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# A Digital Recording System for Structural Research

*by*

*D. Purslow*

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# A DIGITAL RECORDING SYSTEM FOR STRUCTURAL RESEARCH

by

D. Purslow

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SUMMARY

The recording system described measures the output of strain gauge bridges, displacements by determining the position of potentiometer wipers, temperature by use of chromel-alumel thermocouples and the millivolt output of any D.C. transducer. The measurements are recorded on punched cards and in typescript.

The methods used to measure the different types of transducer signal are surveyed and detailed operating procedures are given in Appendices.

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## 1 INTRODUCTION

The number of transducers used in a structural research test may be a few of similar type, or as many as several thousand of various types. Measurements of mechanical strain, displacement and temperature are frequently required during one test. Manually operated instruments are still acceptable for small tests. Fast automatic recorders, requiring elaborate data processing, and recording the information in binary code on punched or magnetic tape, are suitable for very large installations.

The Recorder described here bridges the gap between these extremes and satisfies the basic requirements of economical connection of a large number of transducers and accurate measurements of low voltage signals in the presence of considerable interference. Recording in decimal on punched cards and typescript, the data may be analysed manually or automatically as desired. Several alternative functions may be performed; the transducer may form part of a Wheatstone Bridge circuit, e.g. strain gauge or potentiometer, or produce a small steady voltage e.g. thermocouple. The Recorder is a null balance instrument and if a balance is not obtained the measurement is not printed, but replaced by a series of dashes. Primarily a 'static' Recorder, it will, however, record signals that vary moderately with time. Nine Recorders have been installed in the Measurement Room of the Structures Research Laboratory. Figs.1 and 2.

The description given in the main text is elaborated in Appendices, which also contain operating procedures.

## 2 SPECIFICATION

### 2.1 Strain Gauges and Potentiometers

Scale - $4^1/3\%$ change of resistance = 865 or 8665 digits. Gauge resistance 50Ω - 5000Ω
Terminal Unit - 12 or 18 gauges
Selector Unit - up to 12 Terminal Units
Maximum Capacity - 216 gauges per Selector Unit

### 2.2 Thermocouples

Scale - 865°C = 865 or 8665 digits for chromel/alumel thermocouples
(1 or 0·1°C per digit)
(cold junction temperature 0° to 50°C)
Terminal Unit - 12 thermocouples in const. temp. cold junction
Selector Unit - up to 12 Terminal Units
Maximum Capacity - 144 thermocouples per Selector Unit

### 2.3 Voltages

Scale - 86·5 mV = 865 digits or 86·65 mV = 8665 digits.
(100 or 10 μV per digit)
Terminal Unit - 12 transducers
Selector Unit - up to 12 Terminal Units
Maximum Capacity - 144 transducers per Selector Unit

2.4 Routing Unit

1-5 Selector Units of above types.
The Maximum capacity of a Recorder may thus be five times that shown above.

2.5 Elevated Temperature Strain Gauges

Scales - as above. Strain gauge and thermocouple recordings synchronised.

| | |
|---|---|
| Strain Gauge Terminal Unit | - 12 gauges |
| Thermocouple Terminal Unit | - 12 thermocouples |
| Selector Unit | - 2 or 4 Strain Gauge Terminal Units<br>2 or 4 Thermocouple Terminal Units |
| Maximum Capacity | - 48 strain gauges and 48 thermocouples per pair of Recorders. |

2.6 Output

Punched Card and Typescript
24 three digit measurements per card or
18 four digit measurements per card
together with a minimum of 7 digits available for identification.

Speed 10 digits/sec: 3 or 4 digits per measurement.
Cycling time per card-approximately 9 secs.
The reading cycle may be initiated externally at a prescribed time or made to cycle continuously.

2.7 Response

The Recorder will correctly measure transient signals from a transducer varying at a rate of up to 10 digits per second. The measurement recorded is the output of the transducer 50 milliseconds before the first digit of that measurement is punched.

2.8 Filtering

Common mode (in-phase interference at input terminals) rejection greater than 100 db under operational conditions.

| | |
|---|---|
| Antiphase interference or signal rejection at | 50 c/s on 3rd digit of measurement - 53 db |
| " " " " | 50 c/s on 4th digit of measurement - 45 db |
| " " " " | 150 c/s on 3rd digit of measurement - 66 db |
| " " " " | 150 c/s on 4th digit of measurement - 66 db |

2.9 Accuracy

Strain Gauges better than ±0·5%. Thermocouples ±1% of measurement.

Stability

Strain Gauges ±2 digits in the fourth decade. Thermocouples ±1% of measurement.

## 3 GENERAL DESCRIPTION

Each Recorder is a single channel instrument to which any number of similar transducers may be switched sequentially. The measurements are recorded as 3 or 4 digit numbers on punched cards, and in typescript simultaneously, at the rate of 10 digits per second. The measurements may thus be inspected visually without decoding. One punched card can record 80 decimal digits, at least 7 of which are available to identify the transducer, load increment, test number, etc. Card sorting machines can be used to present the data in a sequence suitable for subsequent analysis and graphs may be obtained from semi-automatic card-to-graph plotters or a digital computer, e.g. Deuce, can be programmed to carry out automatic analysis.

Several alternative functions may be performed by each Recorder. The transducer may form part of a D.C. Wheatstone Bridge circuit, e.g. strain gauge or potentiometer, or produce a small steady voltage e.g. thermocouple. The Recorder is a null balance instrument with scale lengths of 8665 or 865 digits. If a balance is not obtained the measurement is not printed, but replaced by a series of dashes.

Transient signals varying at a rate of up to 10 digits per sec may be recorded, the measurements being accurate at a time 50 milliseconds before the first digit of the measurement is printed.

Each cycle of measurement may be initiated at the Recorder, the Selector Unit, or by external manual or automatic control. The Recorder may also be made to record continuously.

Terminal Units, to which solder connections are made from several transducers, are located near the specimen. A short multicore cable connects each Terminal Unit to a Selector Unit which routes the transducers to the Recorder. The Selector Unit is situated close to the Terminal Units, but may be up to 100 yards from the Recorder (see Appendix 2).

Large amounts of interference at 50 c/s and its harmonics may be produced by the power wiring for kinetic heating ovens. Interference pick-up in the signal circuits is reduced by connecting only one Terminal Unit at a time to the Recorder, thus reducing the effective size of the installation and further attenuation effected in the Recorder by common mode rejection and the use of a low pass filter. Since only one Terminal Unit is connected to the Recorder at a time, a faulty gauge can only affect the measurements of those gauges on the same Terminal Unit.

All signal cables are screened and run at a distance from the power wiring. The use of a d.c. system eliminates the need of trimming capacitors and individually screened leads.

The recording system is earthed at one point only. To minimise common mode interference, earthing points are provided on each Terminal Unit, Selector Unit and Simulator.

The earthing system is shown in Fig.4 and a typical installation in Fig.5.

## 4 STRAIN MEASUREMENT

### 4.1 General

A change of strain in an electrical conductor produces a proportional change in its resistance. Thus, if a wire, or foil 'gauge' is bonded to the specimen so that the change of strain in the gauge equals that in the specimen, the resulting percentage change of resistance of the gauge will be proportional to the change of strain in the specimen. The ratio of percentage change of strain in the specimen to the corresponding percentage change of resistance is known as the gauge factor, and is a measure of its sensitivity.

Each electrical resistance strain gauge forms the active arm of a Wheatstone Bridge circuit. Two 100 ohm precision resistors form the fixed arms of the bridge; the remaining arm may be a dummy or active gauge used for temperature compensation.

It is common practice in strain gauge installations to obtain an approximate bridge balance at zero strain by the use of balancing potentiometers. The necessity for these potentiometers is eliminated in the Recorder by the provision of a long stable scale. Errors due to the poor contact of the potentiometer wipers are thus removed and the quantity of wiring reduced. The Recorder will not, however, measure strain directly, but the change of strain as the difference of two measurements. The bridge is balanced during measurements by automatically switching resistors in parallel with the fixed arms of the bridge.

### 4.2 Strain Gauge Terminal Unit Fig.6

Up to 18 active strain gauges may be soldered to each Terminal Unit. Each gauge should be wired individually the leads being kept as short as possible. (See Appendix 2.) The active gauge is connected between a positive terminal and a numbered gauge point, and the dummy or second active gauge between a negative terminal and the same gauge point. Only one wire per gauge point and 6 supply wires common to all 18 gauges are thus taken to the Recorder. The two fixed arms of the bridge are situated in the Terminal Unit, and are shared by the 18 gauges there being therefore no plug and socket connections in the bridge circuit. The bridge supply is fused at 1 amp at the Terminal Unit, thus a short circuit will only render 18 gauges unserviceable.

### 4.3 Strain Gauge and Potentiometer Selector Unit Fig.7

Up to 12 Strain Gauge Terminal Units may be connected to a Selector Unit. One Selector Unit may thus scan 216 strain gauges, and record them as 4 digit numbers, in approximately 100 secs. Each Terminal Unit and gauge is connected in sequence to the Recorder for measurement.

The 7V bridge supply, stabilised at the Selector Unit, is known as the 'Test Supply' and is only connected to the one Terminal Unit being recorded. This ensures that a faulty gauge may only affect a maximum of 17 other gauges, and reduces the amount of interference pick-up coupled to the Recorder.

To maintain thermal stability, the remaining Terminal Units are connected to a Standby Supply, controlled at the same voltage as the Test Supply at the Selector Unit.

### 4.4 Selector Routing Unit Fig.8

For large scale experiments, a Selector Routing Unit is available, which, in conjunction with five Selector Units, enables up to 1080 gauges to be measured sequentially by one Recorder. A Standby Power Unit is connected to each Selector Unit.

## 5 DEFLECTION MEASUREMENT

By making the wiper of a resistance potentiometer follow the displacement of a specimen, that displacement may be measured and recorded as a fraction of the potentiometer stroke. The complete stroke is represented by 0 to 865 or 7 to 8658 digits.

Up to 18 potentiometers may be connected to a Strain Gauge Terminal Unit and 12 Terminal Units routed to the Recorder via a Strain Gauge and potentiometer Selector Unit as described above.

## 6 THERMOCOUPLE THERMOMETRY

### 6.1 General

When a circuit is formed by two wires of dissimilar metals, an emf is generated in the circuit proportional to the difference in temperature of the junctions. If one junction, known as the cold junction, is held at a constant known temperature, the emf in the circuit may be used to determine the temperature of the hot junction.

A scale has been provided to record temperature, by use of chromel-alumel ($T_1/T_2$) thermocouples, directly in degrees centigrade up to a maximum of 865°C for cold junction temperatures from 0° to 50°C. The deviation of this scale from the $T_1/T_2$ standard calibration[3] is shown in Fig.44. When using other types of thermocouples, the measurements may be recorded directly in millivolts up to 86·5 mV on the millivolt scale of the Recorder and converted to temperature in analysis.

### 6.2 Thermocouple and Radiometer Terminal Units Fig.9

Twelve pairs of terminals are provided on each Terminal Unit. These Terminal Units are designed for use in a thermostatically controlled oven which acts as a cold junction at a temperature of 45°C when measuring thermocouples. If a thermocouple is not earthed at the specimen, the positive wire must be connected to the Terminal Unit earth terminal.

6.3 Thermocouple Terminal Units Fig.10

The wiring of these units is identical to that of the Thermocouple and Radiometer Terminal Units but are of similar mechanical design to the Strain Gauge and Potentiometer Terminal Units. These can be used if a controlled cold junction is not required or voltages from other transducers are to be measured.

6.4 Thermocouple and Voltage Selector Unit Fig.11

The Thermocouple and Voltage Selector Unit routes twelve Terminal Units to the Recorder in sequence, thus handling 144 transducers. 144 three digit measurements or 108 four digit measurements may be made in less than 60 secs.

6.5 Selector Routing Unit Fig.8

For large scale experiments a Selector Routing Unit is available which, in conjunction with 5 Selector Units, enables 720 transducers to be measured sequentially by one Recorder.

## 7 VOLTAGE MEASUREMENT

The voltage from any d.c. transducer may be recorded on the millivolt range up to 86·5 mV with 10 or 100 μV/digit. A zero adjustment is provided.

Twelve transducers are connected to a Thermocouple Terminal Unit, Fig.10 and coupled to the Recorder via a Thermocouple Selector Unit, thus enabling 144 transducers to be recorded sequentially as 3 digit measurements by one Recorder in less than 60 secs.

## 8 ELEVATED TEMPERATURE STRENGTH TESTING (STRAIN GAUGES WITH THERMOCOUPLE TEMPERATURE CORRECTION)

8.1 General

Temperature compensation of an active strain gauge by use of a dummy gauge is inadequate in transient elevated temperature testing, since the active and dummy gauges are unlikely to be at the same temperature. The dummy gauges are therefore replaced by precision resistors held at a constant temperature if necessary, and the strain and temperature of the active gauge measured simultaneously. For this purpose a thermocouple is located adjacent to the active strain gauge. Two Recorders are used, one to measure strain, the other to measure temperature, and are coupled to ensure synchronisation of the temperature and strain measurements.

8.2 Terminal Units

The standard Strain Gauge Terminal Units and Thermocouple Terminal Units are used. Only the first 12 positions, i.e. 1 to 9,11,12 and 13, of the Strain Gauge Terminal Units are connected.

8.3 Strain Gauge and Thermocouple Selector Unit Fig.12

Four Strain Gauge and four Thermocouple Terminal Units are routed by a dual purpose selector unit feeding a pair of Recorders. The two Recorders are synchronised in order that the temperature of the gauge is measured at the same time as the strain.

## 9 CONCLUDING REMARKS

Major strength tests, under both 'cold' and 'hot' cases, have proved the accuracy and repeatability of the 3 digit measurements to be satisfactory for moderate sized installations. For 'cold' tests the time taken for several Recorders to cycle through a large installation may be acceptable, but the speed of operation of each Recorder is insufficient for large scale transient kinetic heating tests which must be recorded in 'real' time.

For smaller tests, such as the load calibration on the ground of strain gauges for flight research, the long scale length afforded on 4 digit operation has been required and shown to give repeatable and accurate measurements. The design of the Recorder is ideally suited to such experiments.

Unreliability has been caused by faulty relays and uniselectors which could be replaced by transistor or reed relay switching as appropriate. The Card Punches are not suited to the long, continuous running required on a large scale test and have caused considerable unreliability under such conditions. The typewriters, which are used mainly as monitors, have operated more satisfactorily: a sequential typescript may, however, be obtained automatically from the punched cards.

To satisfy the requirements of the large scale major strength tests a faster Recorder, with slightly less resolution, is under development which will record on punched tape. It has also been found necessary to develop a temperature controlled Strain Gauge Terminal Unit for use with elevated temperature strain gauges due to the appreciable temperature coefficient of precision resistors.

The facilities available with these Recorders provide a comprehensive recording system which should satisfy all the requirements envisaged.

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# APPENDIX 1

## DETAILED RECORDER OPERATION

### 1 GENERAL DESCRIPTION

The Recorder is a null balance instrument attaining a final balance in three or four decimal steps. A digitiser converts the amplified out-of-balance into a number (0-15) × $10^n$, where the decade, n = 3, 2, 1 or 0. At each decade the digitised output from the amplifier operates appropriate balancing relays which switch resistors to decrease the out-of-balance. The value of n is changed at each decade to amplify the smaller unbalance remaining by changing the amplifier feedback resistors, thus altering its gain. A convenient scale length of 8665 is obtained by using a range of 0-7, representing 0-7000 digits, on the first decade. This 15 bit digitiser output, in the binary form 8-4-2-1, provides a redundancy of digits in each decade. This redundancy makes possible the use of a method of successive approximations[1] in the balancing technique, permitting the low accuracy in the amplifier and digitiser. A low frequency galvanometer amplifier is used, and the increase in tolerance also enables the signal to be digitised earlier in each decade cycle, before the amplifier output has stabilised completely.

The use of this redundancy in the balancing technique is indicated in Table 1 [2]. Also listed in Table 1 are the allowable amplifier errors at each decade of the measurement, if the final recording is required to $\pm 1\frac{1}{2}$ digits. In practice, corrections are made so that the allowable amplifier tolerances are symmetrical, and the probability of exceeding these tolerances must be very small. Consider a balance at 4388; this balance can be obtained by two different digital combinations: 4000 + 300 + 80 + 8 or 3000 + 1300 + 80 + 8. Therefore at the first decade the null-detecting amplifier may measure the unbalance as 3000 or 4000 and this ambiguity can be resolved at the next decade by digitising $3 \times 10^2$ or $13 \times 10^2$. The ambiguity between 3000 and 4000 can be tolerated for any balance point between 3999 and 4665, as later decades will correct for it. The number 4333 is particularly interesting as an ambiguity arises at each decade and is resolved by the succeeding one (Table 1).

Since the decision of the last decade may alter the first digit, the final answer is not available until the end of the measurement cycle. This answer is therefore memorised and printed out during the next measurement.

If at some decade, the remaining out-of-balance is outside the range 0-15, then a final balance cannot be obtained. Under these conditions the galvanometer is immediately disconnected from the circuit to prevent damage and a series of dashes is printed instead of a spurious reading. The galvanometer is re-connected as soon as the next transducer is coupled to the Recorder.

The component blocks of the Recorder and their interconnection are shown in Figs.15 and 16 and their operation will be described under those headings.

2 POWER UNIT - Figs.1 and 17

The ±8V supplies are produced from a 6 phase rectifier stack. From these supplies, stabilised ±3·5V rails, known as the Test Supply, are derived. The electrical measurement circuits are earthed at one point only to minimise common mode interference. For strain gauges and potentiometers the Recorder earth is at a potential of 0 volt to reduce errors due to low insulation resistance and is connected at the junction of two series resistors across the Test Supply. For thermocouples and millivolts the Test Supply is earthed via the transducer. The earth connections are shown in Fig.4.

The Test Supply is stabilised at the Selector Unit for strain gauges and potentiometers. Two wires feed back the Test Supply from the Selector Unit to the Power Unit, where it is compared with the voltage set by the Test Voltage Adjustment. Stabilisation is at the Power Unit for thermocouples and millivolts.

The 24 volt and 48 volt supplies are produced, unsmoothed, from a 6 phase rectifier stack the common negative rail being connected to the chassis in the Balancing and Print Out Unit.

3 STANDBY POWER UNIT - Figs.1 and 18

This unit provides a smoothed D.C. supply for strain gauges from a motor driven single phase variable transformer. Both Test and Standby Supplies are fed back to the two coils of a detector relay. This relay operates the motor to reduce the voltage difference between Test and Standby Supplies at the Selector Switch should it exceed 0·1 volt. The Standby Supply is fused at 10 amps and is isolated from the Test Supply.

4 DIGITISING AMPLIFIER UNIT - Figs.1 and 19

The Digitising Amplifier is shown schematically in Fig.20. The image, reflected by the galvanometer mirror, of the vertical filament of a high efficiency lamp is focussed on to a pair of photocells. These photovoltaic cells and amplifiers are in a series circuit across the 16 volts supply. The differential voltage output from this circuit is amplified and fed back to the input of the galvanometer through precision resistors, thus approximately balancing out the signal. This amplified output is then a measure of the current, or number of digits, required to effect a balance, and is also fed, via a low pass filter, to the digitiser. By the use of relays, the signal circuits are isolated from the control circuits in the digitiser.

The transistor detector is set initially at the 8 transition and decides whether the out-of-balance is greater or less than 8 digits. The transition is then set to 12 or 4, depending upon the 8 decision, by changing the resistors at the detector input to decide whether the remaining unbalance is greater or less than 4 digits. The process is then continued until a 4 bit number is obtained. The 4 bit output is set up on the contacts of four relays. This binary output is then fed to the appropriate Balancing relays via the Decade Selector, thus digitally reducing the signal received by the amplifier, and the Recorder moves to the next decade. The gain of the amplifier is increased by alteration of the feedback resistors and the cycle repeated. The digitising cycle is initiated by a DIGITISING pulse generated in the Timing Sub Unit when the amplifier has almost stabilised.

The unserviceable (U/S) circuit monitors the photocell amplifier current, so that when the light spot moves off the photocells due to an excess signal, the decrease in current is used to disconnect the galvanometer from the circuit and to return the amplifier to the least sensitive decade. The galvanometer may be manually reset by the switch on the Balancing and Print Out unit, but is automatically reset at the commencement of the next measurement cycle.

Simulation of the input voltage to the digitiser is provided by a potentiometer to check the operation of the digitiser. By operation of the Test Amplifier switch the galvanometer is disconnected from the circuit and can be adjusted to its mechanical zero. Adjustable zeros are provided on the millivolt and $T_1/T_2$ scales.

The Function Selector switch determines which type of transducer may be recorded and connects the appropriate precision resistors in the balancing circuit. The null-balance is obtained by switching balancing resistors in the Balancing and Memory unit between the +3·5 and -3·5V rails. These resistors determine the voltage across a precision resistor to balance out the signal e.m.f. when measuring thermocouples or voltages. When measuring strain gauges these balancing resistors are connected in parallel with the fixed arms of the strain gauge bridge in the Terminal Unit. When measuring potentiometers these resistors generate a voltage which is compared with the potentiometer wiper voltage.

5 DECADE SELECTOR SUB-UNIT - Fig.21

This bank of relays routes information from the digitiser to the balancing relays and from the memory and carry relays to the decoder. The relays are operated by Drive Decade Change pulses A and B. The routing is completed in the Balancing and Memory Sub-Unit.

6 BALANCING AND MEMORY SUB-UNIT - Fig.22

A bank of relays, operated by the Drive Decade Change B pulse, further route the incoming and outgoing binary information.

The balancing relays are closed by the Digitising Amplifier output, and are locked by the CANCEL rail voltage. These relays switch resistors, corresponding to the Digitising Amplifier output, to balance out the signal. The balancing resistors for the first decade are in the form (2 + 2 + 2 + 1) × 1000 so that the Recorder accuracy is not degraded by relay contact resistance or resistor manufacturing tolerance. Since, on the first decade, the initial transition of the digitiser is 3 to 4 and not 7 to 8, the 1000's SHIFT line reduces the balance point of the Recorder by 278 digits to make the digitiser transition coincident with the Recorder balance point. To enable the Recorder to follow the $T_1/T_2$ thermocouple calibration, the scale has two slopes; 41 µV/°C from 0 to 433°C and 42·6 µV/°C from 433 to 865°C. This change is effected by inserting a resistor in the balancing network, to reduce its sensitivity, above 433°C.

At the end of each measurement cycle the TRANSFER rails are switched to zero volts causing the memory relays to register the condition of the balancing relays and lock on at the end of the TRANSFER pulse. As a number greater than 9 may be transferred in any decade the second set of contacts of the memory relays are used to compute carry digits and thus simplify the decoder. The information having been transferred to the memory, the balancing relays are reset by the CANCEL rail switching to zero volts.

7 DECODER SUB-UNIT - Fig.23

The memorised binary information is fed, via the Decade Selector, to the Decoder Unit. This relay tree converts the 8-4-2-C2-1 binary code, from the memory unit, to decimal. For numbers greater than 9 the decoder ignores the 10's digit as the carry function has been performed in the Balancing and Memory Sub-Unit. The PRINT pulse is routed by the decoder to the appropriate decimal digit interposer of the Card Punch.

8 CARD PUNCH AND AUTOPLUG UNIT - Figs.24 and 25

Each card has 80 columns, up to 72 of which are used for recording measurements and may record one of 12 digits (Y,X, 0 to 9 sequentially from the top of the card) in each column. A space pulse column is required for starting the Recorder, the remaining 7 or more digits being available for identification. The Card Punch is operated automatically by the Recorder PRINT pulse when recording data and free runs when recording identification columns. The Punch plug board controls identification, skip and space columns, so that it is possible to preset the position of recording the identification data on the card. Identification data can be preset on the Punch plug board or Autoplug Unit. The Autoplug Unit is connected to the Card Punch by means of a 12 core cable. The 12 sets of information selected by the Autoplug Unit switches may be connected to the appropriate column from positions 5/1-12 of the plug board. Fig.24 gives the plug board layout. The Selector Unit, Terminal Unit and Reading numbers available as identification data may be connected to the Punch columns from positions 6/20, 7/20 and 8/20 respectively on the plug board.

9 TYPEWRITER - Figs.3 and 26

The Typewriter is slave to the Card Punch and prints in one line of typescript the information on one card, including identification. Y on the card is - on the typewriter and X is full stop. The carriage return contacts inhibit the commencement of the recording cycle.

10 STRAIN GAUGE TERMINAL UNITS - Figs.6 and 27

Up to 18 gauge pairs may be connected to one Terminal Unit. The active gauge is connected between the gauge point and the positive terminals, and the dummy or other active gauge between the negative terminals and the same gauge point. The positive and negative terminals are connected to the bridge supply which is fused at 1 AMP. Two 100 ohm precision resistors form the fixed arms of the bridge, so that the complete bridge is at the Terminal Unit. The Recorder inserts precision resistors in parallel with the 100 ohm resistors to obtain a null balance. This allows one wire per gauge and 6 supply and control wires per Terminal Unit only, to be taken to the Recorder and enables compensation to be made for lead length. Either 12 or 18 gauge points may be used, any spare positions being paralleled to another gauge. An earth terminal is provided.

11 THERMOCOUPLE AND RADIOMETER TERMINAL UNITS - Figs.9 and 28 and THERMOCOUPLE TERMINAL UNITS - Figs.10 and 28

Twelve transducers may be connected to a Terminal Unit. Two wires are required from each transducer since on metal specimens the transducers may be connected electrically via the specimen at an indeterminate impedance. An earth terminal is provided. If a thermocouple is not earthed at the specimen, the positive wire must be connected to the earth terminal.

The Thermocouple and Radiometer Terminal Unit is designed for insertion in a Survic Controls Ltd. constant temperature oven acting as the cold junction at 45°C. The Thermocouple Terminal Units are for use with transducers not requiring a controlled cold junction.

12 STRAIN GAUGE AND POTENTIOMETER SELECTOR UNIT - Figs.7 and 29

This unit can scan up to 12 Strain Gauge Terminal Units, denoted Y, X, 0 to 9, the number scanned being selected by the switch labelled 'Number of Terminal Units'. Either 12 or 18 gauges per Terminal Unit may be scanned. An earth terminal is provided for connection of the Recorder chassis and screened cables to the laboratory earth.

The Selector Unit incorporates two uniselectors, the 'terminal unit selector' SW.2 and the 'gauge selector' SW.1. Before the commencement of a reading cycle SW.1 is at position 2 and SW.2 at the neutral position. This is known as the Selector Unit 'neutral position' and there is therefore no signal output to the Recorder. On operating the START switch momentarily, either on the Recorder or the Selector Unit, SW.2 moves to position 1 selecting Terminal Unit Y. SELECTOR DRIVE pulses from the Recorder step SW.1 through the 12 or 18 gauges of Terminal Unit Y. SW.1 then skips through its neutral position to return to position 2. As it passes through the neutral position SW.1 steps SW.2 to position X. When SW.2 reaches the position selected by the 'Number of Terminal Units' switch it skips to its neutral position and the Recorder stops.

On position 2 of SW.1, a NOT PRINT pulse is fed to the Recorder while the first measurement is being taken. This measurement is then printed while on position 3. Hence on position 14 or 20, a spurious measurement is taken but never recorded while gauge 12 or 18 is printed. When SW.1 reaches the end of a Terminal Unit and skips, a SKIP pulse is fed, via the Recorder, to the Card Punch which ejects the punched card and resets. The measurement cycle is inhibited until the COMMENCE NEXT CARD line is connected to the Recorder i.e. until SW.1 has returned to position 2.

The 12 Terminal Unit numbers, Y, X, 0 to 9, corresponding to the 12 digits of the Card Punch, are fed to the Card Punch on one column as Terminal Unit Identification. The last digit of the Selector Unit serial number is used as Selector Unit Identification.

A bank of relays, operated in turn by SW.2, connect the Test Supply to and disconnect the Standby supply from the Terminal Unit selected.

A Manual Step switch is provided, stepping the Terminal Unit Selector SW.2.

13 THERMOCOUPLE AND VOLTAGE SELECTOR UNIT - Figs.11 and 30

This unit scans up to 12 Thermocouple and Radiometer Terminal Units, denoted Y, X, 0 to 9, the number connected being selected by the switch labelled 'Number of Terminal Units'. An earth terminal is provided for connection of the Recorder chassis and screened cables to the laboratory earth.

The Selector Unit incorporates two uniselectors, the 'Terminal Unit selector', SW.2, and the 'gauge selector', SW.1. SW.1 scans the transducers from the two Terminal Units selected by SW.2. Either 18 or 24 transducers per card may be recorded; using 18 transducers, only the first six of the second Terminal Unit are selected. Before the commencement of a reading cycle SW.1 is at position 1 and SW.2 at the neutral position. This is known as the Selector Unit 'neutral position' and there is therefore no signal output to the Recorder. On operating the START switch, either on the Recorder or the Selector Unit, SW.2 will move to position 1, selecting Terminal Units Y and X. SELECTOR DRIVE pulses from the Recorder step SW.1 through the 12, 18 or 24 gauges of Terminal Units Y and X, depending upon how many Terminal Units and how many gauges per card have been chosen. SW.1 then skips through its neutral position to return to position 1. As it passes through the neutral position, SW.1 steps SW.2 to position 2, selecting Terminal Units 0 and 1. When SW.2 reaches the position selected by the 'Number of Terminal Units', it will skip to its neutral position.

On position 1 of SW.1, a NOT PRINT pulse is fed to the Recorder while the first measurement is being taken. The first measurement is then printed while in position 2. Hence on position 13, 19 or 25 a spurious measurement is taken while gauge 12, 18 or 24 is being printed. When SW.1 reaches the end of one, or two, Terminal Units and skips, a SKIP pulse is fed via the Recorder, to the Card Punch which ejects the punched card and resets.

The measurement cycle is inhibited until the COMMENCE NEXT CARD line is connected to the Recorder i.e., until SW.1 has returned to position 1. The 12 Terminal Unit numbers, Y, X, 0 to 9 corresponding to the twelve digits of the Card Punch, are fed to one column of the Card Punch as Terminal Unit Identification. The last digit of the Selector Unit serial number is used as Selector Unit Identification. A Manual Step switch is provided, stepping the Terminal Unit Selector SW.2.

14 STRAIN GAUGE AND THERMOCOUPLE SELECTOR UNIT - Figs.12 and 31

This unit will scan 2 or 4 Strain Gauge Terminal Units and 2 or 4 Thermocouple Terminal Units. The selected Strain Gauges and Thermocouples are fed simultaneously to two Recorders, only the first 12 gauges of the Strain Gauge Terminal Units being used. An earth terminal is provided for connection of the Recorder chassis and screened cables to the laboratory earth.

The Selector Unit incorporates two uniselectors, the gauge selector, SW.1, and the Reading Number selector SW.2. By arranging pairs of wipers, A and B, 180° out-of-phase, SW.1 is converted to a 60 way selector and can route two sets of 24 gauges to one Recorder.

The Selector Unit can be made to scan either 24 or 48 gauges by operation of the Channel Switch.

The Recorder measuring strain gauges is nominated Master Recorder. Before the commencement of a reading, SW.1 is in the 'neutral position' and there is no output to the Recorders. On operating the Start switch, either on the Selector Unit or the Master Recorder, SW.1 will move to position 1, routing the first Strain Gauge and first Thermocouple to the appropriate Recorder. When more than one pair of Recorders are required to be started simultaneously, an external Synchronising Unit is used.

SELECTOR DRIVE pulses from the Recorder step SW.1 through the 24 gauges of the first two Terminal Units. SW.1 will then skip through neutral position A to the first gauge of the third Terminal Unit, or to neutral position B if only 24 gauges are being recorded. As SW.1 passes through its second neutral position, B, it steps SW.2 on to change the Reading Number Identification. This is a 1 to 50 cyclic counter which automatically resets to 1 on first switching on. When SW.1 skips, a SKIP pulse is fed via the Recorder to the Card Punch, which ejects the punched card and resets.

