NATIONAL BUREAU OF STANDARDS REPORT

5810

Series Resistance Dimming Controls
for
Types AN 3140-327 and AN 3140-328 Lamps

by
Wade H. Askew
Photometry and Colorimetry Section
Optics and Metrology Division

Test 21N-6/58

Sponsored by
Lighting Section
AE 821
Bureau of Aeronautics
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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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1. SCOPE

This report presents the results of an investigation of series resistance dimming controls for Types AN 3140-327 (28-volt) and AN 3140-328 (6-volt) lamps. A previous report (NBS #1852) published during 1952 gave such requirements for the Type 327 lamp operating from a 28-volt supply source. Since that time these lamps have been used in assemblies operating from supply sources considerably higher or lower than the rated voltage of the lamp. Also, the Type 328 lamp is being used for similar applications. Contained herein is information showing dimming-resistance requirements for both types of lamps when operated from any voltage supply now considered practical.

2. INTRODUCTION

Types 327 and 328 lamps are used mainly, but not exclusively, for instrument and control panel illumination. Except for the filaments the two lamps are geometrically similar. The 327 is rated at 0.04 ampere, 28 volts, and at this voltage the light output is approximately 0.34 spherical candle. The 328 is rated at 0.2 ampere, 6 volts, and at rated voltage produces about 0.6 spherical candle. In military aircraft the dimming controls are usually designed so that the intensity of the lamps can be reduced to about one percent of the intensity at rated voltage. In some instances the voltage supplied to the lamps is significantly different from the rated voltage, as in the case of lamps which are sealed in the instruments. In this example the lamps so installed should be operated at lower than design voltage to assure lamp life at least equal to the life expectancy of the instruments. In the case of the Type 327 lamps used in the signal paddles and in the lighting strips of the Landing Signal Officer's suit, an occasional burnout would not be critical, so that in order to attain a higher intensity when needed, the lamps operate from a 32-volt supply source.

3. VOLTAGE RANGE OF SUPPLY SOURCES

The following criteria were used for estimating the voltage range over which the lamps might be usefully operated.

(1) Luminous intensity not less than 1% of the intensity at rated voltage.

(2) Lamp life expectancy not less than 1% of the expectancy at rated voltage.

Photometric measurements showed that the luminous intensity of both types of lamps dropped to 1% when the voltage was reduced to about 1/3 of the rated voltage.

It is generally accepted that for larger lamps life is inversely proportional to approximately the 13.5 power of the voltage. There is some question as to the accuracy of this exponent for smaller lamps and for relatively large voltage changes. However, for the purpose of this report, it was used for approximating the voltage which would reduce the life expectancy of these lamps to 1% of normal life. This voltage was computed to be approximately 140% of rated voltage.

4. ELECTRICAL AND PHOTOMETRIC CHARACTERISTICS OF THE LAMPS

Lamp current was measured at potentials from 8 to 40 volts for the Type 327 lamp and from 1.5 to 9 volts for the Type 328. In Figure 1 the current-voltage relationship is plotted on a percentage basis, 100 representing the current and potential at 40 volts for Type 327 and at 9 volts for the Type 328. The plotted points indicate that an exponential curve is applicable for both types of lamps throughout the ranges of lamp voltage considered. The power and filament resistance curves in this figure were computed from the voltage-current relationship and are considered to be reasonably accurate for either type lamp for the voltage range of approximately 30% to 140% of rated voltage.

Figure 2 shows the voltage-luminous intensity relationship for both types of lamps. The intensity coordinate is in percentage of the lamp intensity at rated voltage.

5. DIMMING RESISTANCE REQUIREMENTS

Figure 3 shows the amount of series resistance required to reduce the lamp voltage to any level down to 30 percent of the supply voltage. It also shows the amount of power dissipated in this resistance, and the current in the circuit. The abscissa scales of resistance, power, and current, are in percent of lamp resistance, wattage, and current, when operated at the full supply-voltage. Within the voltage ranges covered by this report, the curves in Figures 1 through 3 can be used to determine the dimming resistance requirements for any number of Types 327 or 328 lamps. Two examples showing use of the curves are as follows:

(A) Given - 20 Type 327 lamps operating from a line voltage equal to the rated voltage of the lamps. It is desired to design a dimming rheostat to provide intensity control down to 3% of the rated-voltage intensity.

The Type 327 lamp is rated at 28 volts, 0.04 ampere, and at this voltage the current for 20 lamps is 0.8 ampere, the filament resistance 35 ohms, and the power dissipation 22.4 watts.

From Figure 2 - The luminous intensity will be reduced to the desired minimum at $\frac{12 \text{ volts}}{28 \text{ volts}}$ or 43% of the power source voltage.

From Figure 3 - To reduce the lamp voltage to 43% will require a dimming resistance equal to 90% of the 28-volt filament resistance, i.e., 90% of 35 or 31.5 ohms. Similarly, the maximum power dissipated in the rheostat will be 36% of the 28-volt lamp power, i.e., 36% of 22.4 or 8 watts. The maximum current the rheostat will have to carry will approach the 28-volt current of 0.8 ampere.

(B) Given - 20 Type 327 lamps operating from a 35-volt power source. A rheostat is needed to provide intensity control down to 5% of the intensity at 35 volts.

