NATIONAL BUREAU OF STANDARDS REPORT

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PHOTOMETRIC TESTS

OF AN

AVQ-2A AIRCRAFT SEARCHLIGHT

EQUIPPED WITH EACH OF SEVERAL REFLECTORS

by

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Test 21N-25/53

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I. Introduction

The AVQ-2A aircraft searchlight employs a precision-grade, back-silvered glass parabolic reflector. From time to time, other types of reflectors have been proposed or considered, including drop-molded back-silvered glass (non-precision), aluminum, and aluminum-base reflectors with special reflectance-increasing coatings. Among other factors to be considered in determining whether such alternative types of reflectors are satisfactory for use in the AVQ-2A searchlight, is that of the relation between reflector quality and searchlight performance. It is the purpose of this report to present the results of a preliminary investigation of this relationship as determined for five reflectors, as follows:

#A5149, Precision-grade, back-silvered glass. This reflector was selected from among the AVQ-2A reflectors on hand at NBS as having the most nearly perfect parabolic figure.

#A6375, Similar to the above except that its deviation from perfect figure is about as large as is found in this class of reflector.

#A324, "Non-roll-off" reflector, - similar to above except that it was manufactured by an improved process, permitting maintenance of figure farther out to the periphery of the reflector. In "roll-off" reflectors as previously supplied (A5149 and A6375 are of this type) the peripheral zone extending in from the edge about 1/2 inch departs appreciably from the parabolic figure of the remainder of the reflector and therefore does not contribute significantly to the searchlight beam.

#Alum. 901-1, Aluminum base with a dichroic surface film designed to produce maximum reflectance in the region of the peak of the ICI luminosity curve.

#Alum. 901-2, Similar to 901-1.

II. Test Procedure

Candlepower distribution measurements were made on a 277-meter (909 ft.) outdoor range. The searchlight was mounted on a goniometer at one end of the range and the illumination measured at the other end with a luminosity-corrected photocell whose output was fed into one axis of a Leeds & Northrup automatic recorder. In order to obtain horizontal candlepower distributions, the goniometer on which the searchlight was mounted was rotated around its vertical axis so that the beam traversed the photocell. Vertical distributions were obtained in a similar manner by rotation of the goniometer around its horizontal axis. Runs of 50-second duration were made at 0.5-degree intervals, and the average candlepower of the last 30 seconds of each

run, allowing 20 seconds for stabilization, was computed. Two runs were made at each point in the distributions, except at the peaks where at least 10 runs were made.

An AVQ-2A searchlight with modifications as described in NBS Report 1354, "Instruction Book for Modification of AVQ-2A Aircraft Searchlight", was used for the tests. This light burns 11 mm carbons, and normally draws an arc current of 120 amperes. Previous experience has shown, however, that more stable operation can be obtained at reduced current. For these tests, therefore, the current was held at approximately 104 amperes. A special arc regulating circuit was employed which limited the current variation to about ± 4 amperes. The optical figure and surface quality of each reflector was evaluated by examining the projected shadow patterns for each reflector as obtained on a shadow-projection device designed and built by NBS for this purpose. The general operating principle of this device is described in NBS Report 2234, "Methods of Focusing the AVQ-2A Aircraft Searchlight" (Focusing Method #3) and in the NBS Technical News Bulletin for June 1953, pp. 93-94.

To facilitate comparison of the reflectors, curves of spectral reflectance obtained previously (NBS Report 2358, Test 21N-63/52) for the two aluminum base reflectors and for a back-silvered glass reflector are presented. These curves give the total reflectance (specular plus diffuse) for a small circular area, approximately 1 inch in diameter, at nearly normal incidence. The luminous reflectance for each reflector was computed from these curves and is also presented in this report.

III. Results

Figure 1 gives the average horizontal and vertical candlepower distributions of the AVQ-2A searchlight when equipped with each of the five reflectors tested. It should be pointed out that these curves are on a comparison basis only and do not represent peak performance of the searchlight since the arc was operated at reduced current.

Figures 2 through 6 are photographs of the projected shadow pattern for each of the reflectors.

Figure 7 gives the spectral reflectance curves of a typical back-silvered glass reflector, the two aluminum dichroic coated reflectors and the standard CIE (ICI) luminosity curve. The computed value of the luminous reflectance and the peak candlepower obtained with each reflector is given in the following table.

Table I

Reflector No.	Luminous Reflectance (Percent)	Peak Candlepower (Megacandles)
A5149	93	67.1
A6375	93	61.8
A324	93	65.2
Alum. #901-1	90	59.1
Alum. #901-2	92	65.7

IV. Discussion

Optical Figure and Distortion.