The measurement cycle cannot proceed on the next pair of Terminal Units until the COMMENCE NEXT CARD line is connected to the Recorder, i.e., until SW.1 has returned to position 1.

The two Strain Gauge punched cards are identified by numbers 5 and 7 and the two Thermocouple punched cards are identified by numbers 1 and 3. No Selector Unit identification is provided since not more than one Selector Unit is connected to one Recorder.

15 <u>SELECTOR ROUTING UNIT</u> - Figs.8 and 32

This unit will route the information from up to 5 Strain Gauge and Potentiometer or Thermocouple and Voltage Selector Units, numbered A to E, to one Recorder. A uniselector routes the control pulses from the Selector Units; the signal leads of the Selector Units are continually connected in parallel so that the Selector Units not connected to the Recorder must be in the neutral position, indicated by the green lights. The red lights show which unit is selected.

The Routing Unit is stepped manually by the Step switch. When the last Selector Unit has been read, stepping the Routing Unit will return it to position A. Selecting the 'Number of Selector Units' also varies the resistance of the Simulated Test Supply load so that a constant voltage is fed from the zener diode circuit to stabilise the Standby Supplies. The Standby Power Units, one for each Selector Unit, and an auxiliary 24 volt supply are also connected to the Selector Routing Unit.

16 STRAIN GAUGE AND POTENTIOMETER SIMULATOR - Figs.13 and 33

This unit contains a complete Wheatstone Bridge, fixed resistors being switched across two arms to provide an out-of-balance from -112 to +8000 digits. The simulation is only accurate for changes of out-of-balance. When simulating potentiometers, the fixed arms are open circuited. The Simulator is normally connected direct to the Recorder by the 8 core signal cable to the Digitising Amplifier and a 12 core cable to the Power Unit. The Test Supply is stabilised at the Simulator. An earth terminal is provided for connection of the Recorder chassis and screened cables to the laboratory earth.

17 TEMPERATURE SIMULATOR - Figs.14 and 34

Outputs from 0 to 1100°C at a constant resistance of 100 ohm are provided in four scales:-

0 to 110°C, 0 to 220°C, 0 to 550°C and 0 to 1100°C

each divided into 11 equal steps. The twelve outputs of any one scale are available at a 25 pin unitor plug simulating a Thermocouple Terminal Unit and 12 thermocouples. Any step may also be routed to any channel of a galvanometer Recorder via two 12 pin unitor plugs or to a single channel recorder via an 8 pin unitor plug. A mercury cell provides the e.m.f., the meter reading full-scale when the battery is at full voltage. An earth terminal is provided for connection of the Recorder chassis and screened cables to the laboratory earth.

18 TIMING SUB-UNIT - Fig.35

In the quiescent state the Selector Unit is in the neutral position and the READY (green) lamp is illuminated. The reading cycle cannot commence until the SPACE START relays are operated. These relays are closed by the SPACE pulse from the Card Punch if the 'carriage-return' contacts in the Typewriter are closed, and lock in the closed position. On operation of the START switch, (see Appendix 6) the Selector Unit moves out of the neutral position and the COMMENCE NEXT CARD line is fed to the Recorder. This closes the CONTROL relay, if the CONTROL switch is OFF, and the timing sequence commences. When synchronising two Recorders the CONTROL switch is ON and the CONTROL relay does not close until the SPACE START relays in the second Recorder have operated. Since the measurement of one gauge is memorised and printed out while the next gauge is being measured, a NOT PRINT pulse is fed to the Recorder to inhibit the Card Punch and Typewriter while the first gauge of each card is measured. Once started, the Recorder cycles until the Selector Unit has scanned the first one or two Terminal Units. The Selector Unit then feeds a SKIP pulse to the Recorder and Card Punch, which unlocks the SPACE START relays, shunts the galvanometer while the Selector Unit skips and resets the Card Punch and Typewriter. (The Card Punch may be skipped manually at the Recorder by operating the RESET ZERO button.) The Card Punch now prints the identification on the second card and feeds a SPACE pulse to the Recorder which re-starts when the COMMENCE NEXT CARD line is connected. This cycle of operations continues until all the gauges on all the Terminal Units have been scanned, when the Selector Unit returns to the neutral position.

If the START switch is permanently operated the Selector Unit immediately initiates a further reading cycle.

Each measurement consists of a 3 or 4 digit cycle known as the measurement cycle. The description given below is that of a four digit measurement cycle and is divided into four decade steps. The 3 digit cycle is similar, the pulses marked* in the text occurring one decade earlier than in the 4 digit cycle. The sequences for 3 and 4 digit measurement cycles are shown diagrammatically in Figs.36 and 37.

The four 100 m sec decimal decades of each measurement cycle are of decreasing significance, denoted 1000, 100, 10, 1 and commence on the 1000 position. Outputs are fed to the Digitising Amplifier to change its gain at each decade and two DRIVE DECADE CHANGE pulses (A and B) operate the Decade Selector Sub-Unit. At each decade a DIGITISING pulse stimulates the Digitising Amplifier and a PRINT pulse is fed to the Card Punch via the Memory and Decoder Sub-Units. During the last decade of each cycle the TRANSFER*, SELECTOR DRIVE* and CANCEL* pulses are generated, the SELECTOR DRIVE pulse also shunting the galvanometer while the Selector Unit moves.

A transistor multivibrator, locked to the mains frequency feeds a 50 c/s square wave to a dividing chain to obtain pulses with a 100 m sec period corresponding to the 10 decimal digits per second operating speed of the Recorder. A further ÷ 3 or ÷ 4 chain generates pulses with 300 or 400 m sec period corresponding to the time of one measurement cycle. The divider chains are used to drive the timing relays. It is possible to drive through the timing sequence manually in 20 m sec steps by operation of the Manual Step switch. When operating manually, to avoid generating a prolonged SELECTOR DRIVE pulse, the timer should be pulsed straight through the last 20 m sec step of each measurement cycle.

Similarly, care must be taken not to burn out a Punch solenoid by generating an extended PRINT pulse and for this reason the NOT PRINT switch should be operated when stopping manually.

A DRIVE switch disconnects the relay supply from the divider chain to allow synchronous operation driven by a second Recorder.

Unitors are provided to allow for external starting and coupling of Recorder pairs. See the Block Diagram Fig.16. The external synchronisation when using a pair of Recorders for elevated temperature testing must initiate reading cycles at intervals of not less than 10 secs for 24 gauges or 20 secs for 48 gauges.

## APPENDIX 2

## LEAD LENGTH COMPENSATION

List of Symbols used in this Appendix

$R_1$ Resistance of active gauge

$R_2$ Resistance of dummy gauge

$R_3$ $R_4$ Resistances of fixed arms of bridge

L Length of lead wires from Terminal Unit to gauge

T Temperature of wire °C

$\alpha$ Temperature coefficient of resistance of 14/0076 lead wires $= 50 \times 10^{-6} \Omega$ per ft per °C

$\rho$ Resistivity of 14/0076 lead wires $= 14 \times 10^{-3}\ \Omega$ per ft at 20°C

$\rho_T$ Resistivity of 14/0076 lead wires $= 24 \times 10^{-3}\ \Omega$ per ft at 220°C

Consider the strain gauge bridge, for example, as shown in Fig.38. The Wheatstone Bridge is formed by resistors $R_1$, $R_2$, $R_3$ and $R_4$, ($R_1$ and $R_2$ being the active and dummy gauges). The bridge is balanced by the digital potentiometer operated by the balancing relays. Spurious resistances $R_5$ to $R_{15}$ are introduced by lead, plug and socket resistances. Since $R_5$ and $R_6$ reduce the voltage to the bridge, while $R_9$ and $R_{10}$ reduce the sensitivity of the galvanometer, without affecting the balance point of the bridge, these four resistances may be ignored provided that measurements are not taken with an unbalanced bridge and that the voltage drop in $R_5$ and $R_6$ is not excessive.

The scale factor of the digital potentiometer is reduced by the resistors $R_{11}$, $R_{12}$ and $R_{13}$. For a Recorder which is 120 yards from the Terminal Unit, $R_{11} = R_{12} = R_{13} = 360\rho = 5\Omega$, which will reduce the scale factor by 0·2% since the effective resistance of the digital potentiometer is greater than 5000Ω.

The Strain Gauge Terminal Unit, illustrated in Fig.6, is designed to ensure that $R_7$, $R_8$, $R_{14}$ and $R_{15}$ are kept to a minimum by mounting the Terminal Unit in close proximity to the gauges being measured. Wiring between the Terminal Units and the Recorder has therefore a negligible effect on system accuracy. All signal connectors are gold plated to a thickness of 0·0003 in. to reduce contact potentials, resistance and corrosion and the uniselector contacts are of solid silver.

There are two methods, in current use, of wiring the gauges $R_1$ and $R_2$ to the Strain Gauge Terminal Unit, the '2 wire' and '3 wire' systems. The effect of variation of the four parameters L, T, $\alpha$ and $\rho$ on these systems for room temperature and elevated temperature tests will be examined using 120Ω gauges wired with 14/0076 leads.

## 1 ROOM TEMPERATURE TESTING

It is required that any errors shall be less than 1 digit, i.e. 0·0005% change of resistance, and shall not alter the gauge factor by more than 0·1% i.e. $R_7 \simeq 0{\cdot}1\%\ R_1 = 0{\cdot}1\Omega$.

We have, for 1 digit error,

$$0{\cdot}0005 = \frac{\alpha \times L \times T \times 100}{R_1}$$

or

$$\alpha \times L \times T = 6 \times 10^{-4}\Omega$$

Two wire system: This method requires two wires from the gauge $R_1$ to the Terminal Unit and two separate wires from the dummy $R_2$ to the Terminal Unit.

For $R_7$ to equal 0·1Ω the total length of lead from the gauge must not be greater than 8 ft. Hence the gauge must not be more than 4 ft. from the Terminal Unit.

(a) Consider the two wires comprising $R_7$, matched in length and $\alpha$ with those of the dummy wires $R_8$, but differing in temperature by T°C.

$$T = \frac{6 \times 10^{-4}}{\alpha \times L} = \frac{6 \times 10^{-4}}{50 \times 10^{-6} \times 8} = 1{\cdot}5^\circ C \quad .$$

Hence care must be taken to ensure that the wires are isothermal.

(b) Assume $R_7$ and $R_8$ differ in length by L and during a test both change temperature from 15°C to 25°C.

$$L = \frac{6 \times 10^{-4}}{\alpha \times T} = \frac{6 \times 10^{-4}}{50 \times 10^{-6} \times 10} = 1{\cdot}2 \text{ ft} \quad .$$

Under these conditions the length of wiring must be matched to within 1 ft.

(c) If the four 4 ft leads comprising $R_7$ and $R_8$ are matched in length and α, and vary from 15°C to 25°C during test, but differ in resistance due to unequal resistivities i.e. $R_7 - R_8 = 2 \times 4(\rho_7 - \rho_8)$ then

$$\frac{8(\rho_7 - \rho_8)}{\rho} = \frac{6 \times 10^{-4}}{\alpha \times T}, \qquad \frac{(\rho_7 - \rho_8) \times 100}{\rho} = \frac{6 \times 10^{-2}}{50 \times 10^{-6} \times 10 \times 8} = 15\% \ .$$

For a lead resistance of 0·1Ω a resistivity tolerance of 15% is required. Standard wire is normally within this tolerance.

(d) Similarly, if in the above case (c) instead of differing resistivities, $\alpha_7$ and $\alpha_8$ were unequal,

$$\frac{\alpha_7 - \alpha_8}{\alpha} = \frac{6 \times 10^{-4}}{L \times T}, \qquad \frac{(\alpha_7 - \alpha_8) \times 100}{\alpha} = 15\% \ .$$

The temperature coefficient of resistance must also be matched to 15%.

<u>Three Wire System</u>: This method requires 3 wires from the gauge $R_1$. One wire 'A' to the Terminal Unit positive terminal, one wire 'B' to the Terminal Unit gauge point, and one wire 'C' direct to the dummy $R_2$.

The dummy $R_2$ should be situated at the Terminal Unit so that the wire 'D' from $R_2$ to the negative terminal is very short.

Leads 'A' and 'C' are now in opposite arms of the bridge and are represented by $R_7$ and $R_8$ in Fig.38. Lead 'B' is now included in $R_9$ and merely reduces the galvanometer sensitivity as discussed above.

Wires 'A' and 'C' can now be run together and the tolerance on L and T is thus less exacting.

The effect of any variation of the parameters L, T, α, ρ will be similar to the above four cases (a) to (d).

## 2 <u>ELEVATED TEMPERATURE TESTING</u>

The desired measuring accuracy may be reduced in this case to 0.005% change of resistance and the gauge factor tolerance increased to 1% i.e. $R_7 = 1\% \ R_1 = 1\Omega$. This is a maximum value for $R_7$ and, since the temperature may change by 200°C, the room temperature resistance $R_7$ is given by:

$$R_7 \left[ 1 + 200 \frac{\alpha}{\rho} \right] = 1\Omega$$

$$R_7 = 0{\cdot}6\Omega \qquad \text{and} \quad \alpha \times L \times T = 6 \times 10^{-3}\ \Omega .$$

The high temperatures to which the leads may rise makes the use of the Three Wire System imperative, and for this system the gauge $R_1$ may be 45 ft from the Terminal Unit before the gauge factor tolerance is exceeded.

(a) At approximately 220°C the leads $R_7 = R_8 = 1\Omega$, and assuming they are equal in length and matched in $\alpha$ and $\rho$, but differ in temperature by T,

$$T = \frac{6 \times 10^{-3}}{\left(\frac{\alpha}{\rho}\right) \times (1\Omega)} = \frac{6 \times 10^{-3}}{\left(\frac{50 \times 10^{-6}}{14 \times 10^{-3}}\right) \times 1} = 1{\cdot}7°C$$

hence the need to keep the wires at the same temperature is still stringent.

(b) If, in the hot area, the leads rise 200°C during test and differ in length by L (or a resistance of L $\rho_T$)

$$L\ \rho_T = \frac{6 \times 10^{-3}}{\left(\frac{\alpha}{\rho}\right) \times T} = \frac{6 \times 10^{-3}}{\left(\frac{50 \times 10^{-6}}{14 \times 10^{-3}}\right) 200} = 8{\cdot}4 \times 10^{-3}\ \Omega$$

$$L = \frac{8{\cdot}4 \times 10^{-3}}{24 \times 10^{-3}} = 0{\cdot}35 \text{ ft}$$

and thus the length of lead in the hot area must be matched to within 4 in.

(c) If in the above case (b) the difference in resistance $R_7 \sim R_8 = 8{\cdot}4 \times 10^{-3}\ \Omega$ was due to a difference of resistivity between leads.

$$\frac{\rho_7 - \rho_8}{\rho} = \frac{R_7 - R_8}{R} = \frac{8{\cdot}4 \times 10^{-3}}{1} = 0{\cdot}8 \times 10^{-2} \quad .$$

The resistivity tolerance is 0·8% and probably means that with leads matched to 2% for resistivity the maximum length given by gauge factor **considerations,** must be reduced from 45 ft to 20 ft.

(d) Similarly if the difference of resistance at 220°C is due to difference in temperature coefficient of resistance.

$$\frac{\alpha_7 - \alpha_8}{\alpha} = \frac{R_7 - R_8}{R} = 0{\cdot}8 \times 10^{-2}$$

and the tolerance of 0·8% also therefore applies to $\alpha$.

The change in gauge factor under any of the above conditions may be allowed for in analysis if the lead resistance and its variation with temperature is known, but this is not the most stringent consideration in Elevated Temperature Testing.

The resistivity tolerance is 0·8% and probably means that with leads matched to 2% for resistivity the maximum length given by gauge factor **considerations,** must be reduced from 45 ft to 20 ft.

(d) Similarly if the difference of resistance at 220°C is due to difference in temperature coefficient of resistance.

$$\frac{\alpha_7 - \alpha_8}{\alpha} = \frac{R_7 - R_8}{R} = 0{\cdot}8 \times 10^{-2}$$

and the tolerance of 0·8% also therefore applies to $\alpha$.

The change in gauge factor under any of the above conditions may be allowed for in analysis if the lead resistance and its variation with temperature is known, but this is not the most stringent consideration in Elevated Temperature Testing.

## APPENDIX 3

## SCALE LINEARISATION - STRAIN GAUGES AND POTENTIOMETERS[2]

List of Symbols used in this Appendix

| | |
|---|---|
| a | Scale constant = $2 \times 10^5$ digits |
| b | Minimum Value of $R_1/R_2$ |
| c | Unit digital resistor $39{\cdot}54 \times 10^6$ ohm |
| d | Resistor constant for bridge balance at 4333 when $R_1 = R_2$ |
| G | Galvanometer |
| m | Maximum value of numerical balance of Recorder = 8665 |
| n | Numerical balance point of the Recorder |
| $R_1$ | Resistance of active gauge |
| $R_2$ | Resistance of dummy gauge |
| $R_3$ $R_4$ | Resistances of fixed arms of bridge |
| V | Energising voltage at strain gauge bridge |
| $V_1$ | Voltage across $R_1$ |
| $V_2$ | Voltage across $R_3$ |

Since the Recorder is required to balance bridges containing gauge pairs the resistances of which may be between 50 and 5000Ω and in which the initial out-of-balance may exceed that due to strain, a given small change in strain at the gauge $R_1$ must produce the same change in the reading whatever the initial values of $R_1$ and $R_2$. If dn is the change in the reading, this means that for a fixed value of $R_2$ we must have

$$dn \propto \text{strain} \propto dR_1/R_1 \propto d(\ell n\, R_1) \quad .$$

The resistance of the unstrained gauge is such that $R_1/R_2$ is independent of temperature. Thus the following equation must hold for varying temperature,

$$dn = a\, d\{\ell n(R_1/R_2)\}$$

giving

$$\frac{R_1}{R_2} = b \exp\left(\frac{n}{a}\right) \tag{1}$$

as the required scale slope for the Recorder.

With the notation of Fig.39 we have

$$\frac{V_1}{V} = \frac{R_1}{R_1 + R_2}$$

$$= \left\{1 + \frac{1}{b}\exp\left(-\frac{n}{a}\right)\right\}^{-1} \quad \text{from (1)} \quad .$$

Expanding the exponential powers of n/a (assumed small) gives:

$$\frac{V_1}{V} = \frac{b}{1+b}\left\{1 - \frac{n}{a(1+b)} + \frac{n^2}{2a^2b(1+b)} \cdots\right\}^{-1}$$

and using the binomial expansion of $(1 + x)^{-1}$ where $x = \frac{-n}{a(1+b)} + \ldots$ gives

$$\frac{V_1}{V} = \frac{b}{1+b}\left\{1 + \frac{n}{a(1+b)} - \frac{n^2}{2a^2b(1+b)} + \frac{n^2}{a^2(1+b)^2} \cdots\right\} \quad .$$

If (b - 1) is a small quantity of order n/a (as it must be from (1), if $R_1 = R_2$ at some point within the scale), the coefficient of $n^2/a$ is zero and

$$\frac{V_1}{V} = \frac{b}{1+b}\left\{1 + \frac{n}{a(1+b)} + \text{terms in } \frac{n^3}{a^3}\right\} \quad . \tag{2}$$

The resistance network in Fig.39 gives

$$\frac{V_2}{V} = \frac{c + 100(d+n)}{2c + 100(d+m)} \quad . \tag{3}$$

The balance condition $V_1 = V_2$ therefore leads to a value of n linearly related to strain if c and d are given values which make the right hand sides of (2) and (3) equivalent.

The equations to be satisfied are:

$$\frac{c + 100\,d}{2c + 100(d+m)} = \frac{b}{1+b} \quad \text{and} \quad \frac{100}{2c + 100(d+m)} = \frac{b}{a(1+b)^2}$$

giving

$$c = 100\left\{a\left(1 + \frac{1}{b}\right) - m\right\} \tag{4}$$

and

$$d = a\left(b - \frac{1}{b}\right) + m \quad . \tag{5}$$

We require that $m = 8665$, $a = 2 \times 10^5$ and that $n = 4333$ when $R_1 = R_2$. Hence from (1)

$$b = \exp - \frac{4333}{2\times10^5} = e^{-0\cdot02} = 0\cdot9802$$

and the condition that $b \simeq 1$ is satisfied. (4) and (5) now give

$$c = 100(2 \times 10^5 \times 2\cdot0202 - 8665) = 39\cdot54 \times 10^6$$

$$d = 2 \times 10^5 \times (-\ 0\cdot04000) + 8665 = 665$$

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## APPENDIX 4

## SCALE LINEARISATION - MILLIVOLTS AND THERMOCOUPLES

List of Symbols used in this Appendix

| | |
|---|---|
| $b_1$ | Scale constant for millivolts - 100 μV/digit |
| $b_2$ | Scale constant for thermocouples 0 - 433°C, 41 μV/digit |
| $b_3$ | Scale constant for thermocouples 433 - 865°C, 42·6 μ/digit |
| c | Unit digital resistor $3{\cdot}954 \times 10^6$ ohms |
| m | Maximum value of numerical balance of Recorder = 865 |
| n | Numerical balance point of the Recorder |
| $r_1$ | Precision Resistor determining balance voltage for millivolts |
| $r_2$ | Precision Resistor determining balance voltage for thermocouples |
| R | Matched resistor pair |
| $R_c$ | Linearising resistor for $T_1/T_2$ thermocouples |
| V | Stabilised voltage supply |
| $v_r$ | Voltage generated to balance transducer input |
| y | Hinge point of $T_1/T_2$ thermocouple scale |

Millivolts

The basic circuit given in Fig.40 may be redrawn, using Thevenin's theorem, as in Fig.41 since the stabilised voltage supply V is of negligible impedance. From the latter diagram, using Kirckoff's laws, we obtain the voltage $v_{r_1}$ developed across $r_1$ to balance the transducer input voltage.

$$v_{r_1} = \frac{V\, r_1 \left(\frac{c}{m}\right)}{c\left(\frac{c}{m} + R + 2r_1\right)}\, n \qquad (1)$$

Thus $v_{r_1}$ is proportional to n and the scale slope $b_1$ is given by

$$b_1 = \frac{V\, r_1 \left(\frac{c}{m}\right)}{c\left(\frac{c}{m} + R + 2r_1\right)} \qquad (2)$$

Hence the value of $r_1$ is obtained.

$T_1/T_2$ Thermocouple

The $T_1/T_2$ scale has two slopes $b_2$ and $b_3$ hinged at the point y as shown in Fig.42. Consider the cold junction to be at 0°C. For temperatures from 0°C up to n = y, the circuit, Fig.43a is similar to that in Fig.41 for millivolts, and we obtain:

$$v_{r_2} = \frac{V\, r_2 \left(\frac{c}{m}\right) n}{c\left[\left(\frac{c}{m} + R_c\right) + R + 2r_2\right]} \quad . \tag{3}$$

Thus $v_{r_2}$ is proportional to n and the scale slope $b_2$ is given by

$$b_2 = \frac{V \left(\frac{c}{m}\right)}{c\left[\left(\frac{c}{m} + R_c\right) + R + 2r_2\right]} \quad . \tag{4}$$

From n = y to n = m the circuit is modified to that shown in Fig.43b. Again applying Kirckoff's Laws we obtain an expression for the balance voltage across $r_2$,

$$v_{r_2} = \frac{V\, r_2 \left(\frac{c}{m} + R_c\right) n - V \frac{m\, r_2}{2} R_c}{\left\{c\left[\left(\frac{c}{m} + R_c\right) + R + 2r_2\right] + \frac{R_c}{2}\left(R + 2r_2\right)\right\}} \quad .$$

Since

$$c\left[\left(\frac{c}{m} + R_c\right) + R + 2r_2\right] >> \frac{R_c}{2}\left(R + 2r_2\right) , \quad v_{r_2} \simeq \frac{V\, r_2 \left(\frac{c}{m} + R_c\right) n}{c\left[\left(\frac{c}{m} + R_c\right) + R + 2r_2\right]}$$

$$- \frac{V\, m\, r_2\, R_c}{2c\left[\left(\frac{c}{m} + R_c\right) + R + 2r_2\right]} \tag{5}$$

hence

$$b_3 = \frac{V\, r_2 \left(\frac{c}{m} + R_c\right)}{c\left[\left(\frac{c}{m} + R_c\right) + R + 2r_2\right]} \tag{6}$$

and

$$y = \frac{1}{(b_3 - b_2)} \frac{V\,m\,r_2\,R_c}{2c\left[\left(\frac{c}{m} + R_c\right) + R + 2r_2\right]} \quad . \tag{7}$$

From equations (4) and (6)

$$R_c = \frac{(b_3 - b_2)}{b_2} \frac{c}{m} \tag{8}$$

and substituting for $R_c$ in equation (6) the value of $R_2$ is obtained. From equation (4) and (7) and substituting for $R_c$ from equation (8) the value of y is given as $\frac{m}{2}$. Hence the hinge point from $b_2$ to $b_3$ is at 433°C.

The full scale of the millivolt and thermocouple zero adjustments alter the scale slopes by less than 0·05%.

The deviation of the Recorder thermocouple scale from the true $T_1/T_2$ calibration[3] is shown in Fig.44.

# APPENDIX 5

## SETTING UP AND CALIBRATION PROCEDURE

### 1 SETTING-UP PROCEDURE FOR DIGITISING AMPLIFIER

1.1 Adjustment of resistors.

(a) Insert simulator, and earth.

(b) Set mechanical zero of DIGITISER INPUT meter (M1).

(c) Switch on and leave for 1 minute.

(d) Set 7 volt TEST SUPPLY in power unit to 7V ±0·01V.

(e) Adjust R11 to give full swing from -ve to +ve rail on M1, using SIMULATE DIGITISER INPUT potentiometer.

(f) Adjust DIGITISER ZERO SET FOR 12/13 transition as indicated on M1.

(g) Adjust SENSITIVITY control for 2/3 transition to occur as indicated on M1.

(h) If necessary, repeat (e) and (f).

(i) Check all transitions to occur at positions indicated on M1.

1.2 Check procedure (to be performed at regular intervals).

(a) Depress Test Amplifier switch to SIMULATE DIGITISER INPUT and set to read 1 on 0-15 digital scale of meter (see Fig.46).

(b) Operate Start switch and, at the end of each card, increase simulation by one digit, up to 15.

(c) Switch TIMER off during ejection of the 15th card and check the cards read as follows:-

3 digits/measurement

| Card | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | 011, | 122, | 133, | 244, | 255, | 366, | 377, | 488, | 499, | 610, | 621, | 732, | 743, | 854, | 865 |

4 digits/measurement

| Card | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | 0111, | 1222, | 1333, | 2444, | 2555, | 3666, | 3777, | 4888, | 4999, | 6110, | 6221, | 7332, | 7443, | 8554, | 8665 |

(d) Raise to TEST AMPLIFIER and adjust mechanical zero of galvanometer (fine adjustment made by moving lamp).

(e) Return TEST AMPLIFIER switch to mid position and START switch to mid position.

(f) Switch TIMER on and run until the Selector Unit reaches the neutral position.

## 2 CALIBRATION PROCEDURE

### 2.1 Digitising Amplifier (A) Fig.19

(a) Set FUNCTION SELECTOR to STRAIN GAUGES and plug in Strain Gauge Simulator.

(b) Set Timing Unit to 1's position by operating MANUAL STEP switch. Adjust FEEDBACK potentiometer till a change of 10 digits (1 on X10 range of Simulator) produces a digital change of 10 ±1 on meter M1.

(c) Set Timing Unit to 1000's position.
Measure the number of digits change on Simulator required to produce 6 digits change on M1. Adjust R56 till number is 6000 ±60.

(d) Set Timing Unit to 100's position.
Measure number of digits change on Simulator required to produce 14 digits change on M1. Adjust R57 till number is 1400 ±14.

(e) Set Timing Unit to 10's position.
Measure number of digits change on Simulator required to produce 14 digits change on M1. Adjust R58 till number is 140 ±2.

### 2.2 Balancing and Memory Unit

(a) With analogue scale of M1 at 1, digitise - check M1 now reads 9

(b) " " " " " 13, " " " "

(c) " " " " " 11, " " " "

(d) " " " " " 10, " " " "

The above procedure should be carried out on 1000's, 100's and 10's position. (d) is not used on 1000's position.

### 2.3 Digitising Amplifier (B - $T_1/T_2$ scale) (3 digits/measurement)

(a) Disconnect feedback wire from emitter VT2 and set to SIMULATE DIGITISER INPUT.

(b) Set FUNCTION SELECTOR to $T_1/T_2$ THERMOCOUPLE.

(c) Set $T_1/T_2$ ZERO potentiometer to mid position.

(d) Check that approximately 42·6 µV/digit are produced across R62 from 433 to 865 digits by changing balancing relays from 4000 + 300 + 30 to 7000 + 1500 + 150. If necessary adjust R62.

(e) Check that with the balancing relays at 0 (4000, 800 and 80 relays operated), approximately 1 mV (25°C) is produced across R62. Adjust $T_1/T_2$ ZERO, and if the above condition is not fulfilled with the potentiometer near its mid position, adjust R70.

(f) Repeat (d) to within ±0·1%.

(g) Adjust R13 (in Balancing and Print Out Unit) to give 41 µV/digit from 0 to 432 (3000 + 1200 + 120) to ±0·1%).

N.B. On $T_1/T_2$ scale $V_T = 41 \times T$ µV up to 433°C

$V_T = (42{\cdot}6 \times T - 693)$ µV above 433°C

(h) Reconnect feedback wire to VT2 emitter.

2.4 Digitising Amplifier (C - mV scale) (3 digits/measurement)

(a) Disconnect feedback wire from emitter VT2 and set to SIMULATE DIGITISER INPUT.

(b) Set FUNCTION SELECTOR to MILLIVOLTAGE.

(c) Set M.VOLT ZERO potentiometer to mid position.

(d) Check that approximately 100 µV/digit are produced across R61 from 0 to 865 by changing balancing relays from 0(4000, 800 and 80 operated) to 7000 + 1500 + 15. Adjust R61 if necessary.

(e) Check that with the balancing relays at 0, no voltage is produced across R61. Adjust M.VOLT ZERO and if this condition is not fulfilled with the potentiometer near its mid position, adjust R67.

(f) Repeat (d) to within ±0·1%.

## APPENDIX 6

## OPERATING THE RECORDER

The universal nature of the Recorder necessitates a minimum setting-up procedure for each type of measurement. A listed outline of the initial switch settings is given, followed by a detailed explanation of the identification facilities and operating procedure.

### 1 INITIAL SWITCH SETTINGS

Recorder. Function Selector: Strain Gauges, Potentiometers, Millivolts, $T_1/T_2$ Thermocouples

Digits: 3 or 4 digits per measurement cycle

Control: OFF

Timer: OFF

Drive: ON

Start Switch: OFF

Selector Unit. Number of Terminal Units 1,2,3 ..... 10 or 12.

Number of Gauges per Terminal Unit: 12 or 18.

Start switch OFF

Card punch. Plug board

Auto plug identification.

(For method of setting up this information see note below.)

For elevated temperature testing, connect up Recorder pairs and switch Control ON on all Recorders.

N.B. The Recorder power supplies should be switched on at least 1 min. before measuring thermocouples and voltages, or 1 hour before measuring strain gauges.

### 1.1 Card Punch Identification See Figs.3 and 24

Definitions

(a) a 'measurement' or 'measurement cycle' consists of the 3 or 4 digits corresponding to one transducer,

(b) a 'set of measurements' is the block of 12, 18 or 24 'measurements' punched on one card,

(c) a 'reading' or 'reading cycle' is the complete scanning and recording of all the transducers connected to one Selector Unit.

