Procedure Title:	Procedure for the Calibration of Angle Blocks by Comparison (14010)
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Revision/Date:	Revision 1, February 24, 2004
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1.0 Scope

The purpose of this procedure is go give detailed instruction on measuring angel blocks by comparing the test blocks to the NIST Master blocks using two autocollimators as the comparator. The procedure gives instructions for preparing the blocks for test, setting up the equipment, making the measurements, entering the data into the computer, analyzing the data, and preparing a calibration report. It assumes the angle blocks are the standard set of 16 blocks (1, 3, 5, 20 and 30 arc seconds, 1, 3, 5, 20 and 30 arc minutes, and 1, 3, 5, 15, 30 and 45 degrees). It also assumes the blocks are the standard size, which is has faces that are approximately 25 mm by 50 mm.

2. Definitions

Cross talk – the vertical angle read due to improper rotational alignment of the autocollimator when the instrument is set to read a horizontal angle, or the horizontal angle read when the autocollimator is set to read the vertical angle.

3.0 References

Reeve, C.P., The Calibration of Angle Blocks by Intercomparison, NBSIR 80-1967, NIST, 1980.

Reeve, C.P. The Calibration of Indexing Tables by Subdivision, NBS Internal Report 75-750, 1975.

Hume, K.J. Metrology with Autocollimators, Hilger and Watts, Ltd, London, 1965, Chapters 6 and 7.

T. D. Doiron and J. R. Stoup, “Uncertainty and Dimensional Calibrations,” Journal of Research of the National Institute of Standards and Technology, Volume 102, pp.647-676, 1997.

4.0 Equipment List

Two Davidson D-800 autocollimators with 0.01 second resolution
Two Davidson D-665 autocollimators with 0.1 second resolution
Two Kepco 0-20
Data acquisition system to add or subtract the output voltages from the autocollimators and display results
Moore rotary table with 1 second resolution
Interferometer for measuring flatness

5.0 General

NIST measures customer angle blocks by comparing the test blocks to an NIST master block using an autocollimator as the comparison device. The measurement can be made with one autocollimator. By placing the first master block against a stop and nulling the autocollimator, and then replacing the master block with the test block, the autocollimator will read the difference in the angle of the two blocks. Because it is difficult to position the blocks in exactly the same position, two autocollimators are used in a differential mode.

In most sizes of blocks, the limitation in accuracy is the block geometry, not the method of measurement. Blocks with large flatness errors tend to give different readings when measured in different orientations. They also tend to give different readings in the same orientation if the autocollimator is changed. The first part of any calibration is to check the flatness of the faces. the flatness should be checked with the Zygo Phase-Shifting Interferometer if they have not been previously measured for flatness. The results should be recorded for use in determining the uncertainty budget.

