Final Report

Shearography NDE of NASA COPV

Tests Performed at NASA White Sands Test Facility, NM
Sept. 12-16, 2006

Prepared By
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October 25, 2006
# Final Report - Shearography NDE of NASA COPV

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1. 21 Composite Over-wrapped Pressure Vessels (COPV) consisting of Kevlar Space Shuttle Fleet Leaders and Graphite COPV were inspected at NASA WSTF, NM from Sept. 12 through Sept 16.

2. The inspection technique was Pressurization Shearography, tests designed to image composite material damage, degradation or design flaws leading to stress concentrations in the axial or hoop strain load path.

3. The defect types detected consisted of the following:
   • Intentional impact damage with known energy.
   • Un-intentional impact damage.
   • Manufacturing defects.

4. COPV design features leading to strain concentrations detected include:
   • Strain concentrations at bosses due to fiber closure pattern.
   • Strain concentrations in body of COPV due to fiber wrap pattern.
   • Strain concentrations at equator due to liner weld/fiber lay-up.
Summary, Cont’d.

5. Shearography compliments other NDE techniques, such as Visual Inspection.
   • Of 51 shearography indications detected on Kevlar COPV and Graphite Cylinder COPV, 9 were not detected visually. (See 7.0 Defect Guide)
   • The extent of subsurface composite matrix damage and delamination due impact, can be measured with Pressurization Shearography.

6. Kevlar COPV results are presented in Section 9.0, herein. Graphite COPV results are presented in Section 10.0, herein.

John Newman
Laser Technology Inc.
October 25, 2006
Shearography NDE of Space Shuttle COPV

COPV Types Inspected

10 Inch Graphite Sphere

6 x 22 Graphite COPV

26 Inch Diam. Kevlar Fleet Leader

10 Inch Kevlar Fleet Leader

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Shearography NDE of NASA COPV
Significance of Test and Results

1. Shearography inspection of COPV is a new, promising tool for the evaluation of manufacturing defects, damage from impact or degradation from high temperature, chemical or radiation exposure. Although used by the author on Delta IV COPV and on other programs, this series of tests at WSTF is the first application of Digital Phase Shearography for NASA COPV.

2. Shearography COPV NDE has the capability to image and measure sub-surface, non-visible matrix damage, quickly and with excellent repeatability.

3. These tests were designed to detect local changes in surface axial and hoop strain caused by damage to the composite matrix or manufacturing defects. Lessons learned during these tests will improve technique and results in the future.

4. While the damage detection capability has been clearly demonstrated, the specific effect of such damage on COPV creep rupture characteristics, reduction in burst strength and life time performance has not been established.
Section 3.0

Shearography NDE Team Performing Tests NASA
White Sands Test Facility, NM    Sept. 12-16, 2006

Paul Ogletree     USA KSC
Dr. Brad Regez    USA KSC
Jim Landry        USA KSC
Leo Going         USA KSC
John Newman       Laser Technology Inc.
Ken Tauer         USA KSC
Section 4.0

Background On Shearography NDE
Equipment used for these tests was the LTI-5100 All Mode, Digital Shearography System

Features:
- Z Axis deformation to 2 nm.
- Quantitative displacement measurement capability.
- Damage/Defect size area measurement.
- Remote control of all camera parameters allows testing in hazardous environments.
- Eye safe Class Illa Laser System.
- Training to ASNT TC-1A Level II and III.
Flat Circular Plate Deformation
With Center, Single Point Load

Phase Maps for: \( \frac{\partial W}{\partial x} \) and \( \frac{\partial W}{\partial y} \)

120 mm. Diam.
5mm. Thick
Flat Plate

Z Axis Displacement change \( W \), measured mechanically as 7µ

\( \frac{\partial W}{\partial x} \)

\( \frac{\partial W}{\partial y} \)

Horizontal 0° Shear Vector

Vertical 90° Shear Vector
Flat Circular Plate Deformation With Center, Single Point Load: 
Quantitative Z Axis Displacement Measurement

120 mm. Diam. 
5mm. Thick 
Flat Plate

Z Axis Displacement change \( W \), measured mechanically as 7\( \mu \)

Phase Map \( \frac{\partial W}{\partial x} \)

Integration \( \int \frac{\partial W}{\partial x} \, dx \)

3-D Plot and measurement of Z Axis displacement

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Aerospace Inspection Systems
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Section 5.0

Background On Shearography COPV NDE
Shearography NDE of COPV

• Full field laser interferometric imaging of COPV composite materials for damage, liner to composite disbonds or design flaws, leading to stress concentrations affecting hoop strain.

