NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

April 22, 2011

Computed Tomography Specialist's Factual Report

CEN-11-IA-193

A. INCIDENT

Operator:	Gulfstream Aerospace
Location:	Outagamie County Regional Airport (ATW), near Appleton, Wisconsin
Date:	February 14, 2011
Time:	Approximately 1315 local time
Airplane:	Gulfstream Aerospace GV-SP airplane, N535GA

B. GROUP

Computed Tomography Specialist:	Scott Warren National Transportation Safety Board Washington, D.C.

C. SUMMARY

On February 14, 2011, about 1315 central standard time, a Gulfstream Aerospace GV-SP airplane, N535GA, incurred minor damage during a landing overrun on runway 30 (6,501 feet by 150 feet, dry concrete) at the Outagamie County Regional Airport (ATW), near Appleton, Wisconsin. The flight crew reported a loss of a hydraulic system. The two certificated airline transport pilots and one passenger were not injured. The maintenance test flight was conducted under the provision of 14 Code of Federal Regulations Part 91. Visual meteorological conditions prevailed and an instrument flight rules flight plan was on file for the flight. The local flight departed from ATW.

Radiographic studies were done on March 24-25, 2011 in Chicago, Illinois to examine and document the internal configuration of the hydraulic swivel assembly from the nose landing gear. The hydraulic swivel assembly was documented using a combination of computed tomography (CT) scans and digital radiography. The swivel assembly was imaged using a total of 11 digital radiographs and 3,021 CT slices.

Review of the images indicated that there were areas within the center swivel that contained irregular gaps between the inner spool and outer housing. In some areas, the gaps were wider than adjacent areas, and in other areas, the gaps were smaller than adjacent areas. Some thin pieces of unknown debris were noted in one of the seal cavities, and in other seal cavities, there were appeared to be abnormalities in the seal positions within the cavities.

D. DETAILS OF THE INVESTIGATION

1.0 General

The hydraulic swivel assembly for the nose landing gear was subjected to x-ray computed tomography (CT) and digital radiography scanning to document its internal condition. The complete assembly was imaged using digital radiography, while only the center swivel, which was reported to be unable to rotate, was imaged using CT. The scanning was conducted from March 24-25, 2011. The scans were performed by Varian Medical Systems, Inc (formerly Bio-Imaging Research, Inc. (BIR)) under the direction of the NTSB.

To conduct the scans, Varian used an ACTIS 800/450-225 CT system with a 225 kV MicroFocus source using an x-ray source strength of 220 kV and 350 µA. The system recorded the x-ray attenuation information using a Perkins-Elmer flat panel detector system.

For the CT scans, the assembly was loaded into the imaging unit and placed on a turntable. The assembly was then rotated in front of the x-ray source, and the x-rays were captured by a detector after they went through the assembly. The x-ray source produced a cone of x-rays, and the portion of the assembly imaged by this

slice was adjusted slightly after each scan volume was completed until the entire assembly (or region of interest of the assembly) was scanned. The x-ray energy levels captured by the detector were recorded at 2,160 different points during each rotation, and this information was converted into slice images using reconstruction algorithms.

The scan volumes resulting from the CT work were divided into 3,021 slices. Each slice was 2,048 x 2,048 pixels wide and had a resulting image file size of slightly over 8 megabytes (Mb). The slices were created with a thickness of 0.150 mm at a spacing of 0.030 mm with a cross sectional pixel dimension within each slice of approximately 0.027 mm x 0.027 mm.

For the digital radiograph (DR) images, the assembly was subjected to a process similar to a conventional x-ray. The image was gathered using the same detector used for the CT scans, but the assembly did not rotate, and the images contain elements superimposed on each other. Each swivel joint was imaged at least twice, and the separate images were rotated by up to 90 deg.

Each data set of slice images was evaluated using the VGStudioMax software package to create a three-dimensional reconstructed image of the component. As part of the evaluation, some sections of the actuator were digitally removed to allow closer observation of interior parts.

For the purposes of this study, the individual swivel units making up the full assembly were arbitrarily numbered 1, 2, and 3 corresponding to their positions in the Pneu Draulics, Inc. drawing 7438-4. In this drawing, the swivel containing the inlet pressure port and outlet return port was the furthest to the right, or number 3 (this swivel was reported to be attached to the nose landing gear drag brace), the center swivel was number 2, and the remaining swivel was number 1 (this swivel was reported to be attached to the nose landing gear strut).

The images of the assembly were examined for any signs of missing or damaged parts, contamination in the hydraulic passageways, or any other anomalies. Specific results (including example images) are presented in subsequent sections of this report.

2.0 Digital Radiograph Results

The digital radiographs for the assembly are presented in figures 1 through 6. Note that in figure 1, the swivels are in a different orientation than that shown in Pneu Draulics, Inc. drawing 7438-4, and they are labeled accordingly. A close up of the inner spool of the center swivel showing possible irregularities in the gap between the inner spool and the outer housing is shown in figure 4.

