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NUCLEAR INSTRUMENT MODULE MAINTENANCE MANUAL

PART 34

MSRE TEST MODULE, ORNL MODEL Q-2634

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ABSTRACT

The MSRE Test Module is a special purpose unit designed to supply calibration signals for testing the response of parts of the safety system of the Molten-Salt Reactor Experiment. It is packaged in a standard "two-unit" plug-in module of the ORNL Modular Reactor Instrumentation Series.

This report describes the circuit, applications, acceptance procedures, and acceptance tests for the MSRE Test Module.

CONTENTS

1. DESCRIPTION

1.1 General

The MSRE Test Module is a special purpose unit designed to supply calibration signals for testing the response of parts of the safety system of the Molten-Salt Reactor Experiment. The module provides two calibrated current ramps at different rates to check the response and approximate calibration of the flux amplifier and associated fast-trip comparators. An adjustable steady-state current can be substituted for the ramps for more precise calibration. In addition, the module provides two steady-state currents for calibration of the "log current" portion of the period safety module, and two voltage ramps for calibration of the "period" portion of the period safety module and associated fast-trip comparator. An ionization chamber undervoltage monitoring circuit is provided in this module.

All of these are initiated by pushbuttons from the module front panel.

1.2 Construction

The MSRE Test Module is 2.83 in. wide, 4.72 in. high, and 11.90 in. deep. It is a standard "two-unit" plug-in module of the ORNL Modular Reactor Instrumentation Series depicted on drawings Q-2600-1 through Q-2600-5.

The circuitry is constructed on two large printed-circuit boards mounted within the module.

1.3 Application

The MSRE Test Module is intended to supply signals for both pre-operational and on-line testing of the nuclear safety system of the ORNL Molten-Salt Reactor Experiment. Although the signal types and circuitry used are generally applicable to any reactor safety system employing the ORNL Modular Reactor Instrumentation Series, the signal levels and rates for this module Q-2634 are tailored especially for the MSRE.

1.4 Specifications

1.4.1 Output Ramps

The basic ramp generator supplies a voltage ramp of 0 to +14 v with a rate +1 v/sec. This ramp voltage is applied to suitable multiplier resistors to obtain the required current ramp. The output currents are:

High rate (300 kilohms)	0 to 46.7×10^{-6} amp.
Low rate (300 megohms)	0 to 46.7×10^{-9} amp.

1.4.2 Output Currents, Steady State

The output currents are adjustable with a 10-turn precision potentiometer on the front panel calibrated to be direct reading from 0 to 100. The output currents are:

High current (200 kilohms)	0 to 100×10^{-6} amp.
Low current (200 megohms)	0 to 100×10^{-9} amp.

1.4.3 Log Current, Steady State

Two calibration currents are derived from the ionization chamber high voltage by suitable multiplier resistors for current calibration of the period safety module. They are:

High (25 megohms)	10^{-5} amp.
Low (250,000 megohms)	10^{-9} amp.

1.4.4 Period Calibration

The +1 v/sec ramp is applied to the log-current amplifier in the period safety module through a suitable input resistor. This produces a constant output at the period amplifier for calibration purposes. Two approximate calibration points are provided: +1 sec period (500 kilohms) and +2 sec period (1 megohm).

1.4.5 Undervoltage Monitor

The circuit continuously monitors the polarizing voltage of the ionization chamber on a return lead from the chamber. When the chamber voltage is greater than 200 ± 10 v, a green light labeled "Normal" on the front panel is lit. When the chamber voltage for any reason drops below 200 ± 10 v, the circuit changes state and lights both a red "Low" indicator lamp and a yellow "Latch" indicator lamp. When the voltage is restored, the "Low" indicator is extinguished, and the "Normal" light again comes on. The "Latch" light remains on until the front panel "Reset" pushbutton is depressed. The relay that actuates the indicator lamps has additional single-pole, double-throw contacts for use in external circuits. An additional front-panel pushbutton labeled "Test" simulates a low-voltage condition to the monitor circuit without affecting actual chamber voltage.

1.4.6 Power Requirements

The module requires +32 ± 4 v unregulated and +25 ± 0.1% regulated.

1.4.7 Ambient Temperature Range

The ambient temperature range is 10 to 55°C.

