CONSTRUCTION OF A GONIOMETER FOR USE IN DETERMINING THE CANDLEPOWER CHARACTERISTICS OF BEACONS

By

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National Bureau of Standards

Technical Development Report No. 39

February 1944

U. S. DEPARTMENT OF COMMERCE

CIVIL AERONAUTICS ADMINISTRATION

WASHINGTON, D. C.

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CONSTRUCTION OF A GONIOMETER FOR USE IN DETERMINING THE CANDLEPOWER CHARACTERISTICS OF BEACONS

SUMMARY

This report describes the construction and testing of a goniometer of sufficient capacity to mount a Civil Aeronautics Administration 36-inch double-end beacon or a 60-inch reflector. This goniometer was designed to rotate this equipment through horizontal and vertical angles, and to set and hold these angles to an accuracy of ±0.01° about either axis.

The goniometer was built on the frame and mounting of an obsolete 60-inch coast defense searchlight.

INTRODUCTION

In order to test the distribution of a light projector in the laboratory, a photometer is set up at one end of a photometric range, and the projector is mounted on a goniometer at the other end of the range. The goniometer consists of a mounting platform which is designed so that the projector can be set accurately at any desired angle, either vertical or horizontal, from the line joining the projector and the photometer. With the light projector so mounted, it is rotated about the horizontal axis and the vertical axis so that any desired portion of the beam will fall on the photometer. By this means traverses are taken through planes across the beam, and measurements are made by means of the photometer.

A goniometer for this purpose must be rigid in any setting and must provide means of reading accurately the horizontal and vertical angles at which the light projector is set. The actual positioning of the projector with respect to the horizontal and vertical axes of the goniometer is of less importance than the angle, as the resultant errors caused by a shift of position are relatively minor at the range employed.

Where large equipment, such as a 36-inch beacon or a 25-inch floodlight, is to be tested on a goniometer, the physical requirements for rigid positioning require an exceptionally sturdy and rigid mechanism.

REQUIREMENTS

The goniometer must provide a table on which lighting units can be mounted and rotated about either a vertical or a horizontal axis. The equipment should be built to carry a beacon as large as the C.A.A. 36-inch beacon. Preferably it should be so designed that a 60-inch reflector can be mounted for rotation in place of the beacon as the use of such reflectors for aviation beacons is a future possibility. The goniometer should be constructed with sufficient rigidity and precision that angles may be set and held with a reproducibility of ±0.01° about either axis. The angular measurements should be accurate within ±1 percent for angles down to 2°. As this is the width of the narrowest beams which have to be considered, it is not necessary to maintain this accuracy for angles smaller than 2°. This limit requires an accuracy of ±0.2° on small angles with a larger tolerance possible on larger angles.

CONSTRUCTION

Prior to actual design and construction of the goniometer, since the funds for this project were limited, it was decided to make a careful search of obsolete Army and Navy equipment which could be utilized and readily made available to the Civil Aeronautics Administration. Having in mind the need for considerable capacity and great rigidity, a surveyed 4-inch gun mount was obtained through the courtesy of the Bureau of Ordnance, Navy Department. This gun mount seemed to provide a satisfactory vertical axis, but the trunions of the gun were too close together to be used for the horizontal axis A surveyed 60-inch coast-defense searchlight was then obtained through the courtesy of the United States Engineer Board with the idea of mounting the arms and trunion bearings of the searchlight on the gun mount

Upon receipt of the 60-inch searchlight, it seemed advisable to determine how accurately and reproducibly angles could be set with the bearings provided in the searchlight The results were so satisfactory that it was decided to use the searchlight for both the vertical and the horizontal bearings.

Figure 1 is a reproduction of a picture of this type of projector and shows the appearance of the searchlight as it was received The front and rear covers, the sheet metal work, and all the various accessories were removed from the framework of the drum leaving a cradle in which to mount beacons The handwheels and training mechanism were removed leaving, however, the principal horizontal gear and vertical sector, together with the pinions which engage in these gears This left the base, turntable, trunion arms, and skeleton of the drum.

