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MASTER

ABSORBER ROD CONTROL CIRCUIT

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by

L. CALDAROLA, G. DONDI and J. R. DEAN

[redacted]

A.E.E. Winfrith, Dorchester, Dorset, England

October, 1963

ABSORBER ROD CONTROL CIRCUIT

by

L. CALDAROLA,

G. DONDI

and

J. R. DEAN

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<u>FIGURE</u>

ABSORBER ROD CONTROL CIRCUIT

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1. INTRODUCTION

The Dragon reactor is controlled by twenty-four absorber rods, containing boron carbide, arranged in the reflector as a curtain round the core. The rods and their drive mechanisms are all identical.

The mechanisms are linked to the electrical control circuit through the special stepping motors and the limit and load sensing switches, and the circuit determines the way in which the rods are employed in controlling the reactor. This report sets out the control functions of the system and particulars of the electrical equipment and circuits. Items referred to briefly in the general description (Section 2) are more adequately described in later sections.

The design of the control mechanisms is fully described in principle in D.P. Report 145: the most complete physical description is in the maintenance manual.

2. GENERAL DESCRIPTION OF THE SYSTEM

Any mechanism may be controlled by suitably plugging in its circuit, so that its rod falls into any one of the categories:

(a) safety rods. Normally fully raised and adequate to compensate for any incident envisaged. There will probably be three safety rods.

(b) operation rods. Manually operated, one at a time, for adjustment of power. There will probably be twenty.

(c) automatic rod. To keep outlet gas temperature at a constant value during steady power running. There will be one.

The stepping motors are driven by sequentially energising two of three phases with direct current: the direction of movement is determined by the sequence. The motor and its mechanism may be held stationary by continuously energising one or two phases. Completely de-energising releases the motor and allows the rod to fall.

The sequenced feed to a motor is supplied from a "driving circuit" which contains appropriate amplifiers, switches, etc. and a ternary ring circuit, which is triggered by signal pulses. The frequency of the pulses determines the average motor speed. There is one driving circuit for all of the operation rods and the safety rods. Only one mechanism at a time is connected, by means of a twenty-four way selector switch. When a mechanism is not connected to the drive circuit, the same switch transfers it to a "hold line" at earth potential which continuously energises one phase of the motor. A special "stop circuit" ensures that a motor always stops on the same phase so that it can be transferred without the energisation being interrupted.

The triggering pulses to the operation driving circuit are generated by a capacity pick-up and motor-driven toothed disc, incorporated in a "limited pulse generator", mounted on the control desk. This generator may be pre-set to produce only enough pulses for 1½, 3, 6 or 12% of total rod travel, the movement being initiated in either direction by raising or depressing a separate hand lever and then releasing it. The movement is stopped by a circuit controlled by a binary pulse counter; but if this fails, it will be stopped by the limit switches in the generator or, if these also fail, by the mechanism reaching the selected mechanical end stop.

Pre-setting the generator to a position called "inching" enables the operator to move the rod only so long as the hand lever is held raised or depressed. In this case, movement cannot exceed 12% without being re-started.

The automatic rod is driven by its own drive circuit fed from pulses produced in the same way by a continually running generator. The on-off controller will receive a signal derived from tachio-generators on the primary circuit blowers and from a potentiometer setting equivalent to the demanded gas temperature rise across the core. This signal will be the equivalent of multiplying helium mass flow by temperature rise to represent demanded power and it will be compared with measured flux, representing power being produced in the core. It will operate to keep constant the outlet gas temperature, which it measures in effect by dividing the power by helium mass flow. This method gives considerable anticipation compared with measuring the gas temperature directly. A small integral term derived from direct gas temperature measurement will compensate for variations in the fission product decay heat after reducing power from various levels.

A switch is provided to couple the automatic drive circuit to the manual controls instead of the controller, at the operator's will.

Various interlocks and inhibitors are built into the circuit. These are mentioned in various sections below and in the Table Section 4.1. The secondary guard lines for reactor safety are not included in this circuit but the primary guard lines are. These include the final trip relays which break the supplies to all of the motors, allowing the rods to fall.

The position (along its travel) of the particular mechanism selected for manual operation is shown on a "fine position indicator" on the control desk. The switch which selects the mechanism at the same time couples a 400 cps synchro-transmitter to the display unit which incorporates a matching synchro in a position servo driving numbered discs, giving a "digital" display. The automatic rod has an identical display unit to which it is always coupled.

The position of every rod is displayed at all times on one of the "coarse position indicators", which are vertical voltmeters in a horizontal bank on the wall panel behind the control desk. Each meter is fed from a 400 cps rotary magnetic pick-off (variable transformer) in the rod mechanism. One side of the meter needle is illuminated with red light and the other with green.

3. DESCRIPTION OF ELECTRICAL UNITS

For this description it is convenient to divide the units into five natural groups, viz:-

3.1 Equipment in the control mechanisms

3.2 Transistorised equipment

3.3 Circuitry

3.4 Equipment on the control desk

3.5 Equipment provided only for experiments.

3.1 Equipment in the Control Mechanisms

The mechanical arrangement of this equipment is described in the Maintenance Manual for the Control Mechanisms.

3.1.1 Motors in Control Mechanisms

Each mechanism is driven by a stepping motor, made by Sperry and designated "Vernier motor Type 2." The performance of these is specified in D.P. Specification 21. The principle of operation is illustrated in Fig.1.

The simple laminated iron rotor has 50 teeth and the six salient poles of the laminated stator have teeth at spacing equivalent to 48 teeth on a complete circle. The poles can be energised with DC current in opposite pairs. When poles AA' are energised the rotor teeth align themselves at these poles, in the position of minimum reluctance. The teeth at BB' are then displaced by a third of a tooth pitch and at CC' two thirds (or one third in the opposite direction).

Sequentially energising the poles causes the rotor to rotate in steps of a third of a pitch, i.e. $\frac{360^\circ}{3 \times 50} = 2.4^\circ$. The sequence A, B, C gives one direction of rotation, A, C, B the other. The proposed sequencing frequency of 12.5 changes per second will give a speed of $\frac{60 \times 12.5}{150} = 5$ rpm.

If one or two phases are energised continuously the motor remains magnetically locked and if de-energised completely it runs free. This free-running when de-energised is used to release the control rods to drop under gravity for emergency suppression of reactivity. The motor will also run free if all three phases are energised simultaneously, but this condition is not used in this application. In order to reduce the electrical heating of a locked motor, a resistance in the "hold" line will reduce the current to about half the value it would have with the motor resistance alone. The "break-away" torque of the stationary motor will still be adequate to support the load, since no torque is required to overcome inertia forces. Moreover, the reduced current is easier to break, and it will take less time for the magnetic flux in the motor to decay when the rod is released.

So that at least one phase is energised at any time during switching, the phases will be energised in pairs, i.e., AB, BC, CA or AB, CA, BC for reverse.

3.1.2 Switches in Control Mechanisms

Because they will operate in pure helium and must be very reliable, tilting mercury switches are used throughout the mechanisms. The normal glass container, filled with nitrogen, is encapsulated in an epoxy-resin capsule, set on a Tufnol base. This encapsulation provides strength against pressure differences, protection against damage, and would retain the mercury in a cracked glass container.

The containers have pockets at each end to give "snap" action to the mercury. Without this feature there would be a tendency for the connections to be uncertain for a considerable time, causing the relays they control to chatter.

3.1.2.1 Limit Switches in Gearbox

Duplicate up limit switches, U and U′ (Fig. 2) and duplicate down limit switches, D and D′ are arranged to close at the limits of travel of the gearbox, which determine the travel of the control rod. They in turn energise relays UL and DL respectively. Only one of each of the switches is connected into the circuit. The other serves as a built-in spare and can be brought into operation by one of a bank of toggle change-over switches located behind the front panel (panel 16) in the control room.

3.1.2.2 Switches in Overwind Mechanism

A load sensing switch Z is arranged to open if the load on the mechanism, normally due to the weight of the control rod, is reduced to less than about half its normal value. This is called the "slack wire" switch. When it opens it de-energises relay SL whose contacts control acoustic warnings and annunciators (not covered by this report). If it is a safety rod which is faulty it will convert the SHUTDOWN conditions to SCRAM, unless the reactor is in the initial loading condition or the charge machine is operating.

A second switch O in the overwind mechanism is arranged to close when the mechanism is used to wind the control rod up to its fullest extent beyond the normal range of travel. This is only done in order to remove the control rod from the reactor. Closing switch O directly lights a lamp in the compartment in which the mechanisms are located.

3.1.3 Synchro-Transmitter

A Sperry slab synchro type 523 RS4 SL is driven by the gearbox and transmits to a "fine position indicator" which incorporates a matching synchro in a position servo so that the indicator accurately shows the gearbox position. The indicator is located on the control desk: it is more fully described in Section 3.4.6.

At any time, the only synchros connected to indicators are those of the automatic rod and of the particular "operation" rod which has been selected by the operator to be under manual control.

3.1.4 Rotary Pick-Off

Every gearbox also drives a Sperry type No. 21142 rotary pick-off, energised by a 35 volt, 400 cps supply, which rotates 30.07° for full stroke between gearbox end stops. The pick-off is a variable coupling transformer whose output varies over the range 0-20 volts, approximately, and is fed directly to one of a bank of moving coil meters on the instrument panel behind the control desk, so giving a coarse indication of mechanism position at all times.

The method of adjustment of the pick-off in the gearbox is given in the Maintenance Manual for the Control Mechanisms, as also are the measured signal voltages for every unit.

3.2 Transistorised Equipment

3.2.1 Control Rods Drive Unit

This equipment is incorporated in a single rack-mounted unit, located in the Apparatus Room. A complete spare is provided. The unit incorporates the following separate circuits:-

Operation rod driving circuit.

Automatic rod driving circuit.

Pulse counter.

-16 volt D.C. electrical supply.

3.2.1.1 Driving Circuits

The two driving circuits, one used for the operation and safety rods and the other only for the automatic rod, are identical. The block diagram, Fig. 4 shows the arrangement of elements in which square waves from a "pulse generator" are fed through a differentiating circuit, into a ternary ring circuit which, through a pre-amplifier and amplifier, successively earths two out of three lines. These lines are connected through a system of plugs to the stepping motor to be driven. Pulses to the operation drive circuit are derived from the "limited pulse generator" described in Section 3.4.1 while those to the automatic drive circuit are derived from a generator in the automatic controller described in Section 3.2.2.

The ternary ring circuit is shown in Fig. 5. In a stable condition two transistors are cut-off and the third, say 1, is in saturation. An incoming positive pulse changes 1 to the cut-off condition and switches 2 to saturation. The next pulse will change 2 to cut-off and 3 to saturation.

The sequence of transistors in cut-off is consequently 1,2:2,3:3,1. If the contacts RS-1 and RS-2 between the pre-amplifier and amplifier are closed, the corresponding sequence of the motor phases energised is AB:CA:BC, causing the control rod to be raised. To lower the rod, contacts L-1 and L-2 are closed instead and the sequence is AB:BC:CA.

So that a motor may be transferred from the drive circuit to a "hold line" without the energisation being interrupted, the "stop circuit" is employed. Relay N′ in the stop circuit is connected to the -16 volt supply and its earth connection is controlled by a transistor switching circuit receiving its switching signal from two sources. One source is a -16 volt line opened or closed by the control signals and the other is phase 3 of the ternary ring circuit, which has a negative potential as long as transistor 3 is in cut-off. If either of these negative potentials is applied relay N is energised completing the ternary ring circuit through its contacts N′-1. When the -16 volt line is broken by one of the many switches which serve to stop the motor, the circuit will continue to operate until transistor 3 becomes saturated; then it will stop.

3.2.1.2 Pulse Counter

The electronic pulse counter counts the number of times phase A of the driving circuit amplifier output is energised. The circuit is shown in Fig. 6. It includes eight "divide by two" circuits in cascade. The counter is used to stop the driving circuit when either 16, 32, 64 or 128 pulses have been counted, the appropriate number of stages being selected by connecting the inputs of either the first, second, third or fourth stages to the amplifier by means of bank 3 of selector switch S2 in the limited pulse generator (described in Section 3.4.1).

When counting is completed, the last stage, through a switching transistor, de-energises relay C which stops the system through the stop circuit.

If the automatic rod is under manual control, the counter input must be taken from its amplifier. This is selected, instead of the operation circuit amplifier, by contacts X-2 of relay X, which relay also transfers the manual controls from the "operation" to the "automatic" driving circuit.

3.2.1.3 -16 Volt D.C. Supply

This consists of a regulator fed by the -30 volt D.C. supply described in Section 3.3.3. The circuit for the -16 volt supply is shown in Fig. 7.

3.2.2 Automatic Controller

This equipment has been described briefly in Section 2 above and a separate report, D.P. Report 174, has been devoted to a thorough description of the design and principles of operation. This is not attempted here.

The output from the controller is in the form of pulses at a constant frequency, switched on or off by the controller and fed to the automatic rod drive circuit, whenever automatic operation is selected. The pulse frequency will be slightly higher than that for the generator feeding the operation and safety rods, at present proposed at 12.5 pps. In the automatic system, reversal of direction is not obtained by switching phases but by doubling the pulses when the rod is required to move up, making the ternary ring circuit move two steps in quick succession, too quickly for the motor to follow, and so in effect, run backwards.

3.3 Circuitry

3.3.1 Connecting Box Fig. 8

This box contains the sockets connected to the three circuits, the operation rod circuit, the safety rod circuit and the automatic circuit, by means of any one of which a particular rod mechanism may be controlled. The function of a mechanism is determined by connecting its socket to one of the circuit sockets with a plug link, or, if it is to be used as an operation rod mechanism, by cross connecting in its own socket by using a suitably wired plug. If no plug is fitted in a mechanism socket the mechanism will be electrically isolated. With the exceptions of the overwind switch and lamp, the mechanism can be tested from the socket.

There will be twenty-four mechanism sockets, one "automatic" socket and, to begin with, three "safety" sockets, but space is available to add to the number of special sockets if the circuit is developed later. There will only be a sufficient number of links and wired plugs to suit the sockets, so the numbers of each type of rod must be correct.

The plugging arrangement is displayed on lamps around the rod selector switch, S1 on the control desk, described in Section 3.4.3.

3.3.2 Relay Panels

The two panels, located in the control room, contain eight Londex heavy-duty relays to break significant currents and Clifford and Snell relays elsewhere; all are plug-in type with individual dust-proof covers. Those Clifford & Snell relays used to connect the synchros to the fine position indicators have gold-plated contacts.

The eight Londex relays are in the primary TRIP and SCRAM guard lines, arranged as in Fig. 3, in which two relays at each end of the line each have twelve banks of contacts, one set in the -30 volt supply to each stepping motor. By cross connection through contacts, when any one relay opens the other three in the same line are also automatically opened. The arrangement guards against earth faults in the line.

The secondary guard lines controlling the Londex relays are not included in this report. A report on this subject will be issued.

The need for two primary guard lines is due to differences in the secondary guard lines controlling them. After a TRIP the safety rods can be raised without the condition which caused the trip being cleared, but after a SCRAM no rod can be raised until the fault is cleared.

The panels and the wiring between the groups of electrical units are specified in D.P.S. 77.

3.3.3 -30 Volt D.C. Supply

This is a standard unit capable of delivering 120 amps. It is located in the cable handling area under the control room. A complete stand-by unit is mounted in the same panel.

This supply is specified in D.P.S. 77.

3.3.4 Coarse Position Indicators

The bank of twenty-four, edge-reading, vertical, moving coil voltmeters, made by SIFAM, Torquay, are located on the front panel directly behind the control desk. Each one is always connected directly to the magnetic pick-off on the same mechanism, the sequence from left to right along the panel corresponding to the sequence of the mechanisms round the reactor, beginning at the charge/discharge facility and counting clockwise in plan view.

The meters are described in specification D.P.S. 122. Fig. 9 shows the outline and Fig. 10 the general arrangement. The pointer arm carries an opaque mask which moves in a curved chamber bounded by the Perspex graduated face. The two zones on either side of the mask are illuminated, the lower by red light and the upper by green. Hence, the band of red light rises to replace the green as a control rod is drawn out.

The meters are arranged to indicate a rod fully withdrawn when the signal is 20 volts and fully in when the voltage is in the range 0-0.7 depending on the pick-off. Adjustments to range and zero can be made to each meter to suit the individual pick-off. If the signal should disappear altogether, the meter needle will fall beyond zero. The appearance will then be of a rod fully inserted, which is considered safe since the operator will have more reactivity suppression at his command than he thinks, rather than less.

3.3.5 Lamps and Annunciators on Front Panels

Above each coarse position indicator meter is a lamp which lights when the "up" limit of rod travel is reached and below each meter one which lights at the "down" limit.

Below the down limit lamp is a lamp which lights whenever the slack wire switch of the overwind mechanism opens (see Section 3.1.2), probably indicating that the control rod wire rope has broken, or possibly that the rod is stuck.

Luminous annunciators display which of the three states the control system is in, OPERATION, SHUTDOWN or SCRAM.

3.4 Equipment on the Control Desk

Fig. 11 shows the arrangement of that equipment on the control desk which forms part of the absorber rod control circuit. The units included, and described in the following sections are:-

Limited pulse generator to preset required travel.

Hand lever, to initiate rod movement.

Selector Switch S1 for choosing the rod to operate.

Auto-manual switch.

Various manual controls, such as buttons and key.

Fine position indicators.

3.4.1 Limited Pulse Generator (L.P.G.)

This is specified in D.P.S. 123. For convenience of manufacture, and servicing this unit is in two parts, a mechanism called the "preset travel assembly" and an electrical assembly in a self-contained box, called the "control box", which screws on to the back of the mechanism. The electrical circuit for the whole generator is shown in Fig. 12 and the outline in Fig. 13.

3.4.1.1 Preset Travel Assembly

Fig. 14 shows the general arrangement, the part numbers on it being referred to in the following description.

Pulses are generated by the rotation of a toothed disc on the clutch/brake assembly 18 passing through a capacitance probe 26. The disc is driven by a synchronous motor 21 through gears on the indicator shaft assembly 18. This assembly is built on the shaft which carries the pointer which indicates, on the front dial, the amount the generator has moved, in percentage of full rod travel.

The indicator shaft assembly drives a cam shaft in the limit switch assembly 3. The cams are arranged to operate micro-switches at positions of rotation of the indicator shaft corresponding to approximately 1½, 3, 6 and 12% of full rod travel.

The selector switch shaft assembly 9 can be set to select these amounts of travel. The knob to do this must first be pushed in to clear an interlock. When the assembly is set it does three things:-

(a) sets the circuit of the pulse counter described in Section 3.2.1.2 by means of bank 3 in selector S2 so that it operates the stop circuit and stops the driving circuit when the desired travel has been reached. The counter is quite accurate: the number of steps may be 48, 96, 192 or 384. The total rod travel being 3205, these correspond to 1.498, 2.995, 5.991 and 11.981%.

