

Title: CT Scaling Instructions		Part No: G000135	Rev: E
	Created by: Susan Candell Date: 2/11/09	Approved by: See ECO Date:	
	Product:	Used on:	

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1. Purpose

The purpose of this document is to provide instructions for calibration and application of CT scaling and optional User-Defined Scaling for Carl ZEISS X-ray Microscopy, Inc. images. ZEISS CT scaling is the process by which the images produced have the appropriate Hounsfield units (HU), in which air and water have values of 0 and 1000, respectively. User-Defined Scaling can scale images to any two values, not necessarily 0 and 1000.

The calibration for CT scaling involves scanning a CT scaling phantom and performing analysis on the images. The application of CT scaling involves selecting CT scaling during reconstruction, and the output images have the proper Hounsfield units.

WARNING: CT Scaling and User-Defined Scaling will only be successful if your sample is completely within the field of view in width. If your sample extends in width (side-to-side) beyond the edge of the field of view, and air is not visible on both sides of the sample for the entire rotation of the image, the scaling will NOT be preserved.

Note: General acquisition information may be found in Chapters 3- 6 of the User's Guide.

2. Phantoms for CT Scaling

There are several phantoms available for CT scaling:

- Water Phantom Kit for 1X to 10X objectives: Part# A00732 contains:
 - Small Water Material: Part# A000598
 - Large Water Material: Part# A000597
- QRM 3D Phantom Assembly for Macro objective: Part# A001126
- High Resolution Water Material Assembly for 20X objective: Part# A001186
A001126

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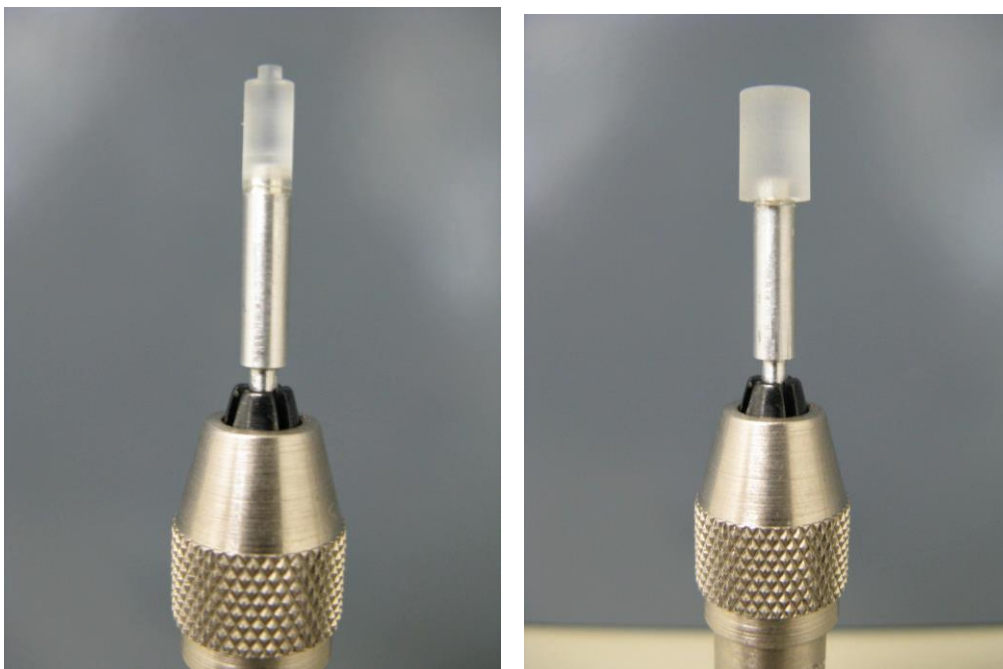


Figure 1: Small Water Material, Part A000598, and Large Water Material, Part A000597 shown in the pin vice sample holder.

3. Description of CT Scaling for ZEISS

For ZEISS, the CT scaling for our tomography images will be offset by +1000 from typical Medical CT Scaling¹:

- air pixels = 0 +/- 100 (density 0),
- water = 1000 +/- 100 (density 1.0)

All CT scaled images must be reconstructed with USHORT format.

¹ Typical Medical CT scaling is: air = -1000, water = 0, objects linearly scaling depending on their physical density as compared to water

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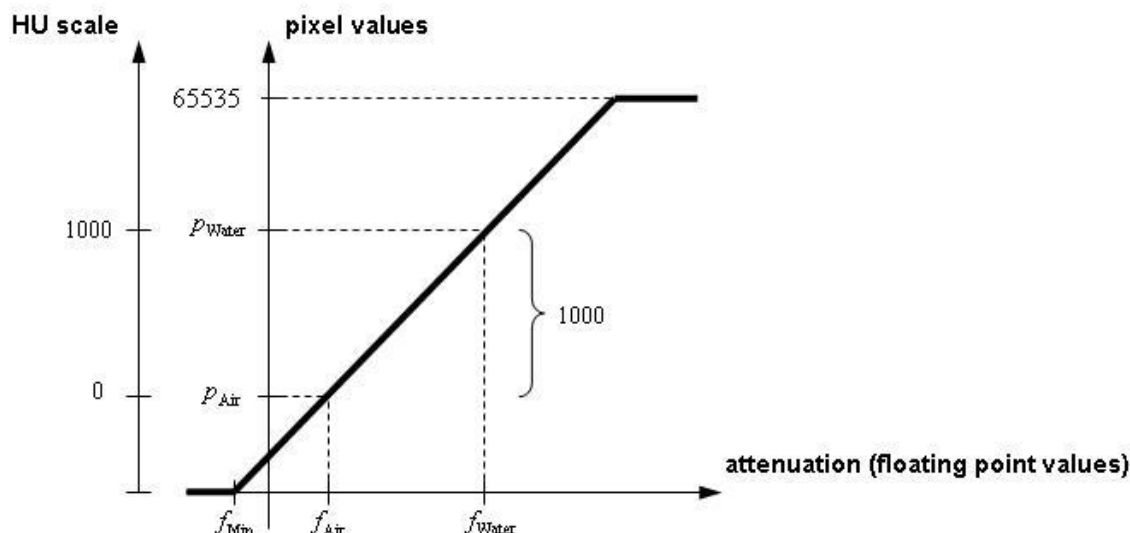


Figure 2: HU Scaling

The calibration for CT scaling must be performed for each of the following variables:

- kV
- Objective
- Beam hardening coefficient
- Source filter

Note: The best method for CT scaling is to define the scanning parameters for your particular sample BEFORE running this CT scaling procedure. This will ensure that the scaling matches the sample data.

All other variables such as source or detector distance, number of projections in a tomography set, exposure, binning, etc., are correctly compensated for in the CT scaling, so separate calibrations do not need to be performed for these variations in acquisition.

For example, if the user would like CT scaled images for 100kV, 8W, source-RA distance of 200mm, detector-RA distance of 80mm, 4x objective, bin 2, exposure 3 sec per projection, 181 projections, -90 to 90 degrees, reconstruction with beam hardening of 1.0, a calibration must have been performed with 100kV, 4x objective, and 1.0 beam hardening. All other parameters will be compensated for in the scaling.

If the calibration does not exist corresponding to their imaging parameters, the user will not be allowed to choose CT scaling for that reconstruction.

