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# NUCLEAR INSTRUMENT MODULE MAINTENANCE MANUAL

## Part 30

## HFIR TEST MODULE, ORNL MODEL Q-2630

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ABSTRACT

The HFIR Test Module is a special purpose module designed to supply signals for testing the response of parts of the safety system of the High Flux Isotope Reactor. The unit supplies calibrated current ramps of two different rates for checking the response and approximate calibration of both neutron flux level and rate-of-change-of-flux-level trips and associated signal amplifiers, adjustable steady-state test currents, and a circuit which continuously monitors ionization chamber polarizing voltage.

The instrument is a standard plug-in module of the ORNL Modular Reactor Instrumentation Series.

The circuit, application, maintenance procedures, and acceptance tests for the unit are described.

CONTENTS

# 1. DESCRIPTION

## 1.1 General

The HFIR Test Module is a special purpose unit designed to supply certain signals for testing the response of parts of the safety system of the ORNL High Flux Isotope Reactor. Basically, the module provides three calibrated current ramps at two different rates to check the response and approximate calibration of both power level and rate-of-change-of-power-level trips and associated signal amplifiers. An adjustable steady-state current can be substituted for the ramps for more precise calibration. Switching is provided for increasing the effective sensitive volume of the safety channel ionization chamber for high-power system response checks. Also included is an ionization chamber undervoltage monitoring circuit.

Most of these tests are initiated remotely from the reactor console by relay circuits, and only the steady-state current test and undervoltage monitor can be operated locally from the module front panel.

## 1.2 Construction

The HFIR 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-2600-6.

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

## 1.3 Application

The HFIR Test Module is intended to supply signals for both pre-operational and on-line testing of the nuclear safety system of the ORNL High Flux Isotope Reactor. The signal types and circuitry used are generally applicable to any reactor safety system employing the ORNL Modular Reactor Instrumentation Series. However, this module, ORNL model Q-2630, has its signal levels and rates tailored especially for the HFIR.

Routine tests are operable only from the reactor console through relay circuits. Controls on the module front panel are intended for use by technicians in trouble shooting.

## 1.4 Specifications

### 1.4.1 <u>Output Ramps</u>

The basic ramp generator supplies a voltage ramp of 0 to +14 v with two ramp rates, 1 v/sec and 3 v/sec. This ramp voltage is applied to suitable multiplier resistors to obtain the required current ramps. The output currents are as follows:

a. Mode 3 (2250 megohms), 0 to $6.23 \times 10^{-9}$ amp.

b. Mode 2 (90 megohms), 0 to $1.56 \times 10^{-7}$ amp.

c. Mode 1 (1.5 megohms), variable 0 to 9.33 μa to 0 to 7.00 μa in accordance with an external potentiometer setting (in Flux Reset Mechanism, Q-2603) corresponding to "reset" gains of 1.0 and 1.33 respectively and proportional within the range. Ranges and rates are selected by energizing appropriate reed relays with remote pushbuttons.

### 1.4.2 Output Current

The steady-state output current is 0 to 10 μa, which is adjustable with a 10-turn precision potentiometer on the front panel. The potentiometer is calibrated to be direct reading from 0 to 100, which corresponds to 0 to 10 μa. The current is to be applied only while the front-panel pushbutton control is depressed.

### 1.4.3 Add-On Chamber Section

Reed-relay switching circuits are arranged to connect the signal lead of a special section of the safety system ionization chamber in parallel with the signal lead of the main sensitive volume of the chamber so as to increase its sensitivity. This test is intended to provide a simple and direct test of the ability of the safety system to respond when the reactor is at full power. The add-on section is grounded by the relay contacts when not in use so as not to build up a charge.

### 1.4.4 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 "Normal" indicator lamp on the front panel is lighted. When the voltage, for any reason, drops below 200 ± 10 v, the circuit changes state and lights a red "Low" indicator lamp and a yellow "Latch" indicator lamp. When the voltage is restored, the "Low" indicator lamp is extinguished, the "Normal" light again comes on. The "Latch" light remains on until the front-panel "Reset" pushbutton is depressed.

The relay which actuates the indicator lamps has additional contacts, single pole, double throw, 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.