In this example the rated voltage of the lamps is only 28/35 or 80% of the supply-source voltage, and it is necessary to determine the lamps' electrical characteristics when operating at the 35 volts.

From Figure 1 - at 80% of the supply voltage the lamps will draw 89% as much current as when operated at the supply voltage. Therefore, at 35 volts the current for 20 lamps will be $\frac{20 \times 0.04}{0.89}$ or 0.9 amperes. At this voltage and current the filament resistance of the group of lamps is 39 ohms, and they dissipate 31.5 watts of power.

From Figure 2 - The required low level of intensity (5% of the 35-volt intensity) occurs at 16 volts, which is 16/35 or 46% of the power-source voltage.

From Figure 3 - Series resistance equal to 82% of the supply-voltage filament resistance will reduce the lamp voltage to 46% (16 volts). The resistance of the rheostat must be 82% of 39 or 32 ohms. Similarly, the maximum power issipated in the rheostat will be 36% of the 35-volt lamp wattage, i.e., 36% of 31.5, or 11.3 watts.

The maximum current carried by the rheostat will approach the 35-volt value of 0.9 amperes.

It is interesting to note from Figure 3 that regardless of the extent of dimming, the power dissipated in a series-resistance dimming control for these lamps cannot exceed approximately 37% of that dissipated by the lamps when operated at full supply-voltage.

6. DIMMING RESISTANCE TAPER

It is desirous that the taper of a rheostat control be such that the amount of dimming per degree of rotation is fairly constant throughout the entire range. The curve in Figure 4 gives the relationship between relative intensity and series-connected dimming resistance for Type 327 lamps from a supply source of 40 volts, dimmed down to approximately 10 volts. It shows that throughout this range of control arithmetical increments of series resistance come very close to providing geometrical changes in luminous intensity. (The curve for Type 328 lamps is not shown, since for the same proportionate voltages above and below the rated value, the curve is practically identical to that for the Type 327.) Since visual perception varies as the logarithm of the intensity, a linear resistance taper closely approximates the ideal taper, and it is recommended for all normal installations because of its simplicity.

In the case of step dimming controls the total amount of resistance required to reach the lowest desired level of intensity should be divided equally into the number of dimming steps desired. For step intensity control of these lamps in Naval aircraft the usual design is such that each dimming step reduces the intensity of the previous step by approximately 50%.

7. RATINGS OF STEP RESISTORS

An examination of Figure 3 will show that each section of a step intensity-control will have a different heat dissipation requirement. Consider the example of seven series-connec ted dimming steps to reduce the voltage of 20 Type 327 lamps from 28 volts to 30% of that amount, or 8.4 volts.

Twenty of these lamps at rated voltage (28 volts) will draw 0.8 amperes, dissipate 22.4 watts, and the filament resistance will be 35 ohms. Figure 3 shows that the total required dimming resistance will be equal to 140% of this filament resistance, or 49 ohms; and 20% or 7 ohms for each of the 7 steps. When only the first step of the dimming control is in the circuit it will dissipate power equal to 14.5% of the full-voltage lamp wattage, i.e. 14.5% x 22.4 or 3.25 watts. Current in the circuit will be 90.5% of 0.8 or 0.724 amperes. When two steps are in the circuit, the total power they dissipate will be 25% x 22.4 or 5.6 watts. However, this wattage will be divided equally in each of the steps, so that the second step will need to be designed for only 2.8 watts. The current will be 82% of 0.8 or 0.656 amperes. Similarly the current and wattage requirement for each step are given below.

				Watts	Amperes
1st step	14.5%	of	22.4/1	or 3.25	0.724
2nd "	25.0%	"	22.4/2	" 2.80	0.656
3rd "	32.5%	"	22.4/3	" 2.43	0.596
4th "	35.5%	"	22.4/4	" 1.99	0.536
5th "	36.5%	"	22.4/5	" 1.64	0.488
6th "	36.5%	"	22.4/6	" 1.36	0.448
7th "	36.0%	"	22.4/7	" 1.15	0.412
	Aggregate			14.62 Watts	

For comparison, the wattage requirements of parallel-connected dimming resistors for the same lamps and same conditions are shown below.

	Watts	Amperes
Resistor in 7th dimming step	8.31	.412
" " 6th " "	1.32	.067
" " 5th " "	1.37	.081
" " 4th " "	1.60	.107
" " 3rd " "	1.86	.149
" " 2nd " "	2.00	.219
" " 1st " "	1.84	.362
Aggregate	18.30 Watts	

Because of their extra aggregate wattage requirements, plus increased cost of manufacture, and the problem of stocking the extra components, parallel-connected dimming resistors are not recommended.

