

Chapter 4**AMPLIFIER UNIT, ULTRA, TYPE A234****LIST OF CONTENTS**

	Para.		Para.
<i>Introduction</i>	1	<i>Thermocouple harness resistance</i> ...	38
Description		<i>Datum temperature, deadband and</i>	
<i>General</i>	5	<i> inching tests</i>	39
Principles of operation	7	<i>Aircraft tests—static conditions</i> ...	42
Circuit description	10	<i>Precautions</i>	43
<i>Feedback circuits</i>	19	<i>Test set batteries</i>	44
<i>Bias circuits</i>	25	<i>Test connections at aircraft</i>	45
<i>Smoothing</i>	26	<i>Voltage, frequency and phasing tests</i> ...	46
<i>Datum trim</i>	27	<i>Removal of test cable QY2216</i> ...	47
<i>Safety resistor</i>	28	<i>Thermocouple harness resistance</i> ...	48
Testing		<i>Datum temperature, deadband and</i>	
<i>Bench tests</i>	29	<i> inching tests</i>	49
<i> Precautions</i>	31	<i>Aircraft jet-pipe temperature indicator</i>	
<i> Test set batteries</i>	32	<i> test</i>	52
<i> Test rig connections</i>	33	<i>Aircraft tests—ground running conditions</i>	53
<i> Voltage, frequency and phasing tests</i> ...	36	<i> Disconnecting supplies</i>	58
<i> Removal of test cable QY2216</i> ...	37	<i> Fault finding</i>	59
		<i> Insulation resistance</i>	61

LIST OF TABLES

	Table
<i>Voltages and resistances measurements</i> ...	1

LIST OF ILLUSTRATIONS

	Fig.		Fig.
<i>Amplifier unit, Ultra, Type A234</i> ...	1	<i>Response diagram...</i>	5
<i>Amplifier unit with top covers removed</i> ...	2	<i>Aircraft test circuit</i>	6
<i>Block schematic diagram of amplifier</i> ...	3	<i>Layout of amplifier showing seal numbers</i>	7
<i>Bench test circuit</i>	4	<i>Circuit diagram of amplifier A234</i> ...	8

LEADING PARTICULARS

Amplifier unit, Ultra, Type A234	Ref. No. 5CZ/5264
<i>Datum temperature</i>	645.5 ± 2.5°C
<i>Input to amplifier</i>	115V, 400 c.p.s. 3-phase
<i>Datum temperature variation using datum trim potentiometer</i>	30°—40°C
<i>Dead band</i>	7°C below datum + 2½°C
	— 1½°C
<i>Feedback band-width</i>	+ 24.5 ± 6°C
	— 24.5 ± 6°C
<i>Length</i>	10 in.
<i>Width</i>	6 in.
<i>Height</i>	4 in.
<i>Weight</i>	8.5 lb.

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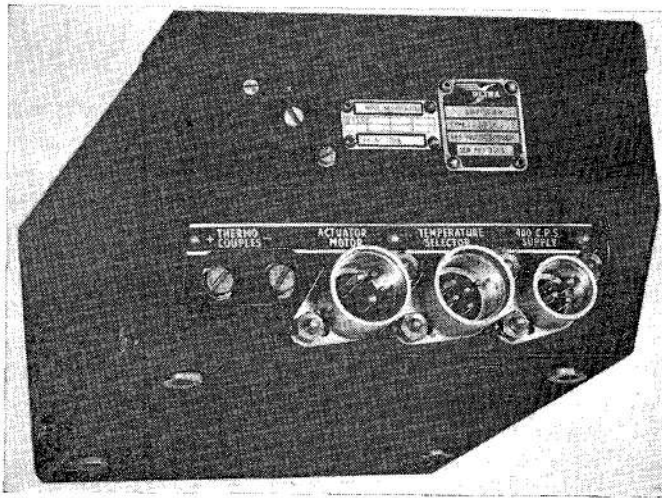


Fig. 1. Amplifier unit, Ultra, Type A234

Introduction

1. The amplifier unit, Ultra, Type A234 (*fig. 1*) is a magnetic amplifier, designed to effect control of the jet-pipe temperature of an aircraft engine to a datum specified by the engine manufacturer, the required datum temperature being obtained by inserting the appropriate datum selector unit into the TEMPERATURE SELECTOR plug of the amplifier. Alternatively, the amplifier can be used as a temperature limiter, i.e., it will limit the engine temperature to a specified, upper, temperature limit.

2. Temperature is sensed by a thermocouple cluster attached to the engine jet-pipe. The thermocouple signal is applied to the amplifier, the output of which supplies the field windings of a reversible motor actuator.

3. The function of the actuator is to trim the main throttle valve, thereby controlling the fuel flow to the engine, and subsequently maintaining the jet-pipe temperature at the specified datum.

4. The principles and applications of magnetic amplifiers are outlined in A.P.4343, Vol. 1, Sect. 1, Chap. 3.

DESCRIPTION

General

5. Stage 1, stage 2, stage 3, the transformer unit, and the cold junction compensator are housed in separate sealed cans and can be seen on removal of the amplifier cover (*fig. 2*). On the same casting are fitted the two changeover relays and also the amplifier controls, namely: gain, stage 1 zero, reference volts (load and balance), and feedback bandwidth (inching range control).

6. A separate end-casting houses the datum trimmer control and the following plugs:—

- (1) Four-pole plug for the 115V, 400 c.p.s. 3-phase supply.
- (2) Five-pole plug for the temperature selector unit.
- (3) Four-pole plug for the d.c. actuator motor.

In addition to the above plugs there are two terminals which accept the compensating leads from the thermocouples.

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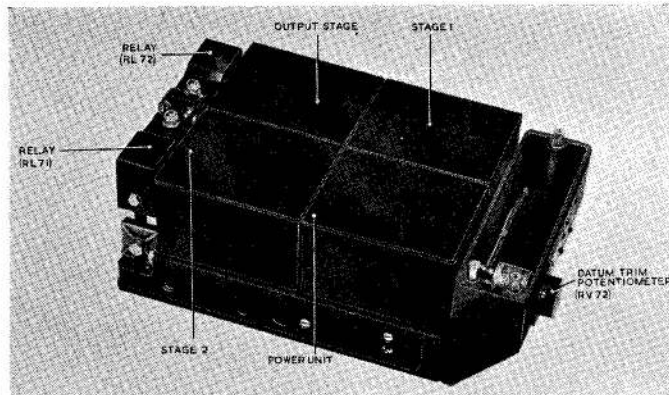


Fig. 2. Amplifier unit with top cover removed

PRINCIPLES OF OPERATION

7. The block schematic diagram, shown in Fig. 3, illustrates the basic principle of the A234 magnetic amplifier unit. A three-phase transformer provides the power supplies for the amplifying stages, stabilizing bridge network and bias circuits.

8. A stabilized voltage output from the voltage stabilizing bridge is applied to the cold-junction compensator (C.J.C.) bridge network. A reference datum temperature voltage is derived from the C.J.C. bridge and is compared with the input signal from the thermocouples. Any difference between these voltages results in a current (error signal) which is directed to the stage 1 control windings and subsequently amplified by the three amplifying stages of the amplifier unit. The magnitude of the error signal is proportional to the difference existing between the engine jet-pipe temperature and the specified datum. The polarity of the error signal is related to an engine jet-pipe temperature in excess of, or below, the specified datum.

9. The amplifier output is applied to the field windings of a d.c. split-field series motor actuator via two changeover relays located in the magnetic amplifier unit. Depending upon the polarity of the error signal, one of the relays will operate, thus causing the actuator to rotate in the appropriate direction to operate the fuel valve and return the jet-pipe temperature to the specified datum.

CIRCUIT DESCRIPTION

10. The circuit diagram (*fig. 8*) shows the connections between the individual components together with the respective seal numbers and terminal identification. The amplifier maintains a temperature deadband of 7°C below datum wherein the error signal is not great enough to operate the relays. As the error signal increases in magnitude the relays operate, and the actuator inches over a feedback bandwidth (inching range) of 56°C about the datum level, i.e., $\pm 28^{\circ}\text{C}$ including the deadband, such that the rate of actuator correction is approximately proportional to the magnitude of the error signal. For larger error signals outside the feedback bandwidth, the actuator motor is continuous-running, in a direction dependent upon the polarity of the error signal, until the end of its travel when it will be stopped by the operation of limit switches.

11. The power unit houses a 115V, 400 c.p.s., 3-phase, delta-connected transformer which provides the following supplies:—

- (1) Power supplies for the transducers of the three amplifying stages.
- (2) A supply, via the half-wave power rectifier, for the voltage stabilizing bridge
- (3) A 9mA current for the bias windings of the three amplifying stages.

