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

December 2, 2011

Computed Tomography Specialist's Factual Report

CEN-11-IA-379

A. INCIDENT

Operator:	Skywest Airlines
Location:	General Mitchell Airport, Milwaukee, Wisconsin
Date:	June 6, 2011
Time:	2132 central daylight time
Airplane:	Bombardier CRJ-2B19, N866AS

B. GROUP

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

C. SUMMARY

On June 6, 2011, about 2132 central daylight time, N866AS, a Bombardier CL-600-2B19, operated as Skywest Airlines flight 4443, landed with the right main landing gear retracted on runway 19R at the General Mitchell International Airport (MKE), Milwaukee, Wisconsin. The flight departed Cincinnati/Northern Kentucky International Airport, near Covington, Kentucky, about 1951, and was destined for MKE. The flight crew reported a gear indication problem to air traffic controllers and performed a low pass for air traffic control tower observation. The tower observed the right main landing gear in the retracted position. After performing troubleshooting checklists, the crew landed the airplane with the right main landing gear retracted.

The airplane sustained minor damage to the right wing tip, right flap assemblies, and right flap pylon assemblies. The right main landing gear door was up and the right main gear was in its wheel well.

Radiographic studies were done on August 25-27, 2011 in Chicago, Illinois to examine and document the internal configuration of the pressure and return hydraulic filters. The filters were documented using a combination of computed tomography (CT) scans and digital radiography. The filters were imaged using a total of 4 digital radiographs (DR) (2 DR's for the pressure filter and 2 DR's for the return filter) and 10,918 CT slices (4,961 slices for the pressure filter and 5,957 slices for the return filter).

There were three particles found in the pressure filter and one particle found in the return filter. There were several cracks noted in the epoxy material in the end caps of the return filter, and there were some high density areas noted in both filters within the filter material itself.

D. DETAILS OF THE INVESTIGATION

1.0 General

The pressure and return filters were subjected to x-ray computed tomography (CT) and digital radiography scanning to document the internal conditions of both filters. The scanning for the pressure filter was conducted from August 25-26, 2011, and the scanning for the return filter was conducted from August 26-27, 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 300 µA for the pressure filter and 200 kV and 300 µA for the return filter. The system recorded the x-ray attenuation information using a Perkins-Elmer flat panel detector system.

For the CT scans, the filters were loaded individually 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 cone 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 2,520 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 4,961 slices for the pressure filter and 5,957 slices for the return filter. Each slice was 2,048 x 2,048 pixels wide and had a resulting image file size of slightly over 8 megabytes (Mb). For the pressure filter, the slices were created with a thickness of 0.050 mm at a spacing of 0.025 mm with a cross sectional pixel dimension within each slice of approximately 0.019 mm x 0.019 mm. For the return filter, the slices were created with a thickness of 0.050 mm at a spacing of 0.025 mm with a cross sectional pixel dimension within each slice of approximately 0.024 mm x 0.024 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 filter was imaged at least twice, and the separate images were obtained at positions rotated by up to 90 deg.

Each data set of CT slice images was evaluated using the VGStudio Max software package to either view the individual slices in detail or to create a three-dimensional reconstructed image of the component. As part of the evaluation, some sections of the filters were digitally removed to allow closer observation of interior parts.

For this study, computing limitations precluded loading the complete data set into VGStudio Max at one time. The filters were examined in segments of approximately 10 mm each.

According to the filter manufacturer's drawings, when in operation, hydraulic fluid flowed from the outside of each filter through a stainless steel mesh and filter element, through another stainless steel mesh, and finally through holes in an inner support core. Once the fluid was inside the inner support core, it exited the filter through the large opening in the top of the filter.

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

2.0 Digital Radiograph Results

An example of a digital radiograph image (from the pressure filter) is presented in figure 1. The same image with markings to denote specific items in the filter's architecture is included as figure 2. These items are common to both the pressure and return filters. No particles or other defects were noted in any of the digital radiographs.

