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Part 35
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NUCLEAR INSTRUMENT MODULE MAINTENANCE MANUAL

Part 35

PERIOD SAFETY MODULE, ORNL MODEL Q-2635

E. N. Fray

ABSTRACT

The Period Safety Module is a current-sensing device which is connected in series with the input of a normal neutron flux-safety amplifier in a reactor safety system. Without disturbing the normal safety functions of the flux safety amplifier (Q-2602), the period safety module derives a signal which is proportional to the logarithm of reactor power (ionization chamber current) and takes the time derivative of the logarithmic signal to yield a signal proportional to inverse reactor period. The circuit is packaged in a standard "one-unit" plug-in module of the ORNL Modular Reactor Instrumentation Series.

This report describes the circuit, applications, maintenance procedures, and acceptance tests for the Period Safety Module.

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1. DESCRIPTION

1.1 General

The input, or current-sensing element (logarithmic diode), of the Period Safety Module is connected in series with the flux amplifier (Q-2602) input. Since the voltage across the logarithmic diode is differentially amplified with a very high input impedance amplifier, the chamber current passes undisturbed into the flux amplifier module. This voltage is further amplified and differentiated to give outputs proportional to the logarithm of the current and its period (time required for the current to increase by one ϵ factor) respectively. The input current range is from 10^{-10} to 10^{-4} amp. In the usual application, the period output serves as an input to a nuclear reactor safety system, hence the name "Period Safety."

1.2 Construction

The Period Safety Module is 1.40 in. wide, 4.72 in. high, and 11.90 in. deep. It is a standard "one-unit" plug-in module of the ORNL Modular Reactor Instrumentation Series depicted on ORNL Drawings Q-2600-1 through Q-2600-5.

The circuits are on a printed circuit board which is completely enclosed by a shield. The outputs are displayed on front-panel meters. Test points and access holes to trimming potentiometers are located along the top of the shield enclosure.

1.3 Application

The Period Safety Module is primarily intended to continuously monitor the neutron flux and period of a nuclear reactor. Since the module is not intended to measure reactor power accurately, the panel meter on the output of the logarithmic amplifier is calibrated in "log current" from 10^{-10} to 10^{-4} amp. The output of the period amplifier is displayed on a panel meter which is calibrated in seconds from -30 to +1 sec.

1.4 Specifications

1.4.1 Period

1.	Output voltage range:	-0.033 to +10 v for -30 to +0.1 sec period.
2.	Output current:	0.1 ma into 100-kilohm load.
3.	Scale:	-30 to +1 sec.
4.	Zero drift:	less than 20 mv/month.

5.	Power required:	±15 v dc with regulation ±0.1%.
6.	Ambient temperature range:	0 to 55°C.

1.4.2 Log Current

1.	Output voltage:	approximately 1.67 v per decade, with zero voltage point determined by "Hi Cal" setting.
2.	Output current:	1 ma into 10-kilohm load.
3.	Scale:	10^{-10} to 10^{-4} amp.
4.	Zero drift:	less than 50 mv/month.
5.	Input leakage current:	less than 10^{-13} amp at 25°C.
6.	Power required:	±15 v dc with regulation ±0.1%.
7.	Ambient temperature range:	0 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 Period Safety Module:

1.	Q-2635-1	Circuit.
2.	Q-2635-2	Details.
3.	Q-2635-3	Metalphoto Panel.
4.	Q-2635-4	Printed Circuit Board.
5.	Q-2635-5	Assembly.
6.	Q-2635-6	Parts List.
7.	Q-2636-4	Printed Circuit Board (Board 3 only).