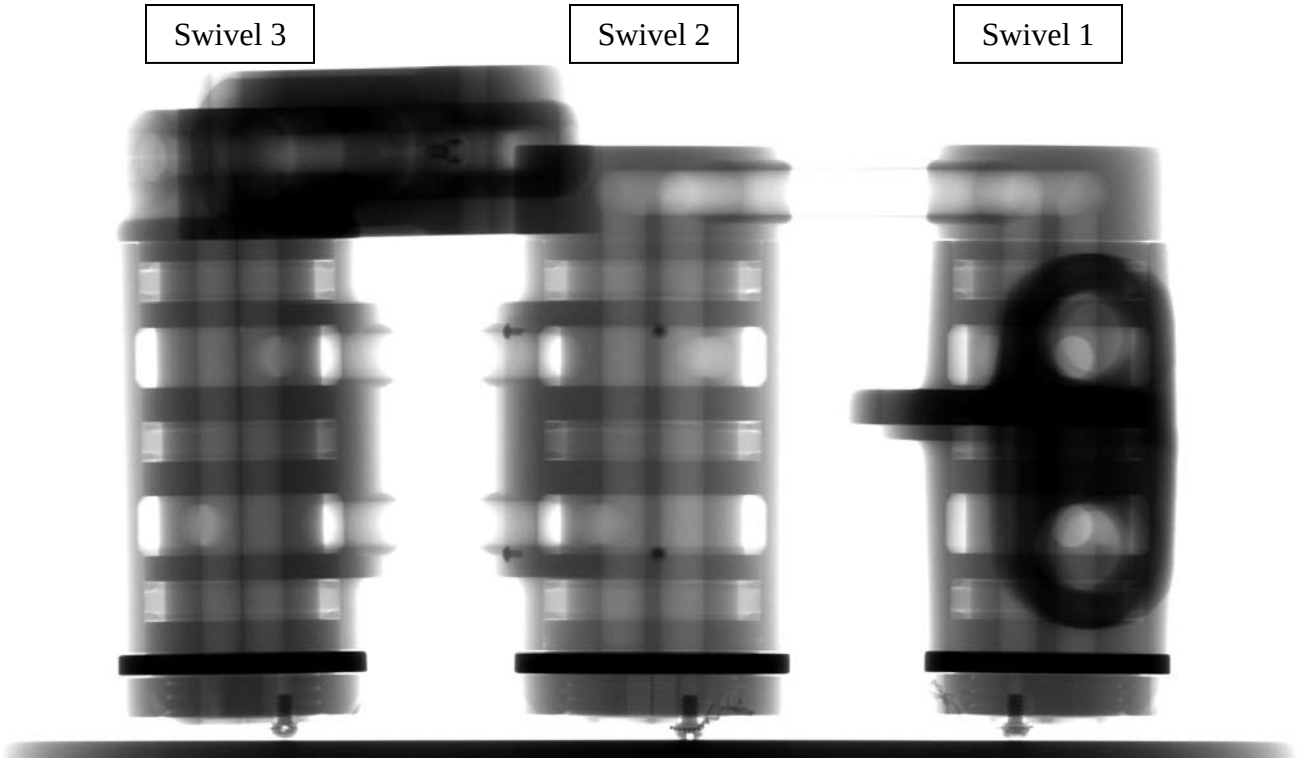

Figure 1
Digital Radiograph – Entire Swivel Assembly

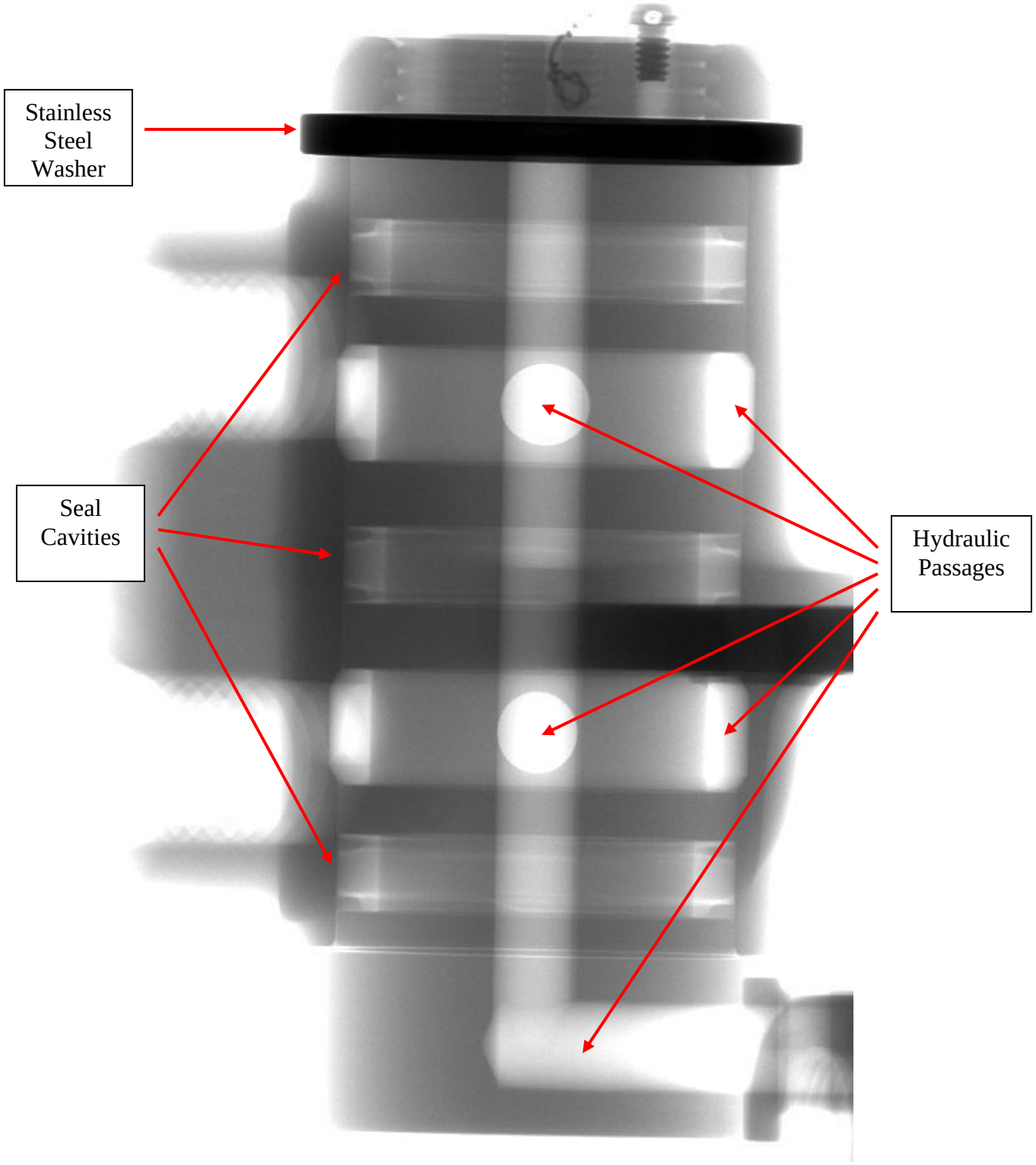

Figure 2
Digital Radiograph – Swivel 1

Figure 3
Digital Radiograph – Swivel 2

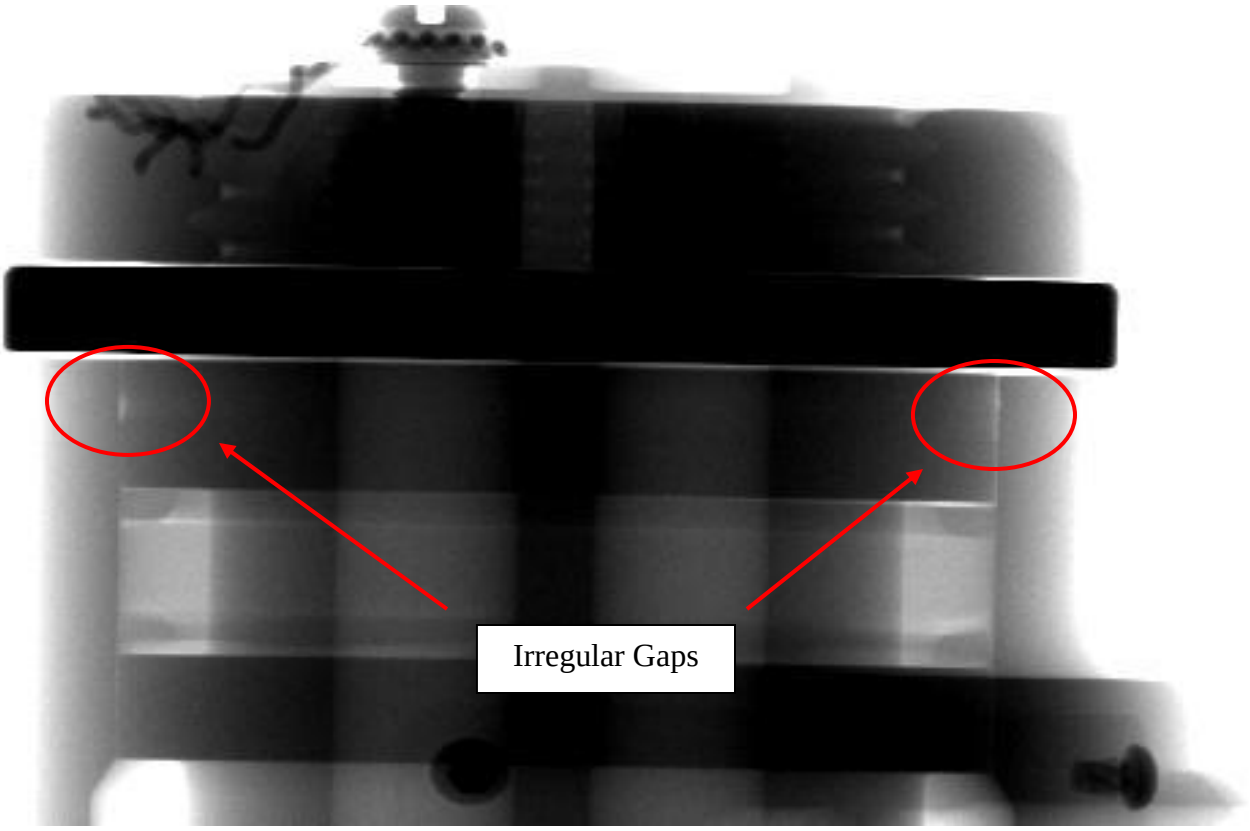

Figure 4
Digital Radiograph – Swivel 2 – Close up

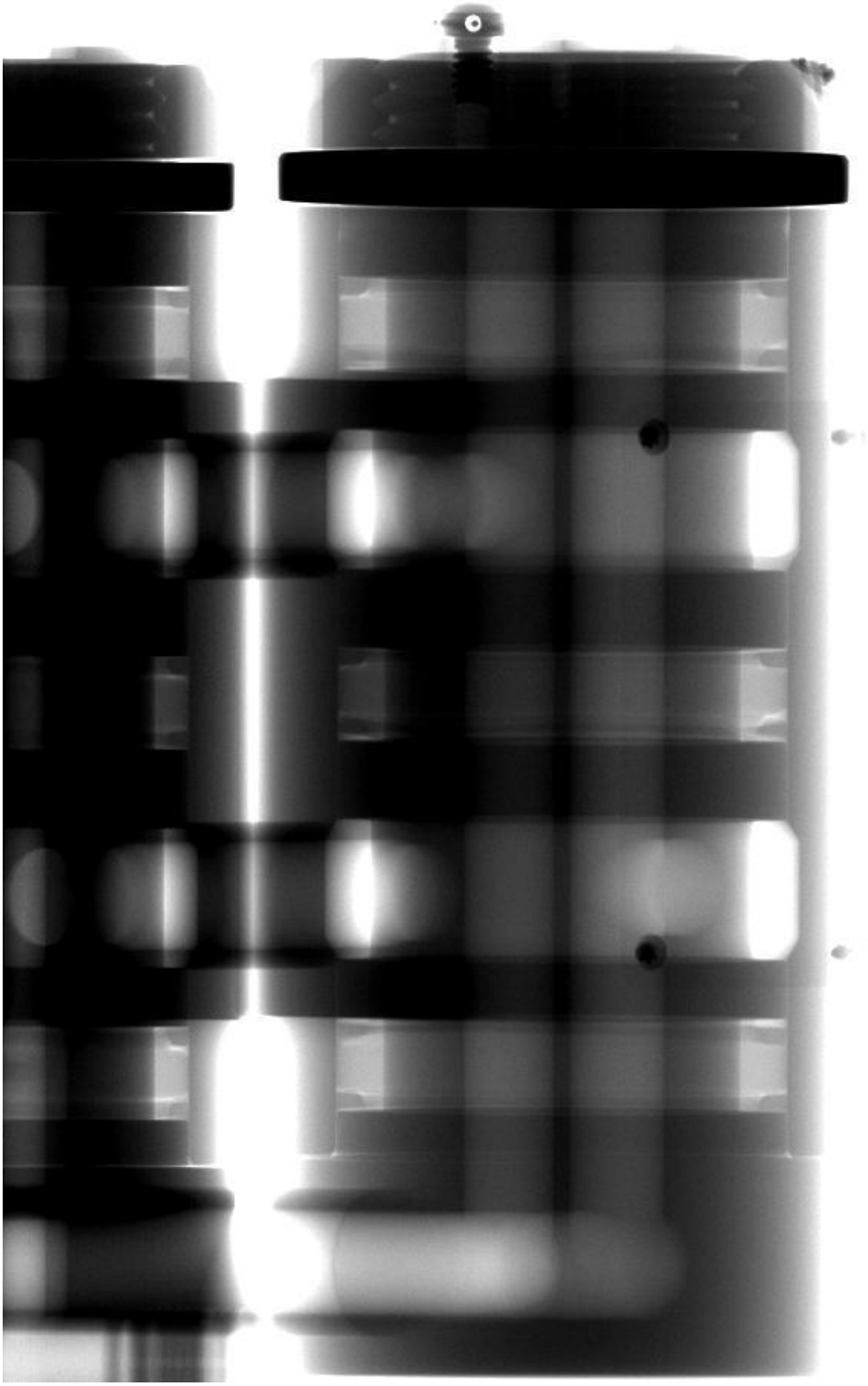

Figure 5
Digital Radiograph – Swivel 2 (rotated 90 deg)

