



# CT Accreditation Phantom Instructions

CT Accreditation Phantom Instructions .....	1
A INTRODUCTION .....	2
B THE PHANTOM .....	3
Module 1 .....	4
Module 2 .....	4
Module 3 .....	4
Module 4 .....	4
C SCANNING INSTRUCTIONS .....	5
1. Fill out the Phantom Data Form: .....	5
2. Calibrate the Scanner: .....	6
3. Perform Phantom and Scanner Alignment: .....	6
4. Scan the Gammex 464 phantom with your facility's protocols: .....	7
5. Evaluate your phantom images: .....	7
• CT Number Calibration .....	8
• Low Contrast Criteria (Contrast to Noise Ratio)(CNR) .....	9
• Uniformity .....	10
• Artifacts - .....	10
Radiation Dosimetry .....	11
Required Materials .....	11
Scanning Instructions .....	12
Preparing Images for Submission .....	13

## A INTRODUCTION

Read this entire document before obtaining images for submission to the ACR CT Accreditation Program. Follow all instructions carefully. If you have any questions about these instructions please contact the ACR.

This document describes the test procedures in sufficient detail to allow a CT technologist or medical physicist to acquire the required images and perform the necessary analysis and calculations using the Gammex 464 phantom. A medical physicist is required to obtain the necessary dosimetric data.

The intent of the CT Accreditation Program is to use the information obtained from the review of both clinical and phantom images to assess overall image quality. Your facility will need to submit up to four specified phantom scans and corresponding dosimetric data using your facility's routine clinical adult head, adult abdomen, pediatric head and pediatric abdomen protocols. The protocols and images required for accreditation depend on your facility's use of the unit, and the clinical modules and patient type chosen on your accreditation application for each unit.

***Please be aware that the requirement for CT accreditation is that facilities use the same protocols for the Gammex 464 phantom that the facility uses for its clinical imaging. Failure to comply with this requirement could result in failure to achieve accreditation. The only exception to this is that automatic mA modulation must be turned off and a display field of view (DFOV) of 21 cm is to be used.***

This document will guide the user through the data acquisition and analysis process in a step-by-step fashion. To facilitate this, and to speed data acquisition, use the appropriate clinical protocol as the starting point for all data acquisitions. Otherwise, some important acquisition parameters (such as use of bowtie filters and special image processing) may be overlooked. You must use average manual techniques for each protocol when scanning the phantom. **Do not use any type of automated dose reduction technique when scanning the phantom.**

It is essential that scan acquisition parameters match your facility's **clinical use** in all portions of your phantom submission:

1. Phantom Data Forms
2. Gammex 464 phantom images
3. Dose Data Forms
4. CTDI phantom images

The Phantom Data Form and the Dose Data Forms are part of the online testing package that you **must** submit using your facility's log in email address and password to the ACR Accreditation database, ACRedit (<https://acredit.acr.org>). There are generic blank forms available at [http://www.acr.org/accreditation/computed/qc\\_forms.aspx](http://www.acr.org/accreditation/computed/qc_forms.aspx) to allow you to gather the data, but you must enter the data into the online testing package and submit the data to ACR. Once you finish the submission of your online testing package, you will be prompted to print out the forms to label with the barcodes mailed to your facility and submit the labeled forms with your images. ***Failure to submit the online testing package or the printed forms for submission directly from the ACRedit database could result in the expiration of your testing cycle, with the requirement of reinstatement at full fee in order for your facility to continue the process of seeking accreditation.***

**The CT Accreditation Testing instructions contain specific requirements for submitting your phantom images for review.**

