CCT228 ATCM Phantom Manual

WARRANTY
THE PHANTOM LABORATORY INCORPORATED ("Seller") warrants that this product shall remain in good working order and free of all material defects for a period of one (1) year following the date of purchase. If, prior to the expiration of the one (1) year warranty period, the product becomes defective, Buyer shall return the product to the Seller at:

By Truck	By Mail
The Phantom Laboratory, Incorporated	The Phantom Laboratory, Incorporated
2727 State Route 29	PO Box 511
Greenwich, NY 12834	Salem, NY 12865-0511

Seller shall, at Seller's sole option, repair or replace the defective product. The Warranty does not cover damage to the product resulting from accident or misuse.

IF THE PRODUCT IS NOT IN GOOD WORKING ORDER AS WARRANTED, THE SOLE AND EXCLUSIVE REMEDY SHALL BE REPAIR OR REPLACEMENT, AT SELLER'S OPTION. IN NO EVENT SHALL SELLER BE LIABLE FOR ANY DAMAGES IN EXCESS OF THE PURCHASE PRICE OF THE PRODUCT. THIS LIMITATION APPLIES TO DAMAGES OF ANY KIND, INCLUDING, BUT NOT LIMITED TO, DIRECT OR INDIRECT DAMAGES, LOST PROFITS, OR OTHER SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER FOR BREACH OF CONTRACT, TORT OR OTHERWISE, OR WHETHER ARISING OUT OF THE USE OF OR INABILITY TO USE THE PRODUCT. ALL OTHER EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANT ABILITY AND FITNESS FOR PARTICULAR PURPOSE, ARE HEREBY DISCLAIMED.

WARNING
The CCT228 has a weight of 32 kg. This exceeds the amount of weight that a single person should lift on their own as defined by US National Institute for Occupational Safety. Appropriate steps should be taken to handle this phantom safely.

This product has an FH3-4 mm/min flame rating and is considered to be flammable. It is advised not to expose this product to open flame or high temperature (over 125° Celsius or 250° Fahrenheit) heating elements.

CCT228 ATCM Phantom Manual

Contents

Indications for Use

The CCT228 ATCM Phantom is intended to be used by, or under the direction of, a Medical Physicist to evaluate image uniformity and noise in a CT scanner with three different body sizes. This phantom can be used to better understand the performance variables between different scanners with automatic tube current modulation and to understand the performance effects of different scanning protocols with a single CT scanner.

Introduction

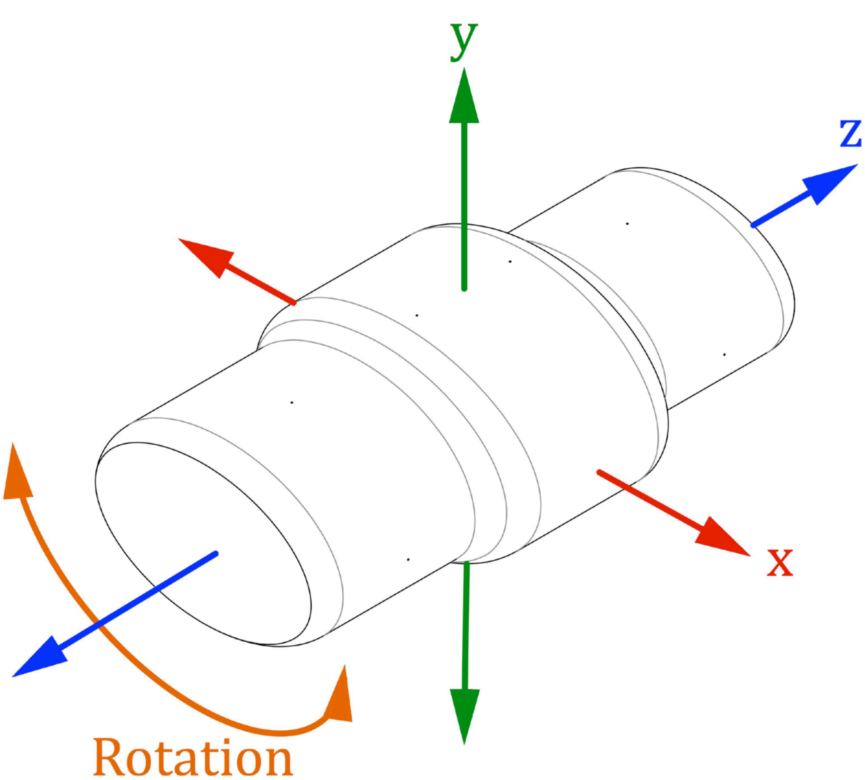
The ATCM (automatic tube current modulation) Phantom was developed by the CT physics group at the Karolinska University hospital in Stockholm Sweden. The development team included Deborah Merzan, Patrik Nowik, Gavin Poludniowski, and Robert Bujila. After realizing there were no established standards and methods ATCM testing and optimization they decided to develop this phantom.