• Shearography camera is used with precision control of COPV internal pressure changes.

• Defective composite material dimensions/area are easily measured.
Raising internal pressure increases hoop and longitudinal strain.

Z axis component of strain concentrations caused by anomalies are detected by the shearography camera.

As pressure increases, strain rates at damage areas are greater than good areas.
Shearography COPV Test Procedure

1. Preparation of COPV Test articles
   - Kevlar COPV were tested without coating
   - Graphite COPV were coated with dye penetrant developer to reduce glare and increase surface reflectivity.
2. Test Article mounted in fixture to provide mechanical stability and allow rotation.
3. Pressure hose fitted with tank gage connected to pressure feed line in blind COPV and to the gage port if present.
4. Pressure in COPV raised to 70 psi. to allow minimum pressure cycle time.
5. An LTI-5100 Digital Shearography Camera System was used with the following parameters:
   - Distance to Part 34 inches
   - Shear Vector 0° (axial) @ 0.25 in.
   - Field of view (8 in. H x 6.2 in. V) and (11 in. H x 7.3 in. V)
Shearography Test Set-Up for COPV Testing
Pneumatic Operation/Shearography Data Capture

1. V1 opened, pressure raised to 70psi., V1 closed.
2. Shearography reference image captured @70 psi.
3. V1 opened, pressure raised to 90psi., V1 closed.
4. Shearography Stressed image captured @90 psi.
5. Final shearography image computed.

150 psi.
Filtered GN2
Supply

Rigid COPV Support
Frame allows tank rotation.

COPV Pressure Gage
0-120 psi.

V1
V2
Vent
Shearography Test Set Up at WSTF 9-12-06
Interpreting Shearography
COPV NDE Results
6 x 22 Inch Graphite COPV Shearography Inspected with 10 psid. Crater like indications are impact induced damage and delamination to the composite.
6 x 22 Inch Graphite COPV Shearography Inspected with 10 psid. Three impact areas are seen and one small un-programmed defect.
10 Inch Diam. Carbon Fiber COPV

No visible damage except 0.15 inch diameter dimple at impact sites.

Shearography Test with 1.2 psid

Impact induced delamination .75 to 2.3 inches in diameter.
10 Inch Diam. Carbon Fiber COPV – Typical Images
Side View Showing Pressure Fitting
Shearography Test, at right with 1.2 psid, rotating 120 Degrees per test.

No visible damage except 0.15 inch diameter dimple at impact sites.

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10 Inch Diam. Carbon Fiber COPV – Typical Images
Side View Showing Pressure Fitting
Shearography Test, at right with 1.2 psid, rotating 190 Degrees per test.

No visible damage except 0.15 inch diameter dimple at impact sites.
10 ¼ Inch Kevlar COPV – Typical Images

Shearography scan Band 1. The pressure port boss is in the center, a stress riser (circled) due to a defect or fiber closure pattern.

Shearography Scan of Band 2 at the equator showing the Strain concentration over the circumferential liner girth weld.
Section 7.0

Shearography COPV NDE Compared to Visual Inspection

Relative Strengths and Weakness
Shearography COPV NDE Compared to Visual Inspection

1. Visual Testing of COPV detects:
   • Surface fiber breakage.
   • Dimpled COPV surface from impact object.
   • Changes in surface color, texture, appearance indicative of damage.

2. Visual Testing is fast, uses low cost magnifiers and lighting.

3. Visual Testing is not affected by COPV color, reflectivity or finish.

4. Shearography detects any non-homogeneity in the COPV composite or liner that leads to local changes in the surface strain. Such defects include:
   • Fiber breakage, surface and subsurface matrix cracking
   • Degradation of composite matrix due to chemical or UV exposure.
   • Design or manufacturing flaws such as poor fiber closure pattern at bosses, bridging at transitions such as those at dome to cylinder areas.

