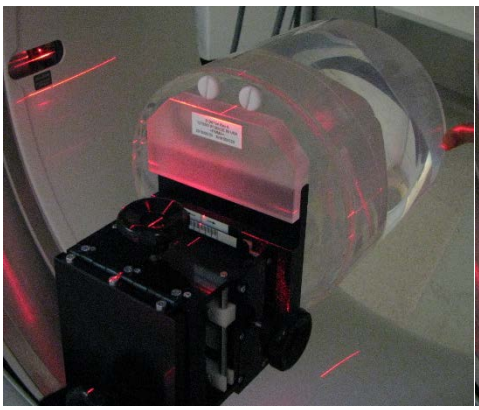
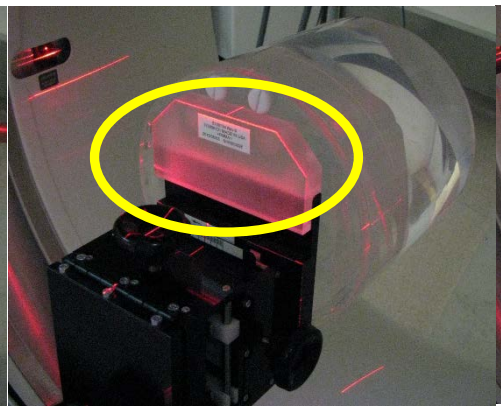
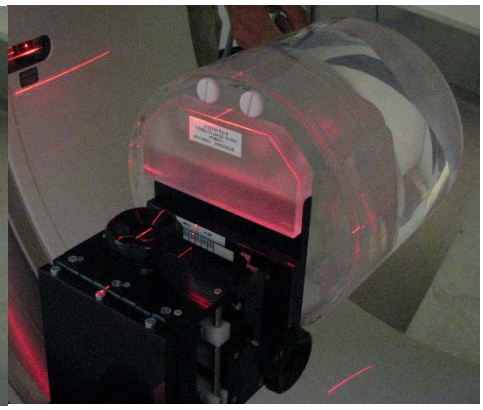
Daily, Weekly, & Monthly QA Testing on CT Scanners

Scanning & Analysis of Phantom Scans

Procedure for Daily QA:

Scanning & Acquiring Images:

1. Set up the QA phantom:
   a. Place it on the phantom holder **and level it**. (see the image below regarding positioning)
   b. The phantom holder has some “slop” in it: You can move the phantom to so that it angles to the right or to the left. Different holders have different amounts of “slop”.
   c. You need to adjust the phantom so that it is straight and not angled. To do this use the lasers to align the phantom properly as shown in the images below. First move the phantom into/out of the bore until the laser light is just skiming the phantom edge as shown below. Then move the phantom holder with your hand until the edge of the phantom looks like the middle image below, with the laser just toughing the back edge of the phantom EQUALLY from right to left.. The left image shows improper positioning with the laser light only shinning on the left side of the edge and the right image shows improper positioning with the laser light only shinning on the right side of the edge.

   d. Position the phantom vertically and horizontally into alignment with the laser lights.
   e. Move the table until the inner axial position lights are right on the circumferential line on the phantom and press the axial inner landmark button.
2. Select New Patient, see below for naming instructions.

   Patient Name: DailyQA(Scanner) ie: DailyQAER

   Acc#: (Scanner)(Date) ie: CTER08/21/2013

   Patient ID: CTQA(Scanner) ie: CTQAER
3. In the patient protocol figure, click under the feet of the adult body to get to Protocols 10.x and then **Select: Protocol 10.1 - ACR DAILY QA**.
4. Perform the first 2 Series in the protocol.
5. **Move the phantom up vertically as far as the scanner lets you**. This will put the top of the phantom outside the 50 cm field of view – this is what we want for this part of the test.
6. Perform the last two series in the protocol. And then you can “End Exam”.

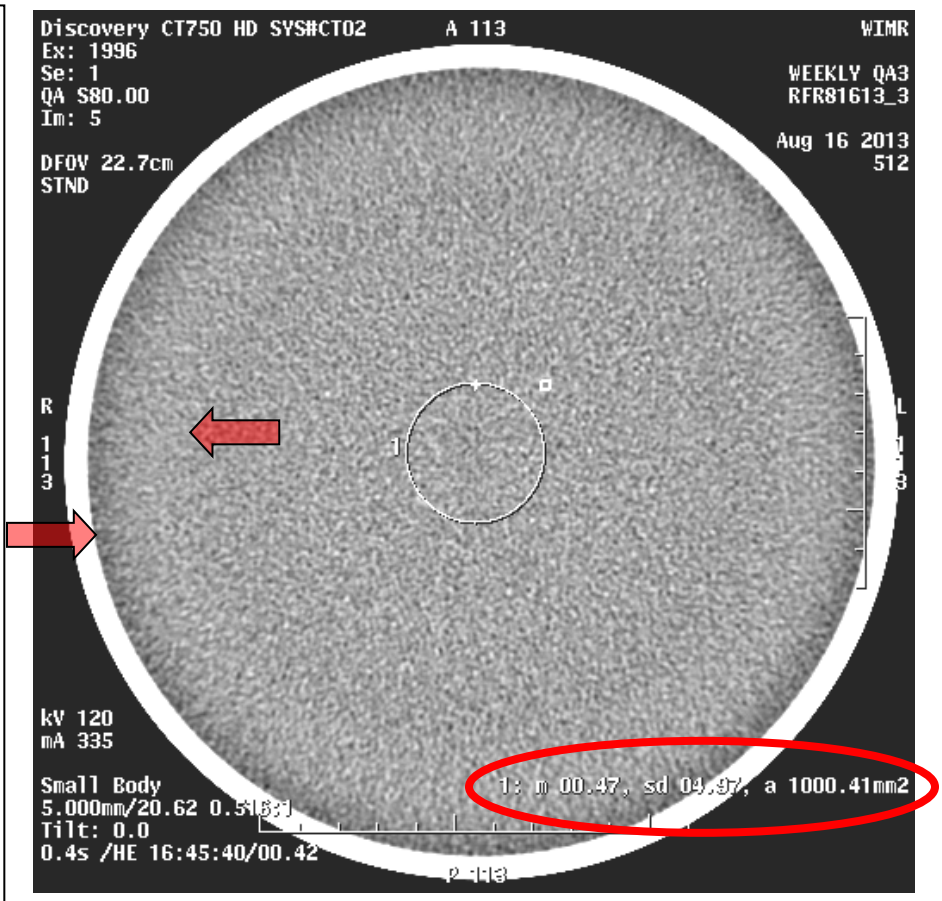
Analyzing Images: Please DO NOT change the Window Width or Window Level for ANY of these tests: They are already set optimally for analysis.

Series 1, 2, & 3 Images:

1. Click on Image Works and select the QA exam just scanned.
2. First perform the "**Water Center Mean CT#**" and "**Water Standard Dev."** Tests.
3. Go to the image at scan location **S80** in the **Series 1**, **Helical scans**.
4. Select Measure in the tools and select a circular ROI. Increase the size of the ROI to about **1000 mm2** and position it in the center of the phantom image. (See Image below
5. **Record both the Mean CT Number and the standard deviation from the ROI into the QA data sheet.**
6. **Look at all the images from and Series 1 (Helical), Series 2 & 3 (Axial). Note if any of the images have artifacts. Pay particular attention to the Axial Images. Any artifacts will most likely show up in the Axial Images, even if the Helical images look fine.**

This is NOT a ring artifact, but is the normal image for the GE water phantom. You will normally see a slightly dark ring just inside of the acrylic ring and a broader slightly light "donut" further inside, as shown between the arrows in the image.

This same normal density variation near the outside of the phantom can be seen in the first image on the next page. However this image really does contain a ring artifact indicated by the red arrow.



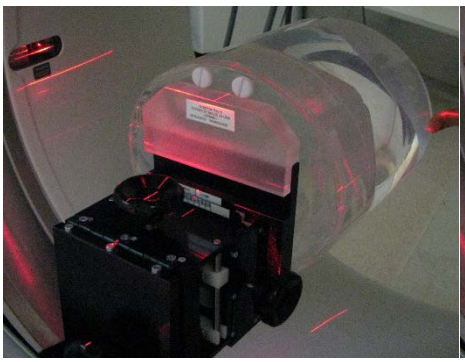
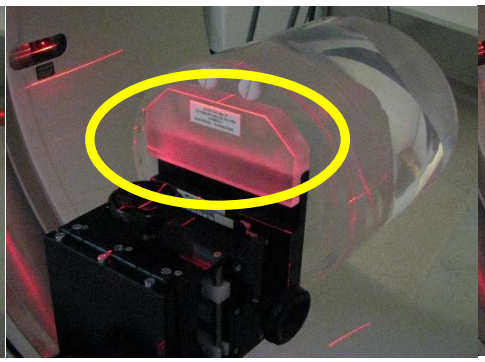
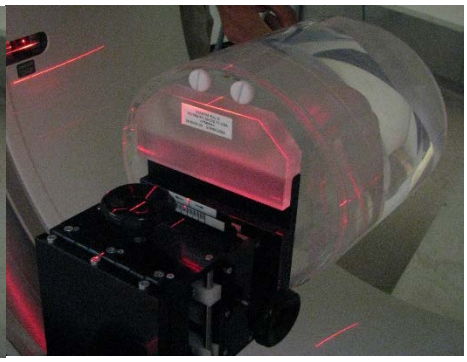
Series 4, 5, & 6 Images (using a 50 cm SFOV):

7. **Look at all the images from and Series 4 (Helical), Series 5 & 6 (Axial). These are the images in which the phantom was raised off iso-center. Note if any of the images have artifacts. Pay particular attention to the Axial Images. Any artifacts will most likely show up in the Axial Images, even if the Helical images look fine.**

Procedure for Weekly QA:

Scanning & Acquiring Images:

1. Set up the QA phantom:
   a. Place it on the phantom holder and level it. (see the image below regarding positioning)
   b. The phantom holder has some “slop” in it: You can move the phantom to so that it angles to the right or to the left. Different holders have different amounts of “slop”.

   c. You need to adjust the phantom so that it is straight and not angled. To do this use the lasers to align the phantom properly as shown in the images below. First move the phantom into/out of the bore until the laser light is just skiming the phantom edge as shown below. Then move the phantom holder with your hand until the edge of the phantom looks like the middle image below, with the laser just toughing the back edge of the phantom EQUALLY from right to left. The left image shows improper positioning with the laser light only shinning on the left side of the edge and the right image shows improper positioning with the laser light only shinning on the right side of the edge.
   d. Position the phantom vertically and horizontally into alignment with the laser lights.
   e. Move the table until the inner axial position lights are right on the circumferential line on the phantom and press the axial inner landmark button.
2. Select New Patient, see below for naming instructions.