(b) puts the correct limit switch into operation in the preset travel assembly so that if the pulse counter were to fail to stop the system the limit switch would stop it a little later.

(c) moves a set of blocker plates, mounted on the selector switch shaft so that the appropriate one is in a position to engage with one of a group of plates carried round on the indicator shaft. If both counter and limit switches fail to stop the system, the plate on the indicator shaft will strike the blocker plate on the selector switch shaft and stop further movement. The plates are so arranged that the selector shaft is moved in equal steps while the intervals of movement of the indicator shaft, and of the control rod movement, are logarithmic.

While the generator is being driven by the synchronous motor, a spiral spring, coupled to the indicator shaft, is wound up. At the end of the driven travel the synchronous motor is switched off and the clutch CL1 remains energised so that the indicator shaft is held stationary by the irreversible gearbox connecting it to the motor through the clutch. The pointer consequently shows the rod travel that has just been applied.

When another movement is initiated the clutch CL1 is de-energised to allow the spiral spring to return the mechanism.

3.4.1.2 Control Box

A schematic circuit is shown in Fig. 12. Changes in capacity induced in the probe 26 are transformed by the "capacity transducer" into variations in D.C. voltage which in turn is fed into the "square wave forming circuit". The square waves form the output from the generator: they are fed into a differentiating circuit forming the first stage in the driving circuit described in Section 3.2.1.

3.4.1.3 Operating Sequence of L.P.G.

The unit will normally be in the state in which it finishes its motor-driven travel, i.e. motor switched off, clutch CL1 energised, pointer shaft locked by the irreversible gearbox and clutch/brake CL2 de-energised so that the pulse generating disc is held to the frame by the brake. From this position, the next step may be either to select a different travel for the next operation or to initiate the same travel once more.

Consider first the selection of a different travel and refer to Figs. 2, 3 and 12. Pressing the selector knob opens switch SW1A in the stop line, Fig. 2, which de-energises relay ST in that line and, if a control rod is moving, it will be stopped by the stop circuit. Switch SW1B is also opened when the knob is pressed. This opens the line energising clutch CL1 and so allows the mechanism to spring back, which it will do in less than a second. On reaching zero position a cam on the limit switch shaft closes switch SWA which shorts out the contacts H-1 which are in series with the relay H so that the relay can only be energised when the mechanism is in this position. Further operation is now initiated by operating a separate hand lever described in Section 3.4.2 below. Through the chain of relays RS or L, the raise and lower relays, and N, the stop circuit relay, this energises relay H. Relay H, through contacts H-2 energises clutch CL1 coupling the motor to the indicator shaft, through contacts H-3 energises clutch CL2 coupling the generator disc to the indicator shaft, and through contacts H-4 switches on the synchronous motor. When the mechanism moves, switch SWA opens out the relay H remains energised through its contacts H-1.

When the pulse counter has reached the prescribed count its relay C is de-energised, contacts C-1 stop the control rod motor through the stop circuit and contacts N-3 on the stop circuit relay open, de-energising relay H of the L.P.G. Contacts H-3 also open: they are in the feed line to clutch CL1 but the clutch remains energised at this stage through the switch SW1B (operated by the knob) and contacts N-4 of the stop circuit relay, both of which are closed. Contacts H-3 open de-energising clutch/brake CL2 and contacts H-4 open switching off the motor. The generator is now back in the starting condition.

Consider next the action of initiating travel without selecting a different stroke. Moving the hand lever again energises the relay chain RS and N. This time switch SW1B is not opened by the knob, but it is in series with contacts N-4 which serve to de-energise clutch CL1 and allow the mechanism to spring back. At the zero position, limit switch contacts SWA close and complete the relay chain circuit so that relay H is energised. The sequence above is then repeated, relay H energises both clutches, switches on the motor and locks itself in.

If the selector is set beyond the 12% setting, to a setting marked "INCH", the mechanism will stop running whenever the hand lever is released to spring back to the neutral position. With this setting, and the OFF setting, bank 5 of selector S2 does not complete the -16 volt signal line to the stop circuit, as it does in the other settings. This circuit is completed in the INCH setting only when the control lever is raised or depressed, when the lever contacts directly by-pass bank 5.

If the pulse counter should fail to stop the system, the appropriately selected limit switch will change over, closing contacts to light the lamp in the face of the generator and opening contacts to de-energise relays K and KM. Relay K stops the system through contacts K-1 and the stop circuit, the L.P.G. being de-energised through relay H, as above. Relay KM has an RC delay circuit causing it to open after a few more pulses have been generated when it independently de-energises clutch/brake CL2 and the motor. This gives extra safety should the stop circuit also fail to work.

3.4.2 Control Lever, Fig. 15

This is a "joystick" lever made by Pye as a standard product. It is mounted on a control desk face which is inclined at 30° to the to the vertical. It has four positions, the central spring-loaded rest position, the lever raised, the lever depressed and the lever pushed in axially. The raised and depressed movements correspond to the "raise" and "lower" commands and pressing to "stop".

The lever operates five micro-switches. Referring to Figs. 2 and 3, their functions are as follows:-

(i) CLR-1, closed for "raise". If an operation rod is being controlled the relay chain RS, N′, N is operated. If it is the automatic rod which is being controlled the relay chain is RS, RA, N′A, NA. These chains result in:-

(a) the contacts CLR-1 are by-passed

(b) the "lower" circuits, operation and automatic, are rendered ineffective

(c) the pre-amplifier of the operation drive circuit is appropriately connected to the amplifier to give the required direction of travel or, if it is the automatic rod which is being controlled, either the single or double pulse circuit is selected

(d) the stop circuit (Section 3.2.1.1) starts the ternary ring circuit

(e) the limited pulse generator (Section 3.4.1) is started

(f) the pulse counter (Section 3.2.1.2) is set ready to count.

(ii) CLL-1 closed for lower. The relay chains are LS, N′, N or LS, LSA, N′A, NA for operation and automatic rods respectively. The only difference in the results are that the connections controlling direction are now appropriate for lowering.

(iii) CLS, closed to stop a moving rod. These contacts de-energise the relay chain ST, N′ and so the stop circuit stops the ternary ring circuit. The stop relay ST is reset by contacts RS-7 or L-7 when the lever is again moved to "raise" or "lower".

(iv) and (v) CLR-2 and CLL-2 used for "inching". When the "inch" position is chosen on the selector switch of the limited pulse generator (Section 3.4.1) the -16 volt signal line to the stop circuit is channelled through these two switches which are normally open and in parallel. The rod will only move if either the CLR-2 switch is closed, when the lever is raised, or the CLL-2 switch is closed when the lever is depressed. If the lever is released to spring back to the central position, the rod stops.

Adjacent to the control lever on the desk are two lamps, one of which is lit whenever a circuit is completed to cause a rod to rise and the other whenever a circuit is completed to cause a rod to be lowered.

3.4.3 Selector Switch, S1

Figs. 16 and 17 show respectively the outline and the wiring diagram. This is a rotary switch with twenty-six equally spaced positions: twenty-four correspond to mechanisms and the two bottom ones are spare. The switch can be moved right round in either direction without restriction, but a mechanical interlock requires that the knob is first pressed in before it can be rotated.

Referring to Figs. 2 and 3, in pressing the knob, three contacts are operated, CO-2 which breaks the line to the stop relay ST and stops the drive circuit if it should happen to be running, and two contacts CO-1 and CO-3 which break the supply to banks 1 and 2, discussed below, so that all the transfer relays A and B which they control are de-energised and ensure that every safety and operation rod motor is connected to the "hold" earth line, and not to the driving circuit. To make sure that the motor has stopped before this transfer is made a delay is introduced by a static RC network across the transfer relays A_i (where i may be 1...24 corresponding to any of the mechanisms). Rotating the switch operates five banks of contacts:-

Bank 1 The selected contacts energise one of the relays B_i whose contacts B-1, B-2, B-3 connect the stepping motor to the hold line. Contacts B-4 close in the control lines of relays A_i, in series with switch bank 2.

Bank 2 The selected contacts energise the relay A_i, corresponding to the selected relay B_i, which due to the contacts B-4 is sure to operate after the B_i relay, and due to its delay circuit operates after a delay of about $\frac{1}{2}$ second. The A_i contacts A_i-1 open the connection between the motor and the hold earth line. At the same time the A_i-2 contacts close, shorting out bank 1 so ensuring that when the selector is next moved relays A_i operate first, with the delay, and then relays B_i operate through contacts A_i-2. In this way the motor can never be disconnected from both earth lines; if it were the rod would drop.

A number of interlock circuits make banks 1 and 2 inoperative, unless other controls are correctly set, by interrupting the supply to them at relay contacts ZA-1 and J-1. Banks 3 and 4 are included in the interlock circuits which may energise the relays and close these contacts.

Bank 3 Relay ZA will be energised only if the master key is in SHUTDOWN and the supply line to it is fed through bank 3 contacts connected to the safety rod plug in the connecting box described in Section 3.3.1.

Bank 4 Relay J will be energised only if the master key is in OPERATION, all three safety rod up limit switches are closed and the supply line to it is fed through bank 4 contacts connected to "operation" rod plugs or the "automatic" rod plug.

Other interlock circuits establish the conditions under which the automatic rod may be controlled manually or by the automatic controller. Bank 5 is included in these circuits.

Bank 5 The manual controls are transferred to the auto rod drive circuit by energising relay X. This is done by having the master key in OPERATION, all three safety rod up limit switches closed, the Auto-Manual switch in MANUAL, so closing contacts AN-2 through the relay chain AM-2, AN, and the supply to the relay fed through the bank 5 contact connected to the "automatic" plug.

If all these conditions are correct except that the Auto-Manual switch is in AUTO, relay X will not be energised but relay Y will be and this makes the "released rod selected" button operative to release the auto rod.

Two rings of lamps, twenty-four in each ring, are mounted round the Selector knob. The lamps of the inner ring are engraved A, for automatic, and the outer ring S, for safety. Some of these are illuminated as a result of connections made in the connecting box described in Section 3.3.1, when the rod functions are determined, and so they indicate the rods connected to the special circuits.

3.4.4 Auto-Manual Switch, S3

The appropriate setting of the switch is required for the auto rod to be operated either manually or by the automatic controller.

Referring to Figs. 2 and 3 the switch energises relays AM and MA in the AUTO and MANUAL Settings respectively. Relay contacts energise relay AN which has an RC delay circuit. The three sets of relay contacts AM, MA, AN, between them connect the automatic drive circuit to either the controller or the limited pulse generator and other manual controls. The connection between auto drive circuit and manual controls will not be completed unless relay X is energised by the completion of the interlock circuit including bank 5 of selector S1, as explained in Section 3.4.3. The delay in relay AN ensures that, if either drive circuit is running before the transfer, it has time to reach the correct phase to stop.

3.4.5 Various Manual Controls

In addition to the limited pulse generator and the main hand lever, there are on the control desk, arranged as in Fig. 11, the following controls:-

3.4.5.1 SCRAM button to release all control rods. A large red button is pressed to break spring-loaded contacts in the "manual SCRAM line" and so de-energise the self-holding relays MS1 and MS2. These in turn open contacts in the SCRAM primary guard line.

3.4.5.2 RELEASE button to release only the control rod selected for manual control at the time. This button is pushed to break the spring-loaded contacts in the actuating circuits of relays G and GA in the "manual" and "automatic" rod release lines respectively. The contacts are by-passed in the "automatic" line by relay contacts Y-1 unless the automatic rod has been selected on S1. Contacts G-1, G-2 and G-3 open the connections between the stepping motor and the operation drive circuit. Contacts GA-1, GA-2 and GA-3 open the connections between the stepping motor and the automatic drive circuit.

Note that a safety rod cannot be selected during normal operation and so it cannot be released by this button.

3.4.5.3 RESET button to re-establish many relays in their self-holding state. Pressing the button energises the relays

R_1.....R_{10} whose contacts by-pass the self-holding contacts in many relay circuits. The reset button is in series with contacts MA-1 of the Auto-Manual selector, S3, and with contacts in bank 1 of the travel selector switch S2 in the limited pulse generator. The reset button is consequently ineffective unless the pre-set travel setting is OFF and the automatic rod setting is MANUAL.

3.4.5.4 MASTER KEY to obtain "OFF", "SHUTDOWN" or "OPERATION" conditions of the reactor. A three position, four bank switch is operated by a tumbler lock key, which can only be inserted or withdrawn in the OFF position. The contacts of banks 1, 2 and 3 are in the SCRAM and TRIP primary guard lines.

In the OFF position, both circuits are completely open-circuited and so all TRIP and SCRAM relays are de-energised. The twenty-four mechanisms move to the lower limit, closing their down limit switches. These in turn energise the twenty-four relays DL all with one pair of contacts in series with the OFF lamp, and the lamp lights.

In the SHUTDOWN key position, the TRIP primary guard line is open circuited but the trip contacts in the SCRAM primary guard line are shorted out leaving only the SCRAM signals operative. This results in the TRIP relays T1, T2, T3 and T4 opening for all mechanisms except the safety rods. The operation and automatic rods fall, the down limit switches close, relays DL are energised and the down limit lamps light for these mechanisms.

In the OPERATION key position, the switch contacts of banks 1, 2 and 3 complete both TRIP and SCRAM primary guard lines.

The master key bank 4 contacts form part of the interlock circuits discussed in Section 3.4.3 (see Bank 5 of that section) which establish the conditions under which the selector S1 is effective. In the SHUTDOWN position, a bank 4 contact energises relay W whose contact W-1 in series with DL-3 of all twenty-one of the released rods, lights the SHUTDOWN lamp.

3.4.6 Fine Position Indicator

These units receive signals from the transmitter synchros in the gearboxes of the control rod mechanisms and, by means of a position servo, display the gearbox (and hence the control rod) position on three numbered decimal drums marked in tenths, units and tens percent of total travel. 100% indicates a fully raised rod, and is equivalent to 3,205 motor pulses or 80.41 inches travel.

Coupled to the drums is a painted disc which moves behind a slot so that as the rod is raised orange replaces black from left to right.

Since 100% does not correspond to one revolution of the disc, running the drums through more than one cycle puts the disc out of phase with them. If this happens the indicator must simply be run back.

The outline and face of the indicator is shown in Fig. 18. The circuit, including the transmitter synchro is shown in Fig. 19. The transmitter and receiver synchro stators are directly connected. One of the pair of quadrature windings on the transmitter rotor is energised, the other being shorted. Any lack of parity in the rotor positions produces a signal in the receiver rotor which is fed to the phase-sensitive transistor amplifier and from there to the appropriate winding in the split phase motor M to give the direction of rotation to null the signal. A tachometer T coupled to the motor adds a negative feed-back signal to the rotor signal before amplification: this permits high gain and rapid response with stability. The motor drives the display through a gearbox.

Two cam operated switches MS1 and MS2 are arranged to open when the indicator moves into the last 20% of travel at the lower and upper ends respectively. These signals are used to warn the operator if the automatic rod moves out of the middle 60% of travel: he must then "trim" it back nearer to the centre. The contacts are by-passed by relay contacts MA-2, MA-3 if MANUAL operation is selected on the Auto-Manual switch. Otherwise they de-energise relays AD and AU which cause an acoustic alarm to sound and light lamps adjacent to the fine position indicator.

Three units are supplied, by Sperry Gyroscope Co., who designate it type D. Two of these will be installed on the control desk, as shown in Fig. 12, one connected to the automatic mechanism and one to the operation or safety rod currently selected by means of the selector switch S1. The third is a spare which can be fitted easily in place of either of the others by means of Plessey plugs at the back and the four face fixing screws. All the units are identical and are identically adjusted to zero by a screw on the back. They must not be re-adjusted independently. The relationship between the transmitter synchros and their mechanisms have been adjusted within the mechanisms as described in the maintenance manual, to suit the adjustment of the indicators as received from the supplier.

3.5 Equipment for Experiments

3.5.1 Rod Grouping Box

In this box are twenty-four manual toggle switches which make it possible to drop any number and any combination of rods from any combination of heights. The toggle switches each by-pass one set of normally closed relay contacts in the -30 volt supply line of each stepping motor, as shown in Fig. 2. The contacts are on two relays RG-1 and RG-2 which are energised when the RELEASE pushbutton, also in the box, is pressed, as shown in Fig. 3.

The box is located in the experiments room and has a lockable glass door.

3.5.2 Control Rod Drop Timing Unit

Fig. 20 shows the schematic arrangement. Clock pulses derived from mains frequency (accuracy 0.2%) are fed to two chains of scaler decade units. One of these measures the rod drop time and the other provides a delayed start signal to operate relay RLB, which starts an "experimental neutron counting equipment" (not included in this report).

The required delay is set on switches SWA and SWB to a value up to 9.9 seconds in 0.1 second increments. At the selected count a coincidence unit is operated through the switch contacts, in turn operating relay RLB.

Both scales are started simultaneously, their gates being opened by relay contacts RLA-1. Switch S can be positioned so that relay RLA is energised by either the RELEASE button on the control desk, which closes relay contacts G-5, Fig. 3, as explained in Section 3.4.5.2, or by the RELEASE button in the rod grouping box, described in Section 3.5.1, which closes relay contacts RG_x-1.

The rod drop timing scaler gate is closed when contacts RLA-1 opens as a result of the down limit relay contacts DL_1-4 or DLA_2, Fig. 3, opening. The delay scaler chain runs on until its gate is opened by the coincidence unit.

3.5.3 Fast Recorder

Provision is made to connect a fast recorder to receive the signal from the rotary pick-off of the mechanism currently selected. Referring to Fig. 2, relay contacts B-7 and B-8 connect the pick-off to the fast recorder lines, the relay being energised when the mechanism is selected, and the lines terminate in a plug located in panel 52 in the experiments room.

It is intended that periodic checks should be made on the functioning of the mechanisms by using the recorder. A suitable instrument used in experimental work on prototype mechanisms is a LUMISCRIPT ultra-violet light high speed recorder, type SE 2200.

3.5.4 Transfer Function Analyser (T.F.A.)

This unit is being designed and built under contract and it will eventually be described fully in its own operation and maintenance manual. It is described briefly here for convenience Fig. 21 is a block diagram and Fig. 22 is a circuit diagram of the connections to the absorber rod control circuit.

The T.F.A. consists of three parts, the control rod oscillator system, the measuring circuit and the power supplies. The power supplies are quite standard.

