FINAL REPORT

INFRARED COMMUNICATION AND TEST DEVICES

PART 2

Summary Report on

Z-4x Optical Test Set

By

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Contract NObsr-52387

Project No. 1963

27 October 1955

PREFACE

Subsequent to issuing the final report (No. 1963-10-F dated 15 August 1954) on the subject contract, additional funds were made available to complete the prototype model of the Z-4x optical test set. This report covers the work done in completing the test set and also gives operating instructions and recommendations for future models.

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INTRODUCTION

The Z-4x optical test set described in this manual was developed, designed and built at the Engineering Research Institute of the University of Michigan under Contract NObsr-52387 between the Bureau of Ships and the University of Michigan, as requested by BuShips letter NObsr-52387(853) Ser. 853-401, dated 15 December 1952. The specifications indicated that the test set was to be a self-contained unit for determining the sensitivity and resolution of image-forming receivers, with a continuous illumination test range of 0.001 to 5.0 n.m.c. and a resolution test range of 1/2 to 10 minutes of arc. After a design and study program, one prototype test set (U. of M. Serial No. 241) was built, and was shipped to the New York Naval Shipyard Material Laboratory on July 15, 1955.

DESIGN PROCEDURE

The first step in the design of the new instrument was to decide how to attenuate the light continuously from 5 down to 0.001 n.m.c., a ratio of 5,000 to 1. A system previously used in this laboratory, that of attenuating the light with a series of lenses, was tried and found to be satisfactory over the desired range, but this method presented the mechanical problem of accurately moving and positioning the lenses. About this time the Eastman Kodak Company introduced a new circular density wedge having a density range of four, which corresponds to a ratio of 10,000 to 1 in transmission. Correspondence with Eastman indicated that one type of wedge could be obtained which was neutral with wavelength throughout the visible and extending at least to 2 microns in the infrared, beyond which no data were available. Such a wedge was obtained and tested for neutrality in the infra-red. The transmission of the more transparent end of the wedge is shown in Figure 1. Although the transmission varies as much as 17% over the range from 0.6 to 2.8 microns, it can be seen that this variation is much less over the range in which the image tube is sensitive. Furthermore, the variations shown here become smaller in the more opaque region of the wedge.

On the basis of these measurements it was decided that the wedge would provide a satisfactory means of varying the illumination in the test set over the range desired. It has the additional advantage that the change in illumination is obtained by turning the disk about its axis, which makes possible a much simpler mechanical arrangement than when using lens attenuators.

The next problem in the design of the test set was to determine the method of collimating the radiation into a parallel beam. This collimator must present a collimated beam at least 4 inches in diameter, and must not distort the resolution patterns in the wavelength range of 0.7 to 1.1 microns. Several optical companies were contacted to determine whether they had available a lens designed for the visible or infrared which would give the necessary resolution in the near infrared region, but no such lens was found. This should not be too surprising, inasmuch as the resolution of image forming devices has always been limited by the image-forming tubes, and optics corrected for the infrared have not come into demand. However, in the case of the optical tester, the quality of the lens is the determining factor, and it must present the desired resolution patterns without distortion. It should be noted that the highest resolution test step is only 15 times the maximum attainable resolution as determined by Rayleigh's formula.

It was finally decided that the simplest and best solution to this problem of resolution would be the use of a parabolic mirror instead of a lens for collimating the radiation. Design work had been carried out on single- and double-component lens systems for the infrared in order to get some idea of the quality of lens attainable for this region. It was found that the aberrations of single- or double-component lenses were higher than could be tolerated, but that a three-component lens would probably give the necessary resolution. However, even if a lens of satisfactory quality were available, there would still remain the problem of testing and aligning it in the region of 0.7 to 1.1 microns. Here again a parabolic mirror has the advantage that all testing and alignment can be done in the visible, inasmuch as neither its focal length nor aberrations vary with wavelength.

DESCRIPTION

The optical arrangement of the test set is shown in Figure 2.

The source of radiation is a calibrated No. 82 incandescent lamp, delivering about 7.8 candlepower when operated at a color temperature of 2850°K. This radiation passes through the circular neutral wedge, which when turned through 340 degrees, varies the transmitted radiation by a factor of 10,000 to 1.

Adjacent to the neutral wedge is a sector disk with 8 indexing positions to locate successively 8 chambers at the focal point of the collimating mirror. Three chambers for sensitivity testing contain opal glass disks, infrared filters, and additional attenuating films. The other 5 chambers contain opal glass disks, resolution test patterns, and attenuating films. The outer surfaces of the opal glass disks are located in the focal plane of the collimating mirror, as shown in Figure 2. The three chambers first mentioned give the following ranges of illumination:

A - 10 to 50,000 n.m.c. of unfiltered radiation for checking the test set alignment.

B - 0.005 to 4 n.m.c. of unfiltered radiation

C - 0.005 to 4 n.m.c. of filtered radiation.

The chambers have a 5/8-inch aperture, so that the test set presents a small circular spot object to the receiver rather than a point object as used in previous test sets. Tests in this laboratory have shown the spot object to be advantageous in making threshold measurements for three reasons: First, a spot image on the receiver more closely simulates the image as received in field use. Second, a point image is frequently lost in the observed field when working near threshold with an instrument of large field of view. Third, local variations in sensitivity over the surface of the receiving element can be detected more easily with a spot image.

