**Westinghouse**
**Savannah River Company**
**Aiken, SC 29808**

April 12, 2006

WSRC-MSD-DIS-2004-09663

Mrs Debbie Caver, Technical Information Officer
U. S. Department of Energy - Savannah River Operations Office

Dear Mrs. Caver:

REQUEST FOR APPROVAL TO RELEASE SCIENTIFIC/TECHNICAL INFORMATION

The attached document is submitted for classification and technical approvals for the purpose of external release. Please complete Part II of this letter and return the letter to the undersigned by 5/24/2006. The document has been reviewed for classification and export control by a WSRC Classification staff member and has been determined to be Unclassified.

Hope Roy for

Kevin Schmidt, Manager
WSRC Technical and Management Information

**I. DETAILS OF REQUEST FOR RELEASE**

**Document Number:** WSRC-TR-2006-00060
**Author's Name:** BOYD HOWARD
**Location:** 781-A Phone (803)725-3765
781-A
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**Location:** AIKEN SC U.S.A.
**Meeting Date:** 3/28/2006 to 3/30/2006
**Intended Distribution:** Unlimited (Release to Public)

**II. DOE-SR ACTION**

**OSTI REPORTABLE**
Date Received by TIO _____

☐ Approved for Release
☐ Approved Upon Completion of Changes
☐ Approved with Remarks
☐ Not Approved
☐ Revise and Resubmit to DOE-SR

Remarks: _____

_____

_____ _____
Debbie Caver, Technical Information Officer, DOE-SR Date

OSR 14-357 (Rev 1-14-2005)

# Westinghouse Savannah River Company
# Request for Information Review and Release

Proc. Ref. 1B, 3.25

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| Document No. | Requested Approval Date |
|---|---|
| WSRC-TR-2006-00060 | 3-20-2006 |

| Title | Document Date |
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| DIGITAL RADIOGRAPHY OF SPECIAL NUCLEAR MATERIAL TEST PACKAGES | 2/2/2006 |

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|---|---|
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Has an invention disclosure, patent application or copyright application been submitted related to this information? ○ Yes ◉ No

If YES, Date Submitted: | Disclosure No. (If Known): | Title:

If NO, do you intend to submit one? ○ Yes ◉ No

If YES, Projected Submittal Date:

**Information Product Description (Column 1)**

- ☒ Technical Report
- ☐ Journal Article (Journal Name) _____ (Submission Date) _____
- ☐ Book/Book Chapter (Book Name) _____
- ☐ External Conference Materials

Conf. Material Type ☐ Abstract ☐ Conf. Paper ☒ Other CONFERENCE PRESENTATION

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Conf. Location (City/State/Country): AIKEN | SC | U.S.A.

Conf. Dates: 3/28/2006 to 3/30/2006

Conf. Sponsor: SAVANNAH RIVER NATIONAL LABORATORY; DEPARTMENT OF ENERGY

References

- ☐ Approved for Release/Publicly Available
- ☐ Included as Attachment(s)
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- ☐ Other WSRC-TR-2006-00060

Records Track No.:

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- ☐ Administrative/Financial/Management Report
- ☐ Engineering Drawing
- ☐ Marketing/Public Relations Materials
- ☐ Multimedia/Videotape ○ Audio ○ No Audio
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REPRESENTATIVES OF THE WEAPONS AGENCIES NONDESTRUCTIVE TESTING ORGANIZATION WILL BE MEETING AT SRS. INFORMATION CONTAINED IN THIS PAPER IS SCHEDULED TO BE THE FIRST

| DC Reviewer | DC Review Date |
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| RICK HAGGARD | 3/2/2006 |

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**Author**

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BOYD HOWARD — Author's Name (Print) | 2/28/2006 — Date

**Manager's User ID** Y8740 **Manager's Full Name (Last, First)** SMAIL, TIMOTHY R

# Requested Reviews

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Unclassified

**Submittor Name**

| | |
|---|---|
| BOYD | HOWARD |

**Approval Expiration Date**

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APPROVED by Shankle, Bob on 3/9/2006

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☐ PAD **Review**

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WSRC-TR-2006-00060

# DIGITAL RADIOGRAPHY OF SPECIAL NUCLEAR MATERIAL TEST PACKAGES

by

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DOE Contract No.

# Digital Radiography of Special Nuclear Material Test Packages

**Boyd Howard, Joel Jones, and Mark Farrar**

FEBRUARY 2006
WSRC-TR-2006-00060

**Washington Savannah River Company**
**Savannah River National Laboratory**
**Aiken, SC 29808**

**Digital Radiography of Special Nuclear Material Test Packages**

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WSRC-TR-2006-00060

**Washington Savannah River Company**
**Savannah River National Laboratory**
**Aiken, SC 29808**

**Digital Radiography of Special Nuclear Material Test Packages**

Objectives

The purpose of this document is to provide a brief introduction to digital radiography (DR), and a description of the DR configuration that was used to radiographically image the Special Nuclear Material (SNM) Test Packages before and after function tests that have been conducted. Also included are (1) Attachment 1, a comprehensive index that describes at which phase of the certification process that digital radiographic images were acquired, (2) digital radiographic images of each of the six packages at various stages of the certification process, and (3) Attachment 2, imaging instructions, that specify the setup procedures and detailed parameters of the DR imaging methodology that were used..

Introduction to Digital Radiography

The diagram to the right shows a typical lens-coupled, CCD-based, area- detector, digital radiography imaging system configuration. The scintillator converts X-ray photons into light. The turning mirror allows the CCD camera to be placed outside of the high-intensity X-ray beam. As the beam of X-rays pass through the test object (in this case a SNM test package), the scintillating screen's rare earth compound interacts with incoming X-ray photons at the atomic level and a visible image appears. The visible image on the scintillation screen is photographically "captured" by an ultra-high resolution digital camera equipped with a scientific grade 2000 by 3000 pixel array imaging chip. The captured image is then stored in a designated work station, after which it is archived on compact discs for evaluation and reporting.

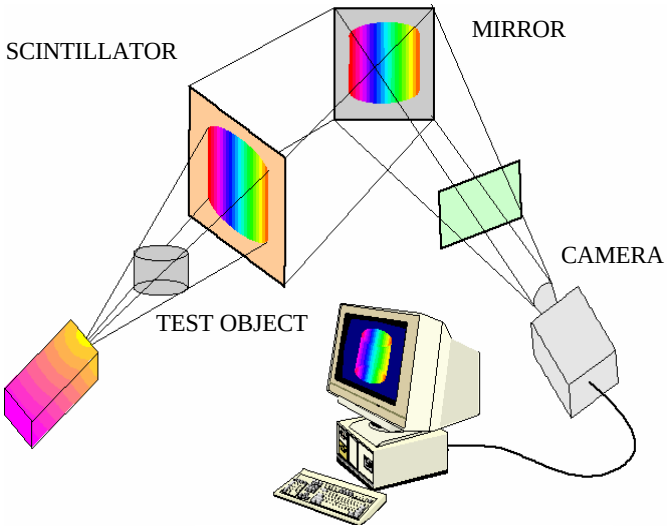



Figure 1: Typical DR Configuration

Digital Radiography of SNM Test Packages

Shown in Figure 2 on the following page is a photo of WSRC's 711-6N test package digital radiography imaging system. The gadolinium oxysulfide (GOS) large area-detector scintilation screen is mounted to the back side of the white panel that is directly behind the mixed waste drum in the photo. The large support panel can accommodate up to twenty (20) 17 inch by 17 inch GOS scintillation screens tiled together than can creat a scintillator 68 inches high and 85 inches wide. The full height of each test package can be imaged in each digital radiographic exposure in this facility.

The platform on which each test package was placed has both vertical and rotational motions. Around the outer circumference of each of the test packages 0, 30, 60, 90, 120, 150, and 180 degrees were marked in a counter clockwise direction, **as viewed from the top of the test package**, thus the

test package rotated through those seven (7) radiographic "views" clockwise, as viewed from the top of the test package.
Lead numbers (0 through 180) were placed on top of the circumferential markings on each test package. Savannah River Packaging Technolgy had stipulated the zero position.

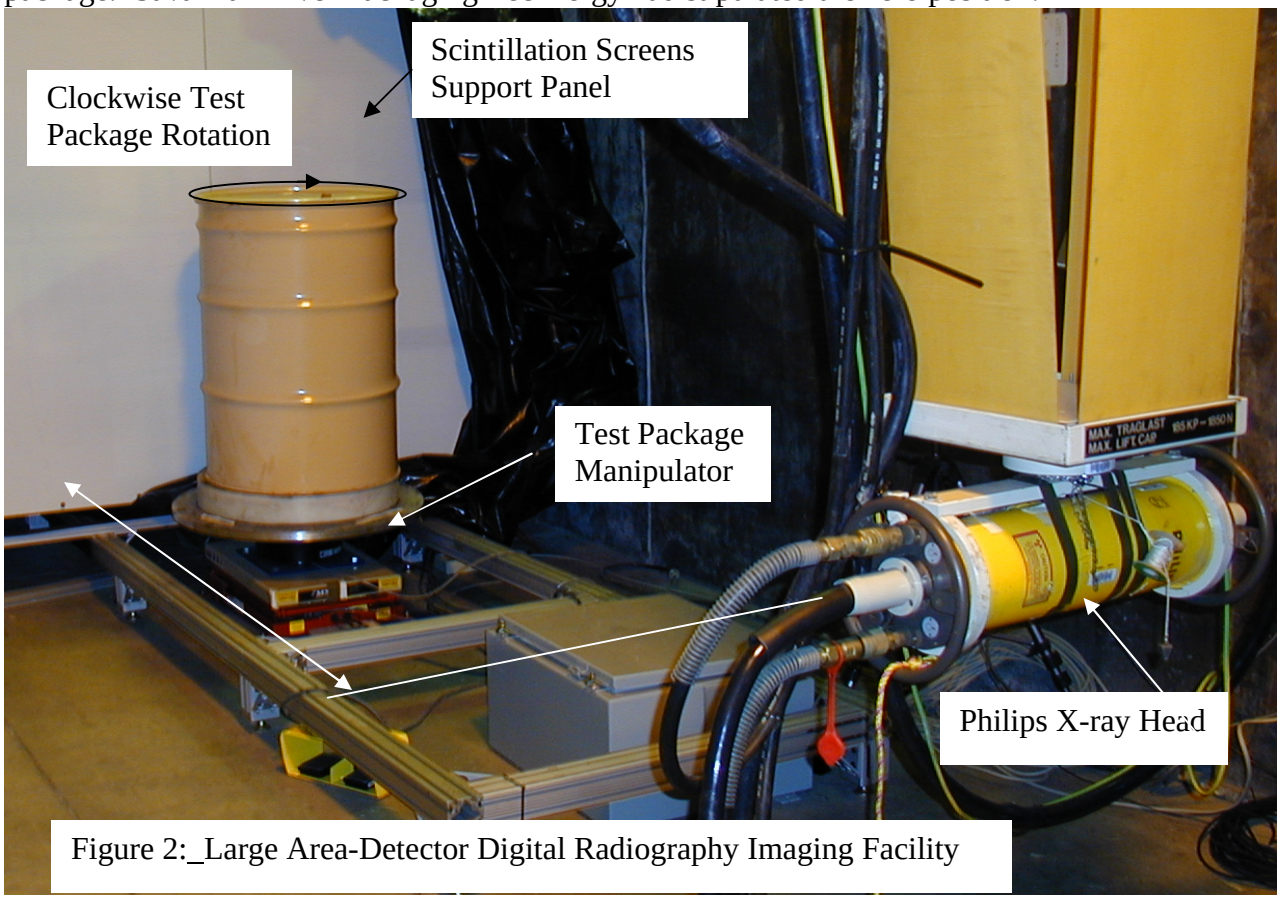



Figure 2:_Large Area-Detector Digital Radiography Imaging Facility

Attachment 2, SNM Test Package Digital Radiography Instructions, provides specific instructions for positioning the drum on the balsa wood spacer, that is on top of the manipulator table. Those instructions are: "For all SNM TEST PACKAGES and SNM TEST PACKAGE UPPER PORTION images, place the test package vertically on the center of the spacer with the 0° mark facing (near) the scintillation panels."

Affixed lead number degree markers can be seen in each digital radiographic image, as is illustrated in Figure 3. These images were acquired of a test package before insertion of a containment vessel. In the left test package image the zero (0) degree marker is near the scintillation panels. In the right test package image the thirty (30) degree lead marker is near the scintillation panel. The linear, vertical and horizontal lines in all digital radiograms delineate the outline of the 17 inch by 17 inch gadolinium oxysulfide scintillation screens.

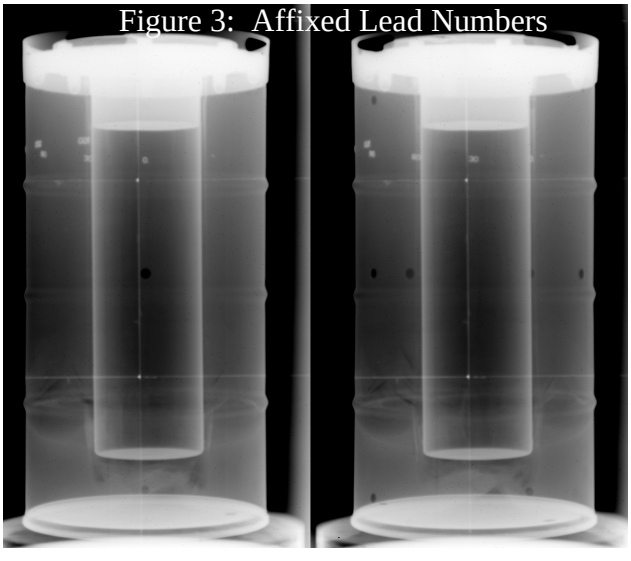


Figure 3: Affixed Lead Numbers

The small, black ovals are intentionally drilled vent holes in the drum.

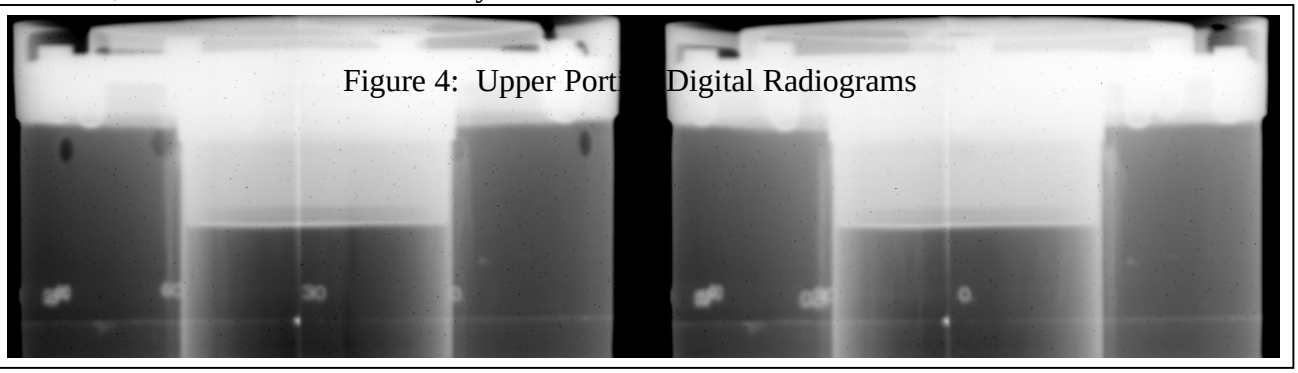


Figure 4: Upper Portion Digital Radiograms

At the specific request of the Savannah River Packaging Technology group, the upper portion of each of the test packages was digitally radiographed. As can be seen in the two digital radiograms in Figure 4 above, the affixed lead numbers can be seen in each digital radiographic image. These images were acquired of a test package before insertion of a containment vessel. In the left test package image the thirty (30) degree marker is near the scintillation panel. In the right test package image the zero (0) degree lead marker is near the scintillation panel.

There is a vertical, dark line just to the right of the 30 degree lead number in the left digital radiogram. The vertical, dark line was judged to be a separation in the polyurethane foam. That anomaly is also revealed in the end to end digital radiograms in Figure 5.

The linear, vertical and horizontal, white lines in all digital radiograms delineate the outline of each of the 17 inch by 17 inch gadolinium oxysulfide scintillation screens.

In accordance with the attached instructions each of the six (6) drums was digitally radiographed from end to end.

**The zero (0) degree reference point is at the top dead center for the end to end exposures.**

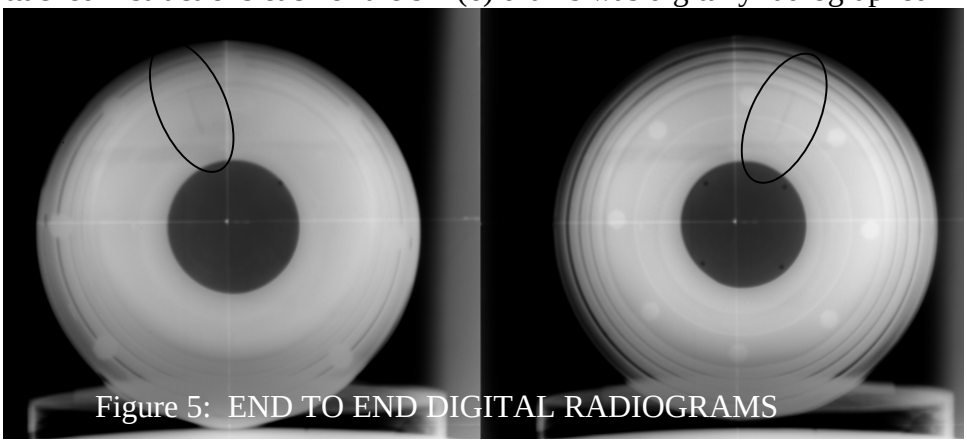


Figure 5: END TO END DIGITAL RADIOGRAMS

In Figure 5 are end to end DR images of TP0005. This test package was initially imaged with the bottom end of the test package near the scintillation panel. After rotating the test package 180 degrees, it was imaged with the top end of the test package near the scintillation panel. The spacing and size of the bolts on the top of the inspection package have not been geometrically enlarged when the top of the test package is nearest the scintillation panel.

The separation in the foam that was noted in the upper portion digital radiograms appear approximately 20 degrees to the left of top dead center. The same separation can be seen approximately 20 degrees to the right of top dead center in the digital radiogram to the right.

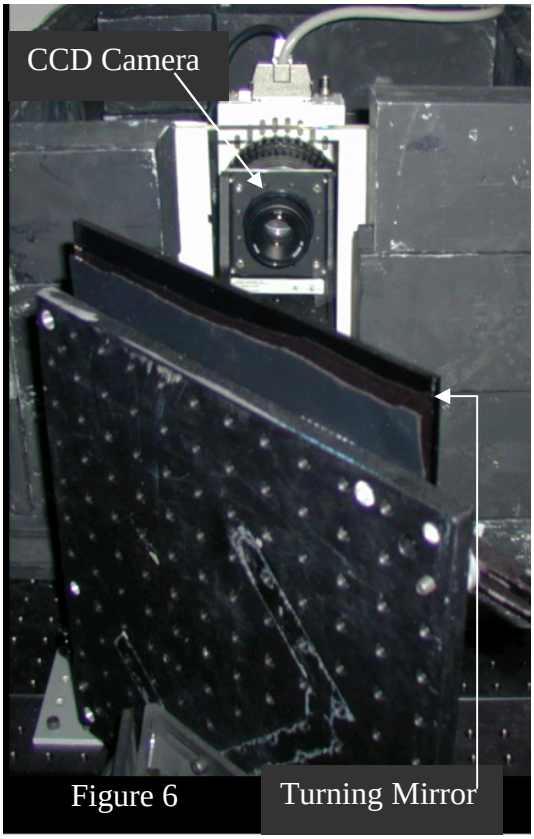


Figure 6

A Photometrics digital camera with a scientific grade 2000 by 3000 pixel array, charge-coupled device (CCD) chip was used to acquire all images. Attached to the camera is a 50 mm focal-length Nikon lens. Because the extra large area-detector, digital radiography imaging system is an "open installation," lead shielding is placed around the camera and its electronics. Optically transparent lead glass, placed between the CCD camera and the turning mirror, blocks scattered X-ray photons that might impinge upon the camera; thus degrading the radiographic image.

A turning mirror is used to focus the CCD camera onto the GOS scintillation screens and to keep the camera out of the direct X-ray beam. Effective resolution of the individual images is approximately 0.030 inches.

The computer controlled acquisition station for the 711-6N DR facility, in which all the Test Packages were radiographically imaged is safely located outside of the imaging enclosure.

Figure 7: Black Plastic Cover

Even though the attached instructions directs the Washington Group X-ray specialists to turn off the lights in the 711-6N X-ray imaging room, the imaging room is still not "light tight," so the entire imaging train, which includes the scintillation screen, the turning mirror, and the lead-shielded CCD camera, is covered with black plastic to exclude unwanted light, as can be seen in Figure x to the right. In the future the imaging train could be enclosed in a more permanent, light-tight structure.

Digital Radiography Configuration and Typical Digital Radiography Imaging Parameters

As can be seen in Figure 1 and Figure y, and specified in the attached Instructions, the distance from the target of the X-ray tube and the scintillation screen is 141 inches. The center of rotation of the rotary stage is as close to the back of the scintillation panel as practicable. The 141 inch X-ray tube focal spot to scintillation screen improves resolution and decreases geometrical enlargement of the object being examined. All radiographic images were acquired at 300 kVp and 5 mA. Each of the seven circumferential exposures of the full test package was 300 seconds. End to end exposure times were 420 seconds.

## EVALUATION OF SNM TEST PACKAGES AT EACH STAGE OF IMAGING

**GENERAL COMMENTS: It is the writer's professional opinion that the containment vessel in the test packages that were subjected to all of the regulatory-specified tests showed no radiographically detectable signs of degradation.**

Note: ***Higher density materials such as metal or Fiberfrax appear "white or whitish" in the digital radiograms. Lower density materials such as polyurethane or anomalies in the polyurethane appear to be "shades of grey."***

A complete index of DIGITAL RADIOGRAPHIC IMAGES TAKEN OF SPECIAL NUCLEAR MATERIAL TEST PACKAGES," and each image is in Attachment 1.

### TP0002 BEFORE AND AFTER INSERTION OF CONTAINMENT VESSEL (CV)

- There is a vertical separation in the polyurethane foam that appears in 30 and 60 degree images. It does not go the full length of the inspection package.
- Excess Fiberfrax sleeve material is visible beneath the drum liner.

### TP0002 AFTER NORMAL CONDITION OF TRANSPORT (NCT) TESTS

- No changes in the containment vessel and/or the polyurethane foam were detected.

### TP0002 AFTER THE THIRTY (30) FOOT DROP TEST

- No changes in the containment vessel and/or the polyurethane foam are radiographically detectable when compared with the DR images acquired after the NCT tests.
- There appears to be a difference in the length of dummy load and in the space between the top load distribution fixture and the bottom of the top lid in the before and after images.
- The drum flange has sustained deformation.

### TP0002 AFTER THE CRUSH TEST

- The drum suffered some rather severe deformation as a result of the crush test.
- The bottom of the drum is deformed and there is apparent "crumpling" of the drum near the top.
- The configuration of the drum liner lid bottom has been altered; however, the containment vessel itself does not appear to be compromised.
- The polyurethane foam appears to be unchanged.

### TP0002 AFTER THE THERMALTEST

- The configuration of the containment vessel and the drum liner are unchanged and in tact.
- There has been a loss of polyurethane foam; however, polyurethane foam still provides a protective layer over the surface of the drum liner except for a gap between the foam and drum top plate.

**TP0003 BEFORE INSERTION OF CONTAINMENT VESSEL (CV)**

- The polyurethane foam and drum liner appear to be in acceptable condition; however, there appears to be lower density (voids) in the foam just beneath the drum liner.
- The Fiberfrax sleeve is visible.

**TP0003 AFTER THE THIRTY (30) FOOT DROP TEST**

- This package was obviously dropped on a bottom edge.
- Quite severe deformation occurred at the point of impact.
- The drum liner in which the CV is placed appears to have "collapsed" slightly; however, the Containment Vessel appears to be unaffected.
- No radiographically detectable damage has occurred in the polyurethane foam.

**TP0003 AFTER THE CRUSH TEST**

- The polyurethane foam appears to have decreased in density most likely because the bottom of the drum bulged out and possible damage to polyurethane foam.
- The drum suffered some rather severe deformation as a result of the crush test. The bottom of the drum is severely deformed.
-

**TP0003 AFTER THE THERMALTEST**

- The configuration of the containment vessel and the drum liner appears to be unchanged and intact.
- Opening in the bottom of drum exposed the polyurethane foam in the bottom section of the drum to the direct flame.
- Direct exposure to the fire has caused a significant loss of polyurethane foam.
- Remaining foam is separated into two lobes around the drum liner.
- Drum liner is only partially covered with undamaged foam.

**TP0004 BEFORE INSERTION OF CONTAINMENT VESSEL (CV)**

- The internal container appears to be in proper position/orientation...
- There appears to be a separation in the foam, visible only in the 90 degree image.
- The separation appears to be one third (1/3) the height of the drum.
- The separation appears in the end to end images at the 285 degree with the bottom of the test package nearest the scintillator panel.
- The Fiberfrax sleeve is visible beneath the drum liner.

**TP0004 AFTER THE THIRTY (30) FOOT DROP TEST**

- No changes in the containment vessel and/or the polyurethane foam are radiographically detectable.
- There does not appear to be any obvious physical deformation.

**TP0004 AFTER THE CRUSH TEST**

- The upper portion of the drum appears to be slightly damaged.
- The configuration of the drum liner lid bottom has been altered.
- The containment vessel itself does not appear to be damaged.
- The polyurethane foam appears to be unchanged.

**TP0004 AFTER THE THERMALTEST**

- The configuration of the containment vessel and the drum liner appears to be unchanged and in tact.
- There has been a significant loss of polyurethane foam; however, polyurethane foam still provides a protective layer over most of the surface of the containment vessel.
- The bottom of the drum liner may not be fully covered with polyurethane foam.
- The configuration of the top plug at the top of the inner has not been altered.

**TP0005 BEFORE INSERTION OF CONTAINMENT VESSEL (CV)**

- The internal container appears to be positioned properly.
- There is a vertical separation in the foam visible in the 30 degree image (1). It may be as much as ½ the entire length of the drum. This separation also appears in the end to end images at approximately 20 degrees counter clockwise from the zero degree mark.
- There are also smaller separations in the polyurethane.

**TP0005 AFTER THE THIRTY (30) FOOT DROP TEST**

- No changes in the containment vessel and/or the polyurethane foam are radiographically detectable.
- There does not appear to be any obvious physical deformation; however, there is a definite "tilt" to the entire test package.

**TP0005 AFTER THE CRUSH TEST**

- The containment vessel appears to be unaffected by this test.
- The top and bottom of the drum appear to be quite severely deformed
- The polyurethane foam appears to be unchanged.

**TP0005 AFTER THE THERMALTEST**

- The configuration of the containment vessel and the drum liner appears to be unchanged and in tact.
- Direct exposure to the fire has caused a significant loss of polyurethane foam; however, a protective layer of polyurethane foam still covers the upper surface of the containment vessel.
- The configuration of the top plug at the top of the inner has not been altered.

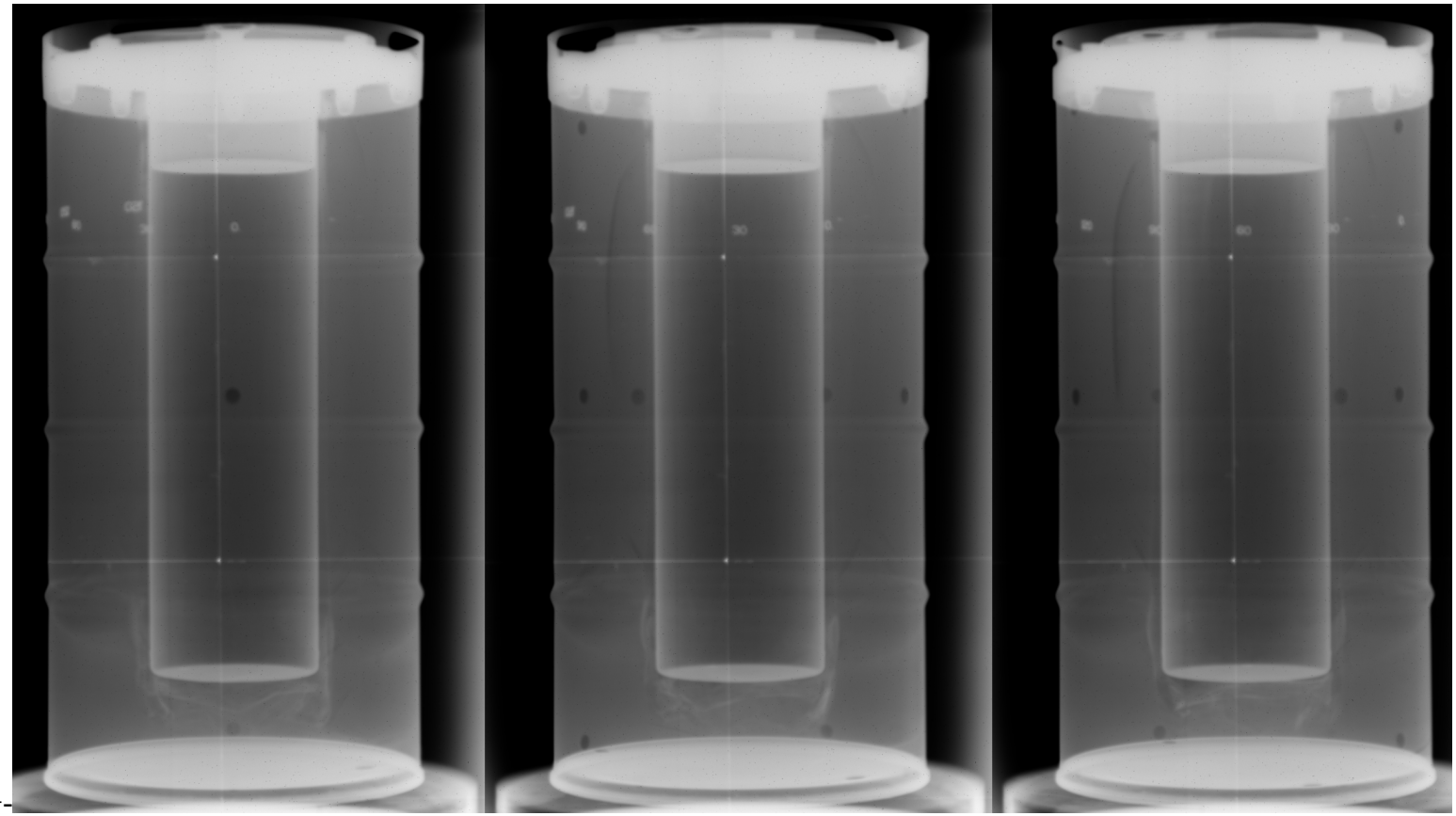
**TP0006 BEFORE INSERTION OF CONTAINMENT VESSEL (CV)**

- The drum liner appears to be positioned properly.
- There is a vertical separation in the foam visible in several of the images (1). It may be as much as 1/3 the entire length of the drum. This separation also appears in at least one of the end to end images.
- Other separations in the foam have also been imaged such as that just underneath the drum liner.

**TP0007 BEFORE INSERTION OF CONTAINMENT VESSEL (CV)**

- The internal container appears to be positioned properly.
- There is a vertical separation in the foam visible in the 30 and 60 degree images (1). It may be as much as 1/2 the entire height of the drum. This separation is just barely detectable in one of the end to end images.
- Other separations in the foam have also been imaged such as that just underneath the drum liner.
- The drum liner appears to be positioned properly in the center of the drum.

**ATTACHMENT 1**
**DIGITAL RADIOGRAPHIC IMAGES TAKEN OF SPECIAL NUCLEAR MATERIAL TEST PACKAGES**



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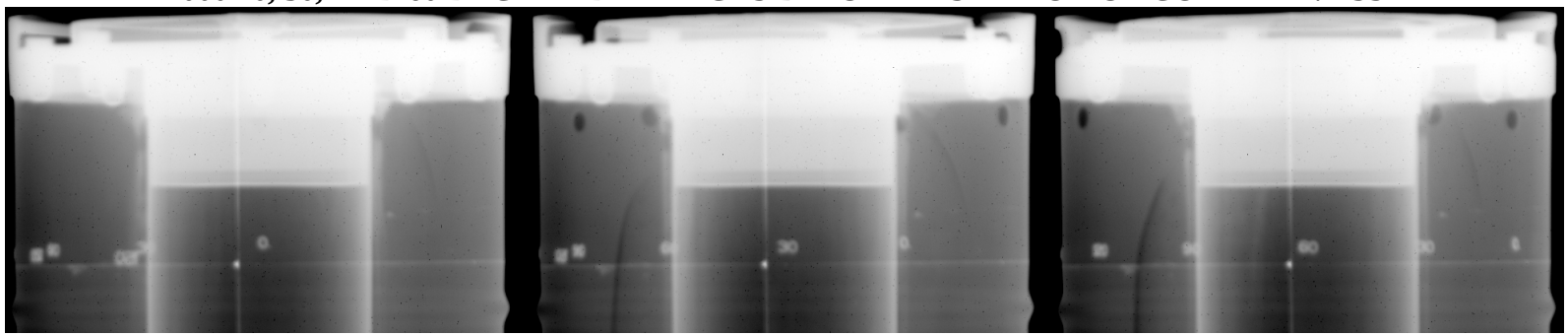
**TP0002 0, 30, AND 60 DEGREE DR IMAGES BEFORE INSERTION OF CONTAIN VESSEL**



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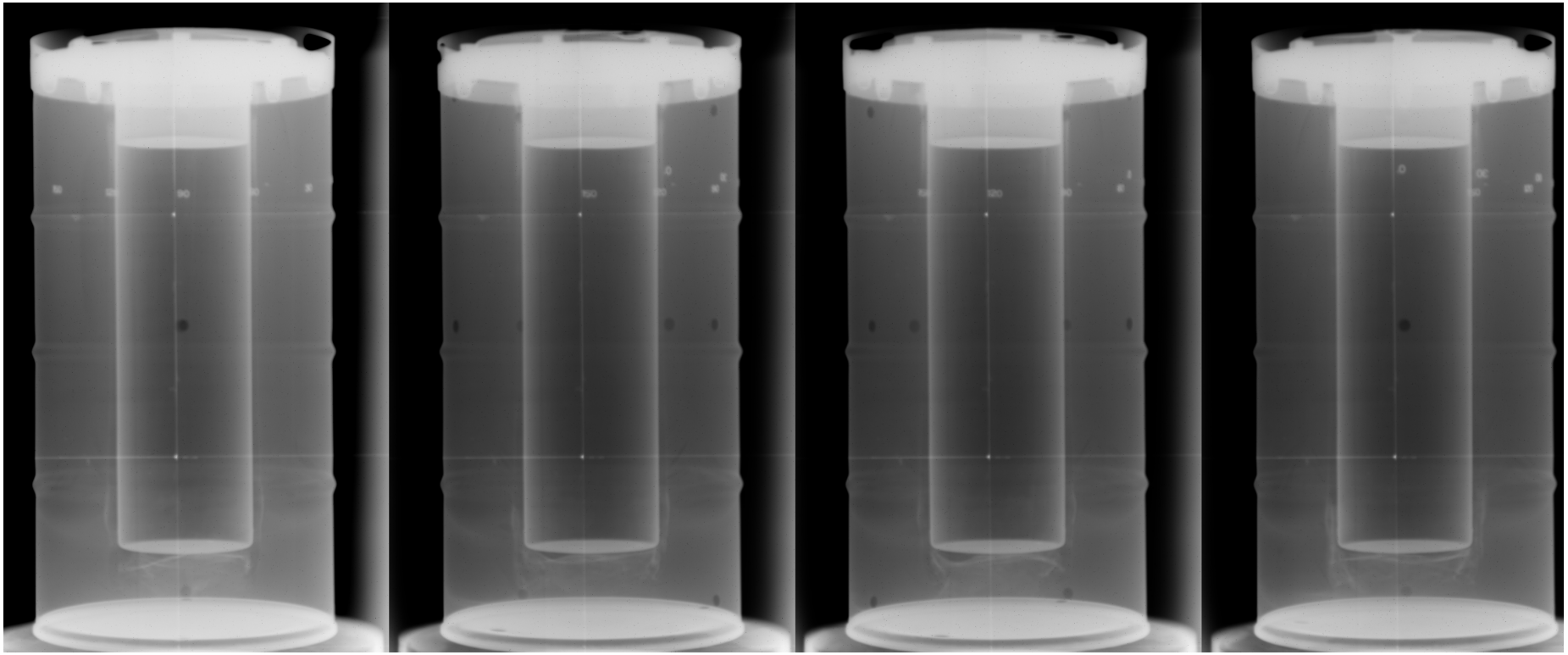
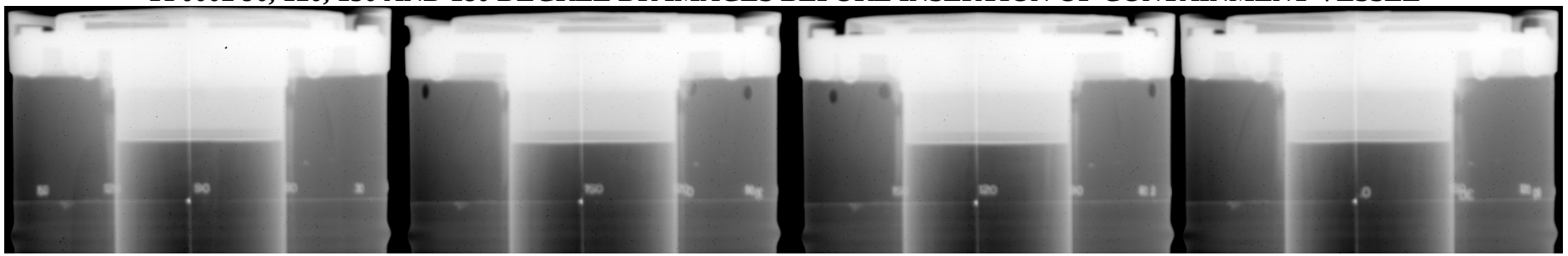


**TP0002 90, 120, 150 AND 180 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



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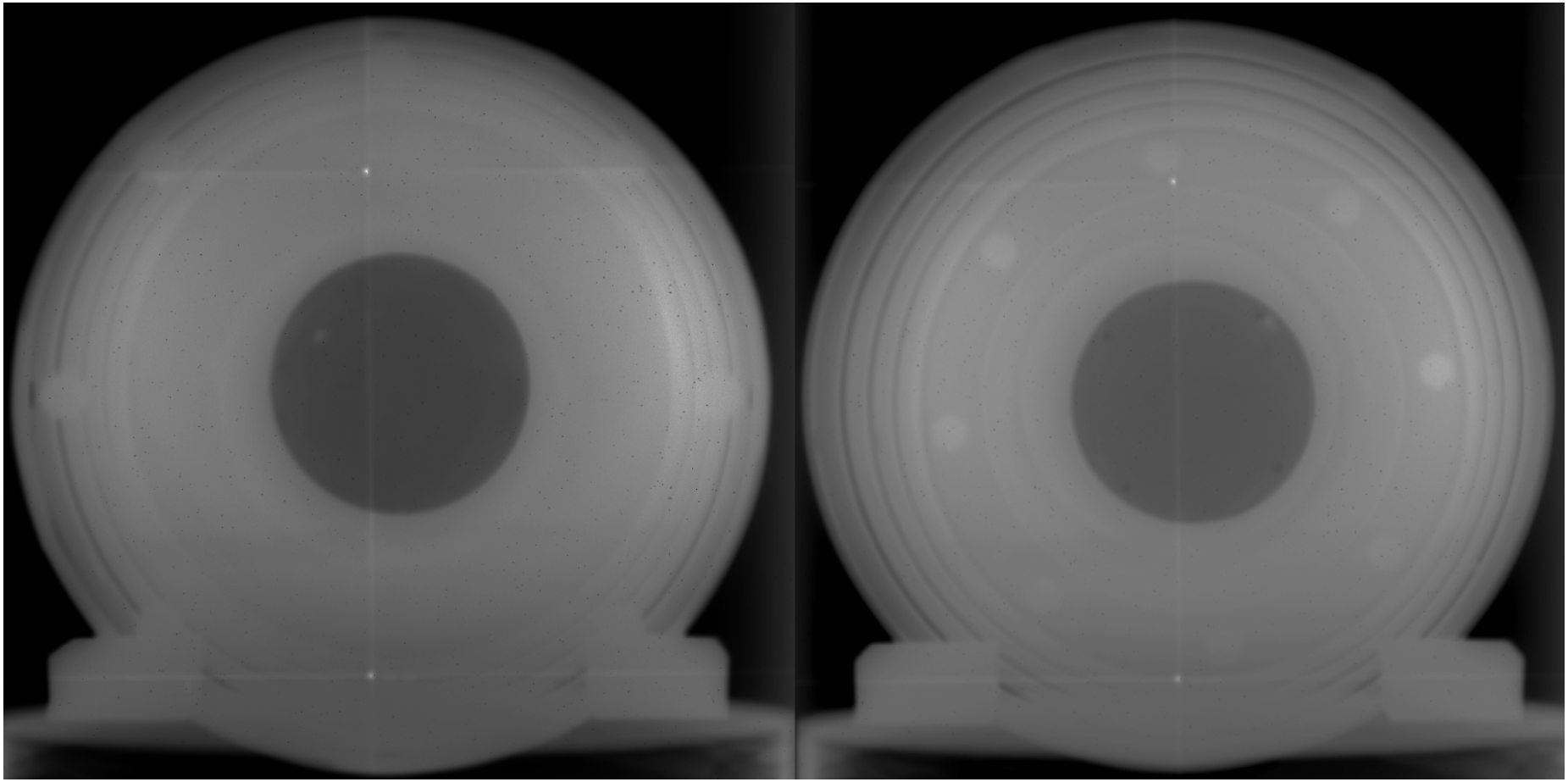
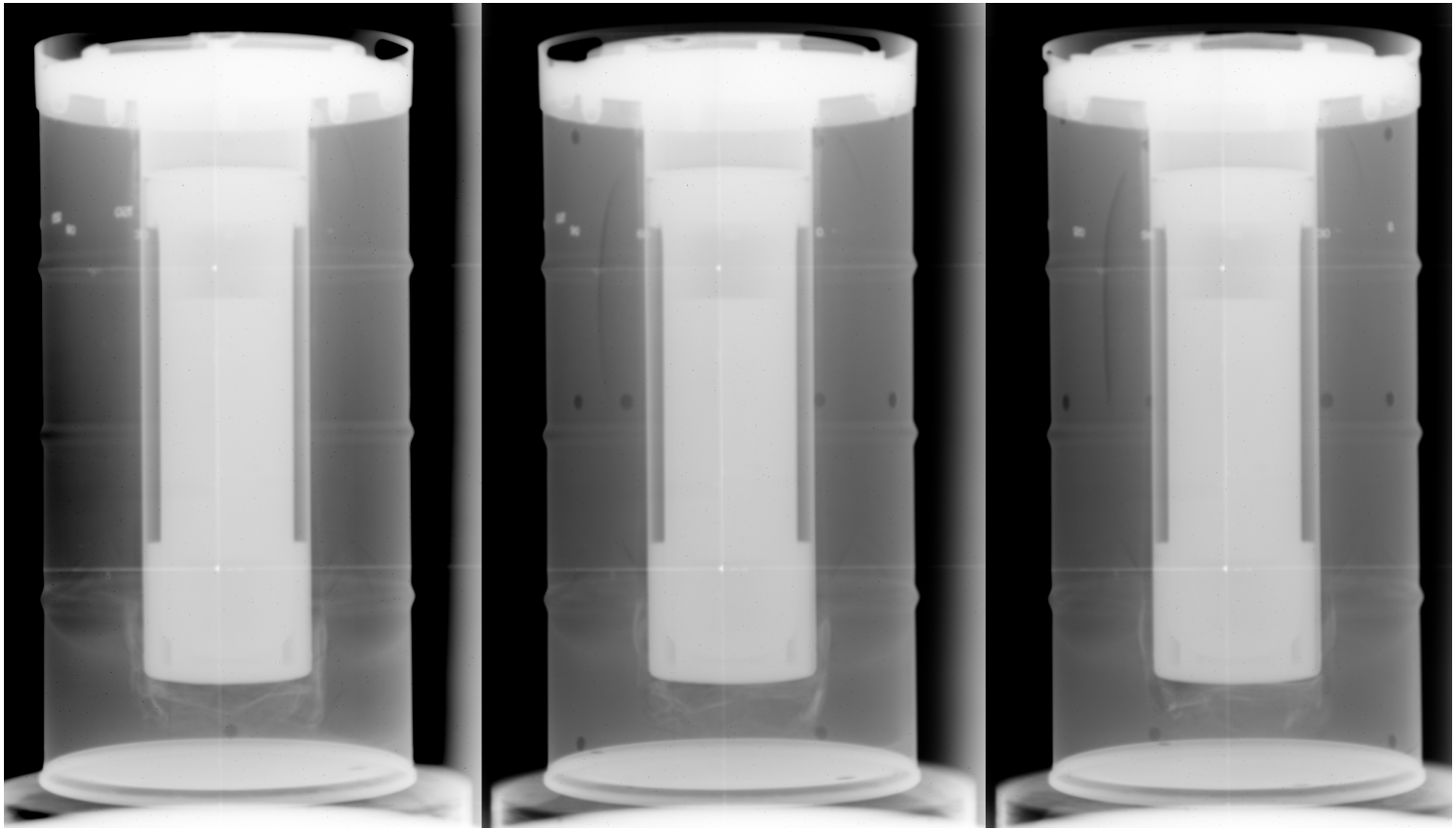
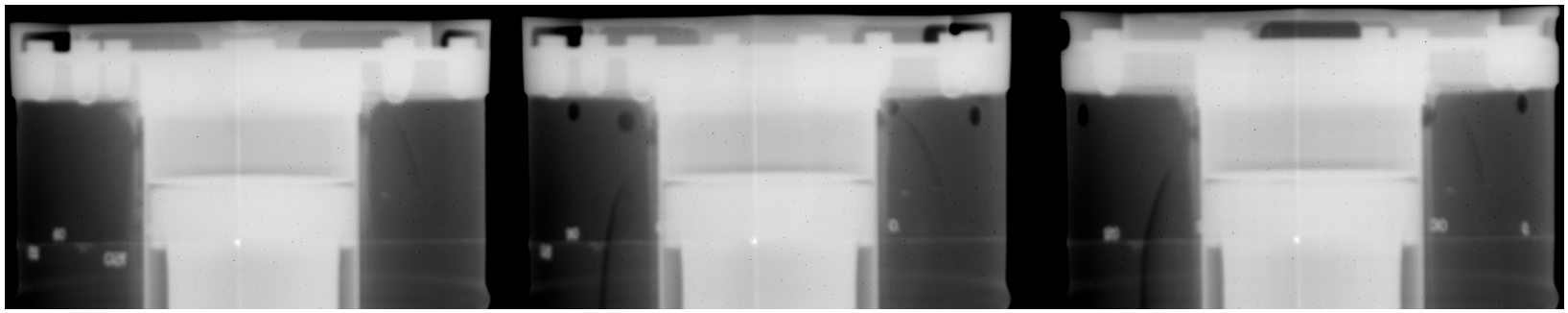