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

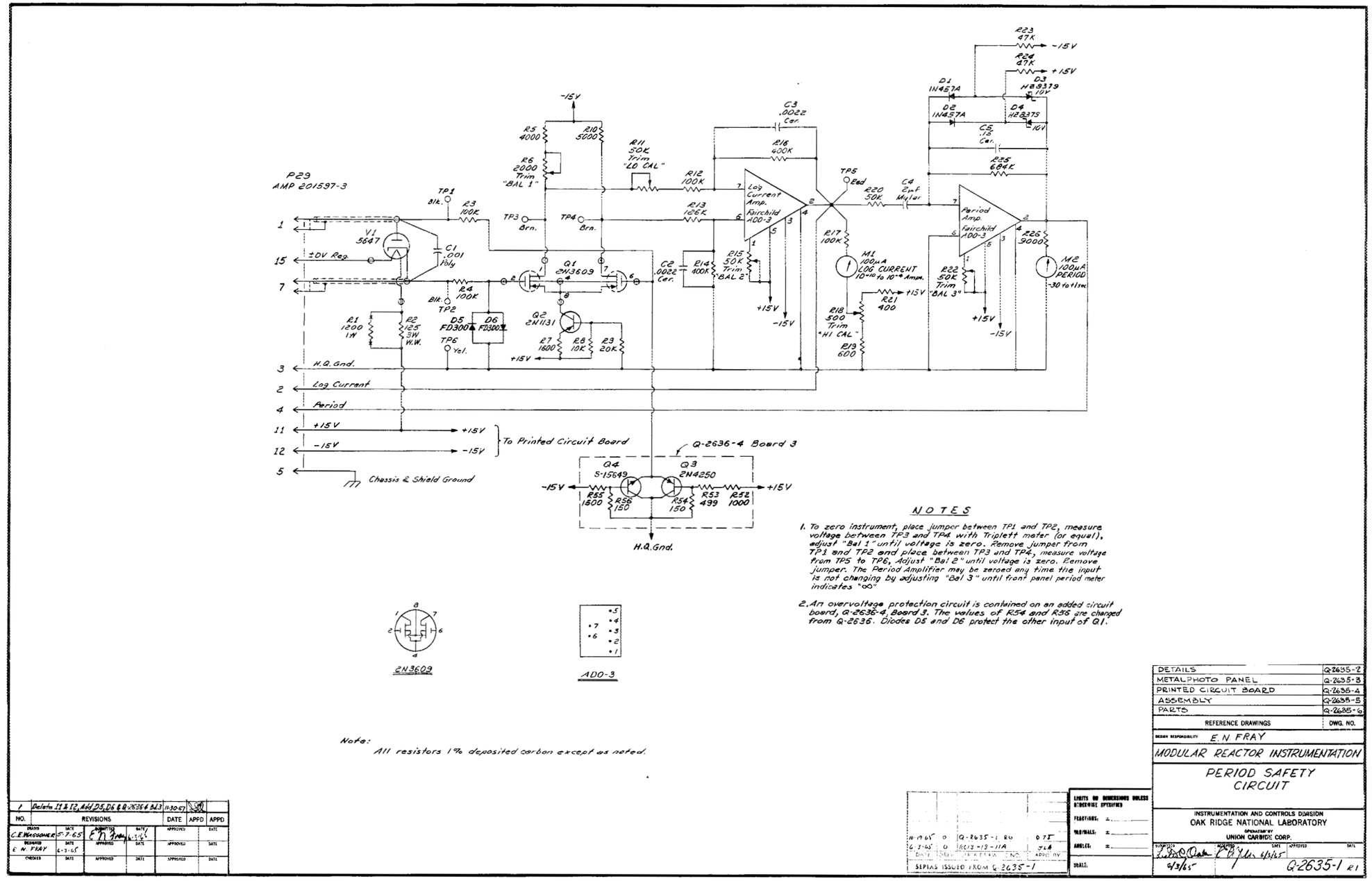
The ionization chamber current passes through a thermionic diode in the Period Safety Module and then into the flux amplifier (Q-2602) or equivalent. The voltage drop across this "log" diode is approximately proportional to the logarithm of the current. The diode voltage is applied to a very low-leakage differential amplifier, whose output is further amplified with a second differential amplifier to give the "log current" output. The "log current" output is differentiated with an operational amplifier to generate the "period" output.

It is required that the leakage of the input difference amplifier be small compared with the flux amplifier input leakage. This leakage current must come from the ionization chamber current, and if the leakage current is excessive, the current amplified by the flux amplifier will be in error.

