Cancelled now Obsolete

Chapter 5

AMPLIFIER UNIT, ULTRA, TYPE A491

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LEADING PARTICULARS

Magnetic amplifier unit, Ultra, Type A491	**Ref. No. 5CZ/5577**
Datum temperature	*(Cruise)* 595°*C* ± 2·5°*C*
Datum temperature	*(Climb)* 620°*C* ± 2·5°*C*
Datum temperature	*(Take-off)* 655°*C* ± 2·5°*C*
Maximum amplifier output (to a.c. actuator)	± 11V a.c.
Input to amplifier	115*V*, 400 *c.p.s. single-phase*
◀*Deadband*	7·5°*C* ± 1·5°C▶
Datum temperature variation, using the datum trim potentiometer	— 17°*C to* + 17°*C approx*
Weight	8·125 *lb.*
Length	10 *in.*
Width	6 *in.*
Height	3¾ *in.*

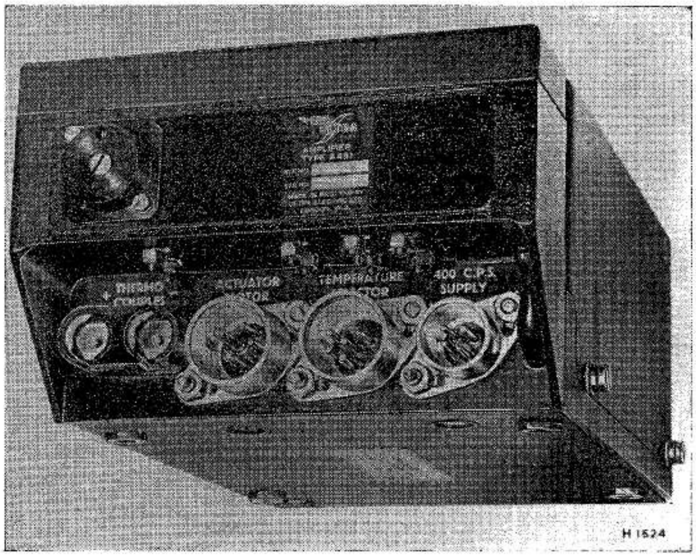

Fig. 1. Magnetic amplifier unit, Ultra, Type A491

Introduction

1. The Magnetic Amplifier, Ultra, Type A491 (*fig.* 1), is designed to effect control and limitation of the jet-pipe temperature of an aircraft engine at any one of three datum levels. These datum levels are specified by the engine manufacturer and, in present applications, correspond to TAKE-OFF, CLIMB and CRUISE conditions. Selection of the required datum is effected by remote control.

2. Jet-pipe temperature is sensed by thermocouples mounted radially in the jet-pipe. The thermocouples provide an input signal, the magnitude of which depends upon the temperature existing at any given instant, to the amplifier, where it is compared with a highly stable reference signal voltage. Any difference between the two signals is termed an error signal and will appear at the amplifier output in the form of an a.c. signal. This a.c. signal is then utilised to operate the control phase of a two-phase a.c. squirrel-cage actuator motor, the quadrature phase of which is supplied by a fixed signal from the amplifier transformer via a capacitor. Adjustment of the reference signal voltage determines the level at which any error signal appears and thus controls the value of the temperature datum.

3. The amplifier output signal is proportional to the error existing between the engine jet-pipe temperature and the selected datum temperature. This output, or error, signal may be in excess of, or below, the selected datum temperature, depending upon the actual engine jet-pipe temperature in relation to the datum temperature at a given instant of time.

The direction of rotation of the a.c. squirrel-cage actuator motor is dependent upon the "sense" of the error signal in relation to the datum level, and will cause a fuel valve in the engine fuel servo system to open or close accordingly. The system is arranged so that the fuel valve will commence to close for an increase in temperaure above datum (positive sensed signal) and commence to open for a decrease of temperature below datum (negative sensed signal). The engine efficiency is thus capable of being controlled within the specified datum levels.

DESCRIPTION

General

4. The components of the magnetic amplifier are mounted on two castings which are assembled to form a single housing. Removal of the two top covers (*fig.* 2) reveals the amplifying stages, power unit, relays and gain and datum trim potentiometers. The amplifying stages, power unit and C.J.C. unit are housed in individual sealed cans and access to their electrical and mechanical connections is gained by removal of the amplifier base-plate. A layout diagram (*fig.* 7) shows the location of these components

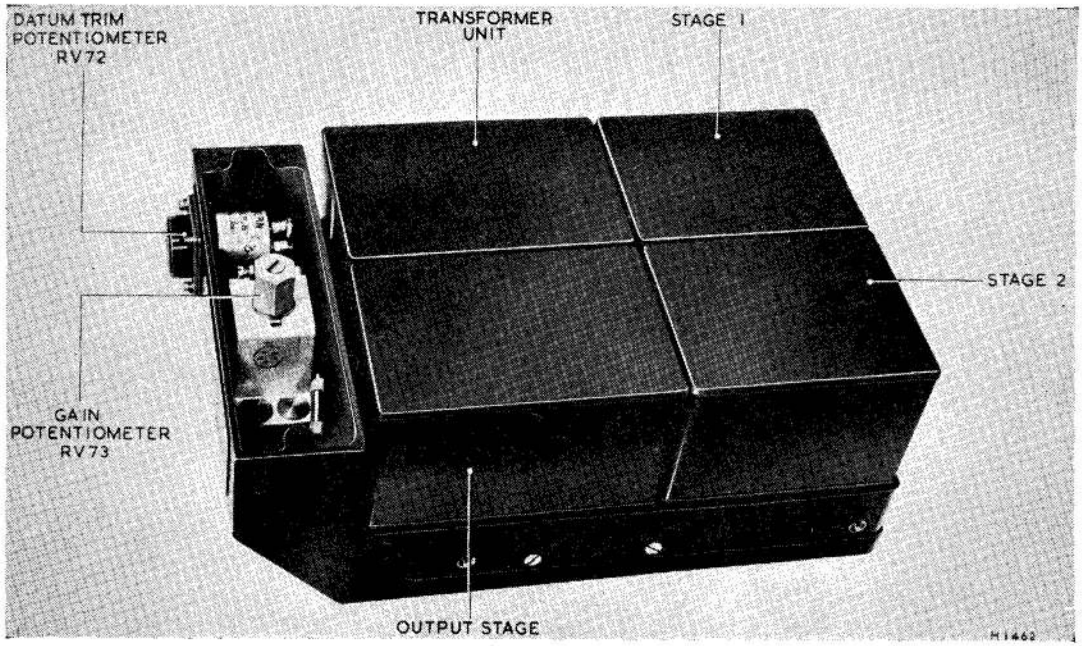

Fig. 2. Amplifier with top cover removed

and identifies their seal numbers and terminal markings. The relay unit and the gain and datum trim potentiometers are immediately accessible when the cover of the extension casting is removed.

5. In addition to housing the relays, gain and datum trim potentiometers, the extension casting also carries the following electrical connectors:—

(1) Four-pole plug for the 115V, 400 c.p.s. single-phase supply.
(2) Five-pole plug for connection to the temperature selector unit.
(3) Four-pole plug for connection to the a.c. actuator motor.
(4) Twin terminal sockets which accept the compensating leads from the thermocouples.

PRINCIPLES OF OPERATION

6. A block schematic diagram (*fig.* 3) illustrates the basic principle of the A491 magnetic amplifier unit. A single-phase transformer provides the necessary power supplies for the amplifying stages, stabilizing bridge network, bias circuits and the reference (quadrature) phase of the two-phase a.c. squirrel-cage actuator motor.

7. 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 voltage 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.

8. The output of amplifier stage 3 (output stage) is applied to the control phase of an a.c. actuator motor which will rotate in a direction determined by the polarity of the error signal. Operation of the a.c. actuator motor causes a fuel valve to regulate the supply of fuel to the aircraft engine thus preventing the engine from overheating.