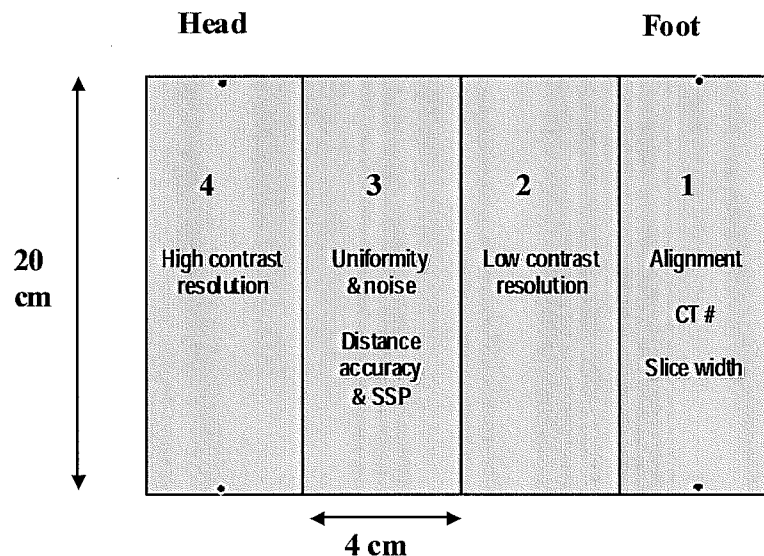
## B THE PHANTOM

The ACR CT accreditation phantom has been designed to examine a broad range of scanner parameters. These include:

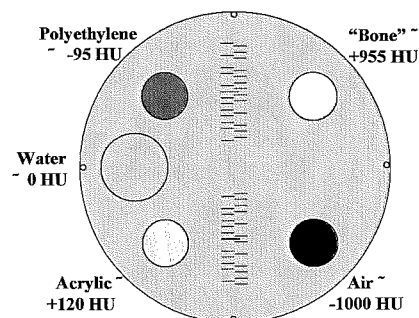
- Positioning accuracy
- CT # accuracy
- Image thickness
- Low contrast resolution
- High contrast (spatial) resolution
- CT number uniformity
- Image noise

You will not have to assess all of the above measurements as part of your phantom submission for accreditation. You will, however, use all of them for your routine QC.

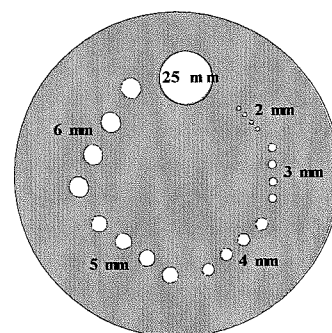
The ACR CT accreditation phantom (Gammex 464) is a solid phantom containing four modules, and is constructed primarily from a water-equivalent material. Each module is 4 cm in depth and 20 cm in diameter. There are external alignment markings scribed and painted white (to reflect alignment lights) on EACH module to allow centering of the phantom in the axial (z-axis, cranial/caudal), coronal (y-axis, anterior/posterior), and sagittal (x-axis, left/right) directions. There are also “HEAD”, “FOOT” and “TOP” markings on the phantom to assist with positioning.



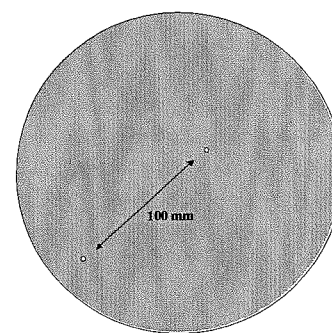
**Module 1** is used to assess positioning and alignment, CT number accuracy, and slice thickness. The background material is water equivalent. For positioning, the module has 1-mm diameter steel BBs embedded at the longitudinal (z-axis) center of the module, with the outer surface of the BB at the phantom surface at 3, 6, 9, and 12 o'clock positions within the field of view (19.9cm center to center). To assess CT number accuracy, there are cylinders of different materials: bone-mimicking material ("Bone"), polyethylene, water equivalent material, acrylic and air. Each cylinder, except the water cylinder, has a diameter of 25 mm and a depth of 4 cm. The water cylinder has a diameter of 50 mm and a depth of 4 cm. To assess image width, two ramps are included that consist of a series of wires that are visible in 0.5-mm z-axis increments.



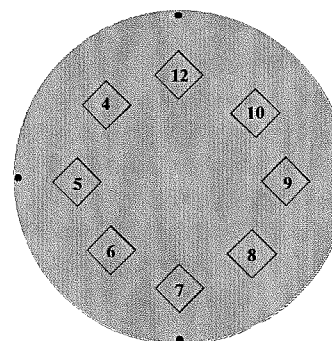
**Module 2** is used to assess low contrast resolution. This module consists of a series of cylinders of different diameters, all at 0.6% (6 HU) difference from a background material having a mean CT number of approximately 90 HU. The cylinder-to-background contrast is energy-independent. There are four cylinders for each of the following diameters: 2 mm, 3 mm, 4 mm, 5 mm and 6 mm. The space between each cylinder is equal to the diameter of the cylinder. A 25-mm cylinder is included to verify the cylinder-to-background contrast level and to assess the contrast-to-noise ratio.



