File Copy

NATIONAL BUREAU OF STANDARDS REPORT

4542

CANDLEPOWER DISTRIBUTION AND COLOR CHARACTERISTICS
OF A DOUBLE OBSTRUCTION LIGHT

by

Robert T. Vaughan

to

Airways Engineering Division
Office of Federal Airways
Civil Aeronautics Administration

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

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

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section is engaged in specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside of the back cover of this report.

Electricity and Electronics. Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Process Technology. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Measurements. Thermodynamics. Cryogenic Physics. Engines and Lubrication. Engine Fuels.

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

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion.

Mineral Products. Porcelain and Pottery. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems.

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services.

Radio Propagation Engineering. Frequency Utilization Research. Tropospheric Propagation Research.

Radio Standards. High Frequency Standards. Microwave Standards.

- Office of Basic Instrumentation
- Office of Weights and Measures

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT | **NBS REPORT**

0201-30-2328 February 1956 4542

CANDLEPOWER DISTRIBUTION AND COLOR CHARACTERISTICS

OF A DOUBLE OBSTRUCTION LIGHT

by

Robert T. Vaughan
Photometry and Colorimetry Section
Optics and Metrology Division

NBS Test 21A-7/55

to

Airways Engineering Division
Office of Federal Airways
Civil Aeronautics Administration
Department of Commerce

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

Candlepower Distribution and Color Characteristics of a Double Obstruction Light

by
Robert T. Vaughan

1. SCOPE

This report presents the results of a study of the candlepower distribution and color characteristics of a double obstruction light. The study was made primarily to provide a basis for evaluating the performance of a neon obstruction light relative to that of the incandescent obstruction lights in common use. The characteristics of the neon obstruction light, designed for use on the catenary of a transmission line, have been reported in NBS Report 4441.

2. DESCRIPTION OF EQUIPMENT TESTED

The equipment tested, shown in figure 1, was taken from stock at Washington National Airport and consists of:

(A) A double obstruction light fitting manufactured by the A.G.A. division of the Elastic Stop Nut Corporation, Elizabeth, N. J. The fitting bears the following marking: "ELIZABETH A'G'A NEW JERSEY."

(B) Two red cover glasses, each a cylindrical fresnel lens closed at the top.

One glass, designated for the purposes of this test as "lens A", is marked

"AP 3522-2-R
K
Made in U.S.A."

This glass was presumably manufactured by Kopp Glass, Inc., Swissvale, Pa. It has inside vertical prisms designed to eliminate the shadows of the lamp filament supports, and it is approximately 4 inches in effective height and 3 1/2 inches in outside diameter at the center belt.

The other glass, designated as "lens B", is marked "PYREX T.M.REG." On the underside of the flange the following marking appears:

"PYREX T.M. REG. U.S. PAT. OFF. MADE IN U.S.A. 530018"

This glass was presumably manufactured by the Corning Glass Works, Corning, N. Y. It is approximately 4" in effective height and 4" in outside diameter at the center belt.

(C) Three G.E. 111A 21/TS traffic signal lamps rated at 111 watts, 120 volts.

3. TEST PROCEDURE

The three lamps were seasoned at their rated voltage, 120 volts, and the total luminous flux from each was measured in a 60-inch integrating sphere at energizing voltages of 110 volts, 115 volts, and 120 volts. The values recorded were converted to "lumens per watt", and, as shown in figure 2, a graph of lumens per watt vs. energizing voltage was plotted for each lamp. The abscissa of the intersection of each of these curves with the curve representing the rated lumens per watt indicates the voltage at which each lamp should be operated to assure that it would be operating at its rated efficiency and hence at its normal color temperature. All candlepower and color measurements were made with each lamp operating at the test voltage so determined. Since no method is provided for focussing the unit, it was tested as received.

To provide measured horizontal and vertical rotations of the test unit, the unit was mounted in a special fixture on the table of a goniometer. The primary axis of rotation was horizontal and normal to the photometric axis. With the goniometer set at the 0°,0° position the fitting was mounted with the axes of the lenses lying in a plane perpendicular to the photometric axis, and with the axis of the right-hand lens, as viewed from the photocell, coincident with the vertical axis of the goniometer. The lenses were oriented so that the notches in the flange of each were in the transverse plane and the lettering on the top of the lenses was right side up when viewed from the photometer side of the goniometer. The lamp-lens combination to be measured was mounted in the right-hand position on the fitting, and the remaining lens, with no lamp, was mounted in the left-hand position.

The measurements were made with an automatic photometer, the recording element of which is a Leeds & Northrup recording potentiometer driven in synchronism with the goniometer table on which the unit under test is mounted. The photometric distance was 10.0 meters.

The photometer was calibrated with standard filter No. 3639 and with standard lamp No. NBS 3315 at a distance of 2.0 meters. The calibration includes a correction factor which is the ratio of the rated lumens of the lamp to the lumens produced by it when operating under the test conditions at its rated color temperature. This calibration has been recorded on the candlepower distribution chart as a line showing the candlepower of the test unit which would give an illumination at the photocell equivalent to that given by the standard lamp multiplied by the correction factor.

Since the luminous transmittance of the type of red glass of which the lenses are made is a function of its temperature, a record was made to determine the time required after the lamp was energized for the transmittance of the lens to reach equilibrium. This record, shown in figure 3, indicates that at an ambient temperature of 75°F the transmittance of the lens became stabilized after the lamp had been operated at its test voltage for a period of about 40 minutes. Each lamp-lens combination was operated, therefore, at its test voltage for a period of at least one hour before the candlepower measurements were recorded.

Measurements were then made of the following lamp-lens combinations in the order indicated.

Measurement No.	Lamp No.	Lens	Traverse	Figure No.
1	1	A	Vertical at 0° Horiz.	4
2	1	A	Horizontal at +7.0° Vert.	5
3	2	A	Vertical at 0° H	6
4	2	A	Horizontal at +7.9° Vert.	7
5	3	A	Vertical at 0° H	8
6	3	A	Horizontal at +9.5° Vert.	9
7	1	B	Vertical at 0° H	10
8	1	B	Horizontal at +8.5° Vert.	11
9	2	B	Vertical at 0° H	12
10	2	B	Horizontal at +9.7° Vert.	13
11	3	B	Vertical at 0° H	14
12	3	B	Horizontal at +8.8° Vert.	15
13	3	B	Set of 8 Vert. traverses at 45° Horiz. intervals	16
14	3	A	Set of 8 Vert. traverses at 45° Horiz. intervals	17

Because lamp No. 3 was found to most nearly approximate the "average" of the three lamps, it was selected for the two sets of vertical traverses, measurements No. 13 and 14. Vertical angles above the horizon were considered as positive angles; those below the horizon, as negative angles.

Using a Lummer-Brodhun photometer head, trained observers compared the chromaticity of the light from the test unit with that transmitted from a standard lamp at 2350°K through standard filters whose chromaticity coordinates for light of that color temperature are known.

4. RESULTS

The maximum candlepower for each lamp-lens combination was found to be as follows:

Lamp	Lens	Max cp.	Vert.	Horiz.	Fig. No.
1	A	104	+7.0°	0°	4
2	A	102	+7.9°	172°	7
3	A	115	+6.5°	225°	17
1	B	90	+8.5°	30°	11
2	B	63	+9.7°	177°	13
3	B	78	+8.8°	348°	15

On the candlepower distribution charts, there is a small discrepancy between the calibration marks and the grids, amounting at most to 1.9%, but this can be disregarded in view of the large variations in the candlepower of the unit with different lamps and lenses.

In figure 17, the narrow peaks in the candlepower distribution curves occurring between the vertical angles +82° and +85° are due to an image of the C-9 filament formed by the top section of lens A. Since this region is one of little importance, the variations in the candlepower due to the image are of little significance.

The results of the chromaticity comparisons are shown in figures 18 and 19. The chromaticities of the standard filter and lamp combinations are shown in the figures as circles. The chromaticity of the test unit differs from each of the known chromaticities in the sense indicated by the arrow in each case.

The chromaticity of the light transmitted by each of the lenses using a lamp of the recommended type at its rated lumens per watt was found to be within the limits for aviation red as defined in Specifications AN-C-56, Fed. Std. No. 3, and MIL-C-25050 (ASG).

5. DISCUSSION

There is a considerable difference between the transmittance of pale-limit red glassware and that of ware of minimum acceptable transmittance. This difference in transmittance causes a corresponding difference in the candlepower of the units on which the glassware is used. It is desirable, therefore, to know how the two lenses measured compare in transmittance with the average for each type to be expected in service in order to know how to interpret the measured values given in this report.

A good approximation to the transmittances for the measured lenses can be estimated from the results of the color tests. Studies of the characteristics of selenium glass filters have shown a correlation between their redness and transmittance, the relationship depending upon the color temperature of the light source. The color temperature, in turn. is a function of the lamp efficiency. The normal color temperature for a gas-filled tungsten lamp operating at the rated lumens per watt of the test lamp (11.7 lpw) is 2750°K. For a light source of this color temperature, the color of lens A is characteristic of glass having a transmittance ratio of 0.18 and that of lens B corresponds to glass having a transmittance ratio of 0.12.