The original work has been documented in these publications

[1] Merzan D, Bujila R, Nowik P. TU F CAMPUS-I-04: A Novel Phantom to Evaluate Longitudinal and Angular Automatic Tube Current Modulation (ATCM) in CT. Medical physics. 2015 Jun 1;42(6):
[2] Merzan D, Nowik P, Poludniowski G, Bujila R. Evaluating the impact of scan settings on automatic tube current modulation in CT using a novel phantom. The British Journal of Radiology. 2016 Dec 20;90(1069).

After the above documented research the Karolinska physics group worked with The Phantom Laboratory to develop the CCT228 ATCM Phantom which is made from the Catphan® uniformity material.

If you have any additional questions please contact The Phantom Laboratory at:
Phone: 800-525-1190 or 518-692-1190
Fax: 518-692-3329
Email: sales@phantomlab.com
Additional product information is available at: www.phantomlab.com



Automatic Tube Current Modulation (ATCM) and the phantom

ATCM is used on Computed Tomography (CT) scanners to obtain a target image quality across varying patient attenuations along a scan. ATCM is an invaluable tool when optimizing CT scans with respect to radiation dose and image quality. The effectiveness of ATCM varies with different technique parameters and the applied ATCM differs between manufacturers.

Generally, a scan projection radiograph (SPR) of the patient is taken prior to a CT scan. Radiographers use the SPR to plan the length and location of the CT scan. From the SPR, the CT scanner estimates the patient's attenuation along the planned scan and uses this information to adapt the tube current that is needed to achieve a target image quality at the different locations along the scan. The attenuation that the CT scanner estimates from the SPR can be affected by the centering of the patient or by the technique (kVp, mA, projection angle, etc.) that has been used during the acquisition.

The definition of a target image quality will vary between manufacturers. Certain manufacturers attempt to achieve a constant image noise along the scan while other manufactures aim at having different levels of image noise for different attenuations. The target image quality can be adjusted in the scan protocol using an Image Quality (IQ) reference parameter, which can be set according to the clinic's image quality preferences.

ATCM can be divided into two distinct components: longitudinal modulation and angular modulation. Longitudinal modulation accounts for variations in patient attenuation along the scan direction (z-axis) and angular modulation accounts for differences in attenuation as the tube rotates around the patient (xy-plane). The importance of angular modulation can be seen in patients that have elliptical cross-sections where more radiation is needed at lateral angles compared to upright angles, to achieve a target image quality throughout a slice. CT scanners can use a longitudinal, angular or a combination of the two during a scan. Take note that certain CT scanners have "online" angular modulation which adapts the tube current based on the detector signal that was acquired from the previous rotation.

The technique and reconstruction parameters that are used for a given CT scan can generally be adjusted freely in the imaging protocol. Technique and reconstruction parameters are selected in a manner that balance image quality (in terms of noise, contrast and resolution) with radiation dose, for a given diagnostic requirement. It is not always trivial to know how variations in imaging protocol can affect the resulting ATCM. Further, depending on the technique that has been selected, there may be technical limitations on the CT scanner, e.g. tube load, that prevent the scanner from achieving the desired target image quality.