The rod oscillator system includes a motor with servo speed control driving a continuously running pulse generator. The unit also contains the ring circuit, pre-amplifier and amplifier to feed one of the standard stepping motors. For half a revolution of the generator the rod will run upwards, for the other half downwards, the reversal being effected by a switch which introduces a delay line and produces multiple pulses, as for the automatic driving circuit described in Section 3.2.2. It is clearly feasible to add further switches if required later to give periods of dwell. A circuit which divides the number of pulses will give various amplitudes of rod oscillation, and the motor speed will determine frequency.

Signals from the reactor flux meter will be modulated and then passed to the stator of a resolver synchro whose rotor is driven by the generator disc drive. The two output windings of the synchro will then give signals in phase and in quadrature with the control rod movement.

4. SUMMARY OF CONTROL OPERATIONS

This summary is in the form of the Table, Section 4.1. It should be possible, by referring back to earlier sections dealing with the electrical units involved to trace the circuit actions and the interlock circuits involved in each operation.

The sequence of operations in the Table is that most probable for an uneventful start-up, power run and complete shutdown. Normal conditions are assumed, i.e., no experiments involving special equipment or by-passes.

5. SAFETY ASPECTS OF THE SYSTEM

The following features are considered to contribute to safety:-

5.1 The limited pulse generator will always fail safe and cannot produce pulses for more than 12% rod travel.

5.2 No single operator action can cause upward (adding reactivity) movement of a rod greater than 12% travel.

5.3 Rods cannot be ganged to move upwards. They can only be ganged for experiments and then only to be dropped.

5.4 Only two drive circuits are available. The power of each is limited to be able to drive only one rod at a time. Only the automatic rod and one other rod can be moving at any time.

5.5 Rod driven speed is limited to 0.795 cm/sec in either direction for operation rods, the same speed upwards only for safety rods which cannot be driven down, and about 0.875 cm/sec in either direction for the auto rod. These speeds are limited by the pulse generator disc motors. If the stepping motor sequencing frequency were increased by a factor of more than three the mechanism would not be able to follow and the rod would drop.

5.6 The following order of priorities gives precedence to actions suppressing greater reactivity:-

(i) Release twenty-four rods with SCRAM condition.

TABLE 4.1

TABLE OF CONTROL OPERATIONS

	Required Function	Control Settings to Select	Control Settings to Avoid Inhibition	State of Mechanisms to Avoid Inhibitions	Initiating Action	Display Changes: Before Action	Display Changes: During Action	Display Changes: At Completion of Action	Remarks
1.	Condition SHUTDOWN	Master key to SHUTDOWN	-	-	Turn key	Annunciator OFF or OPERATION	-	Annunciator SHUTDOWN	-
2.	Reset	-	S.3 at MANUAL L.P.G. at OFF	-	Press re-set button	"Auto control cut off" lamp lit "Auto control set-back" lamp lit Release lamp lit	-	Annunciator SHUTDOWN off Release lamp off	
3.	Select safety rod	Selector S.1	Master key SHUTDOWN	-	Set S.1	-	-	-	-
4.	Raise safety rod	-	L.P.G. set for travel	-	C.L. (control lever) to raise and then release it	Down limit lamp lit Raise lamp off	Down limit lamp off "Safety rods up" lamp lights CPI and FPI move Raise lamp alight	Down limit lamp off "Safety rods up" lamp alight Raise lamp off	Both lamps "Safety rod up" and "down" are lit unless all rods are at one limit
5.	Stop safety rod manually	-	-	-	Press C.L. inwards	Raise lamp lit	-	Raise lamp off	
6.	Rod stopped by pulse counter	-	-	-	Preset number of pulses counted	Raise lamp lit	-	Raise lamp off	
7.	Rod stopped by L.P.G. limit switches	-	-	-	L.P.G. mechanism reaches limit switches	Raise lamp lit L.P.G. warning lamp off	-	Raise lamp off L.P.G. warning lamp lights	
8.	Release safety rod	Selector S.1	-	-	Press release button	Release lamp off Down limit lamp off	-	Release lamp lit Down limit lamp lit	Reset as function 2
9.	Raise safety rod to up limit	Selector S.1	L.P.G. set for travel	-	C.L. to raise and action repeated sufficiently to reach limit of travel	Up limit switch off	- Raise lamp lit	Up limit switch lit Raise lamp off	Limit switch stops system
10.	Condition OPERATION	Master key to OPERATION	-	All safety rods fully up	Turn key	Annunciator SHUTDOWN	-	Annunciator OPERATION	
11.	Select operation rod	Selector S.1	Master key at OPERATION	All safety rods up	Set S.1	-	-	-	
12.	Raise operation rod by pre-set travel	-	L.P.G. set for travel	-	C.L. to raise and then release it	Down limit lamp lit	Down limit lamp off "Raise" lamp on CPI and FPI move	Down limit lamp off	
13.	Lower operation rod by pre-set travel	-	L.P.G. set for travel	-	C.L. to lower and then release it	-	"Lower" lamp on CPI and FPI move	-	
14.	Move operation rod by INCHING	-	L.P.G. set to INCH	-	C.L. raised or lowered and held	-	Raise or lower lamp on CPI and FPI move	-	Rod stops when C.L. released

TABLE 4.1 (Contd.)

Required Function	Control Settings to Select	Control Settings to Avoid Inhibitions	State of Mechanisms to Avoid Inhibitions	Initiating Action	Display Changes: Before Action	Display Changes: During Action	Display Changes: At Completion of Action	Remarks
15. Stop operation rod								As for safety rods
16. Move rod to limit of travel	-	L.P.G. set to travel or INCH	-	C.L. operated a sufficient number of times for rod to reach limit of travel	Limit lamp off		Limit lamp lit	Limit switch stops system
17. Assume manual control of auto rod	S.3 to MANUAL	-	-	-	-	-	-	
18. Raise or lower auto rod manually	Selector S.1 L.P.G. set for travel	S.3 to MANUAL	All safety rods up	Control lever up or down	Limit lamps may be lit	Raise or lower lamp lights	Limit lamps may be lit	Note that warning switches 20% from limit of travel are ineffective
19. Apply automatic control	S.3 to AUTO	-	-	-	-	-	-	-
20. Release auto rod	Select on S.1	-	-	Press release button	Release lamp off Probably limit lamps off		Release lamp lit Down limit lamp lit	If S.3 at MANUAL
							Release lamp lit Down limit lamp lit "Auto control cut-off" lamp lit Down limit approach lamp lit, annunciator lit and acoustical warning sounded	If S.3 at AUTO
21.				Auto rod reaches 20% from end of travel	Limit approach lamp off Annunciator and acoustical warning off		Limit approach lamp lit Annunciator lights and warning sounds until stopped	Operator will trim auto rod to middle range of travel by selecting and moving an operation rod
22. Manual SCRAM	-	-	-	Press SCRAM button			All down limit lamps lit OFF lamp lit SCRAM on annunciator FPI and CPI's show rods down	All twenty-four rods drop
23. Automatic SCRAM	-	-	-	Signal from secondary scram guard line	As for function 22	As for function 22	As for function 22	
24. Trip	-	-	-	Signal from secondary trip guard line			All down limit lamps lit OFF lamp lit TRIP on annunciator FPI and CPI's show rods down	
25. Condition OFF	Master key to OFF	-	-	Turn key		FPI and CPI's move down.	OFF lamp lit SCRAM annunciator lit	

(ii) Release twenty-four rods with TRIP condition.

(iii) Release selected rod.

(iv) Stop selected rod.

(v) Raise or lower selected rod (equal).

5.7 The automatic rod can be taken under manual control and/or rendered inoperative under any conditions. It is always overridden by the safety circuit but to avoid trips as far as possible some fault signals will produce one of two responses in the automatic circuit, viz:-

(a) "Automatic control cut-off" in which the rod remains stationary, and

(b) "Automatic control set-back" in which the automatic rod is driven in at constant speed.

These reactions are considered more fully in D.P. Report 174.

5.8 Some interlocks from other parts of the reactor plant, such as the charge machine, render the "Raise" control inoperative.

6. ILLUSTRATIONS

Many of the illustrations are reduced copies of the original drawings and circuit diagrams. If a detailed study is attempted prints from the originals are available from Dragon Project.

7. ASSOCIATED LITERATURE

7.1 D.P. Report 145, "Design Principles for Control Mechanisms."

7.2 Maintenance and Repair Manual for Control Mechanisms, FIAT, Turin.

7.3 D.P. Report 174. "Reactor Automatic Control."

7.4 Dragon Site Test Specification DSTS 26/2. "Commissioning Test Schedule for Absorber Rods Control Circuit."

7.5 Dragon Project Specification 77 for "Absorber Rods Control Circuit."

7.6 Dragon Project Specification 21 for "Type 2 Vernier Motor."

7.7 Dragon Project Specification 120 for "Transistorised Equipment."

7.8 Dragon Project Specification 123 for "Limited Pulse Generator."

7.9 Dragon Project Specification 124 for "Control Rod Drop Timing Unit."

7.10 Manual for "Transfer Function Analyser," (to be prepared).

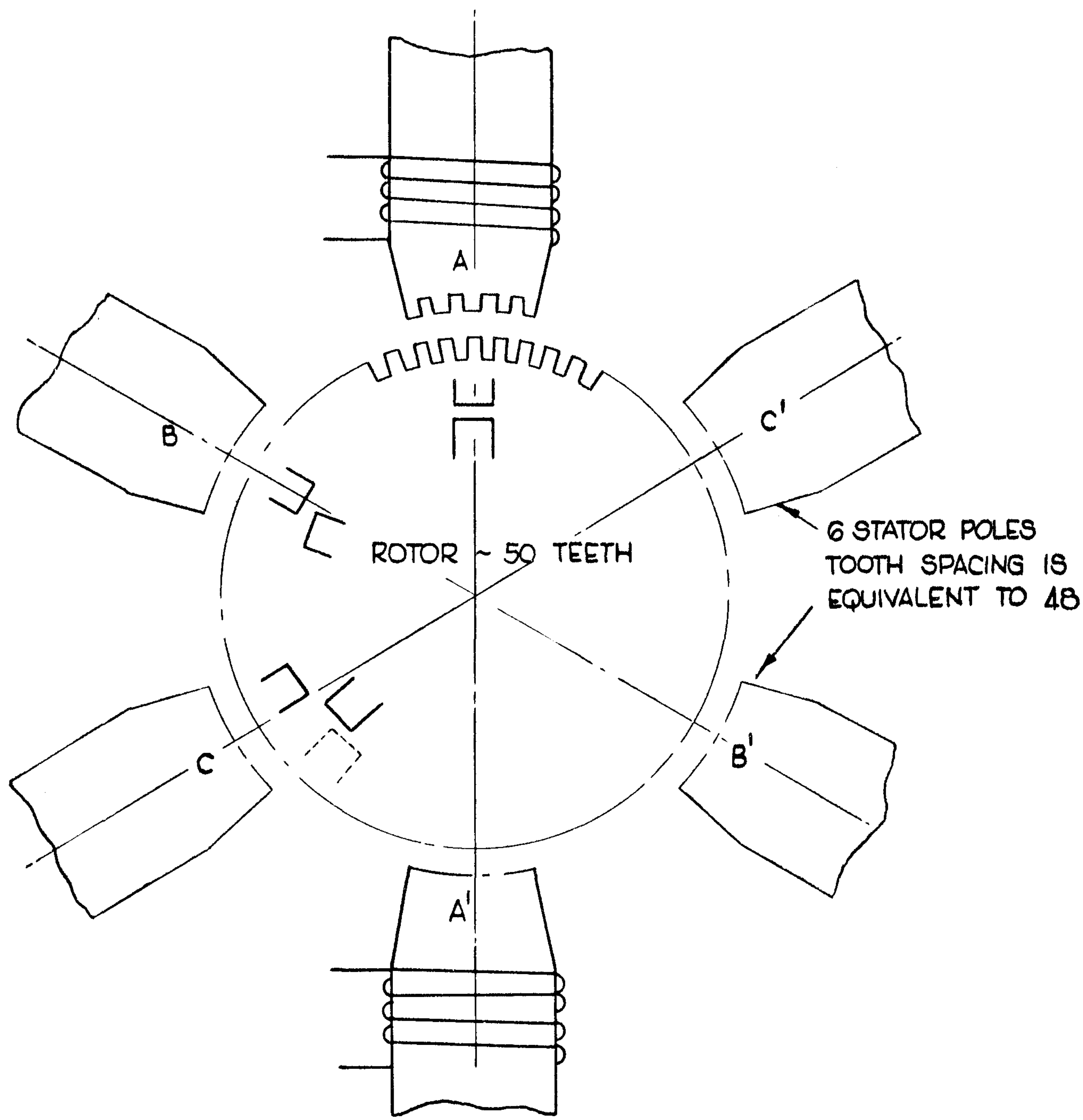
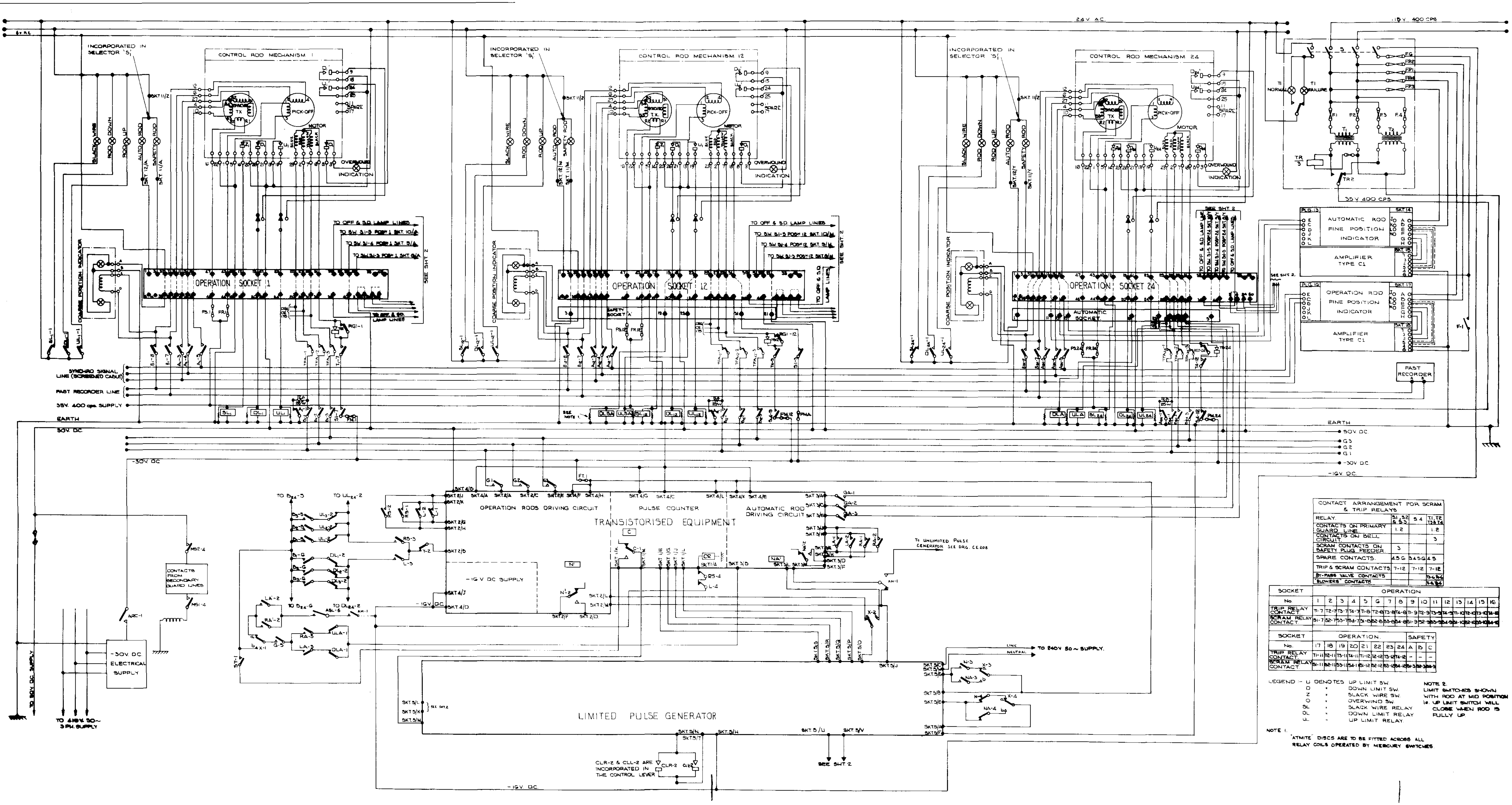


FIG. 1

STEPPING MOTOR - SCHEMATIC.



CONTACT ARRANGEMENT FOR SCRAM & TRIP RELAYS			
RELAY.	S1, S2 & S3	S.4	T1, T2 T3 & T4
CONTACTS ON PRIMARY GUARD LINE.	1.2		1.2
CONTACTS ON BELL CIRCUIT.			3
SCRAM CONTACTS ON SAFETY PLUG FEEDER.	3		
SPARE CONTACTS.	4.5.6	3.4.5.6	4.5.
TRIP & SCRAM CONTACTS	7-12	7-12	7-12
BY-PASS VALVE CONTACTS			T3-6 T4-6
"BLOWERS" CONTACTS			T1-6 T2-6

SOCKET	OPERATION															
No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TRIP RELAY CONTACT.	T1-7	T2-7	T3-7	T4-7	T1-8	T2-8	T3-8	T4-8	T1-9	T2-9	T3-9	T4-9	T1-10	T2-10	T3-10	T4-10
SCRAM RELAY CONTACT.	S1-7	S2-7	S3-7	S4-7	S1-8	S2-8	S3-8	S4-8	S1-9	S2-9	S3-9	S4-9	S1-10	S2-10	S3-10	S4-10

SOCKET	OPERATION.								SAFETY		
No.	17	18	19	20	21	22	23	24	A	B	C
TRIP RELAY CONTACT.	T1-11	T2-11	T3-11	T4-11	T1-12	T2-12	T3-12	T4-12	–	–	–
SCRAM RELAY CONTACT.	S1-11	S2-11	S3-11	S4-11	S1-12	S2-12	S3-12	S4-12	S1-3	S2-3	S3-3

LEGEND :- U DENOTES UP LIMIT SW.
D " DOWN LIMIT SW.
Z " SLACK WIRE SW.
O " OVERWIND SW.
SL " SLACK WIRE RELAY
DL " DOWN LIMIT RELAY
UL " UP LIMIT RELAY.

NOTE 2.
LIMIT SWITCHES SHOWN WITH ROD AT MID POSITION i.e. UP LIMIT SWITCH WILL CLOSE WHEN ROD IS FULLY UP.

NOTE 1.
'ATMITE' DISCS ARE TO BE FITTED ACROSS ALL RELAY COILS OPERATED BY MERCURY SWITCHES.

Fig. 2 SCHEMATIC DIAGRAM FOR ABSORBER RODS CONTROL CIRCUIT - DRG. NO. C112/001 SHT. 1.

