SU/GP-B P0354

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OPERATIONS SUPPLEMENT FOR THE COMPARISON AUTOCOLLIMATOR, D600

GP-B SCIENCE MISSION PROCEDURE

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1. SCOPE

The Comparison Autocollimator, D-600, built by Davidson Optronics, Inc, measures the angular difference between two reflective surfaces to an effective accuracy of approx. ± 0.2 arc-s. This procedure provides a description for operating the Comparison Autocollimator, D-600, for measuring the relative tilts between two quartz surfaces. It is intended as a supplement to other procedures, and is referenced in them where appropriate. Examples are a) Alignment Measurement between Index Plate and Spacer, P0353, and b) Alignment Measurement between Gyro Housing and Quartz Block, P0206. Although these examples are frequently cited in this document, the operations described can be generalized to other applications of measuring relative tilts between two quartz surfaces.

This procedure is not intended to be tutorial on how the Comparison Autocollimator works. This is dealt with more fully in the Instruction Manual of the D-600, listed below in the references.

1.1 Overview

The D-600 measures the relative angle between the light beams reflected back into the two halves of the Comparison Autocollimator's aperture from two surfaces illuminated simultaneously by each half of the instrument. Thus a perfectly flat reflector filling the whole aperture of the autocollimator would naturally yield a relative angular displacement of zero. This is generally done as a "sanity check" prior to the use of the Comparison Autocollimator, to ensure that there is an acceptable zero offset for the measurement about to be performed. Note that the Comparison Autocollimator has proven to be very stable over many years, and thus these measurements do not need to be performed routinely.

1.2 Covered Operations

Note: The procedure described herein assumes the Comparison Autocollimator has been calibrated and zeroed. The latter is described further in the D-600 Manual.

The following operations are contained in this procedure:

1. Setup and Rough Alignment
2. Aperture masking
3. Measurement of tilt about a vertical axis
4. Measurement of tilt about a horizontal axis

1.3 D-600 Calibration

1.3.1 Comprehensive Calibration of the Davidson Optronics (DOI) D-600

Prior to use for determining SM Gyro tilt angles the D-600 will be sent to Davidson Optronics Inc., West Covina, CA, where its calibration will be checked, adjusted if necessary, and recertified. Work to be done includes:

1. Incoming calibration report with a determination of its overall scale factor.

2. Setting of the readout to read 60.00 for zero tilt.
3. Report of small interval measurements taken from 50 to 70 arc-s (± 10 arc-s around "zero") sufficient to determine the "as-received" scale factor to ≤ 2%
4. Perform adjustments, if necessary, to bring the unit fully within D-600 specifications, including a reset of the readout to 60.00 for a zero angular tilt.
5. Measure, and provide data, of actual beam tilts versus Autocollimator readings for known tilt angles in 2 arc-s intervals for D-600 readings of 50 to 70 arc-s

1.3.2 Check of "zero" of the Comparison Autocollimator

A crude check, performed at Stanford, to determine any drift of the Comparison Autocollimator's "zero" (nominally 60.00) can also be done as needed to confirm the more thorough calibration in 1.3.1 above. This check is typically done prior to the use of the D–600 for important measurements, just to ensure that the "zero" has not drifted substantially. The method is to use the D-600 to determine reflections from a mirror with flatness $\leq \lambda/20$. Because of the sensitivity of the human eye to making readings with this instrument ($\pm$ 0.25 arc-s) the unit shall be considered fine if the results lie within that amount of 60.00 arc-s. Otherwise the necessary "zero offset" will be determined and used for the tilt measurements, subject to approval by the ITD.

2. REFERENCES

Davidson Optronics, Inc. Comparison Autocollimator Model D-600 Instruction Manual

3. REQUIRED EQUIPMENT

Comparison Autocollimator, Davidson Optronics, Model D 600
Optical V-Block Stand, Bausch & Lomb
Precision Elevation Instrument Stand, Dividson Optronics D247
Dolan-Jenner Industries Fiberlite Model 190
Optical Table, Oriel Corporation, Model No. 10761
Optically falt mirror to $\lambda/20$ or better, mounted in Mirror Stand
Kapton Tape

4 SET-UP AND ROUGH ALIGNMENT

This procedure is typically conducted on the Optical Table in the Class 10 Cleanroom, and is written for that site. Generalizations to other locations are left to the reader.