The old gearing was removed because of the play and friction in these gears which made it impracticable to set angles with the required precision. This gearing was replaced by two commercial 18-1 reduction gears mounted on one of the trunion arms and connected to the old pinions With the 18-1 ratio, one complete rotation of the handwheel shaft produces one degree of rotation of the goniometer table Two discs, each divided into 100 equal divisions by marks around the periphery, were attached as handwheels Notches were cut at 5-division intervals in each handwheel, and spring catches were provided to engage in these notches. This is a convenience in setting angles at 0.05° intervals, which is a common practice in making traverses through portions of beams that vary rapidly in intensity

Figure 2 is a photograph of the goniometer with the drum of a 24-inch rotating beacon mounted in place for photometry

Figure 3 is a photograph showing the angular setting controls and the measuring device of the goniometer.

The goniometer table was constructed from six 3-inch steel channels One of these was mounted across the lower part of each of the two drum rings, as may be seen in figure 2 The other four were assembled in pairs with spacers to make two movable tracks These tracks are supported on the single channels to which they may be bolted in any convenient position. The unit to be measured is bolted in turn to the tracks The bearing surfaces of the channels were machined to provide positive contact This arrangement has been found convenient for the mounting of a variety of different types of lighting units.

It was not necessary to provide for the vertical centering of the test units in the goniometer because calculation indicated that the extreme errors due to incorrect centering are negligible For example, suppose that a unit is mounted so that its center is 2 feet above or below the center of the goniometer For a vertical rotation of 30° there will be an error of 0 2 percent in the candlepower reading due to the change in photometric distance There will be a corresponding error in the vertical angle reading of 0.015° These errors are negligible, whereas the conditions assumed are extreme Errors in practice are much smaller

RESULTS

Data shown in figures 4, 5, and 6 show the results of checks on the accuracy of the angular settings of the goniometer. A theodolite was mounted on the goniometer and suitable targets and tangent scales set up at the opposite end of the photometric range The theodolite verniers for the horizontal angles were graduated in 10-inch intervals and the verniers for the vertical angles in 30-inch intervals Two verniers were each read once for each angle measured The precision of reading, therefore, was ±0 0015° for horizontal angles and ±0.004° for vertical angles, read with the theodolite

Figure 4 gives the results of a check on the axes of rotation. The theodolite was leveled and aligned on the target The goniometer was then rotated horizontally about its vertical axis of rotation through a given angular interval and the theodolite rotated horizontally about its vertical axis until it was aligned with a vertical line through the target The vertical angular displacement between the target and the direction of alignment was read on the tangent scale and recorded as the deviation This was repeated for several horizontal angles

A similar procedure was followed to check the vertical rotation, except that the alignment of the axis of the theodolite and the axis of the goniometer, with respect to azimuth, was approximate. The deviations shown in figure 4 for the horizontal axis may have been the resultant of several errors, including a small horizontal angle between the horizontal axes of the goniometer and the theodolite, which is of no interest

Figure 5 shows the results of measurements of deviations of the horizontal angle readings from those measured with the theodolite The squares represent the deviations for an independent group of settings made to check the reproducibility.

Figure 6 gives the results of similar measurements on vertical angles In use, the goniometer may be loaded so as to apply a varying torque to the cradle about its horizontal axis of rotation Three sets of readings were accordingly taken with different loadings In the first set, indicated by squares in figure 6, there was no load on the goniometer In the second set, indicated by circles, a torque of approximately 150 pound-feet was applied at the center of the rear mounting ring of the goniometer In the third set, indicated by triangles, a torque of 150 pound-feet was applied to the rear ring about 2 feet from the vertical plane through the center

The data indicate that the axes of rotation are fixed within approximately ±0 01°, and that the horizontal angle scale readings vary from theodolite measurements by approximately ±0 01° for the angles tested. These results are within the requirements

Over a traverse of 20° , the maximum deviations for the vertical angle are approximately ±0 04° This error covers unusually extreme conditions Under the no-load condition, the mounting frame passes a balance point during the traverse The blacklash, taken out at the start, reappears during the traverse In practice, it is desirable to avoid loading the goniometer in such a way as to pass a balance point during a traverse Notwithstanding the extreme loading conditions, the vertical angles for any one setting agree within ±0.015° The symmetrical and asymmetrical loadings gave vertical angle readings which agree within ±0 005°, which is close to the precision of reading