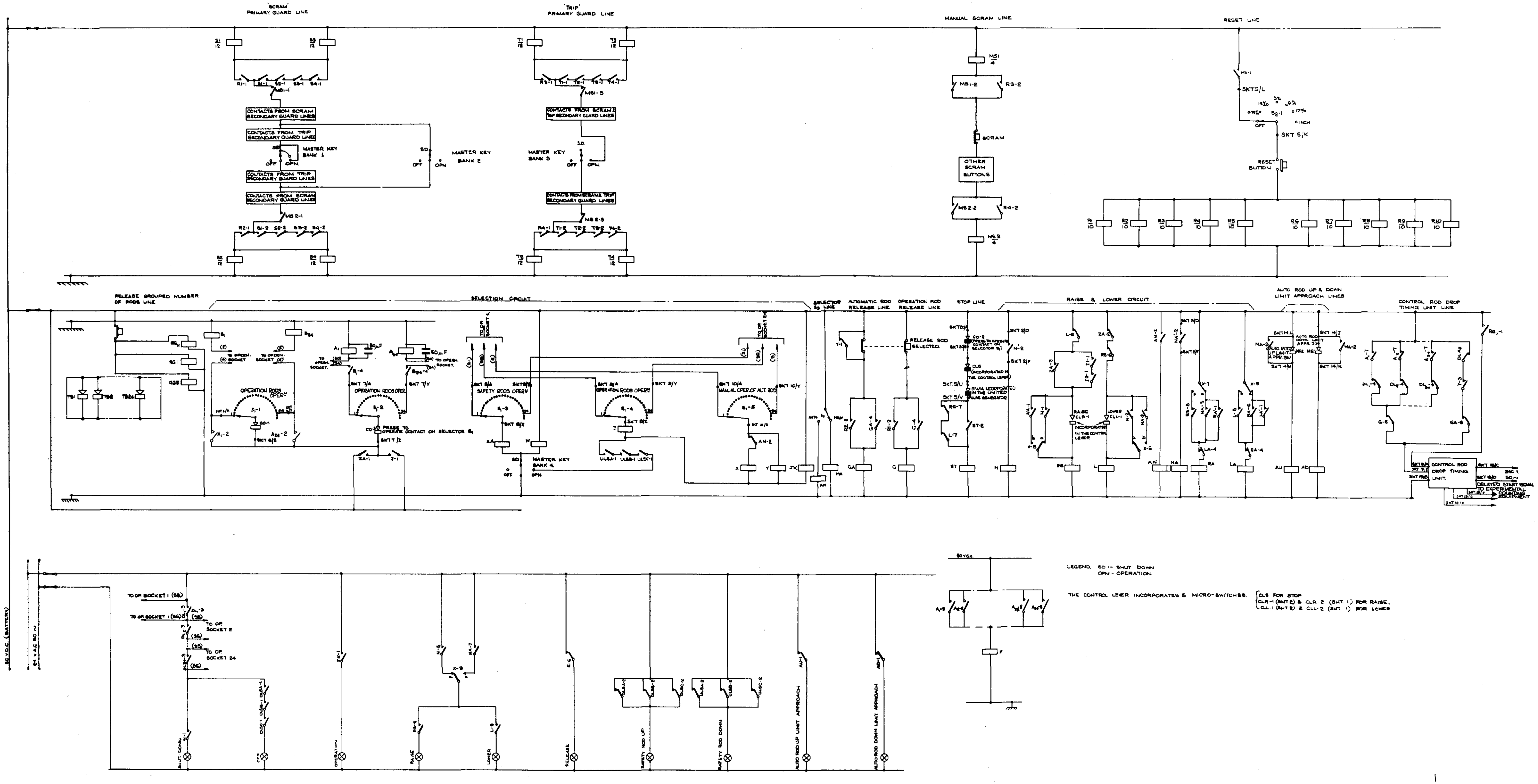


Fig. 3 SCHEMATIC DIAGRAM FOR ABSORBER RODS CONTROL CIRCUIT - DRG. NO. C112/001 SHT. 2.

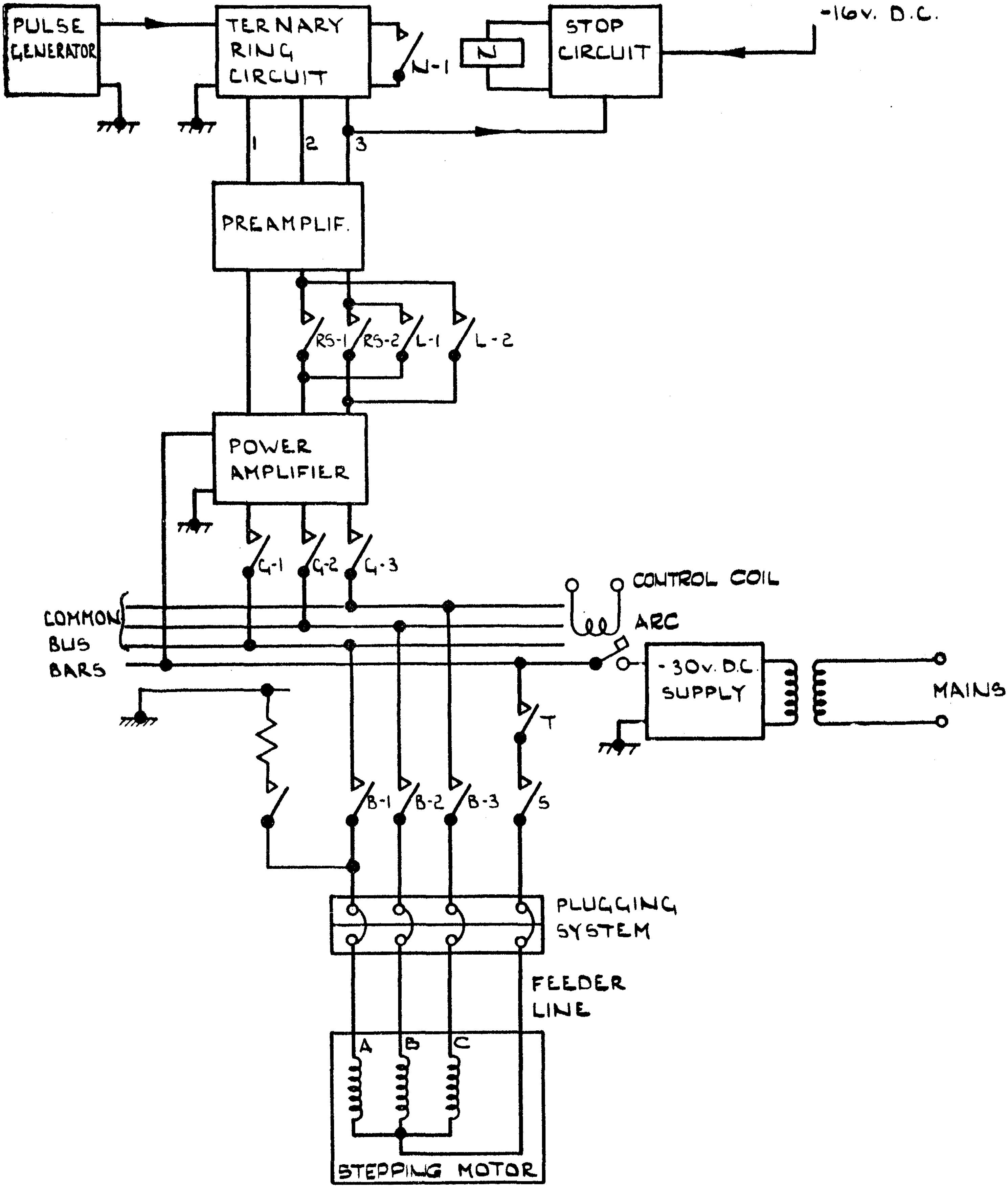


FIG. 4 DRIVING CIRCUIT - SCHEMATIC

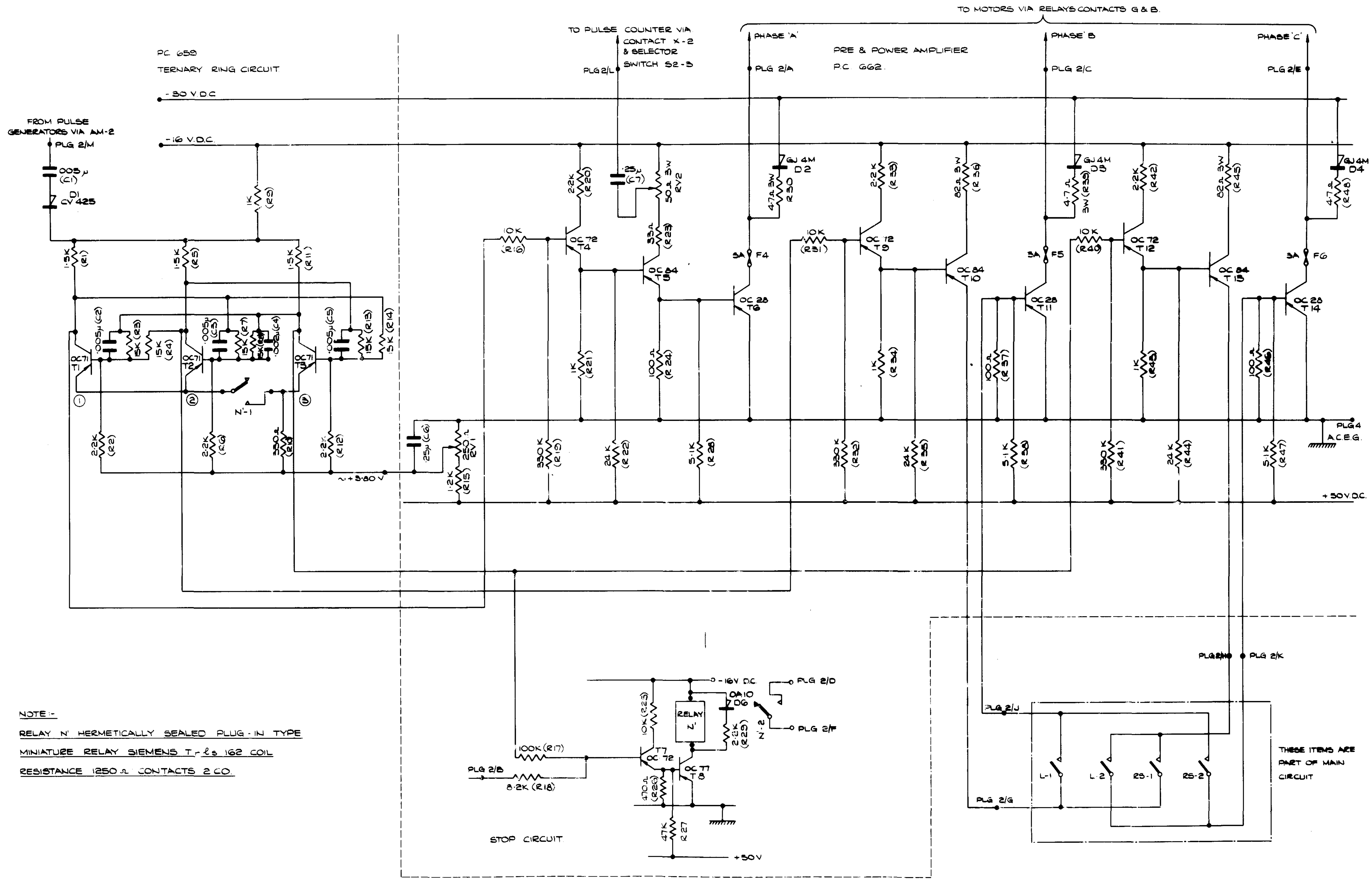
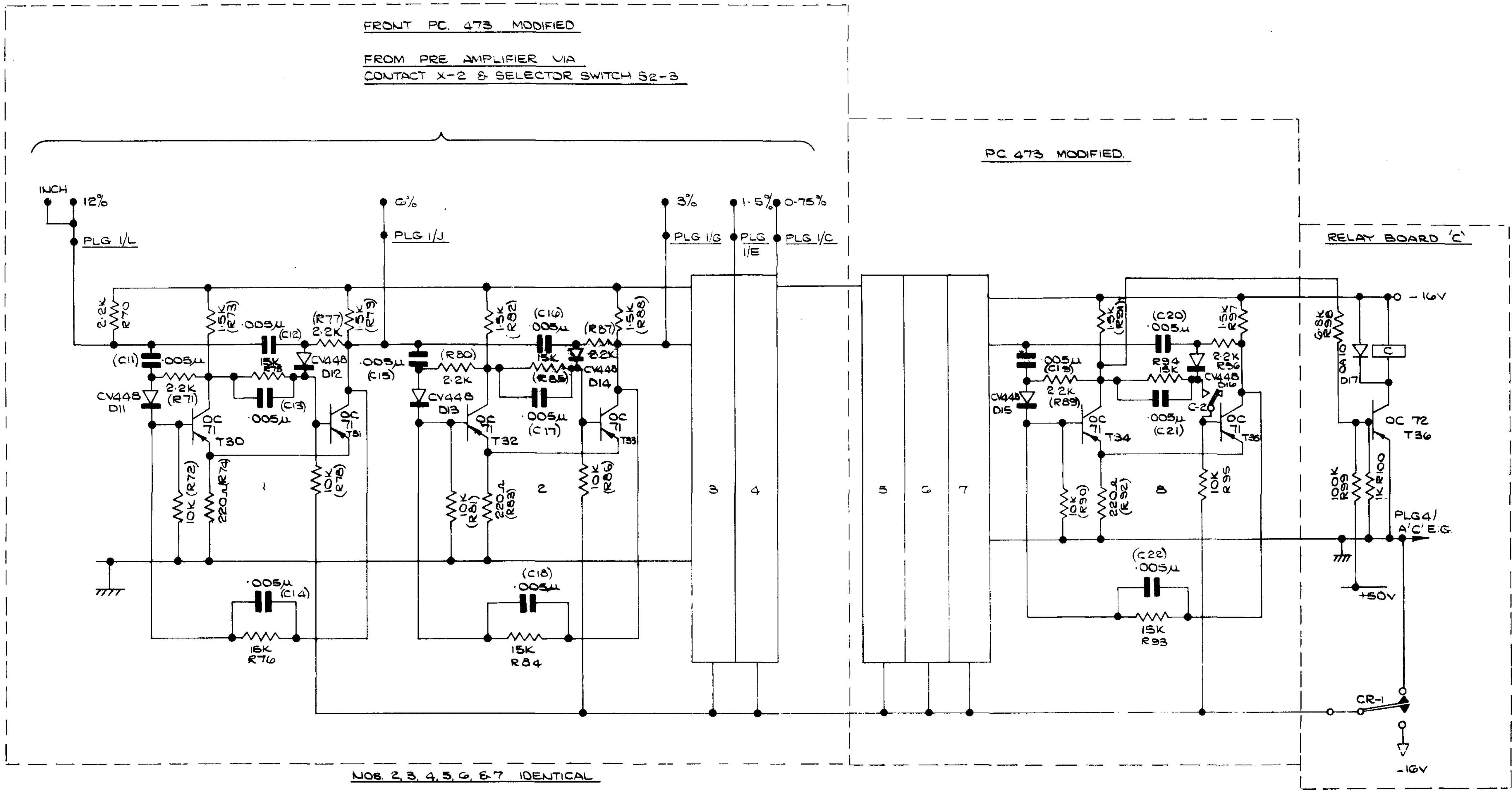


Fig. 5 TRANSISTORISED EQUIPMENT OPERATION RODS DRIVING CIRCUIT - DRG. NO. C114/101/CD36479.



NOTE:

RELAYS C AND CR HERMETICALLY SEALED PLUG-IN TYPE MINIATURE RELAYS

SIEMENS TRS 162 COIL RESISTANCE 1250 Ω 2 CO. CONTACTS.

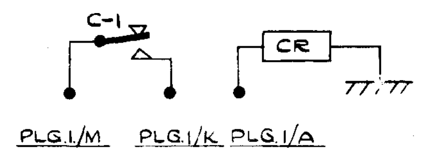


Fig. 6 TRANSISTORISED EQUIPMENT PULSE COUNTER - DRG. NO. C114/101/CD36481.

