

NATIONAL BUREAU OF STANDARDS REPORT

4659

VISUAL RANGES OF FOUR OBSTRUCTION LIGHTS

by

F. C. Breckenridge
Robert T. Vaughan

NBS Test 21A-2/56

to

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



U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Visual Ranges of Four Obstruction Lights

by

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Robert T. Vaughan

SCOPE

This report gives the results of a comparative study of the visual ranges of two catenary neon obstruction lights, a neon light operated by a transformer, and a conventional incandescent obstruction light. The candlepower values used for this study are those presented in two previous reports:

NBS Report 4441, Performance Characteristics of Three Washington State College Neon Obstruction Lights.

NBS Report 4542, Candlepower and Color Characteristics of a Double Obstruction Light.

The study has been limited to nighttime use because it has already been shown in Report 4441 that the large catenary unit even at its full intensity is seen no better than the transmission line in the daytime.

COMPUTATION OF VISUAL RANGES

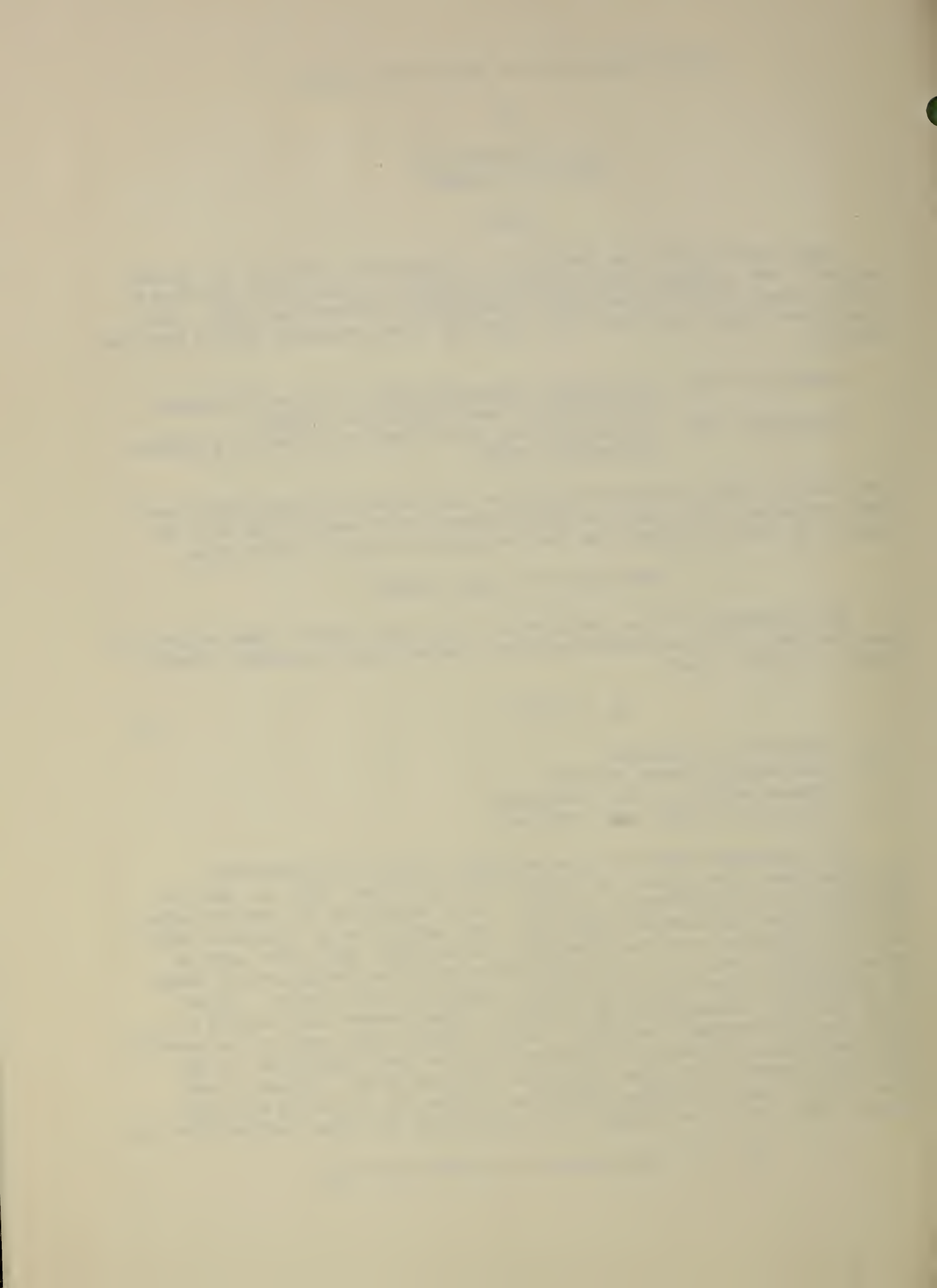
The conversion of the candlepower values into visual range values has been carried out in accordance with the conventionally accepted formula known as Allard's law:

$$E_o = IT^D/D^2 \quad (1)$$

- E_o = Threshold illuminance
- I = Candlepower toward observer
- T = Transmissivity of the atmosphere
- D = Distance of light from observer

The righthand member of this equation, if all its constituent qualities are known, gives the density of light flux, that is, the illuminance, at the observer's position. This member may be derived mathematically from the inverse square law, the definition of transmissivity, and the assumption that the atmosphere is uniform. While the last is never strictly true, it is the only assumption practicable and it leads to calculated values which approximate conditions in service. Allard found that the illuminance, E , at which lights became just visible at night was substantially constant. Later studies have found it to increase with background brightness and decrease as the dark adaptation of the observer improves. For the case of an airplane pilot, allowance must also be made for the limited attention a pilot can concentrate on his lookout for obstruction lights. The value used for these computations is:

$$E_o = 0.5 \text{ mile candles for night conditions.}$$



This value was proposed by Toulmin-Smith and Green (Aircraft Engineering 3, 12, 1931) as a practical threshold for the background brightness and dark adaptation representative of a pilot's situation. The tests made by this Bureau for the C.A.A. at Nantucket indicated this value was reasonable (Illuminating Engineering 40, 816, 1945). Although the value varies greatly with the conditions prevailing, the exact value used for the computations does not seriously affect the relative distances to which the several obstruction lights can be seen.

