now AP113F-0503-1.

Chapter 1

THROTTLE CONTROL SYSTEM, ULTRA, TYPE B.A.P. 3

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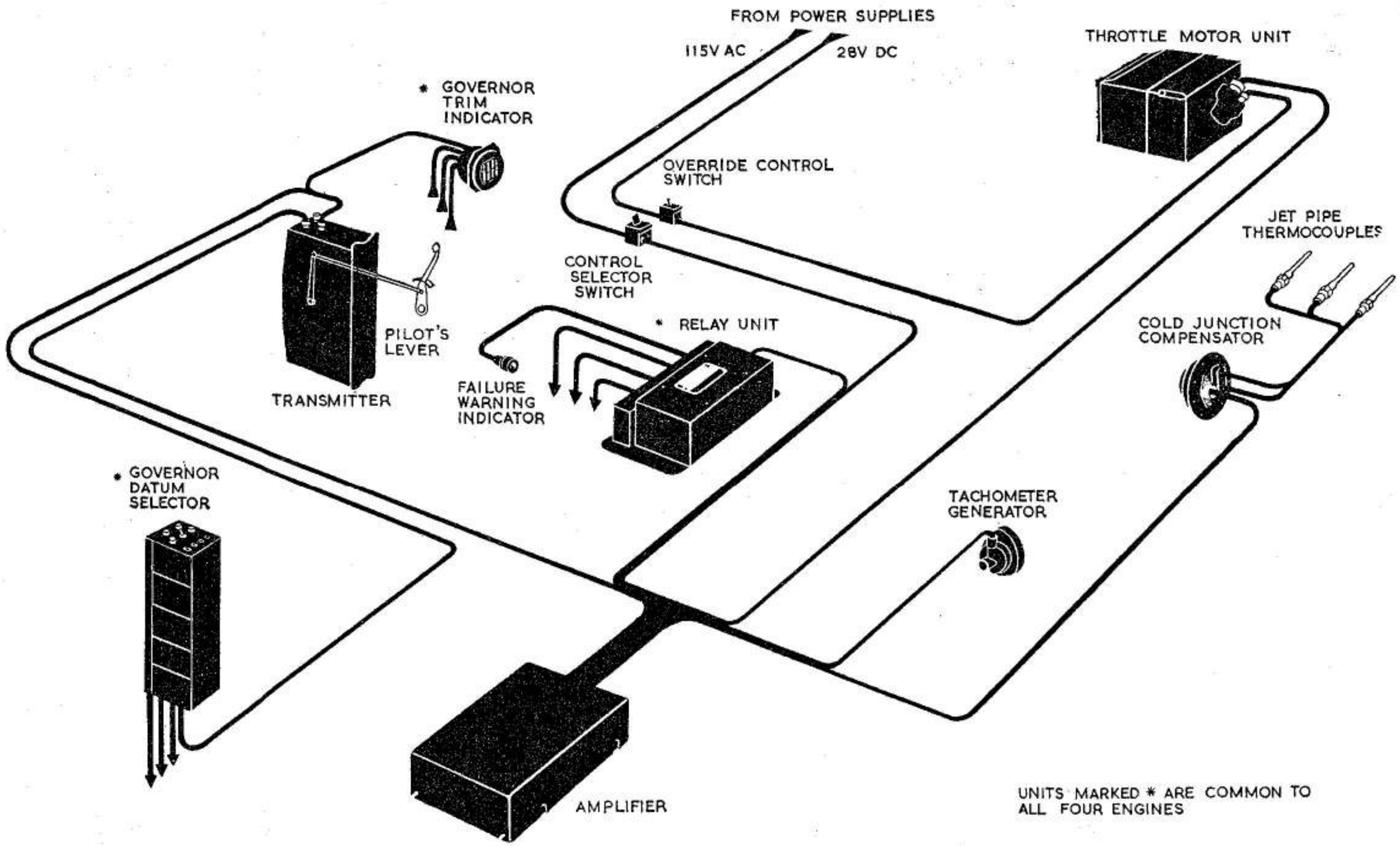


Fig. 1. Layout of B.A.P.3 system for one engine

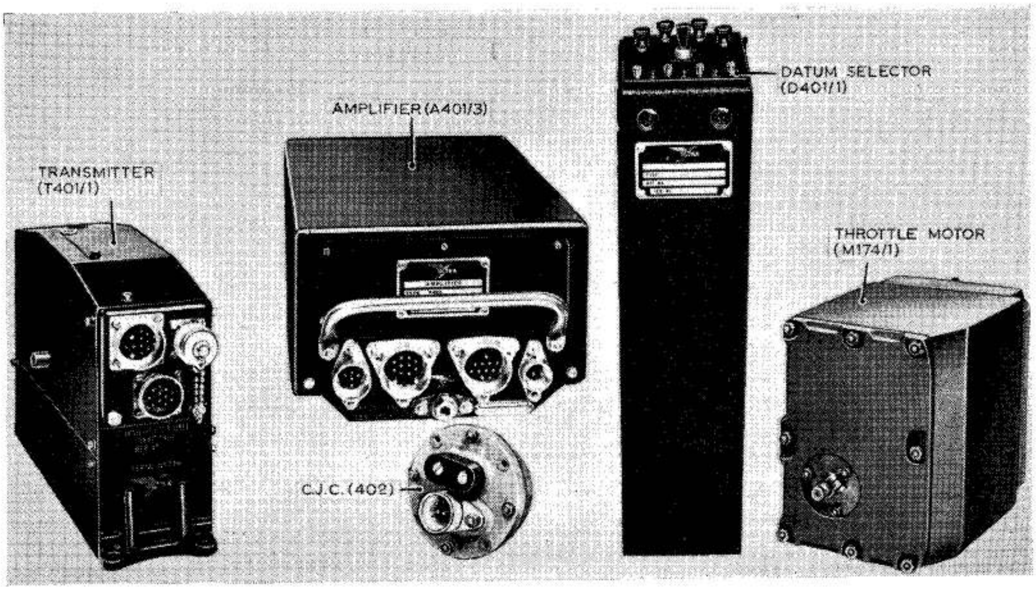


Fig. 2. Main units of the system

Introduction

1. The throttle control equipment, Type B.A.P.3 (fig. 1) provides remote electrical operation of the throttle valves in each of the four engines of the Britannia aircraft. The system is basically a position control servo, in which the position of the throttle valve is dictated primarily by the position of the pilot's throttle lever. The position taken up by the throttle, however, is subject to the influence of a temperature channel; that is, the throttle setting may be trimmed in response to a signal derived from the jet-pipe temperature. Also, when the facility is selected, the position of the throttle is subject to the influence of the engine compressor speed governor channel, that is, the throttle position may again be trimmed by a signal derived from the engine tacho-generator.

2. The signal injected into the positioning loop by the temperature channel is derived from the comparison of the instantaneous jet-pipe temperature, with a preset, steady-state datum temperature. The steady-state datum is automatically raised during an acceleration at any compressor speed above 9500 r.p.m.

3. Manual selection of the optional compressor speed governing (c.r.p.m.) is under the control of the pilot, and either one of two datum speeds may be chosen. The two optional compressor speed datums (high and low), may be varied by the pilot about the datum by $\pm$125 r.p.m. in 20 steps.

4. The throttle opening rate is controlled to obtain a safe acceleration primarily by limiting the throttle lever displacement signal input to the positioner amplifier. The response of the output from the temperature channel is not limited in this way. The temperature signal amplifier has a rapid response characteristic so that any undue rise of jet-pipe temperature is counteracted at an incipient stage.

5. A number of safety circuits are incorporated in this system, and operation of a safety relay mutes the normal throttle control system and gives warning lamp indication of a fault. An independent override throttle motor is also available in each engine channel.

