

TECHNICAL MANUAL
FOR
MODEL 9211A
MULTIRANGE CURRENT SHUNT

NOTICE

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ERRATA

Issue 1, November 30, 2004

Technical Manual (TM9211A-C-00)

Replace any and all references to 1/3 mohm, which is indicated in this Revision C as 0.000333, with the following: "0.000333333".

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GENERAL

The Model 9211A is a self-contained 9 range, 4 terminal shunt, for precision current measurements up to 300 amperes. The design optimizes a number of important factors such as the effects of self-heating, temperature coefficient, size, weight, ease of operation and total measuring range.

PURPOSE OF EQUIPMENT

It provides wide range precise current measuring capability when used with a potentiometer or digital voltmeter as a readout.

DESCRIPTION

The shunt resistors are mounted in air for minimum size and weight, yet self-heating is a negligible source of error from 20°C to 30°C. Self-heating has only a small effect for a still wider range of ambient temperatures. The resistors are made of selected zeranin wire and are non-inductively wound, up to 1 ampere. The unit consists of nine (9) shunts, of the 4-terminal configuration. Each shunt provides a 100mV drop at the nominal rated current. The maximum current rating is 140% of nominal for all ranges except the 100A and 300A ranges, for which the maximum is 110% of the nominal current rating.

SPECIFICATIONS

(a) Electrical

<u>Nominal Resistance</u>	<u>Nominal Current Rating</u>	<u>Nominal Voltage Drop</u>	<u>Accuracy of Nominal Values</u>
0.000333Ω	300A	100mV	±0.1%
0.001Ω	100A	100mV	±0.05%
0.01Ω	10A	100mV	±0.01%
0.1Ω	1A	100mV	±0.01%
1.0Ω	0.1A	100mV	±0.01%
10.0Ω	0.01A	100mV	±0.01%
100.0Ω	0.001A	100mV	±0.01%
1000.0Ω	0.0001A	100mV	±0.01%
10000.0Ω	0.00001A	100mV	±0.01%

(b) Environmental

Temperature Range: The unit performs within specification limits over a temperature range of +40°F to +100°F with corrections, at up to 90% R.H. (Temperature and power coefficient charts are provided).

Storage: The unit is capable of safe storage (non-operating) for extended periods at temperatures from -40°F to +135°F without any deteriorating effects.

Tilt Drop: The unit is capable of operating satisfactorily without permanent damage or degradation of accuracy during and after being subjected to a tilt drop test. This test is performed by raising each of the four (4) sides of the instrument, using the opposite side as a pivot, at least four (4) inches above the horizontal plane and allowing it to drop freely onto a solid wooden table.

Vertical & Lateral Shock: The unit is capable of withstanding vertical and lateral shock of 15 G's for 11 milliseconds.

Vibration: The unit is capable of withstanding a vibration test with the frequency varying between 10 and 55 Hz at a total excursion of 0.01 ±.006 inches; the frequency varying uniformly from 10 to 55 Hz and returning to 10 Hz in approximately five (5) minutes along each of the major axis individually.

(c) Mechanical

Ventilation: The rear cover is ventilated. It extends over the entire rear dimensions of the unit. Cooling is accomplished by air convection only.

Dimensions: Height - 9 inches max.
Depth - 9 1/2 inches max. (from front panel, including slides)
Width - 19 inches

Mounting: Standard 19 inch rack mounting in accordance with MIL-STD-189

Slides: (Optional) Supplied with chassis slides to meet standard dimensions for rack mounting in accordance with MIL-STD-189 and/or E.I.A. Std. SE-102.

Weight: Approximately 18 lbs.

OPERATING INSTRUCTIONS

1. Determine the maximum current to be measured.

NOTICE

If maximum current to be measured is unknown, good instrumentation practice would be to approximate it at a value that is certain not to be exceeded.

2. Insert a pair of range selector plugs into the appropriate female receptacles on the front panel. One plug is inserted over the other (in a vertical line). For example, if the range selected is 10 amperes, insert the two plugs in the two receptacles directly over the engraved portion marked with the numeral "10".
- 3a. For measurements up to and including 10 amperes, connect the shunt in series with the power source and the item under test, (see page 22). Note the polarity of the connections. If a DC ammeter is being calibrated make sure the meter deflects up scale. If not, reverse its lead connections. Use leads of sufficient size to carry the rated current. (Calculate approximately 700 circular mils per ampere). Connect leads to the two binding posts engraved "Input Common" and "10 amp max.". Connect the millivoltmeter being used as a readout instrument (DVM, DC potentiometer, etc., with a range of 0-100mV) to the two binding posts engraved "Potential" in the space between them.

Note 1: Polarity from the source is unimportant insofar as the shunt is concerned as long as the potential and current connections agree, i.e., both "common" binding posts must be connected in the same polarity.

Note 2: If the readout device is a low resistance millivoltmeter, inaccuracies can result proportional to the current drain. DC potentiometers are an example of infinite resistance devices that can properly be employed without loss of accuracy due to circuit loading.

If a DVM is employed, its input resistance should be checked to see that it is sufficiently high to be negligible. For example, worst case would be measurements from 0-10 micro-amperes that use the 10,000 ohm resistor. If the DVM has a 10,000 megohm input resistance, its effect is $\frac{1 \times 10^4}{1 \times 10^{10}}$ or

0.0001%, which would be negligible.

- 3b. For measurements above 10 amperes (up to, and including, 300 amperes), observe the same procedures as described in 3(a) above, except connect one lead to the 100 or 300 amp binding post as required (instead of to the 10 amp binding post).
4. Each shunt has a 100mV output with the application of the rated current. In actual measurement, it is this voltage, or fraction thereof, which the readout instrument indicates. Its reading in mV is directly proportional to the current applied. For example, if connections are made to the 10 ampere shunt, a 100mV reading indicates a 10 ampere flow within $\pm 0.01\%$ (plus the accuracy of the readout instrument). A 90mV reading indicates a 9 ampere flow, etc. Direct readings in amperes can be obtained for all ranges up to, and including, the 100 ampere range by arbitrarily fixing the decimal point of the readout instrument. When making measurements using the 300 ampere range, readings must be interpolated as follows:

<u>Amperes</u>	<u>Readout in mV</u>
300	100
270	90
240	80
210	70
180	60
150	50
120	40
90	30
60	20
30	10

On the 300 ampere range, to obtain a reading in amperes, the indication of the millivoltmeter is multiplied by 3 and the decimal point arbitrarily fixed.

5. Each shunt can be used at rated nominal current to full accuracy with no duty cycle limitations.

CAUTION

If an overload has inadvertently been applied,
for best accuracy, allow shunt to cool for
approximately 30 minutes before using again.

6. It is good instrumentation practice to reduce power to zero before disconnecting the shunt.
7. Minimum accuracy that can be attained overall is the accuracy of the shunt resistor in use plus the accuracy of the readout instrument. This value is in "% of full scale" and/or "% of reading" depending on how the readout instrument is rated. As an example, using a DVM with $\pm 0.01\%$ full scale accuracy and the 10 ampere range of the shunt, overall accuracy is $\pm 0.01\%$ full scale plus $\pm 0.01\%$ of reading. If a DC potentiometer of 0.01% accuracy of reading is employed instead of the DVM, accuracy is in % of reading.

CAUTION

Most readout instruments have a residual error at the low end of their range which may be a significant accuracy factor. Examine the specifications of the millivoltmeter used to determine what these errors are. For this reason, it is good instrumentation practice to use that shunt range which will provide the highest millivolt output for a given current flow. As an example, if the 10 ampere range is being used, for measurements of 1 ampere or below, change to the 1 ampere range.

ADDITIONAL APPLICATIONS OF THE MODEL 9211A

Each shunt can be employed as a separate 4 terminal standard resistor for measurements of resistance. The operating procedure is identical to that described previously. The circuit would include a resistance in series with the "current" connections rather than an instrument under test (although it could include both if desired). By measuring the voltage drop separately across the resistance under test, the two resistors can be compared.

Note: When comparing standard resistors as described above, accuracy of comparison is directly proportional to current stability if using a single millivoltmeter to measure the drop across each resistor and switching from the standard to the unit under test. If two millivoltmeters are employed, overall accuracy must include the accuracy of both readout instruments.

MAINTENANCE, INSPECTION AND CLEANING

1. Inspect the shunt panel before operation. It should be free from physical damage with no broken or bent binding posts.
2. Clean front panel by wiping with a dry, lint-free cloth. Male plugs and receptacles can be wiped with a crocus cloth if they appear discolored. Do not use sand paper. Avoid using a cleanser that may leave a film.

CAUTION

Do not remove rear cover to clean inside of shunt box. Physical movement of shunts can cause mounting stress and changes in resistance values.

TROUBLE SHOOTING

1. A visual inspection is most important. Check to see if rear cover or panel is warped or distorted. If it is, the entire unit should be recalibrated at once.
2. If the binding post heads are broken, they should be replaced from the front panel.
3. If an electrical overload has been applied beyond the rating of each resistor, the entire unit should be recalibrated at once. (Note: A burned shunt will have a distinct charred odor).
4. If an open or intermittent circuit is found in the instrument, (no reading or varying reading on millivoltmeter), check as follows:
 - (a) All lead connections to binding posts must be tight. Leads should be checked for continuity using a circuit tester. See that plugs are firmly inserted in female receptacles.
 - (b) Lead connectors, plugs and receptacles should be checked for clean surfaces. Clean, if required, using a crocus cloth.
 - (c) Readout instrument should indicate and be stable when tested in another circuit in accordance with the manufacturer's instructions.
 - (d) Power source should be tested for output. If no output, trouble shoot in accordance with manufacturer's instructions.