To carry out the computations it is also necessary to select values of T but since it is customary in regulations to express the transparency of the atmosphere in terms of meteorological visibility, rather than transmissivity, it is desirable to base our selection of T on typical values of meteorological visibility. The values of T used in this study have been calculated from (1) with the following assumptions:

- $D_1 = 10$ miles, typical of clear weather.
- $D_2 = 3$ miles, minimum visibility for visual flight rules.
- $D_3 = 1$ mile, a somewhat restricted visibility.
- $I = 25$ candles.
- $E_0 = 0.1$ mile candles, threshold for meteorological observer.

It will be noted that the value of E_0 for the weather observer is lower than the value used for the pilot. This is because of the better dark adaptation and opportunity for concentration of the meteorologist.

When the values given above are substituted in (1), the following values of T are obtained:

$$\begin{aligned} T_1 &= 0.9124 \\ T_2 &= 0.3302 \\ T_3 &= 0.0040 \end{aligned}$$

The laboratory measurements of candlepower give the values of I for different directions so that with the values of T and E_0 selected as stated above the values of D for each direction are determined. There is, however, no simple method of solving (1) for D. This difficulty is overcome by preparing curves showing I as a function of D for the values of T listed above since the value of I may be readily computed for assumed values of D and T. These curves are then used to read the values of D corresponding to the values of I taken from the previous reports. The curves used for this conversion are given in Figures 1 and 2.

SCOPE OF COMPARISONS

A number of variants affect the visual ranges of both the neon and incandescent lights. The ones listed below are included in the present comparison:

- Variation in candlepower in both azimuth and vertical angles; affects all units.
- Variation of atmospheric transmissivity; affects all units.
- Variation with transmission line current; affects both catenary units but measured values are available for the large catenary unit only.
- Variation from lamp to lamp; affects all units, information available for two large catenary lamps and three incandescent lamps.
- Variation with type of lens; affects incandescent unit only, values available for two types of lenses.
- Variation with color; affects incandescent unit only, limits indicated by the color specifications; see discussion in Report NBS 4542.

It is not feasible to prepare visual-range curves for all combinations of these variants. It has, therefore, been necessary to select cases in such a way as to give as good a comparison as practicable of the average visual ranges of the neon and incandescent lights. Since different variants affect the four types of lights, it has been necessary to be somewhat arbitrary in the selection of variants to be included in each figure.

The general plan has been to compare first the azimuthal and vertical variations of the visual ranges for all the lights for favorable conditions such as 10-mile visibility with the maximum line currents for the catenary units and pale-limit glassware for the incandescent unit. Average curves have then been developed from the same candlepower values to serve as a basis for comparing the visual ranges of the lights for less favorable conditions.

AZIMUTHAL LIMITS OF VISUAL RANGE

The first comparison (Figure 3) shows how the visual ranges of each of the lights varies with azimuth under optimum conditions. These assume, as stated above, an atmosphere having 10-mile visibility, a current of 1000 amperes in the transmission line for the large catenary unit and 150 amperes for the small catenary unit, and pale-limit glassware on the incandescent light. The curves for the two catenary units have been oriented as if the transmission line extended horizontally across the center of the figure. It happened in the case of the large catenary unit that lamp A has longer ranges than lamp B when seen from the unobstructed side and shorter ranges than B when seen from the obstructed side. The two half curves for lamp A have, therefore, been used to represent the variations of visual range of this unit as seen from different directions under optimum conditions and these have been shown in the figure on the near and far sides of the axis. In the case of the incandescent light, which has two lenses, lens A gave

the better values but even these intensities do not represent optimum operation. It has been necessary to multiply them by the ratio $5/3^*$ to obtain the intensity to be expected with pale-limit glassware which has been taken as the nearest equivalent to operation with a maximum transmission line current. Since this unit uses two lamps and two lenses, each of which is blocked off by the other at certain angles, the distribution of visual ranges for this light has been based upon a candlepower curve obtained by adding the measured distribution values to the values for the same curve rotated 180° . This rotation simulates the second lens which has its shadow in the opposite direction from the first.

Figure 3 also shows the horizontal limits of visual range for the small catenary light and the Model 300 neon light which is the transformer operated neon unit. The curve for the Model 300 unit corresponds to operation at 117 volts. In the case of the small catenary unit the design is symmetrical, neither side being obstructed more than the other. The candlepower of the Model 300 unit is uniform except for a small periodic variation caused by shadows of the rods in the guard. When the candlepower values were converted to visual ranges, the departure of the shadows from the average was approximately 1% at its maximum. This was considered unimportant.

VERTICAL LIMITS OF VISUAL RANGE

For the determination of the vertical limits of visual range, only those angles between -20° and $+50^\circ$ were considered of importance. Except for helicopters there can be little utility in seeing obstruction lights outside of these angles since airplanes under control do not glide down at angles greater than 50° nor climb at angles greater than 20° .

The second comparison, Figure 4, shows the vertical limits of visual range under the same conditions as were assumed in preparing Figure 3. As in the case of the horizontal limits, the minimum and maximum curves for the large catenary light are both based on the measurements for lamp A and represent the obstructed and unobstructed sides respectively. For the incandescent light, the vertical minimum and maximum curves are based on interior and exterior envelopes of the set of vertical curves shown in Figure 17 of Report NBS 4542. In this case no attempt was made to allow for the shadow but the candlepower curves were corrected to correspond to pale-limit glassware and doubled to take account of the two lenses. Since the large variations in candlepower with azimuth which necessitate the two curves for the large catenary and incandescent unit are not present in the case of the smaller neon lights, these units are each represented by a single curve and these two curves have been turned away from those for the large catenary light to avoid confusion with the minimum curve for this unit.

* See Report NBS 4542

OPERATIONAL VARIATIONS

Figure 5 has been prepared to show the effects of operational variations. It is based upon the candlepower values used for Figure 4 but shows the effect of varying the current in the case of the large catenary light and varying the glassware transmittance in the case of the incandescent light. The curves for the most favorable operating conditions in this figure are based on an average of the minimum and maximum candlepower values used for the same angles in the curves of Figure 4. These represent the operation of the large catenary unit on a transmission line carrying 1000 amperes and the incandescent unit fitted with pale-limit glassware. To represent the other extreme of operating conditions, the candlepower values underlying the curves for favorable operating conditions have been multiplied by suitable factors. In the case of the catenary unit, the factor was selected to give candlepowers corresponding to operation of the catenary light on a transmission line carrying only 100 amperes. For the incandescent light the minimum operating condition has been based on lens (B), which was considered as typical of minimum transmittance glassware. The values for lens B were multiplied by 2 to allow for a second lens. The intersection of this curve with the curve for lens A at $+50^\circ$ is caused by differences in their distributions. The curves included in this figure for the small catenary light and the Model 300 unit are identical with those in Figure 4 since no measurements are available as to how these are affected by transmission line current.