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4. Description of User-Defined Scaling for ZEISS

Some users may wish to define the scaling differently than for HU scaling. This process will be called 'User-Defined Scaling'. For example, a user may wish to set the value of air to 5000 instead of 0, to avoid truncation of data when values are below 0. And the user may wish to set the maximum value to a value in rock, instead of water. The graph of the scaling would appear as follows:

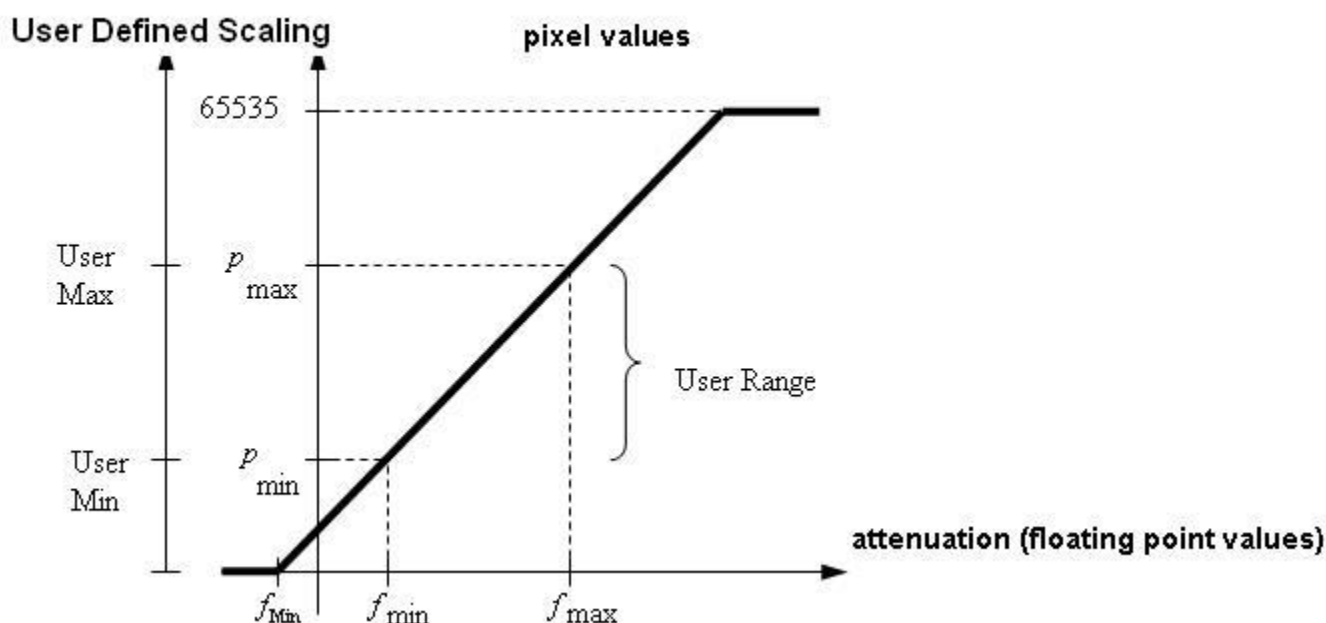


Figure 3: User Defined Scaling

The calibration steps necessary to perform User-Defined Scaling will be described in the calibration section.

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5. Calibration for CT Scaling

The initial step for CT Scaling is to decide which kV, objectives, beam hardening, and source filter combinations the site will require for the CT Scaled images. Follow the appropriate procedure based on the objective chosen.

Note: General acquisition information may be found in Chapters 3- 6 of the User's Guide.

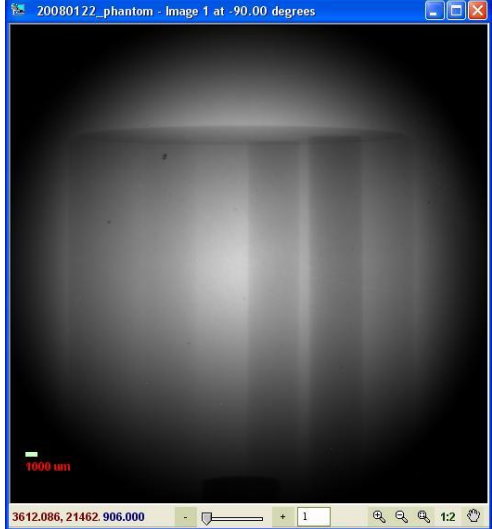
5.1. CT Scaling Calibration for Macro objective

WARNING: CT Scaling will only be successful if your sample is completely within the field of view in width. If your sample extends in width (side-to-side) beyond the edge of the field of view, and air is not visible on both sides of the sample for the entire rotation of the image, the scaling will NOT be preserved.

Two phantoms may be used for scaling the Macro objective. The user should select the correct phantom based on which one matches the overall size of the samples to be imaged. If the sample diameter size is comparable to the large QRM phantom (3.2cm, for in-vivo studies), Part A001126, then CT scaling should use this phantom. If the sample is smaller diameter, <15mm, then CT scale based on the smaller phantom. For instructions to CT scale based on the smaller phantom, see section 5.2.

This procedure is intended to be used with the animal holder either with or without the acrylic shell.

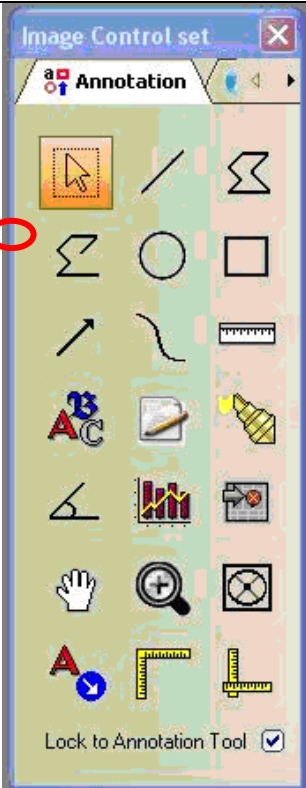
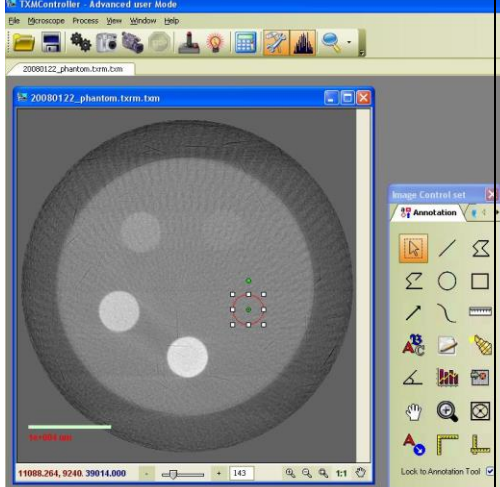
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Step	Picture	Description
1)		Pre-define all CT scaling parameters: kV, beam hardening, and the appropriate source filter. For sites with an optional acrylic shell surrounding the sample, determine whether or not the images will be taken with the acrylic shell animal holder, or with a smaller animal holder. Install or remove the phantom acrylic shell to match the animal scanning.
2)		Set all other values to nominal settings appropriate for your site. <i>Note: You may choose a smaller number of projections and higher binning than normal to speed up acquisition and reconstruction.</i>
3)		Scan the 'Phantom CT Scale – Large' phantom using exact parameters as specified. <i>Note: Ensure that the top of the phantom is below the top of the image so there will be a clean slice of air.</i>

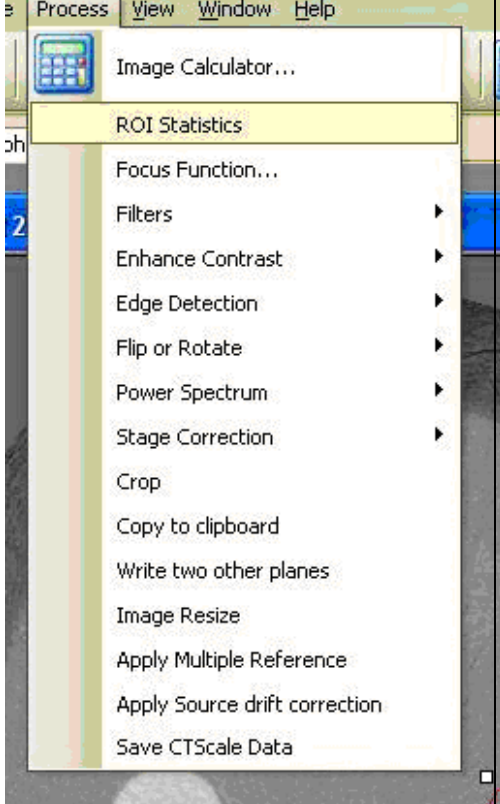
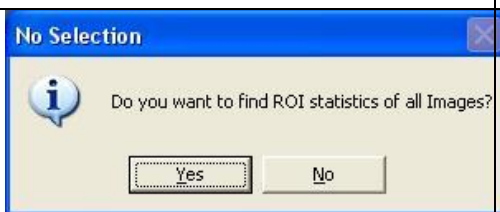
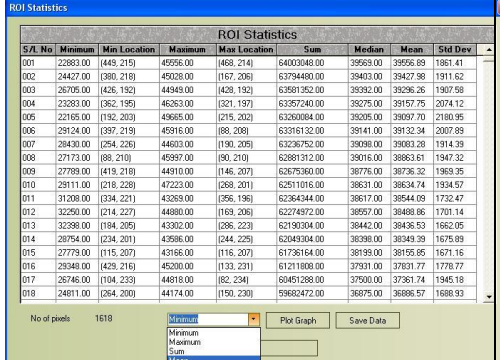
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4)		Make a reference image as desired. In general, use the same exposure time per projection of the tomography set, and take 10 averages. <i>Note: Additional guidance on references may be found in chapter 5 of the chapter 5 of the User's Guide.</i>
5)		Apply the reference filter to the phantom projection set.
6)		Save and close the phantom projection set.
7)		Open up the projection set in XMReconstructor
8)		Perform focal series for center shift, and record the center shift value. <i>Note: Additional guidance on reconstruction may be found in Chapter 6 of the User's Guide.</i>
9)		Select the beam hardening to match the sample imaged (do not optimize based on the phantom).
10)		Reconstruct using global max/min recon, ushort data format, any binning, correct center shift, beam hardening desired, ring filter on or off, and recon filter on.
11)		After reconstruction has been completed, open the reconstructed images in the XMController.
12)		Scroll through the images to about half-way through the images, finding a clean image near the middle.

