# 3. CALIBRATION EQUIPMENT

## *3.1 CALIBRATION ENVIRONMENT*

### 3.1.1 FACILITY AND TEST EQUIPMENT LAYOUT

Subsystem level calibration testing for the NAC and WAC Flight Models was performed at JPL's Environmental Test Laboratory in Building 144 from January to August of 1996. The 7-foot thermal vacuum chamber (Chamber # 7) was used to test these cameras individually. (Note : Limited testing was performed at the Spacecraft Assembly Facility (SAF) and at the Cape with both cameras imaging simultaneously.)

Various pieces of test equipment were used for the calibration testing as shown in Table 3.1.1-1.

| EQUIPMENT | PURPOSE | FIGURE |
|---|---|---|
| SPHERE | used for flat-field testing for both the NAC and WAC | Figure 3.1.1-2 - Sphere Set-Up During Thermal Vac |
| NAC COLLIMATOR | used for tests requiring targets | |
| WAC COLLIMATOR | used for tests requiring targets ; designed to cover WAC's entire wavelength region of 380 -1100 nm (compensated for the Fecker's narrow bandwidth) | |
| WAC FECKER COLLIMATOR | used for tests requiring targets ; bandwidth of 486 - 656 nm (heritage from Voyager) | |
| UV BOX | used for NAC UV filter flat-field testing (for light transfer curve) | Figure 3.1.1-1 - UV Box Set-Up During Thermal Vac |
| NONE | dark current testing ; black cloths used to eliminate outside light | |

