CT Dose Profiler

Probe for evaluation of CT systems

CT Dose Profiler User's Manual - English - Version 7.2A

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CT Dose Profiler

The CT Dose Profiler probe makes it possible to evaluate the performance of modern CT scanners.

RTI
INDEPENDENT X-RAY
QUALITY ASSURANCE

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Intended Use of the CT Dose Profiler probe

Together with the Ocean Software from RTI Group AB it is to be used for quality control, service and maintanance of CT systems.

With the CT system in stand-by condition without patients present, the probe is intended to be used:

- to provide the operator with information on radiation beam parameters that might influence further steps in an examination but not an ongoing exposure.
- for assessing the performance of the CT scanner.
- for evaluation of of examination techniques and procedures.
- for service and maintanance measurements.
- for quality control measurements.
- for educational purposes, authority supervision, etc.

The product is intended to be used by hospital physicists, X-ray engineers, manufacturer's service teems, and other professionals with similar tasks and competencies. The operator need s basic knowledge about the software Ocean before starting to use the CT Dose Profiler probe. This can be achieved by studying the relevant documentation.

The product is NOT intended to be used:
- for direct control of any diagnostic X-ray system performance during irradiation of a patient.
- so that patients or other unquilified persons can change settings of operating parameters during and immediately before and after measurements.

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Chapter 1

Introduction

1 Introduction

Regular quality assurance measurements on CT scanners are necessary in order to monitor the dose levels patients are exposed to during medical examinations. In many countries, governments require regular quality compliance testing information from clinics and hospitals that perform CT examinations.

Today, computed tomography (CT) comprises approximately 70% of the total dose given to patients during X-ray examinations. With the rapid advancements in CT technology, there is increasing demand to develop new testing strategies and measuring equipment to maintain the highest possible standard of patient care. It was found that using the standard 10 cm CT ionization chamber may result in inaccurate measurements due to its tendency to underestimate the dose profile. Our answer to this problem is the CT Dose Profiler (CTDP) probe.

The CT Dose Profiler (CTDP) probe is a highly advanced point dose probe designed to fit into the standard phantoms to evaluate computed tomography systems. There is no limit to the slice width that users can measure with the CTDP. When using this probe for CTDI measurements, the traditional five axial scans with an ion chamber are replaced with one helical (spiral) scan with the CTDP probe in the center hole of the phantom (head or body). The CT Dose Profiler replaces the conventional TLD and OSL methods or film for dose profile measurements.

The CT Dose Profiler probe is designed to be used with the Piranha X-ray multimeter, Mako with a Legacy Module or Cobia and the Ocean Next software. You can measure several different parameters with Ocean Next and the CTDP probe. There are two standard templates, one for CTDI and one for geometric efficiency, that come with Ocean Next which can be used with license level ADVANTAGE and PROFESSIONAL.

As mentioned above, the CTDI measurement can be done with one helical scan. After the helical scan, Ocean Next gives several parameters at the same time such as CT dose profile, $CTDI_{100}$, $CTDI_{W}$, $CTDI_{vol}$, DLP and FWHM.

The scientific methods used in the CT Dose Profiler have been evaluated in a variety of studies; see the reference list (especially 1, 4, 10, 11, 12, 14, 15 and 16).

Note:
This manual will show you how to use the CT Dose Profiler probe with a Piranha, Mako with a Legacy Module or Cobia and the Ocean Next software. It will also give examples of practical measuring methods. It is assumed that you have installed Ocean Next and are familiar it. If you haven't installed Ocean Next yet, do that first. You will find instructions in the Ocean Next User's Manual.

⚠ The CT Dose Profiler shall be handled with care even if it is much more durable than a traditional CT ion chamber. If it is dropped or subjected to strong shocks, the detector chip may be damaged.

Chapter 2

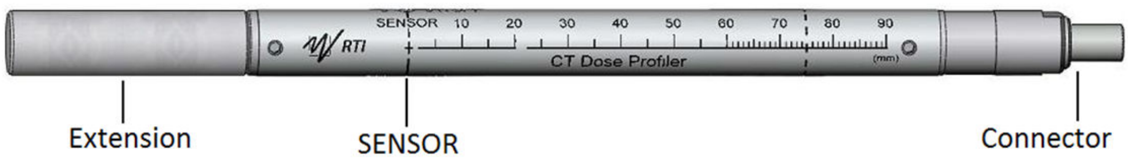
Start measuring

2 Start measuring

The Ocean Next software is used to evaluate and calculate all parameters based on the measured dose profile. Ocean Next is available in three different license levels; QUICK, ADVANTAGE and PROFESSIONAL. You must have at least ADVANTAGE to use the CT Dose Profiler probe.

ADVANTAGE AND PROFESSIONAL
You can use predefined templates available in Favorites to easily get started with the CT Dose Profiler probe. These templates are also found in the database folder "Examples (RTI)" and you can copy templates from here and modify them according top your own needs.

The CT Dose Profiler probe is a point dose detector that has a solid-state sensor placed 3 cm from the end of the probe. The probe can be extended with an extension piece made of PMMA to fill different phantoms. The extension is 45 mm. When this is attached, the detector will be centered in the middle of a 150 mm wide PMMA phantom when the end of the extension reaches the end of the phantom.



The sensor is very thin (250 µm) in comparison to the beam width and is therefore always completely irradiated when it is in the beam.

The sensor collects the dose profile. As radiation hits the sensor, in either direction, the detector registers the dose value at that point and sends the information to the software. The electrometer can collect 2000 such dose values per second. When the dose profile is collected all of the data points are put into a graph. The recommended and most convenient method to measure the dose profile is to use "Timed mode". This mode makes it possible to define exactly how long you want to measure and by that being able to ensure that you don't miss any radiation. You simply check on the CT scanner how long the scan will take and then use a certain margin of your choice in specifying "measuring time".

To be able to collect the dose at the different positions, thereby creating the dose profile, the probe must be moved through the CT beam. This is achieved by placing it free in air or in a phantom and then using the couch movement to scan the probe (perform a helical scan). Therefore it is not possible to use axial scans for measuring the CTDI with the CT Dose Profiler probe. You could, of course, make many axial scans in small steps with the detector and plot a dose profile, but that takes a lot of time. With a helical scan you will receive the dose profile in a few seconds. It has been proven that the CTDI can be measured with helical scans as long as corrections are made for the pitch (see reference 10). This correction is done automatically in Ocean Next.

2.1 Make your first CTDI measurement

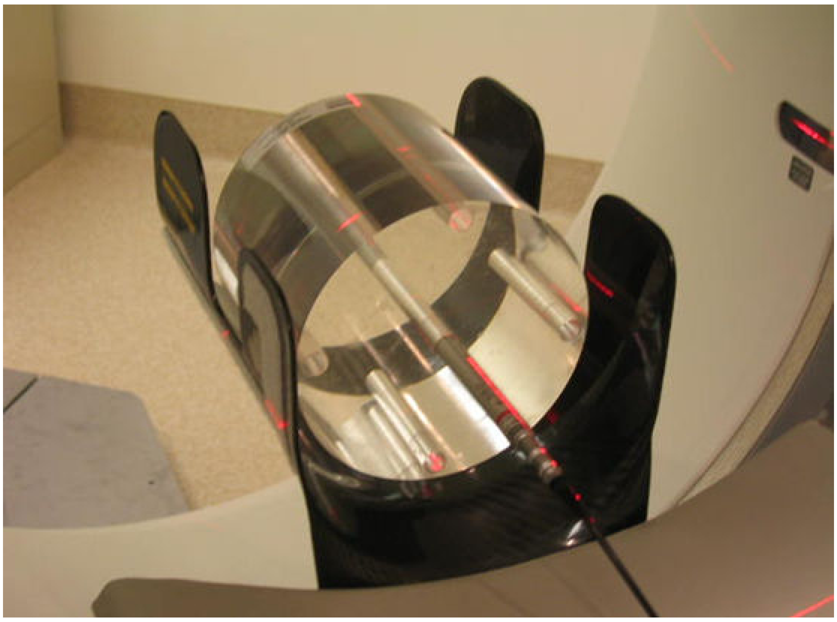
We will use a predefined measuring template that comes with Ocean Next in this first measurement. As mentioned before, it is assumed that you are familiar with Ocean Next. If you need general information about Ocean Next, please consult its User's Manual.

Assume that you want to measure CTDI(100) using a head phantom:

First setup the meter, phantom and probe.

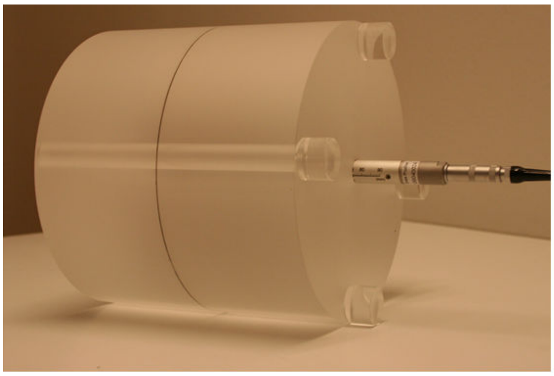
1. Connect the CTDP probe to the Piranha, Mako with a Legacy Module or Cobia via the extension cable.

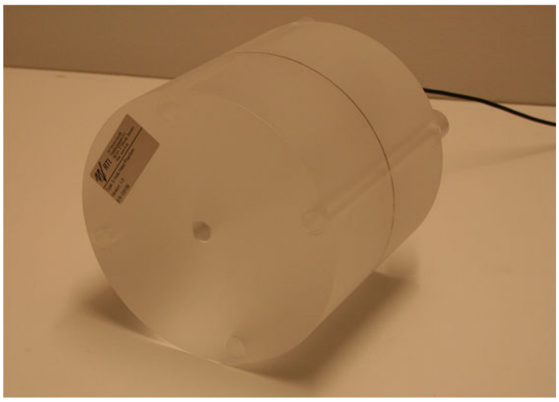
2. Place the CT head phantom on the head support and the CTDP probe in the center hole with the connector pointing towards the couch as shown in the picture.



Note: Only one exposure with the probe in the center hole is required. The section "Theory of CTDI and k-factor" describes the theory behind this method.