Note: A skipping or variable rheostat in the circuit can cause results similar to a broken lead or bad connection.
5. If a short circuit is found in the instrument, check as follows:
 - (a) Proper connection of all leads.
 - (b) Physical condition of vented rear cover. If cover indented badly, it could short circuit two or more resistors by touching them. Remove the cover from the rear panel taking care not to put pressure on any resistors. Straighten the cover. Examine the internal circuit visually for possible shorting of components. Reinstall the cover observing the same precautions.
 - (c) Compare each resistor to a standard resistor.
 - (d) If tests (a) to (c) above are negative, the problem may be in the internal wiring or resistors in the shunt. Each shunt can be tested separately for continuity without removing the rear vented cover, by inserting the two plugs in the paired female receptacles for each range and using an ohmmeter between the "10 amp max." or "100 amp" or "300 amp" binding post and the "Input Common" binding post. If a defective shunt or internal connection is found (or suspected), the entire unit should be returned for possible repair. (See Warranty Card in front of this manual for instructions).

TEST PROCEDURE

(a) Resistor Accuracy

1. General: Each shunt section shall be individually measured as a four terminal resistor against National Laboratory (i.e. N.B.S., N.R.C., etc.) certified standards, under ambient conditions and with power dissipation such that the quality of the test shall not be invalidated.
2. Standards: Decade standard resistors as listed below shall be used for the measurement of each shunt section. The resistance of each standard shall be known to $\pm 0.001\%$ relative to the standards maintained by the National Laboratory and shall bear current calibration reports.

Shunt Section Resistance	Test Current	Standard Resistor	Power Dissipation		Resistance Ratio
			Tested	Std.	
0.000333 Ω	30A	0.33333 Ω	0.3W	0.3mW	1000/1
0.001 Ω	10A	1 Ω	0.1W	0.1mW	1000/1
0.01 Ω	1A	1 Ω	0.01W	0.1mW	100/1
0.1 Ω	0.1A	1 Ω	1mW	0.1mW	10/1
1 Ω	0.1A	1 Ω	0.1mW	0.1mW	1/1
10 Ω	0.01A	10 Ω	1mW	1mW	1/1
100 Ω	0.001A	100 Ω	0.1mW	0.1mW	1/1
1000 Ω	0.001A	1000 Ω	-	-	1/1
10,000 Ω	0.0001A	10,000 Ω	-	-	1/1

Power dissipation in the tested resistor shall not exceed 0.3 watt. In the standard it shall not exceed 0.3mW when checking the 300 ampere section and it shall not exceed 1mW when checking all other sections.

3. Test Environment: The test environment shall be stabilized by immersion of the standard resistor in flowing oil at 25°C temperature controlled to $\pm 0.1^\circ\text{C}$ with a stability better than $\pm 0.01^\circ\text{C}$, such as provided by the Guildline Model 9730CR Constant Temperature Bath.
4. Test Equipment: The 0.000333 Ω shunt shall be compared with a group of three Guildline Instruments Model 9330, 1 ohm, Standard Resistors connected in parallel so as to have a value of 0.33333 Ω . This value shall be established by means of a Guildline Instruments Model 9920 Current Comparator Bridge employing a Model 9330 1 ohm Resistor as a standard. 30 amperes shall be passed through the tested shunt and 30 milliamperes shall be passed through the standards so that approximately 0.3 watts shall be dissipated in the tested shunt and only 0.3 milliwatts shall be dissipated in the standards. This test configuration (which completely avoids the effects of self-heating and the power coefficient in the standard) shall be provided by the Model 9920 DCC Bridge operating in the 1000:1 ratio mode with a required accuracy and resolution of 3 parts in 10^5 of full scale.

(b) Temperature Coefficient

1. Each shunt section shall be measured against standards as detailed above, but with the standard maintained at $25^{\circ}\text{C} \pm 0.1^{\circ}\text{C}$ and the measured shunt sequentially temperature controlled at 4°C , 10°C , 16°C , 24°C , 30°C , 34°C and 40°C .

The various ambient temperatures shall be obtained in the Model 9730CR Constant Temperature Oil Bath adjustable in the range 0°C to 60°C with temperature accuracy of $\pm 0.1^{\circ}\text{C}$ and temperature stability of $\pm 0.01^{\circ}\text{C}$.

The resistance comparisons shall be performed on the Model 9920 DCC Bridge in which, by suitable choice of ratios, the power dissipation in the measured shunts and the standards shall not exceed the values indicated in the table above. A graph of resistance vs. temperature shall be prepared for each shunt section.

2. Maximum Temperature Coefficient: The resistance sections are constructed so as to remain within their accuracy limits at all rated currents and in all ambient conditions from 10°C to 38°C without the use of correction graphs, when the effects of both power dissipation and ambient temperature operate simultaneously.

(c) Power Coefficient

For all shunt sections in which the power dissipation at the rated maximum current exceeds 10mW (0.1Ω , 0.01Ω , 0.001Ω and 0.000333Ω sections), a graph of resistance vs. power dissipation, (or resistance vs. current), shall be prepared.

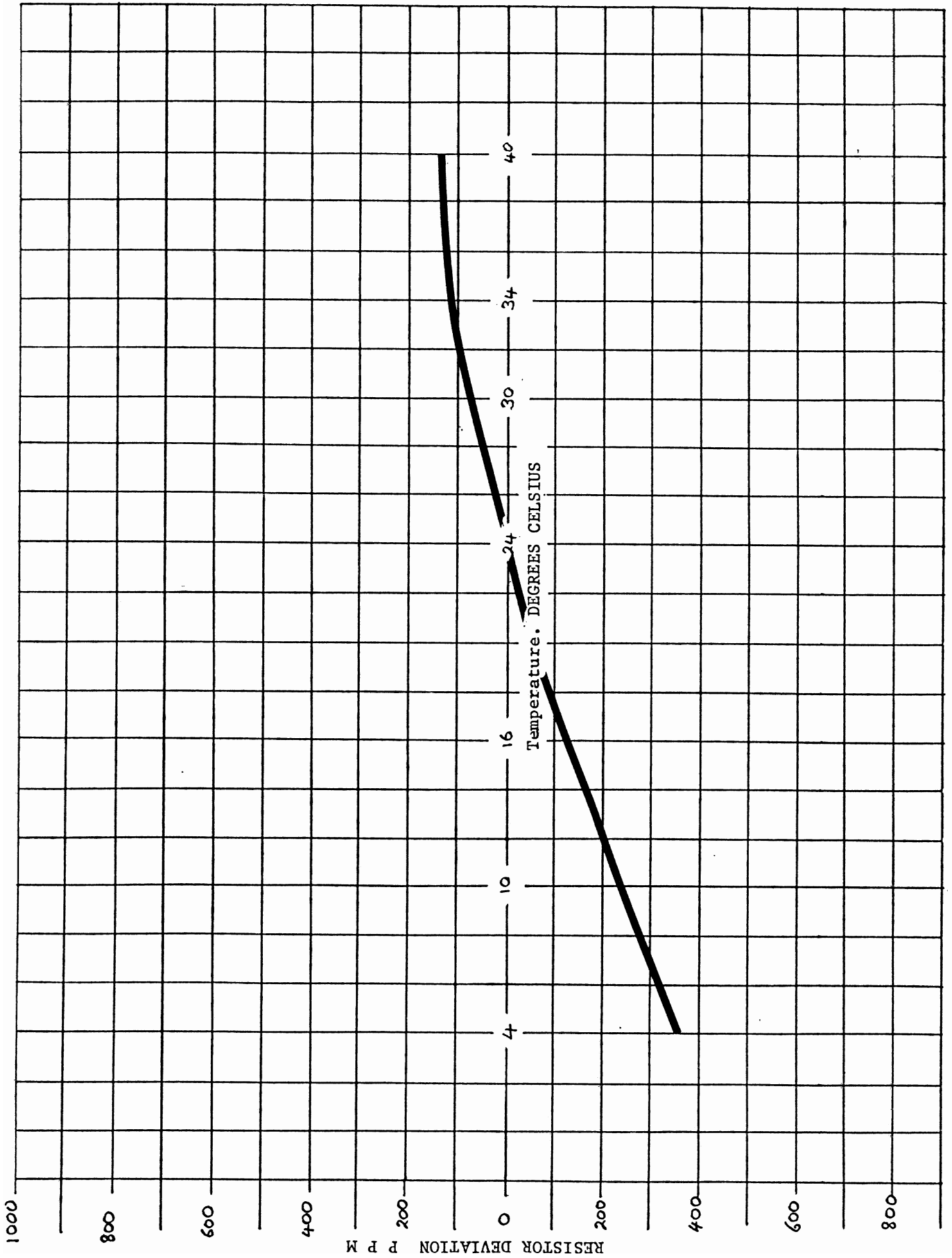
The resistance of each of these shunt sections shall be measured at current levels such that 0.1, 0.25, 0.5, 0.75 and 1.0 of maximum rated power is obtained, under the test condition in which the standard resistor operates over a power range of not more than 1/10 of the power range of the tested shunt section.