**Table 3.1.1-1 - General Calibration Equipment List**

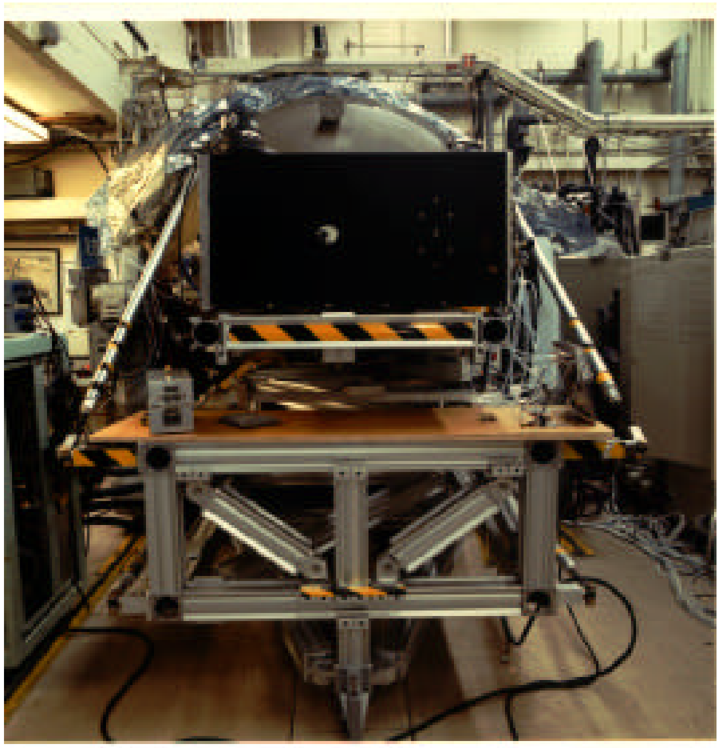

**Figure 3.1.1-1 - UV Box Set-Up During Thermal Vac**

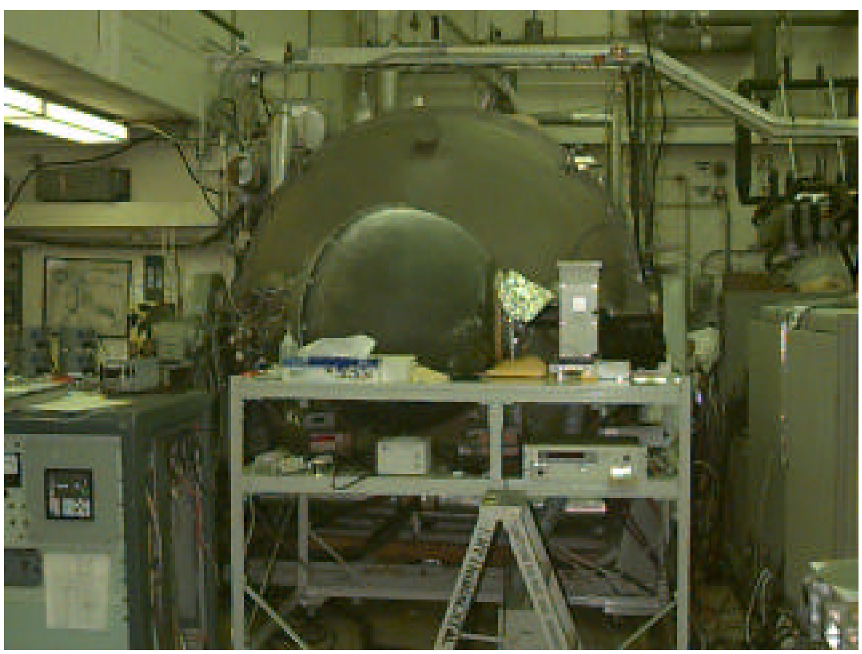

**Figure 3.1.1-2 - Sphere Set-Up During Thermal Vac**

## 3.1.2 GROUND SUPPORT EQUIPMENT

**Reference 3.1.2-1 - D-11307, Rev. B, "Cassini Imaging Science Subsystem Electronic Ground Support Equipment Functional Design/Requirements Document", November 18, 1993**

**Reference 3.1.2-2 - D-12973, " Cassini Imaging Science Subsystem (ISS) Electronic Ground Support Equipment (EGSE) User's Handbook", 1995**

The ISS Electronic Ground Support Equipment (EGSE or GSE) used for calibration testing was SUN SPARC 10 based, with a 1553 Remote Terminal Interface Unit (RTIU) interface, and an X-terminal for science. The GSE consisted of three racks : the science rack (Rack A), the power supply rack (Rack B), and the housekeeping rack (Rack C). These racks are shown in Figure 3.1.2-1 in reverse order (Rack C is the left rack). The ISS EGSE was designed to simulate all spacecraft interfaces and functions : powering on, uploading software, turning heaters on and off, sending commands, and receiving telemetry. Direct access to the instruments was also available for ground testing. All calibration telemetry files and image files were stored on optical disks. Reference 3.1.2-1 and Reference 3.1.2-2 provide more detailed information regarding the design and operation of the GSE.

**Figure 3.1.2-1 - Ground Support Equipment**

## 3.1.3 TEST TEMPERATURES

During subsystem level calibration tests, the camera heads were held at the temperatures shown in Table 3.1.3-1. The low and high endpoints are the operating flight allowable temperatures for ISS. The exceptions to the table are 1) some of the WAC Dark Current data was taken during temperature transitions, and 2) the Focus tests were taken at additional temperatures between the high and low temperature endpoints.

| CAMERA | LOW | NOMINAL | HIGH |
|---|---|---|---|
| NAC | -10 °C | +5 °C | +25 °C |
| WAC | -10 °C | +5 °C | +25 °C |

**Table 3.1.3-1 - Calibration Test Temperatures**

## 3.1.4 VIBRATION EFFECTS

Initially, testing for the Focus, MTF, and PRF calibrations were performed using a steady light source. It was found, via these initial test images, that an unacceptable amount of vibration was being introduced by the test facility. Therefore, in order to minimize the vibrations effects on the test data, the steady light source was replaced with a flash light source, which was found to improve the results of the data sets.

## 3.1.5 GENERAL TEST FLOW

Once the desired temperature was reached and stabilized, typically a interferometric testing of the chamber window and a focus test would be performed, with calibration testing commencing afterwards. The flow of the tests was such that it minimized equipment change-out as much as possible.

Most of the calibration tests were performed using pre-written "scripts", which would load and execute camera set-up and image sequences to the camera under test. There were some tests, however, which precluded the use of scripts, and required individual imaging commands. These included any tests using the flash light source (Focus, PRF, MTF), or the dynamic ramp target (ADC bit-weighting test), where manual timing of initiating the flash or ramp motion, with respect to shuttering the camera, was required.

