This publication replaces T.O. 33K6-4-168-1 dated 30 April 2005.
OPTICAL FLATS AND MIRRORS

1 CALIBRATION DESCRIPTION:

Table 1.

<table>
<thead>
<tr>
<th>Test Instrument (TI) Characteristics</th>
<th>Performance Specifications</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flatness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical</td>
<td>Range: Up to 4 in</td>
<td>Verify with a Plano Interferometer or a Master Flat with a Monochromatic Light Source</td>
</tr>
<tr>
<td></td>
<td>Accuracy: 4 μin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Range: Larger than 4 in</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accuracy: 6 μin</td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>Range: Up to 2 in</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accuracy: 3 μin, Inspection Grade; 10 μin, Working Grade</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Range: Above 2 in and up to 4 in</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accuracy: 6 μin, Inspection Grade; 20 μin, Working Grade</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Range: Larger than 4 in</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accuracy: 10 μin, Inspection Grade; 40 μin, Working Grade</td>
<td></td>
</tr>
</tbody>
</table>

2 EQUIPMENT REQUIREMENTS:

<table>
<thead>
<tr>
<th>Noun</th>
<th>Minimum Use Specifications</th>
<th>Calibration Equipment</th>
<th>Sub-Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 PLANO INTERFEROMETER</td>
<td>Range: 0 to 12 in</td>
<td>Davidson Optronics</td>
<td>Gaertner</td>
</tr>
<tr>
<td></td>
<td>Accuracy: 1 μin</td>
<td>D312L</td>
<td>B8418</td>
</tr>
<tr>
<td></td>
<td>TAR 3:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2 MONOCHROMATIC LIGHT *</td>
<td>Range: 12 in</td>
<td>Van Keuren</td>
<td>Van Keuren</td>
</tr>
<tr>
<td></td>
<td>Accuracy: N/A</td>
<td>C2</td>
<td>L-2A</td>
</tr>
</tbody>
</table>

See footnote at end of Equipment Requirements.
<table>
<thead>
<tr>
<th>Noun</th>
<th>Minimum Use Specifications</th>
<th>Calibration Equipment</th>
<th>Sub-Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3 OPTICAL FLAT * (AFPSL Certified Master Optical Flat)</td>
<td>Range: 10 in Accuracy: 0.5 µin</td>
<td>Davidson Optronics D617-10Q1D</td>
<td>Van Keuren 10INCH</td>
</tr>
<tr>
<td>2.4 ALCOHOL-ETHYL</td>
<td>Range: N/A Accuracy: N/A</td>
<td>As Required</td>
<td></td>
</tr>
<tr>
<td>2.5 KIMWIPES</td>
<td>Range: N/A Accuracy: N/A</td>
<td>As Available</td>
<td></td>
</tr>
<tr>
<td>2.6 PETROLEUM JELLY</td>
<td>Range: N/A Accuracy: N/A</td>
<td>As Available</td>
<td></td>
</tr>
</tbody>
</table>

* Used in Alternate Method only.

3 PRELIMINARY OPERATIONS:

3.1 Review and become familiar with the entire procedure before beginning the Calibration Process.

WARNING

Unless otherwise designated, and prior to beginning the Calibration Process, ensure that all test equipment voltage and/or current outputs are set to zero (0) or turned off, where applicable. Ensure that all equipment switches are set to the proper position before making connections or applying power.

3.2 Bring the TI into the calibration area 12 hours prior to beginning Calibration Process.

3.3 The temperature of the calibration area must be 68 ±1 °F.

WARNING

Alcohol is an eye and skin irritant. Use protective equipment (chemical splash goggles and gloves) where a potential of splash and skin contact may occur. Failure to do so may result in injury. If eye contact occurs, flush eye water and seek immediate medical attention.

WARNING

Alcohol is a flammable liquid and may be ignited by heat, sparks or flames. Vapors may travel to a source of ignition and flash back. Alcohol burns with an almost invisible flame.