For example, the 300 ampere 30 watt shunt shall be measured when dissipating 3 watts, 7.5 watts, 15 watts, 22.5 watts and 30 watts against the standard resistor of 0.33333Ω dissipating 3mW, 7.5mW, 15mW, 22.5mW and 30mW.

To perform this power coefficient measurement, the Model 9920 DCC Bridge shall be used in which, using the 1000:1 fixed ratio configuration, the power dissipation in the measured and standard resistors is then in the ratio of 1000:1 and required resolution and ratio accuracy are 1 part in 10^5 .

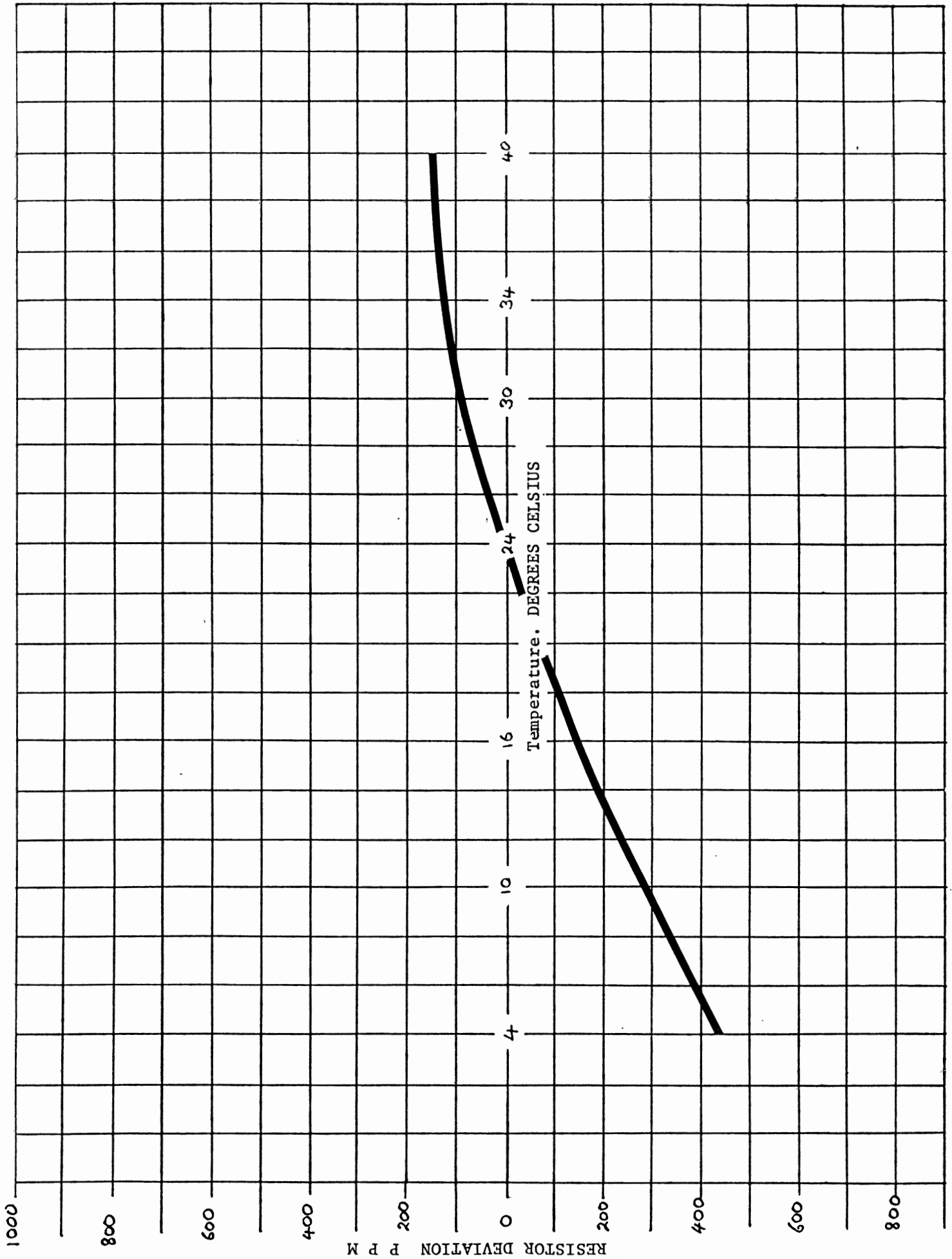
Power Coefficient

<u>Nominal Resistance (Ω)</u>	<u>Power Coefficient (0 - rated current)</u>
0.000333	_____
0.001	_____
0.01	_____
0.1	_____
1.0	_____
10	_____
100	_____
1000	_____
10,000	_____