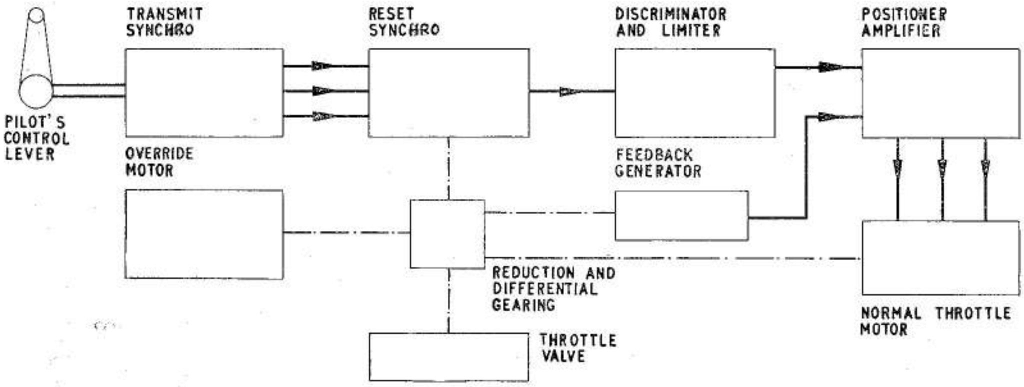


Fig. 3. Block diagram of positioner servo

DESCRIPTION

General

6. The components of the system are shown in fig. 1, and are listed in the leading particulars. The main units of the system are described briefly below, for further details reference should be made to the appropriate section of this book. For details of the Trim Indicator, and Tacho-generator, refer to A.P.1275A, Vol. 1, Sect. 16 and 26.

Transmitter unit T401/1

7. The four transmitter units, one for each engine, are mounted on the pilot's console, and each incorporates a transmit synchro, which is coupled to the pilot's throttle lever via a quadrant and anti-backlash gears; a two-phase, squirrel-cage induction, governor-trim motor and associated reduction gearbox, which drives the governor trim potentiometer; two preset governor gain and governor balance potentiometers; two canisters containing the governor trim control unit and the positioner and frequency safety unit; and a safety relay. External connections are made by means of a 16-way and 12-way cannon plugs and a 6-way cannon socket is provided for test purposes. For further details of the transmitter unit refer to Section 5 of this publication.

Amplifier A401/3

8. Four amplifier units are used in the system one for each engine. Each unit comprises seven canisters, a relay and a number of preset potentiometers mounted on a chassis. The canisters contain the components for the positioner amplifier, power unit, reference voltage and temperature channel, acceleration lift circuit and the temperature voltage safety circuits. The connections are brought out on four plugs and three test points are provided. Further details of the amplifier unit may be found in Section 4.

Governor datum selector unit D401/1

9. Only one governor datum selector unit is used in the system, the unit incorporates the components for the four engine channels. Each engine channel comprises a canister housing the speed discriminator components, two datum level preset controls and a filter circuit.

10. The four toggle switches mounted in line on the front panel select the c.r.p.m. governing independently. The central switch (high or low) of the two governing speeds is common to all four channels. The high and low governing speeds are variable about these preset values by adjustment of the potentiometers with the "press to turn" index knobs, located on the front panel. The four channels are electrically isolated, four cables from the unit being terminated in 9-way sockets.

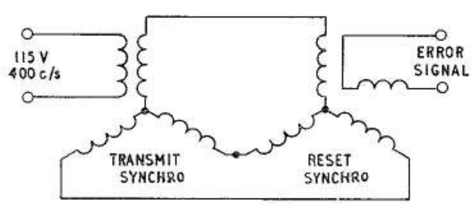


Fig. 4. Basic synchro system

Throttle motor unit M174/1

11. The throttle motor unit is divided into two compartments, the mechanical assembly at the front containing two independent gear trains for normal and override systems, meshing (one each side) with a spur gear differential to drive the output shaft via a clutch.

12. The rear compartment houses the normal a.c. motor, the d.c. override motor, feedback generator, reset synchro, two cam-operated microswitch assemblies, and terminal block. The rear compartment is sealed off from the gearbox to prevent the ingress of oil. The reset synchro is coupled to the output shaft via anti-backlash gears.

13. The combined assembly secured in a box casting with tapped bushes suitable for engine mounting. Front and rear ends of the box castings are closed by cast cover plates. The rear plate contains a 9-way and a 4-way plug, thus separating the routing of the normal and override connecting cables. The splined end of the output shaft is fitted with a pointer which, in conjunction with the index plate on the front cover, indicates the position of the shaft for alignment purposes during installation.

OPERATION

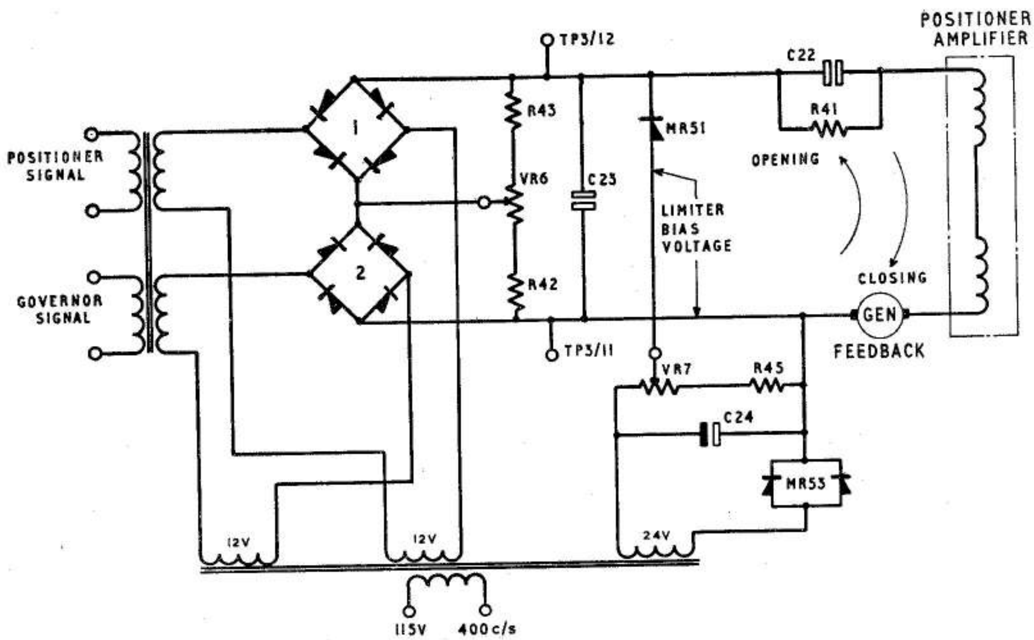
Basic position control

14. The basic position control servo maintains the angular position of the throttle valve lever in relation to the selected position of the pilot's control lever. A block diagram of the basic system is given in fig. 3.

Synchro system

15. To transmit the position of the pilot's control lever a synchro system is employed. The transmitter synchro rotor is mechanically coupled to the pilot's lever, and the reset synchro rotor through the gearbox to the throttle, and the error signal from the reset rotor is fed into the amplifier.

16. The circuit diagram of the basic synchro system is given in fig. 4. The transmitter rotor is energized from the 115V, 400c/s supply and



TP3/11 AND TP3/12 DISCRIMINATOR BALANCE TEST POINTS.
VR6 DISCRIMINATOR BALANCE.
VR7 OPENING RATE CONTROL.

Fig. 5. Basic discriminator and limiter circuit

induces voltages into the transmitter stator; a corresponding field is then set up in the reset stator. When the two synchro rotors are positioned 90° apart there is no output from the reset rotor but when the angle between the rotors is greater or less than 90° an a.c. error signal is induced in the reset rotor. This signal is then fed to the positioner amplifier via the discriminator (fig. 3). The output from the amplifier drives the throttle motor which operates the engine control throttle lever, and at the same time drives the reset synchro rotor until null conditions recur. In this position the error signal is reduced to zero and the throttle motor stops.

Discriminator

17. A schematic diagram of the positioner system shown in fig. 7 and the basic circuit of the phase discriminator (phase sensitive rectifier) is given in fig. 5. Considering only the positioner control, the a.c. output from the reset synchro depends on the positional error of the throttle lever with respect to the pilot's control lever. The magnitude of the error signal is dependent on the magnitude of the throttle lever displacement, and the phase of the error on the sense of the displacement i.e. whether the displacement is in the open or closing throttle sense. The phase discriminator rectifies the error signal and at the same time preserves the sense of the error, thus the output of the discriminator is a d.c. signal which reverses in polarity when the input phase reverses.

18. The circuit which is contained within the amplifier unit, comprises a transformer and two bridge rectifiers. The two outputs from the error transformer are each connected in series with a reference voltage, taken from the 115V supply, which will thus be constant in phase and magnitude. When there is no output from the reset synchro, the reference supplies give an output from bridges 1 and 2 which are equal and opposite; the two output leads (fig. 5) are both negative by equal amounts with respect to RV6 (RV6 is the discriminator balance potentiometer preset to give zero output for zero input).