3.4 Clean uncoated Optical Flats with Alcohol and dry with Kimwipes. Lens tissue and lens cleaner can be substituted. If Kimwipes and Alcohol or lens tissue is used to clean coated Optical Flats and Mirrors, be careful to avoid scratching and/or damaging the coated sub-surfaces. When cleaning coated Optical Flats and Mirrors, it is recommended that the manufacturer be contacted for cleaning instructions.
3.5 Inspect the TI surface(s) and edge for scratches, nicks and/or other damage. If damage prevents the TI from being used within the original parameter, the TI must be downgraded or condemned, whichever is applicable.

3.6 Layout round and square surface TIs as shown in Figure 1. Mark the edge of the TI with two axes, A-B and C-D.

![Figure 1. Round and Square Surface Layouts](image)

3.7 Annotate in the Remarks Block of the Certification Label the worst case calculated flatness deviation for all surfaces calibrated (top and/or bottom). In addition, identify the flatness deviation direction, concave or convex.

Example:

- Top: 2.3 microinches concave
- Bottom: 5.5 microinches convex

4 CALIBRATION PROCESS:

**NOTE**

Unless otherwise specified, verify the results of each test and take corrective action whenever the test requirement is not met, before proceeding.

4.1 FLATNESS CALIBRATION: (Using Plano Interferometer)

4.1.1 For Optical Flats, spread a thin coat of Petroleum Jelly on the TI surface, opposite of the surface being calibrated. When calibrating Mirrors, it is not necessary to put Petroleum Jelly on the opposite surface.

4.1.2 Place TI 4 inches in diameter or larger, on airy points mounted on cardboard or other material. Airy points are three equally spaced support pads placed on an imaginary circle with a radius equal to 0.7 inch of the radius of the instrument being supported.

4.1.3 Place the TI on the Plano Interferometer staging table. The marked axis should be in line with the marked axis on the Plano Interferometer. Lower the Plano Interferometer divider plate to approximately \(\frac{1}{8}\) to \(\frac{1}{4}\) inch above the TI surface being calibrated.

**NOTE**

The coated surface of the Mirror (first surface) is the side of the Mirror that is calibrated.

**CAUTION**

Do not allow the bottom surface of the divider to make contact with the Top Surface of the TI as damage to either surface or incorrect measurements may result.

4.1.4 Two images will be visible when viewing through the Plano Interferometer auxiliary eyepiece. Using the staging table adjusting screws, align the Movable Image in coincidence with the fixed Reference Image. (See Figure 2.)
4.1.5 Swing the Plano Interferometer auxiliary eye piece out of viewing position and observe the TI fringe pattern.

4.1.6 Adjust the Plano Interferometer staging table adjusting screws until 3 to 6 fringes are visible. The center fringe should be nearly parallel to the marked axis being calibrated.

4.1.7 To determine if the TI is concave or convex, the contact point must be identified. Fringes are formed when a small wedge is produced between the TI and the Master Optical Flat. The point where the TI and Master Optical Flat are closest is referred to as the contact point. While viewing through the eyepiece, press on the eyepiece or push up on the staging table in a way which forces the TI and Master Optical Flat closer to each other. The fringes will flow from the contact point.

4.1.8 Determine what percentage of the deviation A is to B by using the eyepiece micrometer, if available, or by visual estimation. In addition, refer to Figure 3 to determine if the observed fringes indicate a concave (-) or convex (+) condition. Be sure to indicate if the percentage of the deviation A is to B is positive or negative. Refer to Figure 3 and calculate the Flatness deviation of the TI. If the observed fringes and contact point appear to be concave, then the percentage of the deviation A to B, must be recorded as negative. If the observed fringes and contact point appear to be convex, then the percentage of the deviation A to B, must be recorded as positive. Refer to Figure 3 and calculate the flatness deviation of the TI.