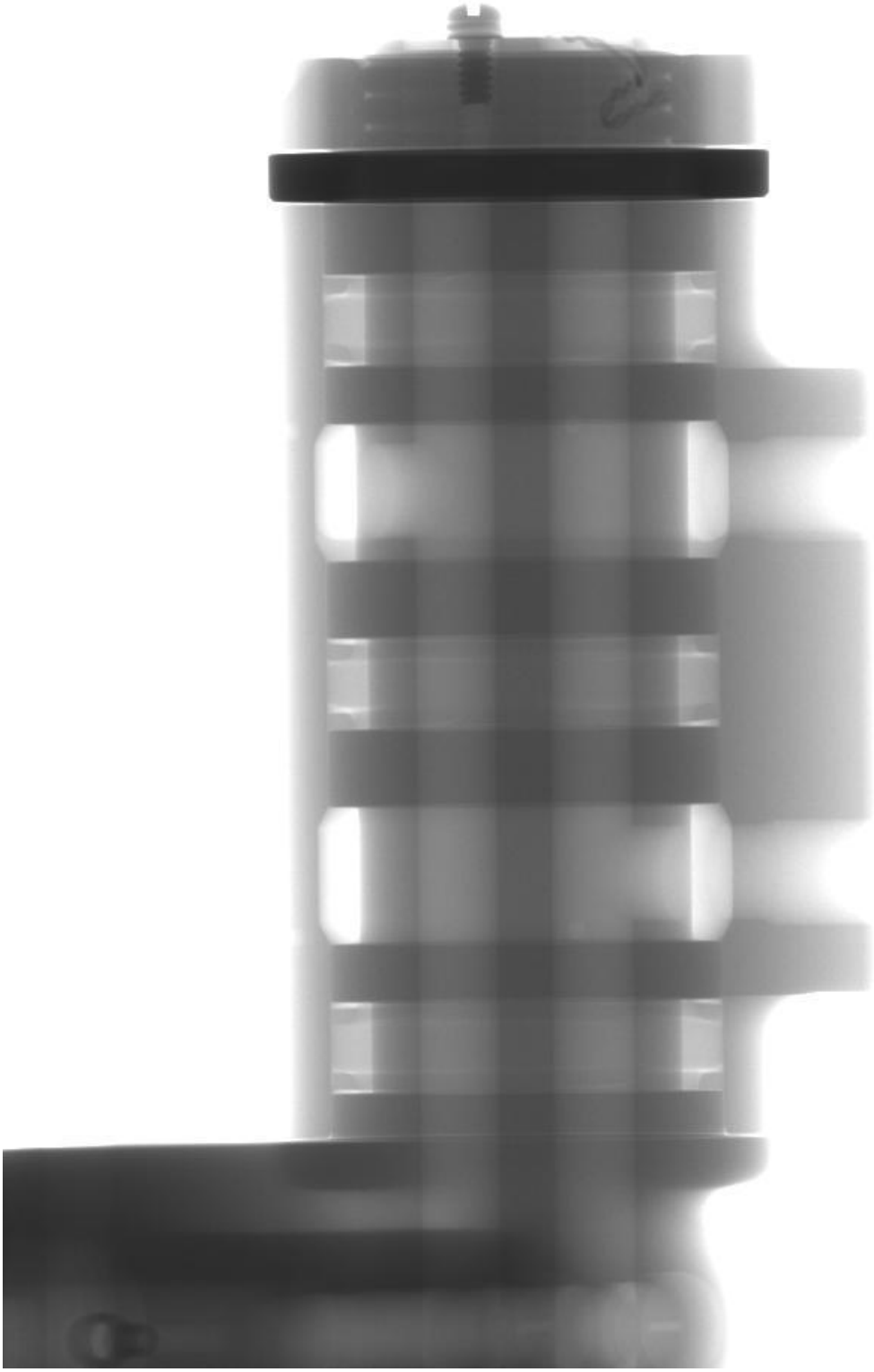

Figure 6
Digital Radiograph – Swivel 3

3.0 Computed Tomography Results – Swivel Two

The computed tomography (CT) results for swivel 2 are shown in figures 7 through 20. Swivel 2 was the only part of the assembly to be imaged using CT. Irregular gaps between the inner spool and outer housing were noted in two different areas of swivel 2. These areas were at opposite ends of the swivel and are shown in figures 9 through 12 and in figures 17 and 18. In addition, an area of potential debris underneath a seal was noted in one set of seals, while a different type of seal abnormality was noted in another set of seals. These abnormal areas are shown in figures 13 through 16 and in figures 19 and 20.

Note that the orientation of the swivel for the CT scans was opposite that used during the DR imaging. In the DR imaging, the stainless steel washer was at the top of the images (except for figure 1, the image showing all three swivels), while in the CT scans, the stainless steel washer was at the bottom of the images.

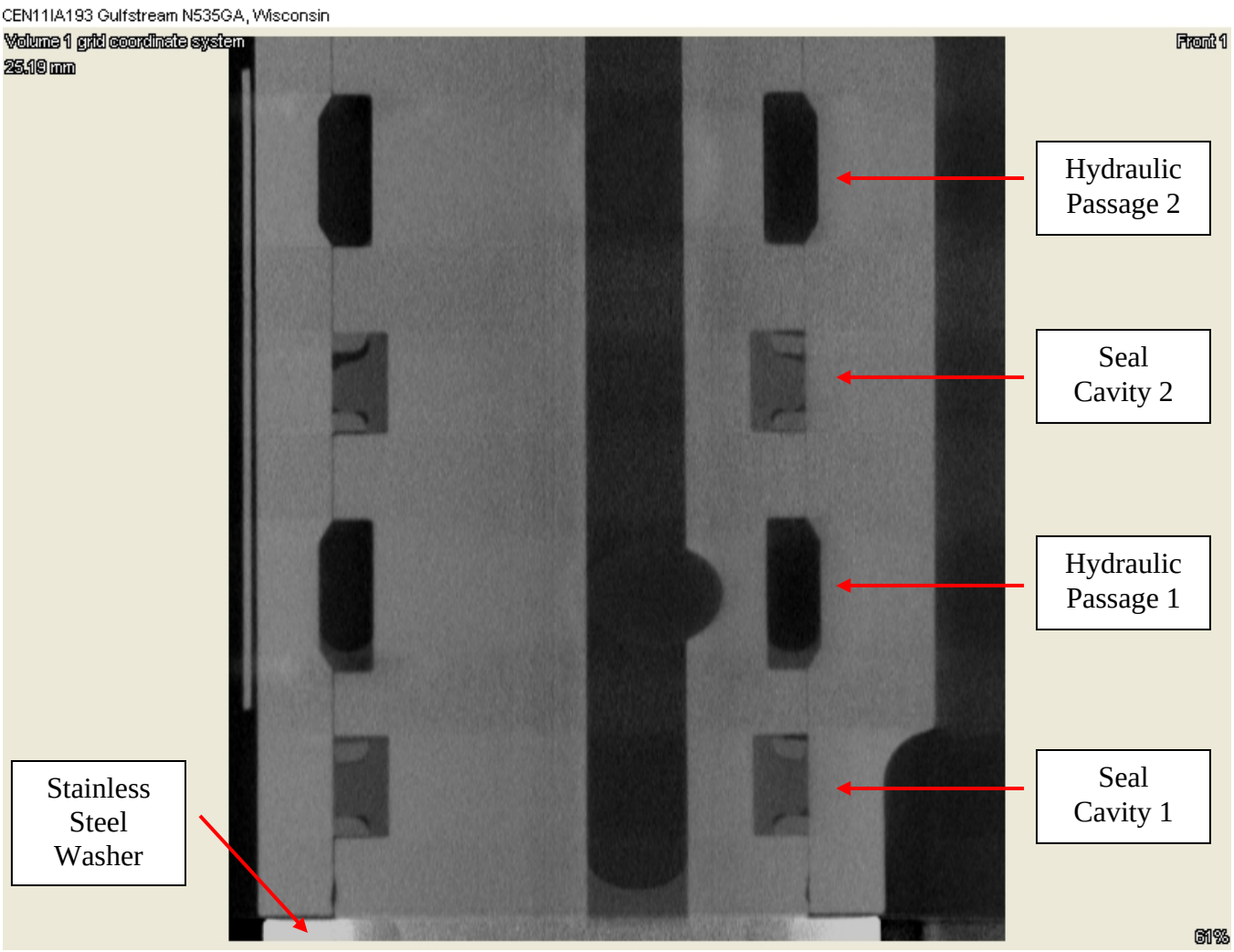

Figure 7
Frontal Cross Section – Swivel 2 – Overall View Showing Lower (as scanned) Portion of the Swivel