The use of the scripts automated the testing to a large degree, with the operator initially preparing for the test by setting up the target and light source level and verifying sufficient optical disk space, as specified in the script comments. Script were modified and re-ran in order to re-take any images which had missing data packets.

While using the sphere (for flat-field testing), the lamp used to illuminate the sphere was calibrated daily (see Appendix E for electronic data).

## 3.1.6 CHAMBER WINDOW

### 3.1.6.1 WINDOW DESCRIPTION

The chamber window was made of Corning 7940 OC grade fused silica and manufactured by ESCO Product, Inc. A subset of the specifications for the window are shown in Table 3.1.6-1. The chamber window phase map and interferograms provided by ESCO, in order to demonstrate meeting the flatness requirement, are shown in Figure 3.1.6-1 and Figure 3.1.6-2, respectively. Corning provided homogeneity phase maps and interferograms, shown in Figure 3.1.6-3 through Figure 3.1.6-6.

| SPECIFICATION | REQUIREMENT | TEST DATA |
|---|---|---|
| Total Inclusion Cross Section | 0.00-0.03 $mm^2$ | |
| Maximum Inclusion Cross Section | 0.10 mm | |
| Homogeneity | $2 \times 10^{-6}$ | $1.4 \times 10^{-6}$ |
| Flatness | 1/20$^{th}$ wave @ 633 nm | PV : 0.047 wave<br>RMS : 0.010 wave |
| Surface Quality | 10-5 | |
| Parallel | 5 seconds or better | |
| Dimensions | diameter : 13.375 ± 0.020 inches | |
| | thickness : 2.0 ± 0.010 inches | |