2.2 Circuit Description

Referring to Fig. 1, it is seen that the input current flowing through the thermionic diode V1 develops a voltage across the diode that is essentially logarithmic over the current range of 10^{-10} to 10^{-4} amp. This voltage is applied to a difference amplifier which uses insulated gate field-effect transistors (FETs) as active elements (Q1). The gate leakage current of the FETs is extremely small, so that essentially all the signal current can flow through the diode and then into the flux amplifier. The gates are protected against overvoltage transients by a pair of diodes D5 and D6 on one gate and a special low-leakage transistor protection circuit (Q-2636-4, Board 3) on the other gate. A constant-current circuit, comprised of transistor Q2 and resistors R7, R8, and R9, furnishes the bias current for the difference amplifier and appears as a large-source load impedance to improve the common-mode rejection ratio. The gain of the difference amplifier is approximately 2.5. Its output is applied to a Fairchild, type ADO-3 differential amplifier whose gain is adjustable from 2.67 to 4 by the trimming potentiometer R11 ("Lo Cal"). The particular gain required is determined by the characteristics of the log diode V1, and it is adjusted to give approximately 1.67 v per decade at the output of the "Log Current" amplifier. Trimming potentiometer R18 ("Hi Cal") is required for proper scale adjustment of meter M1.

The "Log Current" output is differentiated by an additional ADO-3 amplifier whose gain (product of C4 and R25) is such that a 1-v output corresponds to a 1-sec period.



NOTES

1. To zero instrument, place jumper between TP1 and TP2, measure voltage between TP3 and TP4 with Triplett meter (or equal), adjust "Bal 1" until voltage is zero. Remove jumper from TP1 and TP2 and place between TP3 and TP4, measure voltage from TP5 to TP6, Adjust "Bal 2" until voltage is zero. Remove jumper. The Period Amplifier may be zeroed any time the input is not changing by adjusting "Bal 3" until front panel period meter indicates "00"

2. An overvoltage protection circuit is contained on an added circuit board, Q-2636-4, Board 3. The values of R54 and R55 are changed from Q-2636. Diodes D5 and D6 protect the other input of Q1.

Note:
All resistors 1% deposited carbon except as noted.

NO.	REVISIONS	DATE	APPD	APPD
1	Delete T1 & T2, Add D5, D6 & Q-2636-4 Bd 3	11-30-67		

DRAWN C.E. WASSOMER	DATE 5-7-65	SUBMITTED E N Fray	DATE 6-3-65	APPROVED	DATE
DESIGNED E. N. FRAY	DATE 6-3-65	APPROVED	DATE	APPROVED	DATE
CHECKED	DATE	APPROVED	DATE	APPROVED	DATE

10-19-65	0	Q-2635-1 R0	0.7I	
6-3-65	0	16C13-15-11A	J.L.A	
DATE	DRAWN	REFERENCE	CHG. NO.	APPROVED

SEPIAS ISSUED FROM Q 2635-1

LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED
FRACTIONS: ±
DECIMALS: ±
ANGLES: ±
SCALE:

DETAILS	Q-2635-2
METALPHOTO PANEL	Q-2635-3
PRINTED CIRCUIT BOARD	Q-2635-4
ASSEMBLY	Q-2635-5
PARTS	Q-2635-6
REFERENCE DRAWINGS	DWG. NO.

DESIGN RESPONSIBILITY E. N. FRAY

MODULAR REACTOR INSTRUMENTATION

PERIOD SAFETY CIRCUIT

INSTRUMENTATION AND CONTROLS DIVISION
OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORP.

SUBMITTED 6/3/65 | APPROVED 6/3/65 | DATE

Q-2635-1 R1

Fig. 1. Period Safety Circuit.

Two significant smoothing time-constants are associated with the "Period" amplifier. They are determined by the product of R20 and C4, and R25 with C5, and each is approximately 100 msec.

3. OPERATING INSTRUCTIONS

3.1 Installation

The Period Safety Module is a module in 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 Log-Current Panel Meter

The log-current panel meter is calibrated to indicate current from 10^{-10} to 10^{-4} amp. This represents a voltage swing of -10 v; however, the output voltage measured with respect to ground at a particular current will vary from unit to unit. This is determined by the "Hi Cal" setting which adjusts for variations of input diode characteristics.

3.2.2 Period Panel Meter

The period panel meter is calibrated to indicate reactor period from -30 to +1 sec. This is a voltage range from -0.033 to +1.0 v. The meter is mechanically zeroed to give an "∞" indication with no voltage applied.

3.2.3 Zero Adjustment

"Bal 1" is for zeroing the output of the insulated gate, difference amplifier Q1 with TP1 and TP2 shorted together.

"Bal 2" is for zeroing the output of the "Log Current" amplifier with TP3 and TP4 shorted to ground.

"Bal 3" is for zeroing the output of the "Period" amplifier at any time when the input is not changing.