CONCLUSION

This project accomplished the construction of a practical and effective goniometer The tests indicate that for both vertical and horizontal rotation, the accuracy of readings and the reproducibility of settings are within the limits of accuracy required. The goniometer adds a valuable facility in making test measurements on large and bulky lighting projects

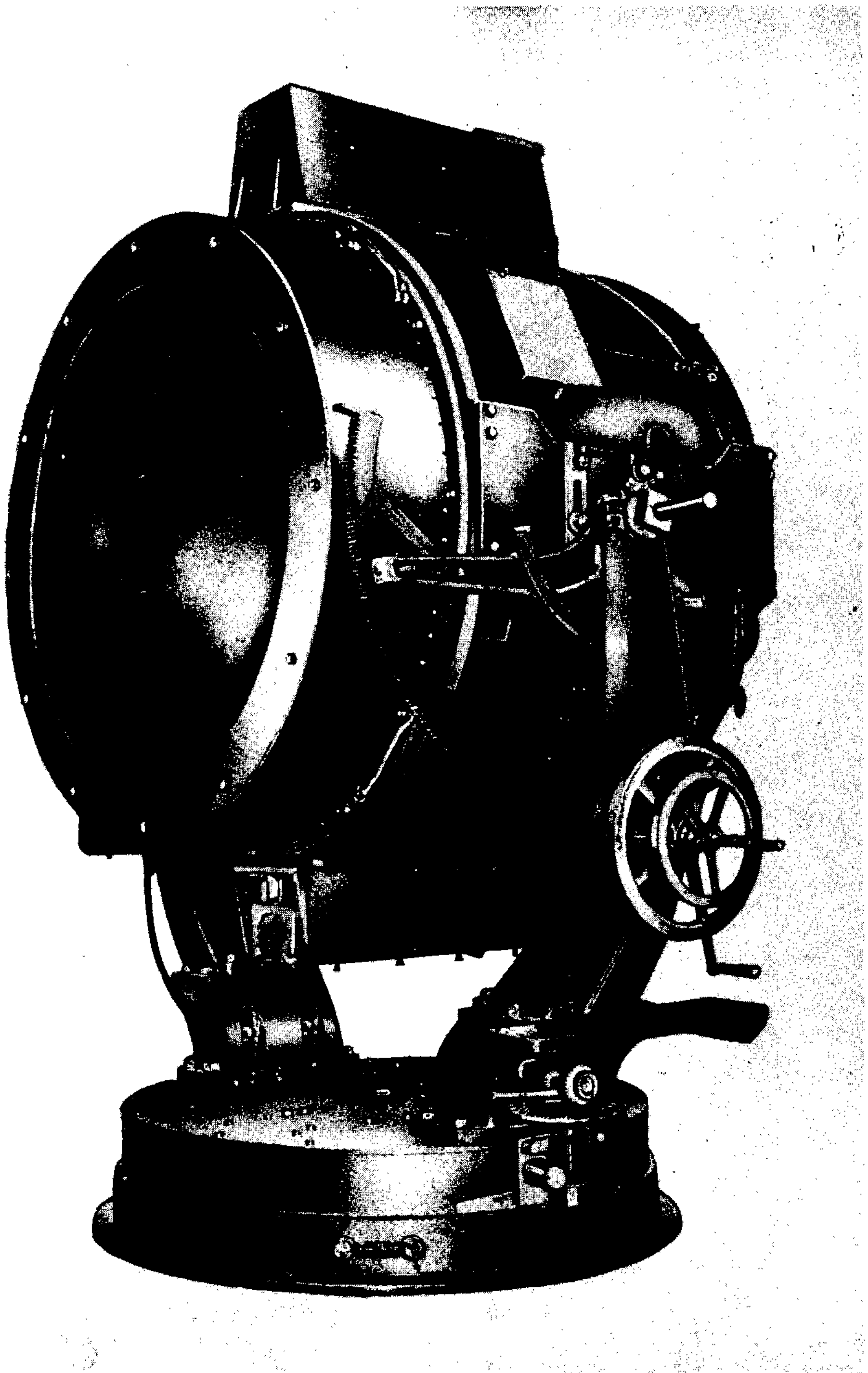

FIGURE 1. Side View of Original Searchlight Projector.