The projected shadow patterns shown in the accompanying figures are very sensitive indicators of the optical quality of the various reflectors. The relative freedom from distortion of glass reflector A5149 (See Fig. 2) is indicated by the close conformance of the edges of the shadow with the lines on the screen representing the outline of the mask (the center line of each group of five lines). The rounding of the corners of the mask shadow is caused by the "roll-off" edge. (The small dark spots on the shadowgraph are associated with pock mark damage on the front surface of the glass. This damage occurred during previous test work but does not significantly reduce the efficiency of the reflector.) Reflector A6375 (Fig. 3) shows similar roll-off distortion as well as pin-cushion distortion. Reflector A324 (Fig. 4) shows pin-cushion distortion but unlike the other two reflectors, its parabolic figure is held accurately much closer to its outside edge. This extra 1/2" of non-roll-off edge amounts to about 10% of its entire reflective area. The additional useful area is indicated by the trade mark and number etched near the periphery of the improved reflector. With the other two reflectors, the trade mark, located in the same position as on the non-roll-off reflector, is cut off almost entirely in the shadowgraphs.

The concentric fringes in the shadowgraphs for the two aluminum base reflectors, Figs. 5 and 6, are the result of the relatively coarse surface finish associated with the grinding operations used in their fabrication. This coarse finish also accounts for the rough edges of the shadow of the mask as compared with the relatively smooth, clean edges obtained with the glass reflectors. In addition to the coarseness of the finish shown by the concentric fringes, moderate deviations from parabolic figure are shown in the shadowgraphs by the departure of the shadow edges from the reference lines representing the edges of the mask, and by the distortion from circular shape of the edge of the beam. It was found also that the aluminum base reflectors were somewhat flexible and care had to be exercised in mounting them in order to prevent excessive distortion resulting from stresses introduced by the mounting clamps.

Reflectance.

The luminous reflectance of the dichroic film coated aluminum reflectors compares favorably with that of back-silvered glass reflectors. It should be noted, however, that the measurements were made at nearly normal incidence, whereas, as used in the searchlight the bulk of the light flux is incident at angles greater than normal. This condition would have negligible effect on the reflectance of the glass reflectors, but since the reflecting properties of the dichroic films of the aluminum reflectors are appreciably affected by angle of incidence, it may be expected that the performance of the searchlight would not be in direct proportion to the measured value of luminous reflectance at normal incidence. With the dichroic film coated reflectors the dominant hue of the reflected light shifts toward the blue with increasing angle of incidence. Fig. 7 shows that the centroid of the reflectance curve for reflector Alum. #901-1 is displaced toward the blue end of the spectrum from the centroid for the ICI luminosity curve while that for Alum. #901-2 lies nearer the red end. A small shift of both curves toward the blue end, resulting from the higher angle of incidence, could result in an increase in liminous reflectance for the #901-2 reflector and a decrease for the #901-1 reflector. This is in accord with comparative data given in Table #I and probably accounts at least in part for the lower candlepower of #901-1.

V. Summary

It is evident from the candlepower distribution curves in Fig. 1, that differences in quality among the reflectors tested are not accompanied by large differences in performance in the AVQ-2A searchlight. The difficulties inherent in the test procedures, the instability of the arc lamp even when operated at reduced current and with special precision current control devices, and the variability of carbons result in uncertainties in the measurements significantly close to the order of magnitude of the differences in performance found. However, the reliability of the differences in peak candlepower is much better than that of the off-axis measurements since much more data was obtained in the axial directions. There seems to be a fair correlation between the quality of the reflectors and the peak candlepowers obtained with them although the magnitudes of the differences are small. The results suggest that small scale imperfections such as the grinding marks left on the aluminum base reflectors, although prominently displayed in the shadowgraphs, do not materially affect performance, but that larger scale imperfections such as the distortion represented by the pronounced pin cushioning of the shadowgraph for reflector #A6375 do result in small but significant reductions in peak candlepower.

A complete analysis of the performance of a reflector in a searchlight would require consideration of the entire beam. Most of the light flux is found at angles off the axis. Unfortunately, as the zone factor by which the candlepower must be multiplied to obtain luminous flux increases with angular displacement from the axis so also does the uncertainty of the candlepower measurement. It is accordingly not meaningful with the limited data on hand to compute the luminous flux in the beam. In order to make a complete analysis of the performance it would be necessary to obtain a considerably greater amount of data and to improve the technique of measurement and the stability of the searchlight. One approach that may be fruitful is to use a more stable source in place of the carbon arc. It might be difficult to simulate the carbon arc with such a source, but it is probable that sources might be found wherein the gain in stability would produce an improvement in the reliability of the data that would outweigh the errors introduced by the inexactness of the simulation.