**Table 3.1.6-1 - Chamber Window Specifications**

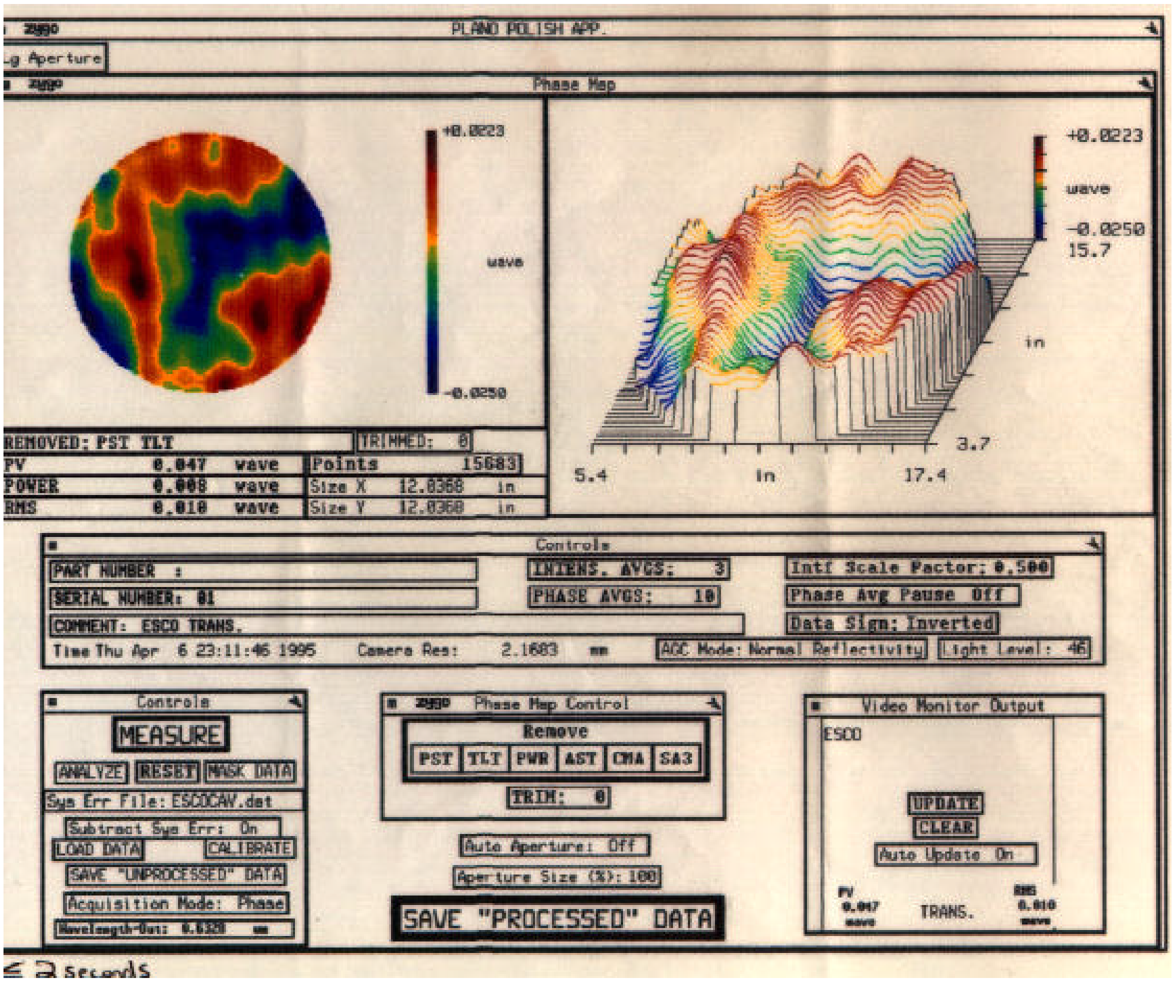


**Figure 3.1.6-1 - Chamber Window Flatness Phase Map from ESCO**

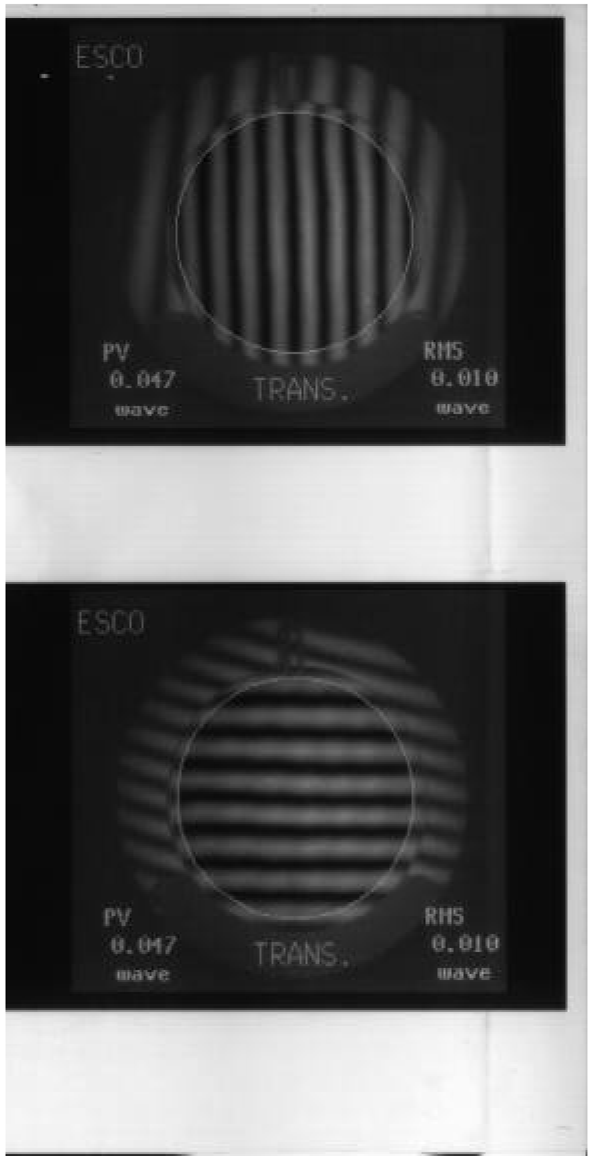


**Figure 3.1.6-2 - Chamber Window Flatness Interferograms from ESCO**

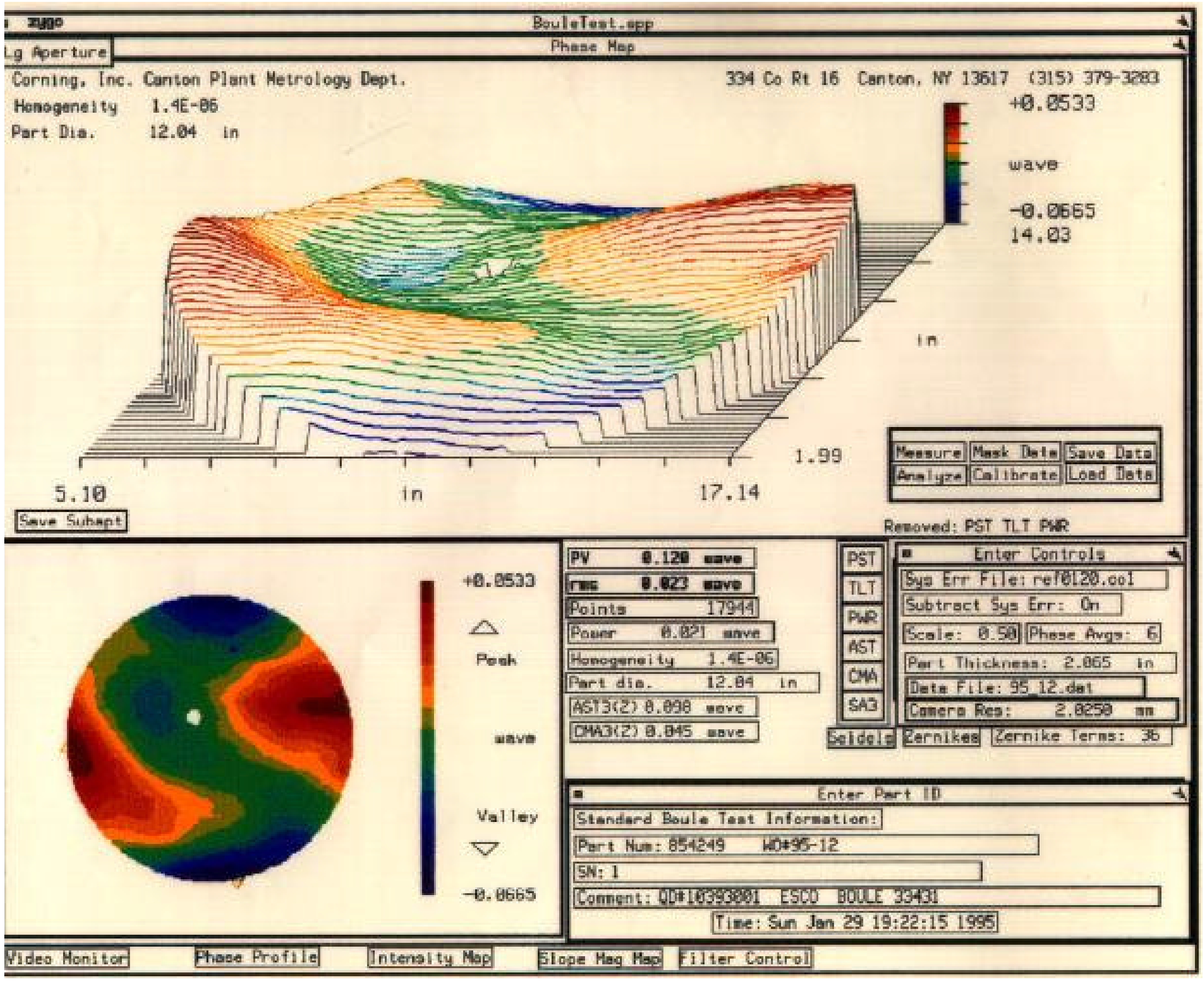