In some instances it may be expedient to use a separate resistor for each dimming step, with each resistor selected for its wattage and current requirements. Generally, it is doubtful that the saving in weight or space over a tapped resistor would justify the added expense of fabrication. With the conventional type of tapped resistor wound on a ceramic or a metal-lined core a considerable amount of heat from the used portion will be transferred to the portion that is not in the circuit, so that the fewer the sections used, the higher the proportional wattage rating of the section. The heat flow into the unused portion will be influenced by a number of factors, such as thermal conductivity and amount of core material, as well as the geometrical construction and type of mounting. These factors will, of course, vary with different manufacturers' products. NBS Report #2591 "Heat Dissipation Limits of Tapped Resistors" covers an investigation of this matter for a representative type of tapped resistor. The tests were based on a maximum temperature of 210°C for any part of the outer surface. Figures 5-A, 5-B and 5-C are duplicated from information covered in that report. Figure 5-A is a drawing and description of the type of resistor used during the

tests covered by that report. Figure 5-B gives the relative wattage limits found for fractional parts of the resistor under different test conditions. Figure 5-C shows some effects of mounting variations, metal liner, and metallic coating on a larger, but similar type resistor. The results in the Figure 5 series are given only as a guide for requirements which could be reasonably be specified for tapped resistors.

8. CONTACT CURRENTS

The design of switch contacts must take into consideration the fact that the large difference in resistance between the cold and the hot filament of a tungsten lamp load causes the "make" current to be considerably higher than the "break" or nominal lamp current. With a load of 25 Type 328 lamps the break current at rated voltage will be 5 amperes, and the make current about 10 times as high, or approximately 50 amperes. A dimming unit to control the lamp voltage down to 40% of the rated voltage will have a total resistance about equal to that of the lamp at full voltage. If this unit has an ON-OFF switch incorporated in such manner that the lamp circuit can be opened and closed only when the full dimming resistance is in the circuit, the make current will be reduced to about 4.5 amperes and the break current to 3 amperes. For step dimming controls, the selector switch should be the shorting type.