12. A smoothed d.c. supply of 9mA is fed from a 126V transformer secondary winding to the voltage stabilizing bridge located in the power unit. The output of the bridge

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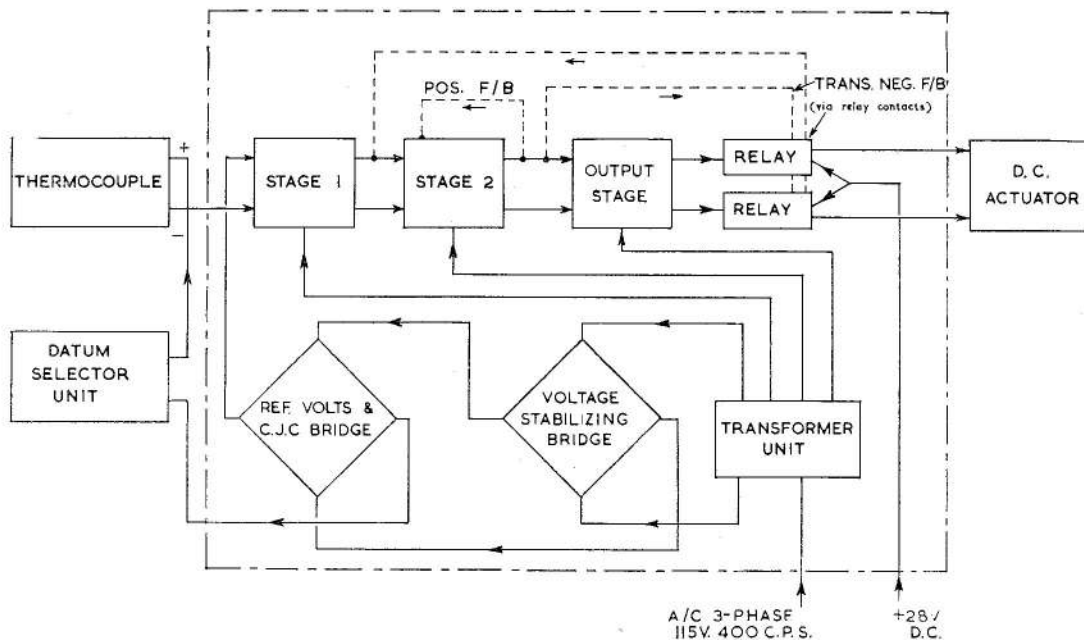


Fig. 3. Block schematic diagram of amplifiers

(terminals 19 and 20) is stabilized against fluctuations of the supply voltage by the Zener reverse voltage characteristic of a Silicon diode, WS52, inserted in one arm of the bridge. Adjustment of this stabilized output is effected via the potentiometers, RV63 (REF. VOLTS LOAD) and RV64 (REF. VOLTS BALANCE), which are pre-set and locked in position during the initial setting-up of the amplifier, to ensure that a stabilized d.c. supply of 2mA is fed to the reference voltage and cold junction compensator (C.J.C.) bridge network. This stabilized d.c. supply enables a reference voltage to be developed in the C.J.C. bridge resistor network (R66 to R68).

13. The reference voltage opposes the thermocouple voltage, which is applied to the C.J.C. bridge. Any difference between these voltages results in a current (error signal) being directed to the stage 1 control winding which is connected in series with the thermocouples and the datum trim potentiometer, RV72. A datum selector unit, when inserted in the amplifier, provides a zero error signal at a specified datum in accordance with the engine requirement. The datum trim potentiometer RV72 (*para.* 27) provides a means of trimming the datum setting to zero, thereby compensating for differences in aircraft installations, e.g., current-drawing temperature gauge Refer-

ence should be made to the Aircraft, or Engine, Handbook to establish the correct datum selector that is to be fitted to the amplifier.

14. The e.m.f. generated by the thermocouples depends upon the temperature difference existing between the hot and cold junctions. Ambient temperature compensation is effected by the inclusion of a copper resistance coil, located adjacent to the thermocouple input terminals, and electrically connected in one arm of the C.J.C. bridge network. The resistance of this coil varies as the ambient temperature varies and therefore modifies the balance of the C.J.C. bridge. The subsequent change in the C.J.C. bridge reference voltage is equal and opposite to the thermocouple voltage change which is due to the change in the cold junction ambient temperature. The amplifier control circuit is therefore referred to a thermocouple voltage which is proportional to the hot-junction temperature.

15. The error signal which ensues from the comparison between the thermocouple input voltage and the reference voltage is applied to the control windings of stage 1 via terminals 2 and 5, where it is amplified by a pair of bias-excited, push-pull transducers and rectified by the rectifier bridges. Since the stage 1 transducers are connected in

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push-pull the output is sensed, i.e., of the same direction as the error signal, and will be applied to terminals 7, 10 and 14.

16. The stage 1 rectified output signal is applied to the control windings of stage 2 (terminals 2 and 5), via a potentiometer, RV62, by which stage 1 is initially balanced. Stage 2 amplifies and rectifies this signal in the same manner as stage 1. Since stage 1 and stage 2 transducers are connected in cascade, the stages are balanced and thus respond to signals of either polarity. The stage 2 output is fed to the control windings of the output stage at terminals 4 and 9.

17. Output stage amplification is by two single-ended auto-self-excited transducers with a common bias circuit. The control windings are arranged so that one or other of the transducers is operative depending upon the polarity of the input signal to the output stage. This is achieved by the inclusion of rectifiers (W32 and W33) in series with each control winding of transducers X and Y. The output from the X transducer is applied to terminals 19 and 11 and supplies the energizing coil of relay RL71. The output from the Y transducer is applied to terminals 15 and 16 and supplies the energizing coil of relay RL72.

18. The relays operate as follows: the 28V d.c. supply enters the amplifier at pin B of the actuator plug, and is applied to pin 1 of relay RL71 and pin 4 of relay RL72 (fig. 8). If RL71 is energized, the 28V d.c. signal can pass via contacts 4 and 5 of RL72 to contacts 2 and 3 of RL71 and thence to pin 1 of the actuator plug. If RL72 is energized, the 28V d.c. signal can pass via contacts 1 and 2 of RL71 to contacts 5 and 6 of RL72 and thence to pin 2 of the actuator plug. Pins 1 and 2 of the actuator plug supply the field windings of the motor actuator.

Feedback circuits

19. Several feedback loops are incorporated in the amplifier to give control and stability. The stage 1 positive feedback loop is applied to winding 3, via terminals 7 and 11, to increase the stage gain if required.

20. The stage 2 positive feedback loop consists of part of the stage 2 output current, derived from the potentiometer RV61 fed back into winding 4. The potentiometer

RV61 acts as a gain control for the amplifier and controls the deadband, i.e., the input temperature zone in which the error signal is too small to operate either of the relays, RL71 and RL72. The deadband is set to approximately 7°C.

21. The stage 2 transient negative feedback loop consists of part of the stage 2 output, derived from a 20 ohms resistor, R602, fed back into the stage 2 input at terminals 2 and 5. This feedback loop is routed via the potentiometer RV68 and the contacts of relays RL71 and RL72. When the amplifier input error signal is within the deadband, the relays are de-energized and the transient negative feedback circuit is broken. When the error signal increases beyond the deadband, one or other of the relays is energized and the transient negative feedback circuit is operative, the circuit being made either through contacts 5 and 6 of relay RL71 or contacts 2 and 3 of relay RL72. The potentiometer RV68 acts as a control for the feedback bandwidth, i.e., the input temperature zone in which the transient feedback is operative. This is normally set to approximately 56°C, i.e., 24.5°C in the close-throttle direction and 24.5°C in the open throttle direction, excluding the deadband range.

22. When the actuator is controlling within the feedback bandwidth (inching range) the motor actuator operates in steps. This action is due to transient negative feedback. The rate of actuator correction is approximately proportional to the magnitude of the error signal since this controls the time during which one or other of the relays is energized.

23. For large input error signals outside the feedback bandwidth, the transient negative feedback is insufficient to reduce the output of stage 2 to the level at which one or other of the relays becomes de-energized. Thus the actuator runs continuously at constant speed until the error signal is reduced sufficiently to bring the error within the feedback bandwidth. When within the feedback bandwidth, the actuator operates in steps until the error is brought within the deadband.

24. The output stage has a fixed negative feedback loop over each of the two output stage transducers. Part of the output is

taken via resistors R33 and R34 and fed back into winding 4 of each transducer to provide stability of the output stage.

Bias circuits

25. The rectified 9mA current obtained from the 126V winding of the transformer provides the necessary bias for stages 1, 2 and 3 in series. Stages 1 and 2 incorporate bias shunts to adjust the bias winding current to the appropriate value.

Smoothing

26. Smoothing of the bias and voltage stabilizing circuits is effected by capacitor C11 connected across terminals 15 and 16 of stage 1. The stage 2 control circuit is smoothed by capacitor C71 connected across terminals 2 and 5 of stage 2, and the X and Y output stage transducer control windings are smoothed by capacitor C22 (terminals 15 and 11 of stage 2) and capacitor C33 in the output stage. The rectifiers W34 and W35 also perform a smoothing function on the relay coil current. This prevents the relays from 'chattering' during operation. Capacitors C31 and C32 in the output stage act as suppressors for the relay contacts.

Datum trim

27. Datum trim control is effected via potentiometer RV72 in the input circuit. This is a 'click' potentiometer giving a range of approximately 37.5°C in fifteen steps of approximately 2.5°C each step. This is used as a final trim when the amplifier is installed in the aircraft.

Safety resistor

28. A 4.7kΩ resistor connected across the thermocouple and selector circuit ensures that, in the event of an open-circuit fault, a negative signal is seen by the amplifier.

TESTING

Bench test

29. A bench test, using Test Equipment Type QE2230, is applied to the amplifier to determine its serviceability prior to being installed in the aircraft. Equipment required for the bench test is detailed below:—

- (1) Test set, Type QT223.
- (2) Nine-core test cable Type QY2212.
- (3) Four-core test cable Type QY2216 for monitoring the 115V, 400 c.p.s. supply.
- (4) Bench test rig (*fig. 4*).
- (5) Three-phase 115V, 400 c.p.s. supply.
- (6) A d.c. reversible split-field series-

wound motor actuator as used in the aircraft jet-pipe temperature control system.

The bench test, applied to the control system amplifier, includes datum temperature, deadband and inching range tests. A response diagram (*fig. 5*) shows the various temperature readings (A, B, C and D) obtained during the bench tests. The readings are interpreted, on completion of the relevant tests, into the deadband, gain and datum temperature of the jet-pipe temperature control system.

30. Prior to commencing bench tests, certain precautions must be observed and preliminary tests undertaken, as described in paras. 31 and 32.

Precautions

31. To obviate possible damage to the test set, QT223, the following precautions must be observed.

- (1) Before switching on the supply to the test set, and unless the testing instructions state otherwise, the REHEAT/SPEED DATUM switch must be in the OFF (centre) position.
- (2) When adjusting the DATUM TEMPERATURE scale, during temperature signal measurements, avoid running the associated potentiometer hard on to its limit stops.