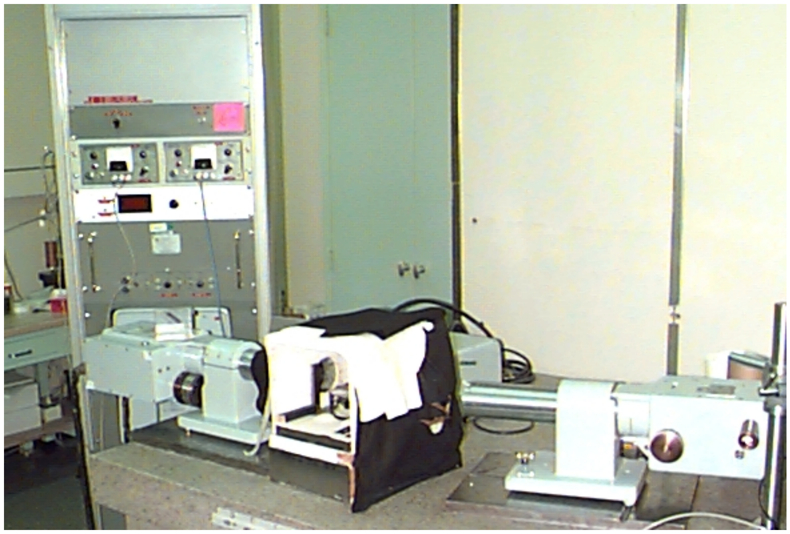
6.0 Setup

6.1 Block Preparation

If the blocks have been coated in heavy grease, which is unusual, they should be cleaned in the Varsol tank. Clean each block individually so they cannot bump together and damage the gaging surfaces. After cleaning in Varsol, or for most blocks shipped with a coating of light oil, clean each block individually with ethyl alcohol to remove any dirt or oil on the surfaces. The cleaning should consist of a first cleaning using a clean cloth and alcohol and a second stage where the alcohol film left is wiped from the block using a lint-free tissue. Do not leave a coating of alcohol on the blocks, especially the steel blocks, as alcohol absorbs some water from the air during storage and use, and the water can produce rust on the steel blocks. Place the blocks for each set to be calibrated in wooden trays near the measuring equipment. Keep the blocks covered when not in use to avoid gathering dust on the surfaces.

6.2 Equipment Used

The calibration is made using two autocollimators in a differential mode. Two model D-800 Davidson autocollimators are set on opposite sides of the angle block fixturing box, as shown in the figure.



The central box holds a serrated anvil with two brass positioning pins glued to the surface. The ends of these pins are the reference points for positioning the angle blocks. The box has a cloth cover that should be closed during the measurement to prevent air currents that make the autocollimator output noisy.

In an initial setup the stops on the autocollimators should be set so they rotate 90 degrees (± a few seconds) when they are rotated against the stops. The stops must be set so there is no cross talk in the autocollimator. Each autocollimator should also be checked to see if the readings on a flat mirror are the same for each quadrant of the beam. This is done by placing a mask over the end of the barrel which allows light in only one quadrant, and then rotating the fixture and observing the readings. The readings should not change by more than 0.10 second.

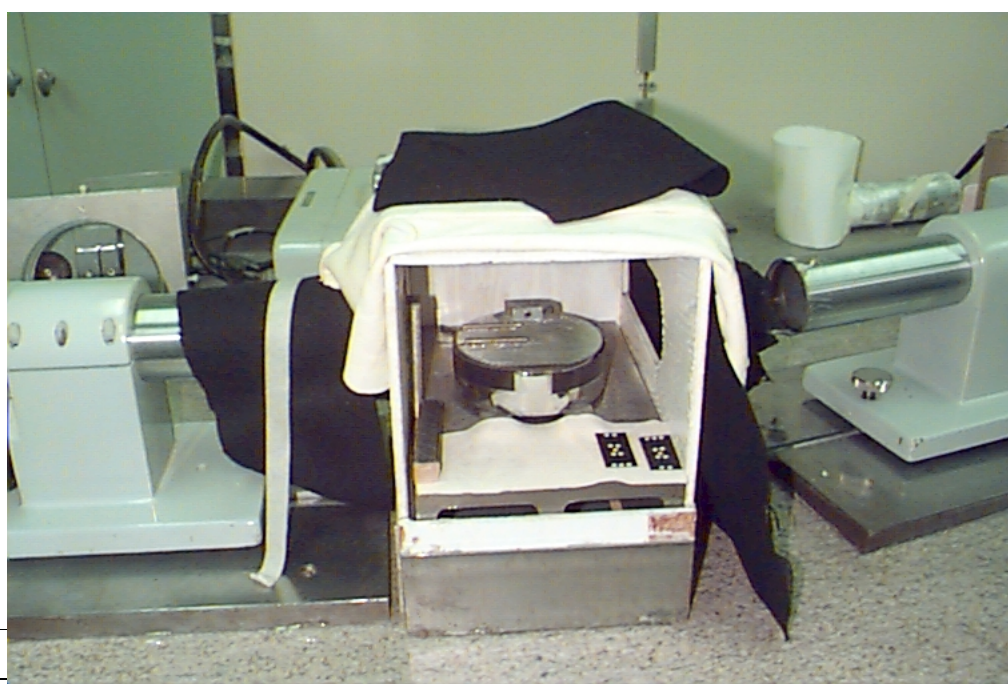
Each autocollimator should be checked to assure that a 12-second change of the autocollimator produces a 12 volt in the autocollimator output. The linearity of the scale should be checked at the same time. Both can be checked by moving the switch on the electronics panel to the appropriate position “A” or “B” depending on the autocollimator being checked. Put the autocollimator in the neutral position, and then manually move the dial from 0 to 12 seconds making sure that the voltage difference between each 1-second interval does not deviate from any other interval by more than 0.03 seconds. If the 0-12 second scale difference does not read a difference of 12 volts, the voltage control know on the poser supply should be adjusted until the reading is correct. If the calibration procedure calls for “calibrate before using”, the autocollimators can be calibrated using a sine plate and mirror, or they can be calibrated in situ using the NBS-7, 5-second angle block, as master. A check for cross talk should be made by setting the autocollimator to read the vertical angle change, then moving the mirror (or angle block) across the field of view to ensure there is no significant change in the vertical reading of the autocollimator from the horizontal change in the mirror orientation.