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13)		Open the Image Control Set, and select the 'Circle' in the Annotation tab.
14)		ROI 1: Background material: Draw a circular ROI in the location below, changing the shape and location using the 'Arrow' control at the top of the Annotation tab. This ROI is NOT in any of the circles, but is in the background material in a location symmetric with the other inserts.

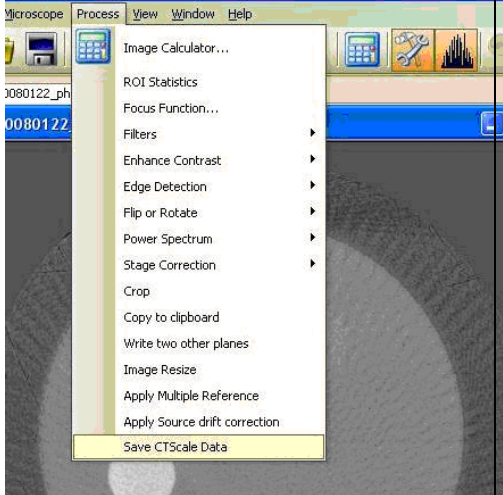
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15)		Generate the ROI1 statistics by selecting Process →ROI Statistics.
16)		Select 'Yes' to statistics for all images.
17)		when the statistics are displayed, choose 'Mean' in the bottom drop-down box, and then press 'Plot Graph'.

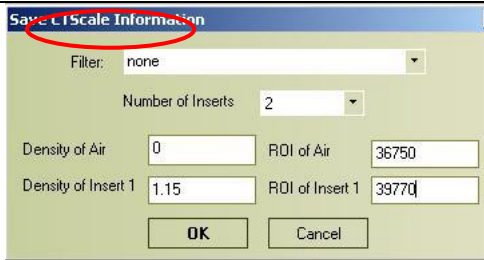
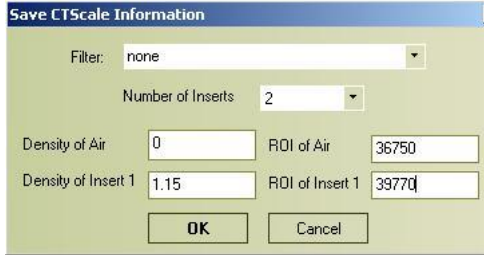
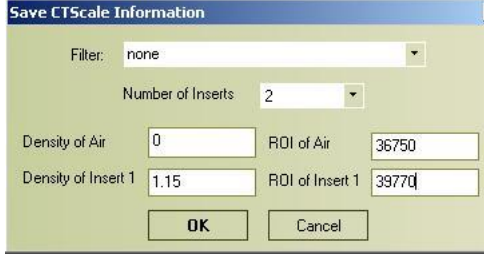
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18)		The graph of the mean values will appear. Press the 'Zoom' button, and draw a square around the peak in the middle.
19)		When the zoomed plot is displayed, record the ROI 1 value. ROI 1 Value = _____ (39770 from this example)
20)		Press 'Reset Zoom' to zoom out the plot.

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21)		Draw a rectangle for Air in the location as in the following figure.
22)		When the zoomed plot is displayed, record the Air value. Air Value = _____ (~36750 from example)
23)		Close the X-Y Plot and the ROI statistics page.
24)		Select 'Process->Save CTScale Data'.

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25)		Enter the name of the filter. Note: This name will be used when applying the CT scaling later during reconstruction. Choose something which will clearly indicate which filter was used for this CT scaling session, or enter 'none' if no filter is used.
26)		Select '2' as the number of inserts for this phantom, and verify that the default insert densities are as below. 0 density of air 1.1 density of insert 1 Note: If you have been shipped with a phantom with other than these densities, enter in the correct densities on this page. The other nominal densities for this phantom are 1.16, 1.26, and 1.66, and 1.86. See exact phantom for actual densities.
27)		Next enter in the ROI of Air value and the ROI of Insert 1 values as determined in the previous steps and press 'OK'.
28)		Repeat all the steps from this section for each kV, Beam Hardening, and the Source Filter desired.

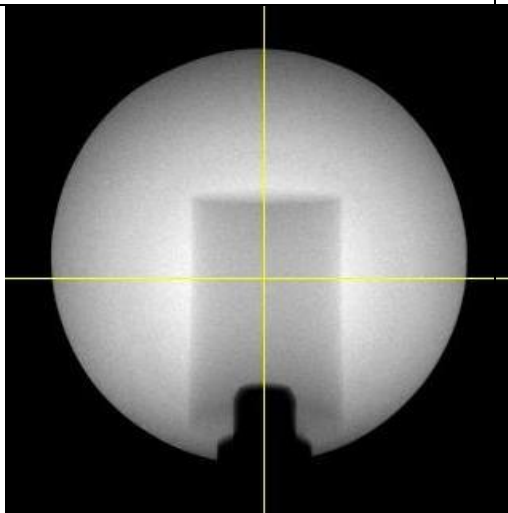
Go to Section 6 to verify that the scaling is implemented correctly.

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5.2. CT Scaling for 1x, 2x objectives

WARNING: CT Scaling will only be successful if your sample is completely within the field of view in width. If your sample extends in width (side-to-side) beyond the edge of the field of view, and air is not visible on both sides of the sample for the entire rotation of the image, the scaling will NOT be preserved.

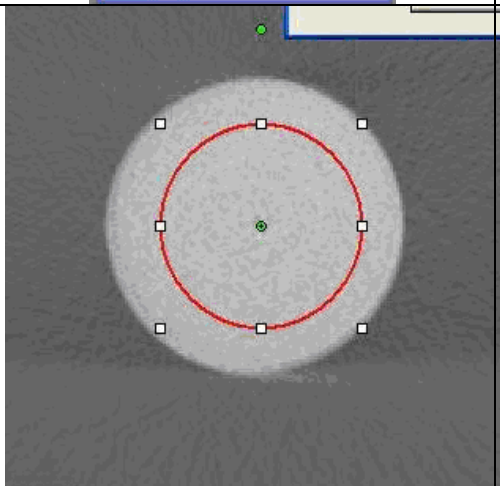
This procedure is intended to be used for 2x magnification objective. The process is the same for all objectives, but the images and regions to use are different enough to illustrate separately below.

Step	Picture	Description
1)		Pre-define all CT scaling parameters: kV, Beam Hardening, and the appropriate Source Filter for the images desired to be CT scaled.
2)		Set all other values to nominal settings appropriate for your site. <i>Note:</i> You may choose a smaller number of projections and higher binning than normal to speed up acquisition and reconstruction.
3)		Scan the 'Large Water Material, Part Number A000597' phantom using the exact parameters as specified. <i>Note:</i> Ensure that the top of the phantom is below the top of the image so that there is a clean slice of air above the phantom.