The resolution patterns are on a number of reticles which present parallel bars on an illuminated background as shown at the lower left of Figure 2. The reticles are mounted in the chambers on the front disk, and cover a resolution range of 0.5 to 16 minutes of arc. On each reticle, the bottom bars give a pattern of twice the spacing or one half the resolution of the top bars, and the coarse pattern of one reticle is the same as the fine pattern of the preceding. This design permits the observer to compare the definition of the image with that of the next coarsest step. The illumination of the reticles can be varied from 0.05 to 400 n.m.c. by turning the neutral wedge. This increased illumination, which is ten times higher than the threshold range, is necessary inasmuch as the resolution measurements are made at a level greater than threshold.

Attached to the neutral wedge is a drum which turns with it. Sensitivity scales on the drum give the illumination for each of the various chamber positions. The neutral wedge and drum are turned through a chain drive mechanism by the large crank knob below the sensitivity scales. The disk containing the 8 chambers is turned by moving its knurled edge, which extends through the front panel.

After the radiation passes through the neutral density wedge and the particular test or resolution chamber, it is directed by a small plane mirror to the parabolic mirror, which collimates it into a parallel beam.

The mount for the collimating mirror was designed to hold a 6-inch diameter precision front surface off-axis parabola, with a 30-inch focal length and ground9° off-axis. However, because of procurement problems, it was necessary to use a 4-inch diameter mirror of the same focal length but ground 7° off-axis. An adapter was made to permit using the smaller mirror in the 6-inch mount. This makes it possible to change to a 6-inch mirror in the future if the larger aperture is desired.

The collimated radiation emerges through the opening on the right side of the front panel. A mounting bracket is provided to hold the receiver to be tested.

The entire unit is mounted on a 21 by 33 inch cast-aluminum base, with all parts constructed rigid enough so that no optical realignment should be necessary after shipment.

OPERATION

The optical test set is to be installed in an area that can be blacked-out, inasmuch as the user must be dark-adapted to test the image-forming devices.

The test set is connected to a 115 volt 60 cycle outlet. When the switch marked "Power" is in its "On" position both the light source and the pilot lamps are burning. Before this switch is turned on, the rheostat marked "Lamp Current" should be turned counterclockwise as far as it will go, to prevent the power surge from damaging the calibrated lamp. The rheostat should be left in this position to extend the lamp life, the current being increased to calibration value as indicated by the long line on the ammeter, only when making measurements.

The amount of scale illumination is controlled by the rheostat marked "Panel Lamps". This illumination should be kept to a minimum while making measurements, but can be turned up when reading the scales.

The image-forming receiver is mounted in place on the mounting bracket, as shown in Figure 3, and both the receiver and test set are turned on.

For sensitivity measurements, the test chambers A, B, & C are used, covering the following illumination ranges:

A: 10 to 50,000 n.m.c., unfiltered.
B: 0.005 to 40 n.m.c., unfiltered.
C: 0.005 to 40 n.m.c., through a XRX-7 filter.

The crank knob is turned until a disk of light is visible in the receiver. The illumination is then decreased until the disk of light is just visible. The threshold sensitivity is then read off of the sensitivity scales, using the scale corresponding to the test chamber being used.

To measure resolution, the disk chambers are rotated until the one marked 8.0/16 is in position, and the illumination is adjusted to a value of ten times the threshold illumination (this factor of ten is an arbitrary value used by other workers in the design of previous test sets). The viewer is then focused, both optically and electrically, until the lines in the resolution pattern are in best focus. One then proceeds to closer-spaced patterns to the point where the lower half of the pattern is resolved but not the upper half. The resolution of the image-forming receiver is then between the two values indicated in the window labeled "Resolution". These two values are given in minutes of arc.

MAINTENANCE

The electrical circuit of the Z-4x test set is shown in Figure 4. The source lamp is a No. 82 lamp, selected so that at a current of 1.08 amperes, the color temperature is 2850°K and the intensity is 7.8 horizontal candlepower. There are two resistors in series with this lamp, one within the test set for a coarse adjustment when installing a new lamp, and the fine adjustment on the front panel.

To replace the source lamp and adjust the associated coarse resistance, it is necessary to remove the test set cover. This is done by removing the power cord and removing the screws from each bottom edge, one from the top, and one from the back of the cover. The cover can then be slid toward the back and lifted off.

To replace pilot lights it is necessary to remove the front panel. To do this, the following procedure is used: (1) The power must be off and the top cover removed. (2) The terminal strip (see Figure 5) is removed from the terminal board, and the two cable clamps holding the cable to the base are removed. (3) After removing the 7 panel screws and the crank knob, the panel can be removed.

To change the amount of attenuation, filtering, or test patterns in the test chambers, the disassembly above is continued in the following manner: (4) Loosen the screws holding the small gear box to the base, so that the chain can be removed from the gear box sprocket (see Figure 6). (5) Remove the Allen-head cap screws holding the bearing pedestal to the base, and drive out the locating pins from beneath the base (see Figure 7). (6) The bearing pedestal is then slid off the shaft after removing the nuts and washer from the end of the shaft. There are two washers on the shaft (one on each side of the bearing) and these must not be interchanged, inasmuch as they position the resolution patterns at the focus of the parabolic mirror. (7) With the pedestal removed, the entire shaft and drum assembly can be removed by sliding the other bearing out of its housing in the central vertical base member. (8) To remove the neutral filter and associated plastic drum from the sector disk holding the test chambers, the shaft to which the chain sprocket is attached is slid off the inner shaft. The present make-up of the test chambers is given in Figure 8.

The optics should require little attention, except to be kept covered to prevent the accumulation of dust and foreign matter.