   Patient Name: WeeklyQA(Scanner) ie: WeeklyQAER

   Acc#: (Scanner)(Date) ie: CTER08/21/2013

   Patient ID: CTQA(Scanner) ie: CTQAER
3. In the patient protocol figure, click under the feet of the adult body to get to Protocols 10.x and then **Select: Protocol 10.3 - ACR WEEKLY QA**.
4. Perform the first 4 Series in the protocol including both Groups of Series 4.
5. **Move the phantom up vertically as far as the scanner lets you**. This will put the top of the phantom outside the 50 cm field of view – this is what we want for this part of the test.
6. Perform the last two series in the protocol that have a 50 cm SFOV. And then you can “End Exam”.

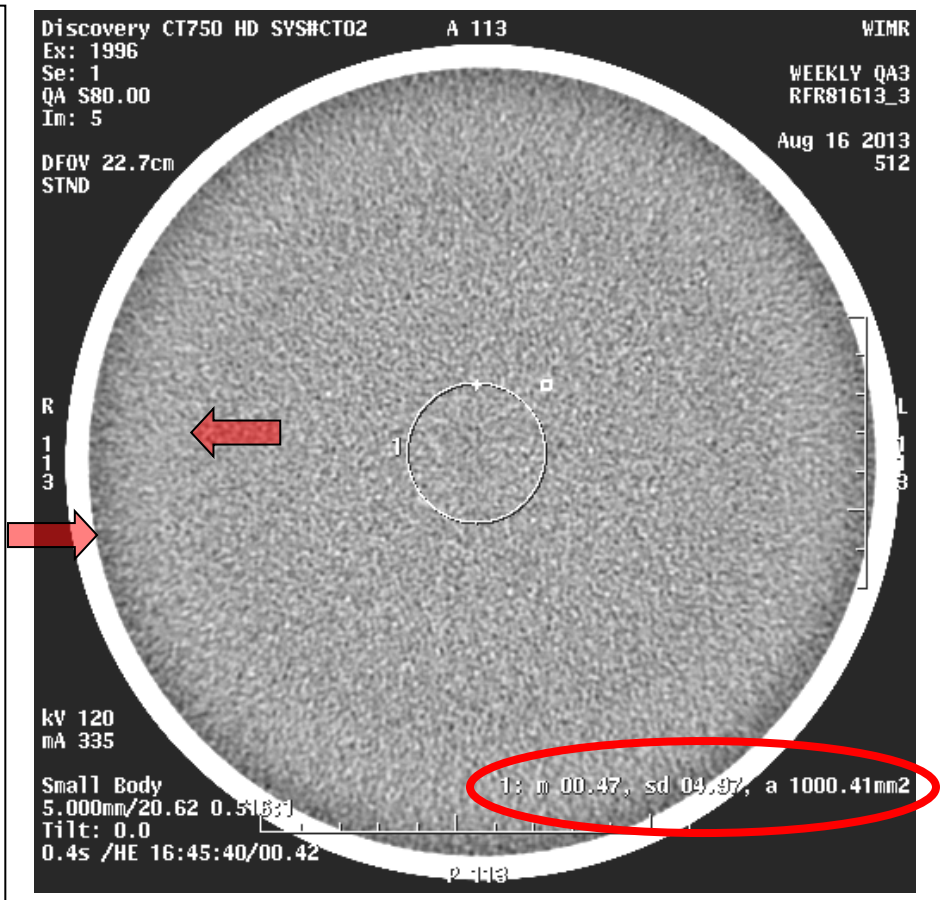
Analyzing Images: **Please DO NOT change the Window Width or Window Level for ANY of these tests: They are already set optimally for analysis.**

Series 1, 2, 3, 5, & 6 Images:

1. Click on Image Works and select the QA exam just scanned. Then click "Viewer" button.
2. First perform the "**Water Center Mean CT#**" and "**Water Standard Dev."** Tests.
3. Go to the image at scan location **S80** in the **Series 1**, **Helical scans**.
4. Select Measure in the tools and select a circular ROI. Increase the size of the ROI to about **1000 mm2,** keeping it circular and in the center of the phantom image.
5. **Record both the Mean CT Number and the standard deviation from the ROI into the QA data sheet.**

This is NOT a ring artifact, but is the normal image for the GE water phantom. You will normally see a slightly dark ring just inside of the acrylic ring and a broader slightly light "donut" further inside, as shown between the arrows in the image.

This same normal density variation near the outside of the phantom can be seen in the first image on the next page. However this image really does contain a ring artifact indicated by the red arrow.



6. **Look at all the images from Series 1 (Helical), Series 2 & 3 (Axial) and also the last two series in which the phantom was raised off iso-center. Note if any of the images have artifacts. Pay particular attention to the Axial Images. Any artifacts will most likely show up in the Axial Images, even if the Helical images look fine.**

For Both Daily and Weekly Tests:

Various types of artifacts may appear on these images. The most common is a ring artifact. Below is an example of a ring artifact and the effect it can have on a clinical image:

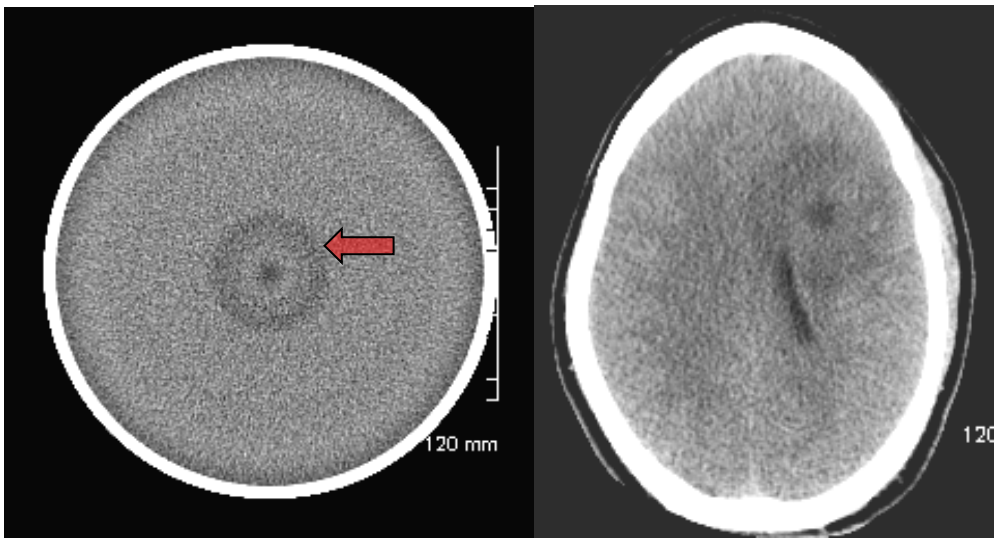
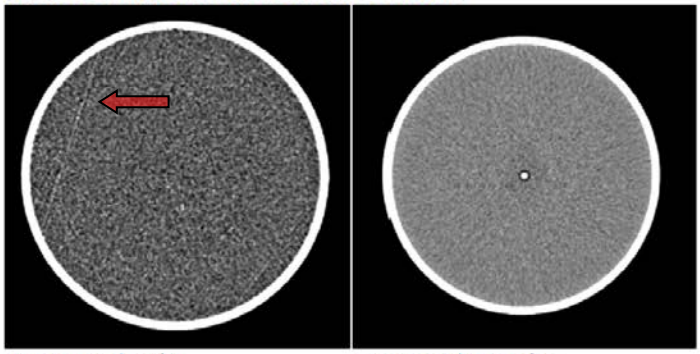
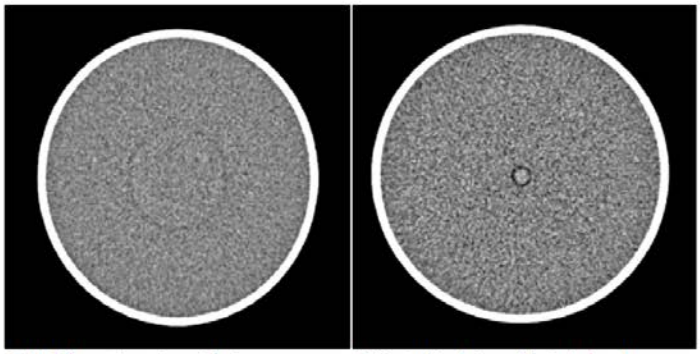