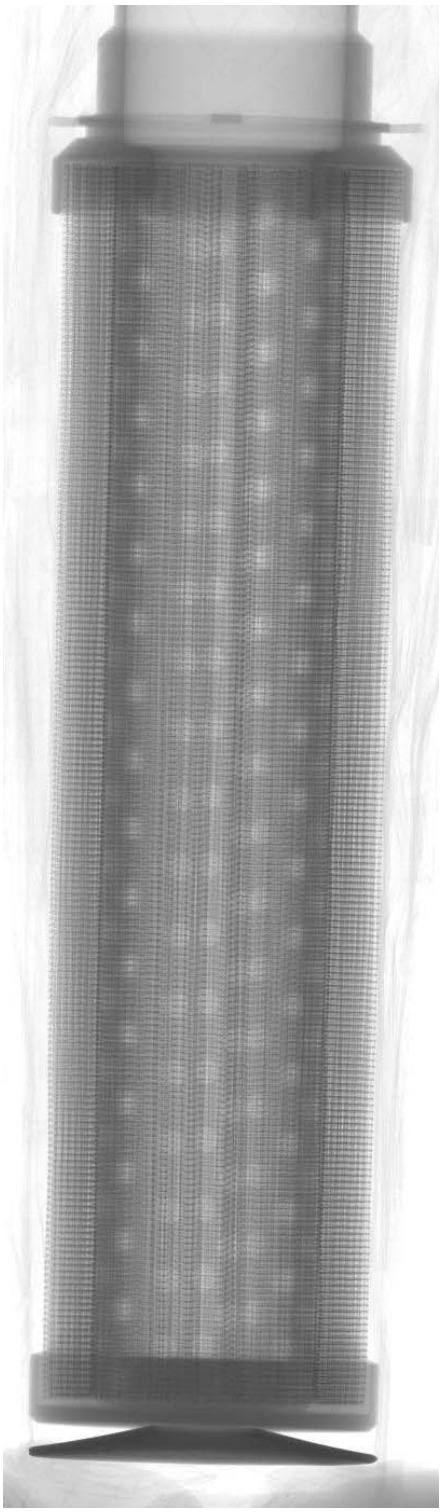

Figure 1
Digital Radiograph – Pressure Filter

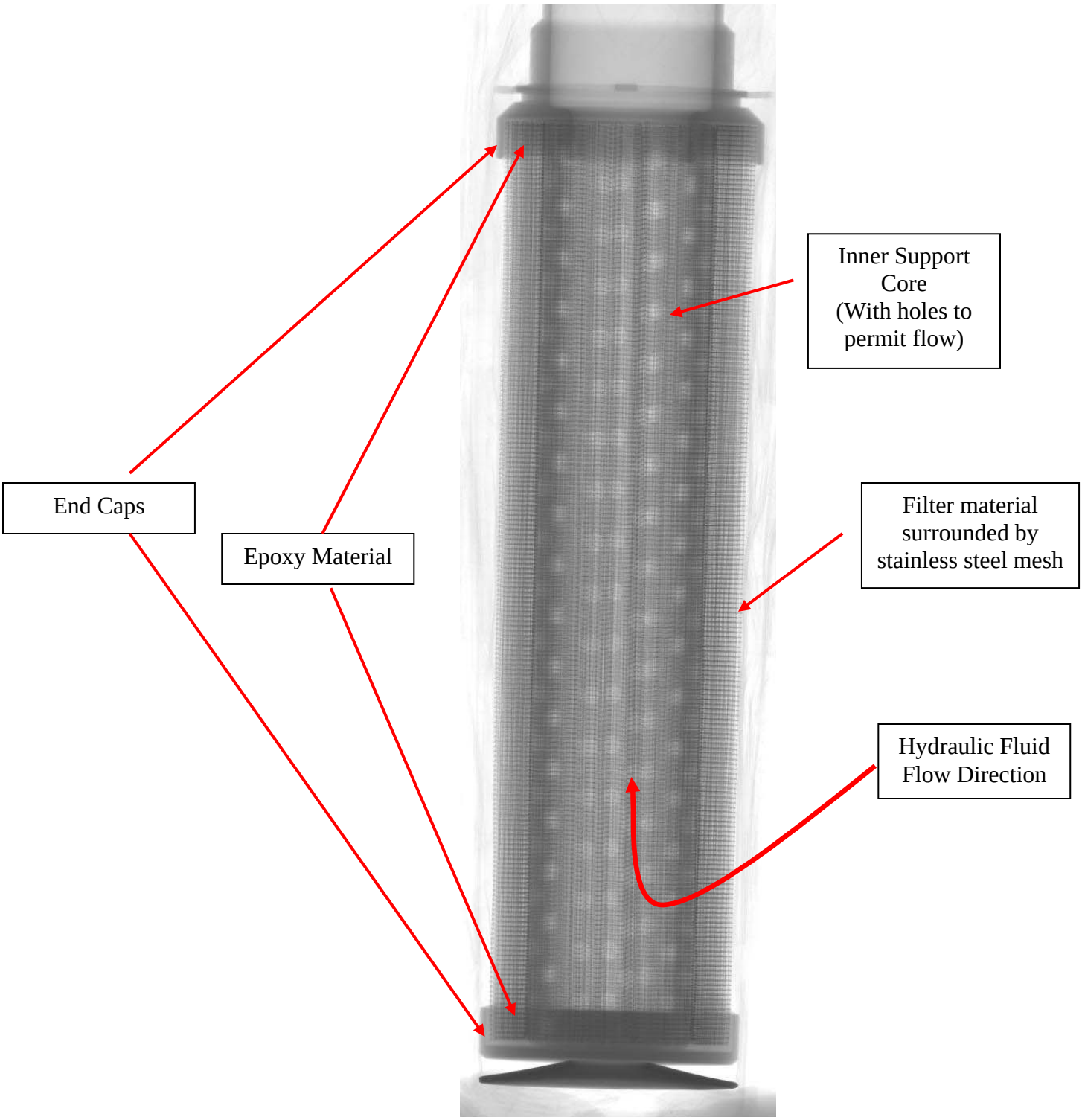

Figure 2
Digital Radiograph – Pressure Filter with components labeled

3.0 Computed Tomography Results – Pressure Filter

The computed tomography (CT) results for the pressure filter are shown in figures 3 through 9. Particles of different sizes and densities were found in the upper portion of the pressure filter. The debris inside the pressure filter was composed of both high density (bright) particles and lower density material. These particles ranged in length from 0.10 mm to 0.32 mm. All of the particles in the pressure filter were found as individual particles.

In the caption for each figure, the section of the filter in which the image was captured is contained in the "Pressure Filter (section xx-xx)" notation, where the section number denotes the 10 mm section of the filter as recorded in the CT scanning equipment. The values are based on the reference system used during the CT scans, and they do not correspond to any drawing coordinates.

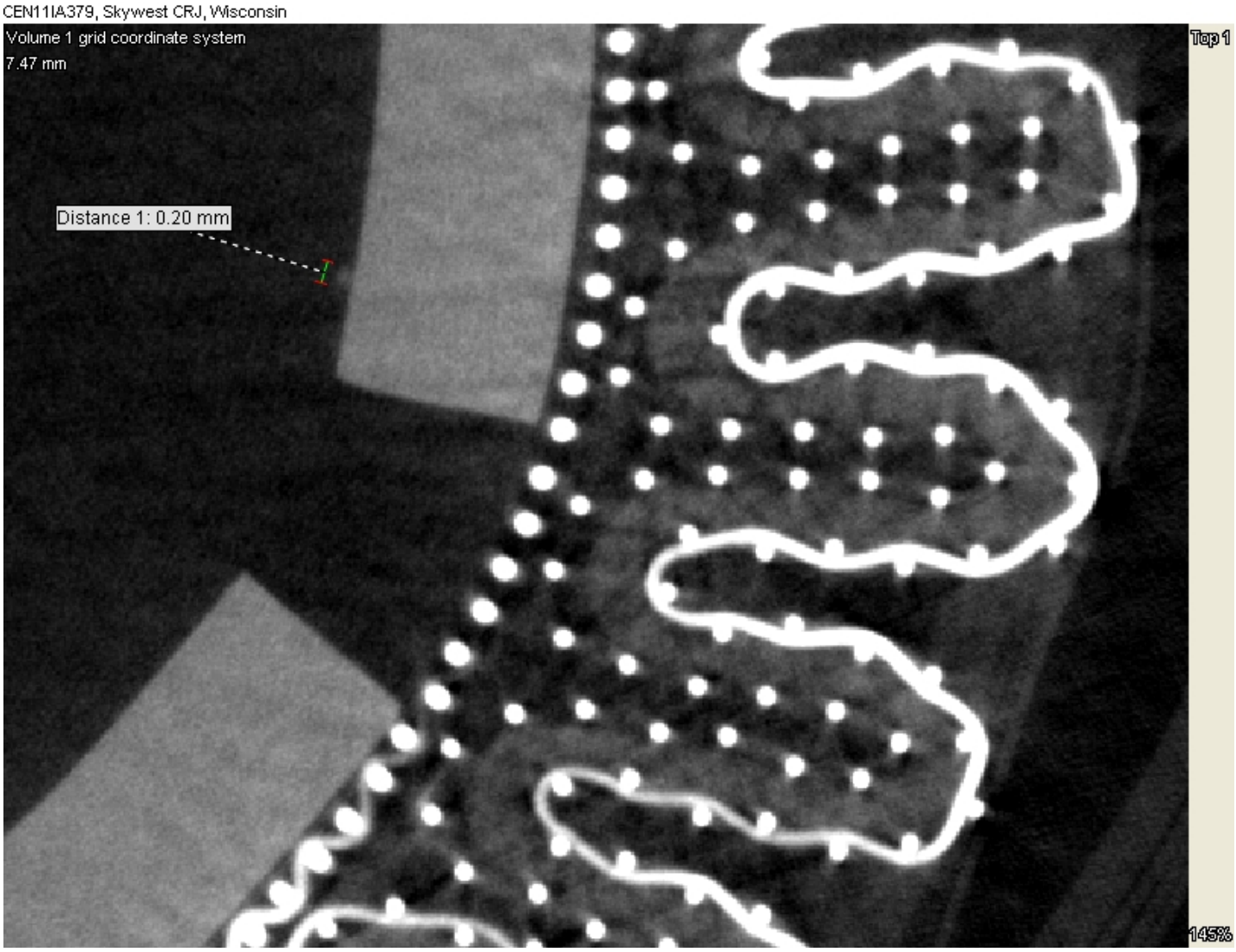

Figure 3
Axial Cross Section – Pressure Filter (section 494-504) – Low density particle, measuring 0.20 mm x 0.32 mm, on the inside surface of the inner support core.