In view of the savings that might be effected by increasing the tolerances for reflector quality and the indications given by the results of this test that this might be done without appreciable reduction in performance, it is recommended that this problem be investigated further as suggested above so that differences in performance may be precisely analyzed and suitable methods of specifying reflector quality be developed.

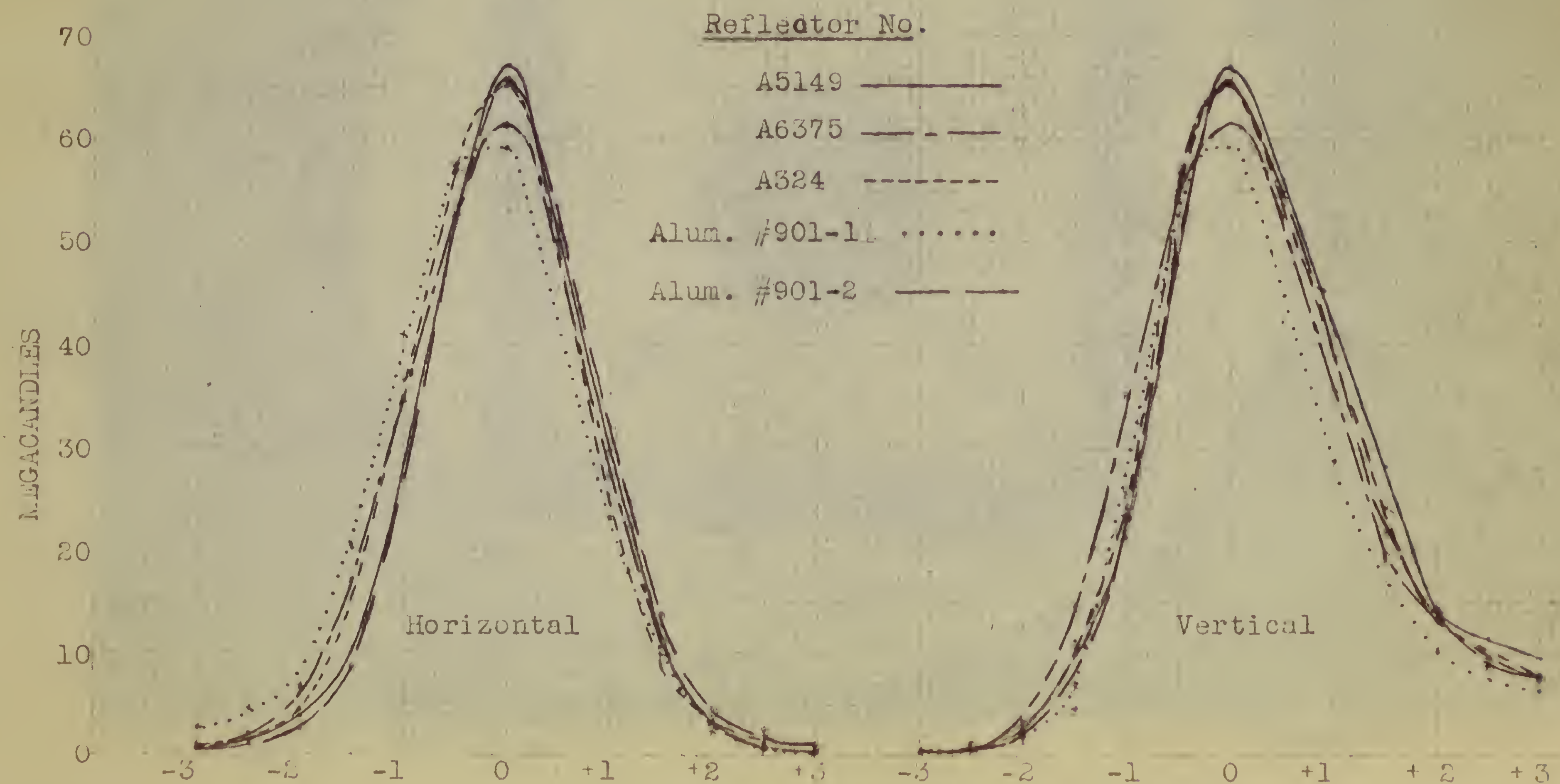
CANDLEPOWER DISTRIBUTIONS

OF AN

AVQ-2A AIRCRAFT SEARCHLIGHT

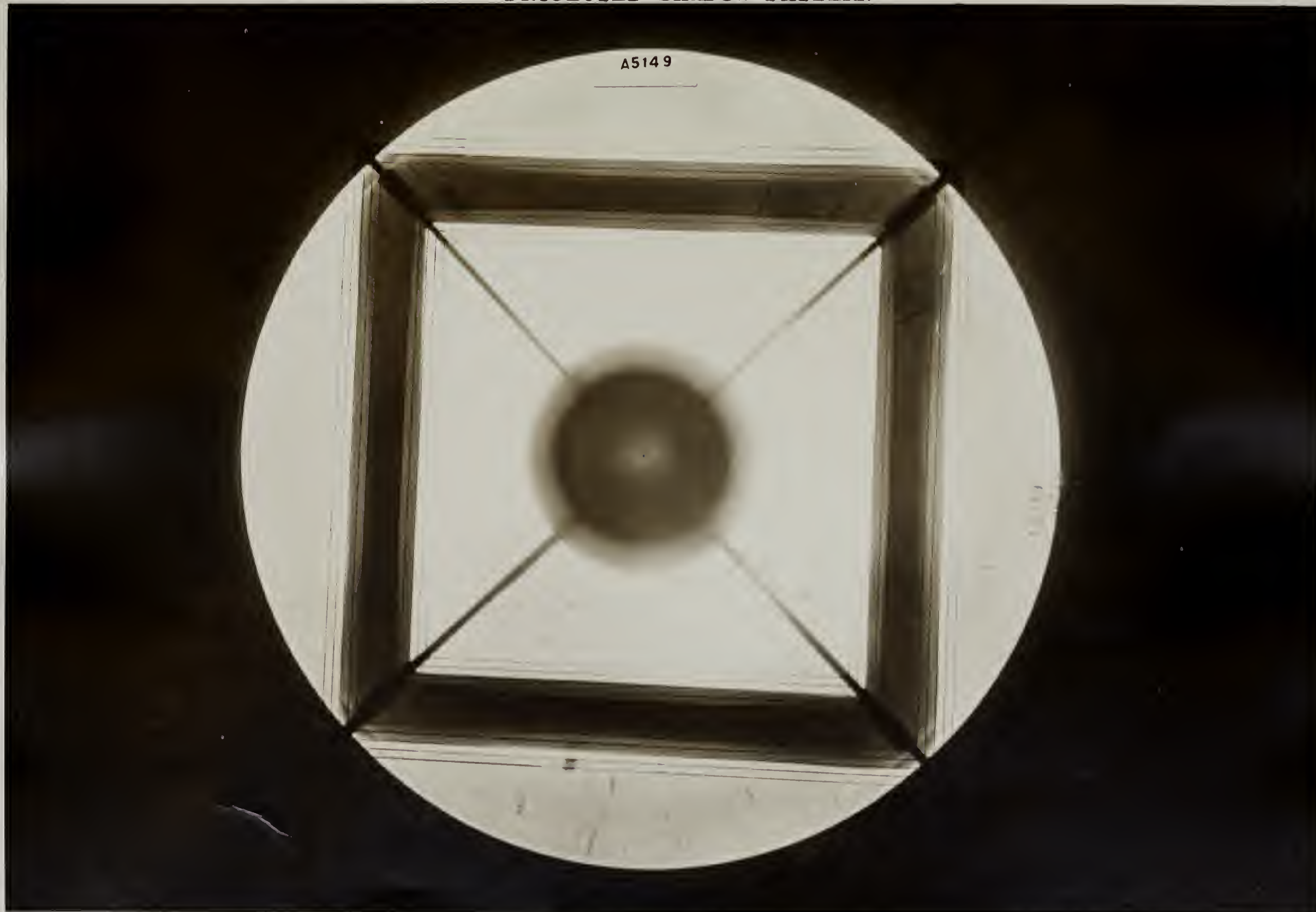
EQUIPPED WITH VARIOUS REFLECTORS

(ARC CURRENT = 104 AMPERES)