Information which will not change during test may be automatically punched by using link plugs to connect the desired digit to the appropriate column, on the plug board. The plug board is situated at the top of the card punch.

Frequently changing information is selected by use of the auto plug unit. The appropriate column is connected to one of the 12 auto plug points on the plug board and the required digit selected on the corresponding switch on the auto plug unit.

Identification information may be positioned in any columns preceding or following the set of measurements. It is essential that a space pulse be plugged in the column immediately preceding the first measurement. The space pulse initiates the reading cycle and can be used as a master switch at the auto plug unit if required. The transducer measurements must be in 36, 48, 54 or 72 sequential columns.

'Cancel skip' if used, should always be called one column earlier than required and any number (not space) be plugged in the following column. This is a safeguard against the Punch carriage over-running the cancel call.

#### 1.1.1 Strain Gauge and Potentiometer Selector Units or Thermocouple and Voltage Selector Units

These are identified by the last digit of their serial number. This will be automatically punched if position 7/20 is connected to the required column on the plug board. Identification of the Terminal Unit being measured may be similarly connected to the appropriate column from position 6/20.

#### 1.1.2 Strain Gauge and Thermocouple Selector Units

The Strain Gauge and Thermocouple Selector Unit provides a Terminal Unit Identification on position 6/20 of the plug board. A 1-50 counter steps on at the end of every set of readings and provides a serial identification of the Reading Number on positions 7/20 and 8/20.

### 1.2 Operating Procedure

This procedure should be followed in detail when commencing a series of recordings, but may be considerably reduced on subsequent operation.

Starting: The reading cycle may be initiated at the Recorder, Selector Unit or the Card punch. Each operation is in itself simple, but because of the different modes some explanation is necessary. The START switch 'A' on the Selector Unit is an ON/OFF switch connected in parallel with the START ON/OFF switch 'B' at the Recorder. When one of the START switches A or B is switched ON the reading cycle commences as soon as a SPACE is received from the Card Punch. A 4 pin unitor plug is wired in parallel with the Recorder START switch 'B', to facilitate remote control.

Operating from the Recorder. Set switch 'A' OFF, switch 'B' to OFF and plug SPACE in the appropriate position on the Card Punch. To start, switch 'B' ON momentarily and the Recorder proceeds through one reading cycle. For continuous cycling, switch 'B' is left ON.

Operating from the Selector Unit. Set switch 'A' OFF, switch 'B' OFF and plug SPACE in the appropriate position on the Card Punch. To start, switch 'A' ON momentarily and the Recorder proceeds through one reading cycle. For continuous cycling, switch 'A' is left ON. Operation from the Selector Unit is not possible when using the Selector Routing Unit.

Operating from Card Punch. Switch 'A' or 'B' is switched ON and the SPACE pulse is connected via the Autoplug unit and the channel switch used is set to the blank position. To start, set the Autoplug switch to SPACE and the Recorder will continuously cycle until the Autoplug switch is returned to the blank position.

In the following sections it is assumed, for sake of clarity, that the reading cycle is started at the Recorder.

Recorder: Switch power supplies ON and check voltages.

Test Voltage Adjustment

Set the Test Supply by depressing the push switch and adjusting the potentiometer until the meter deflection is zero.

Selector Unit: Check the READY (green) lights on all units are illuminated, and the START switch is in the OFF position.

Selector Routing Unit: Check the READY (green) lights, corresponding to those Selector Units in use, are illuminated.
Check that the Routing Unit is in the 1st position (red light).

Card Punch: Insert a card stack and inspect them for bent or snagged edges.
Switch ON and call skip (Blank button on punch control unit).
If there was no card in the punch previously, operate the card eject lever.
Check identification on the card in the punch. After changing the card identification, skip a card through the punch before commencing a reading cycle. (This is not necessary if the identification is positioned after the set of measurements on the card.)

Typewriter: Insert double or extra thick paper at least 8" wide.
Switch ON.

1.2.1 When using one selector unit

Switch TIMER ON.

Operate the START switch on the Recorder momentarily. The Recorder will scan all the gauges once and stop.

If continuous cycling is required, leave the START switch in the ON position.

1.2.2 When using the selector routing unit

Switch TIMER ON.

Operate the START switch on the Recorder. The Recorder will scan all the gauges in the first Selector Unit.

On completion of the first Selector Unit, the green light will reappear on position 1 of the Routing Unit.

Step the Routing Unit to the next Selector Unit 2. The red light on the Routing Unit will move to the next position 2.

Skip a card through the Punch by operating the RESET ZERO button on the Recorder or the blank (SKIP) button on the card punch. (This is not necessary if the identification is positioned after the set of measurements on a card.) Operate the START switch on the Recorder.

Repeat the above procedure for the remaining Selector Units and return the Routing Unit to position 1. Skip a card through the Punch.

1.2.3 When elevated temperature strength testing

Couple up the pair of Recorders and switch DRIVE off on Recorder measuring thermocouples.

Switch TIMER on at both Recorders.

Start reading cycle either by an external synchronising unit, or by switching ON the START switches on both Recorders and initiating the cycle by switching the SPACE pulse on one Card Punch.

At regular intervals the mechanical zero of the galvanometer should be adjusted and the Setting Up Procedure given in Appendix 5.1.2 carried out.

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## APPENDIX 7

## FAULT FINDING

### 1. U/S Measurements

| Unit | | Check | Correct Operation | Possible Faults |
|---|---|---|---|---|
| | | Earth connections | | |
| Digitising Amplifier | 1. | Mechanical Zero of galvanometer | ±2 Digits of indicated position on M1 | |
| | 2. | Setting of U/S circuit, by rotating galvanometer | Relay R.L. 16 opens when INPUT meter exceeds range 0 - 16 | Transistors VT.3 and VT.4 |
| Terminal Unit | 3. | Cables, by interchanging | | Fuse blown or faulty cable |
| Selector Unit | 4. | Cables, by interchanging | | |
| | 5. | Clean uniselector contacts | | |
| | 6. | Adjustment of uniselector motor | Wipers in mid position of segments | |
| Digitising Amplifier | 7. | Digitising of simulated input, 0 - 15. | Digital output lights correspond to digital scale of meter | Relays R.L. 1 - R.L. 15 |
| | | Plot input voltage at SW 1A/2 against transition of digital output lights | Straight Line | Transition points off the line indicate faulty digitising |
| | 8. | Balancing and Memory sub-unit Operation of Balancing relays | As given in Appendix V 2.2 | Relays R.L. 29 - R.L. 40, decade selector or Digitising Amplifier feed diodes. |
| Timing sub-unit | 9. | Timing of Cancel rail | As given in Figs.36 and 37 | Relay R.L.75 |

## 2. Misprints Correctly Digitised Information

| Unit | | Check | Correct Operation | Possible Faults |
|---|---|---|---|---|
| Balancing and Memory sub-unit | 1. | Operation of Memory relays | Operate during Transfer pulse | Feed diodes MR. 7 - MR. 17, decade selector. Relays R.L. 12 - R.L.27 |
| Timing sub-unit | 2. | Timing of Cancel and Transfer rails | As given in Figs.36 and 37 | Relays R.L. 75 and R.L. 76 |
| Decoder sub-unit | 3. | Operation of Decoder | Relays must stabilise before PRINT pulse | Slow operation of relays R.L. 1 - R.L. 9 |
| Card Punch | 4. | Obtain services of punch engineer | | |



### PUNCH FAILS TO FEED CARD

Card punch — Cards warped or badly stacked, Switch off typewriter, Remove bottom 3 cards from stack, SKIP and manually operate card lever. Switch typewriter on.

### CARD JAMS IN PUNCH

Switch off SPACE, typewriter and punch. Remove damaged card and switch on punch. SKIP and manually operate card lever. Switch typewriter and SPACE on.

## 3. Timer will not Operate, or Operates Intermittently

| Unit | Check | Correct Operation | Possible Faults |
|---|---|---|---|
| Timing sub-unit | 1. TIMER switched on 50 c/s lock ON | | |
| | 2. 50 c/s output from multi-vibrator | square wave, 4 volt peak-to-peak | CONTROL circuit or R.L.67 open. |
| | 3. SPACE pulse supplied from punch | -150 volt applied across R. 98 and R.L. 65 | Not plugged or switched at punch. |
| | 4. Typewriter carriage return contacts (C.R.) | closed when C.R. not operating | adjustment of contacts in typewriter |
| | 5. COMMENCE NEXT CARD input | +24 volt on 19/SK.2 | Selector Unit disconnected or in SKIP position |
| | 6. Operation of relays R.L. 58 - R.L. 63 | as given in Figs.36 and 37 | Binary units, transistors V.T. 3 - V.T. 13, relays R.L. 58 - R.L. 63 |
| | 7. Operation of relays R.L. 72 - R.L. 76 | as given in Figs.36 and 37 | Relays R.L. 72 - R.L. 76 |

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## 4. Punch Fails to Print, or Prints Erratically

| Unit | Check | Correct Operation | Possible Faults |
|---|---|---|---|
| | 1. Punch and typewriter ON | | |
| Timing sub-unit | 2. Operation of RESET ZERO switch | Skips punch, indicating -150V supplied | Fuses in punch blown. |
| | 3. Operation of PRINT pulse | as given in Figs.36 and 37 | Relays R.L. 64, R.L. 68 and R.L. 69. |
| Decoder sub-unit | 4. Operation of relay tree | relays must have stabilised before PRINT pulse | Slow operation of relays R.L. 1 - R.L. 9. |
| Balancing and Memory sub-unit | 5. Timing of information input to Decoder | relays must have stabilised before PRINT pulse | Decade Selector or Memory relays. |

TABLE I—**Use of redundant coding to increase amplifier tolerance**

| Decade $10^n$ | The two ways of obtaining balance at 4388 | | Eight ways of obtaining balance at 4333 | | | | | | | | Digitizing-amplifier tolerance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | % full scale | Digits |
| 0–7 thousands | 4000 | 3000 | 4000 | 4000 | 4000 | 4000 | 3000 | 3000 | 3000 | 3000 | + 11·1<br>− 0·033 | + 667<br>− 2 |
| 0–15 hundreds | 300 | 1300 | 300 | 300 | 200 | 200 | 1300 | 1300 | 1200 | 1200 | + 4·8<br>− 0·14 | + 67<br>− 2 |
| 0–15 tens | 80 | 80 | 30 | 20 | 130 | 120 | 30 | 20 | 130 | 120 | + 5<br>− 1·4 | + 7<br>− 2 |
| 0–15 units | 8 | 8 | 3 | 13 | 3 | 13 | 3 | 13 | 3 | 13 | + 11<br>− 11 | + 1½<br>− 1½ |
| | 4388 | 4388 | 4333 | 4333 | 4333 | 4333 | 4333 | 4333 | 4333 | 4333 | | |

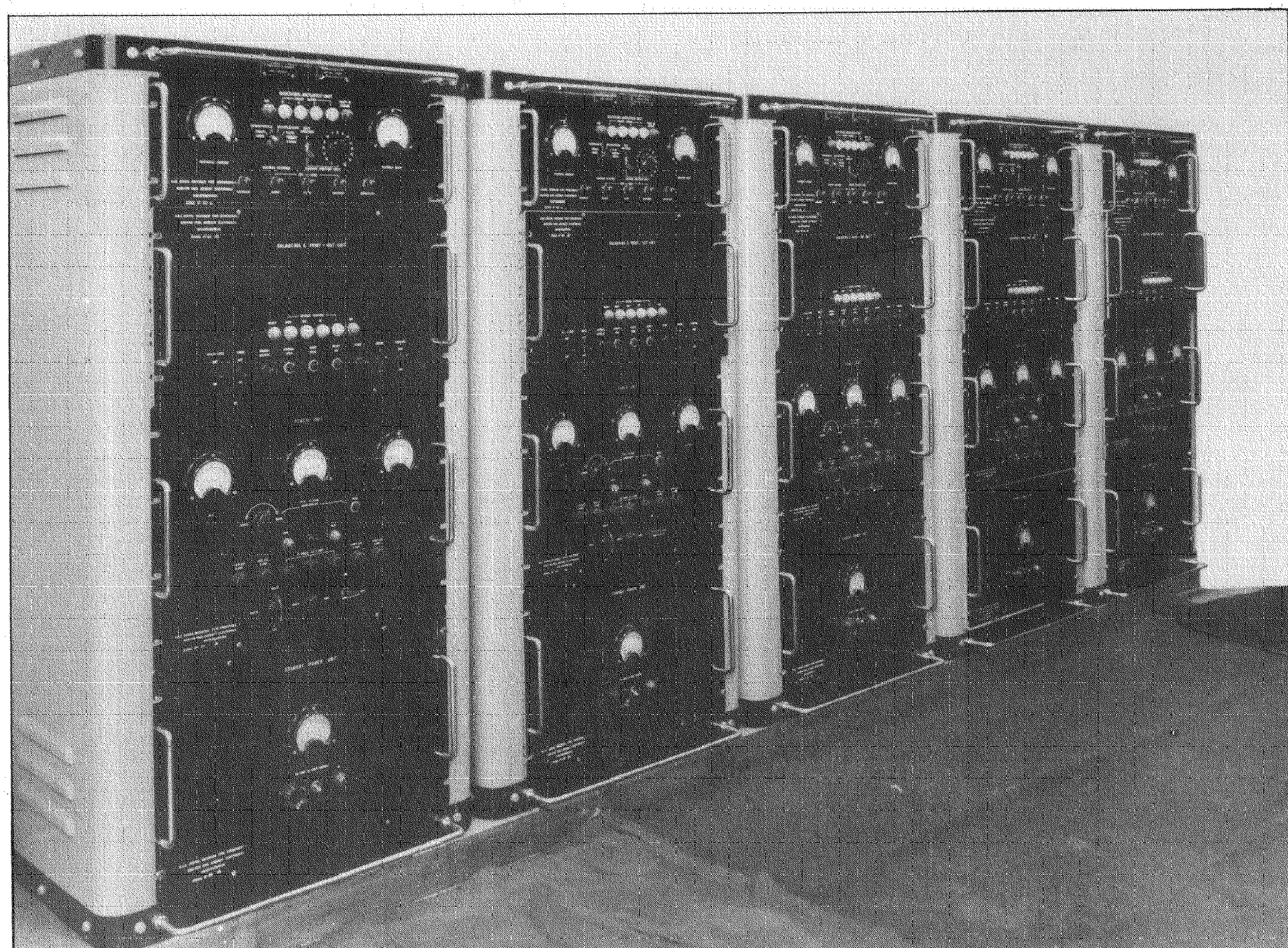


FIG. 1 BANK OF FIVE RECORDERS

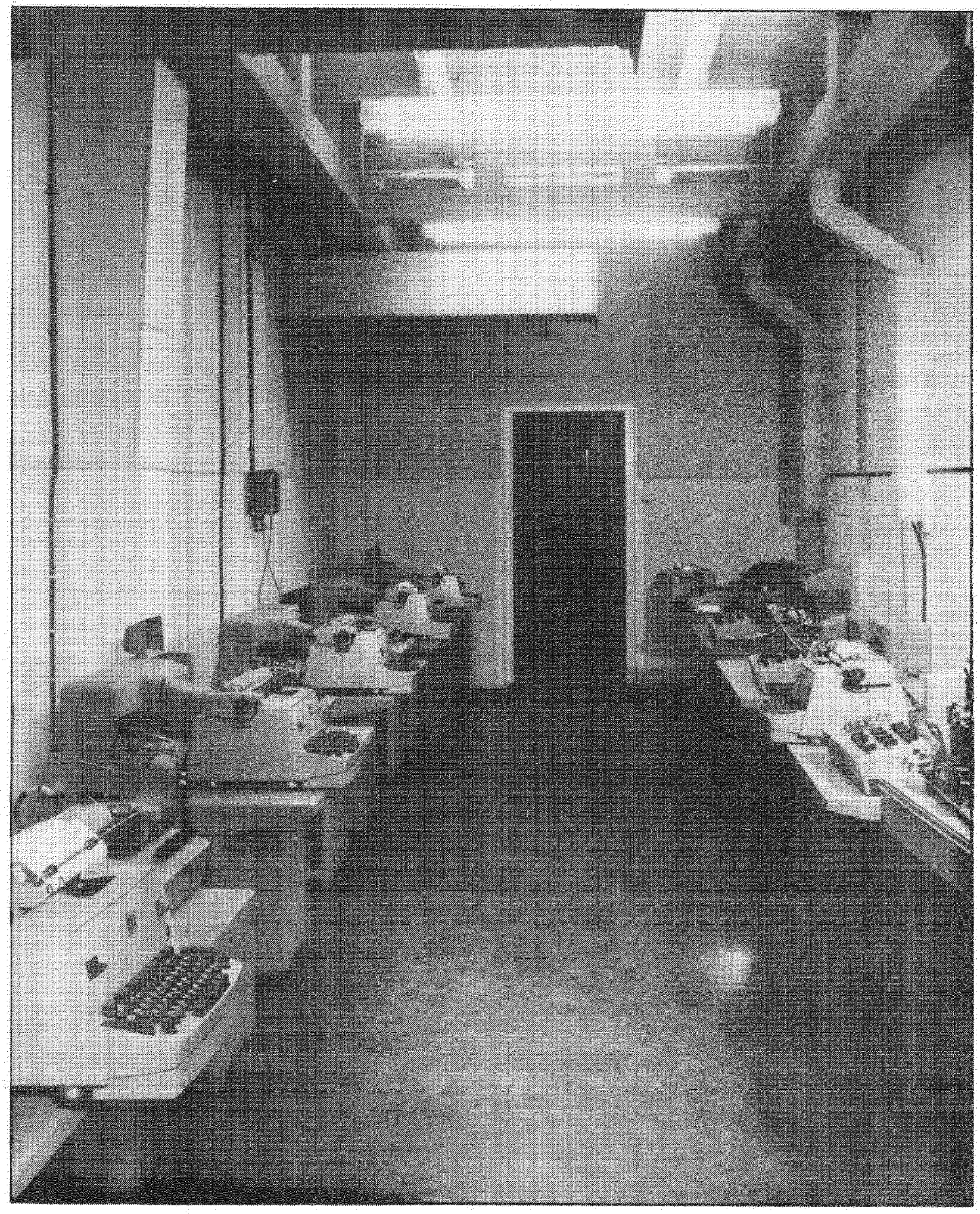


FIG. 2 RECORDING ROOM

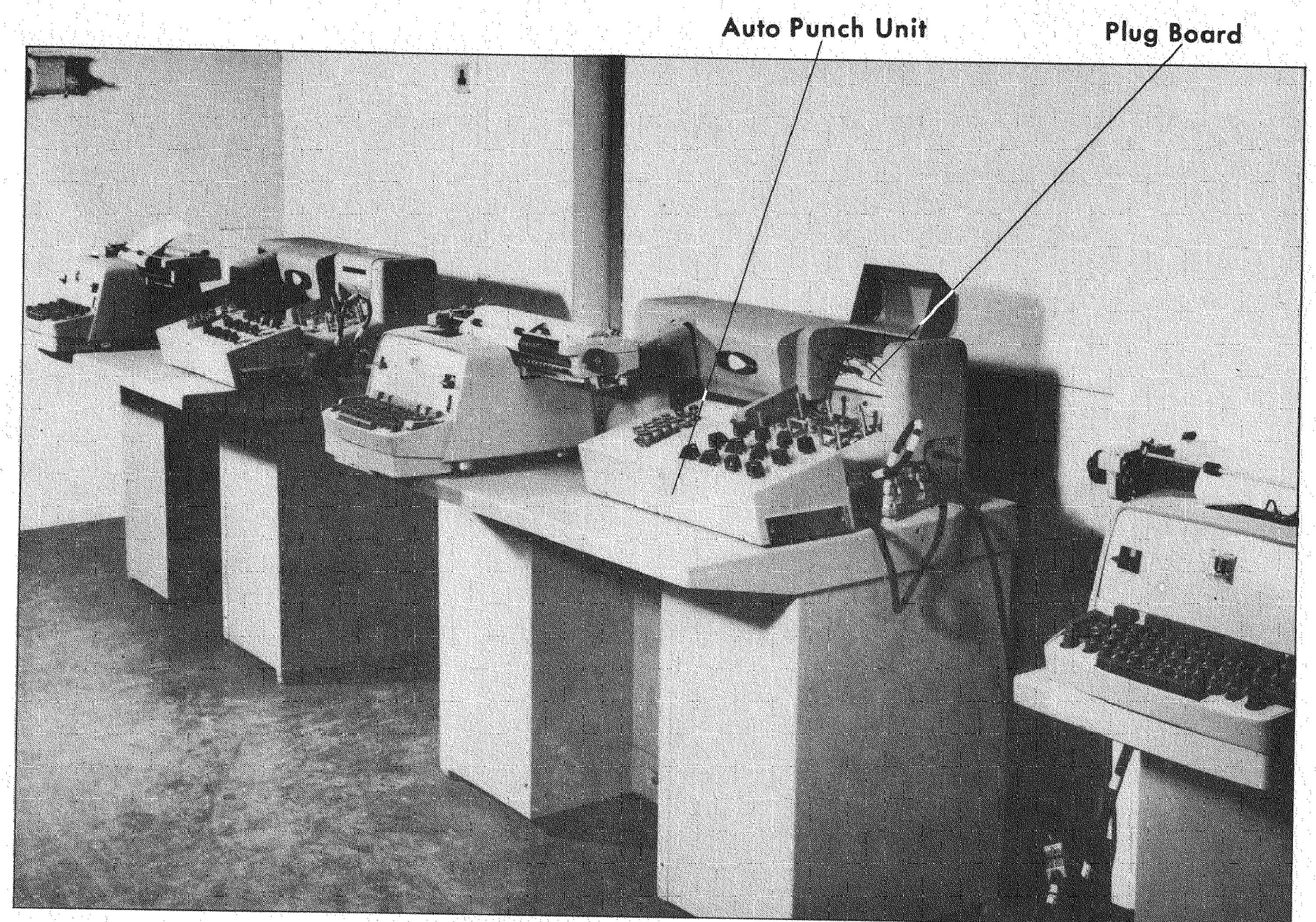



FIG. 3 CARD PUNCHES AND TYPEWRITERS

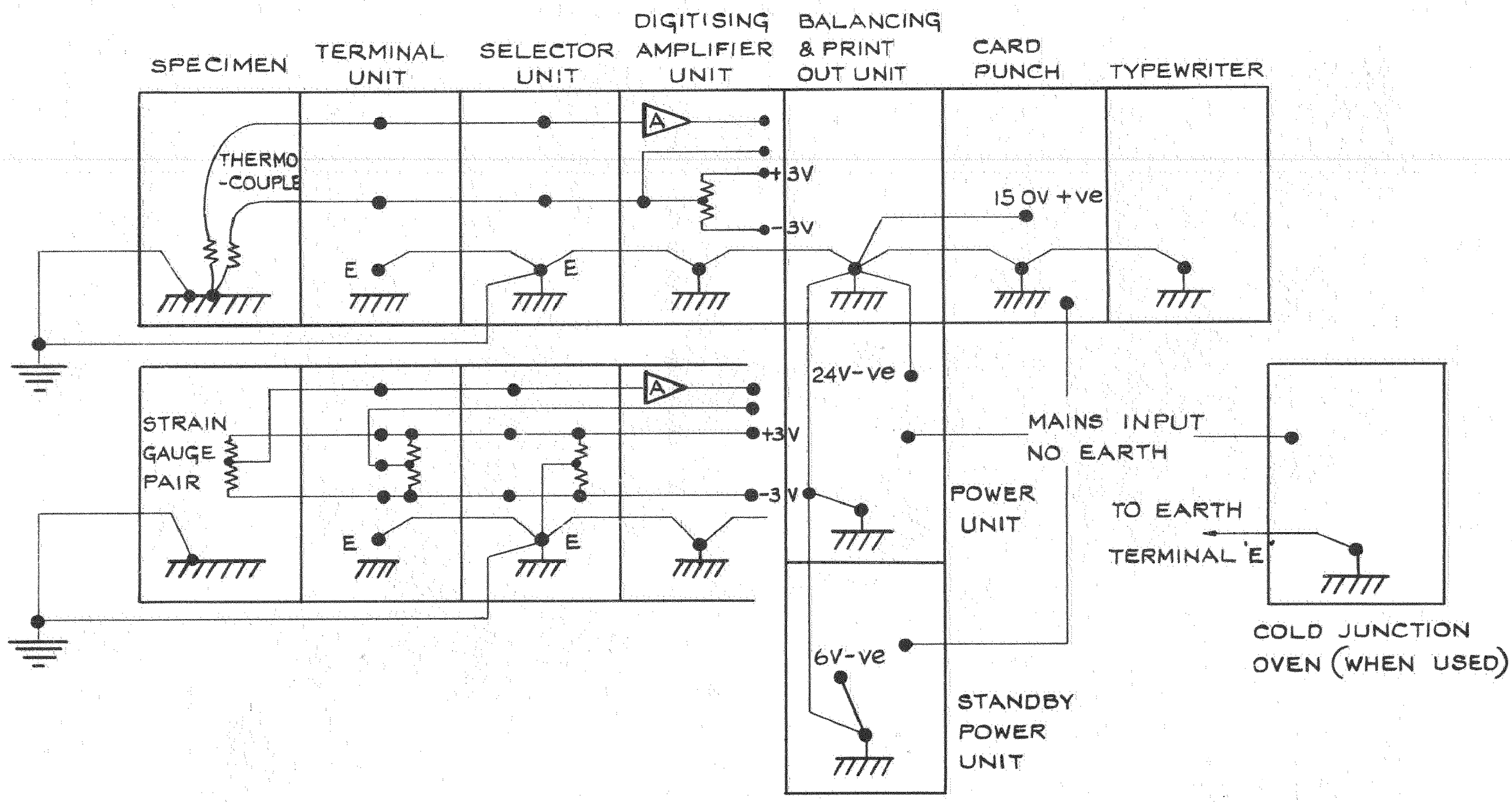



FIG. 4. EARTH CONNECTIONS

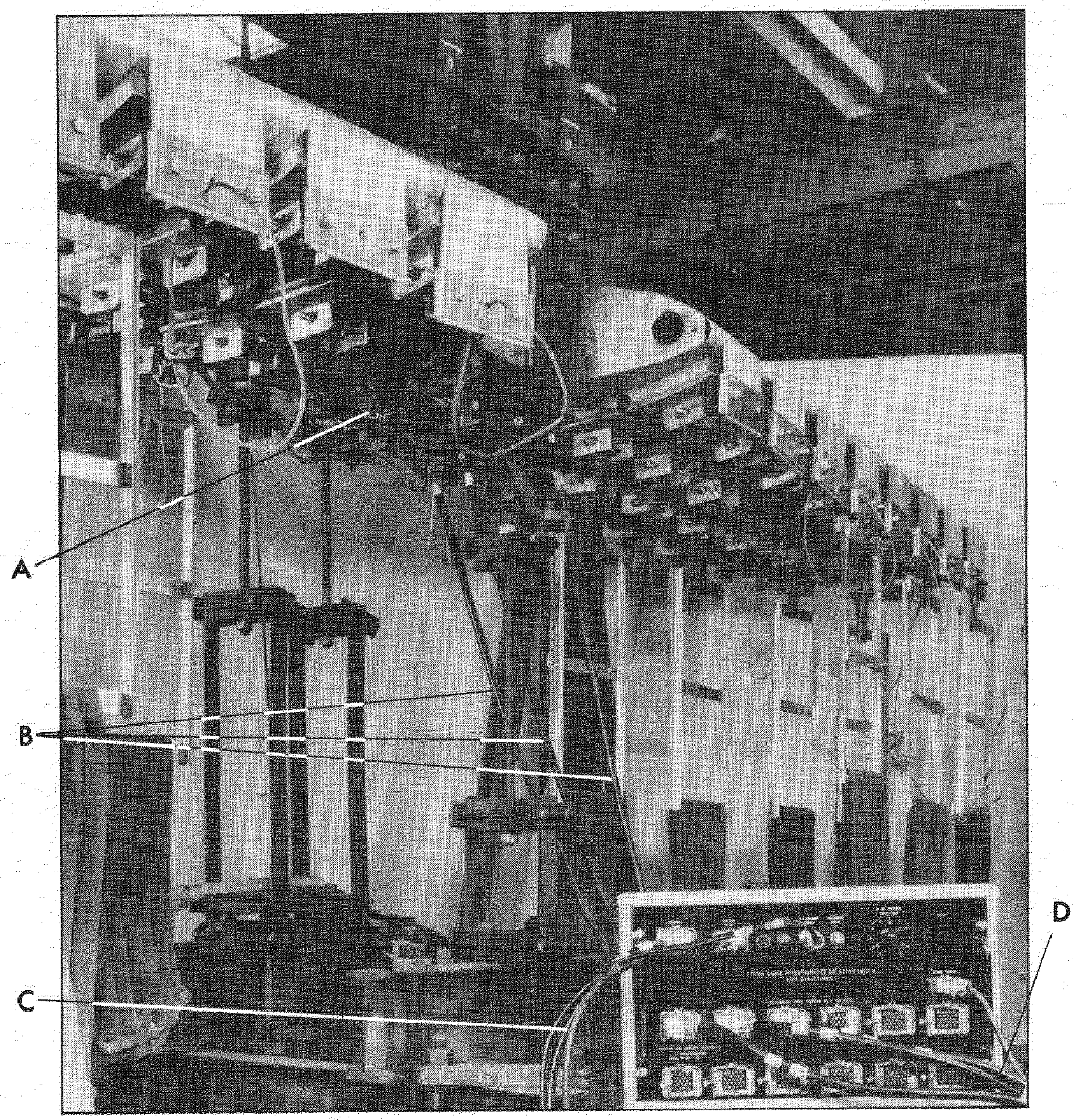



FIG. 5 TAIL PLANE INSTALLATION

NOTE: The Terminal Units(A) are located close to the gauges, and are connected by short multicore cables (B) to the Selector Unit. The control cables (C) from the Recorder 75yds away, are loomed well clear of the signal cables (D).