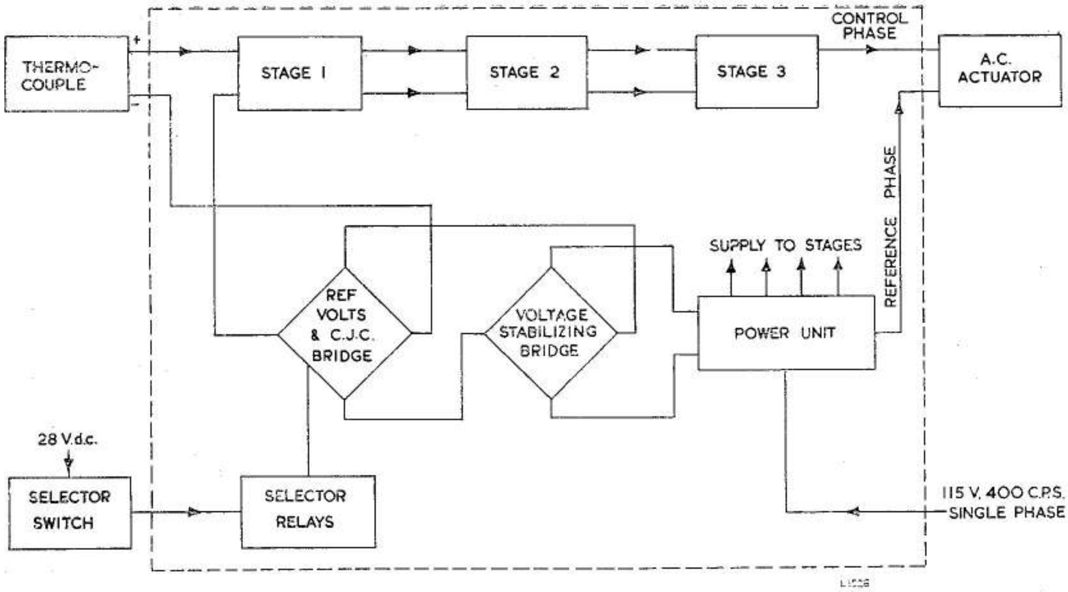

Fig. 3. Block schematic diagram of amplifier

CIRCUIT DESCRIPTION

9. The circuit diagram (*fig.* 8) shows the connections between the individual components together with the respective seal numbers and terminal identification.

10. The power unit houses a 115V, 400 c.p.s. single-phase transformer which provides the following supplies:—

(1) Power supplies for the transductors of the three amplifying stages.

(2) An 8mA supply, via the half-wave rectifiers WS53 and WS54 for the bias circuits (*para.* 23) of the amplifying stages and also for the voltage stabilizing bridge.

(3) A supply, via the capacitors C31 and C32 for the reference (quadrature) phase of the two-phase a.c. squirrel-cage actuator motor.

11. A smoothed d.c. supply of 8mA is fed from a 70V transformer secondary winding to the voltage stabilizing bridge which is located in the power unit. The output of the voltage stabilizing bridge (terminals 15 and 16) is stabilized against fluctuations of the single-phase supply voltage, by the Zener reverse voltage characteristic of the Silicon diode WS52 inserted in one arm of the bridge. Adjustment of this stabilized output is effected via the potentiometers RV64 (REF. VOLTS BALANCE) and RV66 (REF. VOLTS LOAD), 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 C.J.C. bridge. This stabilized d.c. supply enables a reference voltage to be developed in the C.J.C. bridge resistor network (R64 to R69).

12. The reference voltage opposes the thermocouple voltage, derived from the thermocouples located in the engine jet-pipe, which is applied to the C.J.C. bridge. Any algebraic 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. Adjustment of the reference voltage is controlled by RV72 (terminals 5 and 6) which provides for the error signal to be approximately zero at the respective datum temperatures specified by the engine manufacturer.

13. The three datum temperatures are selected by remote control using two change-over relays, RL71 and RL72 (*fig.* 8), operated via the 28V d.c. supply. The position of the relay contacts determines the point on the resistance chain in the C.J.C. bridge from which the reference voltage is taken and hence, the magnitude of the reference voltage. The datum selector control operates as follows:—

(1) With both relays un-energised, a high datum corresponding to TAKE-OFF is selected.

(2) With 28V d.c. positive applied to pin A of the selector plug, a middle datum corresponding to CLIMB is selected.

(3) With 28V d.c. positive applied to pin B of the selector plug, a low datum corresponding to CRUISE is selected.

14. To limit jet-pipe temperature to the specified datum it is necessary to compensate for changes in thermocouple voltages, which are due to changes in the cold junction ambient temperature. Compensation is effected by the inclusion of a copper resistance coil, physically 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 is developed from the comparison of the reference voltage and thermocouple voltage at the C.J.C. bridge, is proportional to the change in jet-pipe temperature above or below the specified datum. The error signal is amplified and rectified by stage 1 which has two amplifying sections, 1A and 1B. Each section comprises a pair of auto-self-excited transductors arranged in push-pull, with series mixing and a separate bias balance control (RV62 and RV67) for each section.

Note . . .

Terminal markings S1A, F1A, S1B, F1B identify the "starts" and "finishes" of transductor core windings, and are not related to the amplifying sections 1A or 1B.

Since the transductors are arranged in push-pull, the stage 1 responds to error signals of either polarity, i.e. above datum (positive) and below datum (negative) temperature signals.

16. The stage 1 output (terminals 1 and 5) is applied to the control winding (terminals 1 and 2) of stage 2 which comprises a push-pull pair of transductors with series mixing. Stage 2 does not incorporate bias balance control as the stage is adequately balanced by negative feedback. The output (terminals 3 and 4) is sensed, as considered for stage 1 and the stage responds to error signals of either polarity.

17. The stage 2 output, via negative feedback winding 6 to terminals 3 and 4, is applied to the control windings of the output stage at terminals 1 and 11. The output stage comprises two auto-self-excited a.c. transductors, the control windings of which are connected in series. Bias windings of the respective transductors are also connected in series and the bias current is adjusted using potentiometer RV63. The respective outputs of the transductors are linked to form a common output (terminal 10). One of the transductors, depending on the polarity of the signal applied to the output stage (terminals 1 and 11), provides a supply for the control phase of the a.c. squirrel-cage actuator motor.

18. The reference phase of the a.c. actuator motor is supplied from a 15 volt transformer secondary winding via capacitors C31 and C32, which are housed in the output stage (terminals 7 and 8). The function of the capacitors is to provide a 90° phase shift between the control and reference (quadrature) phases, to operate the two-phase a.c. actuator motor. Polarity of the temperature signal, i.e. an above or below datum signal applied to the amplifier thermocouple terminals determines whether the control phase leads or lags by 90° and so determines the directions of rotation of the a.c. actuator motor.

◀**19.** Maximum output of the amplifier measured across the control phase, terminals A and B of the output plug, is ± 11 volts a.c. The deadband, i.e. the voltage required to initiate movement of the a.c. actuator motor in either direction is ± 1 volt a.c.

Note . . .

The temperature deadband, i.e. the range of jet-pipe temperature over which the temperature control system exercises no control, is 7·5°C ± 1·5°C. The amplifier voltage output corresponding to this temperature deadband is ± 1 volt a.c.▶

Feedback circuits

20. Several feedback loops are incorporated in the amplifying stages to provide control and stability. A stage 1 negative feedback loop consists of the stage 1 output voltage fed back into winding 5 (at terminal 6) via a series resistor, R19. This feedback loop stabilises the first stage during operation of the amplifier unit.

21. A stage 2 negative feedback loop consists of the stage 2 output voltage fed back into part of windings 3 (at terminal 16) and 2 at (terminal 15) of the same stage, via potentiometer RV73. Control of the amplifier gain is effected by controlling the voltage feedback over stage 2, with RV73 as the gain control potentiometer.

22. An additional negative feedback loop is incorporated in stage 2. The 'X' transductor output is fed via winding 6 of the 'Y' transductor to terminal 4, and the 'Y' transductor output is fed via winding 6 of the 'X' transductor to terminal 3. The negative feedback has a stabilizing and balancing effect in this stage.

Bias circuits

23. The rectified current, obtained from the 70 volt secondary winding of the single-phase transformer, provides the bias for the three amplifying stages. The magnitude of the bias current (8mA) is preset using the bias control potentiometer RV63. Stage 1 uses the bias distribution method, i.e., an arrangement of the bias circuits to facilitate qual biasing of each of the push-pull pairs of transductors used in this stage. Bias-balance potentiometers, RV62 and RV67, are incorporated in the bias circuit.

24. A bias winding, in series with resistor R24, forms the bias circuit for stage 2. A shunt resistor R23 limits the current in this bias circuit to the appropriate value. The output stage bias circuit, which is similar to that of stage 2, consists of a bias winding shunted by resistor R31 to limit the bias current.