RECOMMENDATIONS

The Z-4x test set Serial No. 241 was designed and built to be a prototype, to be followed by five more test sets incorporating desirable changes and improvements. However, funds were not available to go beyond the prototype stage. For this reason, changes which appear desirable from experience with the prototype model as discussed below.

First, provisions should be made for changing the lamp without the necessity of removing the cover. This would be possible by putting an auxiliary opening in the side of the cover near the source housing and redesigning the housing slightly.

Second, it should be made possible to change the test chambers without the necessity of removing the front panel and dismounting the entire assembly. This could be done by redesigning the test chambers slightly and putting a large access hole (about 2-inch diameter) in the central vertical base member.

Third, it would be desirable to have an independent control for placing one or more filters in the optical path when desired. At present, any filter material must be placed in the test chambers, making it a difficult change. A separate control for inserting filters would require some change in the design of the density-wedge mechanism and the test-chamber disk.

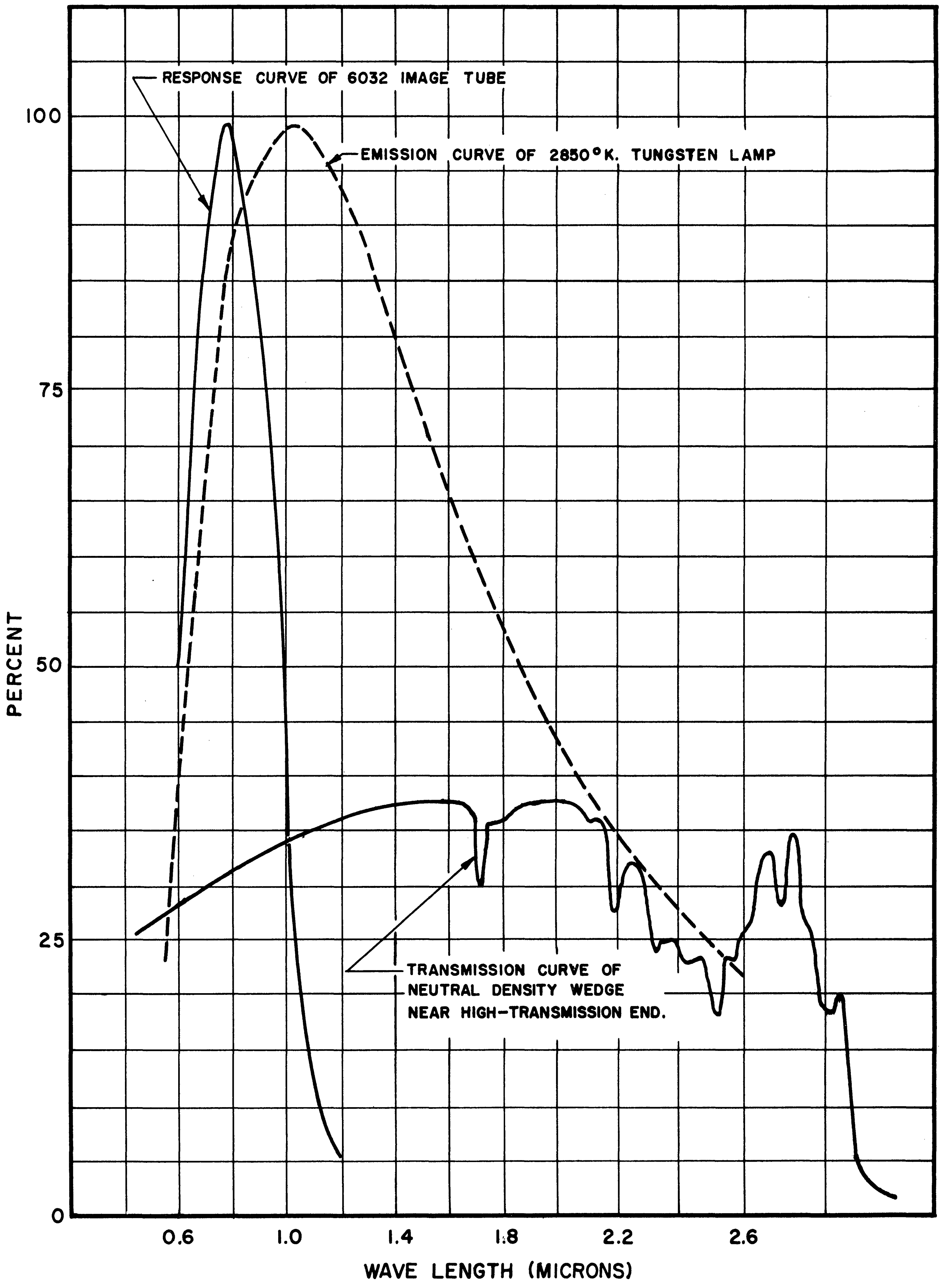

RESPONSE CURVE OF 6032 IMAGE TUBE
EMISSION CURVE OF 2850°K. TUNGSTEN LAMP
TRANSMISSION CURVE OF
NEUTRAL DENSITY WEDGE
NEAR HIGH-TRANSMISSION END.
100
75
50
25
0
PERCENT
0.6
1.0
1.4
1.8
2.2
2.6
WAVE LENGTH (MICRONS)