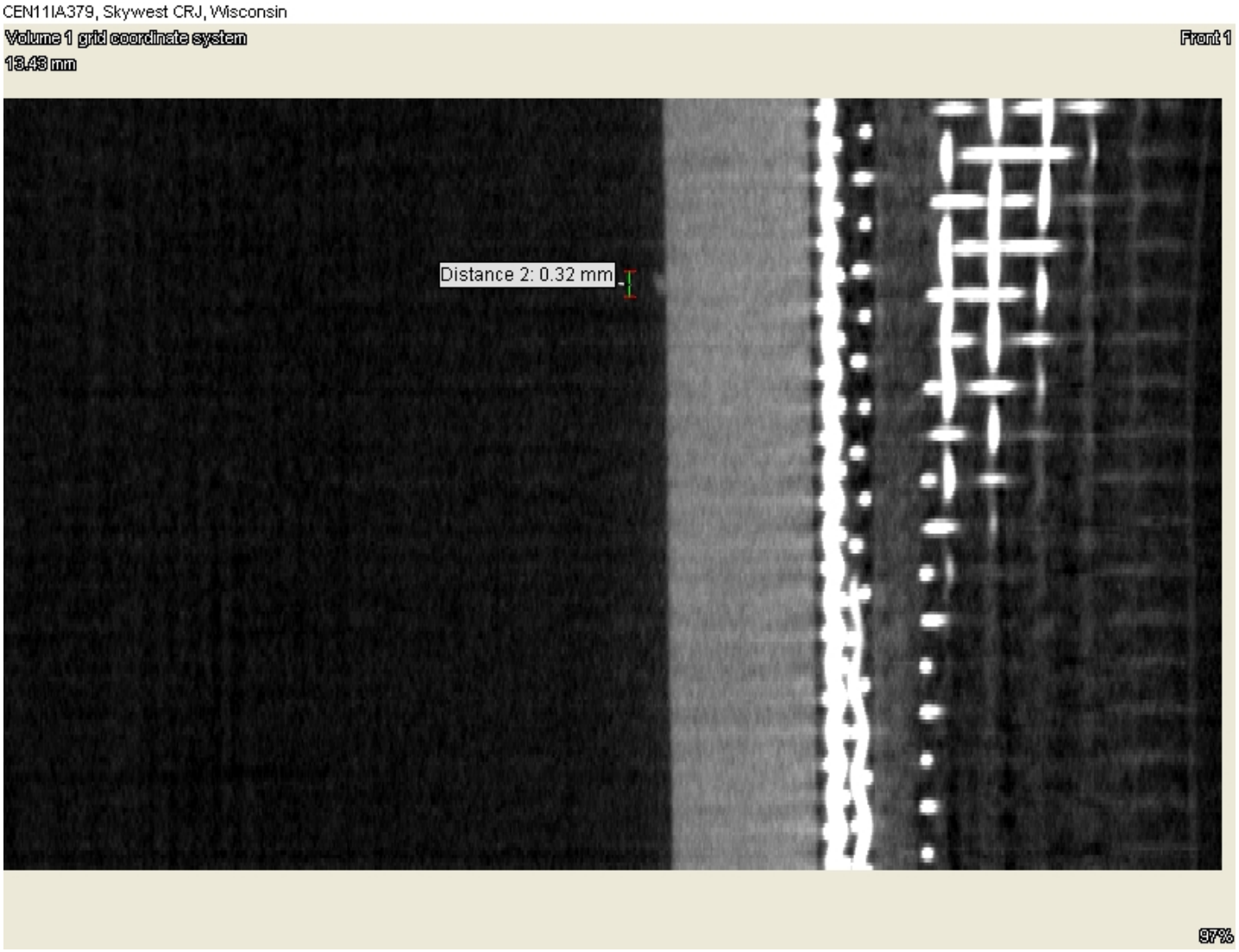

Figure 4
Frontal Cross Section – Pressure Filter (section 494-504) – Low density particle shown in figure 3, measuring 0.20 mm x 0.32 mm on the inside surface of the inner support core

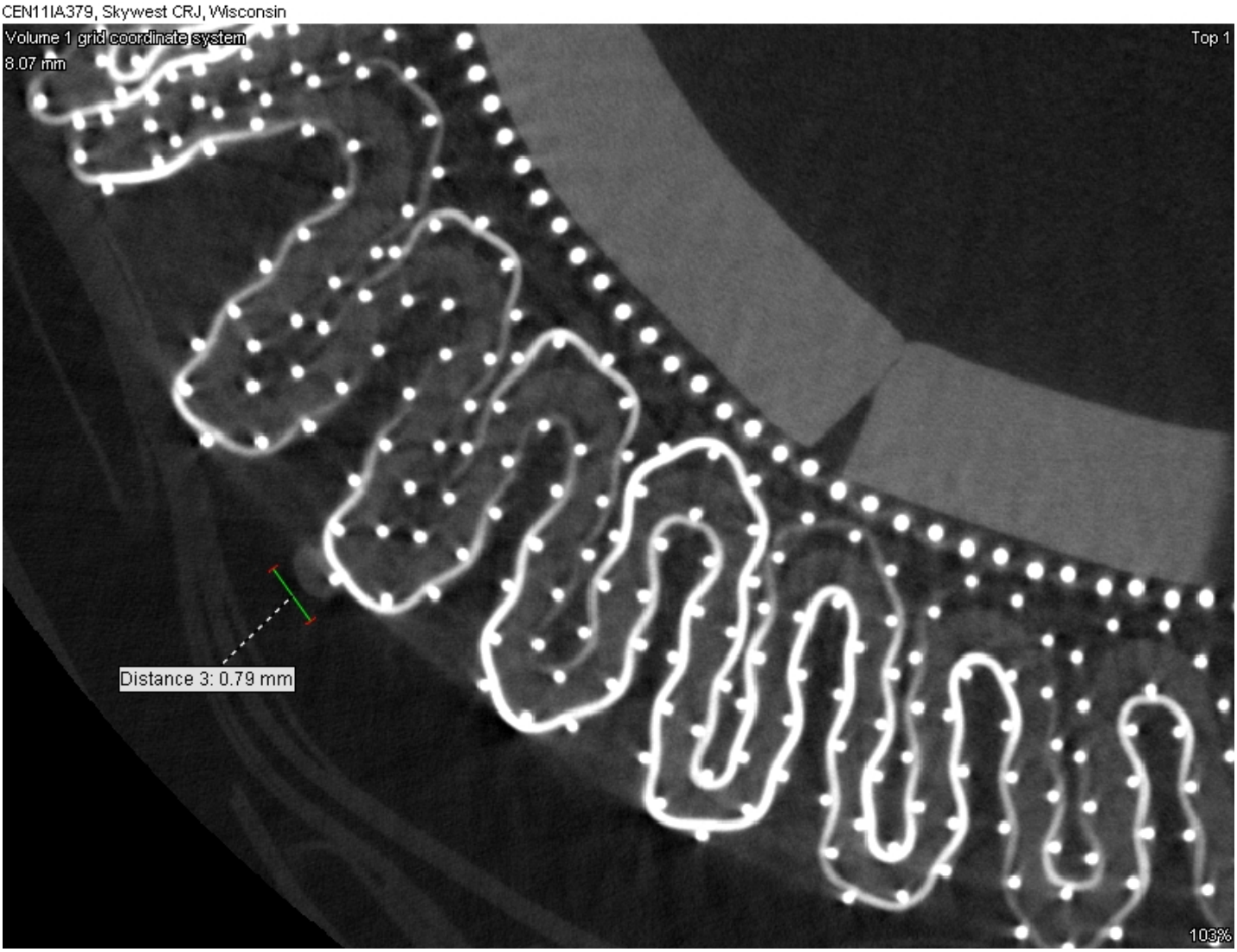

Figure 5
Axial Cross Section – Pressure Filter (section 494-504) – Low density particle measuring 0.79 mm x 1.38 mm, on the outer stainless steel mesh