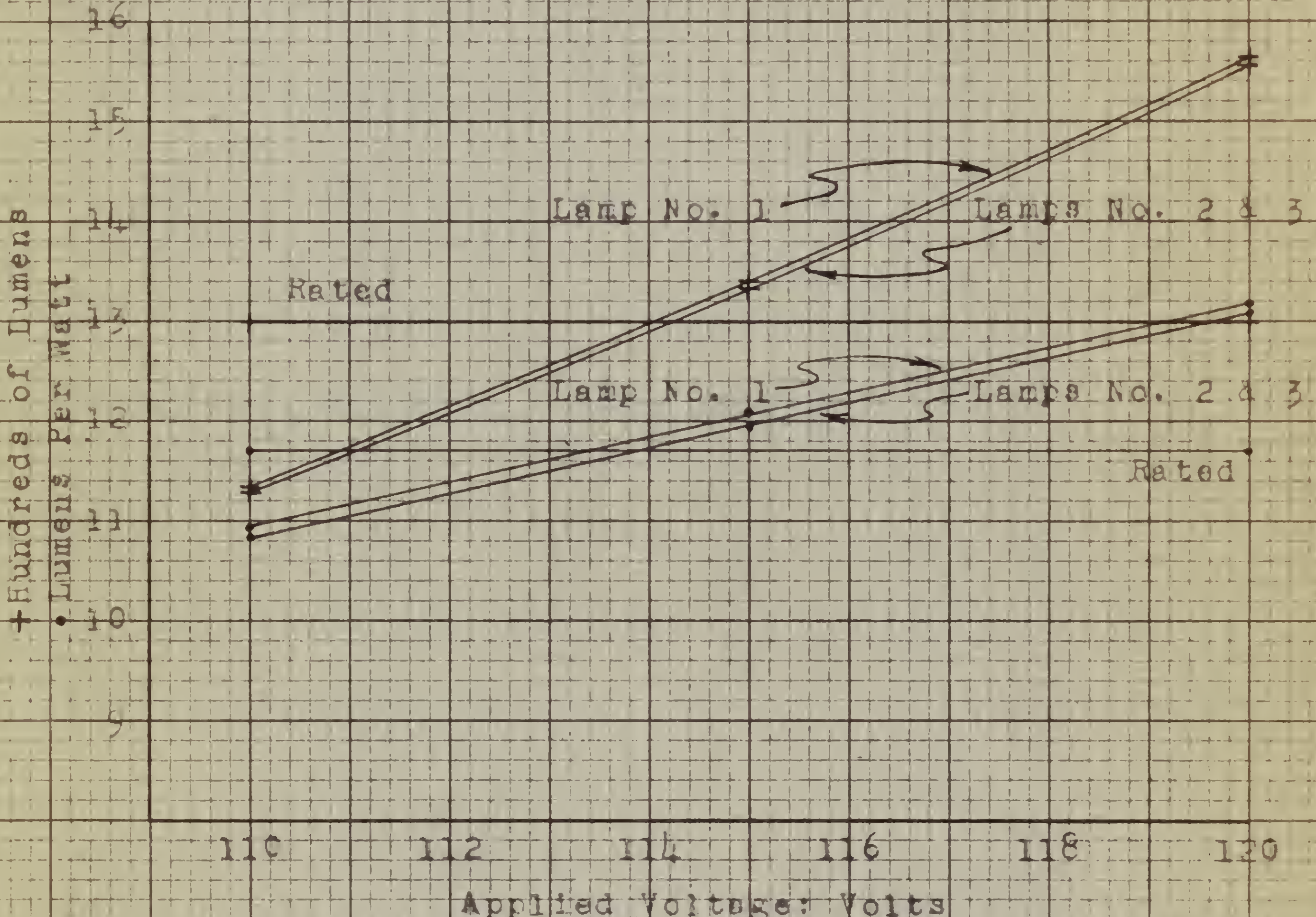
Obstruction light lenses are classed in the color specifications as thicksectioned ware for which the transmittance requirements of Grade D are stipulated. This requirement allows a minimum transmittance ratio of 0.130 for a light source of 2854°K (Spec. AN-C-56, Table IV, Non-diffusing ware, Type I.)With pale-limit ware, the transmittance ratio may be as high as 0.31 which is 2.4 times the minimum.

The transmittance value estimated for lens B would drop even more below the minimum permitted by the specifications if the transmittance measurements were made with a light source of color temperature 2850°K as prescribed in the specifications.

On the basis of the approximate estimates made above, the candlepower of lens B should be regarded as a minimum for incandescent obstruction light units of its design, while the candlepower of lens A is approximately 0.6 of the maximum to be expected from the palest acceptable lenses of its type.

FIGURE 1

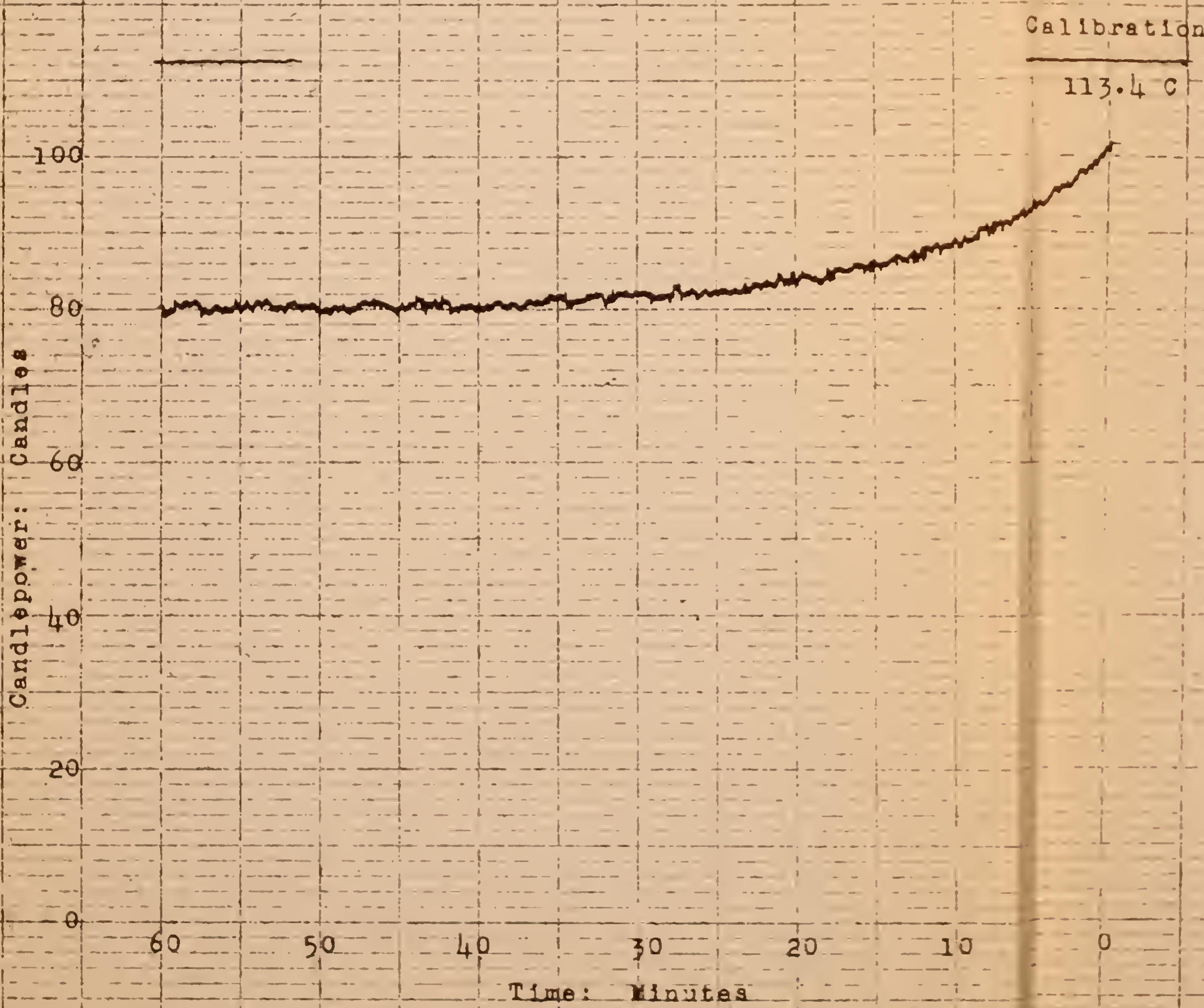
DOUBLE OBSTRUCTION LIGHT
CHARACTERISTICS OF THREE G.E. 111A-21/TS LAMPS
Lumens vs. Voltage
Lumens Per Watt vs. Voltage



