

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

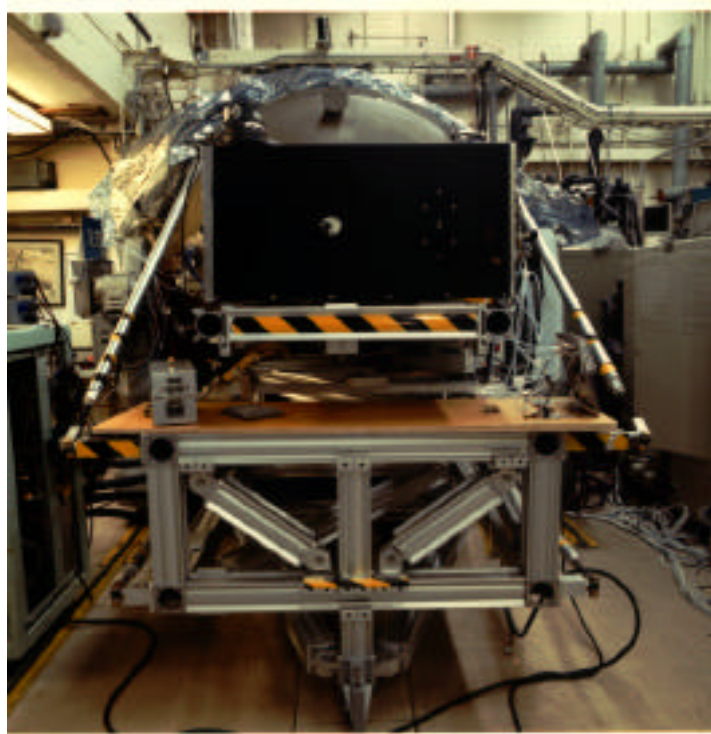


Figure 3.1.1-1 - UV Box Set-Up During Thermal Vac

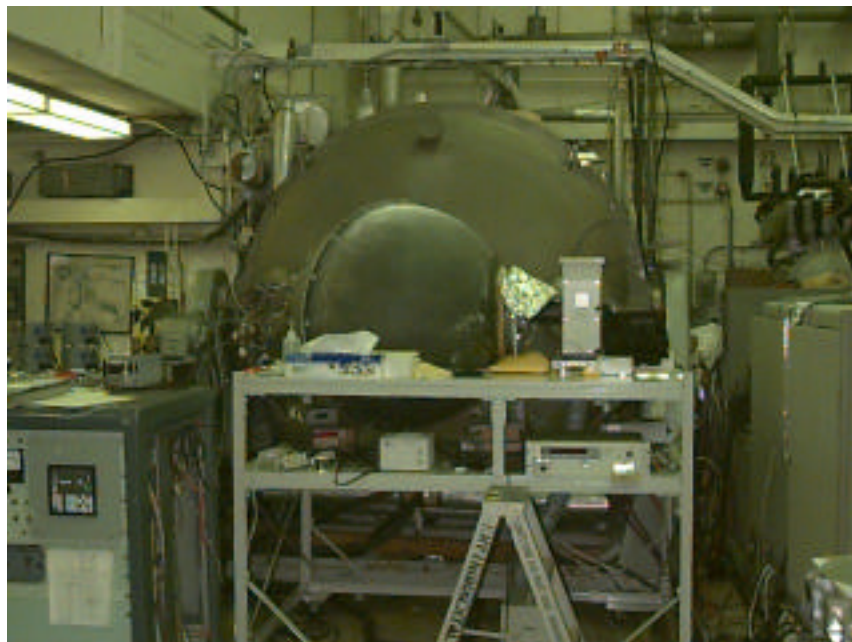


Figure 3.1.1-2 - Sphere Set-Up During Thermal Vac

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	2×10^{-6}	1.4×10^{-6}
Flatness	1/20 th wave @ 633 nm	PV : 0.047 wave 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