**TP0002 END TO END DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**

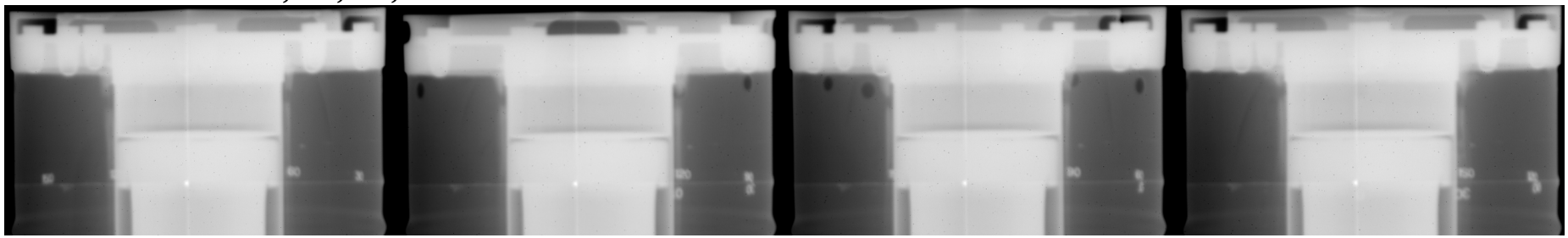


**TP0002 0, 30, AND 60 DEGREE DR IMAGES AFTER INSERTION OF CONTAINMENT VESSEL**

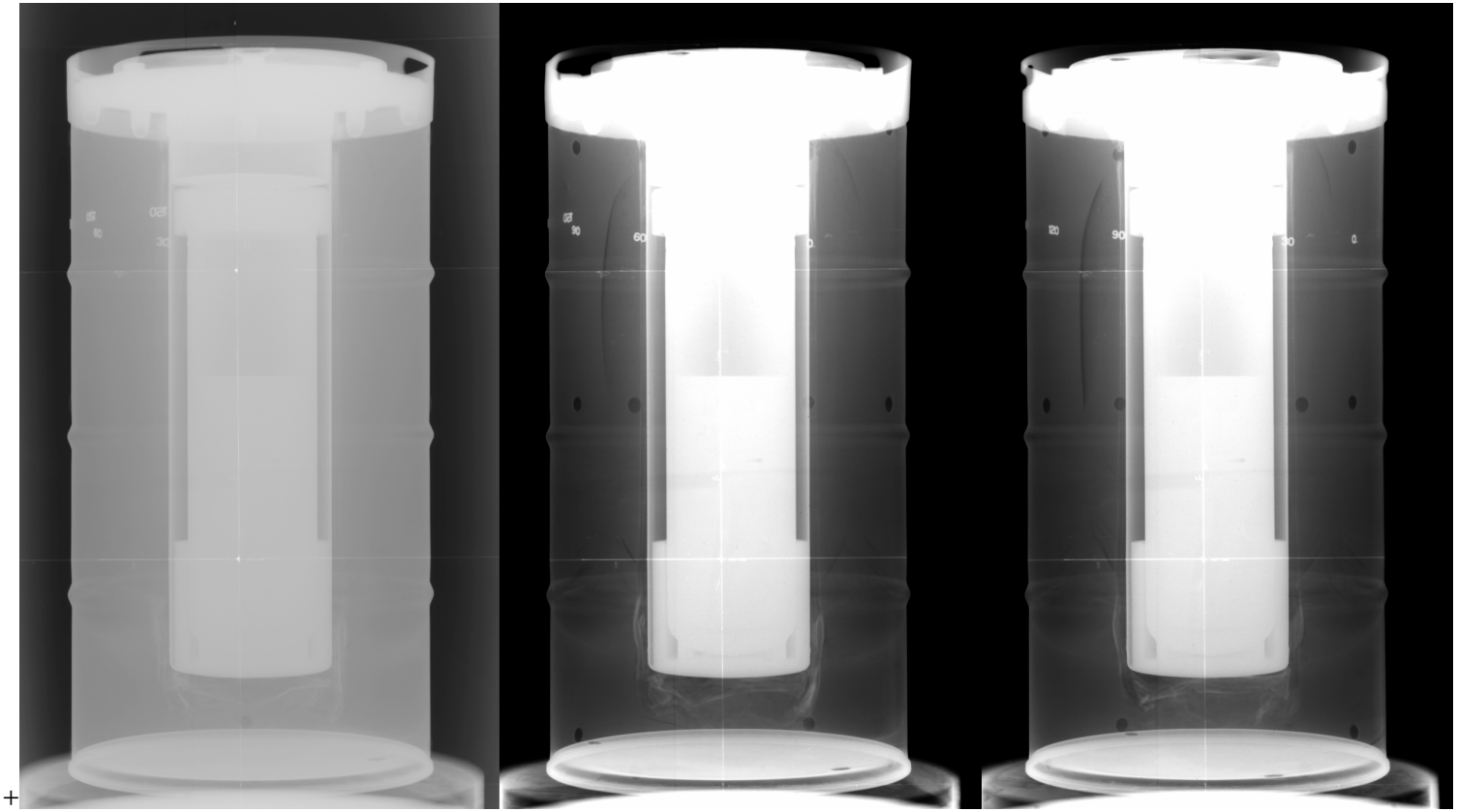


**TP0002 0, 30, AND 60 DEGREE DR IMAGES OF UPPER PORTION AFTER INSERTION OF CONTAINMENT VESSEL**

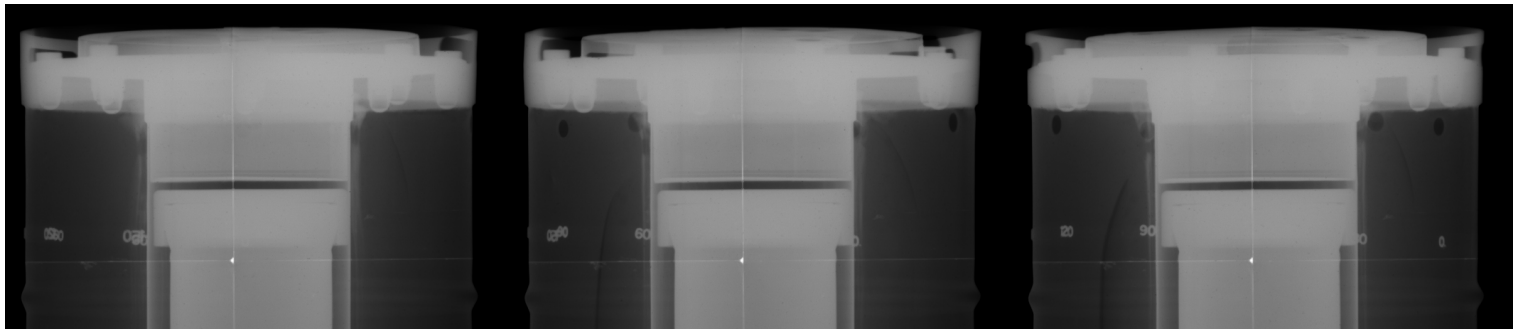
**TP0002 90, 120, 150, and 180 DEGREE DR IMAGES AFTER INSERTION OF CONTAINMENT VESSEL**



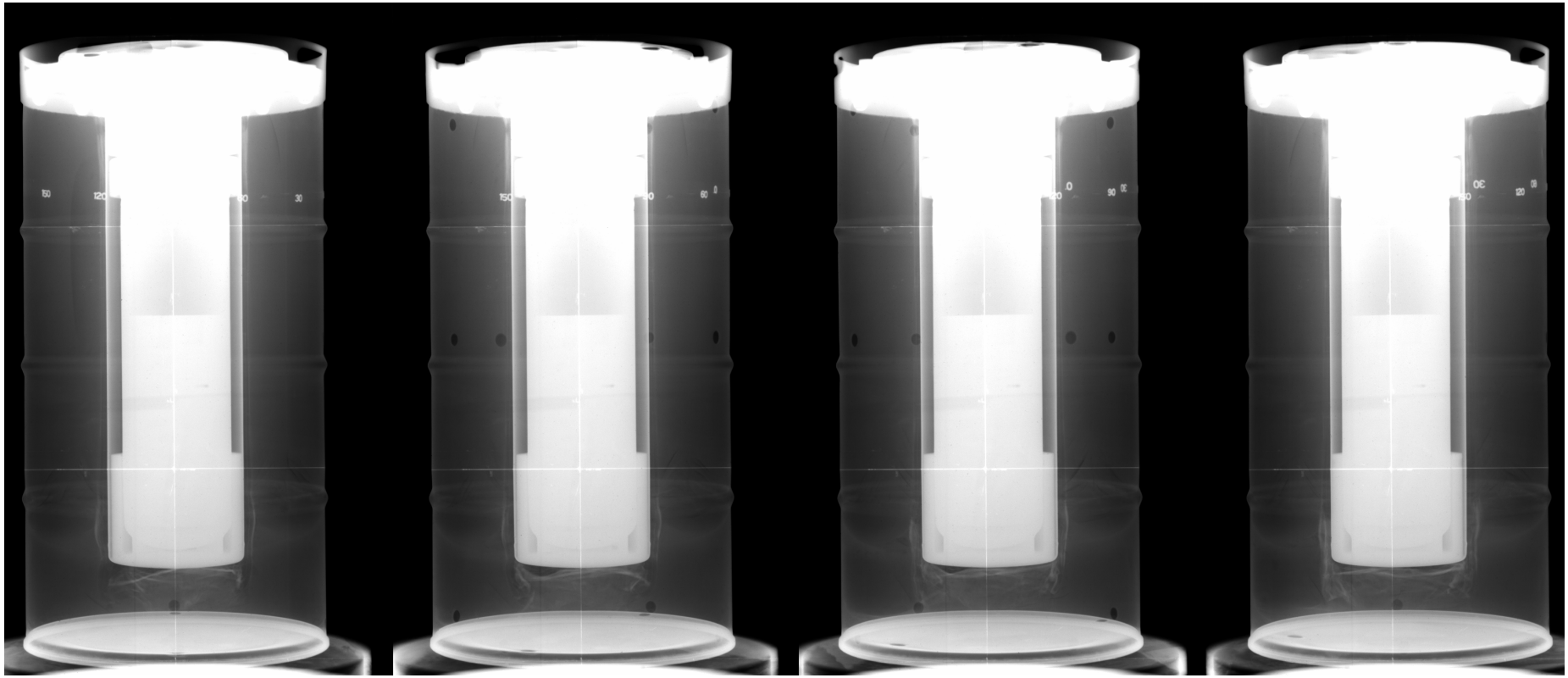
**TP0002 90, 120, 150, and 180 DEGREE DR IMAGES OF UPPER PORTION AFTER INSERTION OF CONTAINMENT VESSEL**



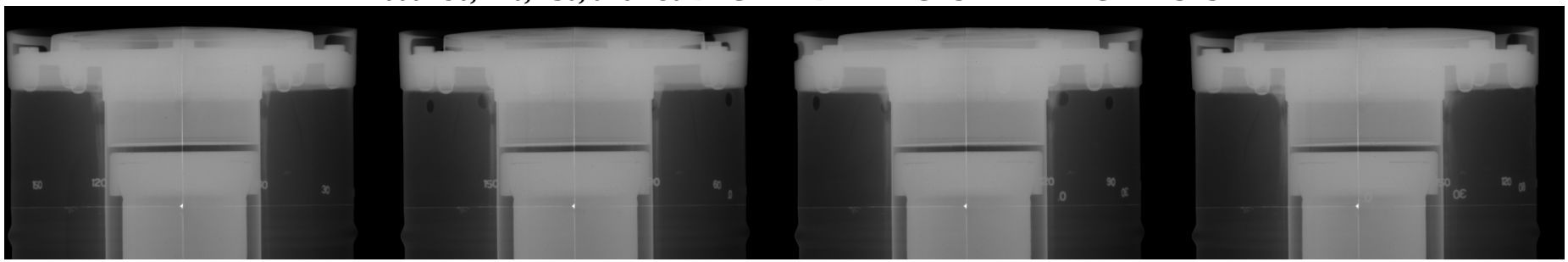
**TP0002 0, 30, and 60 DEGREE DR IMAGES AFTER NCT TESTS**



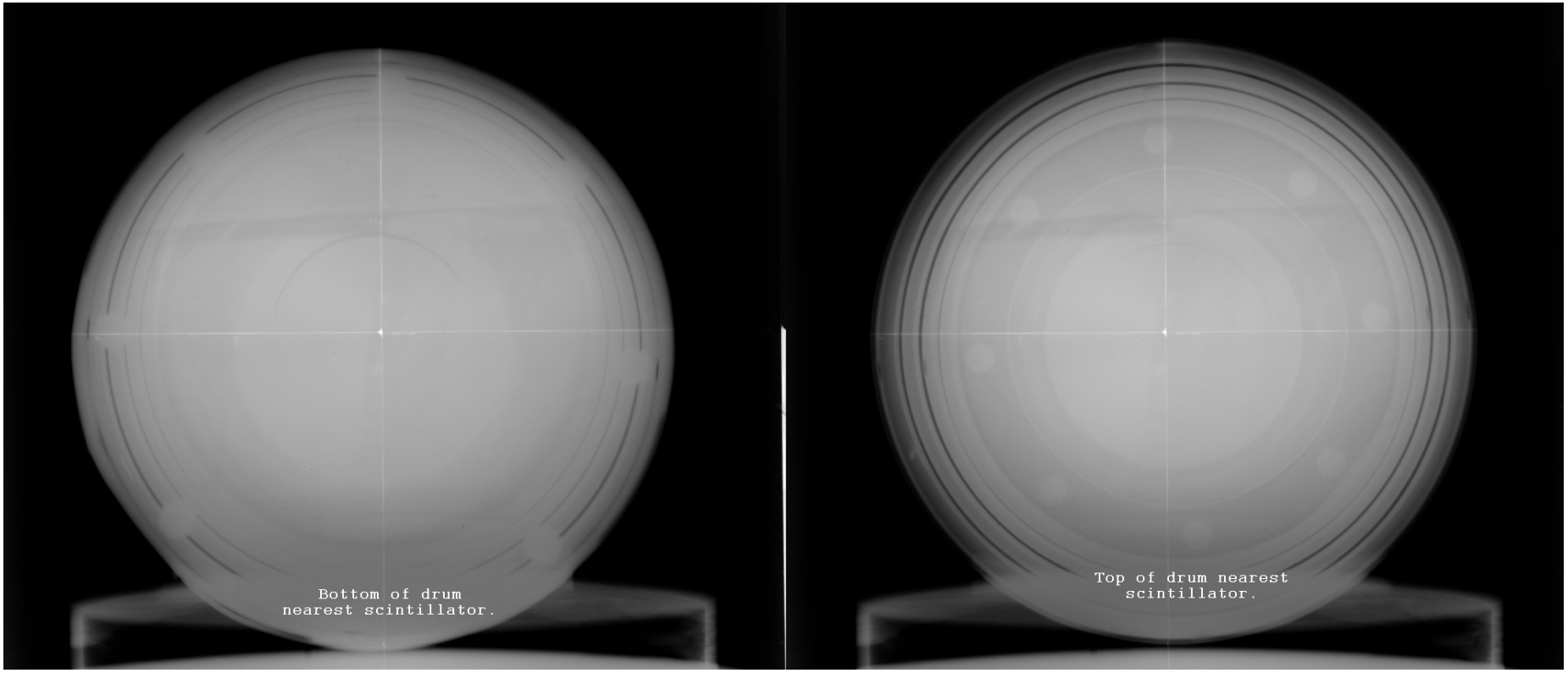
**TP0002 0, 30, and 60 DEGREE DR IMAGES OF THE UPPER PORTION OF THE PACKAGE AFTER NCT TESTS**



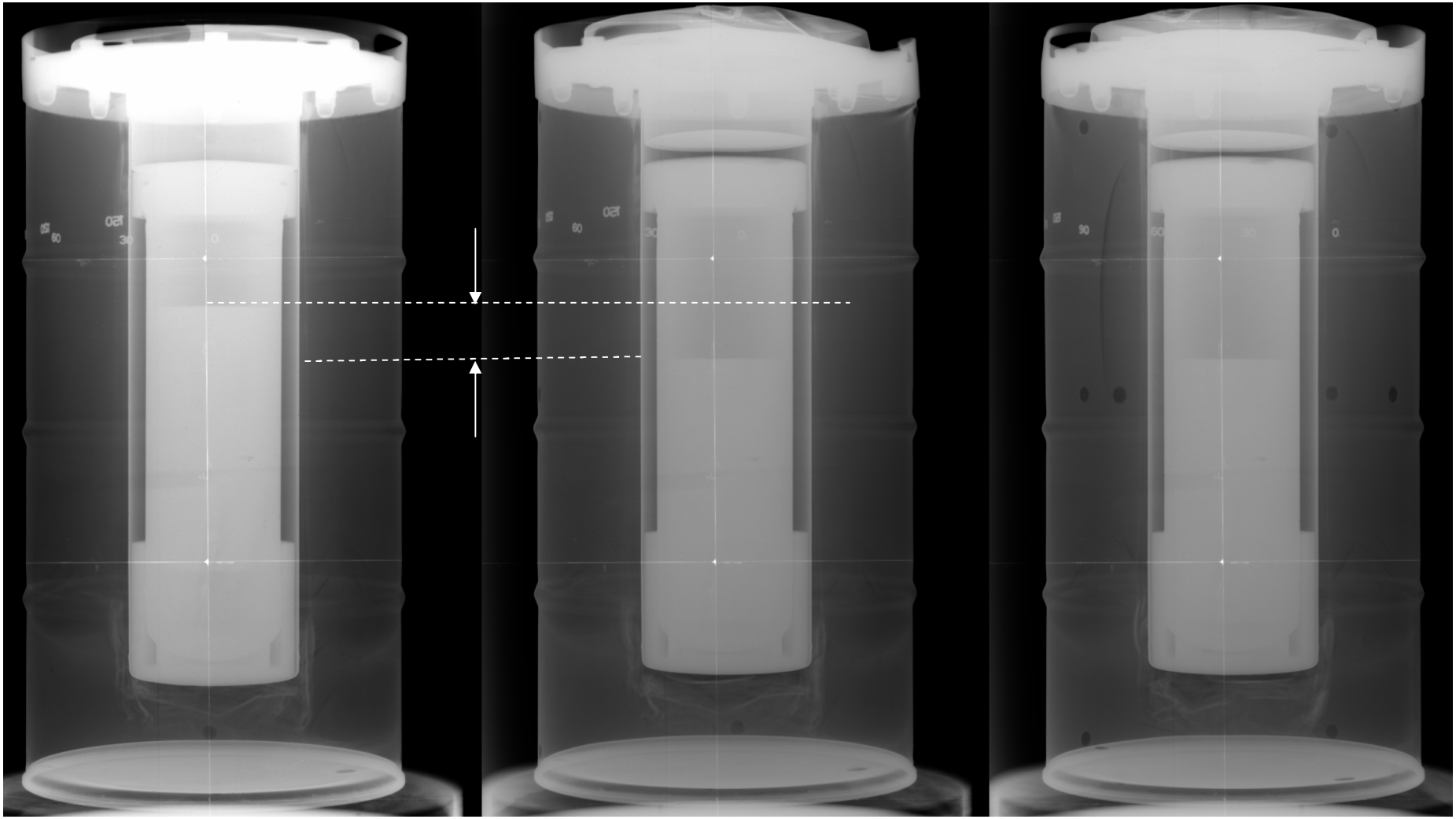
**TP0002 90, 120, 150, and 180 DEGREE DR IMAGES AFTER NCT TESTS**



**TP0002 90, 120, 150, AND 180 DEGREE DR IMAGES OF THE PACKAGE UPPER PORTION AFTER NCT TESTS**



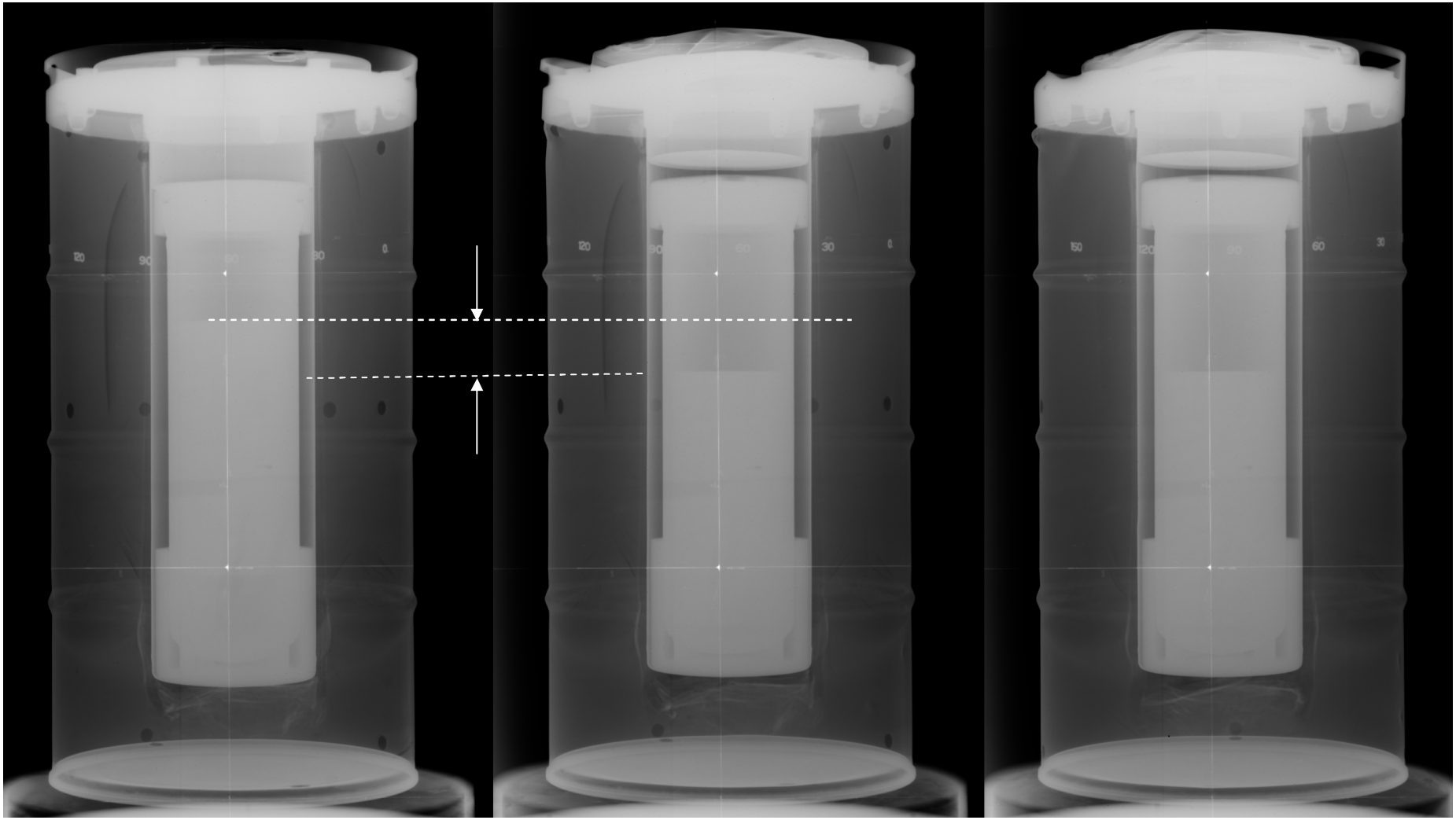

**TP0002 END TO END DR IMAGES OF THE PACKAGE AFTER NCT TESTS**



0 Degree Image Before 30’ Drop Test  0 Degree Image After 30’ Drop Test  30 Degree Image After 30’ Drop Test

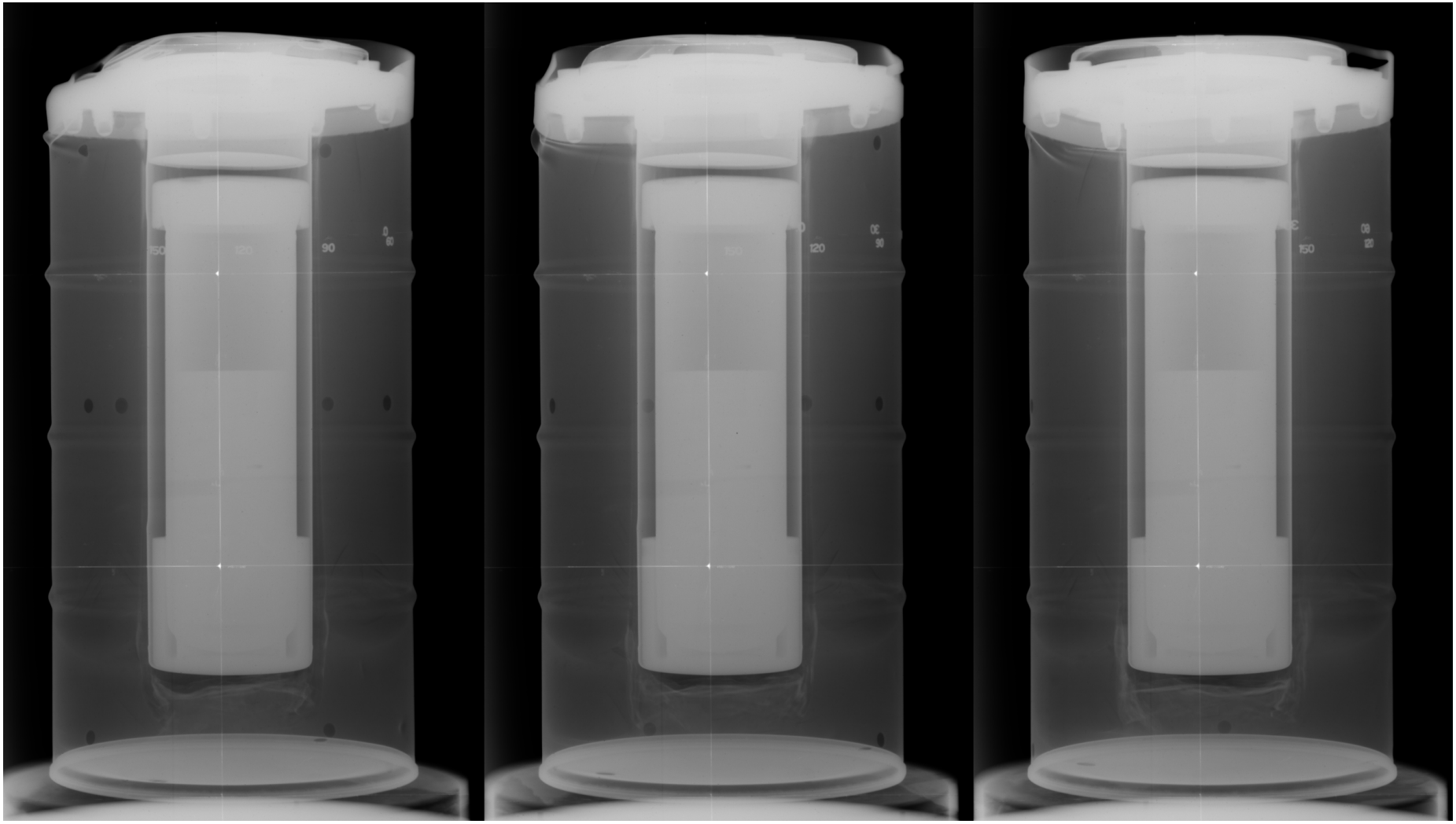
**TP0002 0 AND 30 DEGREE DR IMAGES AFTER 30’ DROP TEST**

.



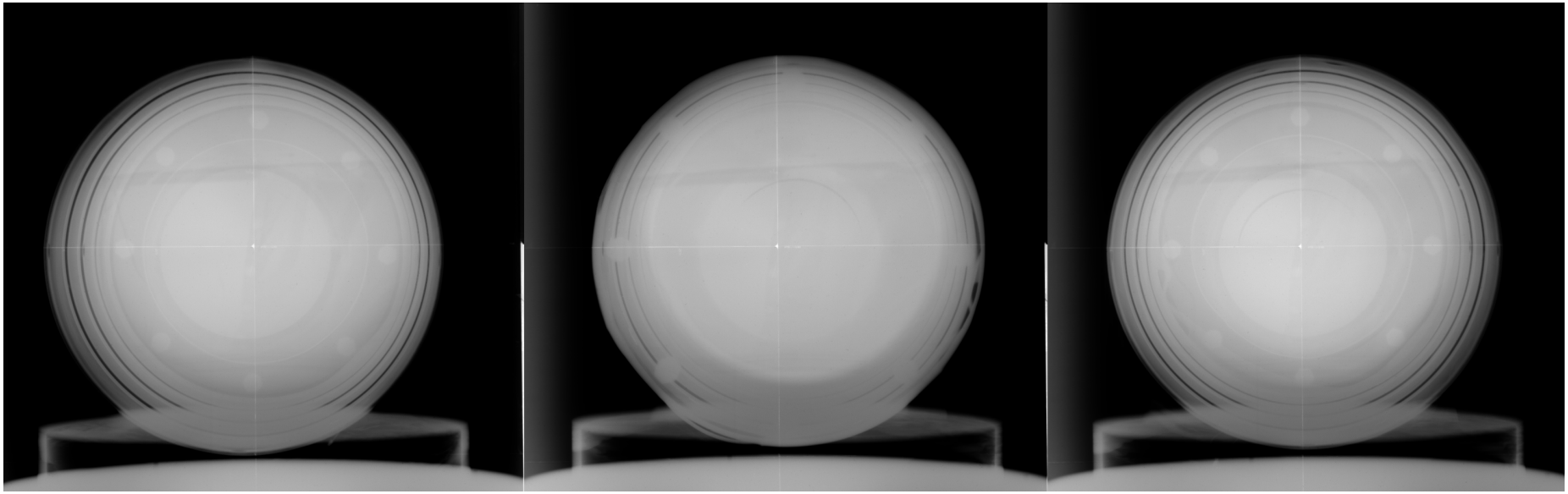
60 Degree Image Before 30’ Drop Test  60 Degree Image After 30’ Drop Test  90 Degree Image After 30’ Drop Test

**TP0002 60 AND 90 DEGREE DR IMAGES AFTER 30’ DROP TEST**



120 Degree Image After 30’ Drop Test 150 Degree Image After 30’ Drop Test 180 Degree Image After 30’ Drop

**TP0002 120, 150 AND 180 DEGREE DR IMAGES AFTER 30’ DROP TEST**

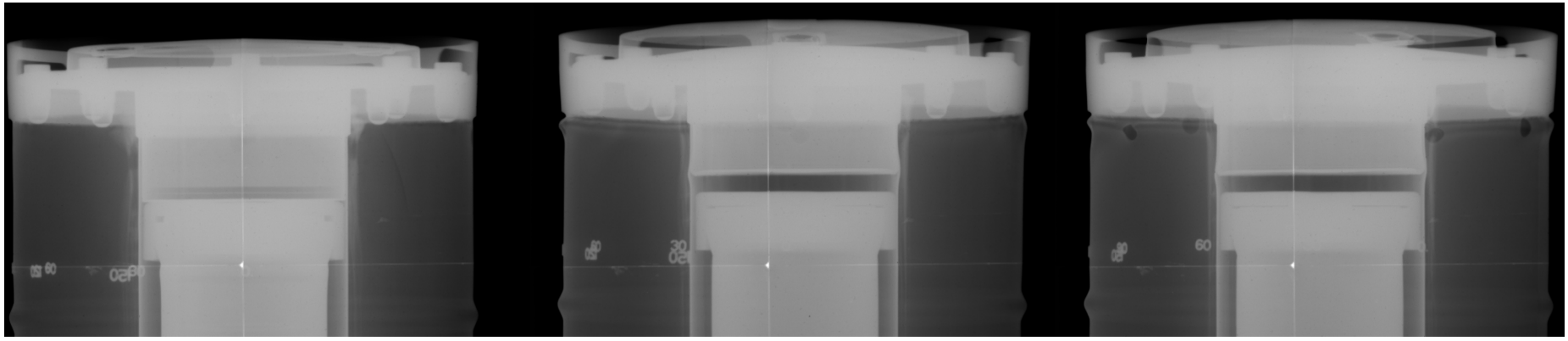


End to End DR Image Before Drop Test
Top of Drum Near Scintillator

End to End DR Image After 30’ Drop Test
Bottom of Drum Near the Scintillator

End to End DR Image After 30’ Drop
Top of Drum Near the Scintillator

**TP0002 END TO END DR IMAGES AFTER 30’ DROP TEST**

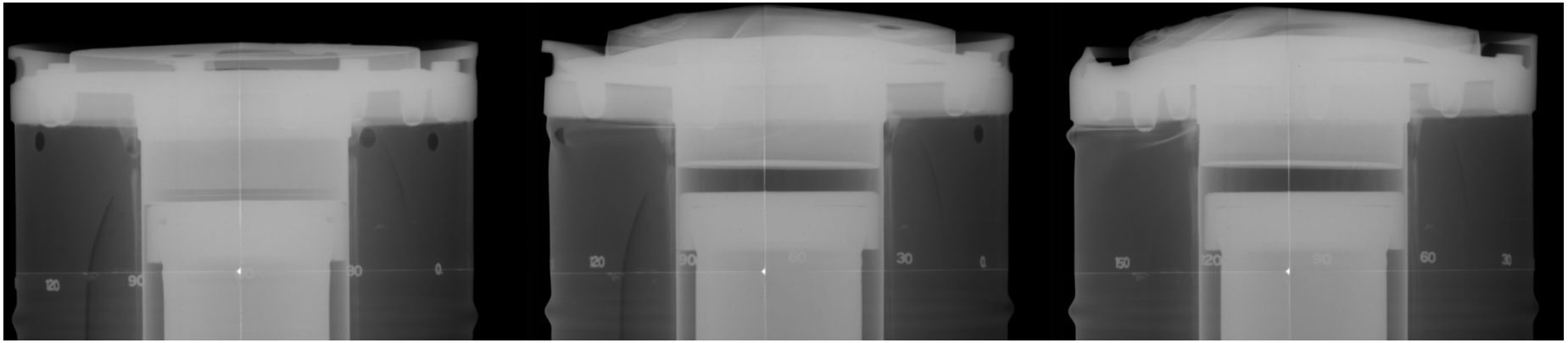


0 Degree Image before 30’ Drop Test

0 Degree Image After 30’ Drop Test

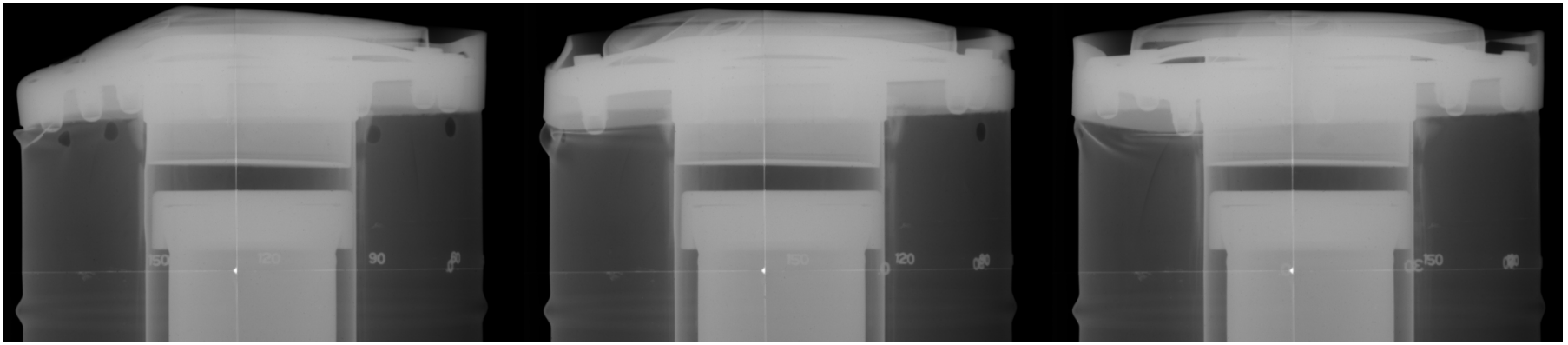
30 Degree Image After 30’ Drop Test

**TP0002 0 and 30 DEGREE DR IMAGES OF THE UPPER PORTION OF THE PACKAGE AFTER 30’ DROP TEST**



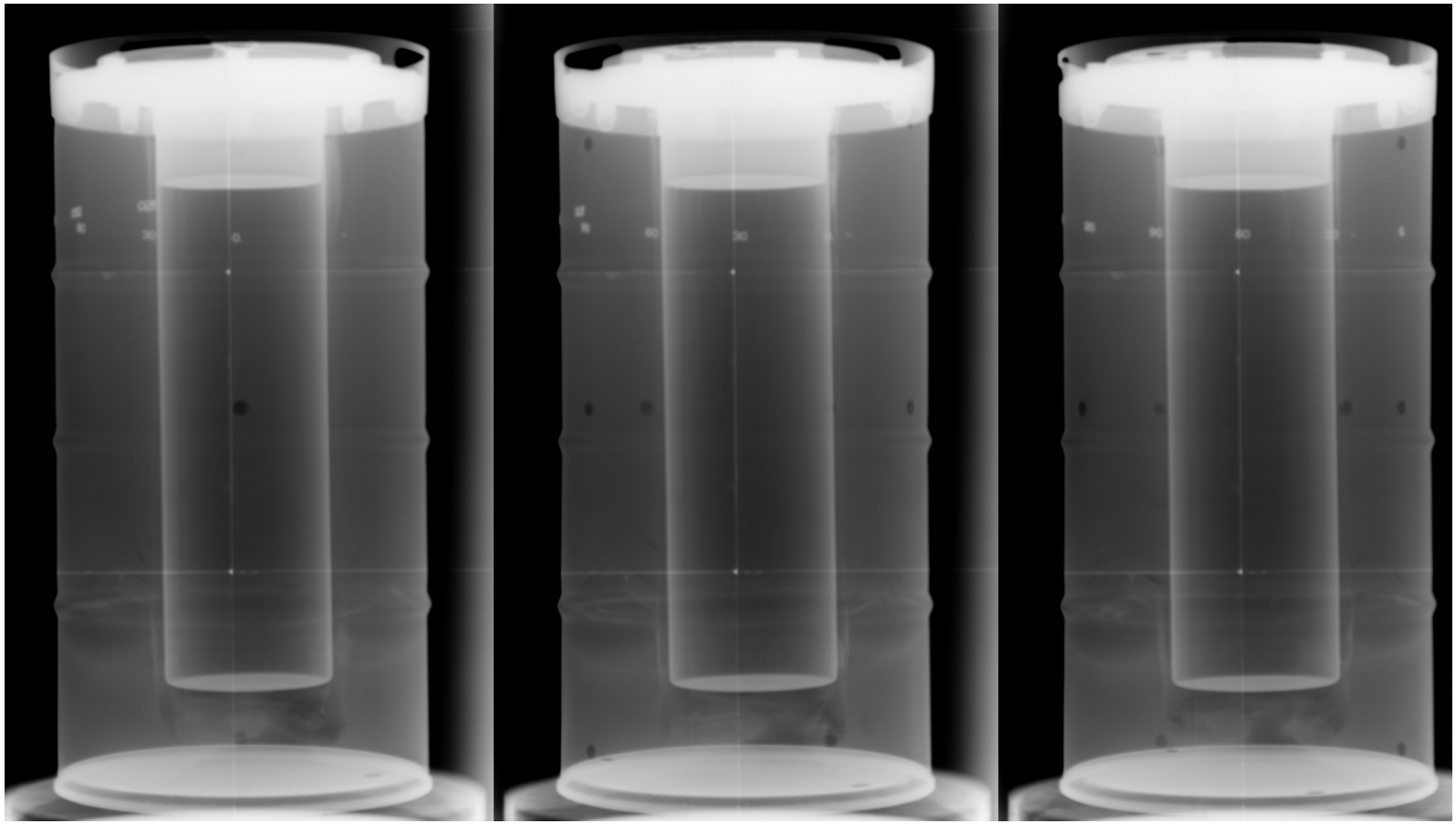
60 Degree Image After 30’ Drop Test 60 Degree Image After 30’ Drop Test 90 Degree Image After 30’ Drop Test