Figure 6
Right Cross Section – Pressure Filter (section 494-504) – Low density particle (shown in figure 5) measuring 0.79 mm x 1.38 mm, on the outer stainless steel mesh

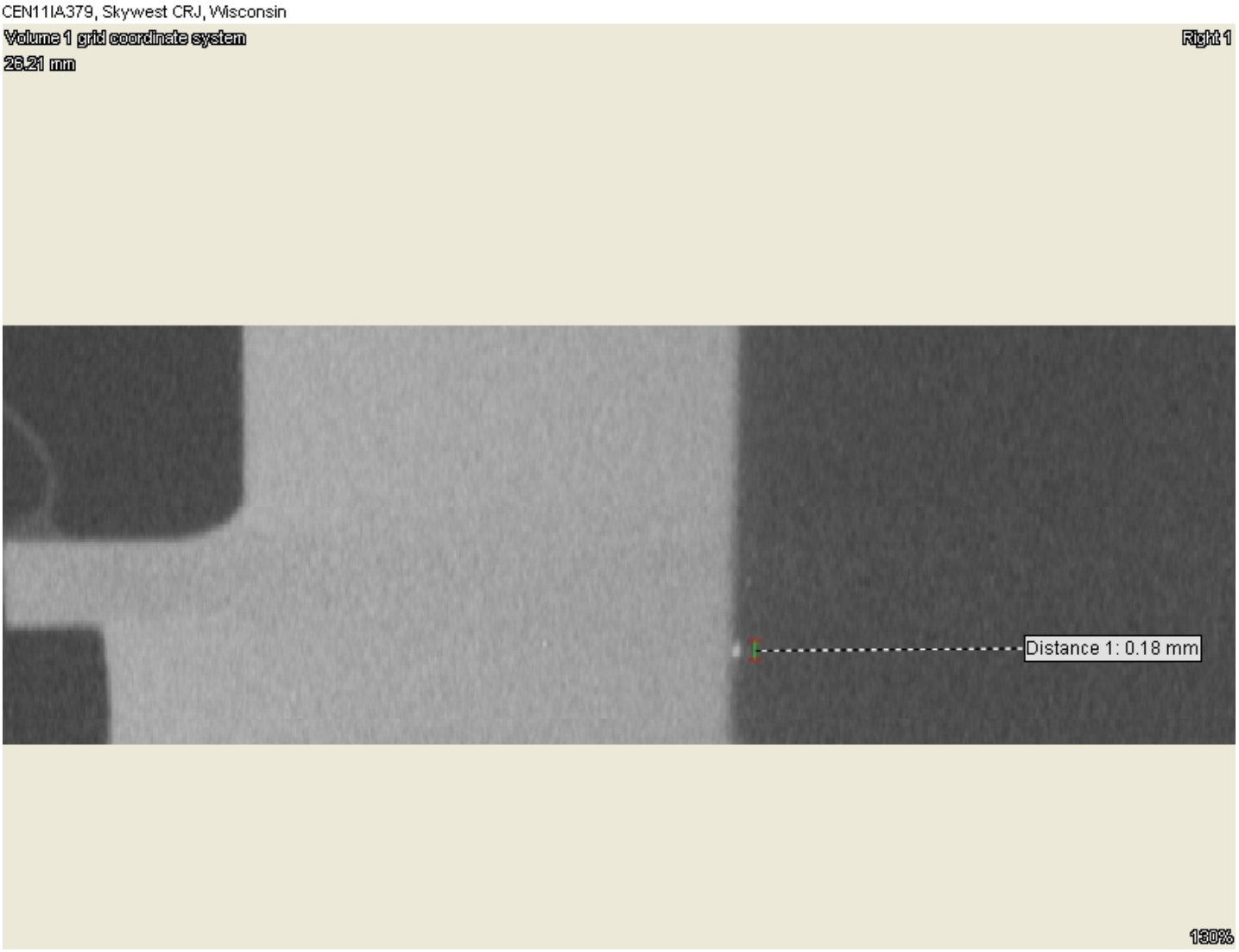

Figure 7
Right Cross Section – Pressure Filter (section 514-518) – Particle, measuring 0.18 mm,
on the inside surface of the inner support core

Figure 8
Axial Cross Section – Pressure Filter (section 514-518) – Particle measuring 0.10 mm x 0.13 mm on inside surface of inner support core

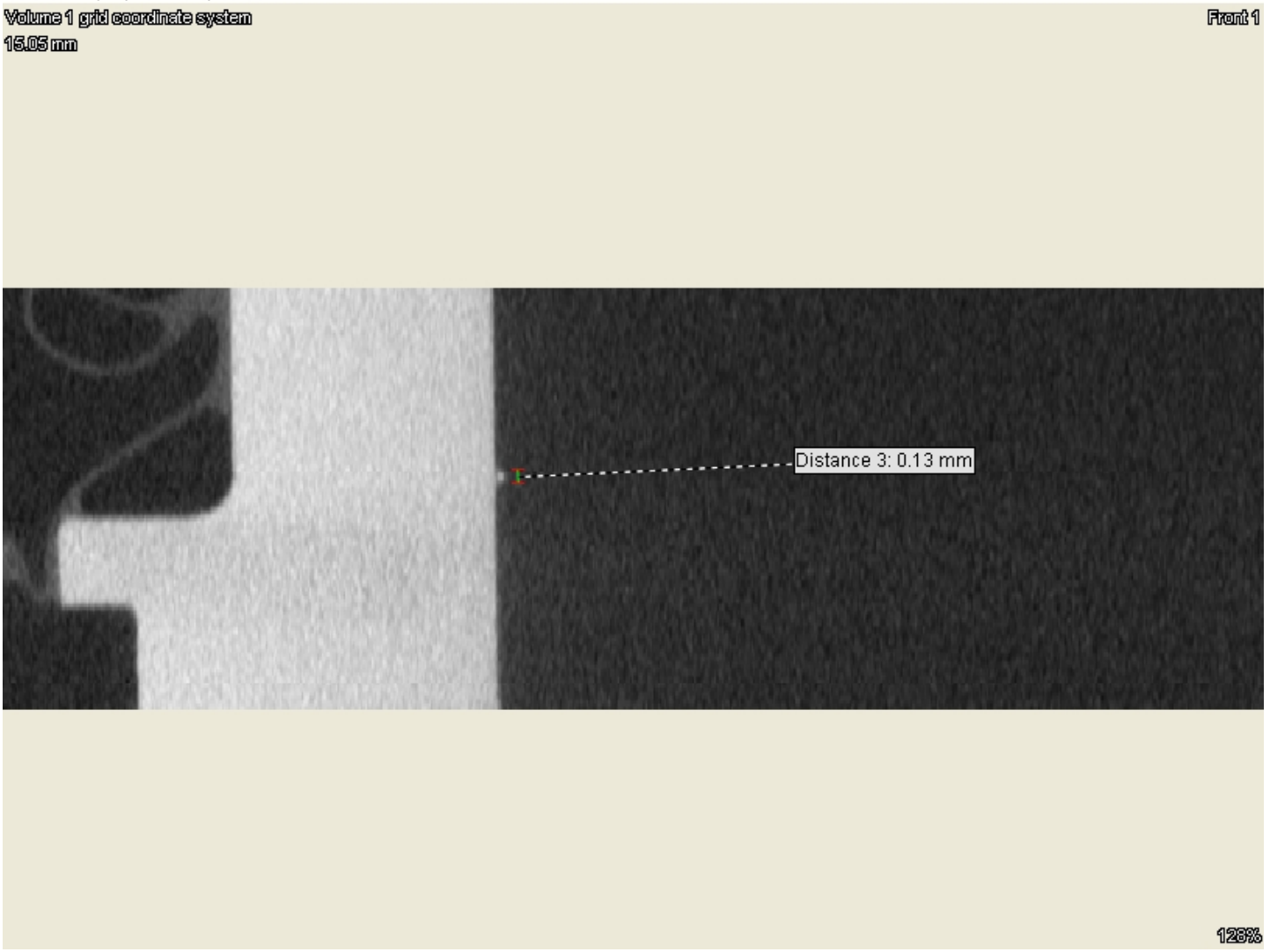

Figure 9
Frontal Cross Section – Pressure Filter (section 514-518) – Particle (shown in figure 8), measuring 0.10 mm x 0.13 mm, resting on the inner surface of the inner support core