1.5 Applicable Drawings

The following list gives the drawing numbers (ORNL Instrumentation and Controls Division drawing numbers) and subtitles for the MSRE Test Module:

1. Q-2634-1	Circuit.
2. Q-2634-2	Details.
3. Q-2634-3	Metalphoto Panel.
4. Q-2634-4	Printed Circuit Boards.
5. Q-2634-5	Assembly.
6. Q-2634-6	Parts List.

The following list gives the drawing numbers and subtitles for the Plug-In Chassis System:

1. Q-2600-1	Assembly.
2- Q-2600-2	Details.
3. Q-2600-3	Details.
4. Q-2600-4	Details.
5. Q-2600-5	Details.

2. THEORY OF OPERATION

2.1 General

The MSRE Test Module is a special purpose module designed to provide signals to test parts of the nuclear safety system of the Molten-Salt Reactor Experiment. Although it was originally intended to have a general purpose test module which would be applicable to several reactors, and such a module Q-2601 was designed, it soon developed that a single test module would not suffice because of the different instrument sensitivities and varied functions of the several reactor systems under design. Consequently, a separate test module was designed for each reactor that uses this type of instrumentation. In spite of the unique project application of the module and because of the general applicability of the circuits used in the module, a "Q" number was assigned to the MSRE Test Module for the convenience of designers of future systems.

2.2 Circuit Description

2.2.1 Ramp Generator

A linear voltage ramp is generated by charging a capacitor with a constant current. In the circuit diagram (Fig. 1) it is seen that the base of transistor Q1 is held at a constant potential with respect to the +25 v supply by Zener diode D1. This, in turn, causes the emitter voltage of Q1 to be constant across a fixed resistor R2, establishing constant emitter current. To a first approximation, transistor collector current is equal to emitter current regardless of collector voltage until saturation is reached, that is, until the collector voltage equals the emitter voltage. Thus, the collector current of Q1 is constant and flows into capacitor C1.

In the standby condition, the capacitor is short circuited by contacts of relays K1 and K2 and by contacts of pushbuttons S7 and S8. When any one of these contacts opens, the capacitor begins to charge. The rate of change of voltage across the capacitor is determined by the magnitude of the current and the size of the capacitor. In this case:

$$\frac{V}{t} = \frac{I}{c}$$

$$= \frac{20 \times 10^{-6} \text{ amp}}{20 \times 10^{-6} \text{ f}} = 1 \text{ v/sec.}$$

The voltage across C1 is sensed by a very-high-beta, Darlington-pair emitter follower Q2 and Q3. The maximum amplitude of the ramp is limited by saturation of Q1 and Zener diode D1 to about 15 v across C1 or to about 14 v at the emitter of Q3.

2.2.2 Current Switching

The MSRE Test Module is designed to provide test currents for both the flux amplifier module and the period safety module. Since the input of the flux amplifier is in series with the log diode of the period safety module, any test current will be sensed and indicated by both instruments. Since the flux amplifier has 100% feedback to the input terminal, there is