NBS Test 21A-7/55

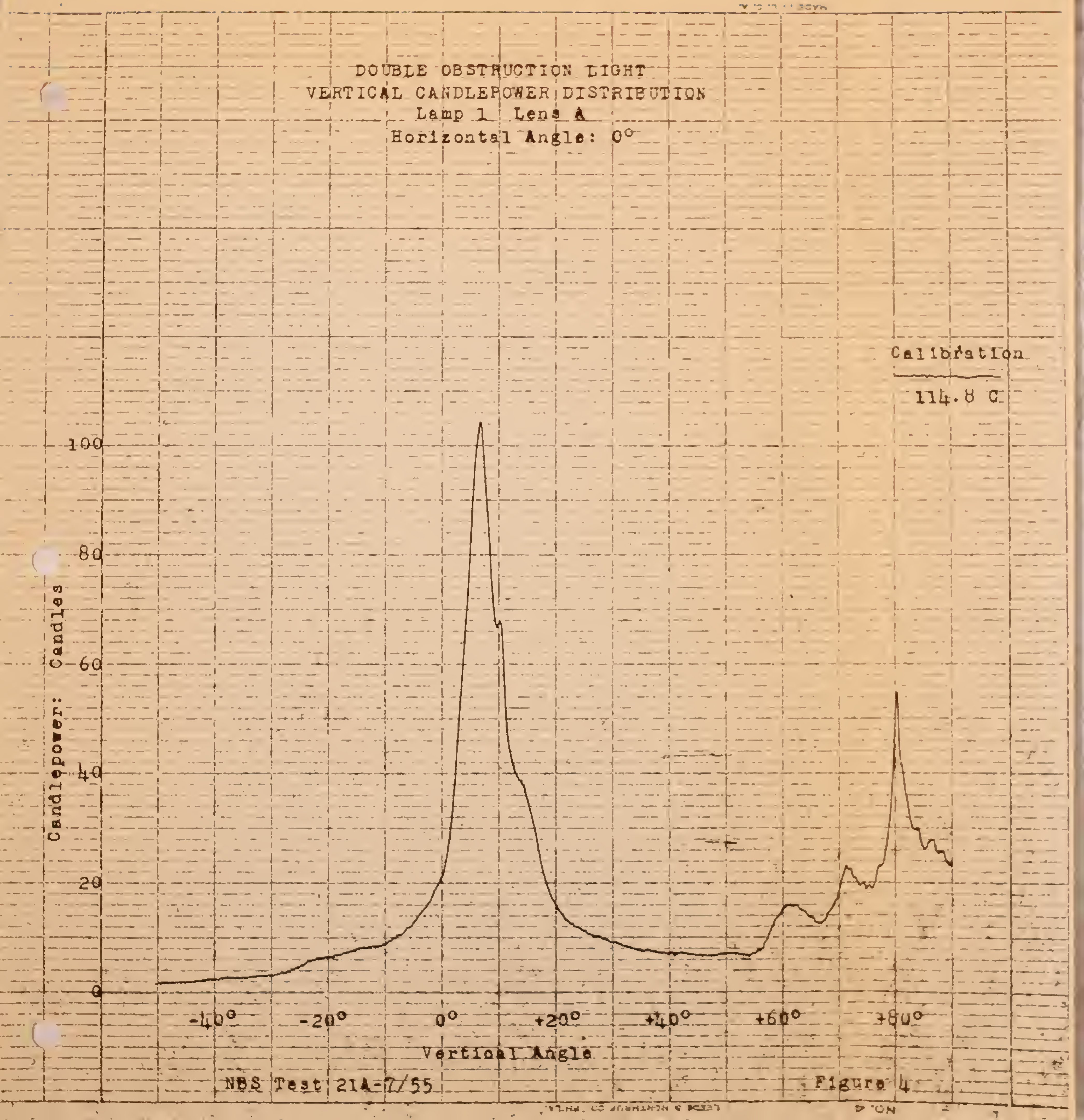
Figure 2

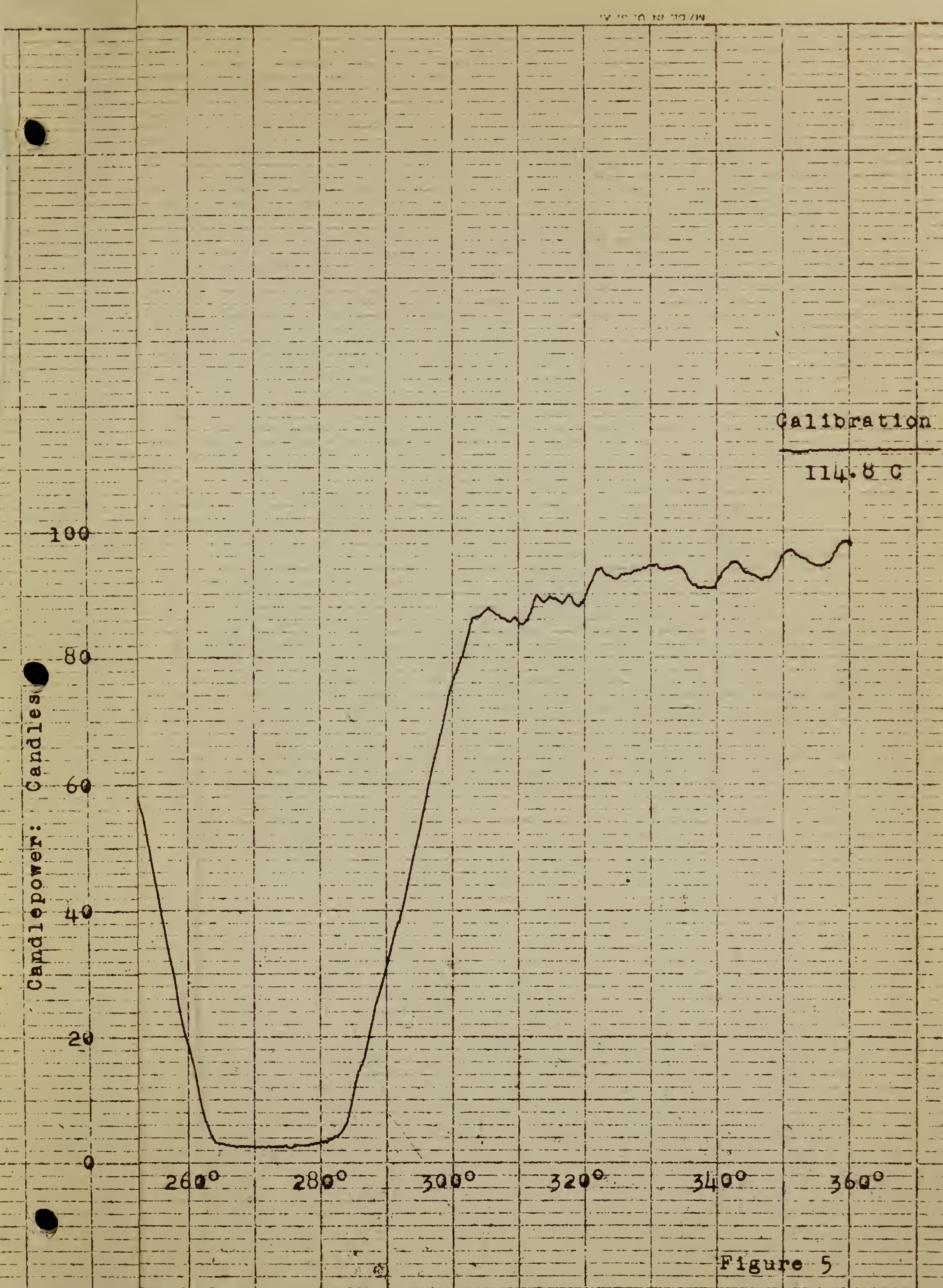
DOUBLE OBSTRUCTION LIGHT
DECREASE IN CANDLEPOWER DURING FIRST HOUR OF OPERATION
Lamp 3 Lens A



NBS Test 21A-7/55

Figure 3


DOUBLE OBSTRUCTION LIGHT
VERTICAL CANDLEPOWER DISTRIBUTION
Lamp 1 Lens A
Horizontal Angle: 0°
Calibration
114.8 C
Candlepower: Candles
100
80
60
40
20
0
-40°
-20°
0°
+20°
+40°
+60°
+80°
Vertical Angle
NBS Test 21A-7/55
Figure 4



Calibration
114.8 C
Candlepower: Candles
100
80
60
40
20
0
260°
280°
300°
320°
340°
360°

Figure 5

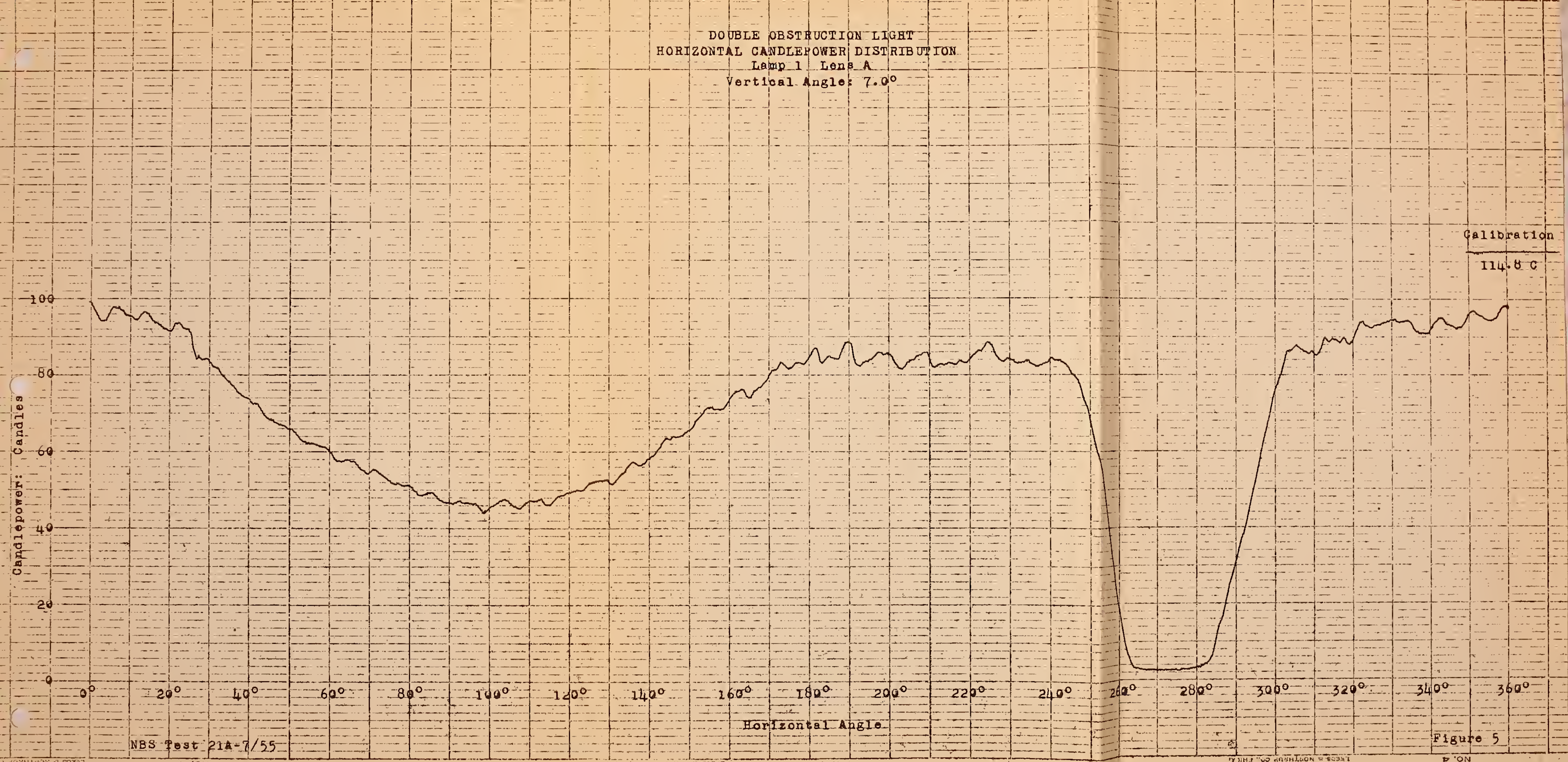
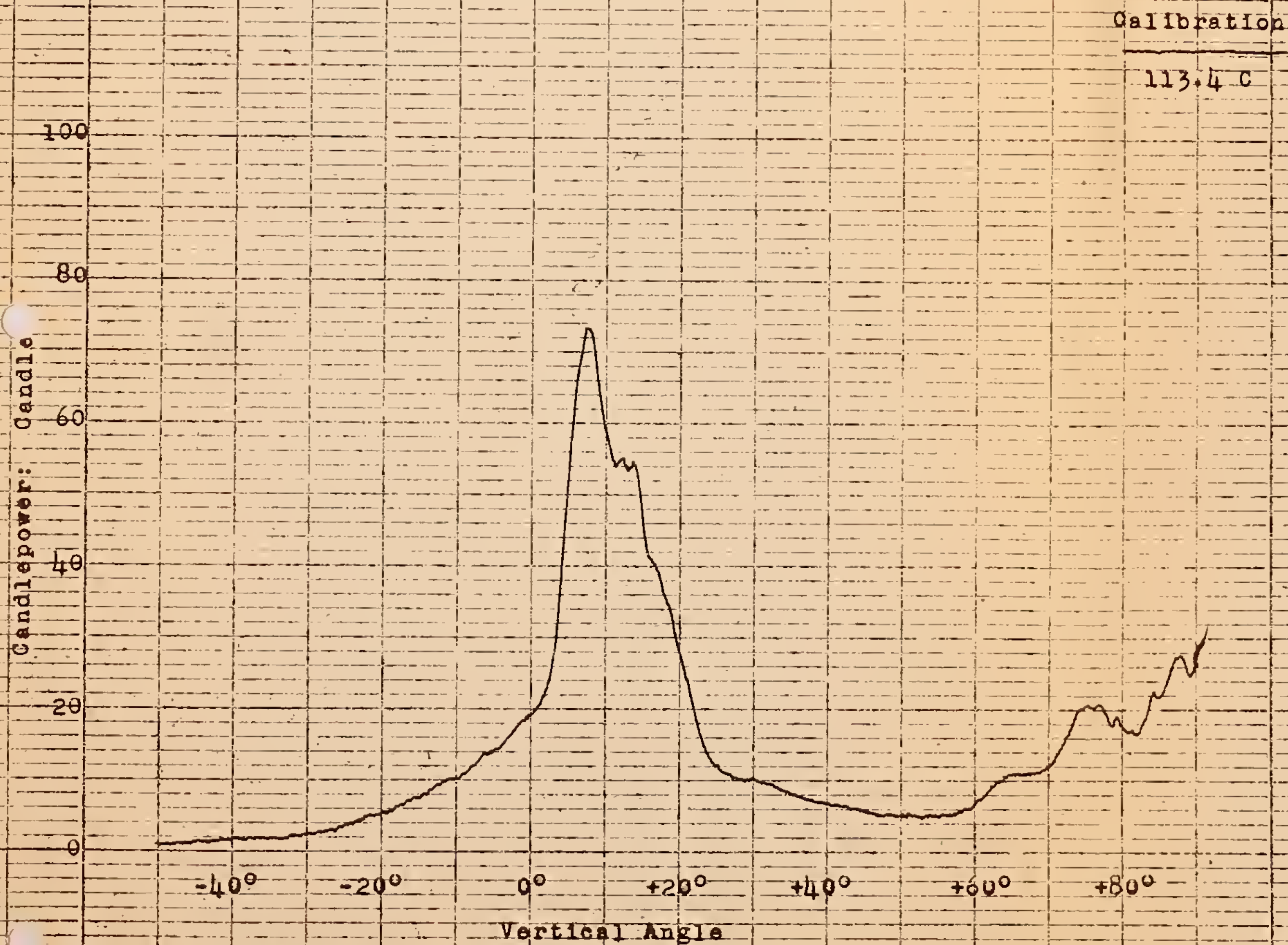