**TP0002 60 and 90 DEGREE DR IMAGES OF THE UPPER PORTION OF THE PACKAGE AFTER 30’ DROP TEST**

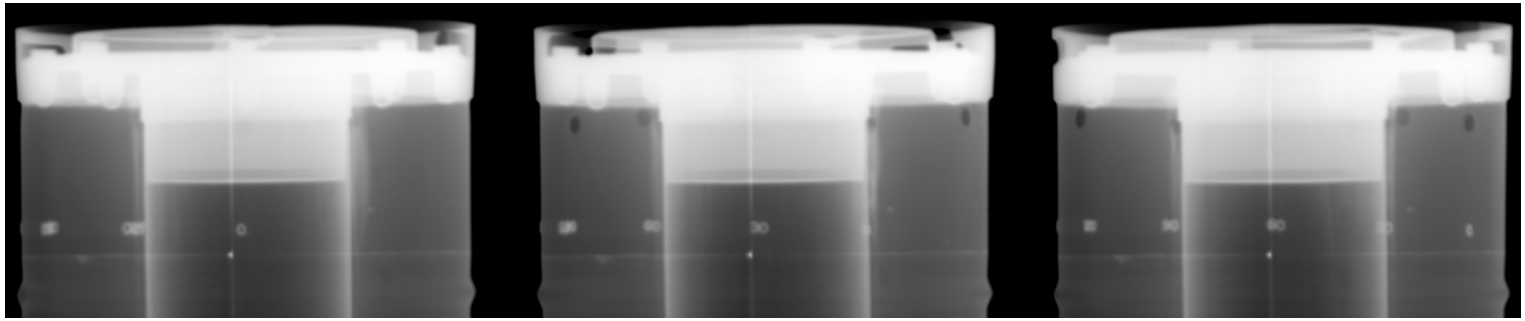


120 Degree Image After 30’ Drop Test 150 Degree Image After 30’ Drop Test 180 Degree Image After 30’ Drop Test

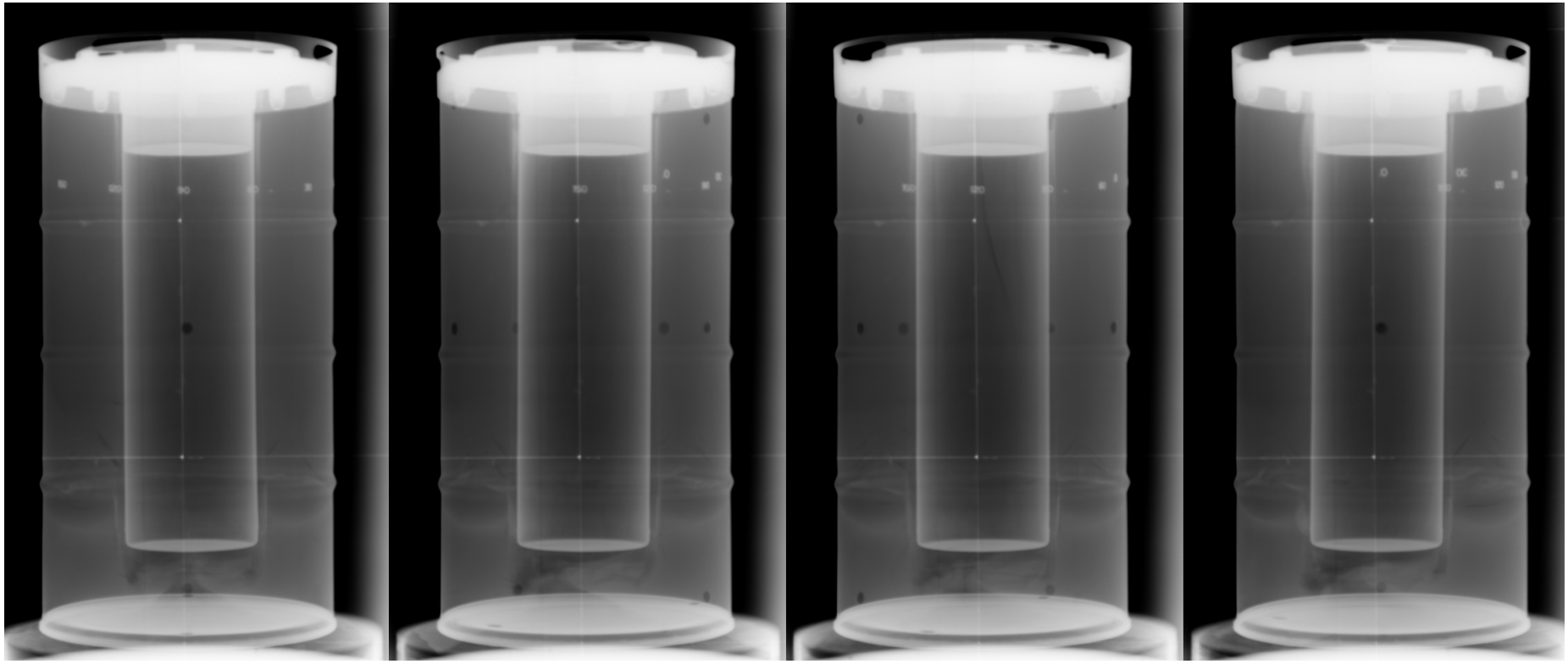
**TP0002 120, 150, and 180 DEGREE DR IMAGES OF THE UPPER PORTION OF THE PACKAGE AFTER 30’ DROP TEST**



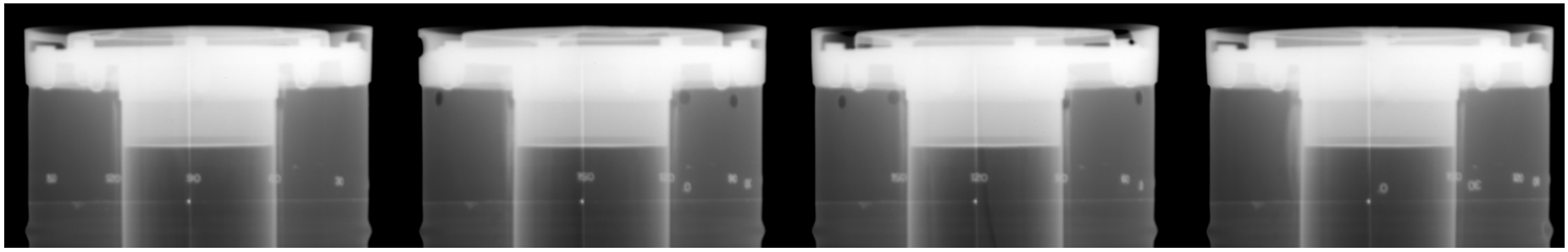
**TP0003 0, 30, AND 60 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



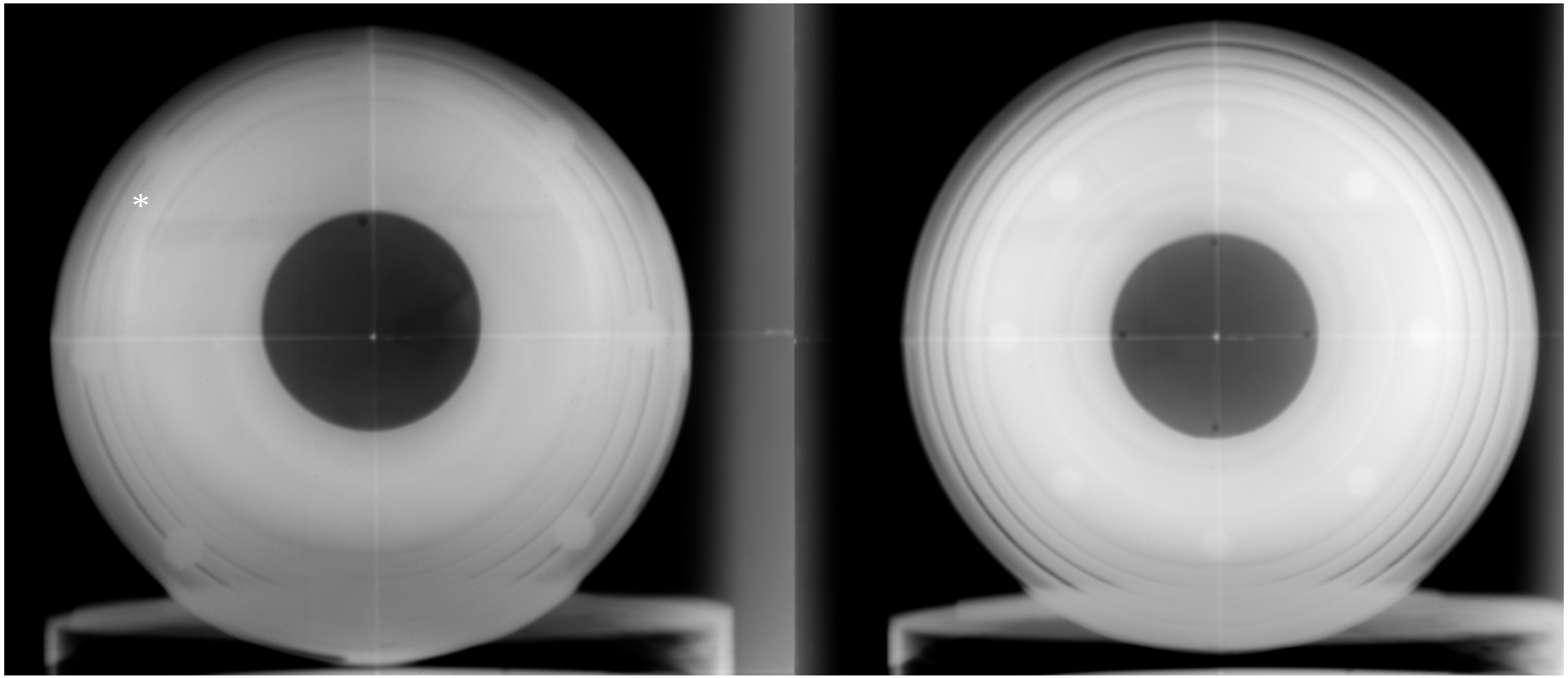
**TP0003 0, 30, AND 60 DEGREE DR IMAGES OF THE UPPER PORTION BEFORE INSERTION OF CONTAINMENT VESSEL**



**TP0003 90, 120, 150, and 180 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



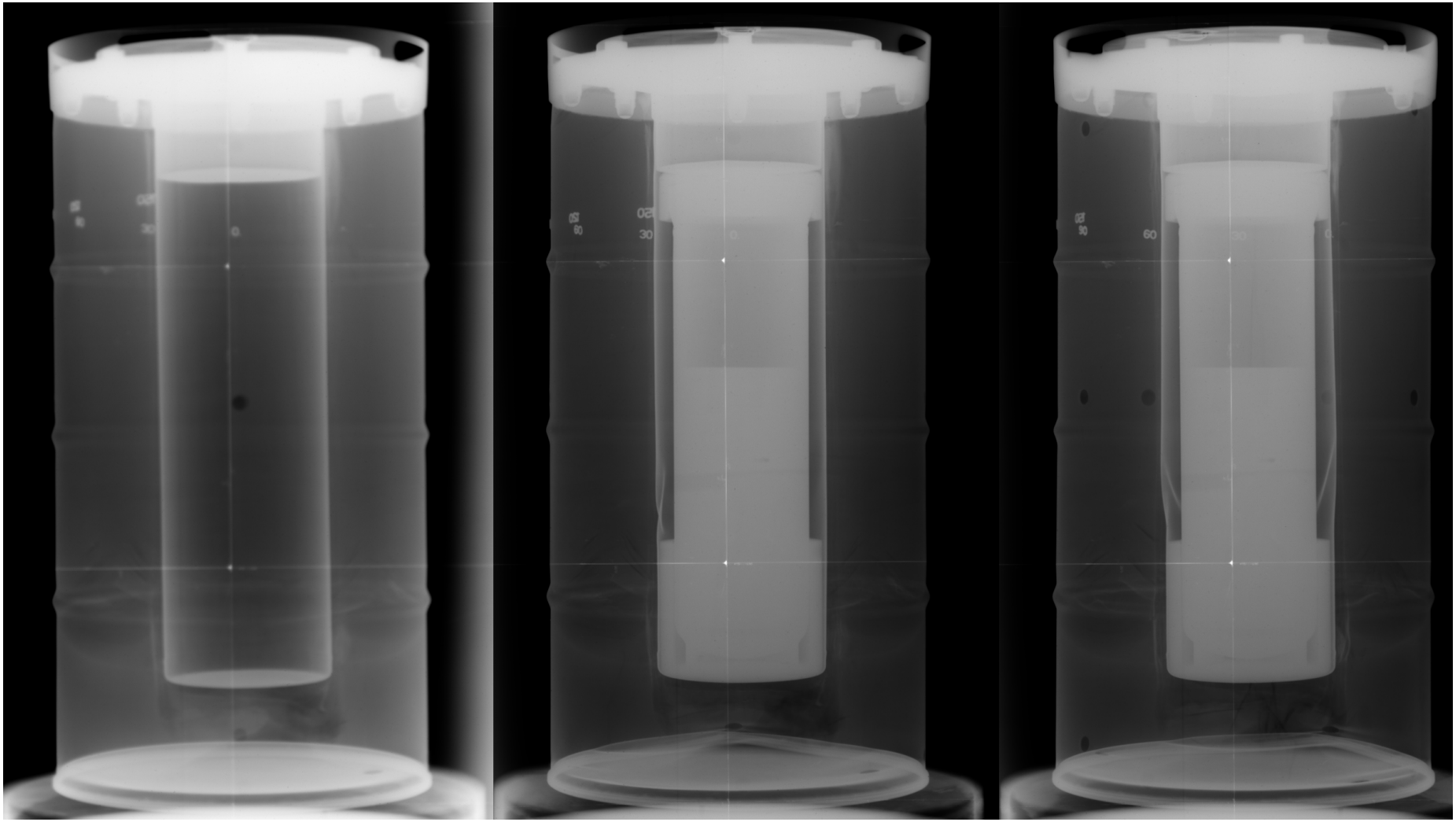
**TP0003 90, 120, 150, and 180 DEGREE DR IMAGES OF UPPER PORTION BEFORE INSERTION OF CONTAINMENT VESSEL**



End to End DR Image
Bottom of Drum is Nearest the Scintillator

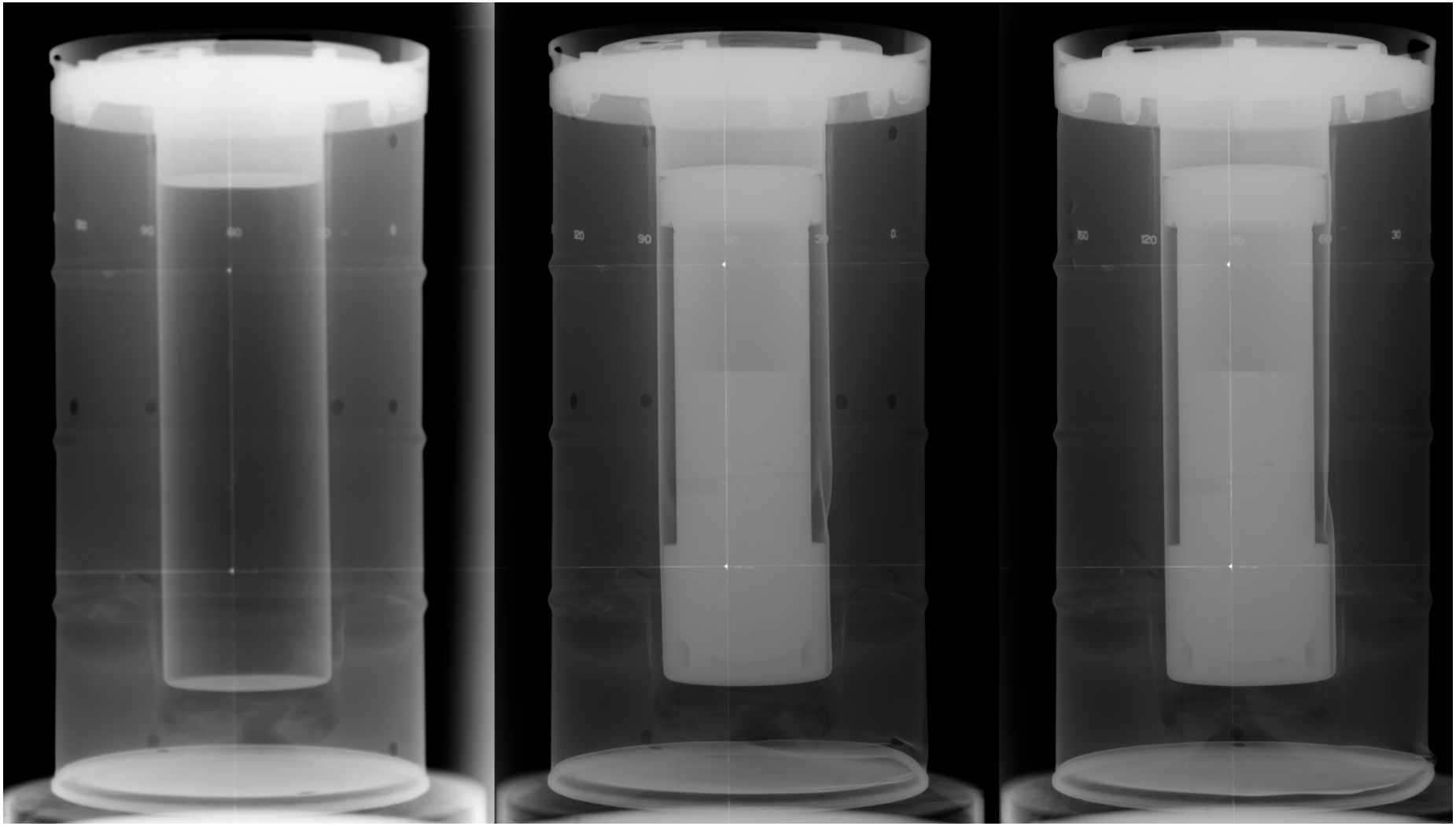
End to End DR Image
Top of Drum is Nearest the Scintillator

**TP0003 END TO END DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



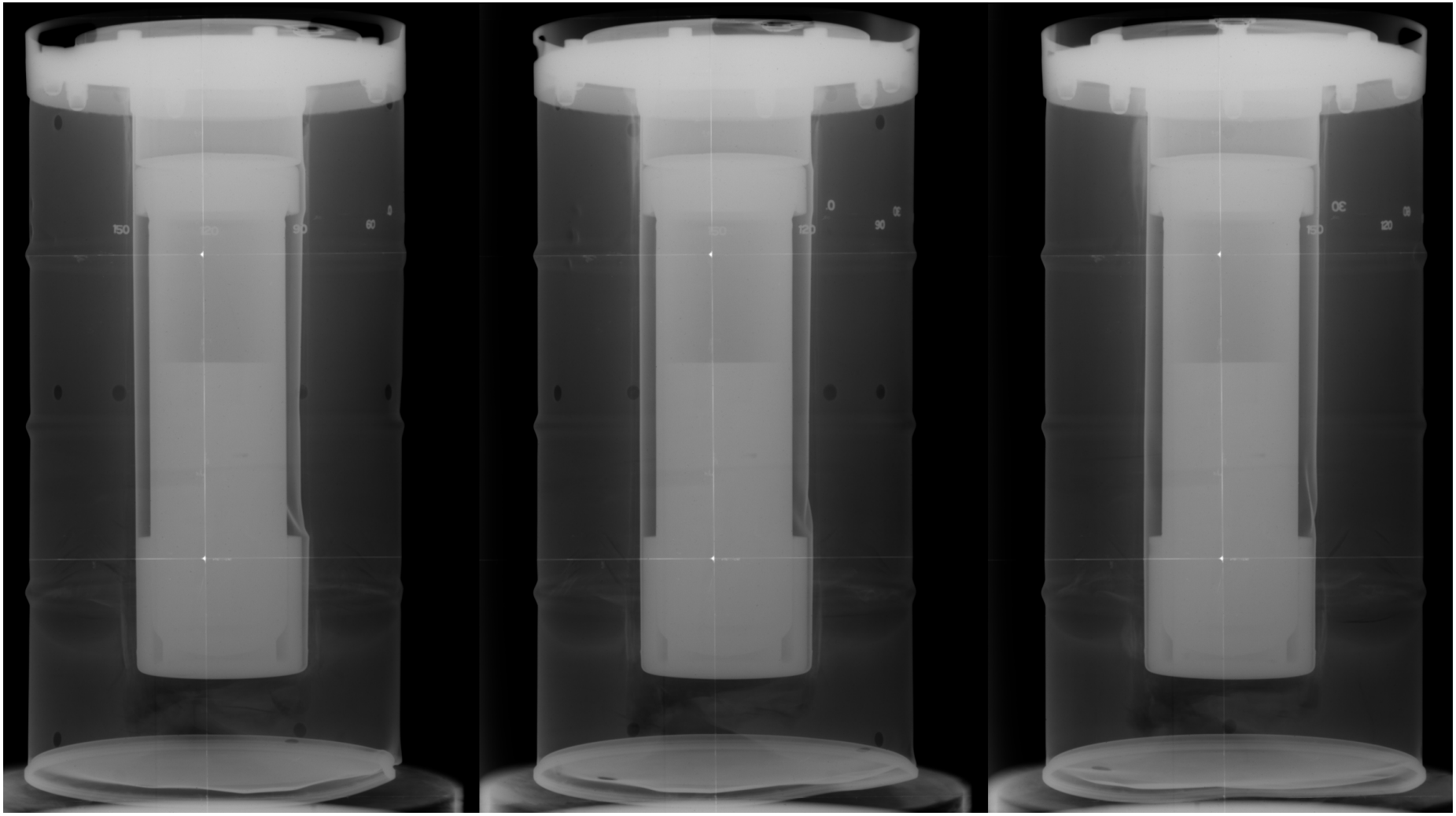
0 Degree Image before 30’ Drop Test 0 Degree Image After 30’ Drop Test 30 Degree Image After 30’ Drop Test

**TP0003 0 AND 30 DEGREE DR IMAGES AFTER 30’ DROP TEST**



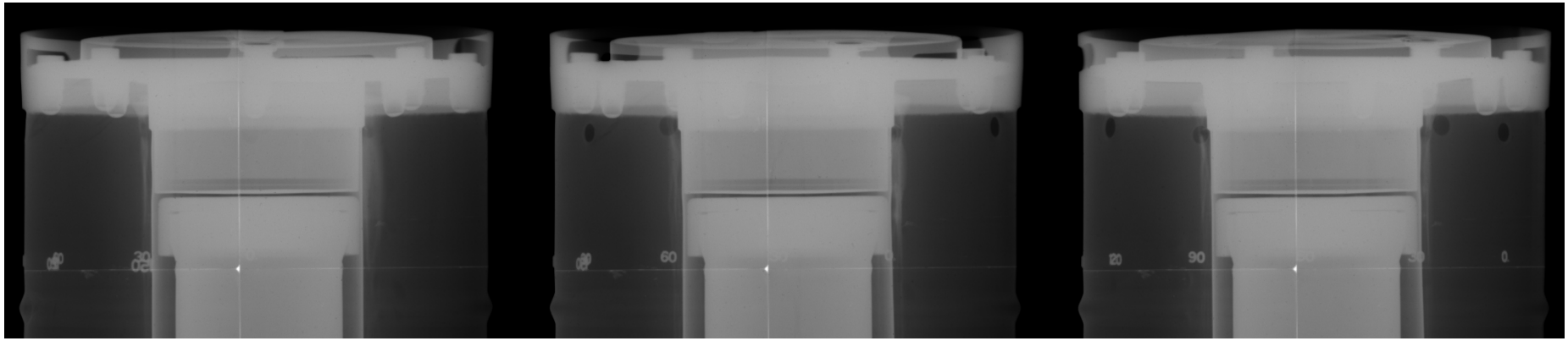
60 Degree Image before 30’ Drop Test 60 Degree Image After 30’ Drop Test 90 Degree Image After 30’ Drop Test

**TP0003 60 AND 90 DEGREE DR IMAGES AFTER 30’ DROP TEST**



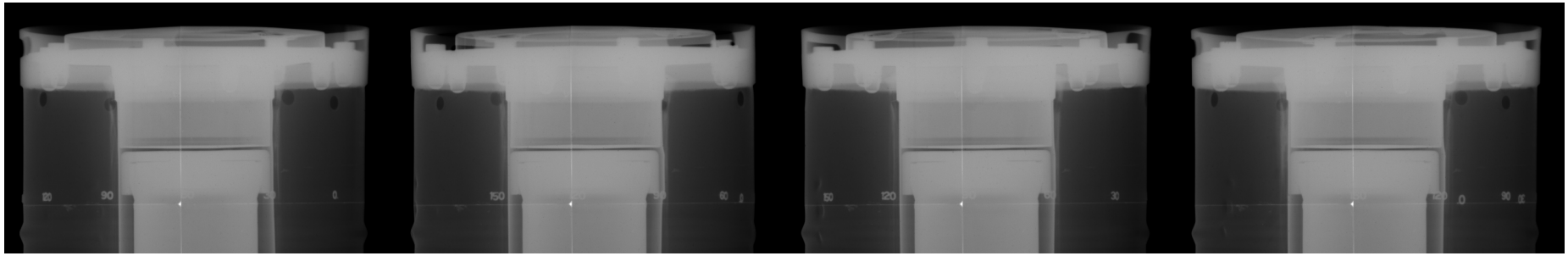
120 Degree Image After 30’ Drop Test 150 Degree Image After 30’ Drop Test 180 Degree Image After 30’ Drop Test

**TP0003 120, 150, and 180 DEGREE DR IMAGES OF THE PACKAGE AFTER 30’ DROP TEST**



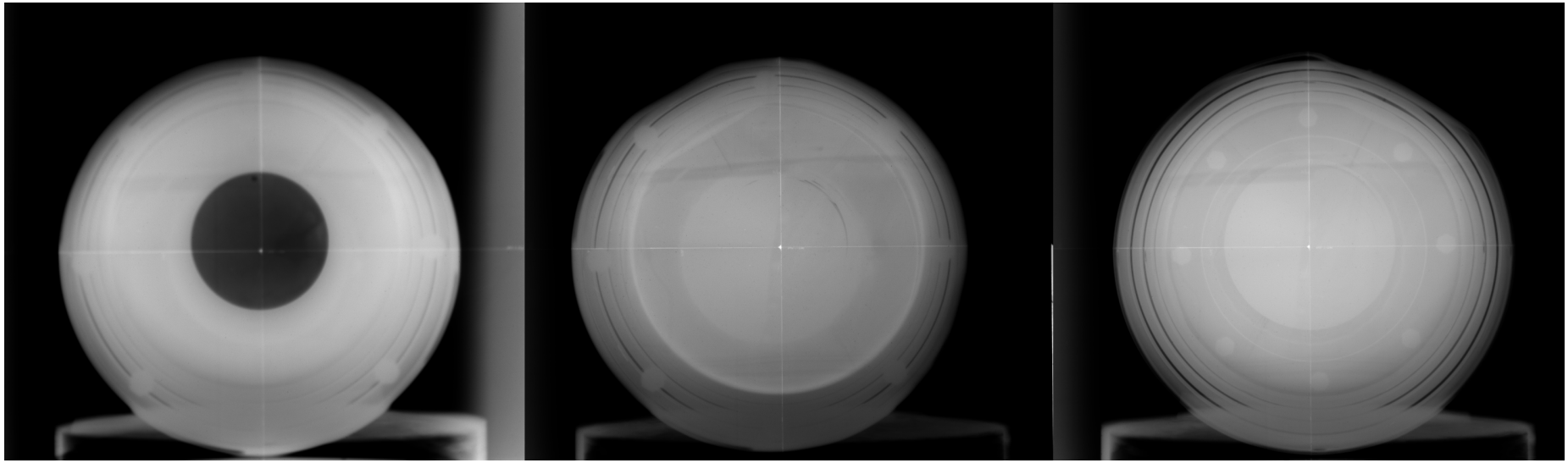
0 Degree Image After 30’ Drop Test  30 Degree Image After 30’ Drop Test  60 Degree Image After 30’ Drop Test

**TP0003 0, 30, AND 60 DEGREE DR IMAGES OF THE UPPER PORTION OF THE PACKAGE AFTER 30’ DROP TEST**



90 Degree Image  120 Degree Image  150 Degree Image  180 Degree Image

**TP0003 90, 120, 150, 180 DEGREE DR IMAGES OF THE UPPER PORTION OF THE PACKAGE AFTER 30’ DROP TEST**

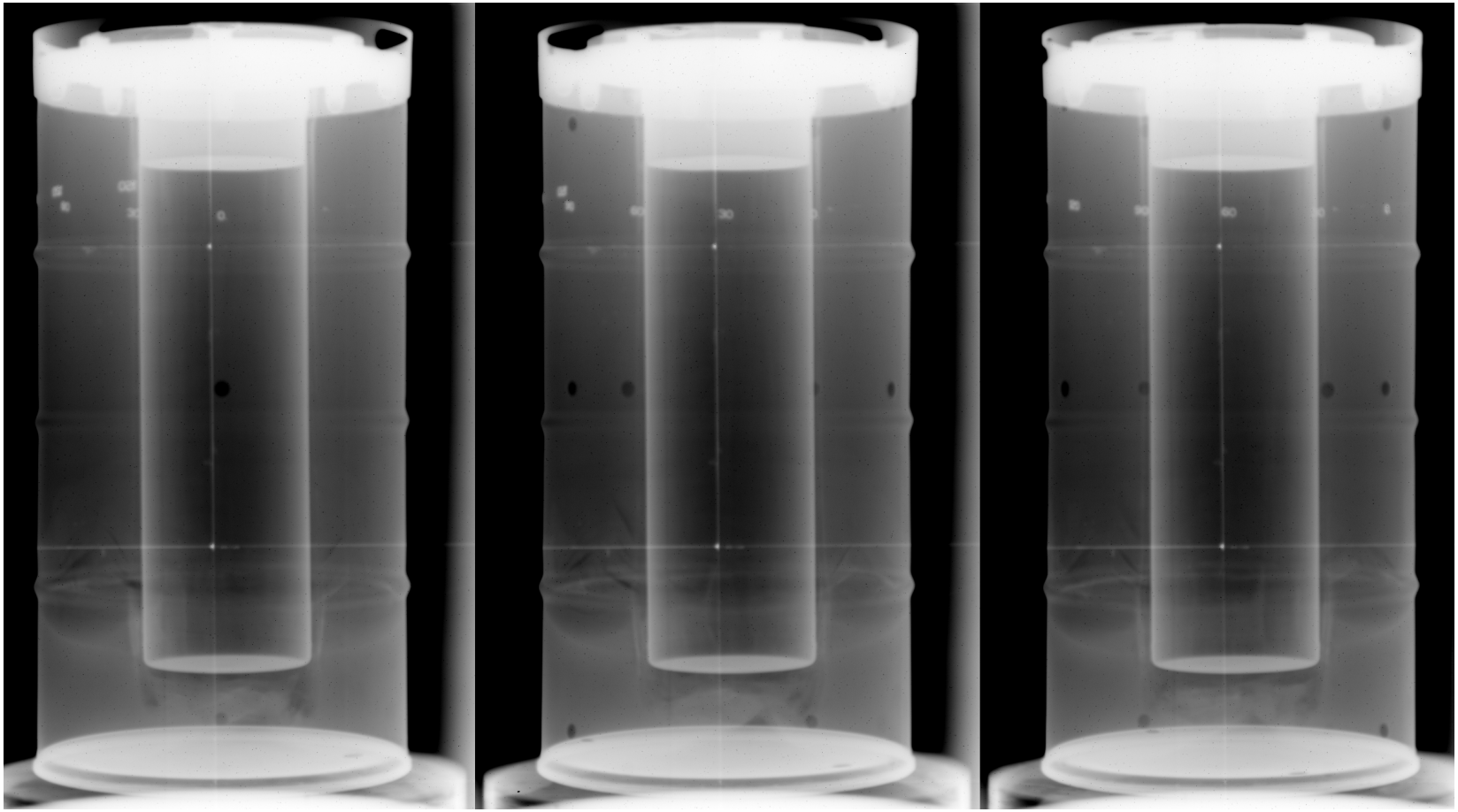


End to End DR Image Before Drop Test
Bottom of Drum Near Scintillator

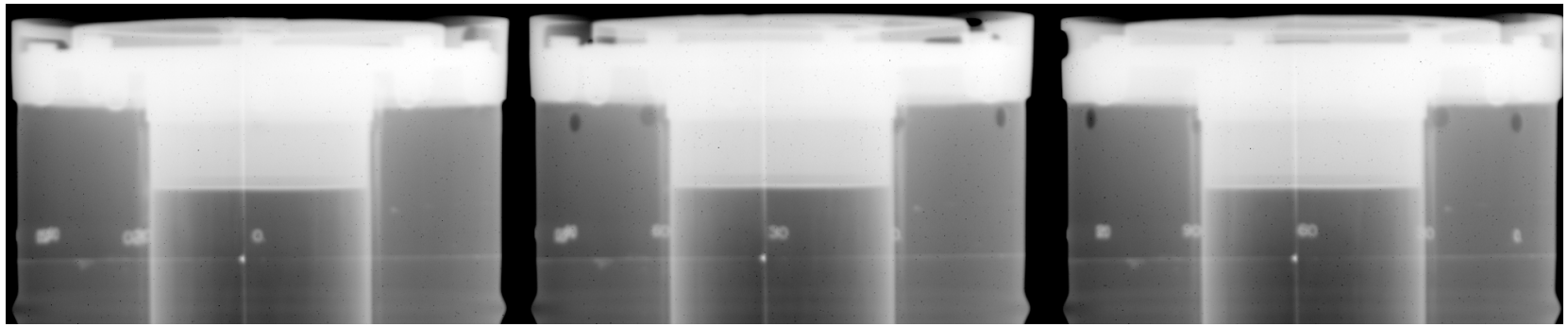
End to End DR Image After 30’ Drop Test
Bottom of Drum Near the Scintillator

End to End DR Image After 30’ Drop
Top of Drum Near the Scintillator

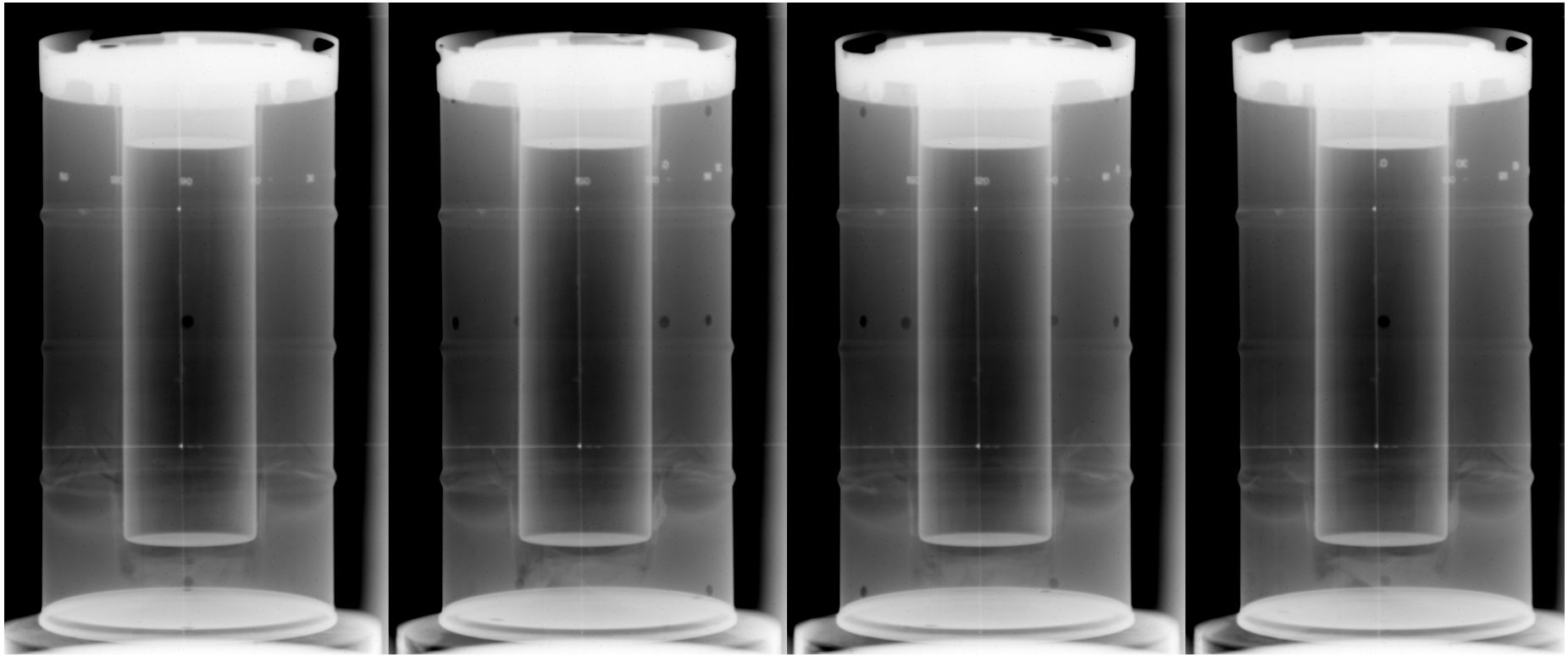
**TP0003 END TO END DR IMAGES AFTER 30’ DROP TEST**



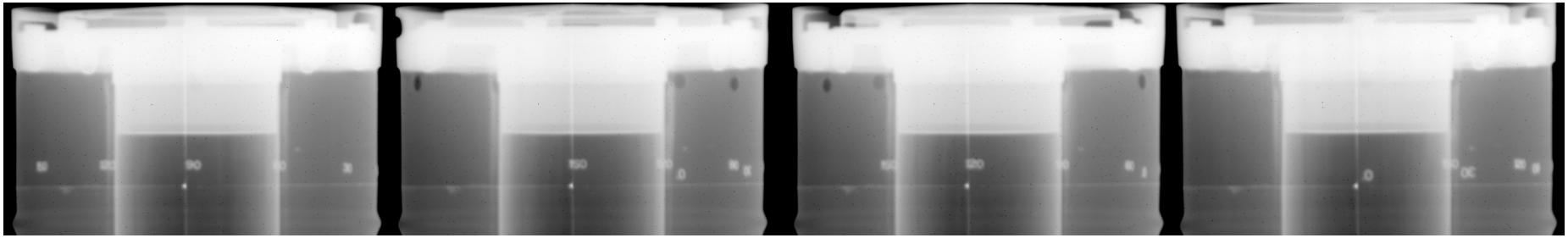
**TP0004 0, 30, AND 60 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



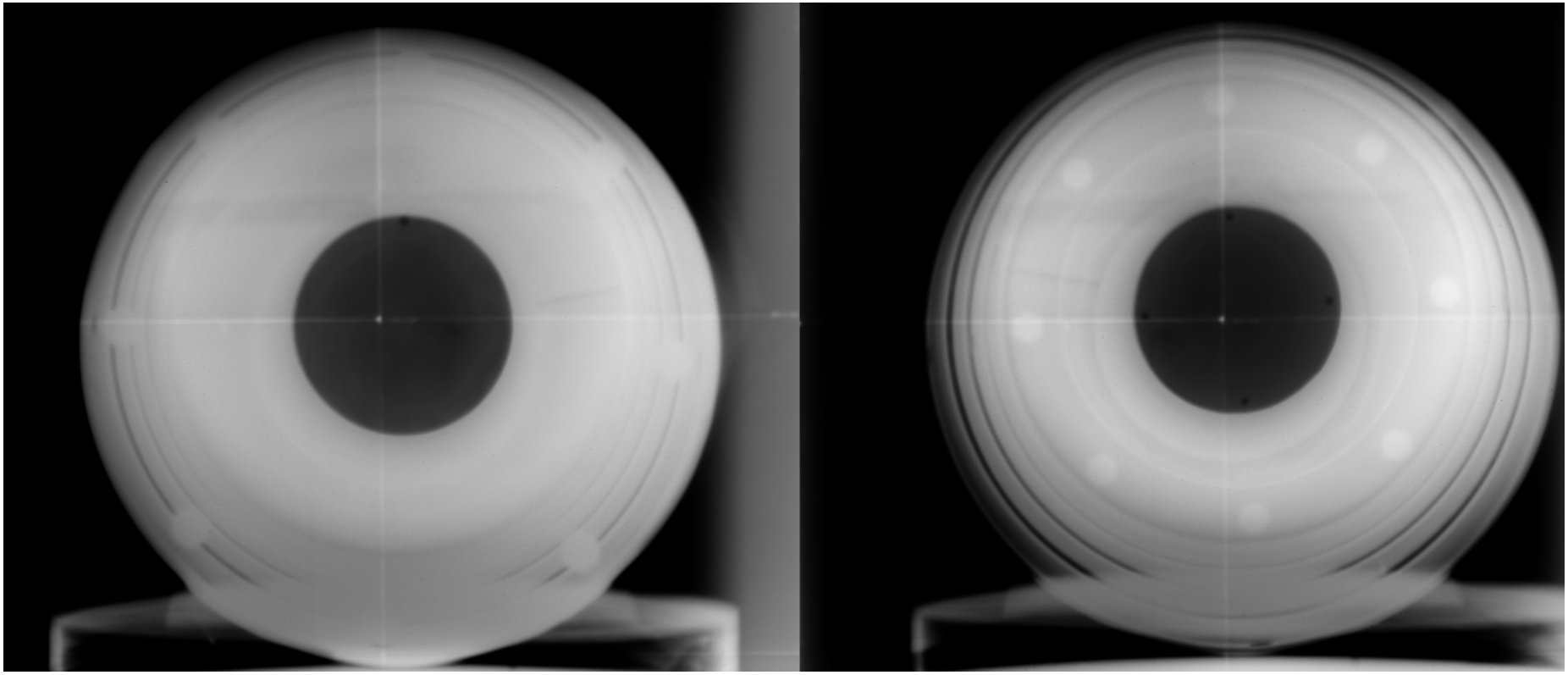
**TP0004 0, 30, AND 60 DEGREE DR IMAGES OF UPPER PORTION BEFORE INSERTION OF CONTAINMENT VESSEL**