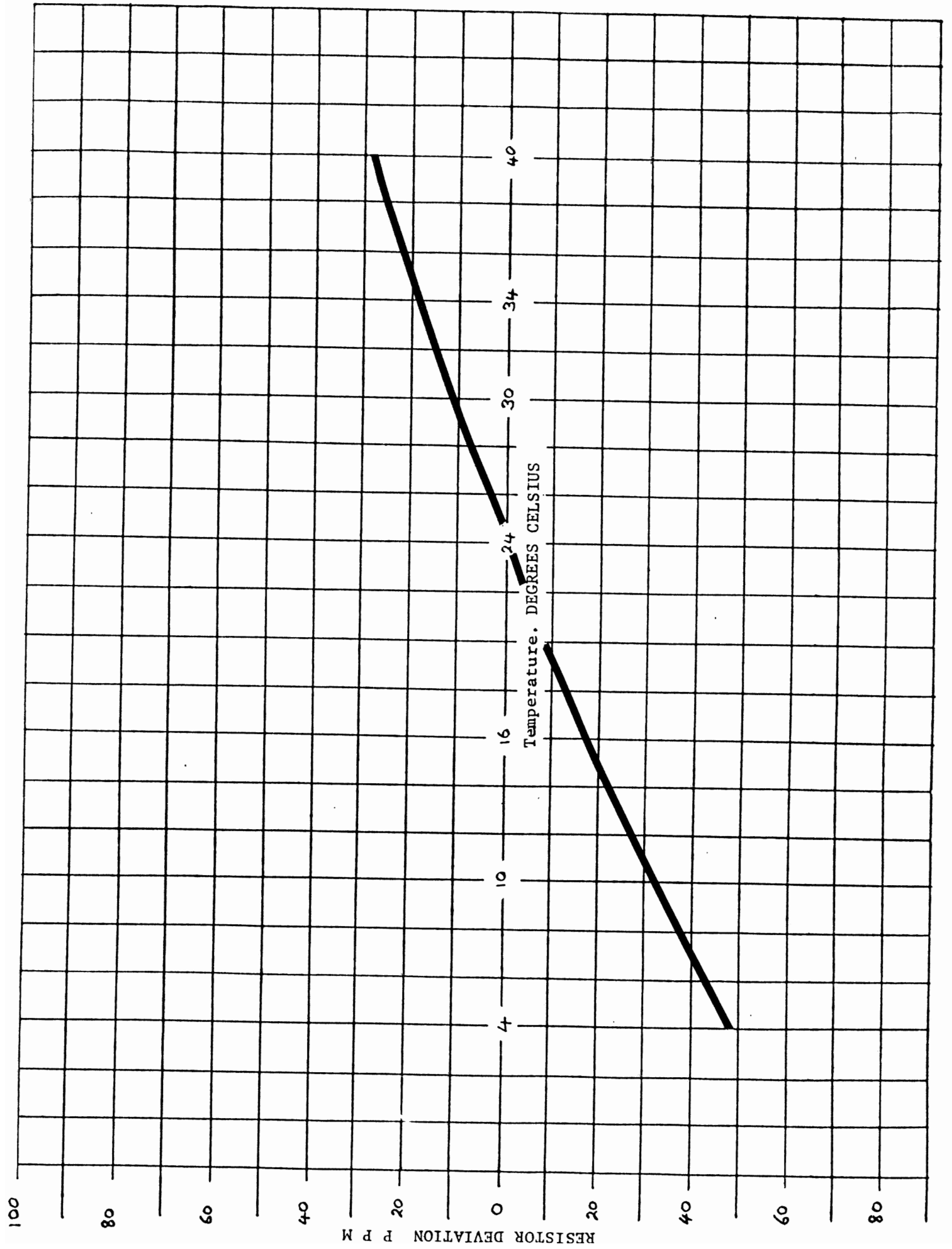


300 AMP

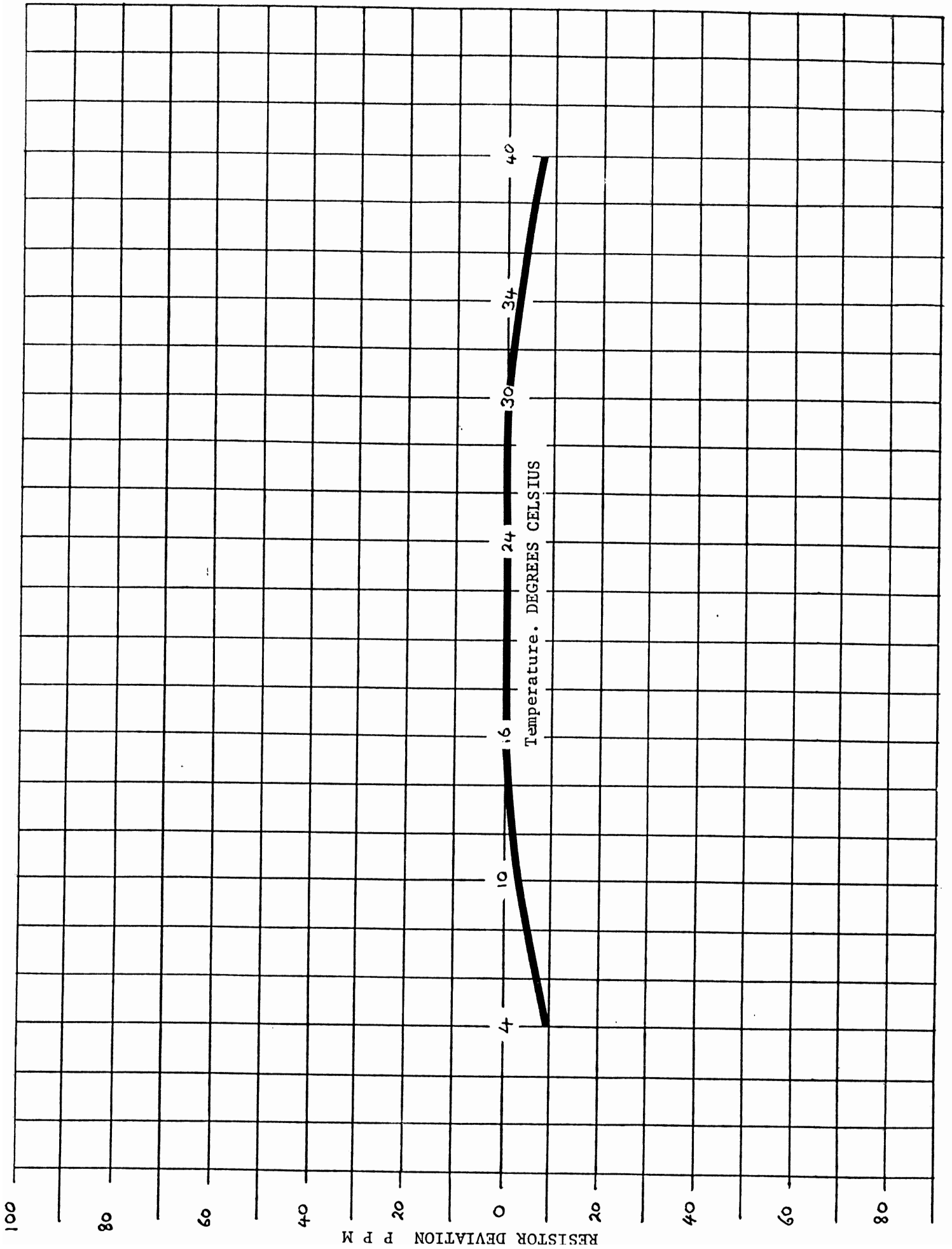
0.000333Ω

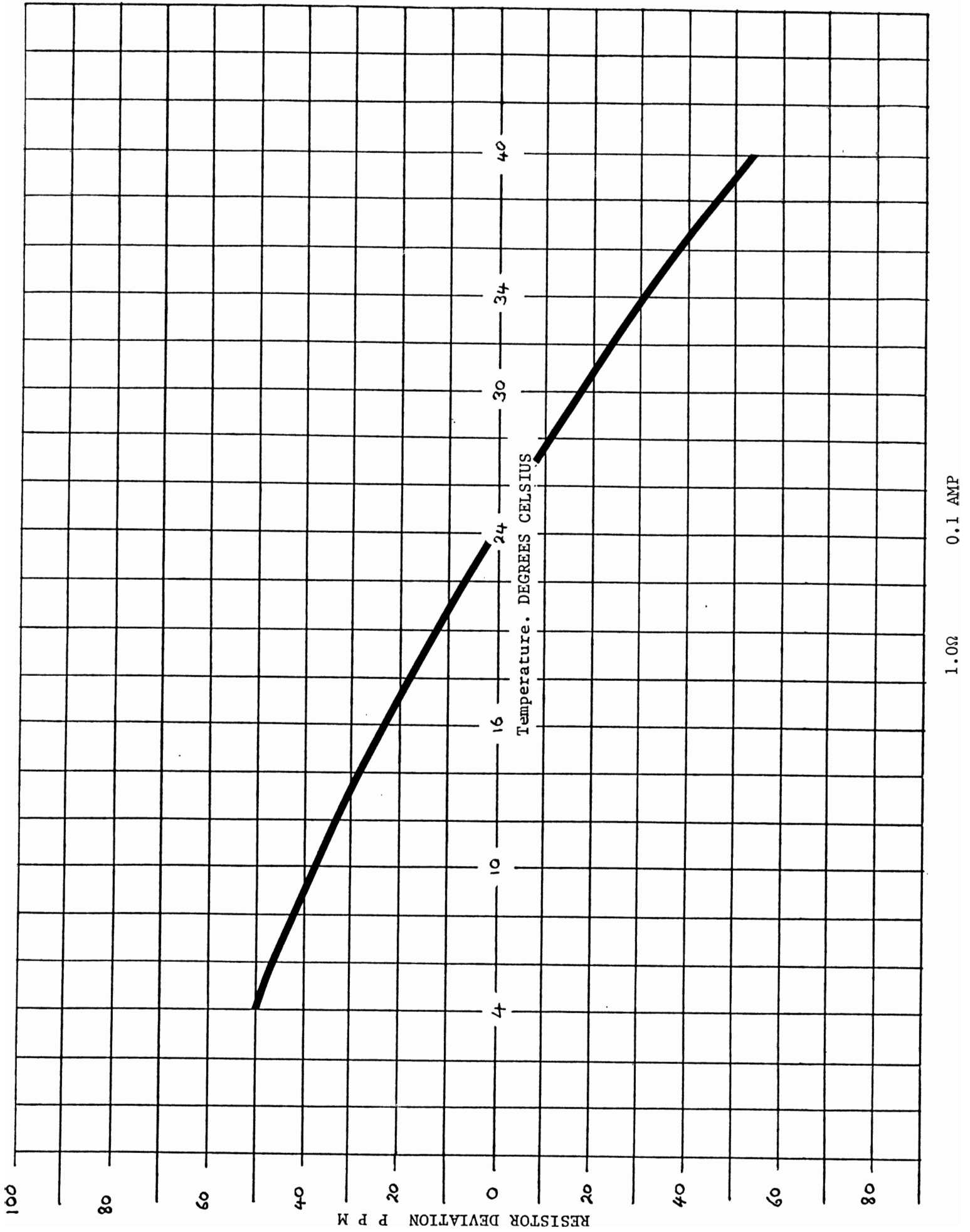


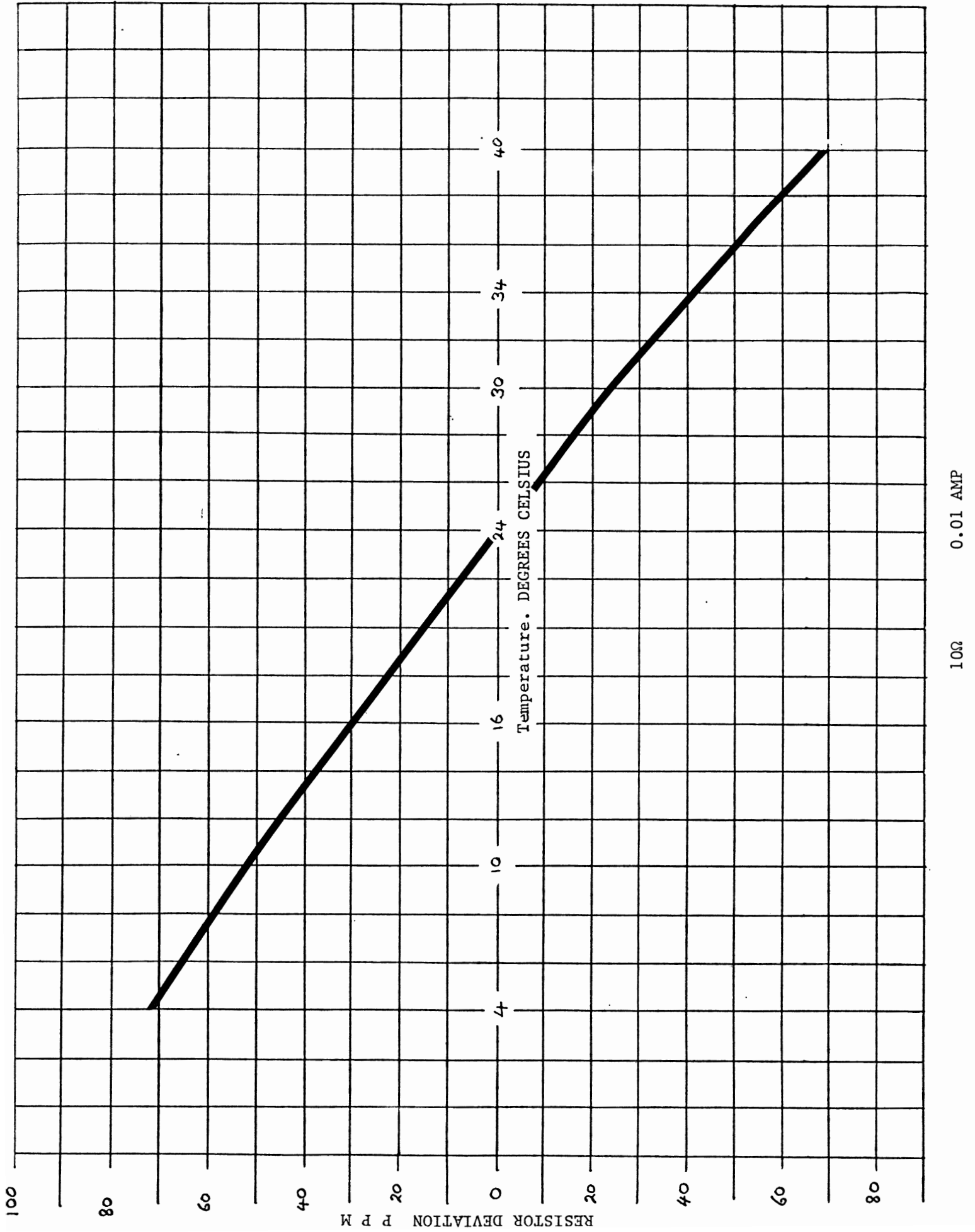
0.001Ω 100 AMP