DOUBLE OBSTRUCTION LIGHT
HORIZONTAL CANDLEPOWER DISTRIBUTION
Lamp 1 Lens A
Vertical Angle: 7.0°
Calibration
114.8 C
100
80
60
40
20
0
Candlepower: Candles
0°
20°
40°
60°
80°
100°
120°
140°
160°
180°
200°
220°
240°
260°
280°
300°
320°
340°
360°
Horizontal Angle
NBS Test 21A-7/55

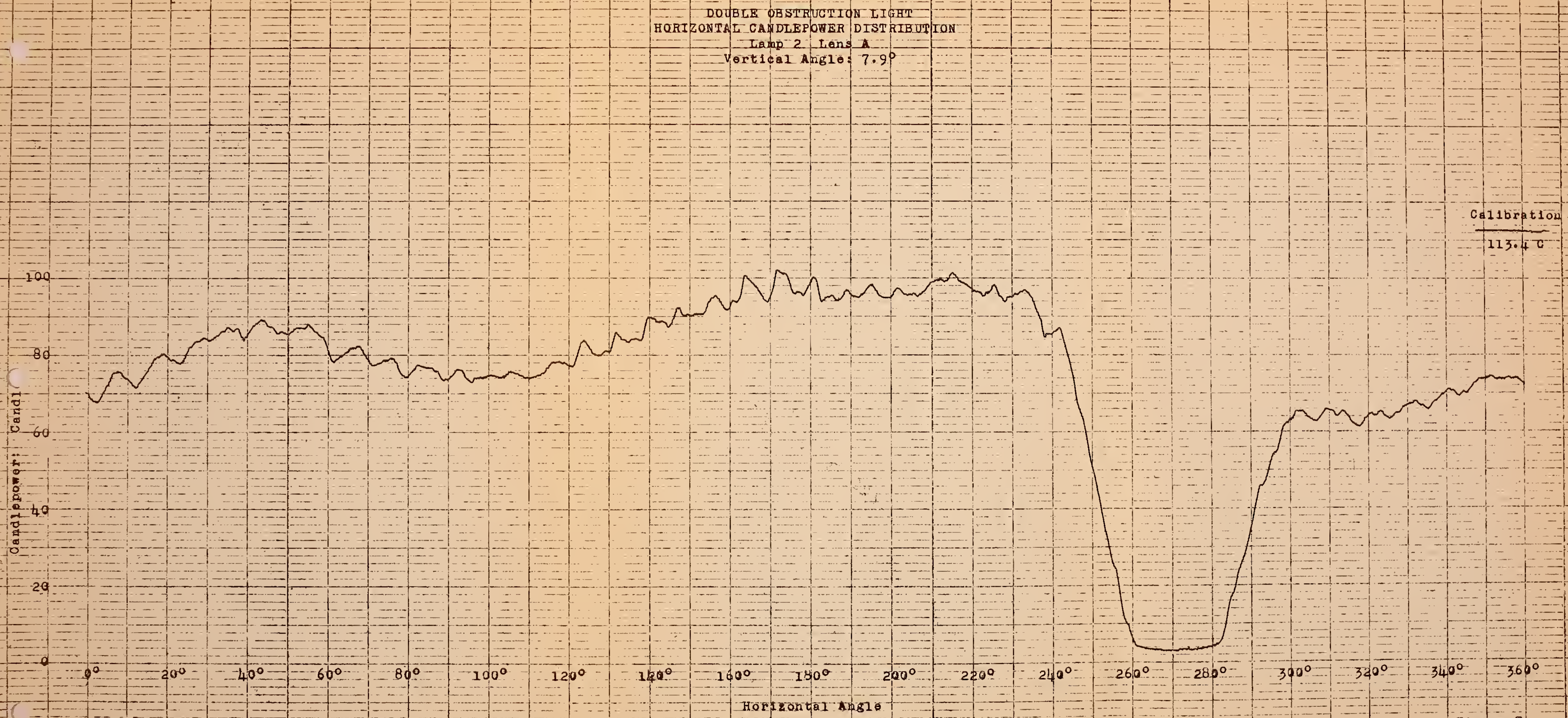
Figure 5

DOUBLE OBSTRUCTION LIGHT
VERTICAL CANDLEPOWER DISTRIBUTION
Lamp 2 Lens A
Horizontal Angle: 0°



NBS Test 21A-7/55

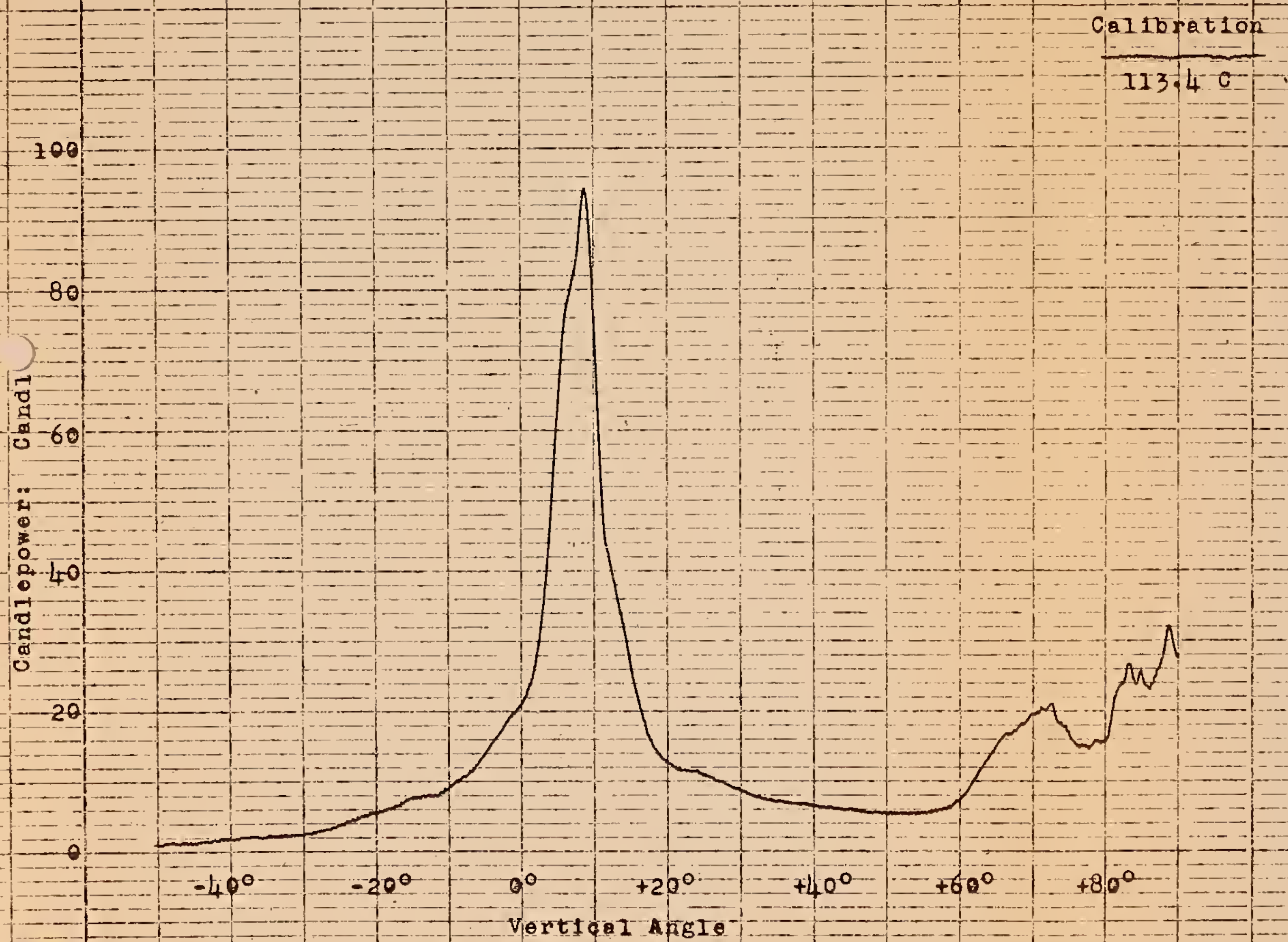
Figure 6



NBS Test 21A-7/55

Figure 7

DOUBLE OBSTRUCTION LIGHT
VERTICAL CANDLEPOWER DISTRIBUTION
Lamp 3 Lens A
Horizontal Angle: 0°