19. An input to the discriminator in one sense or the other will add to the reference voltage in one half of the circuit and subtract from the reference voltage in the other half, hence unbalancing the circuit giving an output of the correct polarity.

Limiter

20. For transmit rotor displacements of up to 8° in the opening throttle sense, the opening rate is proportional to displacement.

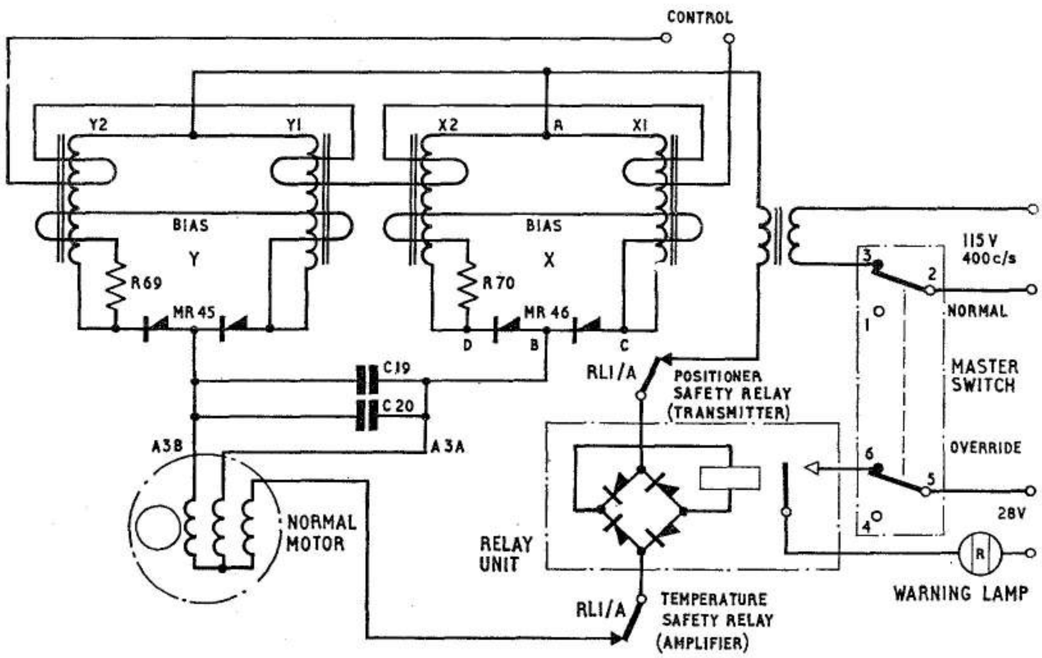


Fig. 6. Positioner output stage and Warning lamp circuit

For displacements greater than 8 °, the opening rate is limited to 20 ° per second. This limiting is achieved by connecting a biased diode across the phase discriminator output (fig. 5). The bias supply to the diode is taken from the amplifier power unit via a rectifier MR53 giving a negative reference voltage at the wiper of RV7. The limiting diode is backed off in the opening throttle sense by the d.c. voltage, and will not conduct for error voltages below the reference voltage, and no shunting of the positioner amplifier input occurs, thus giving an opening rate proportional to the error signal.

21. For transmit rotor displacements of greater than 8 °, however, RV7 is preset so that the limiting diode conducts thus shunting the positioner input winding with R45, so limiting the maximum signal in the winding and also the maximum throttle opening rate to 20 per second. The limiting is not effective in the closing throttle sense and a rate of 90 ° per second can be achieved on rapid shutdown.

Feedback stabilization

22. A small d.c. generator contained in the throttle motor unit is driven by the normal motor, and develops an output voltage proportional to the motor speed (output rate). The output from the generator is connected in series opposition to the error signal, and thus provides damping to the system. Further stabilization is provided by the network C22 and R41, which in addition to providing a signal input proportional to the resultant of the error and feedback voltages (via R41), also provides a signal proportional to the rate of change of voltage.

23. The effect of this damping or stabilization is to prevent overshoot of the throttle, and to bring the throttle quickly into correspondence with the pilot's lever. When the pilot moves the throttle lever to a new position the error signal, sensed by the reset synchro, is fed into the amplifier. The output from the amplifier develops a torque in the normal motor causing the system to accelerate and as the throttle begins to move the error signal reduces. At the same time as the motor speed is increasing the feedback voltage is also increasing, and as the error becomes smaller a point is reached where the feedback voltage is greater than the error voltage, and the input to the amplifier reversed. Thus a decelerating torque is applied to the motor bringing the system to rest with negligible overshoot.

Position amplifier

24. The position amplifier is a two-stage magnetic amplifier, with three inputs and an a.c. output driving the three-phase normal throttle motor. The motor may be operated and hence the throttle trimmed by any one of three signals or combination signals. These are the basic positioning signal, the governor trimming signal and the transient temperature signal. The source of the basic positioning signal was described above, the other signals and their sources are considered below. The output stage of the positioner amplifier is a self-biasing push-pull amplifier stage. When an opening signal is received by the discriminator, the resulting output from the positioner stage 1 will appear as a d.c. voltage across the input winding to the positioner output stage. These are the control winding shown in fig. 6. Current will therefore flow through one half (say X winding) of the control winding, in such a direction as to increase the flux in core X, while the same current flowing in the Y winding will tend to decrease the flux in the Y core, since the two sections of the control windings are reverse wound. As the magnetizing current increases round the X core, so the permeability of the core, and therefore also inductance of the a.c. winding, decreases. Thus as the inductive reactance of the a.c. winding falls and voltage across the X coil is consequently reduced the voltage at A3A is greater than the voltage at A3B (fig. 6). Current therefore flows from A3A to A3B via capacitors C19 and C20, with a consequent phase lead, causing the motor to turn in the opening direction. Similarly for a closing signal, the inductance of the Y coil decreases the voltage at A3B is greater than at A3A.

25. The self biasing of the output stage is derived as follows. If the voltage at A is, say 100V positive with respect to B, the current will flow through the circuit from A to **B**. Assume forward impedance of the rectifiers to be 1/10th that of X_1 or X_2, then the voltage at C will be 10V, and the voltage at D will be 90V with respect to C. Suppose now that B is 100V positive with respect to A current will flow through the circuit from B to A. Then the voltage at D is 90V with respect to C. In either case, therefore, a similar current flows through R70 and X bias winding, resulting in a standing self-bias.

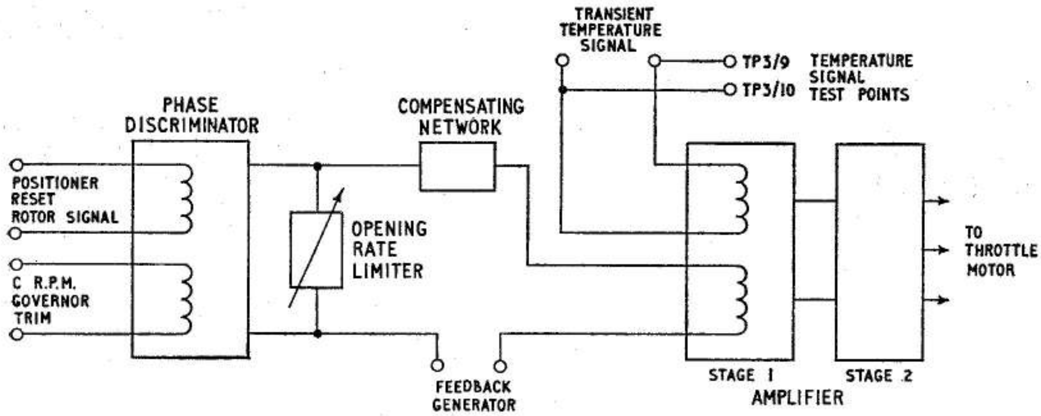


Fig. 7. Schematic of positioner channel

Governor trim of the position control

26. Two settings of the compressor speed governing are provided by the datum selector unit; one corresponding to steady climb (high r.p.m.) and the other to level cruise (low r.p.m.). For both of these governing speeds a variation of ± 125 r.p.m. in 20 steps of 12·5 r.p.m. is available for each engine channel, the system maintaining the speed to within ± 8 r.p.m.

27. An output proportional to the compressor speed, is fed from the tacho generator via a filter network, to a speed discriminator (*fig.* 8). The filter network makes the system independent of the generator voltage waveform, thus the tacho generators are interchangeable. The speed discriminator circuit consists of one arm which is entirely resistive, and a second arm which is capacative, and both arms feed into a rectifier bridge. The d.c. output on the two bridges are fed into two windings, wound in opposition, which are the input windings to the governor stage transductor.