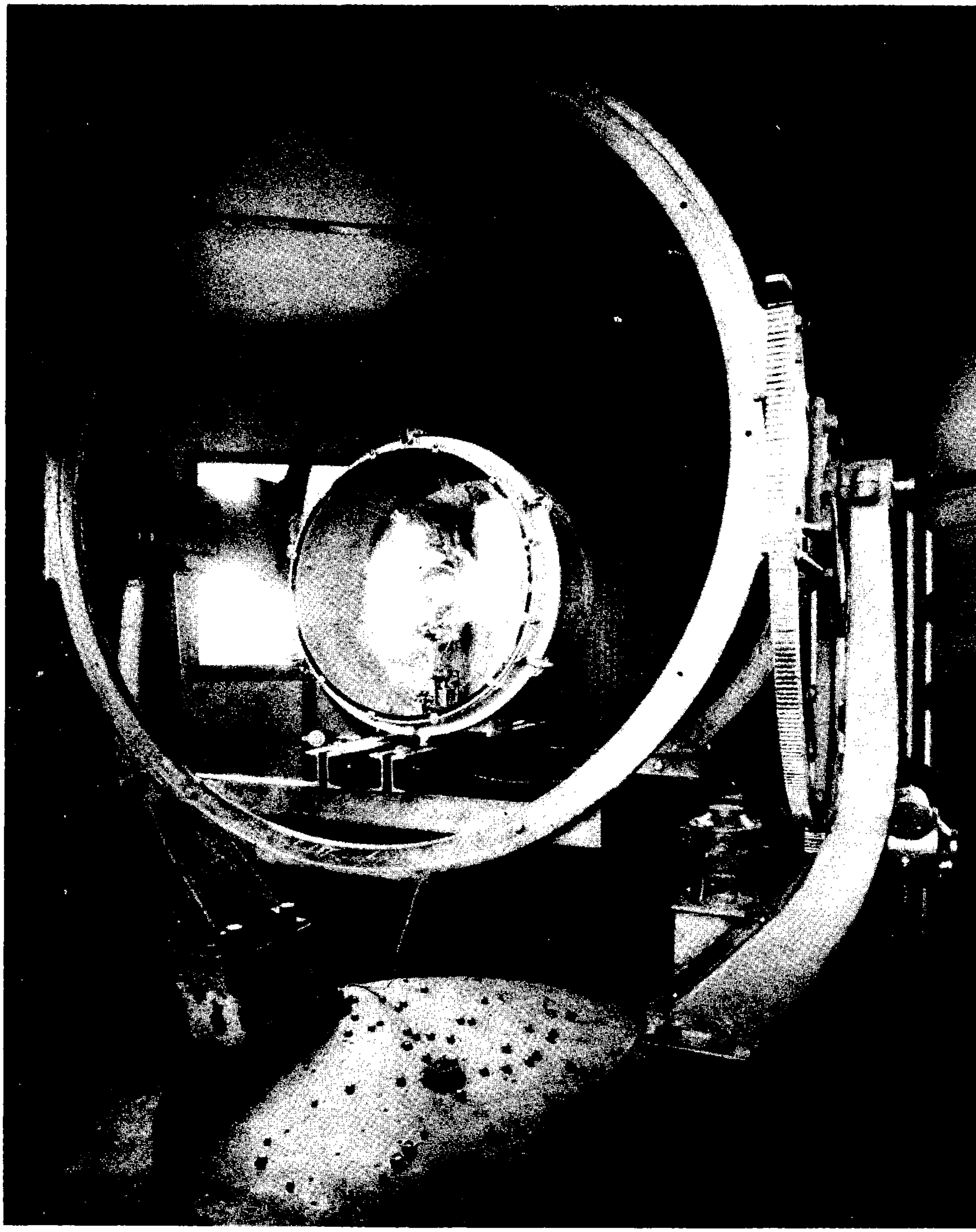

FIGURE 2. Goniometer Showing 24-Inch Projector Mounted for Test.