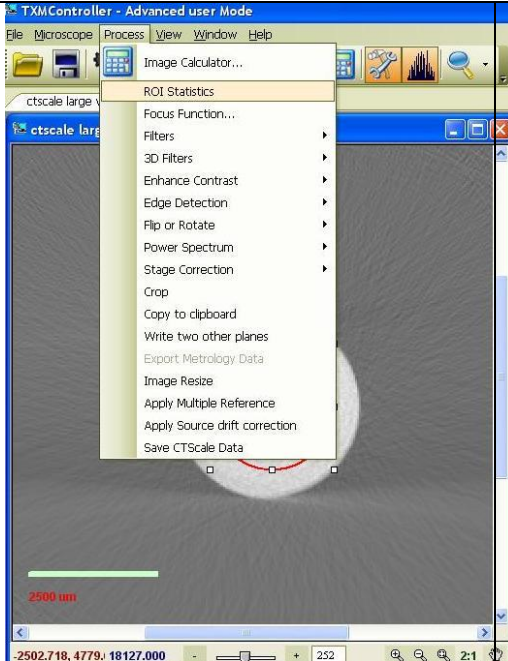
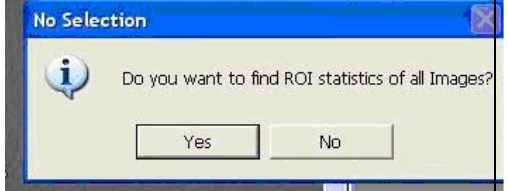
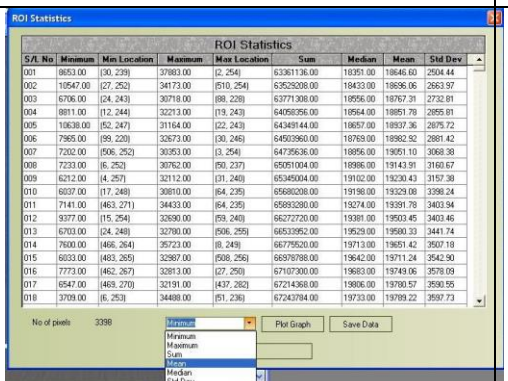
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4)		Make a reference scan as desired. <i>Note: In general, use the same exposure per projection of the tomography set, and take 10 averages.</i>
5)		Apply the reference filter to the phantom projection set.
6)		Save and close the phantom projection set.
7)		Open up the projection set in XMReconstructor.
8)		Perform focal series for center shift, making sure to record the value.
9)		Select the beam hardening to match the sample imaged (do not optimize based on the phantom).
10)		Reconstruct using global max/min recon, USHORT data format, any binning, correct center shift, beam hardening desired, ring filter on or off, and recon filter on.
11)		After reconstruction has completed, open the reconstructed images in XMController.
12)		Scroll through the images to about half-way through the images, finding a clean image near the middle.

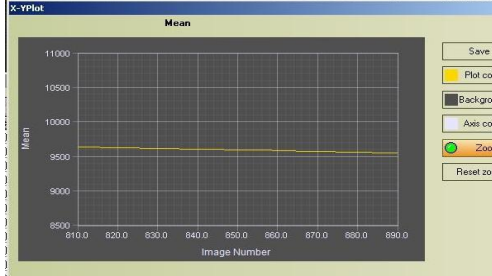
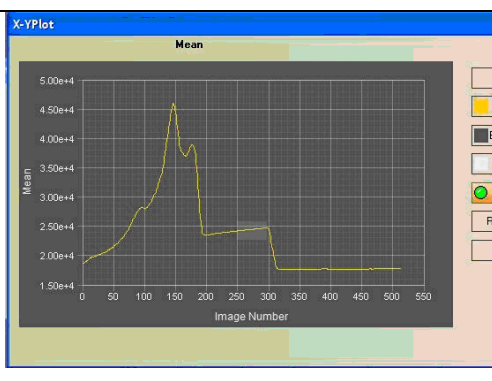
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13)		Open the Image Control Set, and select the 'Circle' in the Annotation tab.
14)		Draw a circular ROI directly in the middle of the phantom, filling up approximately 80% of the phantom. Move and size the ROI using the 'arrow' control.

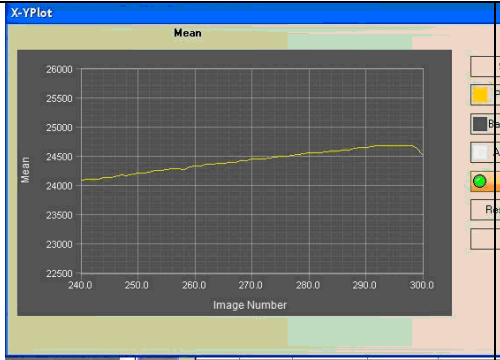
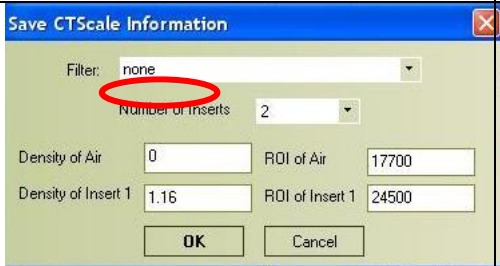
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15)		Generate the ROI statistics by selecting Process→ROI Statistics.
16)		Select Yes.
17)		When the statistics are displayed, choose 'Mean' in the bottom drop-down box, and then press 'Plot Graph'.

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18)		The graph of the mean values will appear as below. Press the 'Zoom' button, and draw a square around the bottom for the Air ROI.
19)		When the zoomed plot is displayed, record Air value Air Value = _____ (17700 from example)
20)		Press 'Reset Zoom' to zoom out the plot.
21)		Draw a rectangle for ROI 1 in the location as in the shown figure. Note: The plot is complicated because of the complicated shape of the small phantom. Please select regions carefully!

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22)		When the zoomed plot is displayed, record the ROI 1 value. ROI 1 Value = _____ (24500 from this example)
23)		Close the X-Y Plot and the ROI statistics page.
24)		Select from the top menu 'Process→Save CTScale Data'
25)		Select '3' as the number of inserts for this phantom, and verify that the default insert densities are as below. 0 density of air 1.16 density of insert 1, water Note: <i>If you have been shipped with a phantom with other than these densities, enter in the correct densities on this page.</i>
26)		Next enter in the ROI values from the previous steps above, and press 'OK'.
27)		Repeat the steps in this section for each kV, beam hardening, and source filter desired.

Go to Section 6 to verify that the scaling is implemented correctly.

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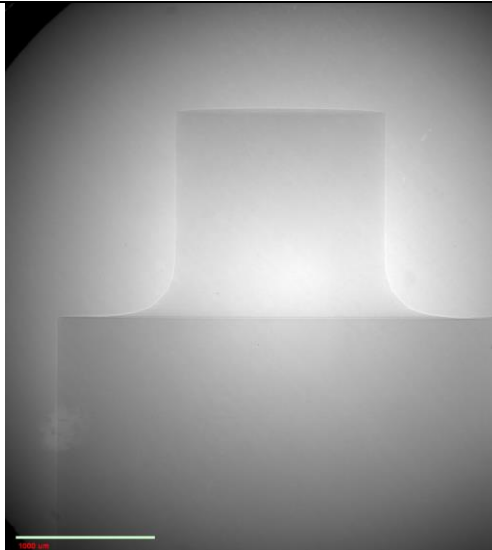
5.3. CT Scaling for 4x objectives

WARNING: CT Scaling will only be successful if your sample is completely within the field of view in width. If your sample extends in width (side-to-side) beyond the edge of the field of view, and air is not visible on both sides of the sample for the entire rotation of the image, the scaling will NOT be preserved.

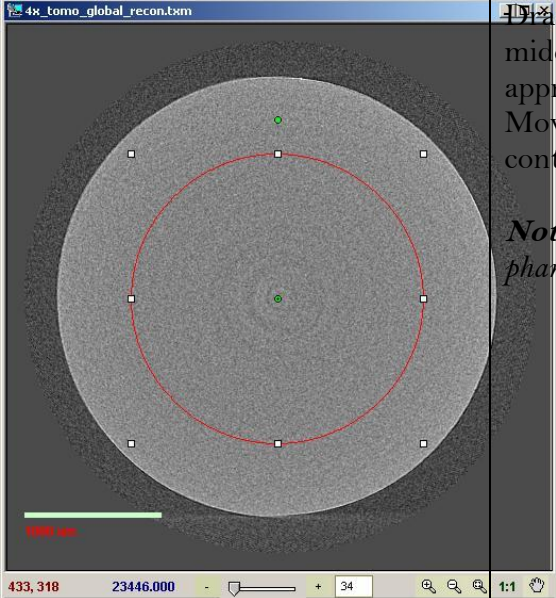
This procedure is intended to be used for 4x magnification objectives.

Step	Picture	Description
1)		Pre-define all CT scaling parameters: kV, beam hardening, and source filter for the images desired to be CT scaled from section 3.
2)		Set up a tomography and all other values to nominal settings appropriate for your site. <i>Note:</i> You may choose a smaller number of projections and higher binning than normal to speed up acquisition and reconstruction. A scan of -90 degrees to 90 degrees, 181 projections, bin 2 may be used.