**TP0004 90, 120, 150, AND 180 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



**TP0004 90, 120, 150, AND 180 DEGREE DR IMAGES OF UPPER PORTION BEFORE INSERTION OF CONTAINMENT VESSEL**

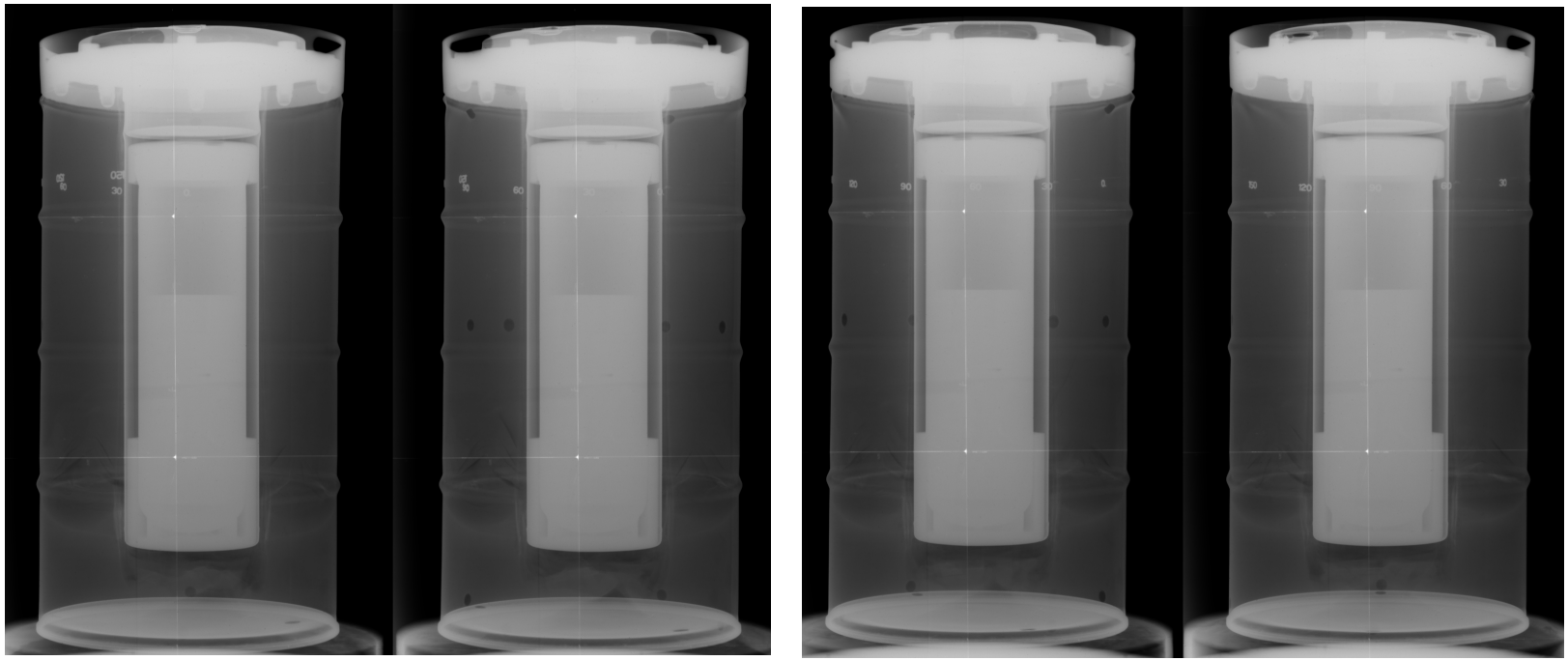


Bottom of the Drum is Nearest the Scintillator

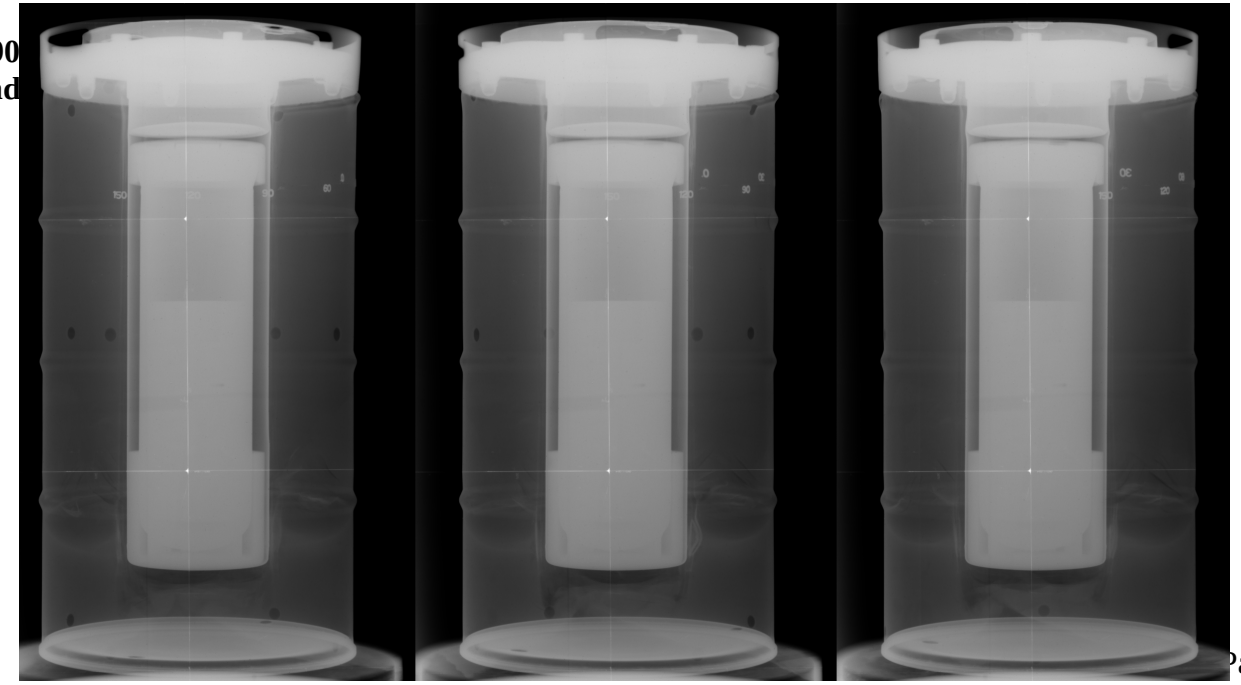
Top of the Drum is Nearest the Scintillator

**TP0004 END TO END DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**

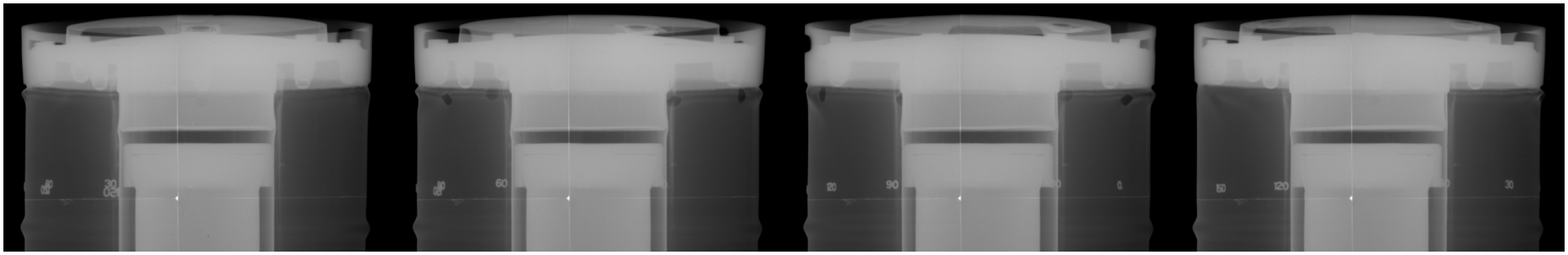
**TP0004 DR IMAGES AFTER 30’ DROP TEST**



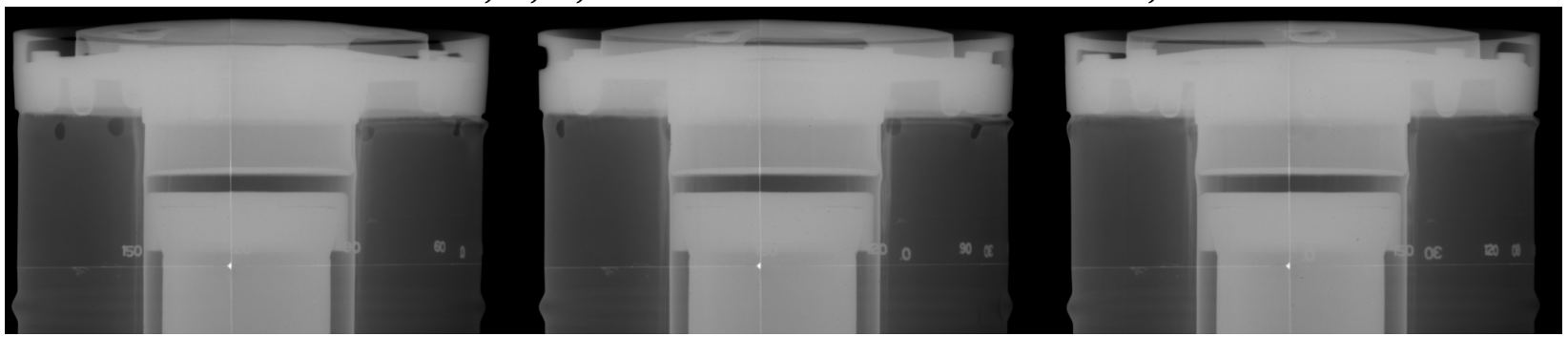
**UPPER IMAGES: 0, 30, 60, & 90**
**LOWER IMAGES: 120, 150, and**

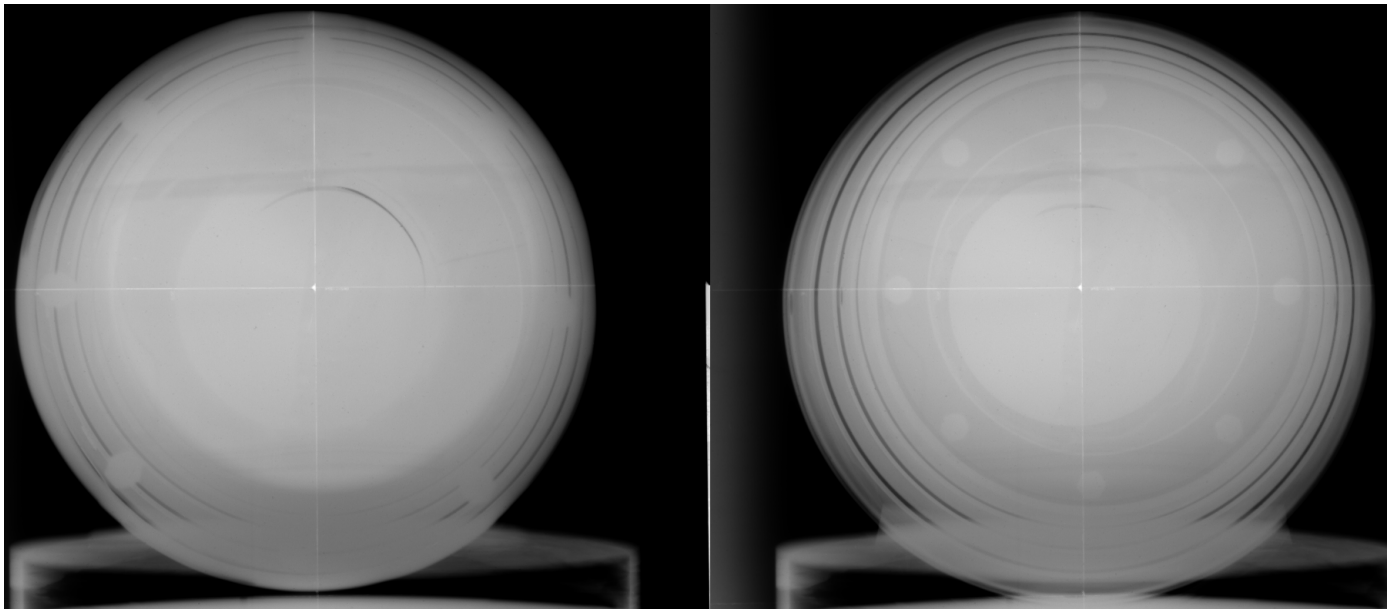


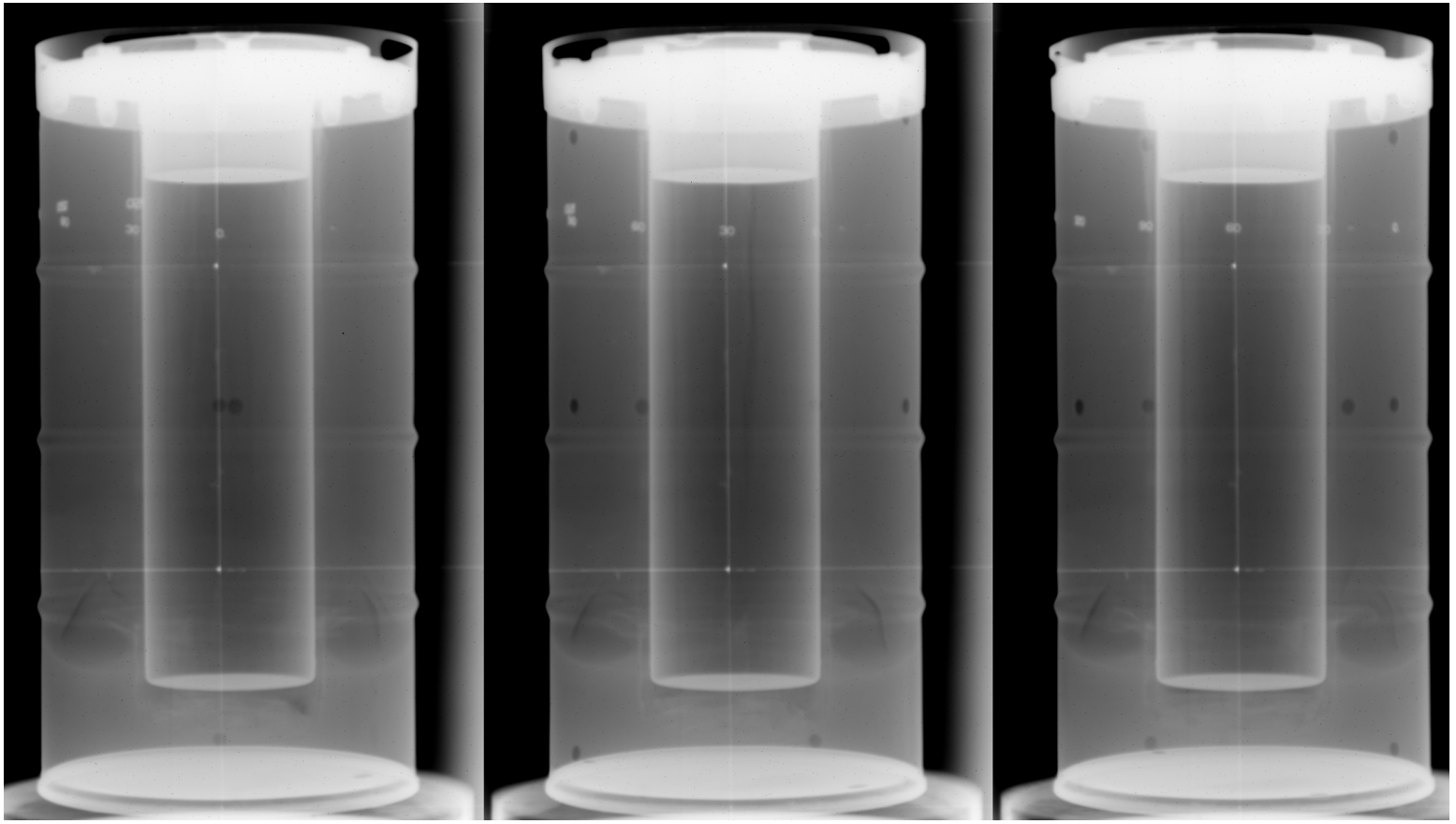
**TP0004 DR IMAGES OF UPPER PORTION AFTER 30’ DROP TEST**



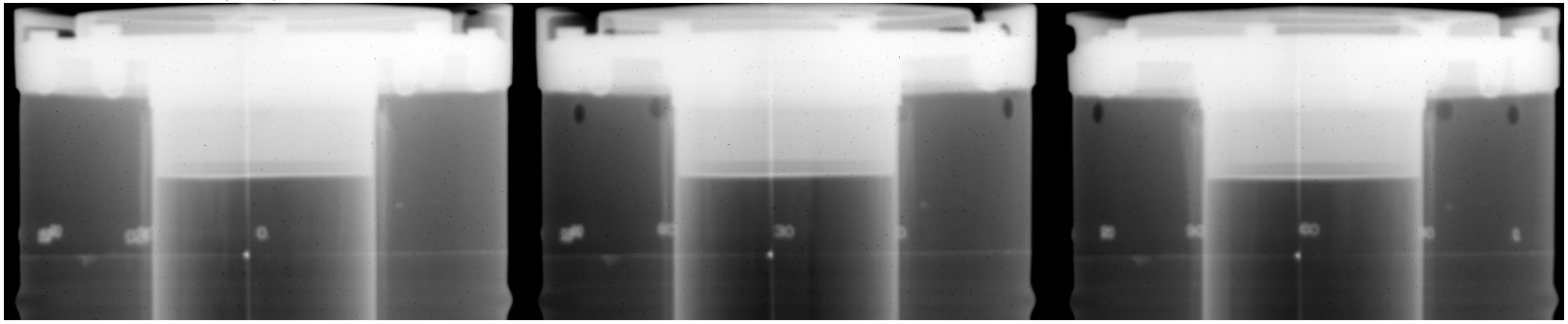
**UPPER IMAGES: 0, 30, 60, AND 90** **LOWER IMAGES: 12, 150 AND 180**



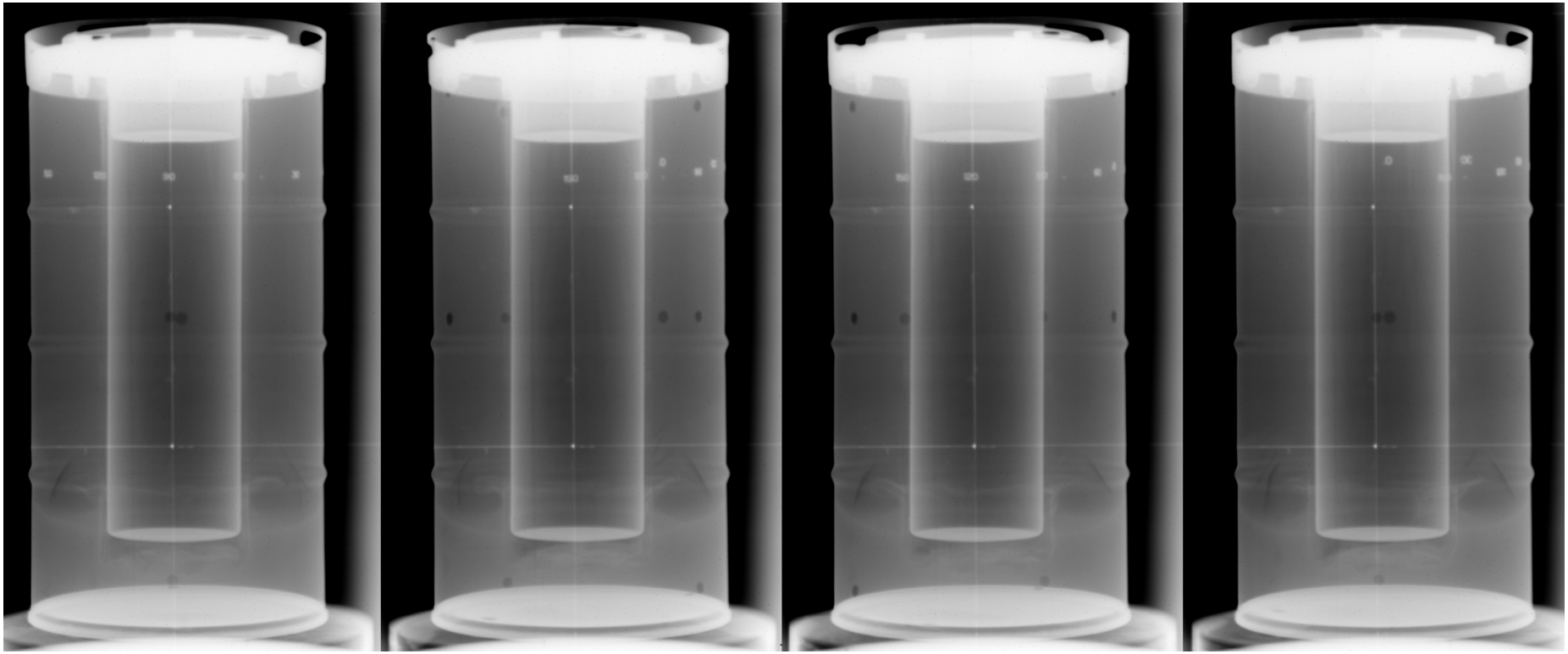




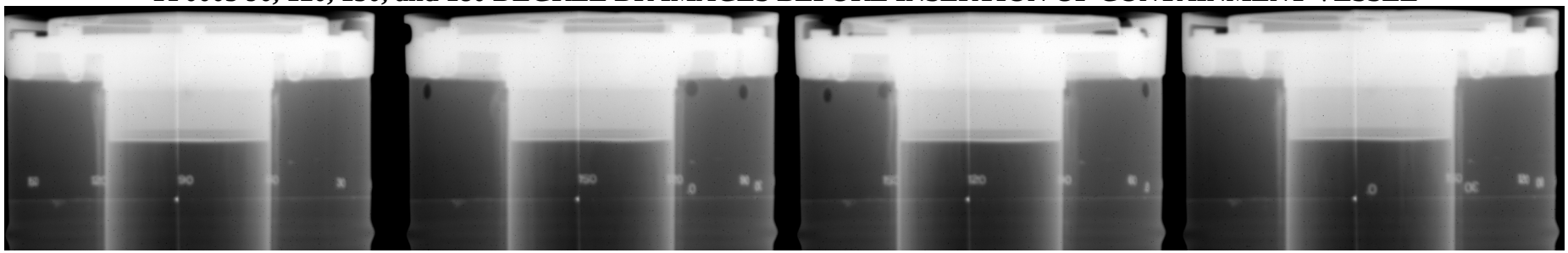
**TP0005 0, 30, AND 60 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



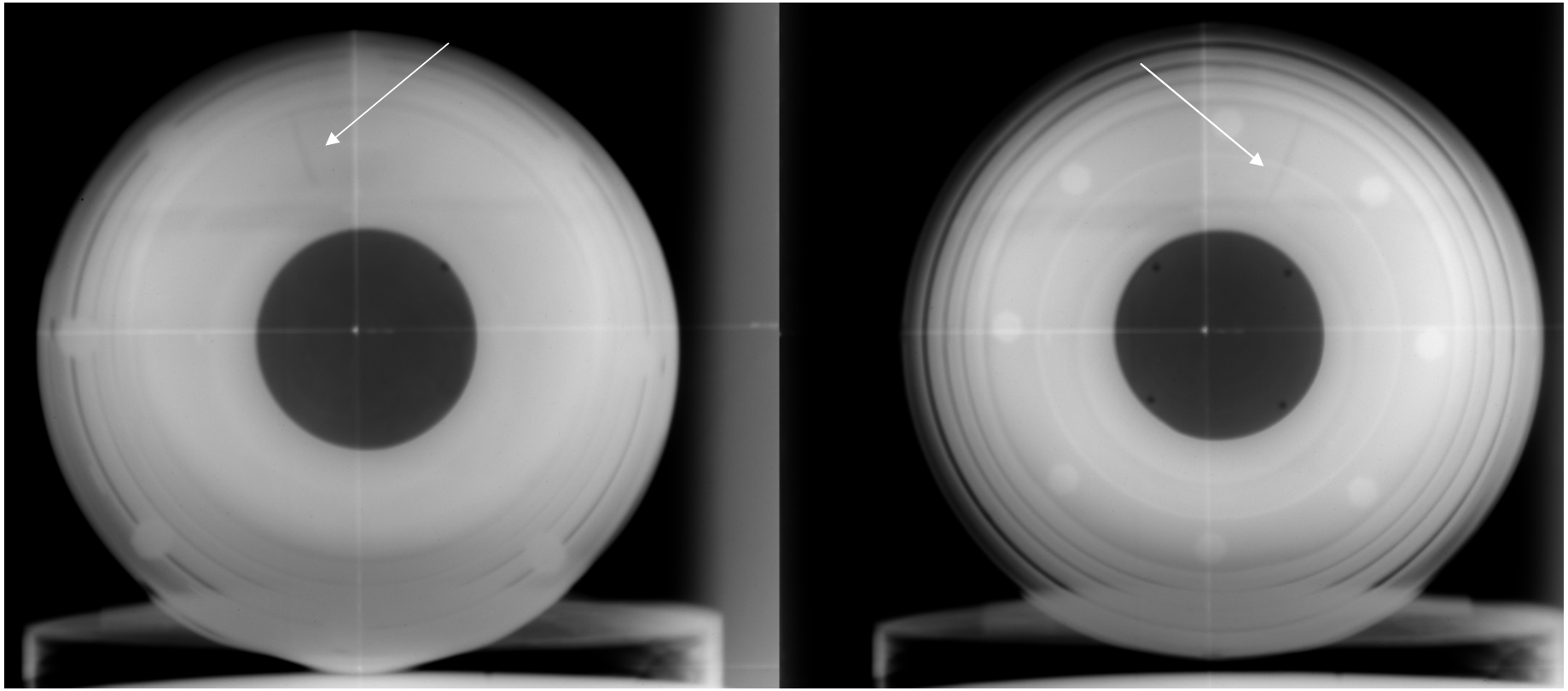
**TP0005 0, 30, AND 60 DEGREE DR IMAGES OF UPPER PORTION BEFORE INSERTION OF CONTAINMENT VESSEL**



**TP0005 90, 120, 150, and 180 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



**TP0005 90, 120, 150, and 180 DEGREE DR IMAGES OF UPPER PORTION BEFORE INSERTION OF CONTAINMENT VESSEL**

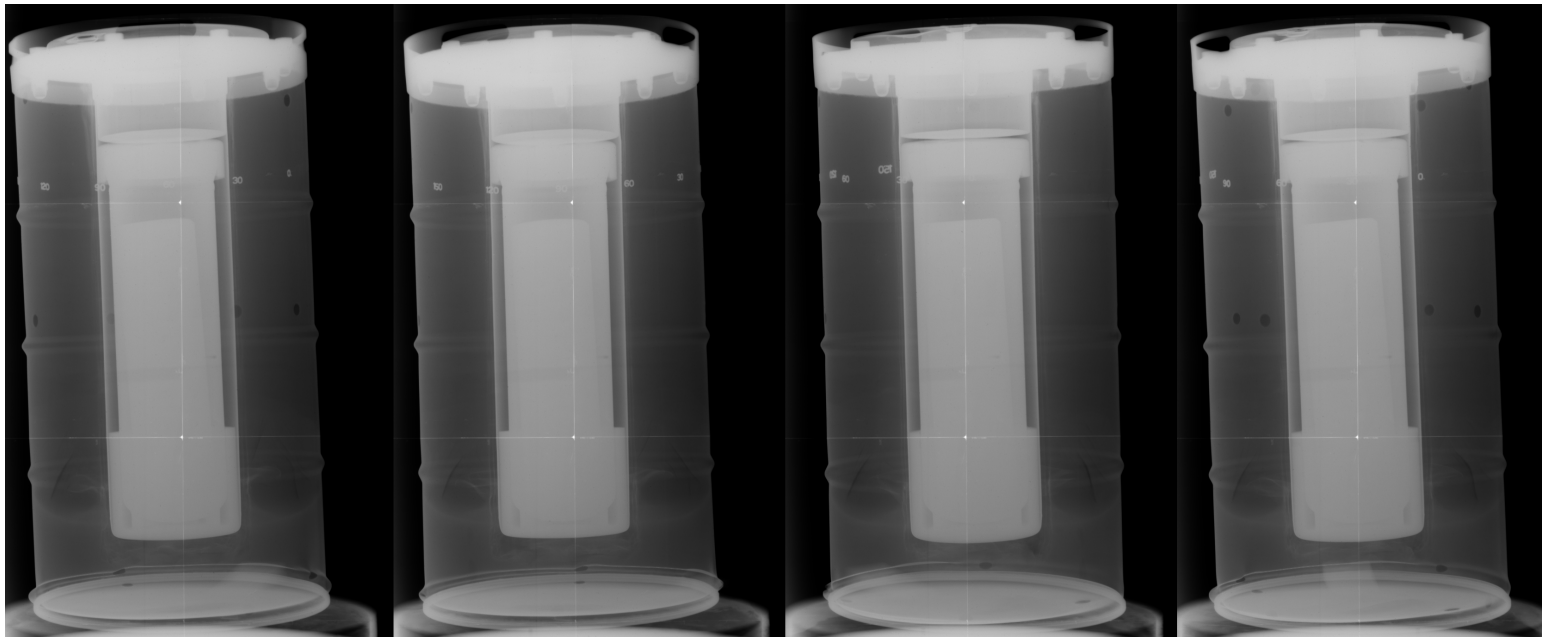


Bottom of the Drum is Nearest the Scintillator

Top of the Drum is Nearest the Scintillator

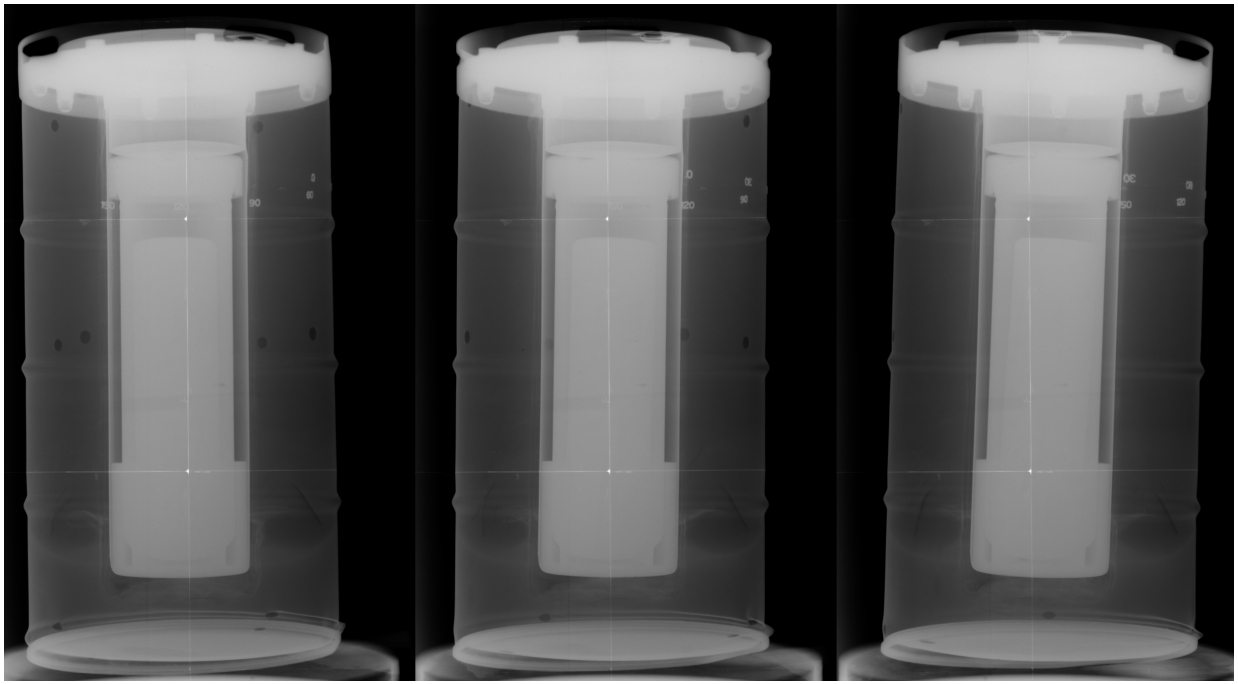
**TP0005 END TO END DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**

**TP0005 DR IMAGES AFTER 30’ DROP TEST**

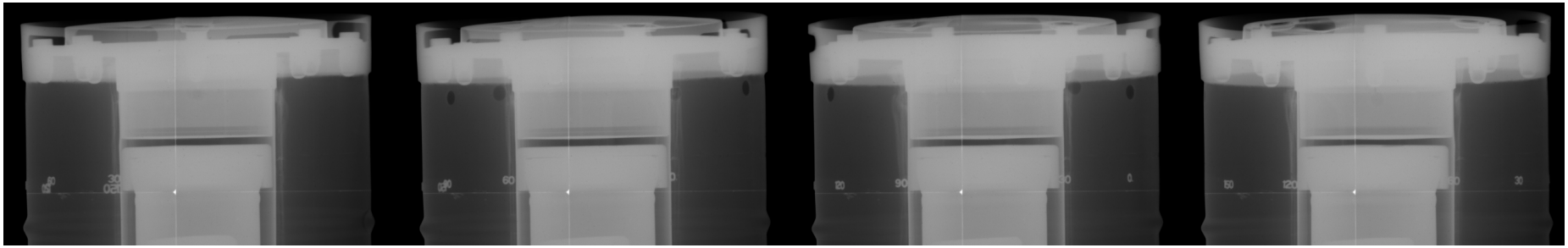


**UPPER IMAGES: 0, 30, 60, AND 90**

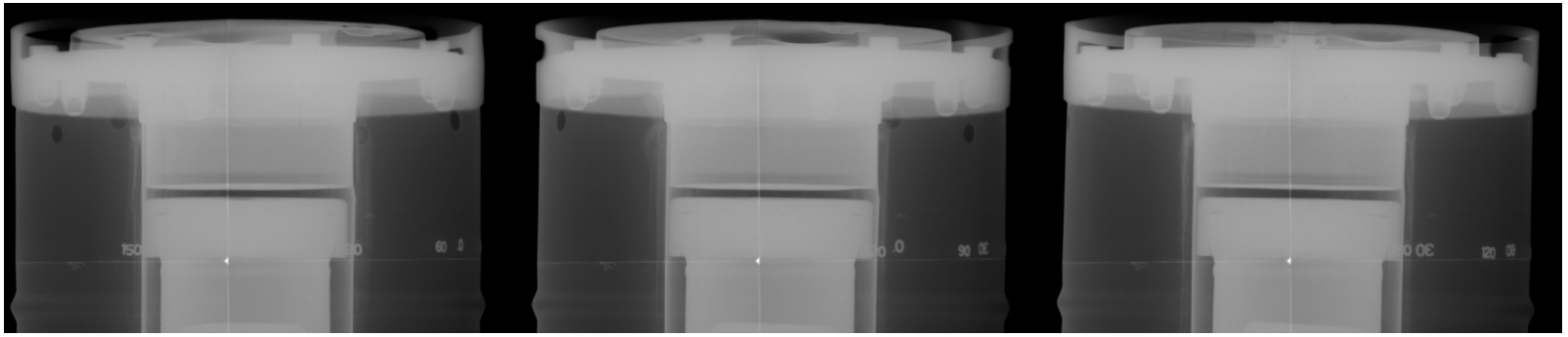
LOWER IMAGES: 120, 150, AND 180



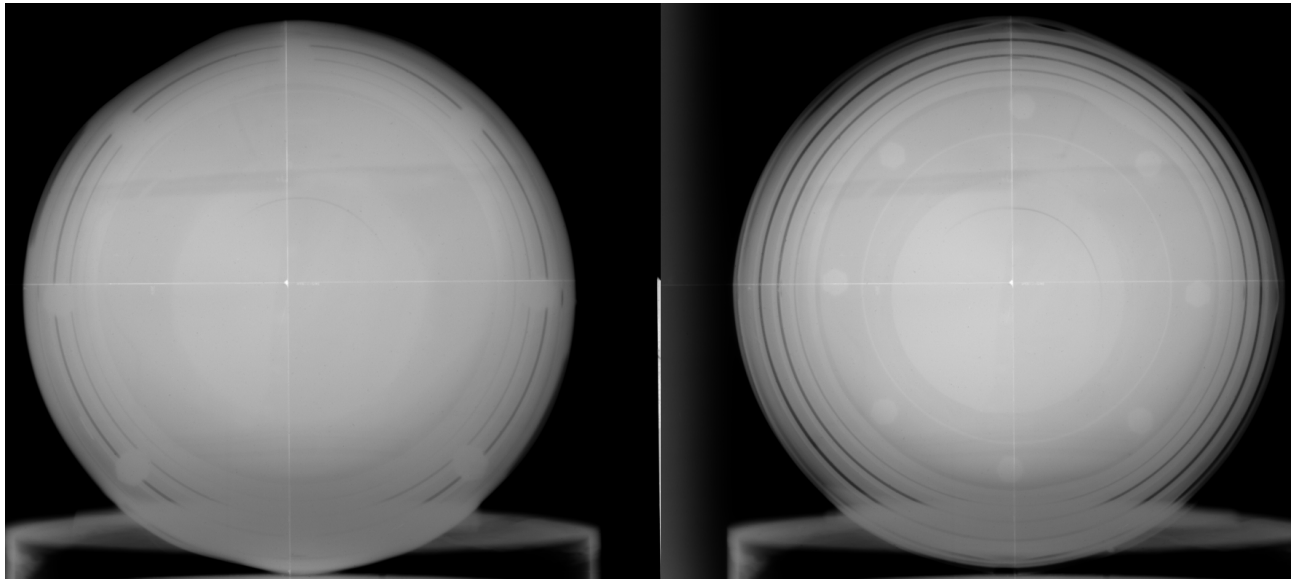
**TP0005 DR IMAGES OF UPPER PORTION AFTER 30’ DROP TEST**

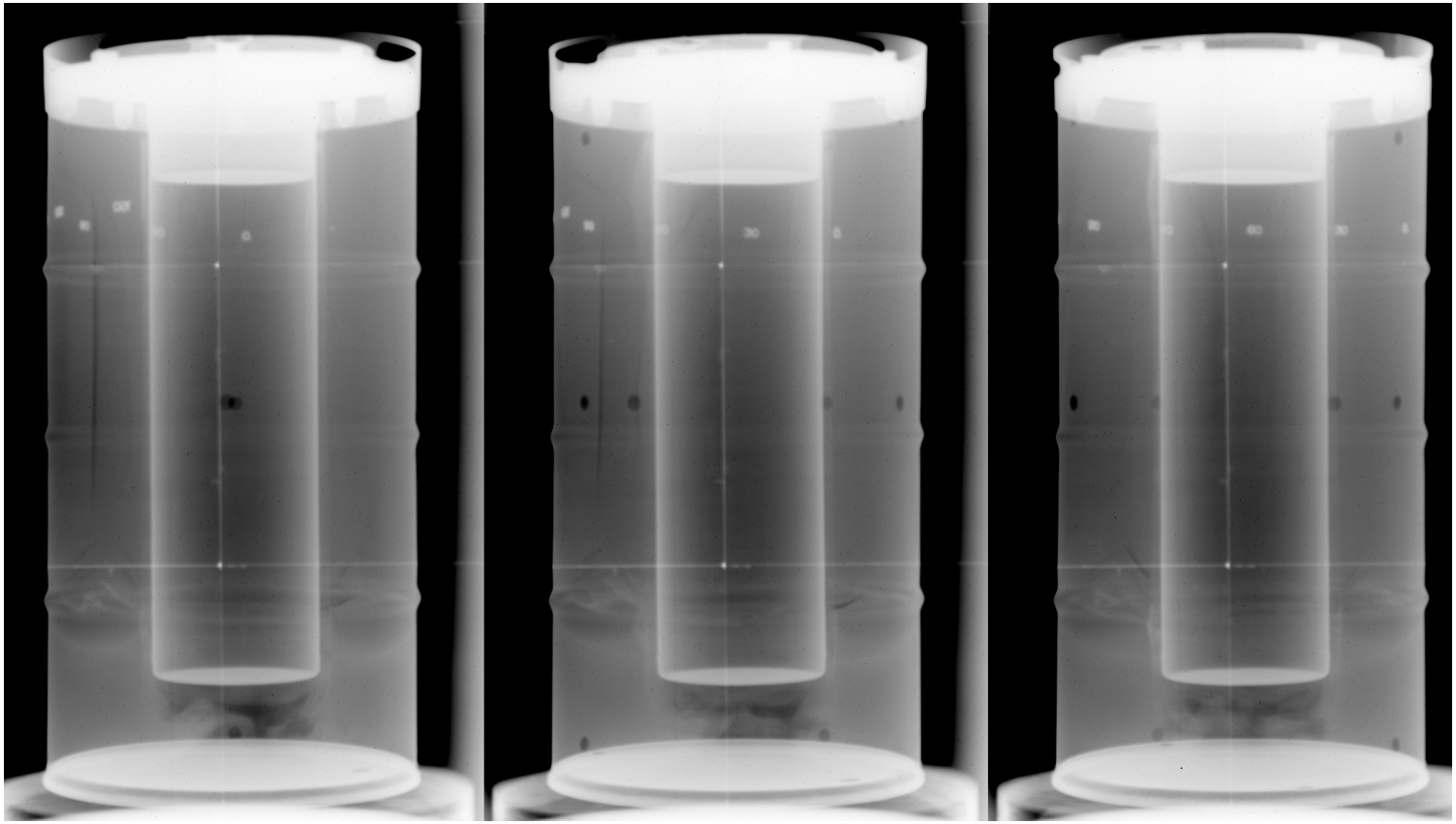


**UPPER IMAGES: 0, 30, 60, AND 90 LOWER IMAGES: 120, 150, AND 180**

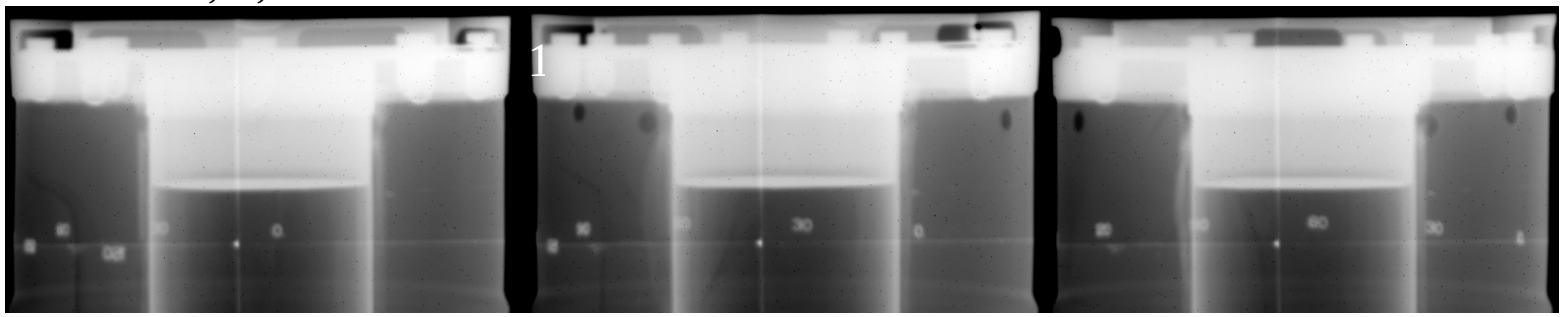


TP0005 END TO END DR IMAGES

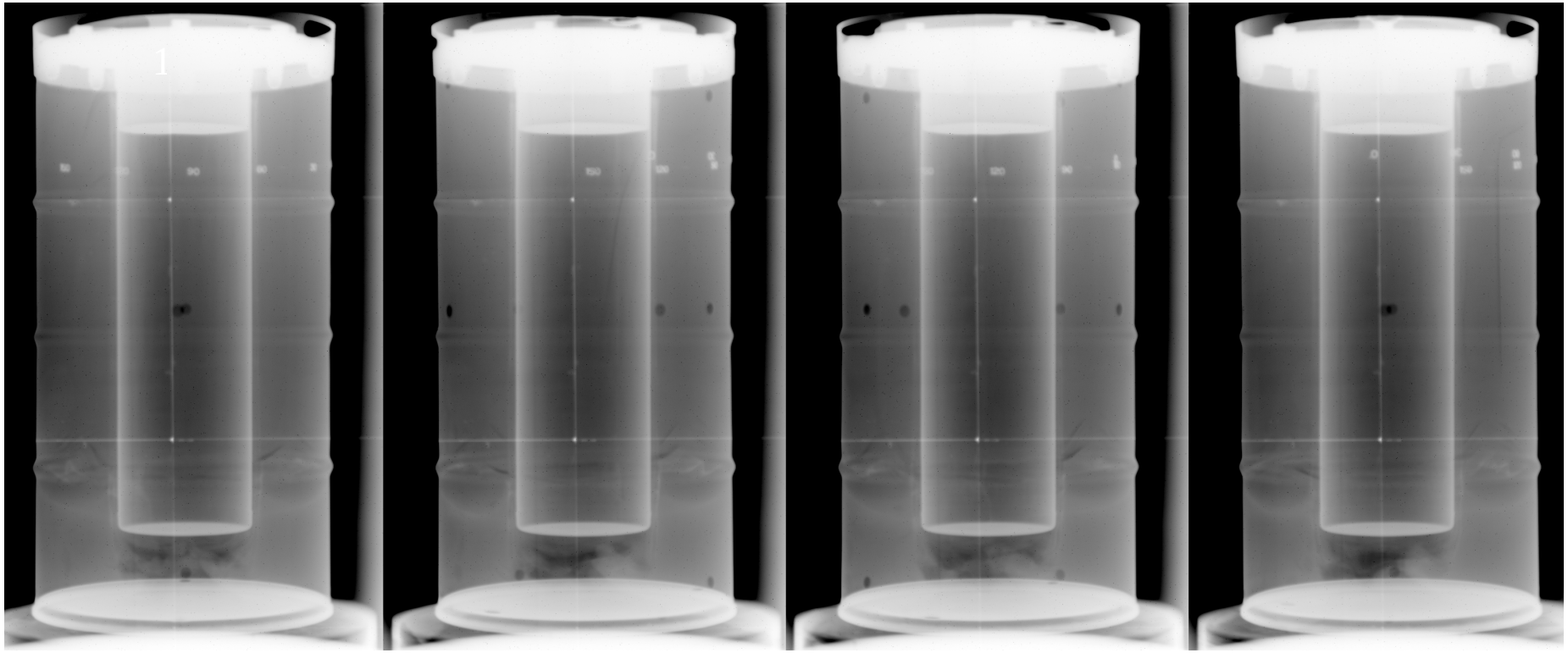




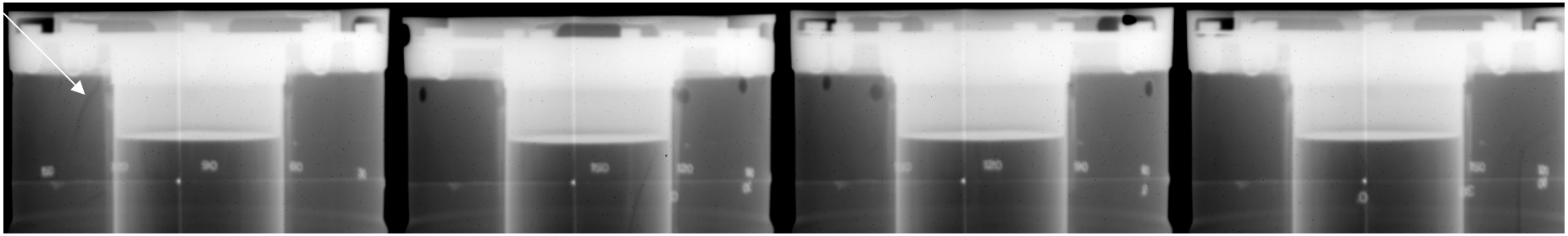
**TP0006 0, 30, AND 60 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