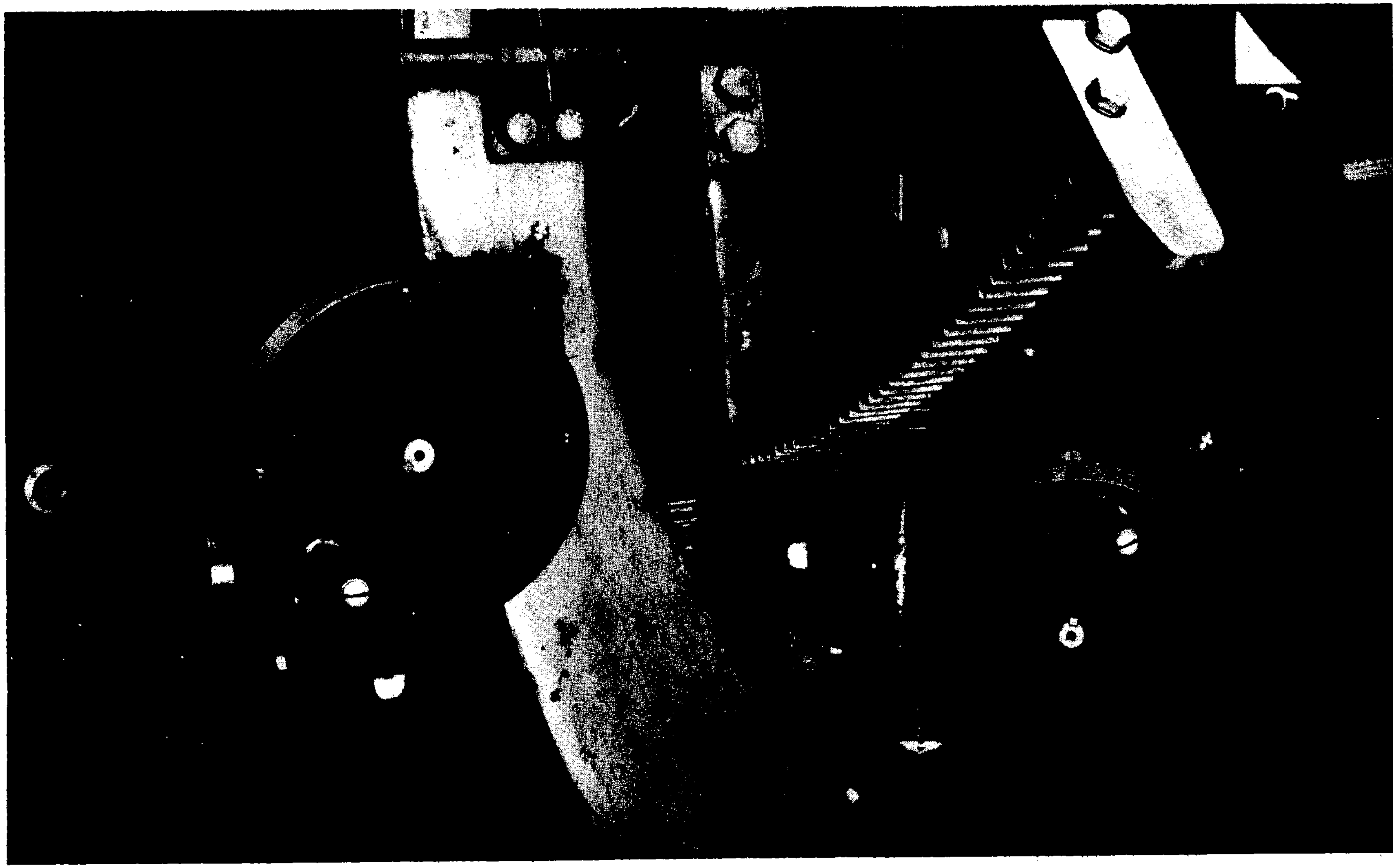

FIGURE 3. Detail of Setting Control.