### 1.4.5 Power Requirements

The power requirements are +32 ± 4 v unregulated and +25 v ± 0.1% regulated.

### 1.4.6 Ambient Temperature Range

The ambient temperature range is 10 to 55°C.

## 1.5 Applicable Drawings and Specifications

The following list gives the drawing numbers (ORNL Instrumentation and Controls Division drawing numbers) and subtitles and the fabrication specification number for the HFIR Test Module:

1. Q-2630-1 Circuit.
2. Q-2630-2 Details.
3. Q-2630-3 Metalphoto Panel.
4. Q-2630-4 Printed Circuit Boards.
5. Q-2630-5 Assembly.
6. Q-2630-6 Parts List.
7. SF-264 Fabrication Specification.

The assembly and details of the Plug-In Chassis System are shown on drawings Q-2600-1 through Q-2600-6.

# 2. THEORY OF OPERATION

## 2.1 General

The HFIR Test Module is a special purpose module designed to provide signals to test parts of the nuclear safety system of the ORNL High Flux Isotope Reactor. It was originally intended to have a general purpose test module that would be applicable to several reactors. Such a module was designed and was designated Q-2601. However, because of the different Instrument sensitivities and varied functions of the several reactor systems under design, a single test module would not suffice. Consequently, a separate test module was designed for each reactor using 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 HFIR 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 resistance 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, K2, and K3. When any one of the relays is energized, one set of the contacts opens and the capacitor begins to charge. The rate of change, or the time slope, of the voltage ramp is determined by the magnitude of the current and the size of the capacitor. In this case:

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

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

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 14 v at the emitter of Q3.

When relay K4 is energized, R1 is switched in parallel with R2, increasing the charging current from 20 to 60 μa and the corresponding ramp rate from 1 to 3 v/sec.

### 2.2.2 Current Switching

The Flux Amplifier (Q-2602), which is fed by the test signals from the HFIR Test Module, has 100% feedback to the input terminal so that there is no input voltage offset. This makes possible the use of voltage signals and suitable multiplier resistors to derive calibration current signals.

For steady-state calibrations or checks, a voltage adjustable from 0 to 25 v by a front-panel Helipot may be applied through a 2.5-megohm resistor to the amplifier input by energizing relay K6. The corresponding current is 0 to 10 μa, and the Helipot dial labeled "Current Adjust" is read directly from 0 to 100 units. K6 is energized only while the front-panel pushbutton S3, labeled "Current Test," is depressed.