28. As the compressor speed increases, there will be a linear voltage rise from the ouput of the rectifier bridge in the resistive arm. The output from the bridge in the capacative arm however, is non-linear, and the point where the two outputs are equal is the datum point; the datum being adjustable by varying the resistance in the resistive arm. When the two outputs are equal, the voltages in the input windings to the amplifier are equal, and there is no output from the governor amplifier.

29. Should the compressor speed now increase, the voltage output from the bridge in the capacative arm exceeds that across the bridge in the resistive arm and current flows in the ouput of the governor amplifier to drive a squirrel cage motor. The output shaft of this motor is coupled, through a gear train and slipping clutch, to the slider of a potentiometer, across which a 30V a.c. supply is connected. Across this slider and one side of the potentiometer is connected the discriminator input winding. As soon as V_c exceeds V_r (*fig.* 8) in the speed discriminator, a signal is applied to the positioner input winding in such a direction as to close the throttle valve. This in turn reduces the compressor speed until V_c is equal to V_r and so maintains the compressor speed at this datum.

30. The output from the a.c. potentiometer is also fed to the trim indicator via rectifier MR20. The pilot's trimmer, on the datum selector, is provided to allow limited adjustment of the datum point by the aircrew. The pilot sets his throttle lever in a position that demands a slightly higher compressor speed than the datum, and then switches on the governor. The governor then trims down the throttle to the required datum. The trim indicator, indicates the position of the slider on the a.c. potentiometer, and the pilot adjusts his throttle lever to show an initial deflection of about one third full scale of the trim indicator, in order that the potentiometer slider has sufficient movement to trim the speed up or down.