**Module 3** consists of a uniform, tissue-equivalent material to assess CT number uniformity. Two very small BBs (0.28 mm each) are included for optional use in assessing the accuracy of in-plane distance measurements. They may also be used to assess section sensitivity profiles.



**Module 4** is used to assess high contrast (spatial) resolution. It contains eight bar resolution patterns: 4, 5, 6, 7, 8, 9, 10 and 12 lp/cm, each fitting into a 15-mm x 15-mm square region. The z-axis depth of each bar pattern is 3.8 cm, beginning at the Module 3 interface. The aluminum bar patterns provide very high object contrast relative to the background material. Module 4 also has four 1mm steel beads, as described for Module 1.



## C SCANNING INSTRUCTIONS

Note: *The Phantom Data Form must be completed by a technologist, accurately reporting the facility's average techniques of clinically used protocols.* The Gammex 464 phantom can be scanned either by a technologist or medical physicist. A medical physicist must perform the dosimetry scans. The dosimetry scans can be done on a different day, but must be within the time frame of all other images required for submission. The medical physicist must verify that the protocols on the Phantom Data Form accurately reflect the clinical use of the unit, and may need to assist the technologist in determining "average" protocols for each examination by viewing previously scanned patients.

**1. Fill out the Phantom Data Form:** This will entail listing information about the CT scanner and the acquisition parameters typically used for several types of clinical scans. **Do not use any type of automatic dose reduction technique when scanning the phantom.** If you use an automatic dose reduction technique for clinical scanning, you must look at images from patients, and determine the average technique (mid-brain for head, mid-liver for body), and enter that on the form; use this value for scanning the Gammex 464 phantom and for dosimetry measurements. You will report your use of an automatic dose reduction technique on the Phantom Data Form, but not use it for scanning the phantom. These parameters will be used for imaging the phantom and should be consistent with the acquisition parameters used for the clinical exams submitted as part of the accreditation process. The examination protocols required for the phantom portion of your accreditation submission depend on the examinations and patient types routinely performed on your unit and chosen in your accreditation application. The Phantom Data Form available to you in your online testing package will reflect the phantom scans necessary for your submission. **Scanning the phantom with any deviation from the protocols recorded on the Phantom Data Form, with the exceptions noted below, may result in failure to achieve accreditation.**

- Adult Abdomen – All units must scan the phantom with an average adult abdomen protocol. This is because some measurements are only analyzed using this protocol. Enter the **average** technique used on a mid-liver image on an average sized patient.
- Adult Head – If your facility chose the head/neck module on your application, you must enter the **average** parameters used for the **cerebrum** portion of your facility's adult brain protocol (for accreditation purposes, adult examinations are patients over the age of 15).
- Pediatric Abdomen – If your facility chose the pediatric patient type and chest and/or abdomen modules, you must enter the **average** mid-liver protocol for a pediatric abdomen examination on a 40 lb child.
- Pediatric Head – If your facility chose the pediatric patient type and the head/neck module, you must enter the **average** parameters for the **cerebrum** portion of your facility's pediatric brain protocol. This protocol must be what you would use on a 1 year old child.

### Important Definitions for Phantom Data Form

**z-axis collimation (T):** the width of the tomographic section along the z-axis imaged by one data channel. In multi-detector row (multi-slice) CT scanners, several detector elements may be grouped together to form one data channel.

**Number of data channels (N):** the number of tomographic sections imaged in a single axial scan.

**Maximum number of data channels (Nmax):** the maximum number of tomographic sections for a single axial scan.

**Increment (I):** the table increment per axial scan or the table increment per rotation of the x-ray tube in a helical scan.