EFFECTS OF WEATHER

The final comparison, Figure 6, shows the effects of the weather. These curves again are based on average operating conditions. For the large catenary unit this was considered to be operation on a transmission line carrying 400 amperes. For the incandescent light an arithmetical average of the candlepower used for the minimum and maximum range curves in Figure 5 was taken as the basis for the visual ranges. The maximum curves in this figure represent weather characterized by 10-mile meteorological visibility, as do all the curves of Figures 3, 4, and 5. The other curves of Figure 6 are derived from the curves for the 10-mile visibility by multiplying the candlepower values by factors to allow for the difference in transmissivity between 10-mile visibility and 3-mile and 1-mile visibility, respectively. In the case of the large catenary light, it was also necessary to make a small reduction amounting to approximately .1 mile in the visual range values for 1-mile visibility in order to allow for the size of the unit which is large enough so that the light is not as effective as if it came from a point source.

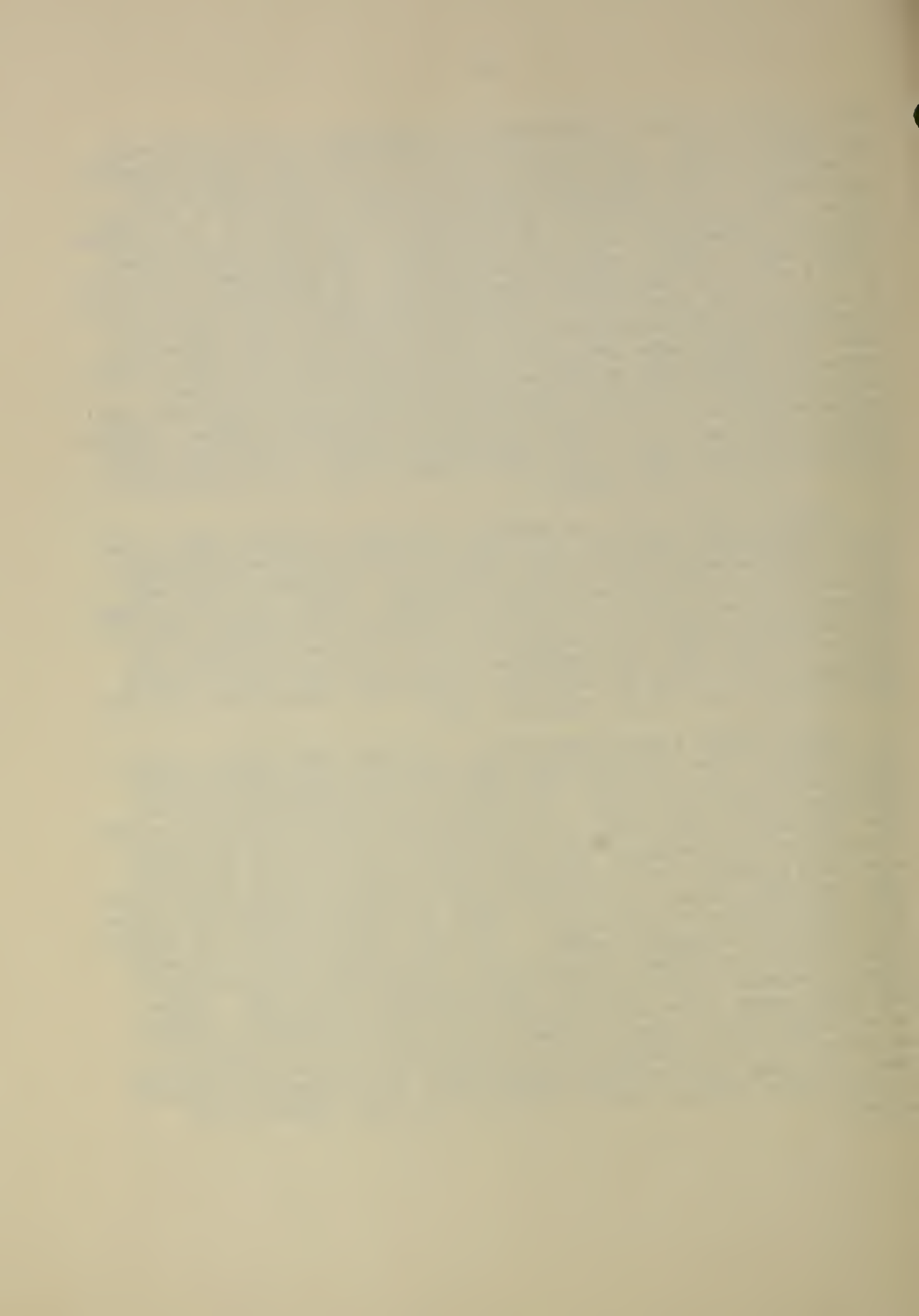
COMPARISON OF VISUAL RANGES

The azimuthal distribution of visual ranges shown in Figure 3 should

not be unduly weighted in comparing the performance of the incandescent and catenary units. It must be borne in mind that these curves represent a comparison at the most favorable vertical angles which improves the performance of the incandescent light more than it does that of the neon units. These curves, however, do bring out the fact that in one direction along the transmission line the large catenary light has a much reduced visual range. This is caused by the shadow of the transformer on the end of that unit. In the opposite direction along the transmission line there is a gap in this curve which is caused by the shadow of the goniometer. A comparison of the construction of the two ends of the unit shows that there is a fairly large gear at this end, and although this gear will not reduce the visual range as much as the transformer, it will cause a definite dimple in the curve, indicating that the visual range along the transmission line in this direction also is considerably reduced. Similar dimples must also occur in the corresponding sectors of the curve representing the visual range of the small catenary light, but the Model 300 unit is free from these dimples.