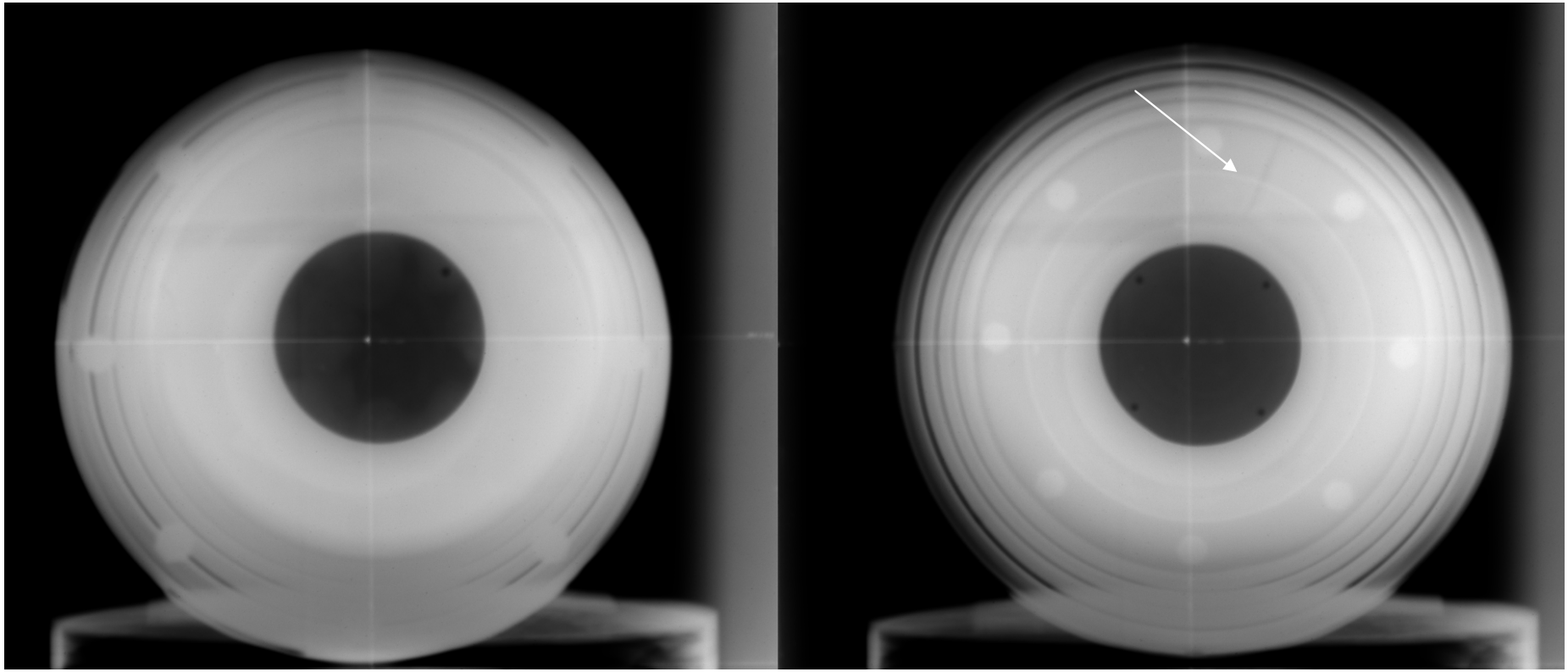
**TP0006 0, 30, AND 60 DEGREE DR IMAGES OF UPPER PORTION BEFORE INSERTION OF CONTAINMENT VESSEL**



**TP0006 90, 120, 150, and 180 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



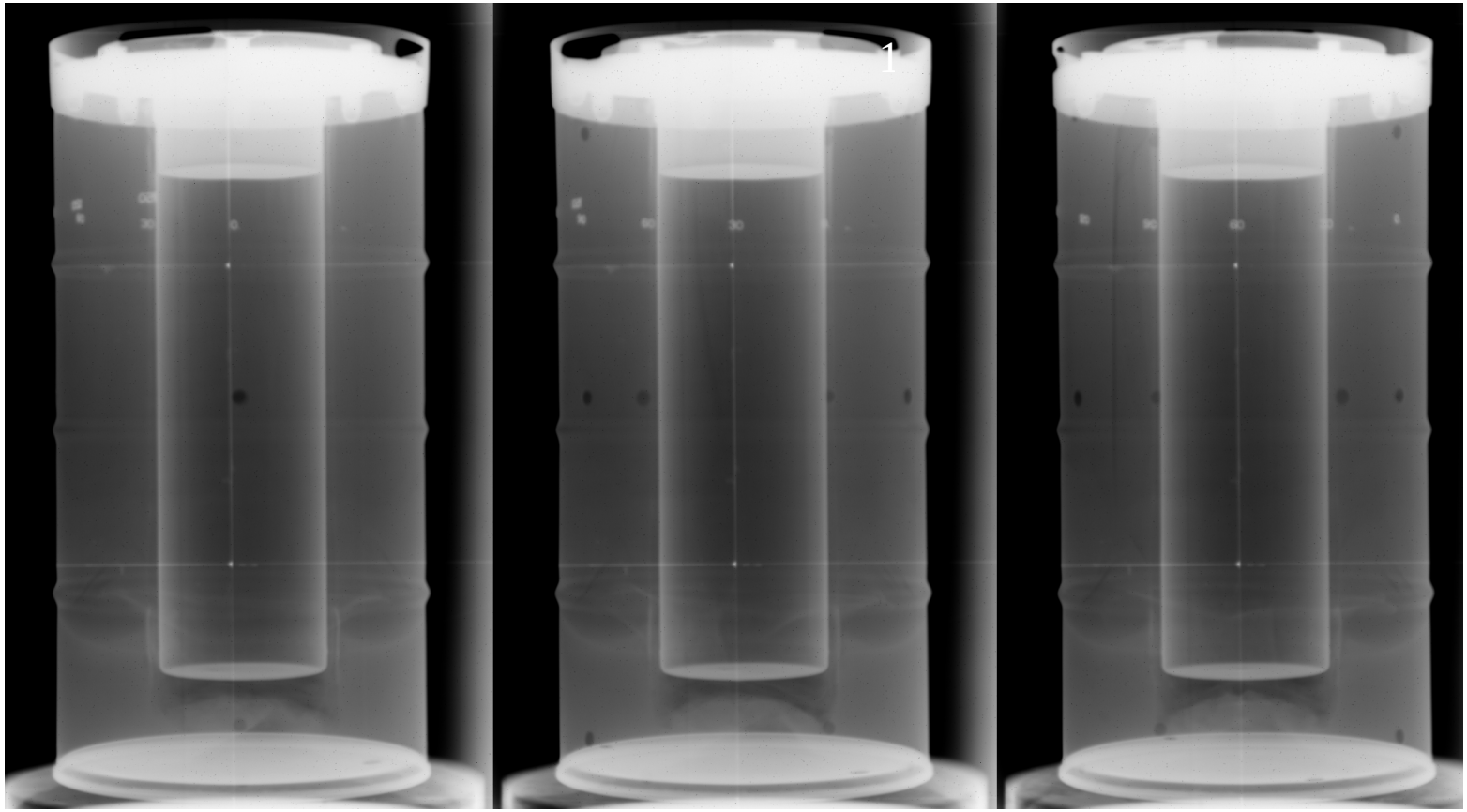
**TP0006 90, 120, 150, and 180 DEGREE DR IMAGES OF UPPER PORTION BEFORE INSERTION OF CONTAINMENT VESSEL**



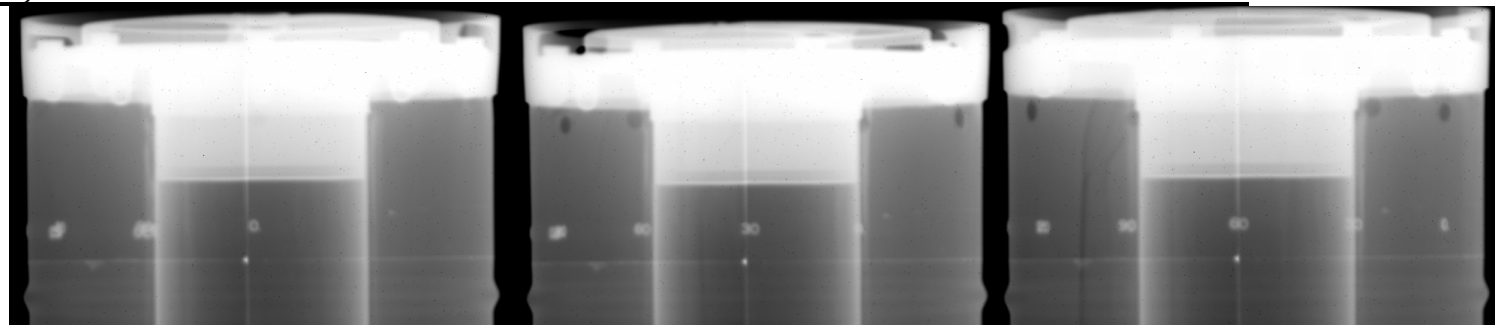
Bottom of the Drum is Nearest the Scintillator

Top of the Drum is Nearest the Scintillator

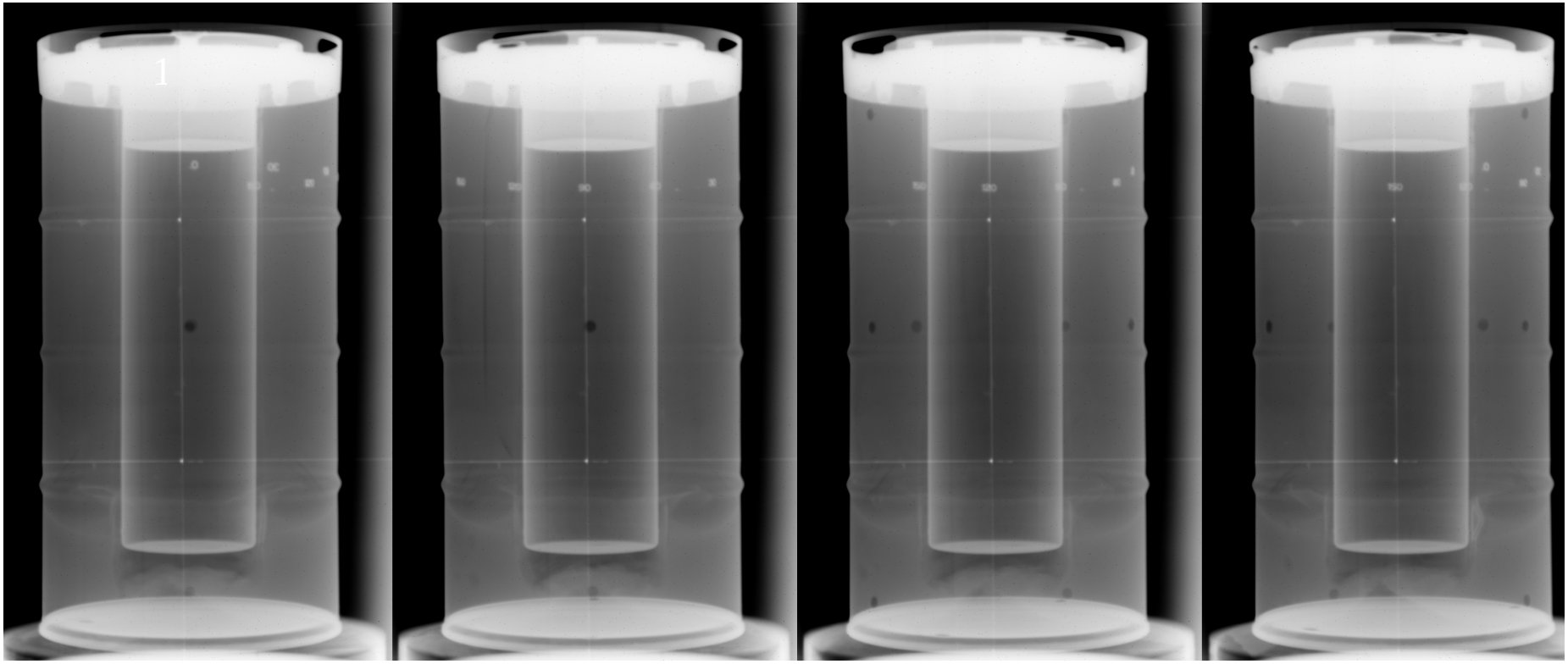
**TP0006 END TO END DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



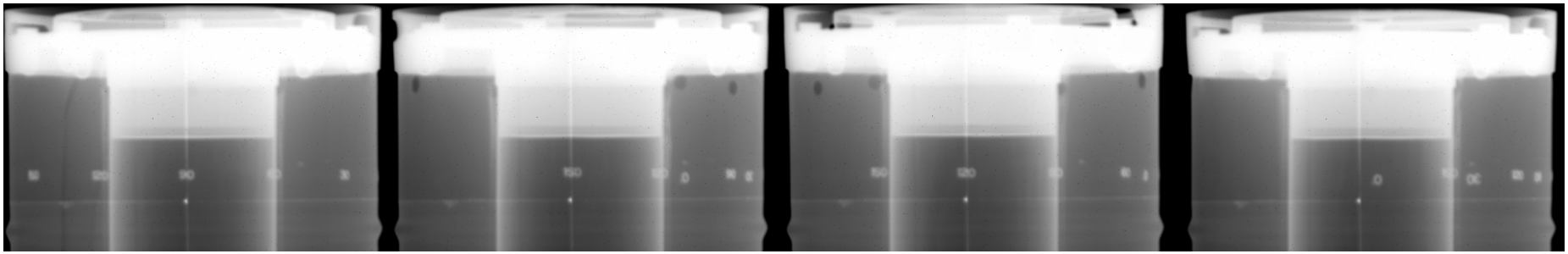
**TP0007 0, 30, AND 60 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



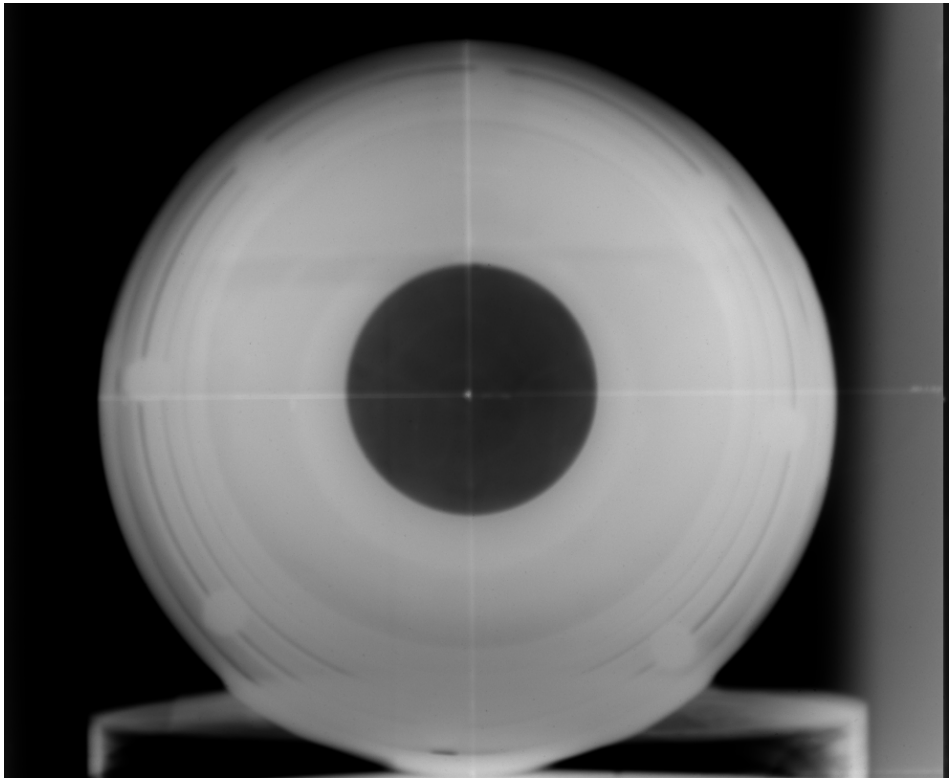
**TP0007 0, 30, AND 60 DEGREE DR IMAGES OF THE UPPER PORTION BEFORE INSERTION OF CONTAINMENT VESSEL**



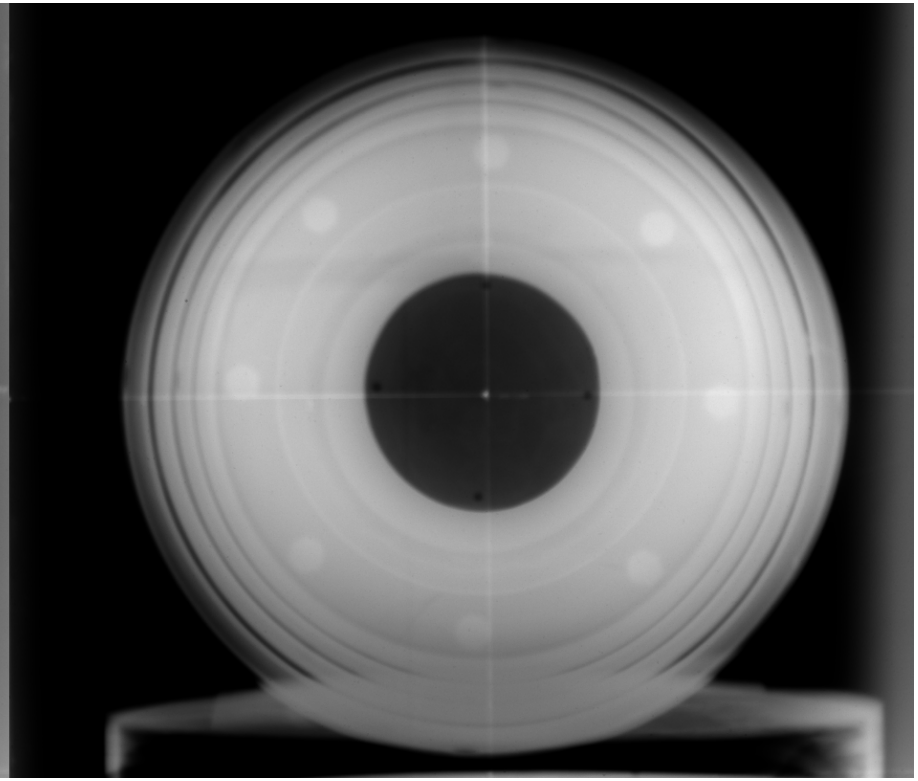
**TP0007 90, 120, 150, and 180 DEGREE DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



**TP0007 90, 120, 150, and 180 DEGREE DR IMAGES OF UPPER PORTION BEFORE INSERTION OF CONTAINMENT VESSEL**

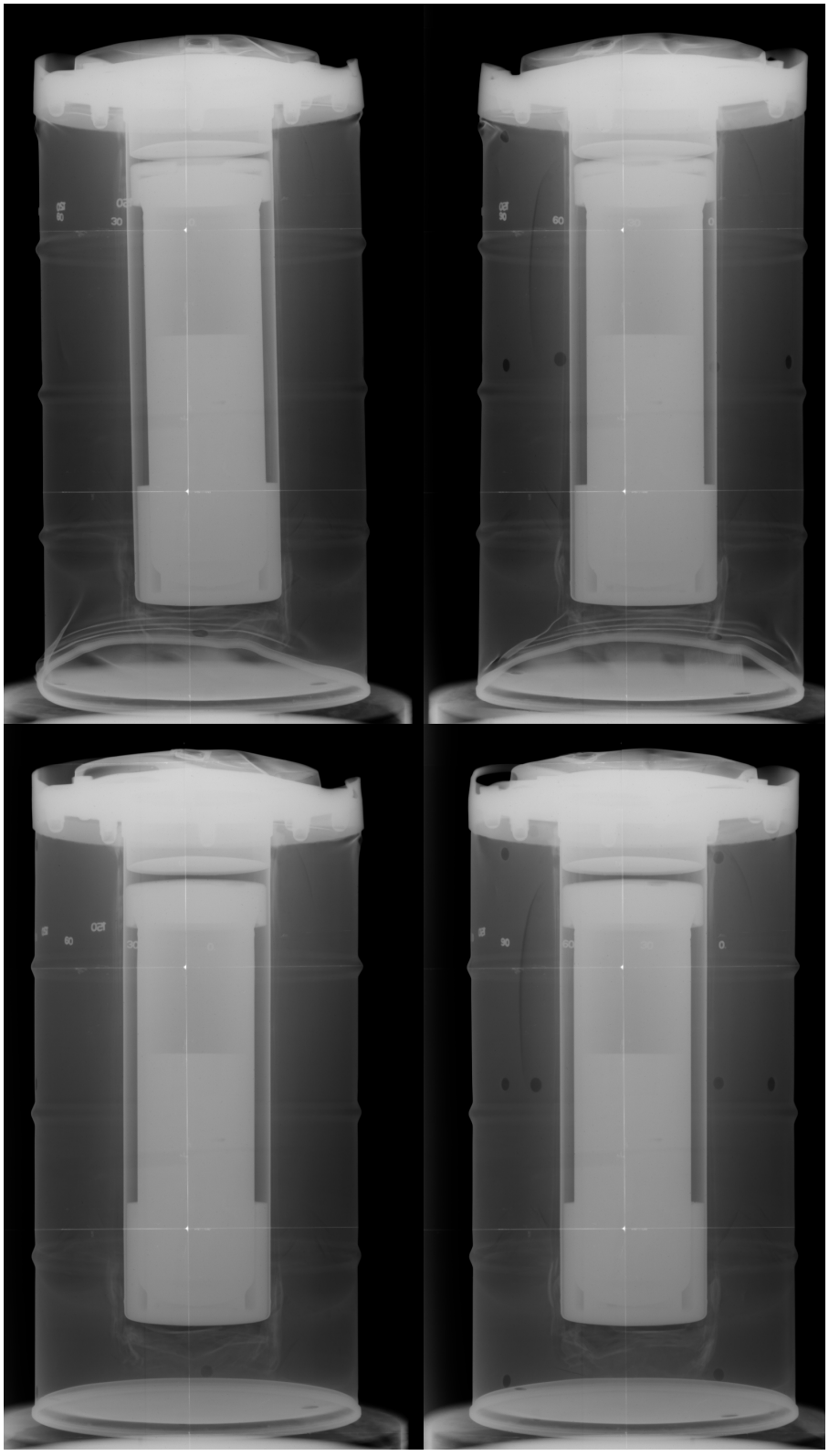


Bottom of the Drum is Nearest the Scintillator



Top of the Drum is Nearest the Scintillator

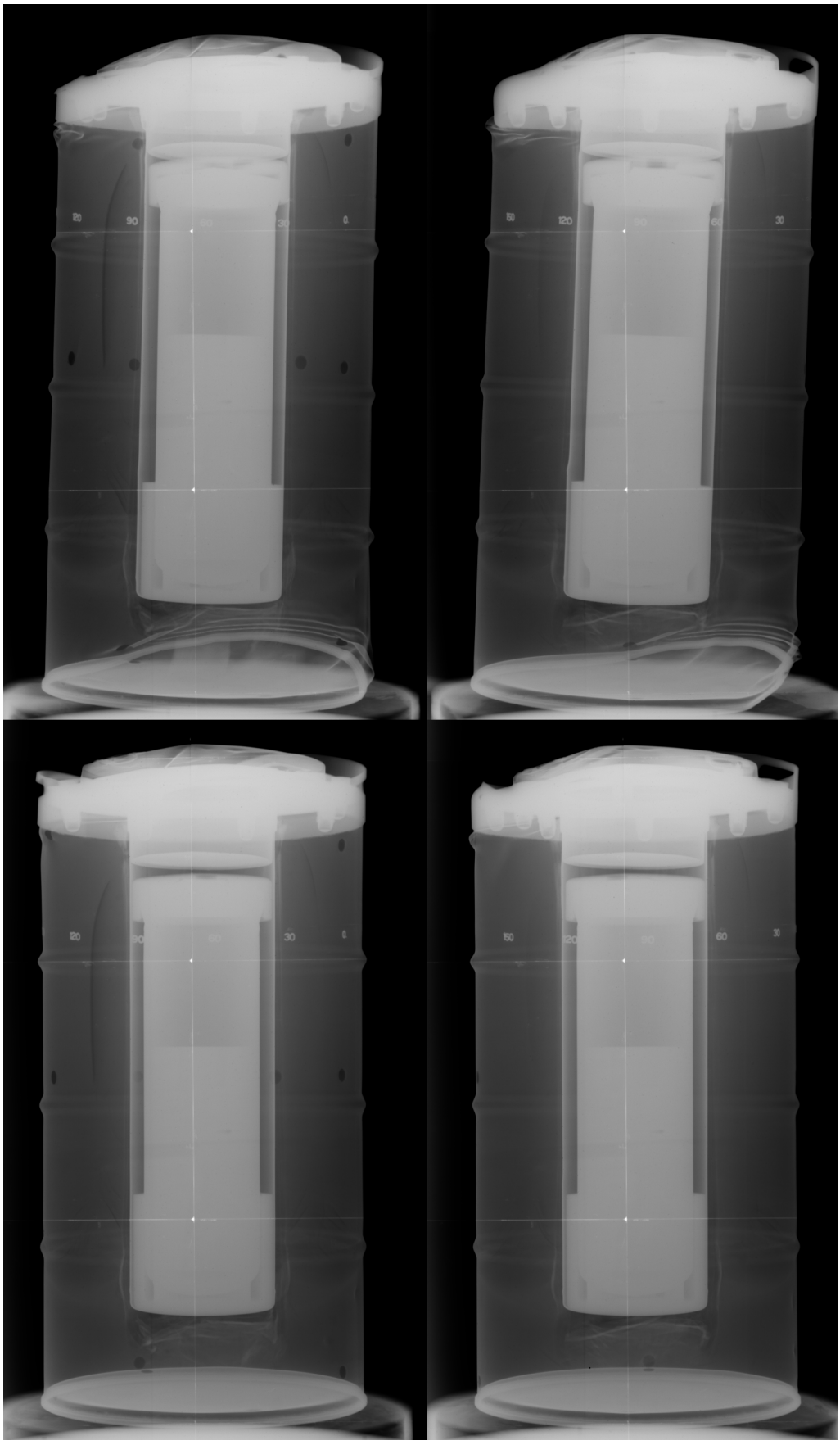
**TP0007 END TO END DR IMAGES BEFORE INSERTION OF CONTAINMENT VESSEL**



**GPFP0002 0 AND 30 DEGREE DR IMAGES AFTER CRUSH TEST**

The two upper images were acquired after the crush test.

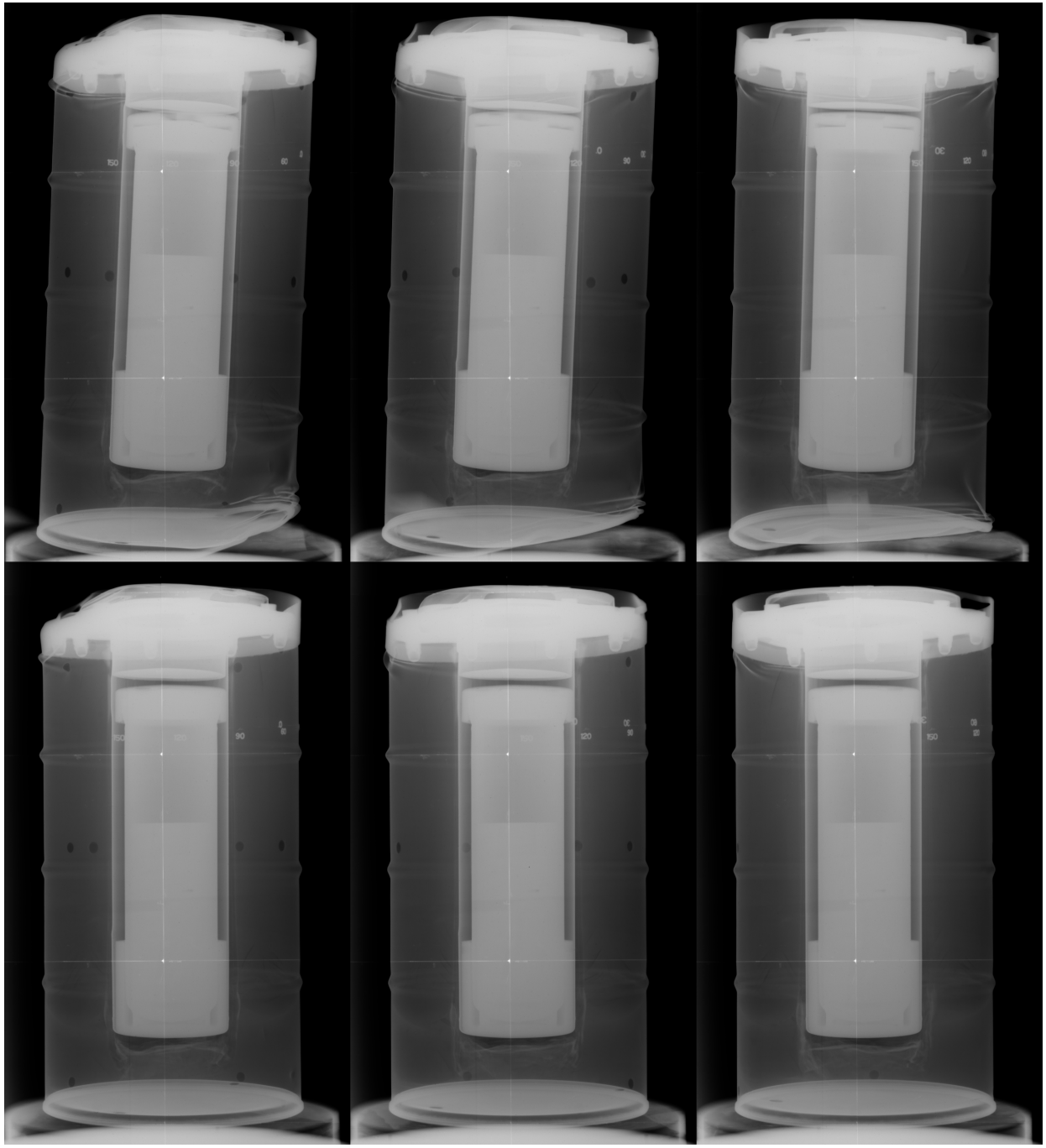
The lower images were acquired after the 30 foot drop test and are included here for comparison purposes.



**TP0002 60 AND 90 DEGREE DR IMAGES AFTER CRUSH TESTS**

The two upper images were acquired after the test that was conducted after the crush tests

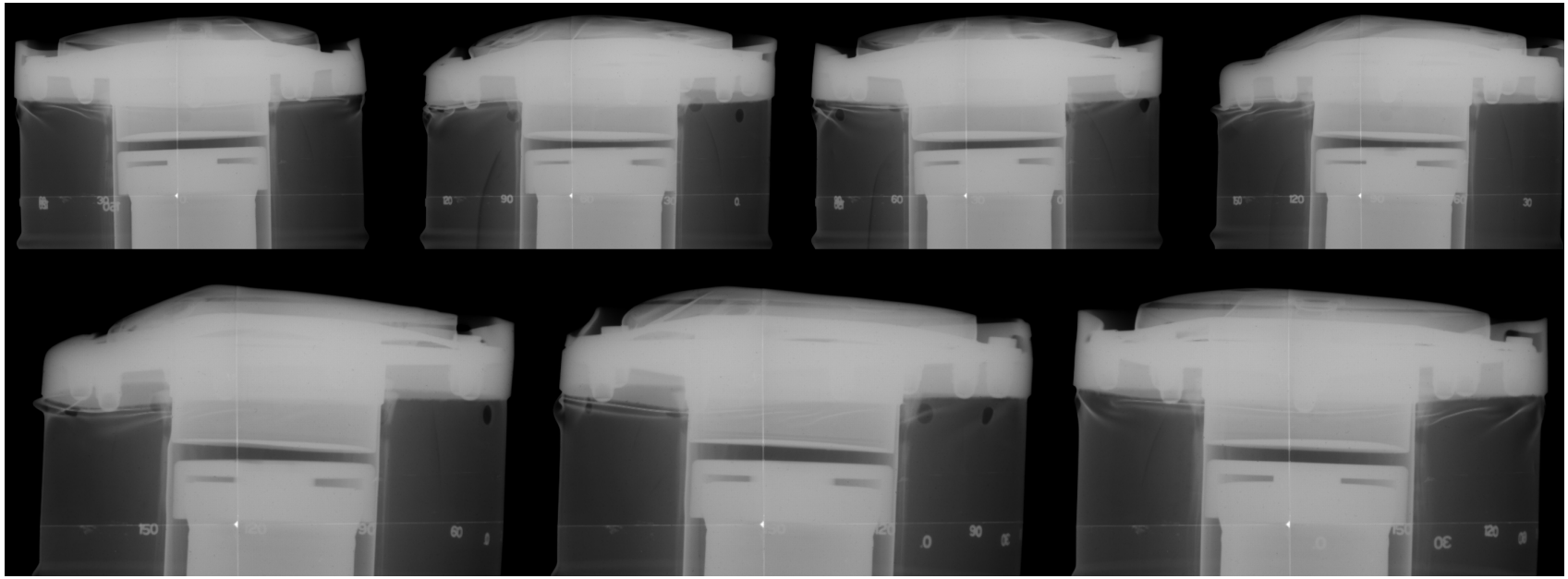
The lower images were acquired after the 30 foot drop test and **are included here for comparison purposes**.



**TP0002 120, 150, AND 180 DEGREE DR IMAGES AFTER CRUSH TESTS**

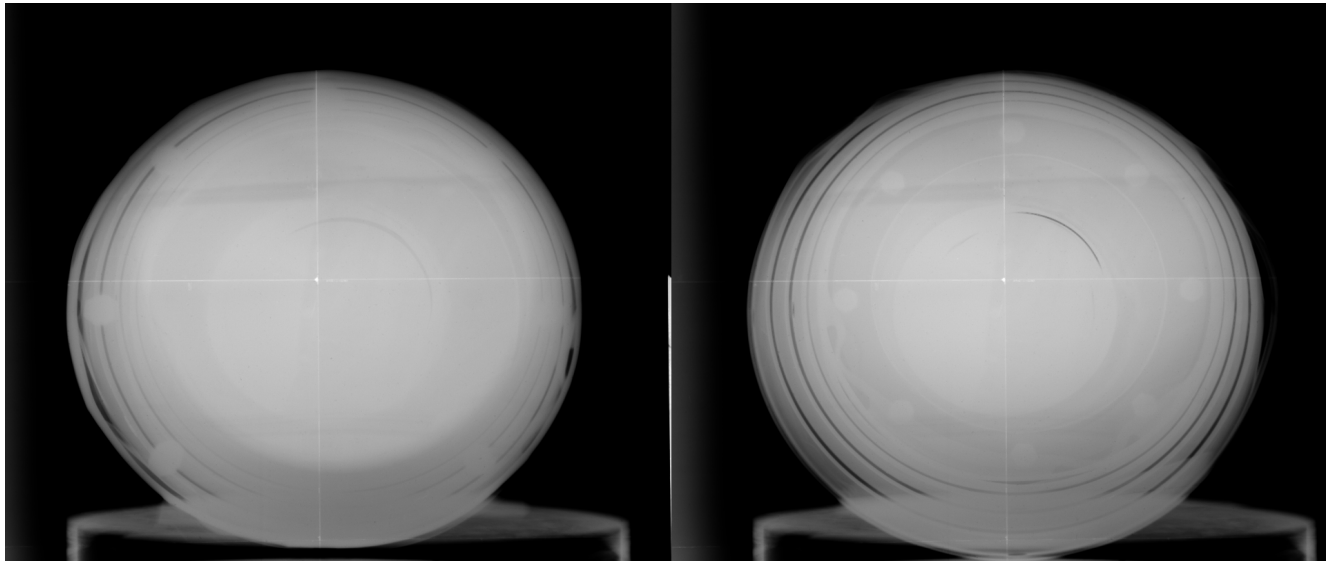
The three upper images were acquired after the test that was conducted after the crush tests.

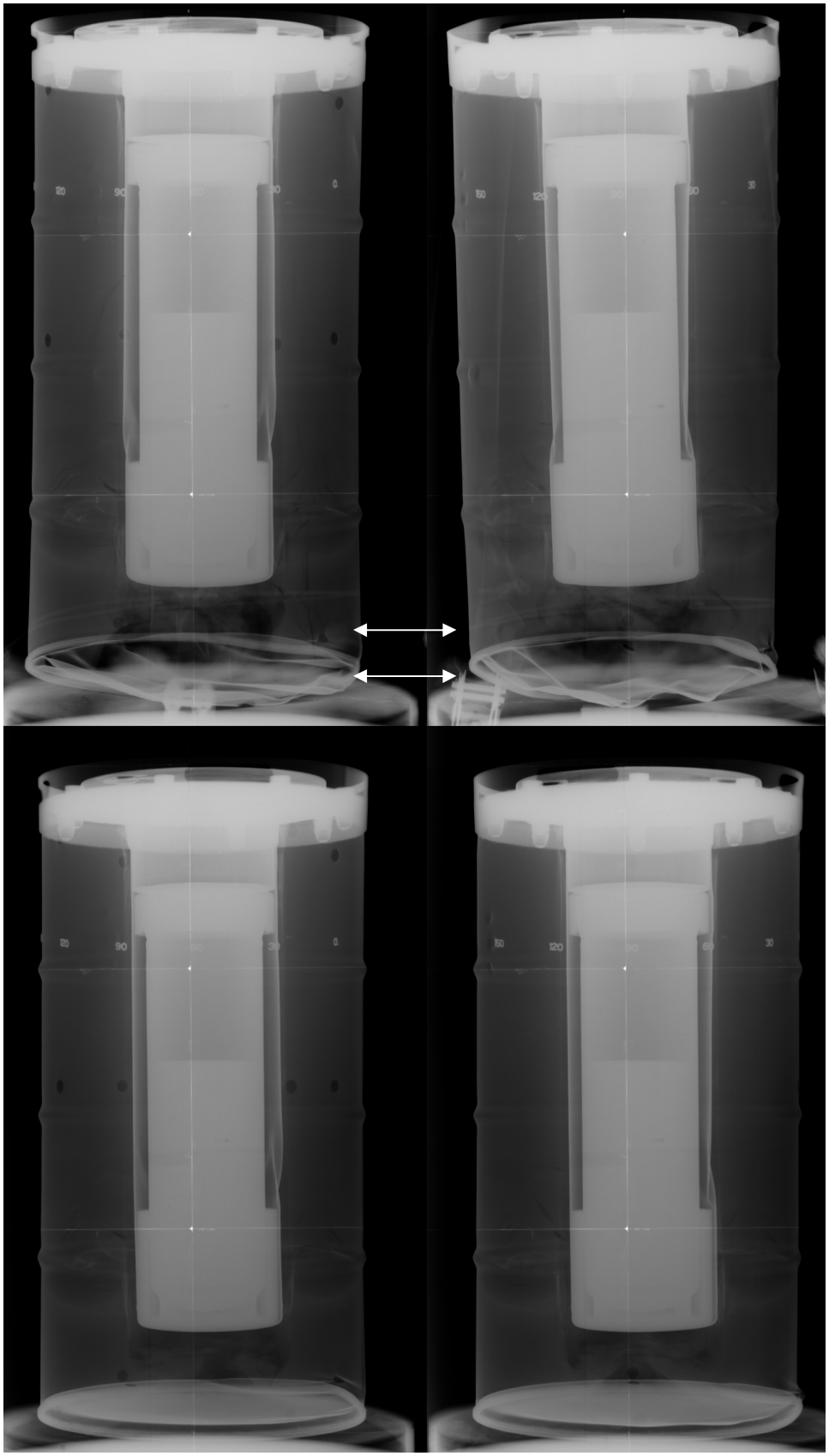
The lower images were acquired after the 30 foot drop test and **are included here for comparison purposes**.