NBS Test 21N-25/53 ANGLES IN DEGREES Figure 1

PROJECTED SHADOW PATTERN



NBS Test 21N-25/53

Figure 2

PROJECTED SHADOW PATTERN

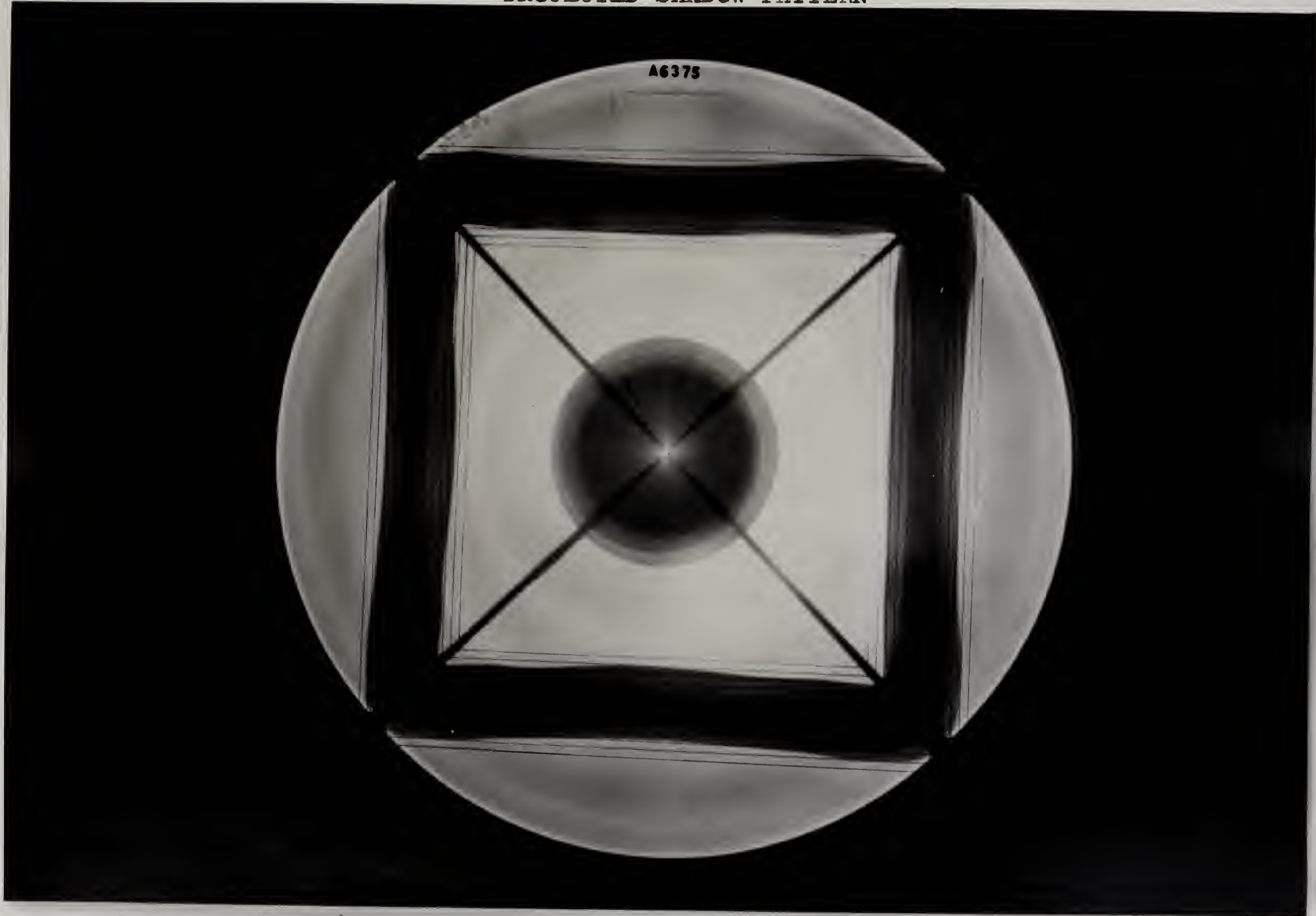


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Figure 3