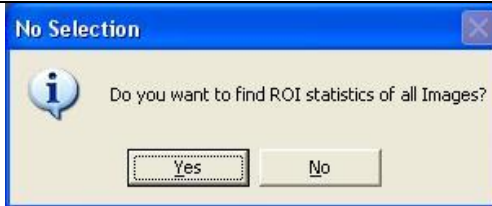
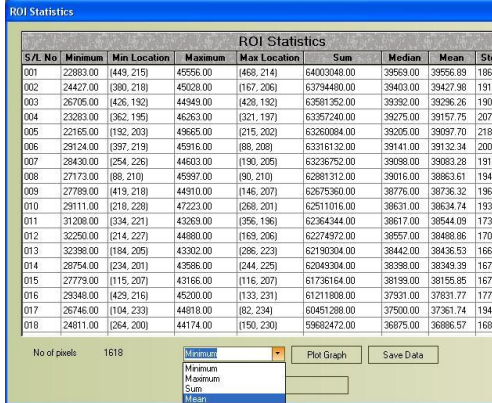
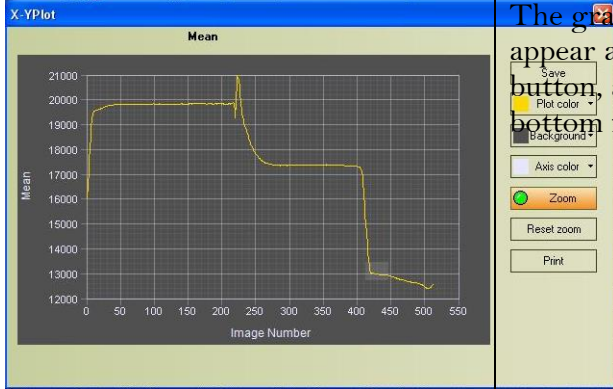
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3)		Take a continuous image of the 'Small Water Material', Part Number A000598, phantom using exact parameters as specified. Note: Ensure that the top of the phantom is below the top of the image so that there is a clean slice of air above the phantom.
4)		Move Sample Theta = -90 degrees, and center using the Sample Z stage or by double clicking the samples center.
5)		Perform a reference image as desired. Note: In general, use the same exposure per projection of the tomography set, and take at least 10 averages. Multi-reference may also be used, ensuring that the total number of images is 10 or more. Additional guidance may be found in Chapter 5 of the User's Guide
6)		After acquisition, apply the reference filter to the phantom projection set.
7)		Save and close the phantom projection set.
8)		Open up the projection set in XMReconstructor.
9)		Perform focal series for center shift, and record the center shift value. Note: Additional guidance on reconstruction may be found in Chapter 6 of the User's Guide.

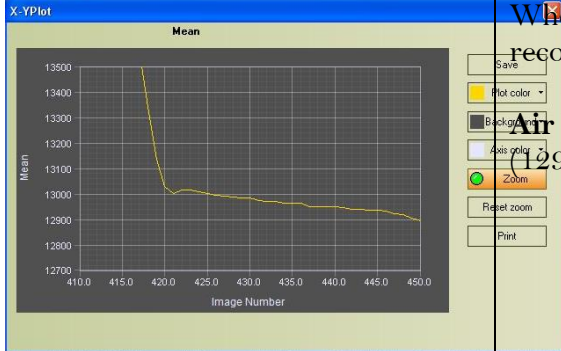
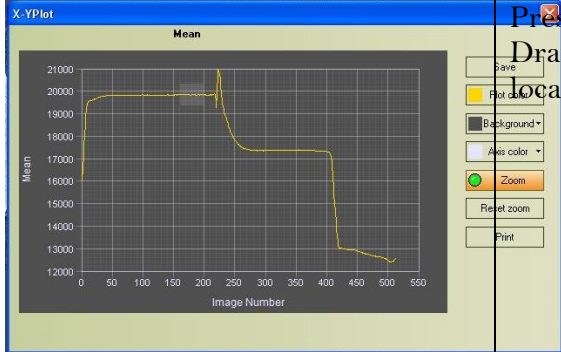
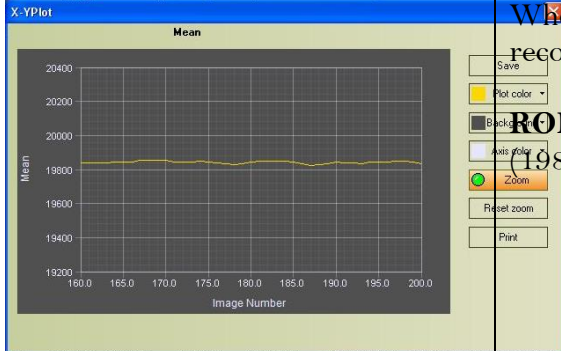
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10)		Select the beam hardening to match the sample imaged. <i>Note: Do not optimize based on the phantom.</i>
11)		Reconstruct using global max/min recon, USHORT data format, any binning, correct center shift, beam hardening desired, ring filter on or off, and recon filter on, CT Scaling OFF.
12)		After reconstruction has completed, open the reconstructed images in XMController.
13)		Scroll through the images to about half-way through the images or when finding a clean image near the middle.
14)		Open the Image Control Set, and select the 'Circle' in the Annotation tab.
15)		Draw a circular ROI directly in the middle of the phantom, filling up approximately 80% of the phantom. Move and size the ROI using the 'arrow' control. <i>Note: Do not place ROI in the smaller phantom section at the top of the phantom</i>

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16)		Generate the ROI statistics by selecting Process→ROI Statistics, and selecting 'Yes' to statistics for all images.
17)		When the statistics are displayed, choose 'Mean' in the bottom drop-down box, and then press 'Plot Graph'.
18)		The graph of the mean values will appear as below. Press the 'Zoom' button, and draw a square around the bottom for the Air ROI.

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19)		When the zoomed plot is displayed, record Air value below. Air Value = _____ (12950) from example above)
20)		Press 'Reset Zoom' to zoom out the plot. Draw a rectangle for ROI 1 in the location in the figure to the left.
21)		When the zoomed plot is displayed, record ROI 1 value below. ROI 1 Value = _____ (19850 from example above)
22)		Close the X-Y Plot and ROI statistics page
23)		Select from the top menu 'Process->Save CTScale Data'

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24)	1. 0 density of air 2. 1.16* density of water	Select '2' as the number of inserts for this phantom, and verify that the default insert densities are as below
25)		Enter in the source filter string desired. If no filter was used, enter 'none' <i>Note: If you have been shipped with a phantom with other than these densities, enter in the correct densities on this page</i>
26)		Enter in the ROI values as saved in steps above, and press 'OK'
27)		Repeat for each kV, beam hardening, and source filter desired
28)		Verify that the CT scaling worked correctly by re-reconstructing the phantom images with CT Scaling ON in the XMReconstructor

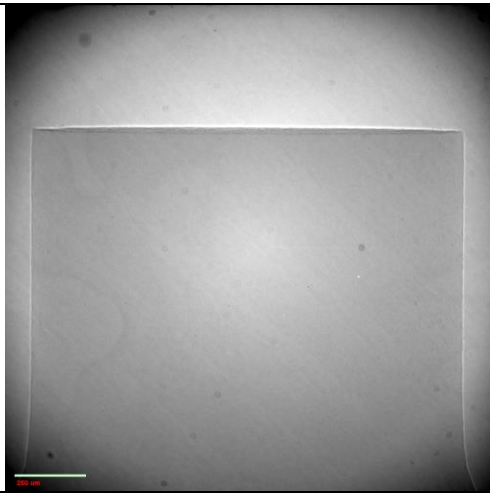
Go to Section 6 to verify that the scaling is implemented correctly.

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5.4. CT Scaling for 10x objectives

WARNING: CT Scaling will only be successful if your sample is completely within the field of view in width. If your sample extends in width (side-to-side) beyond the edge of the field of view, and air is not visible on both sides of the sample for the entire rotation of the image, the scaling will NOT be preserved.