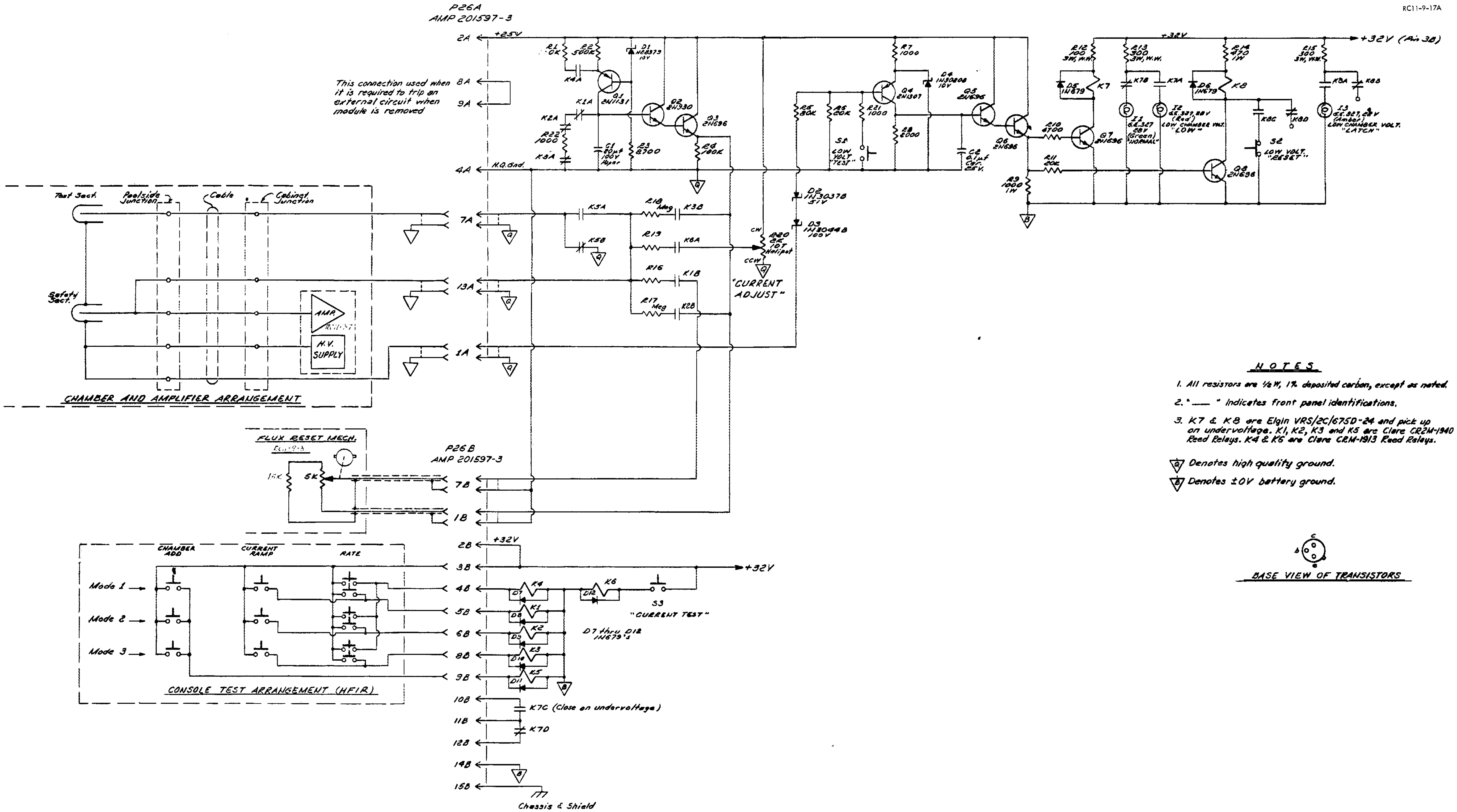


Fig. 1. HFIR Test Module Circuit.

The voltage ramp described in Sect. 2.2.1 may be applied through a 2250-megohm resistor R18 by energizing K3, resulting in a current ramp ranging from 0 to $6.23 \times 10^{-9}$ amp. The ramp is initiated by a second contact of K3 which removes the short circuit from capacitor C1. K3 is energized by depressing a pushbutton on the reactor console. This range and ramp rate provide an operational check of the level safety system in reactor Mode 3. The rate test is accomplished by simultaneously energizing K3 and K4. This provides the same current range, but at a ramp rate which is 3 times faster.

Similarly, for reactor Mode 2, a current range of 0 to $1.56 \times 10^{-7}$ amp is derived from the same voltage ramp and a 90-megohm resistor R17 by energizing K2, or K2 and K4 simultaneously.

The reactor Mode 1 test varies slightly from Modes 2 and 3. The ramp generator output is passed through an external attenuator located in the Flux Reset Mechanism module Q-2603. This attenuator is a gang of a potentiometer which adjusts the gain of the Flux Amplifier Q-2602 over a range of 1.33 to 1. The amplitude of the ramp is adjusted over a corresponding range of 0.75 to 1 so that the output of the Flux Amplifier will have the same response to the ramp test regardless of the amplifier gain. The "adjusted" ramp voltage is applied through a 1.5-megohm resistor R16 by energizing relay K1 or, for the faster ramp, K1 and K4 simultaneously. The resulting current ranges from 0 to 7.0 to 0 to 9.33 μa. These ranges correspond to an adjusted reactor power range of 0 to 140% at rates of 10 %/sec and 30 %/sec respectively. There is no direct power calibration of the test currents in Modes 2 and 3.

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

### 2.2.3 Add-On Chamber Section

When relay K5 is energized, a second section of the safety ionization chamber is connected in parallel with the main section, increasing its sensitivity by approximately 50%. This provides an overall operational check of the safety system when the reactor is operating near full power in any of the three modes. A normally closed contact of K5 keeps the add-on section normally grounded to avoid charge buildup during standby periods and reduce switching transients. This test is useful only when substantial ionization chamber current exists.