Figure 4, which shows the vertical variations in visual range, gives a more significant comparison than Figure 3 of the relative performance of the large catenary unit and the incandescent obstruction light under optimum operating conditions and clear weather. In this case the obscured variation is the reduction of the visual range for the catenary units in both directions along the transmission line. In these directions, the comparison would favor the incandescent light even more than the curves of Figure 4. The Model 300 unit has a shadow cone downward but it is not large enough to cut off any necessary light.

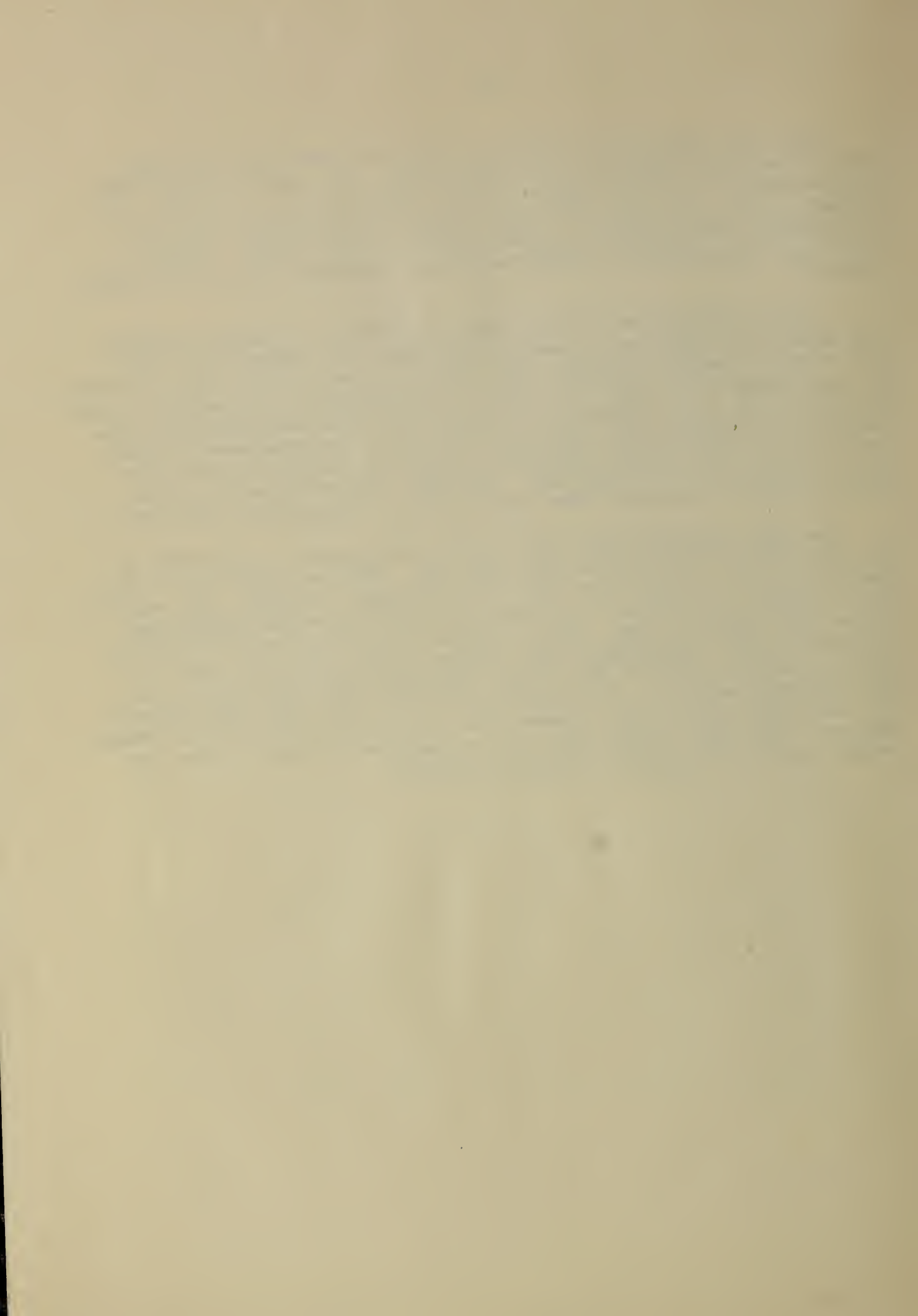
Figure 5 gives a more comprehensive comparison than Figures 3 and 4 since Figure 5 shows how the visual range falls off when the operating conditions are less favorable. The effect of the transmittance of the glassware on the visual range of the incandescent light is seen to be much less than that of the current in the transmission line on the distances to which the large catenary light can be seen, and even with the poorest acceptable glassware the incandescent light provides a longer visual range than the large catenary gives with maximum line current between the angles of 4° and 14° above the horizontal. These are angles at which the obstruction lights are frequently needed. If we make a comparison on the basis of the minimum transmission line current, 100 amperes, the incandescent light is superior at all vertical angles between -20° and $+50^{\circ}$. While the visual range of the small catenary unit at its minimum line current is not shown, we can make an estimate of its range for this current if we assume that its candlepower is proportional to the line current as is nearly the case with the large catenary unit. This assumption indicates a visual range slightly under 4. miles for the small catenary at 60 amperes.