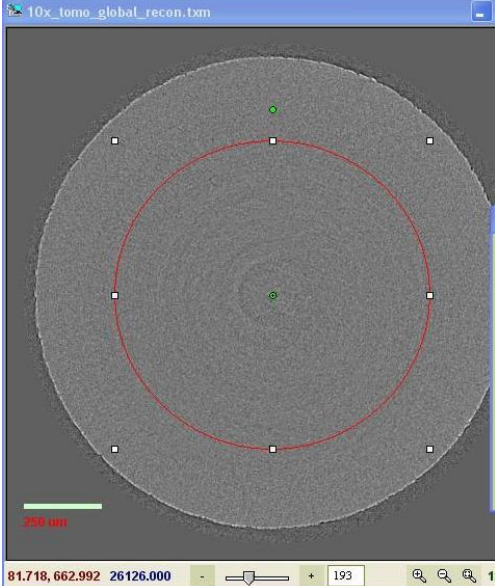
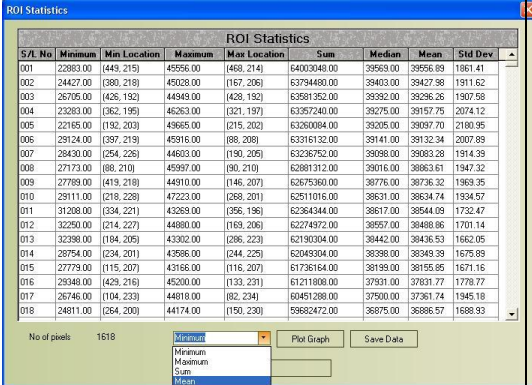
This procedure is intended to be used for 10x magnification objectives.

1)		Pre-define all CT scaling parameters: kV, beam hardening, and source filter for the images desired to be CT scaled.
2)		Set all other values to nominal settings appropriate for your site. <i>Note:</i> You may choose a smaller number of projections and higher binning than normal to speed up acquisition and reconstruction. A scan of -90 degrees to 90 degrees, 181 projections, bin 2 may be used.
3)		Scan 'Small Water Material', Part Number A000598, phantom using exact parameters as specified. <i>Note:</i> Ensure that the top of the phantom is below the top of the image so that there is a clean slice of air above the phantom.
4)		Move Sample Theta = -90 degrees, and center using the Sample Z stage.

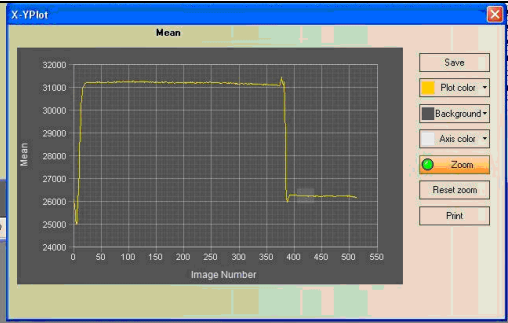
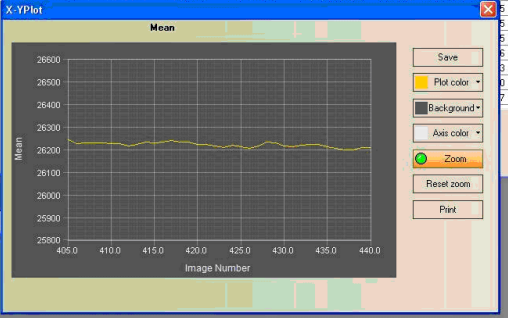
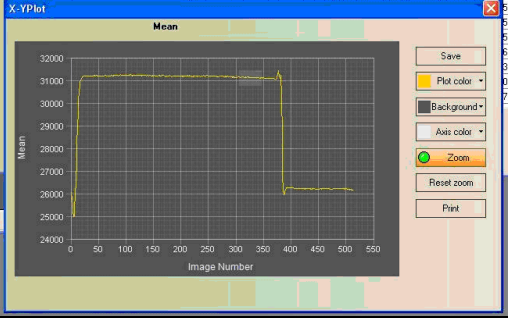
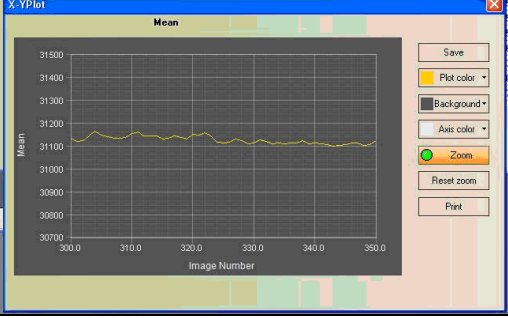
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5)		Perform reference scan as desired. In general, use the same exposure per projection of the tomography set, and take at least 10 averages. Multi-reference may also be used, ensuring that the total number of images is 10 or more.
6)		After acquisition, apply the reference filter to the phantom projection set.
7)		Save and close the phantom projection set.
8)		Open up the projection set in the XMReconstructor
9)		Perform focal series for center shift, and record the center shift.
10)		Select the beam hardening to match the sample imaged (do not optimize based on the phantom).
11)		Reconstruct using global max/min recon, USHORT data format, any binning, correct center shift, beam hardening desired, ring filter on or off, and recon filter on, CT Scaling OFF.
12)		After reconstruction has completed, open the reconstructed images in the XMController.
13)		Scroll through the images to about half-way through the images, finding a clean image near the middle.
14)		Open the Image Control Set, and select the 'Circle' in the Annotation tab.

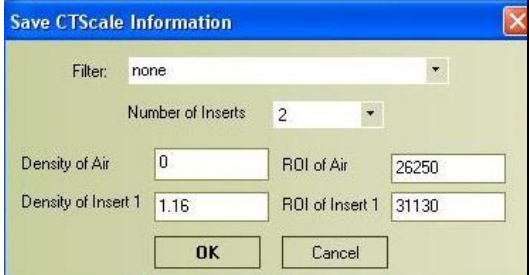
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15)		Draw a circular ROI directly in the middle of the phantom, filling up approximately 80% of the phantom. Move and size the ROI using the 'arrow' control.
16)		Generate the ROI statistics by selecting View->ROI Statistics, and selecting 'Yes' to statistics for all images.
17)		When the statistics are displayed, choose 'Mean' in the bottom drop-down box, and then press 'Plot Graph'

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18)		The graph of the mean values will appear as below. Press the 'Zoom' button, and draw a square around the bottom for the Air ROI.
19)		When the zoomed plot is displayed, record the Air value. Air Value = _____ ((26250) from the example)
20)		Press 'Reset Zoom' to zoom out the plot. Draw a rectangle for ROI 1 in the location as in the figure
21)		When the zoomed plot is displayed, record ROI 1 value below. ROI 1 Value = _____ (31130 from the example)
22)		Close the X-Y Plot and ROI statistics page.

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23)		Select from the top menu 'Process→Save CTScale Data'.
24)		Select '2' as the number of inserts for this phantom, and verify that the default insert densities are as below. 0 density of air 1.16* density of water Enter in the source filter string desired. If no filter was used, enter 'none' <i>Note: If you have been shipped with a phantom with other than these densities, enter in the correct densities on this page.</i>
25)		Next enter in the ROI values as saved in the steps above, and press 'OK'
26)		Repeat all the steps in this section for each kV, beam hardening, and source filter desired

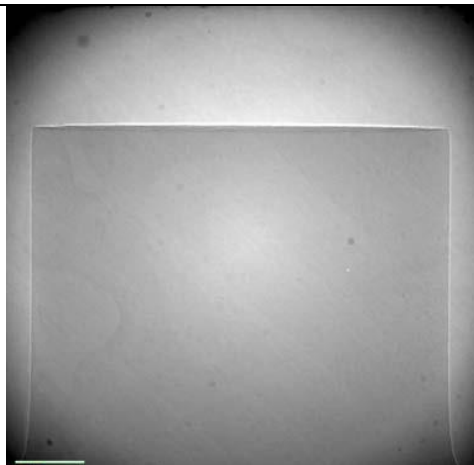
Verify that the CT scaling worked correctly by re-reconstructing the phantom images with CT Scaling ON in Reconstructor (see section 6 below).

Go to Section 6 to verify that the scaling is implemented correctly.