Figure 2. Example Artifacts from Water Phantoms



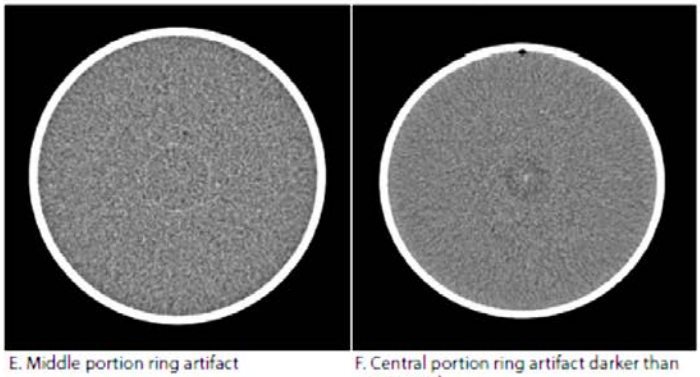
A. Linear streak artifact

B. Centralized ring artifact



C. Middle portion ring artifact

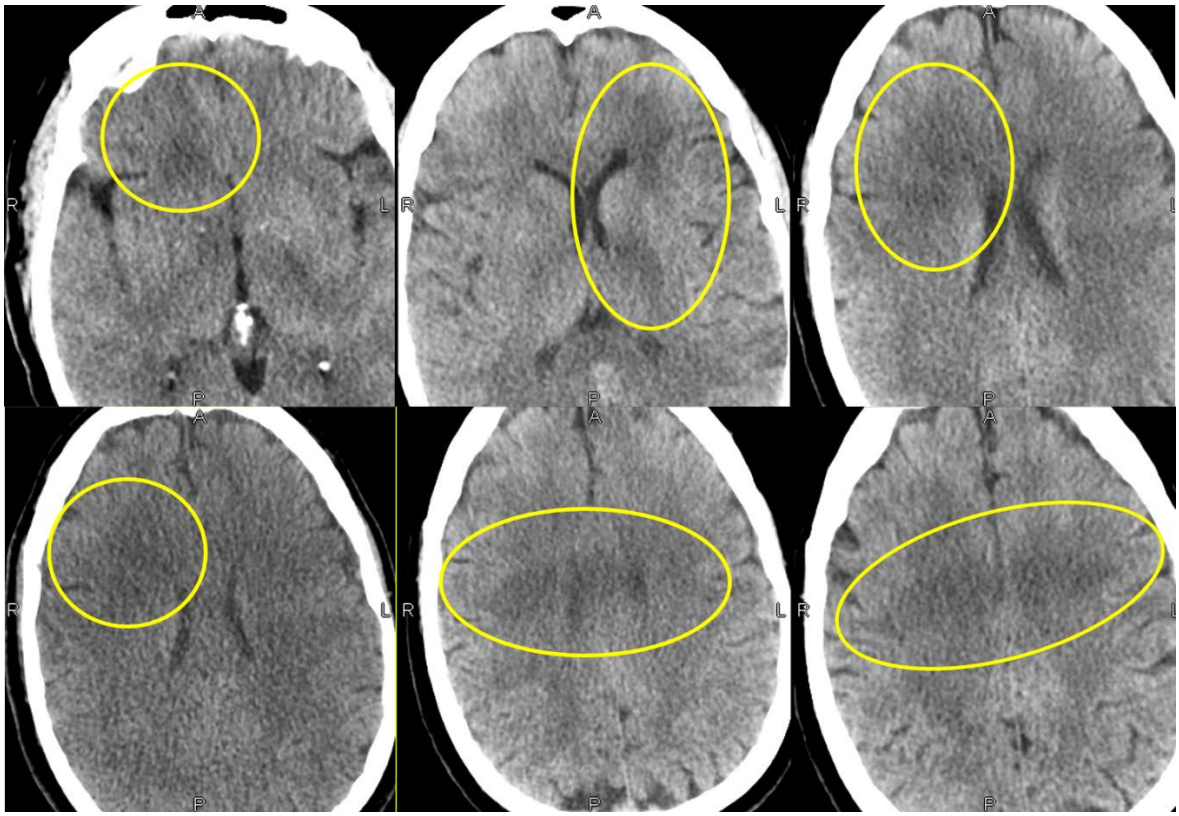
D. Centralized ring artifact darker than surround



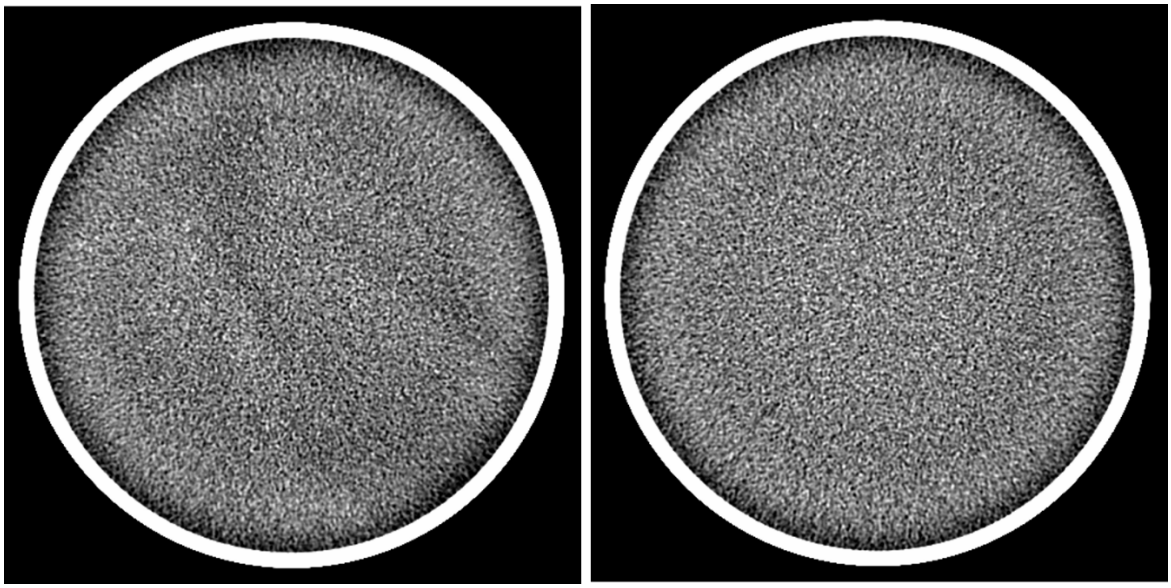
E. Middle portion ring artifact

F. Central portion ring artifact darker than surround

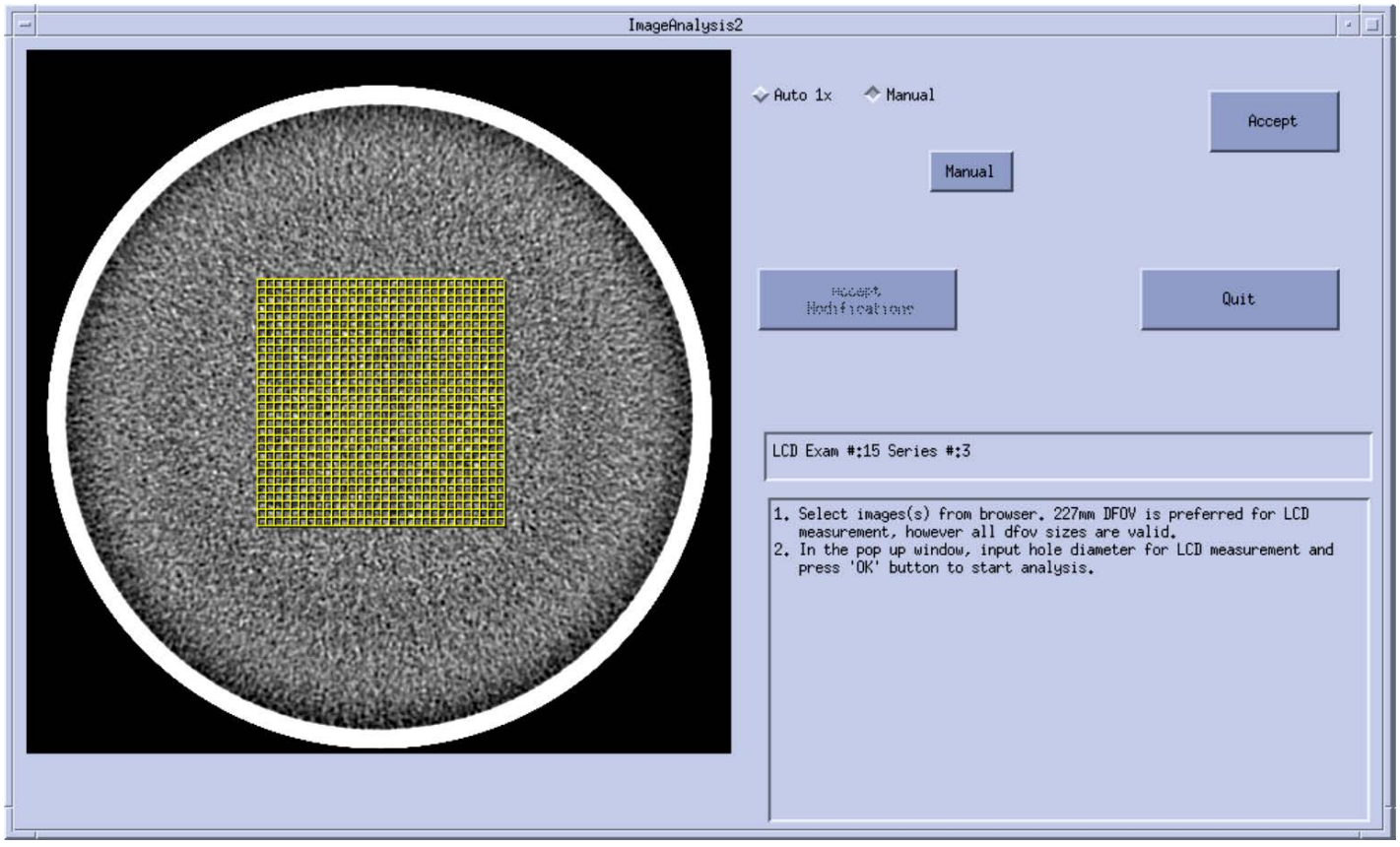
Below are artifacts that are NOT ring artifacts and can very easily be mistaken for pathologies in the patient. The cause turned out to be an air bubble inside of the x-ray tube housing.