FIGURE I

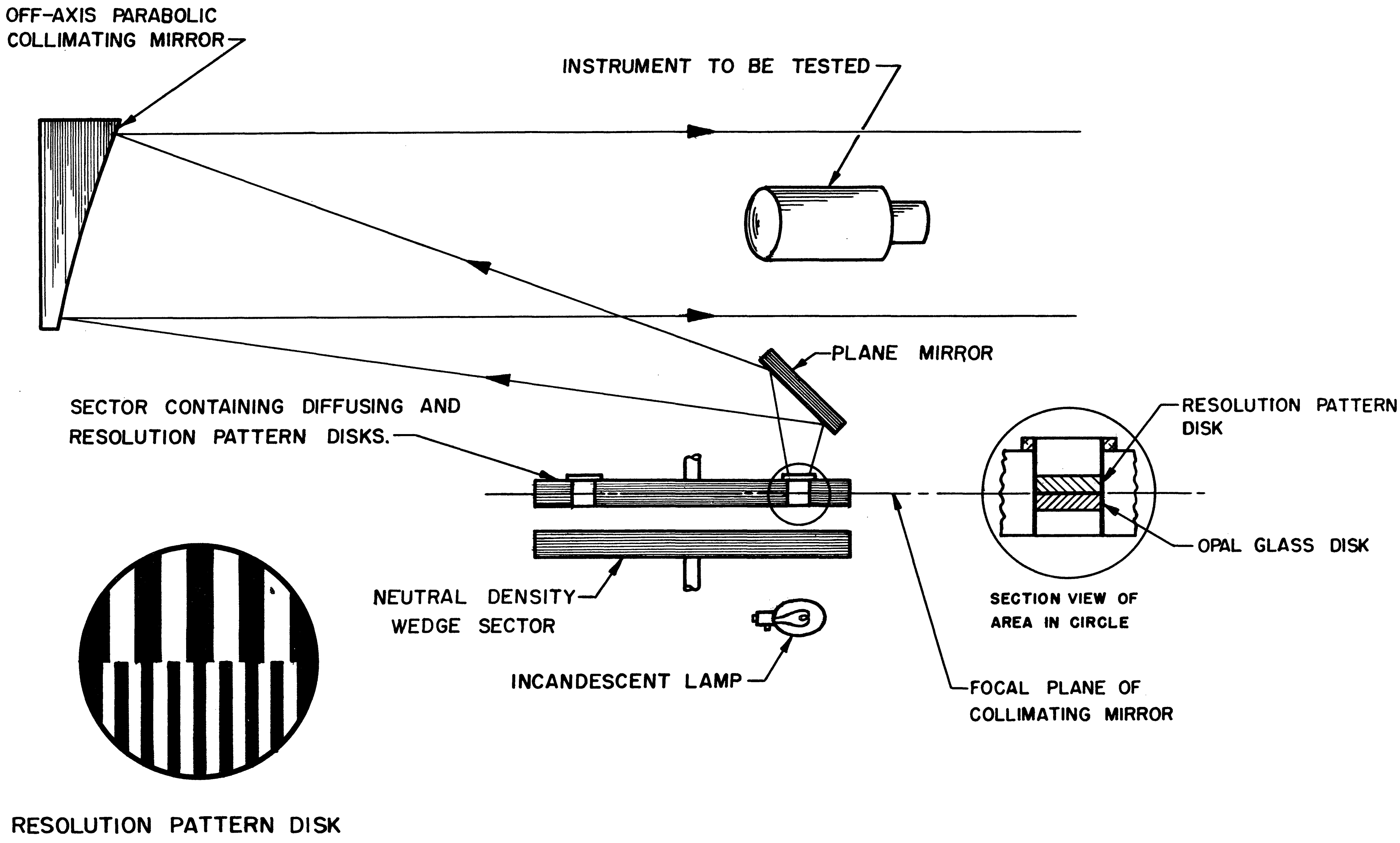


FIGURE 2. OPTICAL LAYOUT OF Z-4x TEST SET.