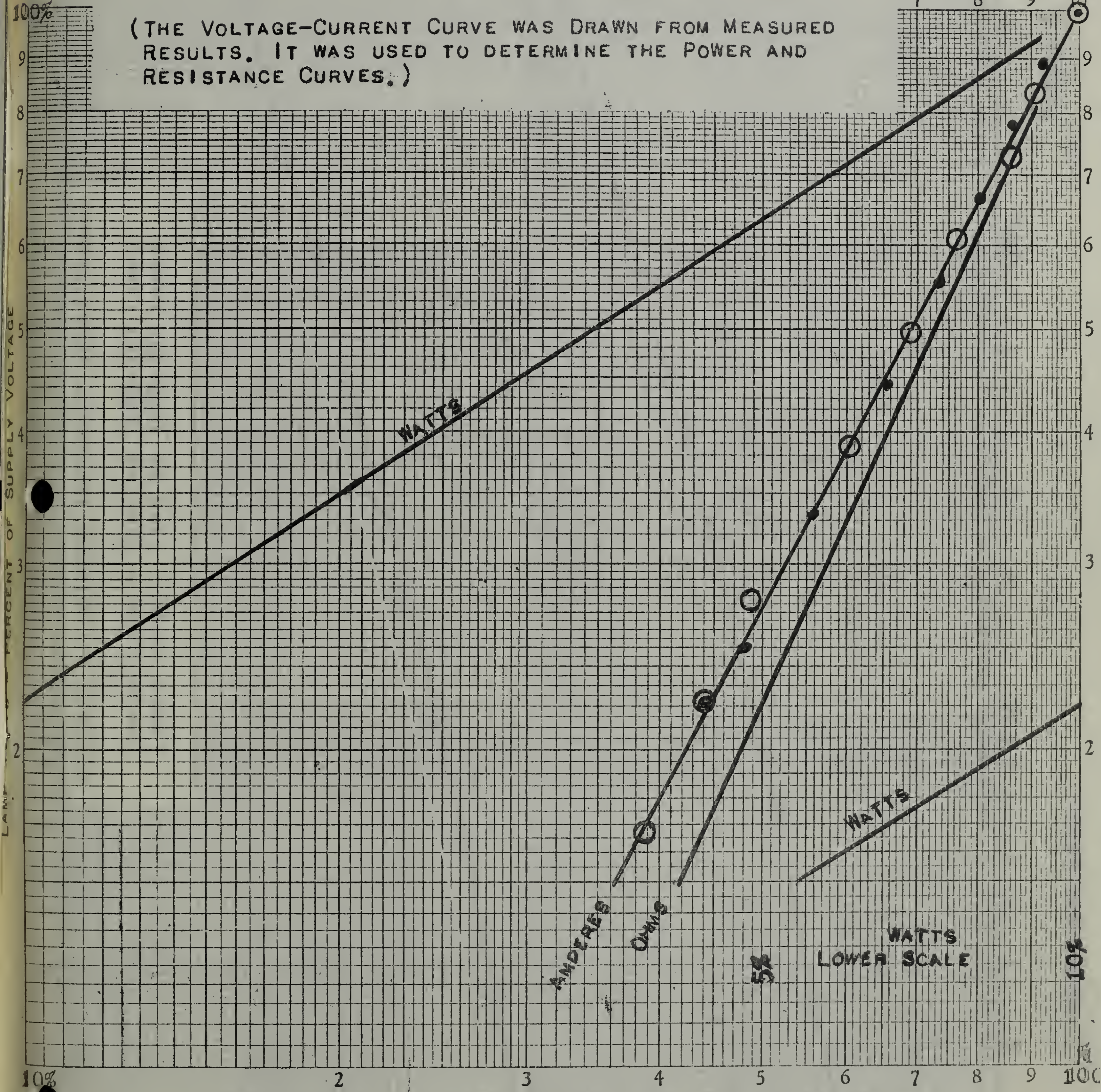
9. EFFECT OF VOLTAGE ON LAMP LIFE

In considering the use of supply sources at voltages different from those at which the lamps are rated, it should be pointed out that small changes in operating voltage have large effects on the life of the lamps. An unsuccessful search of available literature was made in an effort to obtain definite information as to the effect of wide ranges of overvoltage and undervoltage on the life of miniature lamps. Since more specific information appears to be lacking, it is suggested that the relationship given by the Illuminating Engineering Society for large lamps over a limited voltage range, i.e., lamp life inversely proportional to the 13.5 power of the applied voltage, be used to estimate the effect of voltage on the life of Types 327 and 328 lamps. The curve in Figure 6 shows this relationship.

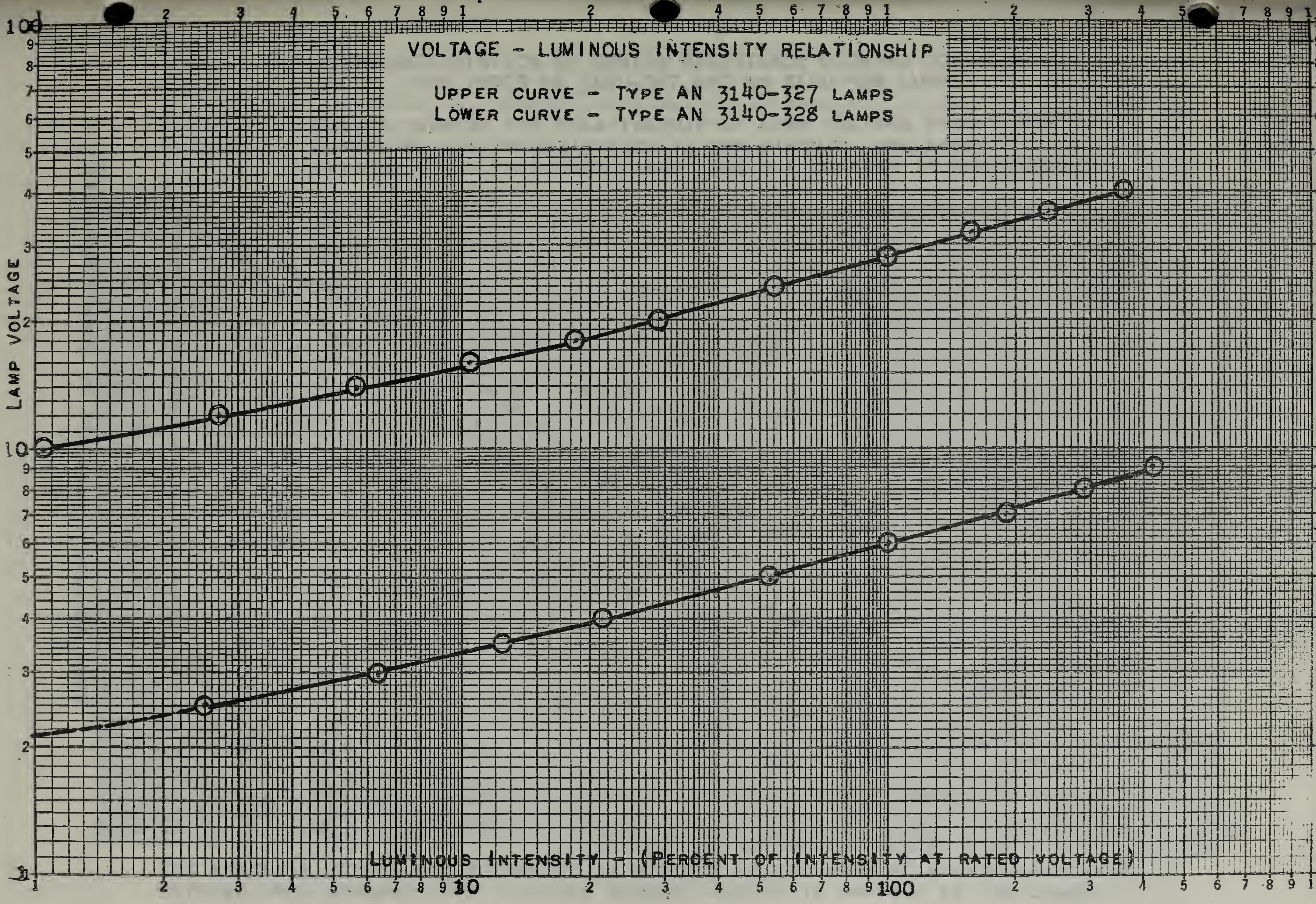
ELECTRICAL CHARACTERISTICS OF TYPES 327 AND 328 LAMPS

● TYPE 327

○ TYPE 328



LAMP CURRENT, RESISTANCE, AND POWER DISSIPATION
(PERCENT OF VALUES AT FULL SUPPLY VOLTAGE)