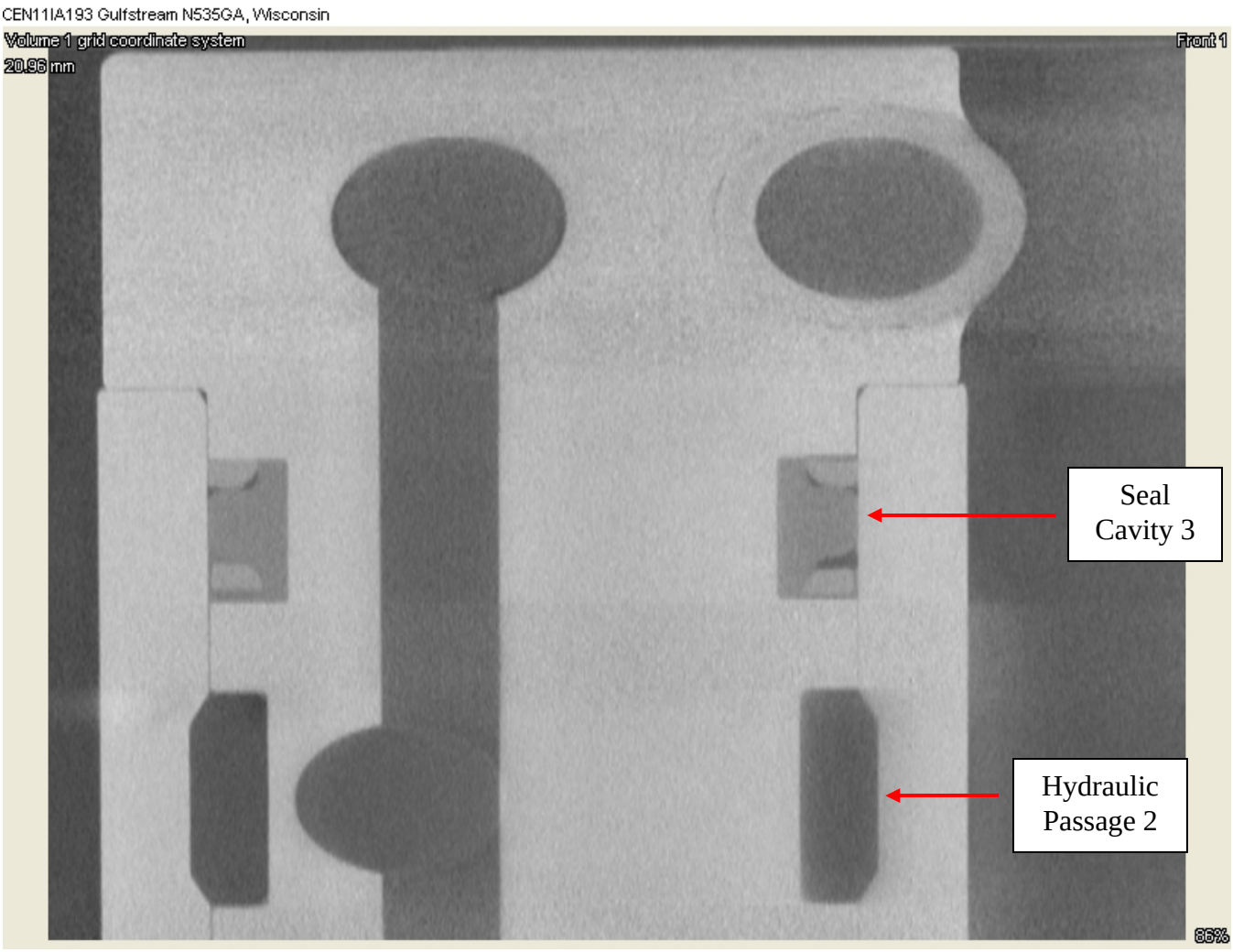

Figure 8
Frontal Cross Section – Swivel 2 – Overall View Showing Upper (as scanned) Portion of the Swivel
Note: Hydraulic Passage 2 is Shown in this Figure and also in Figure 7

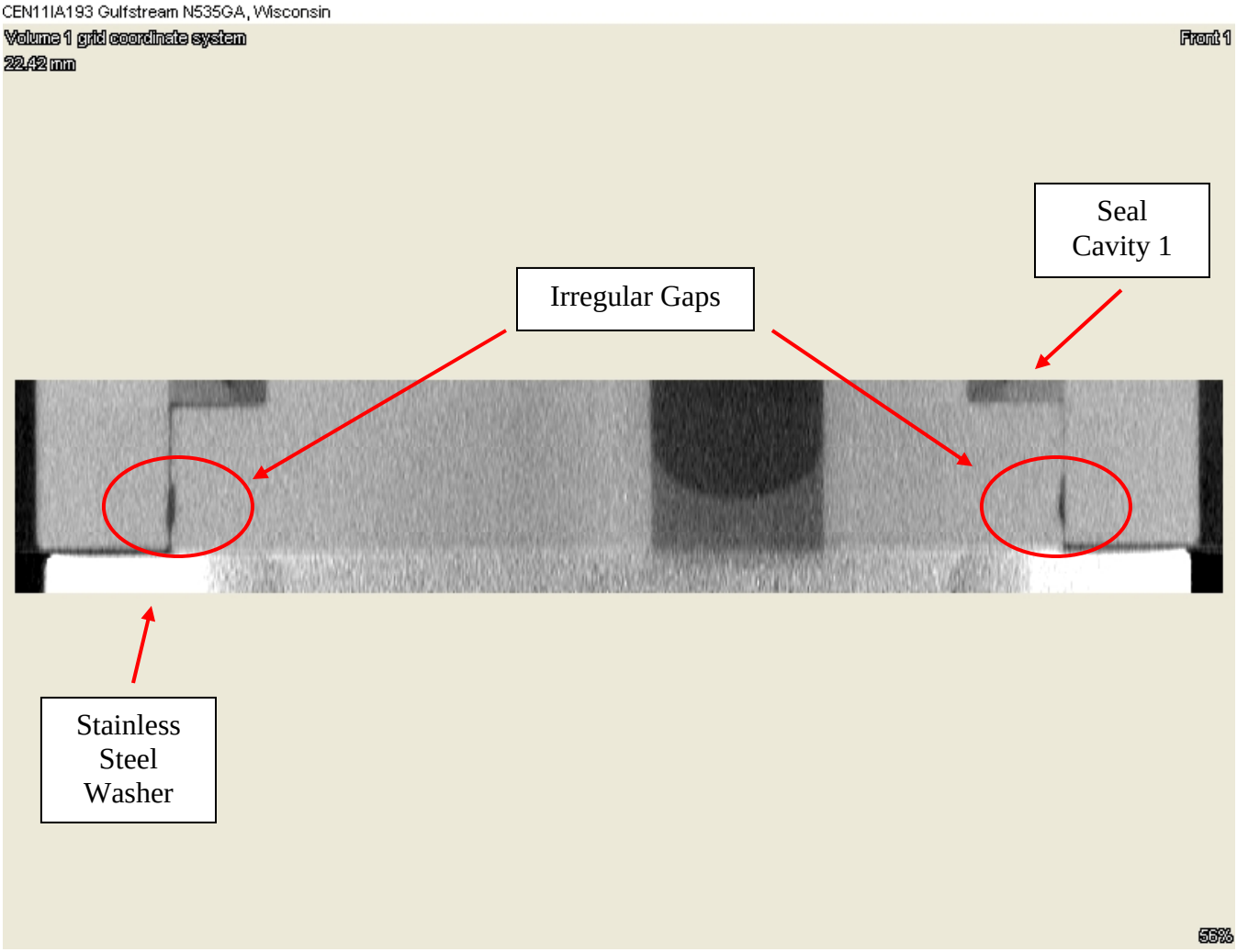

Figure 9
Frontal Cross Section - Swivel 2 – Irregular Gaps Between Inner Spool and Outer Housing Located Between Stainless Steel Washer and First Seal Cavity

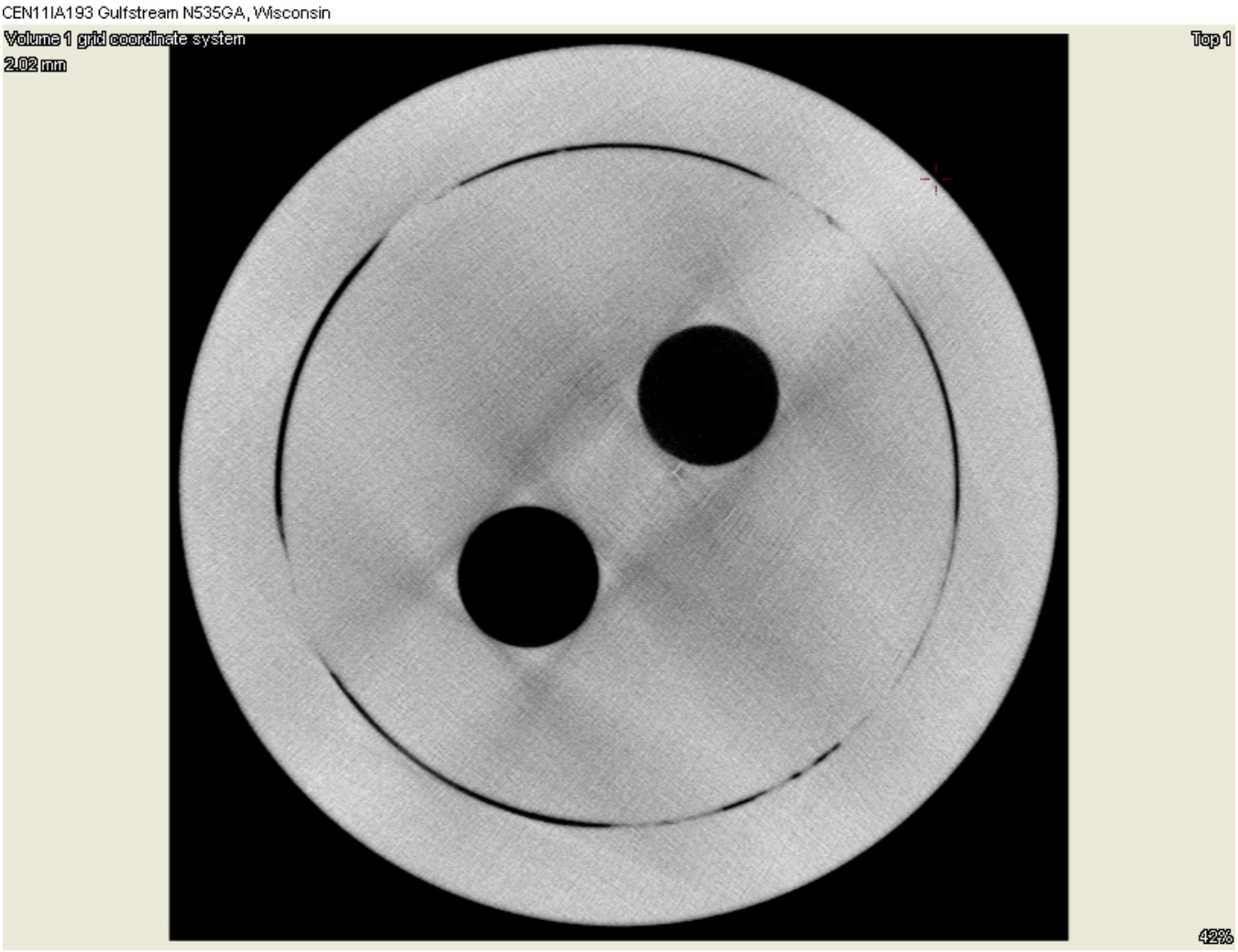

Figure 10
Axial Cross Section - Swivel 2 – Irregular Gaps Between Inner Spool and Outer Housing Located Between Stainless Steel Washer and First Seal Cavity