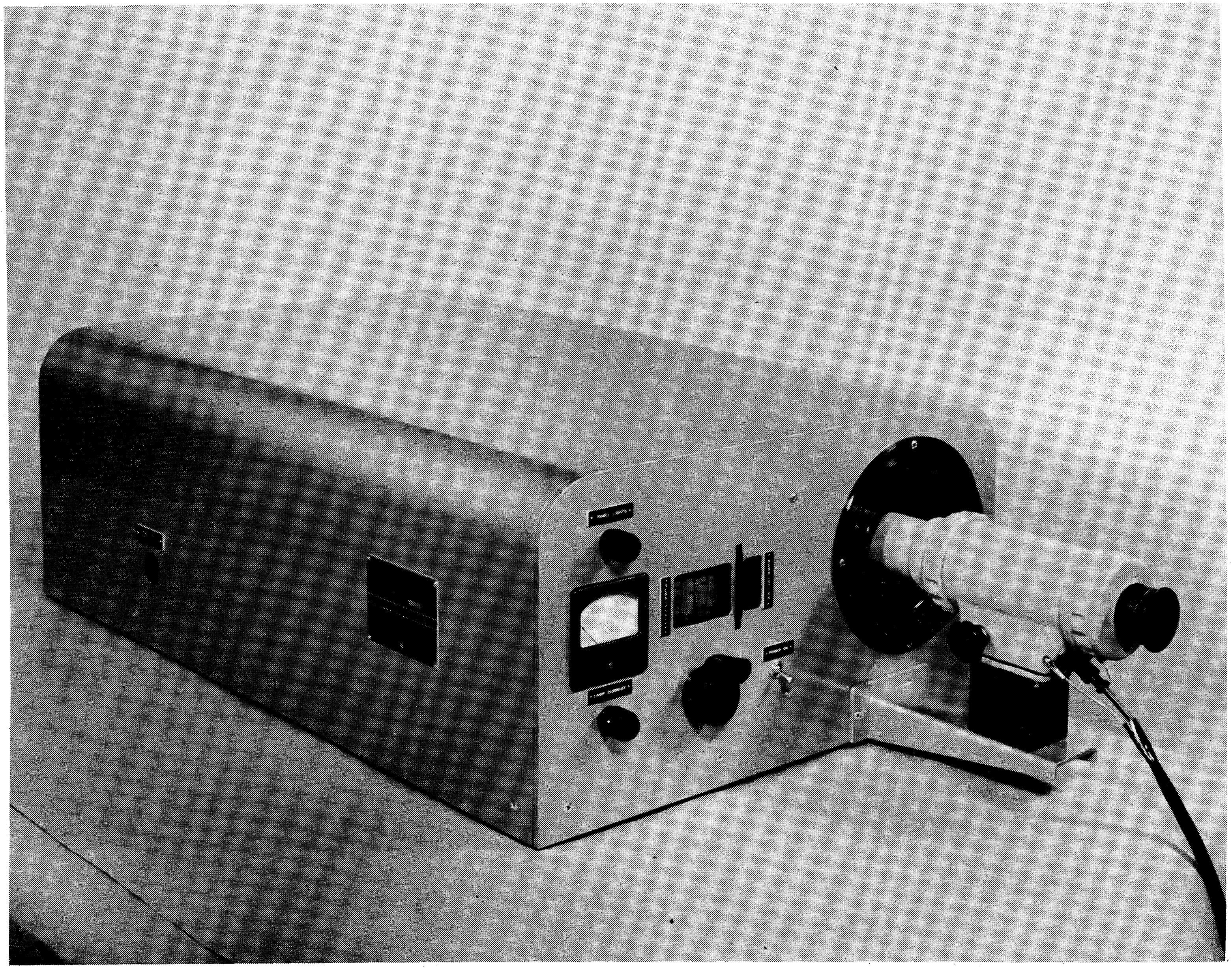
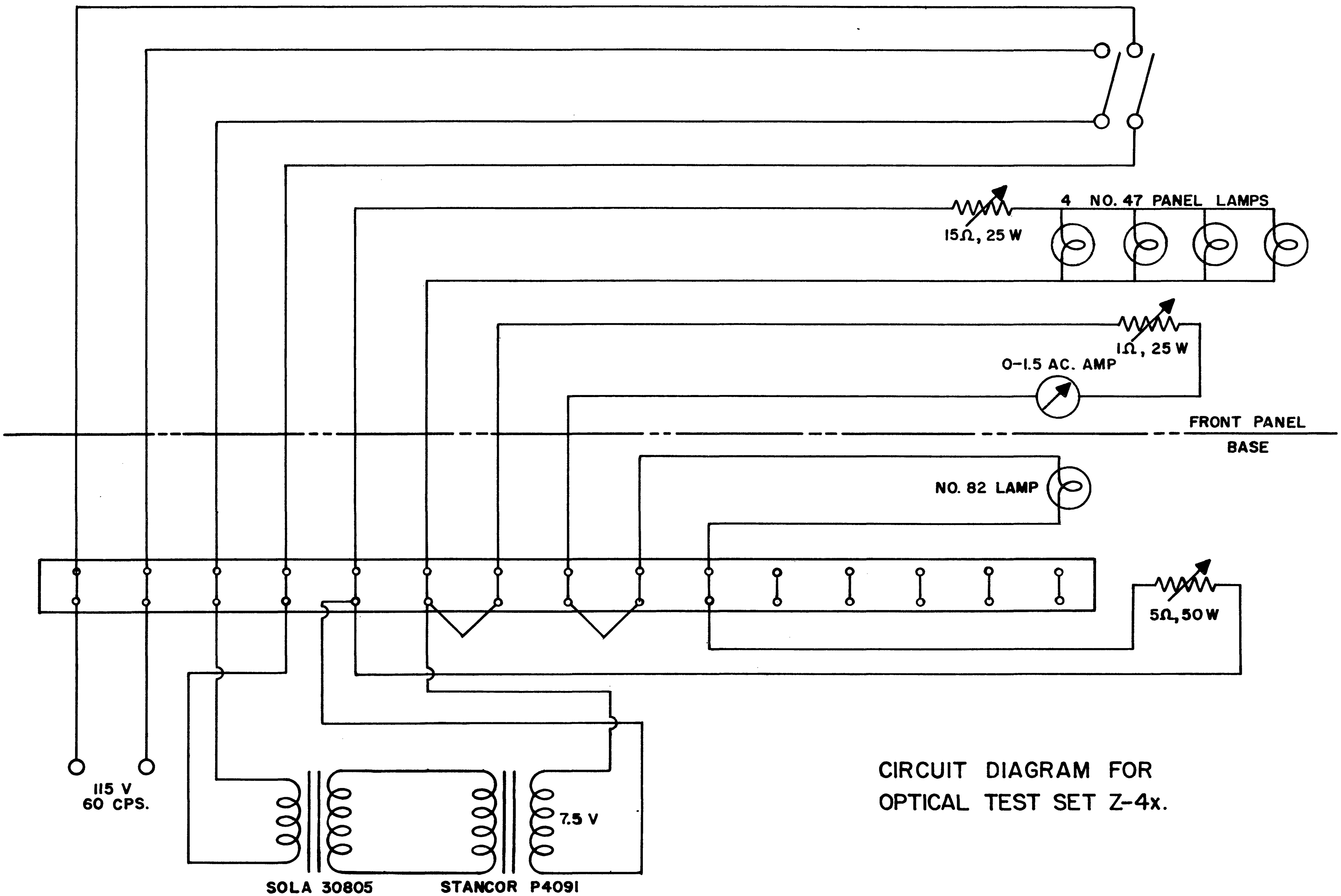


Figure 3. Z-4x optical test set.