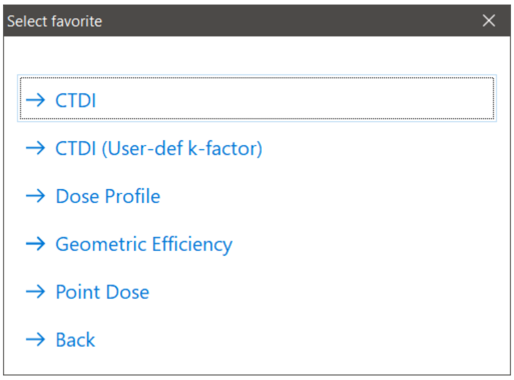
3. Make sure that the sensor is in the center of the phantom. This can be accomplished easily by using the graded scale on the CTDP probe. Assuming you are using a standard phantom with a length of 150 mm, the stitched mark at 75 mm on the CTDP probe should be place in the phantom opening and the end of the extension should then be at the end of the phantom as shown in the pictures below:



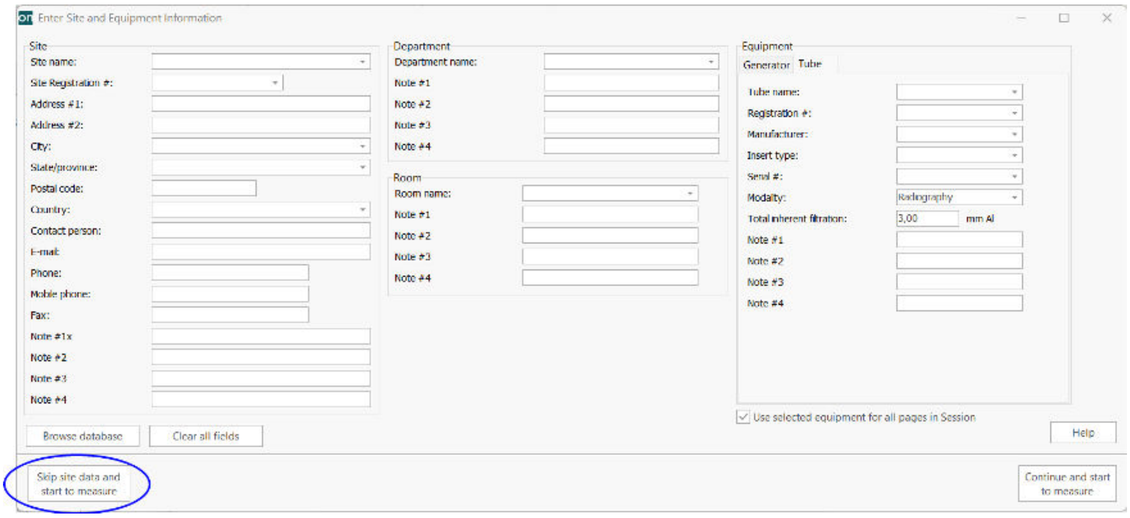


4. Make sure that the two horizontal CT lasers are visible on the probe, approximately in the middle of it. Also verify that the vertical laser is approximately in the middle of the phantom. Center the CT at this position (put this position to zero).
5. Put a piece of tape along the probe, attaching it to the phantom. This is to ensure that the probe is not dislodged within the phantom when the couch starts to move.
6. Start Ocean Next.
7. Power on the meter and the CT Dose Profiler probe.
8. Connect to the meter.
9. Click on the Favorite button. A dialogue will be shown. It may include more options but select "RTI CT Dose Profiler".

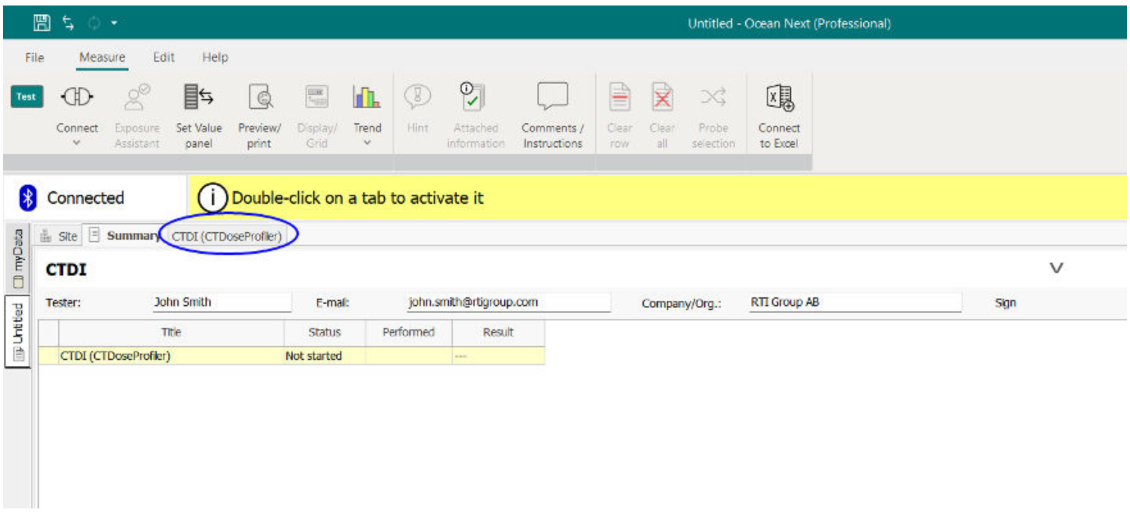
   The following list will be shown, select "CTDI".



10. A dialogue is shown where you can select a site from your site database or leave the site information blank and enter it later, select "Skip site data and start to measure".



11. The measurement template loads and the session summary page is show:



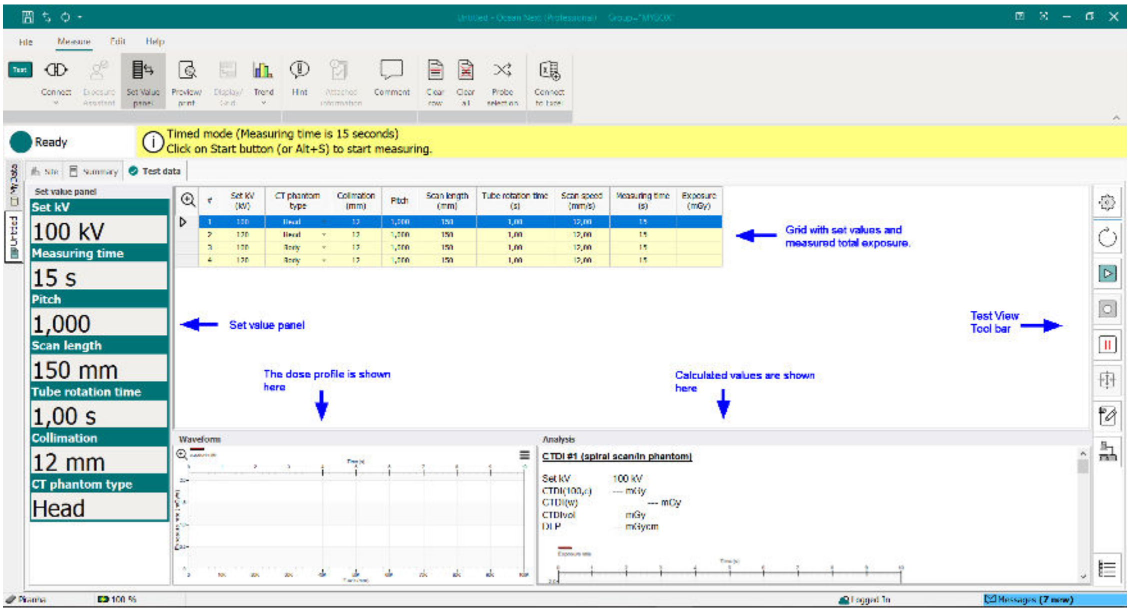
12. Double-click on the tab to activate the test page.

13. A hint with some instructions is shown. Click OK to close it.

14. A list with manufacturer is shown, select the one. If you can find what you want, select "Generic Manufacturer". You can later read more about this in the section "Unlisted CT scanners".

15. A list with scanner models and supported kV settings is shown. Select one and make sure to note which kV settings are supported. If you don't find the model you want, select the "Generic scanner". You can also read more in the section "Unlisted CT scanners".

16. The Test View loads and you can start to measure:



Note: Waveform grid, cursor data and analysis are empty right now, since no measurement has been performed yet.

17. The template performs four different CTDI measurements (only one exposure is needed for each one), two with head phantom and two with body phantom. You can easily change the set values for current exposure by clicking directly on the value in the Set value panel. Alternatively, you can edit values directly in the grid.

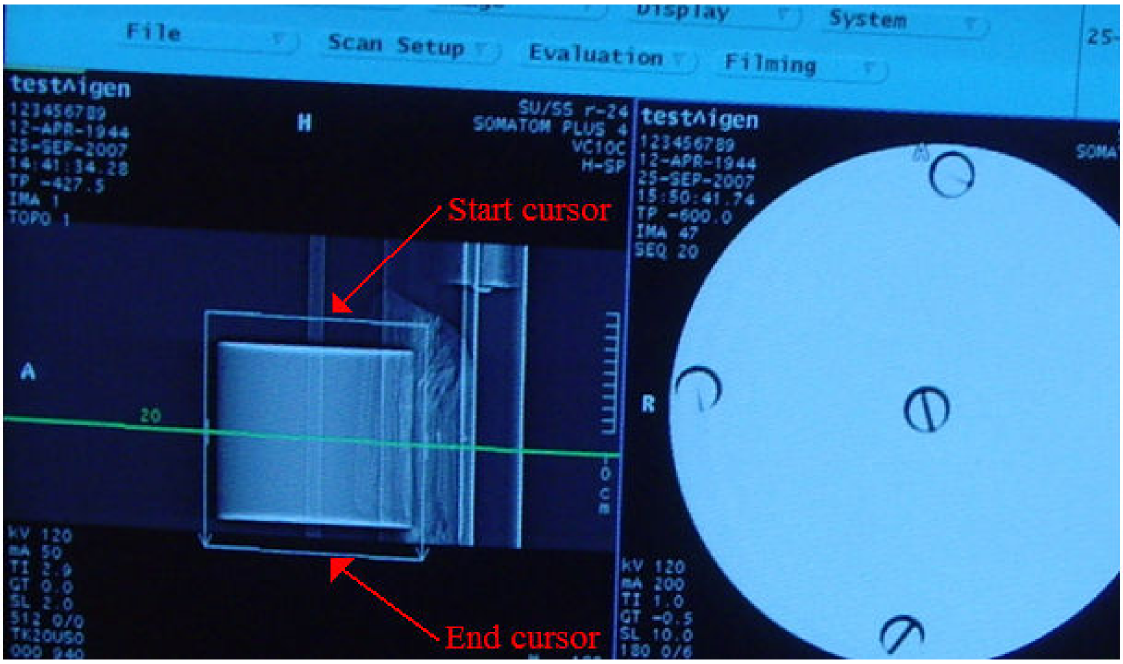
18. When you select the CT scanner model the required data will be pulled into your measurement from a database including energy correction factors and the k-factor. You can read more about the k-factor in the section "Theory of CTDI and k-factor". A more complete list of k-factors is available in the "Appendix" section of this manual.