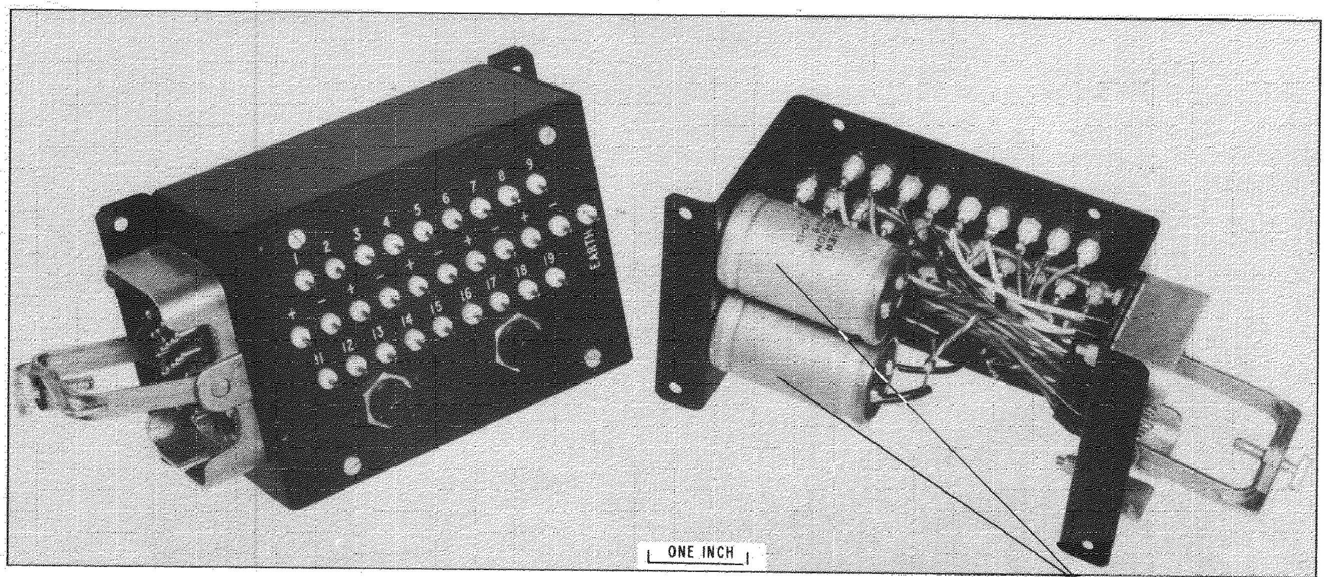



FIG. 6 STRAIN GAUGE TERMINAL UNIT

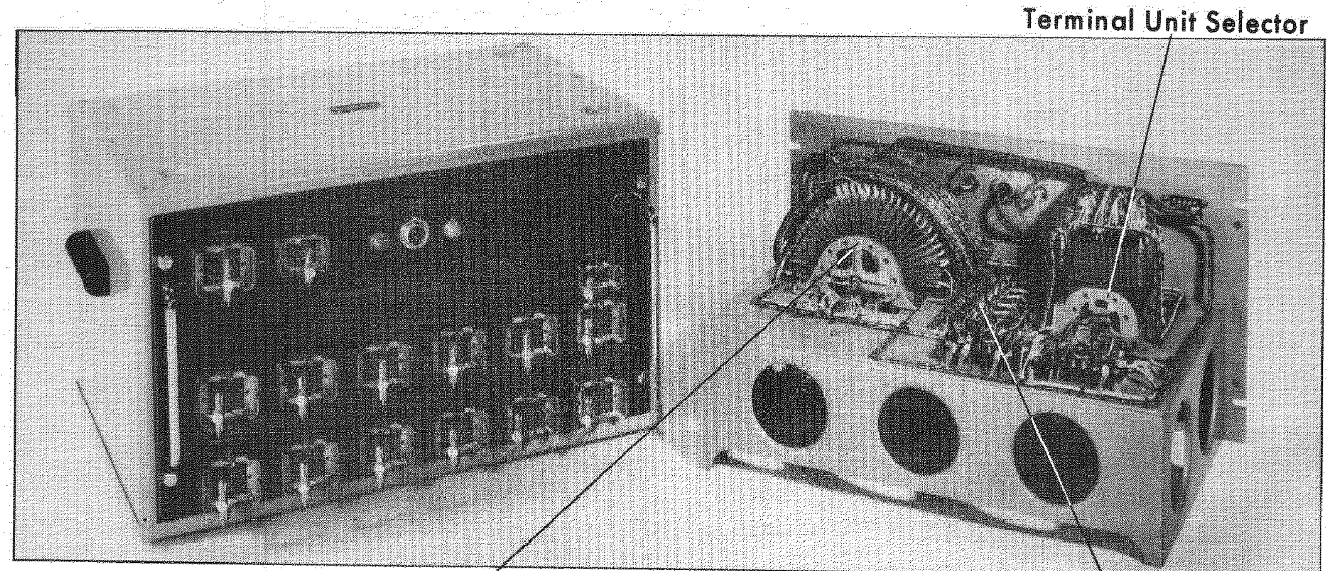



FIG. 7 STRAIN GAUGE AND POTENTIOMETER SELECTOR UNIT

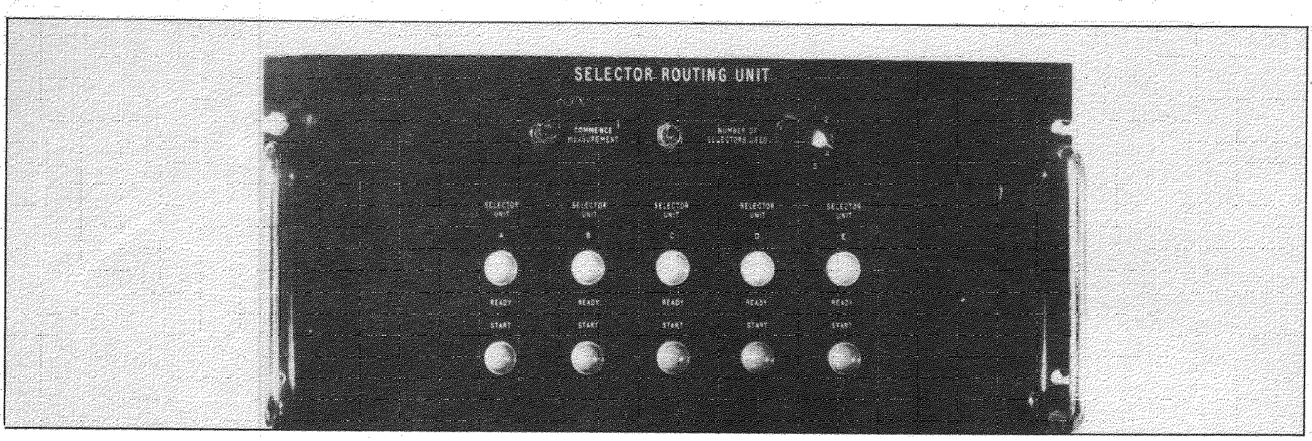



FIG. 8 SELECTOR ROUTING UNIT

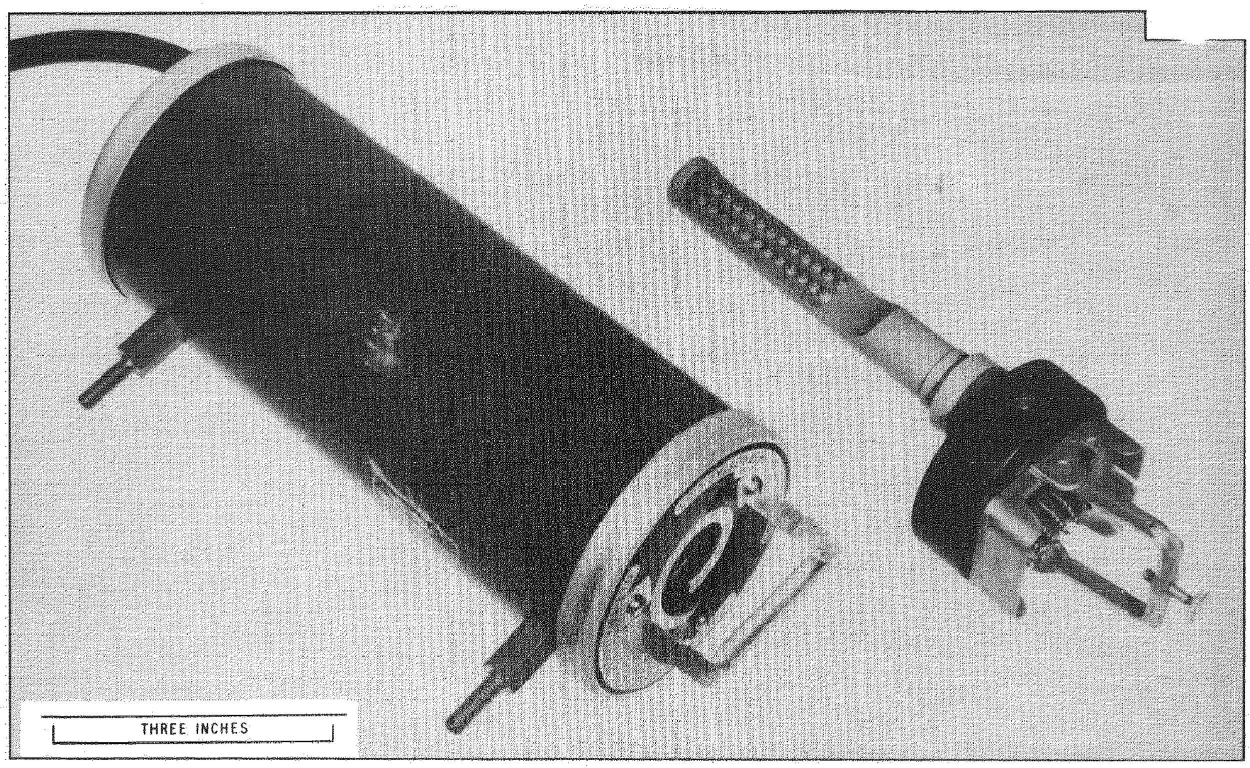



FIG. 9 THERMOCOUPLE AND RADIOMETER TERMINAL UNIT AND COLD JUNCTION OVEN

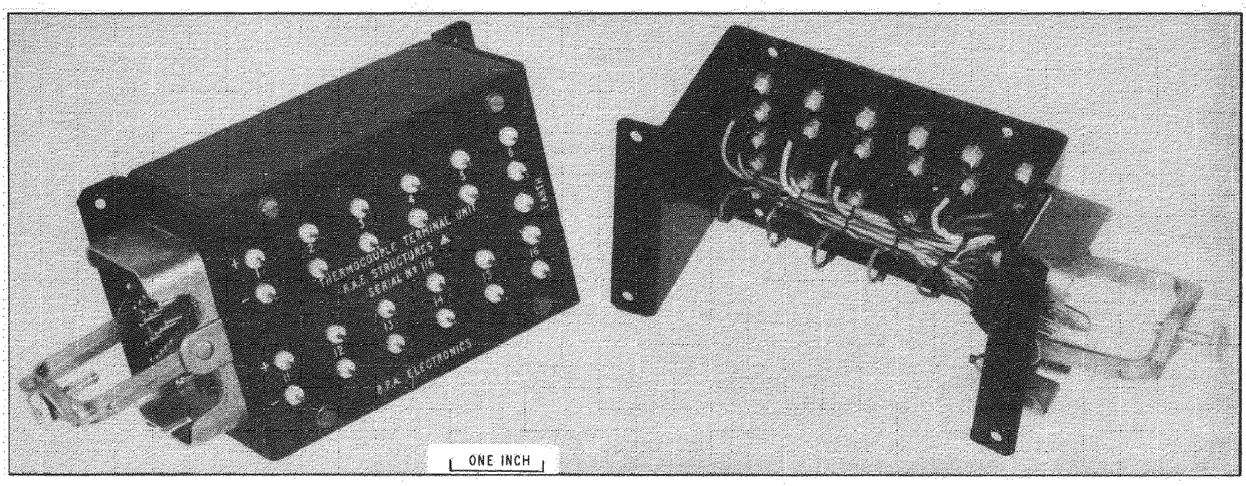



FIG. 10 THERMOCOUPLE TERMINAL UNIT

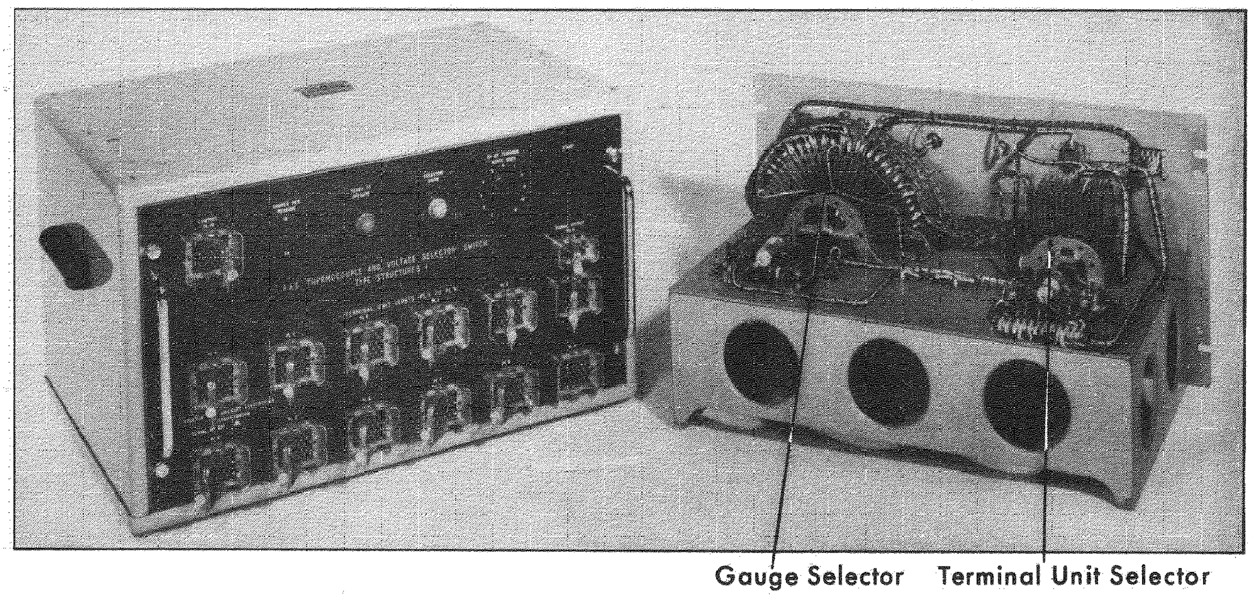



FIG. 11 THERMOCOUPLE AND VOLTAGE SELECTOR UNIT

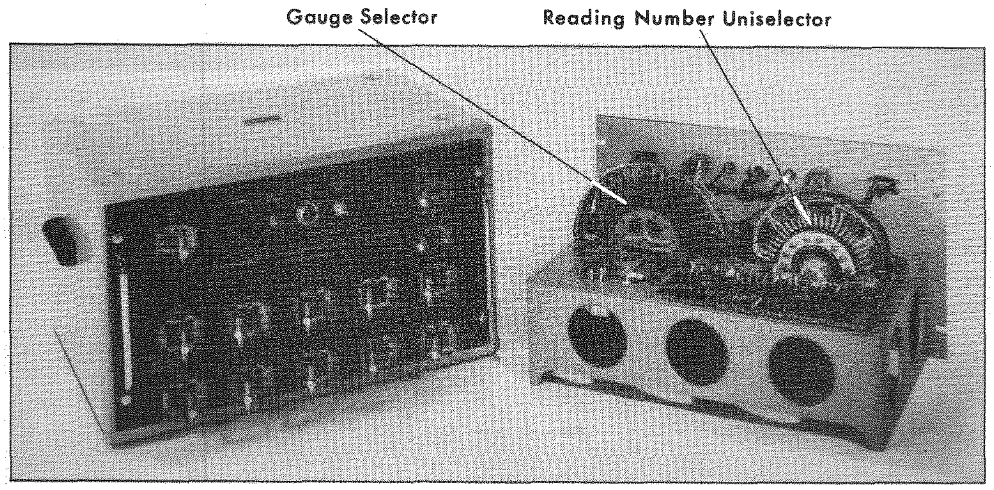



FIG. 12 STRAIN GAUGE AND THERMOCOUPLE SELECTOR UNIT


FIG. 13 STRAIN GAUGE AND POTENTIOMETER SIMULATOR


FIG. 14 TEMPERATURE SIMULATOR

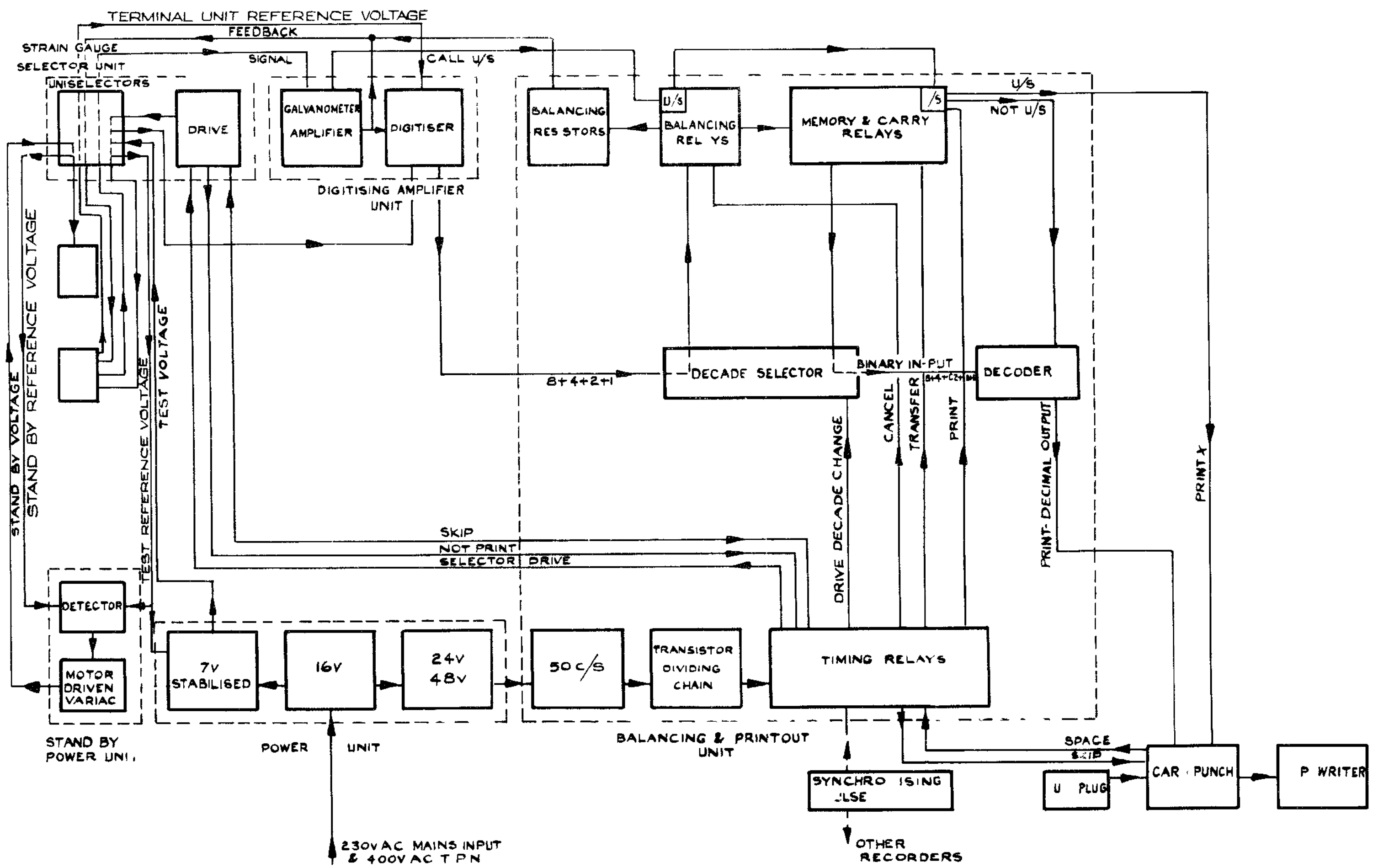



FIG. 15. FUNCTIONAL DIAGRAM OF STRAIN GAUGE INSTALLATION

KEY

| CABLE | 25 | 25 CORE |
|---|---|---|
| UNITORS | PL 5 / 8 | 8 PIN PLUG (GP-GOLD PLATED) |
| BULGIN | PL 4 / 3B | 3 PIN PLUG |
| PLESSEY | SK 3 / 2P | 2 PIN SOCKET (SMALL) |
| ELECTROMETHOD | PL 1 / 26E | 26 PIN PLUG |

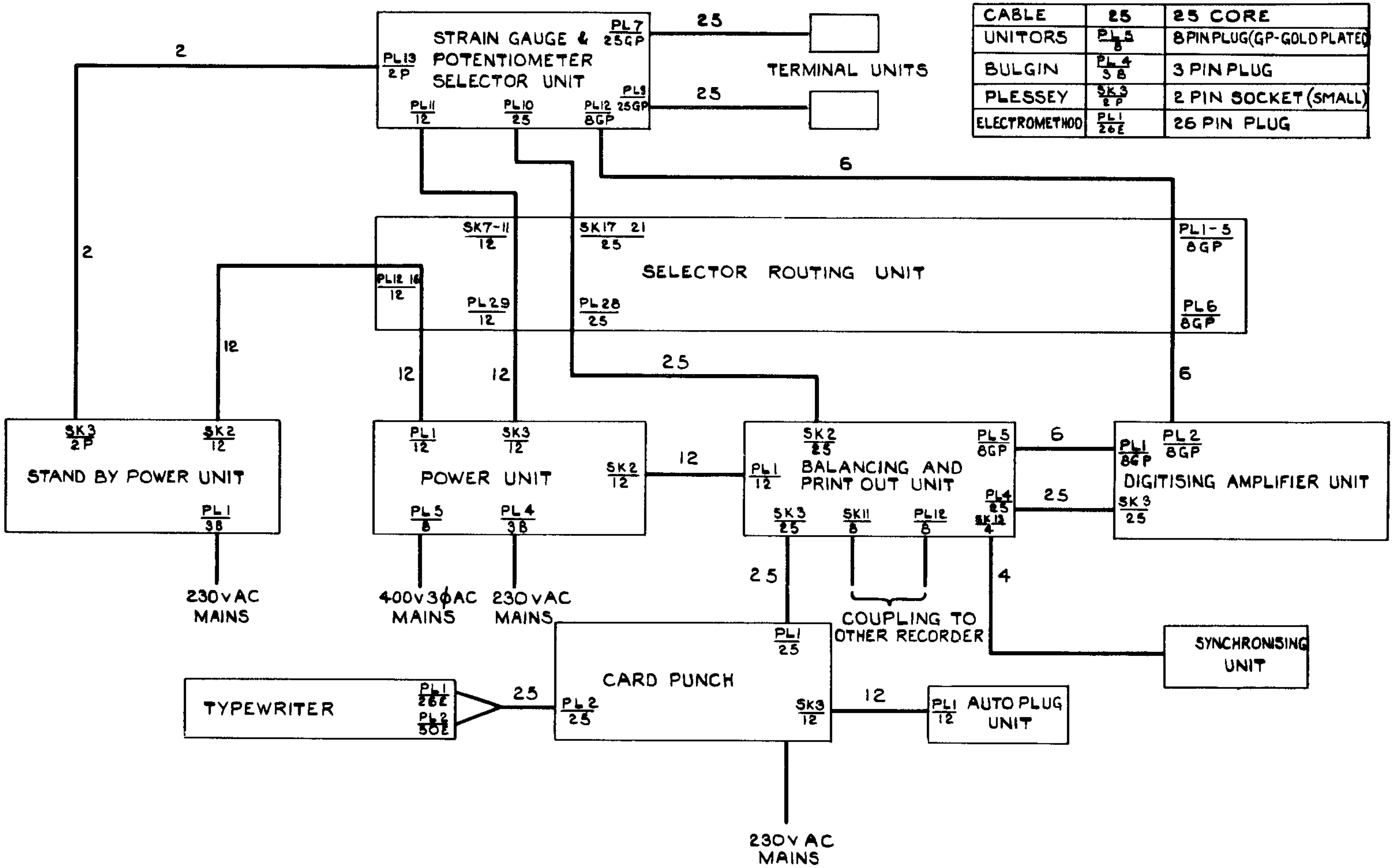
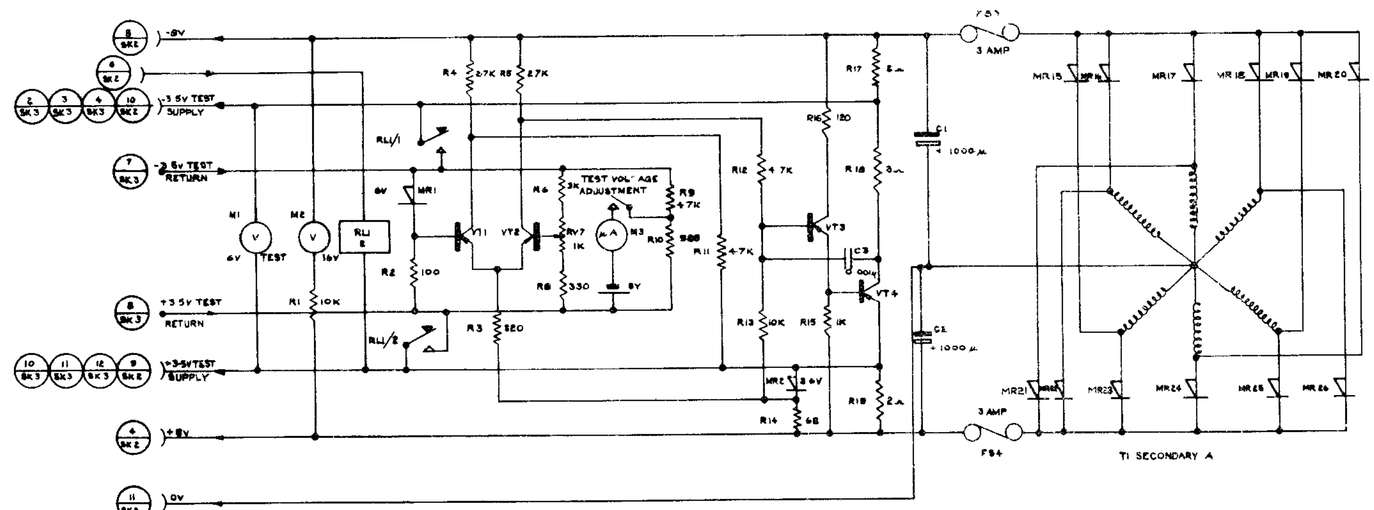
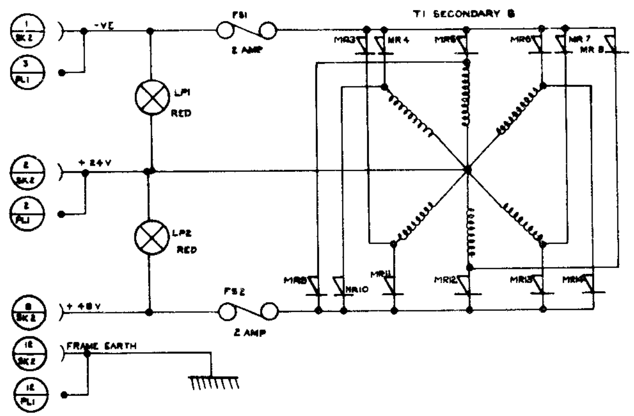


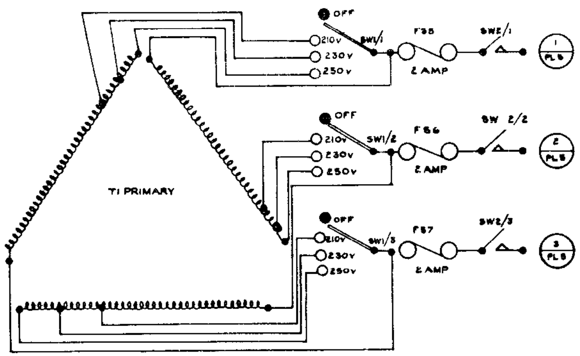

FIG. 16. BLOCK DIAGRAM SHOWING CHASSIS INTERCONNECTIONS.













| CIRC. REF | DESCRIPTION | TYPE | SPEC | SERVICE REF Nº |
|---|---|---|---|---|
| PL5 | MULTIPOLE GENERAL PURPOSE PLUG 12 WAY | UNITOR Nº 102 | DEF 5321 | 5935-99 056 2806 |
| SK2 & SK3 | MULTIPOLE GENERAL PURPOSE PLUG 12 WAY | UNITOR Nº 102 | DEF 5321 | 5935-99-056 2806 |
| PL4 & PL5 | 3 PIN PLUG | | | BULGIN |
| MR1 | 6V ZENER DIODE 1W | | | STC |
| MR2 | 3-6V ZENER DIODE 1W | | | STC |
| MR3 TO MR26 | GERMANIUM RECTIFIER | GU 5-M | | CV 7039 |
| FS1 TO FS8 | FUSE UNITS | | RCL 262 | 2591056 |
| R1 & R13 | RESISTOR FIXED COMPOSITION ¼W 10KΩ | RC 2C | RCL 112 | 0216003 |
| R2 | RESISTOR WIREWOUND 1½W 100Ω | RWV3-J | RCL 111 | 0113231 |
| R3 | RESISTOR WIREWOUND 1½W 820Ω | RWV3-J | RCL 111 | 0113253 |
| R4 & R5 | RESISTOR WIREWOUND 1½W 2.7KΩ | RWV3-J | RCL 111 | 5905-99-011 3265 |
| R6 | RESISTOR FIXED COMPOSITION ¼W 3KΩ | RC 2C | RCL 112 | 0219298 |
| RV7 | RESISTOR VARIABLE WIREWOUND 1W 250Ω | RV W7 | DEF 5181 | 5905-99 027-1606 |
| R8 | RESISTOR FIXED COMPOSITION ¼W 330Ω | RC 2C | RCL 112 | 0216183 |
| R9 R11 R12 | RESISTOR FIXED COMPOSITION ¼ 4.7KΩ | RC 2C | RCL 112 | 0216323 |
| R10 | RESISTOR FIXED COMPOSITION ¼W ADJUSTED TO 985Ω ± 1% | RC 2C | RCL 112 | |
| R14 | RESISTOR WIREWOUND 1½W 68Ω | RWV3-J | RCL 111 | 0113227 |
| R15 | RESISTOR WIREWOUND 1½W 1KΩ | RWV3-J | RCL 111 | 5905 2113254 |
| R16 | RESISTOR WIREWOUND 1½W 120Ω | RWV3-J | RCL 111 | 0113233 |
| R17, R19 | RESISTORS WIREWOUND 5x10Ω 3W | RWV4-J | RCL 111 | 0113272 |
| R18 | RESISTORS WIREWOUND 4x12Ω 3W | RWV4-J | RCL 111 | 0113274 |
| C1, C2 | ELECTROLYTIC CONDENSER 1000µF 25 | CE 4 | RCL 4 | 910-99 014 5826 |
| C3 | 0.001 µF PAPER CAPACITOR | CPL 3B | RCL 13 | 5910-2119212 |
| VT1 To VT3 | JUNCTION TRANSISTOR | GET 104 | | GEC |
| VT4 | JUNCTION TRANSISTOR | OC 35 | | CV 7084 |
| SW1 | 3 POLE 4 WAY ROTARY SWITCH | SR 139 D | | SANTON |
| SW2 | 3 POLE ON/OFF ROTARY SWITCH | SR | | SANTON |
| SW3 | PUSH BUTTON SWITCH NON LOCK 1G | 50404 | | PAINTON |
| SW4 | SINGLE POLE ON/OFF SWITCH | S-6 | DEF 5181 | 0510801 |
| M1 | MOVING COIL METER 10V | | | |
| M2 | MOVING COIL METER 20V | | | |
| M3 | MOVING COIL METER 50 0 50µA | | | |
| BY | 1.0 18V WESTON CELL | SM 5A-N94 | RCL 165 | 5945 99 011 9879 |
| T1 | 3 PHASE TRANSFORMER PRIMARY 210V 230V, 250V SECONDARY A 6 WINDINGS 8V ON 230V INPUT SECONDARY B 6 WINDINGS 26V ON 230V INPUT | | | |
| T2 | CONSTANT VOLTAGE TRANSFORMER 190-260V INPUT, 6V OUTPUT, 18 WATT LOAD | CV 18E | | ADVANCE |
| LP1 & LP2 | 28V LAMP & HOLDER | | | THORN |