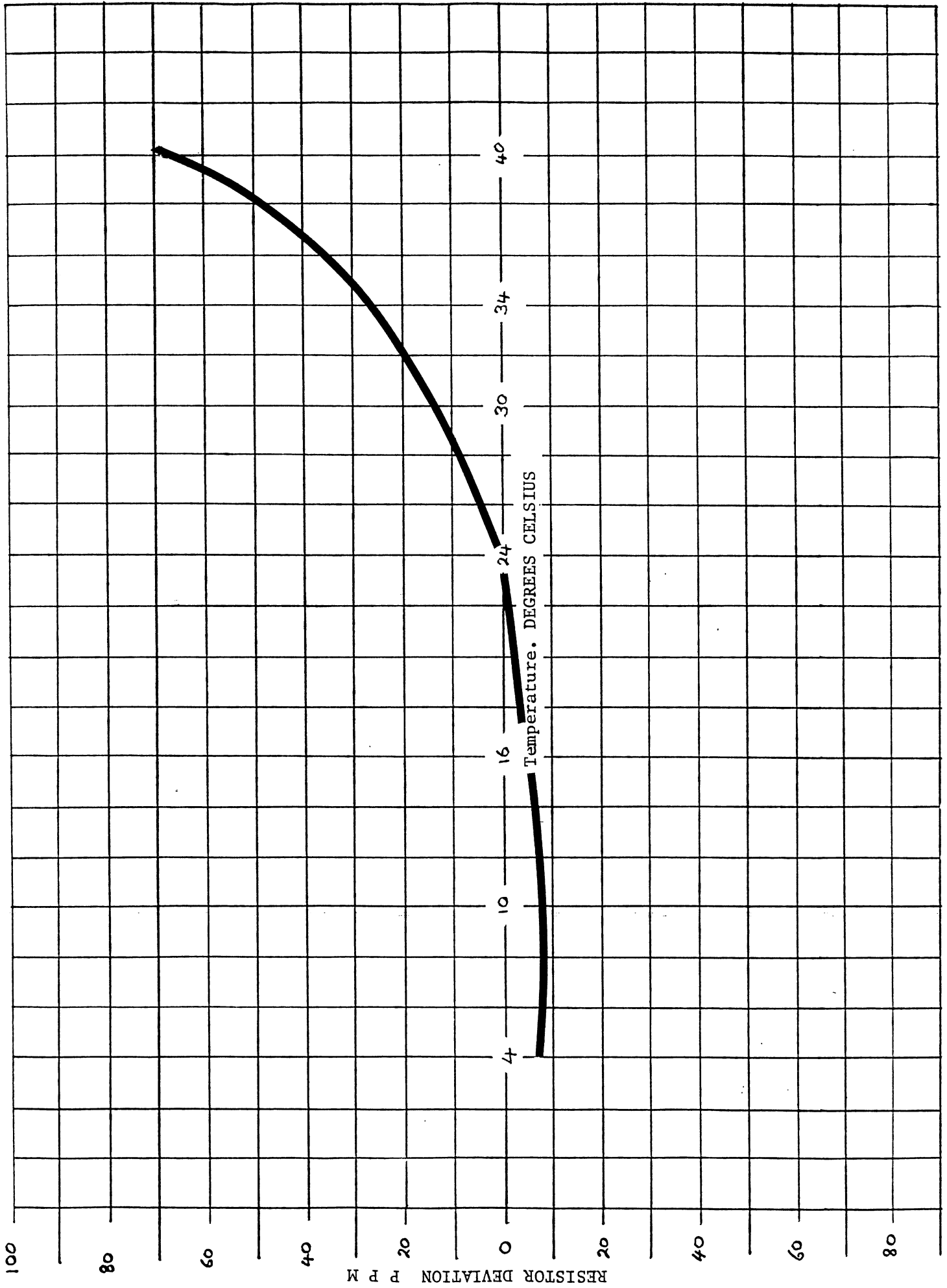


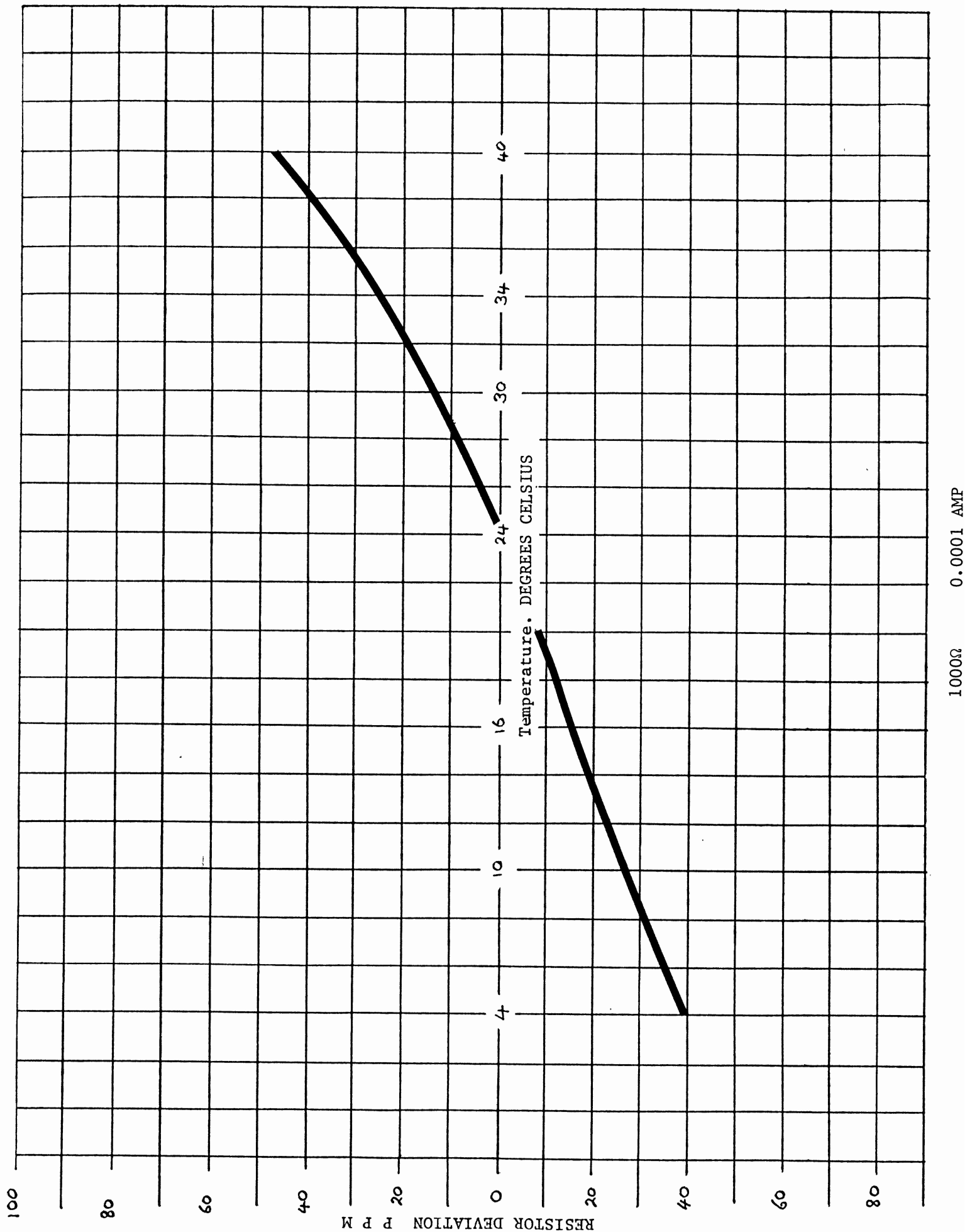
0.01Ω 10 AMP

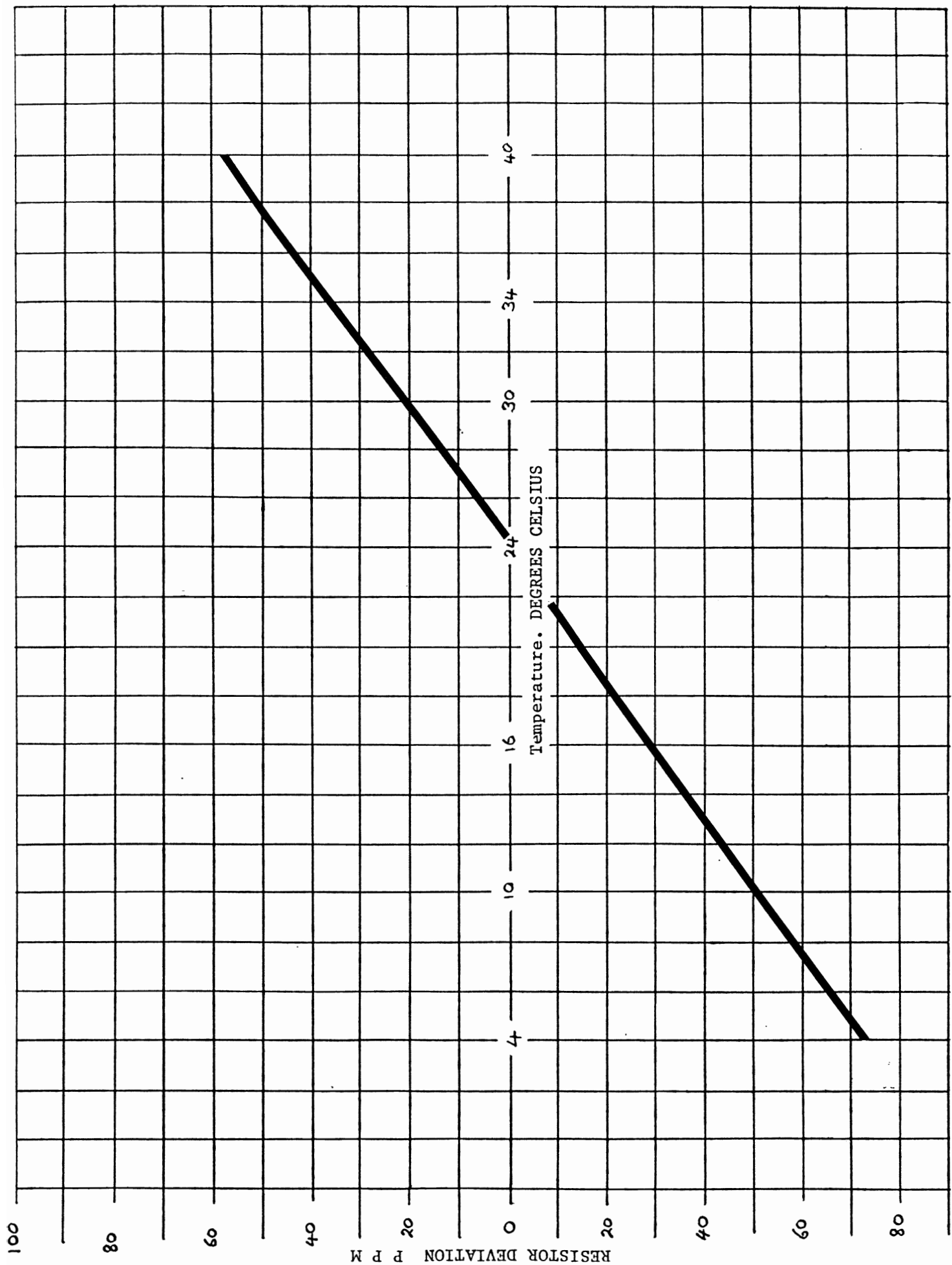




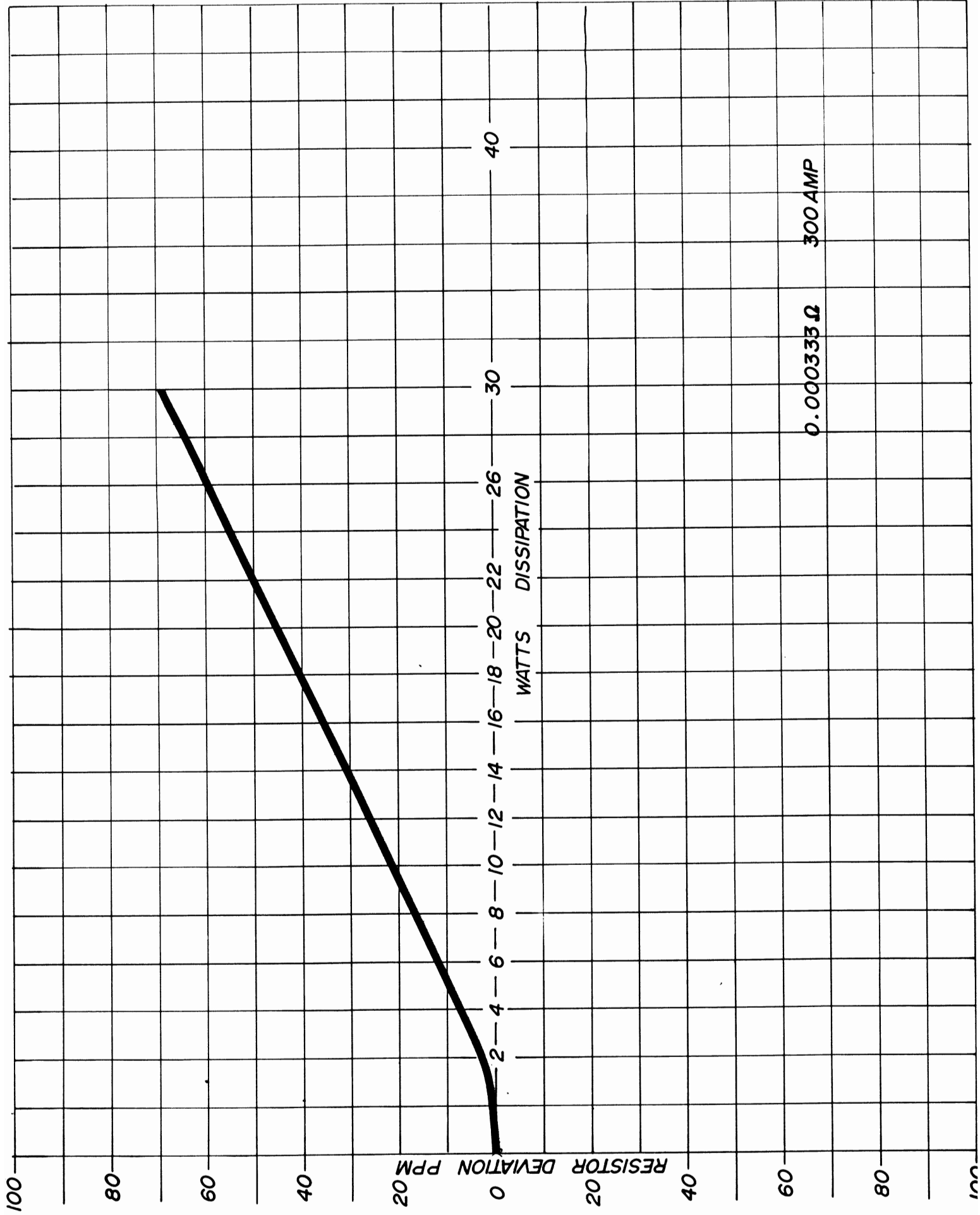