CIRCUIT DIAGRAM FOR
OPTICAL TEST SET Z-4x.

FIGURE 4.

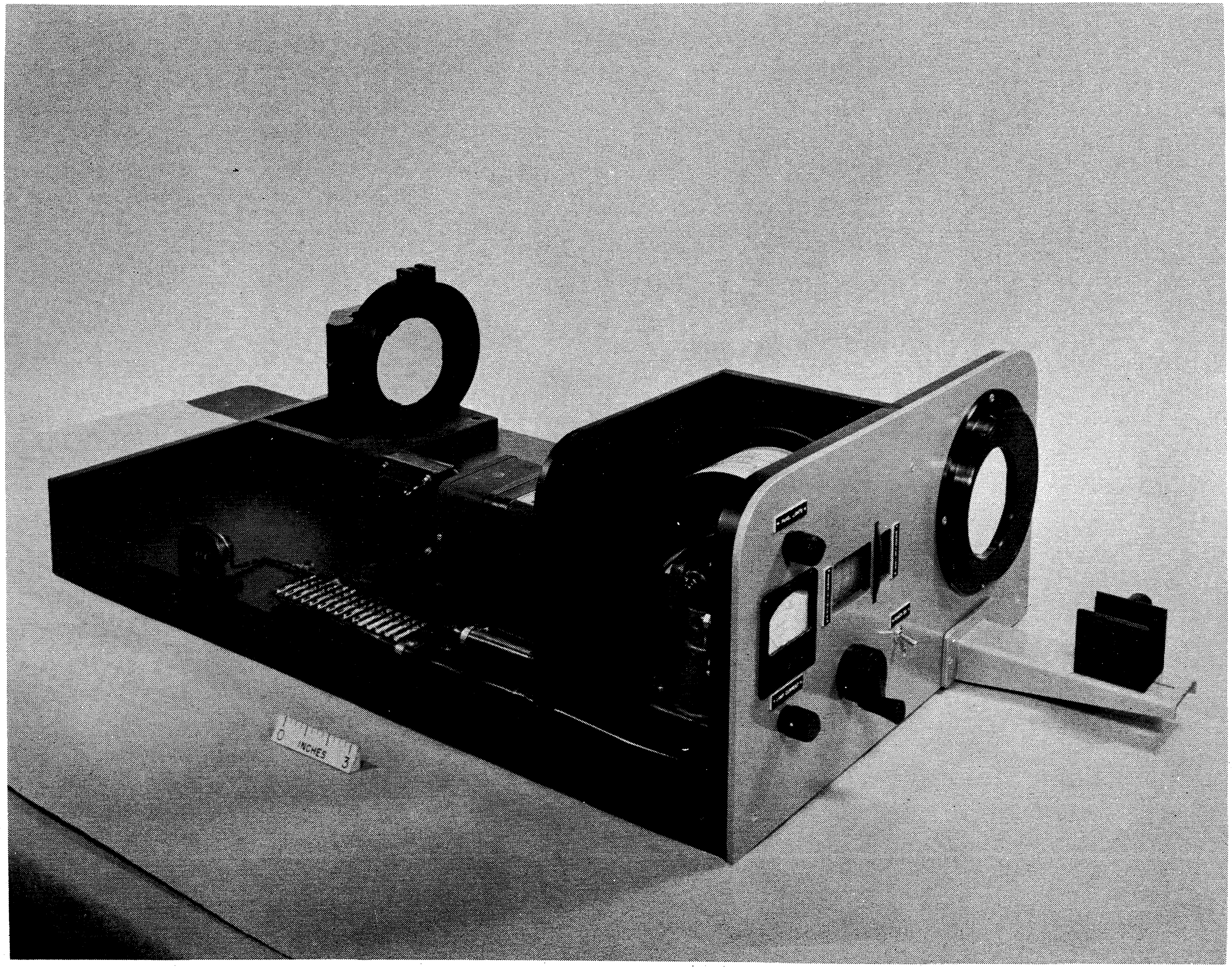


Figure 5. Z-4x optical test set: cover removed.