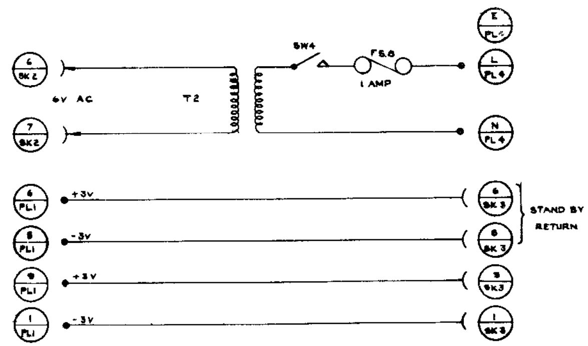
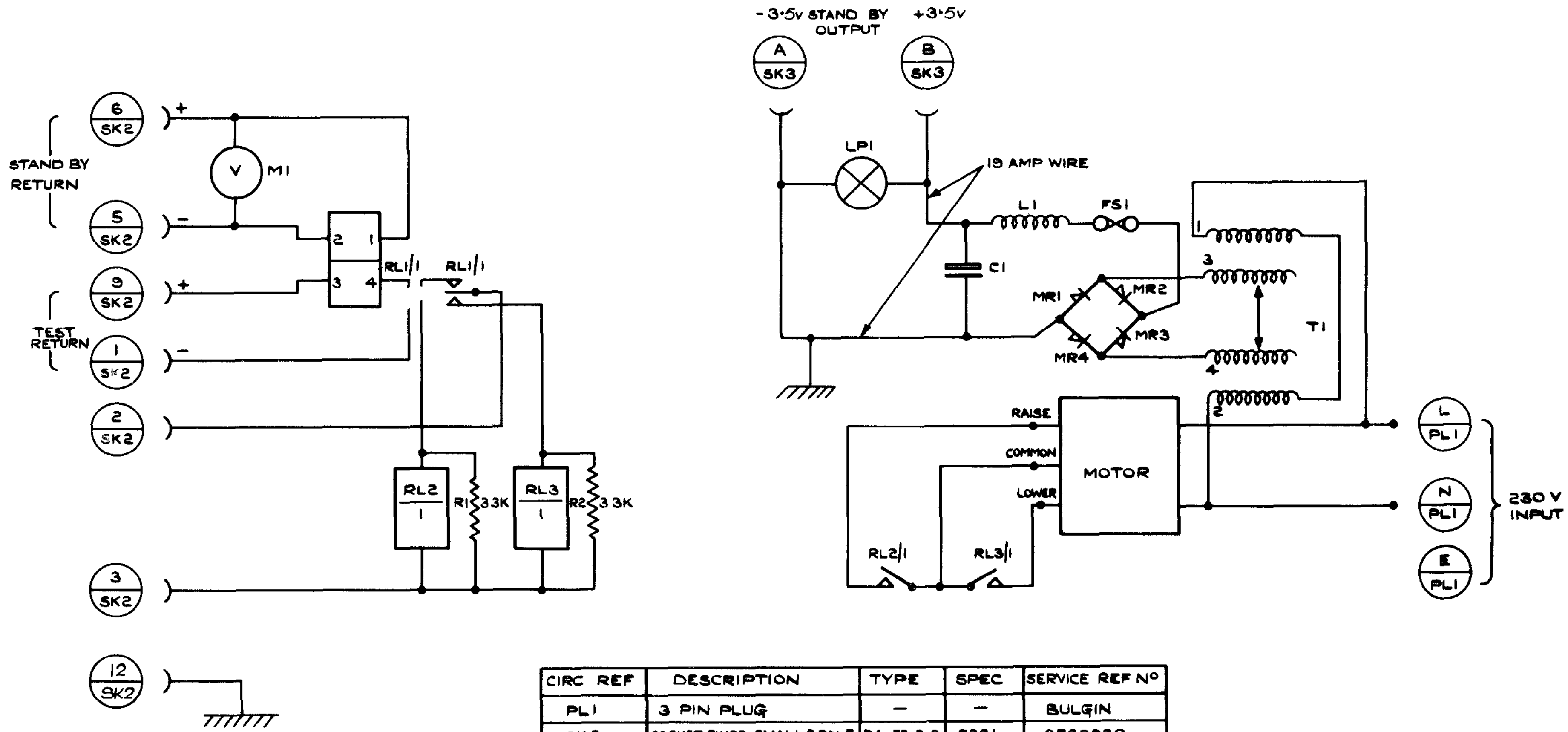


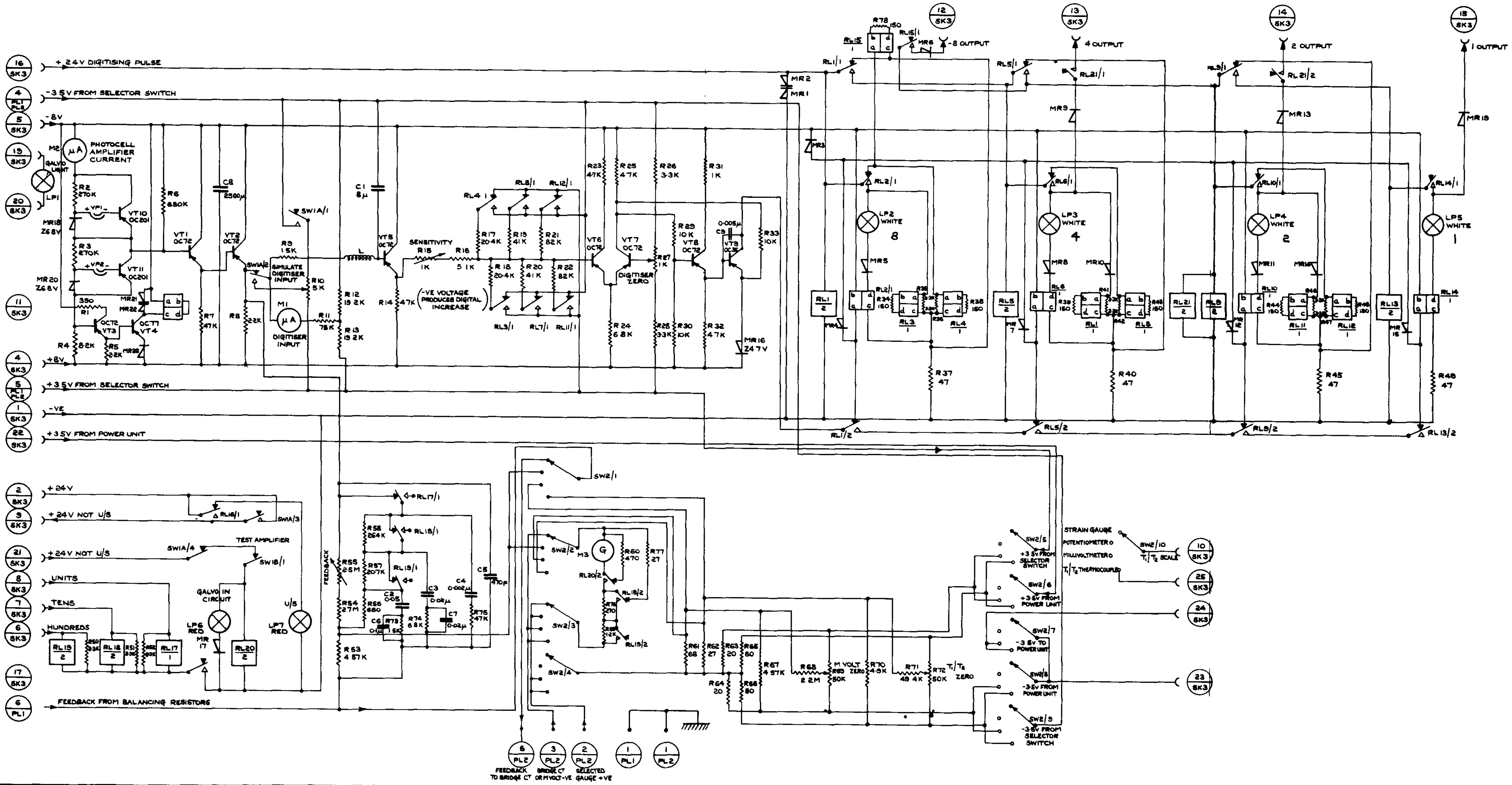


FIG.17 POWER UNIT




| CIRC REF | DESCRIPTION | TYPE | SPEC | SERVICE REF N° |
|---|---|---|---|---|
| PL1 | 3 PIN PLUG | — | — | BULGIN |
| SK3 | SOCKET FIXED SMALL 2 POLE | P4xF2 2 0 | 5321 | 0560230 |
| SK2 | MULTIPOLE GENERAL PURPOSE 12 WAY SOCKET | UNITOR N° 102 A | DEF 5321 | 5935-99-056-2508 |
| RL1 | RELAY CARPENTER COIL 37 | SIM | — | T M C |
| RL2 & RL3 | RELAY HEAVY DUTY 6V 45 Ω | SMSA-H77 | RCL 165 | 5945-99-0U-9884 |
| MR1 TO MR4 | RECTIFIER FULL WAVE | 13 K2 VA713 | | ENGLISH ELECTRIC |
| T1 | VARIAC TRANSFORMER ZENITH ELECTRIC 10 | 80-A6-358 | — | — |
| M1 | VOLTMETER MOVING COIL 10 V DC | — | — | — |
| L1 | CHOKE 0 01 H 15 A | — | — | — |
| C1 | CAPACITOR ELECTROLYTIC 25 V 1000 μF | CE4 - U | RCL 134 A | Z 145520 |
| FS1 | FUSE 15 AMP | — | — | — |
| LP1 | 6V LAMP AND HOLDER | — | — | THORN |
| R1 & R2 | RESISTOR FIXED COMPOSITION 1/4 W 3·3 KΩ | RC2 - E | RCL 112 | 0215301 |

FIG.18. STAND BY POWER UNIT




| CIRCUIT REF | DESCRIPTION | TYPE | SPEC | SERVICE REF Nº |
|---|---|---|---|---|
| PL1 & PL2 | MULTIPOLE GENERAL PURPOSE PLUG 6 WAY GOLD PLATED | UNITOR Nº 102 | | |
| SK3 | MULTIPOLE GENERAL PURPOSE SOCKET 25 WAY | UNITOR Nº 102 A | DEF 5321 | 5935-99-056-2510 |
| RL1 RL5 RL9 RL13 & RL17 TO RL21 | 24V NORMAL DUTY RELAYS | SM5A-N56 | RCL 165 | 5945-99-011-9881 |
| RL2 TO RL4 RL6 TO RL8 RL10 TO RL12 & RL14 TO RL16 | 12 V HIGH SPEED RELAYS | SM8-3 | RCL 165 | 2530038 |
| MR1 | GERMANIUM DIODE | GJ5-M | | CV 7039 |
| MR2 & MR17 | 15V 1W SILICON ZENER DIODE | | | STC |
| MR3 MR18 MR20 TO MR22 | 6 8V SILICON ZENNER DIODE | SX 68 | | CV 7071 |
| MR8 TO MR14 MR15 MR19 & MR21 | GOLD BONDED DIODE | OA5 | | CV 7047 |
| MR16 TO MR23 | 4 7V 1W SILICON ZENNER DIODE | | | STC |
| VT1 & VT4 | JUNCTION TRANSISTOR | OC77 | | MULLARD |
| VT2-VT3 & VT5-VT8 | JUNCTION TRANSISTOR | OC72 | | MULLARD |
| VT9 | JUNCTION TRANSISTOR | OC35 | | MULLARD |
| VT10 & VT11 | JUNCTION TRANSISTOR | OC201 | | MULLARD |
| VP1 & VP2 | PHOTO CELLS VOLTAIC | MS8 | | FERRANTI |
| LP2 TO LP5 | LAMPS 6V 0 1A | | | THORN |
| LP6 & LP7 | LAMPS 24V | | | THORN |
| LP1 | LAMP FILAMENT 6V 8W | | | MAZDA |
| M1 | MOVING COIL METER 50 Ω 50μA RE-ENGRAVED | | | |
| M2 | MOVING COIL METER 0 100μA | | | |
| M3 | 28 CPS GALVO | | | NEP |
| C1 | CAPACITOR 8μF PAPER DIELECTRIC | | | DUBILER |
| C2 | CAPACITOR 0 05μF PAPER DIELECTRIC | CPM 4 | RCL 136A | 0119825 |
| C3 C6 & C7 | CAPACITOR 0·02μF PAPER DIELECTRIC | CPM 5 | RCL 136A | 0120115 |
| C4 | CAPACITOR 0·002μF PAPER DIELECTRIC | CPM 5 | RCL 136A | 0120108 |
| C5 | CAPACITOR 470pF MICA | CMM1-G | DEF 5132 | 0123947 |
| C8 | CAPACITOR 2500μF ELECTROLYTIC | | | |
| C9 | CAPACITOR 0 005μF PAPER DIELECTRIC | CPM 5 | RCL 136A | 0120113 |
| L | FERROX CUBE LA 73840 TURNS 43 SWG ENAMELLED CU | | | MULLARD |
| SW1 | SWITCH KEY OPERATED 4 BM | 198 | | PO |
| SW2 | WINKLER SWITCH 4 WAY 3 POLE 4 BANK (GOLD PLATED CONTACTS) | | | PAINTON |

| CIRCUIT REF | DESCRIPTION | TYPE | SPEC | SERVICE REF Nº |
|---|---|---|---|---|
| R1 | RESISTOR 390Ω 1½W WIRE WOUND | RWV3-J | RCL 111 | 5905-99-011-3245 |
| R2 & R3 | RESISTOR 270KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-6727 |
| R4 | RESISTOR 8 2KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-5353 |
| R5 & R8 | RESISTOR 2·2KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-5283 |
| R6 | RESISTOR 680KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-6747 |
| R7 & R75 | RESISTOR 47KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-6083 |
| R9 & R73 | RESISTOR 1 5KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-5263 |
| R10 | RESISTOR 5KΩ 1W VARIABLE WIRE WOUND | RVW-7 | DEF 5121 | 5905-99-027-2005 |
| R11 | RESISTOR 75KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-6108 |
| R12, R13 | RESISTOR 19·2KΩ ¼W FIXED COMPOSITION | A70 | | MUIRHEAD |
| R14 R23, R25 & R32 | RESISTOR 4·7KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-5328 |
| R15 & R27 | RESISTOR 1KΩ W VARIABLE WIRE WOUND | RVW-7 | DEF 5121 | 5905-99-027-1605 |
| R16 | RESISTOR 5 1K ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-5323 |
| R17 & R18 | RESISTOR 20·4KΩ ±1% 1W WIRE WOUND | A70 | | MUIRHEAD |
| R19 & R20 | RESISTOR 41KΩ ±1% 1W WIRE WOUND | A70 | | MUIRHEAD |
| R21 & R22 | RESISTOR 82KΩ ±2% ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-6432 |
| R24 & R74 | RESISTOR 6 8KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-5343 |
| R26, R28 | RESISTOR 3 3KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-5303 |
| R29, R30 & R33 | RESISTOR 10KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-6003 |
| R31 | RESISTOR 1KΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-5243 |
| R34, R38, R39, R43, R44, R48 & R76 | RESISTOR 150Ω 1½W WIRE WOUND | RWV3-J | RCL 111 | 5905-2113235 |
| R35, R36, R41, R42, R46, R47, R50 TO R52 | RESISTOR 3·3KΩ ¼W FIXED COMPOSITION | RC2-E | RCL 112 | 5905-99-021-5031 |
| R37, R40, R45 & R49 | RESISTOR 47Ω 3W WIRE WOUND | RWV4-J | RCL 111 | 5905-Z113223 |
| R53 & R67 | RESISTOR 4·57KΩ ±1% 1½W WIRE WOUND | RWV3-J | RCL 111 | |
| R54 | RESISTOR 2·7MΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-6851 |
| R55 | RESISTOR 2·5μΩ ¼W VARIABLE CARBON | RVC3-A | RCL 122 | 5905-99-026-2943 |
| R56 | RESISTOR 660Ω ±1% 1½W WIRE WOUND | RWV3-J | RCL 111 | |
| R57 | RESISTOR 207KΩ ±1% WIRE WOUND | D333A | | MUIRHEAD |
| R58 | RESISTOR 264KΩ ±1% WIRE WOUND | D333A | | MUIRHEAD |
| R59 | RESISTOR 1 2KΩ 1½W WIRE WOUND | RWV3-J | RCL 111 | 5905-99-011-3257 |

| CIRCUIT REF | DESCRIPTION | TYPE | SPEC | SERVICE REF Nº |
|---|---|---|---|---|
| R60 | RESISTOR 470Ω 1½W WIRE WOUND | RWV3-J | RCL 111 | 5905-99-011-3247 |
| R61 | RESISTOR 68Ω 1½W WIRE WOUND | RWV3-J | RCL 111 | 5905-99-011-3227 |
| R62 & R77 | RESISTOR 27Ω 1½W WIRE WOUND | RWV3-J | RCL 111 | 5905-99-011-3217 |
| R63 & R64 | RESISTOR 20Ω ±1% WIRE WOUND | A70 | | MUIRHEAD |
| R65 & R66 | RESISTOR 80Ω ±1% WIRE WOUND | A70 | | MUIRHEAD |
| R68 | RESISTOR 2·2MΩ ¼W FIXED COMPOSITION | RC2C | RCL 112 | 5905-99-021-6845 |
| R69 & R72 | RESISTOR 50KΩ 1W VARIABLE WIRE WOUND | RVW-7 | DEF 5121 | 5905-99-027-2410 |
| R70 | RESISTOR 4·97KΩ ±1% WIRE WOUND | D333A | | MUIRHEAD |
| R71 | RESISTOR 49·4KΩ ±1% WIRE WOUND | D333A | | MUIRHEAD |
| R76 | RESISTOR 270Ω 1½W WIRE WOUND | RWV3-J | RCL 111 | 5905-99-011-3241 |

FIG.19. DIGITISING AMPLIFIER UNIT.

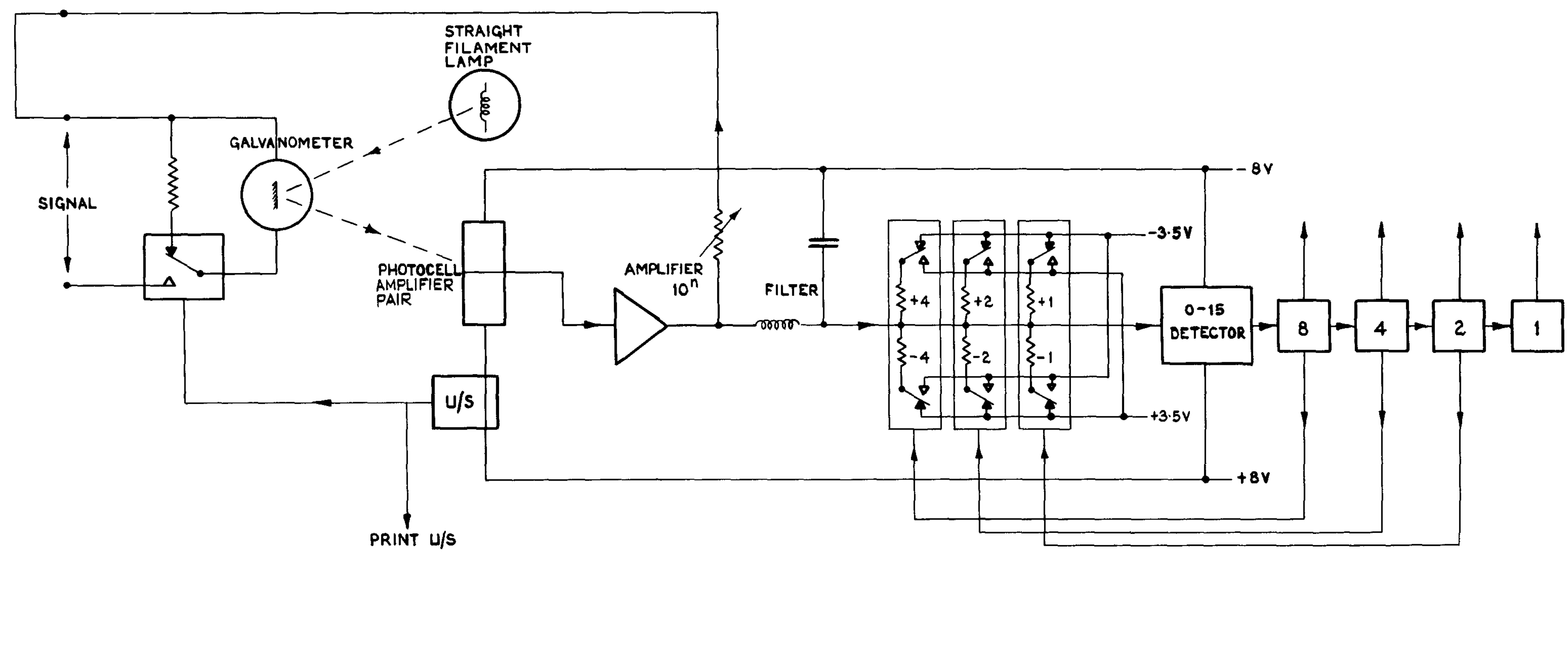
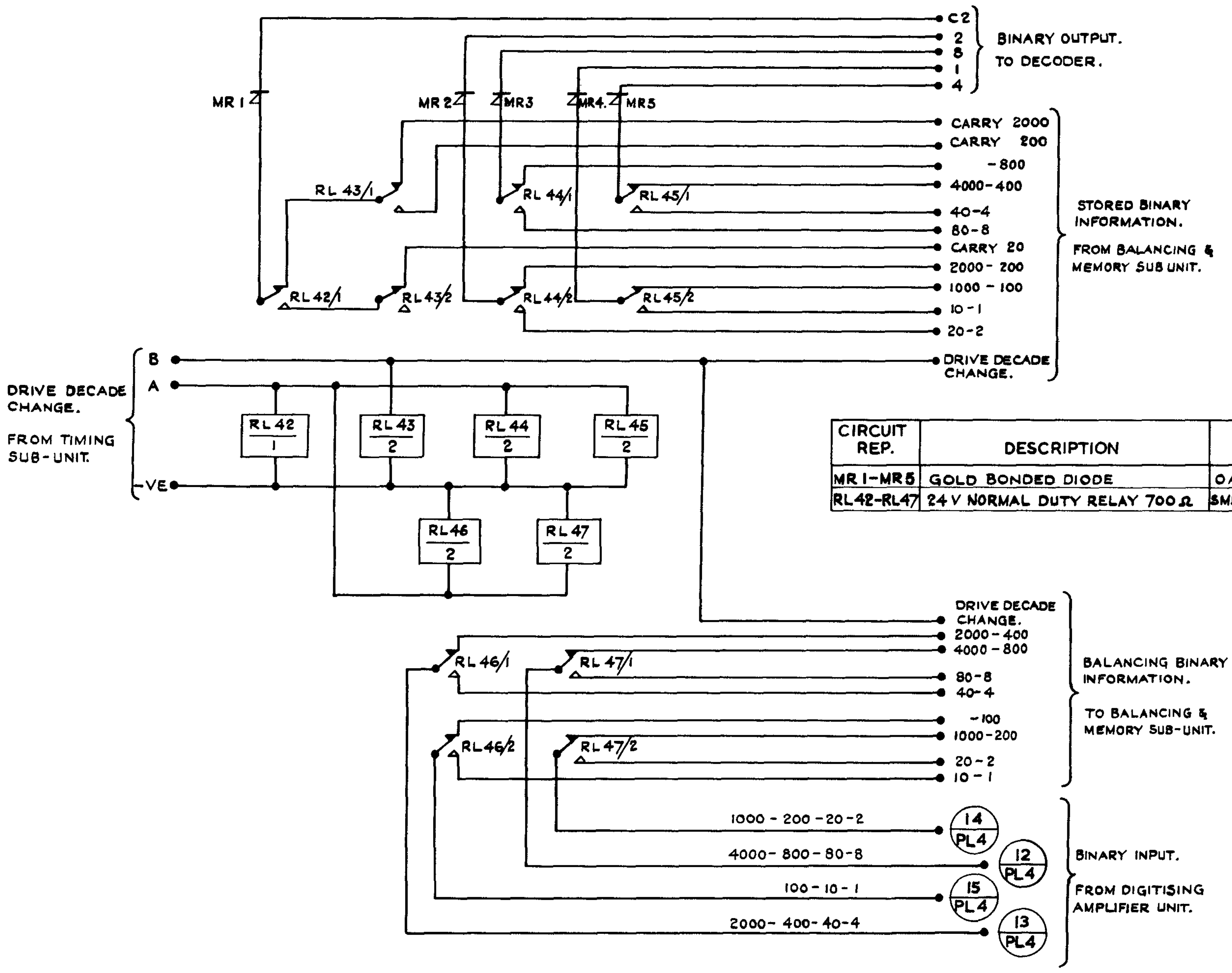
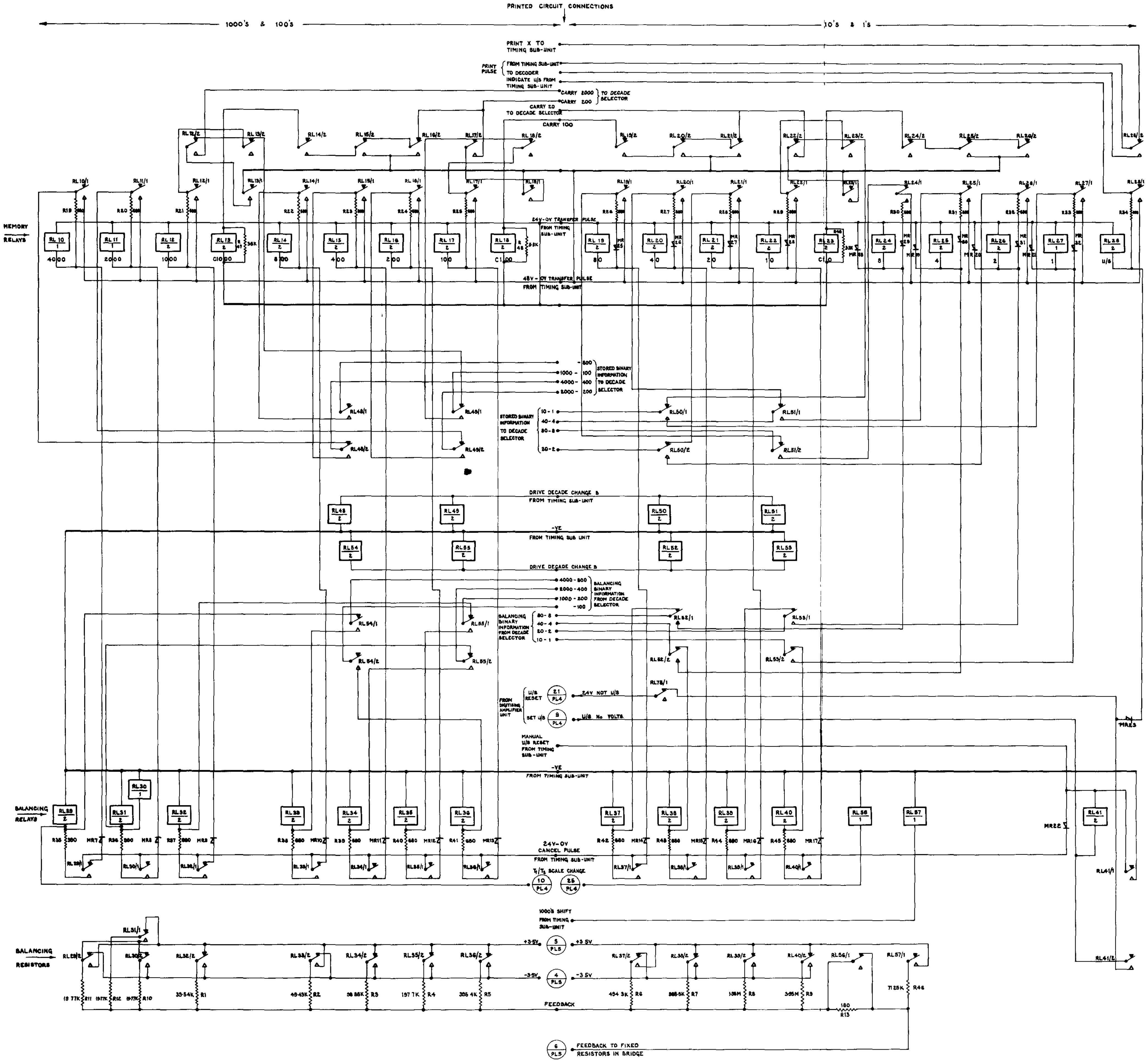



FIG.20. DIGITISING AMPLIFIER SCHEMATIC.




| CIRCUIT REP. | DESCRIPTION | TYPE | SPEC. | SERVICE REF. Nº |
|---|---|---|---|---|
| MR 1-MR5 | GOLD BONDED DIODE | OA5 | | CV 7047 |
| RL42-RL47 | 24 V NORMAL DUTY RELAY 700 Ω | SM5A-N96 | RCL 165 | 5945-99-011-9881 |

FIG. 21. DECADE SELECTOR SUB UNIT.




| CIRC. REF | DESCRIPTION | TYPE | SPEC | SERVICE REF No |
|---|---|---|---|---|
| PL4 | 25 PIN UNITOR No 102 PLUG | A | DEF 5321 | 5935-99-056-2505 |
| PL5 | 5 PIN UNITOR No 102 PLUG | B | DEF 5321 | 5935-99-056-2502 |
| RL10 TO RL41 RL48 TO RL57 | 24V NORMAL DUTY RELAY 700 Ω | [illegible] | RCL 168 | 5945-99-011-9881 |
| MR7 TO MR32 | GOLD BONDED DIODE | OA5 | | CV 7047 |
| R1 | RESISTOR SEALED 33·54 KΩ ± 0·1 % WW | TWW2 | | DUBILIER |
| R2 | RESISTOR SEALED 49·43 KΩ ± 0·1 % WW | TWW2 | | DUBILIER |
| R3 | RESISTOR SEALED 98·86 KΩ ± 0·1 % WW | TWW2 | | DUBILIER |
| R4 | RESISTOR SEALED 197·7K Ω ± 0·2 % WW | TWW2 | | DUBILIER |
| R5 | RESISTOR SEALED 395·4 KΩ ± 0·5 % WW | TWW2 | | DUBILIER |
| R6 | RESISTOR SEALED 494·3 KΩ ± 0·5 % WW | TWW2 | | DUBILIER |
| R10 TO R12 | RESISTOR SEALED 19·77 KΩ ± 0·1 % WW | TWW2 | | DUBILIER |
| R46 | RESISTOR SEALED 71·25 KΩ ± 0·1 % WW | TWW2 | | DUBILIER |
| R7 | RESISTOR FIXED COMPOSITION ADJUSTED TO 988·5KΩ ± 1% | RC2-C | RCL 112 | |
| R8 | RESISTOR FIXED COMPOSITION ADJUSTED TO 1·98MΩ ± 2% | RC2-C | RCL 112 | |
| R9 | RESISTOR FIXED COMPOSITION ADJUSTED TO 3·95MΩ ± 2% | RC2-C | RCL 112 | |
| R13 | RESISTOR WW 180 Ω 1½ W | RWV3-J | RCL 111 | 5905-99-011-5237 |
| R19 TO R34 R37 TO R45 | RESISTOR WW 680 Ω 1½ W | RWV3-J | RCL 111 | 5905-Z113291 |
| R35, R36 | RESISTOR WW 390 Ω 1½ W | RWV3-J | RCL 111 | 5905-Z113245 |
| R47 TO R48 | RESISTOR FIXED COMPOSITION 3·3K ¼ W | RC2-E | RCL 112 | 5905-99-021-5361 |

FIG. 22. BALANCING AND MEMORY SUB UNIT.

| CIRC REF. | DESCRIPTION | TYPE | SPEC | SERVICE REF No. |
|---|---|---|---|---|
| PL 1 | MULTIPOLE GENERAL PURPOSE 12 WAY | UNITOR No 102 | DEF 5321 | 5935-99-056-2503 |
| SK. 3 | MULTIPOLE GENERAL PURPOSE 25WAY (A) | UNITOR No 102 | DEF 5321 | 5935-99-056-2510 |
| RL1 TO RL9 | 24V NORMAL DUTY RELAYS. 700 Ω | SM5A-N96 | RCL 165 | 5945-99-011-9881 |
| MR62 TO MR66 | DIODE GOLD BONDED | OA5 | | CV 7047 |