**TP0002 0, 30, 60, 90, 120, 150, AND 180 DEGREE UPPER PORTION DR IMAGES AFTER CRUSH TESTS**

**TP0002 END TO END DR IMAGES AFTER CRUSH TESTS**

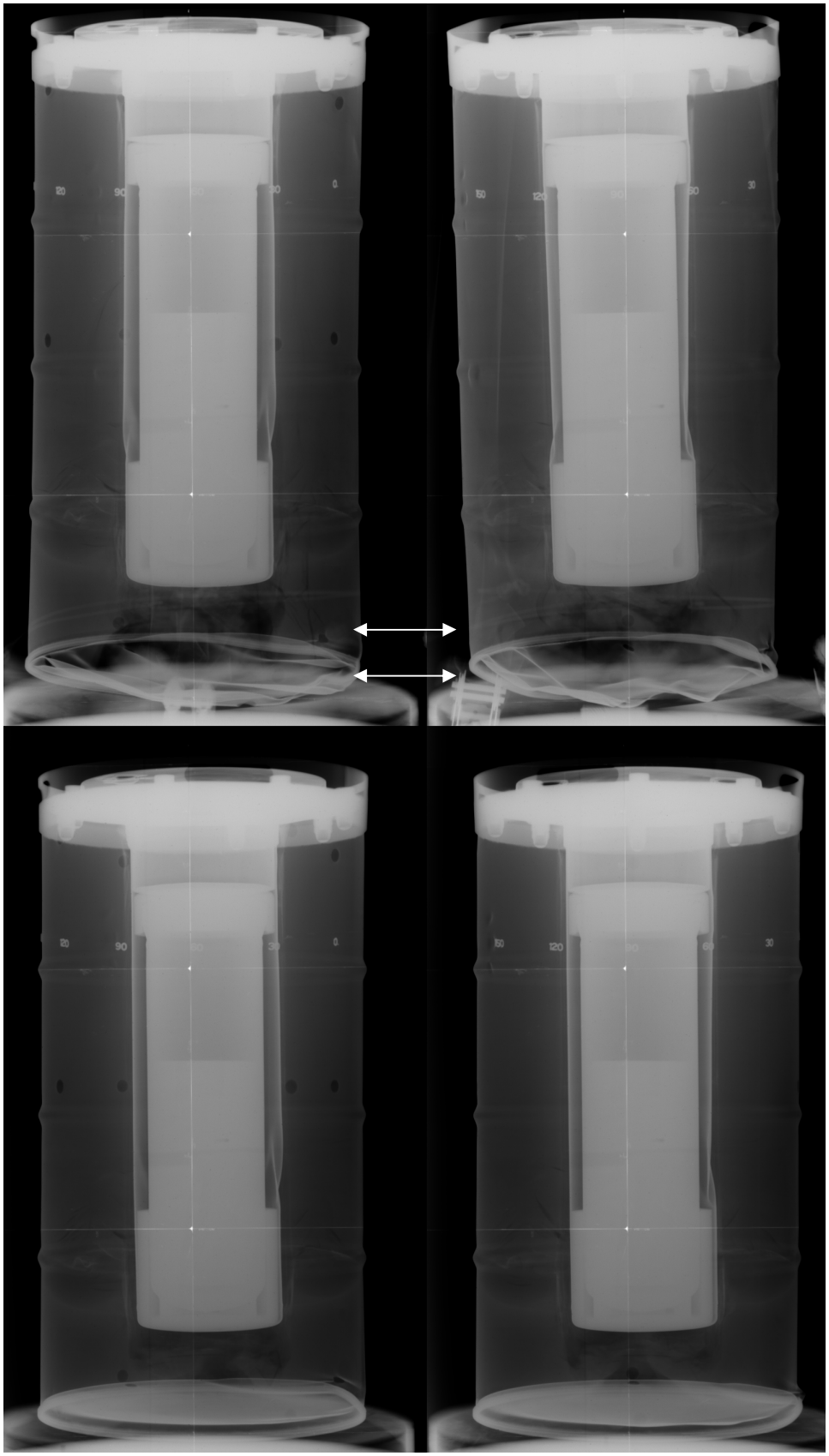




**TP0003 0 AND 30 DEGREE DR IMAGES AFTER THE CRUSH TESTS**

The two upper images were acquired after the crush tests.

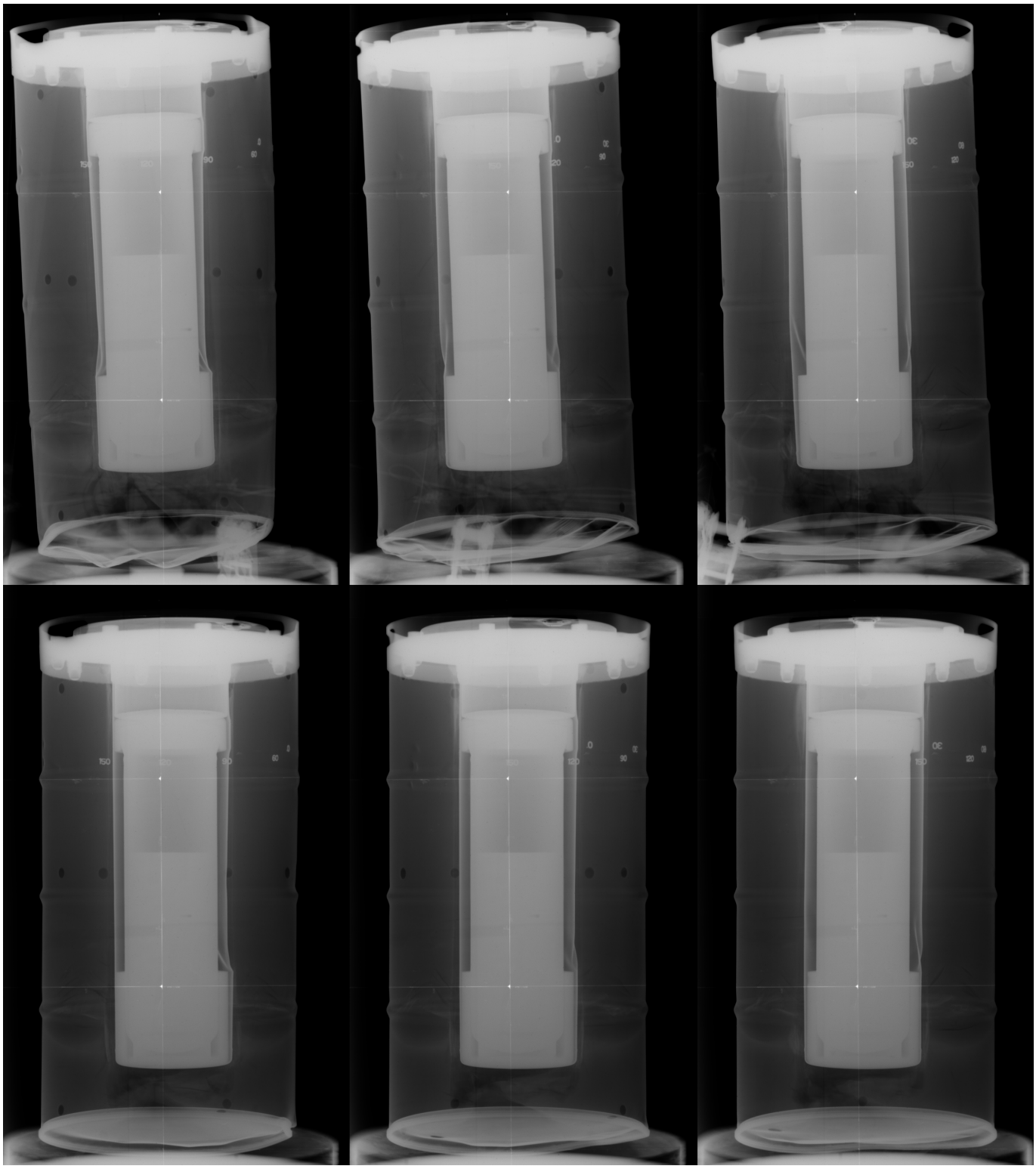
The lower images were acquired after the 30 foot drop test and **are included here for comparison purposes**.



**TP0003 60 AND 90 DEGREE DR IMAGES AFTER CRUSH TESTS**

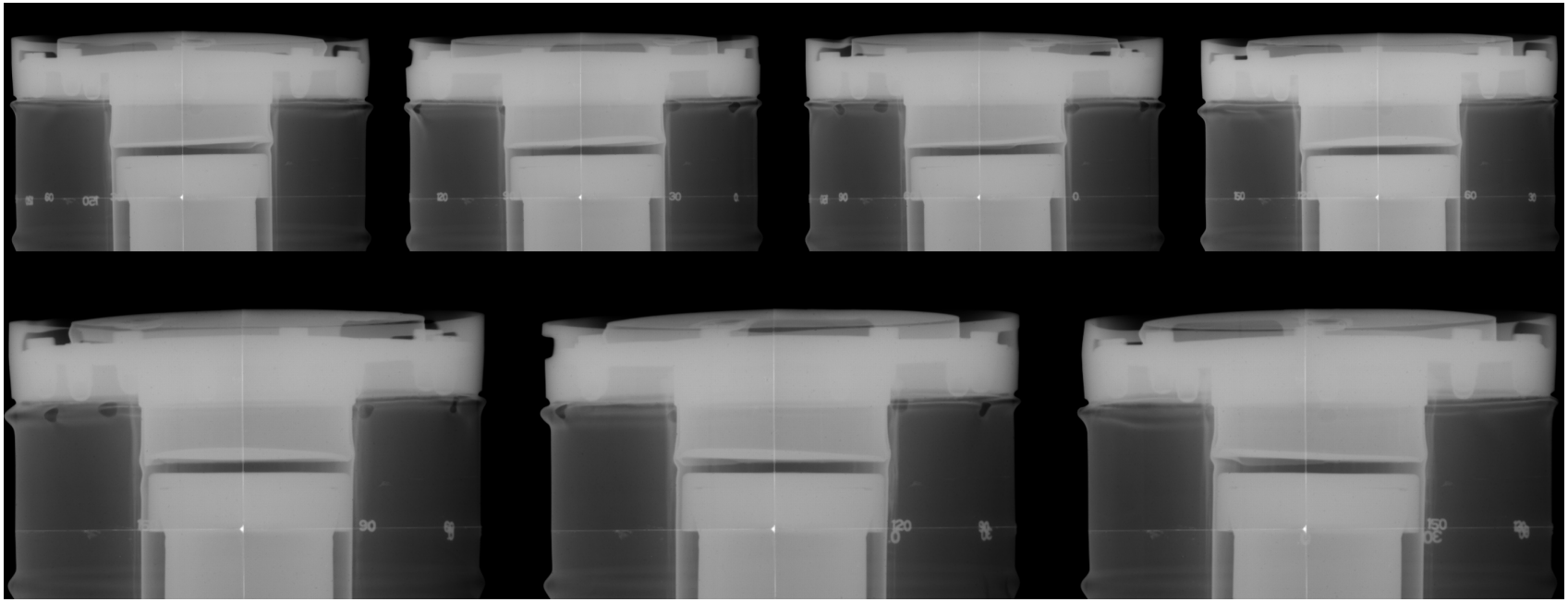
The two upper images were acquired after the test that was conducted after the crush tests.

The lower images were acquired after the 30 foot drop test and **are included here for comparison purposes**.



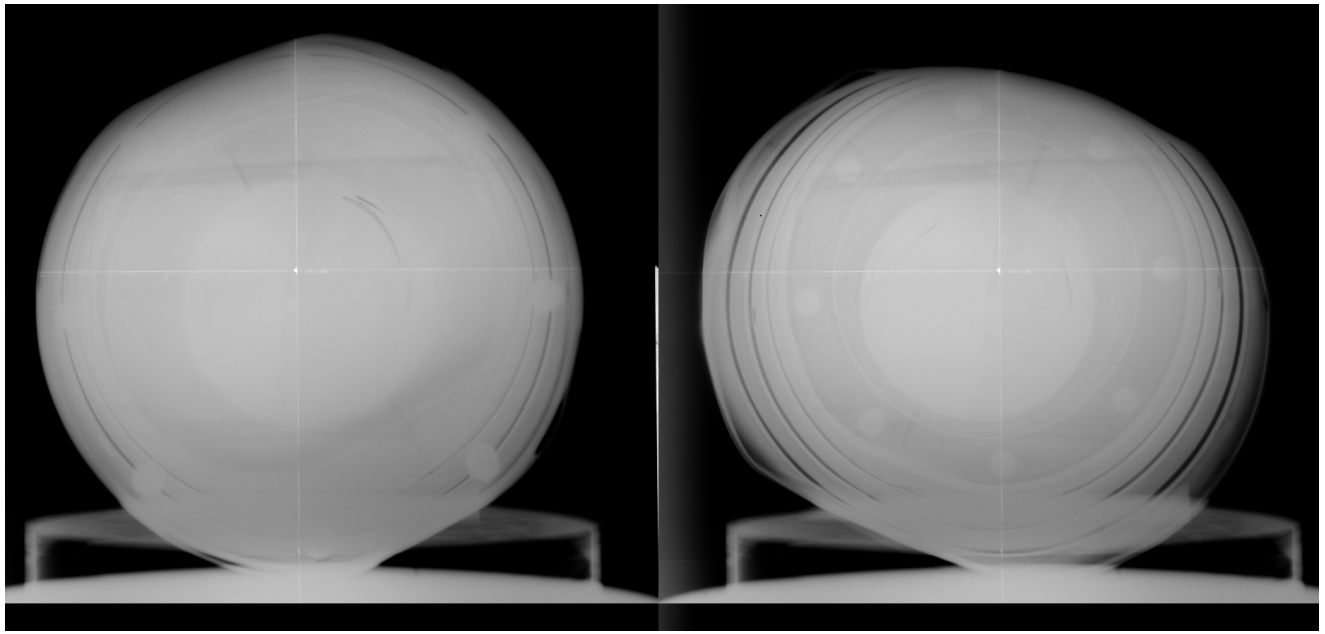
**TP0003 120, 150, AND 180 DEGREE DR IMAGES AFTER THE CRUSH TESTS**

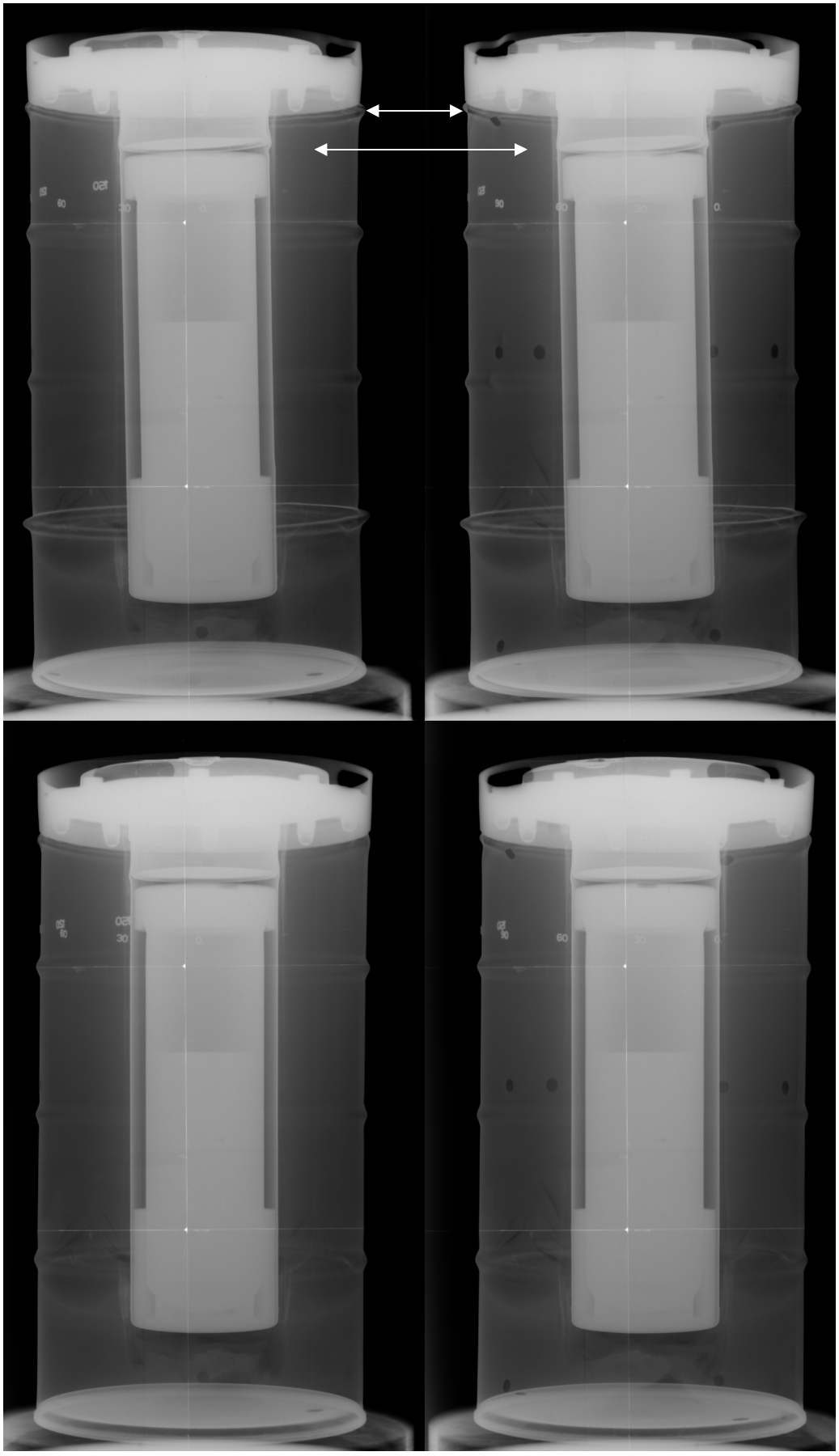
The three upper images were acquired after the test that was conducted after the crush tests. The lower images were acquired after the 30 foot drop test and **are included here for comparison purposes**.



**GPFP0003 0, 30, 60, 90, 120, 150, AND 180 DEGREE UPPER PORTION DR IMAGES AFTER CRUSH TEST**

**TP0003 END TO END DR IMAGAGES AFTER CRUSH TESTS**

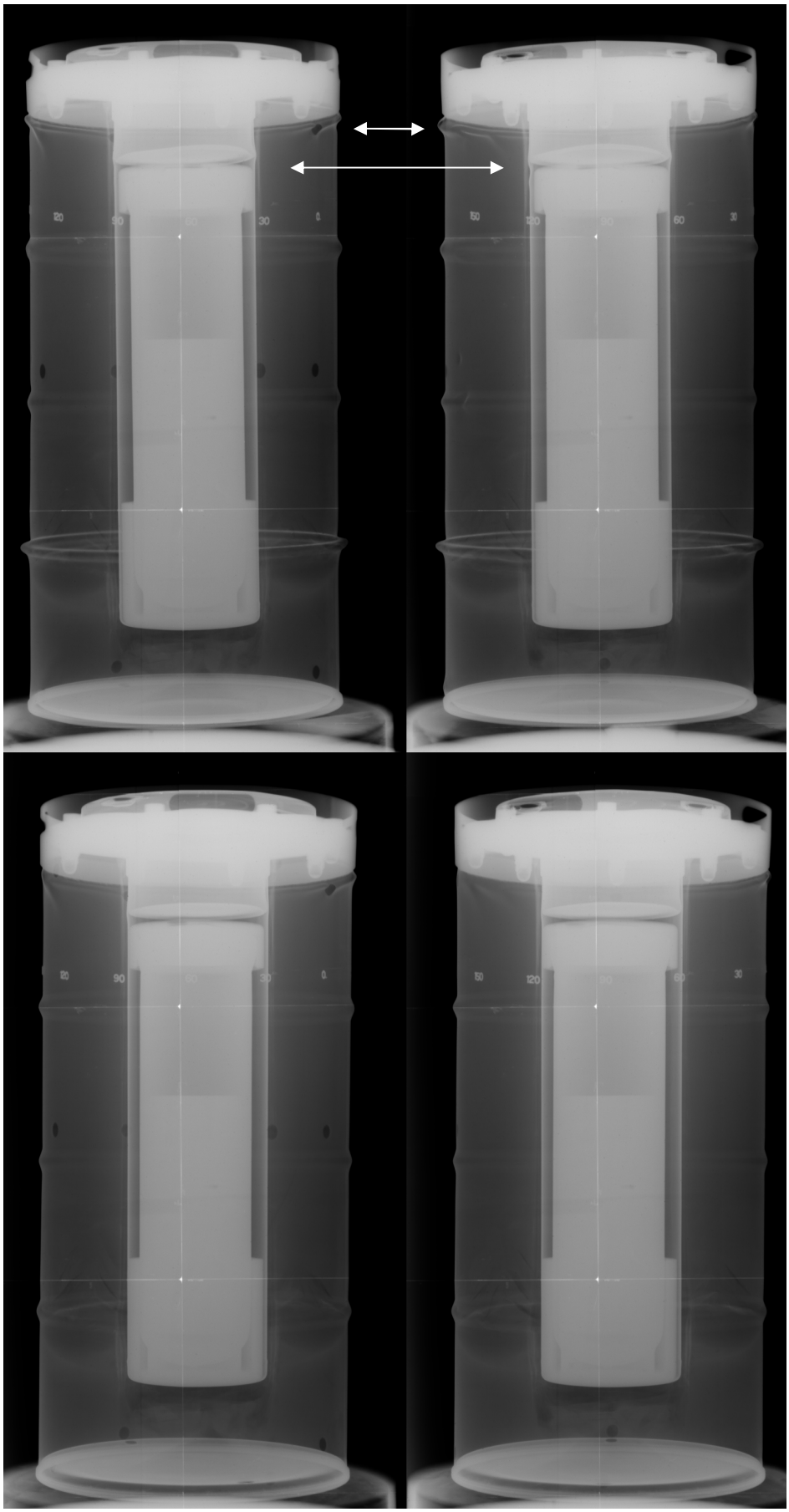




**TP0004 0 AND 30 DEGREE DR IMAGES AFTER CRUSH TESTS**

The two upper images were acquired after the crush tests.

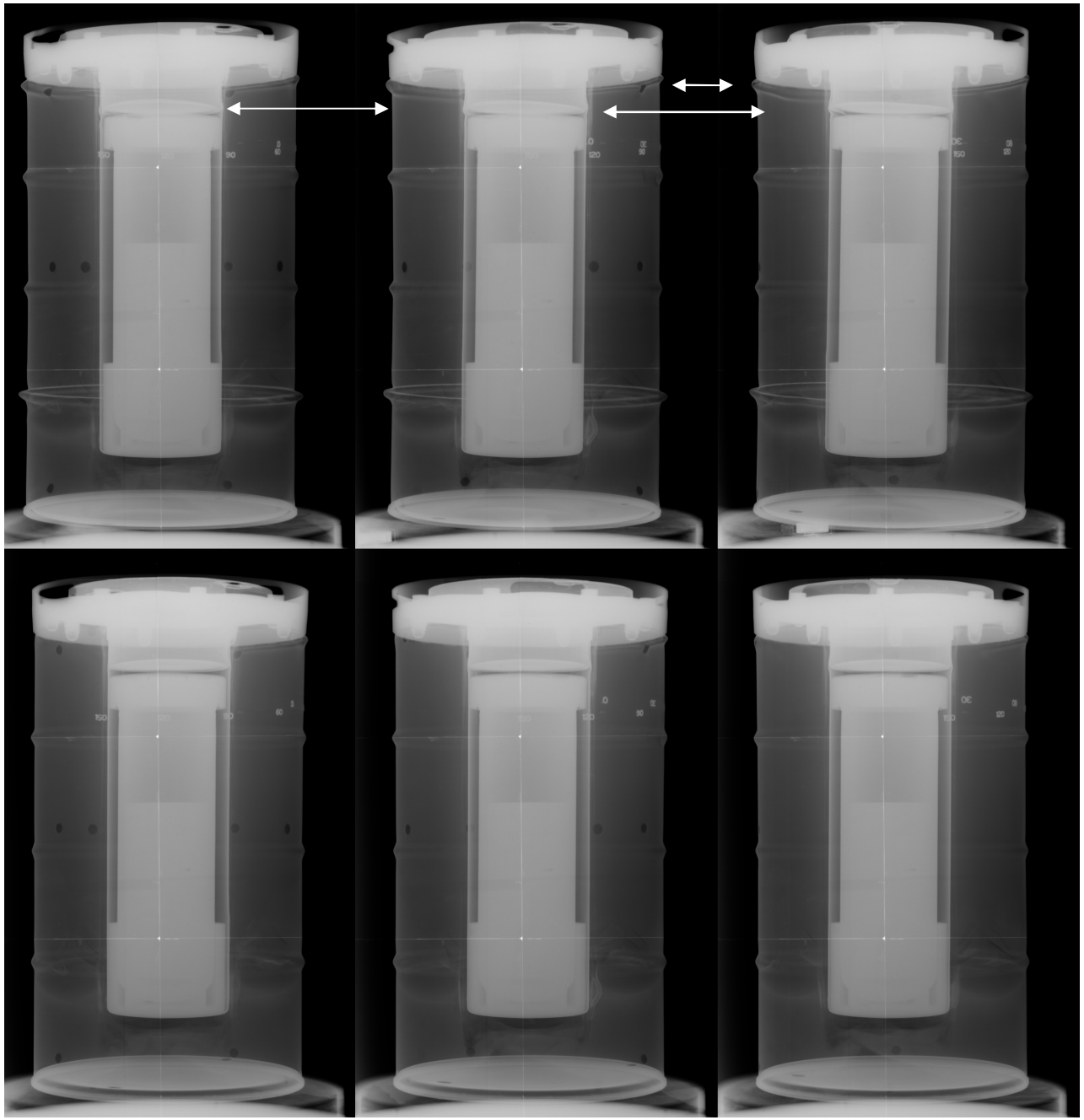
The lower images were acquired after the 30 foot drop test and **are included here for comparison purposes**.



**TP0004 60 AND 90 DEGREE DR IMAGES AFTER CRUSH TESTS**

The two upper images were acquired after the crush tests.

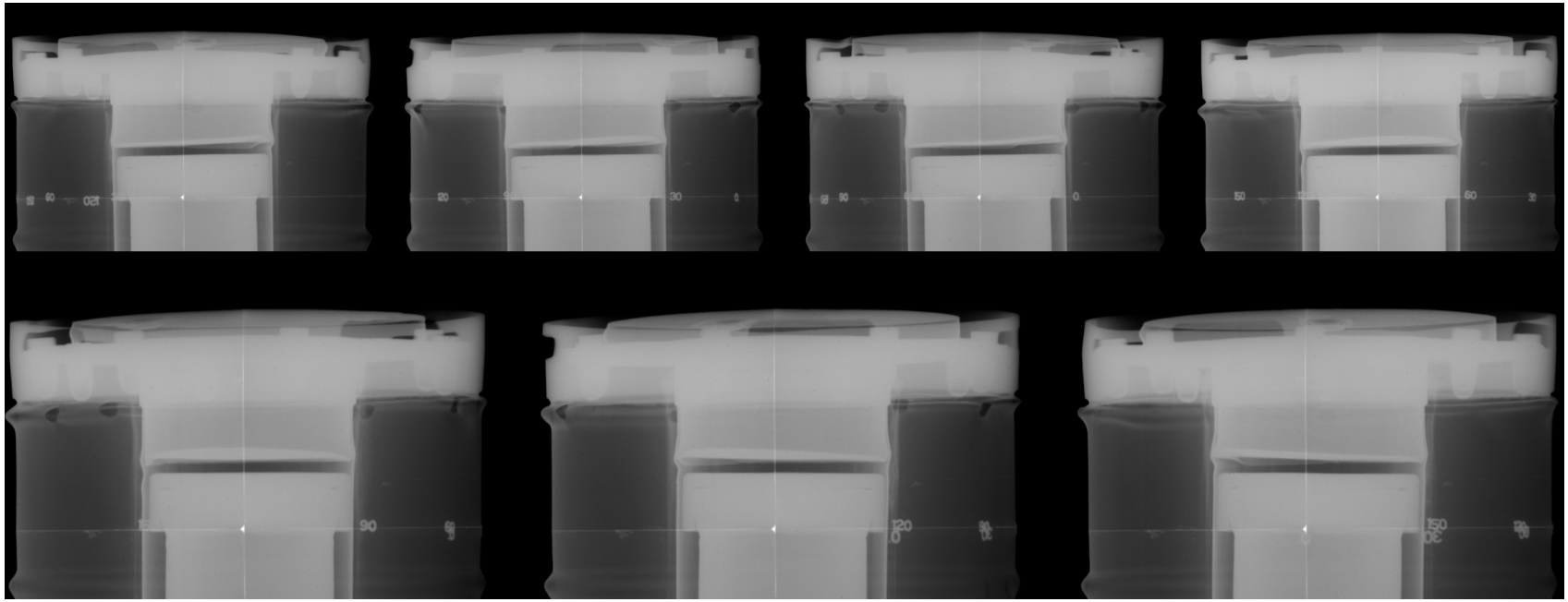
The lower images were acquired after the 30 foot drop test and **are included here for comparison purposes**.



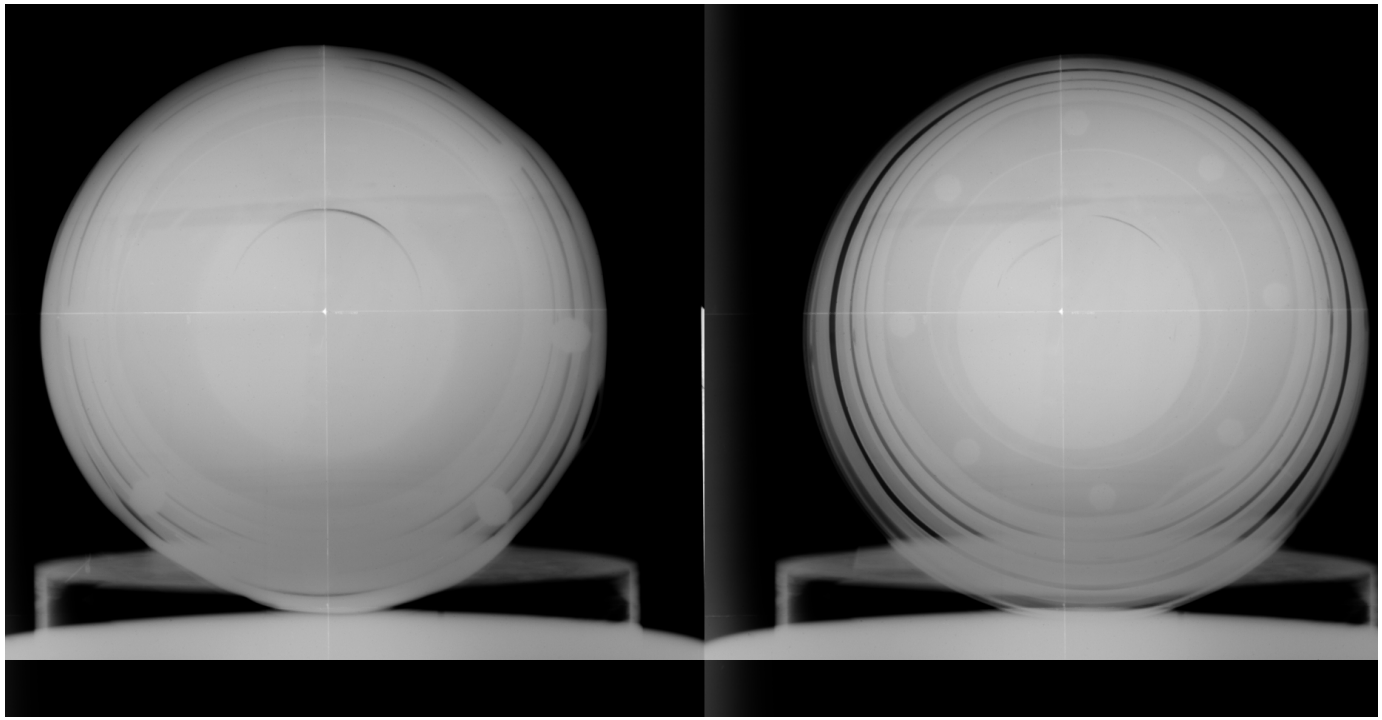
**TP0004 120, 150, AND 180 DEGREE DR IMAGES AFTER CRUSH TESTS**

The three upper images were acquired after the crush tests.

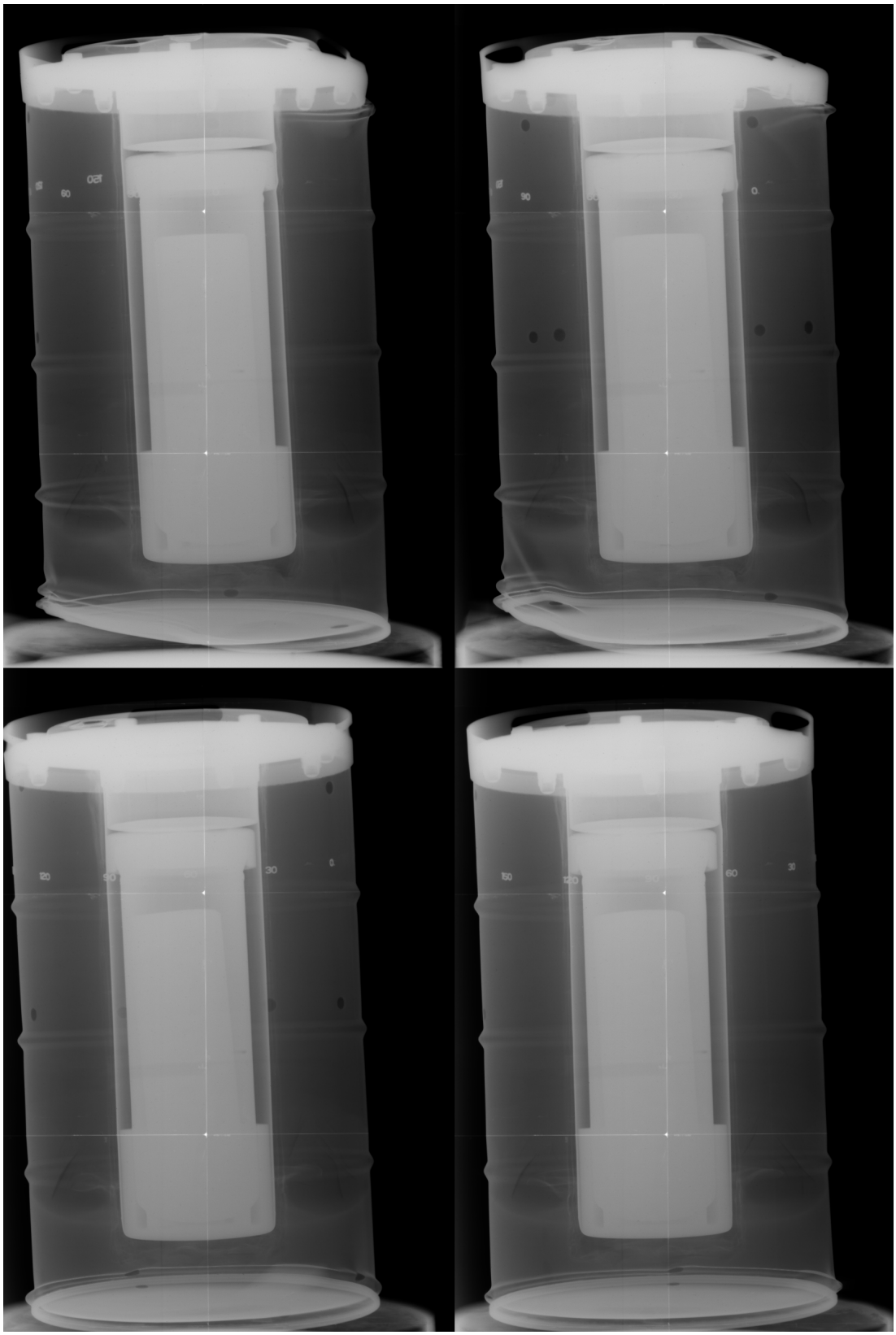
The lower images were acquired after the 30 foot drop test and **are included here for comparison purposes**.



**TP0004 0, 30, 60, 90, 120, 150, AND 180 DEGREE UPPER PORTION DR IMAGES AFTER CRUSH TESTS**



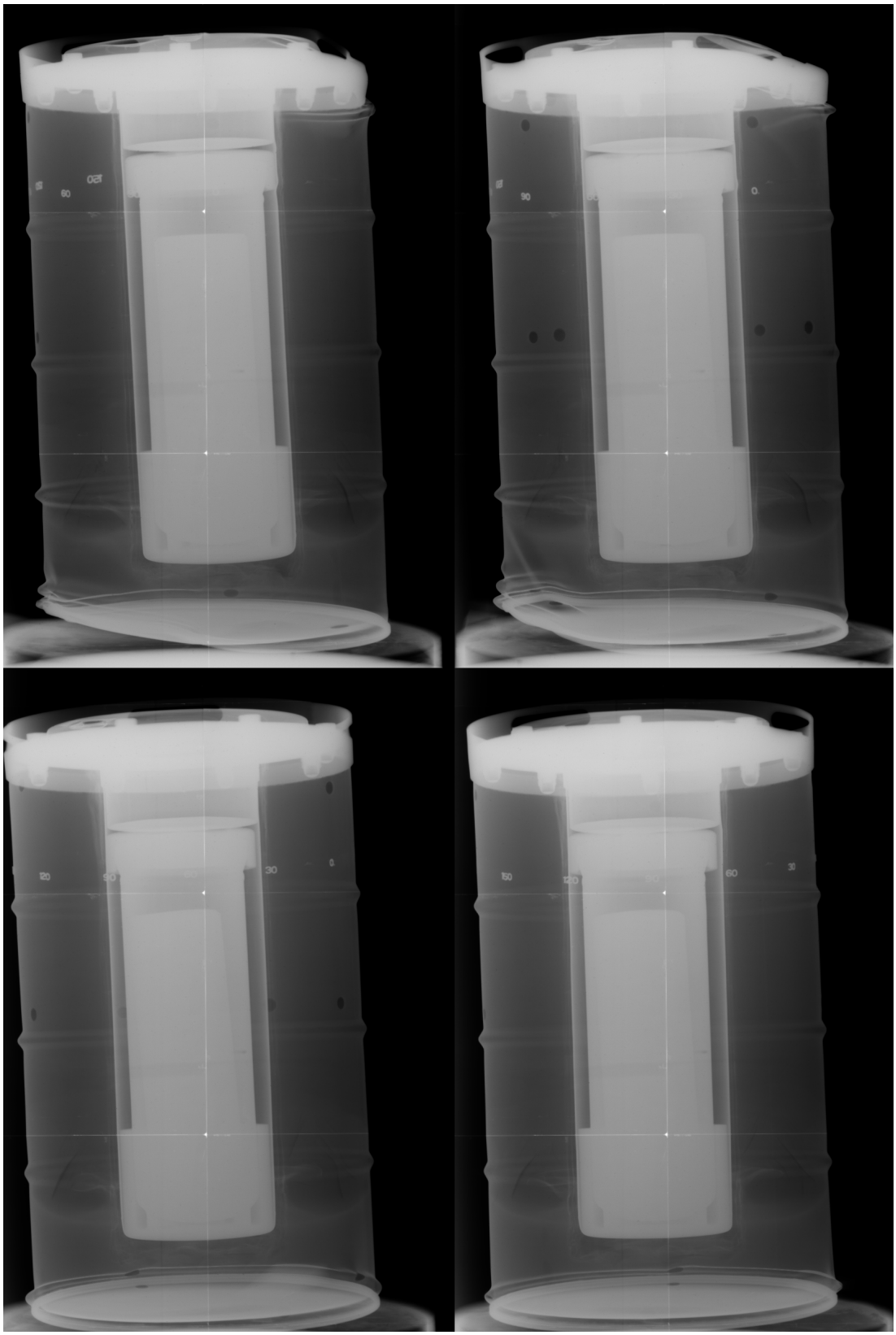
**TP0004 END TO END DR IMAGES AFTER CRUSH TESTS**



**TP00005 0 AND 30 DEGREE DR IMAGES AFTER CRUSH TESTS**

The two upper images were acquired after the crush tests.

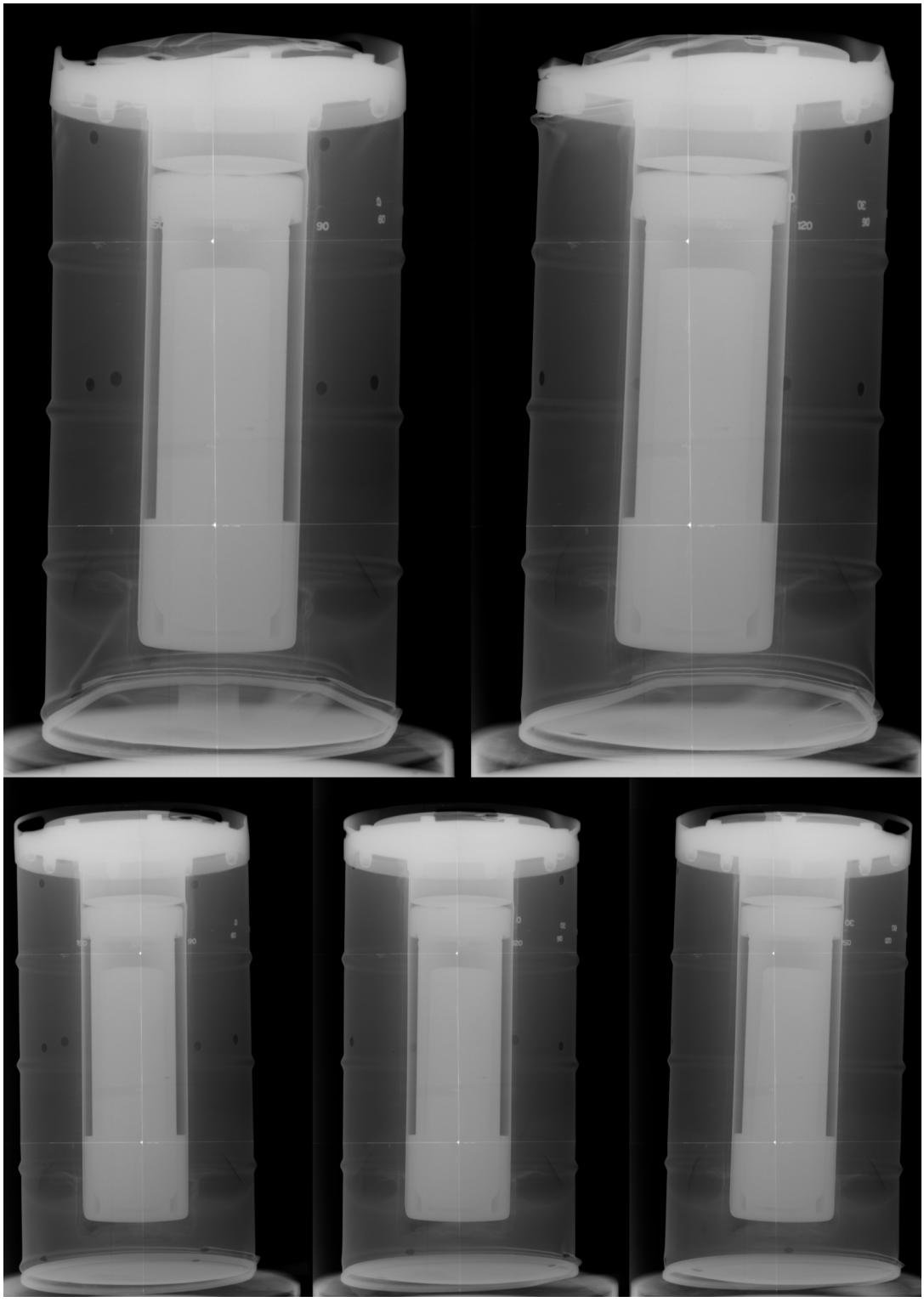
The lower images were acquired after the 30 foot drop test and **are included here for comparison purposes**.