19. If you know the total filtration, go to the Tube tab and enter it. If you don't know, use the default value (7 mm).

20. Now it is time to prepare the CT settings. You will be required to perform the following: perform a topogram (a scout image), know how to set the cursors to define the scan area for the spiral/helical scan and be able to perform the scan. It is very important that these CT-parameters are read and set correctly; otherwise the measurement will be incorrect.

21. First, perform a topogram (scout image) over the whole CT Dose Profiler when it is positioned inside the phantom. Ocean Next is not used at this stage and the meter will not record any data. You do not have to be concerned with any settings or measured data since the reason for this scan is to find out where to set the cursors of the CT machine for the helical scan.

22. The CT console will show the scanned image similar to the one below.



23. Locate the sensor in the scanned image. Set the start cursor approximately 3 cm before the phantom and the end cursor approximately 3 cm after the phantom. While these are not exact numbers the measurement should start a little bit before the phantom and stop a little bit after it. Note down the scan time that the CT unit needs to perform this scan as you will need this value later on to select a suitable measuring time.

24. You must enter the following parameters before you can perform your first measurement.

    - kV
    - Pitch (-)
    - Tube rotation time (s)
    - Collimation (mm)
    - Phantom type (head or body)

    To be able to acquire DLP you also need to specify:

- Scan length (mm)

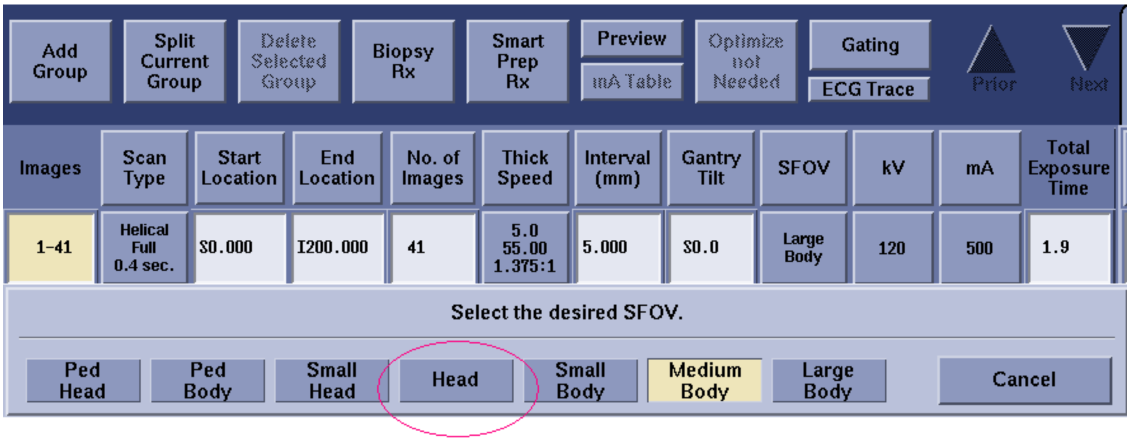
The scan speed is automatically calculated.

You now have to find the corresponding parameters on the CT console. Parameters may have different names on units from different manufacturers.

25. First select spiral/helical scan on the CT scanner.

26. Choose the correct Scan Field of View (SFOV) on the CT console. The SFOV should be chosen according to the type of phantom that is used. Click in Select "CT phantom type" on the Set Value panel to the left in Ocean Next.

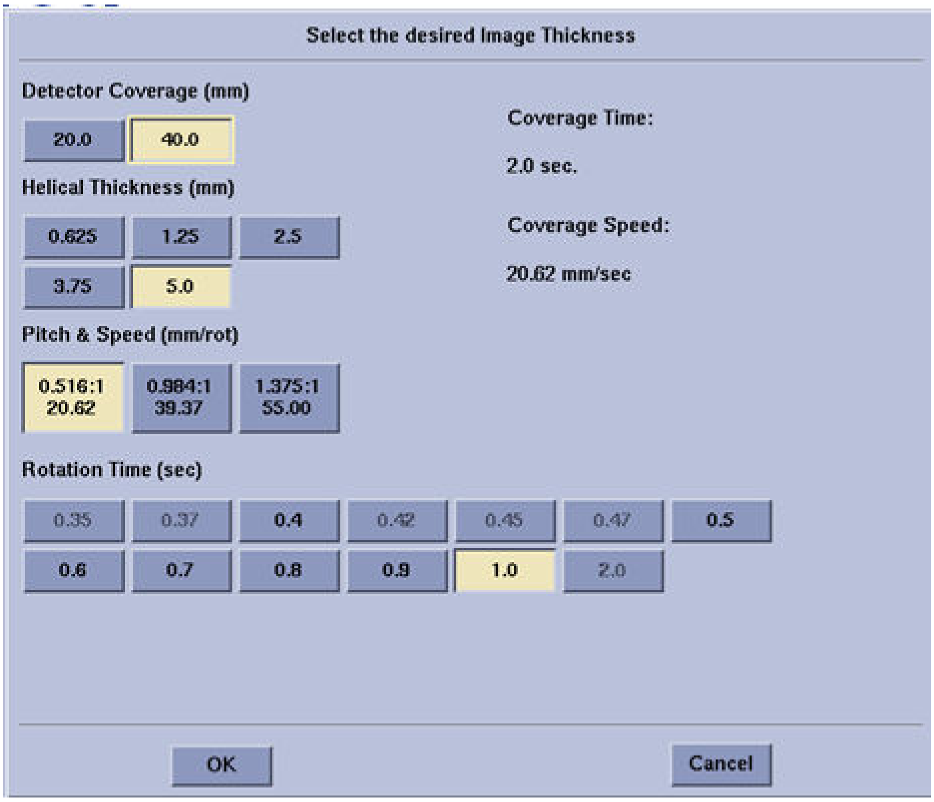
    Here is an example of how a console may appear on a GE CT scanner when SFOV is selected.



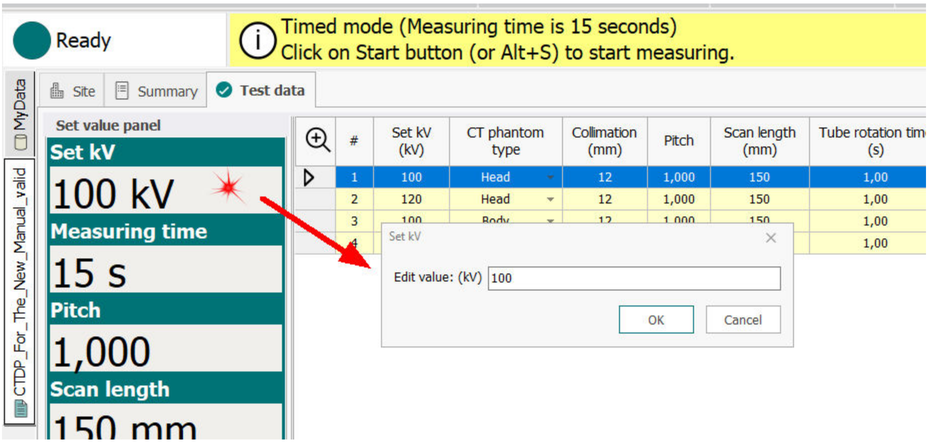
Select SFOV according to what kind of phantom you use:

SFOV type	CTDI phantom
Ped Head	16 cm Phantom
Ped Body	
Small Head	
Head	
Small Body	32 cm Phantom
Medium Body	
Large Body	

Set values on the console:



27. Select the kV at which you want to do the measurement and click on "Set kV" on the Set value panel and enter it in Ocean Next. Select one of the supported kVs that was shown when you selected the scanner model (see point #11).



28. Select the pitch and click on "Pitch" on the Set Value panel in the enter it in Ocean Next.

29. Select the tube rotation time and click on "Tube rotation time" in the Set Value panel and enter it in Ocean Next.

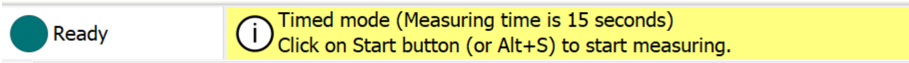
30. Select Collimation and click on "Collimation" in the Set Value panel and enter it in Ocean Next. Ocean Next defines Collimation as the total width of the beam, the number of slices multiplied by the width of each slice.

31. If you want DLP, enter the scan length in Ocean Next. Click on "Scan length" in the Set Value panel and enter the value.

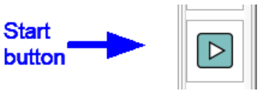
32. Make sure that the "Measuring time" is set to the same or a slightly larger value than the scan time ?????? (if you specify a too long measuring time than you actually need, you lose resolution in the dose profile).

#	Set kV (kV)	CT phantom type	Collimation (mm)	Pitch	Scan length (mm)	Tube rotation time (s)	Scan speed (mm/s)	Measuring time (s)	Exposure (mGy)
1	100	Head	12	1,000	150	1,00	12,00	15	
2	120	Head	12	1,000	150	1,00	12,00	15	
3	100	Body	12	1,000	150	1,00	12,00	15	
4	120	Body	12	1,000	150	1,00	12,00	15	

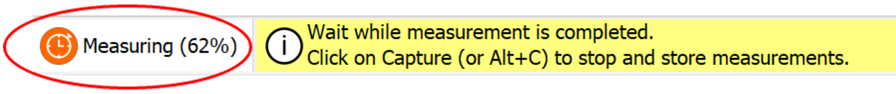
33. You are now ready to perform the measurement. **Timed mode** will be used and you must start the measurement manually before you start the CT scan.