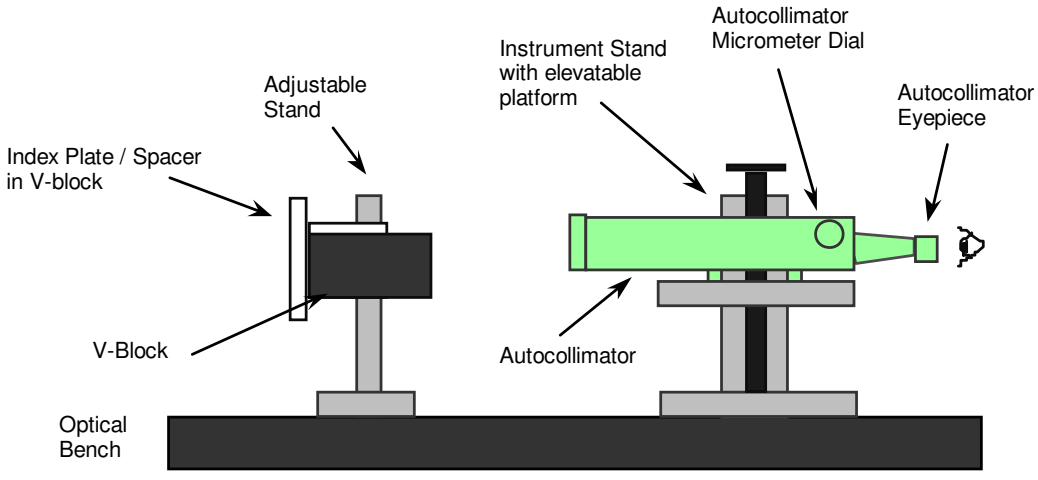
4.1 Clear the Optical Table, and the area around it, to prevent accidental bumping or tripping.

4.2 Place the reflecting surfaces near the back of the Optical Table. In the case of the Index Plate and Spacers, they will be placed on a V-block and stand. In the case of the Gyro Housing and Quartz Block, the SIA will be on the Roller Mechanism.

4.3 Place the Instrument Stand for the Comparison Autocollimator on the Optical Table, in front of the surfaces to be measured.

4.4 Place the Comparison Autocollimator on the Stand, pointing at the measurement surfaces. The measurement surfaces should be approximately perpendicular to the autocollimator line of sight. In the case of the IP/S unit, place the unit on the V-block, such that the Spacer rests in the "V", and the Index Plate butts up against the V. The Spacer side faces the autocollimator, such that its notch is parallel to the dividing line on the autocollimator. See Figure 1 for the case of Index Plate and Spacer. In the case of the Gyro and QB, rotate the Roller Mechanism so that the bore of the gyro being measured is parallel to the table, with the polished surface facing the autocollimator side.

Note: The Comparison Autocollimator is supported by three ball feet, two aft and one forward. These feet are located on two sides of the D-600 so that tilt angles about two orthogonal axes can be measured. For tilt measurements around a horizontal axis, the micrometer dial is located on the side of the autocollimator, while for tilt measurements around a vertical axis, the micrometer dial is located on the top of the autocollimator.



SideView of Autocollimator Setup - Not to scale

Figure 1. Setup on Optical Table

4.5 Connect the Fiberlite Model 190 (illuminator) to the Comparison Autocollimator in the slot near the eyepiece. See Figure 2 below.