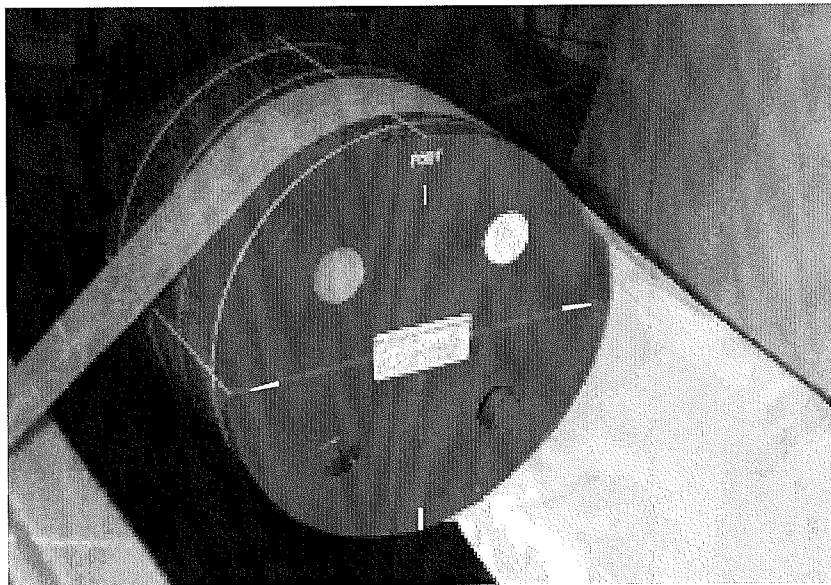
**Image thickness:** the thickness of a single slice after post- processing, whether automatic or manual post processing is used.

**Reconstructed Scan Interval:** the distance between the center of one slice to the center of the next slice. This distance takes into consideration a gap between slices, or an overlap.

**2. Calibrate the Scanner:** Prior to scanning the ACR CT accreditation phantom, perform tube warm-up and any necessary daily calibration scans (air scans, water scans) as recommended by the manufacturer. The ACR recommends that the site's water phantom be scanned and tested for accuracy of the CT number of water, absence of artifacts, and uniformity across the field of view **prior to proceeding. Stop and contact your field service engineer or medical physicist if any problems are found.**

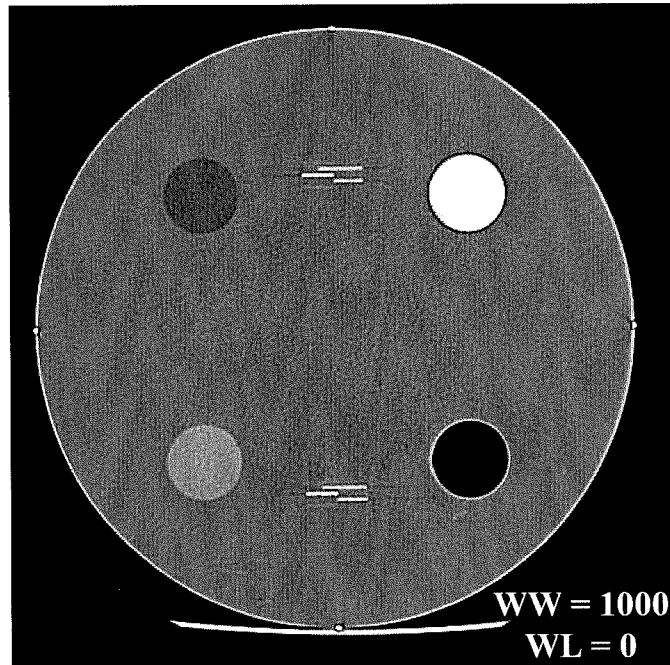
**3 Perform Phantom and Scanner Alignment:** Pull back the table padding and position the ACR CT accreditation phantom so that it is "HEAD" first into the gantry. (Be sure to choose a patient orientation of "supine head first" on the scanner.) Carefully position the phantom so that the CT scanner's alignment lights are accurately positioned over the scribe line corresponding to the center of Module 1 (FOOT END of the phantom). Use the set of alignment lights, internal or external, that are used clinically. Align the phantom in the sagittal, coronal, and axial planes. Zero (or landmark) the table at this point (or be sure to note the table location, as all scans will be acquired in reference to this location). While maintaining careful alignment, secure the phantom so it will not move (Figure 1).

Use a single axial scan at the landmark location (0 or S0). Use an image thickness  $\leq 2$  mm to verify adequate alignment. **Use a display field of view (reconstructed image diameter) as close to, but not smaller than, 21 cm.**



**Figure 1**

Examine the image to determine whether all four BBs are visible in the image (Figure 2). Use WW = 1000 and WL = 0. All four BBs should be visible. The longer central wires should be symmetrically located in the center of the image. This indicates good positioning of the phantom.