34. Click the **Start** button on the Test View toolbar on the right side and directly after start the CT scan from the console.



35. You will see how the measurement is progressing on Ocean Next's status bar.



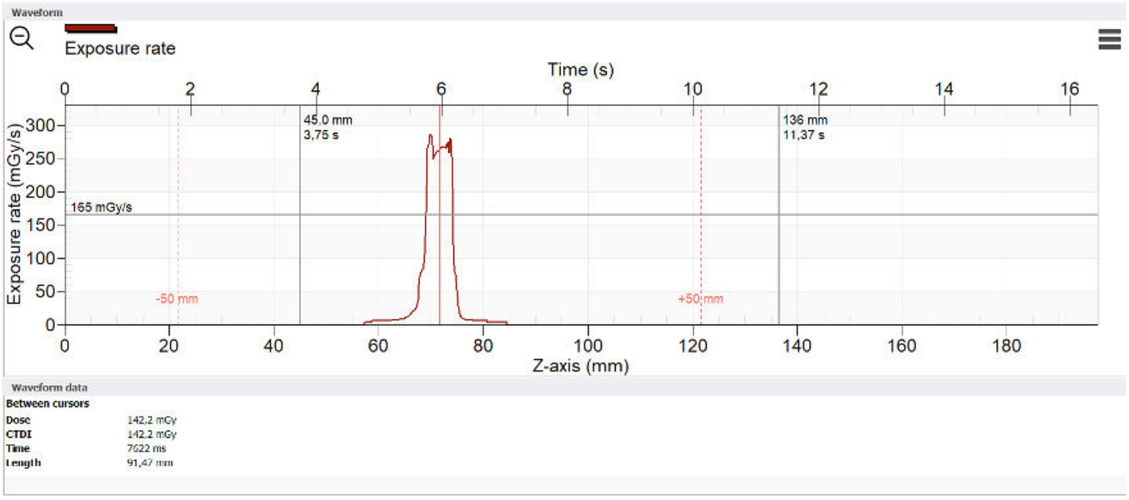
The dose profile will now be measured. Be sure that the entire scan is covered by the measuring time you have chosen. If not, you should increase the measuring time in Ocean Next and redo the measurement.

36. As soon the measurement is completed Ocean Next will display the dose profile and calculated data. The dose profile is shown in the waveform window and the total measured dose is shown in the Exposure column in the grid.

#	Set kV (kV)	CT phantom type	Collimation (mm)	Pitch	Scan length (mm)	Tube rotation time (s)	Scan speed (mm/s)	Measuring time (s)	Exposure (mGy)
1	100	Head	12	1,000	150	1,00	12,00	15	143,3
2	120	Head	12	1,000	150	1,00	12,00	15	
3	100	Body	12	1,000	150	1,00	12,00	15	
4	120	Body	12	1,000	150	1,00	12,00	15	

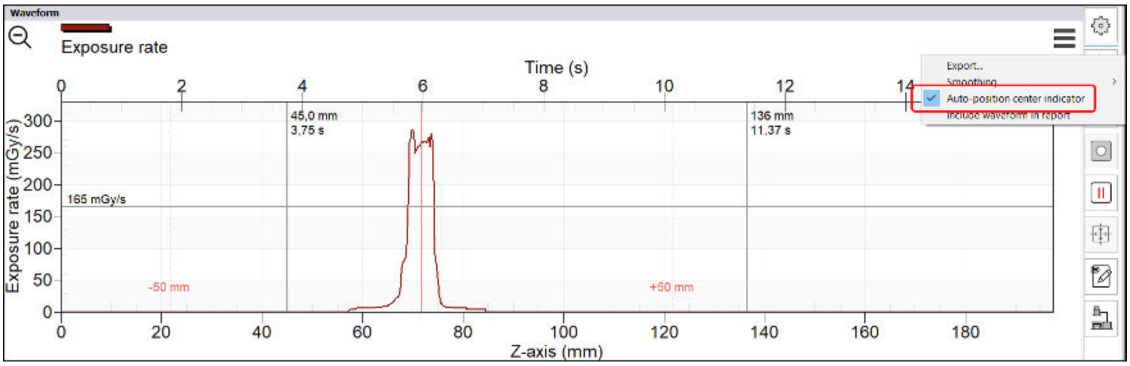
37. Make the necessary adjustments and redo the measurement if you don't get a value in the Exposure column.

You can enlarge the waveform if you click on the magnifying glass in the upper right corner. The waveform graph shows the dose profile:

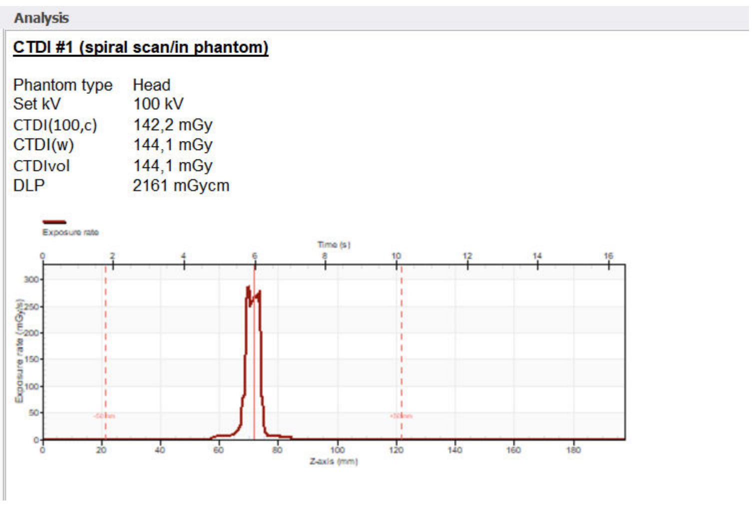


There are two cursors that can be moved. Corresponding cursor values are shown in the waveform data window.

The center indicator can be moved manually. This can be useful in situations when Ocean Next isn't able to find the correct center position. When the center indicator is moved all values related to its position and the +/-50 mm indications are recalculated. To move the center indicator just move mouse pointer over it and use drag-and-drop. Right-click on the graph and select **Auto-position center indicator** if you want to restore the automatically calculated position.



38. The calculated values are shown in the Analysis window. You can right-click on the analysis window and select "Maximize".

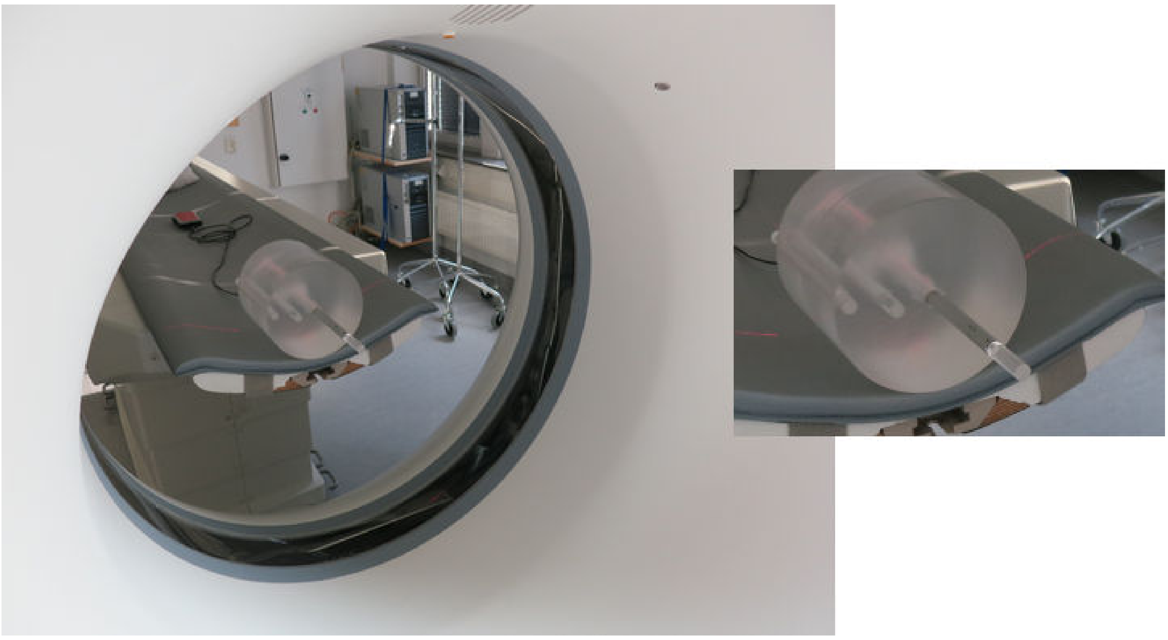


39. The first CTDI measurement is now done. You can now measure the remaining CTDI values using the above method.

2.2 Measurement free-in-air

The second standard template that comes with Ocean Next is for measurements free-in-air. This template calculates CTDI free-in-air and Geometric Efficiency. You perform this measurement the same way as described in the previous section but in this case is no phantom used.

Hint
When you do the free-in-air measurement, you may use the phantom as a holder for the probe as shown in the picture below:



The description below assumes that you have read previous topic that describes how do to a CTDI measurement.