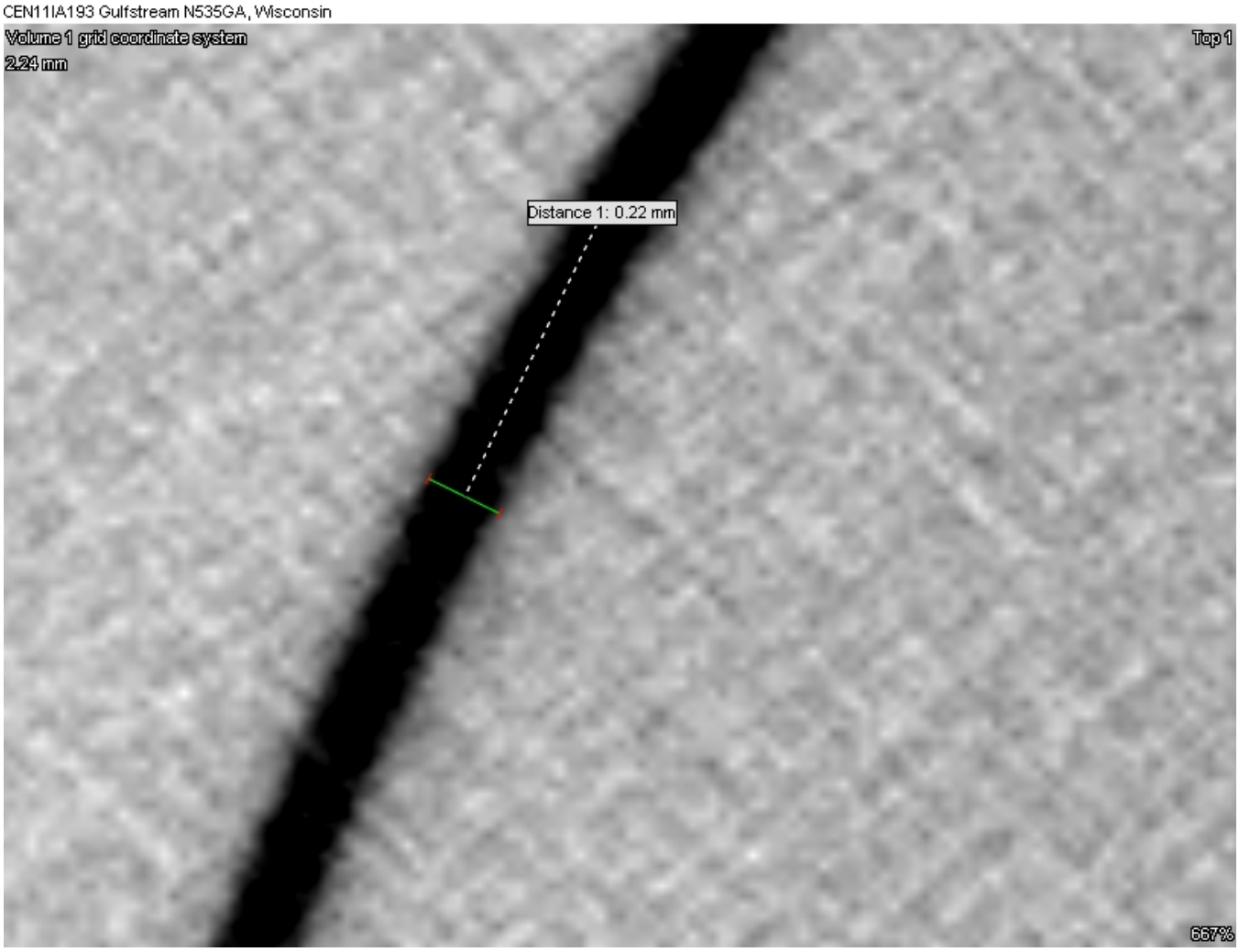

Figure 11
Axial Cross Section - Swivel 2 – Gap Between Inner Spool and Outer Housing with Measurement of 0.22 mm

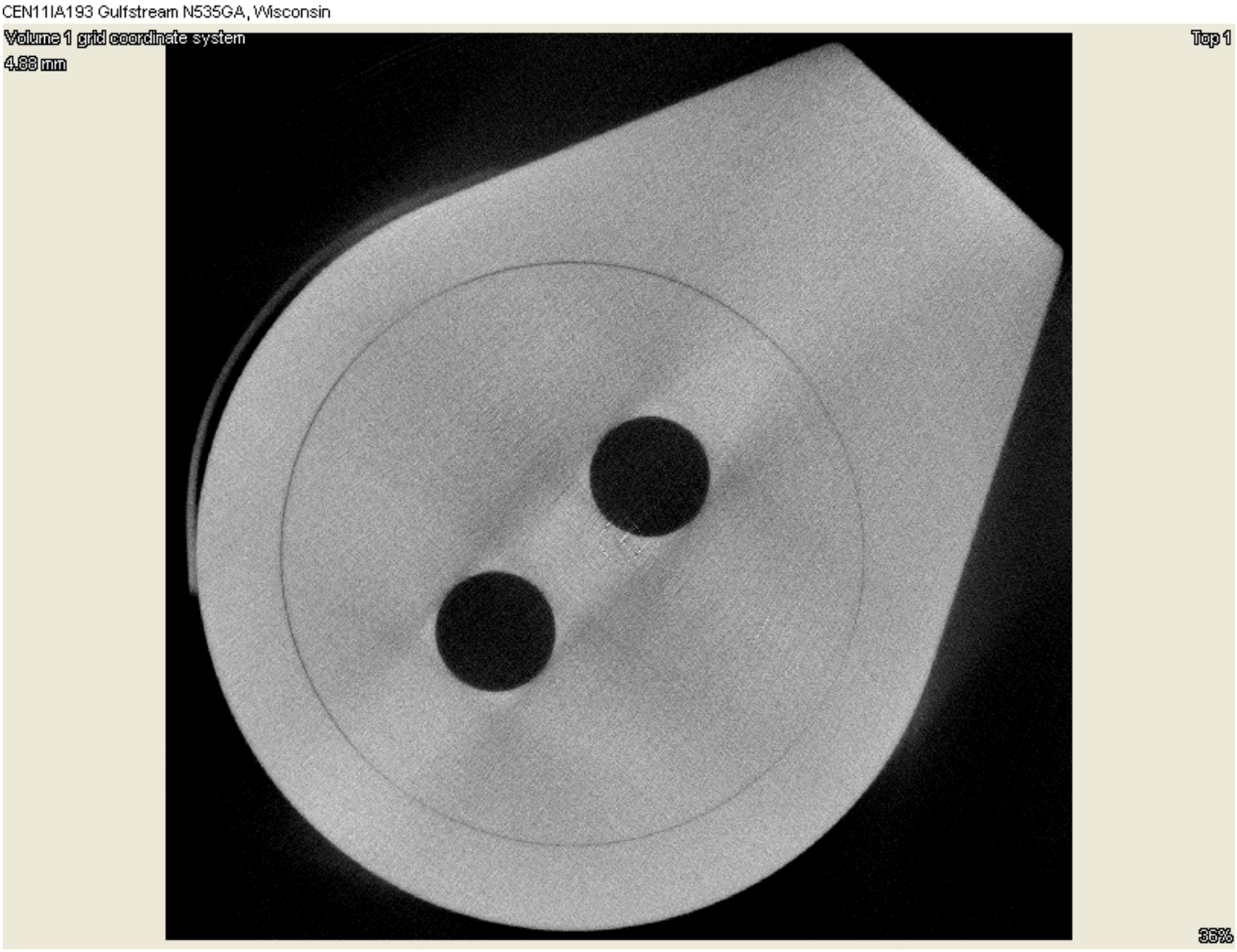

Figure 12
Axial Cross Section - Swivel 2 – Irregular Gaps Between Inner Spool and Outer Housing at a Point Just Above the First Seal Cavity