NBS Test 21A-7/55

Figure 8

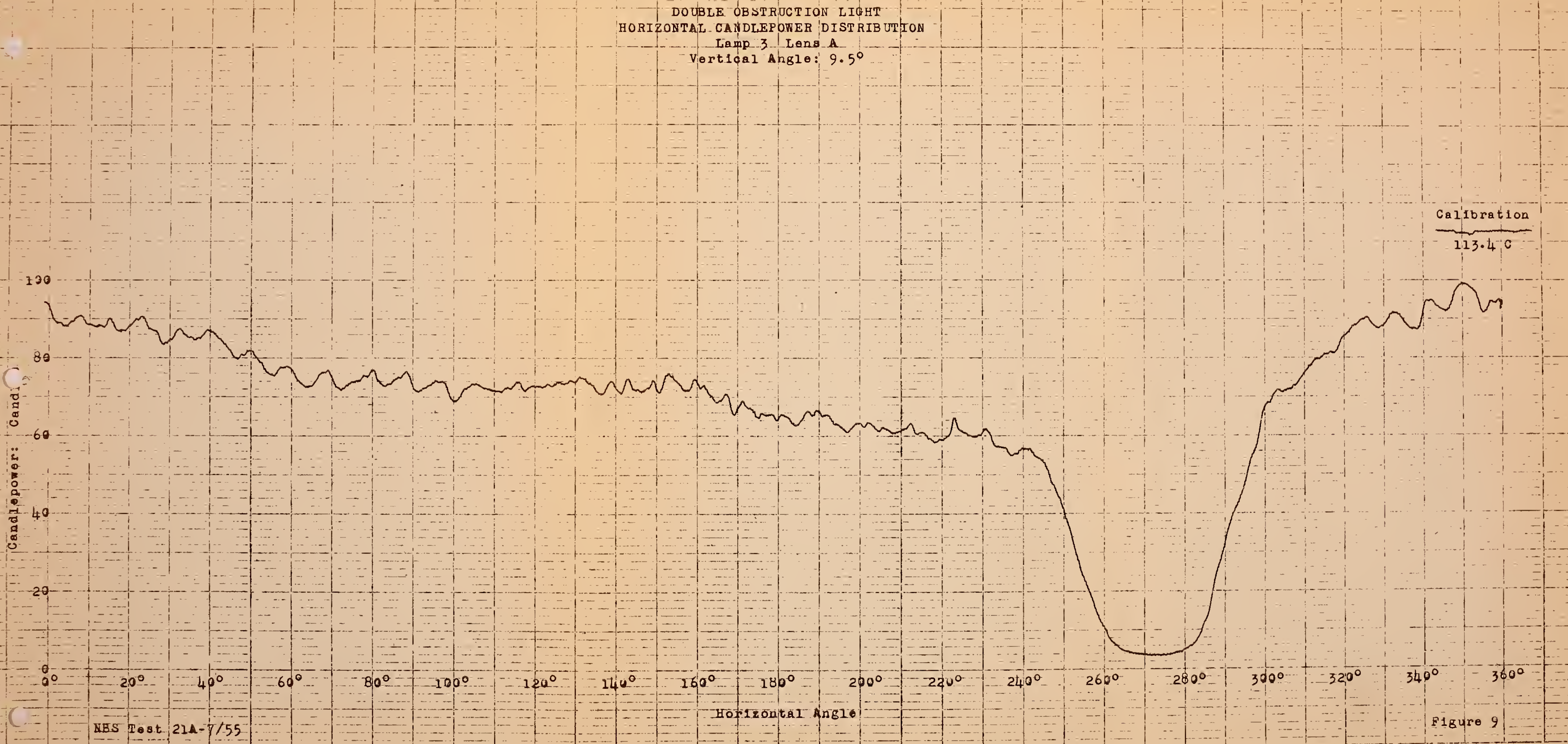
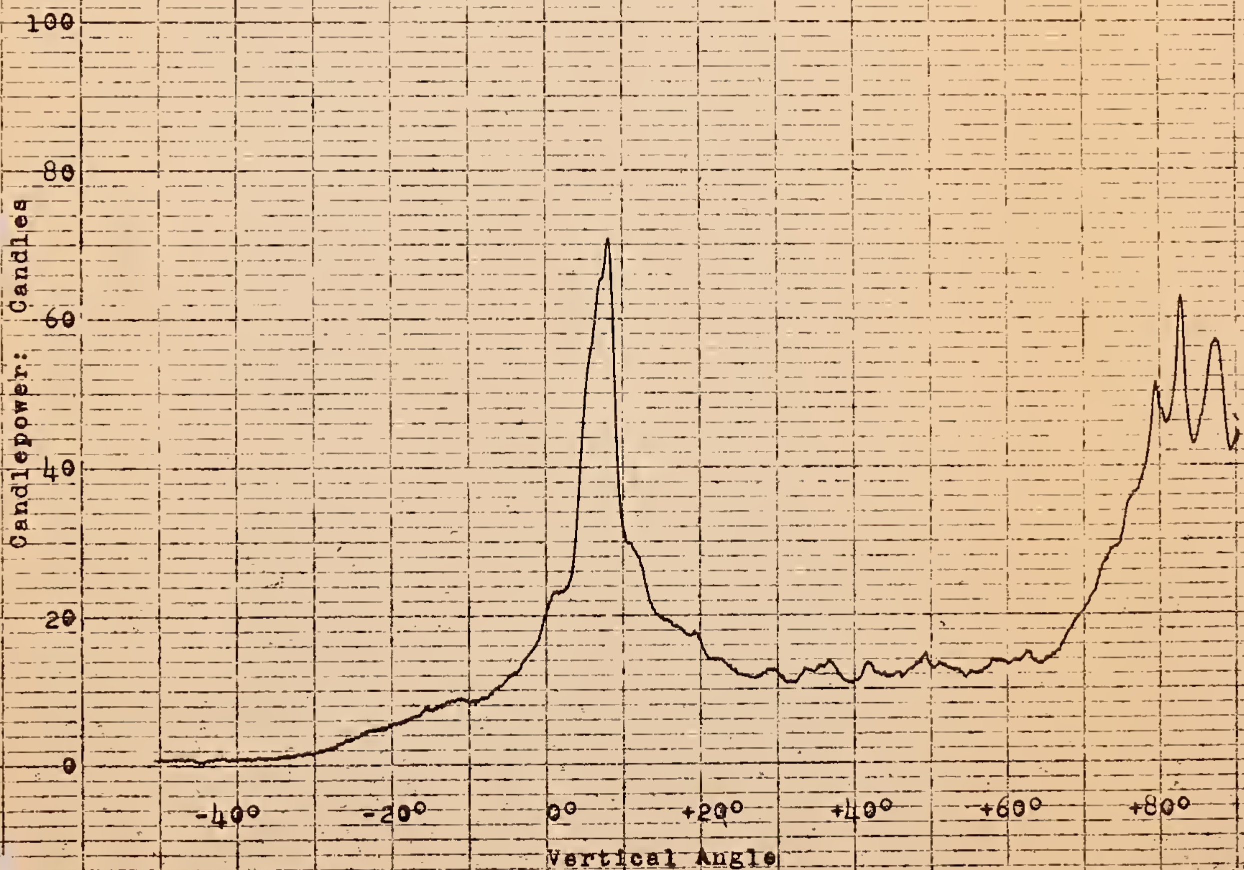

DOUBLE OBSTRUCTION LIGHT
HORIZONTAL CANDLEPOWER DISTRIBUTION
Lamp 3 Lens A
Vertical Angle: 9.5°
Calibration
113.4 C
Candlepower: Candles
100
80
60
40
20
0
0°
20°
40°
60°
80°
100°
120°
140°
160°
180°
200°
220°
240°
260°
280°
300°
320°
340°
360°
Horizontal Angle
NBS Test 21A-7/55

Figure 9

DOUBLE OBSTRUCTION LIGHT
VERTICAL CANDLEPOWER DISTRIBUTION
Lamp I Lens B
Horizontal Angle: 0°



NBS Test 21A-7/55

Figure 10

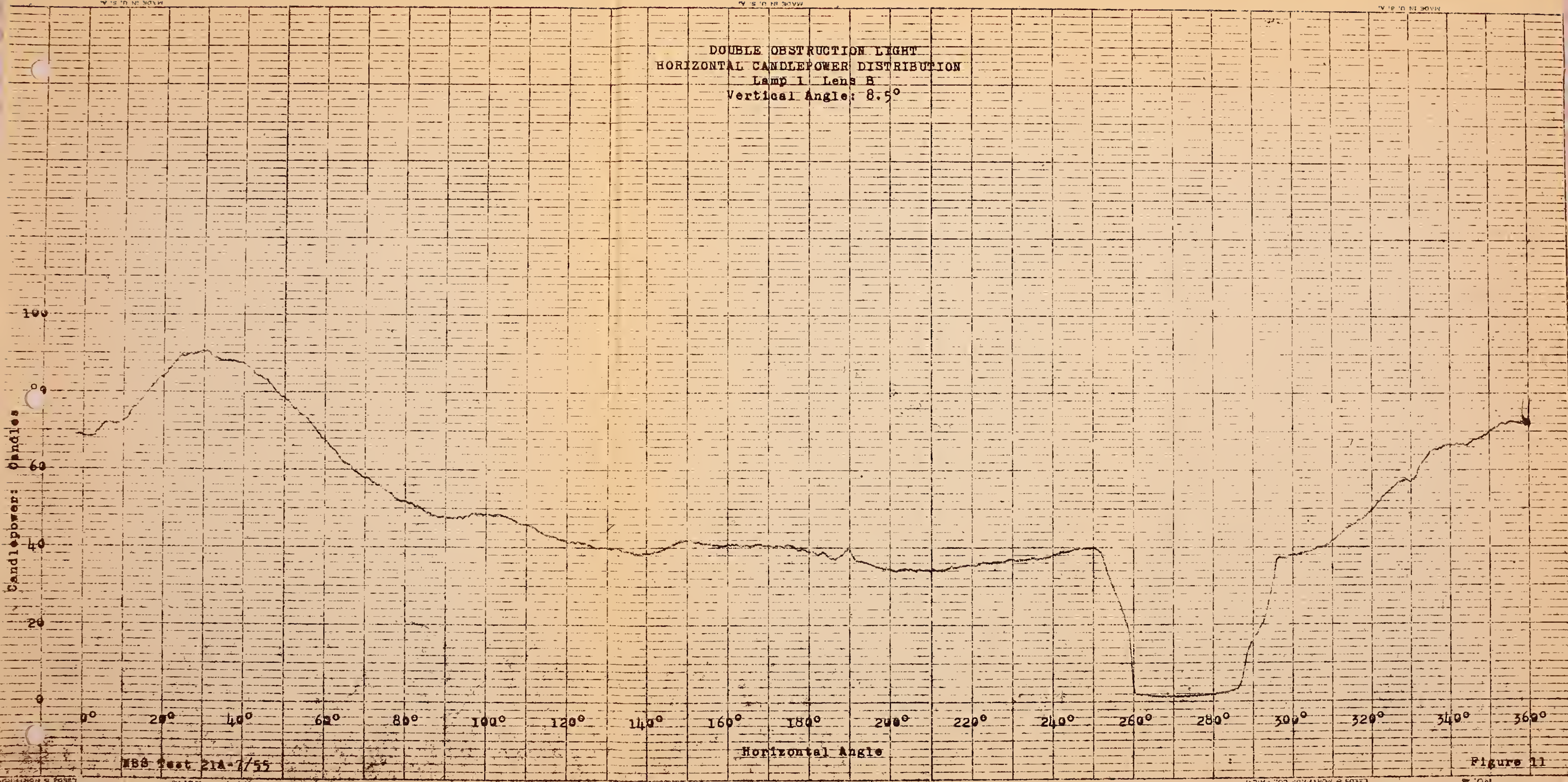
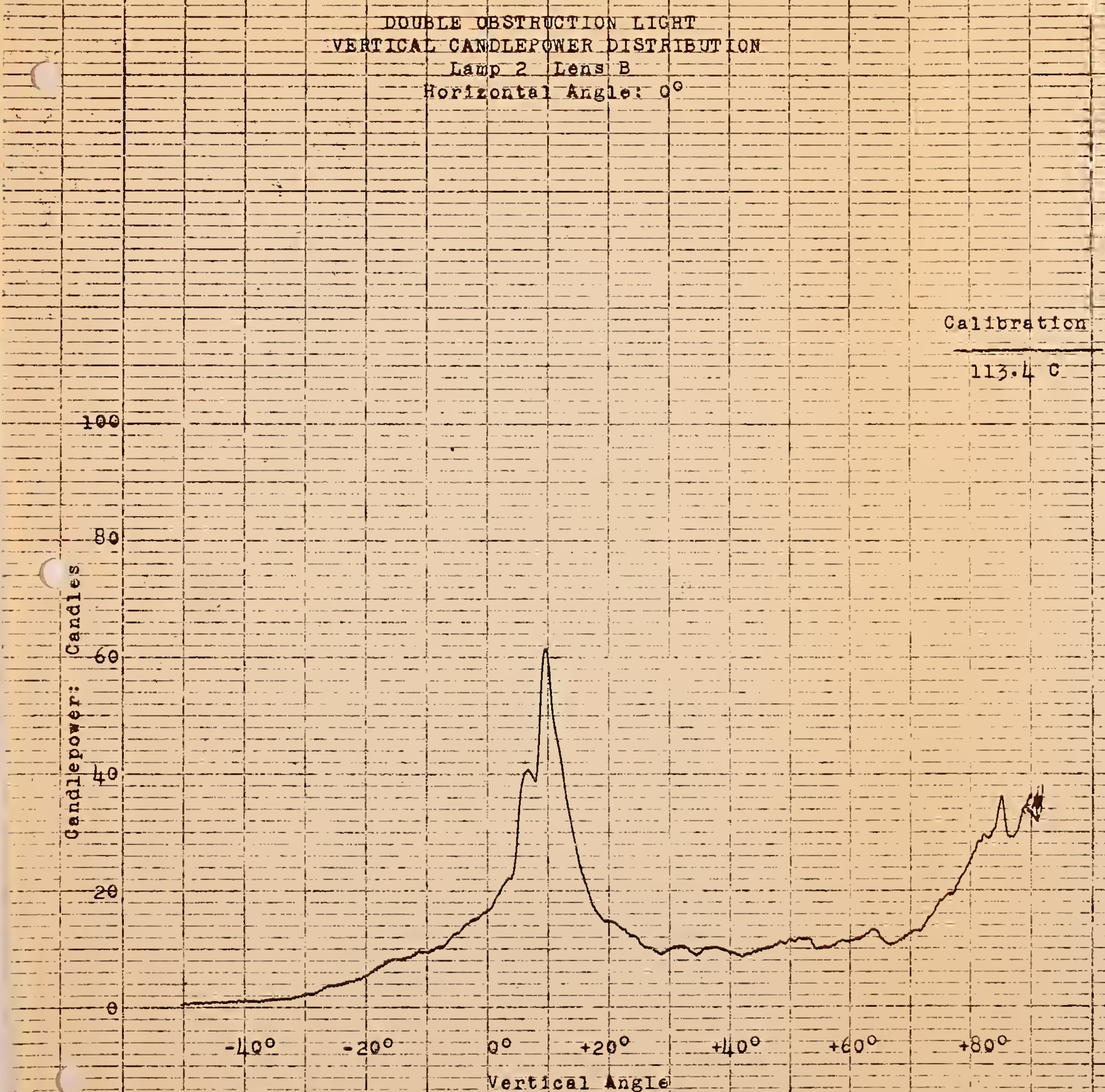