1. Go to the Backstage and click on the Favorite button.
2. Select "RTI CT Dose Profiler" followed by "Geometric Efficiency".
3. Select to enter site data late, manufacturer and CT scanner model.
4. The measurements loads and the Test View is shown

	#	Set kV (kV)	Collimation (mm)	Pitch	Scan length (mm)	Tube rotation time (s)	Scan speed (mm/s)	Measuring time (s)	Exposure (mGy)
▷	1	80	12	1,000	150	1,00	12,00	10	
	2	100	12	1,000	150	1,00	12,00	10	
	3	120	12	1,000	150	1,00	12,00	10	

5. You must enter the parameters below before you can perform your first measurement.

   - kV
   - Pitch (-)
   - Tube rotation time (s)

- Collimation (mm)

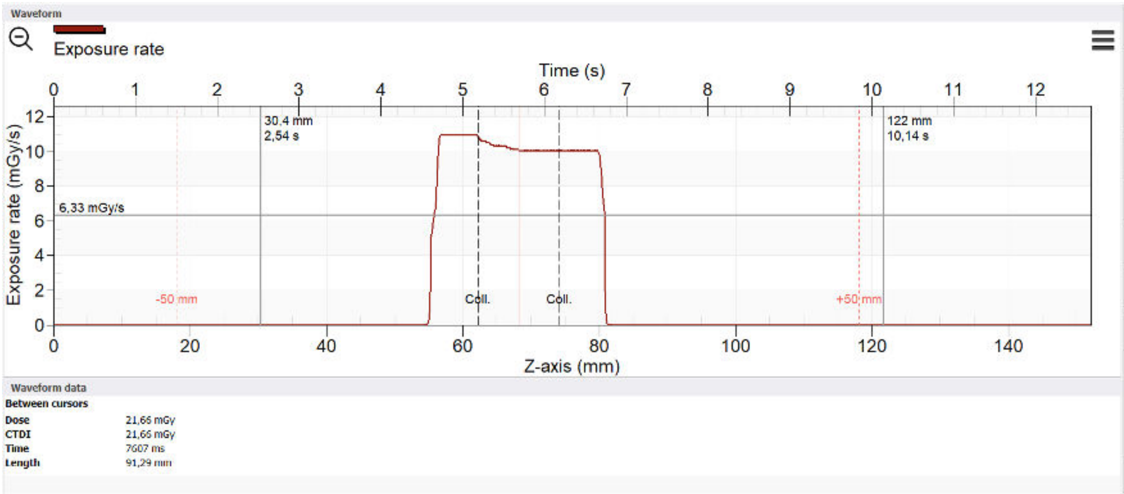
6. Now perform the measurement the same way as the CTDI measurement described in the previous section.

7. As soon the measurement is completed Ocean Next will display the dose profile and calculated data. The dose profile is shown in the waveform window and the total measured dose is shown in the Exposure column in the grid.

#	Set kV (kV)	Collimation (mm)	Pitch	Scan length (mm)	Tube rotation time (s)	Scan speed (mm/s)	Measuring time (s)	Exposure (mGy)
1	80	12	1,000	150	1,00	12,00	10	21,42
2	100	12	1,000	150	1,00	12,00	10	
3	120	12	1,000	150	1,00	12,00	10	

8. Make the necessary adjustments and redo the measurement if you don't get a value in the Exposure column.

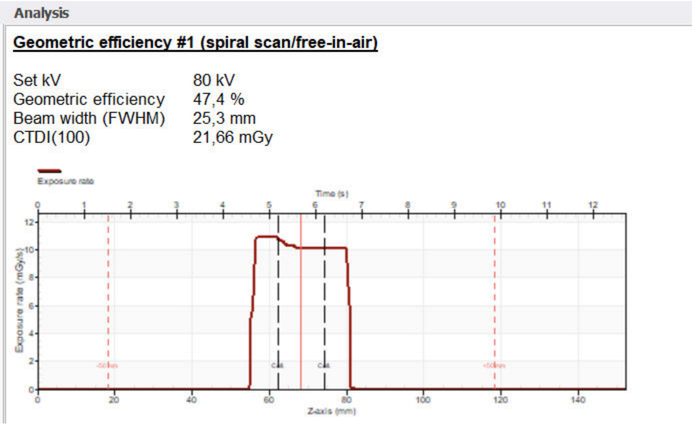
9. The waveform graph shows the dose profile.



There are two cursors that can be moved. Corresponding cursor values are shown in the waveform data window.

If the center point and FWHM can't be found automatically the analysis will show a calculation error. In this case, in the waveform graph (not the analysis graph), use the mouse pointer and grab the center pointer. You can now move it. Position it manually in the center of the dose profile. Two new indicators, for FWHM, become visible. Move these and position in a position where the dose rate is half of the maximum dose rate.Now are all parameters in the analysis calculated based on the manual positions you have done. If you want to go back to automatic calculation; right-click on the waveform graph and check "Auto-position center indicator".

10. The calculated values are shown in the Analysis window.



11. The first measurement Geometric Efficiency is now done. Other parameters measured with this template are the CTDI(100) free-in-air and the Beam width (FWHM = Full Width Half Maximum).

2.3 Dose profile and Point dose

There are three more templates available in Favorites for the CT Dose Profiler:

- Dose profile
- Point dose
- CTDI with user-defined k-factor

These templates are also available from the **Favorite** button. You can also use Quick Check when you measure point dose.

If you want to use these templates as start and modify them, you also find them in the database folder "Examples (RTI)" folder under "Templates - Gy" (or - R) --> "Single-page sessions" --> CT --> "RTI CT Dose Profiler".

2.4 Unlisted CT scanners

The scanners we currently have k-factors for (required for the method to measure CTDI with only one scan) are listed in the topic Appendix k-factors. Note that you can always specify the k-factor after the measurement if you don't know it when you perform the measurement. Add a user-defined k-factor later and specify it. All calculations will be updated according to the new k-factor you specify.

As described in section Make your first CTDI measurement you select the CT scanner by clicking on the binoculars on the Equipment tab after specifying the manufacturer name. If you don't find the scanner model you are looking for do the following:

- Select one that is similar to one in the list
- Use the Generic scanner
- Use your own k-factor. You must then instead select the CTDI with a user-defined factor, modify the template and add a column for the k-factor.

Select one that is similar

1. Select one that you think is similar.

2. Edit the model field.

3. Proceed according to the description in topic Make your first CTDI measurement.

Select "Generic scanner"

1. Select the "Generic scanner".

2. Edit the model field.

3. Proceed according to the description in topic Make your first CTDI measurement.

Use your own k-factor

The k-factor is used by Ocean Next to calculate the weighted CTDI ($CTDI_W$) from only one measurement in the center hole of the phantom. The k-factor is calculated as:

$$k = \frac{CTDI_w}{CTDI_{100(center)}}$$

If you know this factor for a certain CT scanner, you can use it by building your own template and include the k-factor column:

	#	Set kV (kV)	CT phantom type	Collimation (mm)	Pitch	Scan length (mm)	Tube rotation time (s)	Scan speed (mm/s)	Measuring time (s)	Exposure (mGy)	K-factor
▷	1	100	Head	12	1,000	150	1,00	12,00	10		1,080
	2	120	Head	12	1,000	150	1,00	12,00	10		
	3	100	Body	12	1,000	150	1,00	12,00	10		
	4	120	Body	12	1,000	150	1,00	12,00	10		

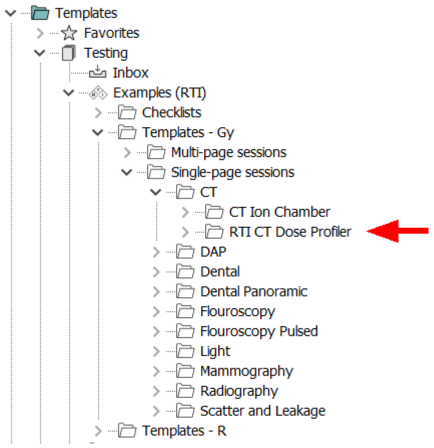
As soon as you enter a value in the k-factor column, this value is used for the calculation. It will overrule any value available in Ocean Nexts's database.

Chapter 3

Create your own templates

3 Create your own templates

The templates we have used so far have been the standard templates delivered with Ocean Next. These templates are available to you in the folder "Examples (RTI)". There are two main folders with the same structure with templates, one for templates using "Roentgen" and one using "Gray":



You can use these templates as starting point if you want to build your own Session templates and include more than one Test page (more than one Test page requires license level PROFESSIONAL).

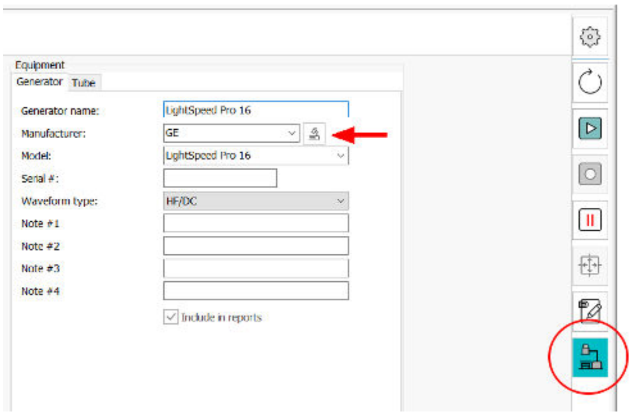
Ocean Next's help text and User's Manual give a general description of how to create a template. The next two topics give specific information about required columns, calculations and other information required to measure CTDI and Geometric Efficiency using the CT Dose Profiler and Ocean Next.

3.1 CTDI template (in phantom)

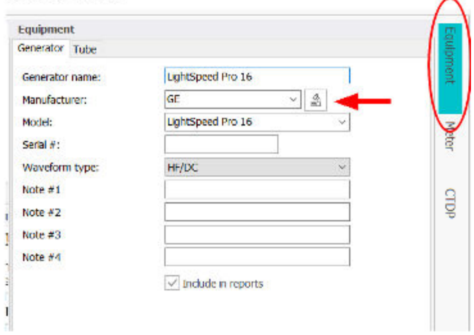
The theory behind the method of only one helical scan with the probe in the center hole of the phantom used in Ocean Next to measure the CTDI is described in the section CTDI and k-factor. This section describes what columns and analyses you must include in a template to evaluate $CTDI_{100}$, $CTDI_w$, $CTDI_{vol}$ and DLP.

The CTDI analysis is used to evaluate the CT dose index on computed tomography systems using the RTI CT Dose Profiler detector. Ocean Next uses one helical scan exposure with the CTDP in the center hole of a 5-hole phantom and calculates the $CTDI_w$, $CTDI_{vol}$ and DLP. Since a known relationship exists between the the center hole and the peripheral holes, only one helical scan measurement is done in the center hole of the phantom to calculate the CTDI. This relationship is unique for each CT scanner and is defined in Ocean Next as the k-factor. A list of k-factors Ocean Next uses is available in the Appendix. Use the binoculars to select a scanner from the list or just activate the test page and Ocean will ask for the type of scanner if no k-factor is available. Ocean Next will choose the correct k-factor based the CT scanner name you selected. You find the binoculars in the following way in Test View and Studio View respectively:

Test View



Studio View



If you want to modify the standard analysis (Ocean Next, ADVANTAGE or PROFESSIONAL is required), see topic **Modify analysis** and **Advanced analysis** in the Ocean Next Reference Manual.