It is important that the autocollimators receive no light from the opposing autocollimator when a measurement is made. It is necessary to mask off at least one of the autocollimators to the size of the angle block. The masked area must also match the position of the block. Because the block needs to be centered in the field of view, the masked area will be nearly in the center of the autocollimator barrel. The easiest way to do this is for one person to look at the reflected image from the block using a magnifying glass and have someone else mask off the field of view with masking tape so you see only the reflection from the block and no light from the opposing autocollimator. On the other hand, you want to see all the block except perhaps a 2 mm band along the edges of the block face. It is more convenient to do the masking on the left autocollimator, as it remains in a fixed position for most of the readings. As a check to make sure you are seeing no light from the opposing autocollimator, block the opposing autocollimator beam and observe if there is a change in the reading. You should see no measurable change. The aluminum masks with holes punched in them – three at one end and two at the other – can be used to ensure the block is centered in the field of view. Make sure that the wires are properly connected by comparing a 1-second block to a 5-second block. Check the vertical alignment of the autocollimators by adjusting the front screw so the split image is in the center of the field of view. It is also important to ensure that the openings around the autocollimator barrels are sealed.

7. Measurement

Four sets of measurements are taken for each size angle block. The blocks are measured with the small end in for both the top-up and top-down. The blocks are measured using the data sheet designed for the computer program. Two options are available. Choose the one that requires the least readings.

A glove should be used to handle the blocks. The operator should place the angle block against the stops, close the lid and wait 15 seconds for the air to stabilize, then observe the readout for approximately another 15 seconds.



The figure above shows the serrated anvil with two brass rods mounted horizontally to fix the angle the face of the block makes with the left autocollimator. There is another stop at the back of the anvil, pointed towards the viewer, to set the position of the block in the autocollimator field of view. During measurements the cloth cover is pulled down to cover the front of the box and there are tubes in place to extend the autocollimator barrels into the box through holes on either side of the box.

Record the average reading during those 15 seconds. Care should be taken that the blocks are in the correct orientation and that the blocks do not get mixed up during the measurement. They look much alike and misidentification is relatively easy to do. It is also possible to incorrectly position the block so neither autocollimator gets a return image; even so, you may get a reasonable reading because the autocollimator reading may not have changed form the previous block. For this reason, a prism should be set so the operator can view at least one of the instrument readings after placing the block against the stops.

The 1-second through 5-degree blocks can be measured by changing only the position of the right autocollimator. For sizes larger than 5-degrees, both autocollimators must be moved to ensure that the autocollimators are viewing the central potion of the block.

8.0 Data Analysis and Report

The computer does the data analysis. If any statistical control test fails the block size must be re-measured. If this happens twice an examination of the basic set-up should be made. If the problem cannot be found the Group Leader should be consulted.

9.0 Uncertainty

The uncertainty of the measurements will be calculated for each block. The uncertainty will be a fixed number based on pooled historical data. It is likely that the uncertainty will be different for each block, but should be between 0.15 second and 0.20 second. In addition, another component may be added to the base figure depending on the flatness of the block and the variation found in the two orientations measured. Blocks with flatness problems so large that the uncertainty exceeds 0.75 arc seconds should not be measured.

10.0 Data Sheets

Sample data sheets are appended to this procedure.