5. Shearography NDE requires relatively expensive equipment, operator training, part stability and fixture.

6. Shearography is affected by and procedures must accommodate COPV color, reflectivity and glare.
Visual impact damage for the graphite COPV ranged from severe fracture seen below, enhanced with dye penetrant coating, to little or no discernable damage beyond the very small, 0.1-0.2 inch impact sites seen on 10 ¼ inch COPV at right.

Shearography image of area on the 10 ¼ inch COPV above.
Impact Site for intentional Defects are seen visually as dimple, fiber breakage and/or color change.

Visual indication of composite damage ranged from severe fracturing at area around impact site to a small crack or dimple, to no visual indication.

Shearography indications seen in graphite COPV ranged from 0.2 to 4 inches in diameter.
Comparison Between The Measured Shearography Damage Dimensions and Visual Damage of 50 Ft-Lb Impact @ 180°, 10 Inches from Forward Boss.

Shearography Damage Indication
Measures 4.1 inches

Visual Damage
Measured 0.5 in.
Section 8.0

Defect Guide to Found Shearography Indications in Tested COPV
## Defect Guide to Found Shearography Indications in Tested COPV

<table>
<thead>
<tr>
<th>Kevlar COPV Indication Type</th>
<th>Pages</th>
<th>S/N</th>
</tr>
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<tbody>
<tr>
<td>1. Strain Concentrations at Boss</td>
<td>66,76</td>
<td>003</td>
</tr>
<tr>
<td>- 10¼ in. Kevlar Sphere</td>
<td></td>
<td>004</td>
</tr>
<tr>
<td>2. Stain Concentrations at Girth Weld</td>
<td>38,49</td>
<td>001</td>
</tr>
<tr>
<td>- 26 in. Kevlar Sphere</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Fiber Delamination</td>
<td>45</td>
<td>005</td>
</tr>
<tr>
<td>- 26 in Kevlar Sphere</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Defect Guide to Found Shearography Indications in Tested COPV

<table>
<thead>
<tr>
<th>Graphite COPV Indications</th>
<th>Pages</th>
<th>S/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Unintentional Damage</td>
<td>91,92,93,94</td>
<td>015</td>
</tr>
<tr>
<td>6x22 in. Cylinder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Cracks Due to Impact</td>
<td>101</td>
<td>063</td>
</tr>
<tr>
<td>6x22 in. Cylinder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Fiber Bridging at Transitions</td>
<td>105,106,107</td>
<td>139</td>
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Shear image shows crack 5 inches in length.
Kevlar COPV Shearography Test Results

Space Shuttle Kevlar COPV

- 26 Inch Kevlar Sphere  s/n 001
- 26 Inch Kevlar Sphere  s/n 005
- 18 Inch Kevlar Sphere  s/n 001
- 18 Inch Kevlar Sphere  s/n 004
- 10 ¼ Inch Kevlar Sphere s/n 001
- 10 ¼ Inch Kevlar Sphere s/n 003
- 10 ¼ Inch Kevlar Sphere s/n 012
- 10 ¼ Inch Kevlar Sphere s/n 014
- 10 ¼ Inch Kevlar Sphere s/n 015
- 10 ¼ Inch Kevlar Sphere s/n 019
Shearography COPV Test Data

26 Inch Kevlar Sphere s/n 001
26 Inch Kevlar Sphere Scan Plan

5 Bands
12 Sections/Band
30°/Section

Aft
Boss

5 4 3 2 1

Forward
Boss

30° Fiduciary Tape Marks
Shearography COPV Test Data
26 Inch Kevlar Sphere s/n 001

Band 1 Forward Boss End

Results:
No Anomaly Indications Detected
Shearography COPV Test Data
26 Inch Kevlar Sphere s/n 001

Band 2 Forward Boss End

Results:
No Anomaly Indications Detected

0°
Shearography COPV Test Data
26 Inch Kevlar Sphere s/n 001

Band 3 Equator Over Circumferential Girth Weld

Stress Concentration

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Shearography COPV Test Data
26 Inch Kevlar Sphere s/n 001