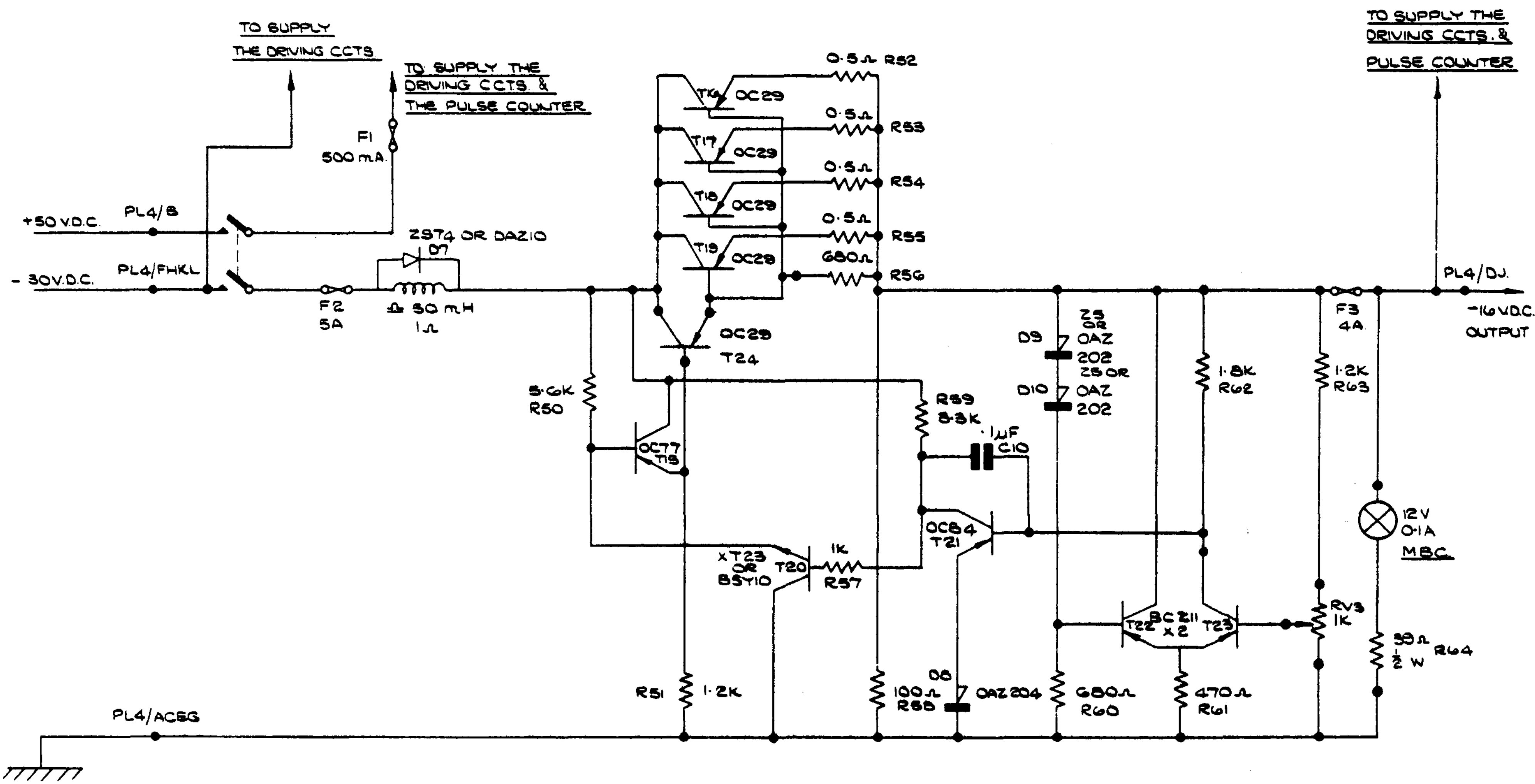


FIG. 7 TRANSISTORISED EQUIPMENT - 16 V.D.C. ELECTRICAL SUPPLY - C114/101/BD36482

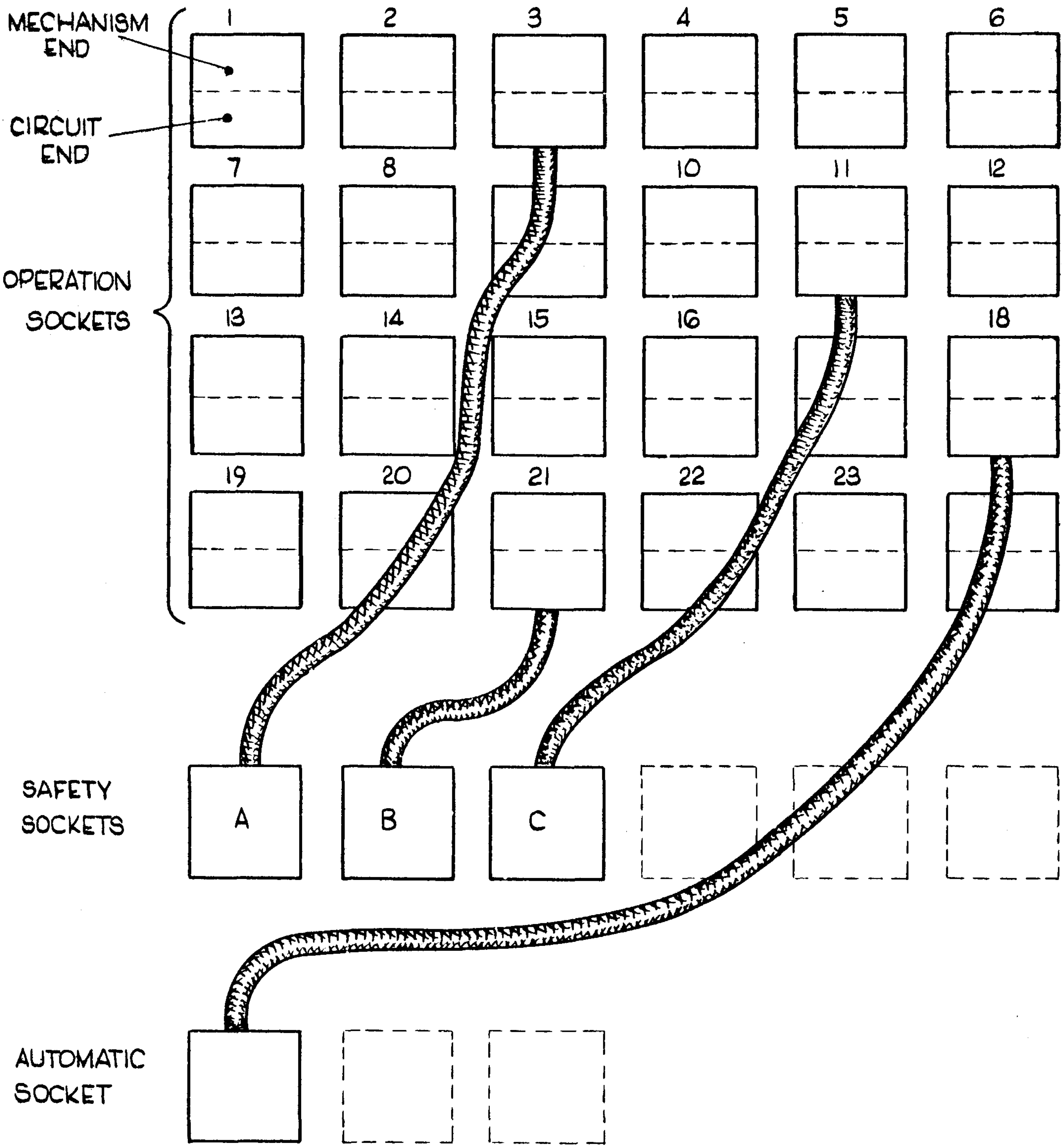


FIG. 8 CONNECTING BOX – SCHEMATIC.

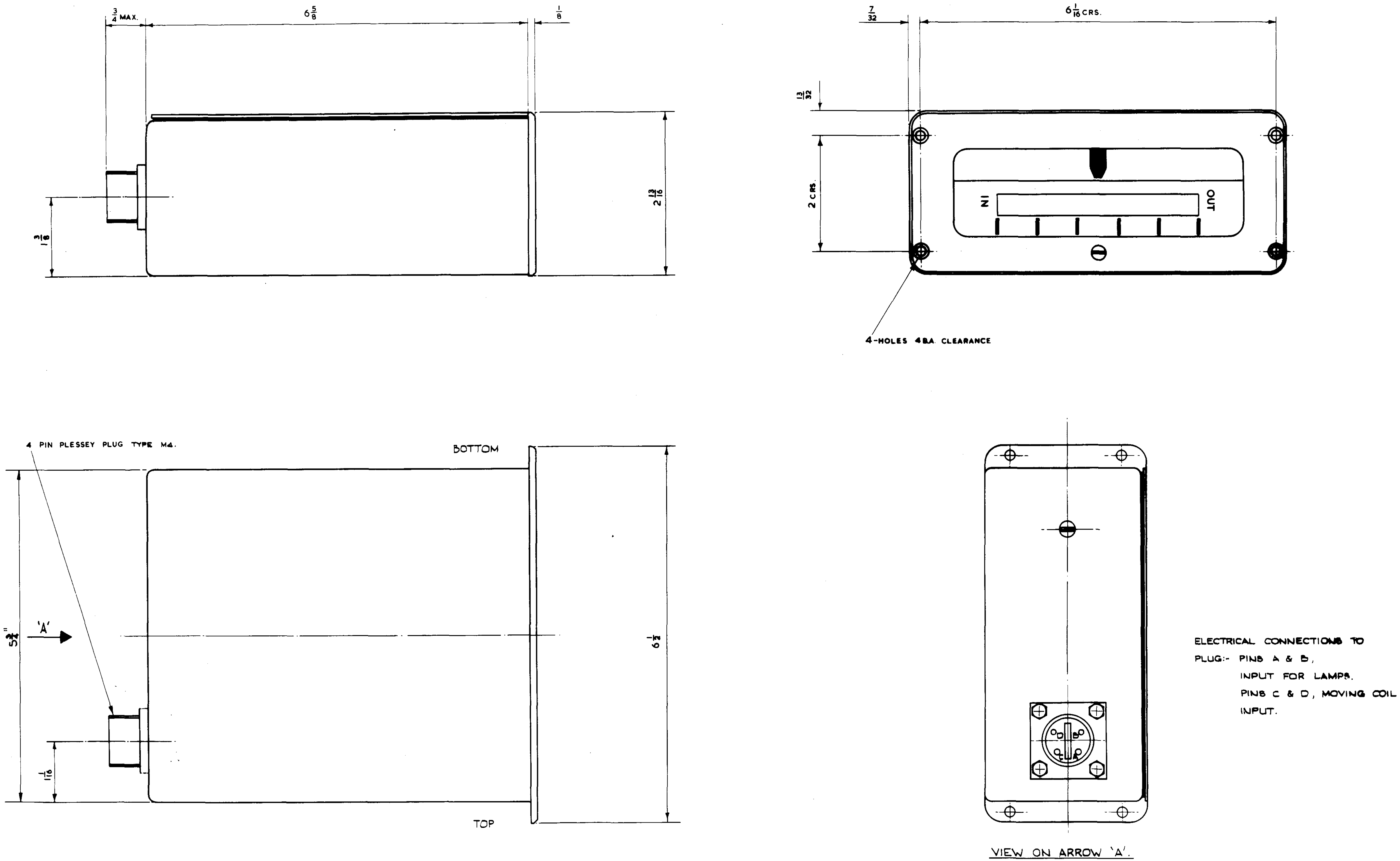
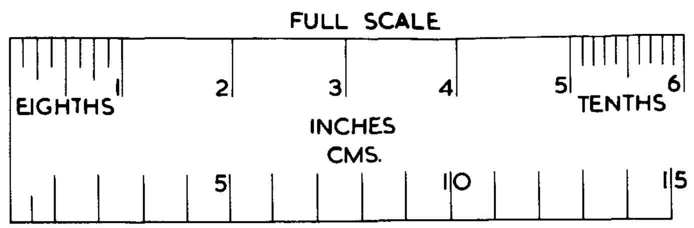
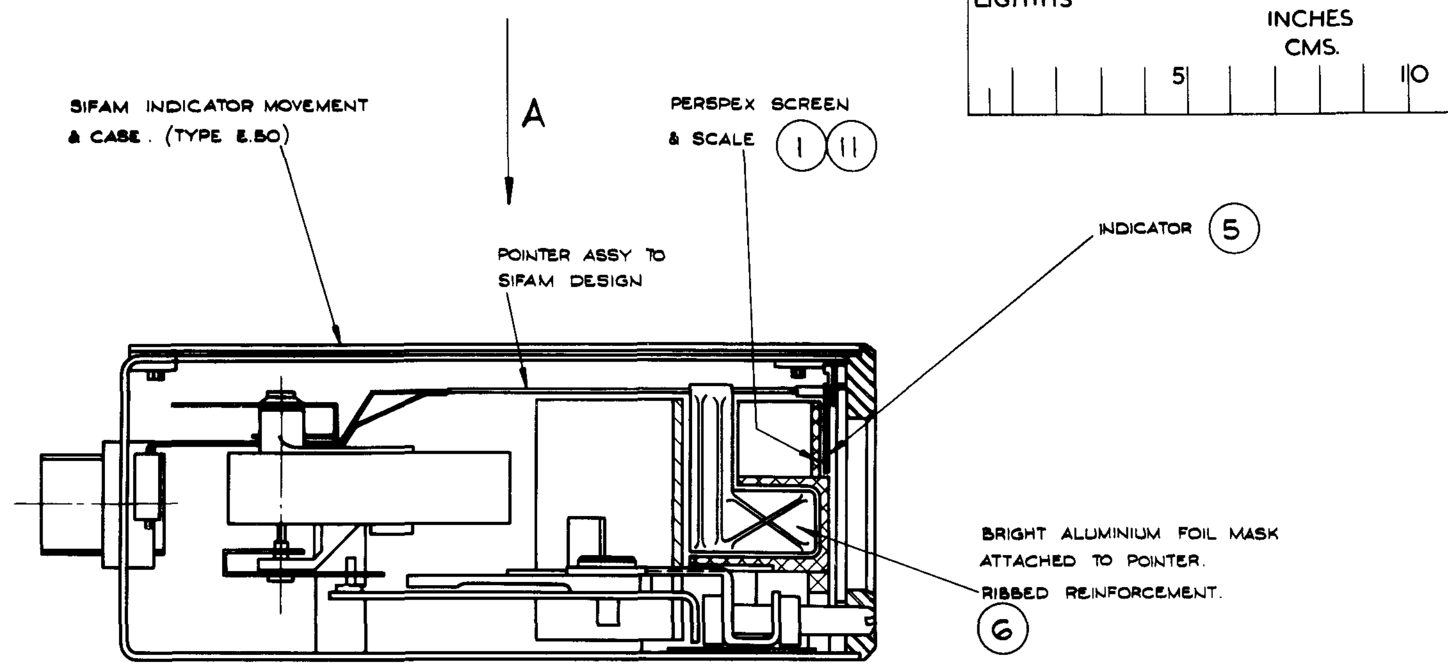
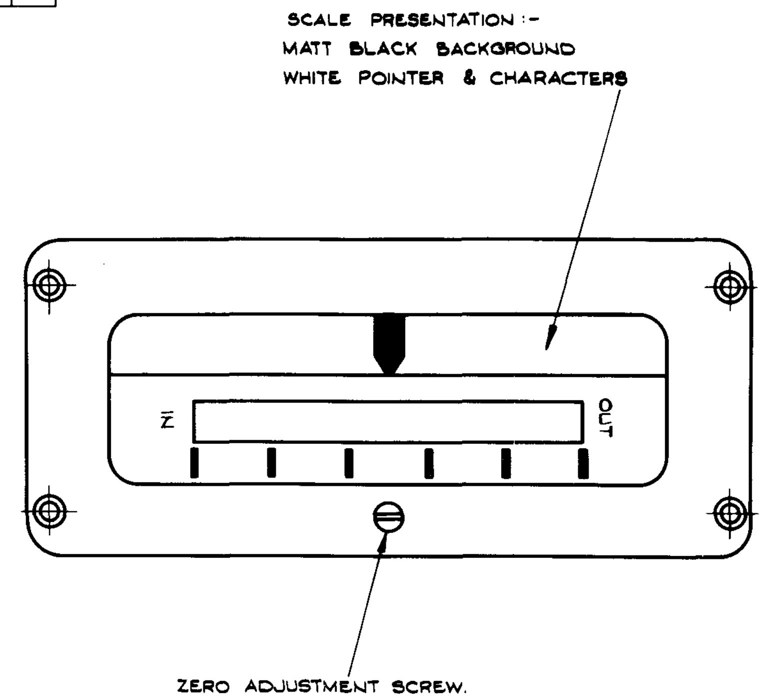
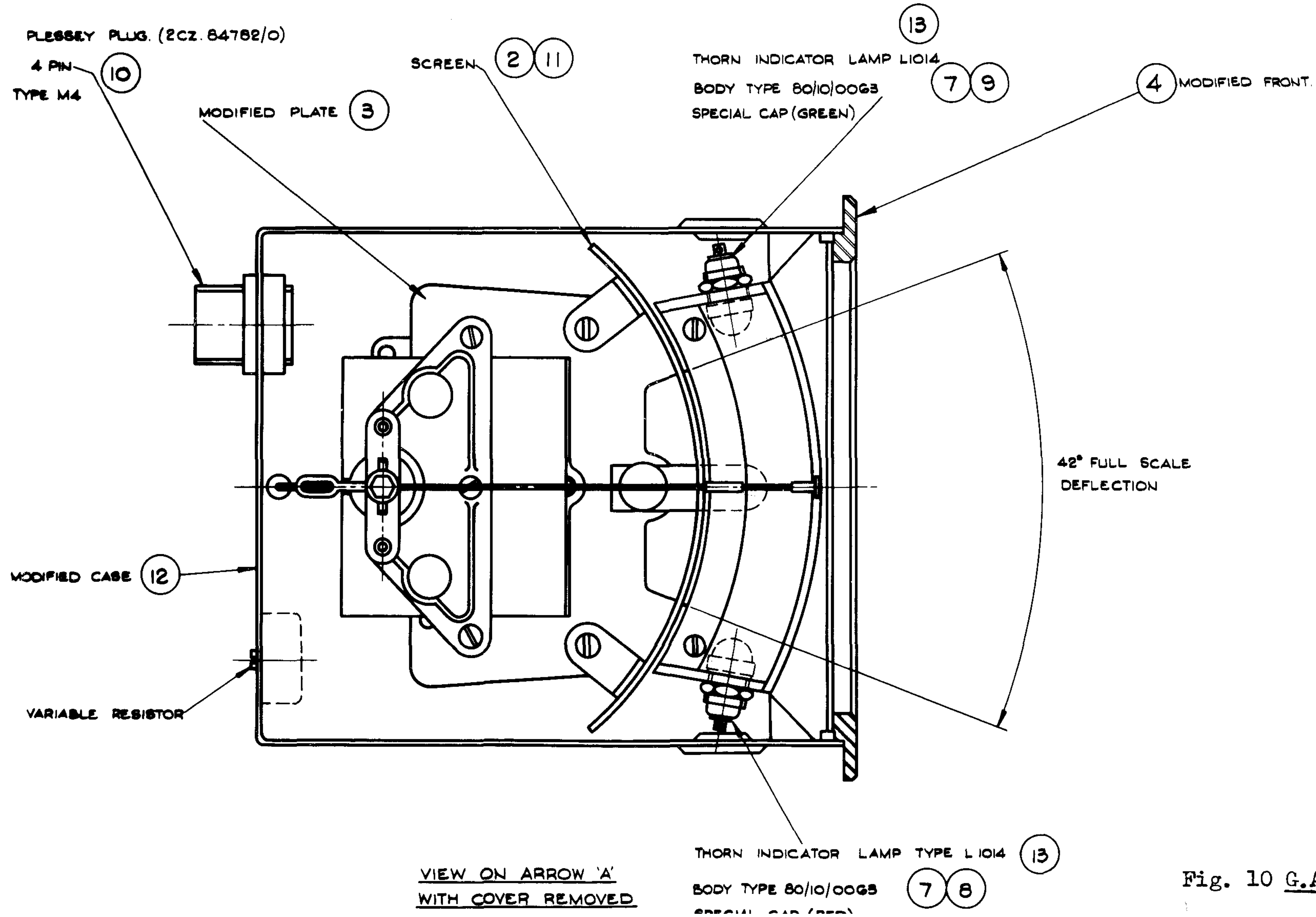


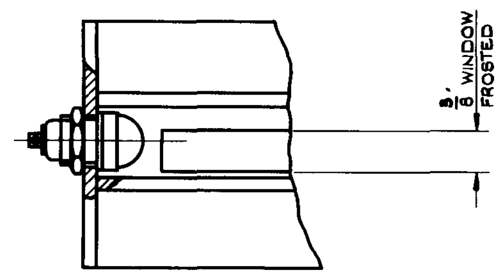
Fig. 9 COARSE POSITION INDICATOR - OUTLINE DRAWING - DRG. NO. C112/002/CD33812.









