Procedure Title: The Calibration Of Optical Reference Planes By Comparison
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1.0 PURPOSE

The purpose of this procedure is to measure the absolute flatness along marked diameters of optical reference flats not exceeding 400 millimeters in diameter.

2.0 SCOPE

The calibration of an optical reference plane or optical flat by interferometric comparison requires two optical flats: a primary master flat of larger diameter than the flat to be measured and a test flat. The optical flats need to be kinematically supported to reduce bending and sagging effects and to control the angle and separation of the two flats during the calibration. A stable and reliable light source and strict temperature control is required to produce good measurement data without introducing nonlinear thermal drift into the results.

3.0 DEFINITIONS AND REFERENCES

NBSIR 75-975 "The Calibration of an Optical Flat by Interferometric Comparison to a Master Optical Flat".

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 PRE-SETUP PROCEDURES

4.1 Equipment

Optical flat, Pulfrich viewer, support pads, gap extensions, template, wedge direction, hood, dubbing, bending, 3-flat method, Tesla coil, eyepiece, etc.

4.2 The optical flat is unpacked and logged into the database.

NOTE: The optical flat must be checked for mounts or enclosures. If the flat is in a mount, it must be removed to perform the measurement. The optical flat must be in a "free" state to be compared to a master flat. Contact the customer before removing the flat from the mount. If the flat can not be removed from the mounting enclosure, it can not be calibrated using this method and must be

returned to the customer.

4.3 All the pertinent data, including serial number, manufacturer, nominal diameter, and the number of sides and diameters to be calibrated are recorded on the data sheets provided in the laboratory.

4.4 The optical flat to be measured is checked for damage or prominent scratches on the optical surface. Any damage should be noted on the data sheets. If the flat was badly damaged during shipment, record all damage on the data sheets and take polaroid photographs then contact the customer for instructions.

4.4 The test flat should be inspected for previously measured marked diameters. These markings will be along the sides of the flat and will usually consist of an arrow denoting the top of the flat and a letter marking; A, B, C, and/or D. The A-B marking should represent one measured diameter while the C-D marking should represent a second measured diameter rotated 90 degrees from the first. These markings should also extend over the chamfered edge of the flat so they are visible while viewing perpendicular to the optical surface. Re-mark each of these markings with a permanent marker and proceed to 5.0. If these markings are not present, proceed to 4.4.1.

4.5.1 Measure the diameter of the flat with a ruler. Using this measurement, find the appropriate support template in the folders located inside the Pulfrich viewer table.

4.5.2 Place the optical flat, the top surface upwards, on the template and find a good location for the diameter markings. Make sure these markings will not interfere with other information on the side of the optical flat.

4.5.3 Using a fine-tipped permanent black marker and a square, mark the "A" position using an arrow to denote the top surface.

4.5.4 Rotate the flat 180 degrees and mark the "B" position. Rotate the flat 90 degrees and mark the "C" position. Rotate the flat 180 degrees and mark the "D" position. Make sure each of these markings extend over the chamfered edge of the optical surface on both sides of the flat.

5.0 SETUP PROCEDURES - BOTTOM FLAT

The optical flat to be measured must first be tested for reflectivity. This will determine the proper orientation of the master flat and the test flat during the measurement. The flat measurement orientation is shown in Figure 1.

5.1 Choose which optical flat is to be on the bottom of the assembly shown in Figure 1. Shine light through the optical flat to be measured. If the flat is coated with a metallic compound the light will not pass through both surfaces of the flat and will not be visible from the other side. If this occurs the test flat must be the BOTTOM flat in the assembly shown in Figure 1. The top flat in the assembly

MUST allow light to pass through to the bottom flat.