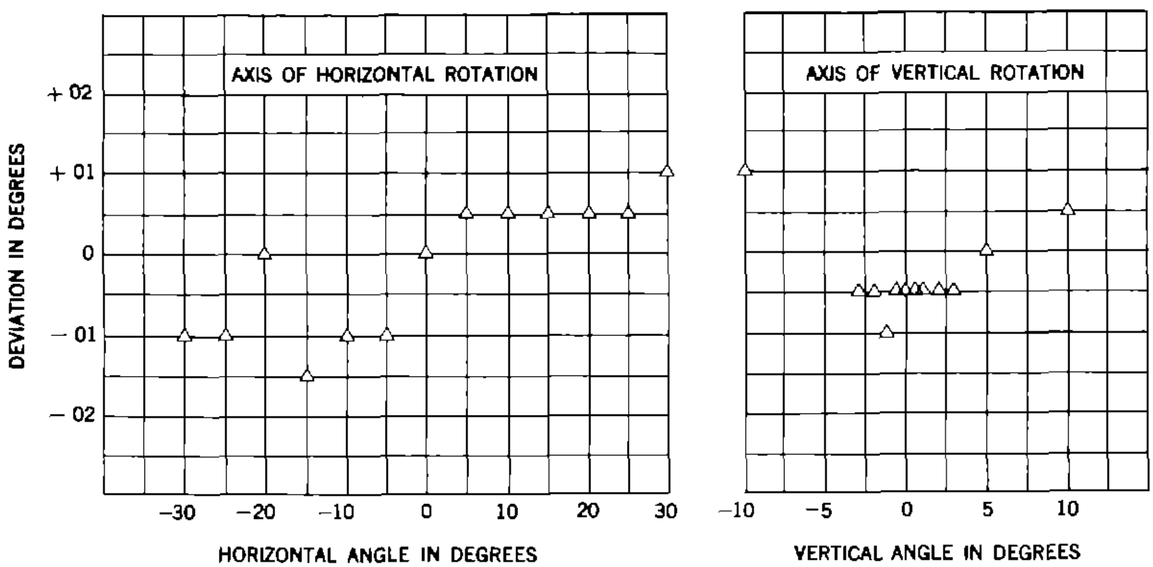

FIGURE 4. Deviation of Axis of Rotation
300-Meter Range Goniometer

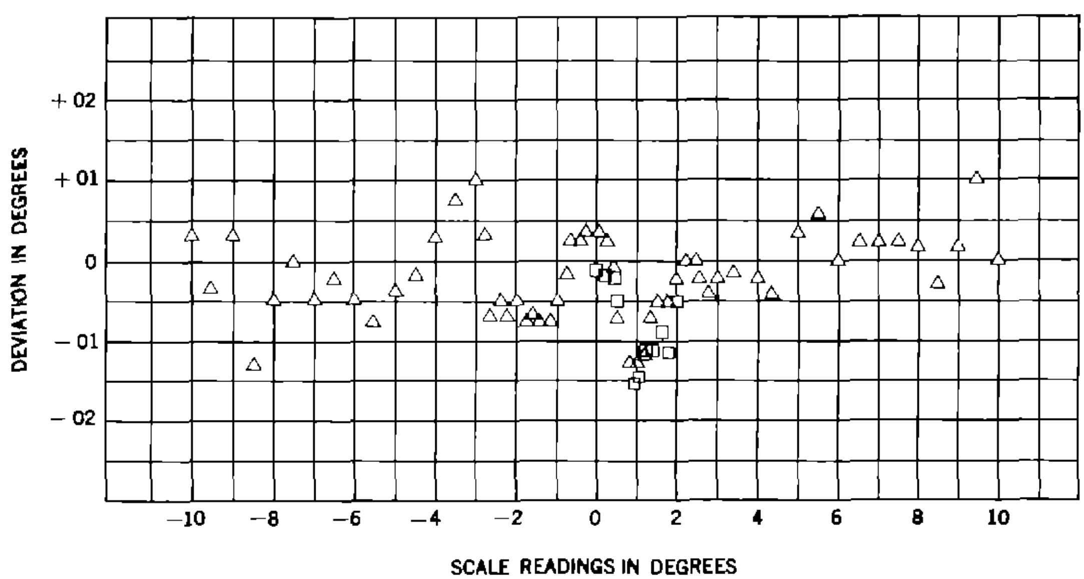