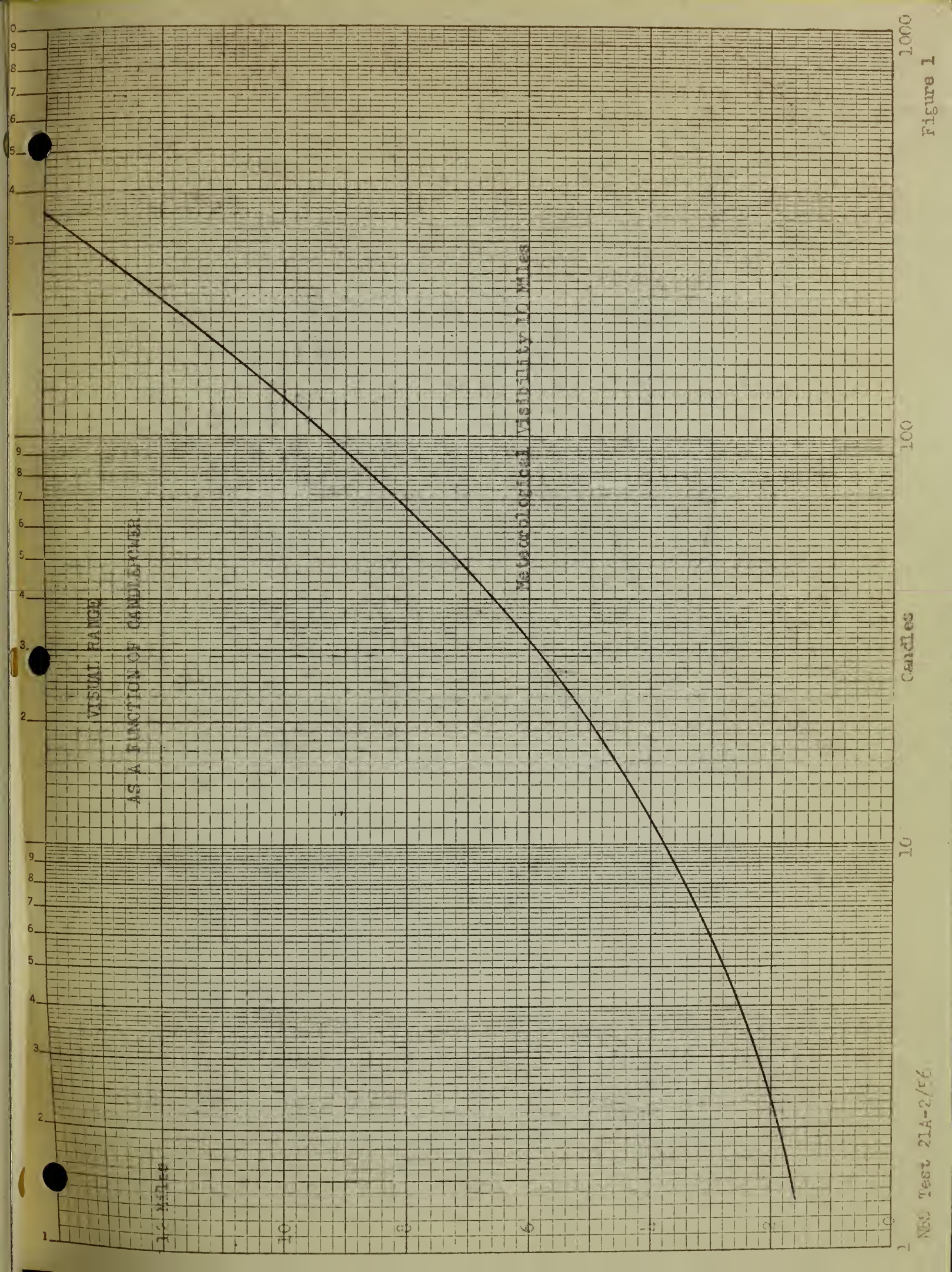


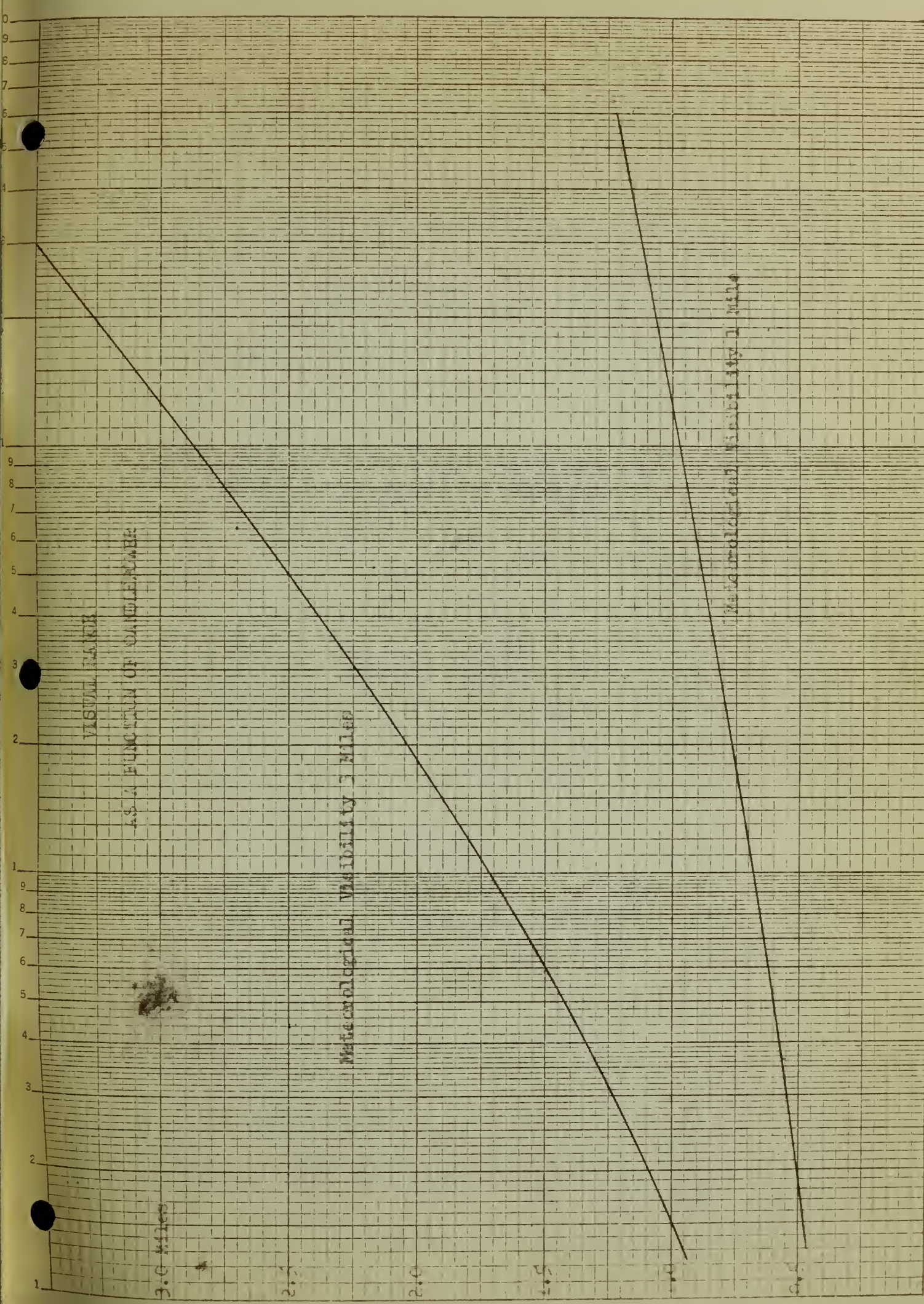
The final comparisons of Figure 6, which are based upon as nearly normal operating conditions as we could select, show that in all weathers the incandescent light is superior at all angles from -14° to $+50^{\circ}$. As already pointed out, except for helicopters, aircraft under control do not approach obstructions at angles outside of these limits. Figure 6 also shows how rapidly the visual ranges are reduced as the weather deteriorates.