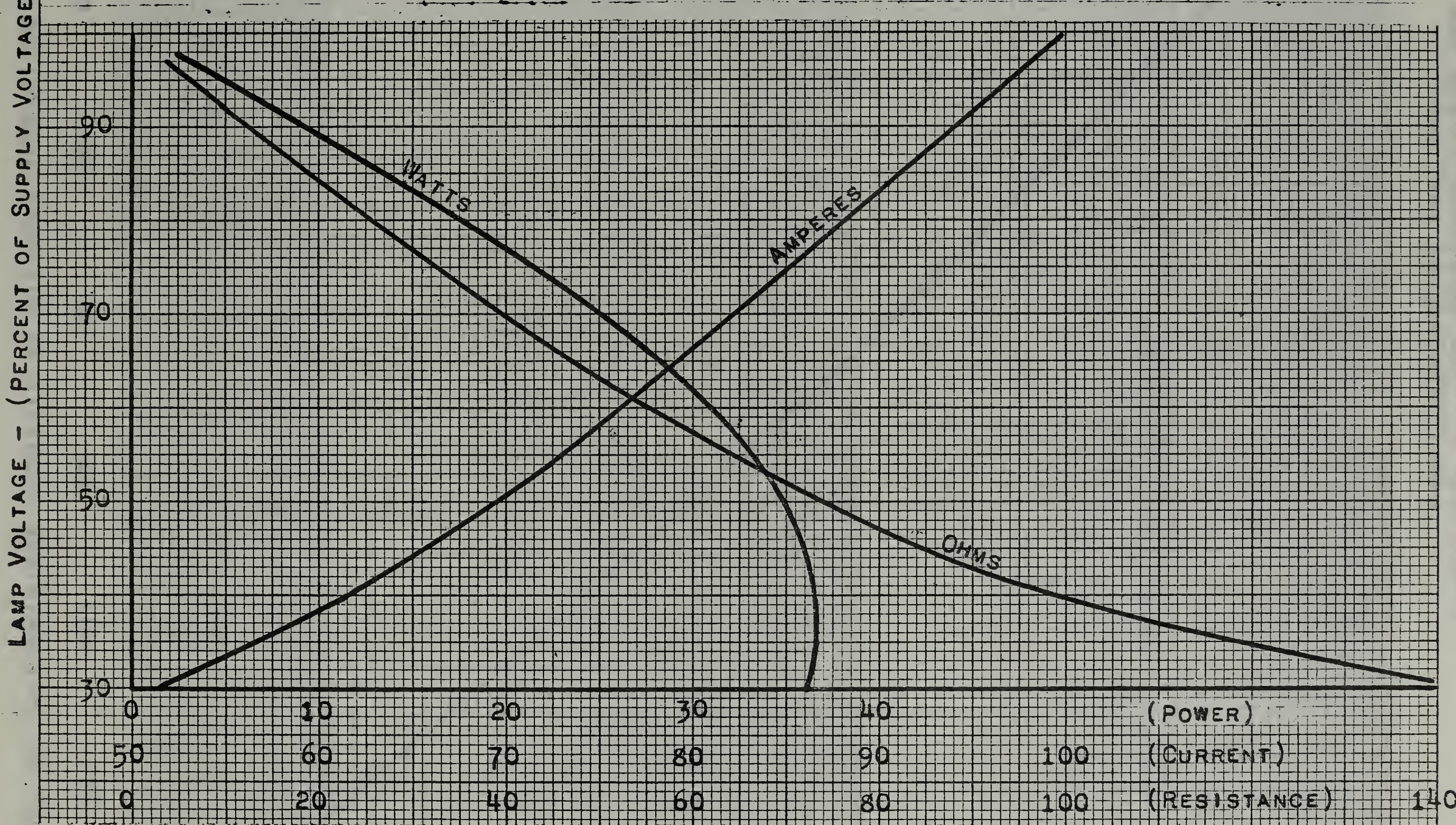


NBS REPORT 5810

FIGURE 2

CHARACTERISTICS OF SERIES RESISTANCE DIMMING CONTROLS
FOR TYPES AN 3140-327 AND AN 3140-328 LAMPS.

CURVES SHOWING THE RELATIONSHIP OF LAMP VOLTAGE VERSUS THE AMOUNT OF SERIES RESISTANCE IN THE CIRCUIT, THE POWER DISSIPATED IN THIS RESISTANCE, AND THE CURRENT IN THE CIRCUIT.