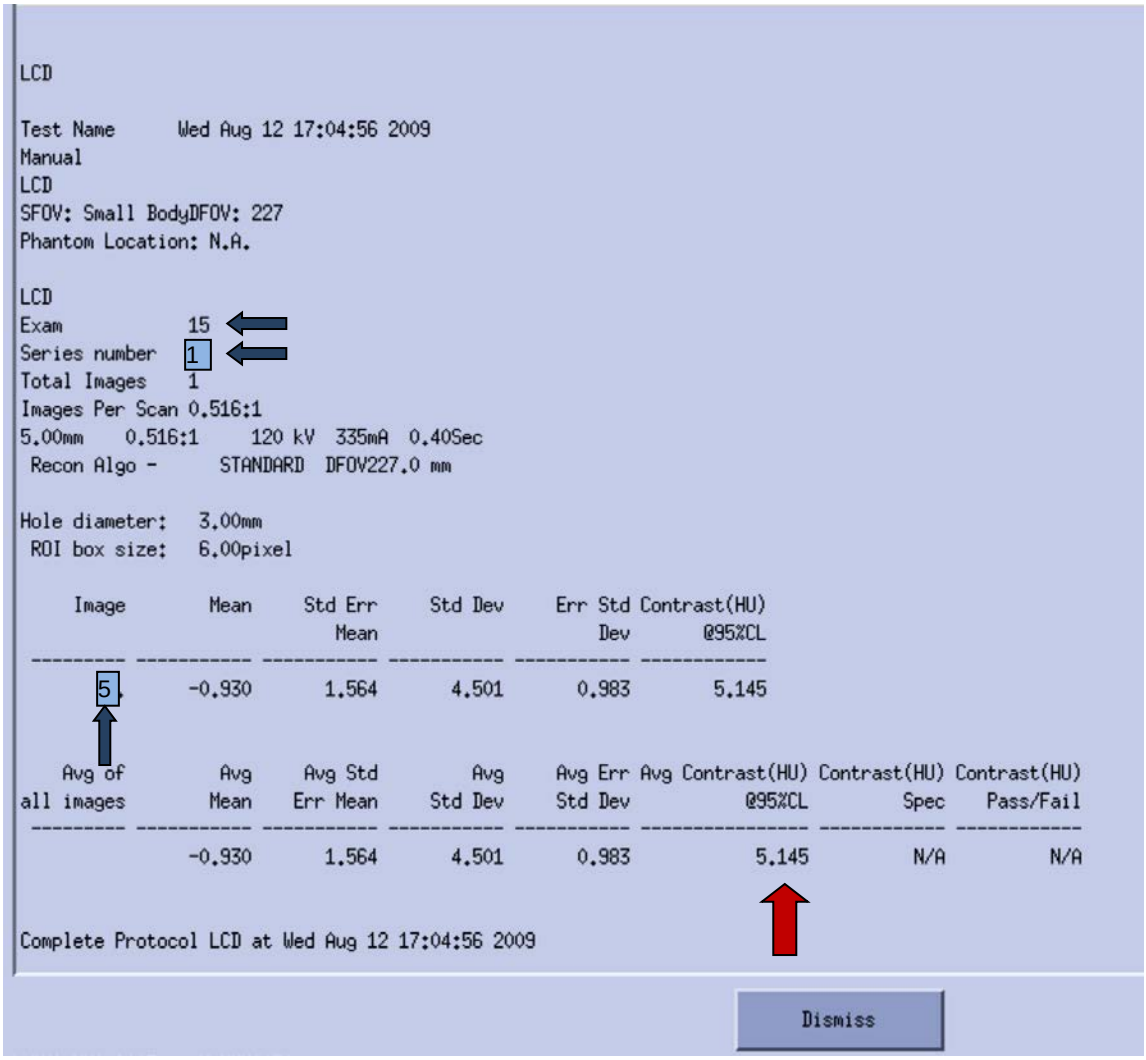


The following were 2 sets of phantom image from the daily QA scans. They were taken a few minutes apart from one another. Notice how you only see the artifact on one of them. Since this artifact is caused by a bubble floating around inside the tube, it is random chance when it will show up. You can see from the repeat scan that the artifact has gone away since the bubble has moved out of the x-ray beam. Therefore, if you see this artifact, do not simply re-scan the QA phantom until it goes away. You should call GE and not use the scanner until the issue is corrected by your vendor field engineer.



7. For the *64 slice scanners only*, perform the "**Low Contrast Detectability**" Test:
   a. Click the service icon on the top of the screen and click OK on the attention screen.
   b. Move the Service dialogue box (and any other analysis box) to the left monitor. **"Sort"** will appear on the right screen with a list of exams. Select the QA exam that you just performed, **Series 1**, and the Helical Image at **S80**. This is exactly the same image on which you performed the previous test for the accuracy of the CT number of water and its standard deviation (noise).
   c. Click the Image Quality Icon and then pick Image Analysis.
   d. The Image Analysis Tool, shown in the image below, will appear
   e. Click the Manual checkbox (a small diamond) and then click on the "Manual" box. A list of manual tool options will then drop down. Select "LCD". Then click on the "Accept" box.
   f. A dialogue box will now open with an Input Hole Diameter of 3.00 already input. Click the "OK" box.
   g. The analysis results will show up in a report, shown below on the next page. Check that the correct exam number, along with "Series 1" and "Image 5" appear on this report. These are shown with blue arrows in the image on the next page.
   h. The bottom line of the report on the right will show a value for "Average Contrast (HU) 95%CL". This is shown with a red arrow pointing to it. **Record this value into the QA data sheet.**
   i. Exit all the service dialogue boxes and click on Image Works.





LCD

Test Name Wed Aug 12 17:04:56 2009
Manual
LCD
SFOV: Small BodyDFOV: 227
Phantom Location: N.A.

LCD
Exam 15
Series number 1
Total Images 1
Images Per Scan 0.516:1
5.00mm 0.516:1 120 kV 335mA 0.40Sec
Recon Algo - STANDARD DFOV227.0 mm

Hole diameter: 3.00mm
ROI box size: 6.00pixel

Image	Mean	Std Err Mean	Std Dev	Err Std Dev	Contrast(HU) @95%CL
5	-0.930	1.564	4.501	0.983	5.145

Avg of all images	Avg Mean	Avg Std Err Mean	Avg Std Dev	Avg Err Std Dev	Avg Contrast(HU) @95%CL	Contrast(HU) Spec	Contrast(HU) Pass/Fail
	-0.930	1.564	4.501	0.983	5.145	N/A	N/A

Complete Protocol LCD at Wed Aug 12 17:04:56 2009

Dismiss

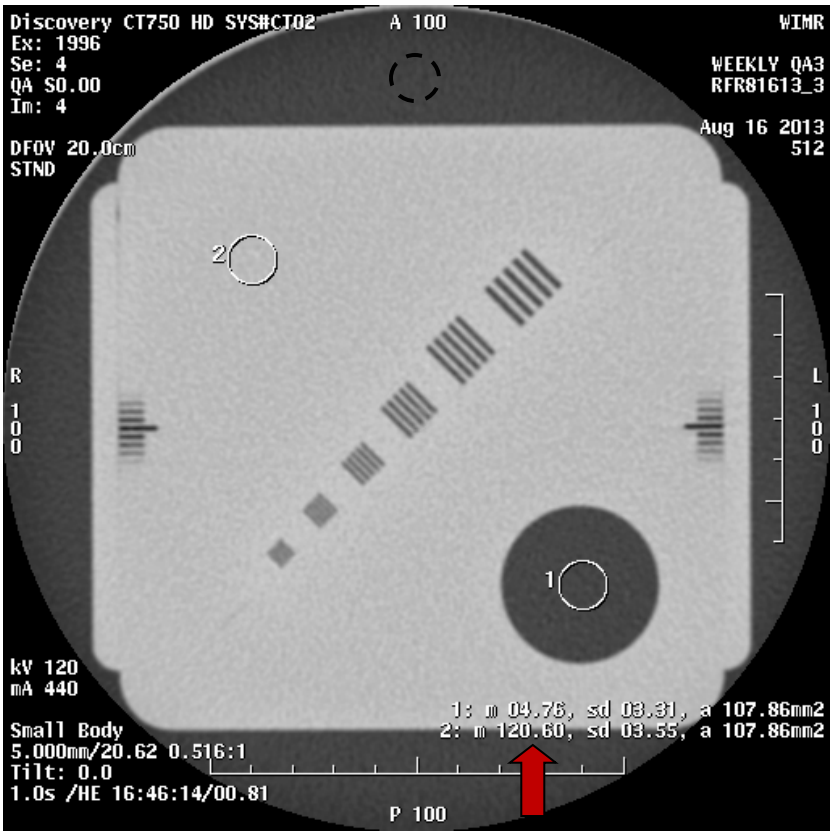
Series 4 Images:

1. Next perform the "**Contrast Scale**" test using the images in Series 4.
2. Select the image of the phantom at **S0** containing all the test patterns.

As shown in the image on the next page:

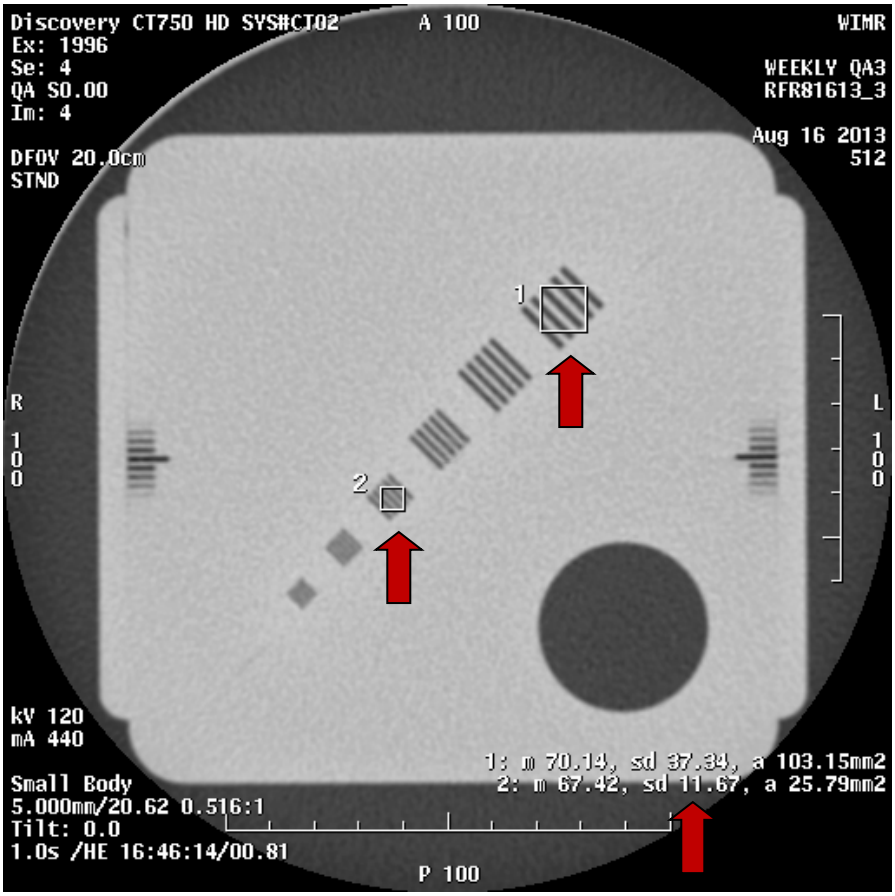
3. Select Measure in the tools and select a **circular ROI**. If the size of the ROI comes up as **100 to 200 mm2** don't adjust it; otherwise adjust it to about 150 mm2. Position the ROI in the center of the water circular hole in the lower right of the phantom image. Leave the ROI highlighted.
4. Again select Measure in the tools and select a circular ROI. It will be the same size as the one highlighted in the water circle. Position it in the upper left of the phantom image in the Plexiglas so that it is about as far in from the corner of the phantom as the first ROI.
5. **Record the values for the mean CT number of the water (lower right ROI) and of the Plexiglas (upper left ROI) into the QA data sheet**

Please note: The 8 slice scanner has an older version of the GE QA phantom which does not have a water filled area in the lower right of the phantom. To obtain the CT number of water in this phantom draw an ROI just above the Plexiglas square in the water area. This is shown as a black dashed circle in the image on the next page