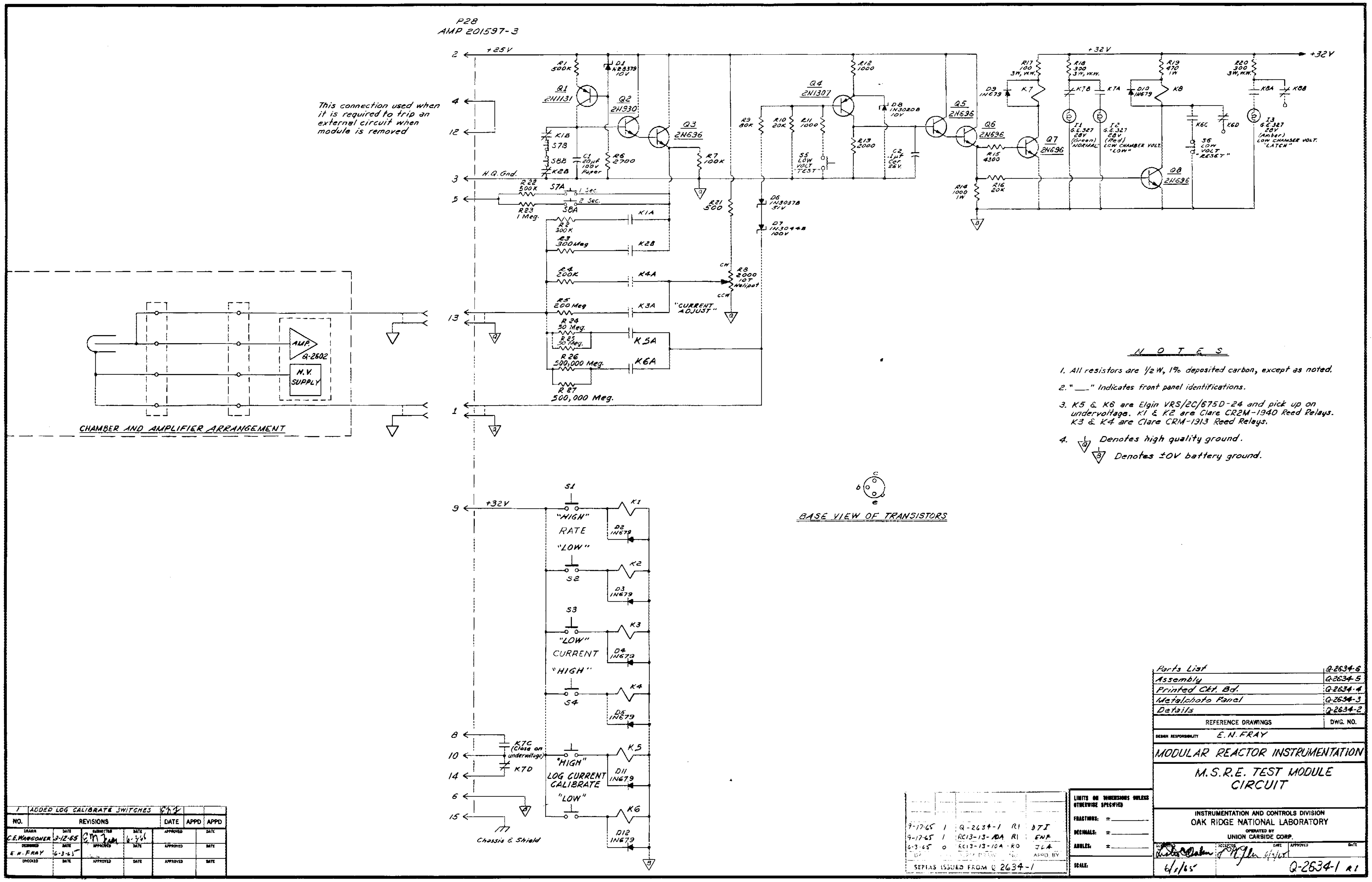

Fig. 1. MSRE Test Module Circuit.

no input voltage offset. This means that a relatively low-voltage current source is adequate for generation of its test currents. For application to the period safety module, a better current source is required, since the voltage across the log diode is not constant but changes with input current. To this end the calibration currents for the period safety module are produced by using the chamber high-voltage supply and suitable multiplier resistors. The "Rate" test currents and the "Adjustable" test currents are intended for use with the flux amplifier only; further, application of either of these currents causes the period safety to indicate an incorrect current, which should be ignored.

Since all test currents are applied by way of a second ionization-chamber signal lead, which is separate all the way to the chamber plates, a test signal must travel to the chamber and back to the safety channel input. In this way, a successful current test verifies that the chamber is connected.

2.2.3 Flux Amplifier

For steady-state calibration or checks, a voltage adjustable from 0 to 20 v by a front-panel Helipot can be applied through either a 200-kilohm or a 200-megohm resistor to the amplifier input by energizing relay K4 or K3 respectively. The corresponding currents are 0 to 100 μa and 0 to 100 nanoamperes (na). The Helipot dial labeled "Current Adjust" is read directly from 0 to 100 units.

The voltage ramp described in Sect. 2.2.1 can be applied through a 300-kilohm or a 300-megohm resistor by energizing relay K1 or K2 respectively, resulting in current ramps ranging from 0 to 46.7 μa and 0 to 46.7 na. The ramp is initiated by a second contact of K1 and K2 which removes the short circuit from capacitor C1.

2.2.4 Period Safety

Fixed calibration currents for the period safety module are generated by applying the chamber high voltage (approximately 250 v) through either a 25-megohm or a 250,000-megohm resistor, resulting in currents of 10^{-5} or 10^{-9} amp. These currents are initiated by energizing relays K5 and K6 respectively.

