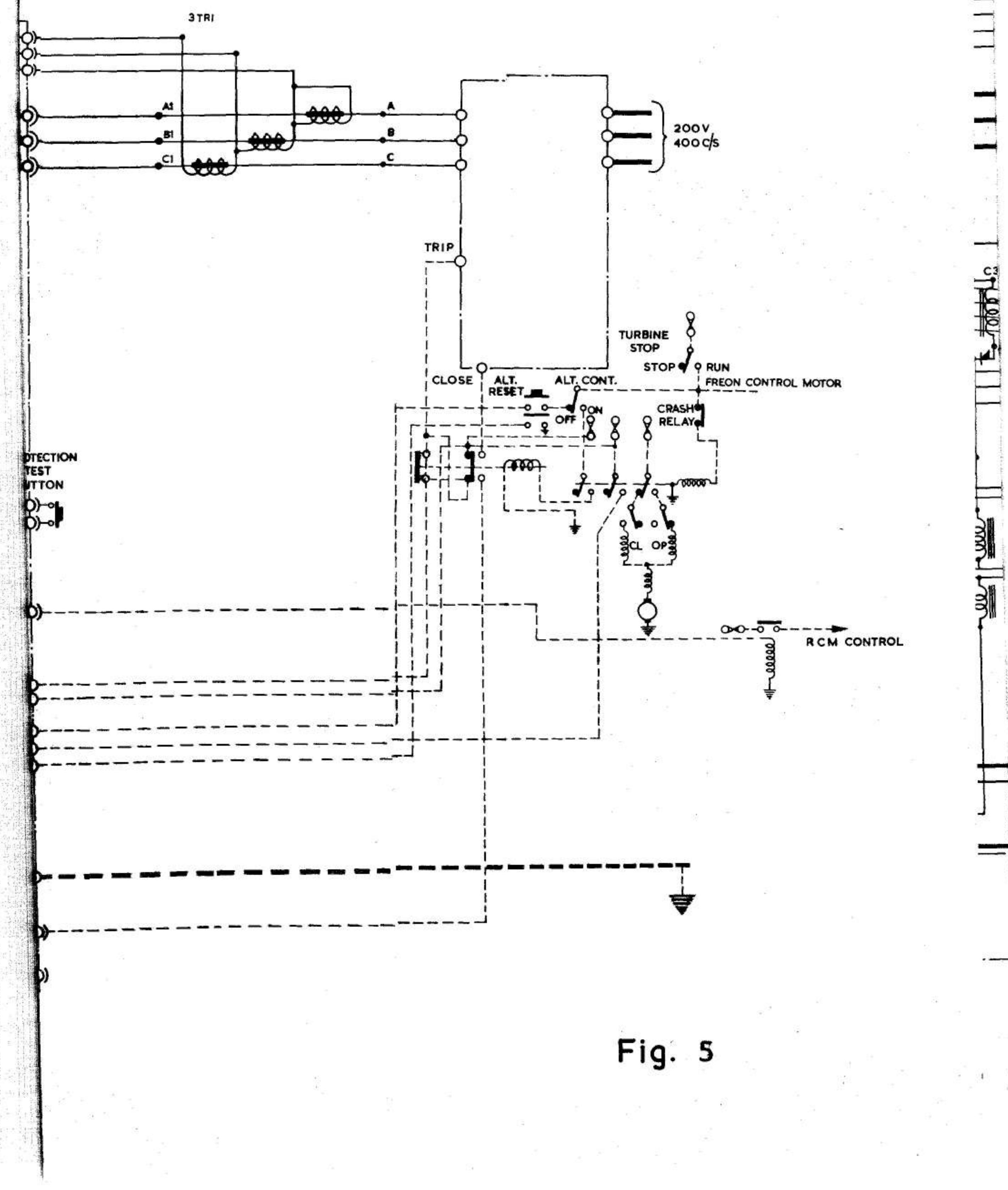
3TRI
A1
B1
C1
A
B
C
200V
400 c/s
TRIP
CLOSE
ALT. RESET
ALT. CONT.
ON
OFF
TURBINE STOP
STOP
RUN
FREON CONTROL MOTOR
CRASH RELAY
CL
OP
RCM CONTROL
OTECTION
TEST
UTTON

Fig. 5

Appendix 1

CONTROL AND PROTECTION UNIT, ROTAX, TYPE U3711

LEADING PARTICULARS

Control and protection unit, Type U3711	*Ref. No. 5UC/7230*
Output voltage	*200V a.c.* $\pm 2\frac{1}{2}$ *per cent*
Phases	3
Frequency	400 *c/s* $\pm$ 2 *per cent*
Load range	0 *to* 30 *kVA*
Power factor	*Unity to* 0.9 *lag.*
Temperature range	−50 *deg. C. to* +70 *deg. C.*
Altitude	60,000 *ft.*
Rating	*Continuous*
Cooling (in flight)	*Blast air at* 2 *lb. per min.*
Dimensions	
Length (including handle)	11·75 *in.*
Width	9·25 *in.*
Height	9·0 *in.*
Weight	23 *lb.*

1. The control and protection unit, Type U3711, is electrically and mechanically similar to the Type U3708, which is described and illustrated in the main chapter. It differs from the Type U3708 in that, in order to prevent overheating under exceptional conditions, the starting resistors 1R9, 1R10 and 1R18 are mounted in a self-contained unit, Type ZA6002. The main characteristics of the Type U3711 are given under Leading Particulars.