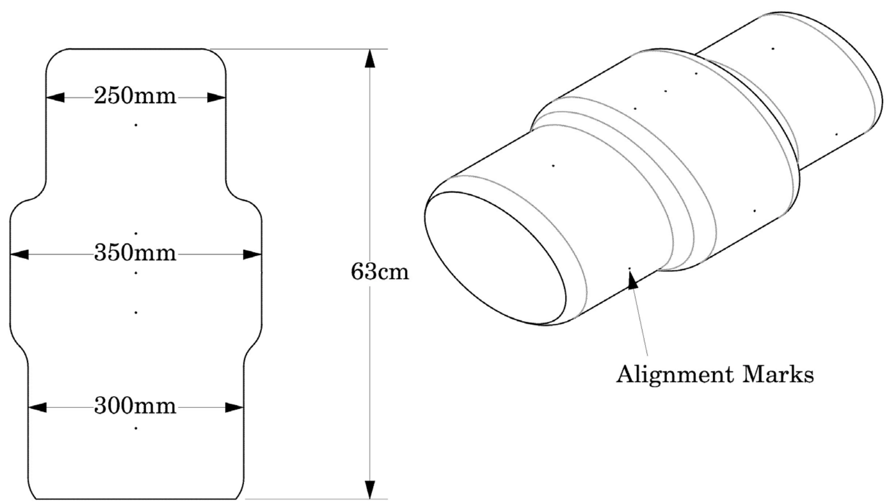
Many considerations were taken into account when designing the ATCM phantom. The phantom has an elliptical cross-section and three uniform sections of varying attenuation, which is appropriate for testing both longitudinal and angular modulation. Each section is wide enough to allow the scanner to make at least one full rotation over uniform attenuation, even for spiral scans with nominal total collimations up to 80 mm. Sharp edges have been eliminated by rounding the ends of the phantom and providing smooth transitions between each of the three uniform sections. The entire phantom is made out of the same material which makes it ideal to measure noise at different slice locations in the reconstructed images.

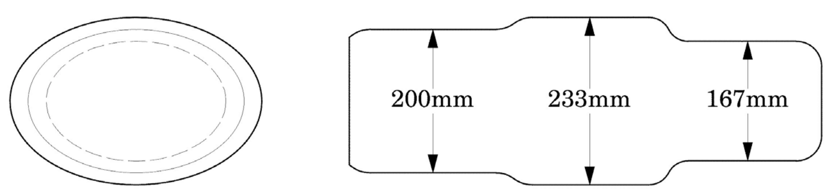
The phantom that was developed by the CT physics group at the Karolinska University Hospital is intended for tests to investigate how the applied tube current and the longitudinal noise distribution may be affected by variations in positioning, acquisition and reconstruction parameters for SPR's and CT scans. Further, the phantom can be used to test the constancy of the ATCM over time.

Phantom Size and Materials

The ATCM Phantom is cast from the durable Catphan® Uniformity material. This material has an electron density around 1% above water or 10HU. Please note that this number is energy dependent so variations in HU numbers between different scanners or protocols does not indicate a problem.

The solid one-piece phantom has 3 sections shaped in an elliptical manor. It is designed so the transitions between these shapes have been smoothed to eliminate hard edge transition artifacts.





There are alignment marks on the sections made from Teflon rods approximately 1.5 mm in diameter and 6 mm long inserted into the edges of the phantom. The markers are designed so they can be visualized in CT scans through the phantom. The markers are designed so they can be visualized with external alignment lights and in CT scans.

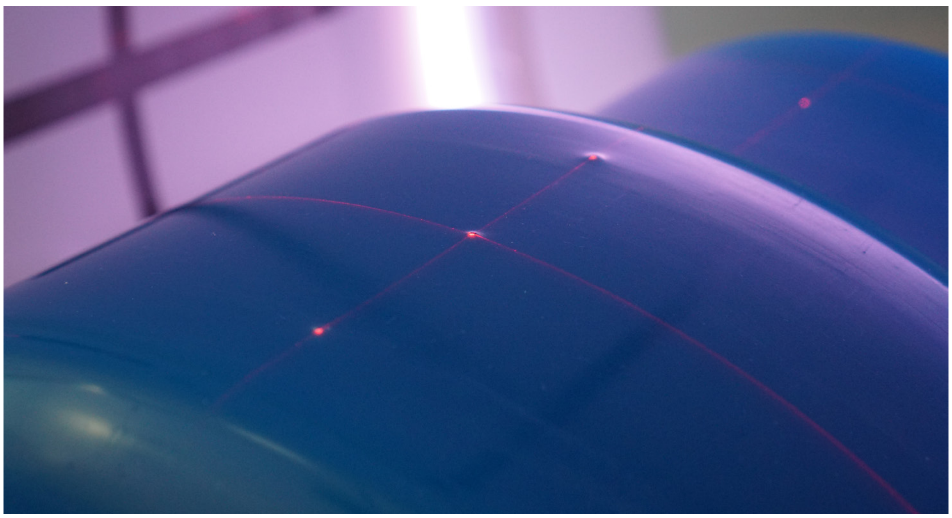
WARNING
The CCT228 has a weight of 32 kg. This exceeds the amount of weight that a single person should lift on their own as defined by US National Institute for Occupational Safety. Appropriate steps should be taken to handle this phantom safely.