To check the calibration of the period amplifier, the voltage ramp is applied to the input (terminal 6) of the log current amplifier. Subsequent differentiation in the period amplifier results in a constant voltage output (constant indicated period) whose magnitude is determined by the generated ramp rate and the gain of the log current amplifier. Two calibration points are provided by applying the voltage ramp through either a 500-kilohm or a 1-megohm resistor; the result is a period indication of about 1 sec and 2 sec respectively. Actually, the 1-sec period test should always generate a period slightly less than 1 sec, so that the 1-sec fast-trip comparator will trip. These tests are initiated by depressing pushbuttons S7 or S8 to generate the 1-sec or 2-sec period.

2.2.5 Chamber Voltage Monitor

In a manner similar to the signal lead, a separate high voltage is returned from the plates of the ionization chamber. This voltage is continuously monitored by a circuit consisting of transistors Q4 through Q8. If the voltage, normally 250 v, is interrupted or reduced below approximately 200 v, an undervoltage alarm occurs.

The sensed voltage is reduced from 250 to 100 v at R5 by two Zener diodes D2 and D3. The voltage is further reduced to 20 v at the base of Q4 by the dividing action of R5 and R6. The emitter of Q4 is biased at 10 v so that the transistor is reverse biased and not conducting under normal conditions. Since the collector of Q4 is near ground potential, the Darlington emitter-follower Q5 and Q6 and the relay drivers Q7 and Q8, driven by the emitter-follower output, are also not conducting. A normally closed contact of K7 energizes the green "Normal" lamp on the front panel.

When the input voltage drops below 200 v, the Q4 base voltage is reduced to below 10 v, and Q4 conducts. The collector voltage of Q4 increases to 10 v, turning on Q5, Q6, Q7, and Q8 and energizing both K7 and K8. The contacts of K7 extinguish the "Normal" lamp and light the red "Low" chamber voltage lamp. A second set of K7 contacts controls external circuits. K8 seals itself in and will remain energized, lighting the "Latch" lamp until the input voltage is restored and "Reset" button S2 is depressed. This enables the operators to identify a momentary chamber voltage fault.

The voltage monitor circuit is tested by pressing "Test" pushbutton S1 on the front panel. This reduces the voltage at the base of Q4, simulating a low input condition without causing significant reduction of the chamber voltage itself.

3. OPERATING INSTRUCTIONS

3.1 Installation

The MSRE Test Module is one of the ORNL Modular Reactor Instrumentation Series. Like the other modules in this series, it has standard connections and dimensions and has a pin- and hole-code on the rear plate so that the module will not be inserted in a wrong location in a drawer. The module is installed by placing it in its proper location, inserting the module firmly, and tightening the thumb screw. The module may be plugged in with power on without damage.

3.2 Operating Controls on Panel

3.2.1 Chamber Voltage Monitor

Three pilot lamps indicate the state of chamber voltage. The green "Normal" light is on when the voltage is greater than 200 v. The red "Low" light is on when the voltage is less than 200 v. The amber "Latch" light comes on when the voltage drops below 200 v and remains on until the "Reset" button is pressed. The "Test" button when depressed causes a simulated low voltage to test the monitor.

3.2.2 High Rate

When the "High Rate" button is depressed, a current ramp of 3.33 μa/sec is applied to the safety channel input.

3.2.3 Low Rate

When the "Low Rate" button is depressed, a current ramp of 3.333 na/sec is applied to the safety channel input.

3.2.4 High Current

When the "High Current" button is depressed, a current adjustable from 0 to 100 μa by the "Current Adjust" potentiometer is applied to the safety channel input.

3.2.5 Low Current

When the "Low Current" button is depressed, a current adjustable from 0 to 100 na by the "Current Adjust" potentiometer is applied to the safety channel input.

3.2.6 High Log Current

When the "High Log Current" button is depressed, a current of 10^{-5} amp is applied to the safety channel input.

3.2.7 Low Log Current

When the "Low Log Current" button is depressed, a current of 10^{-9} amp is applied to the safety channel input.

3.2.8 1-Second Period

When the "1-Second Period" button is depressed, a voltage ramp is applied to the period safety module, resulting in an output indication of approximately a 1-sec period.

3.2.9 2-Second Period

When the "2-Second Period" button is depressed, a voltage ramp is applied to the period safety module, resulting in an output indication of approximately a 2-sec period.

3.3 Connections

All connections are made through the rear connector P28 when the module is inserted. A jumper between pins 4 and 12 is provided so that if the module is removed from a drawer, a warning signal may be given.

3.4 Operating Procedures

All tests are initiated simply by depressing the proper pushbutton on the front panel.