All the comparisons indicate that, if there is a choice as regards the obstruction lights to be used for airplanes, the incandescent units will afford a greater protection than any of the neon units. Since, however, an incandescent light cannot be used on the catenary of a transmission line, the use of one of the catenary neon lights will give some protection even though it is somewhat less than that provided by the incandescent lights. Their use for this purpose, therefore, appears to warrant consideration from the standpoint of visibility. The Model 300 unit appears to have merit for use in locations where helicopters are landing and taking off.

The small catenary light gives better candlepowers in proportion to its size and line current than the large one. This is partly due to the smaller range of currents for which it is designed. However, this suggests that a larger unit similar to the small one might give high candlepower values than either of them. Since a helical tube could not be installed concentric with a transmission line without opening the line, such a unit might be designed with the transformer concentric with the line and the tube supported below it. This construction would also have the advantage that the ends could be less obscured than they are in either of the present designs. This type of unit could also be designed for two or three concentric tubes with separate secondary windings.







VISUAL RANGE
AS A FUNCTION OF CANDLEPOWER

Meteorological Visibility in Miles

Meteorological Visibility in Miles

3.0 Miles

2.5

2.0

1.5

1.0

0.5

210°
150'

200°
160'

190°
170'

180°

170°
190'

160°
200'

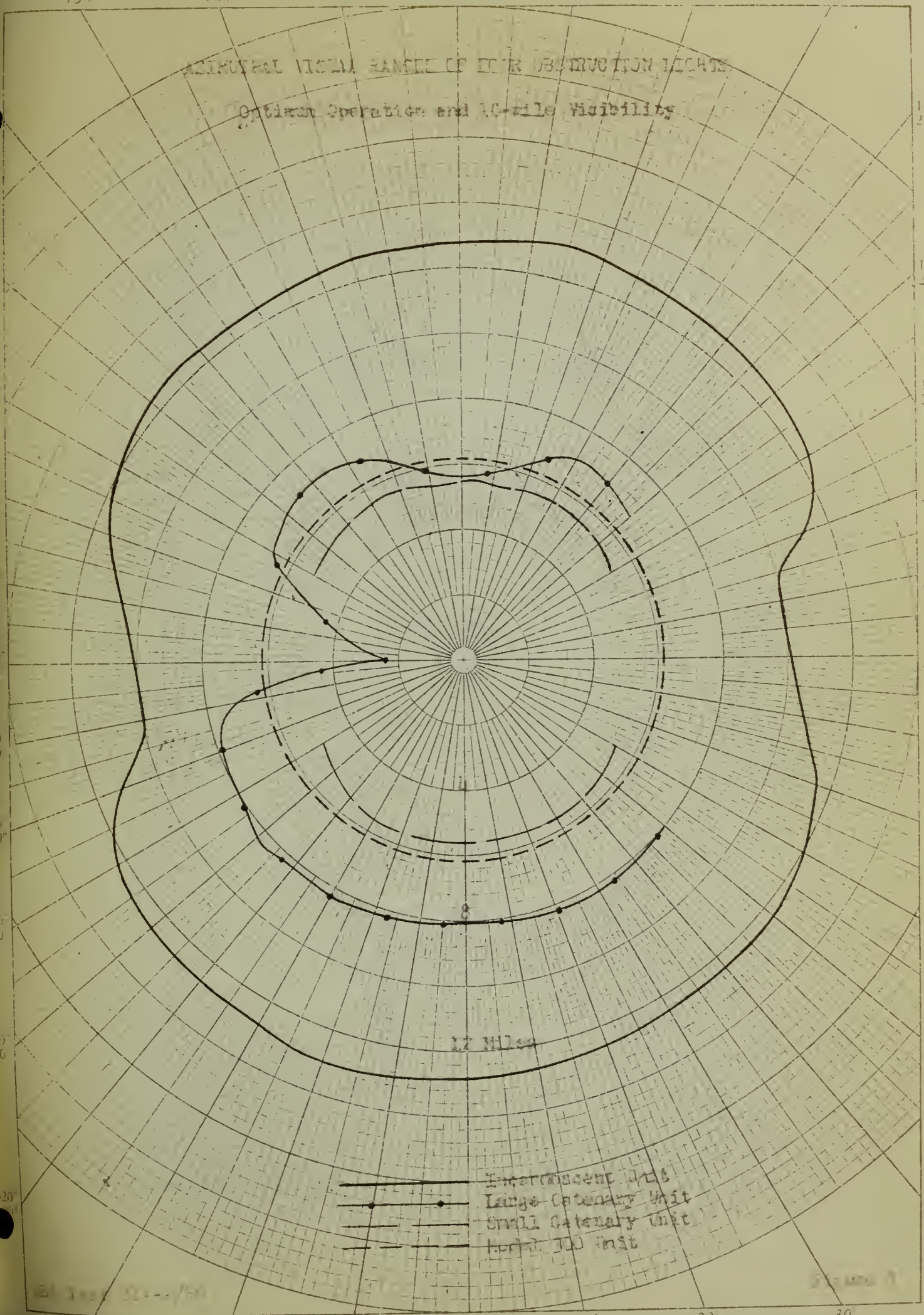
150°
210'

MINIMUM VISIBLE RANGE OF FOUR OBSERVATION LIGHTS

Optimum Operation and 10-mile Visibility

150
240
250
260
270
280
290
300
310
320

140°
220°
130°
230°
120°
240°
110°
250°
100°
260°
90°
270°
80°
280°
70°
290°
60°
300°
50°
310°
40°
320°



17 Miles

- Incandescent Unit
- - -•- - - Large Catenary Unit
- — — Small Catenary Unit
- - - - - Morse 'J' Unit