FIGURE 5 Deviation of Horizontal Angle Scale Reading
300-Meter Range Goniometer

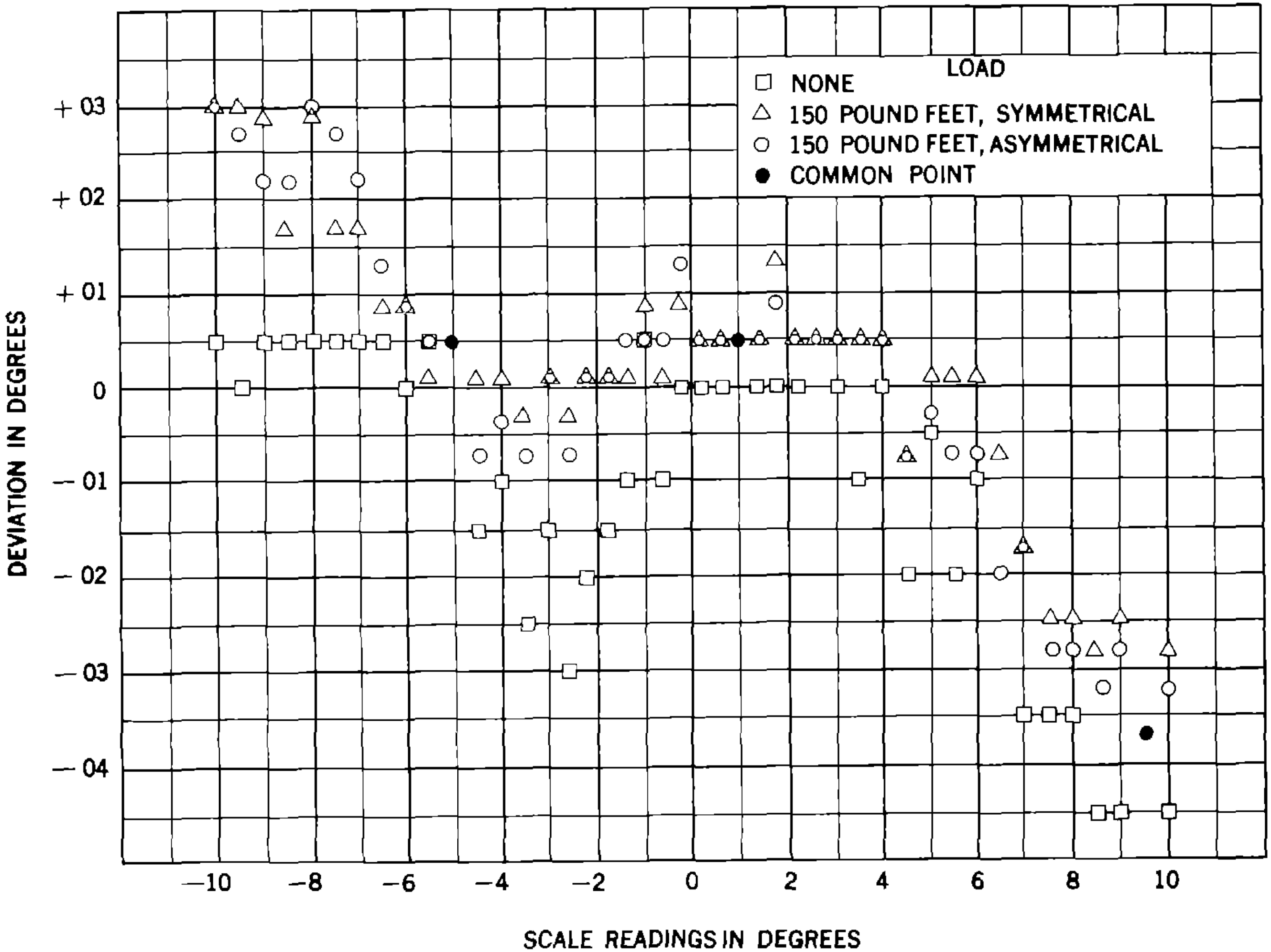

FIGURE 6. Deviation of Vertical Angle Scale Reading
300-Meter Range Goniometer.