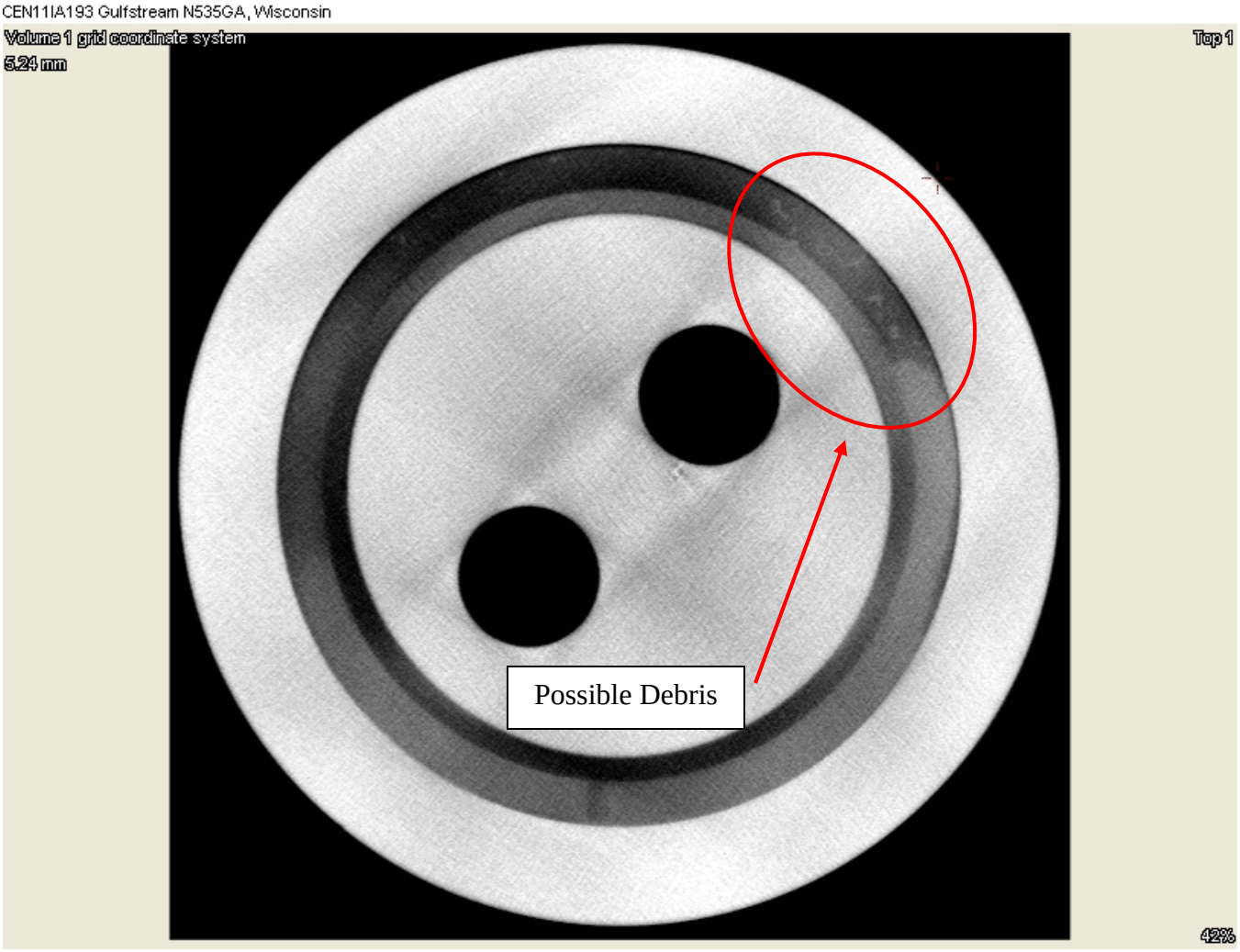

Figure 13
Axial Cross Section - Swivel 2 – Possible Debris in Seal Cavity 1

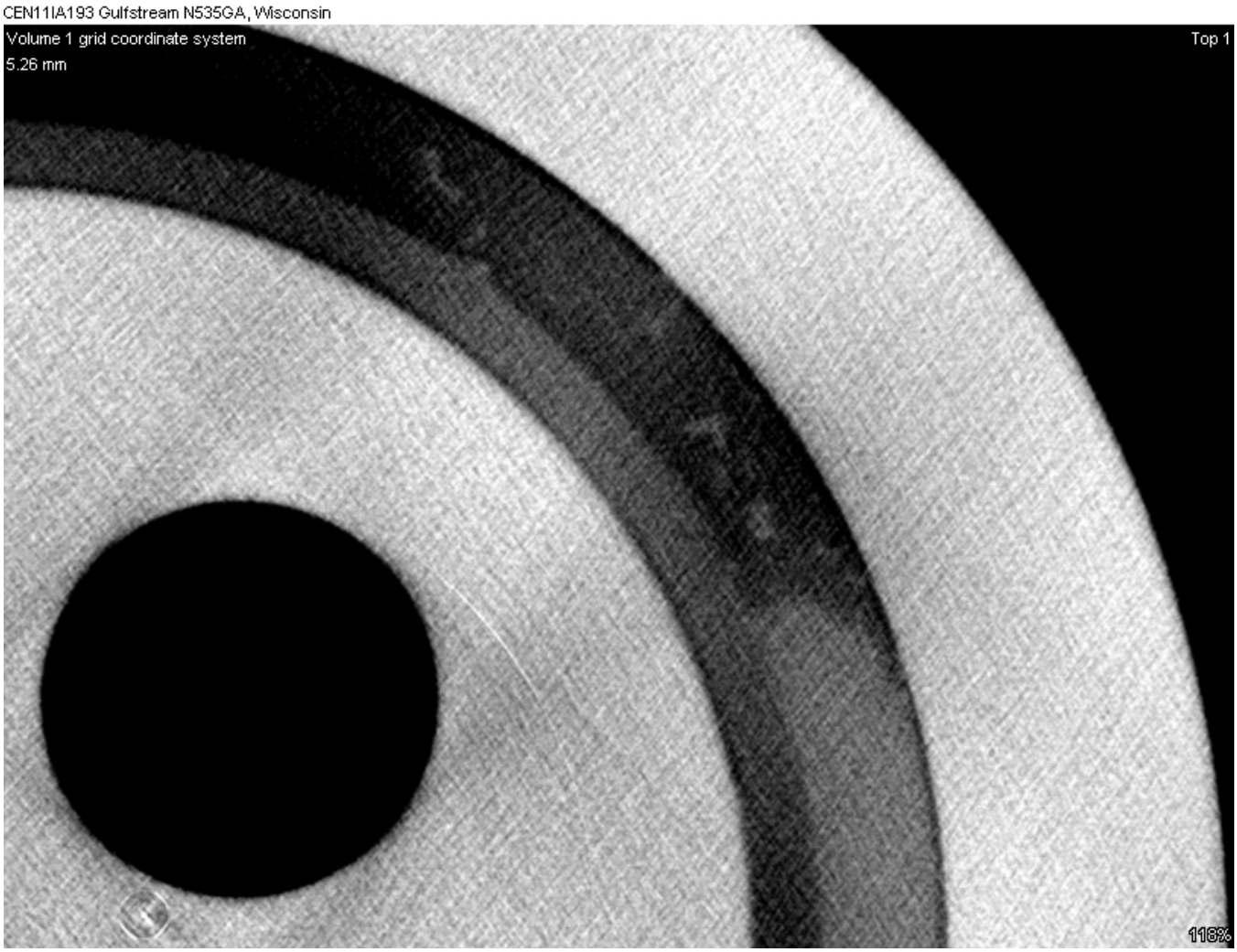

Figure 14
Axial Cross Section - Swivel 2 – Possible Debris in Seal Cavity 1 (Close Up View)

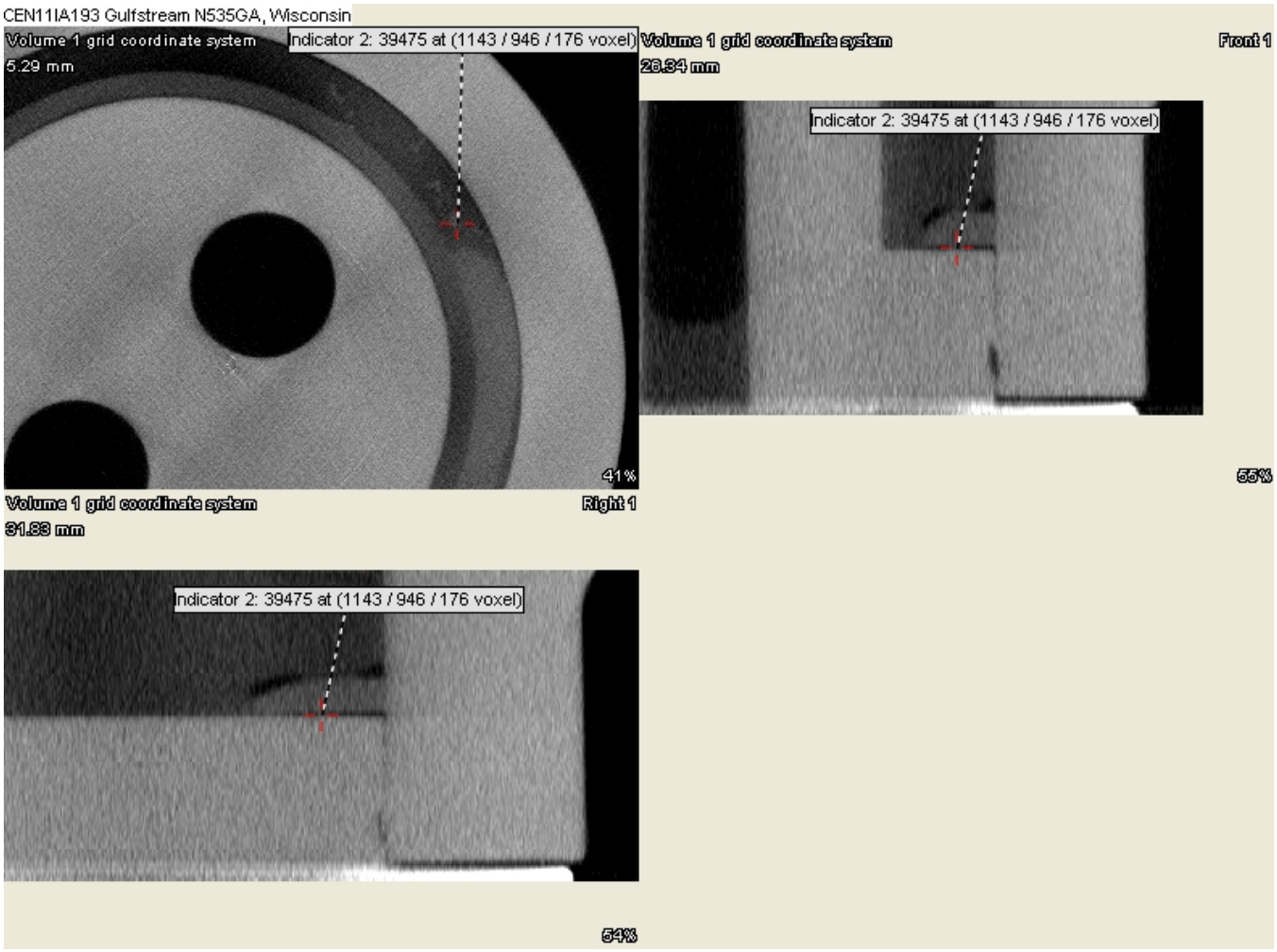

Figure 15
Multiple Views (Axial, Frontal and Right Cross Sections) – Swivel 2 – Possible Debris in Seal Cavity 1 - Location of Possible Debris Relative to the Seals