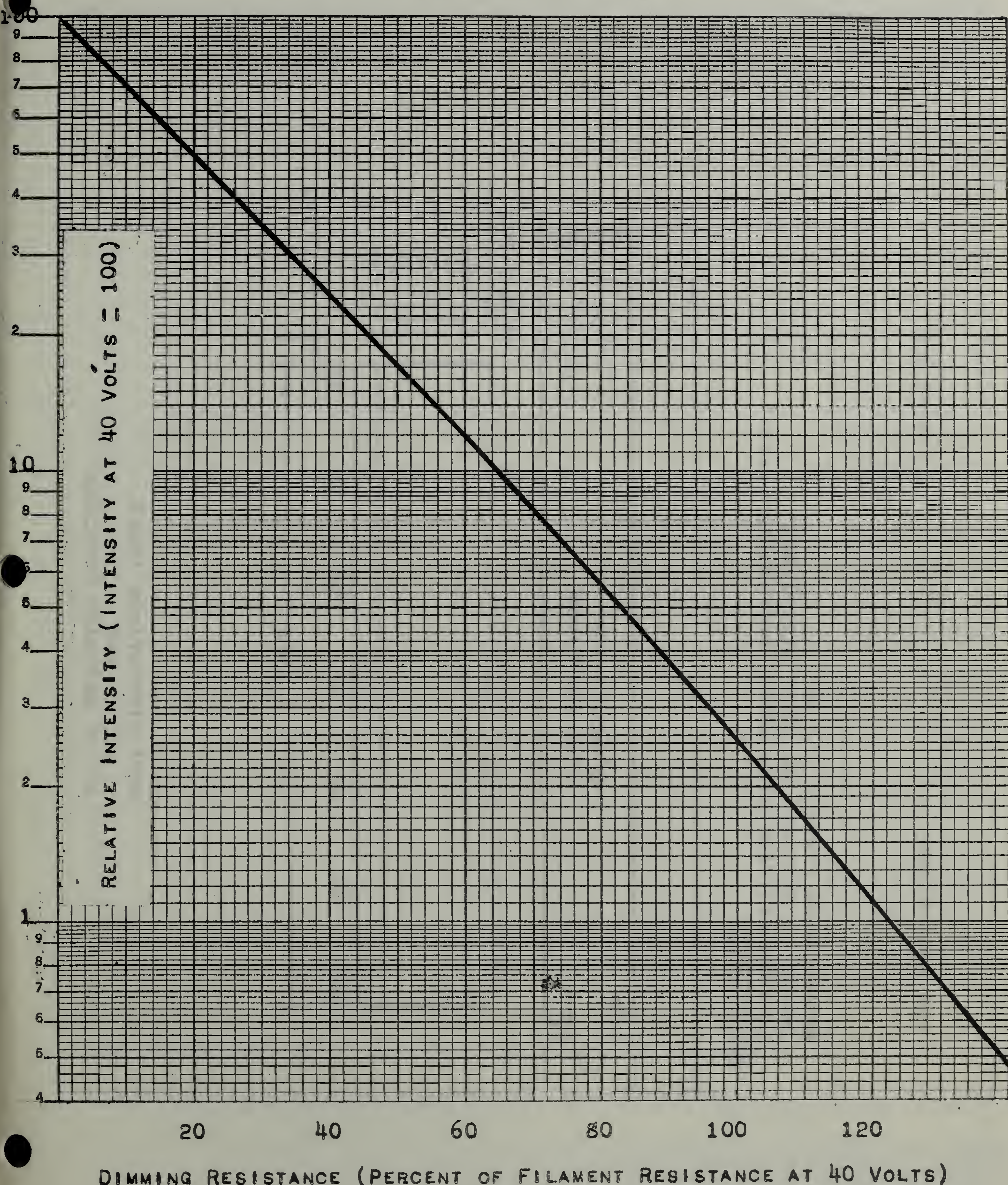


THE ABSCISSA SCALES ARE EXPRESSED IN PERCENT OF THE LAMP FILAMENT-RESISTANCE, WATTAGE, AND CURRENT WHEN THE FULL SUPPLY VOLTAGE IS APPLIED TO THE LAMPS.