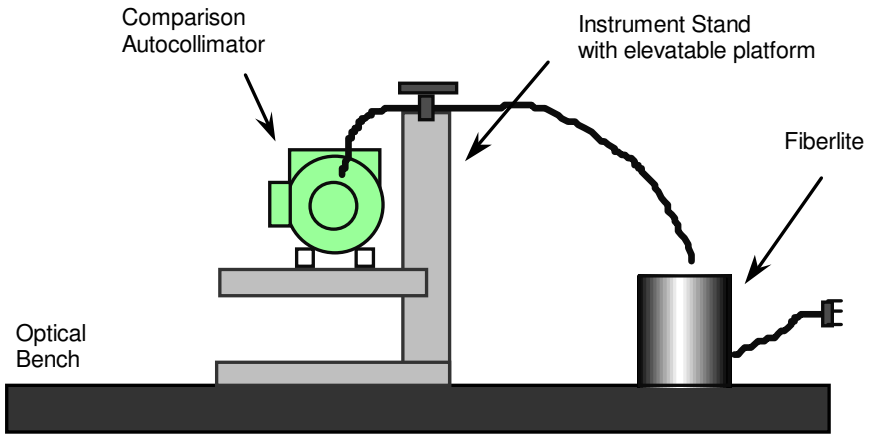


Figure 2. Comparison Autocollimator Setup

4.6 Adjust the height of the autocollimator platform so that the autocollimator boresight is approximately level with the upper (or lower) half of the IP/S or gyro bore. The beam from the autocollimator is split into two beams with the divider bar between these visible when the eyepiece is removed. Ensure that the divider is set so that each half will receive reflected light from only the respective surface of interest. For tilt measurement around a vertical axis the halves are above and below the divider, while for measurement around a horizontal axis the halves are left and right of the divider. The beam in the half further from the micrometer dial is fixed with respect to the autocollimator while the other beam is tilted by a tipping plate controlled by the micrometer, providing the relative angle between the two beams.

5 MASKING

To obtain the most accurate results, only flat surfaces in the field of view of the Comparison Autocollimator which are to be measured should be exposed. All other surfaces need to be masked to avoid image confusion.

5.1 With the eyepiece removed, fine-adjust the Comparison Autocollimator height and angle so that a uniform green reflection is observed from the relevant quartz surfaces. For tilt of the Gyro relative to the QB, the Plumbing Retainer Bar should be on the upper portion of the field of view, so that only the lower half of the gyro is observable. The gyro housing is observed through the lower semicircular hole of the Plumbing Retainer. See Figure 3.

For the Index Plate relative to the Spacer, the Spacer should be on the upper portion of the field of view, and the Index Plate on the lower half (not pictured).

5.2 Cover any portions of the field of view which are extraneous or distracting, by blocking corresponding portions of the Comparison Autocollimator with paper or tape. For the gyro case, the image with the eyepiece removed should look similar to Figure 3 below after masking.

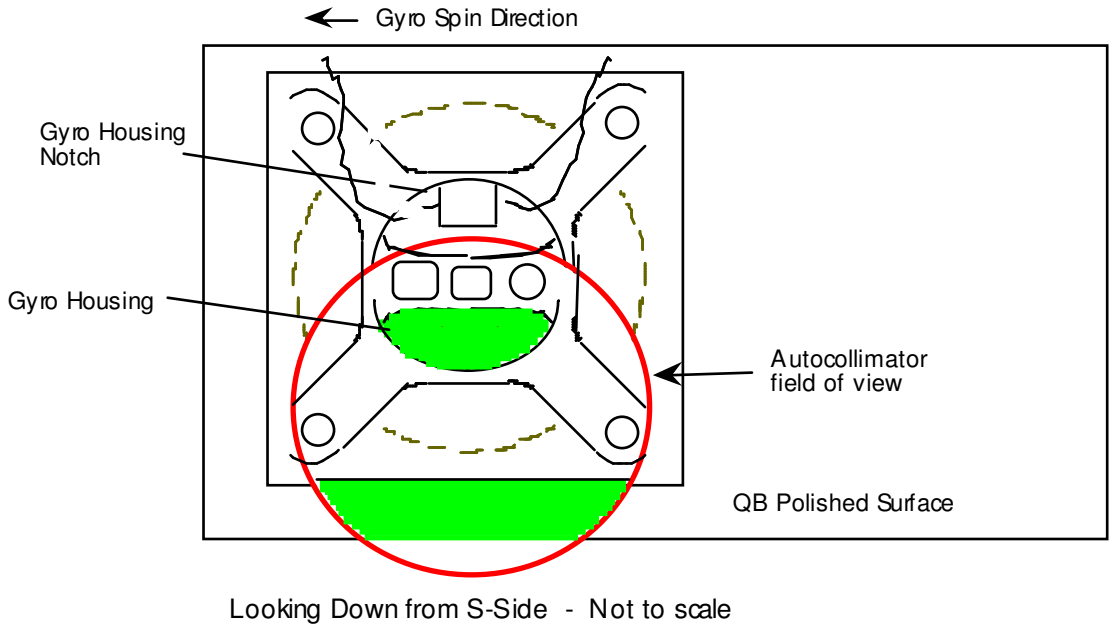


Figure 3. Image through Comparison Autocollimator without Eyepiece for Measuring Tilts about the Vertical Axis

In the case of the IP/S, tape a 3”x3” paper-square, with a 1”x1/2” centered slot on top, to the front of the V-block. This should expose only a part of the spacer (surface which interfaces with gyro) and a section of the IP. Tape a horizontal .125”x 2” paper strip to the front opening of the Comparison Autocollimator. The

strip should roughly sit on top of the divider line. This should block out the remaining IP surfaces which may interfere with viewing the spacer surface.