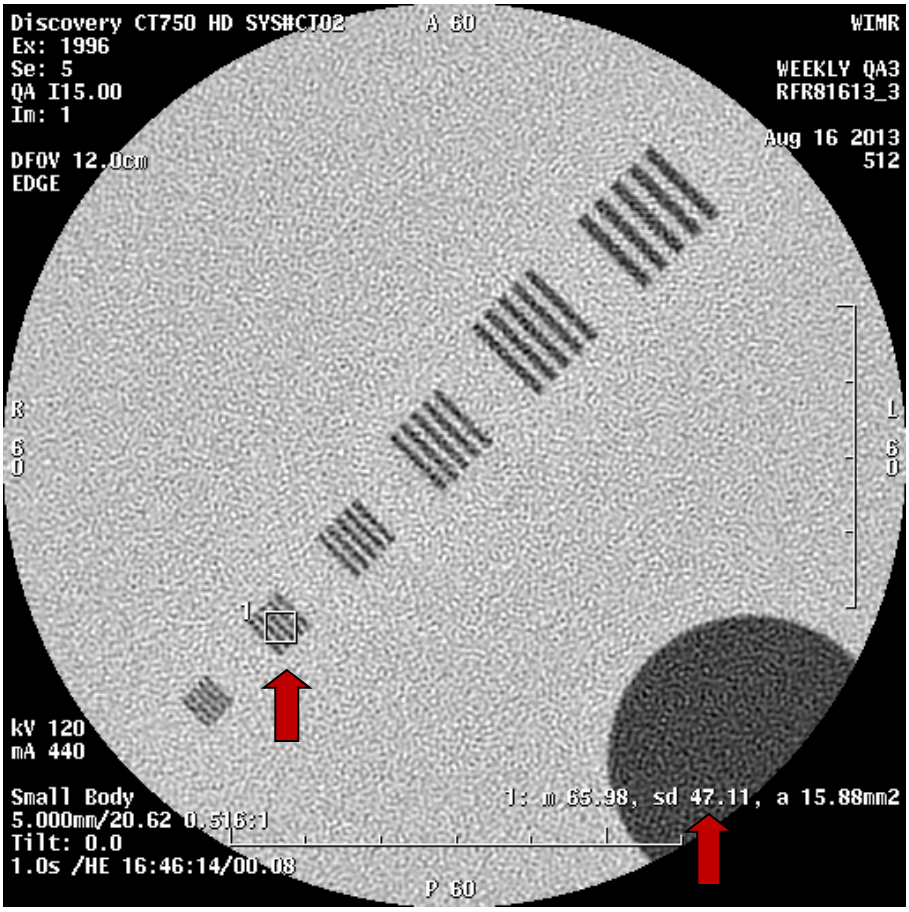


Series 4 & 5 Images:

1. Next perform the "**High Resolution**" tests using the images in Series 4 and 5.
2. The Series 4 images were created using the Standard Recon and a 20 cm DFOV and the Series 5 of images were created using the Edge Recon and a 12 cm DFOV.
3. The resolution block contains the following six different bar sizes, from largest to smallest, 1.6 mm, 1.3 mm, 1.0 mm, 0.8 mm, 0.6 mm, and 0.5 mm. The Standard Recon will analyze the 1.6 mm and the 0.8 mm patterns. The Edge Recon will analyze the 0.6 mm pattern.
4. Select the image at **S0** from the images of the resolution patterns reconstructed using the Standard Recon (Series 4). **This is the same image just used in the Contrast Scale Test.** (Press "Erase All" to remove the ROI information from the contrast scale test.)
5. Select Measure in the tools and select a square ROI. Adjust the size of the ROI to about **10 mm x 10 mm** (or an area of about **100 mm2**) and position it over the **1.6 mm pattern** so that it just covers the pattern.
6. Again select Measure in the tools and select a square ROI. Adjust the size of the ROI to about **5 mm x 5 mm** (or an area of about **25 mm2**) and position it over the **0.8 mm pattern** so that it just covers the pattern.
7. **Record the value of the standard deviation for each of these two ROI's in the proper places in the QA data sheet.**
8. Select the image at **S0** from the images of the magnified resolution pattern reconstructed using the Edge Recon (Series 5).
9. Select Measure in the tools and select a square ROI. Adjust the size of the ROI to about **4 mm x 4 mm** (or an area of about **16 mm2**) and position it over the **0.6 mm pattern** so that it just covers the pattern. (This is the next to smallest pattern.)
10. **Record the value of the standard deviation for this ROI in the proper places in the QA data sheet.**



Positioning of the square ROI's for the STND recon.



Positioning of the square ROI for the EDGE recon.

Series 6 & 7 or 6, 7 & 8 Images:

Reminder: Please DO NOT change the Window Width or Window Level for ANY of these tests: They are already set optimally for analysis.

Please note: For the following tests, the Optima 660CT in CT3, the VCT in the ED and at RP, and the 8 slice at East Clinic sort the 5 mm slices as Series 6, the 2.5 mm slices as Series 7, and the 1.25 mm slices as Series 8. All the other CT scanners (CT1, CT2, CT4, and DHC) sort the 5 mm and the 2.5 mm slices as Series 6, and the 1.25 mm slices as Series 7.

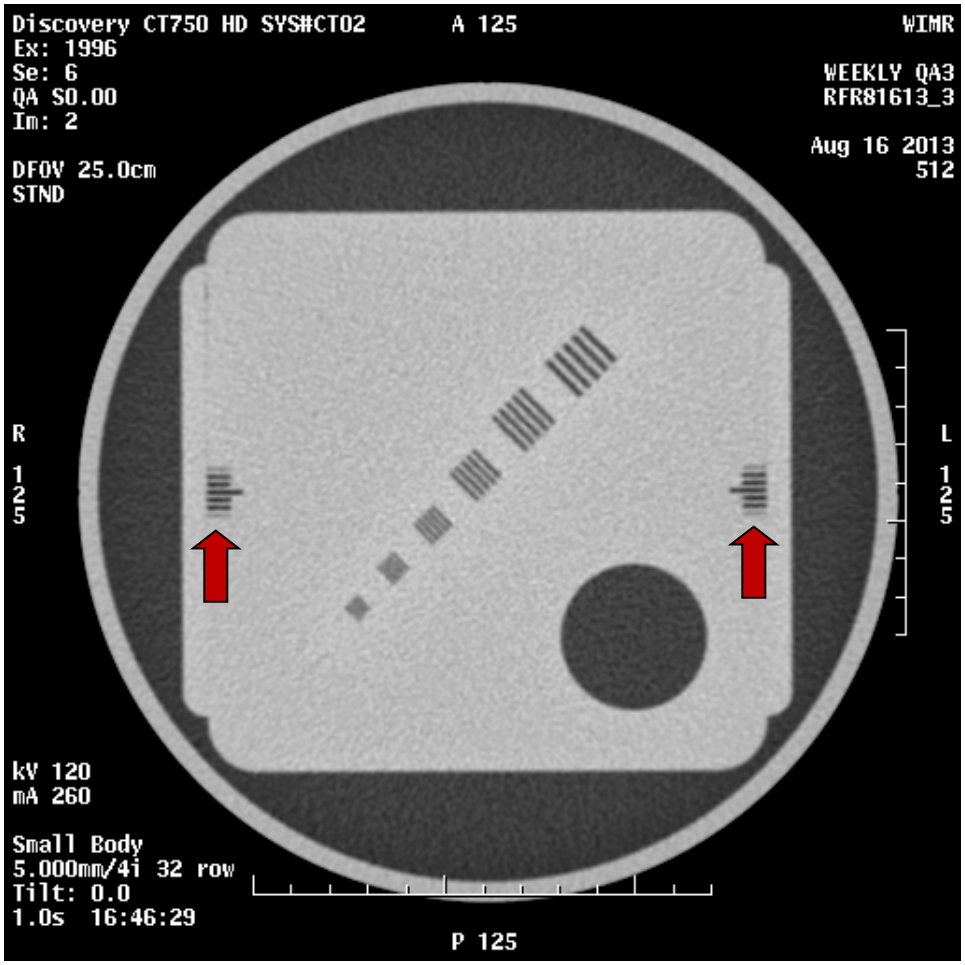
1. Next perform the "**Slice Thickness**" tests using Series 6 and 7 or Series 6, 7, and 8. For the 5 and 2.5 mm slices, there will be an image exactly at S0. For the 1.25 mm slice there will be slices on either side of S0. The same 5 mm slice thickness images will also be used later for the Alignment Light Accuracy test.
2. Look at the image at **S0** imaged at a 5 mm slice thickness and count the number of lines that you observe. Count Black lines as a full mm of slice thickness. Count Gray lines as fractions of a mm. How much of a fraction will depend on how dark is the gray shade of the line. Use your best estimate.
3. Look at the image at **S0** imaged at a 2.5 mm slice thickness and count the number of lines that you observe using the same criteria as above.
4. Finally look at the image **close to S0** imaged at a 1.25 mm slice thickness and count the number of lines that you observe using the same criteria as above.
5. **Record the values of these 3 slice thickness determinations in the proper places in the QA data sheet.**
6. The next test is the "**Alignment Light Accuracy**".
7. Look at the image at **S0** in Series 6 imaged at a 5 mm slice thickness. If you cannot see the Large line that marks center in the phantom, the accuracy is worse than 3 mm and this test Fails. If you can see the Large line that marks center in the phantom, then you should look carefully at the placement of this line relative to the center of the group of visible lines. If the Large line is off center by at most 2 lines then this test Passes, if it off center by more than this, then this test Fails. **If the test passes, simply put "Pass" in the data sheet. If it fails then enter the actual error in the proper place in the QA data sheet.**
8. Finally evaluate the 90/270 (up/down) lasers and the 0(left/right) lasers using the same Series 6 images used for the 5 mm slice thickness test. Select "Grid' in the tools to help you judge if this test is within tolerance. **Enter OK in the QA data sheet if the results are within tolerance, otherwise enter the actual error.**

In the images on the next pages you can see the following:

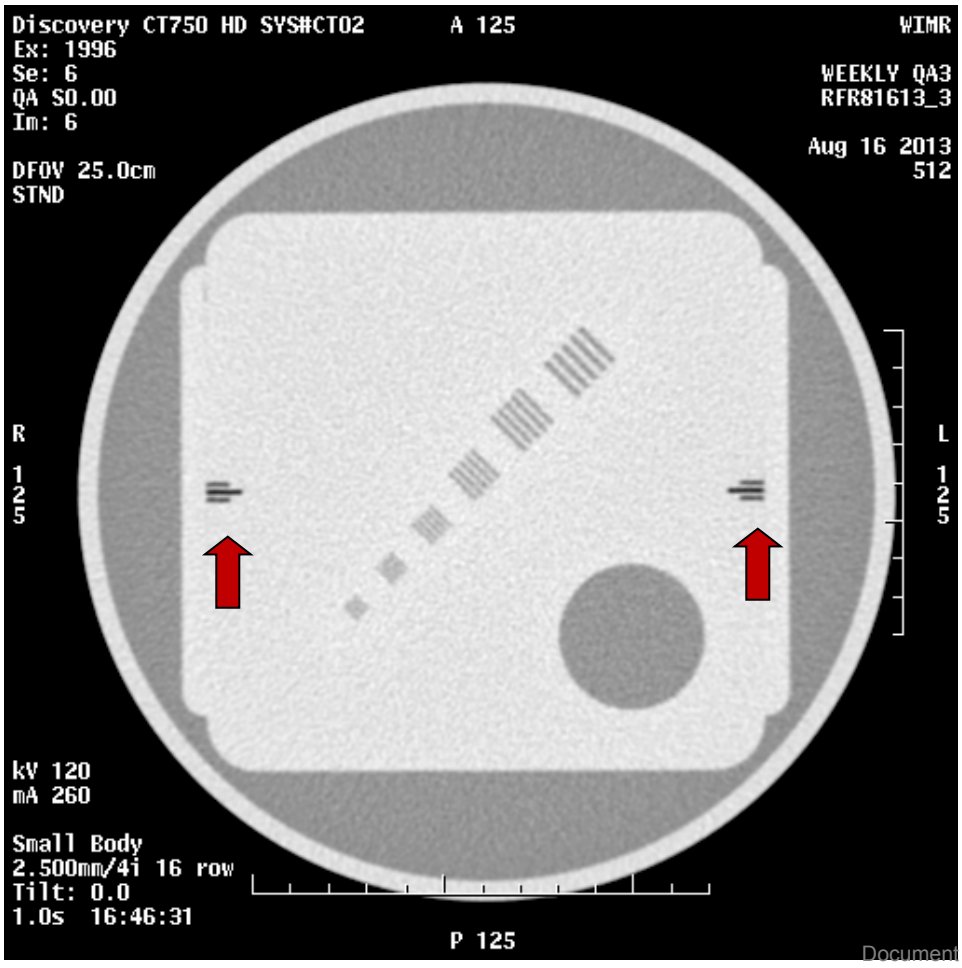
In the 5 mm image you can count 5 dark lines and the lines outside these are very faint and can be ignored. The result of this test is a slice thickness of 5 mm.