Test set batteries

32. The following test should be applied to the test set QT223 to ensure that the batteries are serviceable.

- (1) Reference source battery (Mallory SKB544).
 - (a) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL switch to the TEMPERATURE DATUM AND SIGNAL position.
 - (b) Turn the TEST SELECTOR switch to the BATTERY position.
 - (c) Note the reading of METER II which should be in the green zone.
- (2) Temperature signal source battery (Mallory SKB536).
 - (a) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL switch to the TEMPERATURE DATUM AND SIGNAL position.
 - (b) Turn the TEST SELECTOR switch to T/C RES.
 - (c) Turn the T/C HARNESS SELECTOR switch to position H.

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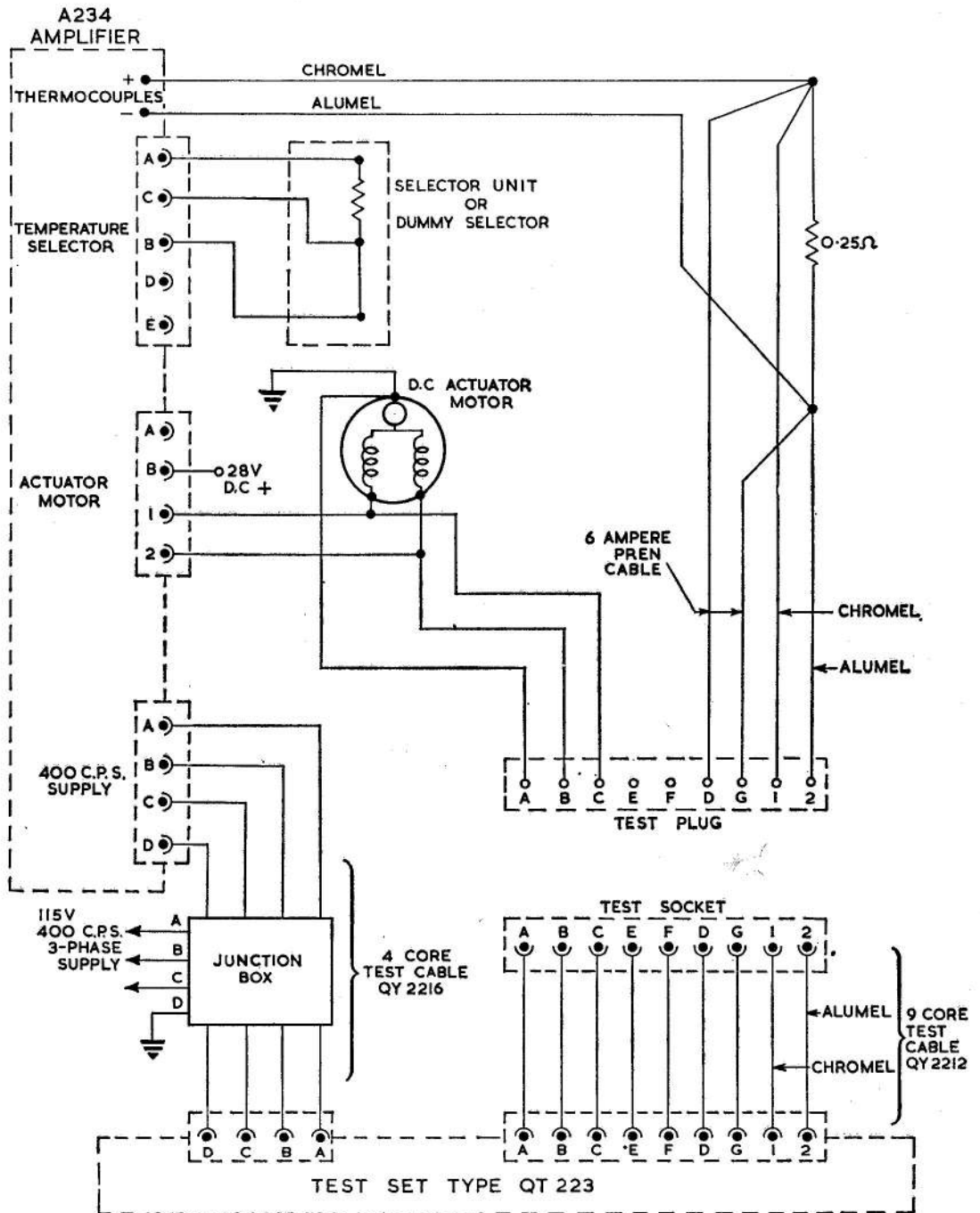


Fig. 4. Bench test circuit

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- (d) Depress the T/C RESIST. TEST key switch to the T/C RESIST. TEST position.
- (e) Rotate the TEMP. SIGNAL, COARSE control slowly clockwise.
- (f) With the COARSE control turned through approximately $\frac{3}{4}$ full travel, METER II should indicate full scale deflection. If the readings of METER II differ from those given, the respective battery must be considered unserviceable and should be renewed. Instructions for changing the batteries are given in Sect. 10, Chap. 1 of this publication.

Test rig connections (fig. 4)

33. The thermocouple commoning leads are connected to the amplifier input (THERMOCOUPLES, terminals + and -) and to the test plug (terminals 1 and 2) by special compensating leads. Therefore, it is essential that the connecting cables used in the bench test shall include Chromel/Alumel leads, as indicated in the bench test circuit (fig. 4).

34. In the test rig, the resistance of the thermocouple cluster is simulated by a 0.25 Ω resistor. It is important to ensure that the connecting leads to this resistor make good electrical contact since additional resistance in this circuit will adversely affect the test results.

35. Connect the amplifier into the bench test circuit prepared as in fig. 4. Switch on the 115V, 400 c.p.s., 3-phase supply.

Note . . .

During the bench tests the thermocouple e.m.f. is simulated by a variable voltage derived from the test set QT223. The test set voltage is obtained by turning the TEMP. DATUM/OFF/TEMPERATURE DATUM AND SIGNAL switch to the TEMPERATURE DATUM AND SIGNAL position, as specified in the relevant tests.

Voltage, frequency and phasing tests

36. These tests provide an indication that the power supply to the control system amplifier is correct. They are not intended to provide an absolute measurement. Allow five minutes to elapse, after switching on the supply, before proceeding with the tests.

- (1) Turn the TEST SELECTOR switch to C.P.S.
- (2) The frequency is indicated on METER I. The scale range is 380—420 c.p.s. in steps of 10 c.p.s. Centre scale reading represents 400 c.p.s.

- (3) Observe the PHASING indicator, the indicator lamp should be extinguished.
- (4) Turn the TEST SELECTOR switch to VOLTS.
- (5) Note the reading of METER II. If the voltage is within the specified limits the meter reading should be within the blue zone.
- (6) Observe the PHASING indicator; the indicator lamp should be alight.

Note . . .

This PHASING indication is the reverse of that quoted in sub-para. (3).

Removal of test cable QY2216

37. Disconnect and remove the test cable QY2216 from the test circuit. Connect the aircraft supply leads to the a.c. supply plug (400 c.p.s. SUPPLY) of the amplifier.

Thermocouple harness resistance

38. If a new thermocouple harness is to be fitted to the aircraft installation, bench tests can be applied to the harness as described in para. 48.

Datum temperature, deadband and inching range tests

39. The amplifier unit should be fitted with the appropriate datum selector unit as specified in the relevant Aircraft, or Engine, Handbook. The following test sequence will then be adopted and the datum temperature will be as specified in the Handbook.

- (1) Prepare for recording simulated temperatures (DATUM TEMPERATURE scale) at which METER I indicates a change in response during the following operations.
- (2) If the aircraft installation is fitted with a temperature indicator of the current-drawing type, set the T/C HARNESS SELECTOR switch to a position appropriate to the thermocouple harness resistance. If the aircraft jet-pipe temperature indicator is of the non current-drawing type the T/C HARNESS SELECTOR switch must be set to the SERVO. POT. position.
- (3) Rotate the TEST SELECTOR switch to the D.C. ACT. position.
- (4) Turn the TEMP. SIGNAL, COARSE and FINE controls fully anti-clockwise.
- (5) Set the DATUM TEMPERATURE scale reading to the approximate datum temperature of the system under test.
- (6) Set the galvanometer clamp to the FREE position and zero the pointer if necessary.

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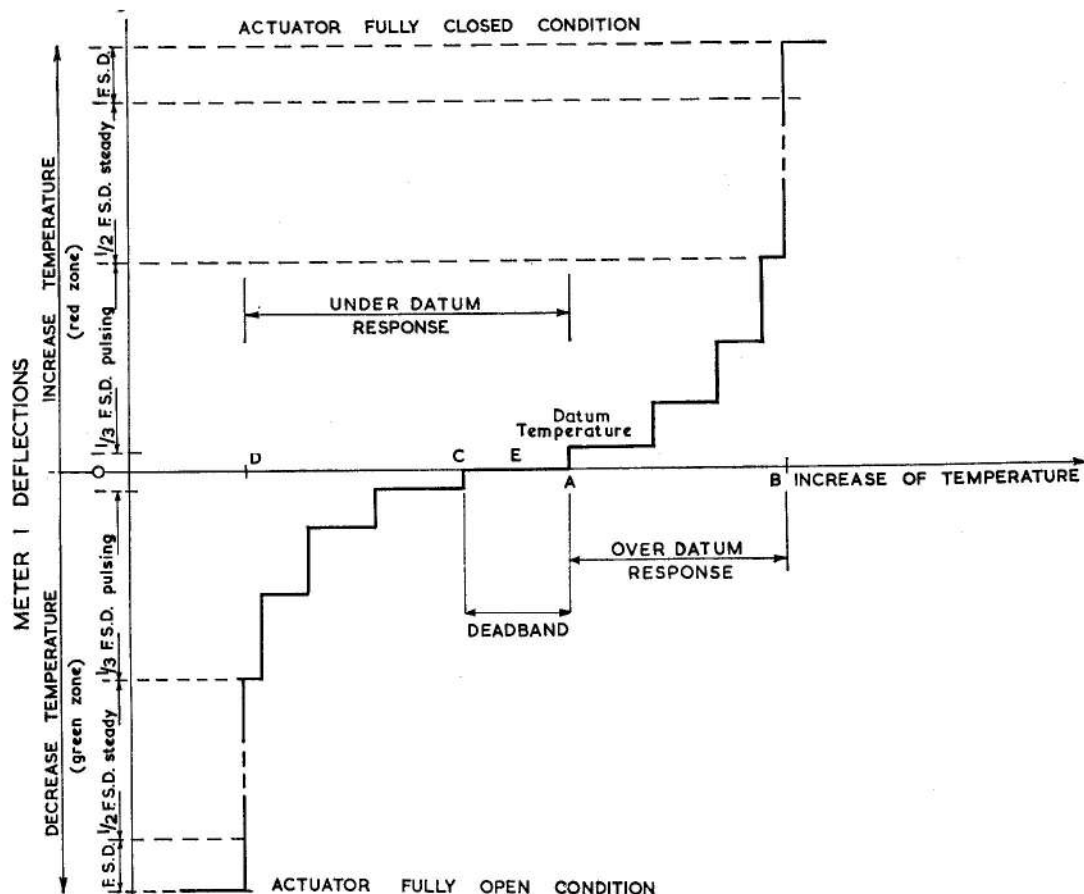