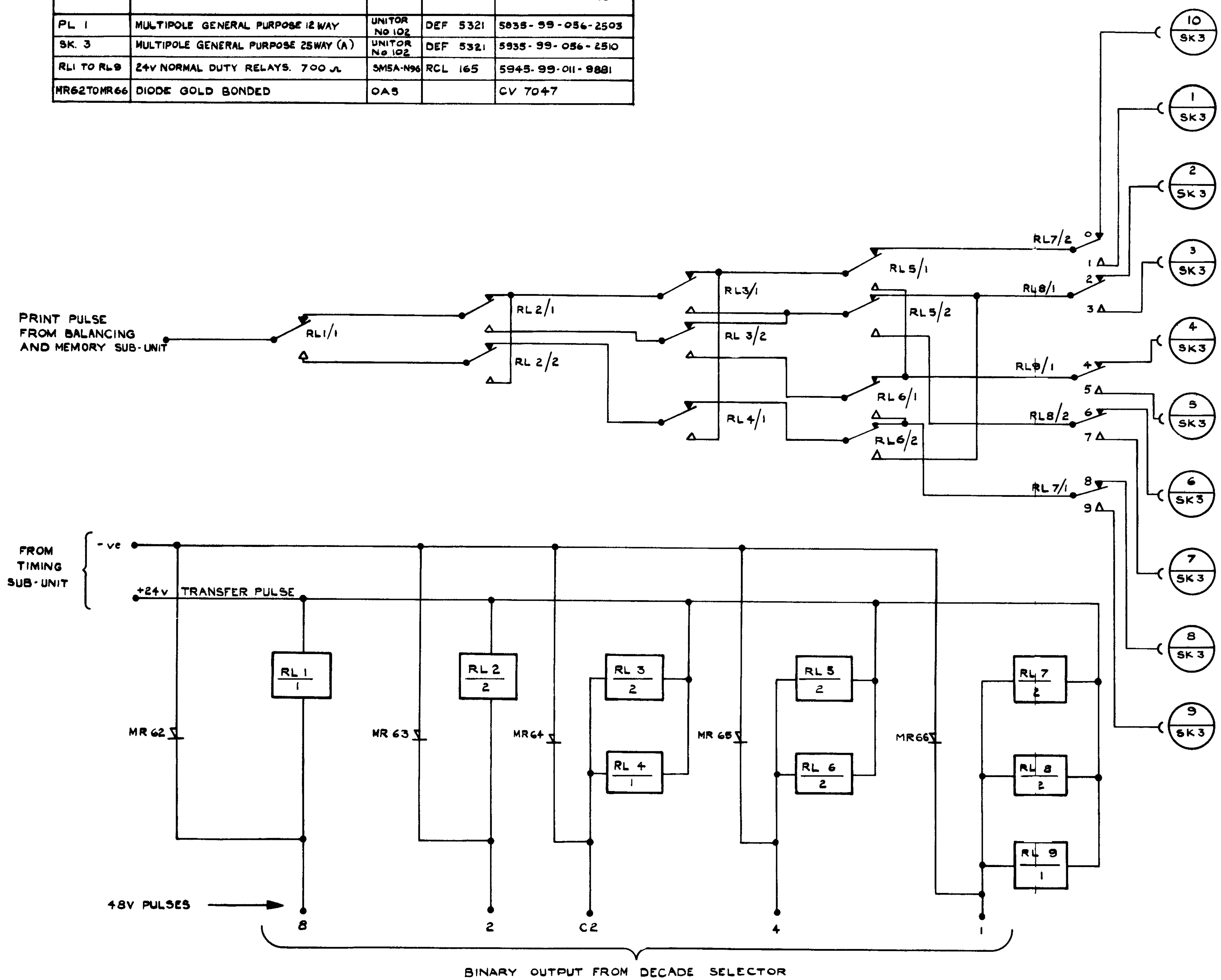
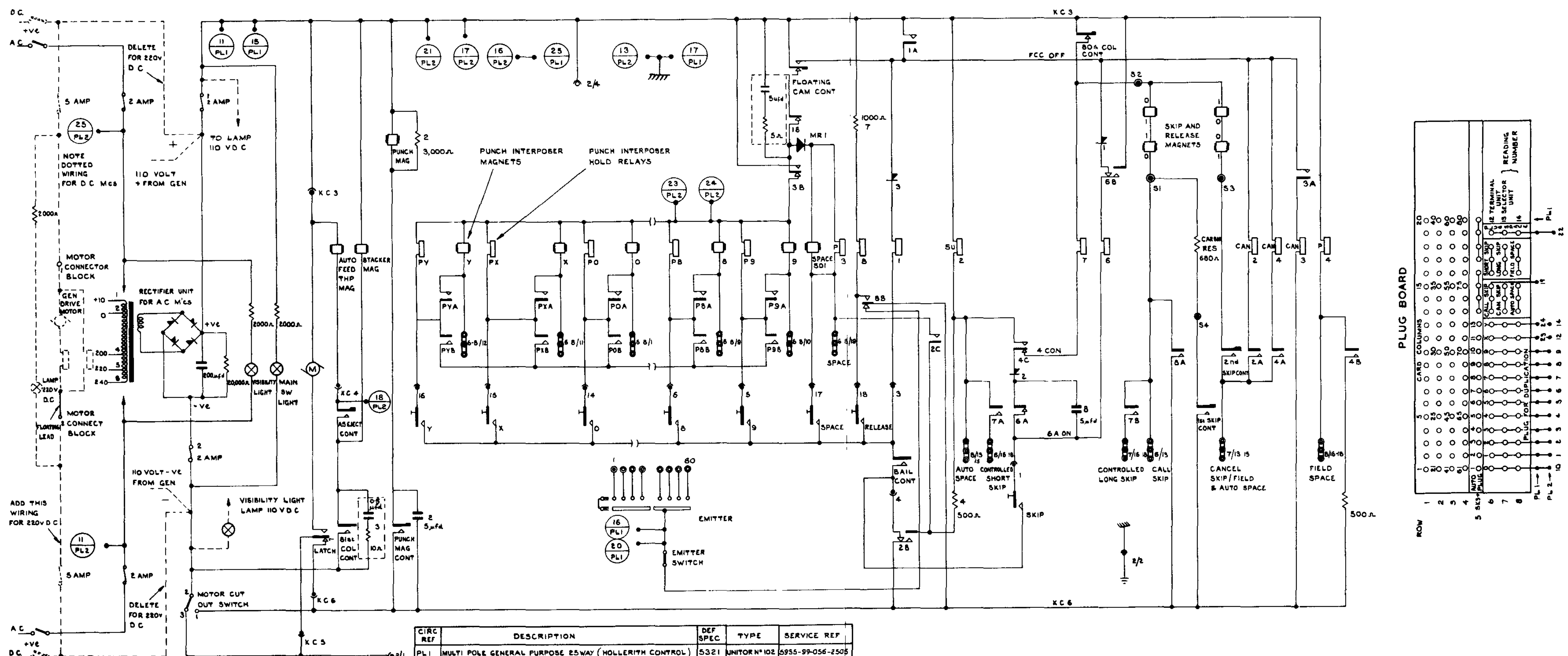
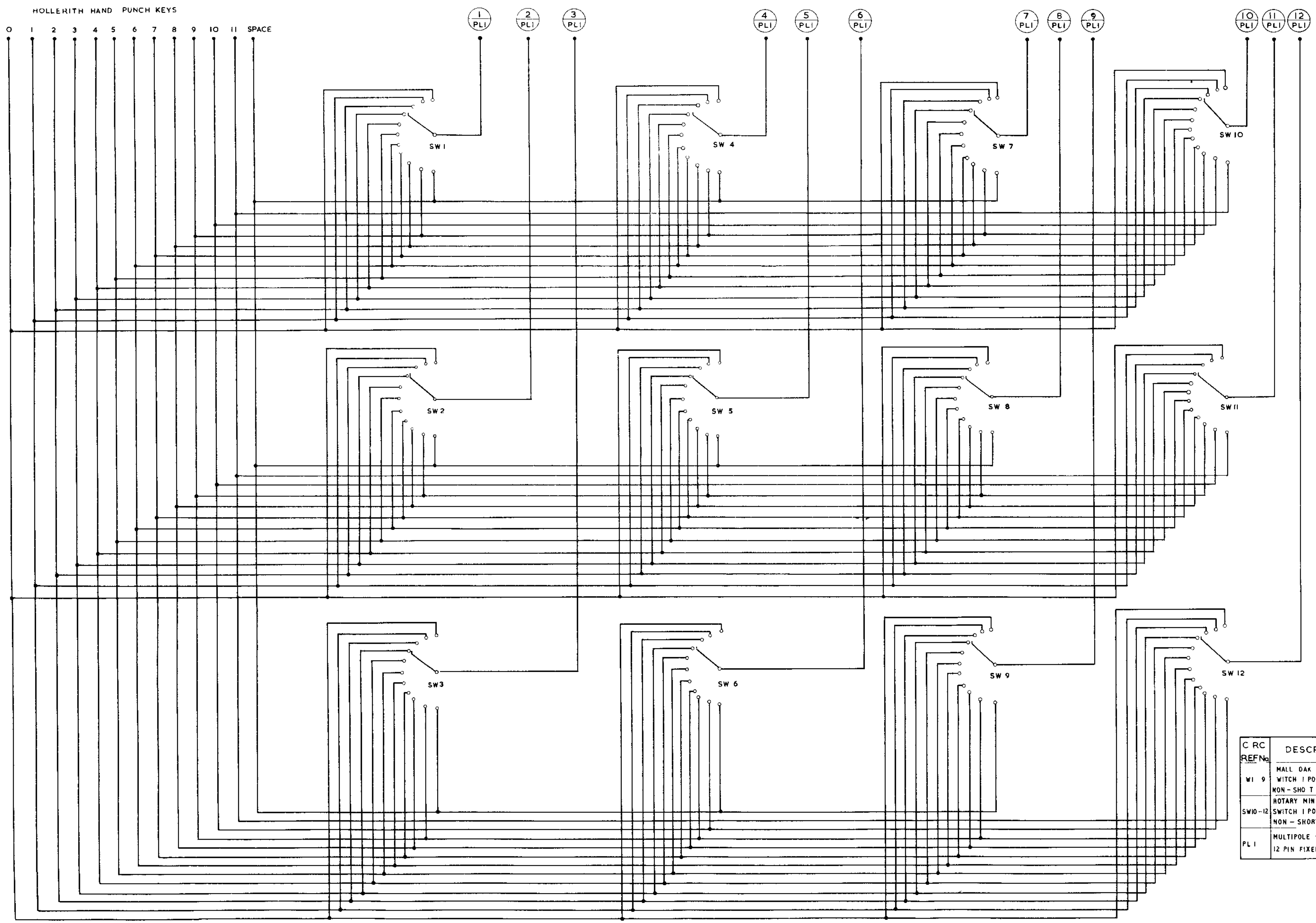



FIG. 23. DECODER SUB-UNIT.




| CIRC REF | DESCRIPTION | DEF SPEC | TYPE | SERVICE REF |
|---|---|---|---|---|
| PL1 | MULTI POLE GENERAL PURPOSE 25 WAY (HOLLERITH CONTROL) | 5321 | UNITOR Nº 102 | 5935-99-056-2505 |
| PL2 | MULTI POLE GENERAL PURPOSE 25 WAY (TYPEWRITER CONTROL) | 5321 | UNITOR Nº 102 | 5935-99-056-2505 |
| SK3 | MULTI POLE GENERAL PURPOSE 12 WAY (AUTO PLUG A P) | 5321 | UNITOR Nº 102 | 5935 99-056-2508 |
| MR1 | RECTIFIER 1 AMP | T14-A19 | | WESTING HOUSE |

FIG. 24. CARD PUNCH




| C RC REF No | DESCRIPTION | T PE | JPEC | SEFVICE REF No |
|---|---|---|---|---|
| WI 9 | MALL OAK WA E1 WITCH 1 POLE – 11 WAY NON – SHO T NG | | RCL 154 A | 10F/NIV/7908 |
| SW10–12 | ROTARY MINIATURE SWITCH 1 POLE – 12 WAY NON – SHORTING | | RCL 154 B | Z510445 |
| PL 1 | MULTIPOLE MK 4 12 PIN FIXED | PLESSEY MK 4 | DEF 5321 | 0560150 |

FIG. 25. AUTO PLUG UNIT

| CIRCUIT REF. | DESCRIPTION | TYPE |
|---|---|---|
| PL 1 | 26 WAY FIXED PLUG – ON SERVOTYPER | ELECTRO METHODS |
| PL 2 | 50 WAY FIXED PLUG – ON SERVOTYPER | ELECTRO METHODS |
| PL 3 | 25 WAY FIXED PLUG – ON CARD PUNCH | BELLING - LEE |

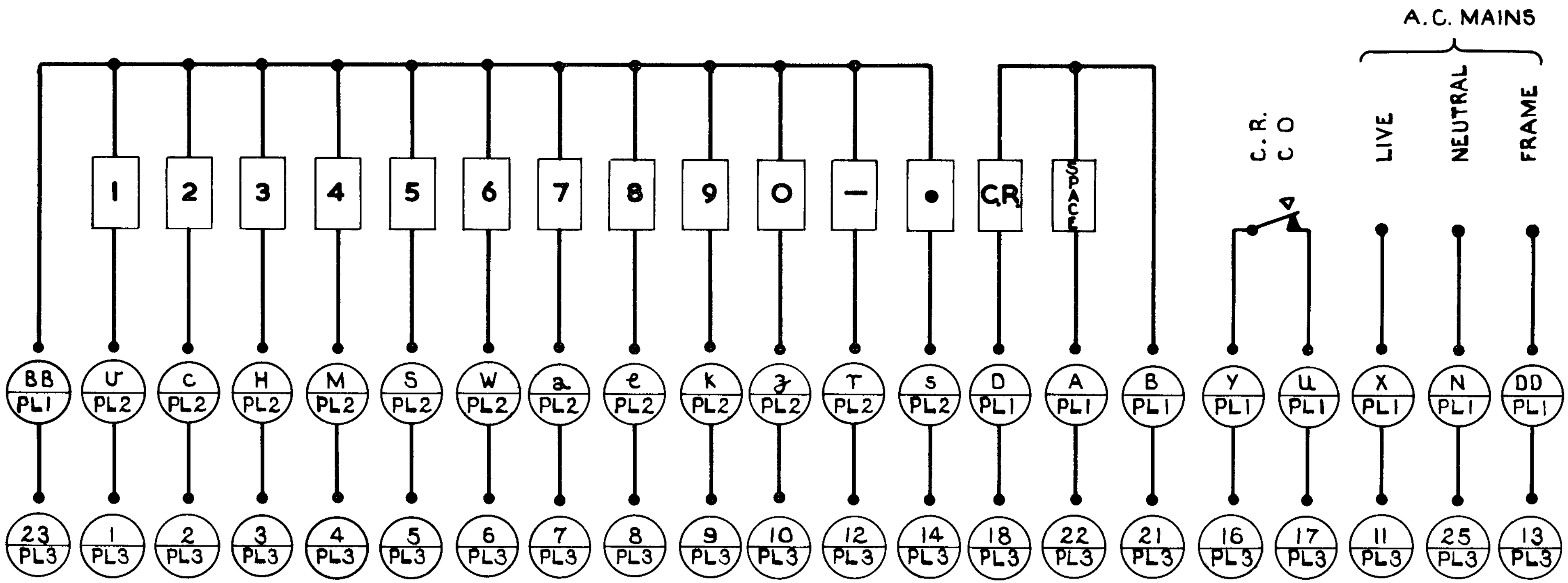
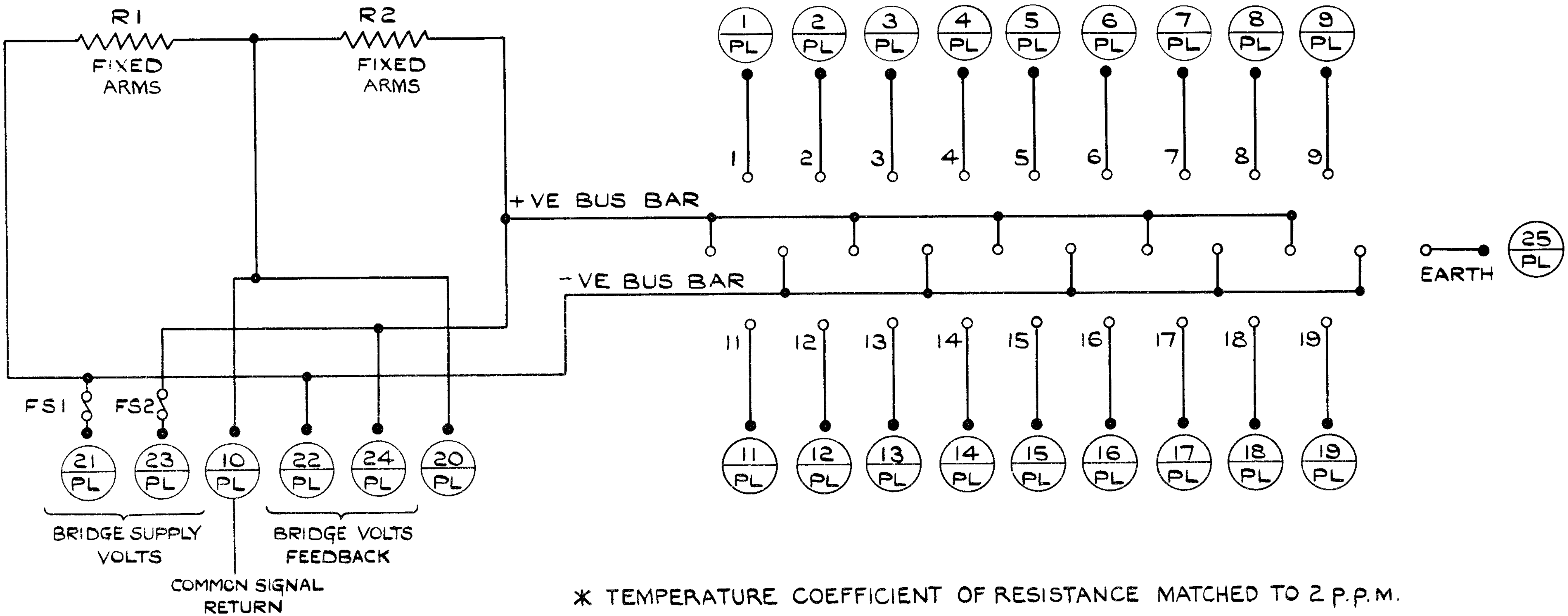


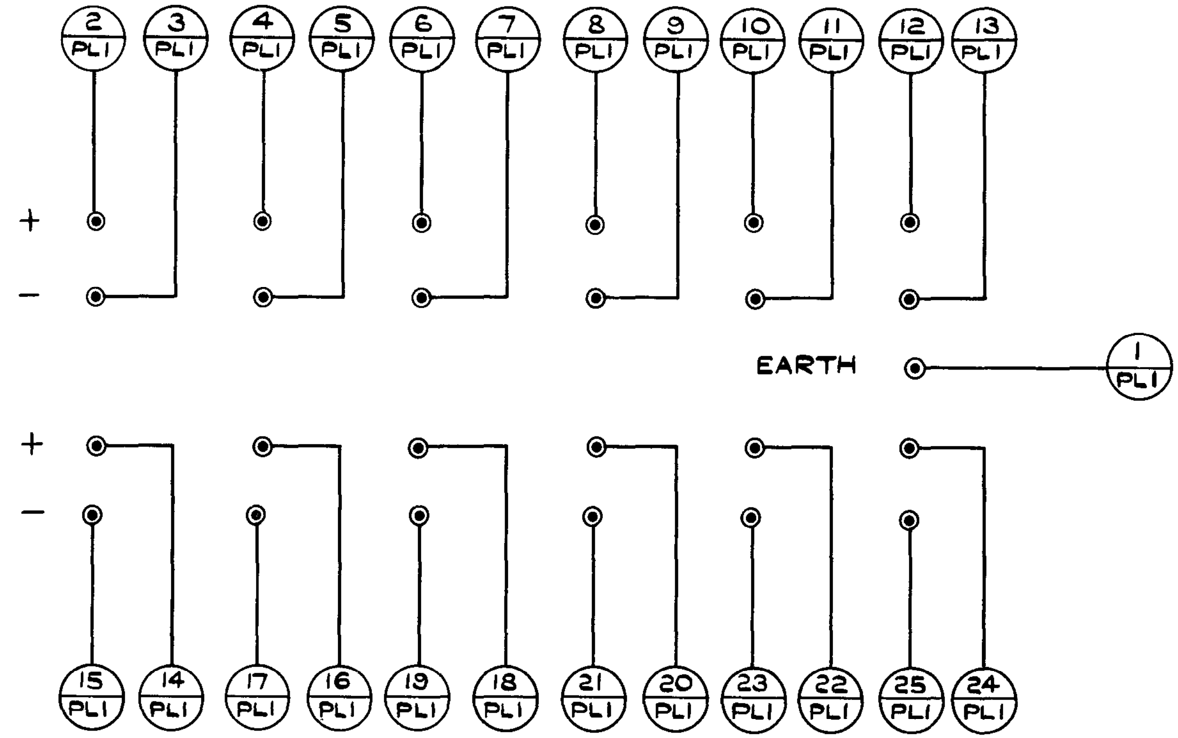

FIG. 26. TYPEWRITER




* TEMPERATURE COEFFICIENT OF RESISTANCE MATCHED TO 2 P.P.M.

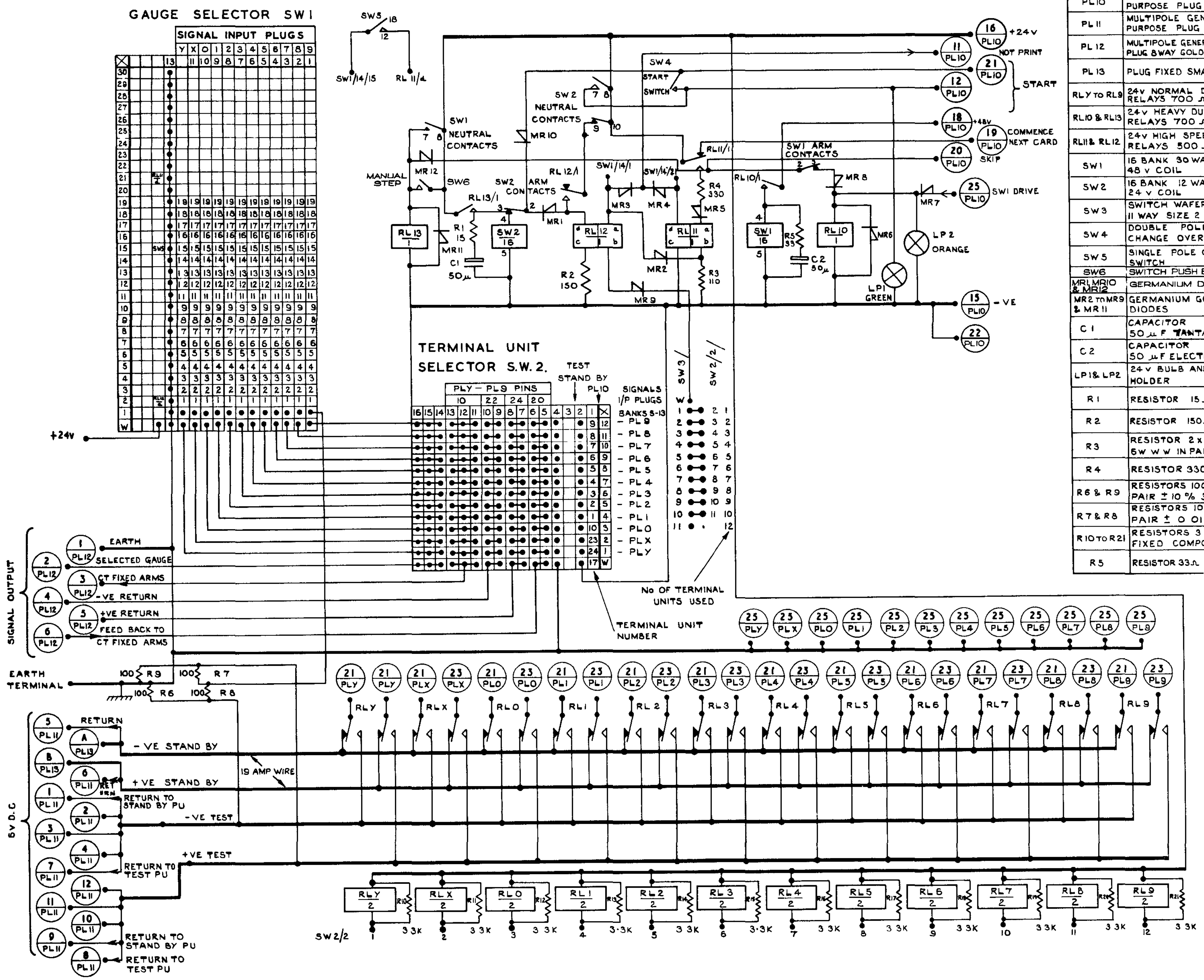
| CIRC REF | DESCRIPTION | DEF SPEC | TYPE | SERVICE REF. No. |
|---|---|---|---|---|
| PL | MULTIPOLE GENERAL PURPOSE PLUG FIXED 25 POLE (WITH GOLD PLATED PINS) | | UNITOR No 102 (B) | BELLING & LEE |
| R1 R2 | 100 Ω ± 0·1 % RESISTOR * | | R5 | BAY & CO (U.K.) LTD. |
| | | | | |
| FS 1-2 | FUSE MINIATURE 1 AMP. | RCL 261 | 5/8" x 3/16" | 5920-99-059-0318 |

# FIG. 27. STRAIN GAUGE TERMINAL UNIT.



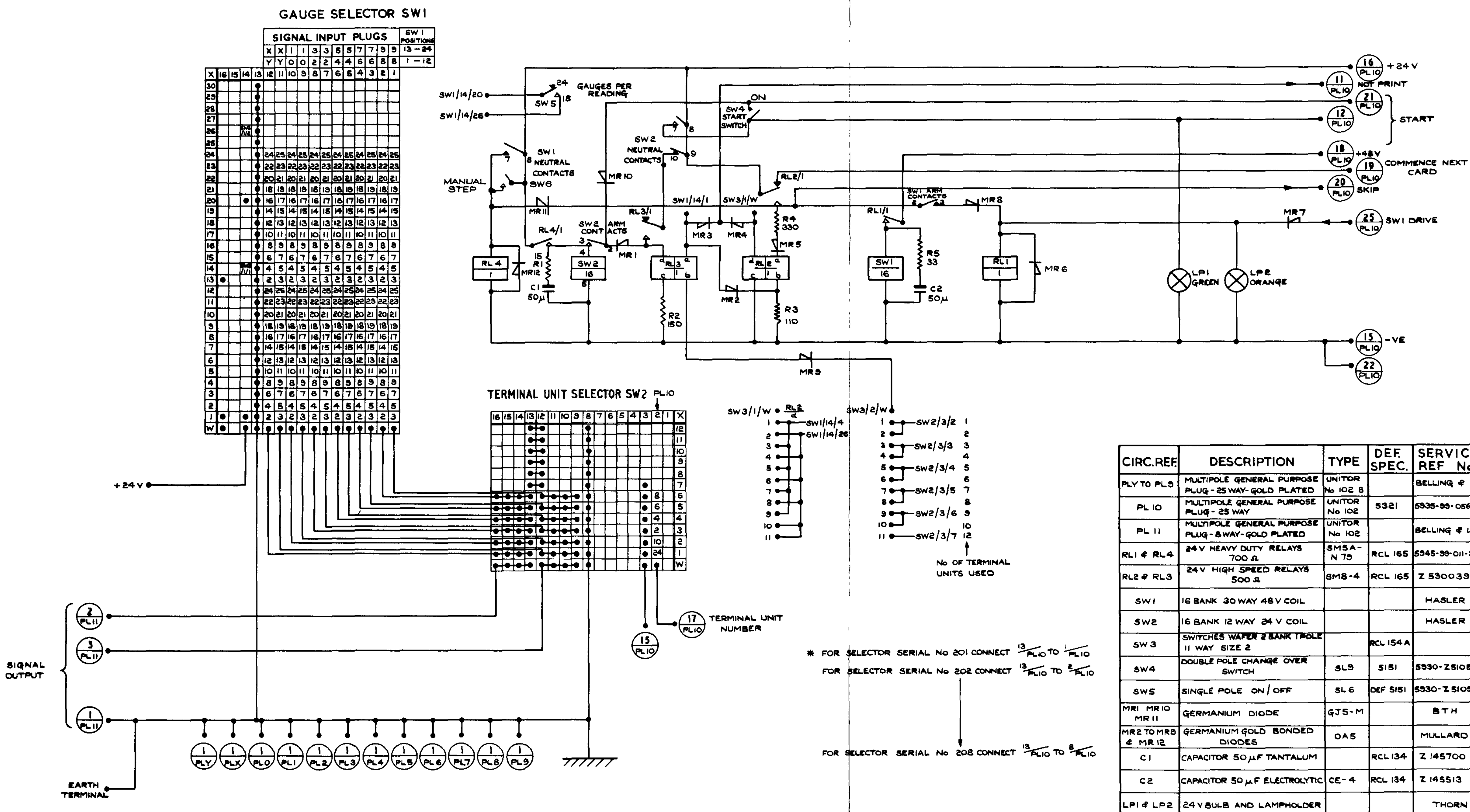

| CIRC. REF. | DESCRIPTION | DEF. SPEC. | TYPE | SERVICE REF. Nº. |
|---|---|---|---|---|
| PL1 | MULTI POLE GENERAL PURPOSE PLUG FIXED 25 POLE (WITH GOLD PLATED PINS) | | UNITOR Nº 102 (B) | BELLING AND LEE |