<table>
<thead>
<tr>
<th>Types of Monochromatic Lights</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light Source</strong></td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Helium-Neon Laser (Bright Red)</td>
</tr>
<tr>
<td>Sodium Vapor (Yellow)</td>
</tr>
<tr>
<td>Mercury Vapor (Green)</td>
</tr>
<tr>
<td>Helium Discharge (Yellow-Orange)</td>
</tr>
</tbody>
</table>
Example:

A = 50% of B

C = 11.6 µin, Refer to Fringe Value from Table 2.

D = -1.1 µin, Refer to the AFPSL 10 Inch Master Optical Flat Calibration Certificate for diameter of TI being calibrated.

TI Flatness Deviation = 50% * 11.6 µin - (-1.1 )

TI Flatness Deviation = 6.9 µin

Note: Be sure to indicate if the percentage of the deviation A is to B is positive or negative. Refer to step 4.1.8.

Figure 3.
4.1.9 Verify that the results are within the values listed in the Limits column of Table 3.

Table 3.

<table>
<thead>
<tr>
<th>Flatness Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
</tr>
<tr>
<td>Optical</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Steel</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

4.1.10 Move the other marked axis on the TI to be in line with the marked axis on the Plano Interferometer and repeat steps 4.1.4 through 4.1.9.

4.1.11 After both axes are calibrated, remove the Petroleum Jelly from the TI surface. If the TI is a single surface Optical Flat, go to step 4.1.13. For double surface Optical Flats, proceed to step 4.1.12.

4.1.12 Double surfaced Optical Flats and Mirrors are finished on both sides. Repeat steps 4.1.1 through 4.1.11 until both axes on both sides are calibrated.

4.1.13 Calibration complete. Set all POWER switches to OFF and secure equipment.

4.1.14 Annotate and attach a Certification Label as per step 3.7.

4.1A OPTICAL FLAT FLATNESS CALIBRATION: (Alternate Method using the Monochromatic Light)

4.1A.1 Determine what side of the AFPSL certified 10 inch Master Optical Flat will be used as the reference and spread a thin coat of Petroleum Jelly on the opposite surface.

4.1A.2 Always support AFPSL certified 10 inch Master Optical Flat on airy points. Airy points are three equally spaced support pads placed on an imaginary circle with a radius equal to 0.7 inch of the radius of the instrument being supported.

4.1A.3 Place the TI on top of the Master Optical Flat. The side of the TI being calibrated must be down and lined up on the 10 inch Master Optical Flat. The marked axes on the TI should be lined up with the marked axes on the 10 inch Master Optical Flat.

4.1A.4 Center the TI on the 10 inch Master Optical Flat and ensure that the center fringe is parallel to the marked axis being calibrated. Be sure to view the fringes as nearly perpendicular to the TI as possible.
NOTE

If the fringes fail to appear, it may be due to the following reasons

1. Dust, burrs, or nicks are holding the TI and Master Optical Flat away from each other. Do not slide the TI against the Master Optical Flat in an effort to make the fringes appear as this may scratch the TI or Master Optical Flat. Instead, try again after recleaning the surfaces or removing the burrs.

2. The natural film of air between the surface of the TI and the Master Optical Flat may be:
   a. Too thick. Press down on the TI with uniform pressure to squeeze out the air film.
   b. Too angular. The Optical Flat may be making too great of angle with the Master Optical Flat, in which case the fringes will be too close together as to be invisible. Try putting pressure at different points around the edge of the TI.
   c. Too thin. If moisture or oil is present, it may cause the TI to wring or adhere to the Master Optical Flat so closely that fringes cannot appear.
   d. Too nearly parallel. This rarely occurs. In this case, the bands would be so far apart that they would not be distinguished as bands.

4.1A.5 While viewing the fringes, move your head backwards. The fringes will flow from the contact point.

4.1A.6 Determine what percentage of the deviation A is to B by visual estimation. In addition, refer to Figure 3 to determine if the observed fringes indicate concave (-) or convex (+) condition. Be sure to indicate if the percentage of the deviation A is to B is positive or negative. Refer to Figure 3 and calculate the Flatness deviation of TI.