Fig. 5. Response diagram

(7) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL switch to the TEMPERATURE DATUM and SIGNAL position. METER I should now show full scale deflection into the green, or DECREASE TEMPERATURE, zone indicating that the actuator is at its limit stop in the open-throttle condition.

(8) Turn the COARSE control very slowly clockwise until the pointer of METER I moves, by a sudden action, to the centre zero position.

Note . . .

Considerable care is necessary to obtain this condition, the null position being very critical.

(9) Increase the TEMP. SIGNAL, FINE control very slowly until METER I shows

a momentary deflection of a quarter to one-third full scale deflection, into the red, or INCREASE TEMPERATURE zone. This denotes a transient inching movement of the actuator in the close-throttle condition. By a sharp action, slightly reduce the setting of the FINE control until deflections cease.

(10) Repeat sub-para. (9).

(11) Momentarily depress the GALVO IN/SET UP key switch to the SET UP position and observe the deflection of the galvanometer pointer. Adjust the DATUM TEMPERATURE scale to reduce the galvanometer deflection, depressing the galvanometer key switch at frequent intervals to observe the effect on the galvanometer.

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When the galvanometer reading is within the eight divisions either side of zero the galvanometer key switch may be placed in the GALVO IN position and the galvanometer reading brought to zero by adjustment of the DATUM TEMPERATURE scale.

Note . . .

Temperature readings must NOT be taken while METER I is showing pulsing deflections, since the pulsing sets up transients which may lead to spurious readings.

(12) Record the simulated temperature reading as indicated on the DATUM TEMPERATURE scale; this represents point A (*fig. 5*) which is the start of the inching range in the close-throttle direction.

(13) Increase the simulated temperature by steadily increasing the TEMP. SIGNAL, FINE control. As this is done, the pointer of METER I will pulsate between zero and one-third full scale deflection, the pulses increasing in frequency as the FINE control is increased. This indicates that the actuator is inching, at increasing speed in the close-throttle direction, and will continue to do so until the applied simulated thermocouple signal (controlled by the FINE control) reaches a level that will cause the actuator to run continuously. This condition will be indicated by the pointer of METER I showing a steady one-third to one-half full scale deflection into the red zone.

(14) Measure the simulated temperature at which the steady deflection is first apparent, as described in sub-para. (11) and record this reading (point B, *fig. 5*).

(15) Allow the actuator to run to its closed limit. This will be indicated by the reading of METER I increasing suddenly to full scale deflection in the red, INCREASE TEMPERATURE, ZONE.

(16) Turn the TEMP. SIGNAL, FINE control fully clockwise. Very slowly reduce the TEMP. SIGNAL, COARSE control setting until METER I again shows, by a sudden action, a zero reading, i.e., reduce the simulated excess temperature to normal for the throttle setting. The actuator will remain at its closed limit but its circuit will be de-energized.

(17) Reduce the TEMP. SIGNAL, FINE control very slowly until METER I shows a momentary deflection of one-quarter to one-third full scale deflection into the green or DECREASE TEMPERATURE ZONE. This denotes an initial-inching movement of the actuator in the open-throttle, or increase fuel, direction.

(18) By a sharp action, slightly increase the TEMP. SIGNAL, FINE control setting until deflections cease.

(19) Repeat sub-para. (18) and (19).

(20) Measure the simulated temperature at which the inching just ceases, described in sub-para. (11), and record this reading (point C, *fig. 5*).

(21) Further reduce the FINE control setting until the METER I reading shows a steady deflection of one-third to one-half full scale deflection into the green or DECREASE TEMPERATURE ZONE. This meter reading indicates that the temperature signal has reached a level that will cause the actuator to run continuously in the open-throttle direction.

(22) Measure the simulated temperature, at which the steady deflection is first apparent, as described in sub-para. (11), and record this reading (point D, *fig. 5*).

(23) Allow the actuator to run to its open limit. This will be indicated by the METER I reading increasing suddenly to full scale deflection into the green or DECREASE TEMPERATURE ZONE.

(24) Turn the TEMP. SIGNAL, FINE control fully anti-clockwise and then very slowly increase the COARSE control setting until METER I again shows a zero reading.

(25) Repeat the operations quoted in sub-para. (7) to (19) and record the simulated temperatures for the significant METER I indications (points A, B, C and D, *fig. 5*).

(26) Compare the two sets of readings and, where they approximate, record a mean value. If any pair of readings are widely divergent, a third set of readings should be taken.

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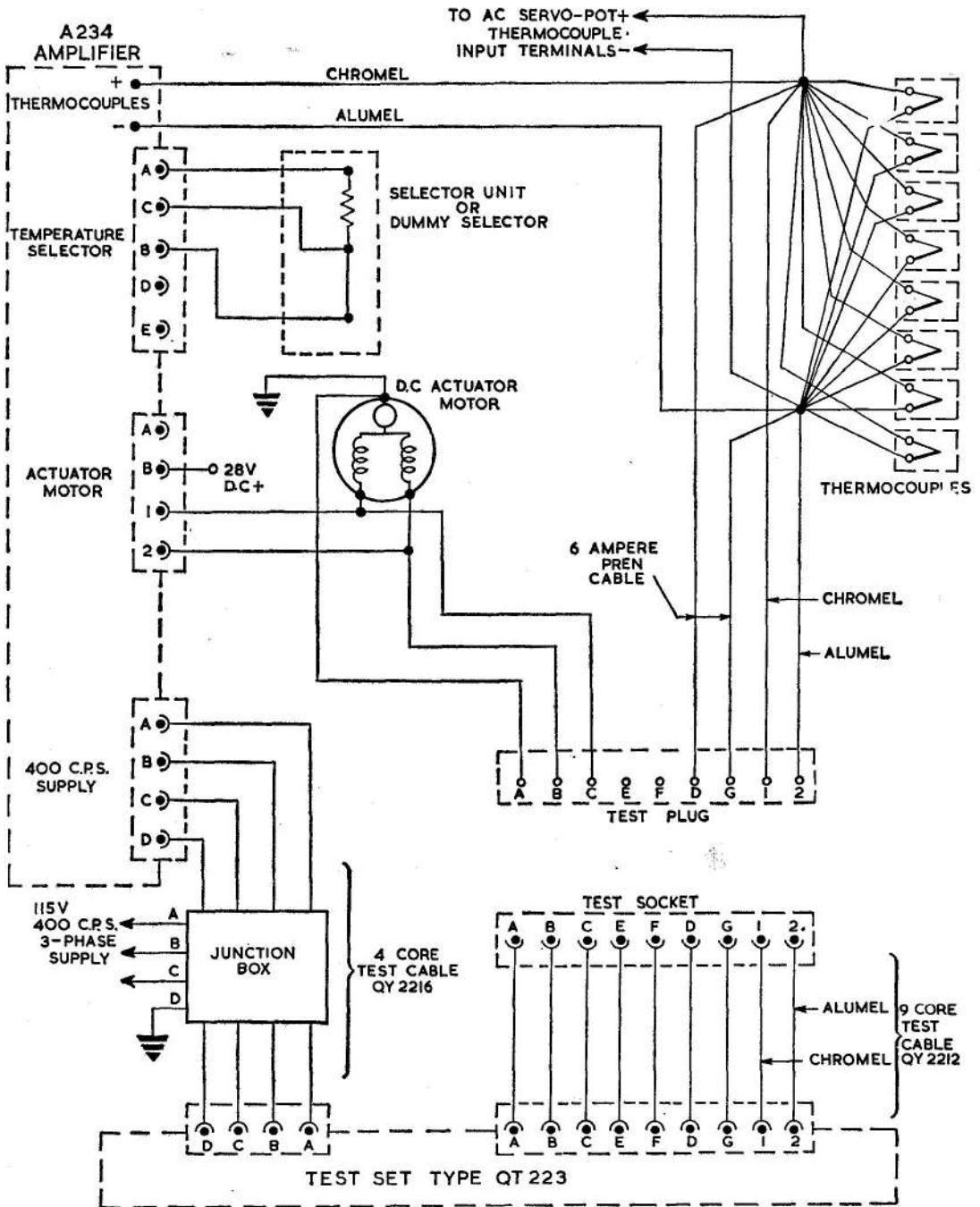


Fig. 6. Aircraft test circuit

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(27) Repeat operations (4) to (25) at the other aircraft engine throttle settings, where applicable.