4. MAINTENANCE INSTRUCTIONS

4.1 General

This module is designed to operate continuously with a minimum of maintenance and no adjustments. Should a failure occur, any part listed in the Replaceable Parts List, Sect. 5, may be replaced.

4.2 Periodic Maintenance

No periodic maintenance is expected to be required.

4.3 Calibration Procedures

There are no calibration procedures. Testing for proper performance is described in Sect. 6, Acceptance Tests.

5. REPLACEABLE PARTS LIST

A description and an ORNL Stores number for replaceable parts are given in Table 1. A complete parts list is given on ORNL Drawing Q-2634-6.

Table 1. Replaceable Parts List

Part No.	ORNL Stores Number	Description
R8	06-930-1122	Potentiometer, 2000 ohms, ±3%, linearity ±0.25%, 10-turn, 1.5 w@ 40°C, 1/4 in. shaft, 3/8-22 bushing, Helipot model 7216R2KL.25.
R17	06-933-6230	Resistor, 100 ohms, 3 w, ww, axial leads, Ohmite code 7/16-A-54-F.
R18,R20	06-933-6250	Resistor, 300 ohms, 3 w, ww, axial leads, Ohmite code 7/16-A-54-F.
R19		Resistor, 470 ohms, ±5%, 1 w, AB.
R14		Resistor, 1000 ohms, ±5%, 1 w, AB.
R24,R25	06-932-0417	Resistor, 50 megohms, ±1%, 1/2 w, carbon film, Pyrofilm type PT1000.
R3	06-932-4538	Resistor, 300 megohms, ±1%, 1/2 w, carbon film, Victoreen type RX-1.
R5	06-932-4536	Resistor, 200 megohms, ±1%, 1/2 w, carbon film, Victoreen type RX-1.
R26,R27	06-932-4580	Resistor, 500,000 megohms, ±1%, 1/2 w, carbon film, Victoreen type RX-1.
R21	06-932-0079	Resistor, 500 ohms, 1%, 1/2 w, carbon film, Stemag SLAK.[1]
R11,R12	06-932-0097	Resistor, 1000 ohms, 1%, 1/2 w, carbon film, Stemag SLAK.[1]
R13	06-932-0113	Resistor, 2000 ohms, 1%, 1/2 w, carbon film, Stemag SLAK.[1]
R15	06-932-0131	Resistor, 4.7 kilohms, 1%, 1/2w, carbon film, Stemag SLAK.[1]
R6	06-932-0121	Resistor, 2700 ohms, 1%, 1/2 w, carbon film, Stemag SLAK.[1]
R10,R16	06-932-0155	Resistor, 20 kilohms, 1%, 1/2 w, carbon film, Stemag, SLAK.[1]
R9	06-932-0185	Resistor, 80 kilohms, 1%, 1/2 w, carbon film, Stemag SLAK.[1]
R7	06-932-0189	Resistor, 100 kilohms, 1%, 1/2 w, carbon film, Stemag SLAK.[1]
R4	06-932-0199	Resistor, 200 kilohms, 1%, 1/2 w, carbon film, Stemag SLAK.[1]
R2	06-932-0209	Resistor, 300 kilohms, 1%, 1/2 w, carbon film, Stemag SLAK.[1]
R1,R22	06-932-0219	Resistor, 500 kilohms, 1%, 1/2 w, carbon film, Stemag SLAK.[1]
R23	06-932-0251	Resistor, 1 megohms, 1%, 1/2 w, carbon film, Stemag SLAK.[1]

[1]All carbon film resistors, "Stemag," double high-temperature varnish coated. Vendor: H. E. Priester Corp., Scarsdale, N. Y. (ORNL supplied).

Table 1 (continued)