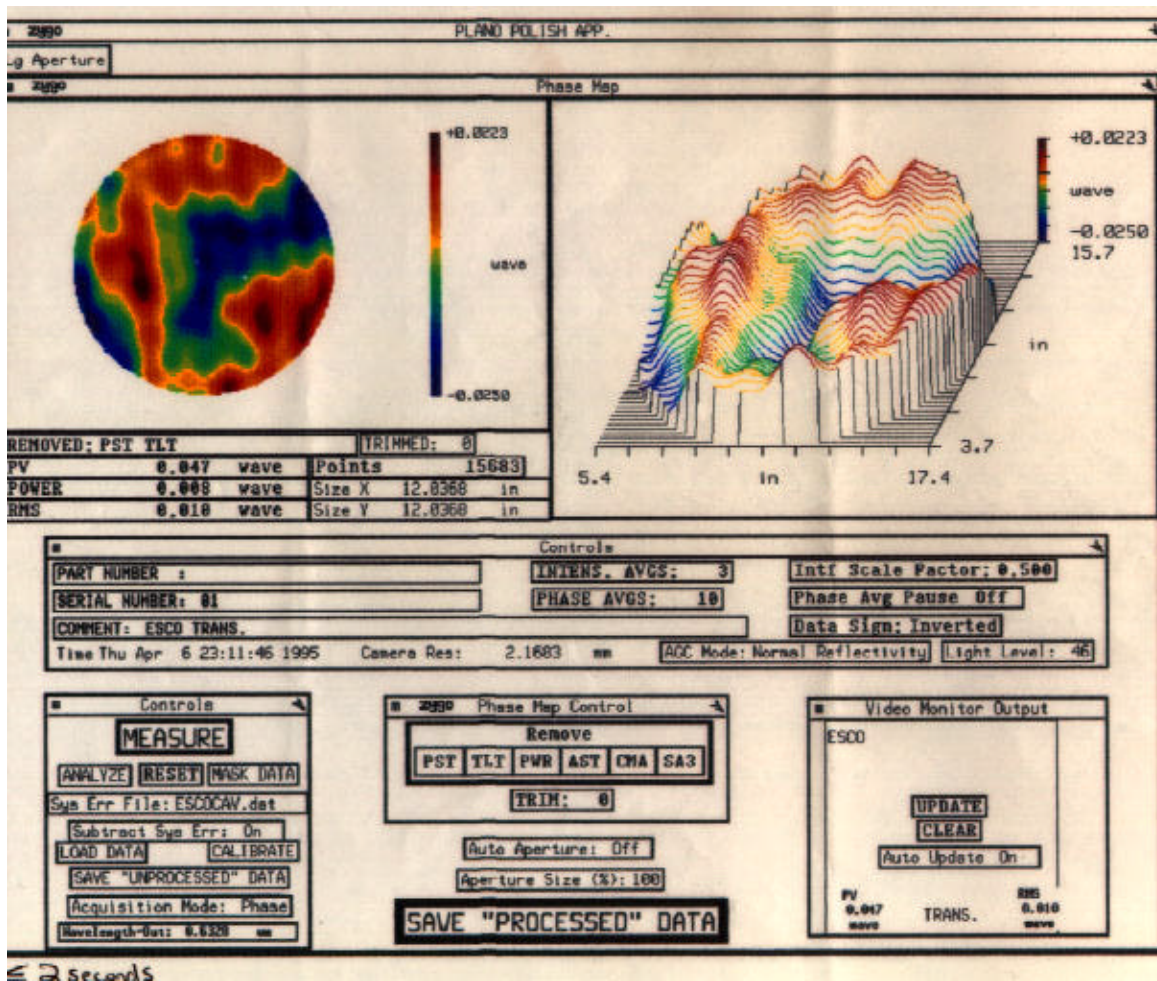


Figure 3.1.6-1 - Chamber Window Flatness Phase Map from ESCO

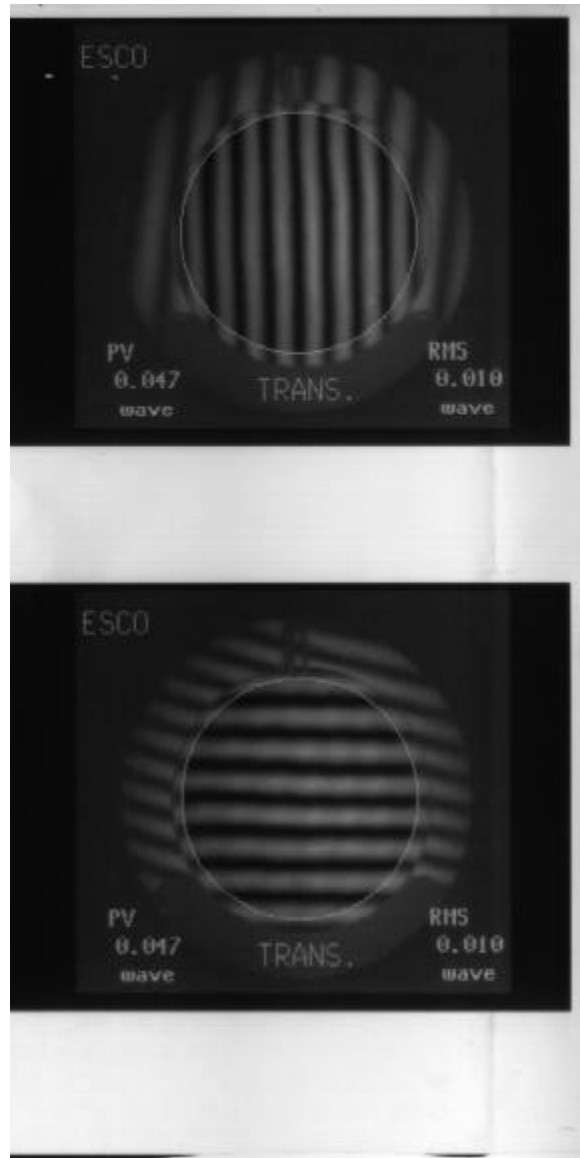