**Figure 3.1.6-3 - Chamber Window Homogeneity Phase Map from Corning**

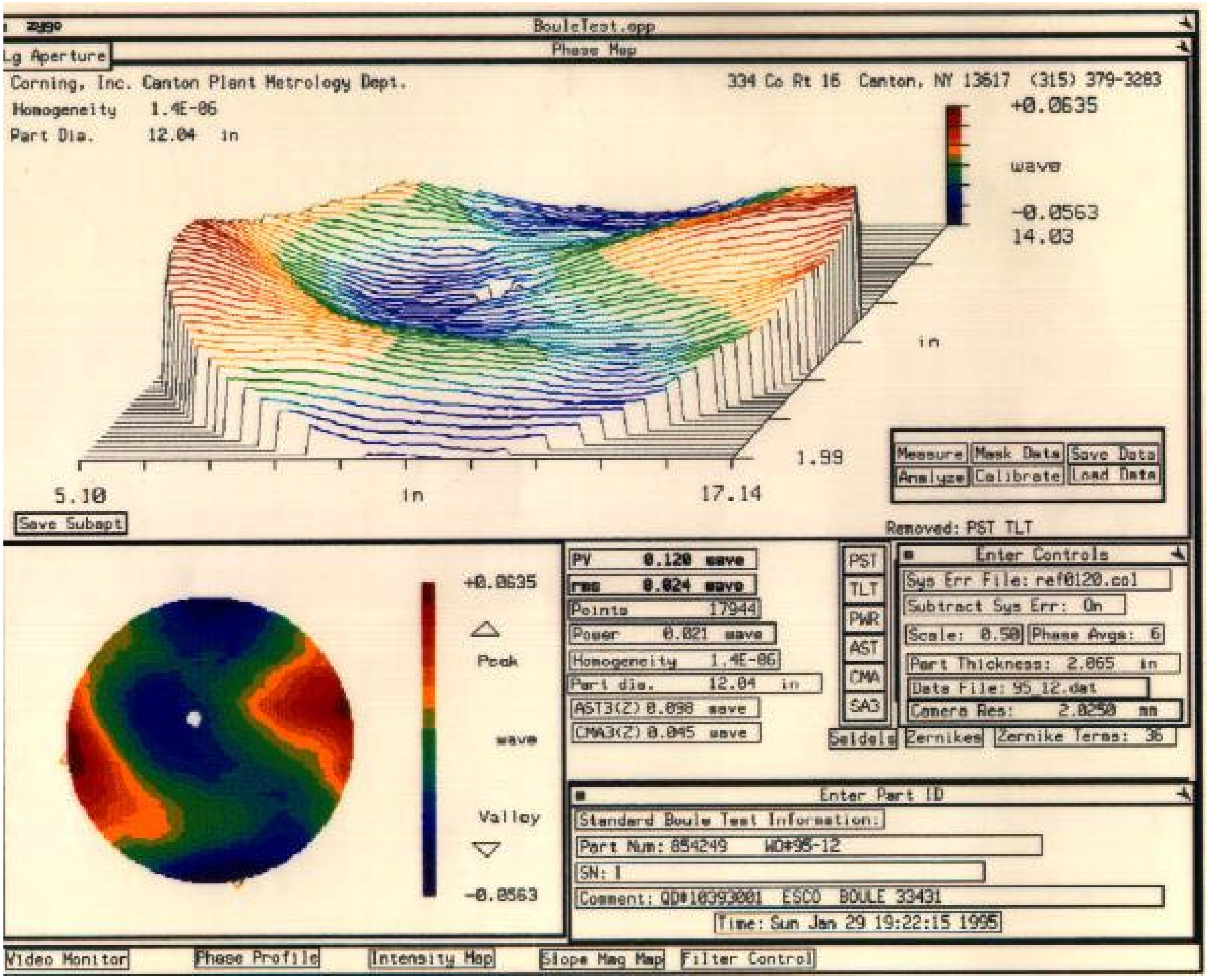


**Figure 3.1.6-4 - Chamber Window Homogeneity Phase Map from Corning**

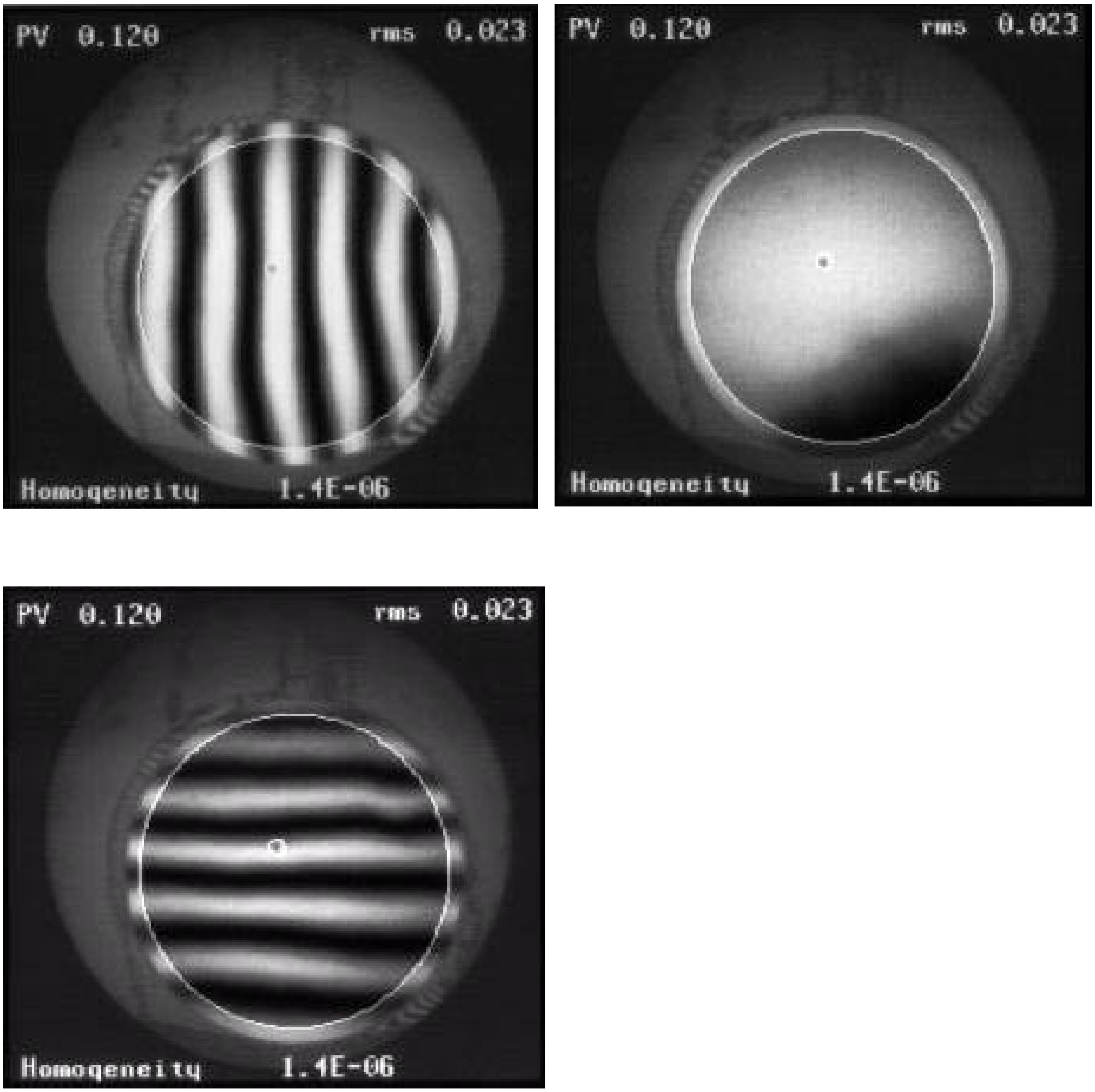


**Figure 3.1.6-5 - Chamber Window Homogeneity  Interferograms from Corning**

## 3.1.6.2 OPTICAL THROUGHPUT MEASUREMENTS

**Reference 3.1.6-1 - UV Lab Data File, Cary Scan of Quartz Window, B. Wallis and K. Manatt, April 26, 1995**

The optical throughput of the window was measured at JPL by B. Wallis and K. Manatt (Reference 3.1.6-1) and has been electronically archived (see Appendix E). The plot and data from the throughput testing are shown in Figure 3.1.6-6 and Table 3.1.6-2, respectively. The data was taken prior to cleaning the window at spacings of 10 nm. The data is a summarization made from 2 separate scans at two different points on the window (2 separate baseline scans were used).