A typical CTDI (in phantom helical scan)

This example shows three measurements, each with its own analysis. Two is a measurement in a head phantom and the other is in a body phantom. In this case is only one measurement performed.

View / Select	#	Set kV (kV)	CT phantom type	Collimation (mm)	Pitch	Scan length (mm)	Tube rotation time (s)	Scan speed (mm/s)	Measuring time (s)	Exposure (mGy)
	1	80	Head	12	1,000	171	1,00	12,00	16	30,04
	2	120	Head	12	1,000	171	1,00	12,00	16	
	3	100	Body	12	1,000	171	1,00	12,00	16	

Note:

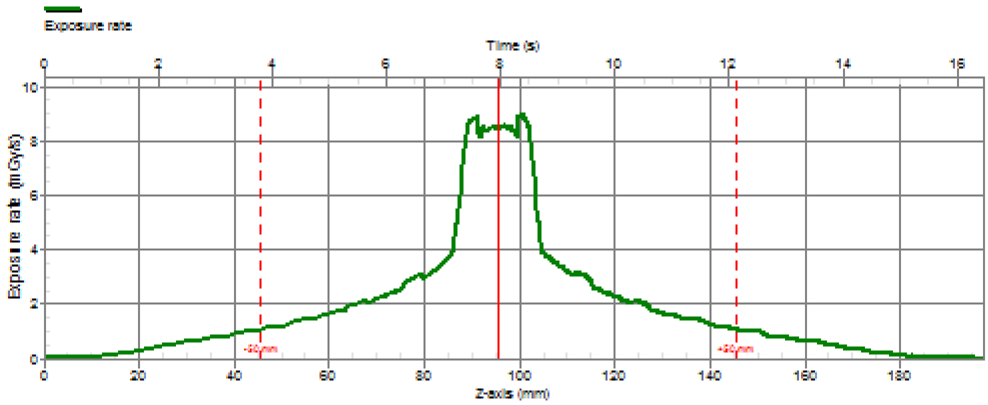
- You must use TIMED MODE for this measurement. The measuring time is defined by the column "Measuring time".
- Use Low sensitivity for Head phantom and free-in-air and High sensitivity for Body phantom if you use Piranha, it is automatically with Cobia.

The calculation (analysis) for the first measurement looks like this:

CTDI #1 (spiral scan/in phantom)

Result: Pass

Set kV	80 kV
CTDI(100,c)	26,52 mGy
CTDI(w)	30,28 mGy
CTDIvol	30,28 mGy
DLP	517,8 mGycm



Default pass/fail criteria

When you add the CTDI (in phantom helical scan) analysis the following pass/fail criteria is shown:

	Min	Max	
☑ Use CTDI(100,w) limit			mGy

You must choose your own default limits for the pass/fail criteria. If you leave a limit blank no pass/fail analysis is performed for that item.

When you modify a CTDI (in phantom helical scan) analysis (Ocean Next Professional is required), all pass/fail criteria are available:

	Min	Max	
☐ Use CTDI(100,w) limit			mGy
☐ Use CTDI(100,w,n) limit			mGy/mAs
☐ Use CTDI(100,vol) limit			mGy
☐ Use DLP limit			mGycm

You must modify the layout to see the results of the additional parameters.

Result layout and macros

As described in the topic **Advanced analysis** in the Ocean Next Reference Manual (or Help text), it is possible to modify the the layout of the analysis result (Ocean Next Professional is required). The layout is defined as text combined with "macros". When the analysis result is shown, the macros are replaced with the appropriate calculated values, set values and measured values. The default layout for the CTDI (in phantom helical scan) analysis looks like this:

```
$Title

Result: $TestResult

Set kV          $SetkV kV
CTDI(100,c)     $CTDIc $Unitw
CTDI(w)         $CTDIw $Unitw
CTDIvol         $CTDIvol $Unitvol
DLP             $DLP $UnitDLP

$DoseProfileGraph
```

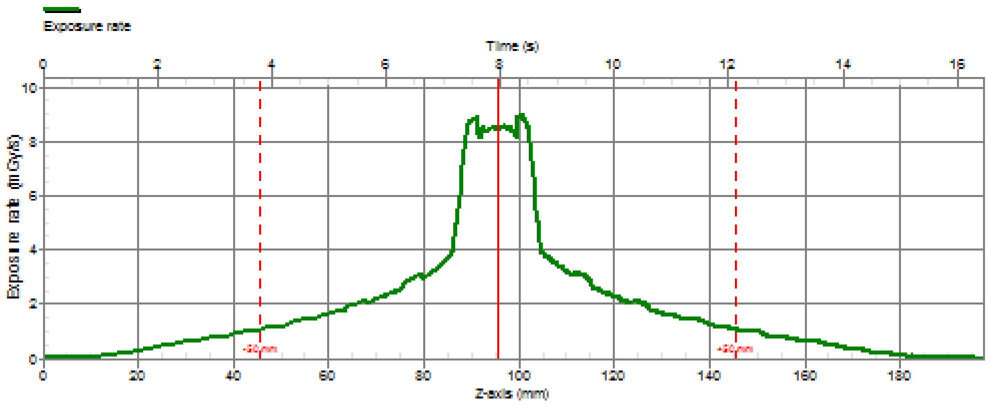
This text can be modified and more macros can be added to show more calculated results, for example, the relative difference. The following macros are available for the CTDI (in phantom helical scan) analysis:

$Title (Specified title)
$Result (Analysis result)
$TestResult (Pass or fail text, the overall result for the test)
$SetkV (Set kVp)
$SetmAs (Set mAs)
$SetPitch (Set pitch)
$SetScanTime (Set value for the scan time)
$SetTubeRotTime (Set tube rotation time)
$SetCollimationNT (Set value for the collimation)
$SetPhantomType (Set value for phantom type)
$ScanSpeed (Calculated scan speed = Set Pitch * Collimation(NT) / Set Tube Rot Time)
$DoseProfileGraph (The CT dose profile graph)
$CTDIc (Measured CTDI(100,c) (center position) from waveform)
$CTDIwn (Measured value CTDI normalized)
$Unitwn (Unit for CTDI normalized)
$MinCTDIwn (Minimum value)
$MaxCTDIwn (Maximum value)
$CTDIw (Measured value CTDI weighted)
$Unitw (Unit for CTDI weighted)
$MinCTDIw (Minimum value)
$MaxCTDIw (Maximum value)
$CTDIvol (Measured value CTDI volume)
$Unitvol (Unit for CTDI volume)
$MinCTDIvol (Minimum value)
$MaxCTDIvol (Maximum value)
$DLP (Measured value for Dose Length Product)
$UnitDLP (Unit for Dose Length Product)
$MinDLP (Minimum value)
$MaxDLP (Maximum value)
$kFactor (Used k-factor (if blank, automatically selected by the analysis))

Calculations

The CTDI(100,c) is calculated in the following way:

All calculations are done from the dose profile waveform.



The waveform is an array of samples where the Z-axis (see graph above) represents the position of the sensor and the y-axis represents the exposure rate. The waveform includes a maximum of 1024 samples.

Ocean Next finds key locations in the waveform in the following way:

1. Find the maximum dose rate that occurred during the scan.
2. Search backward from this point to find where the dose profile goes below 50% of the maximum value and call this position X1 (not shown on graph).
3. Search forward from the point found in step 1 to find where the dose profile goes below 50% of the maximum value and call this position X2 (not shown on graph).
4. Calculate the position halfway between X1 and X2. Call this point X3 (shown as a solid red line in graph above).
5. Calculate "X3-50 mm" and "X3+50 mm" and call these positions X4 and X5, respectively. They are marked with red dotted lines in the graph above and labeled with the text "-50 mm" and "+50 mm", respectively.

If the points X1 and X2 can't be found automatically the analysis will show a calculation error. In this case, in the waveform graph (not the analysis graph), use the mouse pointer and grab the center pointer. You can now move it. Position it manually in the center of the dose profile. Two new indicators, for FWHM, become visible. Move these and position in a position where the dose rate is half of the maximum dose rate.Now are all parameters in the analysis calculated based on the manual positions you have done. If you want to go back to automatic calculation; right-click on the waveform graph and check "Auto-position center indicator".

The central CTDI, CTDI(100,c) is calculated as:

$CTDIc = "Integrated dose between X4 and X5" * Pitch

Pitch must be specified in the grid.

The weighted CTDI, CTDI(100,w), is calculated as:

$CTDIw = $CTDIc * $kFactor

The k-factor is from the table in the Appendix. The k-factor is found based on kVp, phantom type and CT scanner name. If you want to specify your own k-factor add the "k-factor" column to the template.

The volume CTDI, CTDI(100,vol) for a helical scan is calculated as:

$CTDIvol = $CTDIw / Pitch

The dose-length product, DLP, is calculated as:

$DLP = $CTDIvol * Scan length

Recommended columns (or general settings)

The following columns are recommended for the CTDI(in phantom helical scan) analysis.

Parameter	Description
Exposure(Measured)	The measured dose from the CT Dose Profiler detector.
Set kV	The set value for kV
CT Phantom type (Set value)	The phantom type, specifies head or body for this analysis
CT phantom position (Set value)	This specifies where the CT chamber is positioned in the phantom (*not required, enter hole is assumed if not specified*)
Collimation (Set value)	This column specifies the collimation.
Pitch (Set value)	This column specifies the pitch.
Scan length (Set value)	This specifies the length of the scan.
Scan speed (Set value)	This specifies the scan speed.
Measuring time	This is the measuring time for TIMED MODE. This is a meter setting (a value used by the meter).
Tube rotation time (Set value)	This is the tube rotation time.

3.2 CTDI (free-in-air) and Geomtetric Efficiency template

The CTDI (free-in-air helical scan) analysis is used to evaluate the geometric efficiency, CTDI free-in-air and beam width (FWHM) on computed tomography systems using the RTI CT Dose Profiler detector. It uses one helical scan exposure and calculates the geometric efficiency.