While it is recommended that the phantom be lifted by two people or a lifting device, in some situation one person can safely roll the phantom from a cart or table to the patient couch. Because both sides of the phantom have alignment marks there is no need to flip or invert the phantom.

Positioning the phantom

After the phantom is placed on the table, position the phantom on the table, so the Teflon alignment marks on the top of the phantom align with the scanners top centering laser. Adjust the table height to align the side alignment marks on the phantom. Be sure to check both sides to verify the phantom is not rotated.

If possible, create a reference position (zero landmark) after the phantom has been positioned. This reference position will ensure that the scan can be planned around the midpoint of the phantom.



Phantom centered on CT scanner with laser lights illuminating Teflon® markers

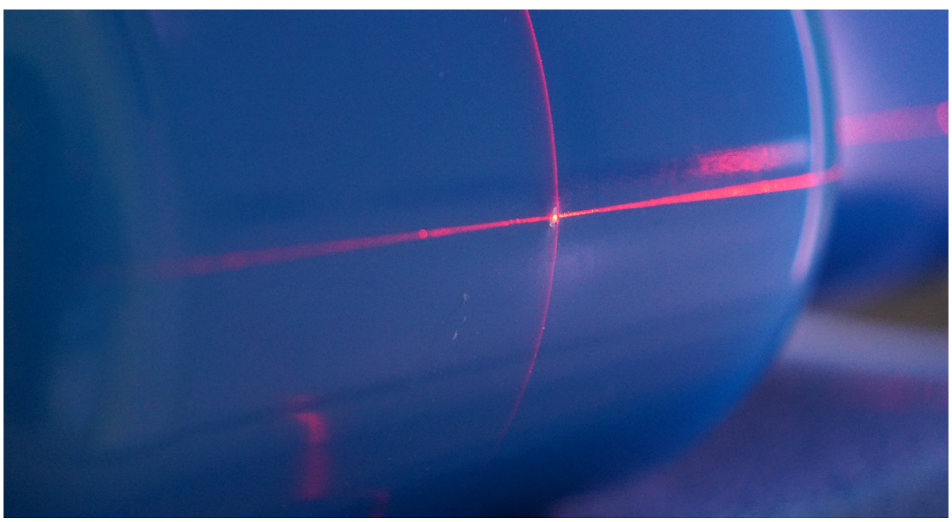
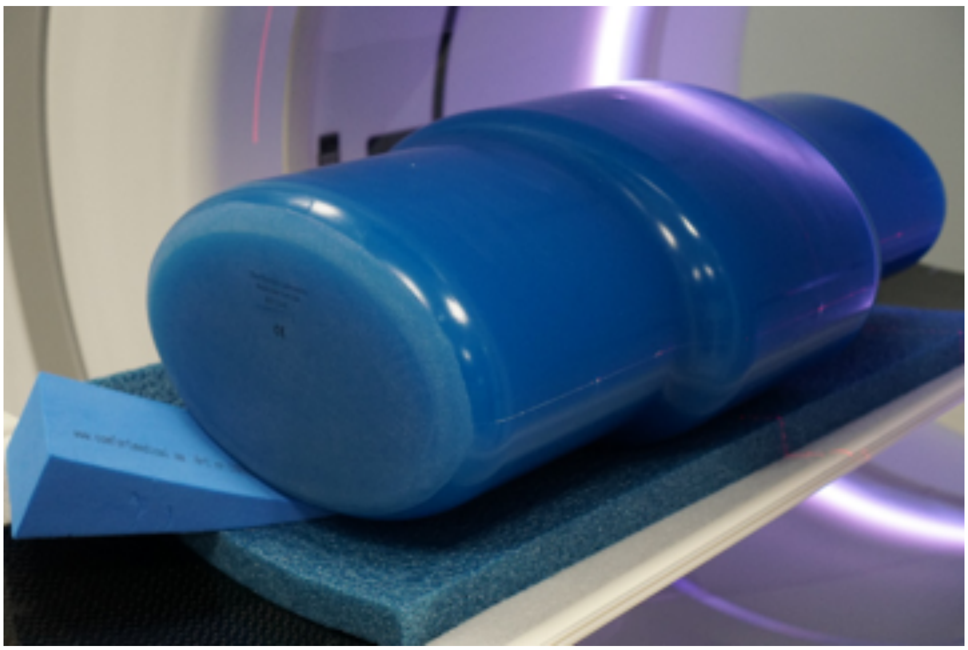