(28) Turn the TEMP. SIGNAL, COARSE control fully anti-clockwise and set the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL switch to the OFF position.

(29) Return the galvanometer clamp to the CLAMP position.

40. From the recorded temperature, at points A, B, C and D, the results of the tests are determined as follows:—

A = DATUM TEMPERATURE (as specified in relevant Aircraft, or Engine, Handbook).

Note . . .

If the TEMPERATURE SELECTOR plug is connected as shown in Fig. 4, the datum temperature will be $645.5 \pm 2.5^\circ\text{C}$.

A-C = DEADBAND =
 $7^\circ + 2\frac{1}{2}^\circ\text{C}$ below datum.
 $- 1\frac{1}{2}^\circ\text{C}$

B-A = INCHING RANGE (close-throttle direction) =
 $24.5^\circ \pm 6^\circ\text{C}$.

C-D = INCHING RANGE (open-throttle direction) =
 $24.5^\circ \pm 6^\circ\text{C}$.

41. The selected temperatures obtained must be compared with those specified for the temperature control system. If there are discrepancies outside the specified limits the temperature trimmer on the amplifier unit should be adjusted to correct these discrepancies. If the specified figures cannot be obtained by adjustment of the temperature trimmer, either the amplifier unit, the selector unit, or the associated wiring is unserviceable.

Aircraft tests—static conditions

42. The thermocouple e.m.f., normally dependent on the jet-pipe temperature, is simulated by the injection of a variable voltage, derived from the test set QT223, at the thermocouple commoning points. This enables the jet-pipe temperature to be tested with the aircraft engine stationary, i.e., under static conditions.

Precautions

43. To obviate possible damage to the test set QT223 the following precautions must be observed:—

(1) Before switching on the supply to

the test set, and unless the testing instructions state otherwise, the REHEAT/SPEED DATUM switch must be in the OFF (centre) position.

(2) When adjusting the DATUM TEMPERATURE scale, during temperature signal measurements, avoid running the associated potentiometer hard on to its limit stops.

(3) On completion of the tests, the galvanometer locking device should be returned to the CLAMP position, the relevant switches returned to their OFF positions, the TEMP. SIGNAL (COARSE and FINE) controls turned fully anti-clockwise, and all cables disconnected and placed behind the hinged flap in the test set lid.

Test set batteries

44. Prior to commencing tests on an aircraft installation the following tests should be applied to the test set QT223 to ensure that the batteries are serviceable.

Reference source battery (Mallory SKB544)

(1) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL switch to the TEMPERATURE DATUM and SIGNAL position.

(2) Turn the TEST SELECTOR switch to the BATTERY position.

(3) Note the reading of METER II which should be in the green zone.

Temperature signal source battery (Mallory SKB536)

(1) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL switch to the TEMPERATURE DATUM and SIGNAL position.

(2) Turn the TEST SELECTOR switch to T/C RES.

(3) Turn the T/C HARNESS SELECTOR switch to position H.

(4) Depress the T/C RESIST. TEST key switch to the T/C RESIST. TEST position.

(5) Rotate the TEMP. SIGNAL, COARSE control slowly clockwise.

(6) With the COARSE control turned through approximately $\frac{3}{4}$ full travel, METER II should indicate full scale deflection.

If the readings of METER II differ from those given, the respective battery must be considered unserviceable and should be renewed.

RESTRICTED

Test connections at aircraft

45. (1) Remove the blanking cap from the aircraft 9-pole test plug and connect the Test Set QT223 (A/C TEST plug) to the aircraft test plug using test cable QY2212. In aircraft not fitted with a 9-pole test plug, the commoning terminal of the thermocouple cluster must be located and leads 1 and D of test cable QY2212 connected to the common positive. Similarly connect leads 2 and G to the common negative of the thermocouples.
- (2) Remove the socket from the a.c. supply plug (400 C.P.S. SUPPLY) of the amplifier and substitute the socket, located on one of the two short leads from the junction box of test cable QY2216. Make the remaining short lead, from the junction box, with the socket previously connected to the amplifier a.c. supply plug. Connect the remaining socket of the test cable QY2216 to the 4-pole plug (PHASING) of the test set.
- (3) Connect a battery truck to the aircraft ground supply point and switch on the inverters.

Voltage, frequency and phasing tests

46. These tests provide an indication that the power supply to the control system amplifier is correct. They are not intended to provide an absolute measurement. Allow five minutes to elapse, after switching on supply, before proceeding with the tests.
- (1) Turn the TEST SELECTOR switch to C.P.S.
- (2) The frequency is indicated on METER I. The scale range is 380-420 c.p.s. in steps of 10 c.p.s. Centre scale reading represents 400 c.p.s.
- (3) Observe the PHASING indicator; the lamp should be extinguished.
- (4) Turn the TEST SELECTOR switch to VOLTS.
- (5) Note the reading of METER II. If the voltage is within the specified limits the meter reading should be within the blue zone.
- (6) Observe the PHASING indicator. With the 3-phase supply the indicator lamp should light.

Note . . .

This PHASING indication is the reverse of that quoted in sub-para. (3).

Removal of test cable QY2216

47. Disconnect and remove the test cable QY2216 from the test circuit. Connect the supply lead to the a.c. supply plug of the amplifier.

Thermocouple harness resistance

48. The tests are effected by comparing the resistance of an aircraft thermocouple harness with that of a standard resistor in the test set. It is important therefore that the value of standard resistor, selected via the T/C HARNESS SELECTOR switch, coincides with the value of thermocouple harness resistance quoted in the relevant Aircraft, or Engine, Handbook.

- (1) Set the TEMP. SIGNAL, COARSE and FINE controls fully anti-clockwise.
- (2) Rotate the T/C HARNESS SELECTOR switch to the position appropriate to the installation under test. The values of standard resistor selected under positions A-J are as follows:—

Selector switch position	Value of standard resistor (Ω)
A	1.5
B	1.0
C	0.8
D	0.5
E	0.34
F	0.3
G	0.25
H	0.2
J	Plug-in resistors.

SERVO POT. Selected when the aircraft temperature indicator is of the non current-drawing type.

- (3) Rotate the TEST SELECTOR switch to T/C/RES
- (4) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL to the TEMPERATURE DATUM and SIGNAL position. Ensure that the REHEAT/SPEED DATUM switch is in the centre position.

RESTRICTED

(5) Turn the TEMP. SIGNAL, COARSE control until the pointer of METER II coincides with the RED line.

(6) Depress the T/C RESIST. TEST switch to the T/C RESIST. TEST position.

(7) If the thermocouple harness resistance is correct, the position of the METER II pointer should still coincide with the RED line. The permitted tolerance, related to the number of divisions on either side of the RED LINE, is dependent on the specific thermocouple installation. Each division represents a deviation of 0.005 Ω from the correct thermocouple harness resistance, and a fault, e.g., an open-circuit thermocouple, can be determined as follows:—

Assume an eight thermocouple installation, the resistance of each thermocouple being 2 Ω :—

Total resistance of installation = 0.25 Ω

With one open-circuit thermocouple, total resistance of installation = 0.2857 Ω

This fault is therefore indicated by an increase on resistance of 0.0357 Ω which will result in a deviation of approximately 7.5 divisions from the RED line. Therefore readings of METER II in this region would indicate an unserviceable thermocouple, which should be tested in accordance with the instructions contained in the relevant Aircraft, or Engine, Handbook.

(8) A meter reading in excess of this tolerance indicates a possible fault on the thermocouple cluster. It should be noted that as the meter readings indicate a voltage drop, firstly across the thermocouple harness and secondly across the standard resistor, a high reading of METER II indicates a probable short-circuited thermocouple. Conversely, a low reading indicates a probable open-circuited thermocouple.

Datum temperature, deadband and inching range tests

49. (1) Prepare for the recording simulated temperatures (DATUM TEMPERATURE scale) at which METER I indicates a change in response during the following operations.

(2) Ensure that the aircraft engine throttle is in the appropriate position.

(3) If the aircraft installation is fitted with a temperature indicator of the current-drawing type, set the T/C HARNESS SELECTOR switch to a position appropriate to the thermocouple harness resistance. If the aircraft jet-pipe temperature indicator is of the non-current-drawing type the T/C HARNESS SELECTOR switch must be set to the SERVO POT. position.

(4) Rotate the TEST SELECTOR switch to the D.C. ACT. position.

(5) Turn the TEMP. SIGNAL, COARSE and FINE controls fully anti-clockwise.

(6) Set the DATUM TEMPERATURE scale reading to the approximate datum temperature of the system under test.

(7) Set the galvanometer clamp to the FREE position and zero the pointer if necessary.

(8) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL switch to the TEMPERATURE DATUM and SIGNAL position. METER I should now show full scale deflection into the green, or DECREASE TEMPERATURE, zone indicating that the actuator is at its limit stop in the open throttle condition.

(9) Turn the COARSE control very slowly clockwise until the pointer of METER I moves, by a sudden action, to the centre zero position.

Note . . .

Considerable care is necessary to obtain this condition, the null position being very critical.

(10) Increase the TEMP. SIGNAL, FINE control very slowly until METER I shows a momentary deflection of a quarter to one-third full scale deflection, into the red, or INCREASE TEMPERATURE ZONE. This denotes a transient inching movement of the actuator in the close-throttle condition. By a sharp action, slightly reduce the setting of the FINE control until deflections cease.

(11) Repeat sub-para. (10).

(12) Momentarily depress the GALVO IN/SET UP key switch to the SET UP position and observe the deflection of the galvanometer pointer. Adjust the DATUM TEMPERATURE scale to reduce the galvano-

meter deflection, depressing the galvanometer key switch at frequent intervals to observe the effect on the galvanometer. When the galvanometer reading is within the eight divisions either side of zero the galvanometer key switch may be placed in the GALVO IN position and the galvanometer reading brought to zero by adjustment of the DATUM TEMPERATURE scale.

Note . . .