4.0 Computed Tomography Results – Return Filter

The CT results for the return filter are shown in figures 10 through 19. There was only one particle found in the return filter (0.53 mm long). In addition, there were some cracks noted in the epoxy used on the upper end of the filter, a high density area noted in the filter material, and a distorted area in the inner stainless steel mesh material.

In the caption for each figure, the section of the filter in which the image was captured is contained in the "Return Filter (section xx-xx)" notation, where the section number denotes the 10 mm section of the filter as recorded in the CT scanning equipment. The values are based on the reference system used during the CT scans, and they do not correspond to any drawing coordinates.

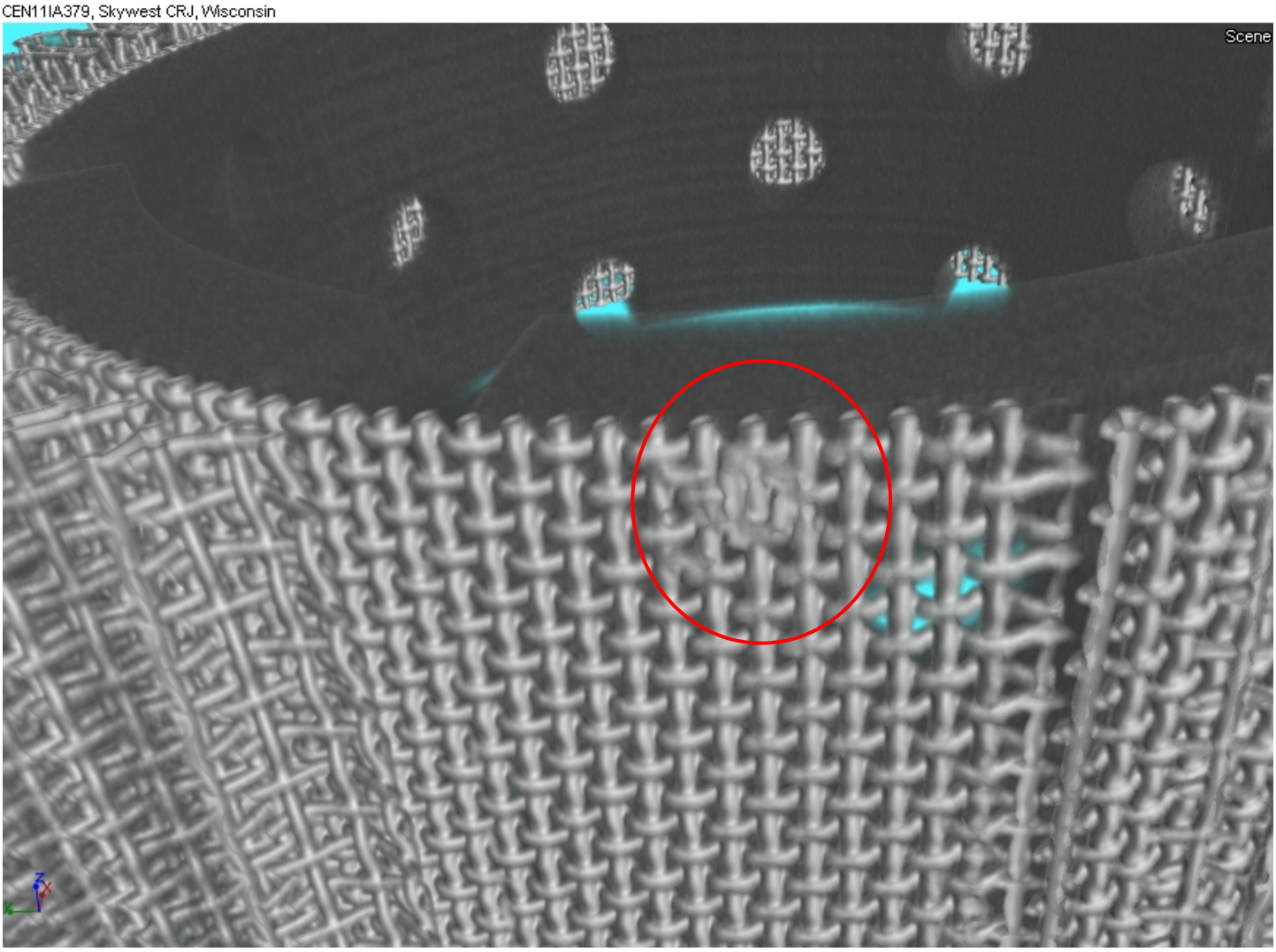

Figure 10
Three dimensional view – Return Filter (section 358-368) – Distortion in the inner stainless steel mesh material