3.2.4 Test Points

The test points are located at the top of the front side of the shielding enclosure. These are used primarily when zeroing or balancing the instrument, as described in Sect. 3.2.3.

3.3 Connections

All connections are made through the rear connector P29 when the module is inserted.

3.4 Operating Procedures

The balance of the insulated-gate difference amplifier, log-current amplifier, and the period amplifier should be checked periodically for drift. If correction is required, the following procedure should be followed:

1. Place a jumper between TP1 and TP2, and measure the voltage between TP3 and TP4 with a Triplett meter (or equal). Adjust "Bal 1" until the voltage is zero.

2. Place the jumper between TP3 and TP4 and TP6 (ground). Adjust "Bal 2" until the voltage TP5 and TP6 is zero.

3. The period amplifier may be zeroed at any time the input is not changing by adjusting "Bal 3" until the front-panel meter indicates "∞" or until the output is zero.

4. MAINTENANCE INSTRUCTIONS

4.1 General

This module is designed to operate continuously with a minimum of maintenance and adjustment. Zero adjustments and voltage test points are accessible from the top of the drawer with the module inserted and the circuits energized. Should a failure occur, any part listed in the Replaceable Parts List, Sect. 5, can be replaced.

4.2 Periodic Maintenance

The balance of the three amplifiers should be checked (Sect. 3.4, Operating Procedures) once every 3 or 4 weeks.

4.3 Calibration Procedures

The instrument can be calibrated periodically by applying a current source to the input (pin 1) and adjusting the "Lo Cal" and "Hi Cal" trimming potentiometers in the following way:

1. Apply a current of 10^{-9} amp and adjust the "Lo Cal" potentiometer until the front-panel meter indicates correctly.

2. With a current of 10^{-5} amp applied, adjust the "Hi Cal" potentiometer until the meter indicates correctly.

3. Repeat this procedure until the meter indicates correctly at both points.

4.4 Calibration Instruments

The current source used in Sect. 4.3 should have at least a 100-v supply battery to avoid errors in calibration.

4.5 Trouble Shooting

The transistors in the module are plugged into sockets and are easily replaced. However, great care should be taken when replacing Q1, since the body charge of a person handling the transistors might be sufficient to damage this device. This can be avoided by grounding the body to the module when the insulated-gate transistor is handled. Special care should be taken when working near the "log diode" (V1) and Q1 to avoid smearing rosin, finger prints, or other contaminants on these high-impedance, low-leakage circuits. Soldering should be done carefully to avoid damage to the printed circuit boards and components.

5. REPLACEABLE PARTS LIST

A description and an ORNL Stores number for all replaceable parts are given in Table 1.

Table 1. Replaceable Parts List

Part No.	ORNL Stores No.	Description
C1	06-813-1007	Capacitor, 0.001 mf ±10%, 400 v dc working, polyethylene, type CPM 08, MIL marking CPM08A1KE102K, John Fast Co.
C4		Capacitor, 2 mf ±5%, 50 v dc w, Mylar, MIDWEC type 7XFR.
C2, C3	06-802-0395	Capacitor, 0.0022 mf, ±20%, 1000 v dc w, ceramic, disc, formulation 40, Sprague No. 20C162.
C5		Capacitor, 0.15 mf, ±20%, 50 v dc w, ceramic, monolithic, Sprague 5C51.
R6	06-930-8210	Potentiometer, trimmer, 2000 ohms, ±10%, 1-1/2 w, conductive glass resistance element, "Helitrim" Series 53 with printed circuit pins, Helipot Div.
R11, R15, R22	06-930-8218	Potentiometer, trimmer, 50 kilohms, ±10%, 1-1/2 w, conductive glass resistance element, "Helitrim" Series 53, with printed circuit pins, Helipot Div.