21 Jan 1950

21 Jan 1950

330 340° 350° 0 10 20 30

210°
150°

200°
160°

190°
170°

180°

170°
190°

160°
200°

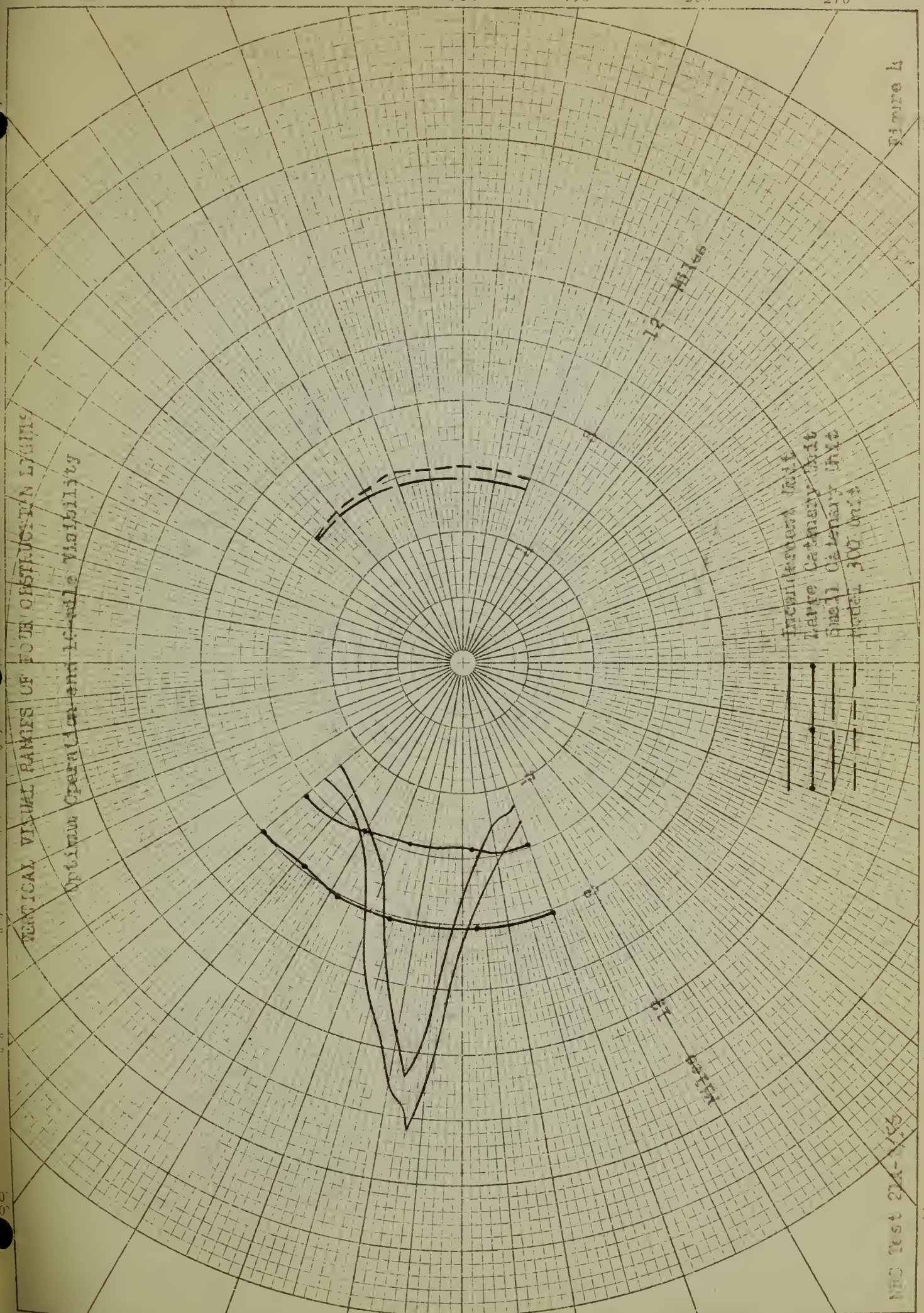
150°
210°

Figure 4

220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°

140°
130°
120°
110°
100°
90°
80°
70°
60°
50°
40°

VERTICAL VISUAL RANGES OF FOG OBSTRUCTION LIGHTS
Optimum Operation and Usable Visibility



NEC Test 214-155

210° 200° 190° 180° 170° 160° 150°
150 160 170 180 190 200 210°

220
230
240
250
260
270
280
290
300
310
320

140°
130°
120°
110°
100°
90°
80°
70°
60°
50°
40°

ANOMALOUS TRENDS IN THE OBSERVATION DATA
Effect of Unusually Small Clouds
Abnormal Visibility