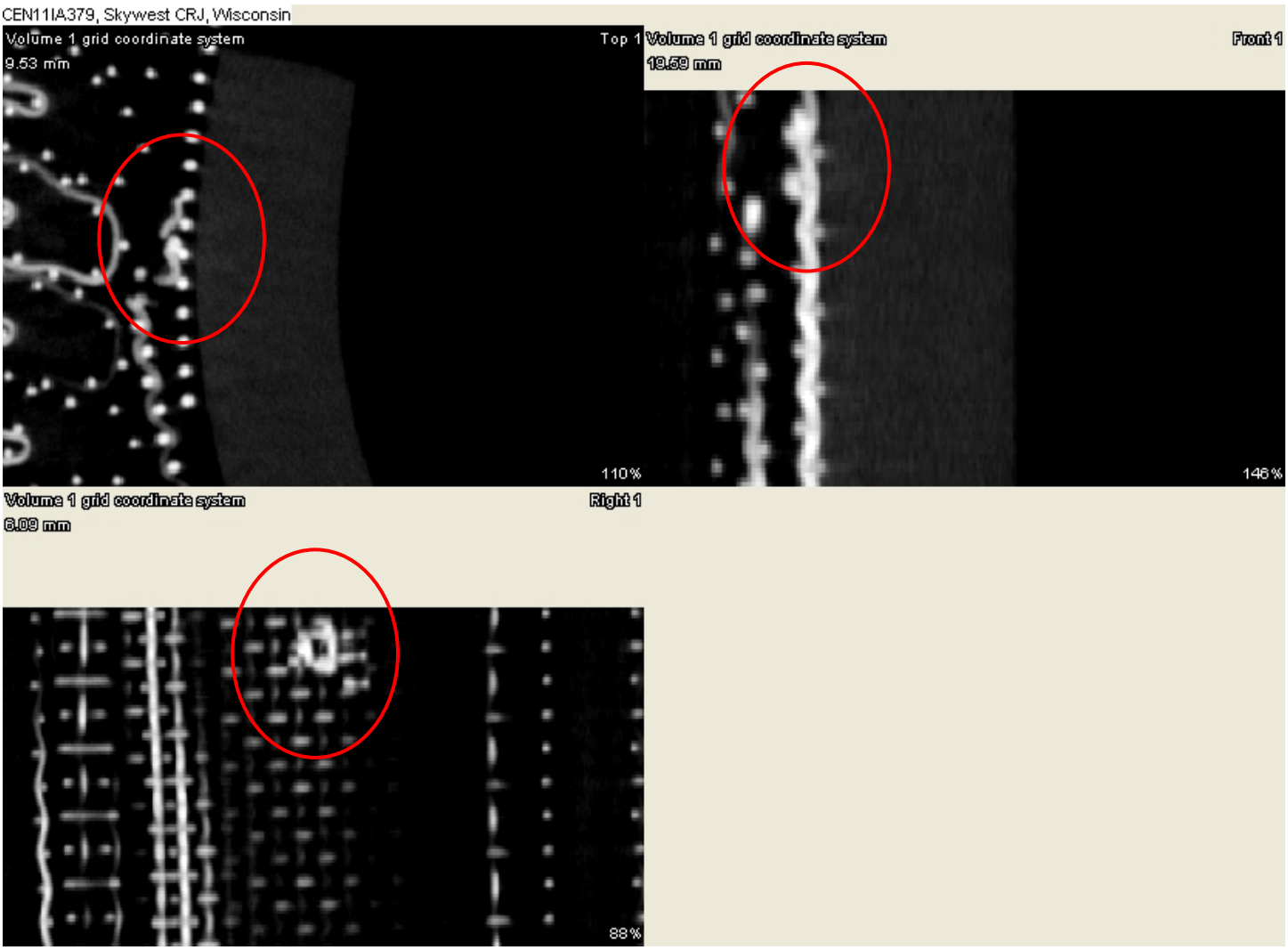

Figure 11
Multiple views – Return Filter (section 358-368) – Distortion in the inner stainless steel mesh material seen in figure 10

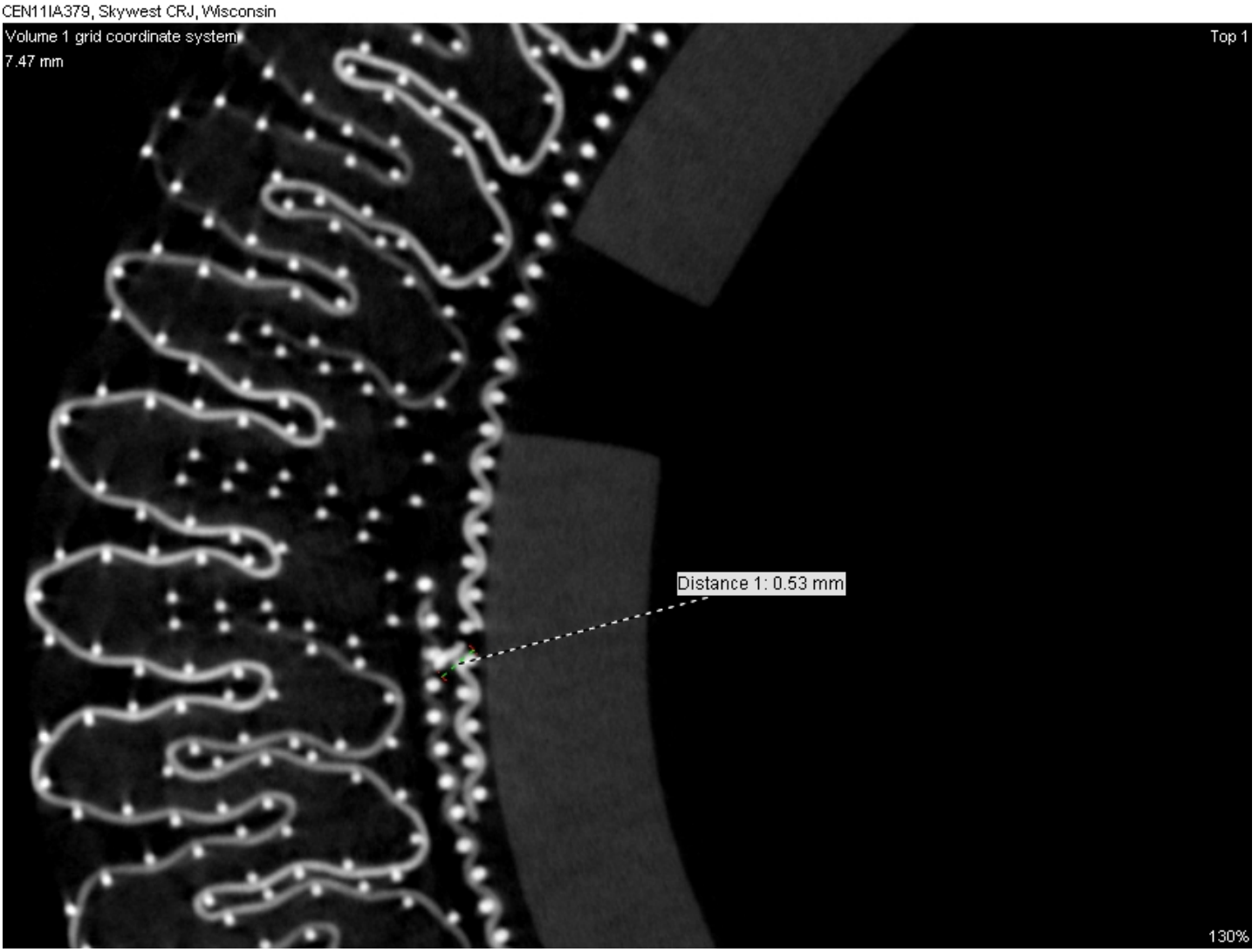

Figure 12
Axial Cross Section – Return Filter (section 408-418) – Particle, measuring 0.53 mm, located within the overlap area of the inner stainless steel mesh