PROJECTED SHADOW PATTERN

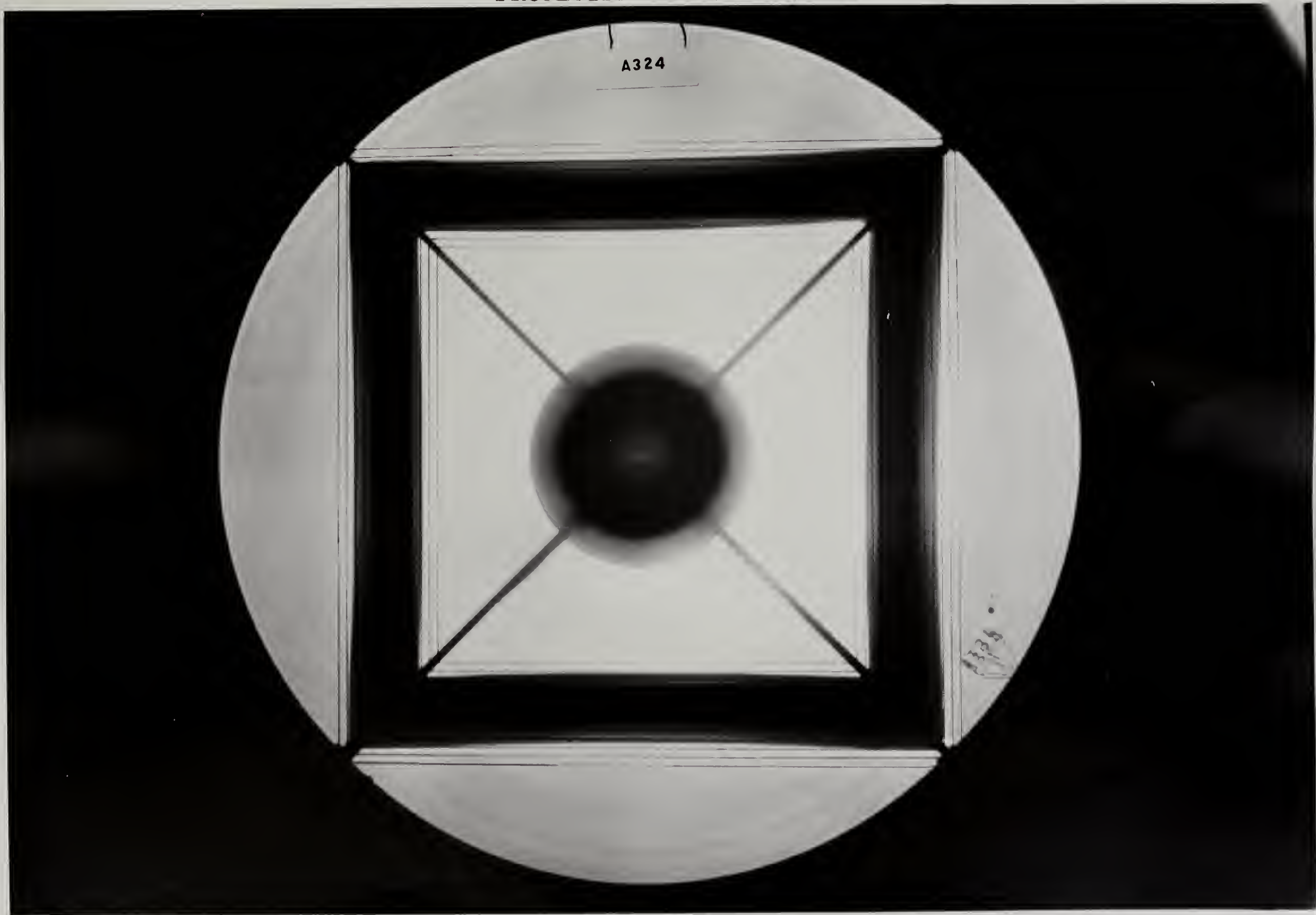

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Figure 4

PROJECTED SHADOW PATTERN