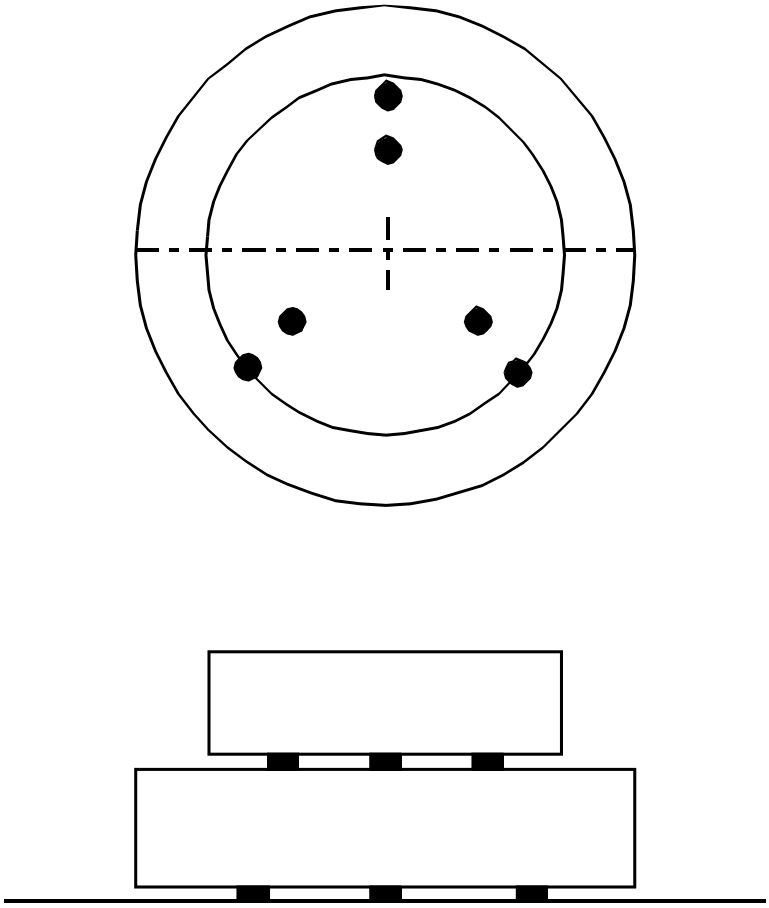

Figure 1

5.1.1 If the test flat must be on the bottom, choose a master flat with approximately the same diameter of the flat to be measured. The master flat must be the same size or slightly larger than the test flat. The choices for master optical flats are located in Appendix A.

5.1.2 If the test flat is clear and allows light to pass through, the master flat can be on the bottom. Choose a master flat with a diameter larger than the test flat. In cases where the diameter of the flat to be measured is less than 260 mm or 10.5 inches, use the NIST 10.6 inch primary master flat No. 1-3.

5.2 Choose the proper support for the bottom optical flat. The support radius must be 0.7*R (R = radius of the flat) to minimize the sagging or bending of the measured diameter.

5.3 Place the bottom flat support on the ways under the Pulfrich viewer. Focus the viewer so the horizontal coordinate line can be seen. The horizontal coordinate on the bottom flat support will be vertical when viewed through the eyepiece.

NOTE: The Pulfrich viewer has several adjustments as follows:

A) Focus the twin hairlines - pull out on eyepiece.
B) Depth focus - knurled knob to the left side of eyepiece.
C) Adjust the vertical position of the field of view - the small knurled knob just beneath the eyepiece.
D) Adjust the side to side position of the twin hairlines - turning of the numbered wheel to the right of the eyepiece.
E) Brightness adjustment - side to side movements of the small knurled pin located behind the spoked wheel.
F) Rotation of the twin hairlines - the spoked wheel on the top of the Pulfrich viewer.
G) Waybed movement - the crank handle on the front of the Pulfrich viewer table.

5.4 Rotate the twin hairlines until they are exactly vertical in the field of view. Use the focusing and positioning adjustments so the hairlines are in clear focus and in the center of the field of view. After the positioning is complete, DO NOT adjust the hairlines.

5.5 Align the horizontal coordinate on the support with the Pulfrich viewer's twin hairlines. The entire length of the coordinate line must be exactly aligned with the twin hairlines.
Use the waybed crank to move the assembly from end to end during this alignment procedure.

5.6 Place the bottom optical flat on the supports with the marked "A-B" diameter upwards along the horizontal coordinate. If the bottom flat is the master, the calibrated "A-B" diameter must be upwards. If the flat to be measured is on the bottom, the marked "A-B" diameter on the top of the flat should be facing upwards. The markings over the chamfered edges of the optical surface become important here. These marks should be seen clearly through the Pulfrich viewer after some focusing adjustments. Position the flat so these marks are in exact alignment with the horizontal coordinate mark and the Pulfrich viewer's twin hairlines.

5.7 Carefully place a precision ruler on the top of the bottom flat and align it with the chamfered edge markings. The ruler must be longer than the flat diameter. Position the ruler to locate the exact center or the optical flat. Mark this point on the flat or on the ruler with a NON-permanent marker.

5.8 Align this center mark with the vertical coordinate on the base support. The optical flat should now be exactly centered on the supports and the flat/support assembly in alignment with the Pulfrich viewer's twin hairlines.

6.0 SETUP PROCEDURES - TOP FLAT

6.1 Position the template.

6.1.1 Clean the bottom optical flat with alcohol and a lint free cloth.

6.1.2 Remove the support pad template from the proper folder located in the Pulfrich viewer table.

6.1.3 Position the template in approx. the center of the bottom optical flat. The top of the template has the markings. The positioning is shown in Figure 2.