**TP0005 60 AND 90 DEGREE DR IMAGES AFTER CRUSH TESTS**

The two upper images were acquired after the crush tests.

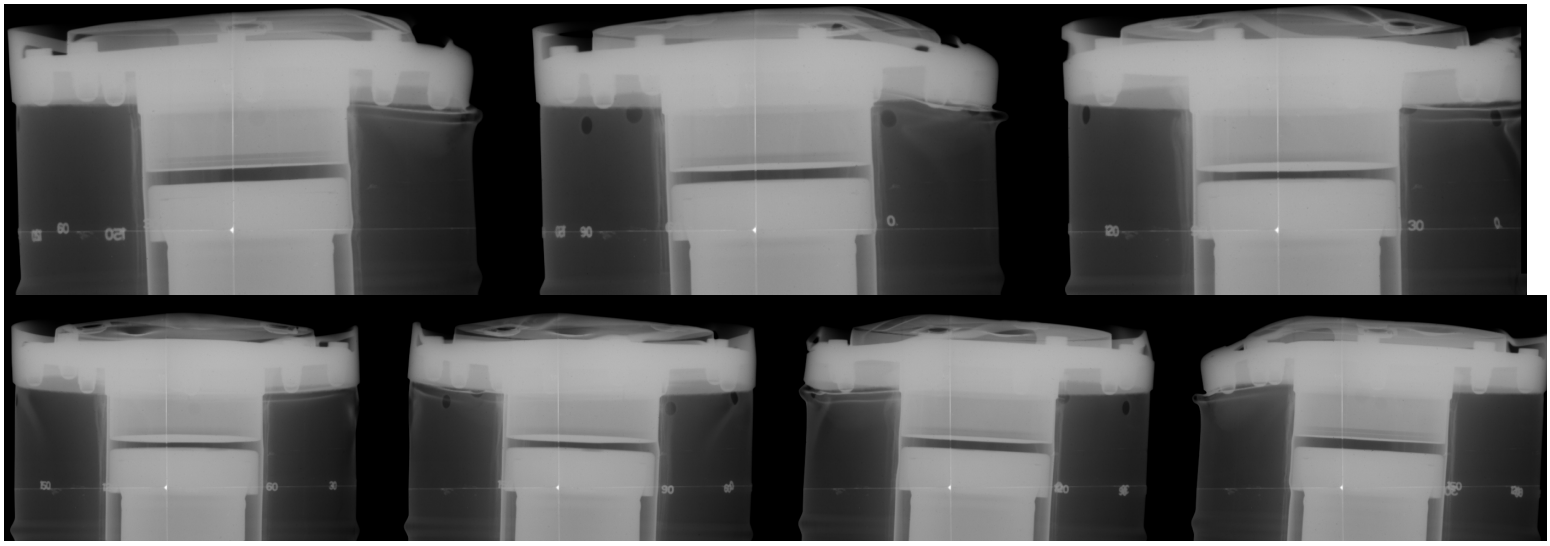
The lower images were acquired after the 30 foot drop test and **are included here for comparison purposes.**



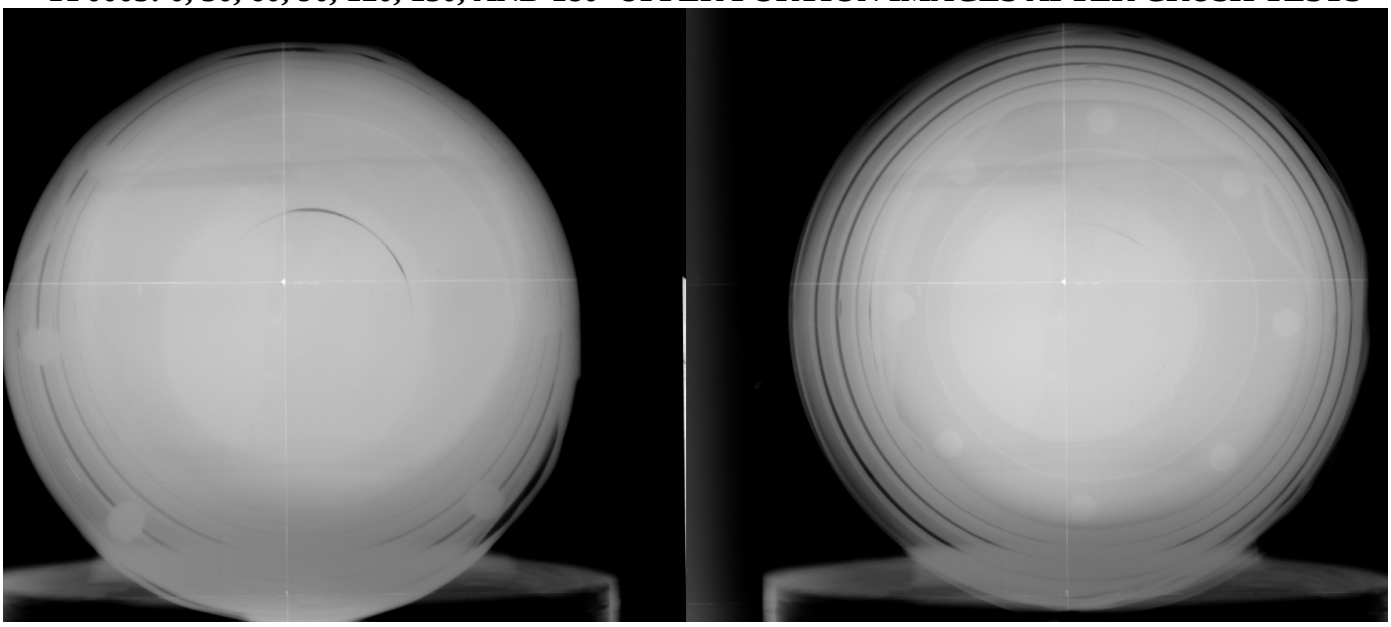
**TP00005 120 AND 150 DEGREE DR IMAGES AFTER CRUSH TESTS**

The two upper images were acquired after the crush tests. No 180 DR.

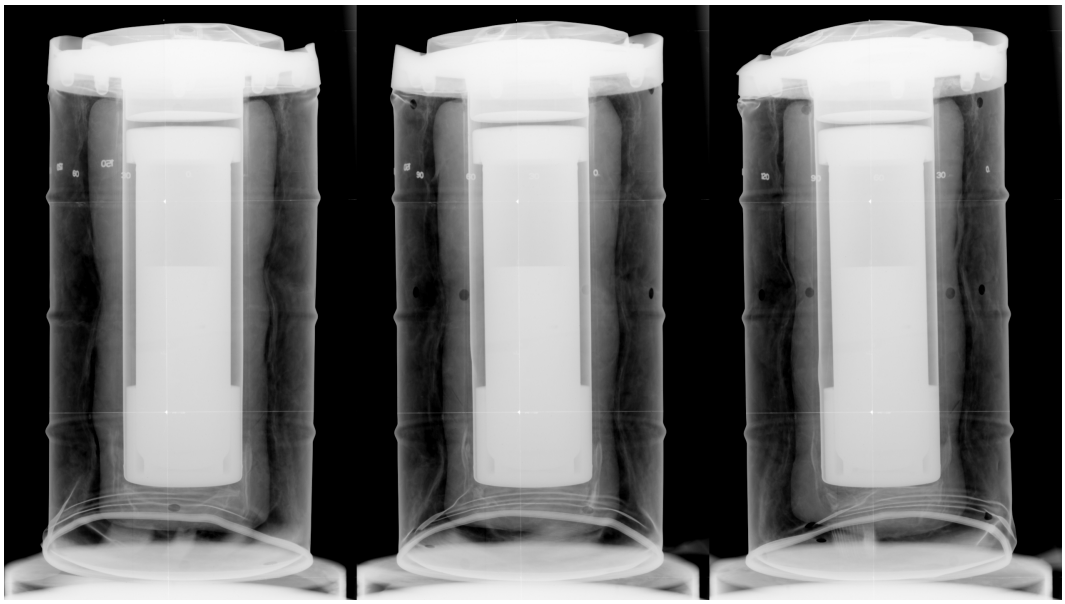
The lower images, TP0005, 120, 150, and 180 were acquired after the 30 foot drop test and **are included here for comparison purposes**.



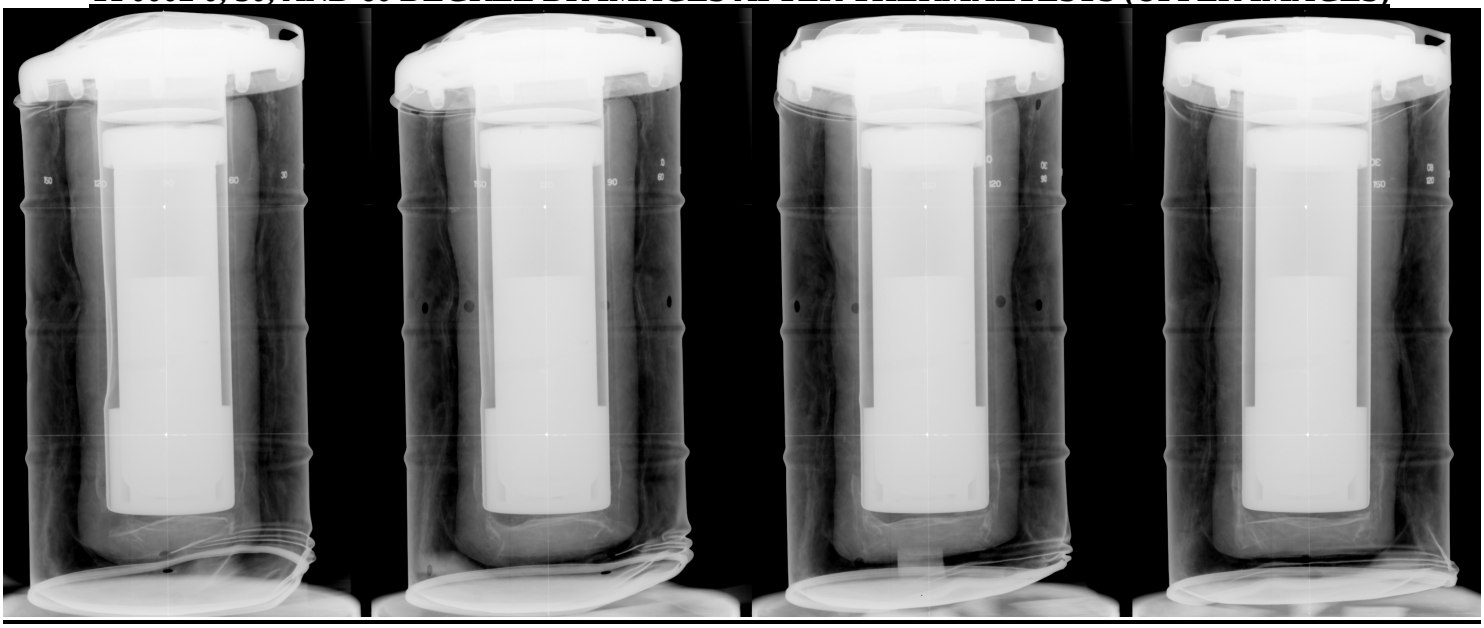
**TP0005: 0, 30, 60, 90, 120, 150, AND 180º UPPER PORTION IMAGES AFTER CRUSH TESTS**



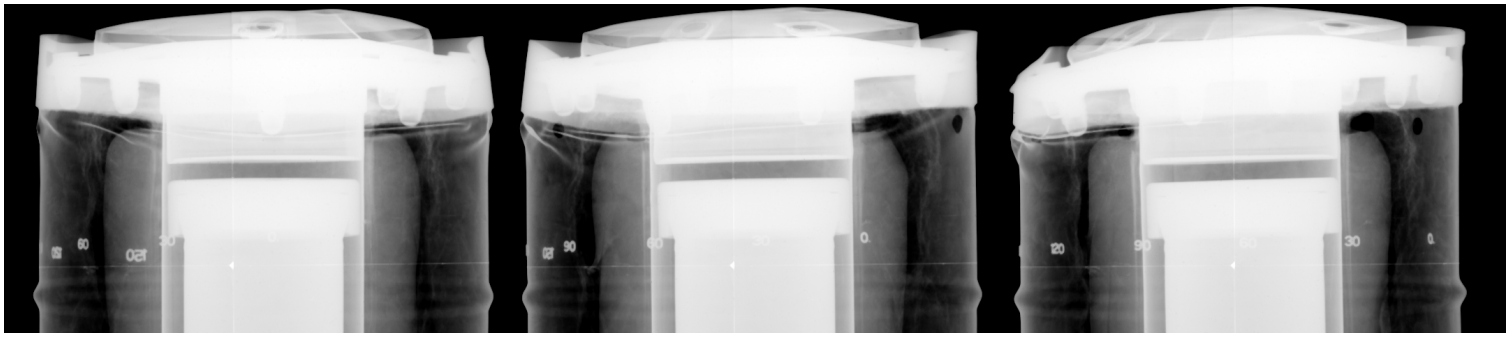
**TP0005 END TO END DR IMAGES AFTER CRUSH TESTS**

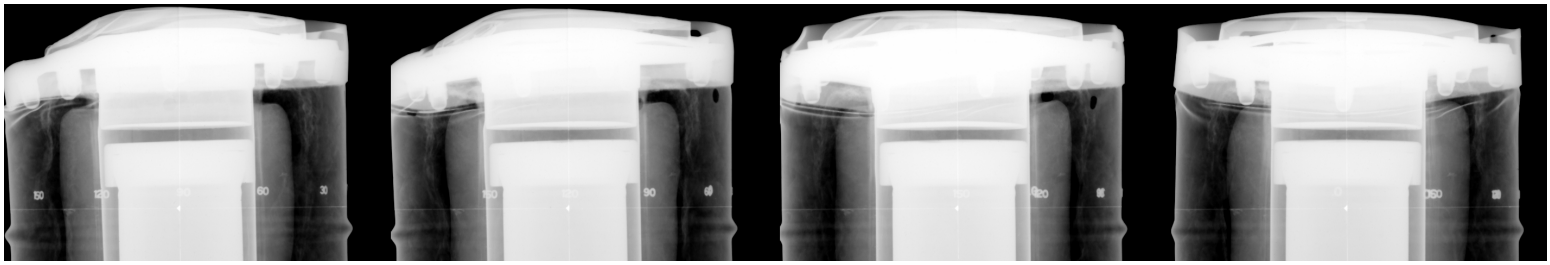


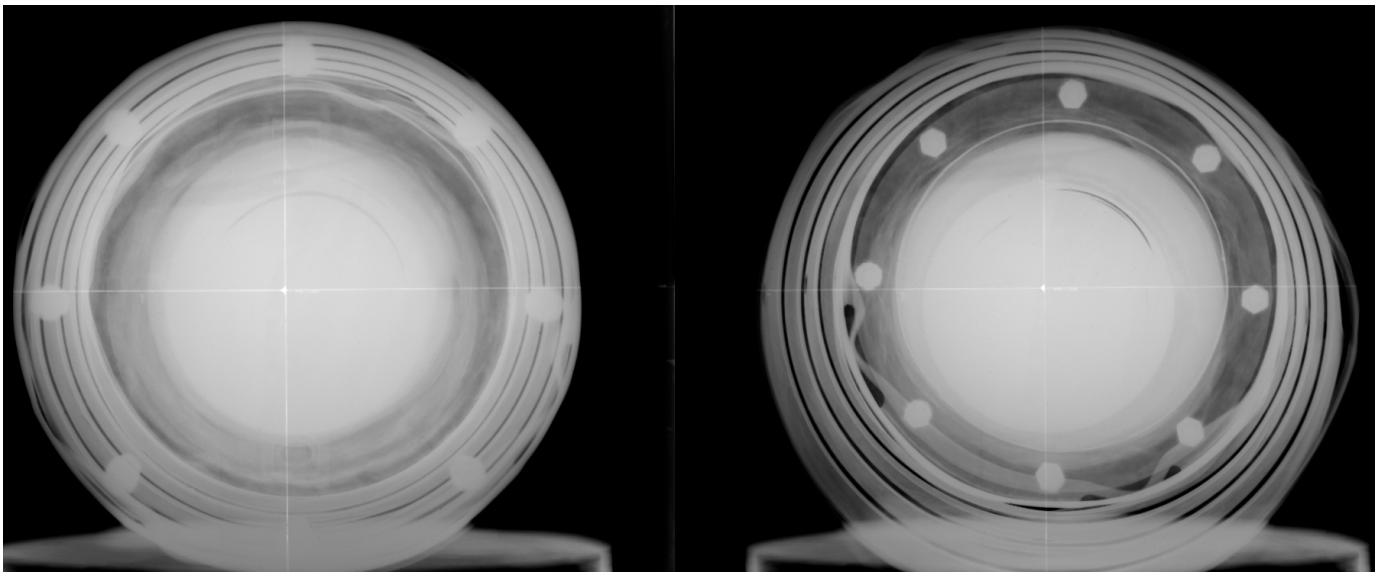
**TP0002 0, 30, AND 60 DEGREE DR IMAGES AFTER THERMALTESTS (UPPER IMAGES)**



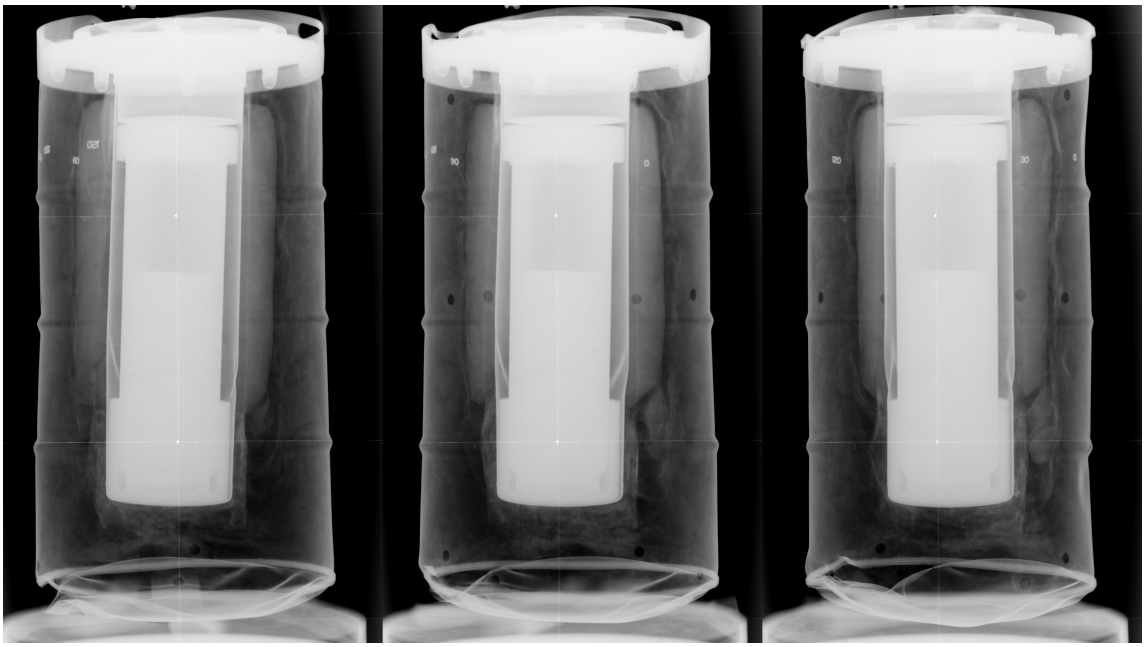
**TP0002 90, 120, 150 AND 180 DR IMAGES AFTER THERMALTESTS (LOWER IMAGES)**



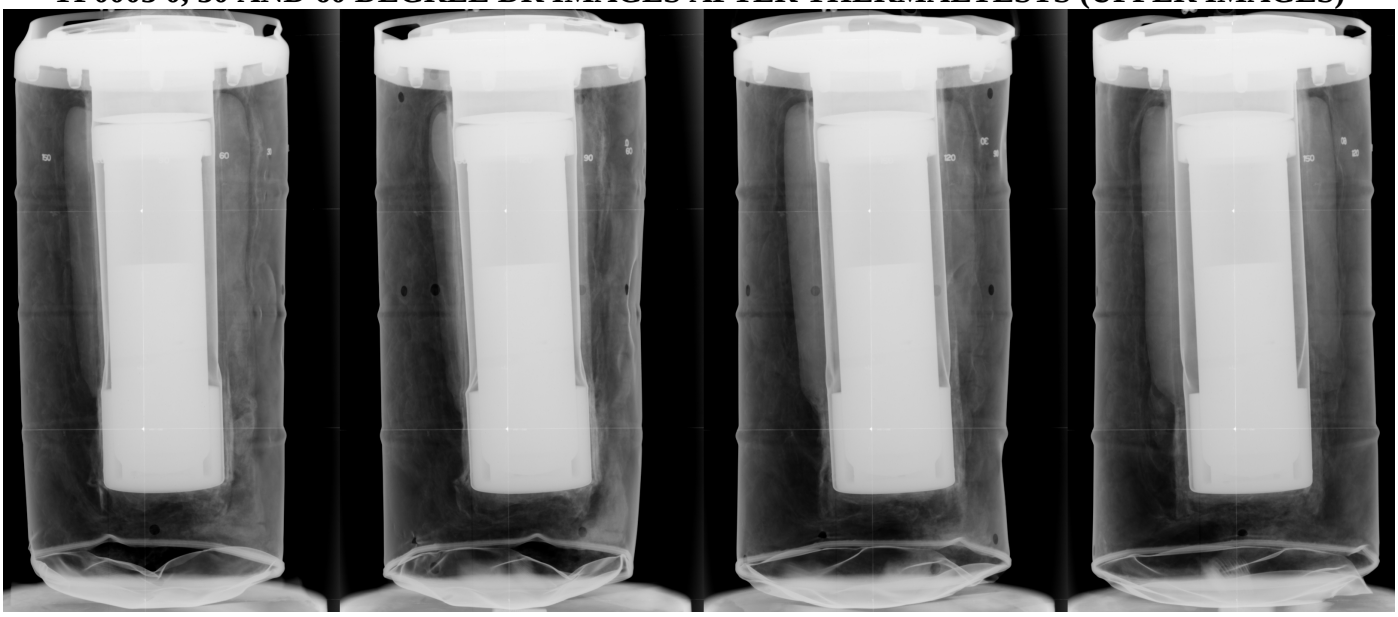




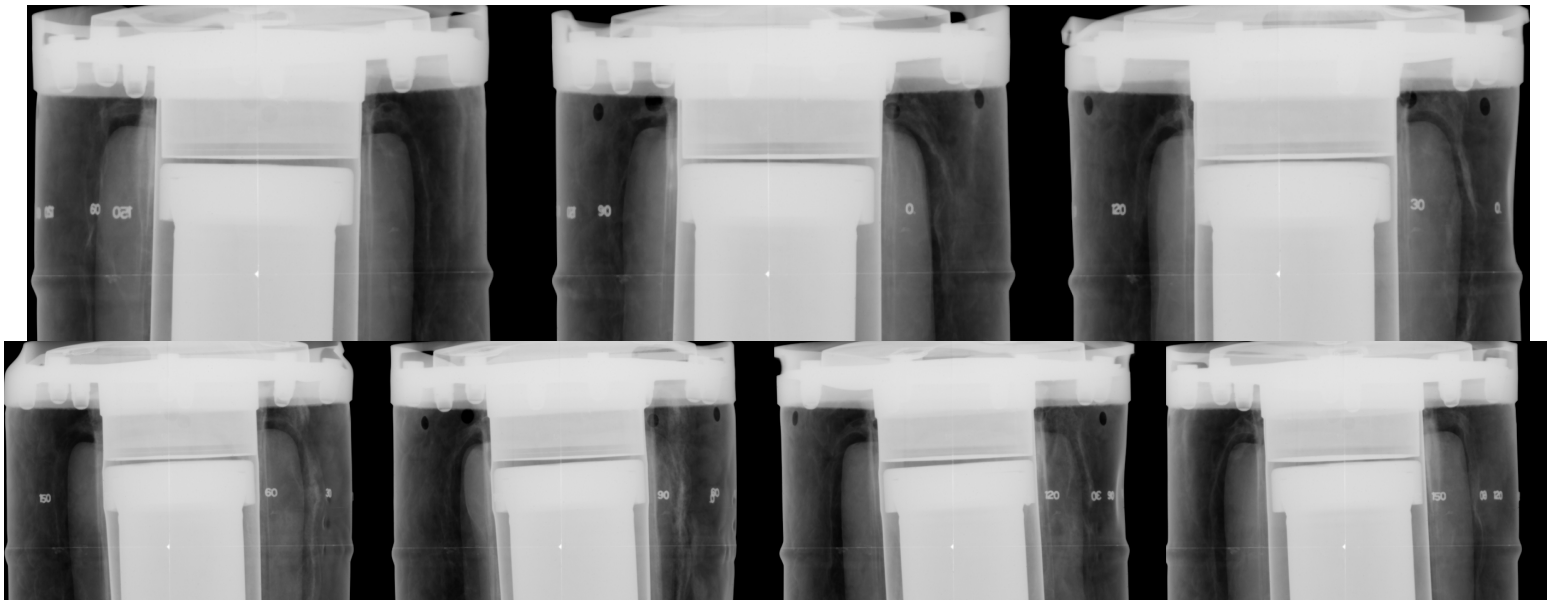
**TP0002 0, 30, 60, 90, 120, 150, & 180º DR IMAGES OF THE UPPER PORTION AFTER THERMAL**
**TP0002 END TO END DR IMAGES AFTER THERMALTESTS**



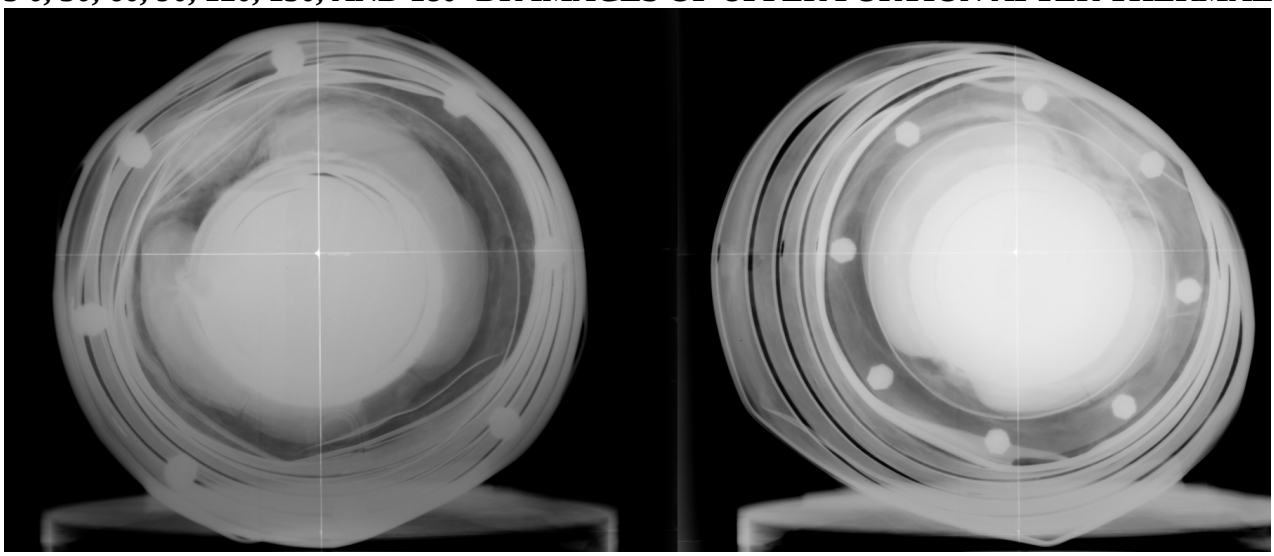
**TP0003 0, 30 AND 60 DEGREE DR IMAGES AFTER THERMALTESTS (UPPER IMAGES)**



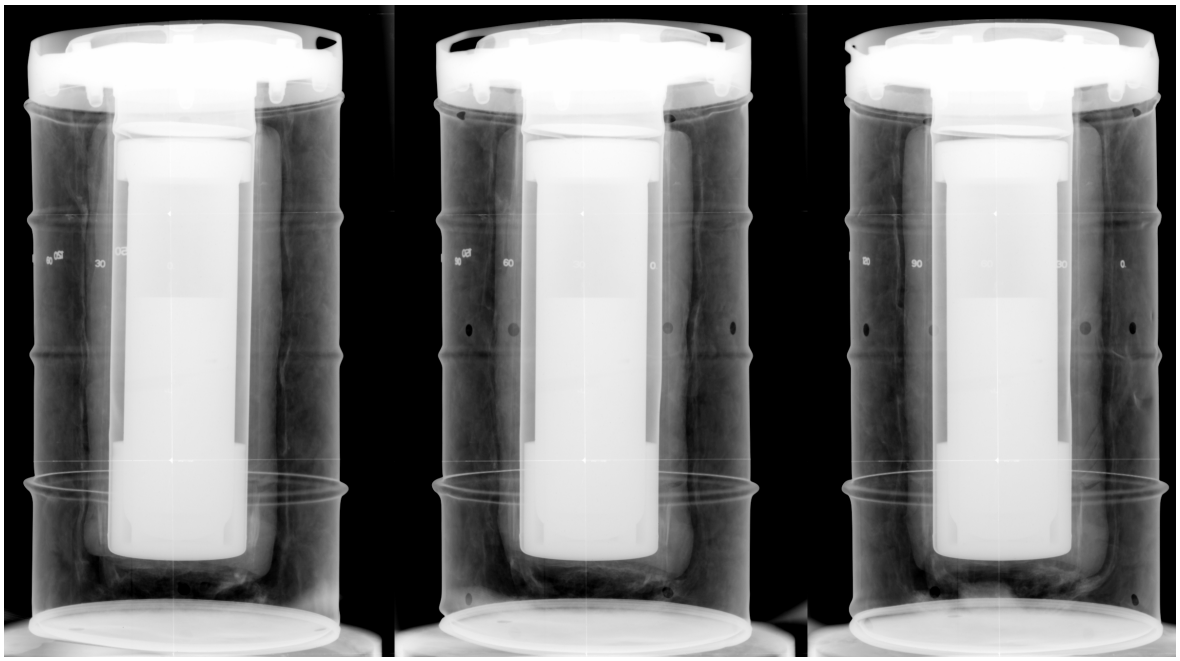
**TP0003 90, 120, 150 AND 180º DR IMAGES AFTER THERMALTESTS (LOWER IMAGES)**



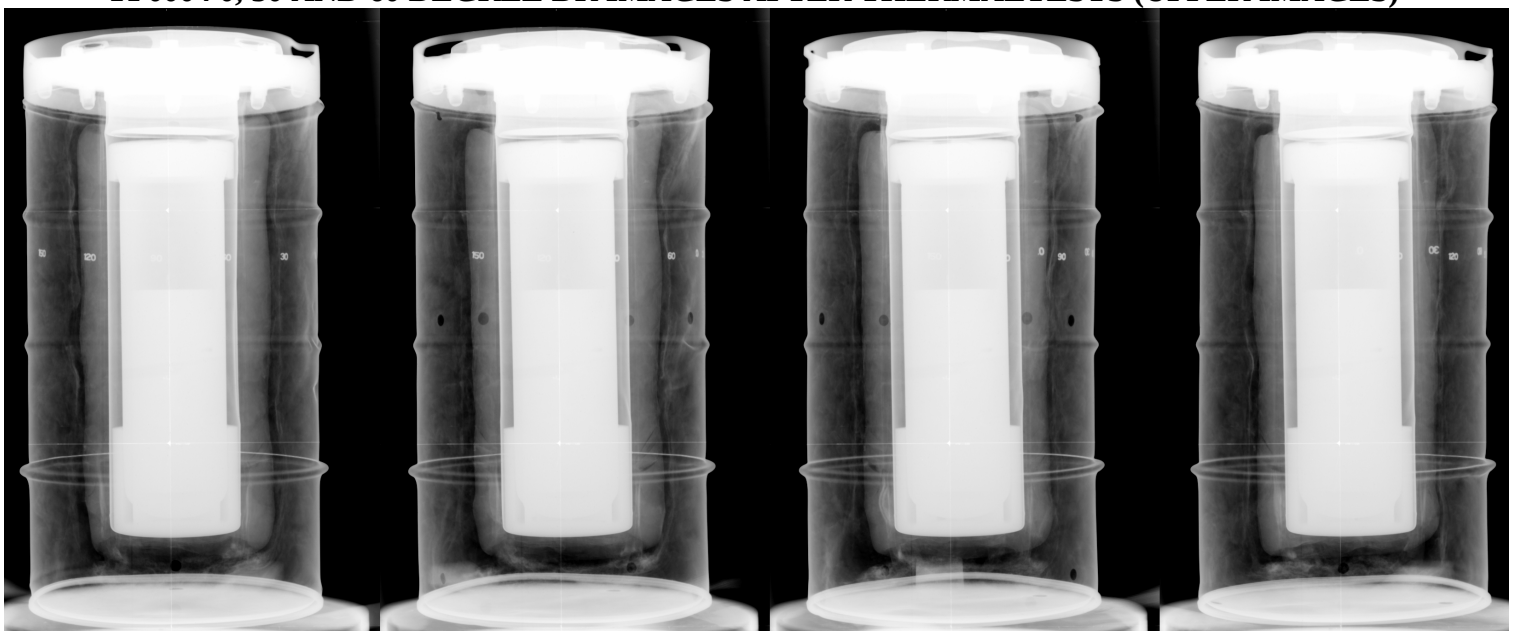
**TP0003 0, 30, 60, 90, 120, 150, AND 180º DR IMAGES OF UPPER PORTION AFTER THERMALTESTS**



**TP0003 END TO END DR IMAGES AFTER THERMALTEST**

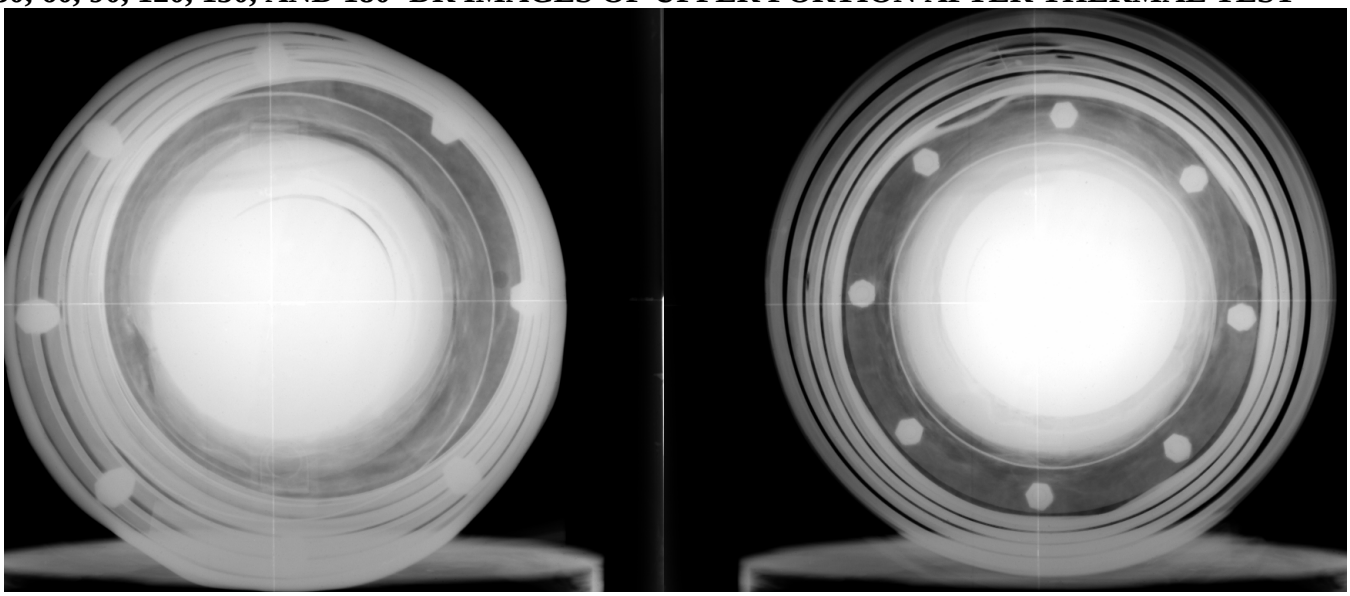


**TP0004 0, 30 AND 60 DEGREE DR IMAGES AFTER THERMALTESTS (UPPER IMAGES)**

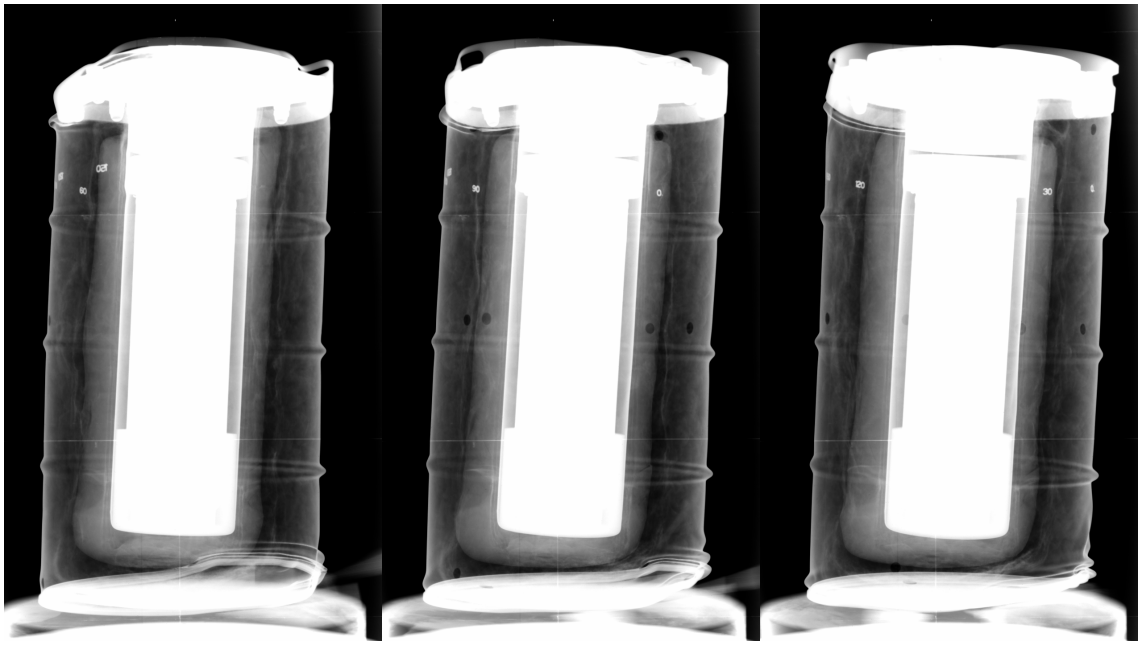


**TP0004 90, 120, 150, AND 180 DEGREE DR IMAGES AFTER THERMALTESTS (LOWER IMAGES)**

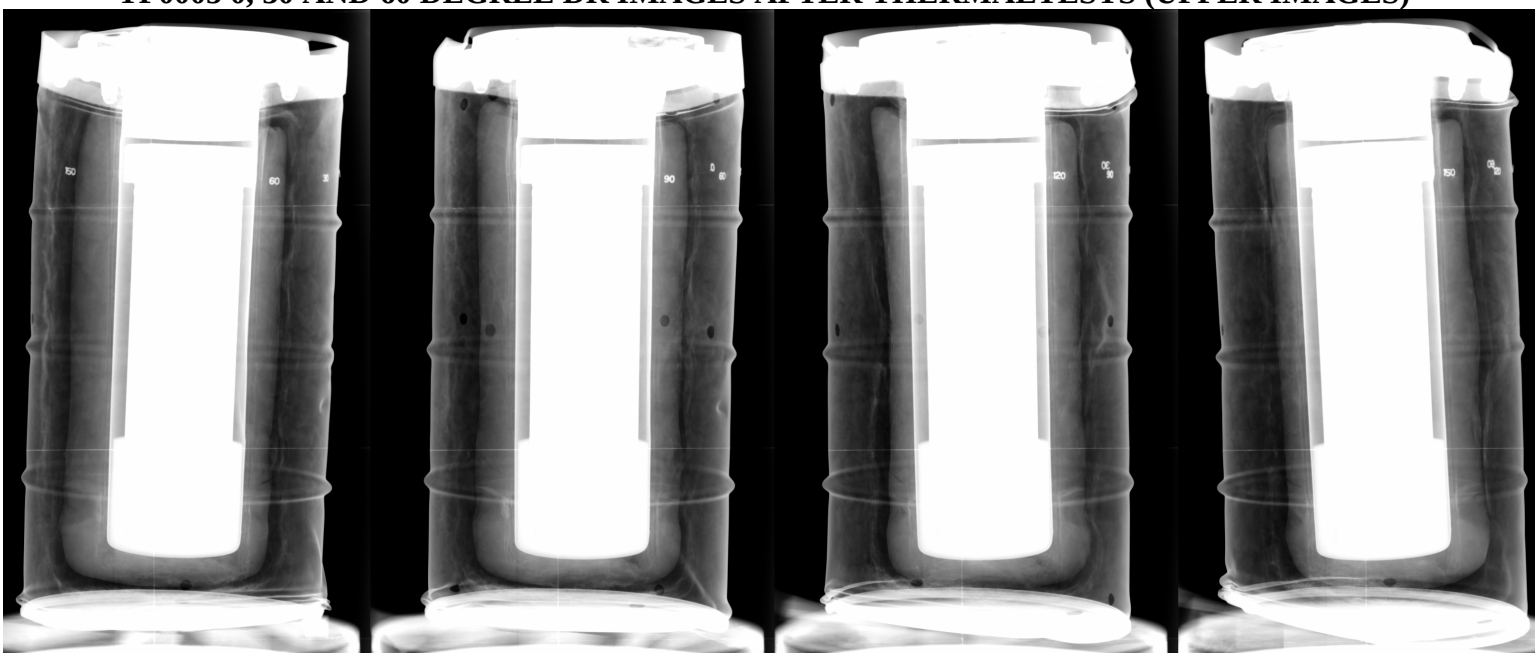
**TP0004 0, 30, 60, 90, 120, 150, AND 180º DR IMAGES OF UPPER PORTION AFTER THERMAL TEST**



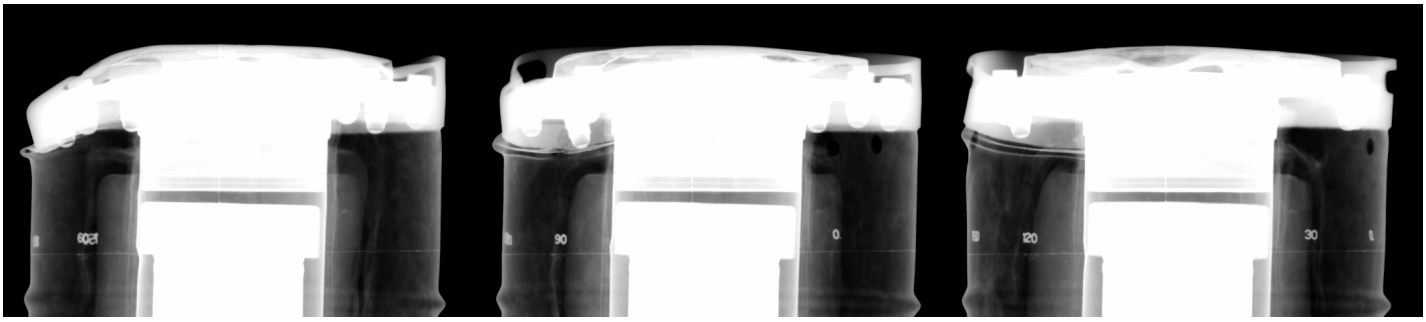
**TP0004 END TO END DR IMAGES AFTER THERMALTEST**

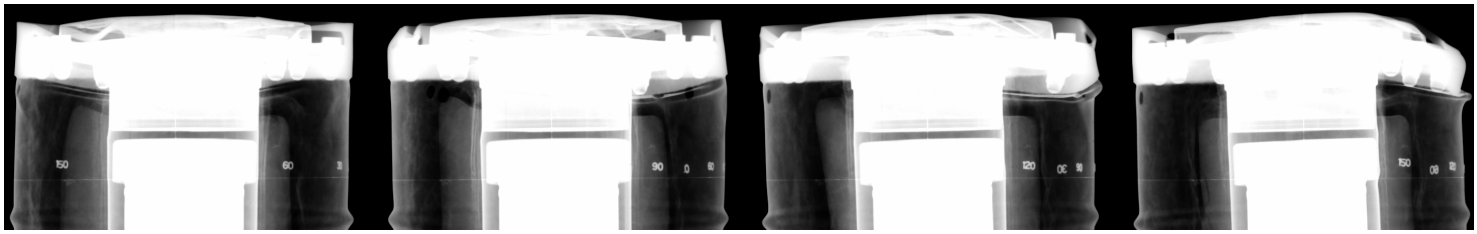


**TP0005 0, 30 AND 60 DEGREE DR IMAGES AFTER THERMALTESTS (UPPER IMAGES)**



**TP0005 90, 120, 150 AND 180 DR IMAGES AFTER THERMALTESTS (LOWER IMAGES)**

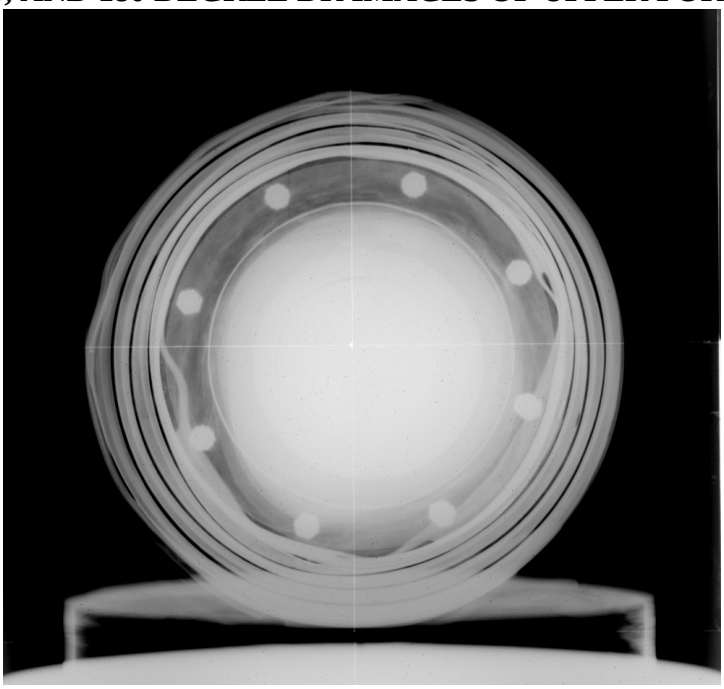




**TP0005 0, 30, 60, 90, 120, 150, AND 180 DEGREE DR IMAGES OF UPPER PORTION AFTER THERMALTEST**

**TP0005 END TO END DR IMAGES AFTER THERMALTEST**

(ONLY THE IMAGE IN WHICH THE TOP OF THE PACKAGE IS NEAREST THE SCINTILLATOR WAS ARCHIVED.)