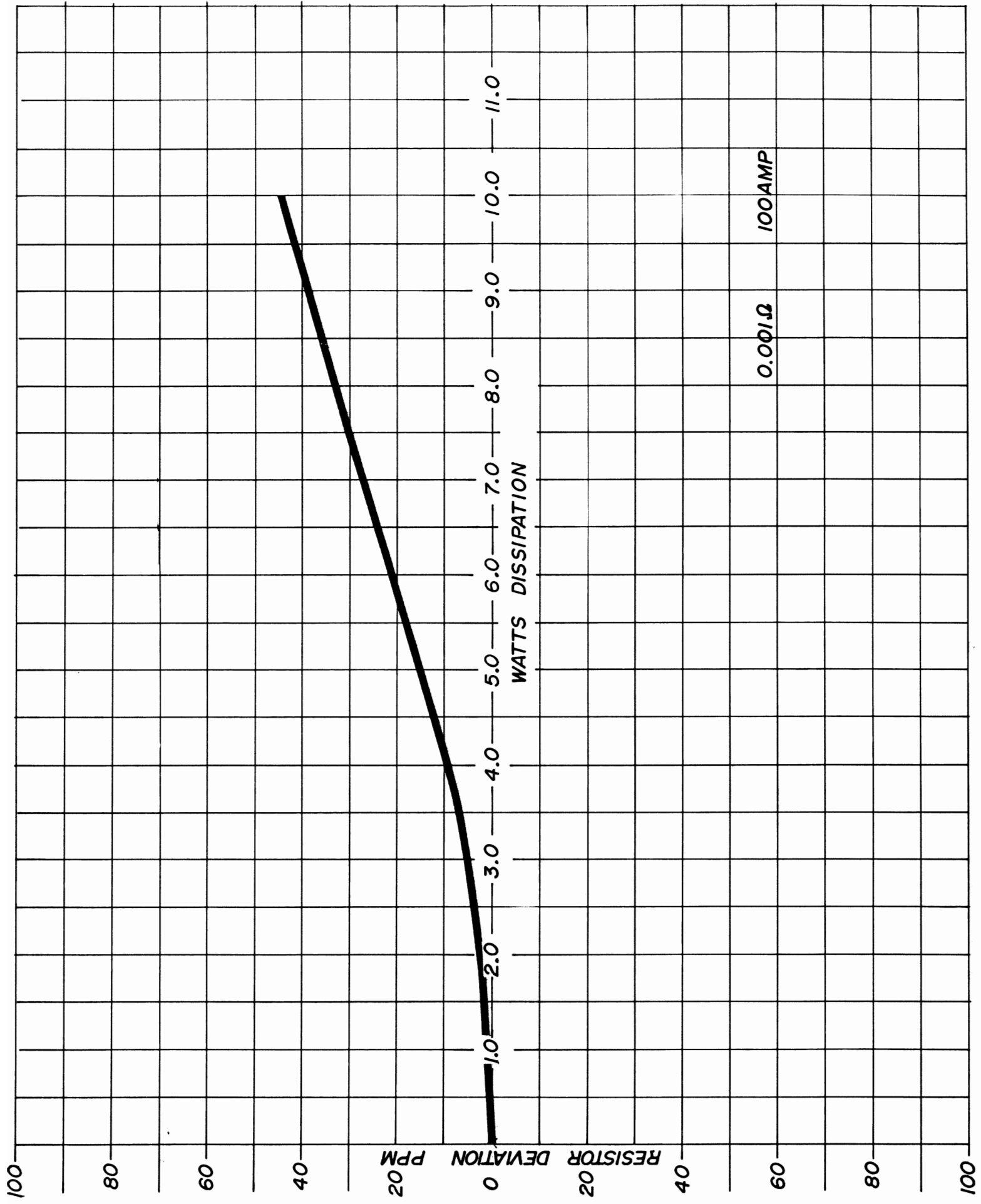


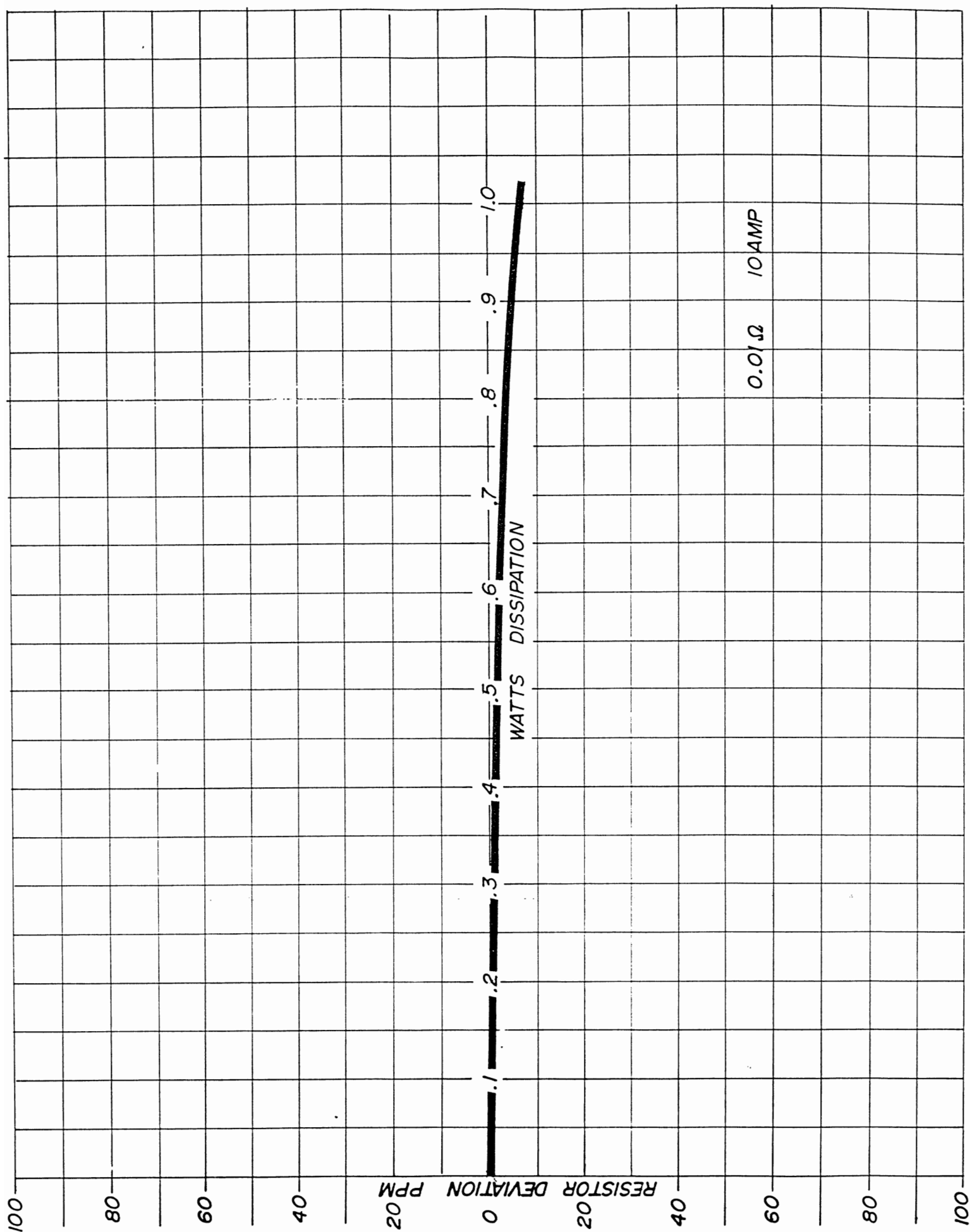


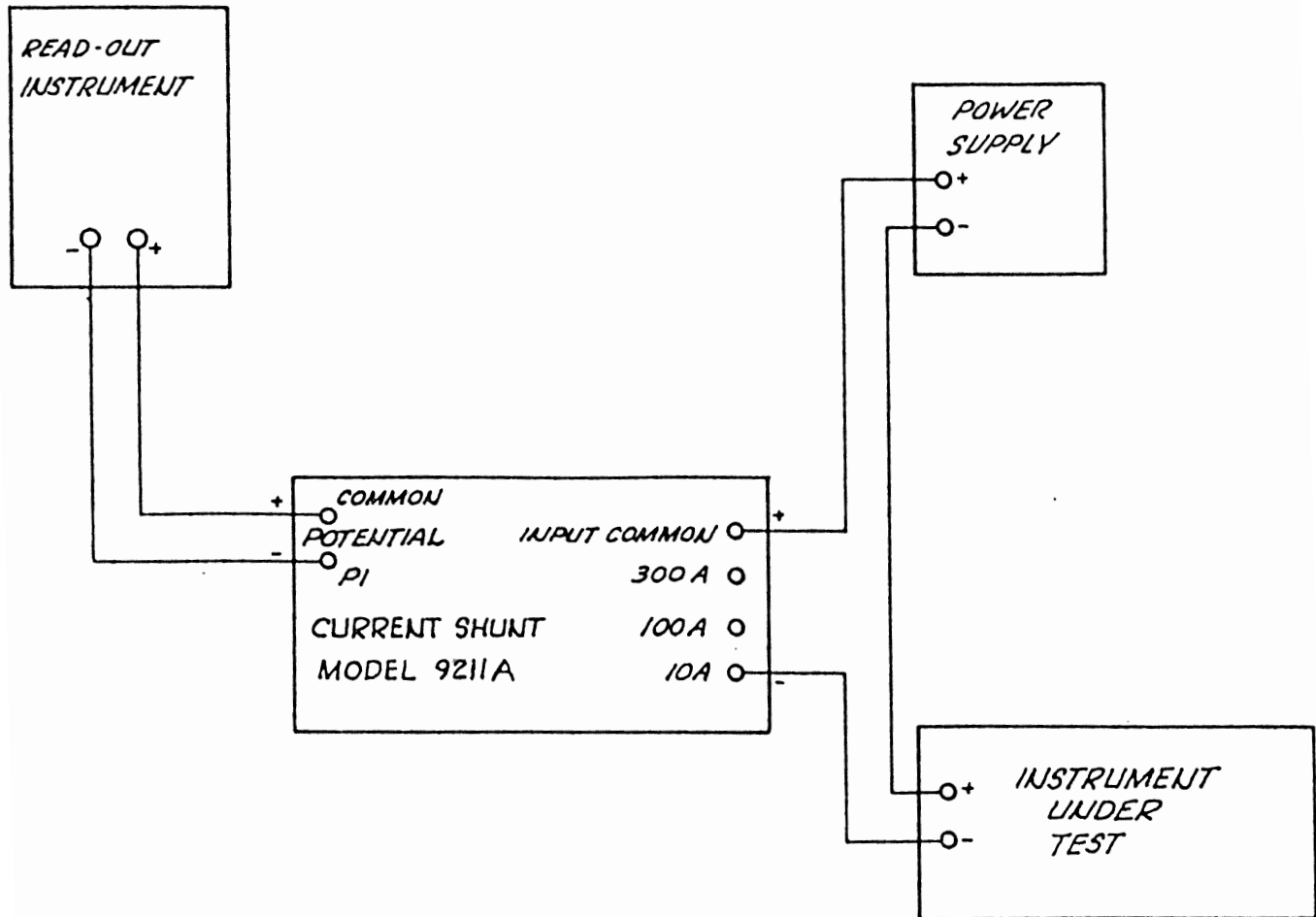


10,000Ω 0.00001 AMP

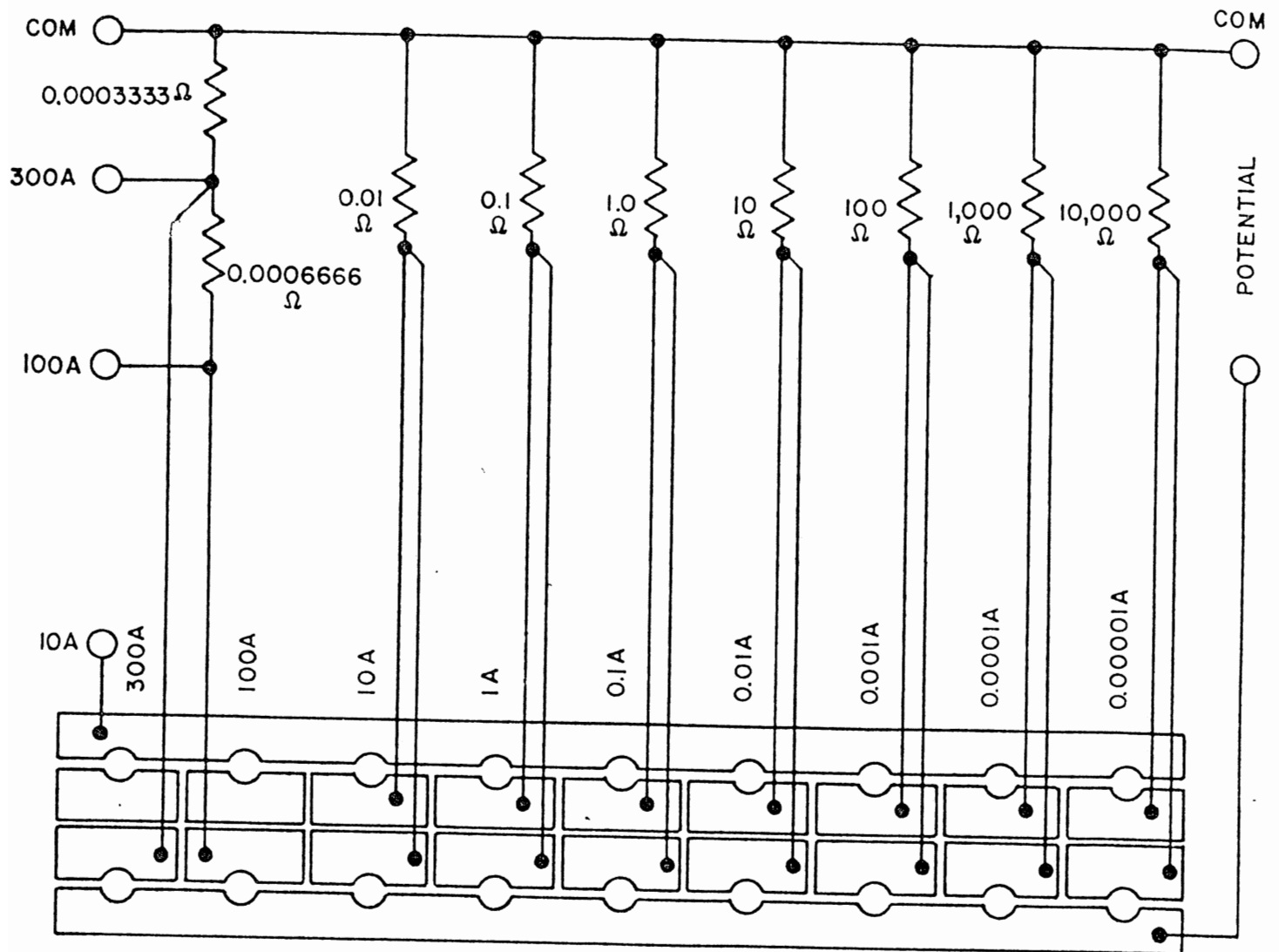