Smoothing

25. A capacitor (C52), located in the transformer unit, provides smoothing for the bias and voltage stabilizing circuits.

Datum trim

26. Trimming of the datum temperature, when the magnetic amplifier unit is installed in the aircraft, is effected by adjusting the potentiometer RV72. This is a "click" potentiometer which has a range of adjustment of approximately 35°C. in fifteen steps of approximately $2\frac{1}{2}$°C. per step.

Safety resistor

27. A 4·7KΩ resistor, connected across the thermocouple terminals, ensures that a negative signal is passed to the amplifier in the event of an open-circuit on the thermocouples.

TESTING

Bench test

28. A bench test using Test Equipment Type QE2230, is applied to the control system amplifier to determine its serviceability prior to being installed in the aircraft.

Equipment required for the bench test is detailed below:—

(1) Test set, Ultra, Type QT223.
(2) Nine-core test cable Type QY2212.
(3) Four-core test cable Type QY2216 for monitoring the 115V. 400 c/s supply.
(4) Bench test rig (*fig.* 4).
(5) Single-phase 115V, 400 c.p.s. supply.
(6) Two-phase squirrel-cage motor actuator, as used in the aircraft jet-pipe temperature control system.
(7) Stop watch.

The bench test, applied to the control system amplifier, includes datum temperature, deadband and gain tests and a timing check. A response diagram (*fig.* 5) shows the various temperature readings (A, B, C, D and E) 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.

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

Precautions

30. 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.

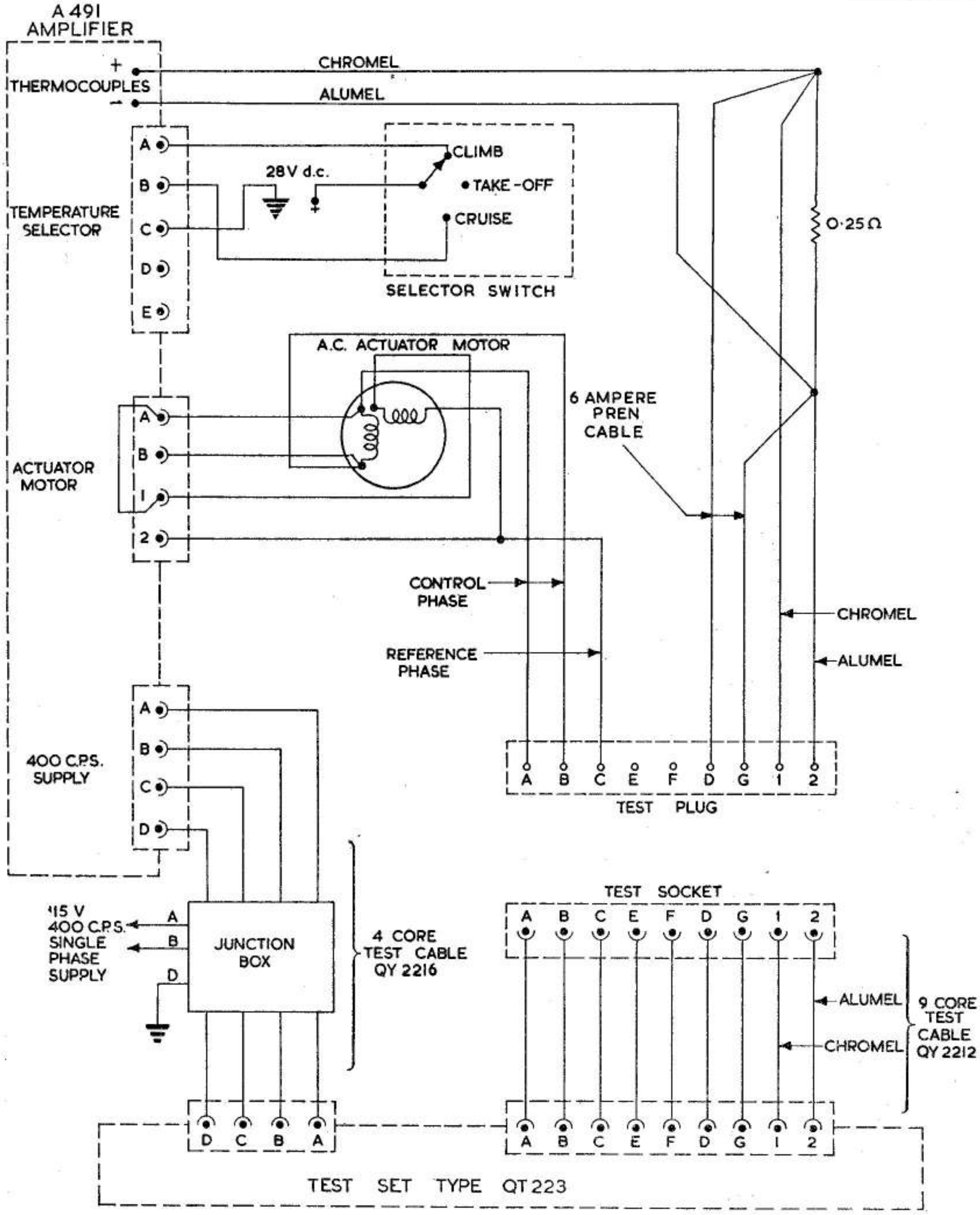

Fig. 4. Bench test circuit

Test set batteries

31. 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.

(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 ¾ 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)

32. 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).

33. In the test rig, the resistance of the thermocouple cluster is simulated by a 0·25 ohm 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.

34. Connect the amplifier into the bench test circuit prepared as in fig. 4. Switch on the 115V, 400 c.p.s. single-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

35. 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 illuminate.

(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 extinguished.

Note . . .

The PHASING *indication quoted in sub-para.* (6) *is the reverse of that quoted in sub-para.* (3).

Removal of test cable QY2216

36. 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 temperature control system amplifier.

Datum temperature tests

37. If a jet-pipe temperature indicator of the current-drawing type is incorporated in the aircraft installation, it is important that, during bench testing, the test set T/C HARNESS SELECTOR switch is set to the position appropriate to this installation. If allowance is not made for the presence of the current-drawing type of indicator, it will be necessary to trim the amplifier output, to obtain the correct datum temperature setting, when the amplifier is installed in the aircraft.

38. To establish the datum temperature setting of the amplifier in the temperature control system, proceed as follows:—

(1) Select the CRUISE datum position on the TEMPERATURE SELECTOR switch.

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

(3) Rotate the TEST SELECTOR switch to the CONT. PH. position.

(4) Turn the TEMP. SIGNAL, COARSE control fully anti-clockwise and the FINE control to its mid-travel position (five complete turns from either limit stop).

(5) If the aircraft has a current-drawing temperature indicator, the T/C HARNESS SELECTOR switch must be in the position appropriate to the resistance of the thermocouple harness, employed in the system under test. If a non current-drawing type of indicator is used, the SERVO. POT. position must be selected.

(6) Set the METER II switch to the 25V a.c. position.

(7) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM AND SIGNAL switch to the TEMPERATURE DATUM AND SIGNAL position. METER I should show a deflection into the red, or INCREASE TEMPERATURE zone, indicating that the actuator is at its limit stop in the open direction.

(8) Set the DATUM TEMPERATURE scale reading to the approximate datum temperature of the system and set the galvanometer clamp to the FREE position. Set the pointer to zero if necessary.

(9) Turn the TEMP. SIGNAL COARSE control clockwise, very slowly, until the pointer of METER I is approximately zero or just into the green zone. Set METER II range to ÷ 5 a.c., and adjust the FINE control until METER II indicates a minimum. Ensure that METER I is still at zero or in the green zone.

Note . . .

Where Fuel Trim Unit M492 is used in the system the readings obtained in sub-para. (9) *should be*: METER I—*green zone,* METER II —1 *volt.*

(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 the eight divisions on either side of zero, the galvanometer key switch can be placed in the GALVO IN position If the reading of METER II has strayed from the above reading, the TEMP. SIGNAL, FINE control must be readjusted to correct the reading. The galvanometer reading may now be brought to zero by adjustment of the DATUM TEMPERATURE scale.