Temperature readings must NOT be taken while METER I is showing pulsing deflections, since the pulsing sets up transients which may lead to spurious readings.

(13) Record the simulated temperature reading as indicated on the DATUM TEMPERATURE scale; this represents point A (*fig. 5*) which is the start of the inching range in the close-throttle direction.

(14) Increase the simulated temperature by steadily increasing the TEMP. SIGNAL, FINE control. As this is done, the pointer of METER I will pulsate between zero and one-third full scale deflection, the pulses increasing the frequency as the FINE control is increased. This indicates that the actuator is inching, at increasing speed in the close-throttle direction, and will continue to do so until the applied simulated thermocouple signal (controlled by the FINE control) reaches a level that will cause the actuator to run continuously. This condition will be indicated by the pointer of METER I showing a steady one-third to one-half full scale deflection into the red zone.

(15) Measure the simulated temperature at which the steady deflection is first apparent, as described in sub-para. (12) and record this reading (point B, *fig. 5*).

(16) Allow the actuator to run to its closed limit. This will be indicated by the reading of METER I increasing suddenly to full scale deflection in the red, INCREASE TEMPERATURE, ZONE.

(17) Set the aircraft OVERRIDE switch to its overriding position (i.e., disconnecting the actuator from the amplifier output). The METER I reading should immediately return to zero if the switch is functioning

satisfactorily. Return the OVERRIDE switch to its original position.

(18) Turn the TEMP. SIGNAL, FINE control fully clockwise. Very slowly reduce the TEMP. SIGNAL, COARSE control setting until METER I again shows, by a sudden action, a zero reading, i.e., reduce the simulated excess temperature to normal for the throttle setting. The actuator will remain at its closed limit but its circuit will be de-energized.

(19) Reduce the TEMP. SIGNAL, FINE control very slowly until METER I shows a momentary deflection of one-quarter to one-third full scale deflection into the green, or DECREASE TEMPERATURE, ZONE. This denotes an initial inching movement, in the open-throttle, or increase fuel, direction.

(20) By a sharp action slightly increase the TEMP. SIGNAL, FINE control setting until deflections cease.

(21) Repeat sub-para. (19) and (20).

(22) Measure the simulated temperature at which the inching just ceases, described in sub-para. (12), and record this reading (point C, *fig. 5*).

(23) Further reduce the FINE control setting until the METER I reading shows a steady deflection of one-third to one-half full scale deflection into the green or DECREASE TEMPERATURE ZONE. This meter reading indicates that the temperature signal has reached a level that will cause the actuator to run continuously in the open throttle direction.

(24) Measure the simulated temperature, at which the steady deflection is first apparent, as described in sub-para. (12), and record this reading (point D, *fig. 5*).

(25) Allow the actuator to run to its open limit. This will be indicated by the METER I reading increasing suddenly to full scale deflection into the green or DECREASE TEMPERATURE ZONE.

(26) Turn the TEMP. SIGNAL, FINE control fully anti-clockwise and then very slowly increase the COARSE control setting until METER I again shows a zero reading.

(27) Repeat the operations quoted in sub-para. (7) to (20) and record the simulated temperatures for the significant METER I indications (points A, B, C and D, *fig. 5*).

RESTRICTED

(28) Compare the two sets of readings and, where they approximate, record a mean value. If any pair of readings are widely divergent, a third set of readings should be taken.

(29) Repeat operations (4) to (26) at the other aircraft engine throttle settings, where applicable.

(30) Turn the TEMP. SIGNAL COARSE control fully anti-clockwise and set the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL switch to the OFF position.

(31) Return the galvanometer clamp to the CLAMP position.

50. From the recorded temperatures, at points A, B, C and D, the results of the tests are determined as follows:—

A = DATUM TEMPERATURE (as specified in relevant Aircraft, or Engine, Handbook).

A-C = DEADBAND = $7^{\circ} + 2\frac{1}{2}^{\circ}\text{C}$
— $1\frac{1}{2}^{\circ}\text{C}$
below datum.

B-A = INCHING RANGE (close-throttle direction)
= $24.5^{\circ} \pm 6^{\circ}\text{C}$.

C-D = INCHING RANGE (open-throttle direction)
= $24.5^{\circ} \pm 6^{\circ}\text{C}$.

These calculations must be made for each throttle setting of the temperature control system, if a temperature selector is fitted to the aircraft.

51. The selected temperature obtained must be compared with those specified for the temperature control system. If there are discrepancies outside the specified limits the temperature trimmer on the amplifier unit should be adjusted to correct these discrepancies. If the specified figures cannot be obtained by adjustment of the temperature trimmer, either the amplifier unit, the selector unit, or the associated wiring is unserviceable.

Aircraft jet-pipe temperature indicator test

52. After the datum temperature of the system has been established the jet-pipe temperature indicator in the aircraft may be checked for accuracy in the following manner.

(1) Set the DATUM TEMPERATURE scale to the established datum temperature.

(2) Adjust the TEMP. SIGNAL, COARSE and FINE controls for a zero reading of the galvanometer.

(3) Check that the aircraft indicator agrees with the DATUM TEMPERATURE scale reading, to within the limits specified for the aircraft installation.

Aircraft tests—ground running conditions

53. The temperature control system can be tested with the aircraft on the ground and its engine run at a specified speed. The thermocouple signal is derived from the jet-pipe thermocouples and is supplemented by the test set voltage, thereby simulating a high temperature output. The TEMP. SIGNAL, COARSE and FINE controls will therefore be more sensitive in operation and will produce rapid changes in the control temperature.

54. Interlock and muting switches which normally render the temperature control system inoperative whilst the aircraft is on the ground, should be made ineffective before proceeding with the test.

55. With the temperature control system connected as described in para. 45, the engine is run up to the normal ground running conditions as indicated on the aircraft jet-pipe temperature indicator. When the engine is stabilized at the normal ground running conditions, the r.p.m. or torque (for constant speed engines) must be noted. The engine operator will then inform the test operator that the engine is ready for test. No further adjustments to the engine setting are to be made until the tests have been completed.

56. The tests consist of injecting the test set voltage, and observing the response as indicated by METER I, of the actuator in the process of cancelling this voltage. With the engine at normal ground running conditions and prepared as in para. 53 to 55, proceed as follows:—

(1) Turn the TEMP. SIGNAL, COARSE controls fully anti-clockwise and the FINE control to its mid-travel position.

(2) Rotate the TEST SELECTOR switch to the D.C. ACT. position.

(3) If the aircraft installation is fitted with a jet-pipe temperature indicator of the current-drawing type, set the T/C HARNESS SELECTOR switch to a position appropriate to the thermocouple harness

RESTRICTED

resistance, i.e., to the position selected during the thermocouple harness resistance test para. 48, sub-para. (2). If the aircraft jet-pipe temperature indicator is of the non-current drawing type, the T/C HARNESS SELECTOR switch must be set to the SERVO POT. position.

(4) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL switch to the TEMPERATURE DATUM and SIGNAL position. METER I should now show full scale deflection into the green or DECREASE TEMPERATURE zone, indicating that the actuator is at its limit stop in the open-throttle direction.

(5) Set the DATUM TEMPERATURE scale reading to the datum temperature of the system.

(6) Set the galvanometer clamp to the FREE position and zero the pointer if necessary.

(7) Turn the COARSE control very slowly clockwise until the pointer of METER I moves, by a sudden action, to a steady centre zero position (considerable care is necessary to obtain this condition, the null position being very critical).

(8) Increase the TEMP. SIGNAL, FINE control very slowly until METER I shows momentary deflections of a quarter to one-third full scale deflection into the red or INCREASE TEMPERATURE zone. This denotes a transient inching movement in the close-throttle direction.

(9) Without altering the settings of the test set, wait until the deflections cease and METER I returns to zero. The temperature will now be at datum level caused by the reduction of engine temperature due to the control exercised by the actuator.

(10) Momentarily depress the GALVO IN/SET UP key switch to the SET UP position and observe the deflection of the galvanometer pointer. Adjust the DATUM TEMPERATURE scale to reduce the galvanometer deflection, depressing the key switch at frequent intervals to observe the effect on the galvanometer. When the galvanometer reading is within eight divisions, either side of zero, the galvanometer key switch may be placed in the GALVO IN position and the galvanometer reading brought to zero by adjustment of the DATUM TEMPERATURE scale.

(11) Record the temperature reading indicated on the DATUM TEMPERATURE scale, this represents point A in fig. 5.

(12) Increase the TEMP. SIGNAL, FINE control slightly, to produce two or three inching cycles into the red or INCREASE TEMPERATURE zone (this will ensure that the actuator is not on its limit stop).

WARNING . . .

Point C (sub-para. 15) must be determined as quickly as possible. A delay in obtaining this reading may result in the actuator being caused to operate due to the rise in engine temperature instead of the change in test set voltage.

(13) Decrease the TEMP. SIGNAL, FINE control very slowly until METER I shows a momentary deflection of a quarter to one-third scale deflection into the green or DECREASE TEMPERATURE zone.

(14) Wait until deflections cease and METER I returns to zero as in (9).

(15) Measure the temperature signal in the manner described in sub-para. (10) and record the reading (point C, fig. 5).

(16) From the recorded temperatures, at points A and C the results of the tests are determined as follows:—

A-C = actuator linkage and fuel-valve DEADBAND range (as specified in relevant Aircraft, or Engine, Handbook).

A = DATUM TEMPERATURE (as specified in relevant Aircraft, or Engine, Handbook).

(17) Remove the test set voltage by returning the TEMP. DATUM/OFF/TEMPERATURE DATUM and SIGNAL switch to the OFF position. The engine should now return to normal ground running conditions.

57. Failure of the actuator to return to normal ground running conditions indicates a fault in the fuel system (including the actuator) as distinct from a fault in the temperature control system.