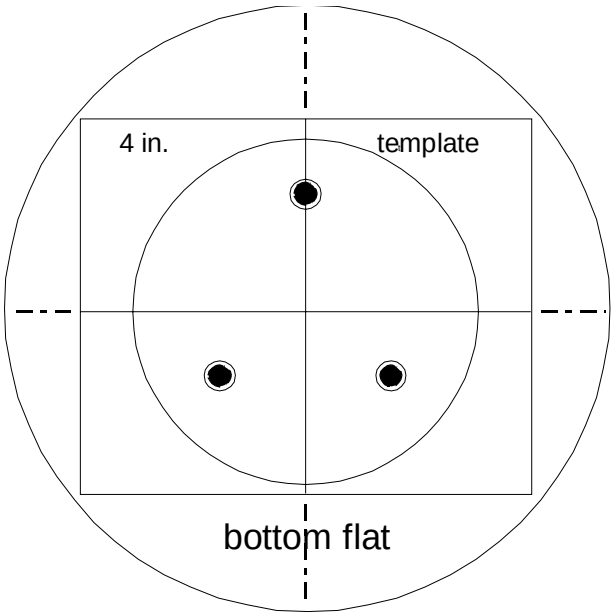

Figure 2

6.1.4 Focus on the bottom support coordinate line and re-align the twin hairlines. The hairlines should cover the coordinate line the full length of the bottom optical flat. After this adjustment, DO NOT rotate the hairlines until the top optical flat is in position.

6.1.5 Using the waybed, bring the edge of the template into view. Focus on the template coordinate line. The bottom support coordinate will go out of focus.

6.1.6 Carefully align the template horizontal coordinate with the twin hairlines by moving the template with a finger. This is very delicate. move the waybed to the other end of the template and align this end. Continue back and forth until the template is in exact alignment with the hairlines.

6.1.7 Move to the center intersection on the template. The vertical coordinate axis should be in the field of view. Carefully push the template to align the verticle coordinate with the bottom support lines. Be careful not to rotate the template too much.

6.1.8 Re-align each axis on the template as in 6.1.5 - 6.1.7. The result of this alignment is that the template is exactly centered on the bottom optical flat.

6.2 Position the support pads.

6.2.1 Remove the pads from the folder. Each packet should contain three pads (two of one color). The single pad is thicker than the other two pads. This is necessary to create the proper wedge between the optical flats. Extra pads are located in the Pulfrich Viewer table.

6.2.2 Using the small tweezers, place the thicker pad in the top position on the template.

6.2.3 Place the other two pads in the bottom two positions on the template as in 6.2.2. Be sure the pads DO NOT touch the template.

6.2.4 Using the Tesla coil, remove any static charge from the template or the optical flat that may not allow the pads to seat properly on the flat. DO NOT touch the optical flat surface with the Tesla coil tip.

6.2.5 Very carefully remove the template WITHOUT touching the pads. If the pads move, the template will need to be repositioned as in 6.1.3 - 6.1.8. Then the support pads will need repositioned as in 6.2.2 - 6.2.4.

6.2.6 Use the Tesla coil to remove any static charge on the optical flat surface. DO NOT move the support pads.

6.3 Position the top optical flat.

6.3.1 Clean both sides of the top flat with alcohol and a lint free cloth.

6.3.2 Use the Tesla coil to remove any static charge from the top flat. This is critical for the positioning of the top flat. If static charge is present when the top flat is placed on the bottom flat, the support pads WILL move.

6.3.3 Place gap extensions on the bottom flat between each of the support pads. These extensions are much thicker than the support pads and will hold the top flat up off the pads while final positioning

adjustments are being made.

6.3.4 Choose the diameter of the top flat to be used. If the top flat is a NIST master flat, use the calibrated and marked "A-B" diameter. If the top flat is the customer flat, choose the diameter to be calibrated.

6.3.5 Taking careful note of which side is being measured and which diameter is being measured, place the top flat in approx. the center of the bottom flat. Watch the support pads to see if they move as the flat is being positioned. The flat is now resting on the gap extensions.

NOTE: Refer to Figure 3. The bottom flat diameter "A-B" is being compared with the top flat diameter "C-D". The diameters that are being measured are facing each other in the setup. The fluctuations in this small gap between the flats is the measured quantity.