Band 4 Forward Boss End

Results: No Anomaly Indications Detected

0°
Shearography COPV Test Data
26 Inch Kevlar Sphere  s/n 001

Band 5 Aft Boss End

Results:
No Anomaly
Indications Detected
Shearography COPV Test Data

26 Inch Kevlar Sphere s/n 005
Shearography COPV Test Data
26 Inch Kevlar Sphere         s/n 005

Band 1 Forward Boss End

Results:
No Anomaly Indications Detected
Shearography COPV Test Data
26 Inch Kevlar Sphere s/n 005

Band 2 Forward Boss End

Results: No Anomaly Indications Detected
Shearography COPV Test Data
26 Inch Kevlar Sphere  s/n 005

Band 3 Equator Over Circumferential Girth Weld

Results:
No Anomaly Indications Detected
Shearography COPV Test Data
26 Inch Kevlar Sphere s/n 005

Band 4 Forward Boss End

Results: Fiber Delaminations Detected @ Approx. 240°
Shearography COPV Test Data
26 Inch Kevlar Sphere s/n 005

Band 5 Aft Boss End

Results: No Anomaly Indications Detected

0°
Summary
Shearography COPV Test Results

26 Inch Kevlar Sphere
s/n 001
s/n 005
Shearography Inspection of 26 Inch Kevlar COPV Band 3 – Equator, Over Circumferential Girth Weld

- Pressure Shearography inspected with 20 psid.
- COPV s/n 001 and 005 tested.

**Test Results:**

- s/n 001
  - Strain concentration @255°
- s/n 005
  - Fiber Delaminations Detected
  - Band 4 @ approx. 240°
Shearography COPV Test Data

18 Inch Kevlar Sphere s/n 001
18 Inch Kevlar Sphere Test Fixture
18 Inch Kevlar Sphere Scan Plan

3 Bands
10 Sections/Band
36°/Section

AN-8 Boss

AN-4 Boss

Pressure Port

45° Fiduciary Tape Marks
Shearography COPV Test Data
18 Inch Kevlar Sphere  s/n 001

Band 1 AN-4 Boss (Pressure Port)

Results: No Anomaly Indications Detected

0°
Shearography COPV Test Data
18 Inch Kevlar Sphere s/n 001

Band 2 Equator over Circumferential Girth Weld

Results:
No Anomaly Indications Detected
Shearography COPV Test Data
18 Inch Kevlar Sphere s/n 001

Band 3 AN-8 Boss (Blank End)

Results: No Anomaly Indications Detected

0°
Shearography COPV
Test Data

18 Inch Kevlar Sphere
s/n 004
Shearography COPV Test Data
18 Inch Kevlar Sphere  s/n 004

Band 1 AN-4 Boss (Pressure Port)

Results:
No Anomaly Indications Detected

0°
Shearography COPV Test Data
18 Inch Kevlar Sphere s/n 004

Band 2 Equator over Circumferential Girth Weld

Results: No Anomaly Indications Detected

0° 360°
Shearography COPV Test Data
18 Inch Kevlar Sphere  s/n 004

Band 3 AN-8 Boss (Blank End)

Results: No Anomaly Indications Detected

0°
10 ¼ Inch Kevlar Sphere Scan Plan

3 Bands
8 Sections/Band
45°/Section
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere    s/n 001

Band 1 Pressure Port End

Results:
No Anomaly Indications Detected

0°
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere  s/n 001

Band 2 Equator over Circumferential Weld

Results:
No Anomaly Indications Detected
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere     s/n 001

Band 1 Pressure Port End

Results: No Anomaly Indications Detected

0°
Shearography COPV Test Data

10 1/4 Inch Kevlar Sphere s/n 003
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere s/n 003

Band 1 Pressure Port End

Stress
Concentration
at Boss

Results:
Anomaly
Indications
Detected. Unusually
High Stress
Concentration
At Pressure
Port Boss

0°
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere s/n 003

Band 2 Equator over Circumferential Weld

Results:
No Anomaly Indications Detected
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere s/n 003

Band 3 Blank Boss End

Results:
No Anomaly Indications Detected

0°
Shearography COPV Test Data

10 1/4 Inch Kevlar Sphere s/n 012
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere s/n 012

Band 1 Pressure Port End

Results: No Anomaly Indications Detected
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere s/n 012