### 2.2.4 Chamber Voltage Monitor

In a manner similar to the signal lead, a separate high-voltage lead 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 reversed biased and not conducting under normal conditions. The collector of Q4 is near ground potential so that 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. K7 contacts extinguish the "Normal" lamp and lights the red "Low" chamber voltage lamp. A second set of K7 contacts controls external circuits. K8 seals itself in and remains 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.

A test of the voltage monitor circuit is accomplished 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 loading of the chamber voltage itself.

## 3. OPERATING INSTRUCTIONS

### 3.1 Installation

The HFIR Test Module is one of the ORNL Modular Reactor Instrumentation Series. Like the other modules in this series, it has standard connectors 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

#### 3.2.1 Panel Controls

Chamber Voltage Monitor. -- Three pilot lamps indicate the state of chamber voltage: the green "Normal" light is on when the voltage is more than 200 v, the red "Low" light is on when the voltage is less than 200 v, and 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.

Current Test. -- When the "Current Test" button is depressed, a current adjustable from 0 to 100 μa by the "Current Adjust" potentiometer is applied to the Flux Amplifier input.

### 3.2.2 Remote Controls

Three ranges of current ramps may be initiated remotely from the reactor console by energizing appropriate relays. Relays K1, K2, and K3 control ramps appropriate for reactor Modes 1, 2, and 3 respectively. Simultaneous actuation of K4 with any of the three relays increases the ramp speed 3 times to provide a rate test for each mode. K5 controls the add-on chamber section.

## 3.3 Connections

All connections are made through the rear connectors P26 A and P26 B when the module is inserted. A jumper between pins 8A and 9A of P26 A is provided so that if the module is removed from a drawer a warning signal is given.

## 3.4 Operating Procedures

Those functions which are operated remotely from the reactor console will be described in the appropriate reactor operating procedures. The current ramps and chamber-add tests are initiated simply by depressing the proper pushbutton for the selected reactor mode.

The front-panel "Current Test" is intended more as a trouble-shooting tool than as a routine test by reactor operators. It is the only test that applies a current which is accurately known at any instant and can be used to make steady-state checks of accuracy or gain.

# 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-2630-6.

Table 1. Replaceable Parts List

| Part No. | ORNL Stores No. | Description |
|---|---|---|
| C1 | 06-812-6027 | Capacitor, 20 μf, ±10%, 100 v dc w, 1.0 in. diam by 3-9/16 in. long, 1/2-28 thread mtg. stud, complete with No. 6-120C nut and No. 2-54B lockwasher, No. 118P 20691T25, Sprague Electric Co. |
| C2 | 06-802-0087 | Capacitor, 0.1 μf, ±20%, 25 v dc w, monolithic, formulation C23, No. 3C21, Sprague Electric Co. |
| R20 | | Potentiometer, 2000 ohms, ±3%, linearity ±0.25%, 10 turn, 1.5 w at 40°C, 1/4 in. shaft 3/8 x 22 bushing, Helipot model 7216R2KL.25. |
| R12 | 06-933-6230 | Resistor, 100 ohms, 3 w, ww, axial leads, Ohmite code 7/16-A-54-F. |
| R13, R15 | 06-933-6250 | Resistor, 300 ohms, 3 w, ww, axial leads, Ohmite code 7/16-A-54-F. |
| R14 | 06-932-2093 | Resistor, 470 ohms, ±5%, 1 w, AB. |
| R9 | | Resistor, 1000 ohms, ±5%, 1 w, A-B. |
| R16 | 06-932-0382 | Resistor, 1.5 megohms, ±1%, 1 w, TI CDIR. |
| R17 | 06-932-4534<br>06-932-4544 | Resistor, 90 megohms, ±1% (100 M parallel 1000M), Victoreen RX1. |
| R18 | 06-932-4552<br>06-932-4554 | Resistor, 2250 megohms, ±1% (5000 M parallel 4000 M), Victoreen RX1. |
| R19 | 06-932-4538 | Resistor, 2.5 megohms, ±1%, 1 w, carbon film, TI CDIR. |
| R7, R21 | 06-932-0097 | Resistor, 1000 ohms, 1%, 1/2 w, carbon film, Stemag STAK.[1] |