In the 2.5 mm image you can count 1 dark line and 2 lines at about ¾ darkness. The result of this test is a slice thickness of 1 + ¾ x 2 = 2.5 mm.

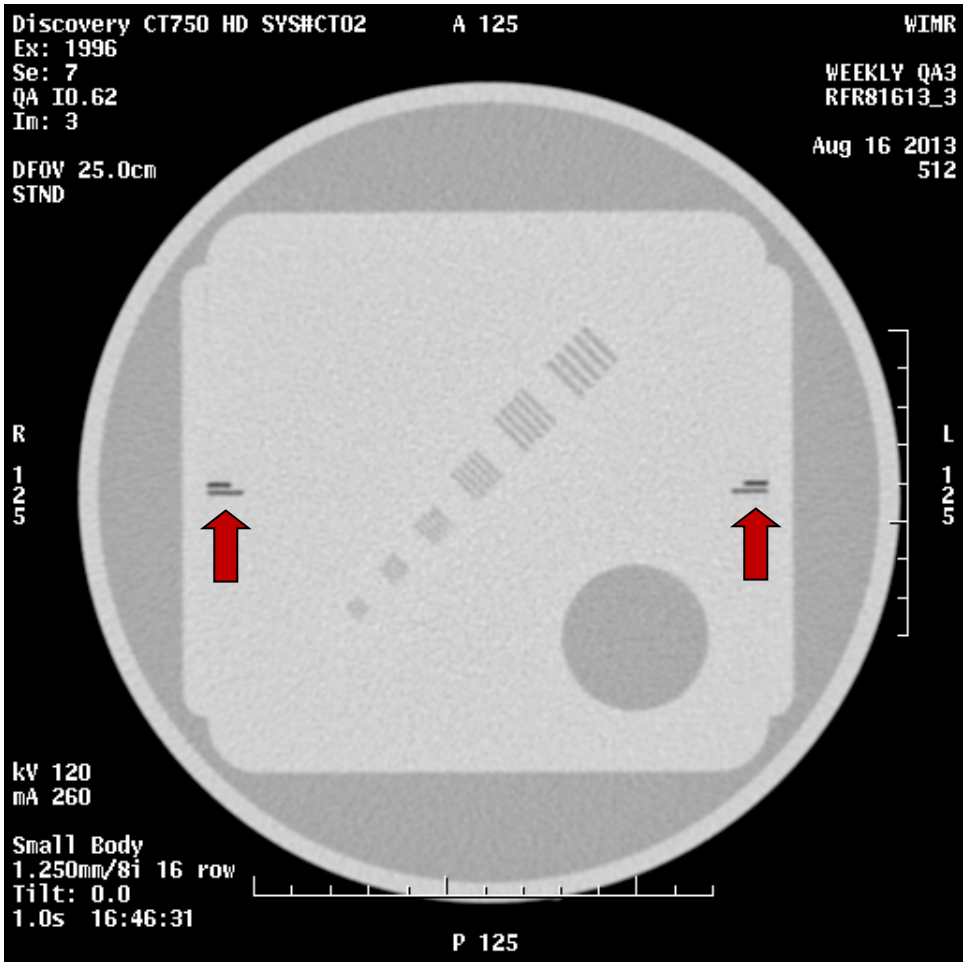
In the 1.25 mm image you can count 1 dark line and 1 line at about ½ darkness. The result of this test is a slice thickness of 1 + ½ x 1 = 1.5 mm.



In this 5 mm image you can count 5 dark lines and the lines outside these are very faint and can be ignored. The result of this test is a slice thickness of 5 mm.



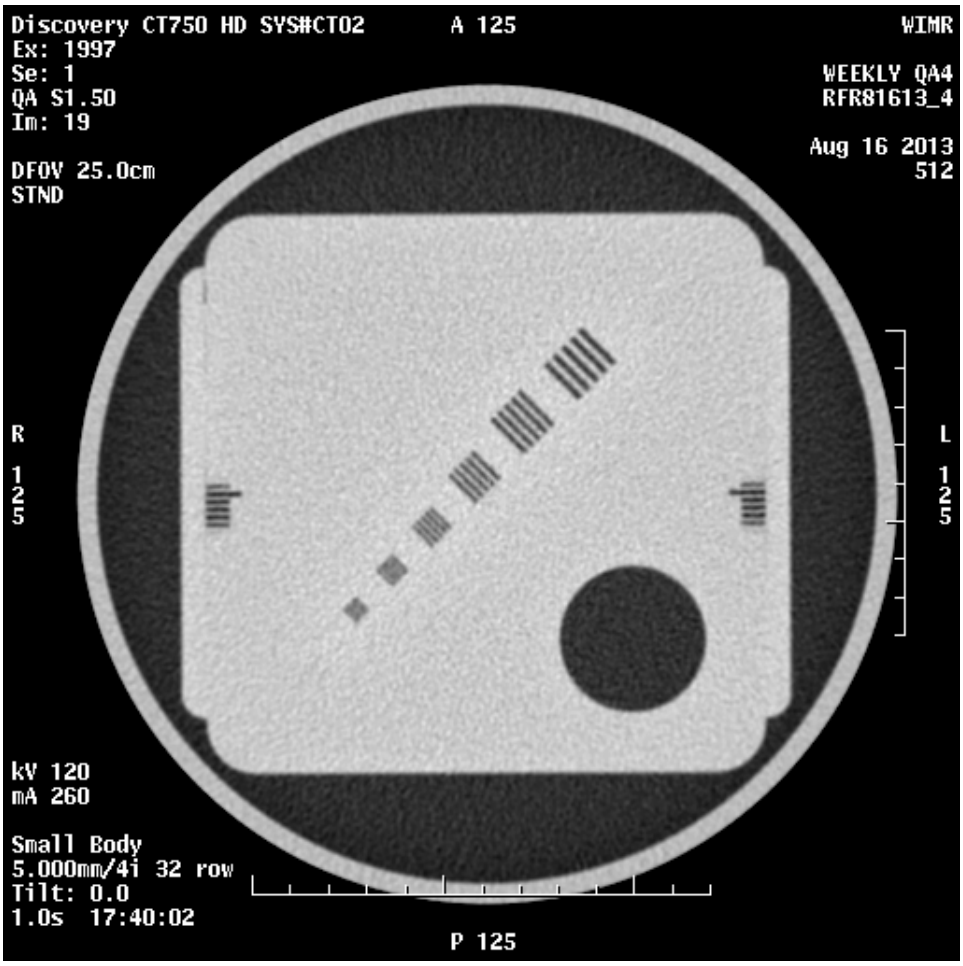
In this 2.5 mm image you can count 1 dark line and 2 lines at about ¾ darkness. The result of this test is a slice thickness of 1 + ¾ x 2 = 2.5 mm.



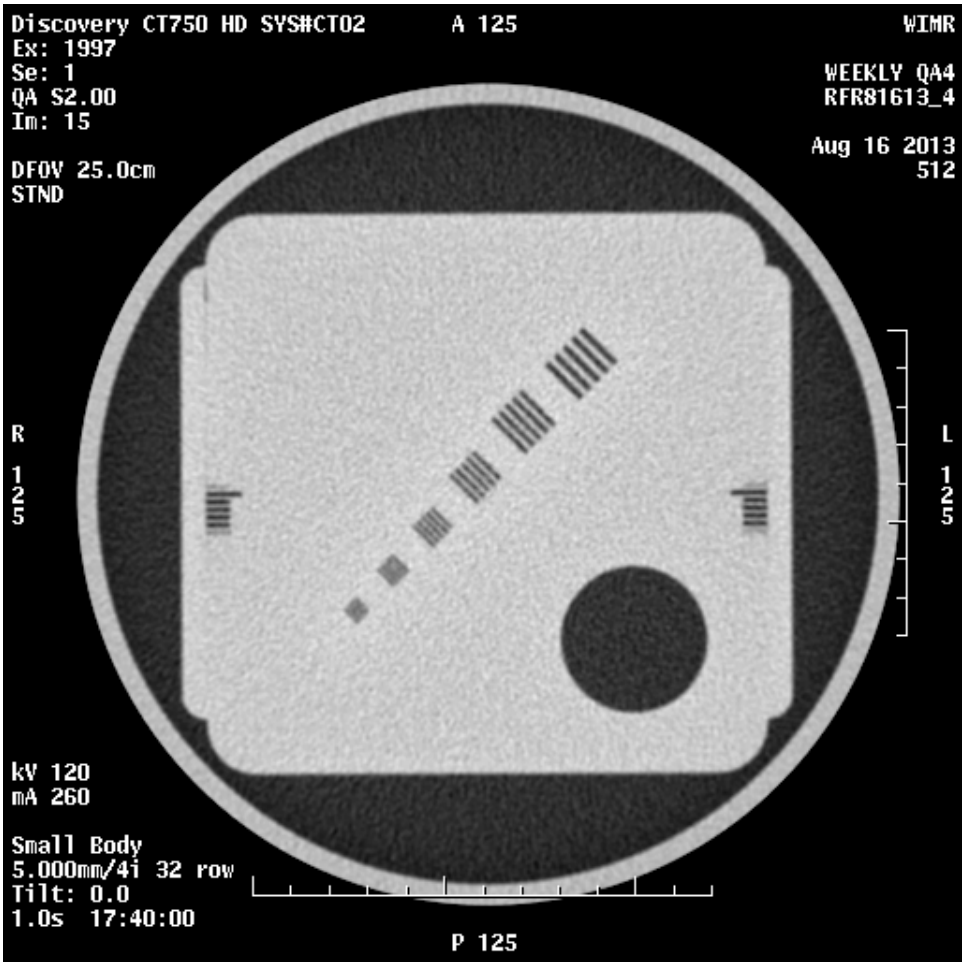
In this 1.25 mm image you can count 1 dark line and 1 line at about ½ darkness. The result of this test is a slice thickness of 1 + ½ x 1 = 1.5 mm.