117 Volts
150 Amperes

1000 Amperes
Pale Light
1000 Amperes

Independent Unit
Large Category Unit
Small Category Unit
Total 300 Unit

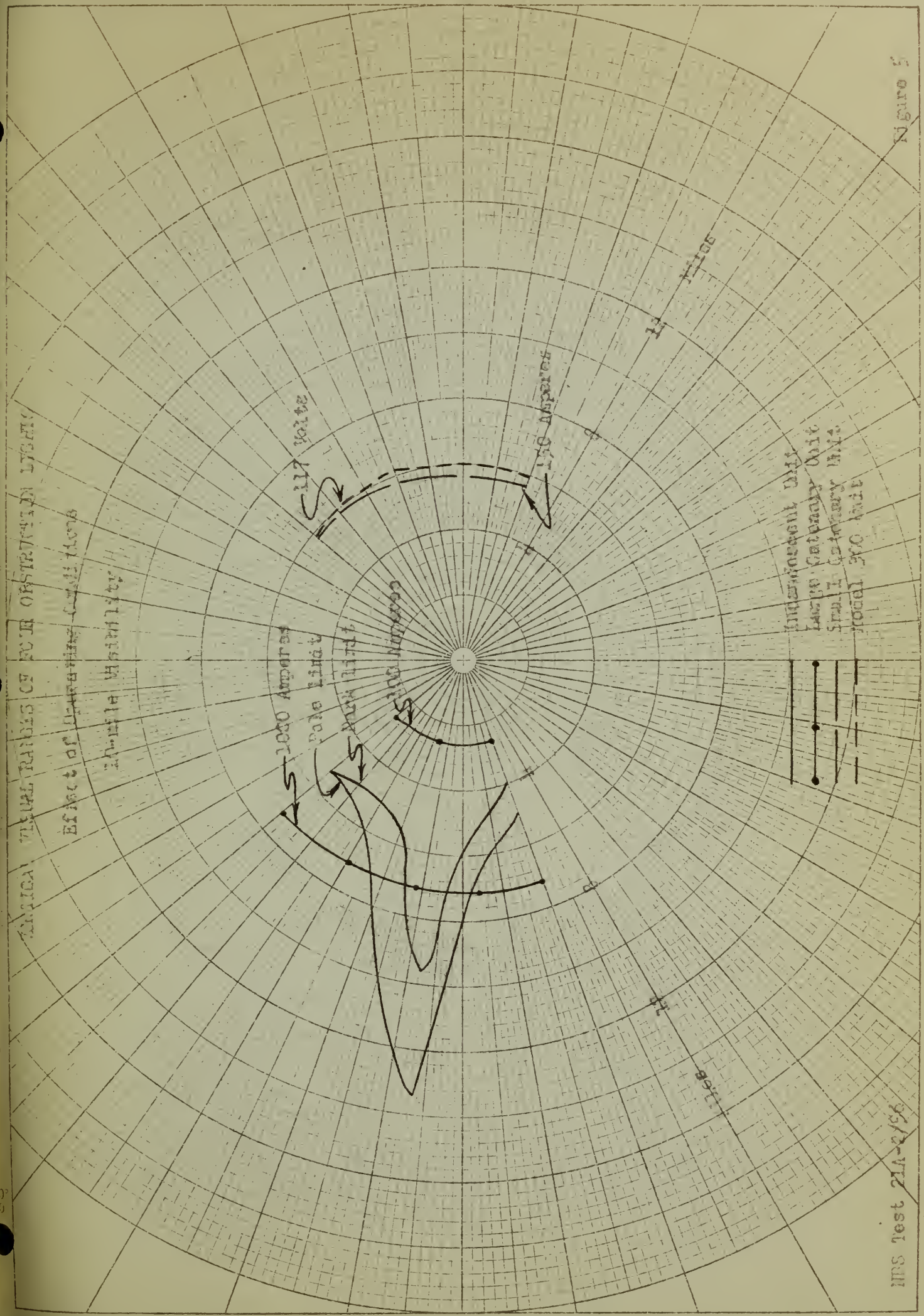
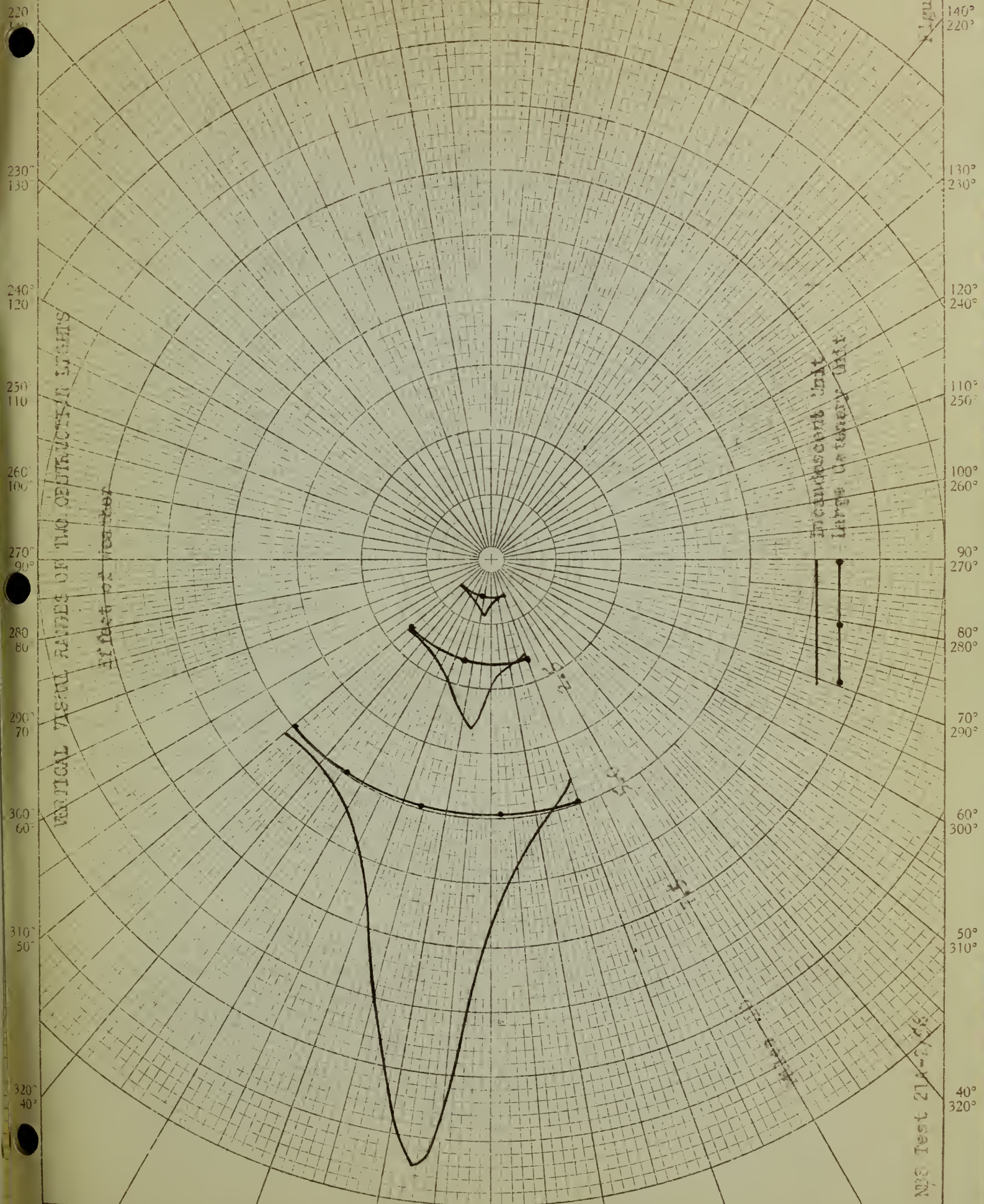


Figure 5

NPS Test 21A-2/56

210 200 190 180 170 160 150
150 160 170 180 190 200 210

Figure 5



NES Test 214-2-06

THE NATIONAL BUREAU OF STANDARDS

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