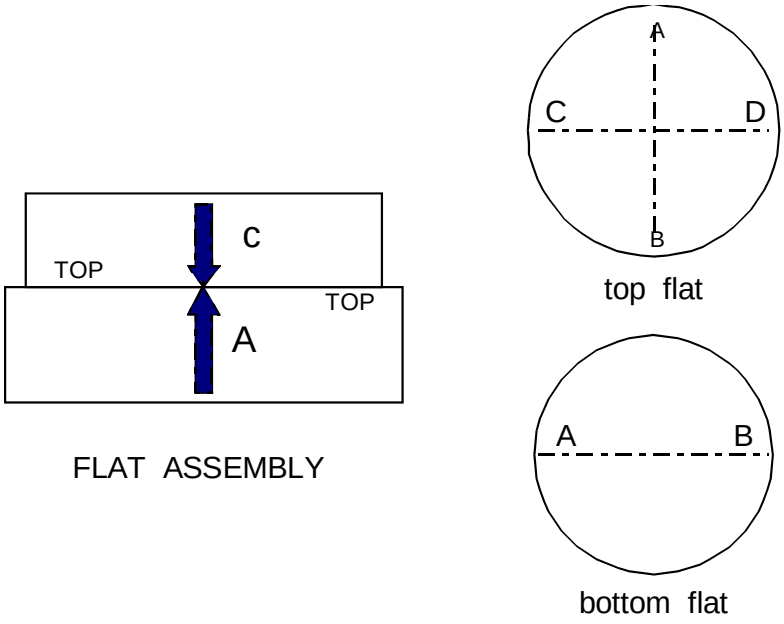

Figure 3

6.3.6 Position the notched ruler from the folder on the top optical flat horizontally across the surface. Position the ruler just behind the diameter markings on the chamfered edge of the flat (approx. 2 mm). The notches in the ruler designate the measurement positions. Center the ruler on the flat.

6.3.7 Focus the Pulfrich Viewer on the left end of the ruler at the edge of the top optical flat. The bottom flat support coordinate, the twin hairlines, and the chamfered edge markings should be

visible after focusing adjustments. The notched side of the ruler should also be in focus.

6.3.8 Carefully align the diameter marks on the chamfered edge of the top flat with the bottom support coordinate and the twin hairlines by moving the top optical flat with a finger. The support pads should not move while this adjustment is taking place. Continue on each end until the chamfered edge marks are aligned.

6.3.9 Bring the center intersection into focus and note the position of the center notch on the ruler. Push the top flat carefully to align the center notch with the vertical coordinate line. Re-align the chamfered edge marks if necessary.

6.3.10 Gently pull each gap extension out to the edge of the top flat. Remove each extension very carefully without moving the top flat position. Once all gap extensions are removed the top flat will be resting on the support pads.

6.3.11 Check the final alignment of each flat. Very small adjustments in positioning can be made. If the adjustment needed is more than the width of the hairlines, the positioning procedure must be followed again. This is critical to maintain the proper location of the diameter of minimum bending.

6.4 Turn on the Helium lamp light source. Fringes should be present through the top flat. If fringes are not present, the alignment of the beam path must be checked. If fringes are present, proceed to 6.5.

6.4.1 Remove the eyepiece from the Pulfrich viewer.

6.4.2 Move the brightness control knob to the right to fully open the reticle.

6.4.3 Using the knurled knobs located on each foot of the Pulfrich viewer base, adjust to bring the brightest reflection into the center of the field of view. Adjust the brightness control knob until a very bright semicircle of light is present in the field of view.

6.4.4 Replace the eyepiece and focus the hairlines. If fringes are still not present, the top optical flat is not allowing the light to pass through and will have to be placed on the bottom of the assembly. Return to 5.0 and continue.

6.5 Push down on the top flat over the position of the thickest pad and view the effect. The fringe gap should increase with increasing pressure. If the gap decreases with increasing pressure the wedge is in the opposite direction as required. The pad assumed to be thickest is actually thinner than the other two pads and will need to be replaced with a pad of proper thickness. Return to 6.0 and continue.

NOTE: The fringes viewed through the eyepiece should be vertical or running from top to bottom. If the fringes are less than one-quarter of a fringe gap from exactly vertical, they do not need

adjusting.

6.6 Adjust the fringes by pushing down on the flat over the pad positions with one finger. Be careful not to move the flat or the entire setup procedure will need repeated. Look through the eyepiece and note the action of the fringes. Move from one end to the other to insure the fringes are very nearly vertical on the flat.

6.7 Using the waybed crank, move the flat assembly to the side farthest away from the Pulfrich viewer. Position the hood and cover over the flat assembly.