**Figure 2:** All four BBs are visible and the central wires are symmetrically located ( $\pm 1$  wire) in the center of the ramps

**4 Scan the Gammex 464 phantom with your facility's protocols:** Using your protocols listed on the Phantom Data Form, scan the Gammex 464 phantom from slice positions 0 through 120. Use a display field of view (DFOV) as close to 21 cm, but not less than, as possible. You may adjust the scan field of view (SFOV) to a size appropriate to the size of the phantom. No other adjustments to your routine protocols should be necessary except as noted above. If you are routinely using other than 120-130 kVp for the adult abdomen protocol and your CT numbers do not meet the criteria listed below, please submit an additional scan of module 1 using 120-130 kVp.

**5 Evaluate your phantom images:** Using the images obtained from scanning the phantom with your facility's protocols listed on the Phantom Data Form, evaluate your images for pass/fail criteria. Use the best images from each scan series for each phantom module to evaluate the images before submitting them to ACR for review. The method and criteria for the measurements below follows:

- CT Number Calibration
- Low Contrast Criteria (Contrast to Noise Ratio) (CNR)
- Uniformity
- Artifacts

**Note:** If the images do not pass, the physicist will inform the supervising physician and service engineer, as corrective action may be warranted. If your site service engineer makes system adjustments and/or the supervising physician makes scan protocol changes, repeat step 1. If your facility makes changes to any clinical protocols used in the phantom portion of your accreditation submission, make sure that clinical images you submit reflect these changes.

- **CT Number Calibration** – Using the best Module 1 image scanned with your facility's adult abdomen protocol. Place a circular region of interest (ROI, approximately 200 mm<sup>2</sup>) within each cylinder (Figure 3) and record the mean CT number for each material for your records. It is important to center the ROIs within each cylinder. The water cylinder is subtly seen as a large gray ring. Be sure to place the water ROI as shown in Figure 3. The CT Number Calibration criteria are shown in Table 1.

Table 1
Polyethylene HU between -107 and -84
Water HU between -7 and +7
Acrylic HU between +110 and +135
Bone HU between 850 and 970
Air HU between -1005 and -970

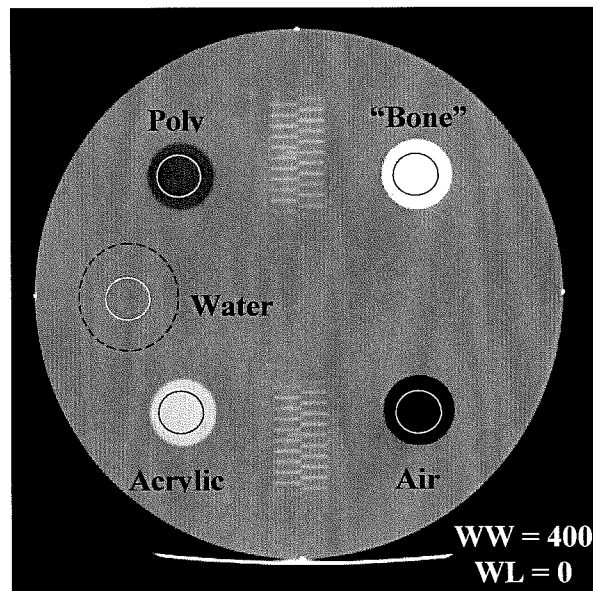
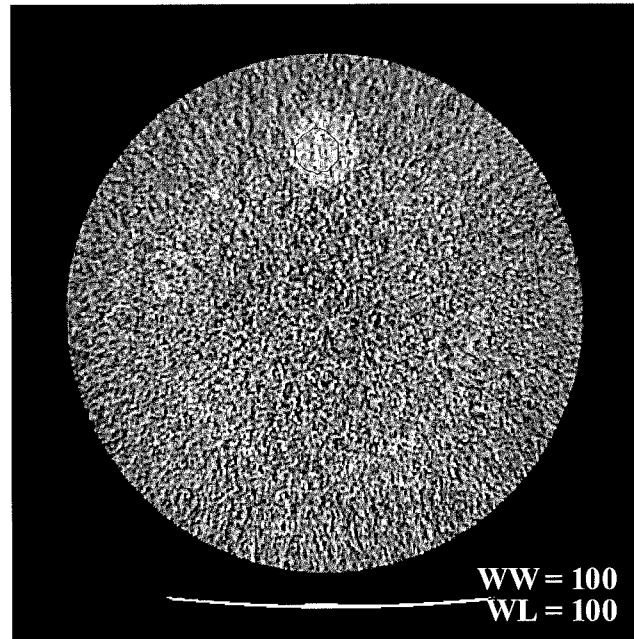


Figure 3. Regions of interest (ROIs) for each material and for the water-equivalent background material.