Table height adjusted so laser lights align with side Teflon markers

Positioning tips

The phantom can be placed directly on the table, or patient pad. If it is positioned on a pad a foam wedge may need to be placed under the large end to keep the phantom from tilting.

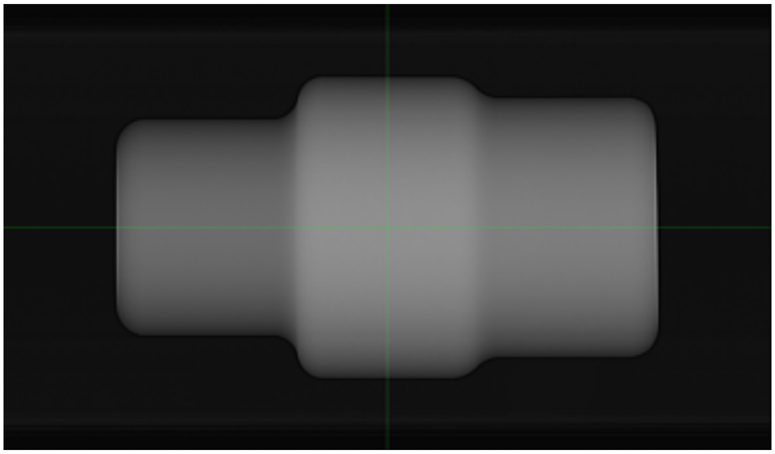
Placing the phantom on a sheet of low attenuating material that reduces friction between the phantom and table may make it easier to slide the phantom into position. Keep in mind that a wedge and a sheet of low attenuating material might contribute to the CT scanner's perception of the total attenuation, which may cause the scanner to use a slightly altered tube current over those locations. Since there is no front and back to the phantom, the phantom can be rolled from a cart onto the table.



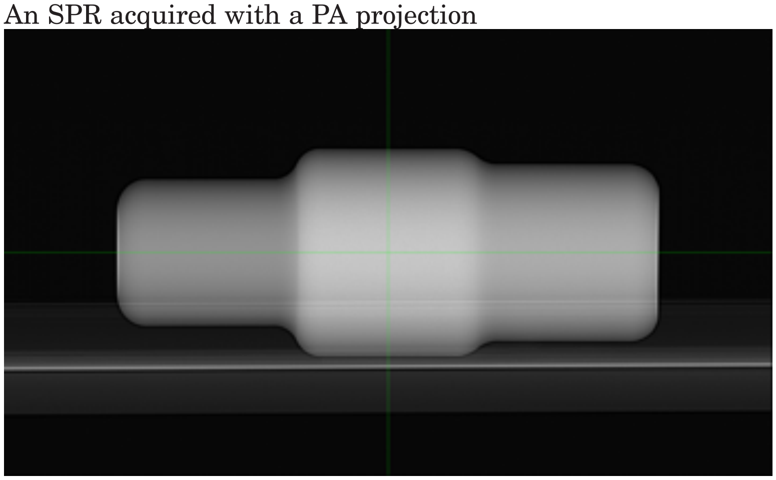
In the above photo the phantom has been placed on a sheet of low density foam with a foam wedge under the large end to level the phantom.

Position verification

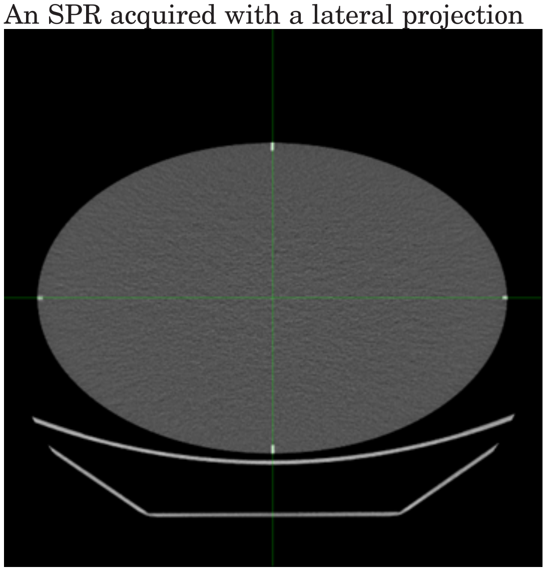
After positioning the phantom, SPR and axial images can be taken of the phantom to verify the phantom position. In the following images the grid overlay feature is used to help verify that the phantom is centered in the images.