Figure 3.1.6-2 - Chamber Window Flatness Interferograms from ESCO

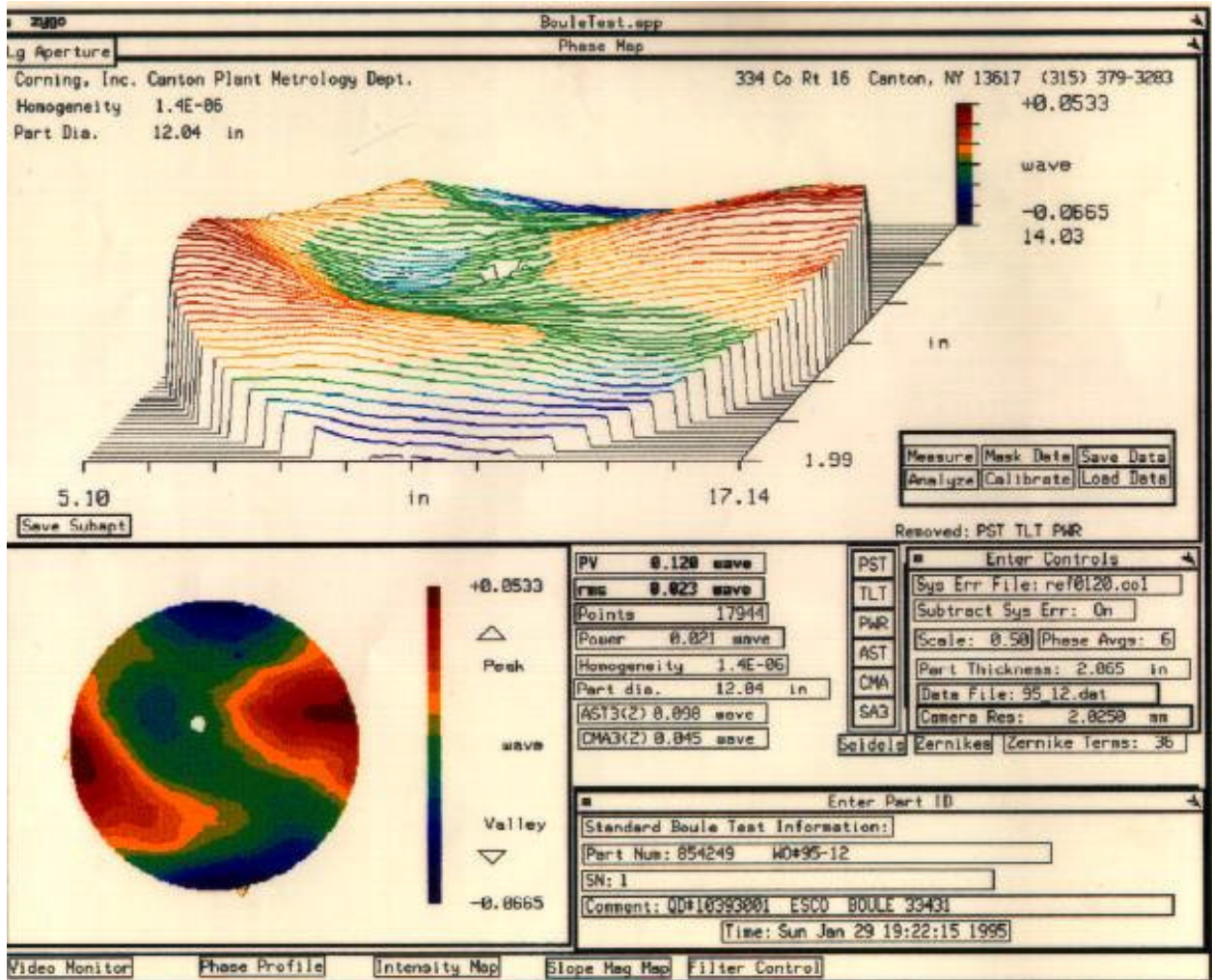


Figure 3.1.6-3 - Chamber Window Homogeneity Phase Map from Corning