6 MEASUREMENT OF TILT ABOUT A VERTICAL AXIS

6.1 Replace the eyepiece, and observe two nearly coincident sets of three line slits - two green vertical parallel lines, and a third horizontal line. One set is fixed, and correlates with the reflection from one surface, while the other pair is movable, and correlates with the other surface being measured.

6.2 Turn the micrometer dial counterclockwise until the two pairs of parallel lines are completely separated. It is not necessary that they be vertically coincident, although it is desirable for them to be nearly in line for ease of measurement. See Figure 4 below.

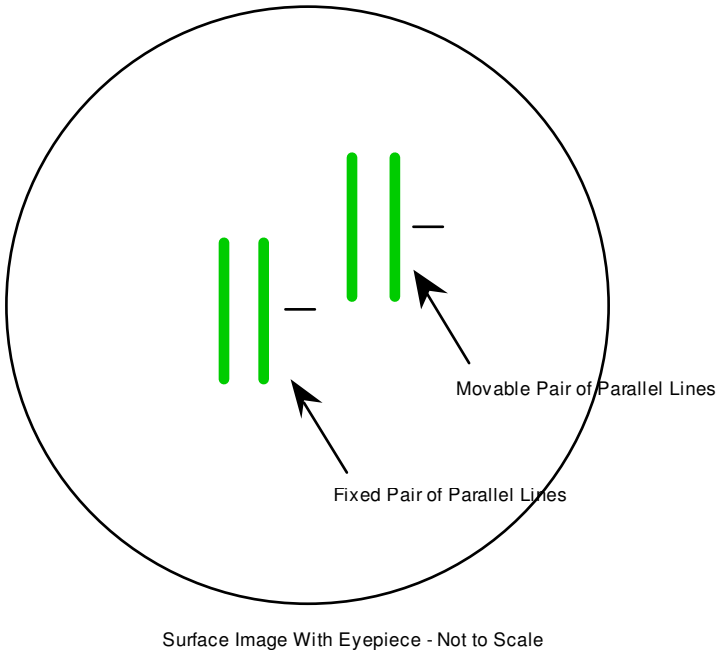


Figure 4. Comparison Autocollimator Image with Eyepiece

6.3 Now turn the dial clockwise until the two sets of parallel lines are co-linear (or superposed).

6.4 Continue turning the dial clockwise until the trailing line of the movable pair splits the fixed pair equally. See Figure 5 below.

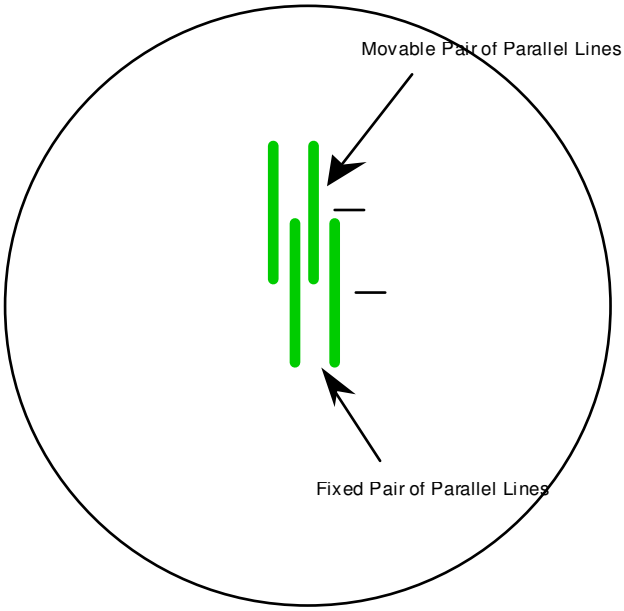


Figure 5. Splitting the Distance

6.5 The tilt between the Gyro Housing and Index Plate around a vertical axis is now read from the micrometer dial. Each tick mark represents 0.1 arc-second of tilt, with each whole arc-second numbered. One full revolution of the dial is 10 arc-s, as indicated on the large scale indicator, which is graduated in 10s of seconds. Nominally, for perfectly parallel surfaces, the reading is ~ 60 arc-s

Note: Although 0.1 arc-second accuracy is claimed by the manufacturer, a more realistic accuracy is approx. ± 0.25 arc-second, due to the subjective nature of observations.