RESTRICTED

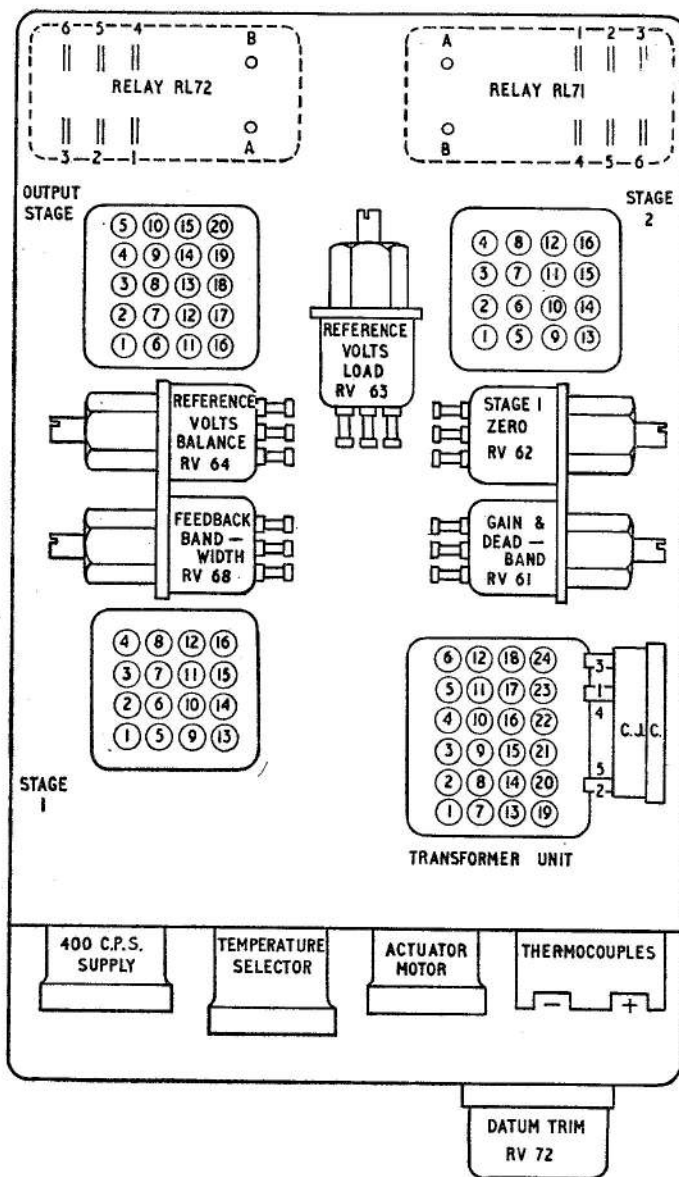


Fig. 7. Layout of amplifier showing seal numbers

Disconnecting supplies

58. On completion of the tests, the following procedure should be adopted:—

- (1) Rotate the TEMP. SIGNAL, COARSE and FINE controls fully anti-clockwise.
- (2) Lock the galvanometer in the CLAMP position.
- (3) Return the relevant switches of the QT223 test set to their OFF positions.
- (4) Switch off the inverters and disconnect the battery truck.

(5) Disconnect the test cables and place them behind the hinged flap in the test set lid.

(6) Replace the blanking cap on the aircraft test plug.

Fault finding

59. Should the preceding bench, or aircraft, tests indicate unserviceability of the amplifier, it may be possible to locate the fault by measuring the voltage and resistance between certain terminals inside the amplifier.

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60. Table 1 gives the values which should be obtained when measuring the voltage or resistance between certain seals, and the function of the relevant winding or resistor. A layout diagram (fig. 7) shows the location of the amplifier components and identifies their seal numbers and terminal markings. This diagram (fig. 7) and the circuit diagram (fig. 8) should be referred to in conjunction with Table 1 when voltage or resistance measurements are undertaken.

Insulation resistance

61. The insulation resistance between the points given below should not be less than 5 megohms when measured with a 500-volt insulation resistance tester.

- (1) All plug pins (except pin D of the 400 C.P.S. plug) and the chassis.
- (2) THERMOCOUPLE +ve and chassis.
- (3) THERMOCOUPLE -ve and chassis.
- (4) THERMOCOUPLE +ve and pin A (400 C.P.S. plug).
- (5) THERMOCOUPLE -ve and pin A (ACTUATOR MOTOR plug).
- (6) Pin A (400 C.P.S. plug) and pin A (ACTUATOR MOTOR plug).

WARNING . . .

The thermocouples must be disconnected from the amplifier when applying the insulation resistance test.

TABLE 1
Voltage and resistance measurements

Unit	Seals	Voltage	Resistance (Ω)
Power Unit	1— 2 (output stage, a.c. supply)	14V a.c.	—
	2— 3 (output stage, a.c. supply)	14V a.c.	—
	5— 6 (output stage, a.c. supply)	14V a.c.	—
	6— 7 (output stage, a.c. supply)	14V a.c.	—
	4— 9 (primary winding)	115V a.c.	—
	9—14 (primary winding)	115V a.c.	—
	14— 4 (primary winding)	115V a.c.	—
	10—15 (stage 1, a.c. supply)	4.7V a.c.	—
	11—16 (stage 1, a.c. supply)	4.7V a.c.	—
	12—17 (stage 1, a.c. supply)	4.7V a.c.	—
	13—18 (stage 1, a.c. supply)	4.7V a.c.	—
	8—21	7.5V d.c.	—
	21—22	42.0V d.c.	—
	19—20	2—3.5V d.c.	—
C.J.C. Bridge	1— 2	12.7mV d.c. (at 20°C ambient)	12.7 (at 20°C ambient)
	1— 3	1.5V d.c.	1.5K
	2— 5	25.34mV d.c.	25.34
	3— 4	1.5V d.c.	1.5K
Stage 1	1— 4 (a.c. winding)	4.7V a.c.	—
	3— 6 (bias winding)	4.1V a.c.	456
	8—12 (a.c. winding)	4.5V a.c.	—
	2— 5 (control winding)	—	90±18
	7—11 (positive feedback)	—	10±2
Stage 2	1— 4 (a.c. winding)	4.7V a.c.	—
	8—12 (a.c. winding)	4.7V a.c.	—
	3— 6 (bias winding)	3.2V d.c.	354±70
	2— 5 (control winding)	—	310±60
	9—13 (positive feedback)	—	24±5
Output Stage	13—19	14V a.c.	—
	6—19	14V a.c.	—
	7—16	14V a.c.	—
	12—16	14V a.c.	—
	10—18	0.25V d.c.	28