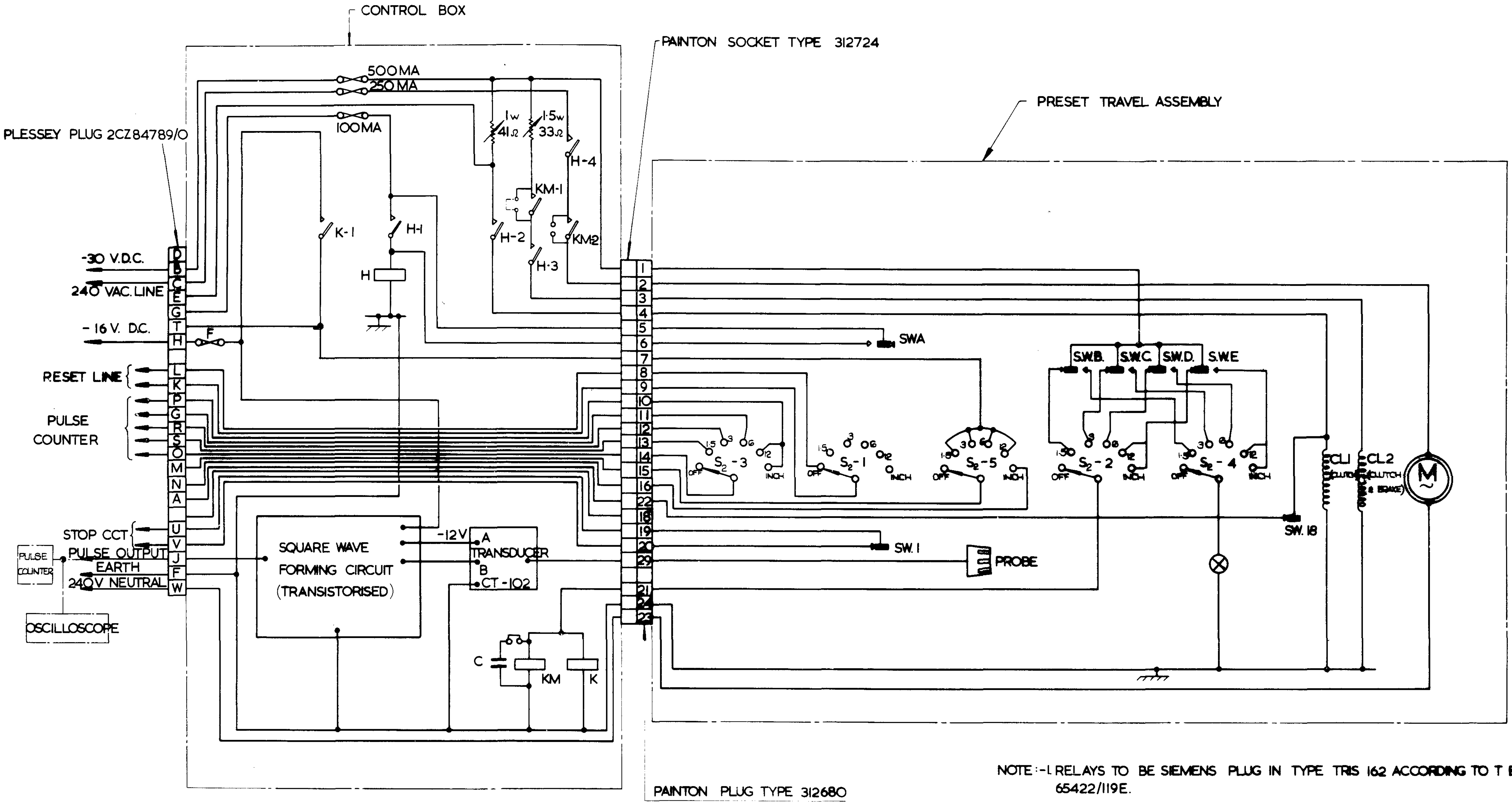


ITEM Nº	DRG Nº	NAME	Nº OFF
1	DD 33821	SCALE	1
2	CD 33822	SCREEN	1
3	BD 33823	MODIFIED PLATE	1
4	AD 33824	MODIFIED FRONT	1
5	AD 33825	INDICATOR	1
6	AD 33826	MASK	1
7		THORN INDICATOR LAMP BODY TYPE 80/10/0063	2
8		SPECIAL CAP (RED)	1
9		" " (GREEN)	1
10		PLESSEY PLUG 4 PIN TYPE M4	1
11		SCREWS 4BA x ¼" LG. ST., CH HD	4
12	CD 33829	MODIFIED CASE	1
13		THORNS 6 VOLT LAMP TYPE L1014	2
	SIFAM DRGS.		
	A 2956	Nº 2 BOBBIN	
	A 3185	DIAL PLATE END BLOCKS	
	C 3093	1/32" RUBBER GASKET	
	C 2867	CASE COVER PLATE	
	D 2969	CASE FLUSH MOUNTING	
	D 2959	MOVEMENT ASSY	
	A 2334	ZERO ADJUSTMENT PIN	
	A 2964	" " BRACKET	
	A 2487	GLASS CLIP	
	A 2882	" " SPACING COLLAR	
	B 1484	GLASS	
	A 2856	INSULATING BUSH	
	A 2336	ZERO AJT. INSULATED PIN	
	A 2968	" " ARM	
	A 2973	" " COLLAR	
	A 3911	" " SHAFT INS PATT ASSY	
	A 3054	INSULATING PAD	

NOTES

1. LAMPS & MOVING COIL TO BE WIRED UP TO PLESSEY PLUG. PINS A & B TO LAMPS PINS C & D TO MOVING COIL. CONNECTIONS CONSISTENT FOR ALL UNITS.
2. ITEMS 8 & 9 'SPECIAL CAP' MADE TO ORDER BY THORN ELECTRICAL INDUSTRIES LTD. SIMILAR TO 80/10/0070 & 0069 BUT WITH THIN SMOOTH FACED GLASS CAPS
3. POINTER, END STOPS :- TO COINCIDE WITH MAX. 'OUT' INDICATION (ON SCALE) & ALLOW MAX POINTER MOVEMENT OFF SCALE AT 'IN' END WITHOUT FLAG FOULING LAMP CAP.
4. LAMP SUPPLY :- 6 VOLTS A.C. ·2 AMP EACH LAMP

Fig. 10 G.A. OF COARSE POSITION INDICATOR - DRG. NO. C113/101.



NOTE:- 1. RELAYS TO BE SIEMENS PLUG IN TYPE TRIS 162 ACCORDING TO T BV 65422/119E.

2. ITEMS SHOWN THUS ⌐⌐ ARE TERMINAL BLOCK CONNECTIONS

3. THE VALUE OF CAPACITOR C SHOULD BE CHOSEN TO GIVE A DELAY TIME OF ·2 SECONDS

4. THE VALUE OF FUSE F SHOULD BE CHOSEN TO SUIT THE REQUIREMENTS OF THE TRANSDUCER AND SQUARE WAVE CIRCUIT

Fig. 12 SCHEMATIC CIRCUIT FOR LIMITED PULSE GENERATOR - DRG. NO. C115/109.

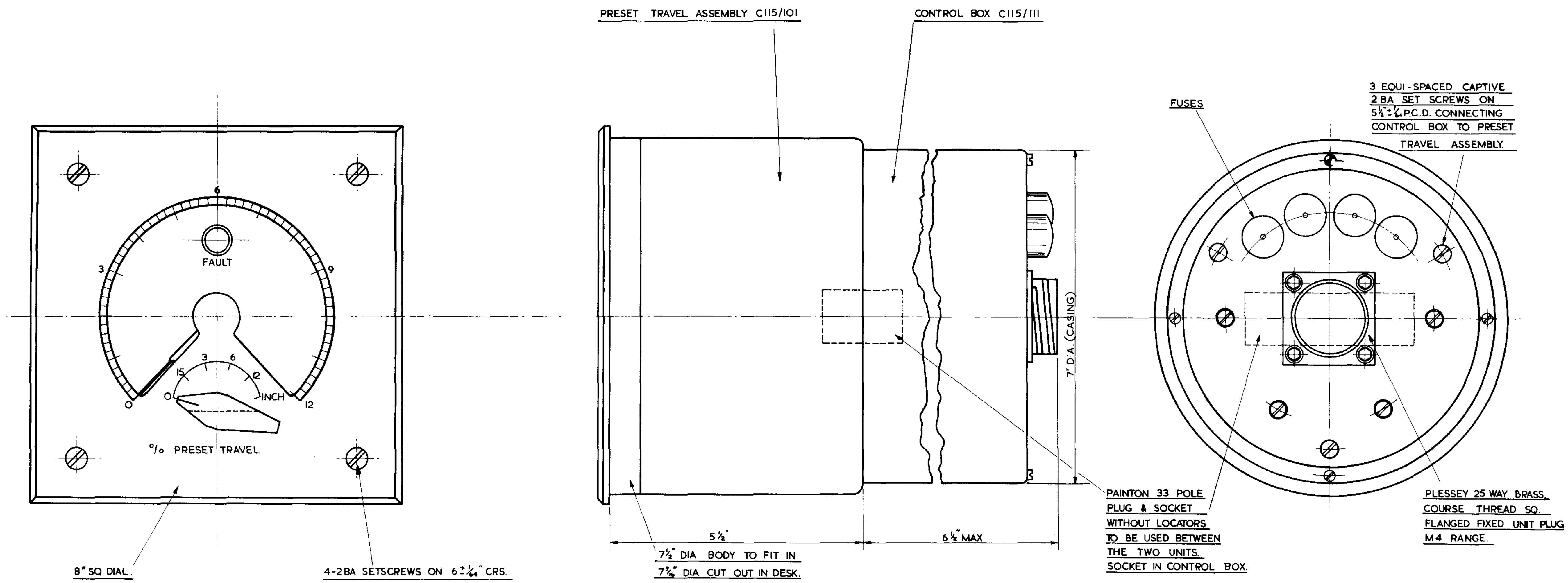


Fig. 13 LIMITED PULSE GENERATOR (OUTLINE) - DRG. NO. C115/110.

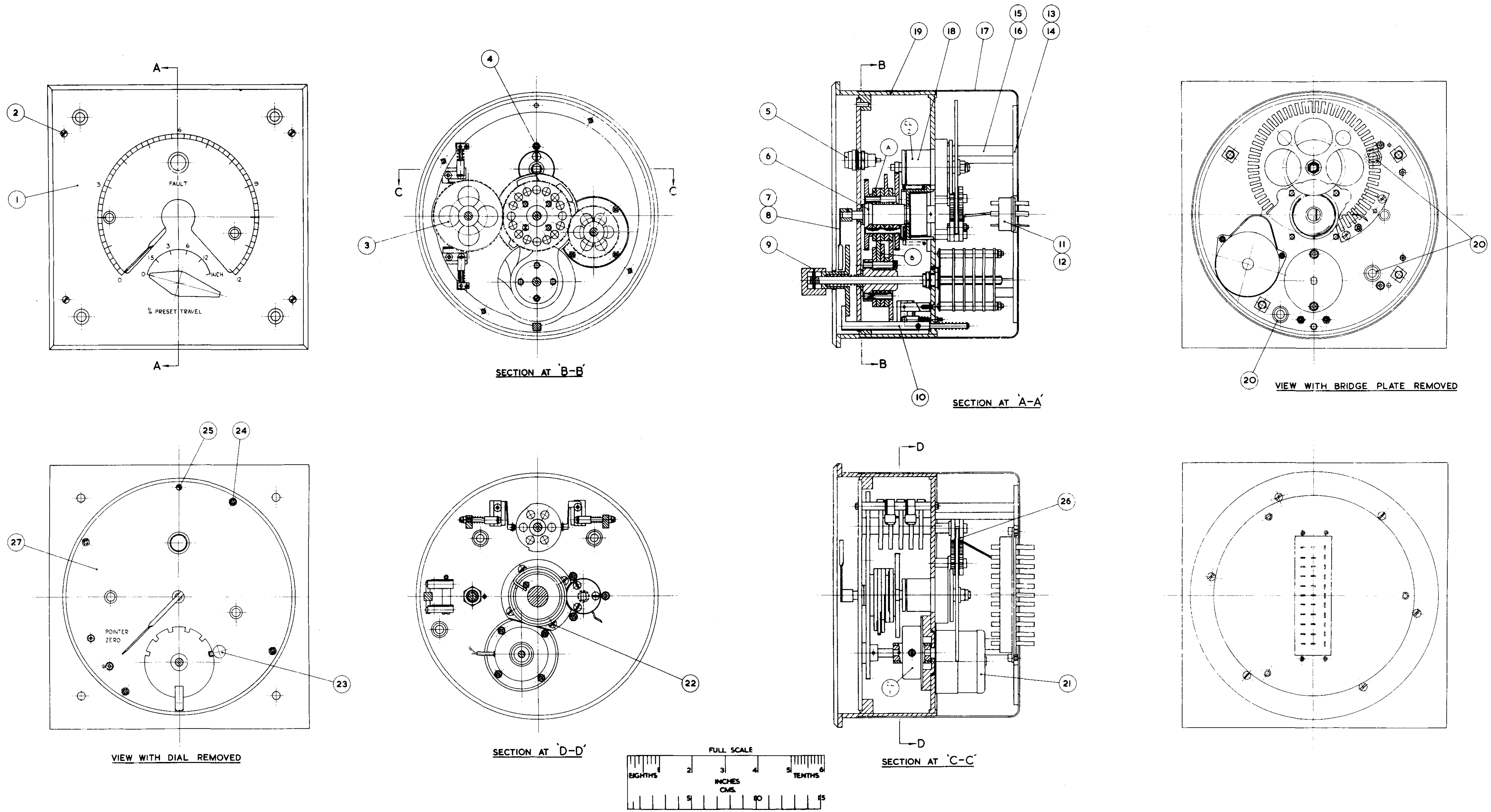


Fig. 14 LIMITED PULSE GENERATOR PRESET TRAVEL ASSEMBLY - DRG. NO. C115/101.

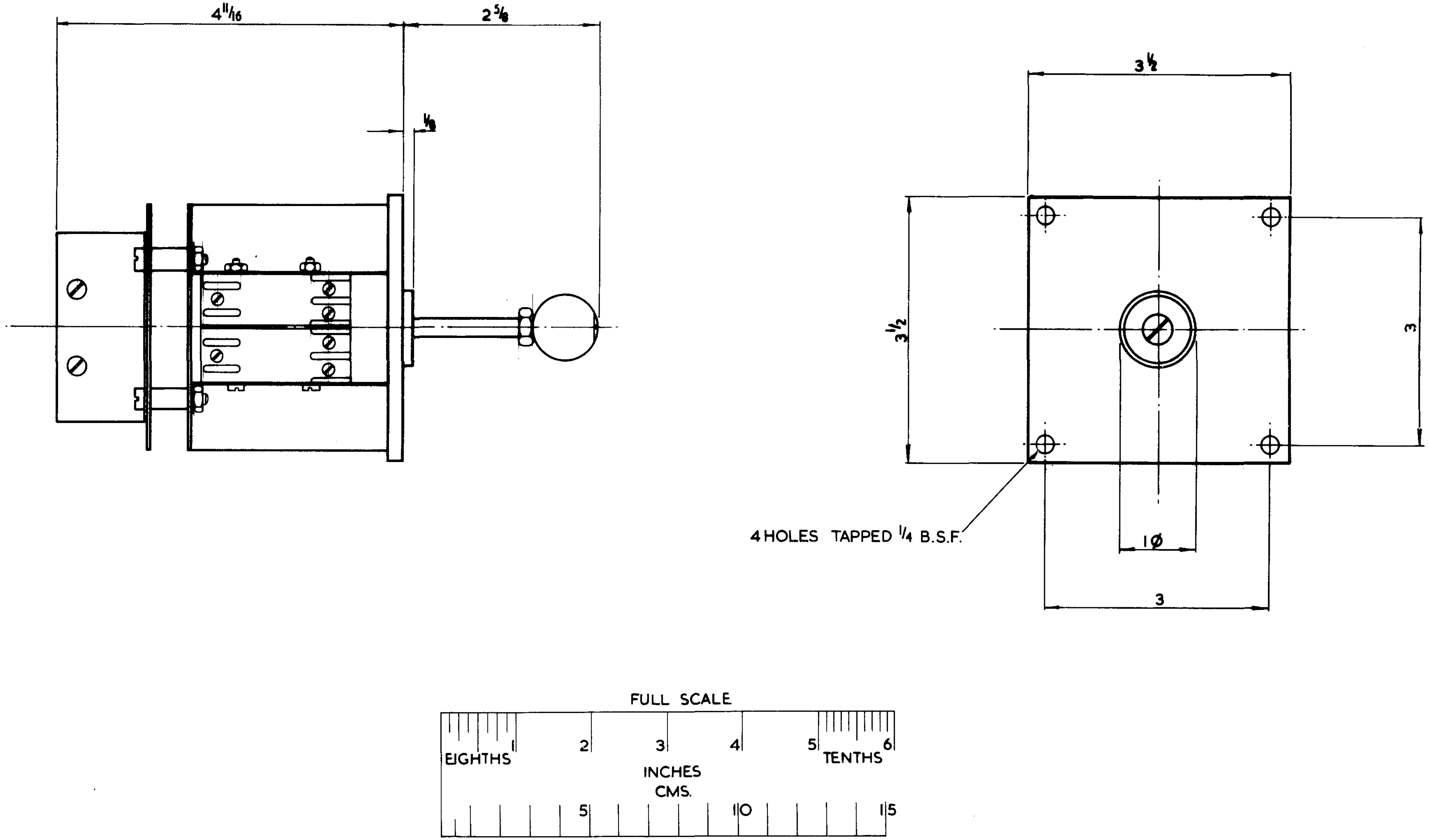
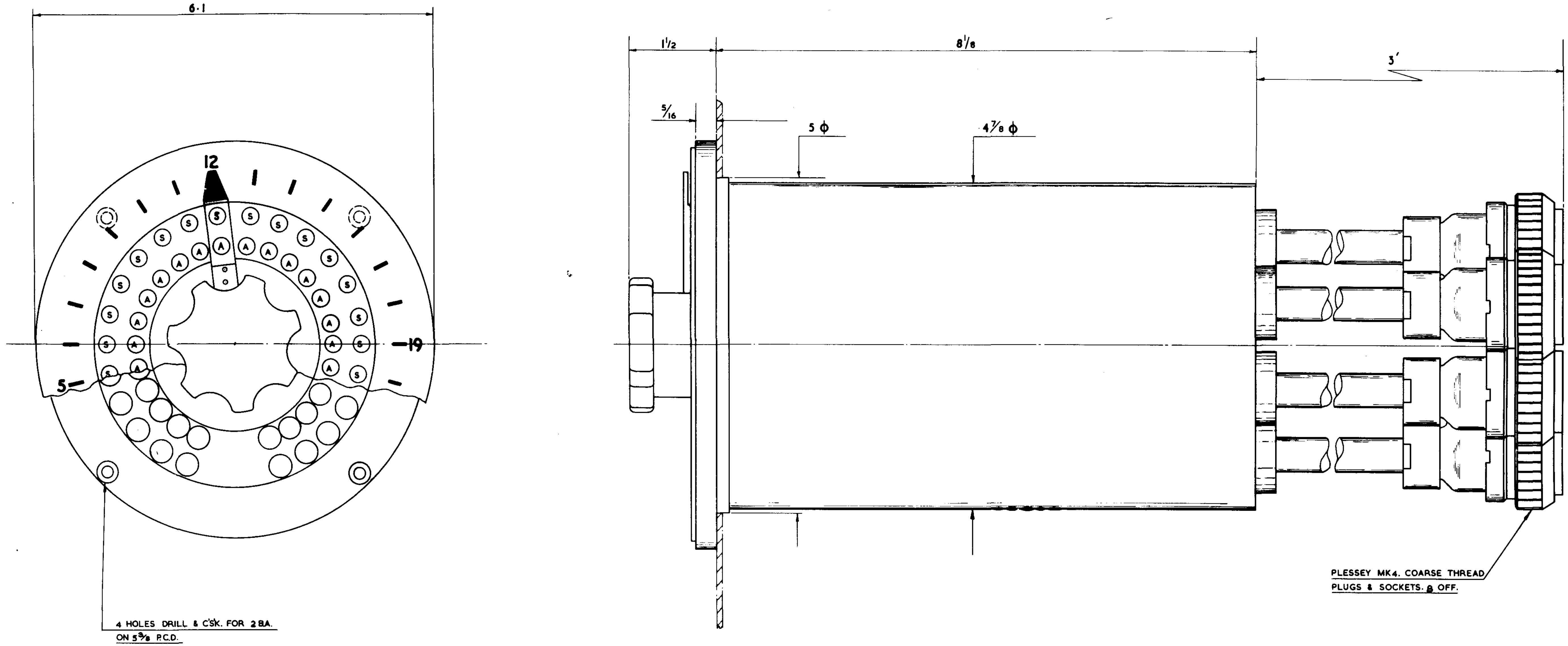