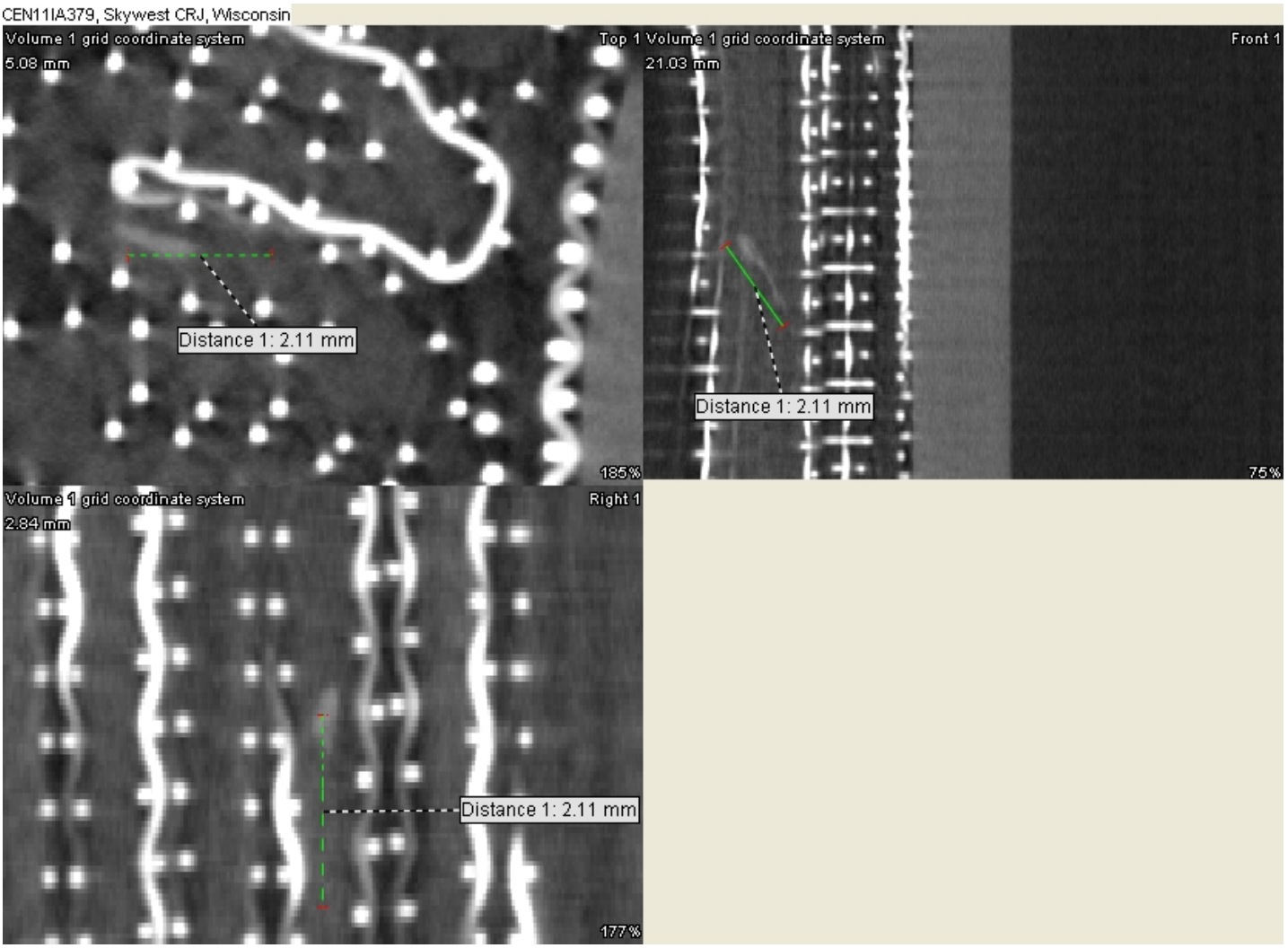

Figure 13
Multiple views – Return Filter (section 428-438) – High density area of filter material, measuring 2.11 mm long

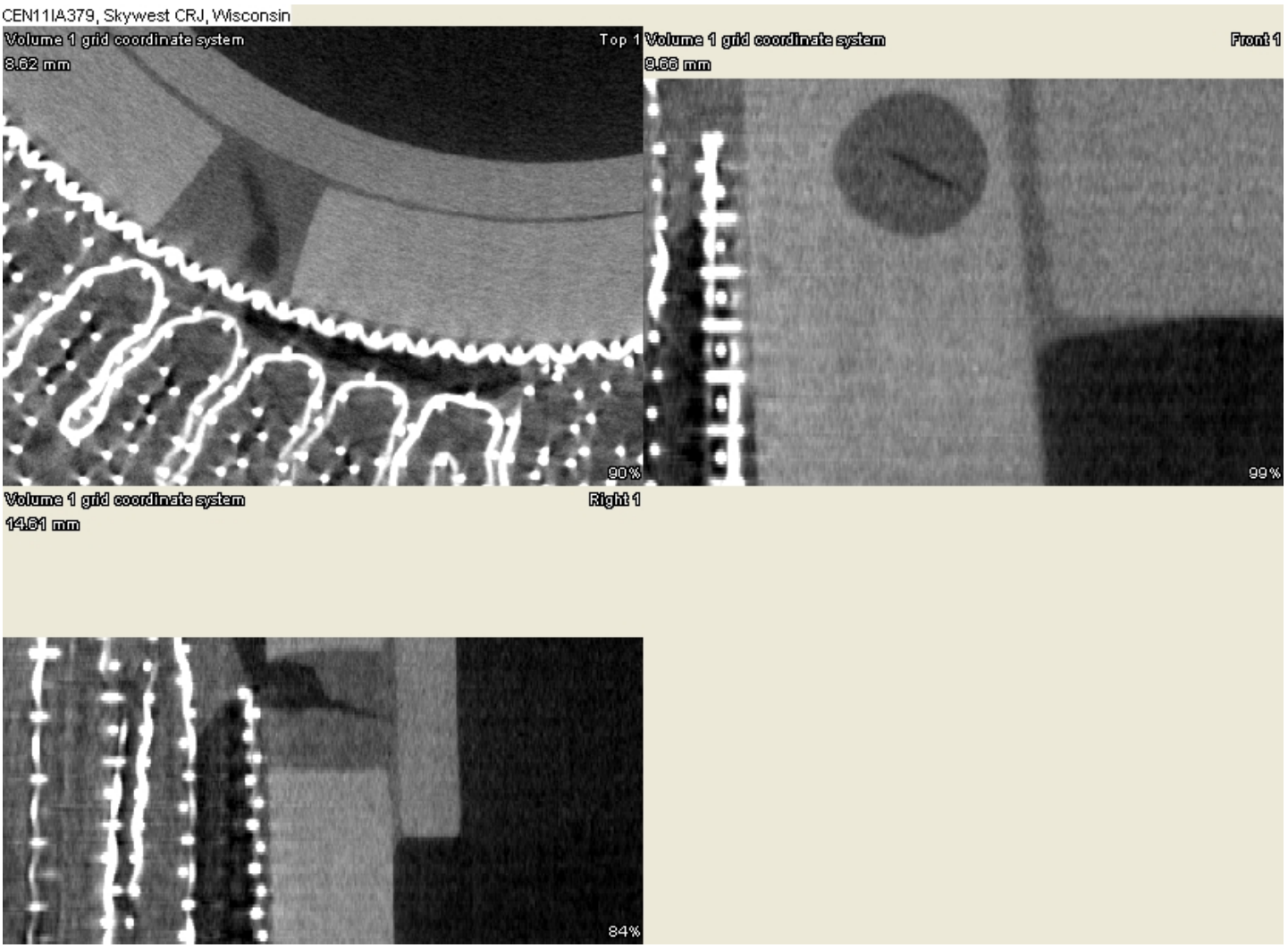

Figure 14
Multiple views – Return Filter (section 458-468) – Cracks in epoxy material used in the filter end cap