Table 1 (continued)

Part No.	ORNL Stores No.	Description
R18	06-930-8206	Potentiometer, trimmer, 500 ohms, ±10%, 1-1/2 w, conductive glass resistive element, "Helitrim" Series 53 with printed circuit pins, Helipot Div.
R2		Resistor, 125 ohms, ±5%, 3 w, ww, vitreous enamel insulation, Ohmite Code 7/16-A-54-F.
R21	06-932-0073	Resistor, 400 ohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R19	06-932-0083	Resistor, 600 ohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R7	06-932-0107	Resistor, 1600 ohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R5	06-932-0129	Resistor, 4000 ohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R10	06-932-0133	Resistor, 5000 ohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R26	06-932-0145	Resistor, 9 kilohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R8	06-932-0147	Resistor, 10 kilohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R9	06-932-0155	Resistor, 20 kilohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R14, R16	06-932-0215	Resistor, 400 kilohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R25	06-932-0225	Resistor, 684 kilohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R23, R24	06-932-0173	Resistor, 47 kilohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R20	06-932-0175	Resistor, 50 kilohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R3, R4 R12, R17	06-932-0189	Resistor, 100 kilohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R13	06-932-0193	Resistor, 125 kilohms, ±1%, 1/2 w, Stemag Type SLAK.[1]
R1		Resistor, 1200 ohms, ±5%, 1 w, A-B.
D3, D4	06-995-7900	Diode, zener, 10 v ±5%, type HZ-8379, Hughes.
D1, D2	06-995-5820	Diode, silicon, 1N457A, Raytheon.
D5, D6		Diode, silicon, FD300, Fairchild

Table 1 (continued)

Part No.	ORNL Stores No.	Description
Q2	06-996-1710	Transistor, PNP, type 2N1131, Texas Instruments.
Q1		Transistor, dual field-effect, type 2N3609, General Micro-Electronics, Inc.
		Amplifier, differential, solid state, encapsulated, 1-1/8 in. by 1-1/8 in. x 5/8 in. thick, for printed circuit board mounting, type ADO-3, Fairchild.
M1, M2		Meter, microammeter, edgewise, 0-100 dc, 1850 ohms coil, vertical, zero bottom 50 division scale, International Inst., Inc., model 1123VB, mark scales as shown on ORNL Dwg. Q-2635-6.
		Printed circuit board from Q-2636-4, Bd. 3.
R52	06-932-0097	Resistor, 1000 ohms, ±1%, 1/2 w, metal film per ORNL Spec. SC-266.
R53	06-932-0079	Resistor, 499 ohms, ±1%, 1/2 w, metal film per ORNL Spec. SC-266.
R54, R56	06-932-0053	Resistor, 150 ohms, ±1%, 1/2 w, metal film per ORNL Spec. SC-266.
R55	06-932-0105	Resistor, 1500 ohms, ±1%, 1/2 w, metal film per ORNL Spec. SC-266.
Q3	06-997-2750	Transistor, PNP silicon, type 2N4250.
Q4	06-997-8980	Transistor, NPN silicon, type S-15649.

[1] "Stemag" resistor, carbon film with double impregnated high temperature varnish. Vendor: H. E. Priester Corp., Scarsdale, N. Y., (supplied by ORNL).

6. ACCEPTANCE TEST PROCEDURE

6.1 Test Equipment

The following test equipment is required:

1. Two dc power supplies, Hewlett-Packard 721 A or equal.

2. One digital voltmeter, Cubic V 71 or equal.

3. One oscilloscope, Tektronix 541 with type L plug-in or equal.

4. One temperature chamber.

5. One current source adjustable from 10^{-10} to 10^{-4} amp (the supply voltage in the current source should be at least 100 v).

6. One MSRE Test Module (Q-2634).

6.2 Adjustment Procedure

6.2.1 Balance

Connect +15 v to pin 11 and -15 v to pin 12; connect pins 15, 3, and 5 to the power supply ground. Allow the module to warm up for a few minutes. Balance the instrument by following the procedure given in Sect. 3.4.

6.2.2 Linearity Test

Connect a current source to pin 1, and ground pin 7. Calibrate the instrument by following the procedure given in Sect. 4.3. If the instrument will not calibrate, replace diode V1. Measure the output of the "Log-Current" amplifier for input currents ranging from 10^{-10} to 10^{-4} amp; the output should be 1.67 v ± 0.2 v/decade. Replace V1 if the variation is too large.

6.2.3 Period Calibration

Calibrate the period amplifier output by following the procedure given in Sect. 2.2.4 of the report for the MSRE Test Module (ORNL-TM-1638, Part 34).

6.2.4 Oscillation Check

Observe the output of the period and the log-current amplifiers for oscillations.

6.2.5 Temperature Stability

Perform a linearity test (Sect. 6.2.2) with the instrument at 55°C. Plot the resulting data and compare the slope of curve at 55°C with the slope of the curve at 25°C (room temperature). The slopes should not deviate more than 5%.

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