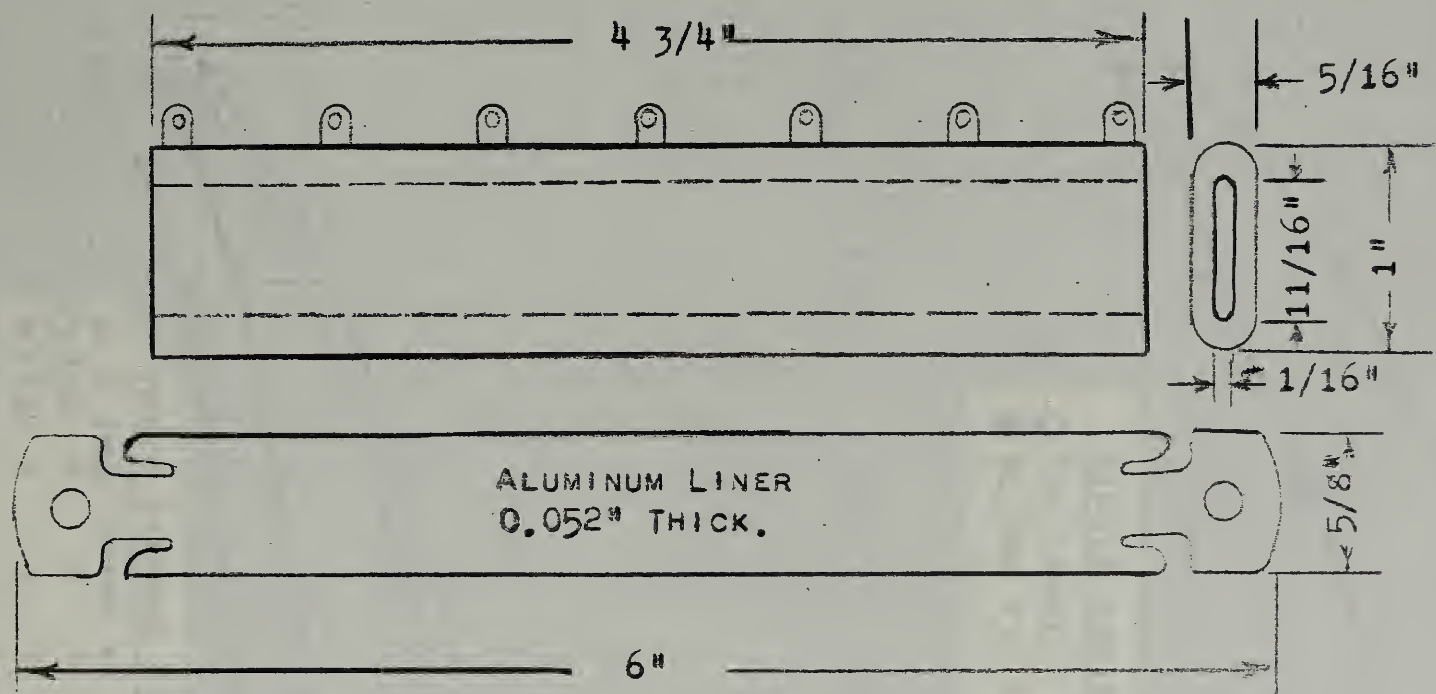
NBS REPORT 5810

FIGURE 3

Relationship Between Relative Intensity and Series-Connected Dimming Resistance for Type AN 3140-327 Lamps.



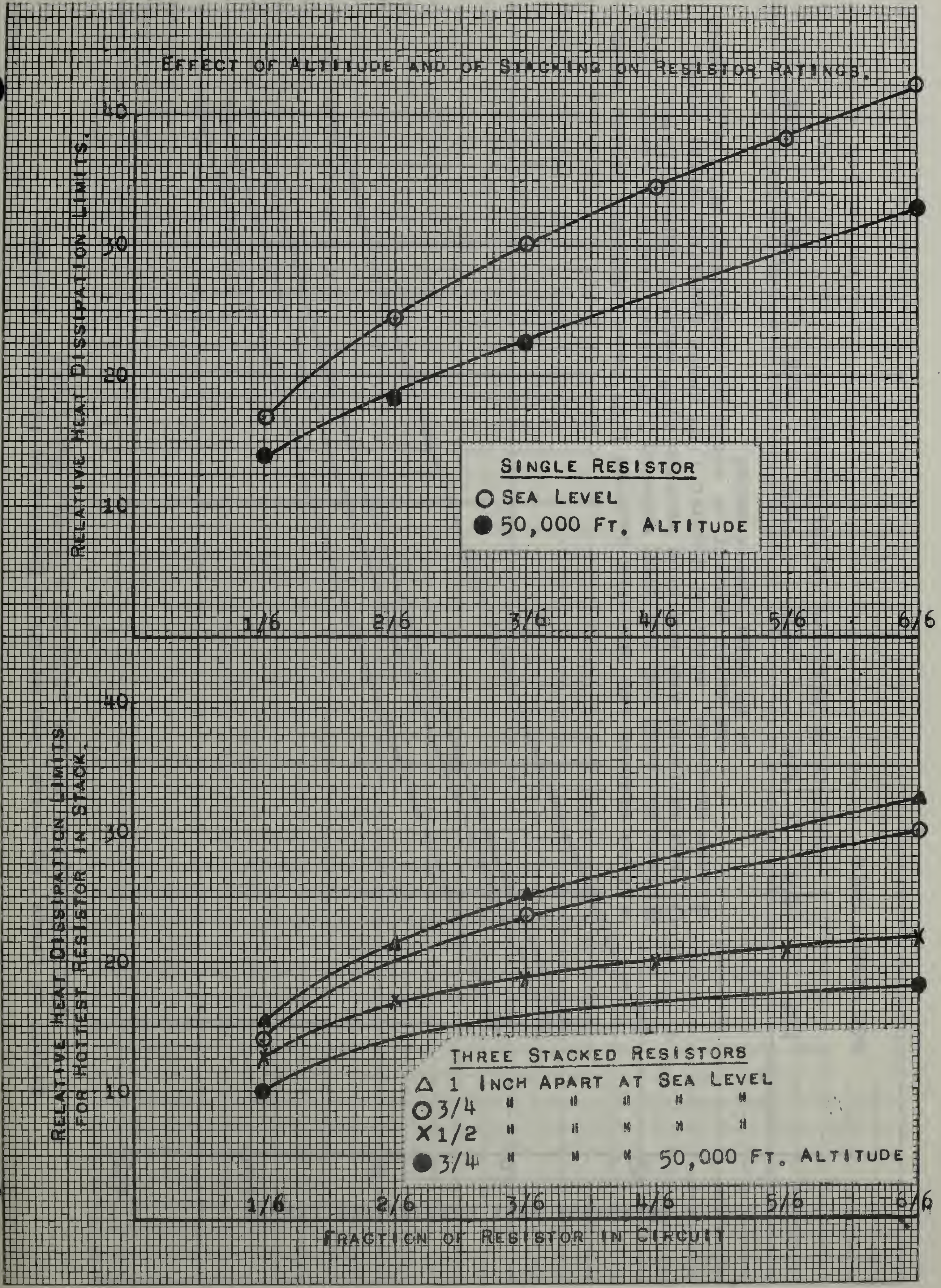
Type of Resistor Selected
for
Heat Dissipation Tests



DESCRIPTION

Ceramic Resistor with rough, dull-green finish.
Tapped, 6 sections of equal resistance.
Weight with liner - 2.5 oz.