In the images on the next pages you can see the following errors in centering using the 5 mm slice thickness image: 1.5 mm, 2.0 mm, 2.5 mm, 3.0 mm, and 3.5 mm. The Large center line may be barely perceptible in the 3.0mm offset image and is not visible at all in the 3.5 mm offset image. It is only visible as a grey line in the 2.5 mm offset image. It is however visible as a dark line in the 1.5 and 2.0 mm offset images, which is in the acceptable range.

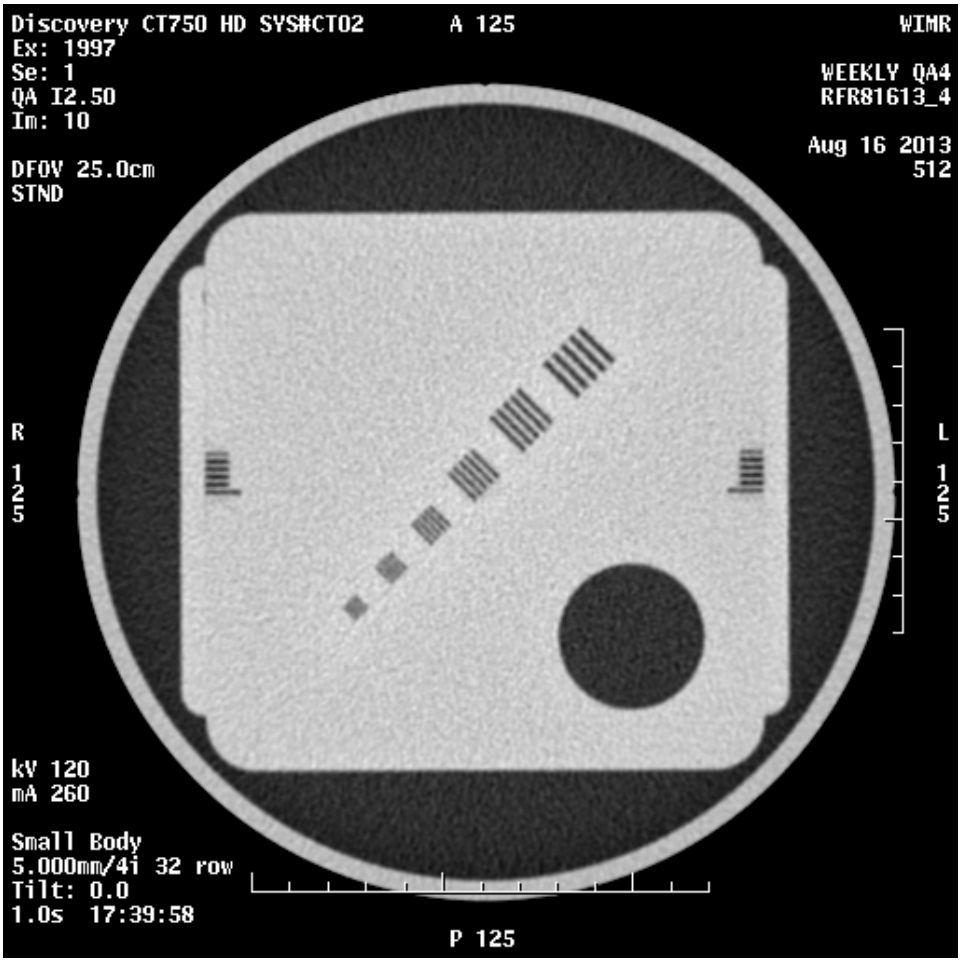
The final image shows the use of the grid to help determine the image offsets, up and down, and left and right. If you look at the position of the grid just inside the light ring, it measures about 9.9 cm at the top and 10.3 cm at the bottom. This is a difference of 0.4 cm or 4 mm. To determine the amount of offset, divide this difference by 2, which yields an offset of 2 mm. This is within tolerance. The difference between where the right and left insides of the ring intersect the grid is clearly less than 4 mm, so this also passes.



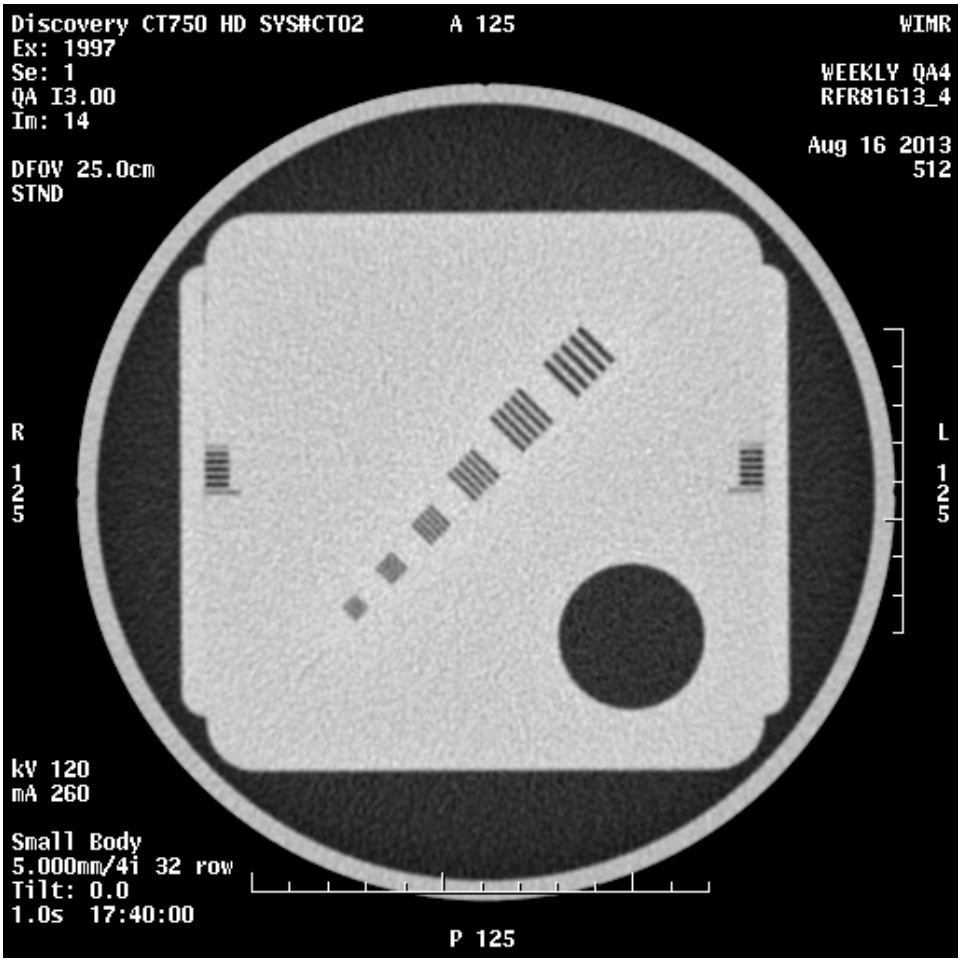
This 5 mm image is off center by 1.5 mm. The Large center line is visible as a dark line in this image, which is in the acceptable range of an offset of 2 mm or less.



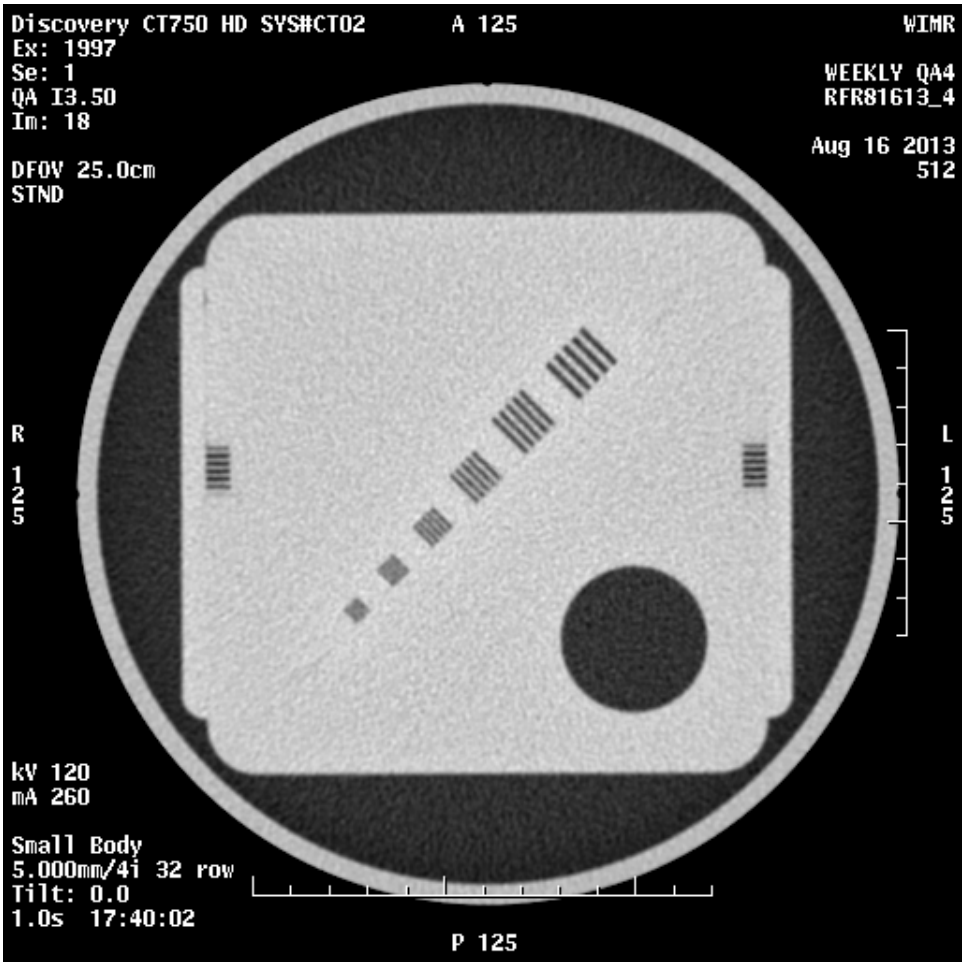
This 5 mm image is off center by 2 mm. The Large center line is visible as a dark line in this image, which is in the acceptable range of an offset of 2 mm or less.