The Geometric efficiency is, simply speaking, the quotient between the dose inside the collimation width NT and the total dose profile along the z-axis expressed in percentage. The exact definition can be seen in reference 13. The Geometric efficiency gives an indication of how good the collimation on the CT system is and how much of the radiation goes outside the detectors. An example of measured Geometric efficiency is shown in the picture below. The two dotted black lines represent the length of NT. Ideally, all the active detectors should receive the same amount of radiation and no radiation should be outside the detectors. That would give a Geometric efficiency of 100%, but that is probably not possible due to the penumbra, etc. A Geometric efficiency over 70% is good for a multi-slice CT (MSCT).

If you want to modify the standard analysis (Ocean Next, ADVANTAGE or PROFESSIONAL is required), see topic **Modify analysis** and **Advanced analysis** in the Ocean Next Reference Manual.

A typical CTDI and Geometric Efficiency (free-in-air helical scan) test

This example shows three measurements, each with its own analysis. Only the first measurement is performed in this case.

View / Select	#	Set kV (kV)	Collimation (mm)	Pitch	Tube rotation time (s)	Scan speed (mm/s)	Measuring time (s)	Exposure (mGy)
	1	120	24	1,000	1,00	24,00	5	87,89
	2	120	12	1,000	1,00	12,00	15	
	3	120	12	1,000	1,00	12,00	5	

Note:
- You should use TIMED MODE for this measurement. The measuring time is defined by the column "Measuring time".

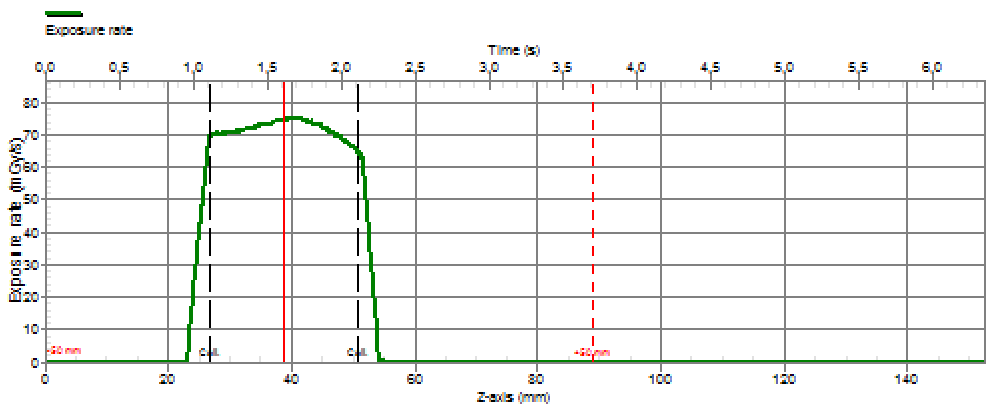
- Use Low sensitivity for Head phantom and free-in-air and High sensitivity for Body phantom.

The calculation (analysis) for the first measurement looks like this:

Geometric Efficiency (spiral scan/free-in-air)

Result: Pass

Set kV	120 kV
Geometric efficiency	86,7 %
Beam width (FWHM)	27,7 mm
CTDI(100)	83,21 mGy



Default pass/fail criteria

When you add the CTDI(helical scan/free-in-air) analysis the following pass/fail criteria is shown:

	Min	Max	
Geometric efficiency:			%
Beam width (FWHM):			mm

No default limits are specified, you must fill out limit. If you leave a limit blank not test for that criteria is done.

Result layout and macros

As described in the topic **Advanced analysis** in the Ocean Next Reference Manual (or in the Help text), it is possible to modify the the layout of the analysis result. The layout is defined as text combined with "macros". When the analysis result is shown, the macros are replaced with the appropriate calculated values, set values and measured values. The default layout of text CTDI (free-in-air helical scan) analysis looks like this:

$Title	
Result: $TestResult	
Set kV	$SetkV kV
Geometric efficiency	$GeometricEfficiency %
Beam width (FWHM)	$BeamWidthFWHM mm
CTDI(100)	$CTDI100 $UnitCTDI100
$DoseProfileGraph	

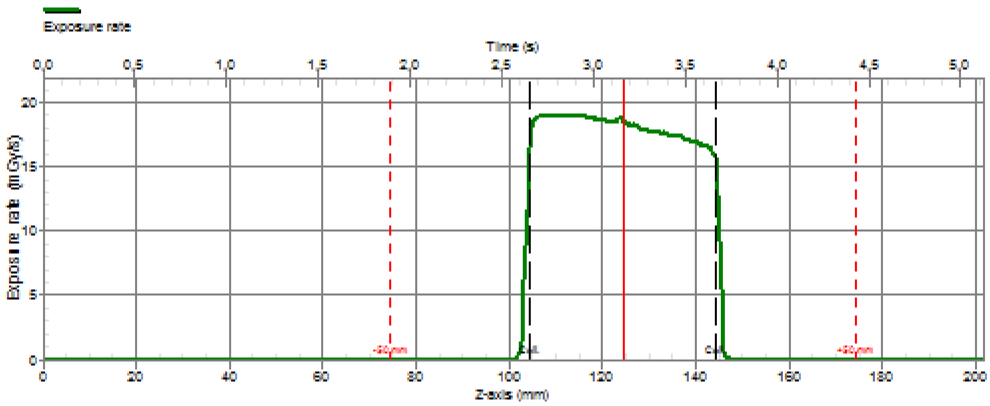
This text can be modified and more macros can be used to show more calculated results, for example the relative difference. The following macros are available for the CTDI(free-in-air helical scan) analysis:

$Title (Specified title)
$Result (Analysis result)
$TestResult (Pass or fail text, the overall result for the test)
$SetkV (Set kVp)
$SetmAs (Set mAs)
$SetPitch (Set pitch)
$SetScanTime (Set value for the scan time)
$SetTubeRotTime (Set tube rotation time)
$SetCollimationNT (Set value for the collimation)
$SetPhantomType (Set value for phantom type)
$ScanSpeed (Calculated scan speed = Set Pitch * Collimation(NT) / Set Tube Rot Time)
$DoseProfileGraph (The CT dose profile graph)
$CTDI100 (Measured CTDI100)
$UnitCTDI100 (Unit for CTDI)
$BeamWidthFWHM (Beam width from waveform)
$MinBeamWidthFWHM (Minimum value)
$MaxBeamWidthFWHM (Maximum value)
$GeometricEfficiency (Geometric efficiency (from waveform))
$MinGeometricEfficiency (Minimum value)
$MaxGeometricEfficiency (Maximum value)

Calculations

The CTDI(100,c) is calculated in the following way:

All calculations are done from the dose profile waveform.



The waveform is an array of samples where the Z-axis (see graph above) represents the position of the sensor and the y-axis represents the exposure rate. The waveform includes a maximum of 1024 samples.

Ocean Next finds key locations in the waveform in the following way:

1. Find the maximum dose rate that occurred during the scan.
2. Search backward from this point to find where the dose profile goes below 50% of the maximum value and call this position X1 (not shown on graph).
3. Search forward from the point found in step 1 to find where the dose profile goes below 50% of the maximum value and call this position X2 (not shown on graph).
4. Calculate the position halfway between X1 and X2. Call this point X3 (shown as a solid red line in graph above).
5. Calculate "X3-50 mm" and "X3+50 mm" and call these positions X4 and X5, respectively. They are marked with red dotted lines in the graph above and labeled with the text "-50 mm" and "+50 mm", respectively.

If the points X1 and X2 can't be found automatically the analysis will show a calculation error. In this case, in the waveform graph (not the analysis graph), use the mouse pointer and grab the center pointer. You can now move it. Position it manually in the center of the dose profile. Two new indicators, for FWHM, become visible. Move these and position in a position where the dose rate is half of the maximum dose rate.Now are all parameters in the analysis calculated based on the manual positions you have done. If you want to go back to automatic calculation; right-click on the waveform graph and check "Auto-position center indicator".

The central CTDI, CTDI(100,c) is calculated as:

$CTDI100 = "Integrated dose between X4 and X5" * Pitch

Pitch must be specified in the grid.

FWHM is calculated as the distance between X1 and X2:

$BeamWidthFWHM = X2 - X1

Calculate Geometric efficiency in the z-direction (according to IEC 60601-2-44) as:

$GeometricEfficiency = 100* (Dose between X6 and X7) / (Total dose)

Note!
The dose profile waveform is adjusted with the following function (X = FWHM) for 3 mm < X < 40 mm:

CorrF = 1.25466313 - 0.43935032 * X +0.34546921 * X^2 - 0.14128364 * X^3 + 0.03057638 * X^4 - 0.00330919 * X^5 + 0.00014071 * X^6

For X < 3 mm, no valid correction available
For X > 40 mm, CorrF = 1.00

This means that the total dose indicated "between cursors" will differ from the dose value shown in the grid (in the Exposure column) when the FWHM is less than 40 mm.

Recommended columns (or general settings)

The following columns are recommended for the CTDI (free-in-air helical scan) analysis.

Parameter	Description
Exposure(Measured)	The measured dose from the CT Dose Profiler detector.
Set kV	The set value for kV
CT Phantom type (Set value)	The phantom type, specifies head or body for this analysis (*not required*)
Collimation (Set value)	This column specifies the collimation.
Pitch (Set value)	This column specifies the pitch.
Scan length (Set value)	This specifies the length of the scan. (*not required*)
Scan speed (Set value)	This specifies the scan speed.
Measuring time	This is the measuring time for TIMED MODE. THis is a meter setting (a value used by the meter).
Tube rotation time (Set value)	This is the tube rotation time.

Chapter 4

Theory

4 Theory

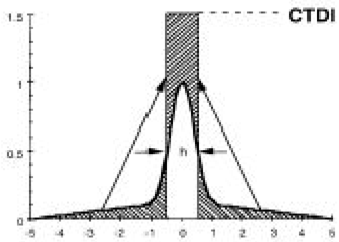
4.1 CTDI and k-factor

A quick and convenient way to determine $CTDI_{vol}$ is to use a method we call the Central Point Method. This method is based on the observation that the ratio between $CTDI_{w}$ and $CTDI_{100,central}$ is a constant for specific CT scanners in combination with the type of phantom used in the measurement (see reference 10). If the k-factor is known, you can perform a $CTDI_{100(central)}$ measurement and the software will then calculate $CTDI_{w}$ and $CTDI_{vol}$ automatically. The Appendix k-factors lists all scanners currently supported in Ocean Next.