DOUBLE OBSTRUCTION LIGHT
HORIZONTAL CANDLEPOWER DISTRIBUTION
Lamp 1 Lens B
Vertical Angle: 8.5°
Candlepower: Candles
100
80
60
40
20
0
0°
20°
40°
60°
80°
100°
120°
140°
160°
180°
200°
220°
240°
260°
280°
300°
320°
340°
360°
Horizontal Angle
NBS Test 21A-7/55

Figure 11



NBS Test 21A-7/55

Figure 12

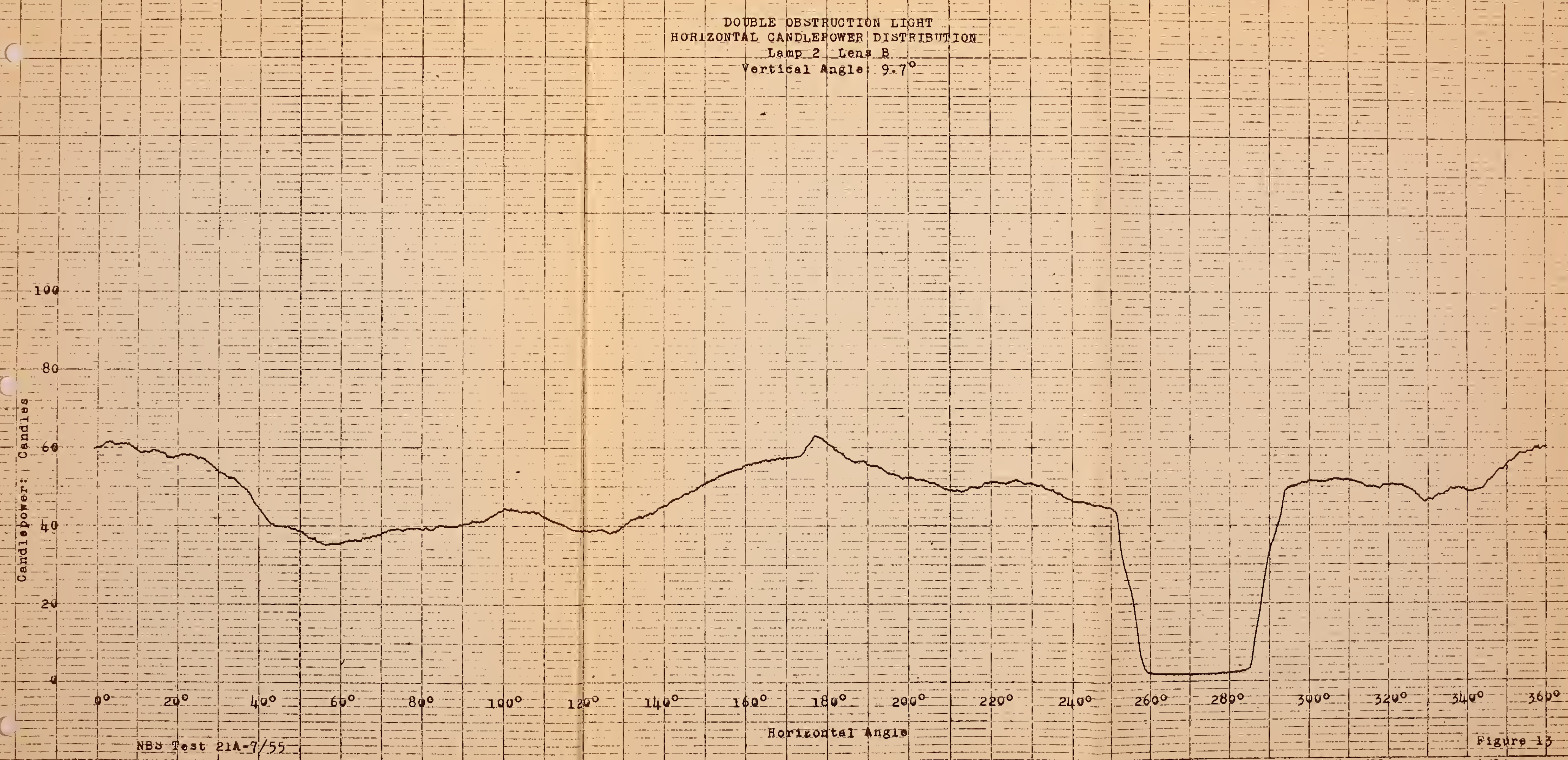
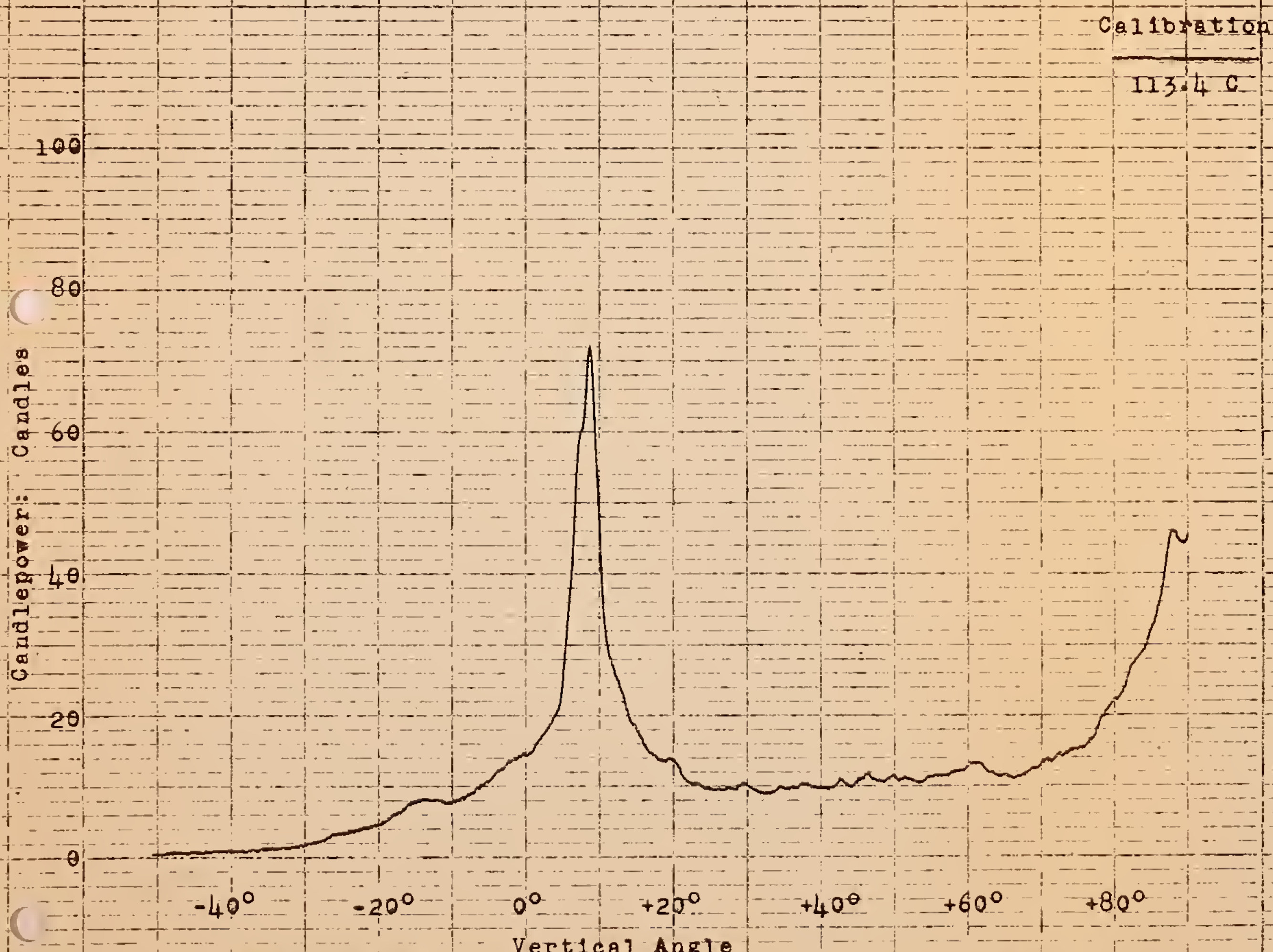