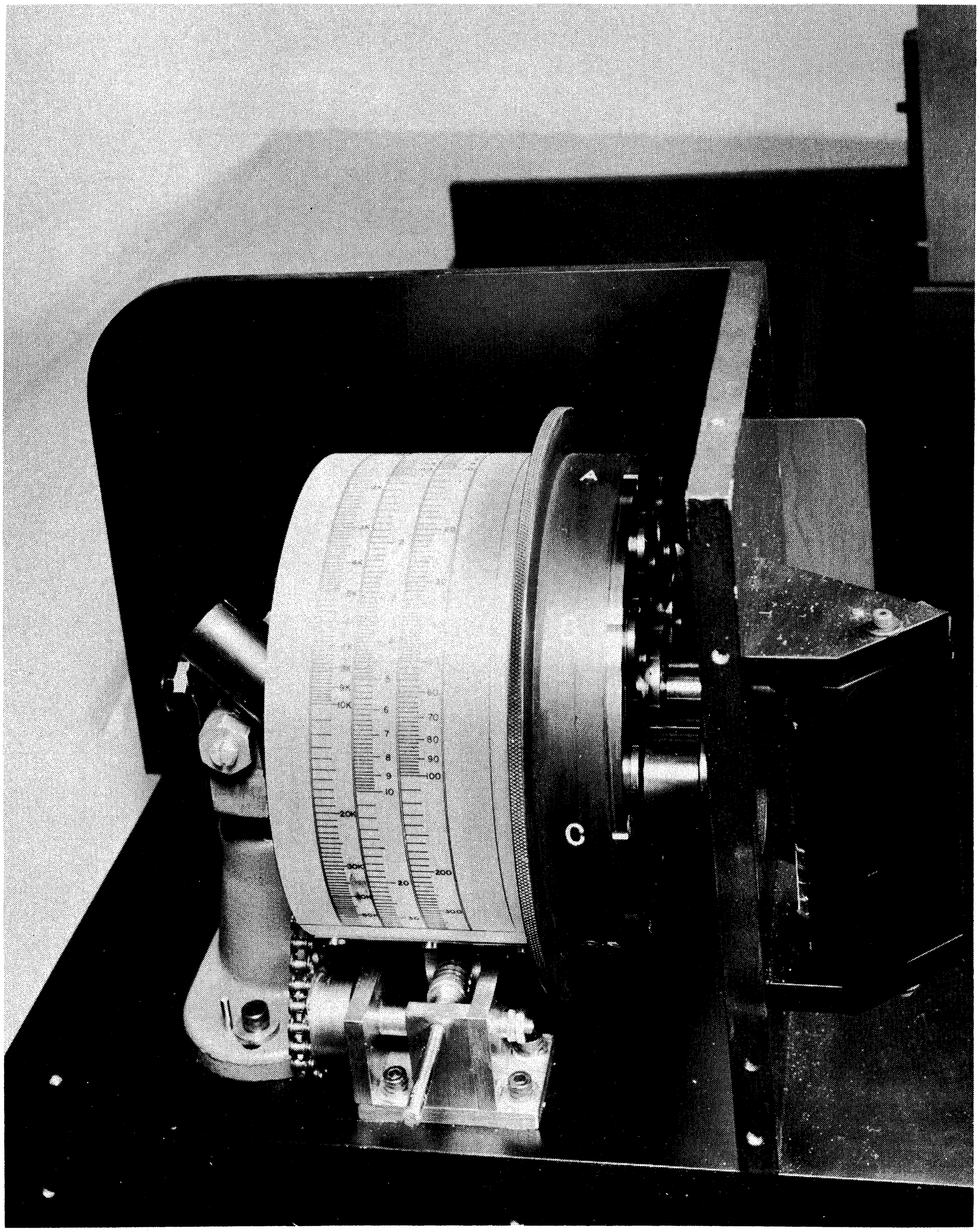


Figure 6. Photograph of resolution test chambers.