Measure only the water number for all of the other protocols you are submitting for the phantom portion of your accreditation submission.



- **Low Contrast Criteria (Contrast to Noise Ratio)(CNR)** – View the best image located in Module 2 for all submitted protocols using a WW = 100 and a WL = 100. Note that there are four cylinders for each of following diameters: 2, 3, 4, 5, and 6 mm (see diagram on Page 3 and Figure 5). Place a ROI ( $\approx 100 \text{ mm}^2$ ) over the large (25-mm diameter) cylinder and between the large cylinder and the 6 mm cylinders (Figure 5b).



**Figure 5** – Module 2 low contrast resolution image at WW = 100 and WL = 100 with correct ROI placement.

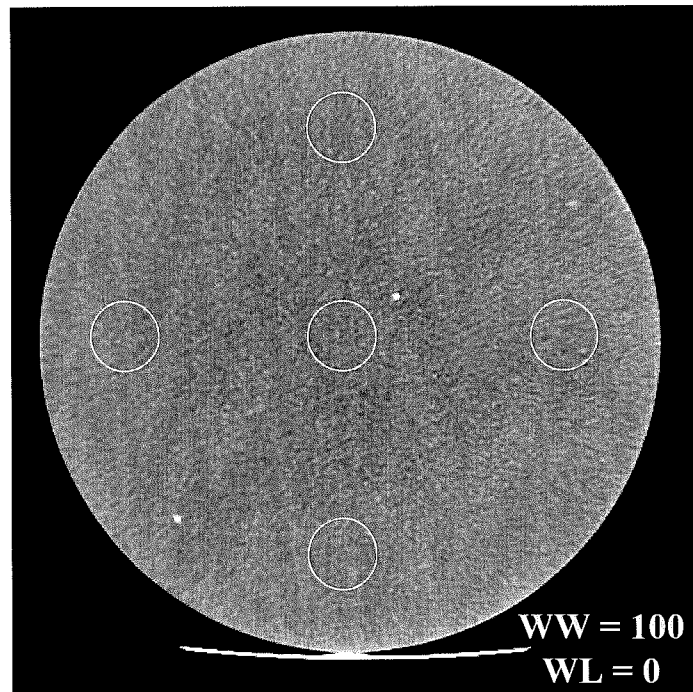
Record the mean signal in the ROI inside the 25mm rod (A), the mean signal in the ROI outside the 25 mm rod (B), and the Standard Deviation (SD) from the ROI outside the 25 mm rod for your records. Use this formula to calculate the Contrast to Noise Ratio (CNR):

$$\text{CNR} = |A-B|/\text{SD}$$

Use the absolute value of the difference – that is, **do not** take into consideration whether the CNR is a positive or negative number. The CNR must be greater than 1.0 for the adult head, pediatric head and adult abdomen protocols. The CNR must be greater than 0.5 for the pediatric abdomen protocol.

NOTE: Pediatric CNR will be analyzed and used to set limits at a later date. They do not currently constitute a deficiency in the accreditation process.

- **Uniformity** – View the Adult Abdomen protocol image in Module 3 (uniformity image) with a WW = 100 and a WL = 0. Place an ROI of approximately 400 mm<sup>2</sup> at the center of the image (A) and the four edge positions shown in Figure 6. For the edge ROIs, place the center of the ROI approximately one ROI diameter away from the edge. Record the mean CT numbers for all five ROIs for your records. Additionally, record the standard deviation of the center ROI. All CT numbers for all five ROIs must be within  $\pm 5$  HU of the center ROI mean value.



**Figure 6** – Placement of uniformity center and edge ROIs

- **Artifacts** - With all graphics turned off, view the same image carefully with the room lighting reduced. Examine the image for artifacts such as rings or streaks and record the presence and appearance of any artifacts. If artifacts are present, your medical physicist or service engineer may be needed to investigate and correct them.