(11) Record the simulated temperature reading as indicated on the DATUM TEMPERATURE scale. This reading is the datum temperature (E. *in fig.* 5) of the temperature control system and should be:—

For the CRUISE datum, 595°C ± 2·5°C
For the CLIMB datum, 620°C ± 2·5°C
For the TAKE-OFF datum, 655°C ± 2·5°C

(12) Turn the TEMPERATURE SELECTOR switch to the CLIMB datum position and repeat sub-para. (2) to (11) inclusive.

(13) Turn the TEMPERATURE SELECTOR switch to the TAKE-OFF datum position and repeat sub-para. (2) to (11) inclusive.

Deadband and gain tests

39. With the datum temperatures of the control system established, the deadband and gain of the control system may be tested as follows:—

(1) Set the METER II range switch to the ÷ 5 position.

(2) Rotate the TEMP. SIGNAL, FINE control slowly clockwise until METER II indicates an UPPER THRESHOLD VOLTAGE of 1 volt (5 volts scale reading) with the pointer of METER I in the green, i.e. DECREASE TEMPERATURE, zone.

(3) Measure the simulated temperature signal in the manner described in para. 38, sub-para. (10), adjusting the FINE control, as necessary, to compensate for the load imposed by the galvanometer. Record this measurement and call it 'A'.

(4) Return the galvanometer key to the centre (OFF) position.

(5) Rotate the FINE control slowly clockwise until METER II indicates a GAIN VOLTAGE of 3 volts (15 volts scale reading) with the pointer of METER I in the DECREASE TEMPERATURE zone.

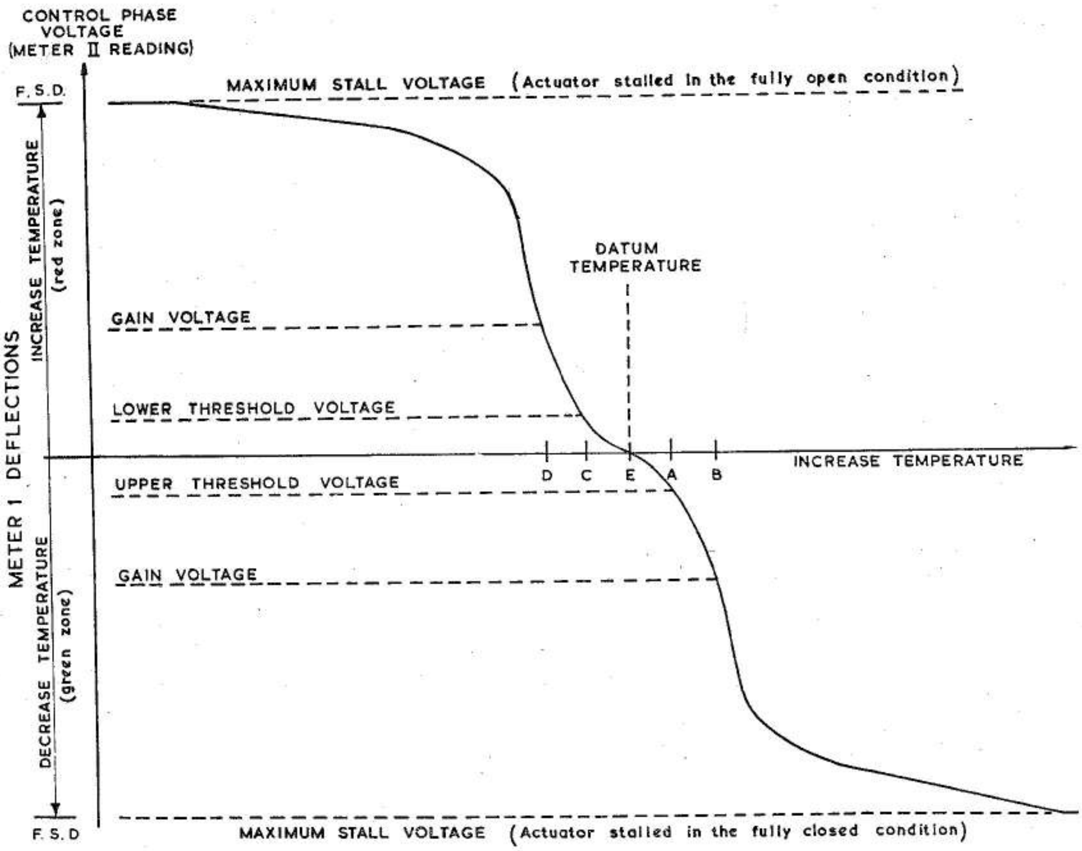

Fig. 5. Response diagram

(6) Measure the simulated temperature in the manner described in para. 38, sub-para. (10), adjusting the FINE control, as necessary, to compensate for the load imposed by the galvanometer. Record this measurement and call it 'B'.

(7) Return the galvanometer key switch to the centre (OFF) position.

(8) Rotate the FINE control slowly, anti-clockwise, until METER II indicates a LOWER THRESHOLD VOLTAGE of 1 volt (5 volt scale reading) with the pointer of METER I in the red, i.e. INCREASE TEMPERATURE zone.

(9) Measure the new temperature, in the manner described in para. 38, sub-para. (10), adjusting the FINE control, as necessary, to compensate for the load imposed by the galvanometer. Record this measurement and call it 'C.'

(10) Rotate the FINE control, slowly anti-clockwise, until METER II indicates a GAIN VOLTAGE of 3 volts (15 volts scale reading) with the pointer of METER I in the INCREASE TEMPERATURE zone.

(11) Measure the simulated temperature in the manner described in para. 38, sub-para. (10), adjusting the FINE control, as necessary, to compensate for the load imposed by the galvanometer. Record this measurement and call it 'D.'

◀(12) From the recorded temperatures, at points A, B, C and D as illustrated in the response diagram (*fig.* 5), the results of the tests are determined as follows:—

DEADBAND = A—C = 7·5°C ± 1·5°C

*DATUM TEMPERATURE = E = $\frac{A+C}{2}$ (approx.) = 595°C ± 2·5°C
620°C ± 2·5°C
655°C ± 2·5°C

GAIN (decrease temperature zone) = E—D = 9·5°C to 12°C

GAIN (increase temperature zone) = B—E + 9·5°C to 12°C

*Value of datum temperatures quoted are for CRUISE, CLIMB and TAKE-OFF datums. Repeat the instructions given in sub-para. (1) to (12) inclusive for each datum setting.▶

Timing check

40. In order to undertake this test a stop-watch must be available to time the running of the actuator in each direction. The test set switches should be in the position selected in para. 38, sub-para. (4) to (6)—it is important that the METER II range switch is set to the 25V a.c. position and the TEST SELECTOR switch should be turned to the REF. PH. position. After ensuring that these switches are in the correct position, proceed as follows:—

(1) Rotate the TEMP. SIGNAL, COARSE control, clockwise until METER I shows full scale deflection in the green, or DECREASE TEMPERATURE zone.

(2) Wait at least 20 seconds. This enables the actuator to travel over its whole range to the closed limited position. METER II should now indicate the reference phase MAXIMUM STALL VOLTAGE, i.e. approximately 20 volts.

(3) Return the TEMP. DATUM/OFF/TEMPERATURE DATUM AND SIGNAL switch to the OFF position, simultaneously starting the stop-watch.

(4) Observe METER II. The actuator will now be running in the close throttle direction and the meter pointer will be showing approximately full scale deflection. When reaching its lower limit stop, METER II will indicate the stalling of the motor by a sudden deflection of the pointer. The stop-watch should be stopped immediately this deflection is observed.

(5) The time recorded on the stop-watch is the time taken for the actuator to travel over its whole range from the actuator closed limit to the actuator open limit and should not be less than 8 seconds and not greater than 25 seconds.

(6) Return the stop-watch hand to zero.

(7) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM AND SIGNAL switch to the TEMPERATURE DATUM AND SIGNAL position simultaneously starting the stop-watch.

(8) Observe METER II once again. The actuator will now be running in the open throttle direction and will indicate the reaching of the upper limit stop by a sudden deflection of METER II. The stop-watch must be stopped immediately the deflection is observed.

(9) The time recorded on the stop-watch is the time taken for the actuator to travel over its whole range from the actuator open limit to the actuator closed limit, and should not be less than 8 seconds and not greater than 25 seconds.

Thermocouple harness resistance

41. If a new thermocouple harness is to be fitted to the aircraft installation, bench test can be applied to the harness in the manner described in para. 49.