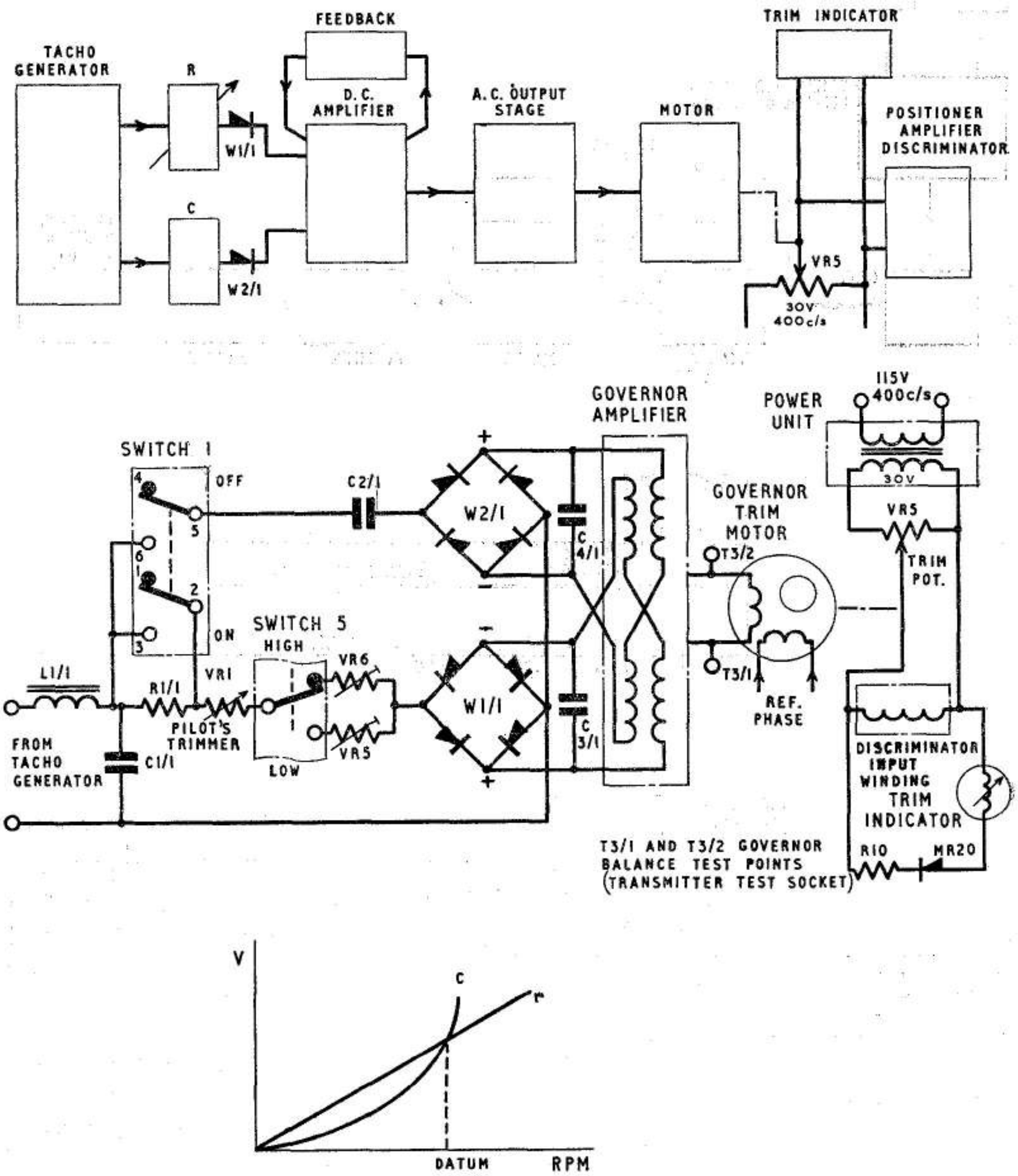


Fig. 8. Governor trim channel

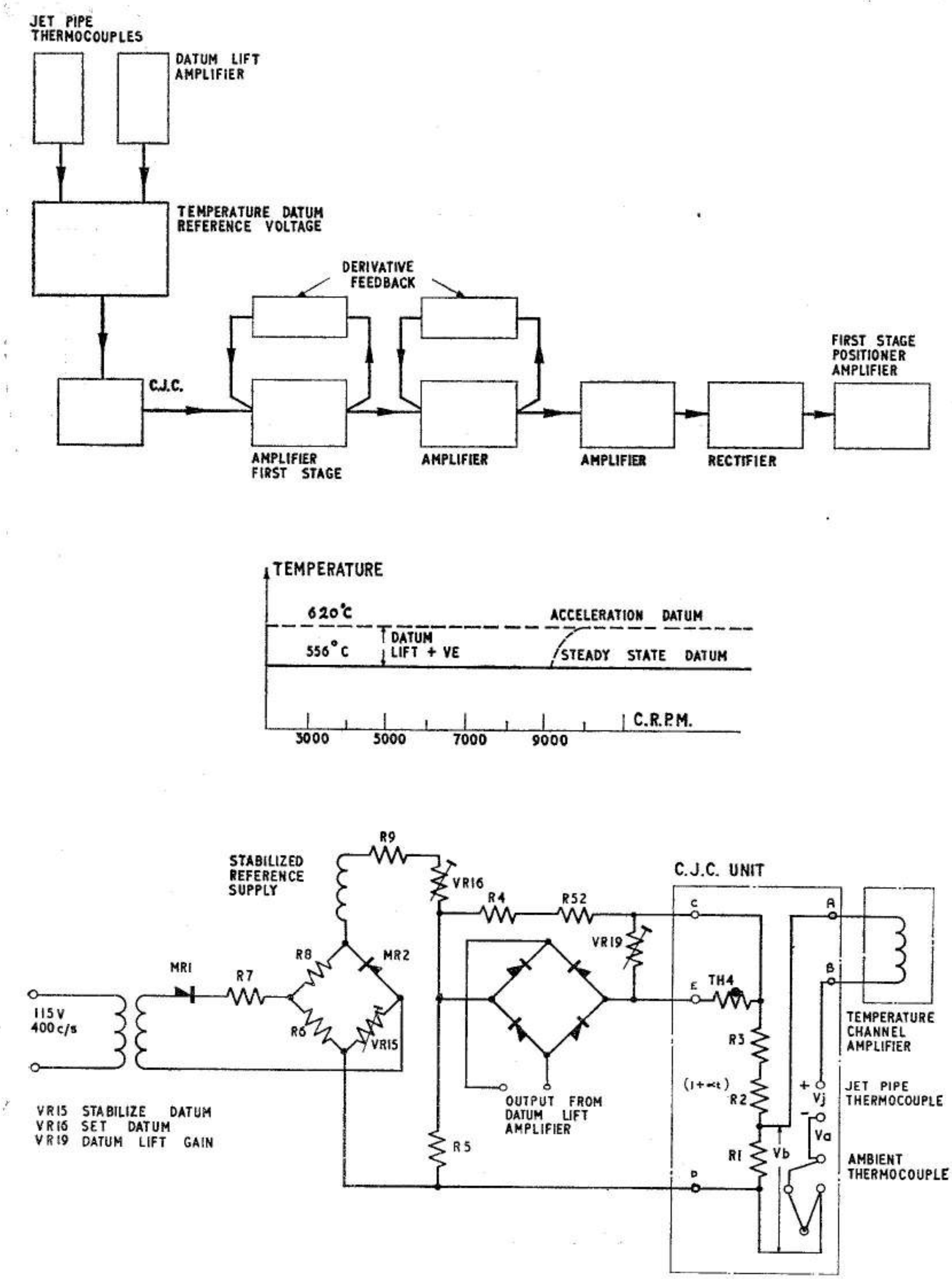


Fig. 9. Temperature channel

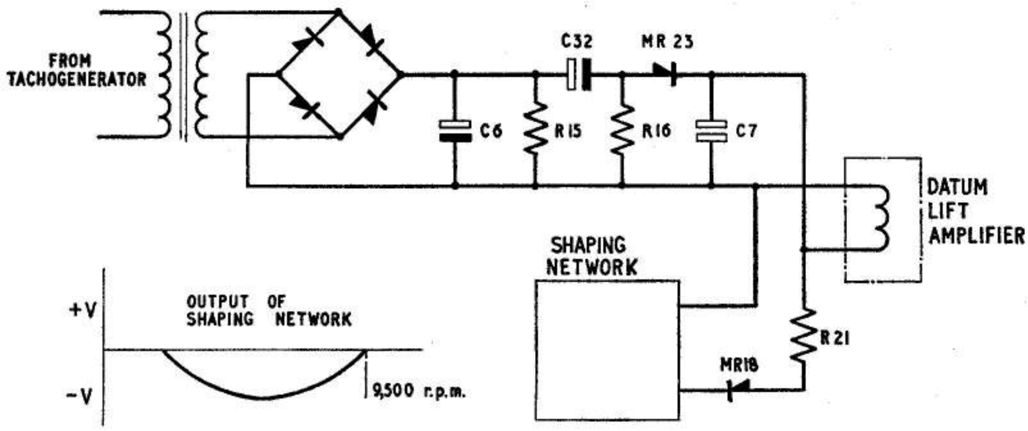


Fig. 10. Datum lift circuit

Temperature signal circuit

31. The temperature signal circuit is shown in fig. 9. The reference voltage is derived from a stabilized source, and is applied to the resistor chain comprising R52, R4, R3, R2 and R1. The steady state reference voltage is determined by V_b across R1. The jet-pipe thermocouples and the ambient thermocouples are connected in series, with the e.m.f.'s opposing each other. This arrangement ensures that the jet-pipe temperature is corrected for changes in ambient temperature and referred to 0 °C. When the output from the jet-pipe thermocouples, V_j is such that $V_b = V_j + V_a$, then there is no input to the temperature control winding and the jet-pipe temperature is at datum. But when $V_j + V_a$ is greater than or less than V_b a resultant error signal is fed into the first stage of the temperature channel amplifier.

32. For a rise in temperature above datum a signal from the temperature channel is fed into the positioner channel in such a direction as to close the throttle. This action reduces the fuel flow to the engine and cools the jet-pipe. When the temperature falls to datum again, the positioning system takes over and opens the throttle again to its original position.

33. Each stage of the temperature amplifier incorporates negative feedback and gain control. The first two stages also include positive transient feedback (phase advance), the 'phase advance' being achieved by supplying the feedback windings through capacitors. The effect of this is to make the temperature channel anticipatory for rapid changes in jet-pipe temperature. Thus for rapid increases in temperature, such as are encountered at the onset of a stall, 'phase advance' is applied to the temperature signal and the throttle starts to close before the temperature exceeds a maximum permissible value.

Temperature datum, steady state and acceleration

34. During steady state conditions, irrespective of the compressor speed, the temperature datum is a straight line as shown in fig. 9. This characteristic is also applicable during accelerations when the compressor speed is below 9500 r.p.m. During accelerations when the compressor speed is above 9500 r.p.m. however, the temperature datum is lifted to an acceleration level. This is achieved by the acceleration datum lift circuit in the main amplifier.

Datum lift circuit

35. At compressor speeds up to 9500 r.p.m. the output from the datum lift amplifier biases the bridge network in the temperature datum circuit (fig. 9) to present a high impedance, and the reference voltage developed across the R1, is the same as for the steady state condition. At compressor speeds above 9500 r.p.m., however, an output from the datum lift amplifier reduces

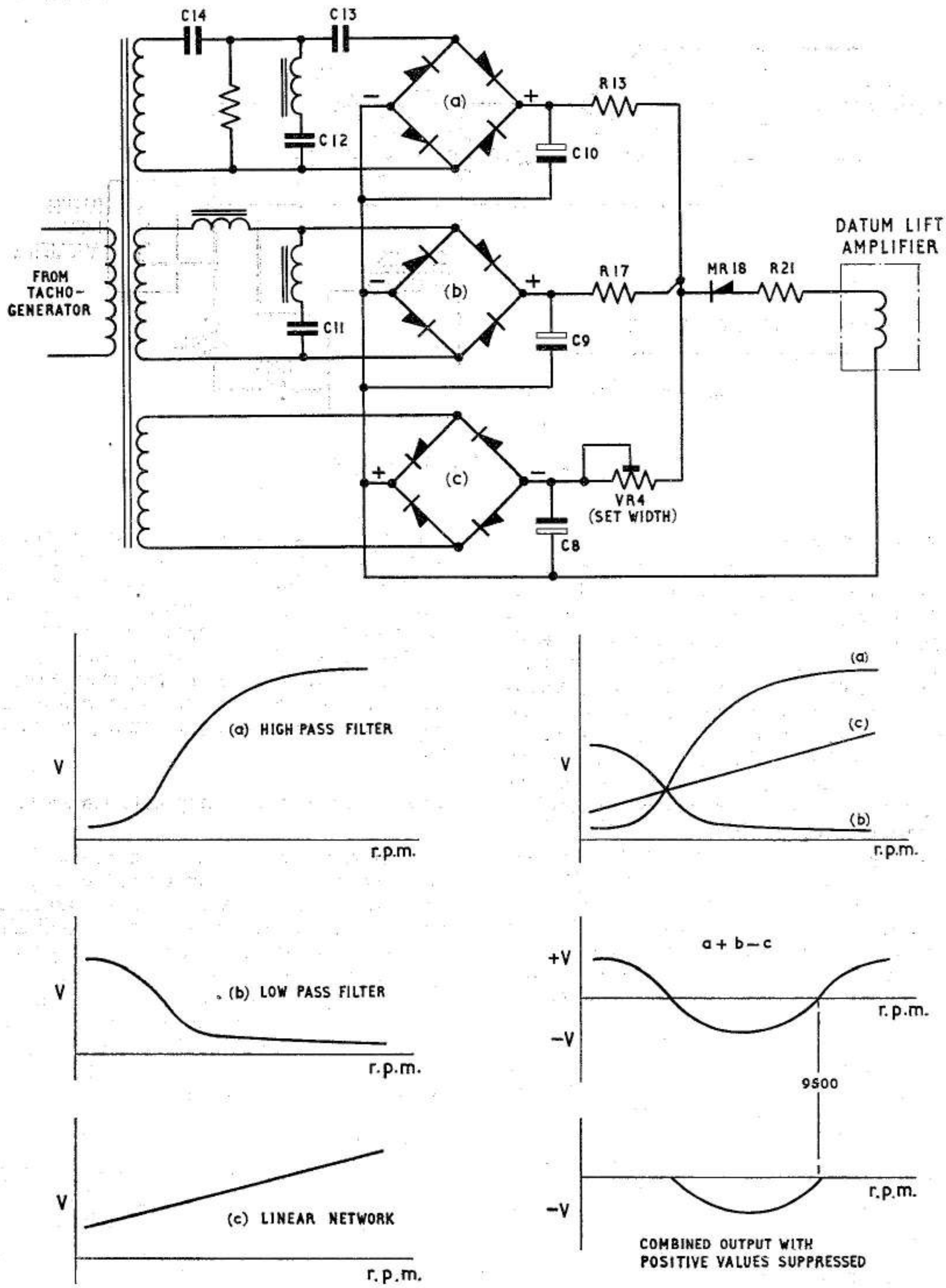


Fig. 11. Shaping network

the impedance of the bridge, and switches the thermister TH4 in parallel with R4 and R52. This increases the current in the resistor chain R1, R2 and R3 (fig. 9), and therefore, the reference voltage developed across R1.