## D Radiation Dosimetry

CTDI<sub>vol</sub> is now one of the pass/fail criteria for adult head, adult abdomen, and pediatric abdomen. Reference levels have also been determined for these examinations. Please refer to the *ACR CT Accreditation Program Requirements* for more information on reference levels and their use. If the CTDI<sub>vol</sub> for your unit is above the pass/fail criteria below, **that unit will fail accreditation.**

Examination	Pass/Fail Criteria	Reference Levels
	CTDI <sub>vol</sub> (mGy)	CTDI <sub>vol</sub> (mGy)
Adult Head	80	75
Adult Abdomen	30	25
Pediatric Head (1 year old)	To be determined	To be determined
Pediatric Abdomen (5 year old, 40-50 lb)	25	20

### Required Materials

- Phantom Data Form, with average facility protocols for each examination to be submitted in the phantom portion of the accreditation testing package.
- Calibrated CTDI (pencil) ionization chamber (typically 10 cm in length)
- Calibrated electrometer
- Acrylic (PMMA) cylindrical phantoms (figure 7), having cylindrical holes (at 1 cm from the edge, and one at the center):
  - Head CTDI phantom: 16 cm diameter
  - Body CTDI phantom: 32 cm diameter
- Dose calculation Excel spreadsheet, available at [http://www.acr.org/accreditation/computed/qc\\_forms.aspx](http://www.acr.org/accreditation/computed/qc_forms.aspx)

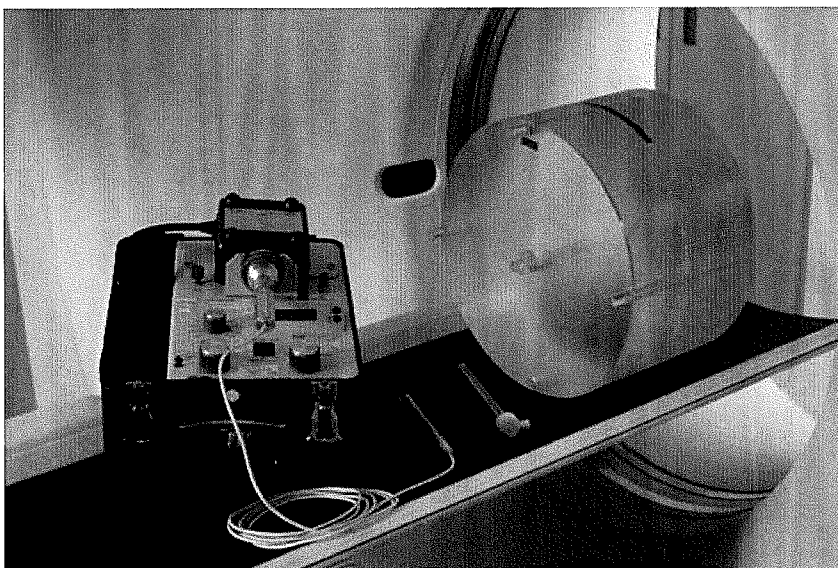


Figure 8: CTDI phantom, pencil ionization chamber, and electrometer

## Scanning Instructions

1. Position the phantom appropriately at the isocenter of the scanner. Ensure that the phantom is correctly aligned in all three planes (sagittal, axial and coronal).
  - a. For the adult and pediatric head scans, position the 16 cm phantom in the head holder.
  - b. For the adult abdomen scans, position the 32 cm phantom on the table top.
  - c. For the pediatric abdomen scans, position the 16 cm phantom on the table top.

\*Note: if head scans are performed without the head holder, perform with the dosimetry scans with the phantom on the table top. Make note of this fact in the submitted materials.

2. Connect the pencil chamber to the electrometer and insert the pencil chamber into the central hole in the phantom. Ensure that all other holes (those at 3, 6, 9, and 12 o'clock positions) are filled with acrylic rods.
3. Using the appropriate protocol **as entered in the phantom data form**, acquire **a single axial slice** at the center of the phantom, with no table increment. If the protocol is normally scanned helically, change to an axial scan, keeping the remaining technical parameters unchanged.

### **All CTDI dose information must be acquired using axial scans.**

In multislice CT, CTDI is a function of detector configuration. It is **imperative** that the detector configuration and total beam width used matches the site's clinical protocol (N•T) as closely as possible.

If N•T used for dosimetry does not exactly match the clinical value, be sure to modify the table increment used in the calculation to yield the same pitch value as used clinically.