An SPR acquired with a PA projection



An SPR acquired with a lateral projection



An axial slice of the center of the phantom with a grid overlay to verify phantom position. The 4 Teflon markers indicate the z axis center of each oval section.

Scanning protocol recommendations

When investigating the ATCM, consult with the CT vendor or technical documentation that corresponds to the current software version of your CT scanner to understand which SPR (Scanned Projection Radiograph, Scout, Scanogram, Topogram, or Localizer), technique or reconstruction parameters may have an effect on the resulting ATCM. Take note, the ATCM algorithms may have changed between the CT scanner's software versions.

The ATCM uses the SPR to calculate the optimal tube current. To prevent problems with the calculation it is important to ensure that the SPR covers the entire phantom. We recommend that an 85 cm long SPR is used so it extends at least 10 cm on both ends of the of the 63 cm phantom.

At the end of most patient tables, there are brackets that are used to mount accessories for the CT scanner (e.g., head holder etc.). Be sure to avoid these brackets because they will create artifacts and changes to the ATCM measurements.

Certain CT scanners use data from multiple SPR's (LAT and AP) when planning the ATCM. For the ATCM to work as intended, follow the vendor's recommendations.

The CT scanner bases the ATCM on a set of static SPR(s), it is therefore important that the phantom is not repositioned without taking a new set of SPR(s).

Depending on the selected parameters, it is possible that the mA will max out for different sections of the phantom. If the mA maxes-out, the system will likely not be able to achieve its targeted image quality.

It is important to consider the Display Field of View (DFOV) when planning a scan with the ATCM phantom. The DFOV should be long enough to include the full length of the phantom and wide enough to include the full width of the phantom.

The resolution in the evaluated mA and image noise curves will depend on the reconstructed slice thickness when scanning and evaluating the phantom.

Evaluations of the ATCM phantom

The ATCM phantom is evaluated with respect to applied tube current and image noise at each slice location along a scan. The DICOM attributes that must be extracted to evaluate the applied tube current at each slice are listed in the table below.

Attributes to extract from DICOM images

Name	Tag
Slice Location	0020,1041
X-ray Tube Current	0018,1151
Exposure Time per Rotation	0018,1150
Spiral Pitch Factor	0018,9311

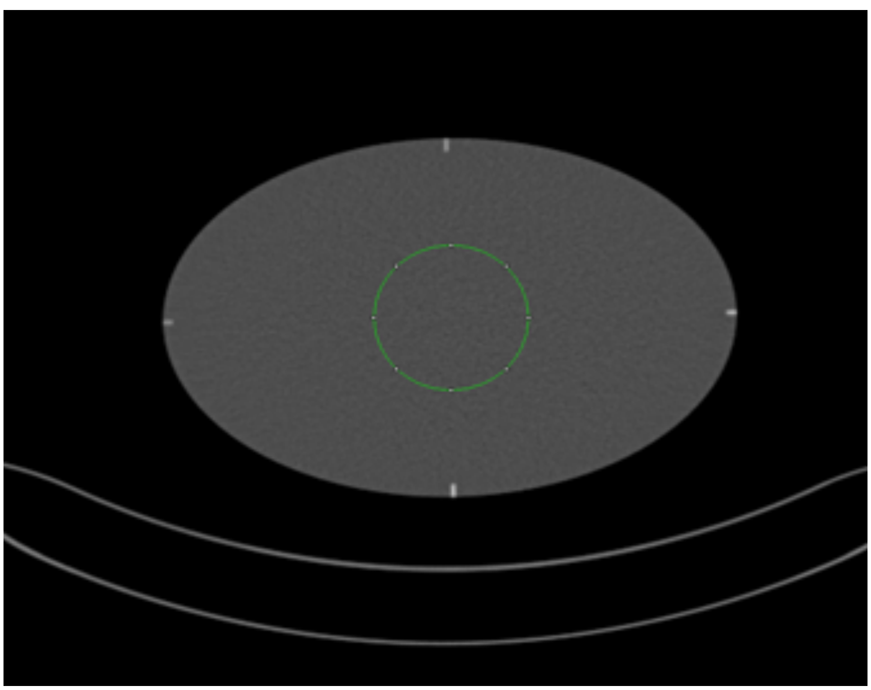
The simplest way of evaluating applied ATCM is to analyze X-ray Tube Current (mA) at different slice locations along the phantom. Alternatively, the x-ray tube current time product (mAs) at different slice locations may be used. The mAs approach factors in the scan's rotation time,