36. A simplified circuit of the datum lift function is shown in fig. 10. The supply to the datum lift circuit is derived from the engine tacho-generator, via a transformer and bridge rectifier. When the engine is running at constant speed the d.c. output from the bridge rectifier is blocked by capacitor C32. When the engine speed is varying, i.e. during accelerations or decelerations, the d.c. output from the bridge will vary. During accelerations a derivative signal (i.e. signal proportional to the acceleration, since C32 and R16 form a differentiating circuit) will flow in the datum lift amplifier control winding, causing the output of the amplifier to reverse, which lifts the bias on the bridge network in the temperature datum circuit (fig. 9), and switches TH4 in circuit. During decelerations, however, the signal is suppressed by series rectifier MR23.

Shaping network

37. The output from the engine tacho-generator is also fed to a shaping network (fig. 11). This network consists of a three filter circuits: a high pass, low pass and linear response circuit. The output from the linear circuit is subtracted from the sum of the outputs from the high pass and low pass filters (fig. 11). Positive signals are suppressed by rectifier MR18. At compressor speeds below 9500 r.p.m. the output of the shaping network is a negative going dip, which is applied to the input winding of the datum lift amplifier opposing the output from the datum lift circuit (fig. 10). During accelerations at compressor speeds below 9500 r.p.m., the datum lift circuit will not lift the bias from the bridge network and the temperature datum will remain as for the steady state condition. VR4 controls the width of the negative going dip.

Safety circuits

38. The various safety circuits included in the B.A.P.3 equipment are outlined below.

Warning lamp relay

39. A high speed relay, mounted in the relay unit is engergized by a constant current flowing in the normal throttle motor supply leads (fig. 6). Failure of the 115V motor supply or the operation of any of the safety relays (resulting in an open circuit in the throttle motor return lead) de-energizes the relay and red warning lamp indication is given. The positioner override system for the particular engine channel is then selected by operating the master control switch mounted below the throttle lever concerned.

Positioner safety relay

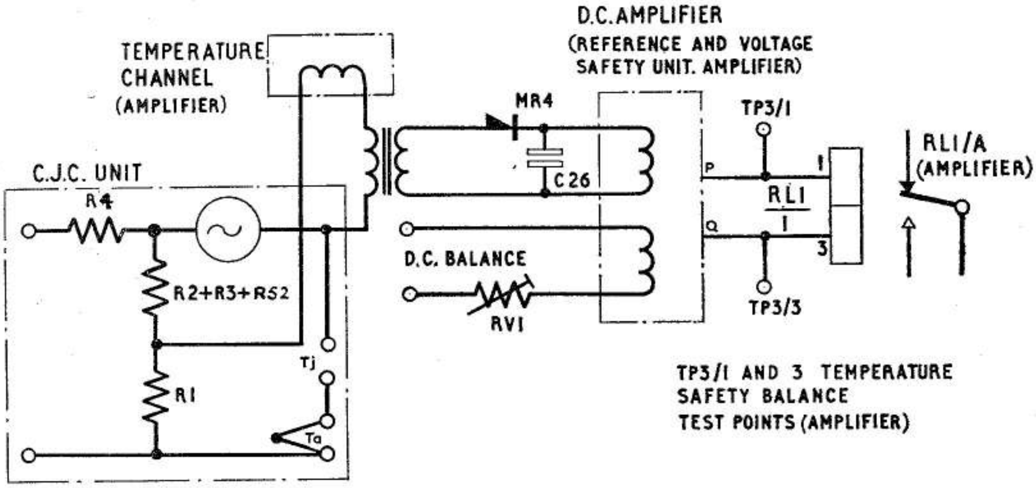
40. A direct current, obtained from the 115V supply, via a stepdown transformer, CR network and rectifier, is injected into one of the three stator lines in the synchro system (fig. 12b). The resultant d.c. voltage produces across a resistor in a second stator line is fed to an input winding of the positioner safety stage of the amplifier.

41. A balancing d.c. supply, derived from the 115V supply through a bridge rectifier circuit, is applied to a second input winding and adjusted so that normally the amplifier gives no output signal. A short or open circuit in the synchro stator system however will unbalance the two inputs. Any resultant output is amplified and energizes a Carpenter relay RL1 in the transmitter unit, opening two normally-closed contacts to effect an open circuit in the normal motor supply leads.

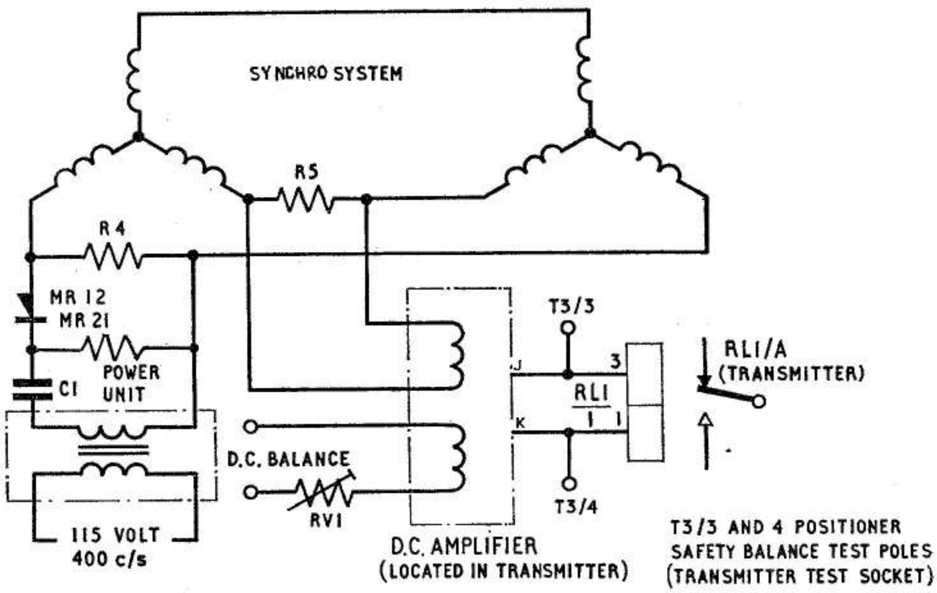
Temperature safety relay

42. Current from a 400 c/s a.c. source is injected into the C.J.C. network, the connecting points being the positive side of the jet-pipe thermocouples and the junction of R4 and R52 (fig. 12a). A small transformer primary winding is in series with the temperature amplifier control winding; the output from the transformer secondary is rectified and is fed into the input winding of a d.c. amplifier, located in the main amplifier unit.

43. A balancing direct current is applied to a second input winding, and any resultant unbalance due to impedance changes, or faults in the C.J.C. network, provides an energizing supply for relay RL1 (amplifier). This opens the normally-closed contacts and introduces an open-circuit in the normal motor supply leads (fig. 6). Changeover of the relay contacts RL1A also places a short-circuit across the primary of the temperature safety transformer, so that the relay remains energized until the master control is switched to OFF, for a few seconds to de-energize the system.