RESTRICTED



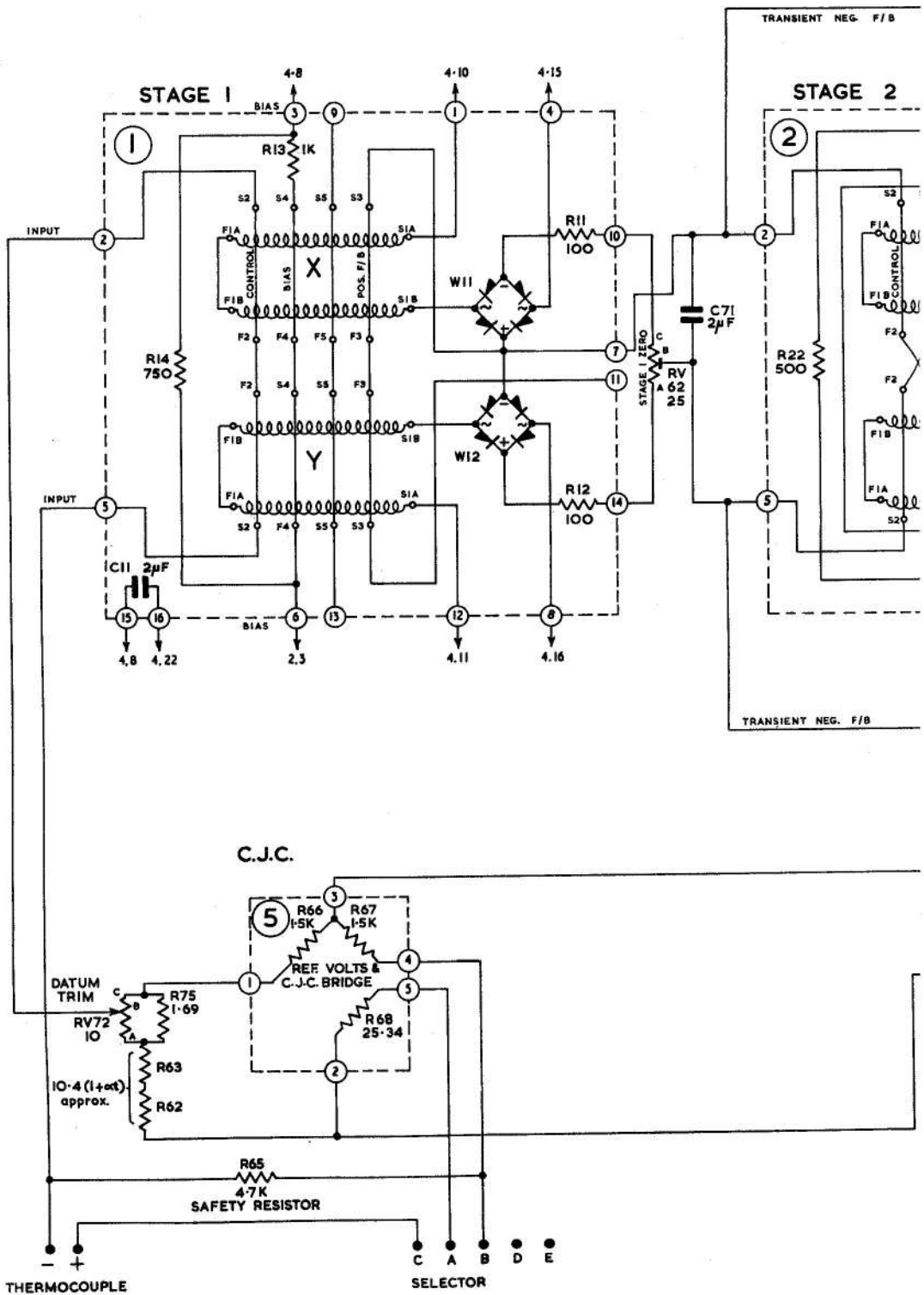
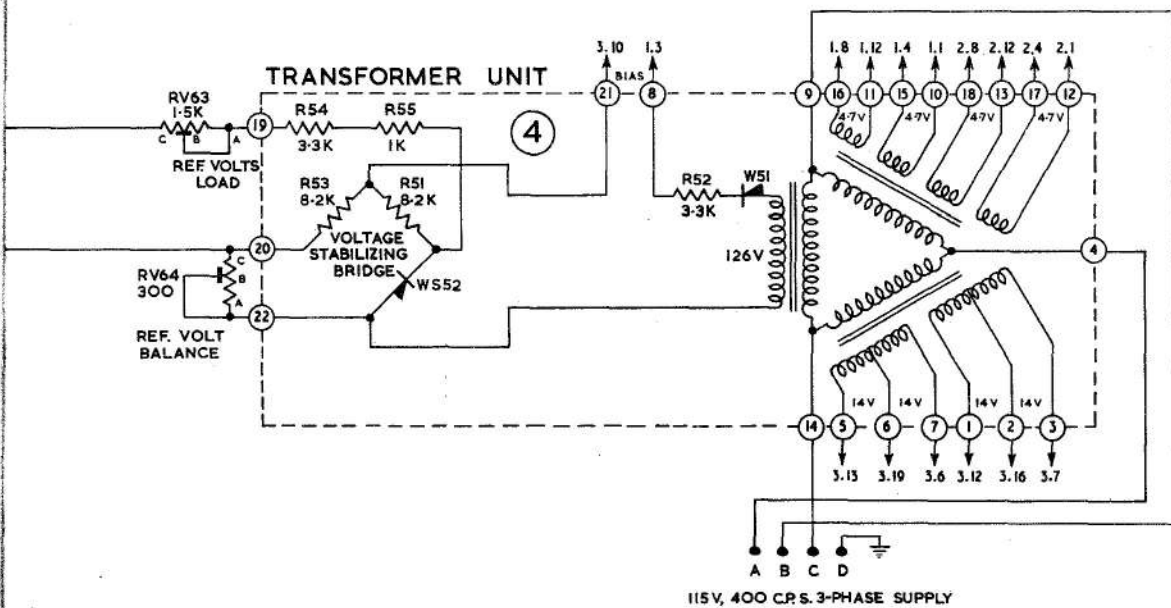
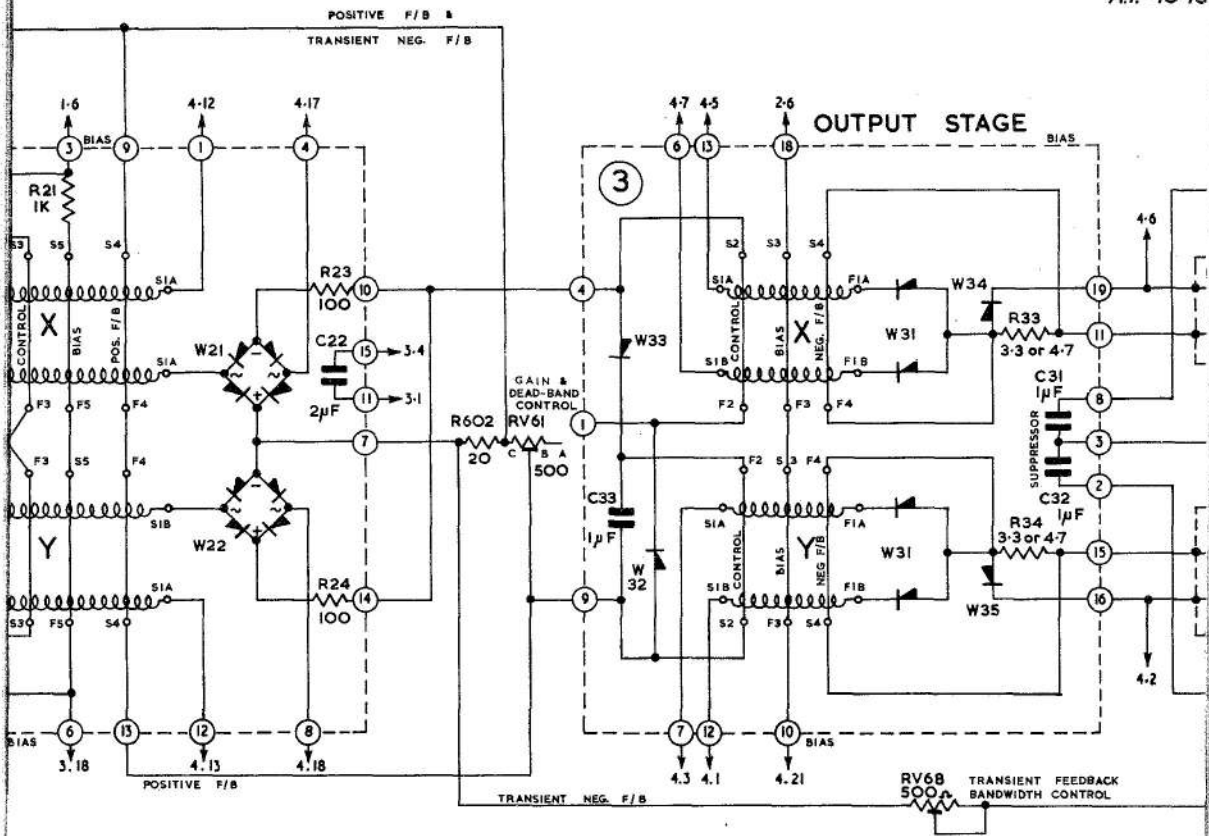


Fig. 8

Cir



circuit diagram of Amplifier A234
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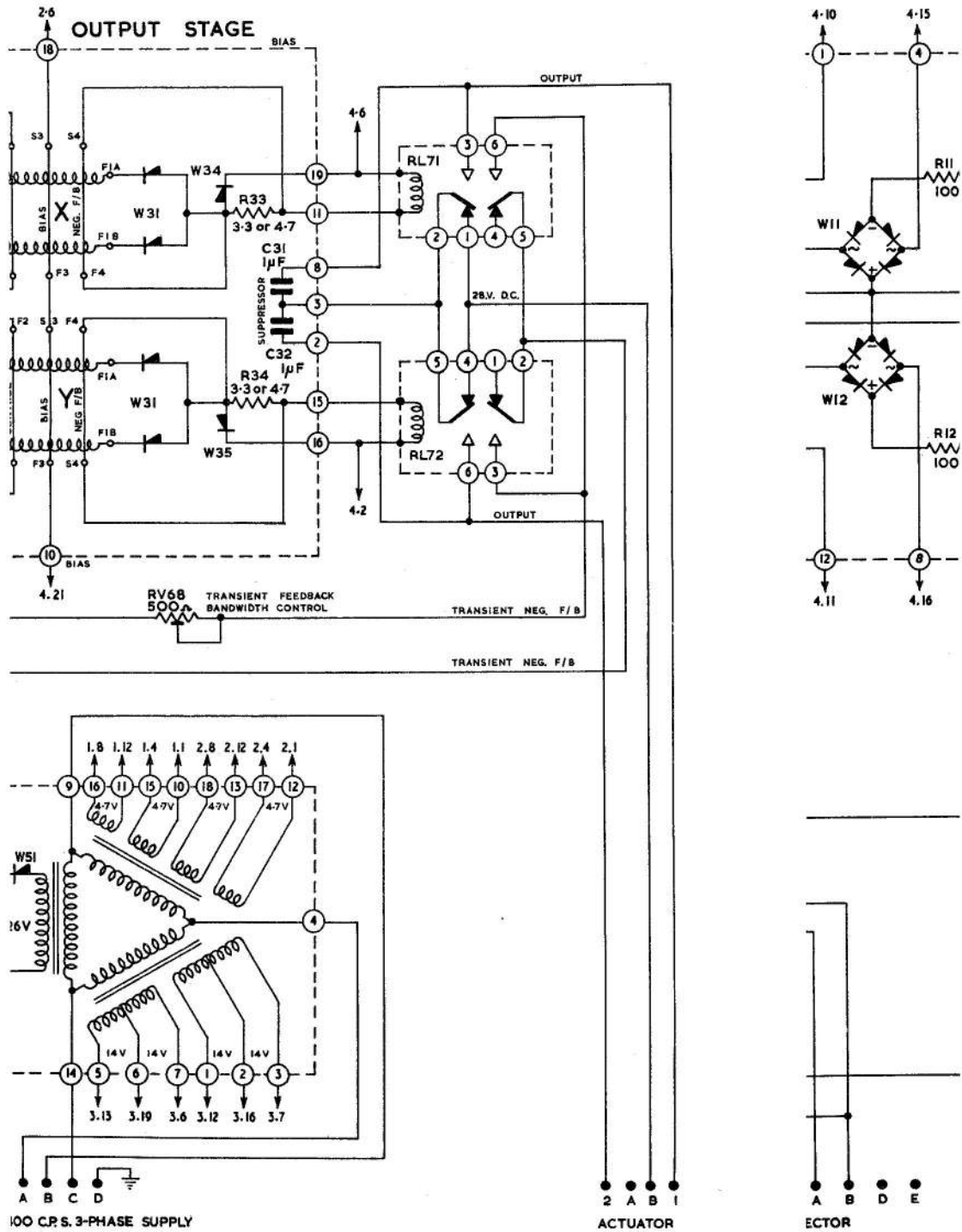


Fig.8

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