Band 2 Equator over Circumferential Weld

Results:
No Anomaly Indications Detected
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere    s/n 012

Band 3 Blank Boss End

Results: No Anomaly Indications Detected

0°
Shearography COPV Test Data

10 1/4 Inch Kevlar Sphere  s/n 014
Shearography COPV Test Data

10 ¼ Inch Kevlar Sphere s/n 014

Band 1 Pressure Port End

Results:
No Anomaly Indications Detected

Normal Stress Concentration Due to Closure Pattern at Boss

0°
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere s/n 014

Band 2 Equator over Circumferential Weld

Results: No Anomaly Indications Detected
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere s/n 014

Band 3 Blank Boss End

Results: No Anomaly Indications Detected

0°
Shearography COPV Test Data

10 1/4 Inch Kevlar Sphere  s/n 015
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere  s/n 015

Band 1 Pressure Port End

Results: Anomaly Indications Detected. Unusually High Stress Concentration At Pressure Port Boss

0°
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere  s/n 015

Band 2 Equator over Circumferential Weld

Results: No Anomaly Indications Detected
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere    s/n 015

Band 3 Blank Boss End

Results: No Anomaly Indications Detected

0°
Shearography COPV Test Data

10 1/4 Inch Kevlar Sphere  s/n 019
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere    s/n 019

Band 1 Pressure Port End

Results:
No Anomaly Indications Detected

0°
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere s/n 019

Band 2 Equator over Circumferential Weld

Results:
No Anomaly Indications Detected
Shearography COPV Test Data
10 ¼ Inch Kevlar Sphere s/n 019

Band 3 Blank Boss End

Results:
No Anomaly Indications Detected

0°
Section 10.0

Graphite COPV Shearography Test Results

Space Station Graphite COPV

• Cylinder 6 x 22 inch s/n 010
• Cylinder 6 x 22 inch s/n 015
• Cylinder 6 x 22 inch s/n 026
• Cylinder 6 x 22 inch s/n 027
• Cylinder 6 x 22 inch s/n 063
• Cylinder 6 x 22 inch s/n 139
• Cylinder 13 x 25 inch s/n 021
• Sphere 10.25 inch s/n 060
• Sphere 10.25 inch s/n 066
• Sphere 10.25 inch s/n 074
• Sphere 18 inch s/n 010
Shearography COPV
Test Data

6 x 22 Inch Graphite Cylinders
Shearography Scan Plan  6 x 22 Inch Graphite Cylinders

- Tank tested in 2 bands, Aft Half and Forward Half
- Tank rotated one frame after each test as shown.
- Shearogram shows damage to scale on tank photo.
Shearography COPV
Test Data

6 x 22 Inch Graphite Cylinder
SCI  s/n 010
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder

SCI s/n 010

Note: Indications at 200°, 215° are not listed on the VT Score Sheet provided.
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder
SCI s/n 015
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder       SCI s/n 015

Note:
Indications at 90°, 45°, 190°, and 230° are not listed on the VT Score Sheet provided. Area at 280° not inspected.
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder  SCI s/n 015
Shearography COPV Test Data
6 x 22 Inch Graphite Cylinder

SCI s/n 015
Shearography COPV
Test Data

6 x 22 Inch Graphite Cylinder
SCI s/n 026
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder  s/n 026

250° x 14.1”  
Damage .9x1.5 in.

320° x 15.25”  
Damage 1.1 x 2.0 inch

145° x 16.0”  
Damage 1.3 x 2.2 inch
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder  s/n 026

- 270° x 7” Damage 1.3 x 2.2
- 290° x 2.8”
- 20° x 5.1 inch Damage .8 x 1.5
- 160° x 2.8 inch Damage .5 x 5
- 180° x 6.0 inch Damage .5 x 9

Note: Indications at 160°, and 290° are not listed on the VT Score Card provided.
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder

SCI s/n 027
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder  s/n 027

90° to 180°

0° to 90°
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder  s/n 027

270° to 360°

180° to 270°
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder
SCI s/n 063
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder  s/n 063

90° to 180°
Crack
30° to 140° x 16.2 inch

0° to 90°

180° x 6 inch Damage
3.5 x 2.1 inch
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder       s/n 063

270° to 360°

180° to 270°
Shearography COPV
Test Data

6 x 22 Inch Graphite Cylinder
SCI s/n 139
Shearography COPV Test Data
6 x 22 Inch Graphite Cylinder   s/n 139

Circled areas are small cracks due to impact.
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder  s/n 139

90°

Bridging Delaminations at base of dome end.
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder  s/n 139

Bridging Delamination at base of dome end.
Shearography COPV Test Data

6 x 22 Inch Graphite Cylinder  s/n 139

Damage

Bridging Delamination at base of dome end.