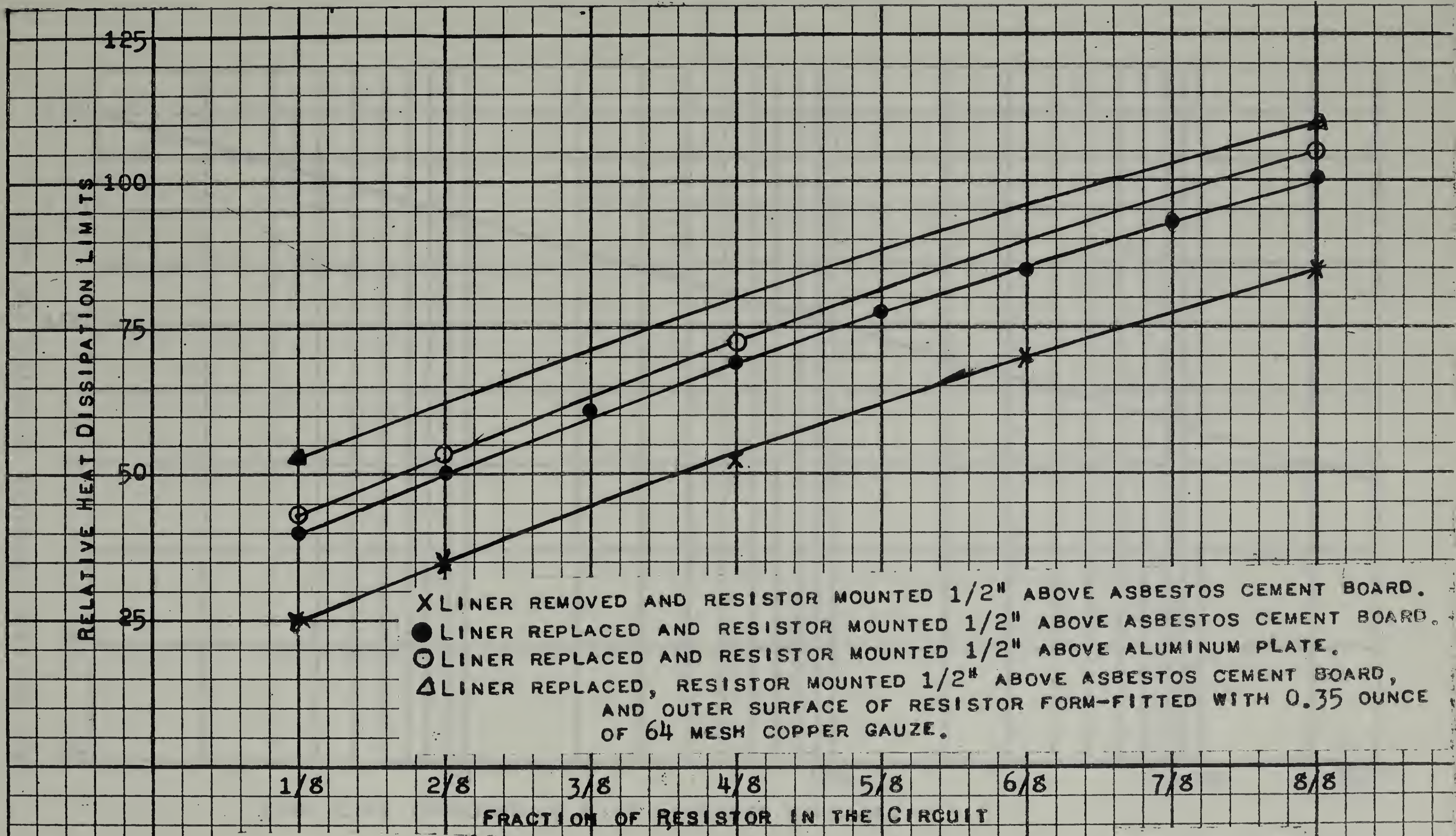
Figure 5-A



EFFECT OF ALTITUDE AND OF STACKING ON RESISTOR RATINGS.
RELATIVE HEAT DISSIPATION LIMITS.
10
20
30
40
SINGLE RESISTOR
SEA LEVEL
50,000 FT. ALTITUDE
1/6
2/6
3/6
4/6
5/6
6/6
RELATIVE HEAT DISSIPATION LIMITS
FOR HOTTEST RESISTOR IN STACK.
THREE STACKED RESISTORS
1 INCH APART AT SEA LEVEL
3/4 " " " " "
1/2 " " " " "
3/4 " " " 50,000 FT. ALTITUDE
FRACTION OF RESISTOR IN CIRCUIT

FIGURE 5-8.

Effect of Liner, Mounting, and Metallic Coating on Resistor Ratings.
(Tests Conducted at Sea Level on a Single Resistor)



NBS Report 5810

Figure 5-C

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Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

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Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment.
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