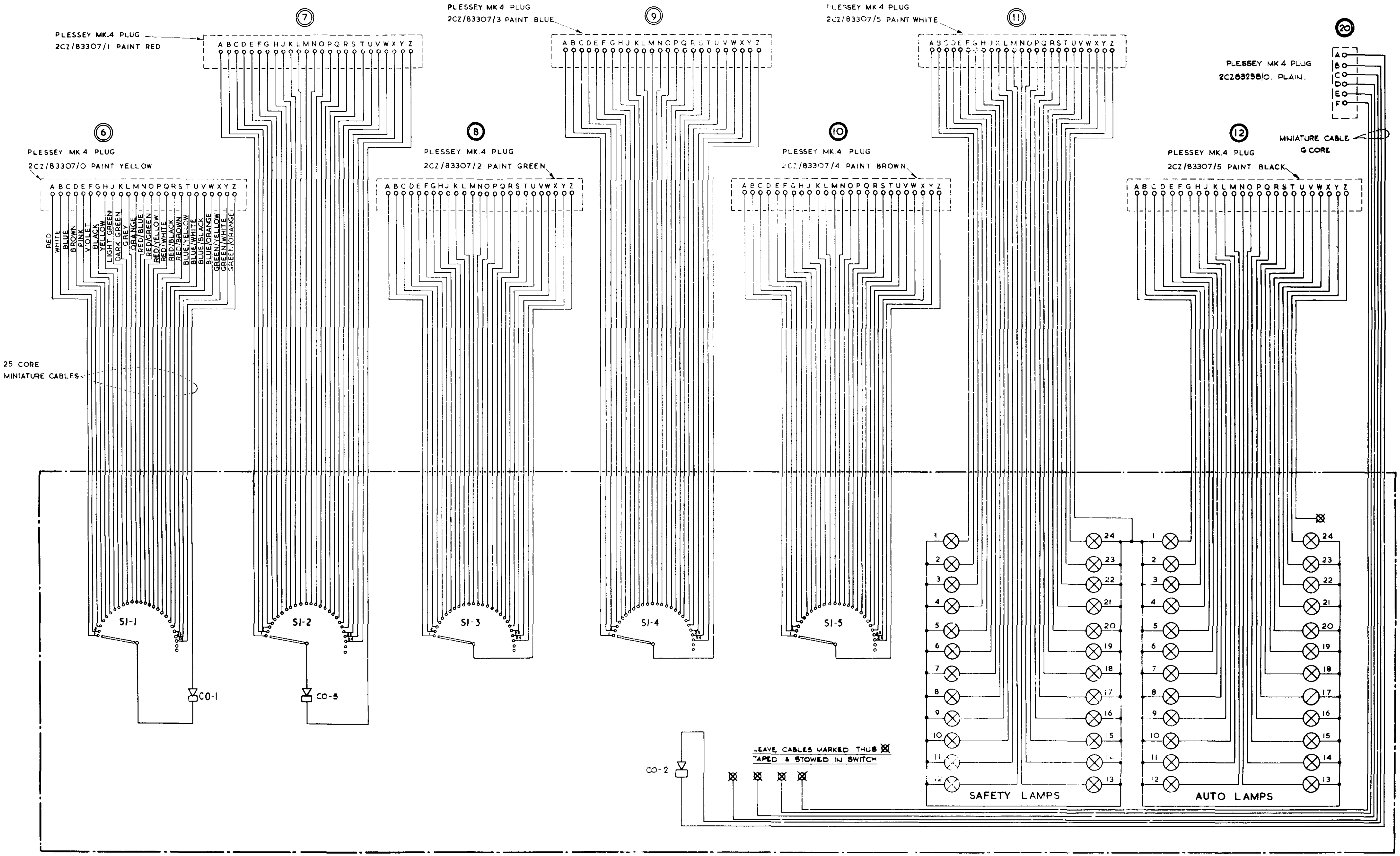
Fig. 15 CONTROL LEVER OUTLINE - DRG. NO. C112/001/CD33816.



NOTE:- 1. FOR WIRING DETAILS SEE DRG. C112/001/CD33807

NOTE:- 2 THIS SWITCH IS MODIFIED FROM SPERRY SWITCH H2G101-82B.
FOR MODIFICATION DETAILS SEE DRAWING C117/101

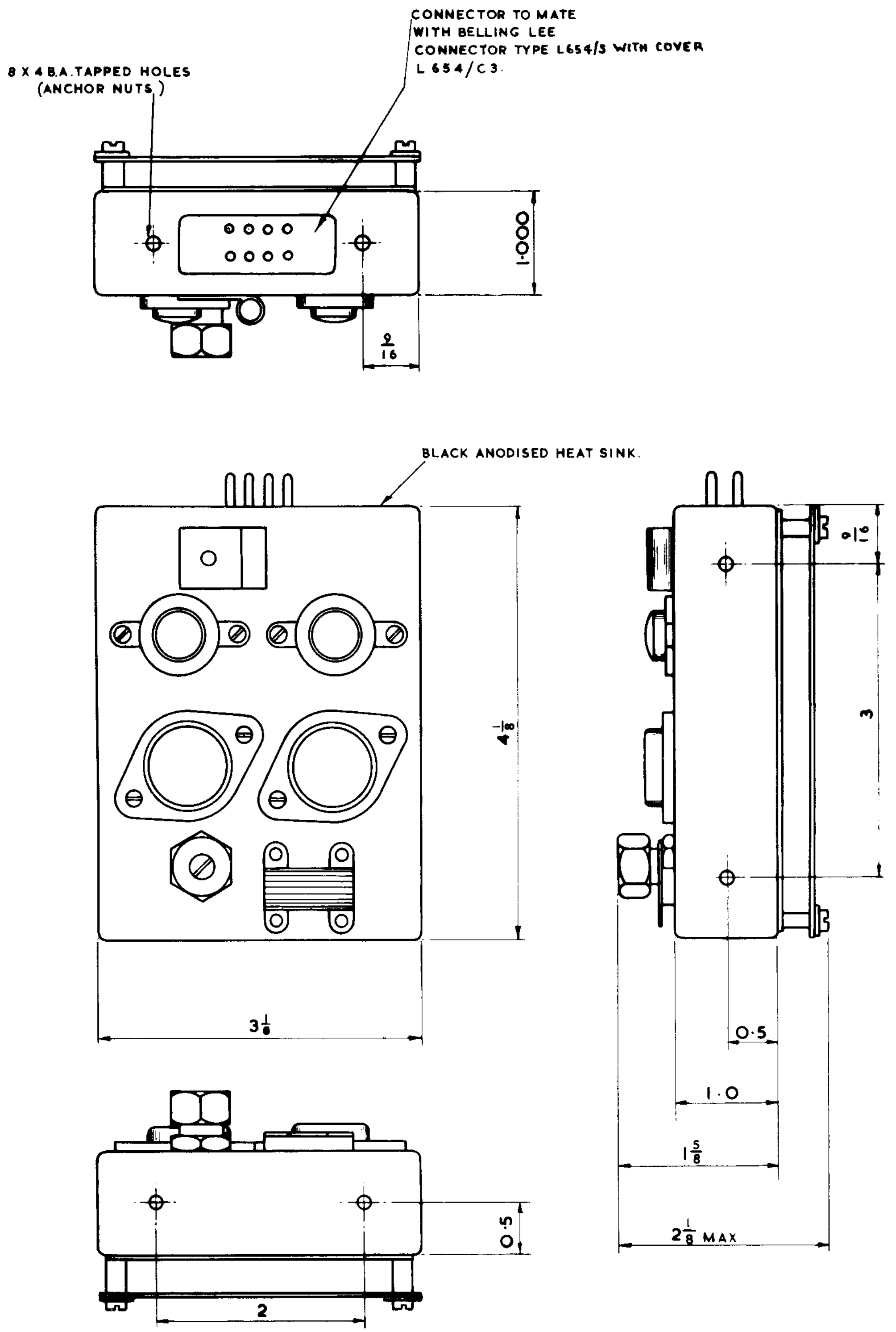
Fig. 16 SELECTOR S1 OUTLINE - DRG. NO. C112/001/CD33733.



NOTE:-

NUMBERS ON PLUGS & SOCKETS
THUS ◎ ARE FOR IDENTIFICATION
ON DRAWING C112/001 SHT 1 & 2 I.E.:—
⑫ SIGNIFIES PLUG 12

Fig. 17 WIRING DIAGRAM SELECTOR SWITCH S1 - DRG. NO. C112/001/CD33807.

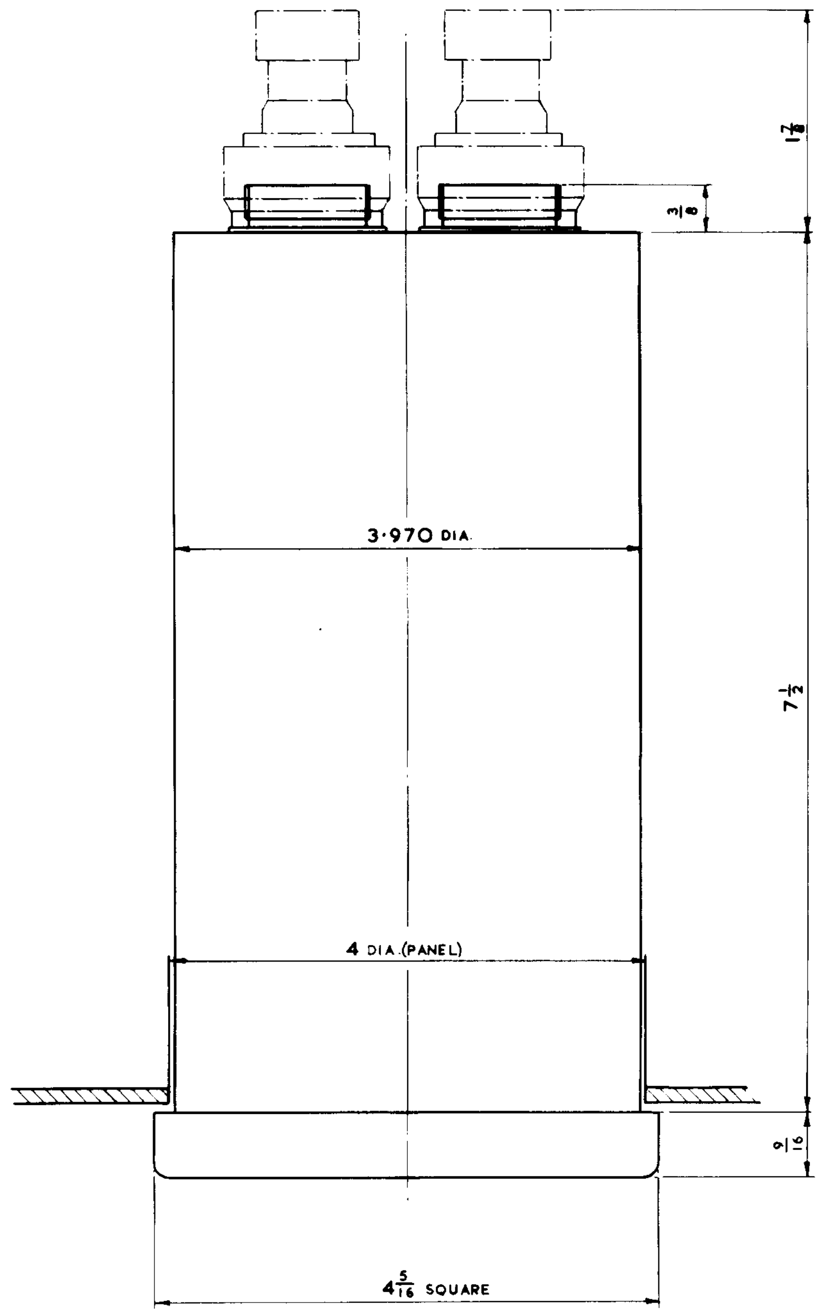


SPERRY AMPLIFIER TYPE C1.

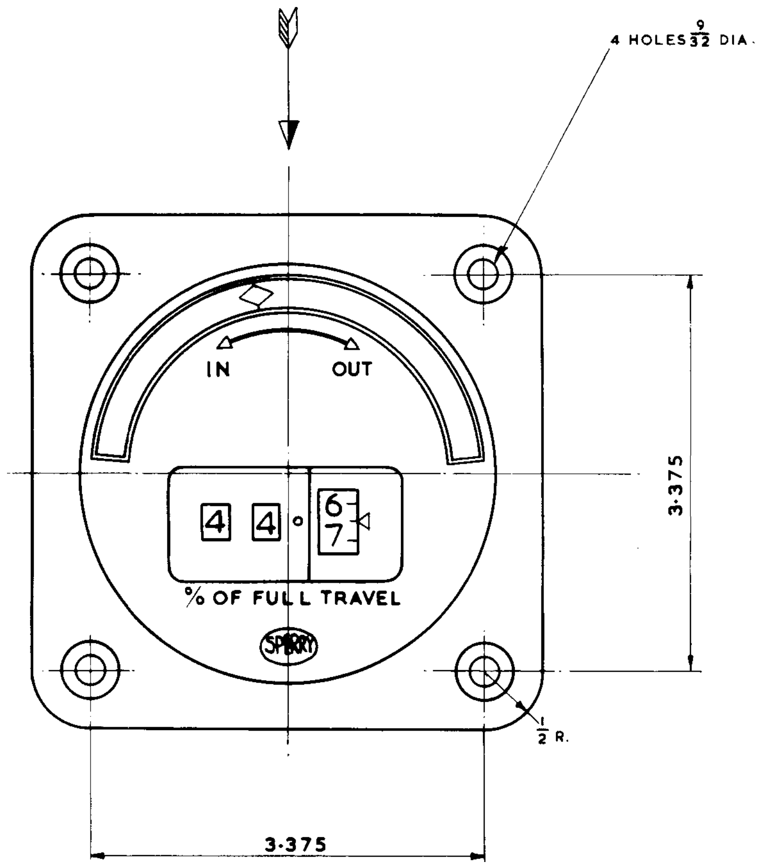
NOTE 1. AMPLIFIER SHOULD BE MOUNTED SO THAT THERE IS A FREE MOVEMENT OF AIR OVER IT. FAILING THIS THE AMPLIFIER SHOULD BE CLAMPED WITH ONE OR MORE OF ITS EDGES IN CONTACT WITH AS LARGE AN AREA OF METAL AS POSSIBLE.