6.8 Check the fringe alignment and adjust if necessary. Turn off the Helium lamp and allow for thermal equalization.

7.0 CALIBRATION PROCEDURE

7.1 Turn on the Helium lamp, reading lamp, and the dial lamp.

7.2 Check the straightness of the fringes from top to bottom. If the fringes have drifted and are no longer vertical, remove the lid of the hood and push down on the flat using the eraser end of a pencil to adjust the fringes. Be careful not to move the flat. Let the flat thermally equalize for 15 minutes.

7.3 Mark on the data sheet the position of each notch in the ruler (Example: 0.25,0.5,1.0,... etc.). These are the positions on the flat that will be measured.

7.4 Using the data sheet and beginning from the top (or left side) of the flat, use the dial to center the twin hairlines on the fringe nearest the mark on the chamfered edge of the flat. Record the value at the position next to this top notch in the ruler (furthest to the left on the ruler). Record the value starting near 500 (Example: if the reading was 27, record 527. This allows for drift in the fringe readings). After the first reading, stay with this convention to maintain continuity in the readings (If the next reading dropped 30 units, record 497).

NOTE: After the first reading it is critical that the focus and rotation of the field of view not be adjusted. This will alter the location of the fringe with respect to the hairlines and result in an error. The measurements must also be taken in an efficient and deliberate manner to insure any thermal drift will be as linear as possible. Pausing is only allowed between cycles.

7.5 Continue taking measurements at each notch in the ruler along the length of the flat. Use the waybed crank to move from notch to notch.

7.6 Repeat the bottom position and return the run to the top. This repetition will allow for thermal drift calculations. The values will drift over time so expect changes at times in the range of 20 to 30 units.

7.7 After reaching the top of the flat, one measurement cycle has been completed. The fringe separation must be measured now. Move the flat to a random position and record the value.

7.8 Without moving the position of the flat, rotate the dial indicator to the next fringe to the right. Be sure to note the units that are rotated. (Most pad combinations have fringe separations around 300 to 600 units.).

7.9 Return to the top of the measured fringe and repeat 7.4 - 7.8.
Complete a total of four cycles.

7.10 Turn off the Helium, reading, and dial lamps.

7.11 This completed the data collection of the measured diameter. If another diameter on the top flat is desired to be measured, repeat 6.0 - 7.10 for the next diameter. Be careful to note the direction of the arrows on the sides of the top flat to insure the correct side or optical surface is being measured.

7.12 If another diameter on the bottom flat is measured, repeat 5.0 - 7.10 for this diameter. Be careful to note the tops of each flat to insure the proper comparison of the correct diameters.

7.13 Continue with these measurement procedures until all required diameters are measured on the customer flat. Be sure to carefully note the diameters and sides measured on the data sheets to avoid confusion with the data.

8.0 COMPILING THE DATA / REPORT GENERATION

8.1 Select and run the program entitled "OPFLAT".

8.2 Follow the instructions presented in the program. Use the green optical flat binder to locate the position corrections for the master optical flat used during the calibration. The uncertainty of the master flat is also recorded in the binder with the correction data.

8.3 Carefully input the data as recorded and recheck the figures. The program will make the proper corrections whether the master flat is on the top or bottom.

8.4 After the data is in the computer, input all required data for the report of calibration according to the program.

8.5 When the option arises to plot the straightness plots, continue so a hardcopy of these plots can be generated. These plots are also the primary method of determining the correctness of the calibration.

8.6 Use the M-book to locate any previous history on the customer flat. Compare the straightness plots or the position deviations for agreement.

NOTE: Any pair of plots on the same side of the flat should be very similar in appearance. Most optical flats are very symmetrical in their surface contours. If these two plots give very different contours, recalibration of the flat is recommended.

9.0 POST-CALIBRATION PROCEDURES

9.1 Follow the post calibration procedure XXXXX for the paperwork generation.

9.2 Compile the lab folder and file accordingly.

9.3 Compile the test folder as required.

9.4 Prepare the shipping documents as required.

9.5 Pack the flat in its original packing material according to NIST packing procedures XXXXX.

9.6 Follow NIST shipping procedure XXXXX to send the artifacts back to the customer.

APPENDIX A

NIST MASTER OPTICAL FLATS

DIAMETER (INCHES)	SERIAL NO.
2.0	1
2.0	VK 21E71 R
3.0	G
3.0	301
5.0	VK 51FN
6.0	150348
6.0	601C
8.4	801

10.6	1
10.6	2
10.6 **	3; 1-3
12.25	TT-181
14.16	Q1996
16.0	150599

** INDICATES THE NIST PRIMARY MASTER