(a) TEMPERATURE SAFETY CIRCUIT



(b) POSITIONER SAFETY CIRCUIT

Fig. 12. Temperature and positioner safety circuits

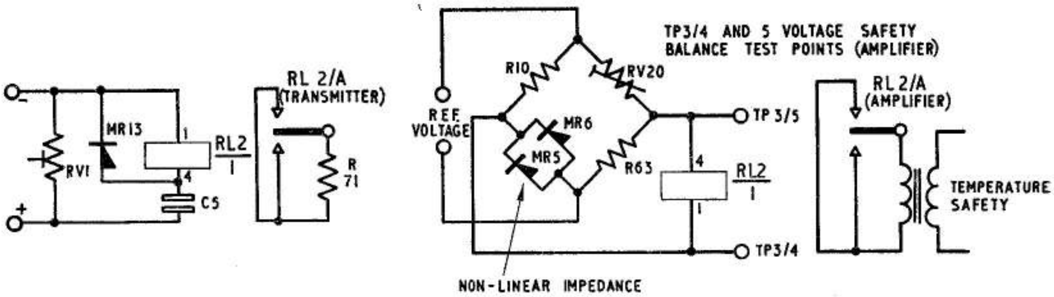


Fig. 13. Intermittent supply and voltage safety circuits

Intermittent supply safety relay

44. It is possible for an interrupted supply fault to simulate a positioner input signal resulting in an unwanted throttled trim. To safeguard against this hazard an output is taken from the balancing d.c. supply (used in the positioner safety circuit) and fed to the intermittent supply safety circuit (fig. 13a.) When the supply is switched on capacitor C5 will charge via rectifier MR13. Should an intermittent supply fault occur the capacitor will discharge through the coil of relay RL2, located in the transmitter. With RL2 energised the contacts RL2/A short-circuit resistor R71, unbalancing the temperature safety system in the amplifier and relay RL1 operates (para. 43).

45. Modification B180 removes the intermittent supply safety relay RL2, from the transmitter and renders the safety circuit inoperative.

Supply voltage safety relay

46. An additional safety circuit is provided across the rectified supply to the datum reference voltage (fig. 13b). One arm of the bridge contains diodes used as impedances that are non-linear with voltage. For a supply that is within the acceptable tolerance the bridge is balanced with an output at zero or sufficiently small not to energise RL2. Any deviation from the supply tolerance will result in an output from the bridge and RL2 will be energised. Contacts RL2/A will close and operate the temperature safety circuit (para. 43).

47. Modification B181 removes the voltage safety supply relay from the amplifier and renders the safety circuit inoperative.

Positioner override

48. When a warning lamp indication of a fault is obtained the Override system is selected by setting the Master Control switch to override. A completely independent positioning control, operated from the 28V d.c. supply is then available. Throttle movement being effected by operating the override switch in the increase or decrease direction. When override is selected the red warning lamp is extinguished.

49. The throttle motor gearbox incorporates a differential which gives independent coupling of the output shaft to the Normal or Override gear train. The limits of the output shaft rotation are set by cam-operated micro-switches mounted in the throttle motor unit. The rate of throttle movement, using the override system is 7° per second, i.e the time taken for full throttle movement in either direction is about 10 seconds.

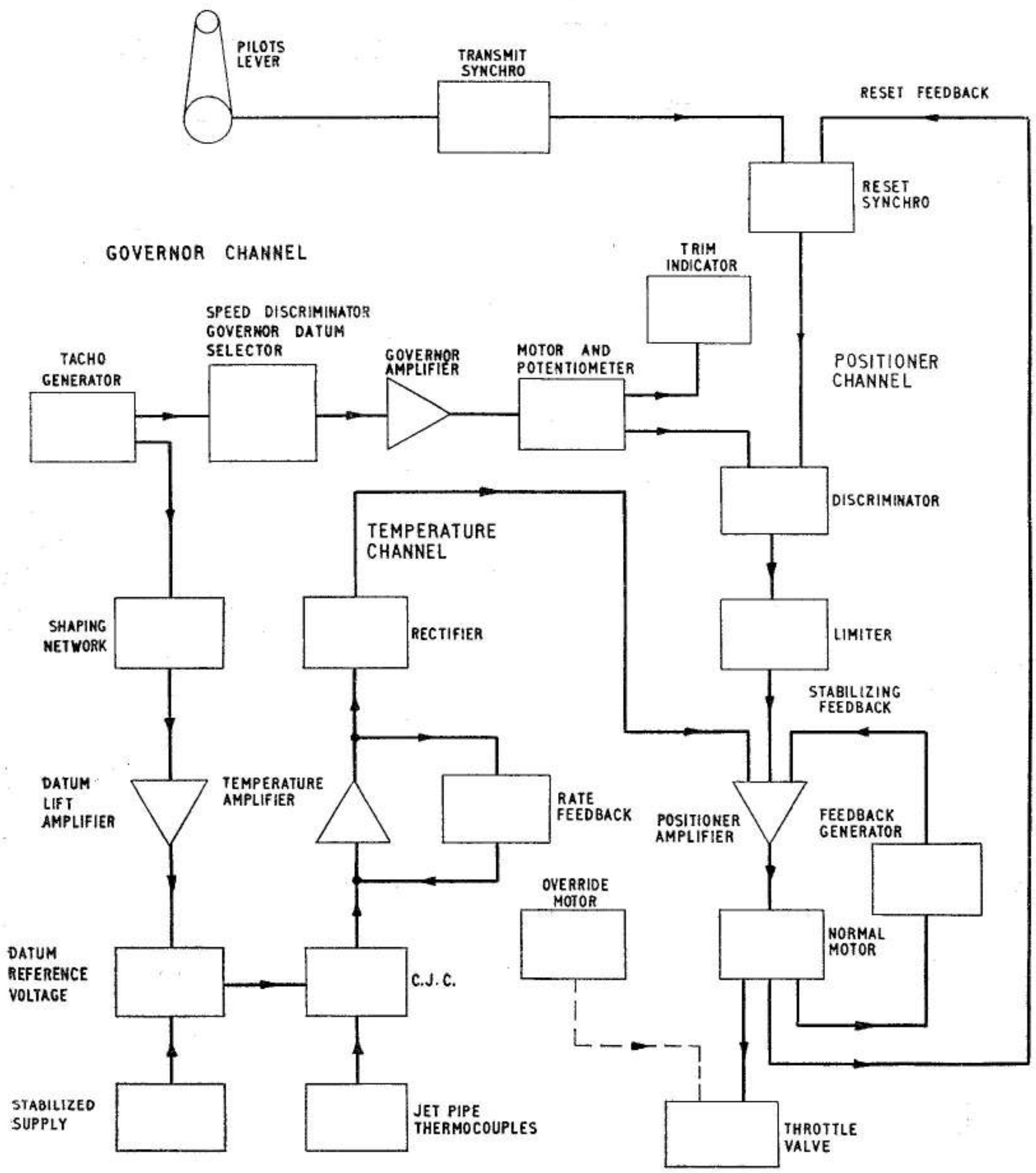


Fig. 14. Block diagram of B.A.P.3 system

SERVICING

General

50. The B.A.P.3 system and associated wiring may be tested at the aircraft, and the components of the system tested on the bench using the following test equipment.

(1) Test equipment, Ultra, Type QE405—a transportable test set used for field testing.

(2) Test equipment, Ultra, Type QE406—a mobile test set used for base testing.
(3) Test equipment, Ultra, Type QT4066, which together with its associated power unit, Ultra type QT4063 provides facilities for testing the individual components of the system on the bench.

51. There are two test points on the system which are accessible when the equipment is installed in the aircraft. They are a 12-way test point at the amplifier (TP3) and a 6-way test point on the transmitter (T3). The amplifier test point is accessible by removing the amplifier and test strip cover; the transmitter test point is a 6-way cannon socket. The connections primarily of interest in testing and fault finding are given in Table 1.

TABLE 1

System test points

Unit	Connection and Reference	Circuit	Remarks
Amplifier	TP3/1 and 3 (fig. 12c)	Temperature Safety	
Amplifier	TP3/4 and 5 (fig. 13b)	Supply Voltage Safety	See para. 47
Amplifier	TP3/9 and 10 (fig. 7)	Output of temp. Channel	
Amplifier	TP3/11 and 12	Discriminator Balance	
Transmitter	T3/1 and 2 (fig. 8)	Governor Balance	
Transmitter	T3/3 and 4 (fig. 12b)	Positioner Safety	See para. 41 note

Field testing

52. The field test equipment, Type QE405 provides facilities for quick testing of the system and associated aircraft wiring. The equipment is described and the detailed test procedures given in Sect. 10, Chap. 2 of this publication. The test procedures and a wiring check table are also engraved on metal plates attached to the inside of the test set cover. The facilities provided enable the following tests to be performed:—

(1) Wiring check

(2) Temperature safety circuit.

(3) Positioner safety circuit

(4) Temperature channel function

(5) Datum lift function—an external speed source signal is required for this test

(6) Amplifier supply voltage.

(7) Transmitter supply voltage

(8) Governor balance

(9) Governor datum—speed source required.