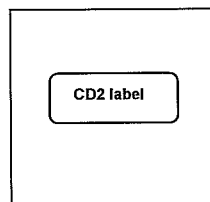
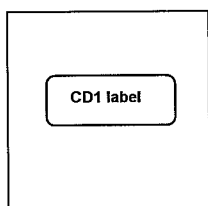
4. Record the following in the Excel Dose Spreadsheet for the appropriate examination:
  - a. kVp
  - b. mA
  - c. exposure time (sec)
  - d. z-axis collimation (T, in mm)
  - e. number of data channels used
  - f. table increment (mm) used to yield the clinical pitch
  - g. active chamber length of pencil chamber
  - h. chamber correction factor
  - i. exposure in mR
5. Repeat the scan two more times and record the measurements from each scan in the Excel Dose Spreadsheet. If the data differ by more than 5%, check your equipment and rescan the data until the three measurements agree within 5%.
6. The spreadsheet will calculate the **average** measurement from scans in mR, and the *CTDI at isocenter in phantom* in mGy.
7. Move the pencil chamber from the center position to the 12 o'clock peripheral position. Ensure that an acrylic rod is then inserted into the vacated isocenter position.
8. Repeat steps 3 through 8 and record the value in mGy as the *CTDI at 12 o'clock position*.
9. The spreadsheet will calculate the following:
  - a. Average of the three measurements from the 12 o'clock position in mR
  - b. Head CTDI at 12 o'clock position in mGy
  - c. CTDI<sub>w</sub> in mGy
  - d. CTDI<sub>vol</sub> in mGy
  - e. DLP in mGy-cm
  - f. Effective Dose in mSv

10. Repeat steps 1 through 9 for each examination protocol you are submitting for the unit. See "Fill out Phantom Data Form" section of this document for more information on the protocols you may be asked to submit.

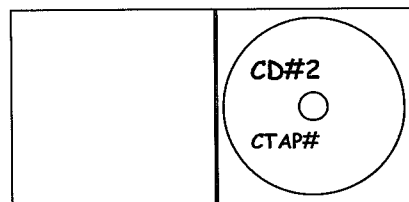
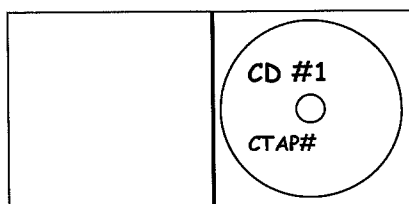
## E Preparing Images for Submission

After scanning the Gammex 464 and all needed CTDI phantoms according to the CT Phantom Instructions, prepare your images for submission:

1. Name each series separately according to the protocol used and the phantom scanned, i.e. Adult Head ACR Phantom, Adult Head CTDI Phantom, etc.
2. You must submit your phantom images in **DICOM format**, on 5 ¼ inch CD or DVD media, 3 inch discs are not acceptable.
3. Burn a total of 2 discs for each unit on your application. Separate units must be burned onto separate discs. **Each disc must contain all required images.**
  - a. One set of images per protocol scanned (adult head, adult abdomen, pediatric head and pediatric abdomen, depending on your use of the unit and the patient type and modules on your application) on the Gammex 464 phantom
  - b. One set of images per protocol scanned on the appropriate CTDI phantom
4. The recommendation is to include an embedded viewer that can perform the following functions (Your facility will not be penalized if you do not include an embedded viewer or if not all of the listed functionality is available, **as long as the images are DICOM**):
  - a. Easy access to the complete and accurate DICOM header
  - b. Window/level adjustments
  - c. Distance measurement
  - d. Region of interest (including measurement of area, pixel mean and pixel standard deviation)
  - e. Magnification
  - f. Show cross reference lines for slice location
5. After burning the discs, you **must open and check each disc** to check that the appropriate images are all included and available.
6. Log in to the ACRedit database to fill in the phantom portion of your online Testing Package.
7. Print the forms you need from the ACRedit database when you *finish and submit* your online testing package for each unit. Two copies of each form will print out. Please keep one copy for your records.
8. Label the discs and forms –
  - a. Use the Phantom Data form barcode to label the phantom data form. Make a copy of the labeled form and submit one form with each phantom CD.
  - b. Place the appropriate CD labels on the disc case. **DO NOT PUT LABELS ON THE DISC.**
  - c. Use a permanent marker to label the discs with your CTAP #



Place ACR label on case



Write CD # and CTAP # on disc with permanent marker

**IMPORTANT:** The correct labeling of your images, forms and discs is critical to properly identify the materials submitted for accreditation. Incorrect or incomplete labeling will delay the accreditation process. The ACR will return your package to you if your images are not labeled properly.