Disconnecting supplies

42. 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 115V, 400 c.p.s. single phase supply.

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

Aircraft tests—static conditions

43. The aircraft tests, to determine the response of the a.c. actuator control system, include thermocouple harness resistance, datum temperature, aircraft jet-pipe temperature indicator, deadband, gain and muting switch tests and a timing check. 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 a jet-pipe temperature control system to be tested with the aircraft engines stationary, i.e. under static conditions.

44. The equipment required for the aircraft tests, using the Test Equipment, type QE2230, is detailed below:—

(1) Test set type QT223.

(2) Nine-core test cable type QY2212.

(3) Nine-core test cable type QY2213, for use on aircraft not fitted with the 9-pole test plug.

(4) Four-core test cable type QY2216 for monitoring the 115V 400 c.p.s. aircraft supply.

(5) Stop-watch.

45. Prior to commencing tests on the jet-pipe temperature control system, certain precautions must be observed and preliminary tests undertaken as previously described in para. 30 and 31.

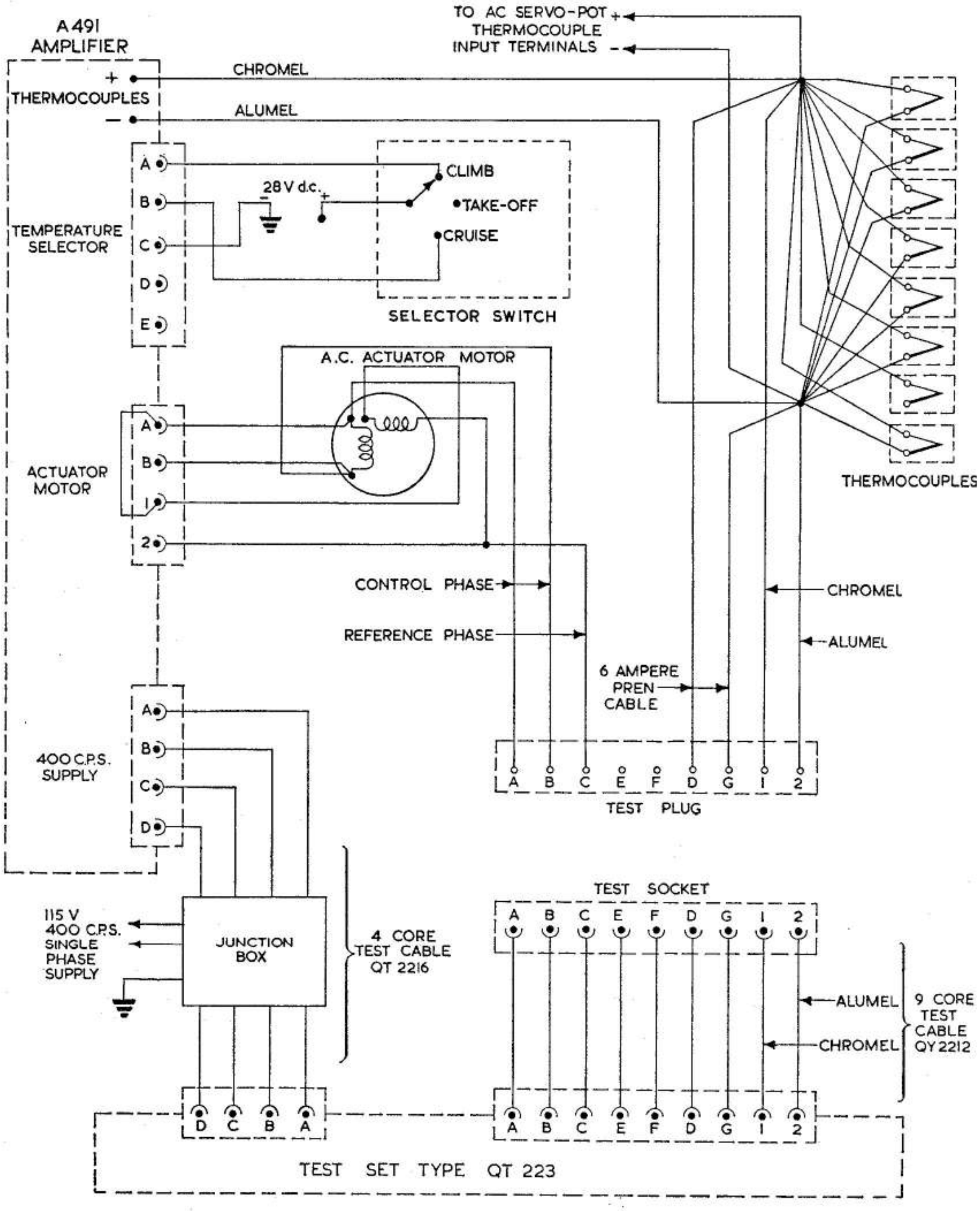

Fig. 6. Aircraft test circuit

Test connections at aircraft

46. (1) Remove the blanking cap from the 9-pole aircraft 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 the test cable QY2213 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 the 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

47. Undertake the test procedure previously described in para. 35.

Removal of test cable QY2216

48. Disconnect, and remove, the test cable QY2216 from the test circuit. Connect the aircraft supply lead to the a.c. supply plug (400 C.P.S. SUPPLY) of the temperature control system amplifier.

Thermocouple harness resistance

49. 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 the standard resistor, selected via the T/C HARNESS SELECTOR switch, coincides with the value of the 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 (ohms)*
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 switch to the TEMPERATURE DATUM AND SIGNAL position. Ensure that the REHEAT/SPEED DATUM switch is in the centre position.

(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 ohm 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 in 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 test

50. To establish the datum temperature of the temperature control system, proceed as follows:—

(1) Select the CRUISE datum position on the TEMPERATURE SELECTOR switch.

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

(3) Rotate the TEST SELECTOR switch to the CONT. PH. position.

(4) Turn the TEMP. SIGNAL, COARSE control fully anti-clockwise and the FINE control to its mid-travel position (five complete turns from either limit stop).

(5) If the aircraft has a current-drawing temperature indicator, the T/C HARNESS SELECTOR switch must be in the position appropriate to the resistance of the thermocouple harness employed in the system under test. If a non current-drawing type of indicator is used, the SERVO. POT. position must be selected.

(6) Set the METER II switch to the 25V a.c. position.

(7) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM AND SIGNAL switch to the TEMPERATURE DATUM AND SIGNAL position. METER I should show a deflection into the red, or INCREASE TEMPERATURE zone, indicating that the actuator is at its limit stop in the open direction.

(8) Set the DATUM TEMPERATURE scale reading to the approximate datum-temperature of the system and set the galvanometer clamp to the FREE position. Set the pointer to zero if necessary.

(9) Turn the TEMP. SIGNAL COARSE control clockwise, very slowly, until the pointer of METER I is approximately zero or just into the green zone. Set METER II range to ÷5 a.c., and adjust the FINE control until METER II indicates a minimum. Ensure that METER I is still at zero or in the green zone.

Note . . .
Where Fuel Trim Unit M492 is used in the system the readings obtained in sub-para. (9) should be: METER I—*green zone*, METER II—1 *volt*.

(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 galvanometer. When the galvanometer reading is within the eight divisions on either side of zero, the galvanometer key switch can be placed in the GALVO IN position. If the reading of METER II has strayed from the above reading, the TEMP. SIGNAL, FINE control must be re-adjusted to correct the reading. The galvanometer reading may now be brought to zero by adjustment of the DATUM TEMPERATURE scale.

(11) Record the simulated temperature reading as indicated on the DATUM TEMPERATURE scale. This reading is the low datum temperature (E *in fig.* 5) of the temperature control system and should be:— 595°C ± 2·5°C.

(12) Turn the TEMPERATURE SELECTOR switch to the CLIMB datum position and repeat sub-para. (2) to (11) inclusive.

(13) Turn the TEMPERATURE SELECTOR switch to the TAKE-OFF datum position and repeat sub-para. (2) to (11) inclusive.

(14) Without altering the test set controls, proceed to the aircraft jet-pipe temperature indicator test.

Aircraft jet-pipe temperature indicator test

51. With the datum temperature of the control system established, ensure that the test set reading compares with that of the aircraft jet-pipe temperature indicator, within the limits specified for the temperature control system. Without altering the test set controls, proceed to the deadband and gain tests.