DOUBLE OBSTRUCTION LIGHT
HORIZONTAL CANDLEPOWER DISTRIBUTION
Lamp 2 Lens B
Vertical Angle: 9.7°
Candlepower: Candles
100
80
60
40
20
0
0°
20°
40°
60°
80°
100°
120°
140°
160°
180°
200°
220°
240°
260°
280°
300°
320°
340°
360°
Horizontal Angle
NBS Test 21A-7/55

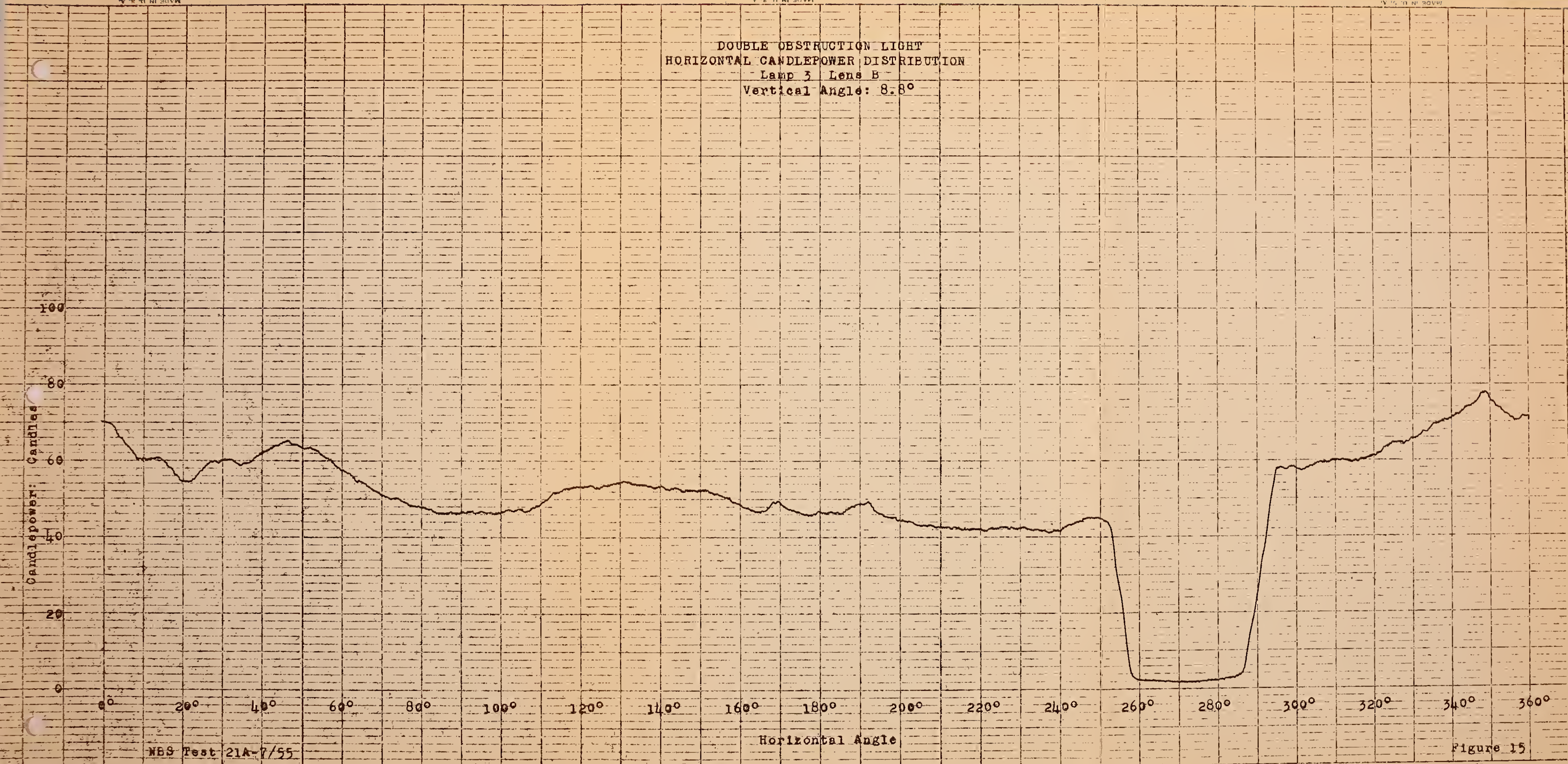
Figure 13

DOUBLE OBSTRUCTION LIGHT
VERTICAL CANDLEPOWER DISTRIBUTION
Lamp 3 Lens B
Horizontal Angle: 0°



NBS Test 21A-7/55

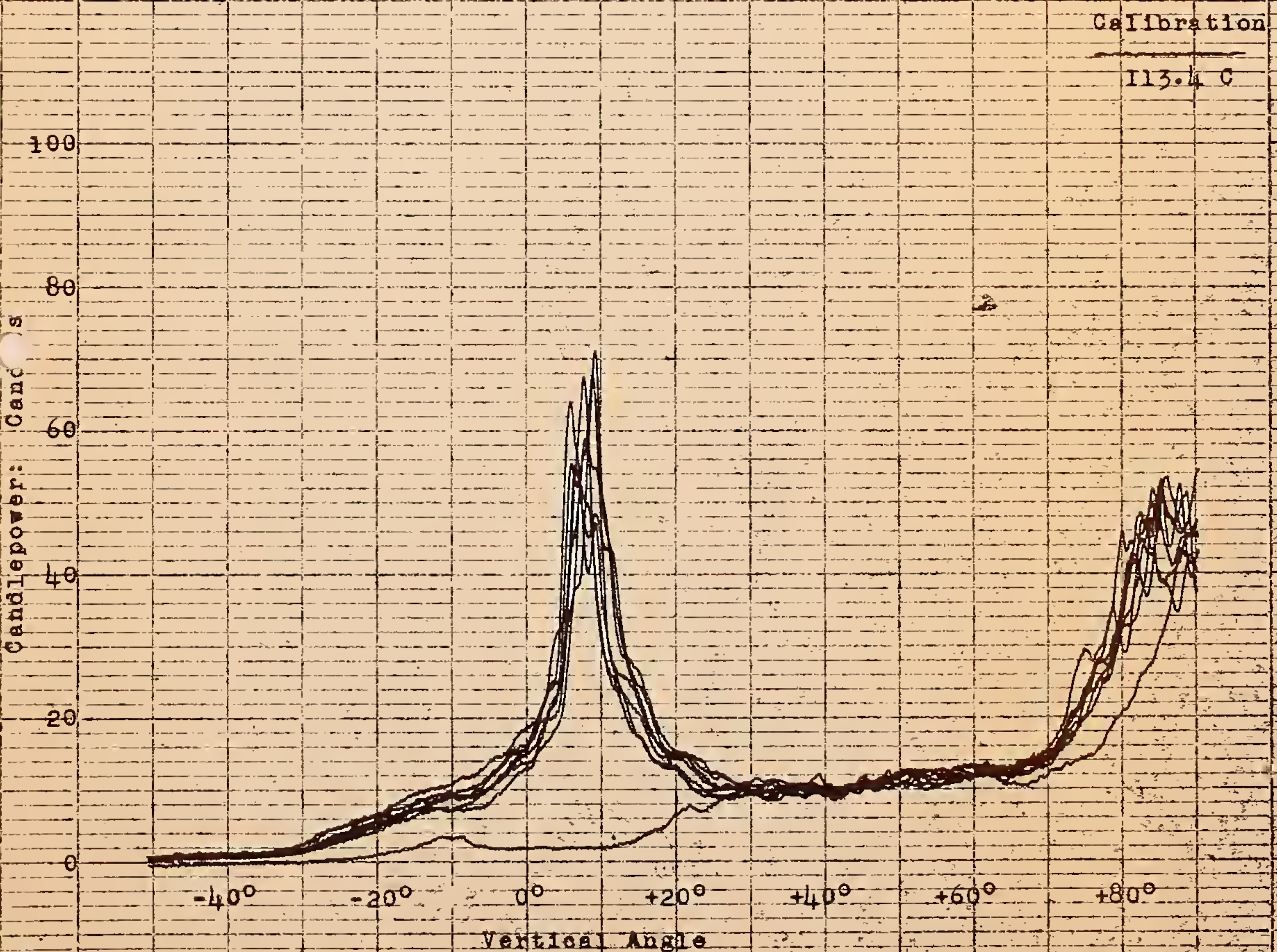
Figure 14



DOUBLE OBSTRUCTION LIGHT
HORIZONTAL CANDLEPOWER DISTRIBUTION
Lamp 3 Lens B
Vertical Angle: 8.8°
Candlepower: Candles
100
80
60
40
20
0
0°
20°
40°
60°
80°
100°
120°
140°
160°
180°
200°
220°
240°
260°
280°
300°
320°
340°
360°
Horizontal Angle
NBS Test 21A-7/55