$$\text{mAs}=[\text{X-ray Tube Current}]*[\text{Exposure Time Per Rotation}]$$

In cases when the spiral pitch is varied, it may be preferable to analyze the effective mAs at different slice locations. The effective mAs is given as,

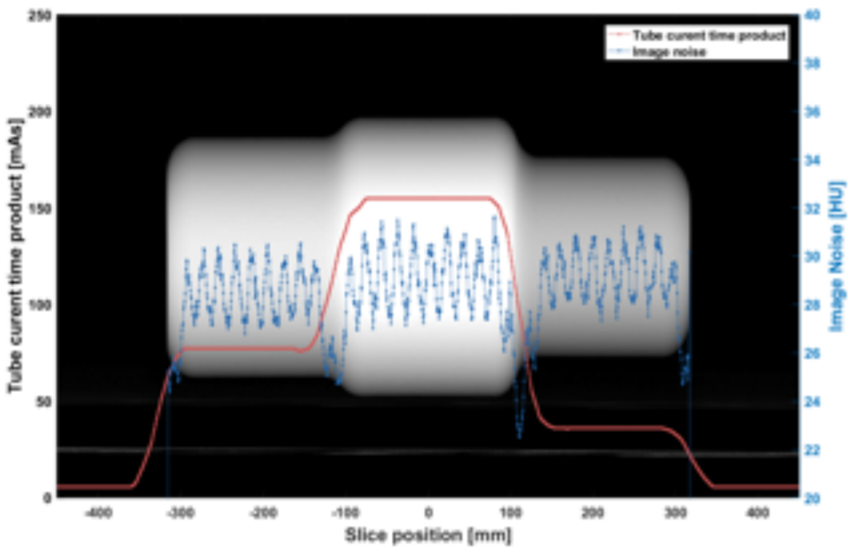
$$\text{Effective mAs} = \frac{[\text{X-ray Tube Current}]*[\text{Exposure Time Rotation}]}{[\text{Spiral Pitch Factor}]}$$

Image noise is evaluated using a region of interest (ROI) approach. Image noise is defined as the standard deviation of pixel values within the ROI. We recommend using a circular ROI that has a diameter that is 40% of the minor axis of the smallest section of the phantom (a diameter of 6.8 cm). The ROI should be positioned in the center of the phantom. An example of the position of the ROI within a slice of the phantom is given in figure 6. The noise should be evaluated at each slice location.



Example of the region of interest that is used to evaluate image noise

If images can be exported from the CT scanner, it is recommended to use a programming script that loops through each slice in the scan and extract the DICOM attributes and image noise. An example of the applied tube current and image noise is given in figure 7. In figure 7, the applied tube current and image noise is overlaid on top of a synthetic SPR. The synthetic SPR was produced by calculating the mean pixel intensity along the x-axis for each slice location.



Example results of the applied tube current and image noise when scanning the ATCM phantom.

Automated analysis of ATCM Phantom images

Image Owl Inc. offers an on-line service for the evaluation of ATCM Phantom images. Subscribers to the Image Owl service can log into their account and simply drag images of the phantom into the browser window. Once the images are uploaded the service will automatically review the images and assemble a report containing information on tube current and noise. For information on the Image Owl ATCM Phantom service contact info@imageowl.com

For additional information go to imageowl.com

Care and maintenance

The ATCM Phantom is cast from a durable urethane material. It can be cleaned with soap and water. The material will change in color over time from the original blue to a greenish blue. Please note the phantom's CT number will change with temperature. This should not be noticeable with normal room temperature fluctuations however it will be seen with extreme cold and hot conditions such as leaving the phantom overnight in a car in -20 C temperatures.