270°
Shearography COPV Test Data

13 x 25 Inch Graphite Cylinder
Shearography Scan Plan 13 x 25 Inch Graphite Cylinders

- Tank tested in 2 bands, Aft Half and Forward Half
- Tank rotated one frame after each test as shown.
- Shearogram shows damage to scale on tank photo.
Shearography Test Set-Up for 13 x 25 Inch Graphite COPV

- Pressure Gage
- Support Frame
- LTI-5100 Shearography Camera
Shearography COPV
Test Data

13 x 25 Inch Graphite Cylinder
s/n 021
Shearography COPV Test Data
13 x 25 Inch Graphite Cylinder  s/n 021

Aft Blind Flange End- No Defect Indication on Dome

Impact on Barrel Section
22.1” from boss@ 225°
Damage 1.5 x 1.4 in.
Shearography COPV Test Data
13 x 25 Inch Graphite Cylinder s/n 021
Barrel Section of COPV

21.25” from boss@ 135°
Damage 3.0 x 3.4 in.

9.75” from boss @45°
Damage 0.15in.

22.1” from boss@ 225°
Damage 1.5 x 1.4 in.

10” from boss@ 130°
Damage 2.5 x 2.1in.

10” from boss@ 180°
Damage 3.2 x 4.1 in.

10” from boss@ 235°
Damage 3.1 x 3.8 in.

11.5” from boss@ 330°
Damage 1.3 x .7 in.
Shearography COPV Test Data

10.25 Inch Graphite Spheres
Shearography Scan Plan  10.25 Inch Graphite Spheres

Blind Flange View  Press. Flange View  Side View

Note: Due to the large number of damaged areas and limited time, images were recorded but no dimensions are provided, nor correlation with VT.
Shearography COPV Test Data

10.25 Inch Graphite Sphere s/n 060
Shearography COPV Test Data
10.25 Inch Graphite Sphere s/n 060

Blind Flange End
Shearography COPV Test Data

10.25 Inch Graphite Sphere s/n 060

Side View Centered on 30°
Shearography COPV Test Data

10.25 Inch Graphite Sphere s/n 060

Centered On 60°  180°  280°
Shearography COPV Test Data

10.25 Inch Graphite Sphere
s/n 066
Shearography COPV Test Data
10.25 Inch Graphite Sphere s/n 066

50°

130°

230°

270°

320°
Shearography COPV Test Data

10.25 Inch Graphite Sphere s/n 074
Shearography COPV Test Data
10.25 Inch Graphite Sphere s/n 074
Shearography COPV Test Data

10.25 Inch Graphite Sphere s/n 074
Shearography COPV Test Data

10.25 Inch Graphite Sphere s/n 074

180°
Shearography COPV Test Data

10.25 Inch Graphite Sphere s/n 074

Blind Flange End View
Shearography COPV Test Data

10.25 Inch Graphite Sphere s/n 074

Gas Pressurization Flange End

255°

75°

Laser Technology Inc.
Aerospace Inspection Systems
www.LaserNDT.com
Shearography COPV
Test Data

18 Inch Graphite Sphere
Shearography Scan Plan  6 x 22 Inch Graphite Cylinder

Aft Half                           Port Half
Shearography Test Set-Up for 18 Inch Graphite Sphere COPV

Aft Blind Boss

Aft Half

Port Boss Fill Tube

Port Half

Laser Technology Inc.
Aerospace Inspection Systems
www.LaserNDT.com
Shearography COPV Test Data
18 Inch Graphite Sphere  s/n 010 - Port Half

50°  215°  310°
Shearography COPV Test Data
18 Inch Graphite Sphere  s/n 010 - Aft Half
For More Information, Please Contact:

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