Deadband and gain tests

52. With the datum temperatures of the control system established, the deadband and gain of the control system may be tested as follows:—

(1) Set the METER II range switch to the ÷5 position.

(2) Rotate the TEMP. SIGNAL, FINE control slowly clockwise until METER II indicates an UPPER THRESHOLD VOLTAGE of 1 volt (5 volts scale reading) with the pointer of METER I in the green, i.e. DECREASE TEMPERATURE zone.

(3) Measure the simulated temperature in the manner described in para. 50, sub-para. (10), adjusting the FINE control, as necessary, to compensate for the load imposed by the galvanometer. Record this measurement and call it 'A'.

(4) Return the galvanometer key to the centre (OFF) position.

(5) Rotate the FINE control slowly clockwise until METER II indicates a GAIN VOLTAGE of 3 volts (15 volts scale reading) with the pointer of METER I in the DECREASE TEMPERATURE zone.

(6) Measure the simulated temperature in the manner described in para. 50, sub-para. (10), adjusting the FINE control, as necessary, to compensate for the load imposed by the galvanometer. Record this measurement and call it 'B.'

(7) Return the galvanometer key switch to the centre (OFF) position.

(8) Rotate the FINE control, slowly anti-clockwise, until METER II indicates a LOWER THRESHOLD VOLTAGE of 1 volt (5 volts scale reading) with the pointer of METER I in the red, i.e. INCREASE TEMPERATURE zone.

(9) Measure the new temperature, in the manner described in para. 50, sub-para. (10), adjusting the FINE control, as necessary, to compensate for the load imposed by the galvanometer. Record this measurement and call it 'C.'

(10) Rotate the FINE control, slowly anti-clockwise, until METER II indicates a GAIN VOLTAGE of 3 volts (15 volts scale reading) with the pointer of METER I in the INCREASE TEMPERATURE zone.

(11) Measure the simulated temperature in the manner described in para. 50, sub-para. (10), adjusting the FINE control, as necessary, to compensate for the load imposed by the galvanometer. Record this measurement and call it 'D.'

◀(12) From the recorded temperatures, at points A, B, C and D as illustrated in the response diagram (*fig.* 5) the results of the tests are determined as follows:—

DEADBAND = A—C = 7·5°C ± 1·5°C

*DATUM TEMPERATURE = E = $\frac{A+C}{2}$ (approx.) ... ...

595°C ± 2·5°C
620°C ± 2·5°C
655°C ± 2·5°C

GAIN (decrease temperature zone) = E—D = 9·5°C to 12°C

GAIN (increase temperature zone) = B—E = 9·5°C to 12°C

*Values of datum temperatures quoted are for CRUISE, CLIMB and TAKE-OFF datums. REPEAT the instructions given in sub-paras. (1) to (12) inclusive for each datum setting.▶

Timing check

53. In order to undertake this test, a stopwatch must be available to time the running of the actuator in each direction. The test set switches should be in the positions selected in para. 50, sub-para. (4) to (6)—it is important that the METER II range switch is set to the 25V a.c. position—and the TEST SELECTOR switch should be turned to the REF. PH. position. After ensuring that these switches are in the correct position, proceed as follows:—

(1) Rotate the TEMP. SIGNAL, COARSE control, clockwise until METER I shows full scale deflection in the green, or DECREASE TEMPERATURE zone.

(2) Wait at least 20 seconds. This enables the actuator to travel over its whole range to the closed limit position. METER II should now indicate the reference phase MAXIMUM STALL VOLTAGE, i.e. approximately 20 volts.

(3) Return the TEMP. DATUM/OFF/TEMPERATURE DATUM AND SIGNAL switch to the OFF position, simultaneously starting the stopwatch

(4) Observe METER II. The actuator will now be running in the close throttle direction and the meter pointer will be showing approximately full scale deflection. When reaching its lower limit stop, METER II will indicate the stalling of the motor by a sudden deflection of the pointer. The stop-watch should be stopped immediately this deflection is observed.

(5) The time recorded on the stop-watch is the time taken for the actuator to travel over its whole range from the actuator closed limit to the actuator open limit and should not be less than 8 seconds and not greater than 25 seconds.

(6) Return the stop-watch hand to zero.

(7) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM AND SIGNAL switch to the TEMPERATURE DATUM AND SIGNAL position simultaneously starting the stop-watch.

(8) Observe METER II. The actuator will now be running in the open throttle direction and will indicate the reaching of the upper limit stop by a sudden deflection in the reading of METER II. The stop-watch must be stopped immediately the deflection is observed.

(9) The time recorded on the stop-watch is the time taken for the actuator to travel over its whole range from the actuator open limit to the actuator closed limit and should not be less than 8 seconds and not greater than 25 seconds.

(10) Without altering the test set controls, proceed to the muting switch test.

Muting switch test

54. The operation of the aircraft muting switch can be tested in the following manner:—

(1) Set the aircraft muting switch to the override position, i.e. with the actuator disconnected from amplifier output.

(2) Note the reading of METER I. If the switch is operating satisfactorily the pointer should have returned to its centre zero position.

Disconnecting supplies

55. 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.

Aircraft test-ground running conditions

56. 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.

57. Interlock or 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.

58. With the temperature control system connected as described in para. 46, Test connections at aircraft, the engine is run up to the normal ground running conditions as indicated on the aircraft jet-pipe temperature indicator. When the engine is stabilised at the normal ground running conditions the r.p.m. or torque (for constant speed engines) is to 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 test has been completed.

59. The test consists of overriding the thermocouple e.m.f. with a temperature signal, i.e. test set voltage, in excess of the datum temperature until the actuator has operated fully in the DECREASE TEMPERATURE direction. During the test the following information is noted:—

(1) The datum temperature.

(2) The engine r.p.m. or torque, before and whilst the temperature signal is applied.

(3) The engine r.p.m. or torque after the temperature signal is removed.

60. With the engine stabilised at the normal ground running r.p.m., or torque, proceed as follows:—

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(1) Rotate the TEST SELECTOR switch to the CONT. PH. position.

(2) Turn the TEMP. SIGNAL, COARSE control fully anti-clockwise and the FINE control to its mid-travel 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 resistance, i.e., to the position selected during the thermocouple harness resistance test para. 49, sub-para. (2). If the 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 METER II switch to the 25V a.c. position.

(5) Set the DATUM TEMPERATURE scale to the datum temperature of the system, set the galvanometer clamp to the FREE position, and zero the pointer if necessary.

(6) Set the TEMP. DATUM/OFF/TEMPERATURE DATUM AND SIGNAL switch to the TEMPERATURE DATUM AND SIGNAL position. METER I should now show a deflection into the red or INCREASE TEMPERATURE zone, indicating that the actuator is at its limit stop in the open direction.

(7) Turn the TEMP. SIGNAL, COARSE control clockwise (approx. 10° of arc) until the pointer of METER I is fully in the green zone, and wait until a slight deflection of the METER I pointer is observed.

(8) Note the reduction in engine r.p.m., or torque.

(9) Turn the TEMP. SIGNAL, COARSE control very slowly anti-clockwise until the pointer of METER I returns to its mid-position, and the pointer of METER II returns to zero (adjustment of the TEMP. SIGNAL, FINE control may be required).

(10) Measure the temperature in the manner described in para. 50, sub-para. (10), using the DATUM TEMPERATURE scale and the galvanometer. The measured temperature represents the DATUM temperature of the system (the reading of the aircraft jet-pipe temperature indicator should be compared with the test set reading).

(11) 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. Failure of the engine 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.

Disconnecting supplies

61. 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

62. 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.