6.6 Record the Tilt Angle in the appropriate location on the parent procedure.

7 MEASUREMENT OF TILT AROUND A HORIZONTAL AXIS

7.1 Rotate the Comparison Autocollimator in the Stand by 90° so that it is supported by the other 3 feet, and the micrometer dial is on the left, as you are looking through the autocollimator.

7.2 With the eyepiece removed, fine-adjust the Comparison Autocollimator height and angle so that a green reflection of the comparison quartz surfaces are simultaneously observed. The beam from the autocollimator is split into two beams, one covering the right half, and the other the left half. It is necessary that the surfaces to be compared are on separate halves of the field of view.

For the Gyro relative to the QB, the QB polished surface is to the left or right of the gyro, depending on the gyro. See Figure 6 below.

For the Index Plate relative to the Spacer, the Spacer should be on the right portion of the field of view, and the Index Plate on the left half (not pictured).

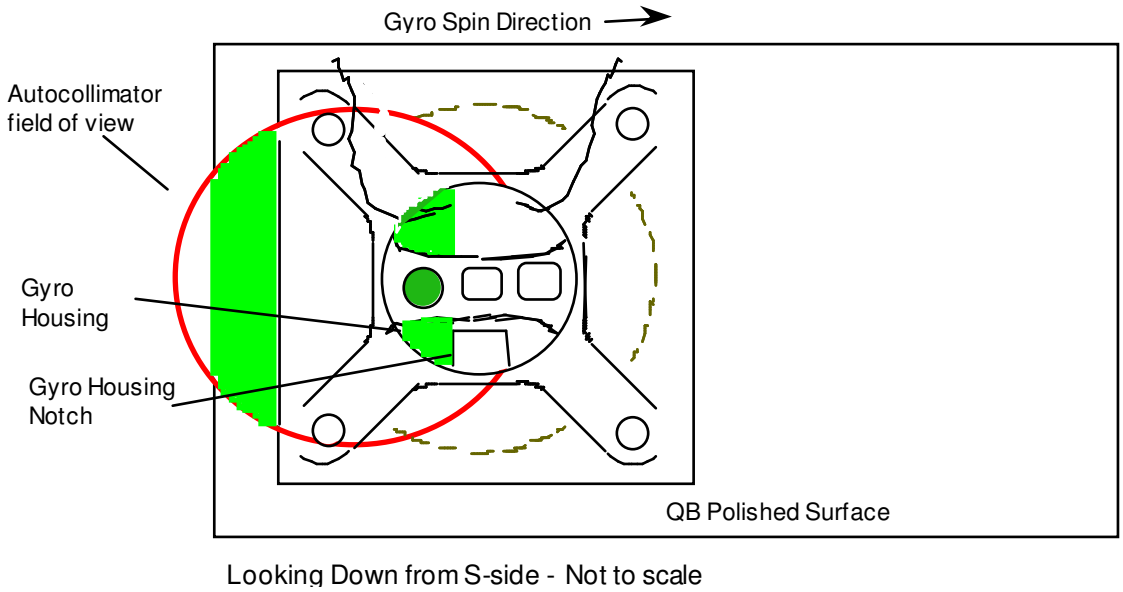


Figure 6. Image through Comparison Autocollimator without Eyepiece - Azimuth

7.3 Replace the eyepiece, and you should see two nearly coincident sets of green parallel lines similar to Figure 4, except horizontal.

7.4 Turn the micrometer dial counterclockwise until the two pairs of parallel lines are completely separated. It is not necessary that they be horizontally coincident.

7.5 Now turn the dial clockwise until the two pairs of lines are co-linear (or superposed).

7.6 Continue in the clockwise direction until the trailing line of the movable pair splits the fixed pair equally. Similar to Figure 5, except horizontal.

7.7 Read the tilt difference between the measurement surfaces from the micrometer dial. Record the tilt angle in the appropriate location in the parent procedure.