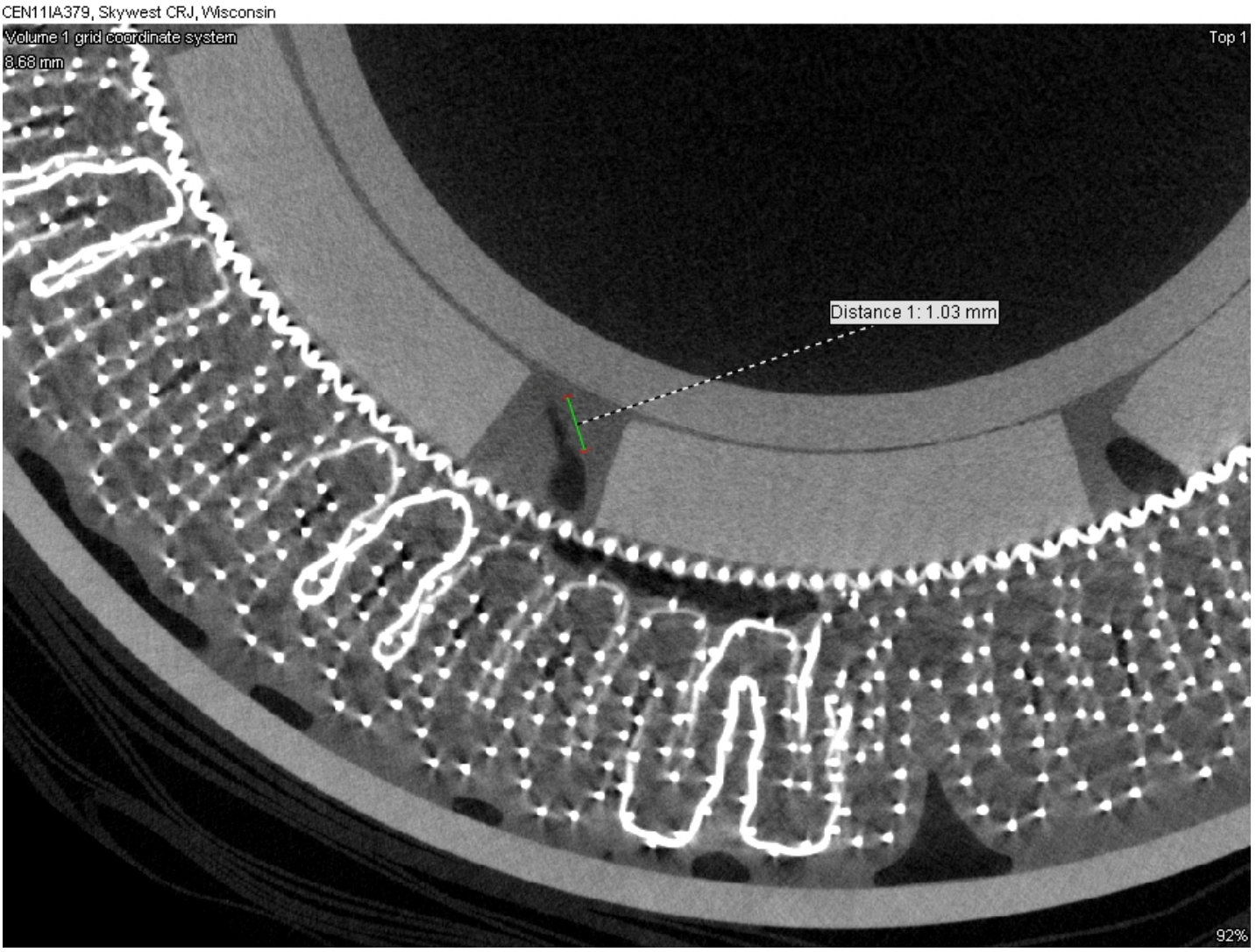

Figure 15
Axial view – Return Filter (section 458-468) – Close up view of crack in epoxy material (shown in figure 14), measuring 1.03 mm

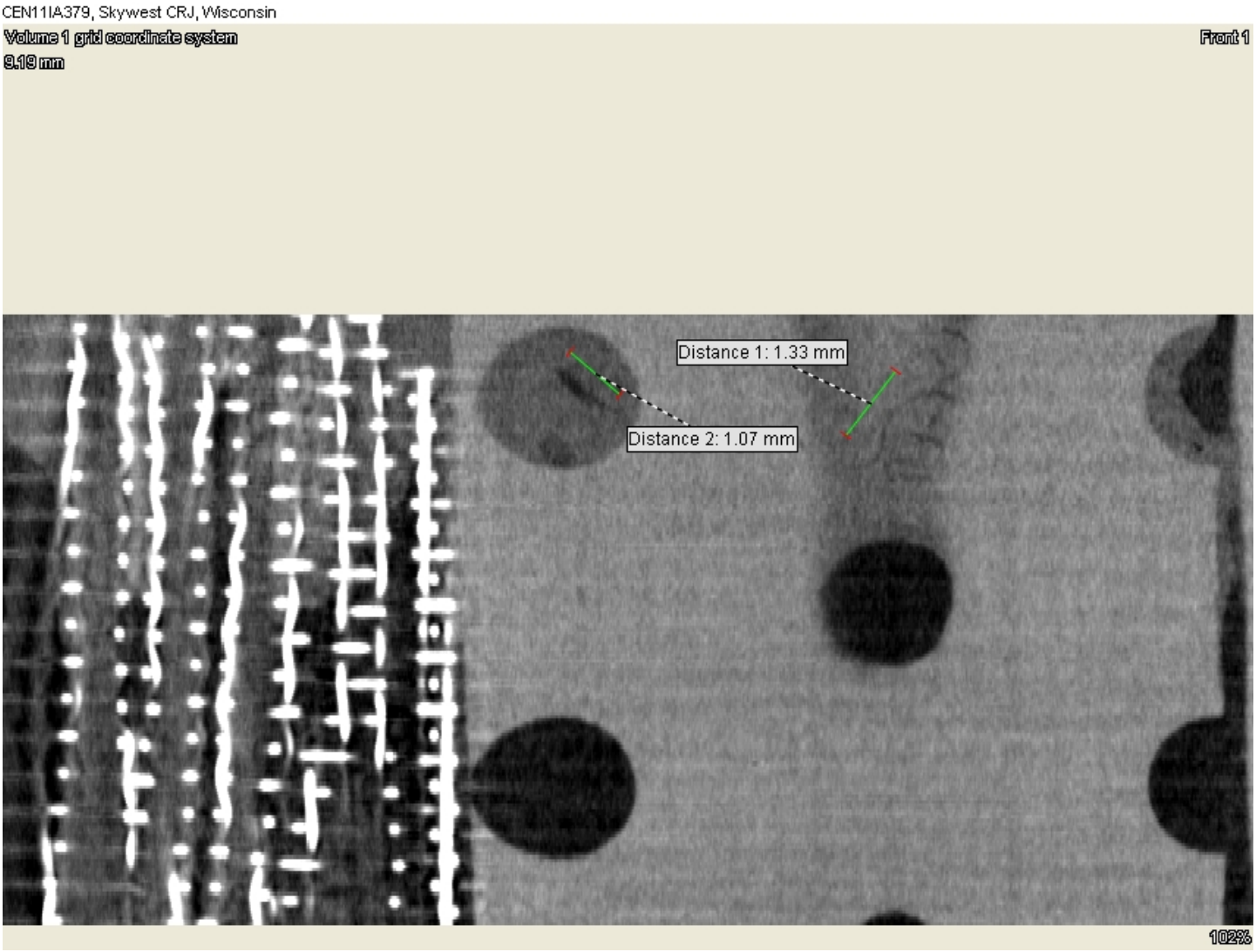

Figure 16
Frontal view – Return Filter (section 458-468) – Cracks in epoxy material measuring 1.07 mm and 1.33 mm

Figure 17
Frontal view – Return Filter (section 458-468) – Close up view of crack (shown in figure 17, labeled 1.33 mm) in epoxy material showing the network of cracks in the material and the distance from the cracks to the hole in the inner support core (0.81 mm)

Figure 18
Multiple views – Return Filter (section 458-468) – Views showing the location of the network of cracks in the epoxy material (shown in figure 17)

Figure 19
Frontal view – Return Filter (section 458-468) – Close up view of crack in epoxy material (not shown in previous figures), measuring 0.72 mm long and 0.04 mm wide

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