2. WHEN NO EXTERNAL HEAT SINK IS USED AMBIENT TEMPERATURE MUST NOT EXCEED 55°C.

3. HEAT SINK IS ISOLATED FROM ALL SUPPLIES & TERMINAL POSTS.

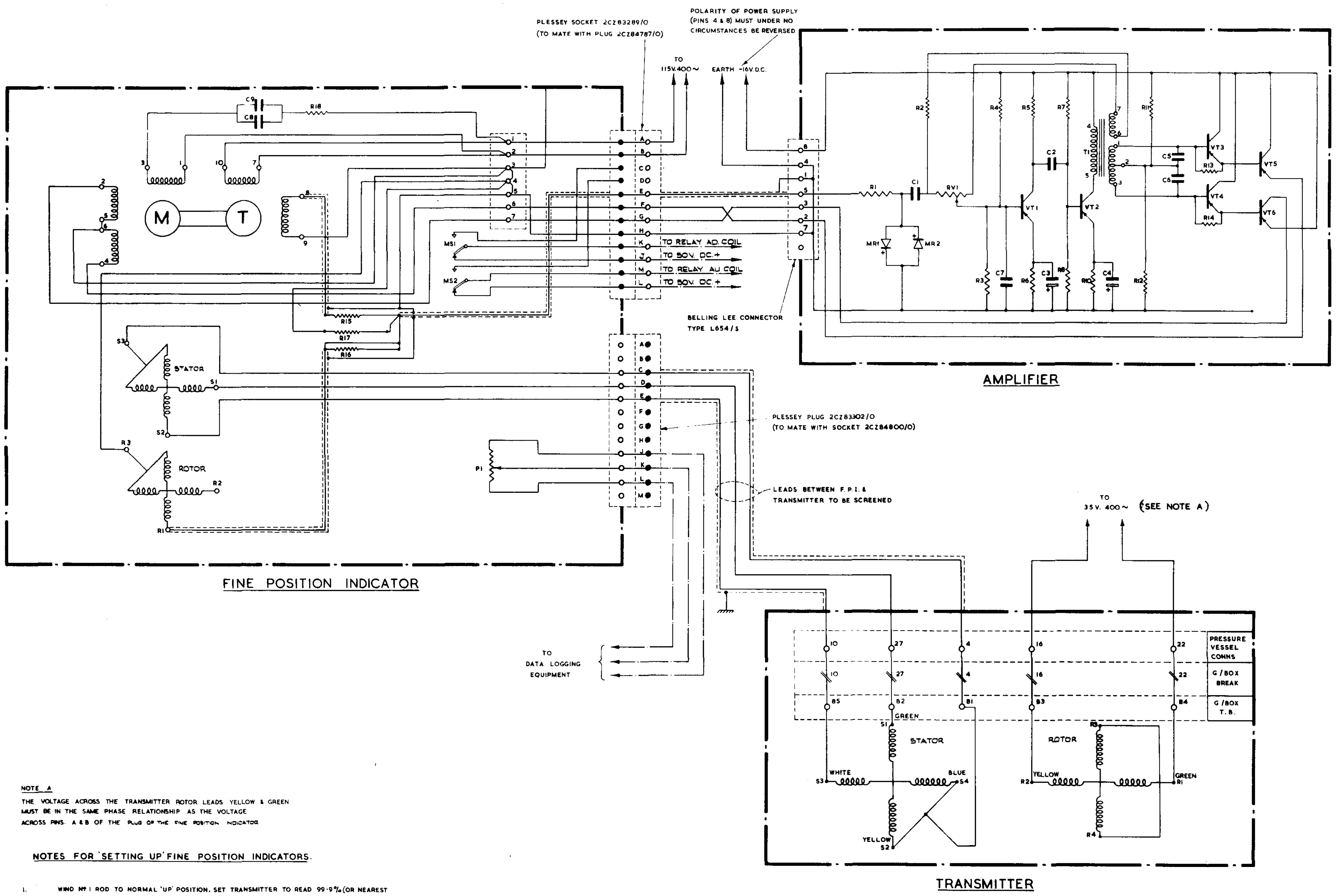


VIEW IN DIRECTION OF ARROW



FINE POSITION INDICATOR TYPE D.

Fig. 18 OUTLINE OF F.P.I. (TYPE D) & AMPLIFIER C1 - DRG. NO. C112/001/CD33731.



REF.	DESCRIPTION	VALUE
R1	RESISTOR WELWYN AW3115	3·3KΩ ± 5% 3W
R2	" ERIE TYPE 16	680Ω ± 5% ¼W
R3	" " " "	4·7KΩ ± 5% ¼W
R4	" " " "	4·7KΩ ± 5% ¼W
R5	" " " "	5·6KΩ ± 5% ¼W
R6	" " " "	1KΩ ± 5% ¼W
R7	" " " "	10KΩ ± 5% ¼W
R8	" " " "	4·7KΩ ± 5% ¼W
R9		
R10	RESISTOR ERIE TYPE 16	1KΩ ± 5% ¼W
R11	" WELWYN AW3101	470Ω ± 5% 1½W
R12	" ERIE TYPE 16	10Ω ± 5% ¼W
R13	" " " "	100Ω ± 5% ¼W
R14	" " " "	100Ω ± 5% ¼W
R15	" RC7-K	22KΩ ± 10% ¼W
R16	" " (SHORTED)	3·3KΩ ± 10% ¼W
R17	" "	2·2KΩ ± 10% ¼W
R18	" RWV4-J	1·5KΩ ± 5% 3W
C1	CAPACITOR PLESSEY CE2B6	50μF $^{+100}_{-20}$% 12V. REV
C2	" " "	50μF $^{+100}_{-20}$% 12V. REV
C3	" " CE201	50μF $^{+100}_{-20}$% 12V.
C4	" " "	50μF $^{+100}_{-20}$% 12V.
C5	" DUBILIER 412	·1μF ± 10% 150V.
C6	" " "	·1μF ± 10% 150V.
C7	"	·02μF
C8	"	·05μF
C9	"	·1μF
T1	TRANSFORMER SPERRY Nº SK8918-322	INTERSTAGE
P1	HELIPOT TYPE T5P BECKMAN	1KΩ LINEARITY ±·2%
RV1	VARIABLE RESISTOR	300Ω 1W
VT1	TRANSISTOR TYPE OC75	
VT2	" " OC84	
VT3	" " V30/201P	
VT4	" " V30/201P	
VT5	" " OC35	
VT6	" " OC35	
MR1	DIODE TYPE OA200	
MR2	" " "	
MS1	MICRO SWITCH HONEYWELL TYPE 11SM1T	
MS2	" " " "	

MICRO SWITCH	FINE POSITION INDICATOR TRAVEL.		
	0-20%	20%-80%	80%-100%
MS. 1	PINS K & J OPEN	PINS K & J CLOSED	PINS K & J CLOSED
	PINS K & C CLOSED	PINS K & C OPEN	PINS K & C OPEN.
MS. 2	PINS M & L CLOSED	PINS M & L CLOSED	PINS M & L OPEN.
	PINS M & D OPEN.	PINS M & D OPEN	PINS M & D CLOSED.

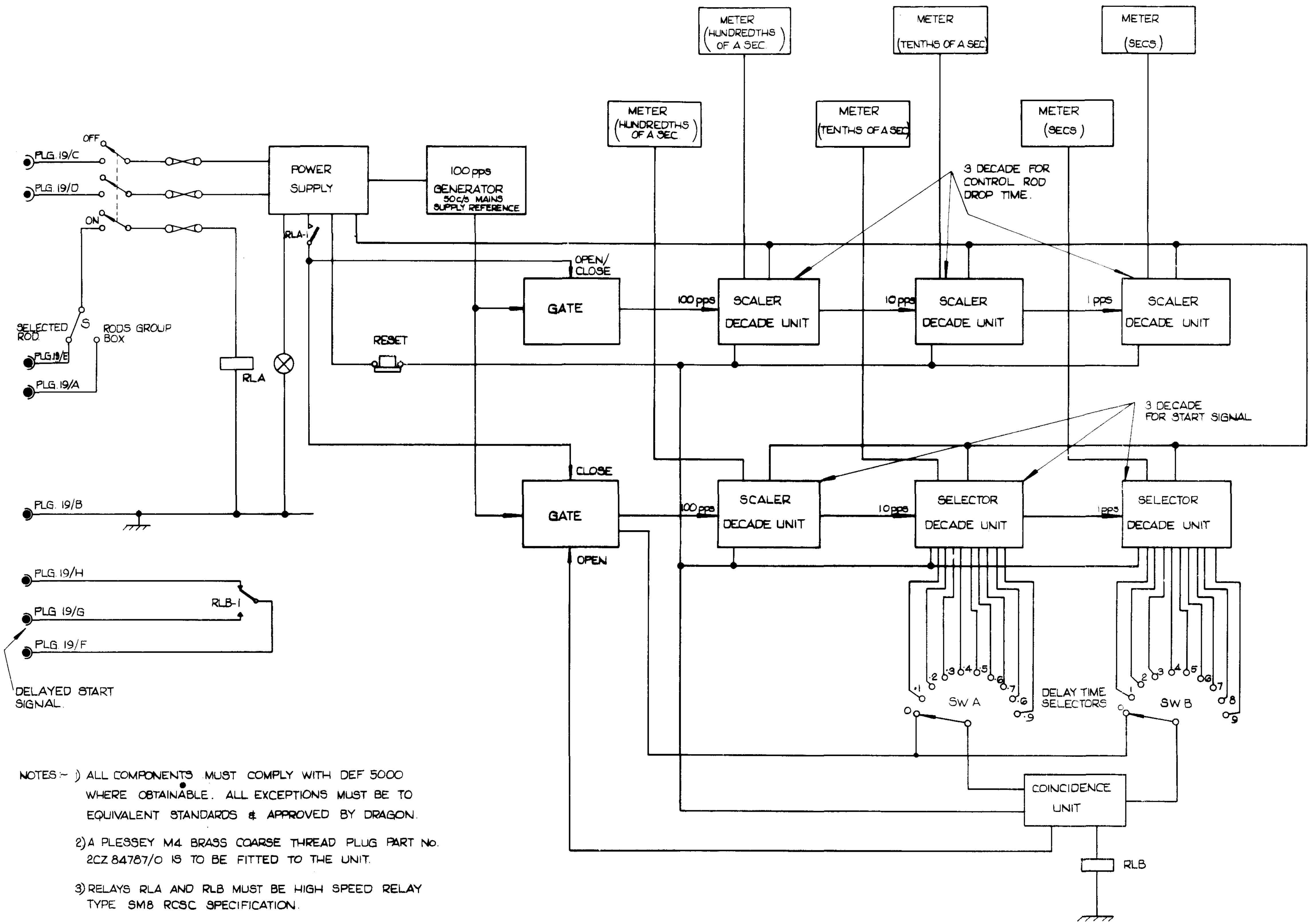
NOTE A

THE VOLTAGE ACROSS THE TRANSMITTER ROTOR LEADS YELLOW & GREEN MUST BE IN THE SAME PHASE RELATIONSHIP AS THE VOLTAGE ACROSS PINS. A & B OF THE PLUG OF THE FINE POSITION INDICATOR

NOTES FOR 'SETTING UP' FINE POSITION INDICATORS.

1. WIND Nº 1 ROD TO NORMAL 'UP' POSITION. SET TRANSMITTER TO READ 99·9% (OR NEAREST POSSIBLE FIGURE TO THIS I.E. 99·8%) ON OPERATION ROD F.P.I.
2. SELECT Nº 2 ROD. WIND ROD TO 'UP' POSITION SET TRANSMITTER TO READ AS Nº 1.
3. REPEAT FOR REMAINDER OF 24 RODS.
4. SWITCH Nº 1 ROD TO AUTOMATIC AND BY MEANS OF SCREW AT BACK ADJUST AUTOMATIC F.P.I. TO READ AS OPERATION F.P.I.
5. THE REMAINDER OF THE RODS SHOULD READ AS Nº 1 WHEN CONNECTED AS AUTOMATIC ROD.
6. NºS 4 & 5 SHOULD BE REPEATED FOR THE 'SPARE' F.P.I.

Fig. 19 FINE POSITION INDICATOR TYPE D & AMPLIFIER C1: WIRING DIAGRAM - DRG. NO. C112/001/DD33732.



NOTES :- 1) ALL COMPONENTS MUST COMPLY WITH DEF 5000 WHERE OBTAINABLE. ALL EXCEPTIONS MUST BE TO EQUIVALENT STANDARDS & APPROVED BY DRAGON.

2) A PLESSEY M4 BRASS COARSE THREAD PLUG PART No. 2CZ 84787/0 IS TO BE FITTED TO THE UNIT.

3) RELAYS RLA AND RLB MUST BE HIGH SPEED RELAY TYPE SM8 RCSC SPECIFICATION.

Fig. 20 CONTROL ROD DROP TIMING UNIT - SCHEMATIC - DRG. NO. C116/001

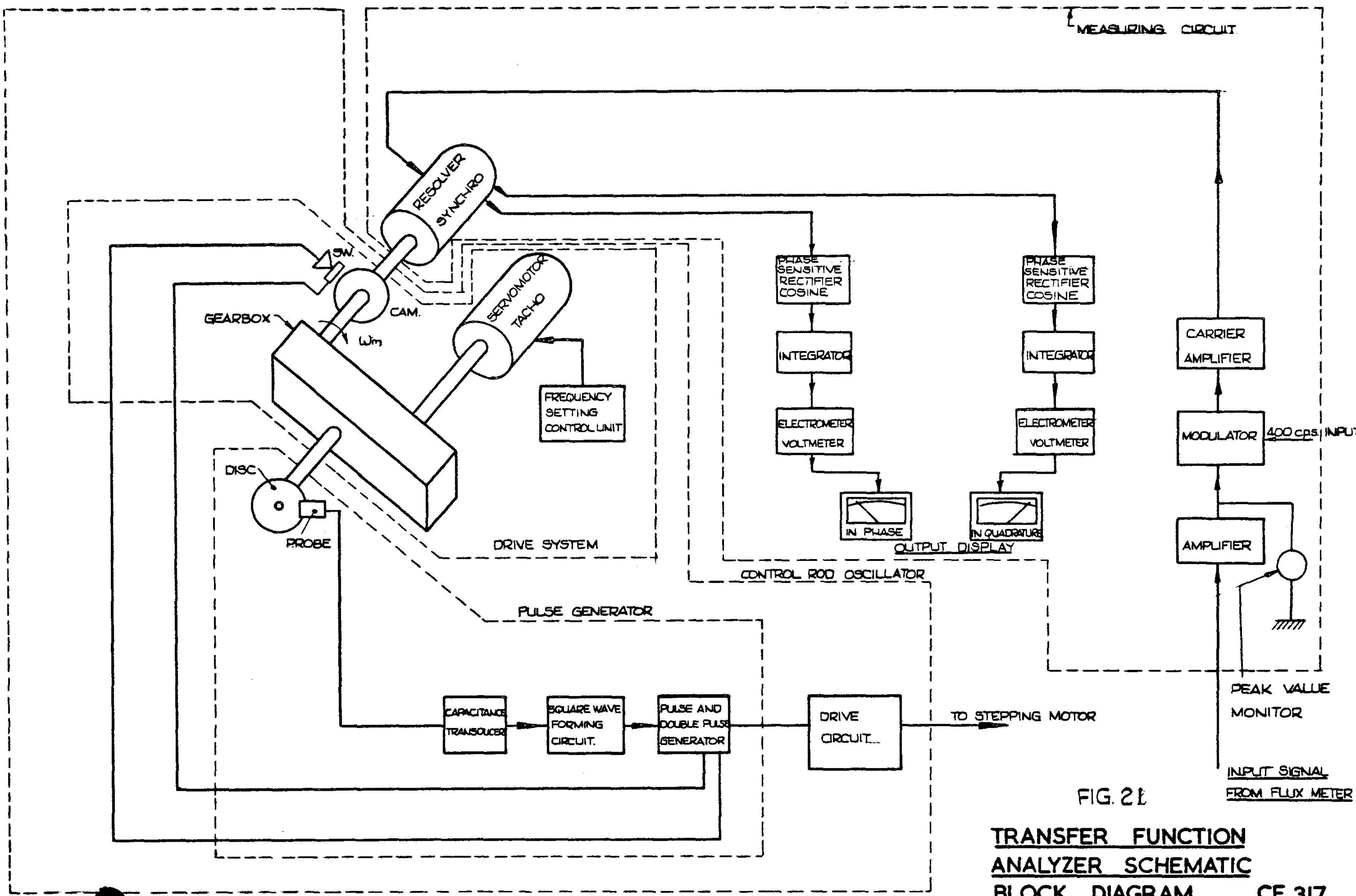


FIG. 21

TRANSFER FUNCTION ANALYZER SCHEMATIC BLOCK DIAGRAM CE 317

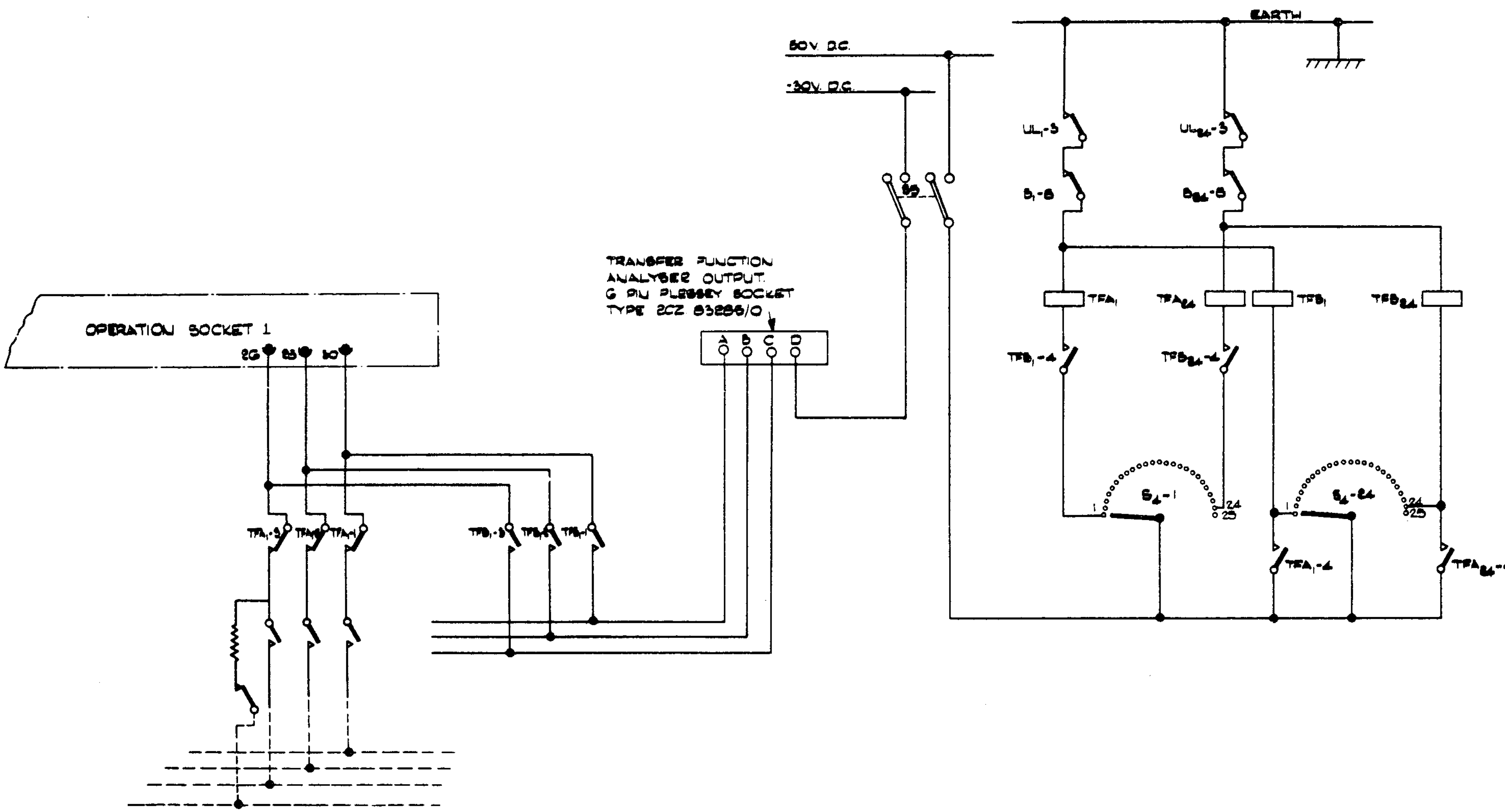


FIG. 22 CIRCUIT FOR TRANSFER FUNCTION ANALYSIS - DRG. NO. CE175