# FIG. 28. THERMOCOUPLE TERMINAL UNIT.



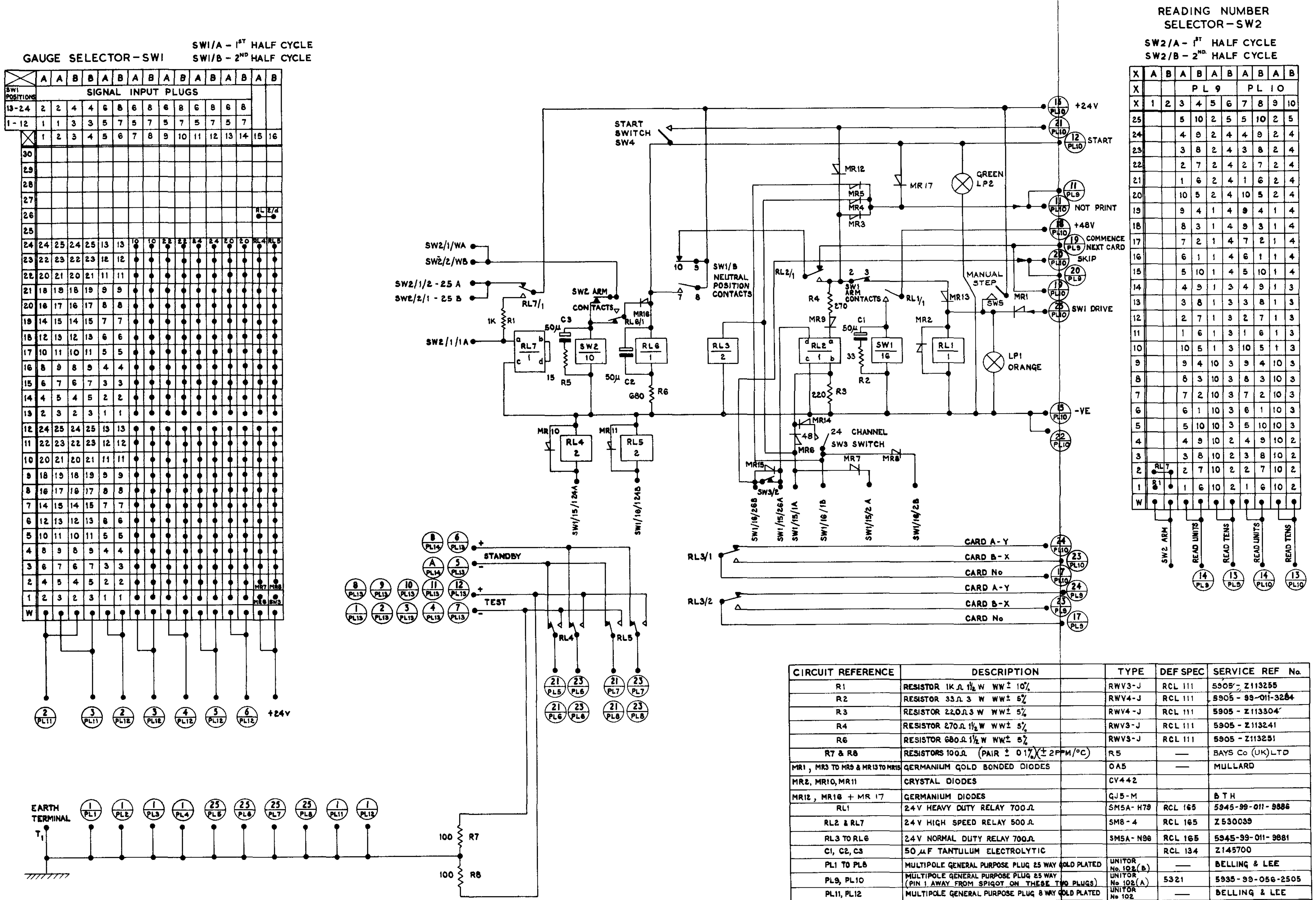

| CIRC REF. | DESCRIPTION | TYPE | DEF.SPEC. | SERVICE REF.No. |
|---|---|---|---|---|
| PLY TO PL9 | MULTIPOLE GENERAL PURPOSE PLUG 25 WAY GOLD PLATED | UNITOR No 102 (B) | | BELLING & LEE |
| PL10 | MULTIPOLE GENERAL PURPOSE PLUG 25 WAY | UNITOR No 102 | 5321 | 5935-99-056-2505 |
| PL11 | MULTIPOLE GENERAL PURPOSE PLUG 12 WAY | UNITOR No 102 | 5321 | 5935-99-056-2503 |
| PL12 | MULTIPOLE GENERAL PURPOSE PLUG 8WAY GOLD PLATED | UNITOR No 102(B) | 5321 | 5935-99-056-2502 |
| PL13 | PLUG FIXED SMALL 2 POLE | P4xF1/2/0 | 5321 | 5935-99-056-0050 |
| RLY TO RL9 | 24V NORMAL DUTY RELAYS 700 Ω | SM5A-N96 | RCL 165 | 5945-99-011-9881 |
| RL10 & RL13 | 24V HEAVY DUTY RELAYS 700 Ω | SM5A-H78 | RCL 165 | 5945-99-011-9886 |
| RL11 & RL12 | 24V HIGH SPEED RELAYS 500 Ω | SM8-4 | RCL 165 | Z 530039 |
| SW1 | 16 BANK 30 WAY 48 V COIL | | | HASLER |
| SW2 | 16 BANK 12 WAY 24 V COIL | | | HASLER |
| SW3 | SWITCH WAFER 1 POLE 11 WAY SIZE 2 | | RCL 154 A | |
| SW4 | DOUBLE POLE CHANGE OVER SWITCH | SL 9 | 5151 | 5930-Z510504 |
| SW5 | SINGLE POLE ON/OFF SWITCH | SL 6 | 5151 | 5930-Z510501 |
| SW6 | SWITCH PUSH BUTTON | | | PAINTON |
| MR1, MR10 & MR12 | GERMANIUM DIODES | GJ5-M | | BTH |
| MR2 TO MR9 & MR11 | GERMANIUM GOLD-BONDED DIODES | OA5 | | MULLARD |
| C1 | CAPACITOR 50 µF TANTALUM | | RCL 134 | Z 145700 |
| C2 | CAPACITOR 50 µF ELECTROLYTIC | CE-4 | RCL 134 | Z 145513 |
| LP1 & LP2 | 24V BULB AND LAMP HOLDER | | | THORN |
| R1 | RESISTOR 15 Ω 3W WW | RWV4-J | RCL 111 | 5905-99-011-3276 |
| R2 | RESISTOR 150 Ω 1½ WWW | RWV3-J | RCL 111 | 5905-Z113235 |
| R3 | RESISTOR 2x220 Ω 6W WW IN PARALLEL | RWV4-L | RCL 111 | 5905-Z113381 |
| R4 | RESISTOR 330 Ω 1½ W WW | RWV3-J | RCL 111 | 5905-Z113243 |
| R6 & R9 | RESISTORS 100 Ω MATCHED PAIR ± 10 % 3 W WW | RWW4-J | RCL 111 | 5905-Z113296 |
| R7 & R8 | RESISTORS 100 Ω MATCHED PAIR ± 0.01 % | R5 | — | BAY & Co (UK) LTD |
| R10 TO R21 | RESISTORS 3.3K Ω ¼ W FIXED COMPOSITION | RC7-J | RCL 112 | Z 222068 |
| R5 | RESISTOR 33 Ω 3W WW | RV4-J | RCL 111 | 5905-99-011-3284 |

FIG.29. STRAIN GAUGE AND POTENTIOMETER SELECTOR UNIT.




| CIRC.REF. | DESCRIPTION | TYPE | DEF. SPEC. | SERVICE REF No. |
|---|---|---|---|---|
| PLY TO PL9 | MULTIPOLE GENERAL PURPOSE PLUG - 25 WAY - GOLD PLATED | UNITOR No 102 8 | | BELLING & LEE |
| PL 10 | MULTIPOLE GENERAL PURPOSE PLUG - 25 WAY | UNITOR No 102 | 5321 | 5935-99-056-2505 |
| PL 11 | MULTIPOLE GENERAL PURPOSE PLUG - 8 WAY - GOLD PLATED | UNITOR No 102 | | BELLING & LEE |
| RL1 & RL4 | 24 V HEAVY DUTY RELAYS 700 Ω | SM5A-N 79 | RCL 165 | 5945-99-011-9886 |
| RL2 & RL3 | 24 V HIGH SPEED RELAYS 500 Ω | SM8-4 | RCL 165 | Z 530039 |
| SW1 | 16 BANK 30 WAY 48 V COIL | | | HASLER |
| SW2 | 16 BANK 12 WAY 24 V COIL | | | HASLER |
| SW 3 | SWITCHES WAFER 2 BANK 1 POLE 11 WAY SIZE 2 | | RCL 154 A | |
| SW4 | DOUBLE POLE CHANGE OVER SWITCH | SL9 | 5151 | 5930-Z510804 |
| SW5 | SINGLE POLE ON / OFF | SL 6 | DEF 5151 | 5930-Z 510501 |
| MR1 MR10 MR11 | GERMANIUM DIODE | GJ5-M | | BTH |
| MR2 TO MR9 & MR 12 | GERMANIUM GOLD BONDED DIODES | OA5 | | MULLARD |
| C1 | CAPACITOR 50 μF TANTALUM | | RCL 134 | Z 145700 |
| C2 | CAPACITOR 50 μF ELECTROLYTIC | CE - 4 | RCL 134 | Z 145513 |
| LP1 & LP2 | 24 V BULB AND LAMPHOLDER | | | THORN |
| R1 | RESISTOR 15 Ω 3 W WW | RWV4 - J | RCL 111 | 5905-99-011-3184 |
| R5 | RESISTOR 33 Ω 3 W WW | RWV4 - J | RCL 111 | 5905-99-011-3284 |
| R2 | RESISTOR 150 Ω 1½ W WW | RWV3 - J | RCL 111 | 5905 - Z113235 |
| R3 | RESISTORS 2 x 220 6 W WW IN PARALLEL | RWV4 - L | RCL 111 | 5905 - Z113381 |
| R4 | RESISTOR 330 Ω 1½ W WW | RWV3 - J | RCL 111 | 5905 - Z113243 |

FIG. 30. THERMOCOUPLE AND VOLTAGE SELECTOR UNIT.




| CIRCUIT REFERENCE | DESCRIPTION | TYPE | DEF SPEC | SERVICE REF No. |
|---|---|---|---|---|
| R1 | RESISTOR 1K Ω 1½ W WW ± 10% | RWV3-J | RCL 111 | 5905-Z113255 |
| R2 | RESISTOR 33 Ω 3 W WW ± 5% | RWV4-J | RCL 111 | 5905-99-011-3284 |
| R3 | RESISTOR 220 Ω 3 W WW ± 5% | RWV4-J | RCL 111 | 5905-Z113304 |
| R4 | RESISTOR 270 Ω 1½ W WW ± 5% | RWV3-J | RCL 111 | 5905-Z113241 |
| R6 | RESISTOR 680 Ω 1½ W WW ± 5% | RWV3-J | RCL 111 | 5905-Z113251 |
| R7 & R8 | RESISTORS 100 Ω (PAIR ± 0 1%)(± 2PPM/°C) | R5 | — | BAYS Co (UK) LTD |
| MR1, MR3 TO MR9 & MR13 TO MR15 | GERMANIUM GOLD BONDED DIODES | OA5 | — | MULLARD |
| MR2, MR10, MR11 | CRYSTAL DIODES | CV442 | | |
| MR12, MR16 + MR 17 | GERMANIUM DIODES | GJ5-M | | B T H |
| RL1 | 24V HEAVY DUTY RELAY 700 Ω | SM5A-H79 | RCL 165 | 5945-99-011-9886 |
| RL2 & RL7 | 24 V HIGH SPEED RELAY 500 Ω | SM8-4 | RCL 165 | Z 530039 |
| RL3 TO RL6 | 24 V NORMAL DUTY RELAY 700 Ω | SM5A-N96 | RCL 165 | 5945-99-011-9881 |
| C1, C2, C3 | 50 μF TANTULUM ELECTROLYTIC | | RCL 134 | Z145700 |
| PL1 TO PL8 | MULTIPOLE GENERAL PURPOSE PLUG 25 WAY GOLD PLATED | UNITOR No. 102(B) | — | BELLING & LEE |
| PL9, PL10 | MULTIPOLE GENERAL PURPOSE PLUG 25 WAY (PIN 1 AWAY FROM SPIGOT ON THESE TWO PLUGS) | UNITOR No 102(A) | 5321 | 5935-99-056-2505 |
| PL11, PL12 | MULTIPOLE GENERAL PURPOSE PLUG 8 WAY GOLD PLATED | UNITOR No 102 | — | BELLING & LEE |
| PL13 | MULTIPOLE GENERAL PURPOSE PLUG 12 WAY | UNITOR No 102 | 5321 | 5935-99-056-2503 |
| SW1 | 16 BANK 30 WAY UNISELECTOR 48 V COIL | — | — | HASLER |
| SW2 | 10 BANK 25 WAY UNISELECTOR 24 V COIL | — | — | 10F/NIV/7810 |
| SW3 | SINGLE POLE ON/OFF SWITCH | SL6 | 5151 | 5930-Z510501 |
| SW4 | DOUBLE POLE CHANGE OVER | SL9 | 5151 | 5930-Z510504 |
| SW5 | SWITCH - PUSH BUTTON | — | — | PAINTON |
| LP1 & LP2 | 24V 0 04A MINIATURE | | | THORN |
| T1 | TERMINAL (EARTH) | | | |
| R5 | RESISTOR 15 Ω 3W WW | RWV4-J | RCL 111 | 5905-99-011-3276 |

FIG. 31. STRAIN GAUGE AND THERMOCOUPLE SELECTOR UNIT.

| CIRCUIT REF | DESCRIPTION | TYPE | SPEC | SERVICE REF No |
|---|---|---|---|---|
| PL1 TO PL6 | MULTIPOLE, GENERAL PURPOSE PLUG 8 WAY GOLD PLATED | UNITOR No 102 | | |
| SK7 TO SK11 | MULTIPOLE, GENERAL PURPOSE SOCKET 12 WAY | UNITOR No 102 | DEF 5321 | 5935-99-056-2508 |
| PL12 TO PL16 TO PL29 | MULTIPOLE GENERAL PURPOSE PLUG 12 WAY | UNITOR No 102 | DEF 5321 | 5935-99-056-2503 |
| SK17 TO SK21 | MULTIPOLE, GENERAL PURPOSE SOCKET 25 WAY | UNITOR No 102 | DEF 5321 | 5935-99-056-2510 |
| PL28 | MULTIPOLE, GENERAL PURPOSE PLUG 25 WAY | UNITOR No 102 | DEF 5321 | 5935-99-056-2505 |
| PL22 TO PL27 | PLUG 3 WAY | | | BULGIN |
| R1 | RESISTOR 33Ω 3W WIREWOUND | RWV4-J | RCL111 | 5905-99-011-3284 |
| R2 | RESISTOR 420Ω 1½W WIREWOUND | RWV3-J | RCL111 | 5905-99-011-3247 |
| R3 | RESISTOR 3.3K ¼W FIXED COMPOSITION | RC7-K | RCL 112 | Z222067 |
| R4 | RESISTOR 130Ω 1½W WIREWOUND | RWV3-J | RCL 111 | 5905-99-011-3234 |
| R5 | RESISTOR 68Ω 1½W WIREWOUND | RWV3-J | RCL 111 | 5905-99-011-3227 |
| R6 | RESISTOR 47Ω 1½W WIREWOUND | RWV3-J | RCL 111 | 5905 99-011-3225 |
| R7 | RESISTOR 33Ω 1½W WIREWOUND | RWV3-J | RCL 111 | 5905-99-011-3219 |
| R8 | RESISTOR 68Ω 6W WIREWOUND | RWV4-L | RCL 111 | 5905-99-011-3369 |
| MR1 | DIODE GOLD BONDED | OA5 | — | CV7074 |
| MR2 & MR3 | DIODE GERMANIUM | GJ5-M | — | CV7039 |
| MR4 | DIODE 7V 1W ZENER | — | — | STC |
| SW1 | 16 BANK 12 WAY UNISELECTOR 48V COIL | — | — | HASLER |
| SW2 | SWITCH DOUBLE POLE CHANGE OVER SPRING SET | SL19 | DEF 5151 | 5930-Z510582 |
| SW3 | SWITCH WAFER OAK PATTERN 5 WAY 2 BANK NON SHORTENING | — | RCL154A | — |
| SW4 | SWITCH DOUBLE POLE CHANGE OVER | SL9 | DEF 5151 | 5930-Z510504 |
| LP1 TO LP10 | 24V LAMP AND HOLDER | | | THORN |

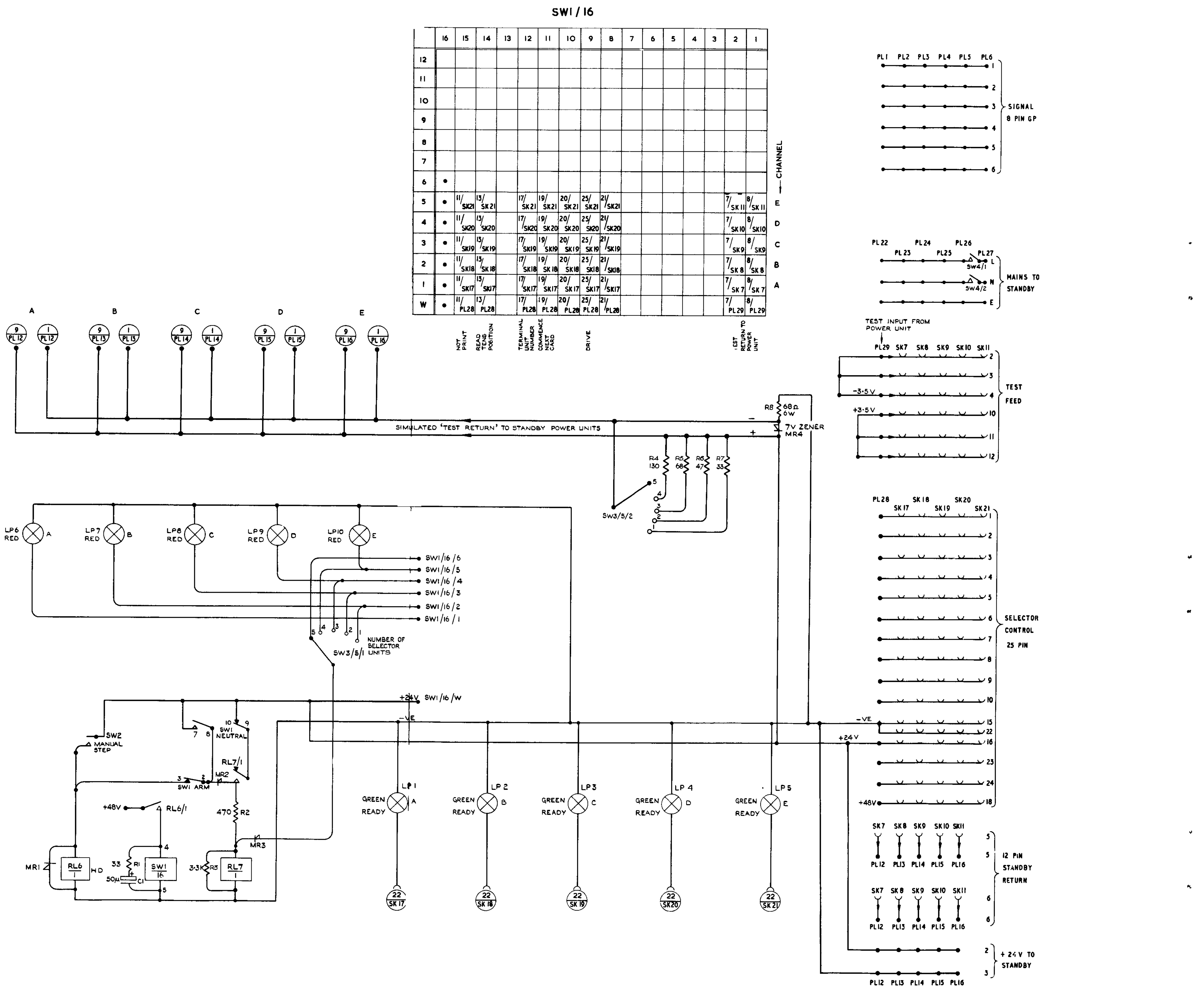
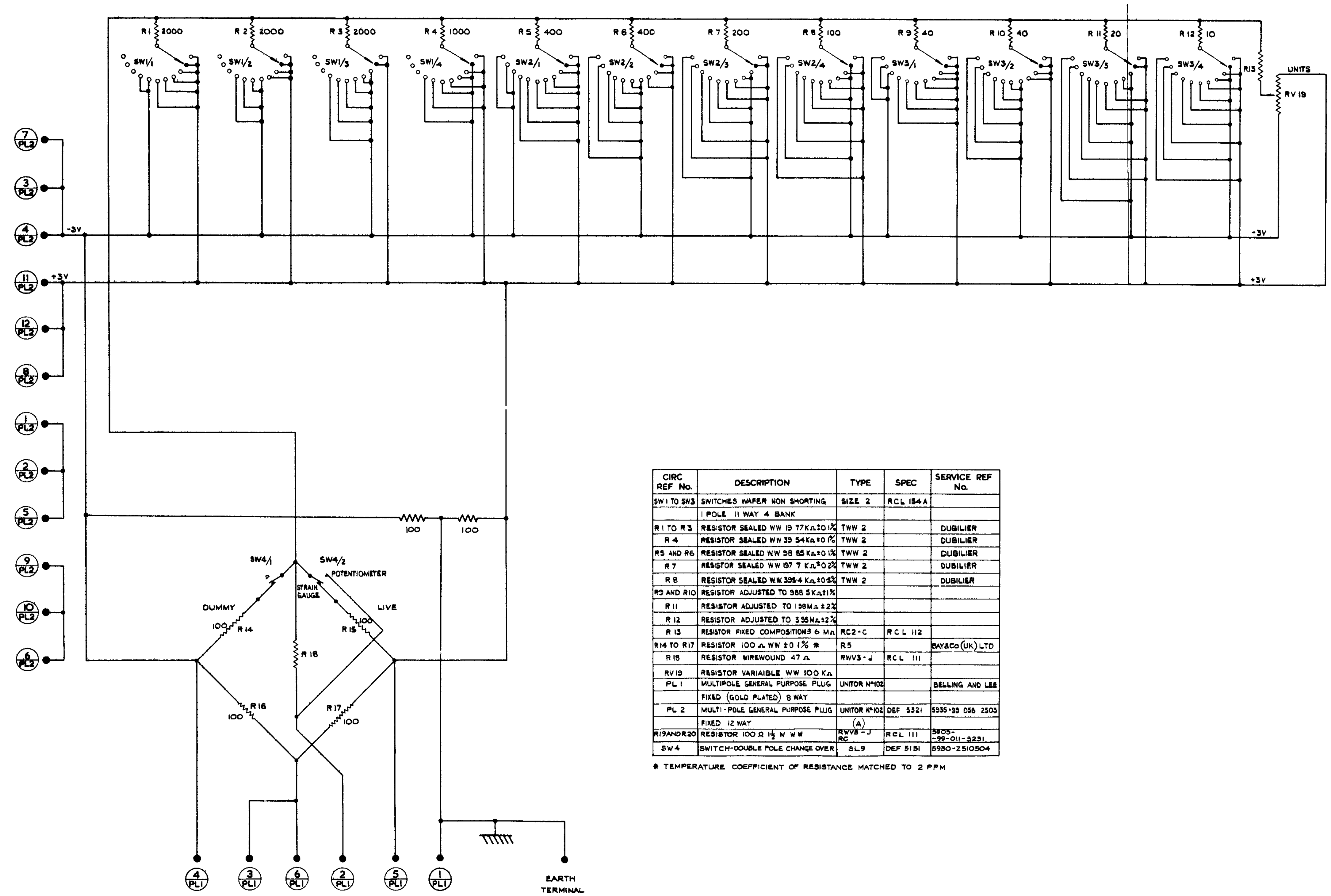


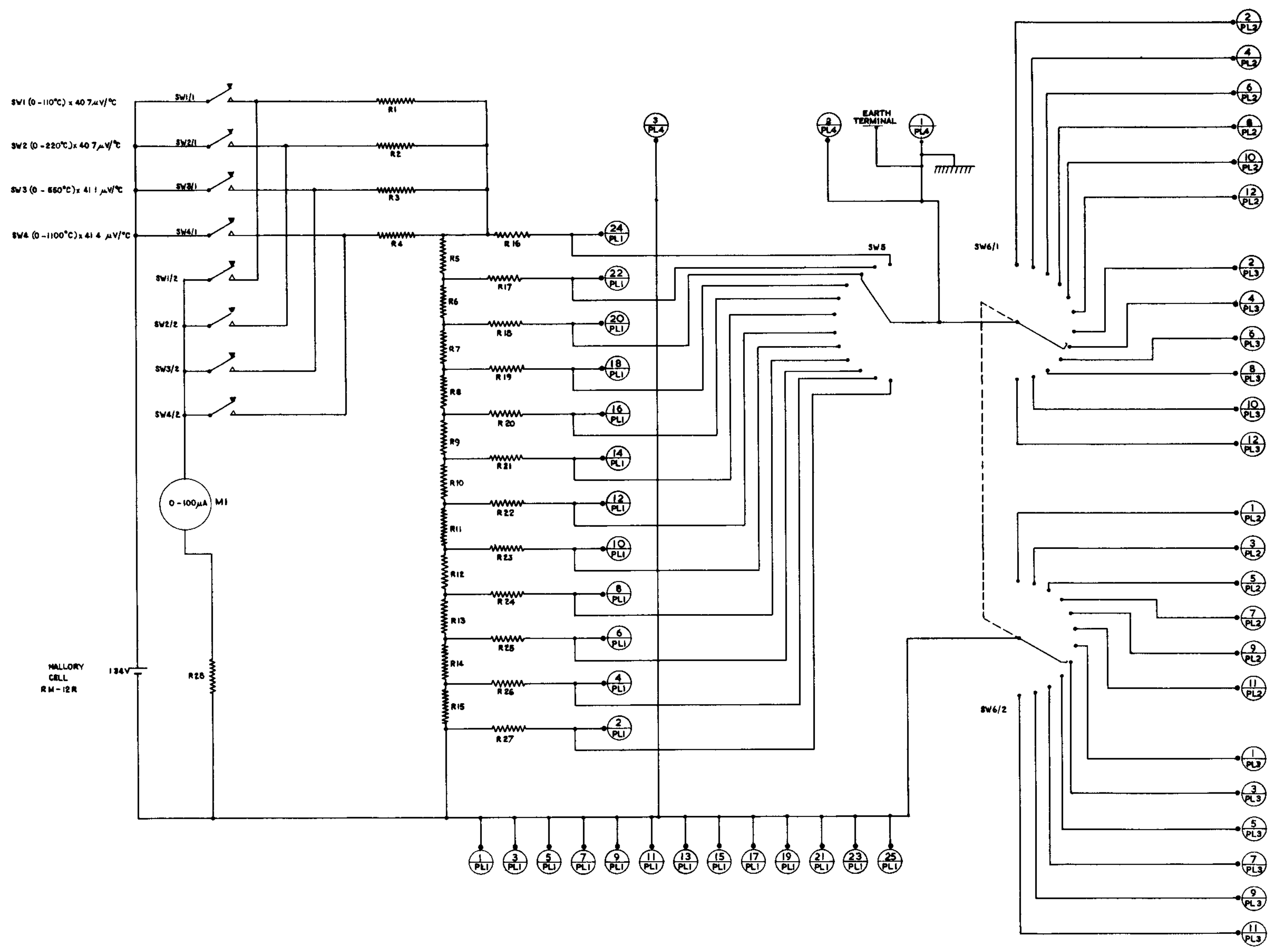

FIG.32. SELECTOR ROUTING UNIT.




| CIRC REF No. | DESCRIPTION | TYPE | SPEC | SERVICE REF No. |
|---|---|---|---|---|
| SW 1 TO SW3 | SWITCHES WAFER NON SHORTING | SIZE 2 | RCL 154 A | |
| | 1 POLE 11 WAY 4 BANK | | | |
| R 1 TO R 3 | RESISTOR SEALED WW 19 77 KΩ ±0 1% | TWW 2 | | DUBILIER |
| R 4 | RESISTOR SEALED WW 39 54 KΩ ±0 1% | TWW 2 | | DUBILIER |
| R5 AND R6 | RESISTOR SEALED WW 98 85 KΩ ±0 1% | TWW 2 | | DUBILIER |
| R 7 | RESISTOR SEALED WW 197 7 KΩ ±0 2% | TWW 2 | | DUBILIER |
| R 8 | RESISTOR SEALED W.W. 395·4 KΩ ±0·5% | TWW 2 | | DUBILIER |
| R9 AND R10 | RESISTOR ADJUSTED TO 988 5 KΩ ±1% | | | |
| R 11 | RESISTOR ADJUSTED TO 1 98 MΩ ±2% | | | |
| R 12 | RESISTOR ADJUSTED TO 3 95 MΩ ±2% | | | |
| R 13 | RESISTOR FIXED COMPOSITION 3 6 MΩ | RC2 - C | RCL 112 | |
| R 14 TO R 17 | RESISTOR 100 Ω WW ±0 1% * | R5 | | BAY&Co (UK) LTD |
| R 18 | RESISTOR WIREWOUND 47 Ω | RWV3 - J | RCL 111 | |
| RV 19 | RESISTOR VARIAIBLE WW 100 KΩ | | | |
| PL 1 | MULTIPOLE GENERAL PURPOSE PLUG | UNITOR No 102 | | BELLING AND LEE |
| | FIXED (GOLD PLATED) 8 WAY | | | |
| PL 2 | MULTI-POLE GENERAL PURPOSE PLUG | UNITOR No 102 | DEF 5321 | 5935-99 056 2503 |
| | FIXED 12 WAY | (A) | | |
| R19 AND R20 | RESISTOR 100 Ω 1½ W WW | RWV3 - J RC | RCL 111 | 5905- -99-011-3231 |
| SW 4 | SWITCH-DOUBLE POLE CHANGE OVER | SL9 | DEF 5151 | 5930-Z510504 |

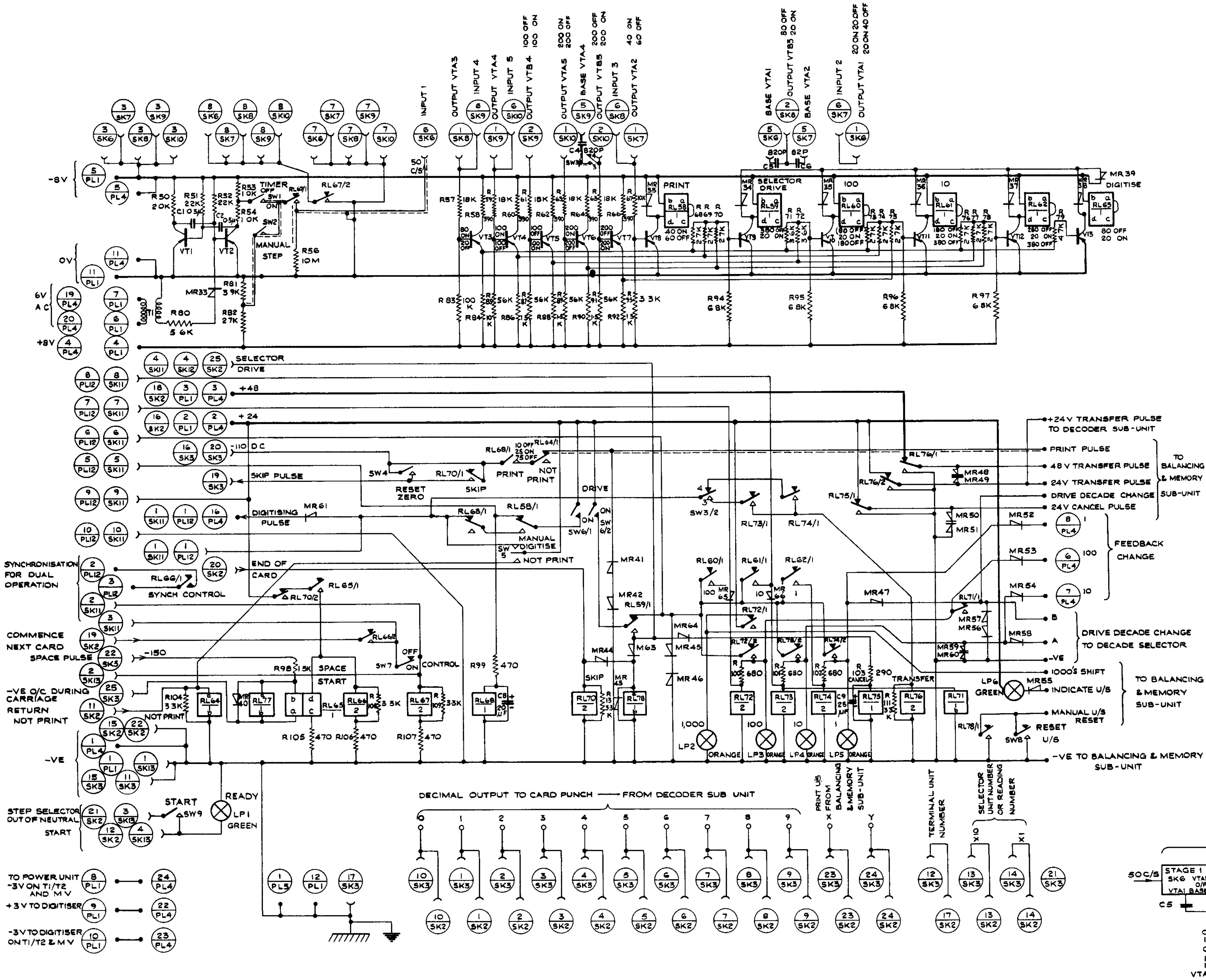
* TEMPERATURE COEFFICIENT OF RESISTANCE MATCHED TO 2 PPM

FIG. 33. STRAIN GAUGE AND POTENTIOMETER SIMULATOR.