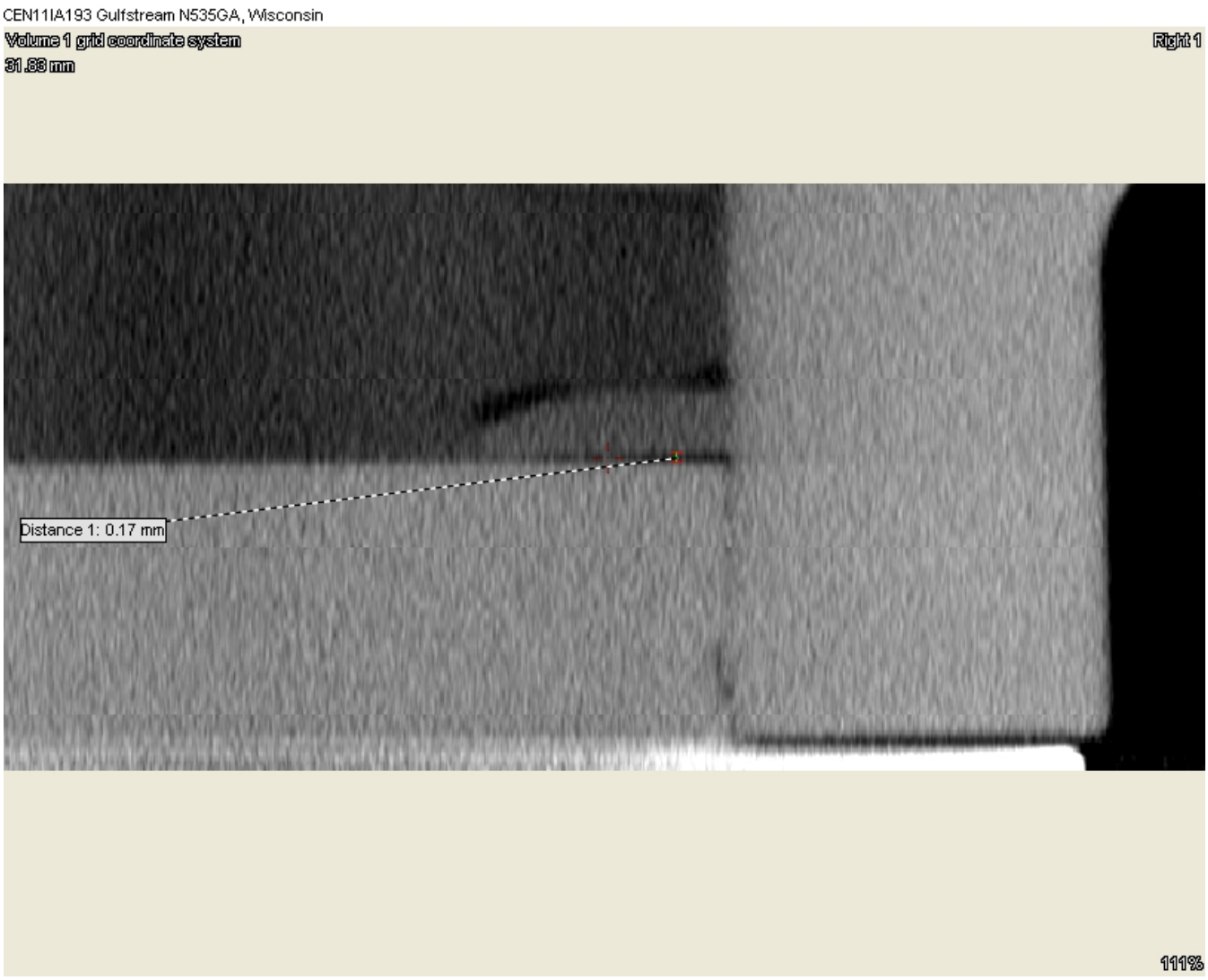

Figure 16
Frontal Cross Section - Swivel 2 – Possible Debris in Seal Area – Side View Showing Gap Dimension of 0.17 mm

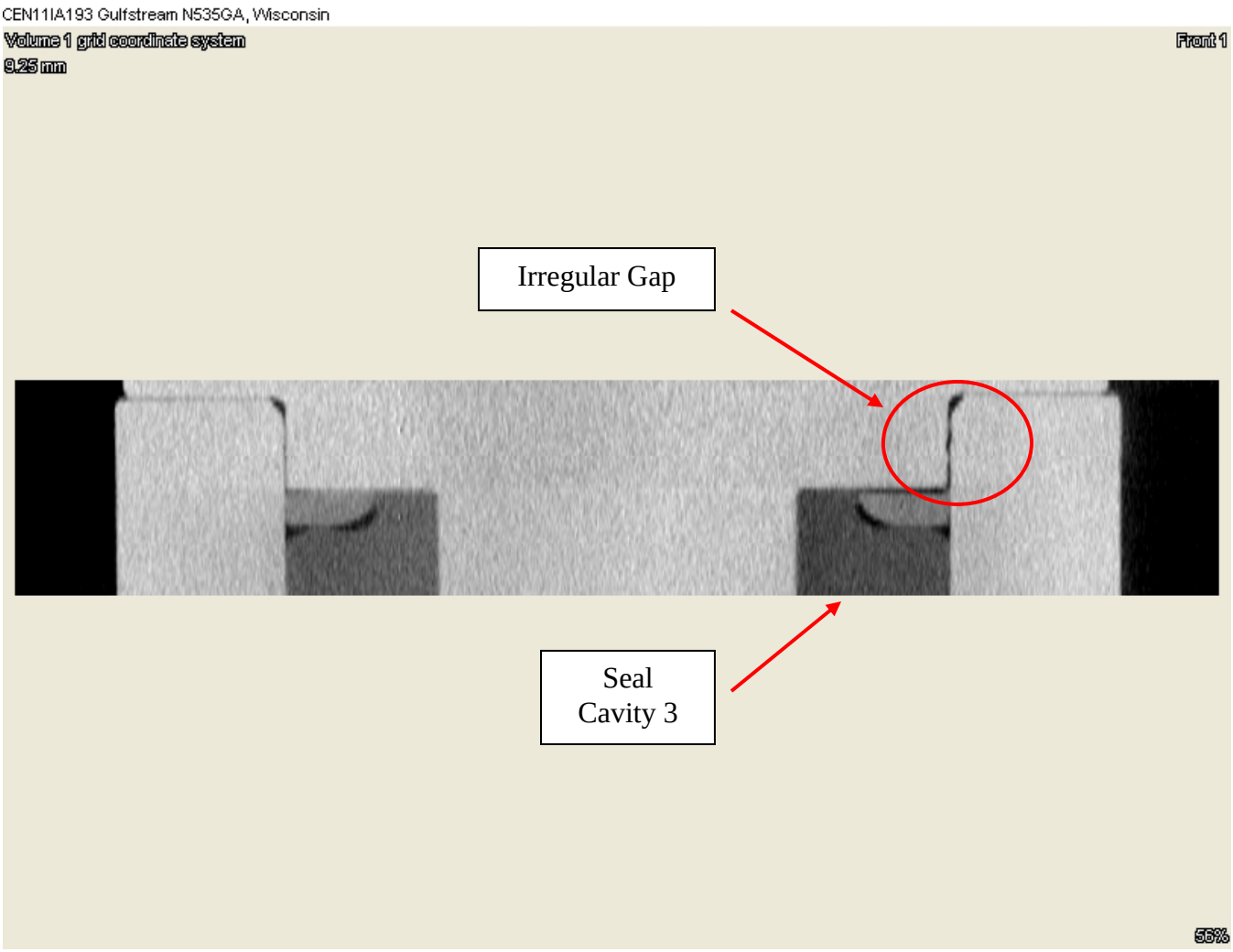

Figure 17
Frontal Cross Section – Swivel 2 – Irregular Gap Between Inner Spool and Outer Housing in Area Above Third Seal Cavity

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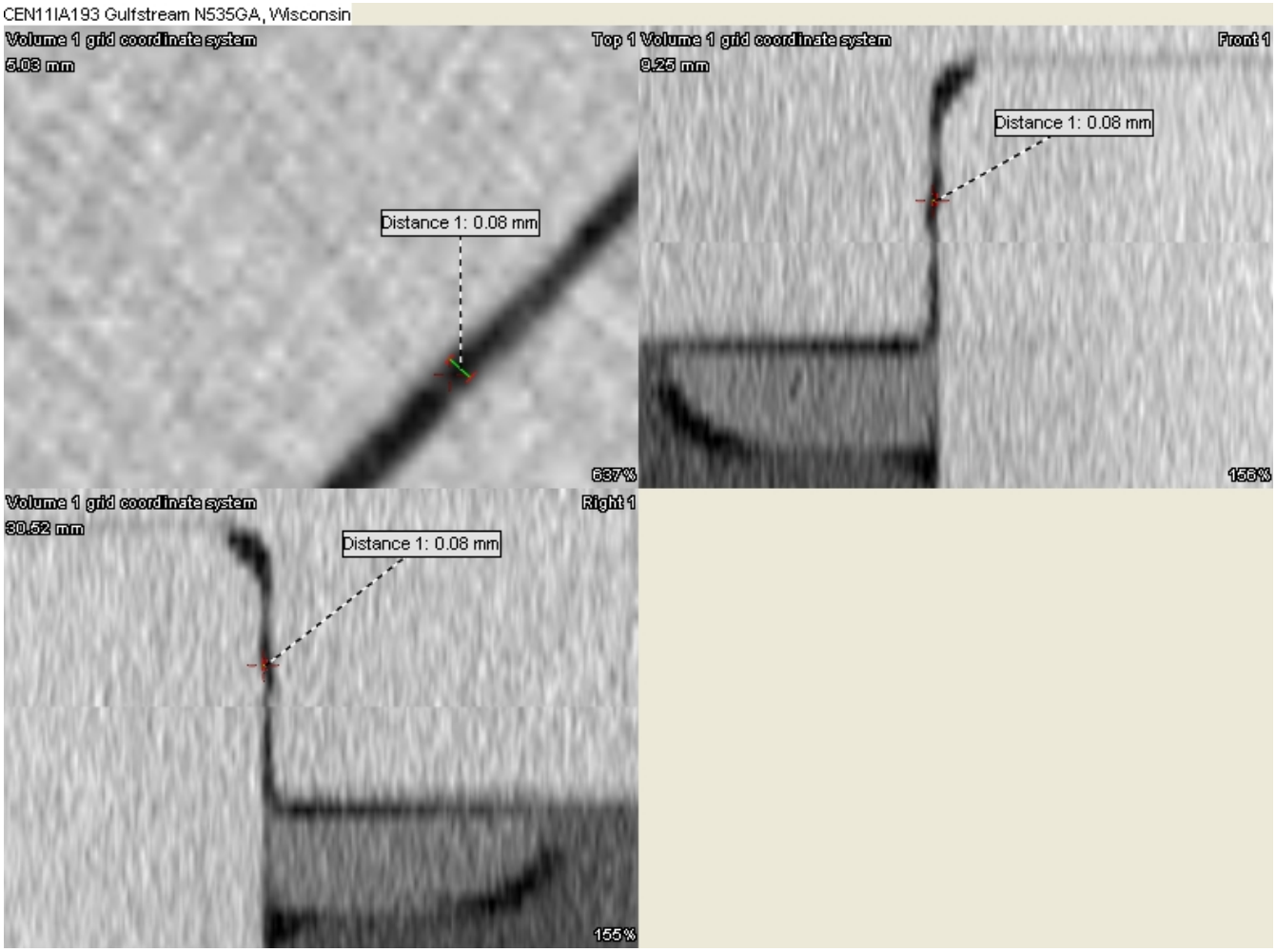