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

Table 1. (continued)

| Part No. | ORNL Stores No. | Description |
|---|---|---|
| R8 | 06-932-0113 | Resistor, 2000 ohms, 1%, 1/2 w, carbon film, Stemag STAK.[1] |
| R10 | 06-932-0131 | Resistor, 4.7 kilohms, 1%, 1/2 w, carbon film, Stemag STAK.[1] |
| R3 | 06-932-0121 | Resistor, 2700 ohms, 1%, 1/2 w, carbon film, Stemag STAK.[1] |
| R6, R11 | 06-932-0155 | Resistor, 20 kilohms, 1%, 1/2 w, carbon film, Stemag STAK.[1] |
| R5 | 06-932-0185 | Resistor, 80 kilohms, 1%, 1/2 w, carbon film, Stemag STAK.[1] |
| R4 | 06-932-0189 | Resistor, 100 kilohms, 1%, 1/2 w, carbon film, Stemag STAK.[1] |
| R1 | 06-932-0205 | Resistor, 250 kilohms, 1%, 1/2 w, carbon film, Stemag STAK.[1] |
| R2 | 06-932-0219 | Resistor, 500 kilohms, 1%, 1/2 w, carbon film, Stemag STAK.[1] |
| D5, 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. |
| D4 | 06-995-7094 | Diode, zener, 10 v, ±5%, 1 w, type 1N3020B, Motorola. |
| D2 | 06-995-7112 | Diode, zener, 51 v, 1 w, type 1N3037B, Motorola. |
| D3 | 06-995-7118 | Diode, zener, 100 v, 1 w, type 1N3044B, Motorola. |
| Q3, Q5, Q6, Q7, Q8 | 06-996-1610 | Transistor, silicon, NPN, type 2N696, Texas Instrument. |
| Q1 | 06-996-1710 | Transistor, silicon, PNP, type 2N1131, Texas Instrument. |
| Q4 | 06-996-1960 | Transistor, germanium, PNP, type 2N1307, Texas Instrument. |

Table 1. (continued)

| Part No. | ORNL Stores No. | Description |
|---|---|---|
| K7, K8 | 06-944-0669 | Relay, dc, microminiature, dpdt, contacts at 3 amp, coil 26.5 v dc, type VRS2C675D-24, Elgin, Advance Electric Co. |
| K1, K2, K3, K5 | | 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. |
| R4, R6 | | Relay, reed type, one form "A" contact, 15 va max, 1650 ohm coil for PC board mounting, C.P. Clare No. CRM-1913. |
| 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. Power supply, dc unregulated, 32 ± 4 v, up to 1 amp.
2. Power supply, dc regulated, 25 ± 0.1 v, regulation ±0.1%, up to 50 ma.
3. Voltmeter, dc, 0.5% accuracy, multirange.
4. Power supply, dc, 0 to 250 v adjustable, 10 ma.

## 6.2 Acceptance Test

### 6.2.1 Ramp Generator

1. Connect the 25-v dc supply positive to pin 2A and the negative to pin 4A. Connect the 32-v dc supply positive to pin 2B and the negative to pins 14B and 15B. Connect an accurate dc voltmeter to measure the ramp generator output on pin 1B with respect to HQ ground, pin 4A. The shield of pin 1B is also HQ ground.

2. To initiate the slow ramp, energize relay K1 by shorting pin 3B to pin 5B and observe the linear increase of voltage on the meter. The voltage should rise from 0 to +14 ± 1 v in 14 ± 1 sec. The voltage should not rise higher than 15 v.

3. To initiate the fast ramp, energize K1 and K4 simultaneously by shorting pins 4B and 5B together to pin 3B. The voltage should rise from 0 to 14 ± 1 v in 4.7 ± 0.5 sec.

6.2.2 Voltage Monitor

1. Connect the 0 to 250 v supply positive to pin 1A and the negative to pin 4A. 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 lighted. 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 become extinguished and the "Normal" lamp should light. The "Latch" lamp should come on simultaneously with the "Low" lamp 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 to less than 200 v.

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