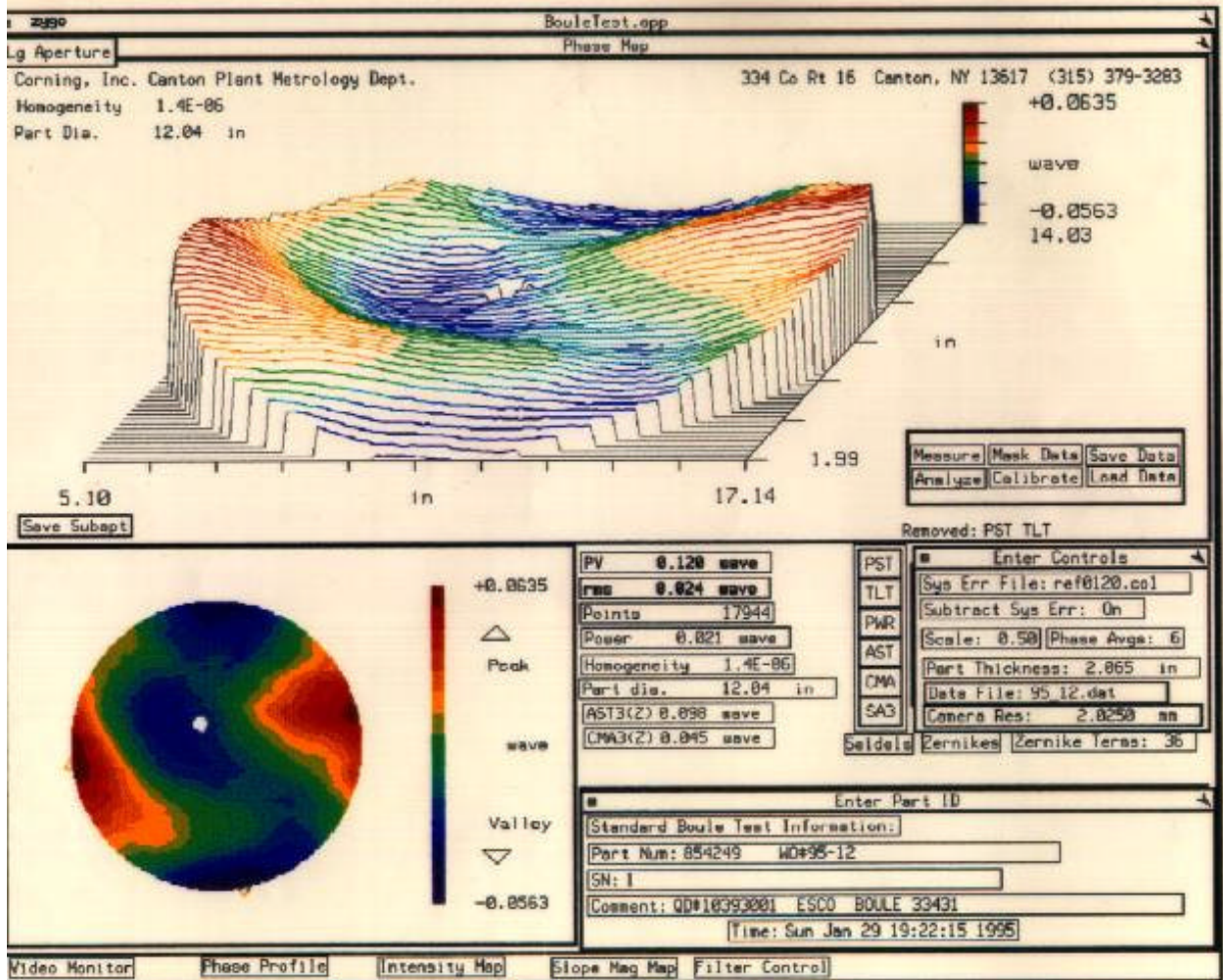


Figure 3.1.6-4 - Chamber Window Homogeneity Phase Map from Corning