**Figure 3.1.6-6 - Chamber Window Optical Transmission**

| WAVELENGTH (nm) | TRANSMISSION |
|---|---|
| 197.5 | 81.654 |
| 207.5 | 86.1839 |
| 217.5 | 88.9119 |
| 227.5 | 90.1375 |
| 237.5 | 90.6973 |
| 247.5 | 91.0474 |
| 257.5 | 91.3315 |
| 267.5 | 91.5988 |
| 277.5 | 91.8187 |
| 287.5 | 92.0307 |
| 297.5 | 92.2199 |
| 307.5 | 92.276 |
| 317.5 | 92.1298 |
| 327.5 | 92.2153 |
| 337.5 | 92.2836 |
| 347.5 | 92.5026 |
| 357.5 | 92.5601 |
| 367.5 | 92.6035 |
| 377.5 | 92.6455 |
| 387.5 | 92.6918 |
| 397.5 | 92.7338 |
| 407.5 | 92.7724 |
| 417.5 | 92.803 |
| 427.5 | 92.836 |
| 437.5 | 92.8658 |
| 447.5 | 92.8891 |
| 457.5 | 92.9173 |
| 467.5 | 92.934 |
| 477.5 | 92.9526 |
| 487.5 | 92.9791 |
| 497.5 | 92.9951 |
| 507.5 | 93.0175 |
| 517.5 | 93.037 |
| 527.5 | 93.0503 |
| 537.5 | 93.0687 |
| 547.5 | 93.0867 |
| 557.5 | 93.1044 |
| 567.5 | 93.1226 |
| 577.5 | 93.1682 |

| WAVELENGTH (nm) | TRANSMISSION |
|---|---|
| 587.5 | 93.1756 |
| 597.5 | 93.1867 |
| 607.5 | 93.2032 |
| 617.5 | 93.227 |
| 627.5 | 93.2492 |
| 637.5 | 93.2616 |
| 647.5 | 93.2873 |
| 657.5 | 93.3102 |
| 667.5 | 93.3369 |
| 677.5 | 93.3631 |
| 687.5 | 93.3771 |
| 697.5 | 93.4028 |
| 707.5 | 93.4165 |
| 717.5 | 93.4096 |
| 727.5 | 93.3834 |
| 737.5 | 93.4495 |
| 747.5 | 93.4771 |
| 757.5 | 93.4858 |
| 767.5 | 93.5116 |
| 777.5 | 93.5117 |
| 787.5 | 93.5285 |
| 797.5 | 93.549 |
| 807.5 | 93.4026 |
| 817.5 | 93.4063 |
| 827.5 | 93.3767 |
| 837.5 | 93.3864 |
| 847.5 | 93.3504 |
| 857.5 | 93.3132 |
| 867.5 | 93.3607 |
| 877.5 | 93.3187 |
| 887.5 | 93.3606 |
| 897.5 | 93.359 |

408-898 mean = 93.22676

**Table 3.1.6-2 - Chamber Window Transmission Data**

### 3.1.6.3 WINDOW HEATERS / INTERFEROMETRIC TESTING

In order to prevent optical distortion being introduced into the test system by the chamber window, the window's temperature was controlled with window collar disk and cylinder heaters. Subsequent to each camera head temperature transition and stabilization, and prior to commencement of any calibration testing, the window was interferometrically tested.

The test set-up consisted of a laser-diode/beam diverger assembly, mounted into a target holder, which fit directly into the collimator's target receptacle. The laser light was reflected from the both surfaces of the window to create interference fringes, which were recorded using a video camera/recorder. The Fizeau interference fringes were examined, and any adjustments to the window temperature were made as required. Typically, once the optimal window temperature was attained, modification to the window temperature control point was not required.