Part No.	ORNL Stores Number	Description
D2, D3, D4, D5, D9, D10, D11, D12	06-995-6160	Diode, rectifier, 200 v piv, 140 v rms, type 1N679.
D1	06-995-7900	Diode, zener, 10 v, type HZ-8379, 250 mw, Hughes.
D8	06-995-7094	Diode, zener, 10 v, ±5%, 1 w, type 1N3020B, Motorola.
D6	06-995-7112	Diode, zener, 51 v, 1 w, type 1N3037B, Motorola.
C1	06-812-6027	Capacitor, 20 µf, ±10%, 100 v dc w, 1.0 in. diameter by 3-9/16 in. long, 1/2-28 thread mtg. stud, complete with No. 6-120C nut and No. 2-54B lockwasher, No. 118P20691T25, Sprague Electric Co.
C2	06-802-0087	Capacitor, 0.1 uf, ±20%, 25 v dc w, monolithic, formulation C23, No. 3C21, Sprague Electric Co.
D7	06-995-7118	Diode, zener, 100 v, 1 w, type 1N3044B, Motorola.
Q2	06-996-1654	Transistor, silicon, NPN, type 2N930, Texas Instr.
Q3, Q5, Q6, Q7, Q8	06-996-1610	Transistor, silicon, NPN, type 2N696, Texas Instr.
Q1	06-996-1710	Transistor, silicon, PNP, type 2N1131, Texas Instr.
Q4	06-996-1960	Transistor, germanium, PNP, type 2N1307, Texas Instr.
K7, K8	06-944-0669	Relay, dc, microminiature, dpdt, contacts, coil 26.5 v dc, type VRS2C675D-24, Elgin, Advance Electric Co.
K1, K2		Relay, reed type, one form "A" contact and one form "B" contact, 15 va max, 930 ohm coil, for PC board mounting, C.P. Clare No. CR2M-1940.
K3, K4, K5, K6		Relay, reed type, one form "A" contact, 15 va max, 1650 ohm coil, for PC board mounting, C.P. Clare No. CRM-1913.
I3	06-918-2150	Lens, holder, amber, for use with T-1-3/4 incandescent lamp, Dialco No. 101-973.
I1	06-918-2147	Lens, holder, green, translucent, for use with T-1-3/4 incandescent lamp, Dialco No. 101-972.
I2	06-918-2149	Lens, holder, red, translucent, for use with T-1-3/4 incandescent lamp, Dialco No. 101-971.
I1, I2, I3	06-916-2576	Lamp, incandescent, 28 v at 40 ma, type 327, General Electric Co.

6. ACCEPTANCE TEST PROCEDURE

6.1 Test Equipment

The following test equipment is required:

1. A power supply, dc unregulated, 32 ± 4 v, up to 1 amp.
2. A power supply, dc regulated, 25 ± 1 v regulation ± 0.1% to 50 ma.
3. A voltmeter, dc, 0.5% accuracy, multirange.
4. A power supply, dc, 0 to 250 v adjustable, 10 ma.
5. A picoammeter, dc, 3% accuracy multirange.

6.2 Acceptance Test

6.2.1 Ramp Generator

1. Connect the +25 v dc supply to pin 2 and the negative to pin 3. Connect an accurate dc voltmeter to measure the ramp generator output on emitter of Q3 with respect to high-quality ground, pin 3. The voltage should rise from 0 to +14 ± 1 v in 14 ± 1 sec. The voltage should not rise higher than 15 v.

2. To initiate the ramp, depress the "High Rate" pushbutton S1 and observe the linear increase on the meter.

Repeat the test by depressing the "Low Rate" pushbutton S2, the "1-Second Period" pushbutton S7, and the "2-Second Period" pushbutton S8.

6.2.2 Current

Connect the picoammeter input to pin 13. Set the "Current Adjust" potentiometer dial to 50. Measure the current with the "Low Current" and "High Current" pushbuttons depressed. The currents should be 50×10^{-9} and 50×10^{-6} amp respectively.

Measure the current with the "High Log Current" and "Low Log Current" pushbuttons depressed. The currents should be 10^{-5} and 10^{-9} amp respectively.

Depress the "High Rate" pushbutton and observe the linear current increase from 0 to 46.7×10^{-6} amp. Repeat with the "Low Rate" pushbutton depressed. The current should rise to 46.7×10^{-9} amp.

6.2.3 Voltage Monitor

1. Connect the 0- to 250-v supply positive to pin 1 and the negative to pin 3. Connect an accurate voltmeter across the 300-v supply terminals.

2. Increase the supply voltage to approximately 250 v, and press the "Reset" button on the module front panel. Only the green "Normal" lamp should be lit. Slowly decrease the supply voltage and observe the voltage when the red "Low" lamp just lights. The voltage should be 200 ± 10 v.

3. Increase the voltage to 250 v. The "Low" lamp should extinguish, and the "Normal" lamp should come back on. The "Latch" light should come on simultaneously with the "Low" light, and should remain on until the "Reset" button is depressed.

4. Press the low voltage "Test" button. The circuit should respond the same as if the voltage were reduced below 200 v.

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