| CIRC REF | DESCRIPTION | | R.C.L | TYPE | SERVICE REF Nº |
|---|---|---|---|---|---|
| SW 1-4 | SWITCH PUSHBUTTON OPERATED D.P | | | SPRING SET | |
| SW 5-6 | WINKLER GOLD PLATED | | | | PAINTON |
| PL 1 | MULTIPOLE GENERAL PURPOSE-25WAY GOLD PLATED. | | | UNITOR Nº102 (B) | BELLING & LEE |
| PL 2-3 | MULTIPOLE GENERAL PURPOSE-12 WAY GOLD-PLATED | | | UNITOR Nº102 | " " " |
| PL 4 | MULTIPOLE GENERAL PURPOSE-8 WAY GOLD-PLATED | | | UNITOR Nº102 | " " |
| R 1 | 29 KΩ | VALUES OF WIREWOUND RESISTORS ADJUSTED TO GIVE AN ACCURACY OF ± 1% (VOLTAGE) | 111 | RWV3-U | |
| R 2 | 14 KΩ | | 111 | RWV3-J | |
| R 3 | 5.3 KΩ | | 111 | RWV3-J | |
| R 4 | 2.7 KΩ | | 111 | RWV3-J | |
| R 5 to R15 | 8.2Ω WW RESISTOR | ± 1% | 111 | RWV3-J | 5905-Z113206 |
| R 16 | 10 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z113207 |
| R 17 | 18 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z113213 |
| R 18 | 24 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z117979 |
| R 19 | 33 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z113219 |
| R 20 | 43 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z113222 |
| R 21 | 51 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z117980 |
| R 22 | 62 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z113226 |
| R 23 | 68 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z113227 |
| R 24 | 75 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z113228 |
| R 25 | 81 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z113229 |
| R 26 | 91 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z113230 |
| R 27 | 100 Ω WW RESISTOR | | 111 | RWV3-J | 5905-Z113231 |
| R 28 | 15 KΩ WW RESISTOR | | 111 | RWV4-J | 5905-Z113346 |
| M 1 | AMMETER 0-100μA MOVING COIL METER | | — | — | — |

FIG. 34. TEMPERATURE SIMULATOR (100 Ω IMPEDANCE)




| CIRC REF | | DESCRIPTION | TYPE | SPEC | SERVICE REF No |
|---|---|---|---|---|---|
| PL1 | | MULTIPOLE GENERAL PURPOSE PLUG 12 WAY | UNITOR No 102 | DEF 5321 | 5935-99-056-2503 |
| SK2 & SK3 | | MULTIPOLE GENERAL PURPOSE SOCKET 25 WAY | UNITOR No 102 | DEF 5321 | 5935-99-056-2510 |
| SK6 - SK10 | | SOCKET XS8 FOR USE WITH VENNER UNITS TS2A | — | — | VENNER |
| SK11 | | MULTIPOLE GENERAL PURPOSE SOCKET 8 WAY | UNITOR No 102 | DEF 5321 | 5935-99-056-2507 |
| PL12 | | MULTIPOLE GENERAL PURPOSE PLUG 8 WAY | UNITOR No 102 | DEF 5321 | 5935-99-056-2502 |
| SK13 | | MULTIPOLE GENERAL PURPOSE SOCKET 4 WAY | UNITOR No.102 | DEF 5321 | 5935-99-056-2506 |
| RL58 TO RL63 | | 12V HIGH SPEED RELAY | SM8-3 | RCL165 | Z530038 |
| RL 64, RL 66, RL77, RL78 | | 24V HIGH SPEED RELAY | SM8-4 | RCL165 | Z530039 |
| RL 66, RL67 RL70 TO RL75 | | 24V NORMAL DUTY RELAY | SM5A-N96 | RCL165 | 5945-99-011-9881 |
| RL68 | | 24V HEAVY DUTY RELAY | SM5A-H79 | RCL165 | 5945-99-011-9886 |
| RL 71 | | 24V HIGH SPEED RELAY | SM5-4 | RCL 165 | 2530039 |
| RL 76 | | 12V NORMAL DUTY RELAY | SM5A-N95 | RCL 165 | 5945-99-011-9880 |
| MR6, MR34 38, MR40, MR52-54 | | CRYSTAL DIODE | — | — | CV442 |
| MR48, MR50, MR45, MR61, MR56, MR57 MR59 MR60 | | ZENER DIODE 15 OV 1W | — | — | STC |
| MR39 | | ZENER DIODE 6 8V | SX68 | — | CV7071 |
| MR49 MR51, MR61 | | GERMANIUN DIODE | GJ5M | — | CV7039 |
| MR42, MR47 MR58 | | SILICON DIODE | 1S113 | — | CV7013 |
| MR33, MR46, MR55 MR43, MR44 MR62-66 | | GOLD BONDED DIODE | OA5 | — | CV7047 |
| SW1, SW7 | | SWITCH - ON /OFF | SL8 | DEF 5151 | 5930-Z510501 |
| SW2, SW4 SW8 | | SWITCH-PUSH BUTTON | — | — | PAINTON |
| SW3 & SW6 | | SWITCH-DOUBLE POLE CHANGE OVER | SL9 | DEF 5151 | 5930-Z510504 |
| SW5 & SW9 | | SWITCH-DOUBLE POLE CHANGEOVER SPRING SET | SL19 | DEF 5151 | 5930-Z510582 |
| LP1, TO LP6 | | 24V LAMP & HOLDER | — | — | THORN |
| VT1 TO VT13 | | JUNCTION TRANSISTOR | GET 104 | — | — |
| C1, C2 | | 0 5µf PAPER DIELECTRIC CAPACITOR | CDM 2K | RCL 1368 | Z115567 |
| C4 TO C6 | | 820pf MICA DIELECTRIC CAPACITOR | CMM1 | DEF 5132 | 5910-Z123957 |
| C8 | | 20µf ELECTROLYTIC CAPACITOR | CET 11 | RCL 134 | Z145289 |
| R50 | | RESISTOR 2 OKΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0215278 |
| R51 & R52 | | RESISTOR 22KΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0216043 |
| R53 & R54 | | RESISTOR 1 OKΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0215643 |
| R80 | | RESISTOR 5 6K Ω ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0215333 |
| R56 | | RESISTOR 1OMΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0216893 |
| R57, R59, R31 R63 R65 | | RESISTOR 18KΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0216033 |
| R58 R60, R62 R64 R66 | | RESISTOR 390 Ω 1½ W WIRE WOUND | RWV3-5 | RCL111 | 0113245 |
| R67, R84 | | RESISTOR 10K Ω ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0216003 |
| R68 TO R70, R73 TO R78 & R82 | | RESISTOR 2 7 Ω ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0215293 |
| R71 & R72 | | RESISTOR 3 6KΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0215308 |
| R79 | | RESISTOR 4 7KΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0215323 |
| R81 | | RESISTOR 3 9KΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0215313 |
| R83 | | RESISTOR 100KΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0216123 |
| R85 R87 R89 R91 | | RESISTOR 56KΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0216093 |
| R86, R88, R90, R92 | | RESISTOR 1 5KΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0215263 |
| R93 | | RESISTOR 3 3KΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0215303 |
| R94 - R97 | | RESISTOR NOMINAL 6·8KΩ ¾ W FIXED COMPOSITION | RC2C | RCL112 | 0215343 |
| R98 | | RESISTOR 1 5KΩ 3 W WIRE WOUND | RWV4-J | RCL111 | 0113524 |
| R99, R105 TO R107 & R109 | | RESISTOR 470 Ω 1½ W WIRE WOUND | RWV3-J | RCL111 | 0113247 |
| R100 TO R102 | | RESISTOR 680 Ω 1½ W WIRE WOUND | RWV3-J | RCL111 | 0113251 |
| R103 | | RESISTOR 270 Ω 1½ W WIRE WOUND | RWV3-J | RCL111 | 0113241 |
| R104, R108, R109, R111 & R113 | | RESISTOR 33 Ω ¼ W FIXED COMPOSITION | RC7-K | RCL112 | 2222067 |
| T1 | | TRANSFORMER MINIATURE | MM1-B | — | NIV/8872 |

PL1 POWER UNIT
SK2 SELECTOR SWITCH
SK3 CARD PUNCH
PL4 DIGITISING AMPLIFIER (CONTROL)
PL5 DIGITISING AMPLIFIER (SIGNAL)
SK6 TO SK10 VENNER BINARY UNITS TS2A
SK11 COUPLING FOR DUAL OPERATION
PL12, SK13 SYNCHRONISING UNIT INPUT

BINARY UNITS
PIN 1 — OUTPUT A
2 — OUTPUT B
3 — SUPPLY-VE
4 — BASE VTB
5 — BASE VTA
6 — INPUT
7 — SUPPLY+VE
8 — SET ZERO

# FIG. 35. TIMING SUB-UNIT.

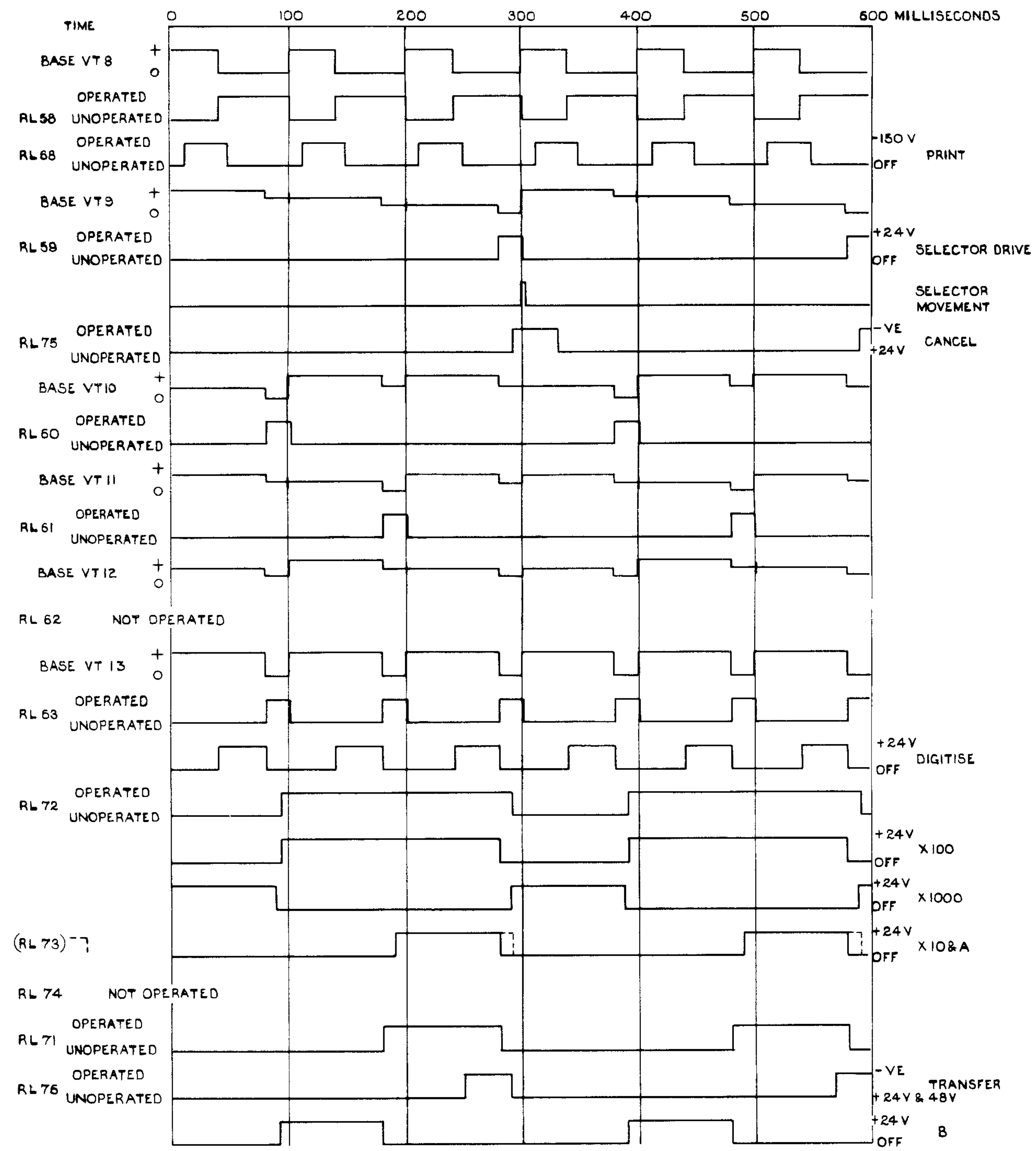



FIG.36. TIMING SEQUENCE — 3 DIGIT CYCLE.

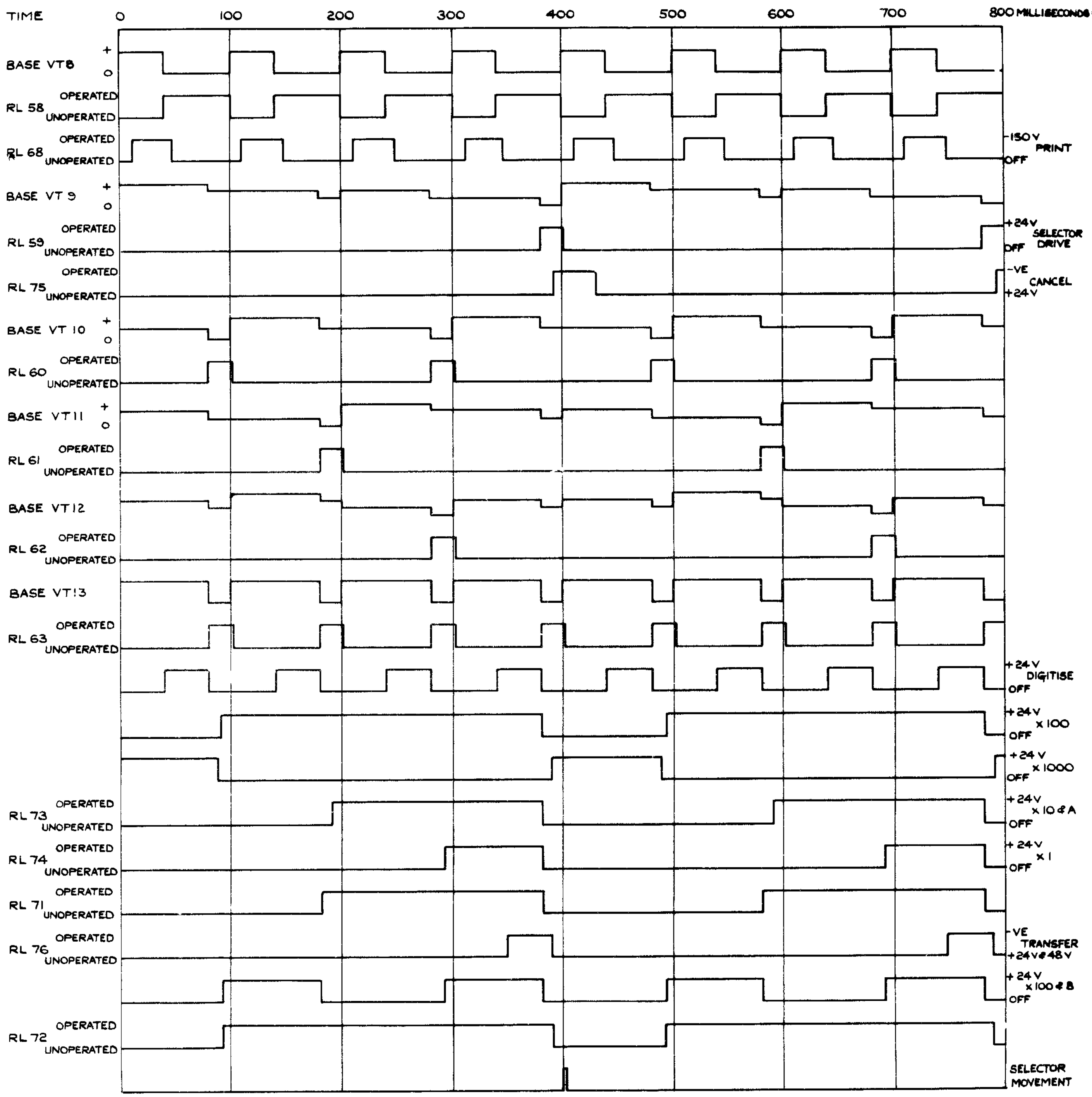



FIG.37. TIMING SEQUENCE - 4 DIGIT CYCLE.

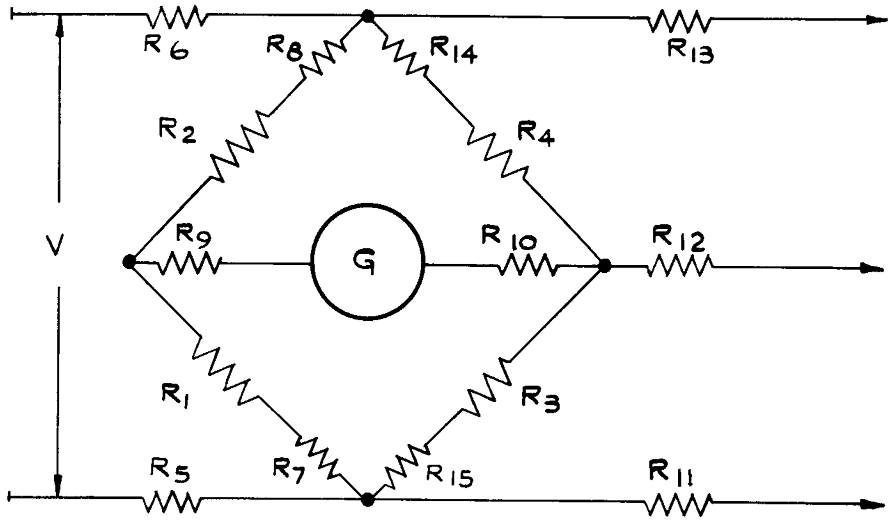



FIG. 38. STRAIN GAUGE BRIDGE WITH LEAD RESISTANCES

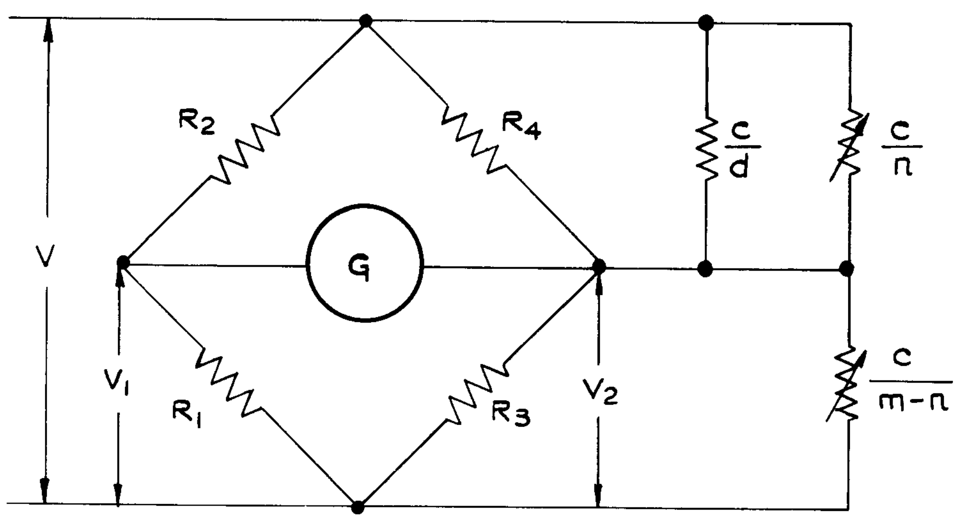



FIG. 39. LINEARIZED STRAIN GAUGE BRIDGE.

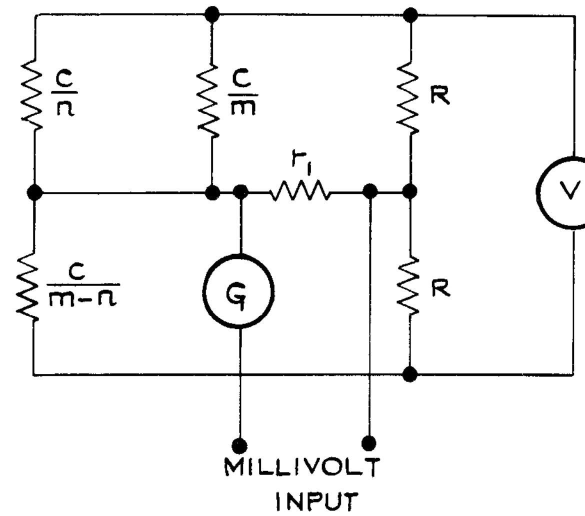



FIG. 40. MILLIVOLT BALANCING CIRCUIT

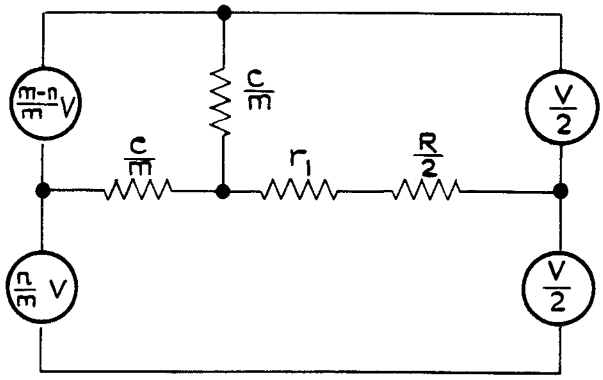



FIG. 41. EQUIVALENT MILLIVOLT CIRCUIT

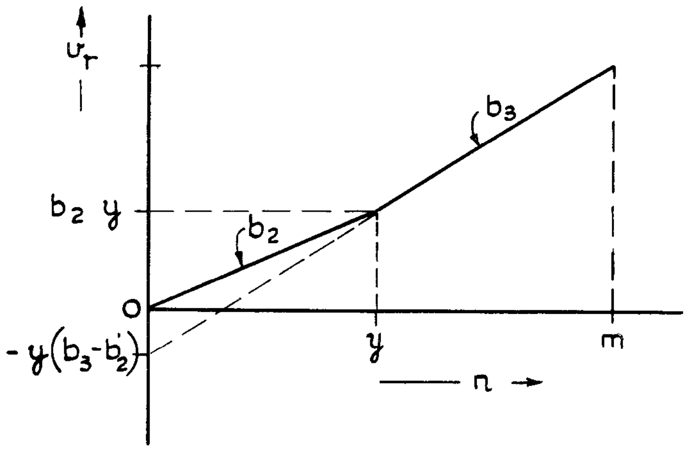
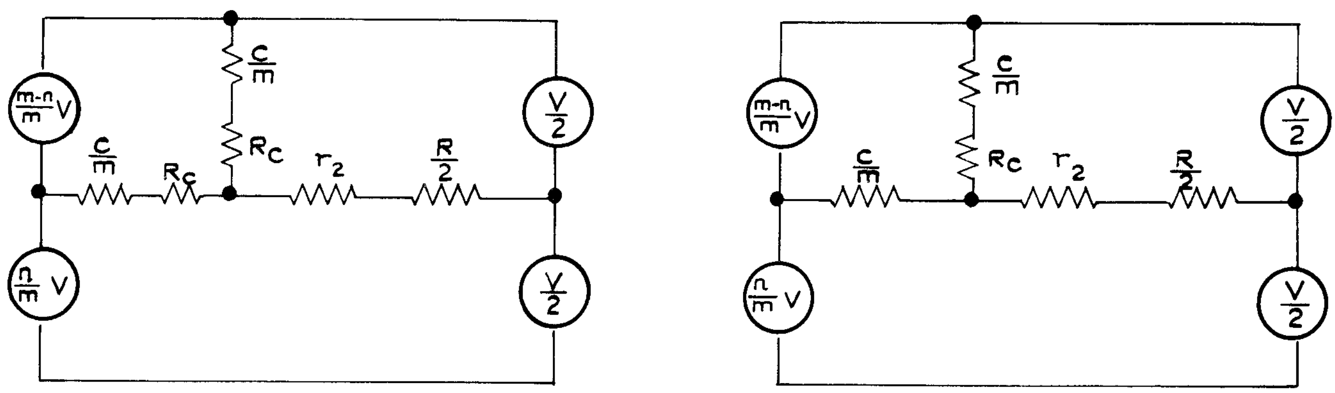



FIG. 42. T1/T2 THERMOCOUPLE SCALE.




(a) UP TO $n = y$

(b) ABOVE $n = y$

FIG. 43. EQUIVALENT THERMOCOUPLE CIRCUIT.

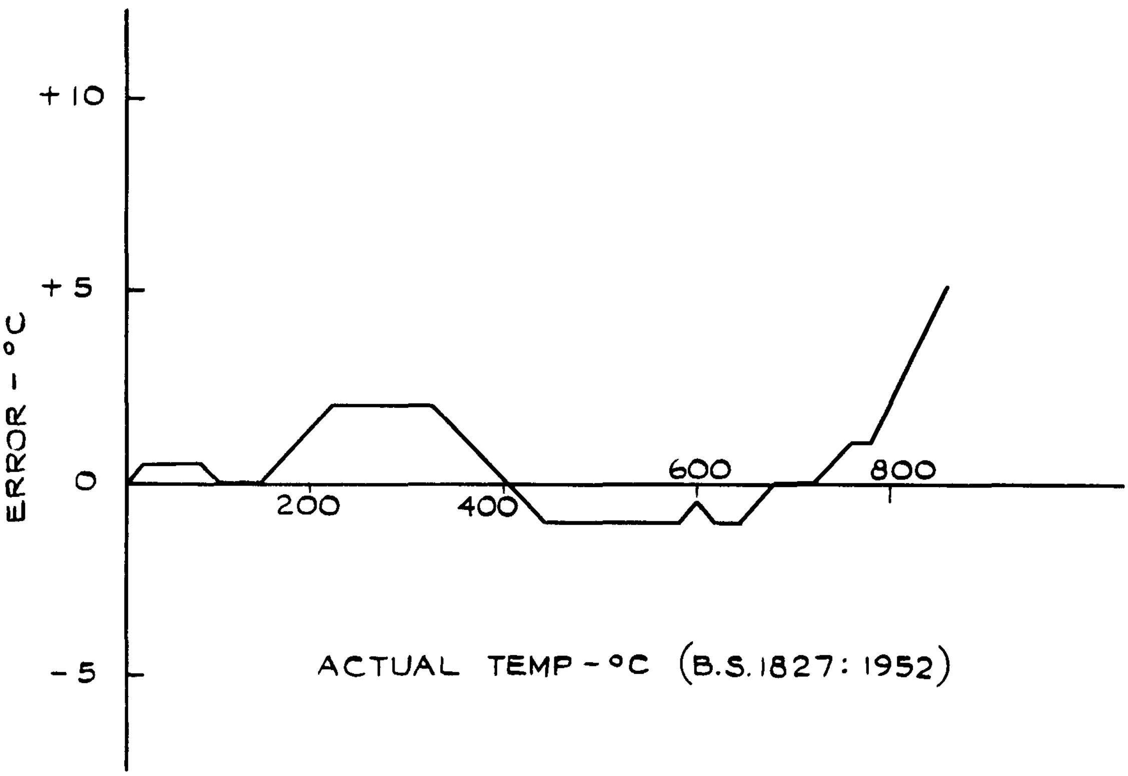



FIG. 44. RECORDER $T_1$ / $T_2$ THERMOCOUPLE SCALE ERROR CURVE.

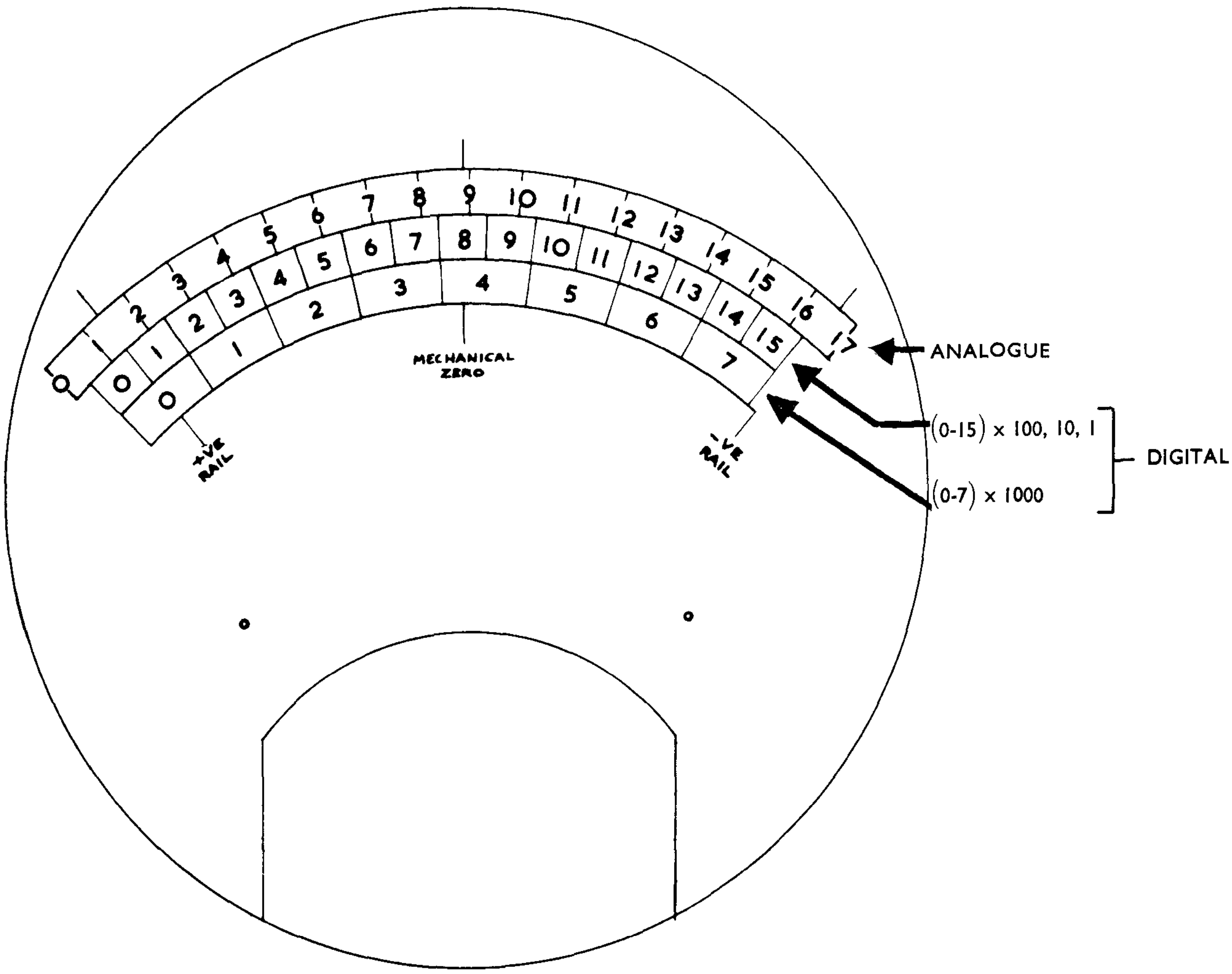



FIG. 45 SCALE OF DIGITISER INPUT METER M.1

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The methods used to measure the different types of transducer signal are surveyed and detailed operating procedures are given in Appendices.

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