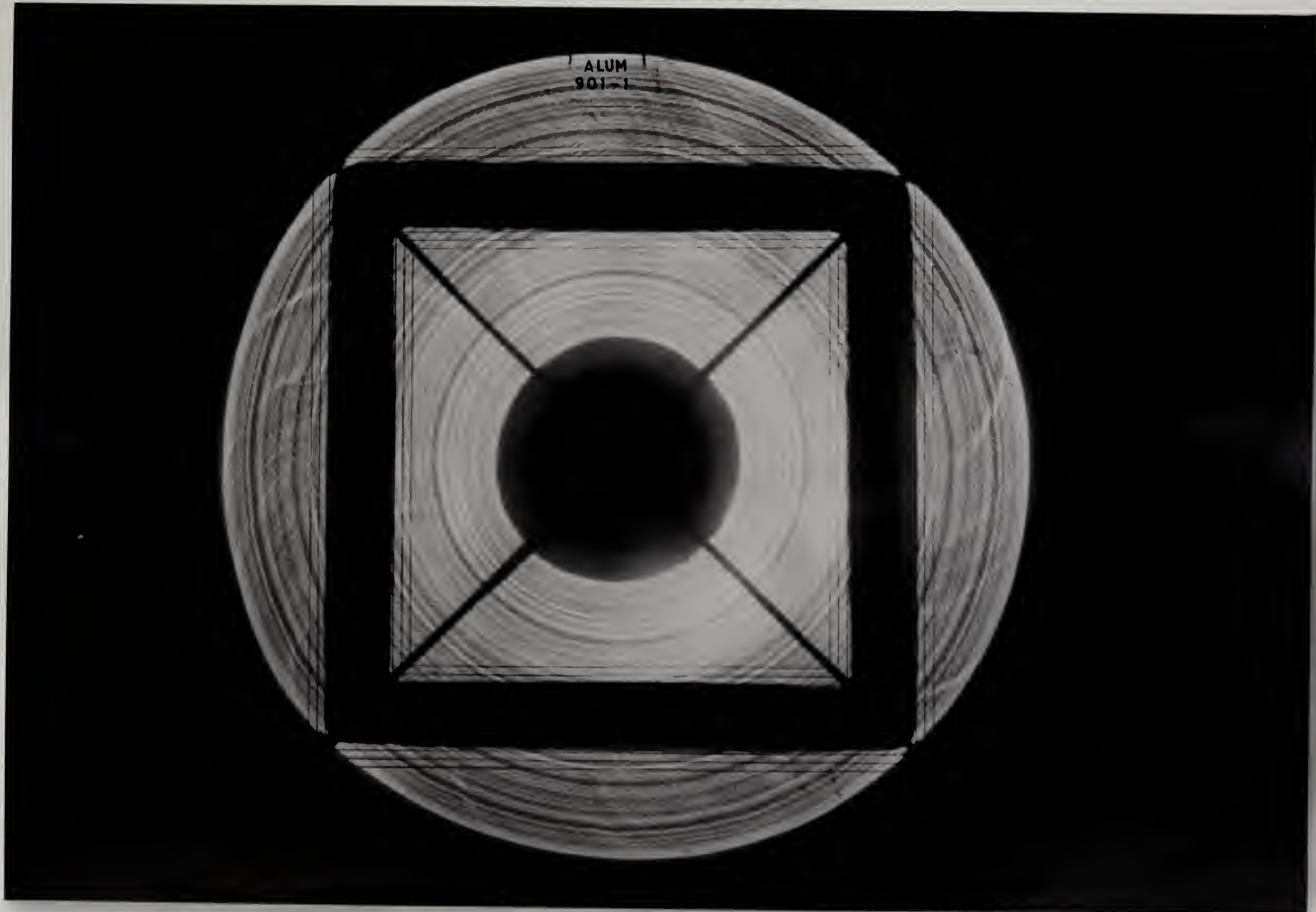

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Figure 5

PROJECTED SHADOW PATTERN

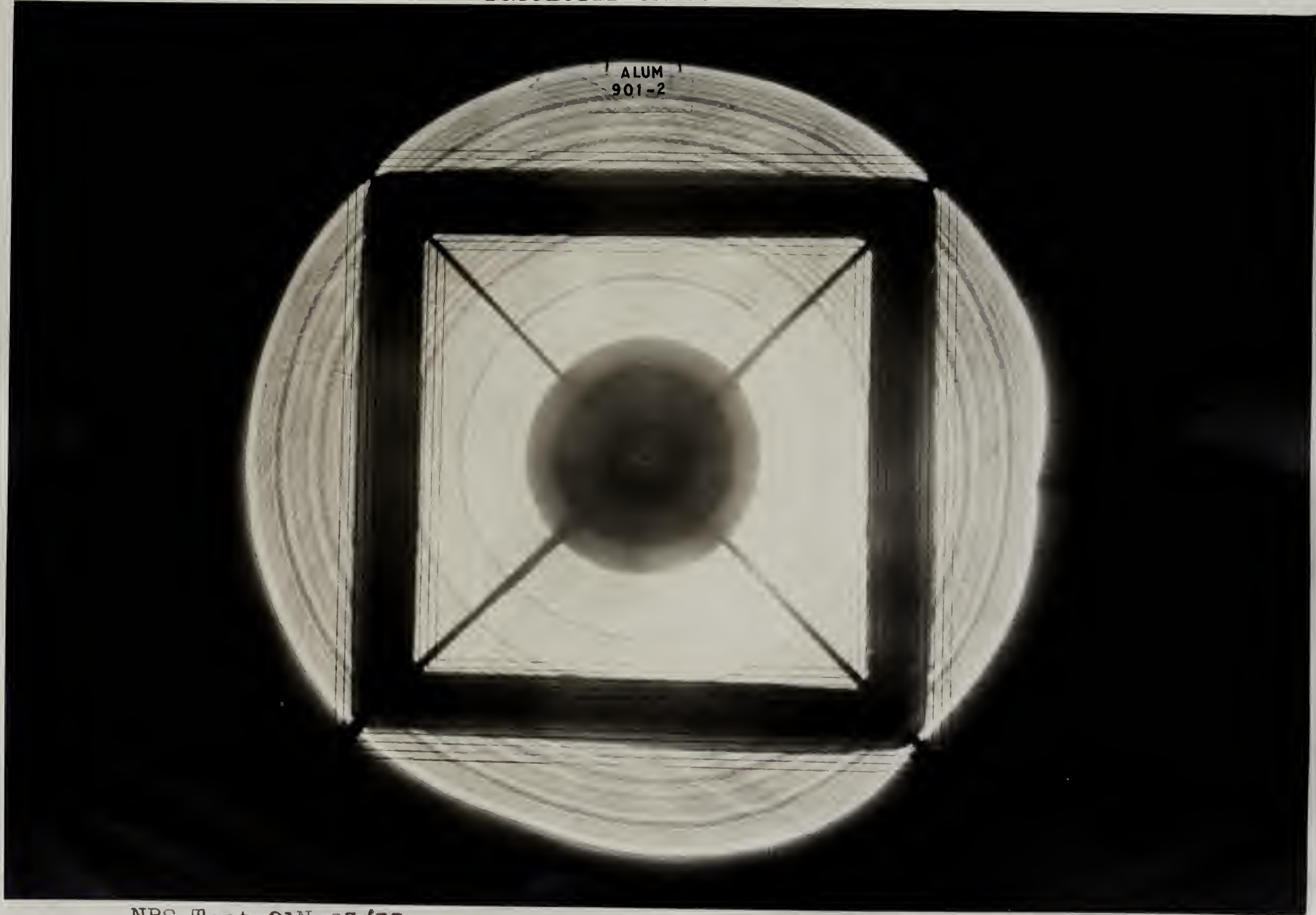

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