63. 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

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

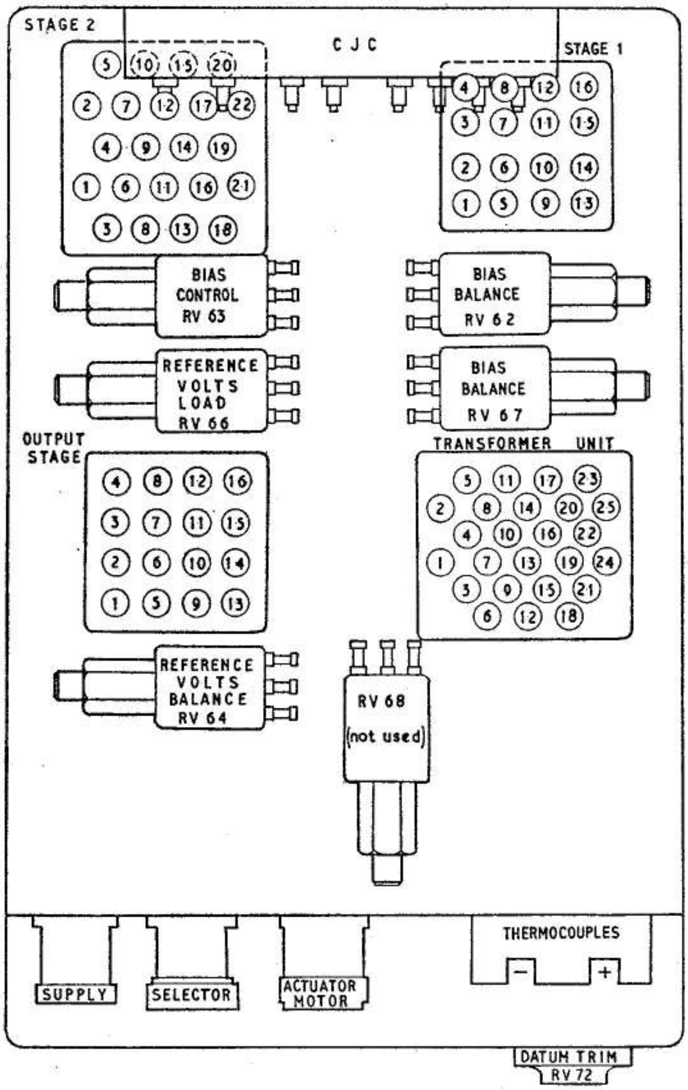

Fig. 7. Layout of amplifier, showing seal numbers

(1) All plug pins (except pin D of the 400, C.P.S. SUPPLY plug) and the chassis.

(2) Thermocouple +ve and chassis.

(3) Thermocouple —ve and chassis.

(4) Thermocouple +ve and pin A (400 C.P.S. SUPPLY plug).

(5) Thermocouple —ve and pin A (ACTUATOR MOTOR plug).

(6) Pin A (400 c.p.s. plug) and pin A (ACTUATOR MOTOR plug).

Note . . .

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

TABLE 1

Voltages and resistances

Component	Function	Seal Ref.	Voltage	Resistance (ohms)
TRANS-FORMER UNIT	(a) Supply to transformer	4–9	115V a.c.	5
	(b) Supply to stage 1	1–2–3	12·6–0–12·6V a.c.	0·8–0–0·8
		5–6–7	12·6–0–12·6V a.c.	0·8–0–0·8
	(c) Supply to stage 2	10–11–12	25–0–25V a.c.	5–0–5
	(d) Supply to output stage	22–23–24	25–0–25V a.c.	3–0–3
	(e) Supply to voltage stabilizing bridge	13–14	48V d.c.	5000
STAGE 1	(a) Supply to sections 1A and 1B	14–15–16	12·6–0–12·6V a.c.	0·8–0–0·8
	(b) Section 1A, control	9–13	—	250
	(c) Section 1B, control	10–11	—	200
	(d) Section 1A, bias	3–4	—	23
	(e) Section 1B, bias	7–8	—	23
	(f) Section 1A feedback	1–6	—	180
	(g) Section 1B output	1–5	—	180
STAGE 2	(a) Supply to power coils	5–6–7	25–0–25V a.c.	5–0–5
	(b) Control	1–2	—	180
	(c) Feedback	15–16	—	100
	(d) Output	3–4	—	160
	(e) Bias	11–12	0·8V d.c.	100
	(f) Bias	11–9	—	18
	(g) Bias	12–9	—	100
OUTPUT STAGE	(a) Supply to power coils	5–6	50V a.c.	8
	(b) Control	1–11	—	75
	(c) Bias	3–4	0·3V d.c.	36
	(d) Output resistor	9–10	—	21

Note . . .

(1) *A Multimeter, Type* 1 (*Ref. No.* 10*S*/16411) *is suitable for making these measurements.*

(2) *Do not short-circuit output terminals, i.e. pins A, B,* 1 *and* 2 *of the output* (ACTUATOR MOTOR) *plug, while testing.*

(3) *Resistance checks are to be undertaken with no external connections to the amplifier.*

(4) *Tolerances to be* ±15 *per cent. for resistance measurements and* ±10 *per cent. for voltage measurements.*

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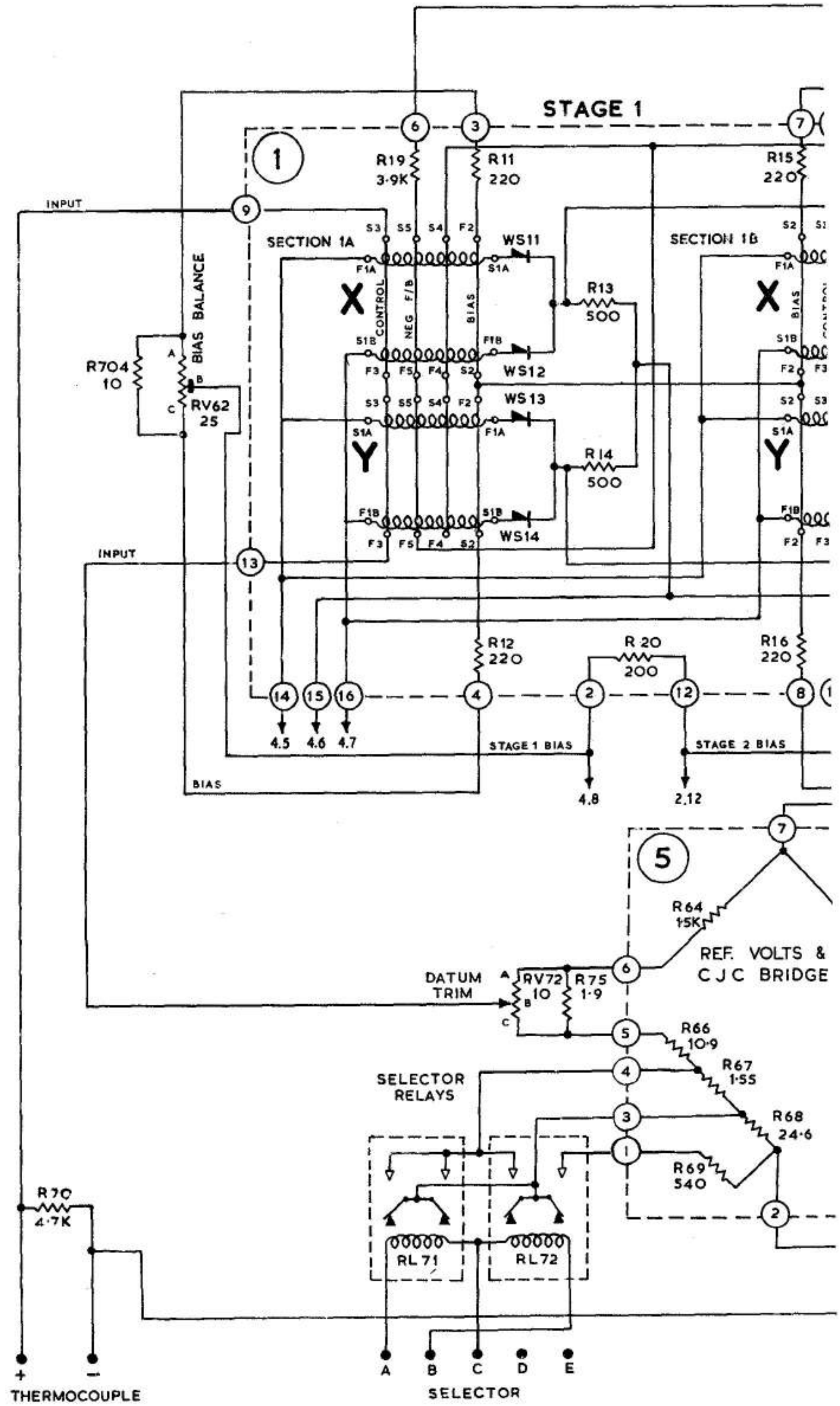