4.1A.7 Verify that the results are within the values listed in the Limits column of Table 3.

4.1A.8 Move the other marked axis on the TI to be in line with the marked axis on the 10 inch Master Optical Flat and repeat steps 4.1A.4 through 4.1A.7.

4.1A.9 After both axes are calibrated, remove the Petroleum Jelly from the TI surface. If the TI is a single surface Optical Flat, go to step 4.1A.11. For double surface Optical Flats, proceed to step 4.1A.10.

4.1A.10 Double surface Optical Flats are finished on both sides. Repeat steps 4.1A.1 through 4.1A.9 until both axes on both sides are calibrated.

4.1A.11 Calibration complete. Set all POWER switches to OFF and secure all equipment.

4.1A.12 Annotate and attach a Certification Label as per step 3.7.

4.2A MIRROR FLATNESS CALIBRATION: (Alternate Method using Monochromatic Light)

NOTE

The coated surface of the Mirror (first surface) is the side of the Mirror that is calibrated.

4.2A.1 Place the TI on airy points. Airy points are three equally spaced support pads placed on an imaginary circle with a radius equal to 0.7 inch of the radius of the instrument being supported.

4.2A.2 Determine what side of the Master Optical Flat will be used as the reference.
4.2A.3 Place the Master Optical Flat on top of the TI. The side of the TI being calibrated must be facing up. The side of the Master Optical Flat chosen from step 4.2A.2 must be facing down. The marked axes on the TI should be lined up with the marked axes on the Master Optical Flat.

4.2A.4 Center the Master Optical Flat on the TI and ensure that the center fringe is parallel to the marked axis being calibrated. Be sure to view the fringes as nearly perpendicular to the TI as possible.

**NOTE**

If fringes fail to appear, it may be due to the following reasons:

1. Dust, burrs, or nicks are holding the TI and Master Optical Flat away from each other. Do not slide the TI against the Mater Optical Flat in an effort to make the fringes appear as this may scratch the TI or the Master Optical Flat. Instead, try again after recleaning the surfaces or removing the burrs.

2. The natural film of air between the surface of the TI and the Master Optical Flat may be:
   a. Too thick. Press down on the TI with uniform pressure to squeeze out the air film.
   b. Too angular. The TI may be making too great of an angle with the Master Optical Flat, in which case the fringes will be too close together as to be invisible. Try putting pressure at different points around the edge of the TI.
   c. Too thin. If moisture or oil is present, it may cause the TI to wring or adhere to the Master Optical Flat so closely that fringes cannot appear.
   d. Too nearly parallel. This rarely occurs. In this case, the bands would be so far apart that they would not be distinguished as bands.

4.2A.5 While viewing the fringes, move your head backwards. The fringes will flow from the contact point.

4.2A.6 Determine what percentage of the deviation A is to B by visual estimation. In addition, refer to Figure 3 to determine if the observed fringes indicate concave (-) or convex (+) condition. Be sure to indicate if the percentage of the deviation A is to B is positive or negative. Refer to Figure 3 and calculate the Flatness deviation of TI.

4.2A.7 Verify that the results are within the values listed in the Limits column of Table 3.

4.2A.8 Move the other marked axis on the TI to be in line with the marked axis on the Master Optical Flat and repeat steps 4.2A.1 through 4.2A.7.

4.2A.9 If the TI is a single surface TI go to step 4.2A.11. For double surface TIs, proceed to step 4.2A.10.

4.2A.10 Double TIs are finished on both sides. Repeat steps 4.2A.1 through 4.2A.9 until both axes on both sides are calibrated.

4.2A.11 Calibration complete. Set all POWER switches to OFF and secure all equipment.

4.2A.12 Annotate and attach a Certification Label as per step 3.7.

**CALIBRATION PERFORMANCE TABLE**

Not Required