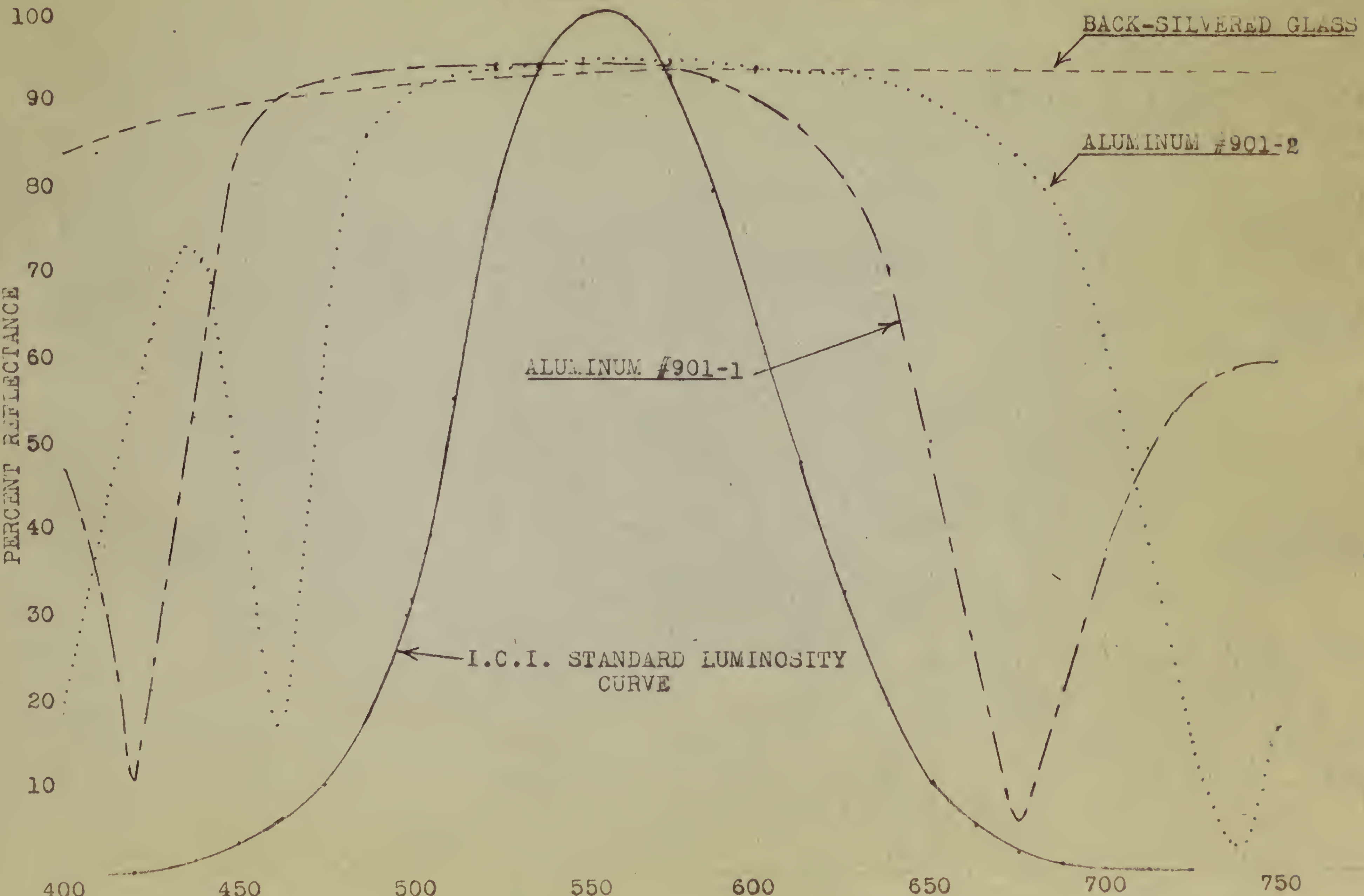
Figure 6

SPECTRAL REFLECTANCE CURVES

PARABOLIC SEARCHLIGHT REFLECTORS



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WAVELENGTH IN MILLIMICRONS

Figure 7