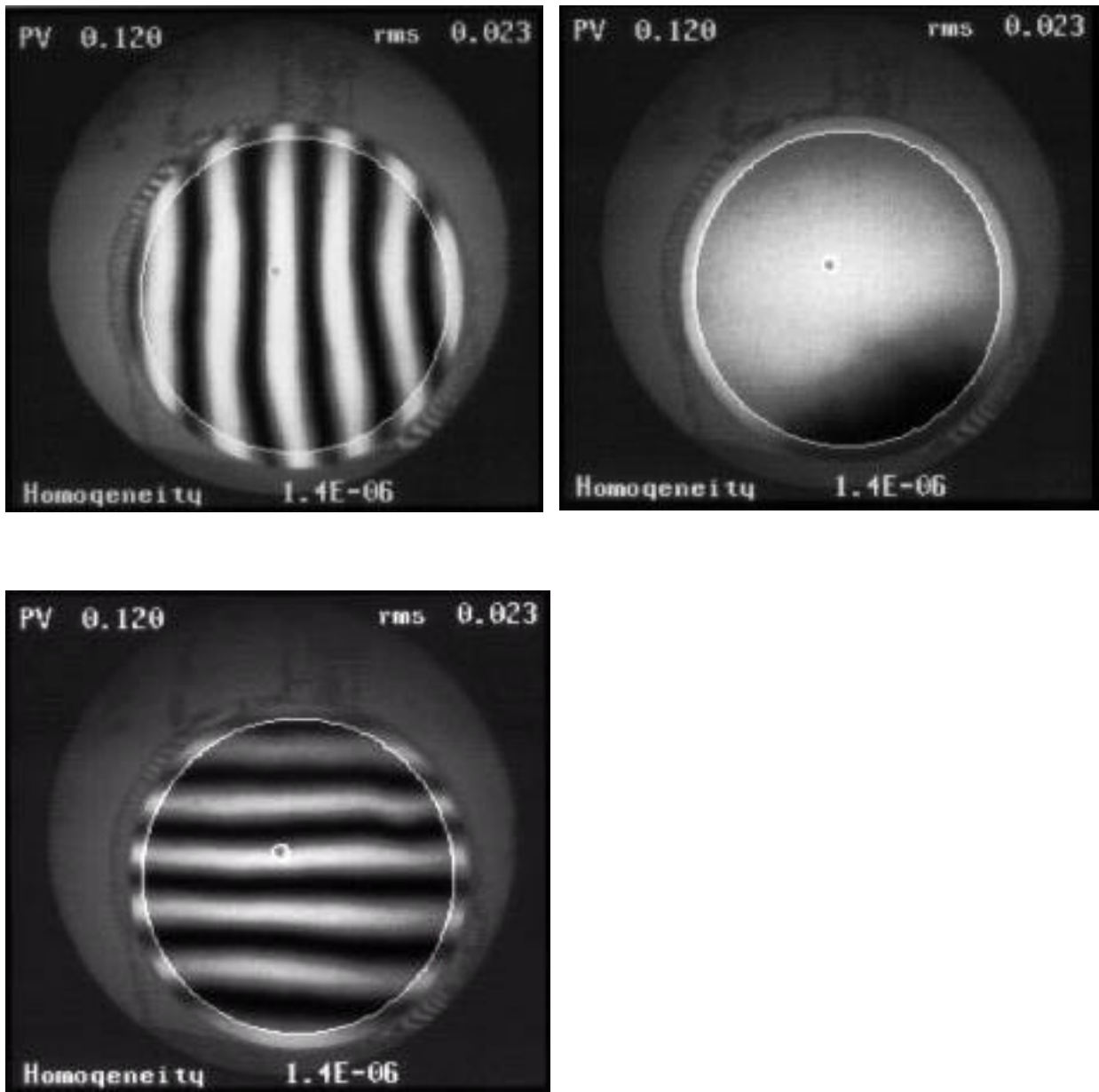


Figure 3.1.6-5 - Chamber Window Homogeneity Interferograms from Corning

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.