SRNL
SAVANNAH RIVER NATIONAL LABORATORY
TM

ATTACHMENT 2

# Engineered Equipment and Systems

# Imaging Instructions

## SNM Test Package Digital Radiography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# SNM TEST PACKAGE Digital Radiography

# Engineered Equipment and Systems

## About Us...

The Engineered Equipment and Systems Department (EES) serves the Savannah River Site (SRS) operations, other Department of Energy (DOE) Sites, and the private sector primarily where **off-the-shelf design cannot fill a need**. We are an **applied engineering house**, employing electrical, mechanical and computer engineering techniques to solve unique customer needs where measurement, fixturing, or inspection is required but limitations in either field conditions or available technology requires a novel solution. IES has experience in modifying or refining commercial equipment, or designing new devices to meet unique design requirements.

EES is a branch of the Savannah River National Laboratory (SRNL) which is operated for the U.S. Department of Energy by Westinghouse Savannah River Company. Our personnel include Mechanical / Electrical engineers, NDE engineers, designers, drafters, Engineering Assistants, certified leak test personnel and more.

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### VISION

To be recognized as the most effective leader in the development and application of technology for the DOE.

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EES Department Manager: (803) 725-2331

# Revision History

| Revision | Date | Author | Summary |
|---|---|---|---|
| 0 | 8/4/2005 | J. D. Jones | Original issue |
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# About This Document

This document provides instructions for performing Digital Radiography on SNM TEST PACKAGES in N-Area. It provides instructions to operate the computer and digital imaging software. It also provides instructions for setting up the test packages for imaging.

This document **does not** provide instructions for operating the X-Ray machine.

This document **is not** intended to be a step by step procedure. It is a **reference guide** to be used by personnel familiar with the operation of the system.

## Conventions Used in This Manual

The following conventions are used in this manual:

| | |
|---|---|
| >> | The >> symbol leads you through nested menu items and dialog box options to a final action. The sequence SHOW>>Temperature Graph directs you to pull down the SHOW menu and select the Temperature Graph option. |
| G | This icon denotes a tip, which alerts you to advisory information. |
| ! | This icon denotes a note, which alerts you to important information. |
| bold | Bold text denotes items that you must select or click on in the software, such as menu items and dialog box options. Bold text also denotes parameter names. |
| italic | Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font also denotes text that is a placeholder for a word or value that you must supply. |
| Microsoft Sans Serif | Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames and extensions, and code excerpts. |

# Contents

# 16 X-Ray Room

This section provides instructions for setting-up a SNM TEST PACKAGE in the 711-6N, N-Area X-ray Room

### Turn Power On

Turn Power On to the equipment as follows:

- Turn outlet strip adjacent to the turntable on. Indicator lights will illuminate if power is available to the strip. This strip provides power to the digital camera, the turntable, and the turntable servo drive control box.
- Plug power into the back of the video camera adjacent to the servo drive control box.

### Position/Prepare the Turntable

Position and prepare the Turntable Assembly as follows:

- Place the turntable close (within 4") to the scintillation screen without touching it. It must be able to rotate freely. Center the turntable with the center of the Scintillation Screen.
- Position the top edge of the turntable approximately 20.5" from the floor.
- Place the round white plastic spacer in the center of the turntable. The spacer is 3.5" high.

### Position Test Package

Position the Test Package on the Turntable as follows:

- For all SNM TEST PACKAGES and SNM TEST PACKAGE upper portion images, place the test package vertically on the center of the spacer with the 0° mark facing the scintillation screen. The 0-180° Axis should be approximately perpendicular to the screen.
- For the SNM TEST PACKAGE END to END TOP image, position the test package horizontally on the spacer with the top of the test package closest to the scintillation screen and the bottom towards the X-Ray source. The 0° mark should be facing upwards opposite the spacer.

- For the SNM TEST PACKAGE END-TO-END BOTTOM image, position the test package horizontally on the spacer with the bottom of the test package closest to the scintillation screen and the top towards the X-Ray source. The 0° mark should be facing upwards opposite the spacer.
- Place the number belt on the test package ~1.5" above the first chime (support band) just below the test package serial number. The 0 number on the belt should be aligned with the 0° marking on the test package. The belt runs from 0° to 180° counter clockwise.

**Position the X-Ray Head**

Position the X-Ray Head as follows:

- Move the X-Ray head horizontally as far back is it will travel away from the turn-table. The head should be approximately 141" from the front of the scintillator screen.
- Position the X-Ray head with the focal spot approximately perpendicular to the scintillator screen.
- For SNM TEST PACKAGE ALL position the center of the X-Ray head focal spot approximately 43" from the floor.
- For SNM TEST PACKAGE upper portion images, position the center of the X-Ray head focal spot approximately 54" from the floor.
- For SNM TEST PACKAGE END-to-END images, position the center of the X-Ray head focal spot approximately 34.5" from the floor (as far down as it will go).

**Turn Out Lights**

Prior to leaving the X-Ray Room to take images:

- Ensure that the black plastic tent is in place around the Digital Camera, turning mirror and Scintillation screen.
- Turn out all lights.

# 17 Imaging Software

This section provides instructions for preparing the control room for SNM TEST PACKAGE Imaging and operating the imaging software. This section does not provide exhaustive instructions for the software. It provides the most prominent features used for imaging the test packages and should provide a useful reference for personnel familiar with the systems operation.

**Turn Power On**

Turn Power On to the equipment as follows:

- Authorized and trained personnel will operate the X-Ray equipment per established procedures not in the scope of this document.
- Turn the video monitor power on.
- Turn the computer power on by pressing the round power button on the front of the computer in the lower right-hand corner.
- When the Log-In prompt appears, log in as user – Administrator without a password. Press the [Enter] key.

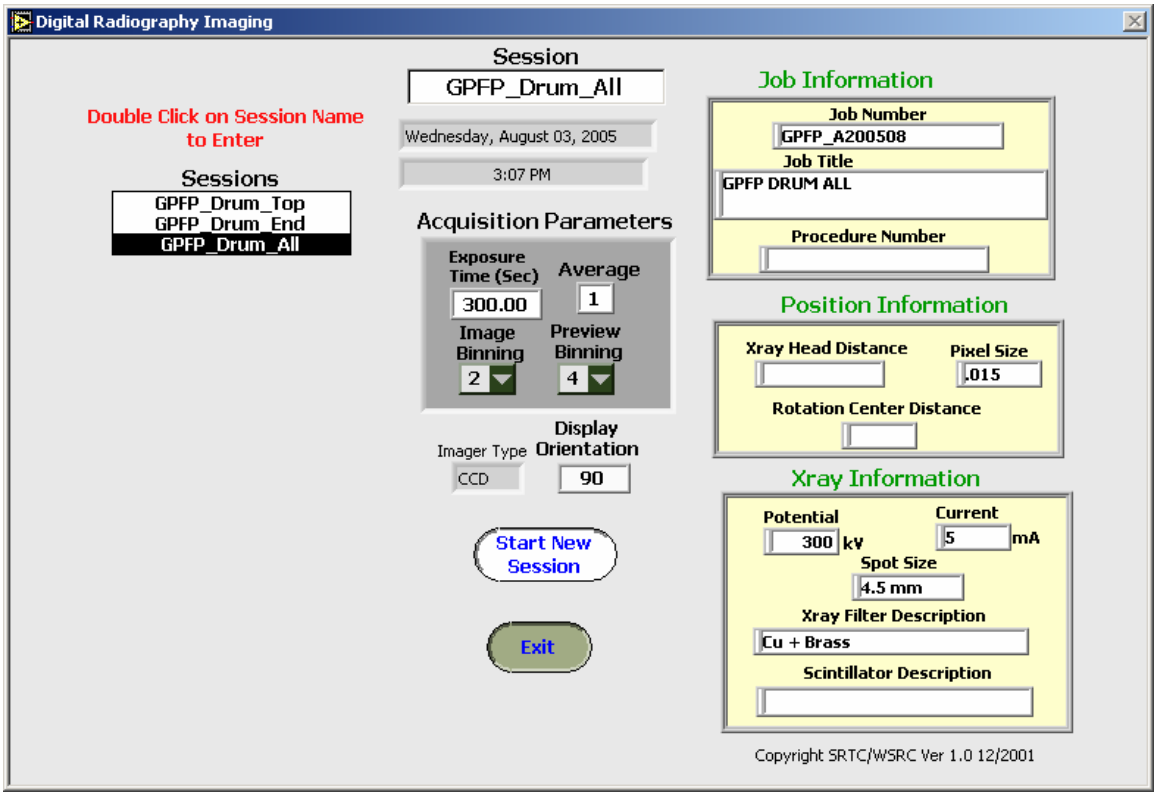
**Start the Imaging Software**

Once the Windows desktop appears and the computer has completed start-up, start the Digital Radiography Imaging Application as follows:

- Double click the Start DR Imaging Icon on the desktop. This launches the LabVIEW application found at C:\ SRS DR Software\SRS\start session.vi.
- When the application starts the session selection window will be displayed.

## Session Selection

When the application is started the initial application window is displayed. It will appear similar to the following:

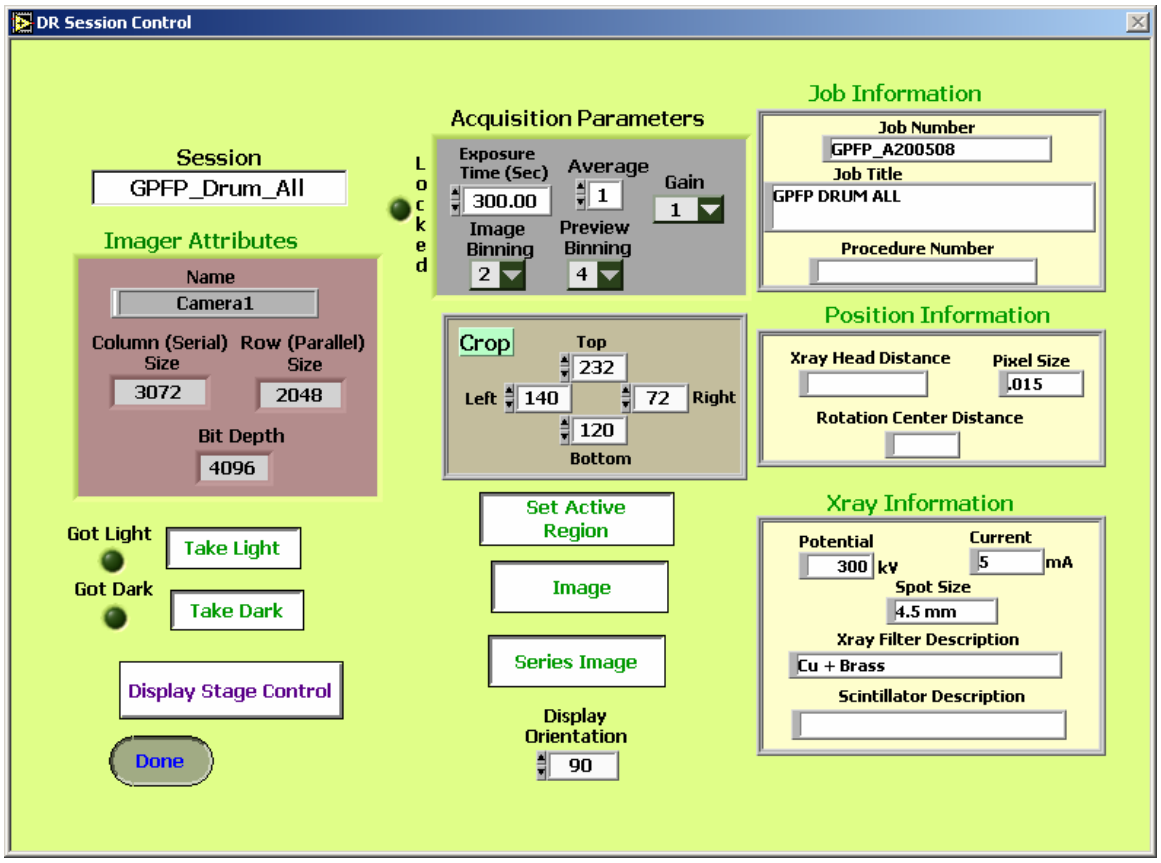



- A list of the previously created imaging sessions will appear in the **Sessions** window. select the appropriate session as follows:
  - For SNM TEST PACKAGE "ALL" images, Double click the SNM TEST PACKAGE_TEST PACKAGE_ALL session.
  - For SNM TEST PACKAGE TOP images, Double click the SNM TEST PACKAGE_TEST PACKAGE_TOP session.
  - For SNM TEST PACKAGE END images, Double click the SNM TEST PACKAGE__END session.
- After you select the session control window is displayed.

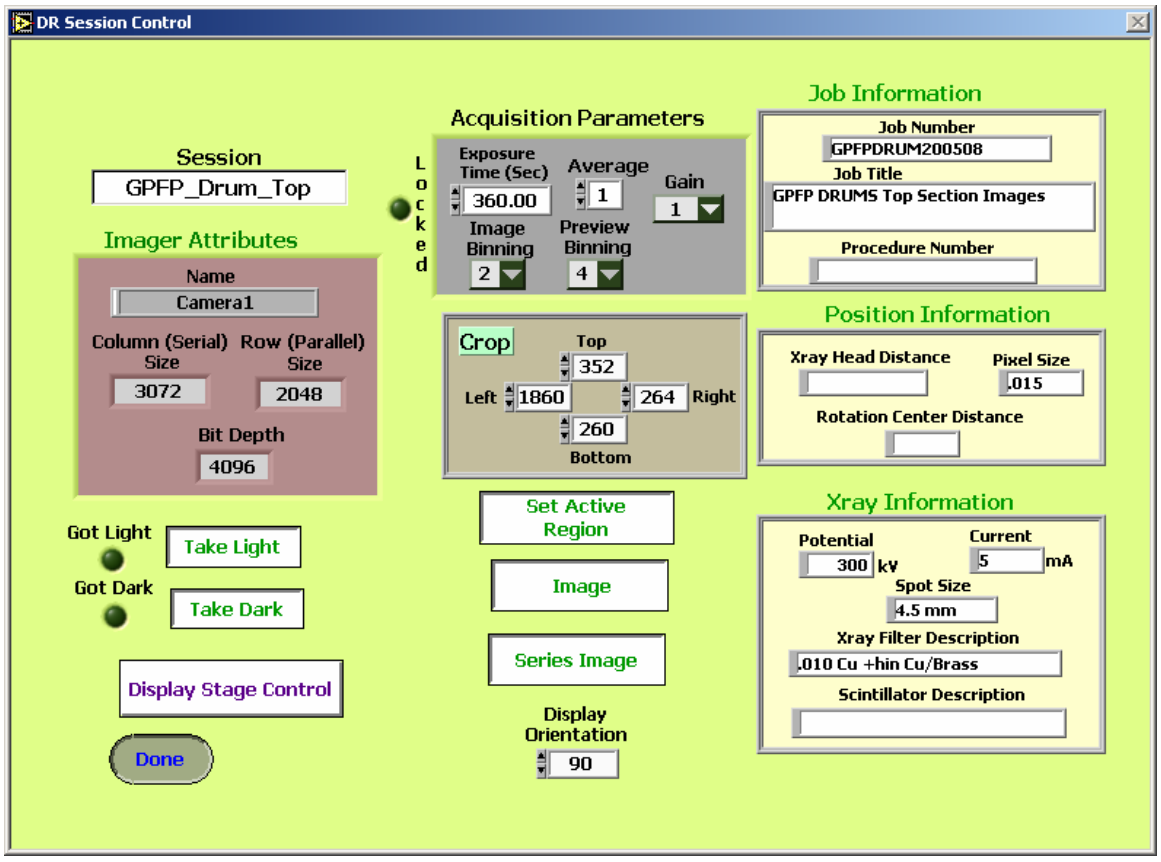
## Session Control

When the Session Control window is displayed, the appropriate parameter values are automatically filled in for the selected session.

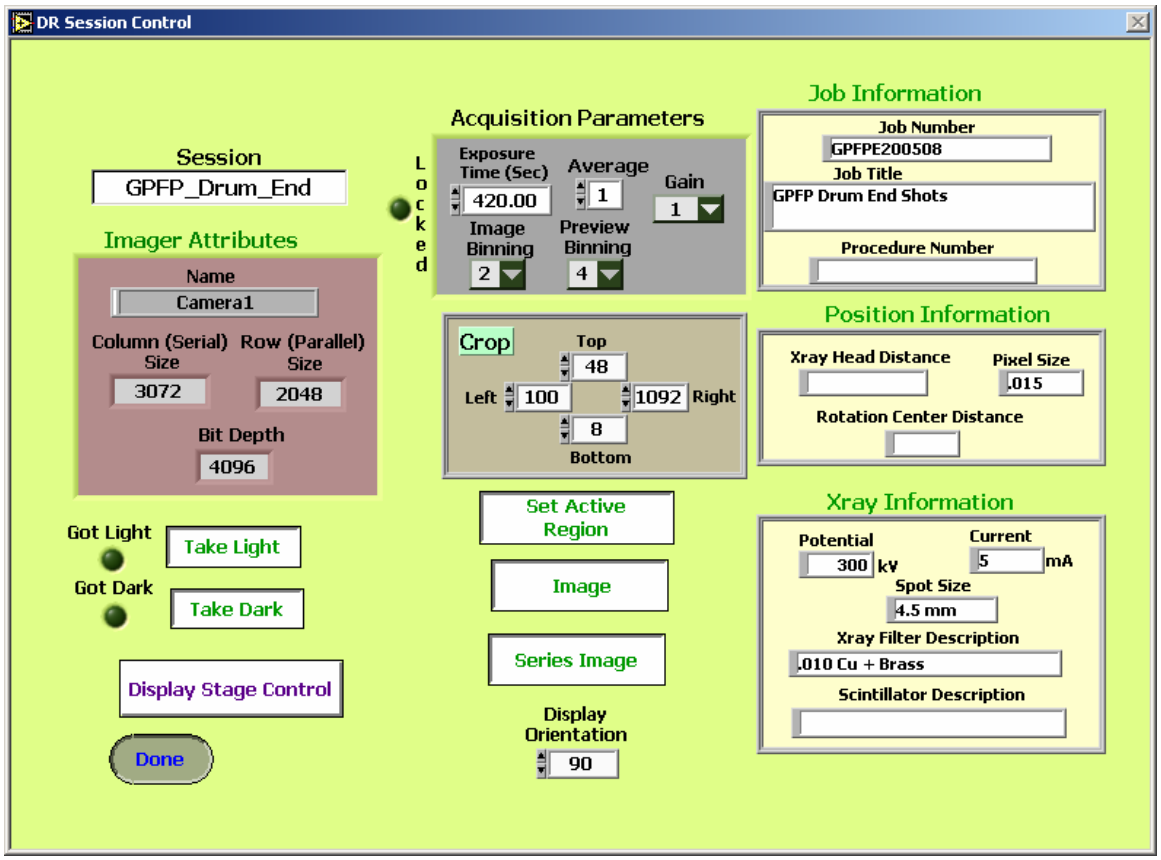
- For SNM TEST PACKAGE ALL images, verify that the Session Control Window values are as follows:



- For SNM TEST PACKAGE TOP images, verify that the Session Control Window values are as follows:

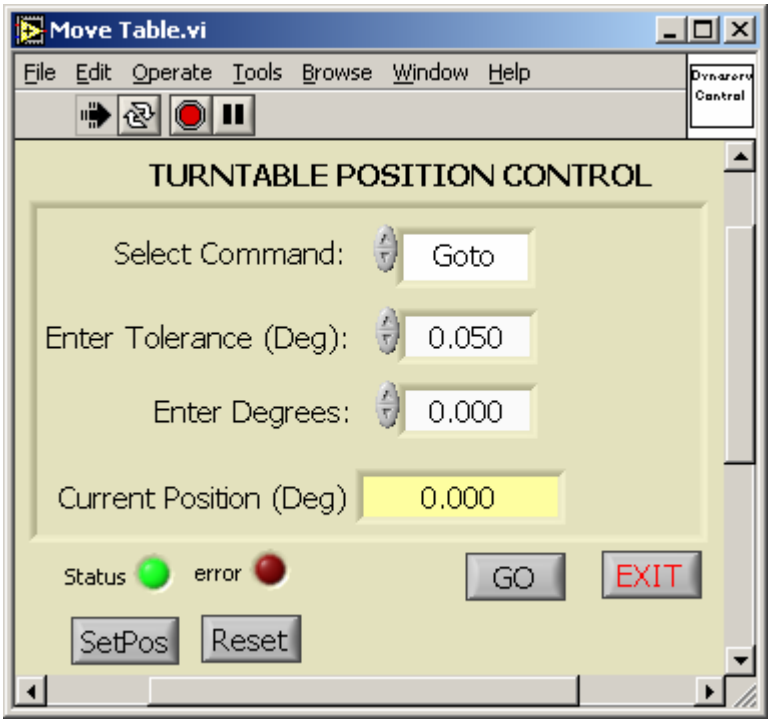


- For SNM TEST PACKAGE END-to-END images, verify that the Session Control Window values are as follows:



**Stage Control**

When the Session Control window is displayed, the Stage Control (Move Table. I) window used to control the turntable is also displayed. If it is not displayed, then select the [Display Stage Control] button to display it.



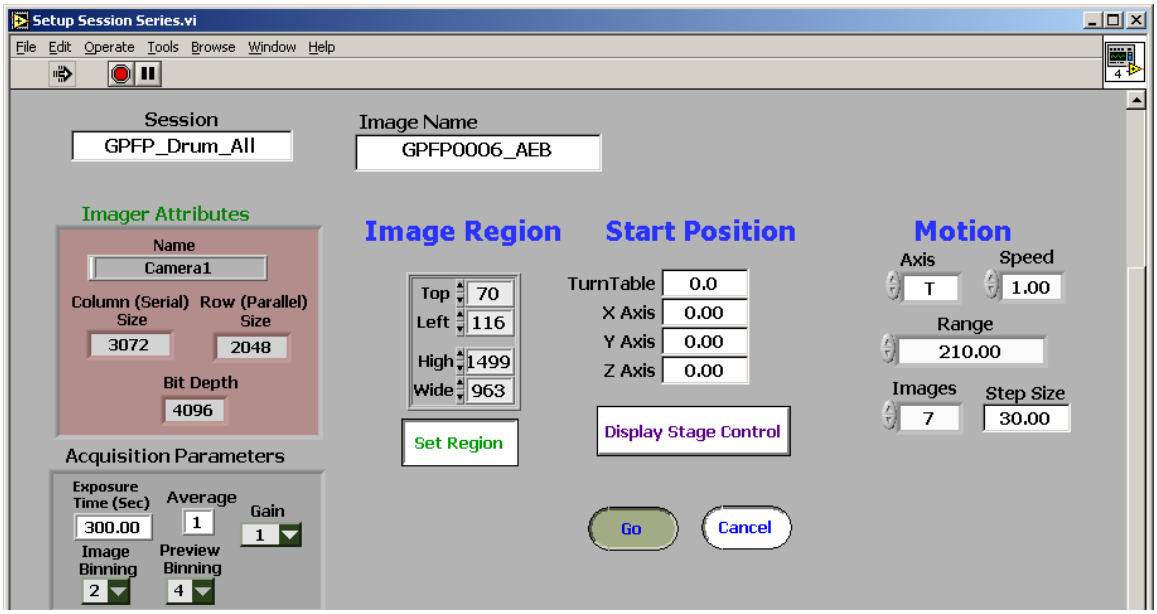

- Prior to performing a series of images, it usually best to select the [Reset] button to reset the turntable's servo drive controller. It takes approximately 10 seconds for the reset to complete.
- After the turntable drive is reset, Enter the current position of the turntable relative to the test packages position to the scintillator screen in the Enter Degrees: entry box. Usually this value will be zero prior to performing a series of images.
- Select the [SetPos] button. The current position will be set to the position in the Enter Degrees: entry box.

## Series Image

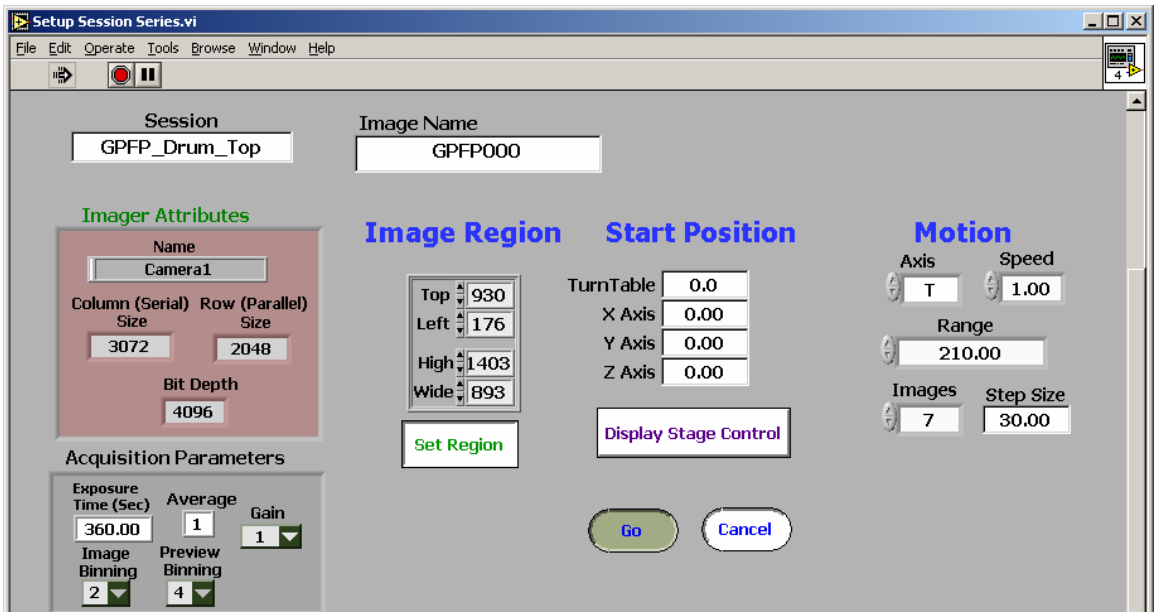
**In the Session Control window select the [Series Image] button to begin a series of images on the Entire Test package or the Test package Top. The Setup Session Series Window is displayed.**

## Setup Session Series

- For SNM TEST PACKAGE ALL images, the Setup Session Series Window will appear as follows:

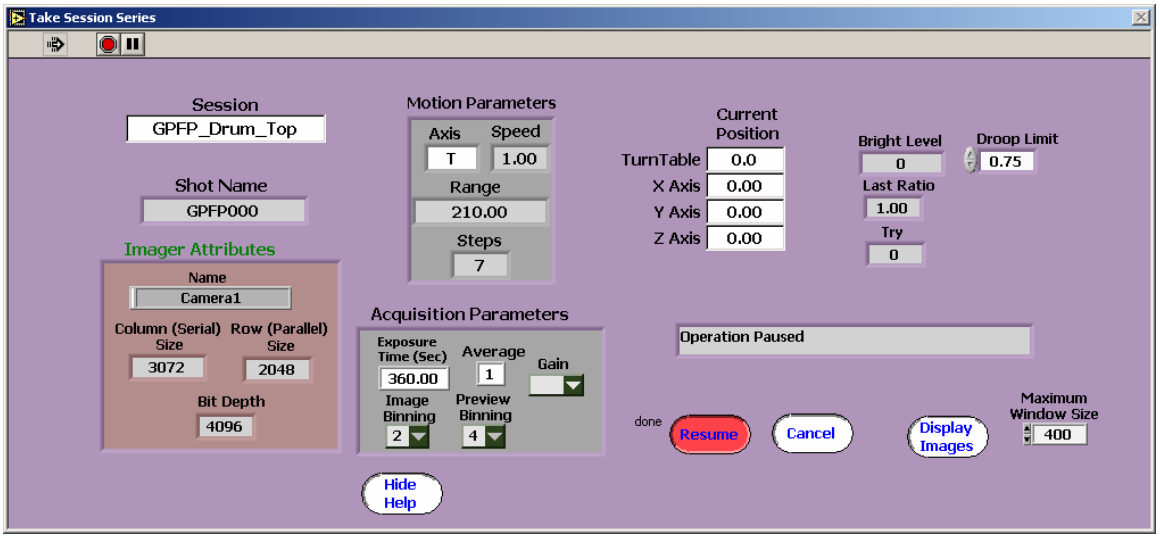


- For SNM TEST PACKAGE Top images, the Setup Session Series Window will appear as follows:

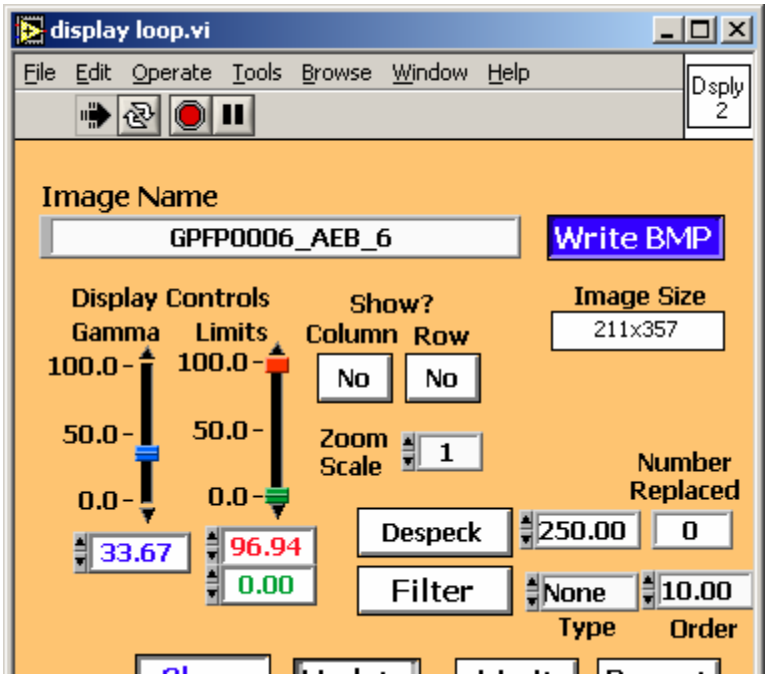



- In the Setup Session Series window
  - Enter the Image Name as described in the Parameter Summary Section of this guide.
  - Verify that the other values are as shown above.
  - Press the [Go] button. The Take Session Series window will be displayed.

## Take Session Series




- After the X-Ray source is ready, Press the [Resume] button to begin taking the series of images.
- After each image is taken, the image will be displayed on the screen. Examine the image to verify that the position is correct and that it is changing after each shot. You can use the display loop.vi window controls to adjust the image for better viewing.



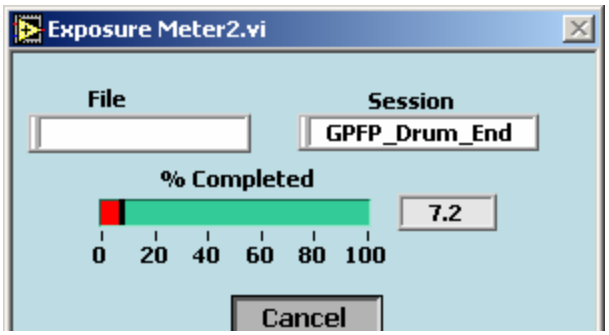
### Single Image

In the Session Control window select the [Image] button to take a single image.

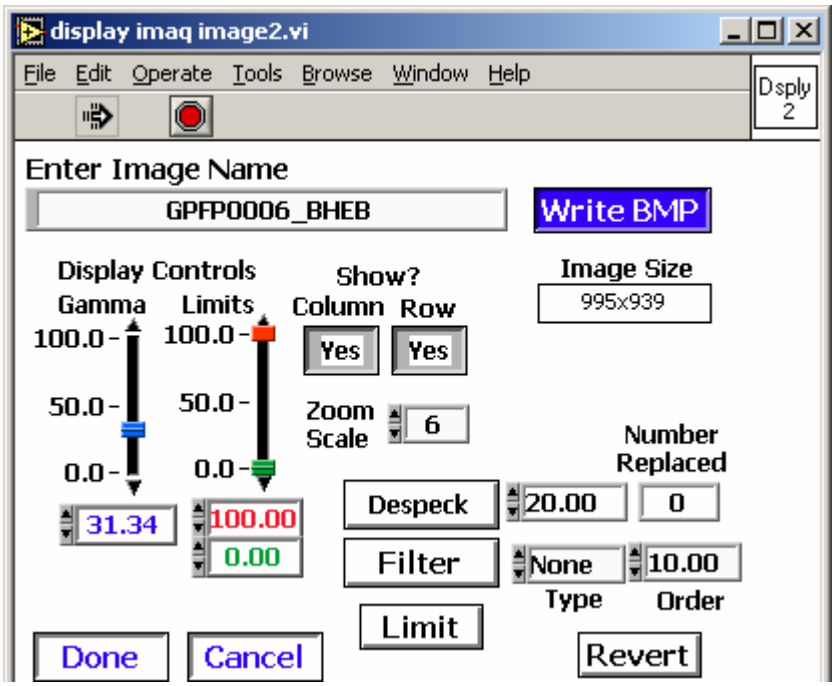
### Preview Image

After selecting the [Image] button.  The application takes a preview image.

- The Exposure Meter window is displayed while the preview is taken.  The Exposure Meter is window is shown anytime an image is being acquired.




- After the image is acquired, the image is displayed along with the Display Image Controls window.



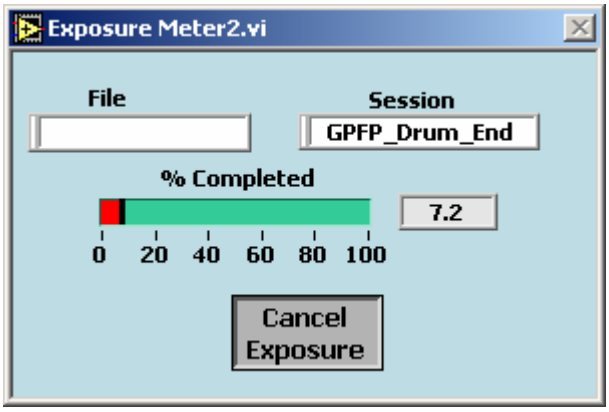

- You can use the controls to improve the displayed image.
- You can write a bitmap of the image.

- Press [Done] if you are ready to take the final image or Press [Cancel] if you need to make adjustments before taking the final image.

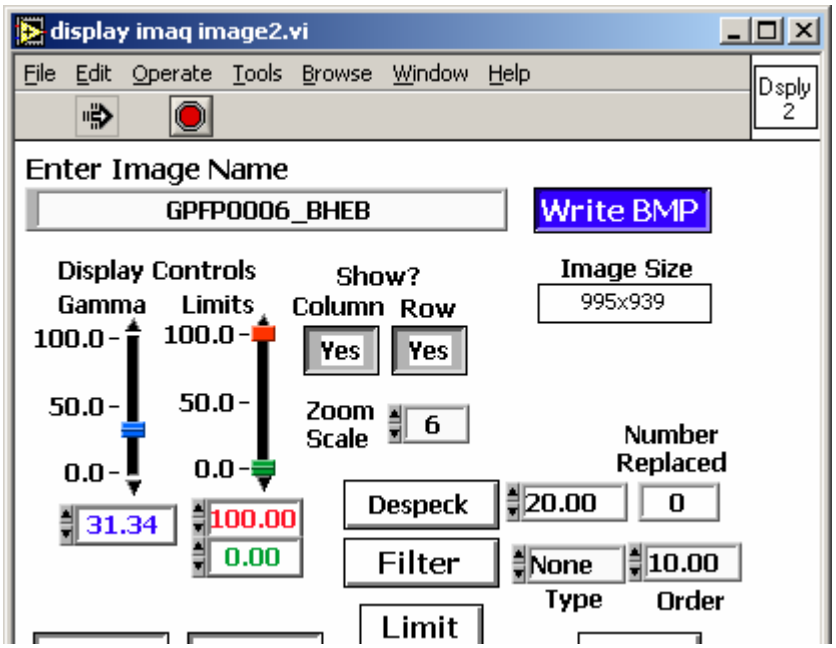
## Final Image

If you select the [Done] button after the preview image is taken, the application takes the final image.

- The Exposure Meter window is displayed while the image is taken.




- After the image is acquired, the image is displayed along with the Display Image Controls window.




- You can use the controls to improve the displayed image.
- You can write a bitmap of the image.
- **To save the raw image data**, Enter the Image Name prior to pressing [Done]. *If you do not enter a name or if you press* [Cancel] *the raw image data will not be saved.*

# 18 Parameter Summary

This section provides a summary of various parameters for each type of SNM TEST PACKAGE Test package Shot.

**X-Ray Parameters**

The following table summarizes the X-Ray parameters used for the SNM TEST PACKAGE Shots:

| **Parameter** | **Test package All** | **Test package Top** | **Test package End** |
|---|---|---|---|
| Source Intensity | 300 kV / 5 mA | 300 kV / 5 mA | 300 kV / 5 mA |
| Exposure Time | 300 Sec | 360 Sec | 420 Sec |
| Num Shots | 7 – 0-180° @ 30° increments | 7 – 0-180° @ 30° increments | 2 – 1 each end |
| | | | |

**Geometric Parameters**

The following table summarizes the X-Ray parameters used for the SNM TEST PACKAGE Shots (Dimensions shown are approximate):

| **Parameter** | **Test package All** | **Test package Top** | **Test package End** |
|---|---|---|---|
| TurnTable Ht (Floor to Top) | 20.5” | 20.5” | 20.5” |
| X-Ray Src Ht (Floor to Focal Spot) | 43” | 54” | 34.5” (All the way down) |
| X-Ray Src Focal Spot to North Wall | 47.5” | 47.5” | 47.5” |
| X-Ray Src to Screen | 141” | 141” | 141” |
| X-Ray Src to Test package Center | 123” | 123” | 123” |

## File Naming

The raw image files should be named as follows:

- For SNM TEST PACKAGE ALL images, The name prefix should be SNM TEST PACKAGE####_Asuffix _seqNum where #### is the serial number of the test package. The test package suffix and seqNum will be described below. For SNM TEST PACKAGE TOP images, The name prefix should be SNM TEST PACKAGE####_Tsuffix where #### is the serial number of the test package. The test package suffix will be described below.
- For SNM TEST PACKAGE TOP END images, The name prefix should be SNM TEST PACKAGE####_THsuffix where #### is the serial number of the test package. The test package suffix will be described below.
- For SNM TEST PACKAGE BOTTOM END images, The name prefix should be SNM TEST PACKAGE####_BHsuffix where #### is the serial number of the test package. The test package suffix will be described below.
- The name suffixes should be as follows:
  - EB - for Empty Baseline
  - CVB - for Containment Vessel inserted Baseline.
  - TA - First Test package Test - Sandia Vibration Analysis
  - TB - Define
  - TC - Define
  - TD - Define
  - TE - Define
  - TF -Define
  - TG -Define
- The seqNum is the sequence number for a series of images. The _# is automatically appended to the Series Image Name for each image in the series. # is as follows:

  > 0 – 0° shot
  > 1 – 30° shot
  > 2 – 60° shot
  > 3 – 90° shot
  > 4 – 120° shot
  > 5 – 150° shot
  > 6 – 180° shot