Base testing

53. The base test equipment, Type QE406 provides facilities for more extensive testing of the system and components. The equipment is described and the detailed operating instructions given in Sect. 10, Chap. 3 of this publication. The test facilities provided are summarized below:—

(1) Insulation resistance tests

(2) Circuit resistance tests

(3) Functional tests

54. The procedure for performing these tests and details of the circuits being interrogated is given in Table 3 of Sect. 10, Chap. 3.

Bench testing

55. The individual components of the system may be tested using Test equipment Ultra, Type QT4066. Details of the test equipment and test procedures may be found in Sect. 10 of this publication. A master set of the system components and an interconnecting harness are required with the test set, and a component to be tested is substituted for the corresponding master unit.

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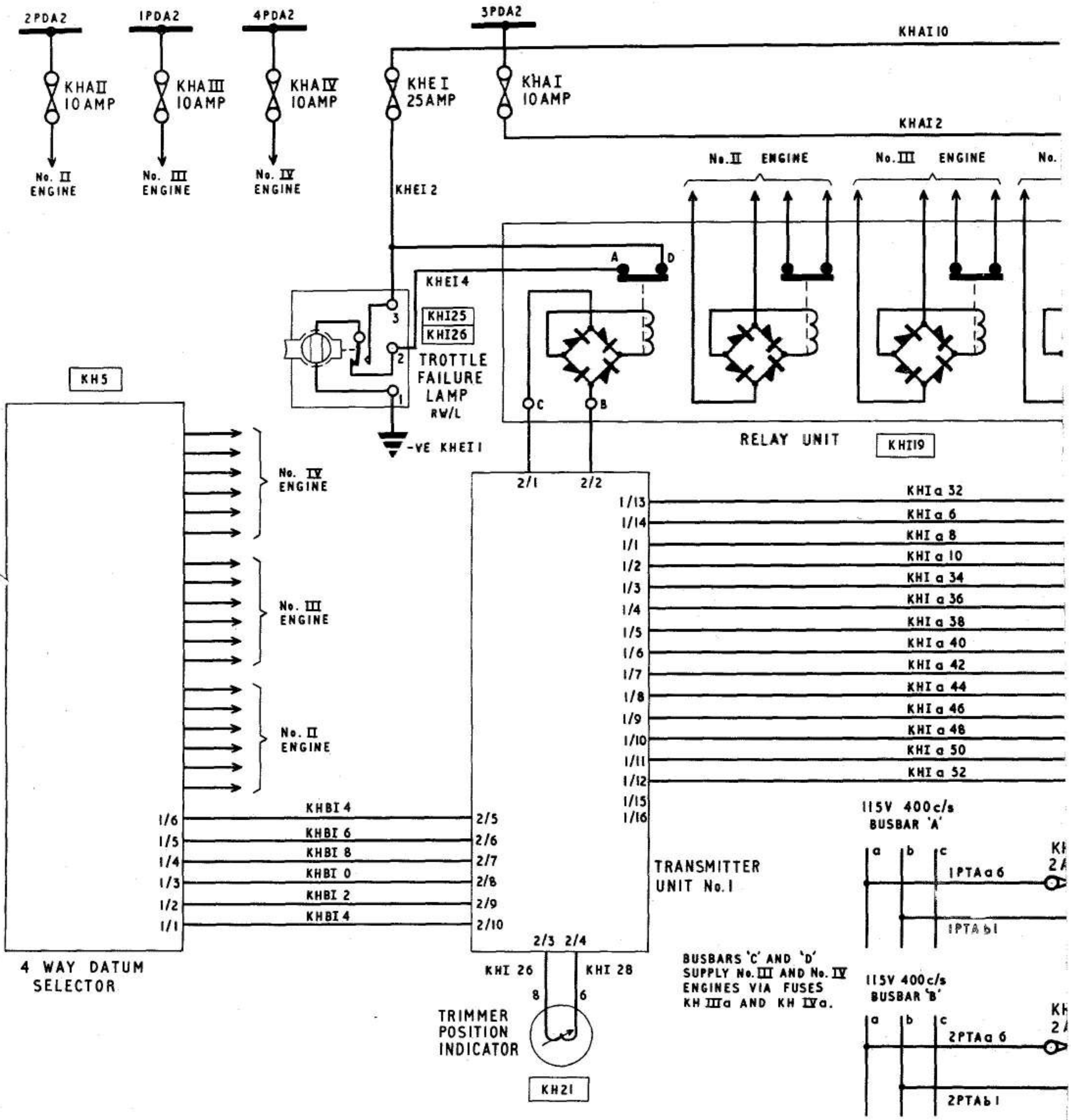

Fig.15

Throttle control syst

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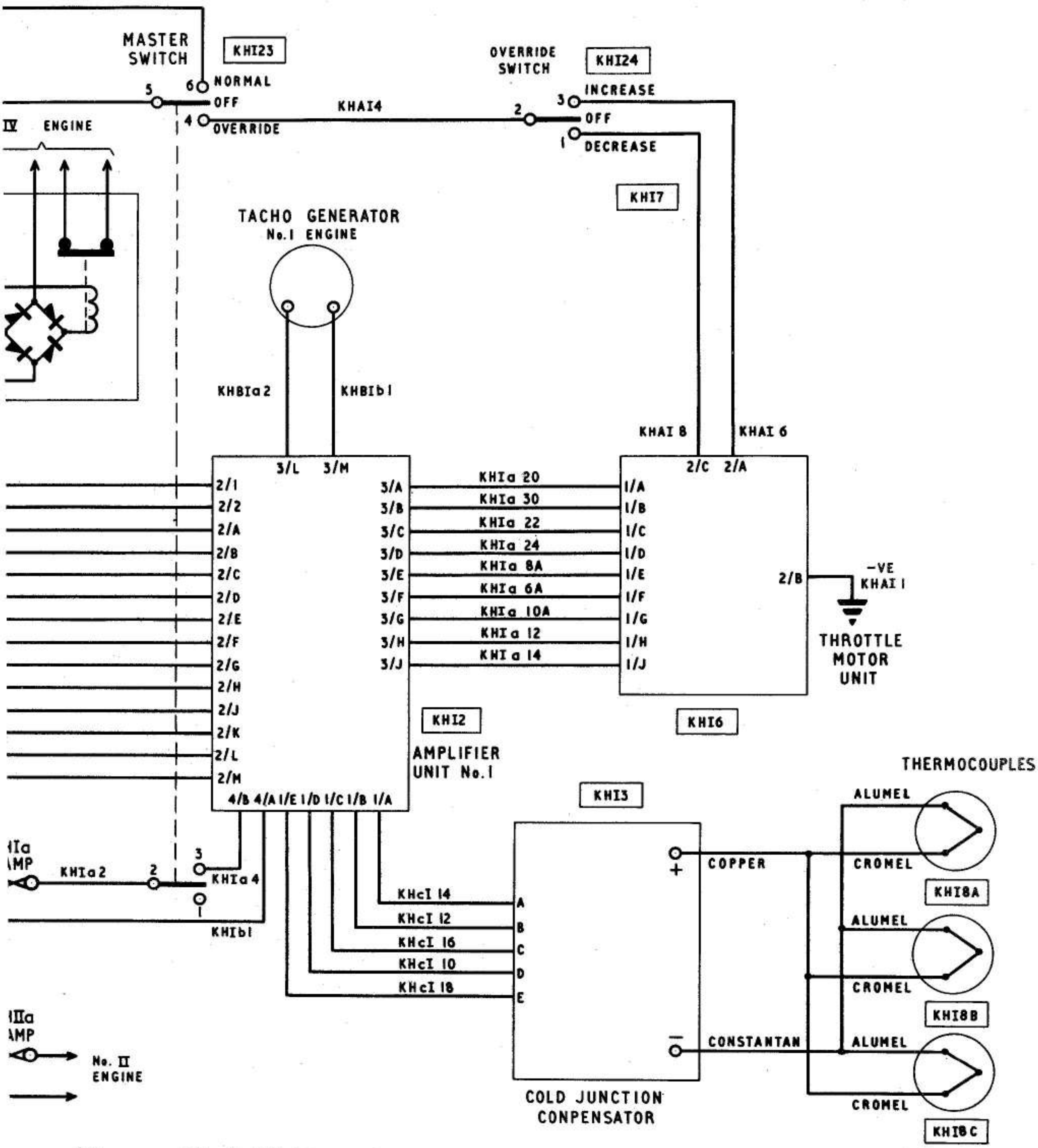

em, Type B.A.P. 3 Fig. 15
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