Figure 18
Multiple Views (Axial, Frontal and Right Cross Sections) – Swivel 2 – Irregular Gaps Between Inner Spool and Outer Housing in Area Above Third Seal Cavity Showing a Gap Dimension of 0.08 mm

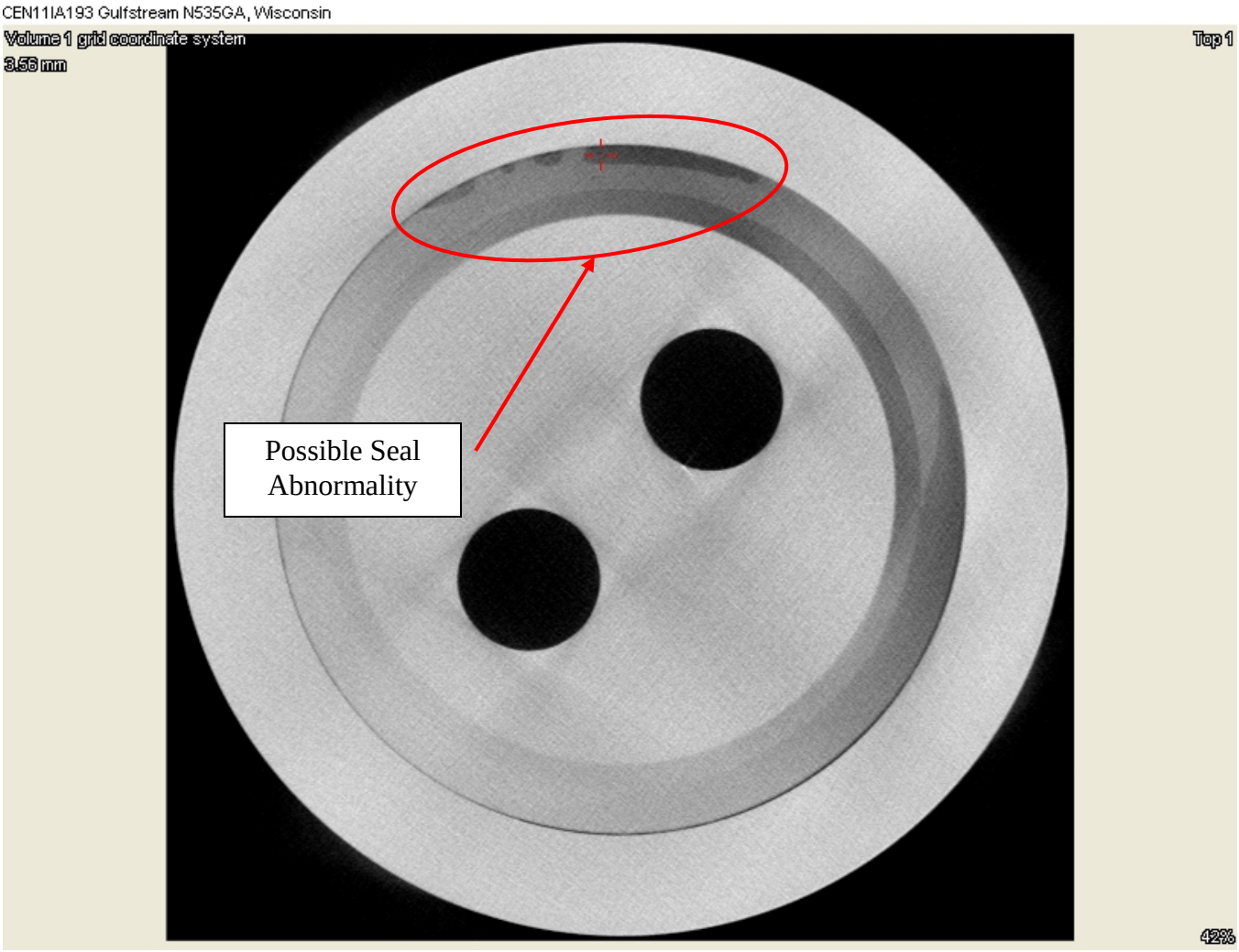

Figure 19
Axial Cross Section – Swivel 2 – Possible Seal Abnormalities in the Third Seal Cavity

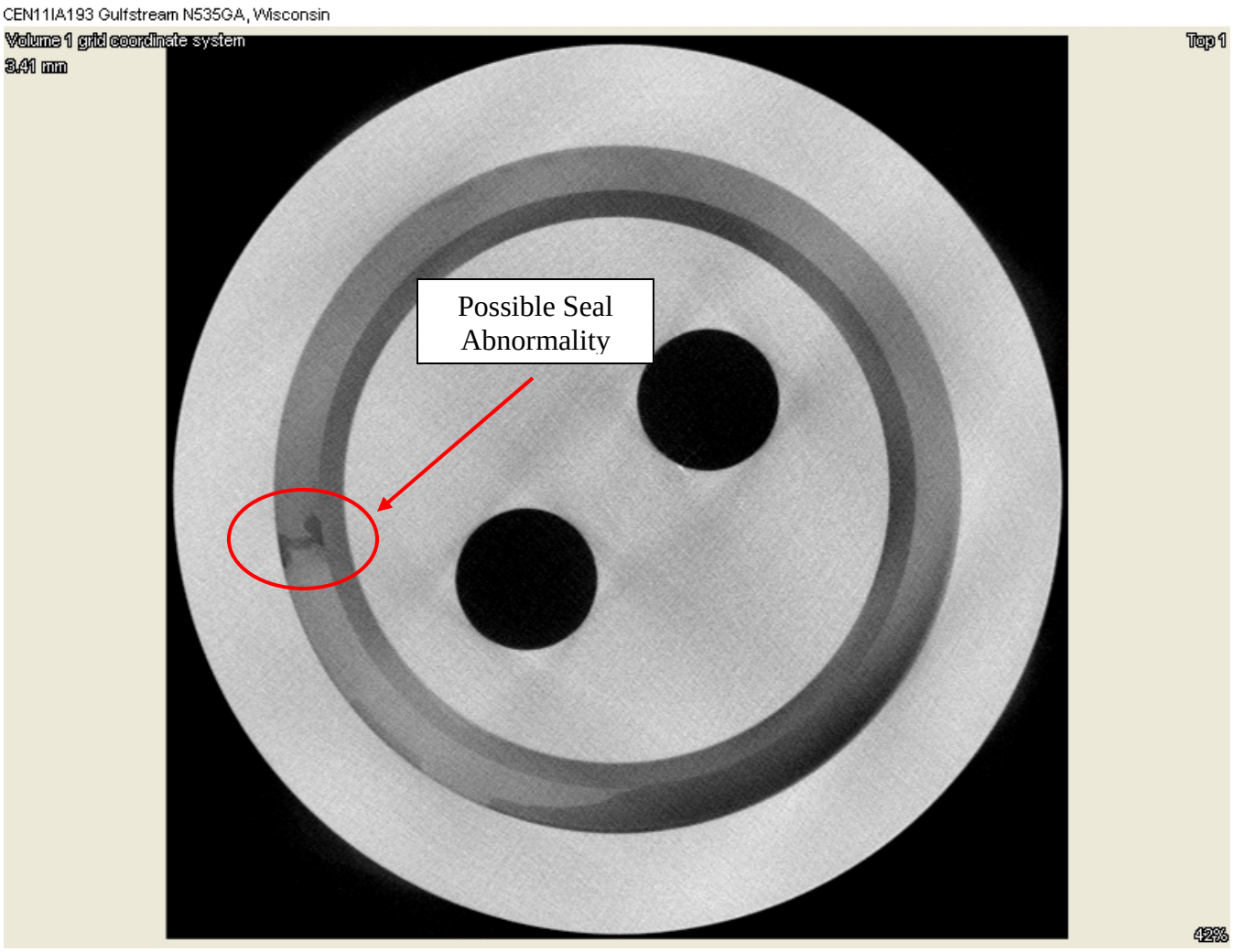

Figure 20
Axial Cross Section – Swivel 2 – Possible Seal Abnormality in the Third Seal Cavity

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