Figure 15

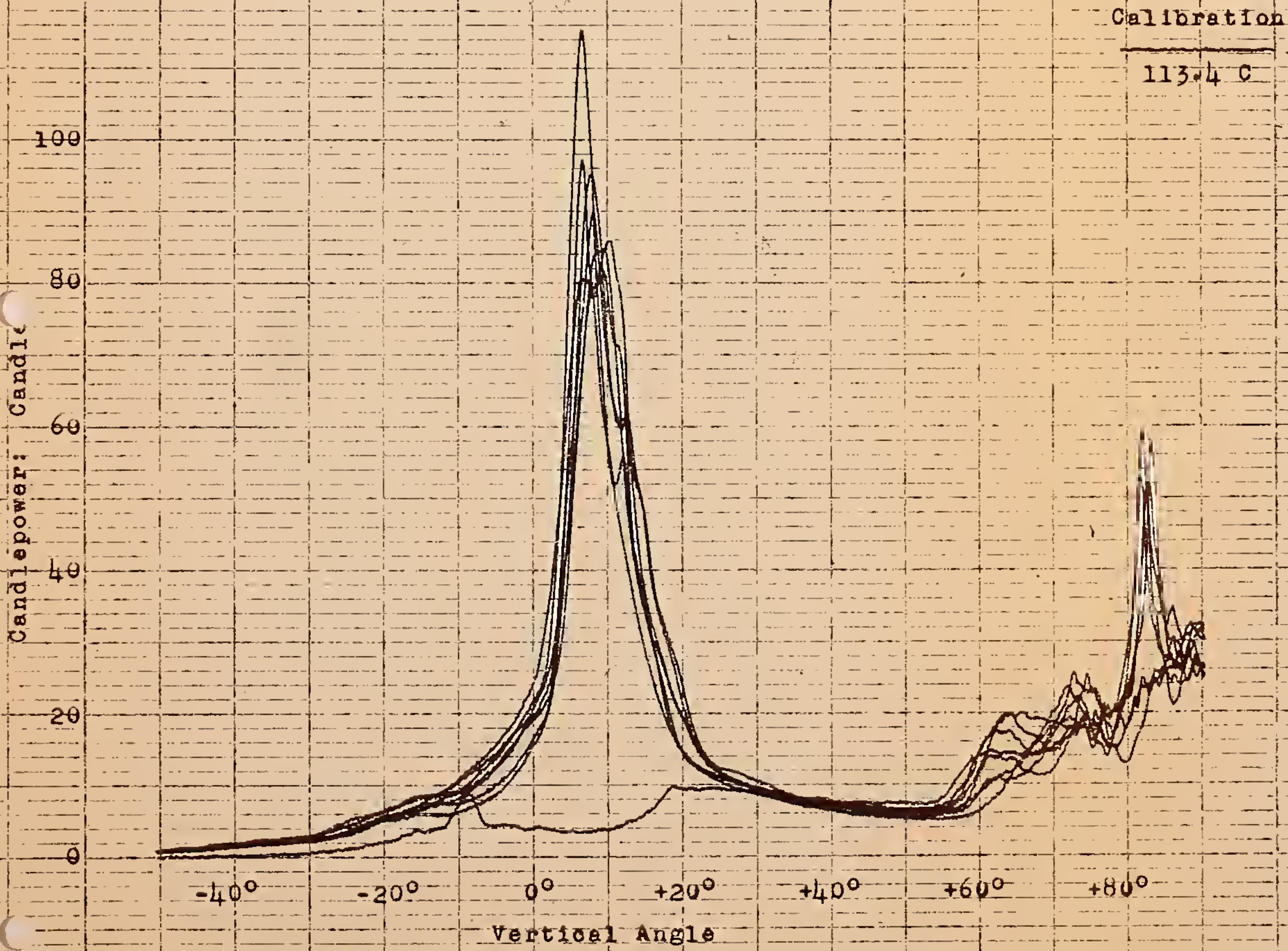
DOUBLE OBSTRUCTION LIGHT
EIGHT VERTICAL CANDLEPOWER DISTRIBUTIONS
Lamp 3 Lens B
Horizontal Interval: 45°



NBS Test 21A-7/55

Figure 16

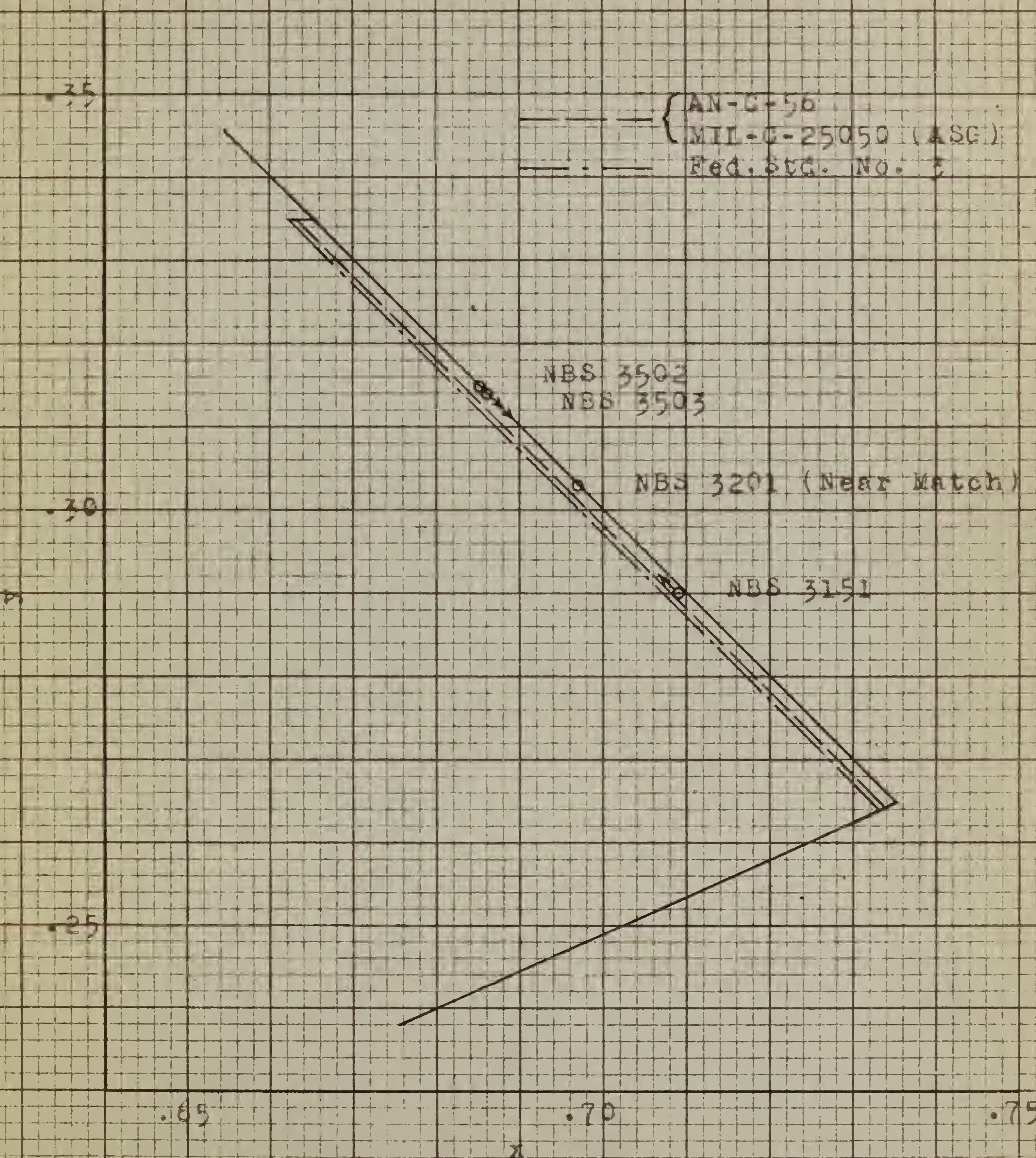
DOUBLE OBSTRUCTION LIGHT
EIGHT VERTICAL CANDLEPOWER DISTRIBUTIONS
Lamp 3 Lens A
Horizontal Interval: 45°



NBS Test 21A-7/55

Figure 17

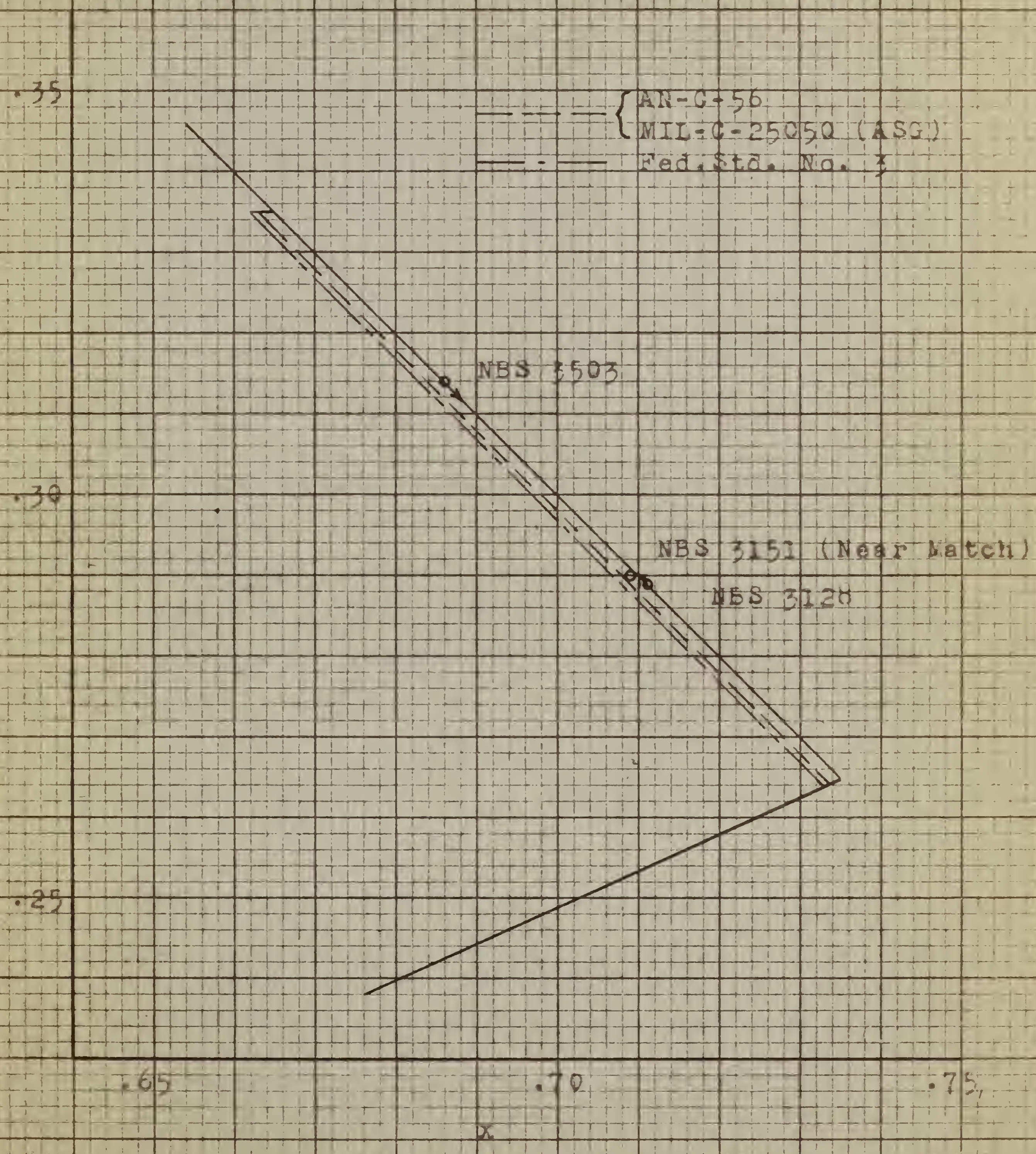
DOUBLE OBSTRUCTION LIGHT
CHROMATICITY OF LENS A
Red Portion of C.I.E. Diagram



NBS Test 21A-7/55

Figure 18

DOUBLE OBSTRUCTION LIGHT
CHROMATICITY OF LENS B
Red Portion of C.I.E. Diagram



NBS Test 21A-7/55 Figure 19

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

NBS