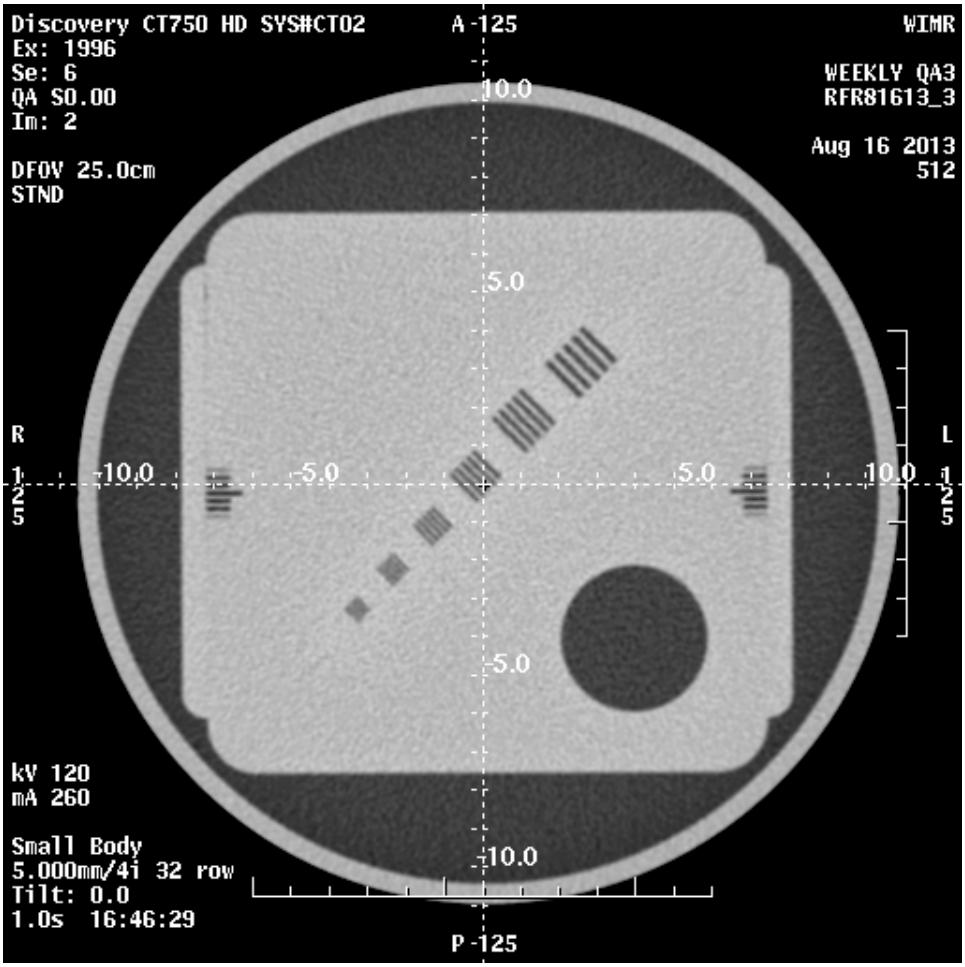
This 5 mm image is off center by 2.5 mm. The Large center line is only visible as a grey line in this image, which is NOT in the acceptable range of an offset of 2 mm or less.



This 5 mm image is off center by 3 mm. The Large center line may be barely perceptible in this image, which is NOT in the acceptable range of an offset of 2 mm or less.



This 5 mm image is off center by 3.5 mm. The Large center is not visible at all in this image, which is NOT in the acceptable range of an offset of 2 mm or less.



This final image shows the use of the grid to help determine the image offsets, up and down, and left and right. If you look at the position of the grid just inside the light ring, it measures about 9.9 cm at the top and 10.3 cm at the bottom. This is a difference of 0.4 cm or 4 mm. To determine the amount of offset, divide this difference by 2, which yields an offset of 2 mm. This is within tolerance. The difference between where the right and left insides of the ring intersect the grid is clearly less than 4 mm, so this also passes.

Monthly Tests:

A visual checklist needs to be filled out to indicate whether a number of scanner functions are performing properly:

Visual Checklist – Gantry Checks & Checks of Control Console:

1. For each of the items in the checklist, indicated if the item passes (P) or fails (F). This test allows you to indicate any item which you believe is malfunctioning.

    a. **Gantry checks** all involve checks of items that are on the gantry or patient table.

        i. **Table height indicator functioning**: Display above gantry opening indicating the table height – Is it operating and appear to track properly with table height change?

        ii. **Table position indicator functioning**: Display above gantry opening indicating the table position (S or I) – Is it operating and appear to track properly with table position change?

        iii. **Angulation indicator functioning**: This is the display above the gantry opening indicating the tilt of the gantry in degrees – Is it operating and appear to track properly with gantry tilt changes?

        iv. **Laser localization lights functioning**: Are the vertical laser lights indicating the patient's S-I positioning, both in the scan plane and external to the scan plane, operating properly? Are the vertical laser lights indicating the patient's L-R positioning operating properly? Are the horizontal laser lights indicating the patient's A-P positioning (height) operating properly and are they consistent from both sides?

        v. **Smoothness of table motion acceptable**: Is the motion jerky or otherwise not as smooth as normal?

        vi. **X-ray on indicator functioning**: Does the X-ray On indicator above the gantry opening turn on when the x-rays are on?

    b. **Control Console** checks all involve checks of items that are on the console outside of the patient room.

        i. Exposure Switch Functioning: Does the system tell you when to press the "move to scan" and the "start scan" buttons and do these buttons operate properly?

        ii. Display window width/ level: Do the present WW/WL keys work properly and do the WW/WL control keys (up-down, left right) work properly?

        iii. X-ray on indicator functioning: Does the Exposure indicator above the keyboard light up when the x-rays are on?

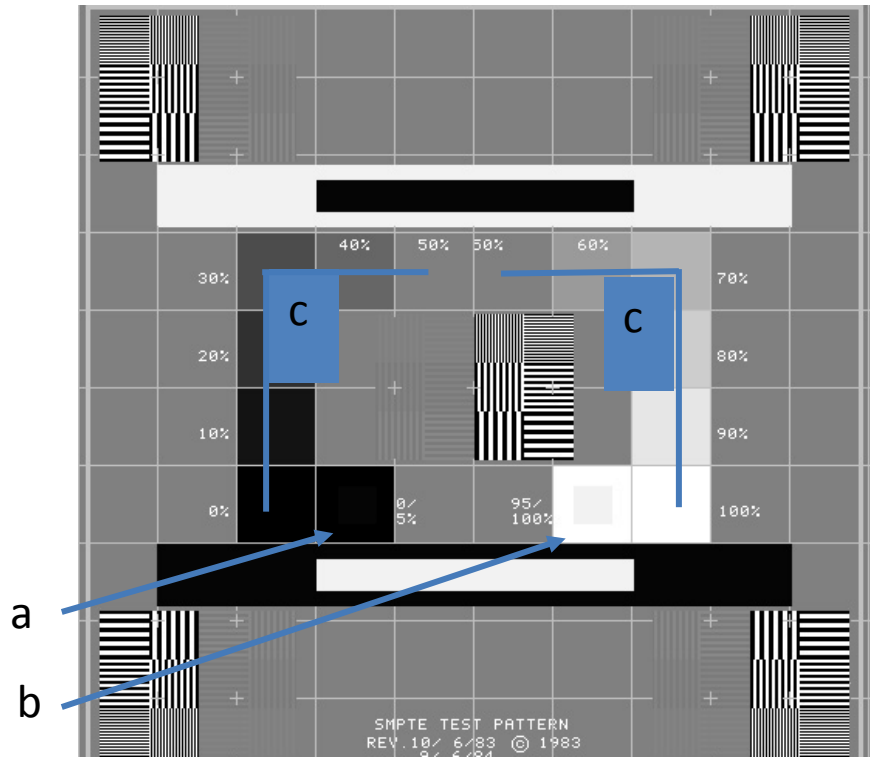
        iv. Panel switches/lights/meters working: This is a catch all for all other items on the control console. Are any not working properly?

        v. Warning labels present: Specifically the warning label about x-rays above the keypad.

        vi. Intercom system functioning: Can voices be clearly heard by the patient and by the operator without excessive static or distortion? Do the volume controls operate properly? Does the talk switch operate properly? Check and adjust the volume if needed at this time.

Gray level Performance of CT Scanner Acquisition Display Monitor:

1. Install the Society of Motion Pictures and Television Engineers (SMPTE) pattern:
   a. Click on the “Service” button (next to image works and exam RX)
   b. Click on the “Image Quality” tab
   c. Click on the bullet labeled “Install SMPTE Image”
   d. A pop-up will appear telling you QA images are being installed, wait for it to finish
2. Go to the image works browser and select the patient with the name “SMPTE” and use the viewer to open the study.
3. Ensure the following:
   a. The small square at 5% contrast can be distinguished from the larger surrounding square at 0% contrast.
   b. The small square at 95% contrast can be distinguished from the large surrounding square at 100% contrast.
   c. Each of the squares around the center of the pattern should have a visibly different density from each other. These squares are labeled 0% to 50% on the left and from 50% to 100% on the right. (Of course both 50% squares at the top should look the same.)



Procedure for when a test fails:

Water center mean CT #: Contact physics if the measurement is outside of specifications.

Water center standard deviation: Contact physics if the measurement is: (1) outside of specifications for more than 1 day in a week or (2) if the measurement is more than 0.2 HU outside of the tolerance for any one day measurement: This means that the measurement is greater than 5.5 or less than 3.6.

Visual artifacts: If any artifacts are observed with either the centered or uncentered phantom images in either axial or helical mode: run a fast calibration and then re-run the artifact test. If any artifacts remain, **CONTACT GE SERIVCE IMMEDIATELY** and also notify physics and the CT manager. The scanner should not be used for clinical imaging if an artifact is present.

Low contrast resolution: Contact physics if the measurement is outside of specifications.

Difference Plexiglas/water: Contact physics if the measurement is outside of specifications.

High contrast resolution (1.6, 0.8, and 0.6 bar sizes): Contact physics if the measurement is: outside of specifications.

Slice thickness (5, 2.5, and 1.25 mm): Contact physics if the measurement is outside of specifications.

Laser light accuracy (internal, 90/270 degree, 0 degree): Contact physics if the measurement is: outside of specifications for more than 1 day in a week (2) more than 1 mm out of bounds for any single day.

Monthly Visual Checklist – Gantry Checks & Checks of Control Console: CONTACT GE SERVICE IMMEDIATELY if any feature of the scanner is not working. Notify the CT manager and physics as well. The CT manager and physic can determine if the scanner is safe to use until the issue with the scanner is repaired.

Monthly Gray level Performance of CT Scanner Acquisition Display Monitor: Contact physics if any of the three tests fail.