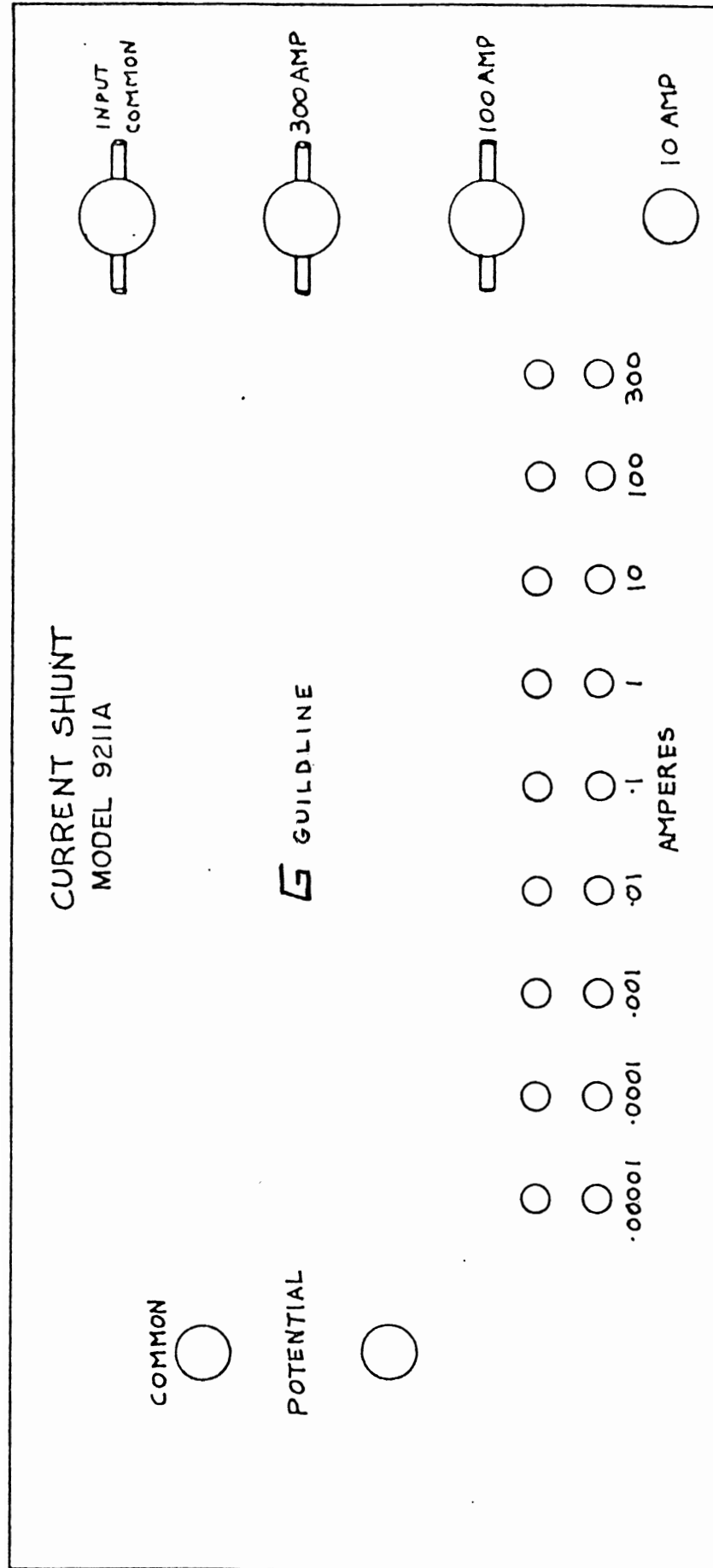




TEST CONFIGURATION



THEORETICAL SCHEMATIC



FRONT PANEL LAYOUT

Field Replaceable Spare Parts:

<u>Part Number</u>	<u>Description</u>
11000.01.10	Large Binding Post Head
17749.01.12	Small Binding Post Head
12294.01.01	Taper Plug Assembly
17798.01.02	1 Ω Resistor
17798.02.02	10 Ω Resistor
17798.03.02	100 Ω Resistor
17798.04.02	1000 Ω Resistor
17798.05.02	10,000 Ω Resistor