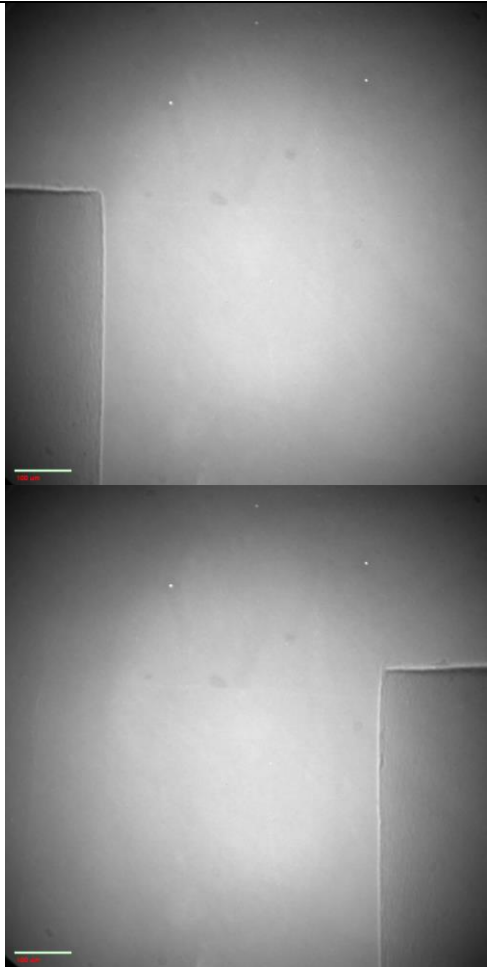
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5.5. CT Scaling for 20x Objective

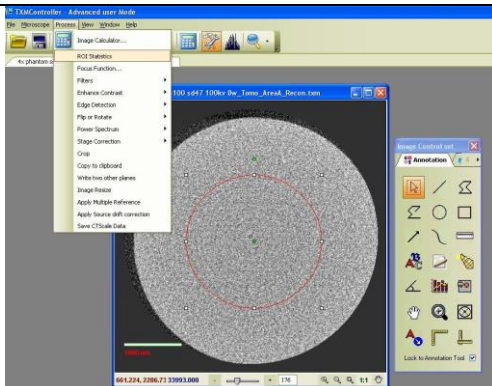
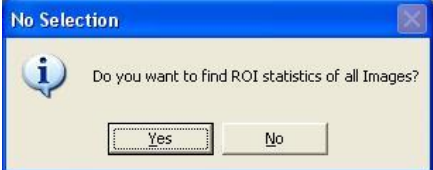
This procedure is intended to be used for the 20x magnification objective.

Step	Picture	Description
1)		Pre-define all CT scaling parameters: kV, beam hardening, and source filter for the images desired to be CT scaled.
2)		Set all other values to nominal settings appropriate for your site. <i>Note: You may choose a smaller number of projections and higher binning than normal to speed up acquisition and reconstruction. A scan of -90 degrees to 90 degrees, 181 projections, bin 2 may be used.</i>
3)		Scan the 'High Resolution Water Material Assembly', Part Number A001186, phantom using exact parameters as specified. <i>Note: Ensure that the top of the phantom is below the top of the image so that there is a clean slice of air above the phantom.</i>

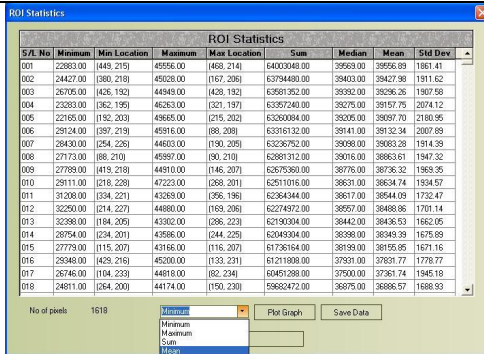
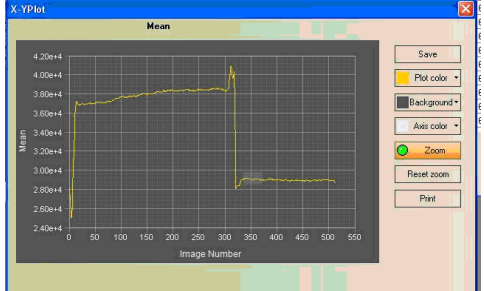
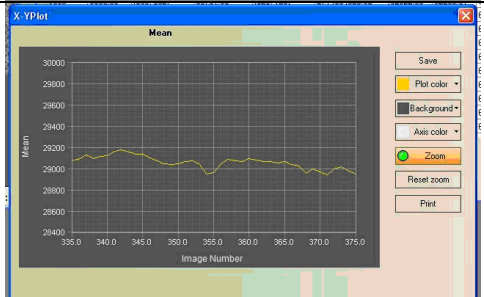
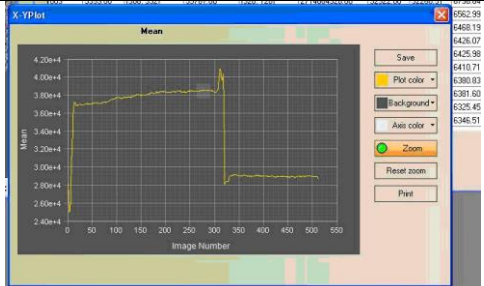
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4)		To center the phantom, at theta = 0 degrees, move the Sample X stage both left and right by a step of 1000um. Move Sample Theta = -90 degrees, move the Sample Z stage both left and right by a step of 1000um. Note: The left and right images should be equally off-centered (Shown)
5)		Make a reference image as desired. Note: In general, use the same exposure per projection of the tomography set, and take at least 10 averages. Multi-reference may also be used, ensuring that the total number of images is 10 or more.
6)		After acquisition, apply the reference filter to the phantom projection set.
7)		Save and close the phantom projection set.

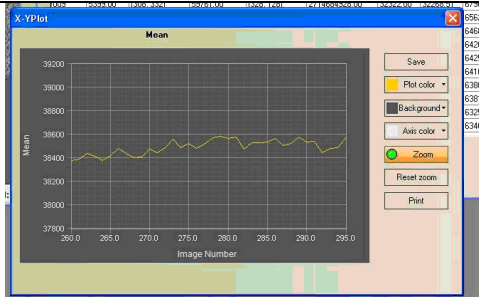
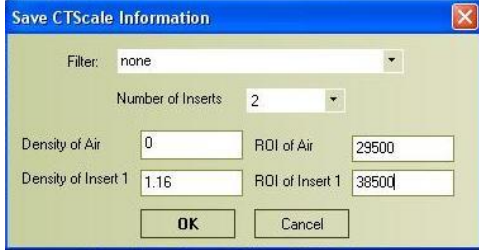
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8)		Open up the projection set in XMReconstructor.
9)		Perform focal series for center shift, and record the center shift.
10)		Select the beam hardening to match the sample imaged (do not optimize based on the phantom).
11)		Reconstruct using global max/min recon, USHORT data format, any binning, correct center shift, beam hardening desired, ring filter on or off, and recon filter on, CT Scaling OFF.
12)		After reconstruction has completed, open the reconstructed images in XMController.
13)		Scroll through the images to about half-way through the images, finding a clean image near the middle.
14)		Open the Image Control Set, and select the 'Circle' in the Annotation tab.
15)		Draw a circular ROI directly in the middle of the phantom, filling up approximately 80% of the phantom. Move and size the ROI using the 'arrow' control.
16)		Generate the ROI statistics by selecting View→ROI Statistics, and selecting 'Yes' to statistics for all images.

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17)		When the statistics are displayed, choose 'Mean' in the bottom drop-down box, and then press 'Plot Graph'
18)		The graph of the mean values will appear as below. Press the 'Zoom' button, and draw a square around the bottom for the Air ROI.
19)		When the zoomed plot is displayed, record Air value below. Air Value = _____ (29500) from example
20)		Press 'Reset Zoom' to zoom out the plot. Draw a rectangle for ROI 1 in the location as in the following figure:

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21)		When the zoomed plot is displayed, record ROI 1 value below. ROI 1 Value = _____ (38500 from example)
22)		Close the X-Y Plot and ROI statistics page.
23)		Select from the top menu 'Process→Save CTSale Data'.
24)		Select '2' as the number of inserts for this phantom, and verify that the default insert densities are as below. 0 density of air 1.16* density of water Enter in the source filter string desired. If no filter was used, enter 'none'. Note: <i>If you have been shipped with a phantom with other than these densities, enter in the correct densities on this page.</i>
25)		Next enter in the ROI values as saved in the previous steps and press 'OK'.
26)		Repeat all the steps in this section for each kV, beam hardening, and source filter desired.

Verify that the CT scaling worked correctly by re-reconstructing the phantom images with CT Scaling ON in Reconstructor (see section 6 below).

Go to Section 6 to verify that the scaling is implemented correctly.