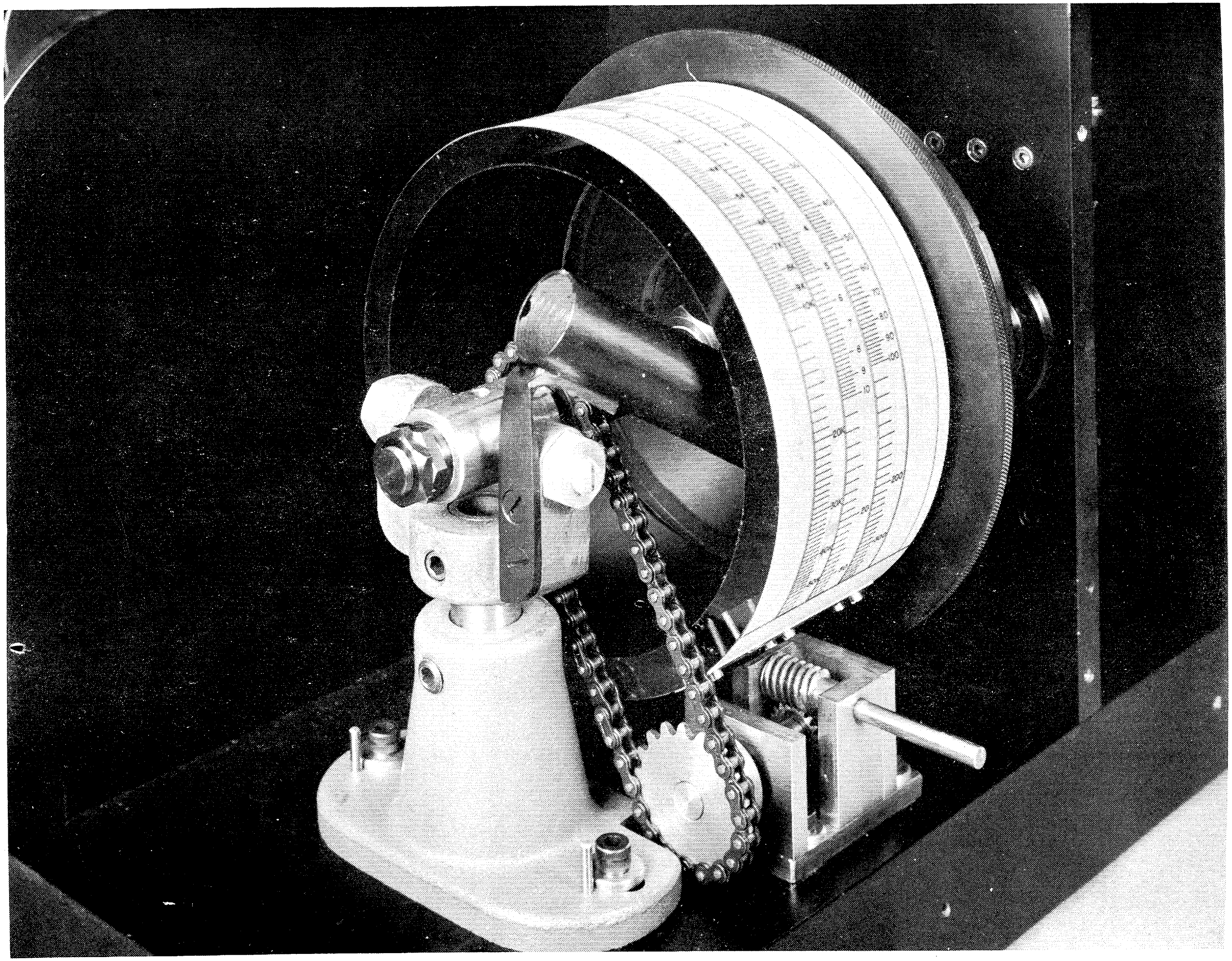


Figure 7. Photograph of drive mechanism.

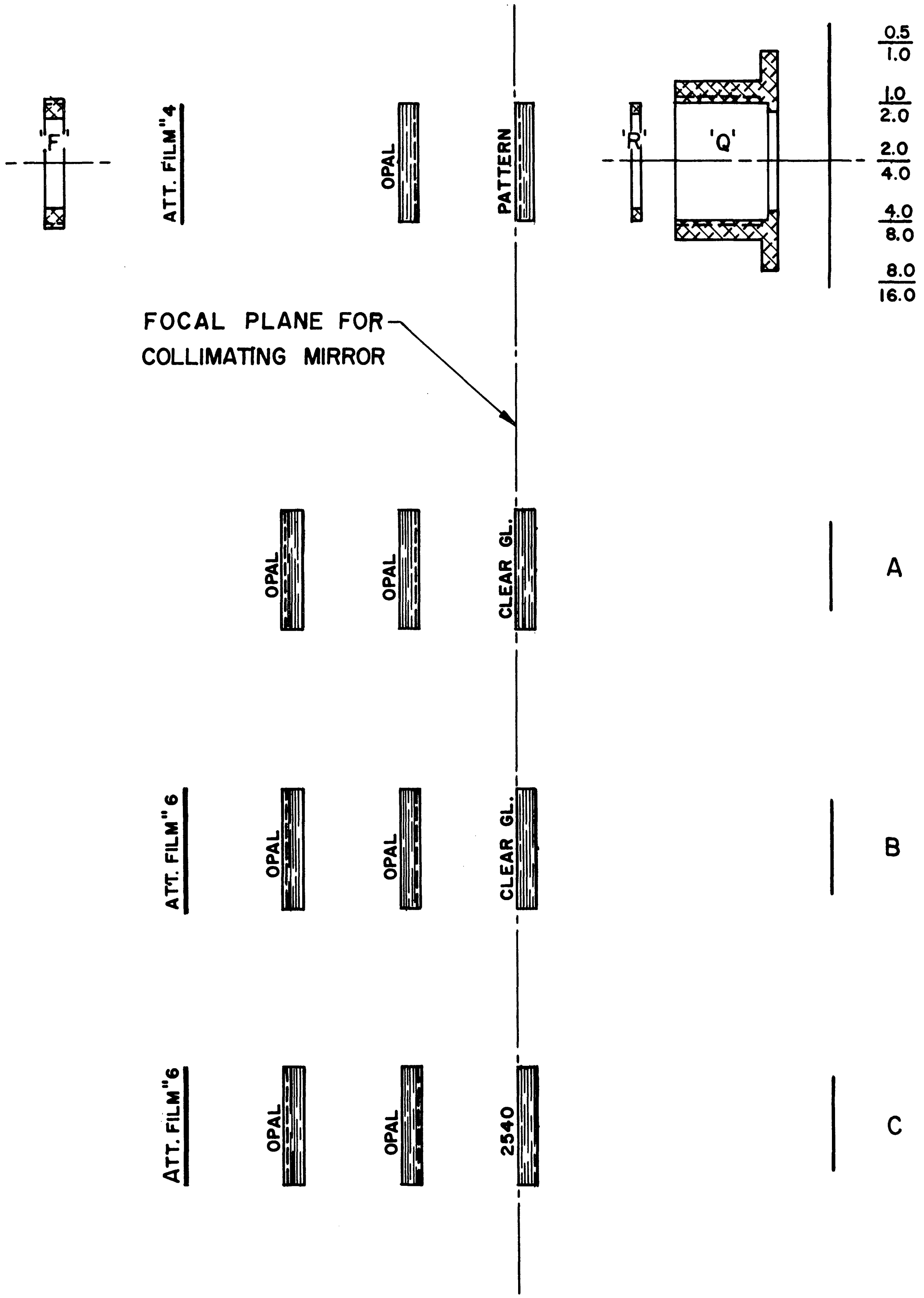


FIGURE 8. TEST CHAMBER ASSEMBLY
FOR OPTICAL TEST SET Z-4x.