Fig. 8

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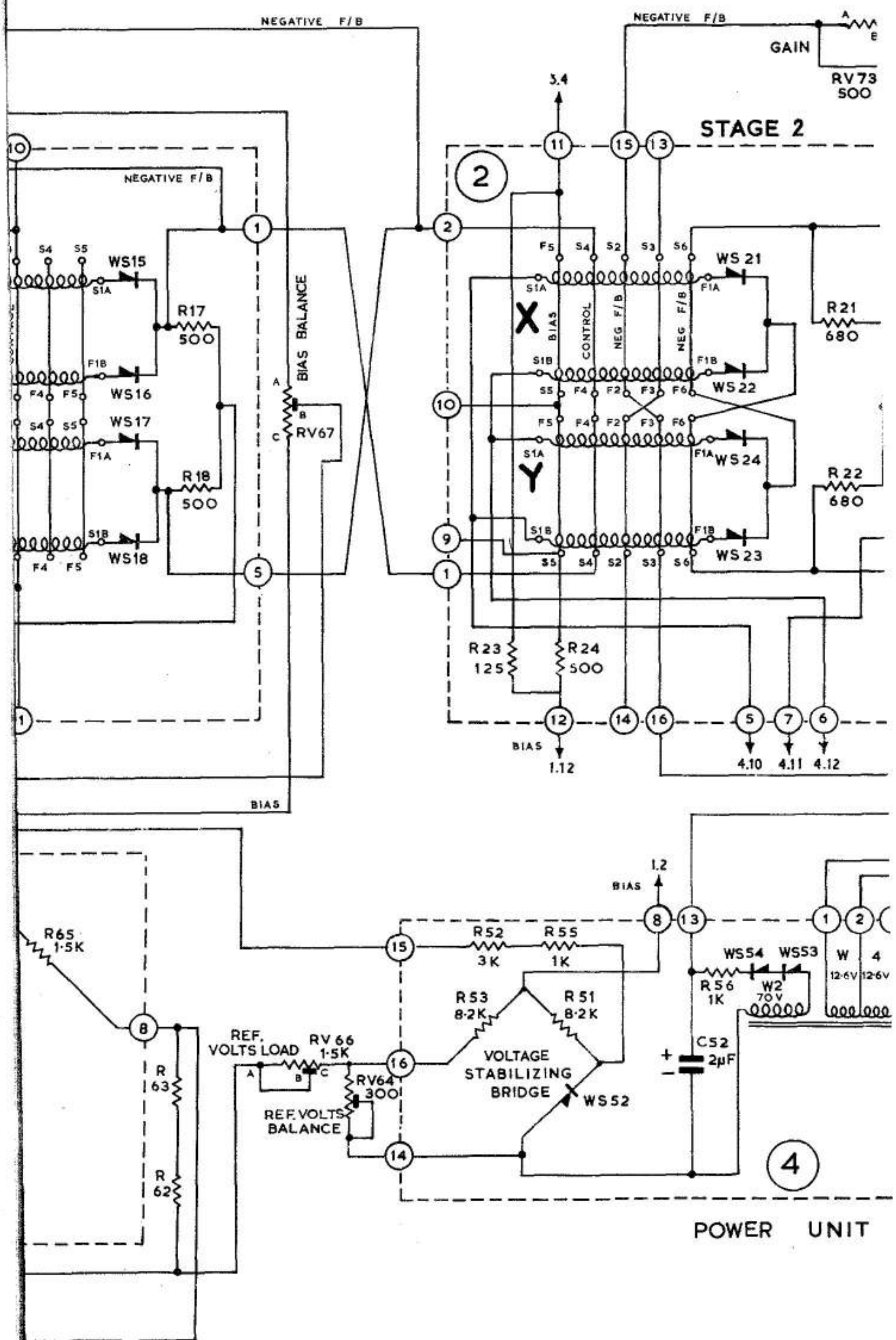

Circuit diagram of Amplifier A 491

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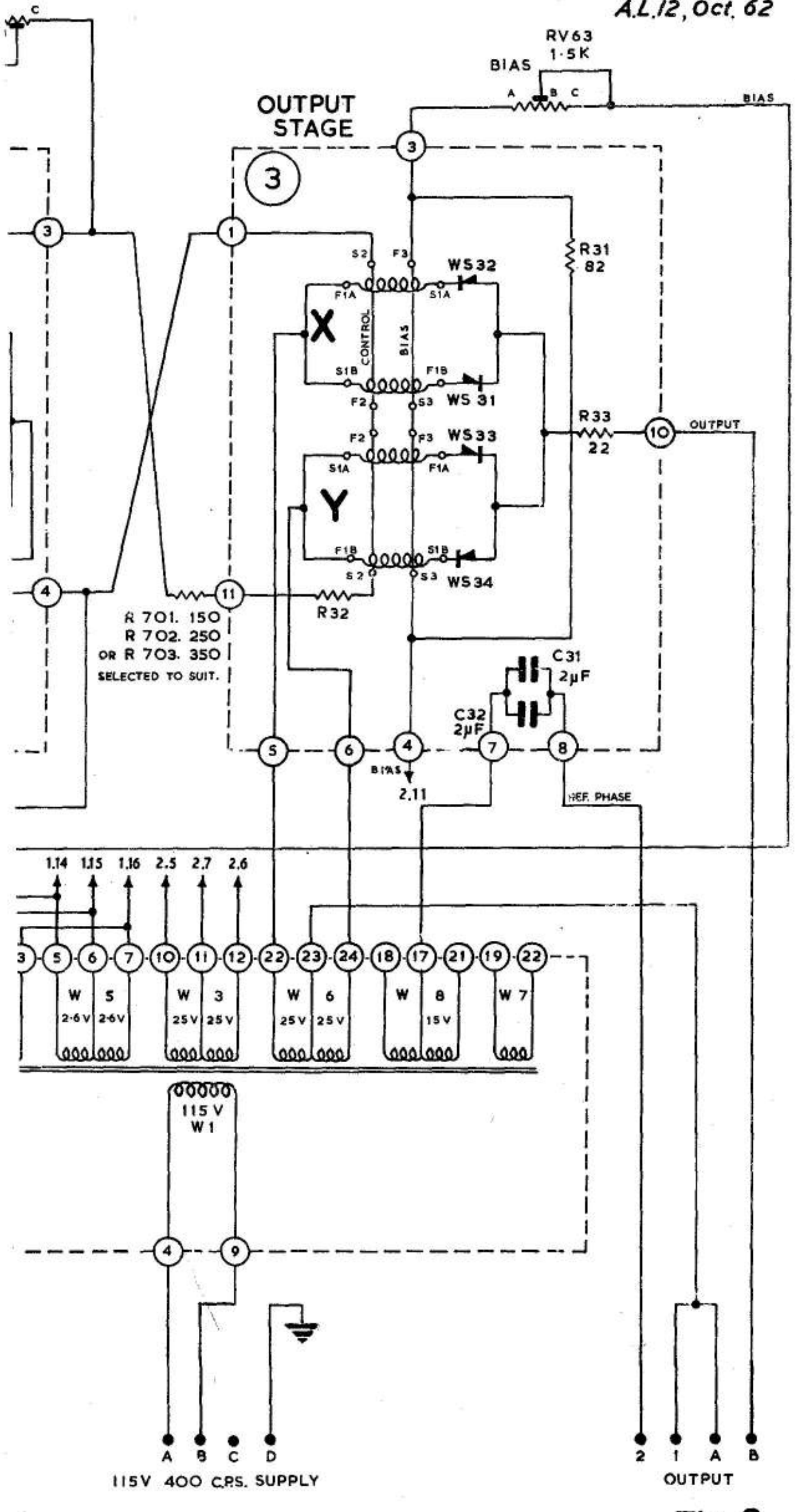
RV63
1·5K
BIAS
OUTPUT
STAGE
3
CONTROL
BIAS
X
Y
WS32
WS31
WS33
WS34
R31
82
R33
22
OUTPUT
R32
R 701. 150
R 702. 250
OR R 703. 350
SELECTED TO SUIT.
C31
2μF
C32
2μF
BIAS
2.11
REF. PHASE
1.14 1.15 1.16 2.5 2.7 2.6
W 5
2·6V 2·6V
W 3
25V 25V
W 6
25V 25V
W 8
15V
W 7
115V
W1
A B C D
115V 400 C.P.S. SUPPLY
2 1 A B
OUTPUT

Fig. 8