6. Calibration for User-Defined Scaling

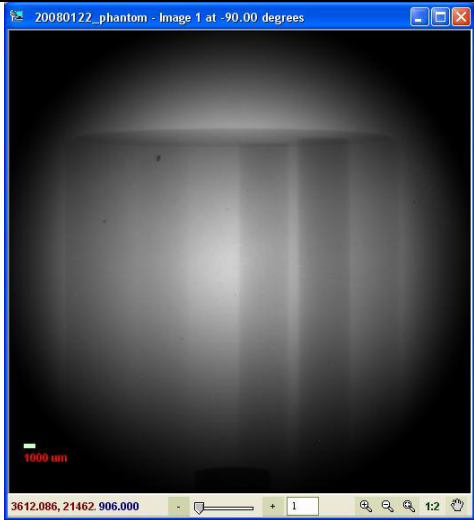
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WARNING: User-Defined Scaling will only be successful if your sample is completely within the field of view in width. If your sample extends in width (side-to-side) beyond the edge of the field of view, and air is not visible on both sides of the sample for the entire rotation of the image, the scaling will NOT be preserved.

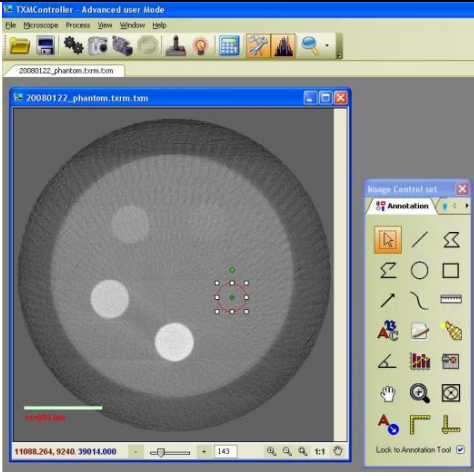
The initial steps for User-Defined Scaling is to decide which kV, objectives, beam hardening, and source filter combinations the site will require User-Defined Scaled images. Then the user will need to scan their sample of choice and follow the procedure below.

6.1. User-Define Scaling Calibration

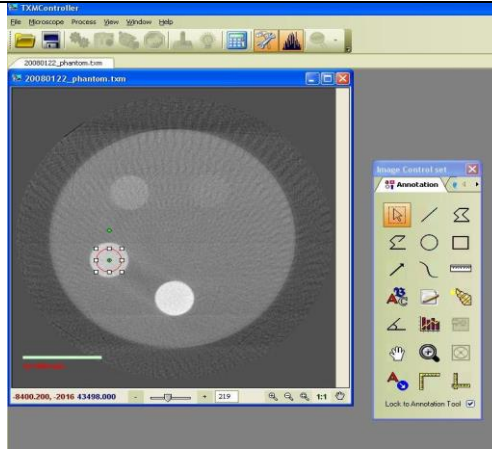
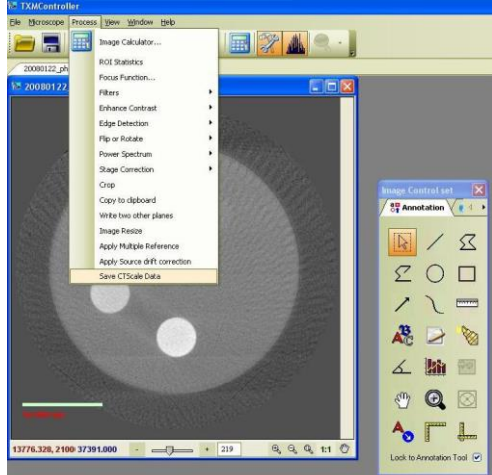
Any sample may be used to define scaling, as long as it remains within the field of view in width for the entire rotation of the sample. Air must be visible on side edges for entire rotation.

Step	Picture	Description
1)		Scan the sample that will be used for the calibration.
2)		Open up the projection set in the XMReconstructor.
3)		Perform focal series for center shift, and record the center shift.
4)		Select the beam hardening to match the sample imaged (do not optimize based on the phantom).

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5)		Reconstruct using global max/min recon, ushort data format, any binning, correct center shift, beam hardening desired, ring filter on or off, and recon filter set to desired setting.
6)		After reconstruction has completed, open the reconstructed images in XMController.
7)		Scroll through the images to about half-way through the images, finding a clean image near the middle. <i>Note: the images presented below show a fan-type artifact because we performed only 60 projections for a 180-degree scan. The User-defined scaling is not effected by the reduced number of projections, but artifacts are seen. This protocol is acceptable for User-defined scaling calibrations, but not for actual imaging.</i>
8)		Find the mean value of the MINIMUM value that you wish to scale to. In the image below, it was drawn in the background material, but it can be drawn in any area, as long as this area has a LOWER mean value than the MAXIMUM (to be determined in the next step). Either draw an ROI around an image area that you wish to scale to, or pass the cursor over an area of interest, noting the mean value of the images in the area. Record this value as ROI 0. ROI 0 Value = _____

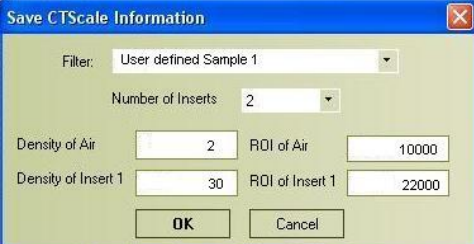
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9)		Find the mean value of the MAXIMUM value you wish to scale to. In the image it was drawn in an intermediate density area material, but it can be drawn in any area, as long as this area has a HIGHER mean value than the MINIMUM value determined in the previous step. Either draw an ROI around an image area that you wish to scale to, or pass the cursor over an area of interest, noting the mean value of the images in the area. Record this value as ROI 1. ROI 1 Value = _____ Ensure that ROI0 is less than ROI1.
10)		Select 'Process→Save CTScale Data'.

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11)		Enter the name of the filter. This name will be used when applying the User-defined scaling later during reconstruction. Choose something which will clearly indicate which filter was used for this User-defined scaling session. Select '2' as the number of inserts for this phantom, and calculate the densities to enter. Select the pixel value of insert 0 (for example 2000) = Pmin = _____ Select the pixel value if insert 1 (for example 30000) = Pmax = _____ Rules for Pmin and Pmax: Pmin must be less than Pmax. Pmin and Pmax must be greater than 0 Pmin and Pmax must be less than 65535.
If you choose Pmin to be close to 0, any values reconstructed with lesser density will be truncated at 0. If you choose Pmax to be close to 65535, any values reconstructed with higher density will be truncated at 65535.		
12)		For the UI, calculate the values to be entered into Density of Air and Density of Insert 1: Density of Air = Pmin/1000 Density of Insert 1 = Pmax/1000 For example, if Pmin = 2000, then the Density of Air = (2000/1000) = 2. For example, if Pmax = 30000, then the Density of Insert 1 = (30000/1000) = 30

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13)		Enter ROI0 value as 'ROI of Air' (for this example, use 10000) Enter ROI1 value as 'ROI 1' (for this example, use 22000). Press 'OK'.
14)		Repeat all steps in this section for each kV, beam hardening, and source filter desired.

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7. Reconstructing CT Scaled Images

Reconstruction for CT Scaling requires that the Calibrations have been performed as in Section 6 above. If the calibration does not exist that matches the current scanning and reconstruction parameters, the user will be warned and not allowed to reconstruct using CT Scaling.

To reconstruct CT Scaled images, follow the procedure below.

Step	Picture	Description
1)		Start XM Reconstructor and load the projection data set to be reconstructed.
2)		Find the appropriate Center Shift using the center shift dialog box.
3)		Open the Reconstruction Setting dialog, and select 'Apply CT Scale'.
4)		If the calibration exists that matches the current settings, then the user will be allowed to press 'OK'. If there is no file one of the critical parameters is incorrect (kV, objective, or beam hardening) and the calibration process must be modified.

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5)		Reconstruct the images. <i>Note: If the user reconstructs the Calibration phantom with CT Scaling, when the ROIs are placed in the locations as specified in the calibration procedure for ROI 1 (the insert closest to water), the mean values in these ROIs should match closely to the (specified densities of the inserts * 1000).</i> For example, for the large phantom, the mean value of ROI 1 should be $(1.12 * 1000) = 1120$, and the mean value for air should be close to 0. Due to non-linear beam hardening effects, the mean values in the other inserts are not exactly matching to $(\text{density} * 1000)$.
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