There are a number of different quantities related to CTDI. The most common are summarized in the table below:

Quantity	Symbol	Remarks
CT Dose Index	CTDI	General dose description for CT
Multiple Scan Average Dose	MSAD	As CTDI but corrected for pitch
CTDI (100)	$CTDI_{100}$	Current definition of CTDI
Weighted CTDI	$CTDI_{w}$	Main descriptor of local dose
Volume CTDI	$CTDI_{vol}$	As $CTDI_{w}$ but corrected for pitch, same as $CTDI_{eff}$
Dose length product	DLP	Takes the irradiated volume into account

The CTDI quantity can be interpreted as the radiation energy deposited in a slice with a thickness corresponding to the nominal beam collimation thickness. The dose inside the slice is the CTDI and the dose outside the slice is excluded (see figure below).



In single slice CT the expression for CTDI is defined as:

$$CTDI = \frac{1}{T}\int_{-\infty}^{\infty} D(z)dz$$

where T is the nominal beam collimation thickness in mm and D(z) is the dose profile. On the y-axis the quantity is relative dose. $CTDI_{100}$ is acquired by reducing the integral to go between -50 and 50.

For MSCT, CTDI is defined as:

$$CTDI = \frac{1}{N \cdot T}\int_{-\infty}^{\infty} D(z)dz$$

where N is the number of detectors and T is the width of a detector.

$CTDI_{w}$ (weighted) represents an average value of the $CTDI_{100}$ inside a phantom (this requires five measurements, one in each hole):

$$CTDI_w = \frac{1}{3} \cdot CTDI_{100(center)} + \frac{2}{3} \cdot CTDI_{100(perpheral)}$$

In the case of single slice CT, the slice thickness is determined by the width of the detector. In multislice CT (MSCT), the slice thickness is determined by the number of detectors and the widths of the detectors.

In spiral CT there is an additional factor called the CT pitch factor. It is defined as the table movement per gantry rotation:

$$Pitch = \frac{\Delta d}{N \cdot T}$$

where Δd is the distance in mm that the couch moves between consecutive serial scans or per 360º rotation in helical scanning. N is the number of detectors and T is the detector thickness in mm (IEC 2003).

$CTDI_{vol}$ is the same as $CTDI_W$ but with respect to the pitch factor in helical (spiral) scanning:

$$CTDI_{vol} = CTDI_w / Pitch$$

The displayed $CTDI_{vol}$ given by a manufacturer may be a representative figure for that model and not the value measured on the particular CT scanner (see reference 13).

The dose-length product, DLP, includes the irradiated volume and represents the overall exposure for an examination and is calculated as following:

$$DLP = CTDI_{vol} \cdot L$$

where L is the scan length of a certain examination.

The scan length is defined as:

$$L = R \cdot p \cdot N \cdot T$$

where R is the number of tube rotations, p is the pitch factor, N is the number of detectors and T is the detector thickness.

The effective dose to a region is defined as:

$$E = E_{DLP} \cdot DLP$$

where DLP (mGycm) is defined in equation 6 and E_{DLP} is the region specific, DLP normalized effective dose (mSv/mGycm).

A quicker way to perform quality assurance has been introduced by using the CT Dose Profiler probe and the Ocean Next software. To be able to use it, the k-factor must be known for the CT-unit and the type of phantom that is used for the measurement. A number of k-factors for common CT-units are used by the software and listed in the Appendix k-factors. The factor is calculated by dividing $CTDI_W$ with $CTDI_{100(central)}$ from measurements obtained with pencil ion chambers:

$$k = \frac{CTDI_w}{CTDI_{100(center)}}$$

For head phantoms the k-factor is around 1 and for body phantom the k-factor is around 1.7 at 120 kV.

4.2 Why use a k-factor?

To measure the $CTDI_{100}$ with the CT Dose Profiler in the center hole of a head or body phantom with one helical scan exposure and then multiply it with the k-factor to get $CTDI_w$ and $CTDI_{vol}$ is, of course, faster than doing the five exposures with the pencil ion chamber. With the CT Dose Profiler you can also see a visible image of the dose profile that will tell you if something is wrong with the system. Another reason why the k-factor should be used is that it is hard to compare axial measurements over a pencil ion chamber with helical measurements over the CT Dose Profiler in the peripheral holes.

The nominal beam width is defined in the center of the CT where it is constant during the rotations. If you move a detector outside the center axis the beam width and dose rate will oscillate during the rotation. The pencil ion chamber is only partly irradiated so it is not affected the same way by the inverse square law and divergence in the beam width as a fully irradiated detector. Measurements with the pencil ion chamber do not tell you if you measure on a thin dose profile with high dose rate or a broad dose profile with a low dose rate if they have the same dose area. It can only measure a value that can foretell the dose but it cannot give a visible image of the dose profile.

The point dose detector can measure the same $CTDI_{100}$ in the center of the CT with helical scans as the pencil ion chamber can measure with axial scans. On the central axis the dose is non-oscillatory and the beam width is constant. When measurements are performed in the peripheral holes the conditions are not the same any more. The dose rate and the beam width in a peripheral hole oscillate during a rotation. The dose rate oscillates due to varying x-ray attenuation and beam divergence with changing distances affected by the inverse square law. The beam width varies due to the divergence from the x-ray source which becomes wider with increasing distance.

A single axial scan irradiates the same amount of dose to a detector with good rotation symmetry for every full 360 degree rotation, it does not matter where the rotation starts and stops as long as it makes one whole rotation and it is very easy to get good reproducibility. It is not the same for helical scans over a point dose detector because then you measure the point dose and not the dose length of, for example, 100 mm. The beam divergence from the x-ray source will have a big influence over the helical dose distribution among the peripheral holes in the phantom. That makes it hard to measure reproducible values if a suitable pitch is not used; a so called target pitch. The target pitch can be calculated with the following equation:

$$Target\ pitch = \frac{FWHM}{NT} \times \frac{(S-R)}{S}$$

where S is the distance between the x-ray source and CT center and R is the distance between the CT center and the detector. Observe that you have to know the FWHM in the center of the CT. Few CTs have the possibility to scan with any pitch value which makes it hard to perform this measurement. A pencil ion chamber is not affected by the divergence in beam width and distance the same way as a point detector. The $CTDI_{100}$, p from a measurement with the pencil ion chamber and the point dose detector are a little hard to compare but the point doses simulate the dose to a point in a phantom better.

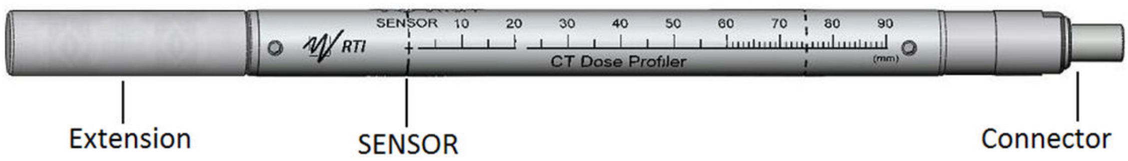
This is the reason why it is recommended to use the one exposure method with the k-factor.

Chapter 5

The CT Dose Profiler Probe

5 The CT Dose Profiler Probe

The CT Dose Profiler has one solid-state sensor placed 3 cm from the end of the probe. The probe can be extended with an extension piece made of PMMA to fill different phantoms. The standard extension is 45 mm. When this extension is on, the detector will be centered in the middle of a 150 mm wide PMMA phantom when the end of the extension reaches the end of the phantom.



The sensor in the CT Dose Profiler probe is very thin (250 µm) in comparison to the beam width and is therefore always completely irradiated when it is in the beam.

The sensor is used to collect the dose profile and it can also be used as a trigger. As radiation hits SENSOR, in either direction, the detector registers the dose value at that point and sends the information to the software. The electrometer can collect 2000 such dose values per second. The recommended and most convenient method to measure the dose profile is to use the update mode called Timed. This mode makes it possible to measure exactly the length of time you like. You simply check on the CT-system how the scan will take and then use a margin in your choice of Measuring time.

To be able to collect the dose at the different positions, thereby creating the dose profile, the probe must be moved through the CT. This is achieved by placing it free in air or in a phantom and then using the couch movement to scan the probe. In short, do a helical (spiral) scan. Therefore it is not possible to use axial scans for measuring CTDI with the CT Dose Profiler probe and Ocean Next, since then the dose profile is not measured. When the table is not moving, the CT Dose Profiler acts as an ordinary dose detector and simply gives the point dose reading at that position. You can, of course, make many axial scans in small steps with the detector and plot a dose profile, but that takes a lot of time. With a helical scan you will receive the dose profile in a few seconds. It has been proven that the dose profile can be measured with helical scans as long as corrections are made for the pitch (see reference 10).

5.1 Specifications

Supported meters:	Barracuda with EMM-1Ch, EMM-2Ch, EMM-Bias, EMM-BiasB and EMM-BiasW (with Ocean) Piranha with external input (with Ocean Next)
Typical cal. factor:	0.28 mGy/nC
Material:	Al and PMMA
Connector:	Triaxial LEMO
Length (Detector + extension):	165 mm + 45 mm
Diameter:	12.5 mm
Sensor width:	250 um
Max sensitivity variation:	Less than ±5 %
Weight (Probe + extension):	40 g + 10 g

5.2 Energy correction

When using the Piranha with Ocean Next and the CT Dose Profiler probe in the radiographic range, all dose and rate values measured are automatically compensated for the energy dependence of the sensor.

The kV range is 55-150 kV and the total filtration ranges from 1 to 55 mm Al for measurements free-in-air and from 3 to 22 mm Al for measurements in head and body CT phantoms. The reference point for all correction factors is at 120 kV with 2.5 mm Al filtration free-in-air (calibration R3 (RQR)).

Energy correction factors free-in-air (beam quality RQR)

Al (mm)	1	2	2,5	3	5	7	10	13	15	19	22	25	29	34	38	44	55
55 kV	1,30	1,15	1,07	1,02	0,91	0,86	0,82	0,81	0,79	0,77	0,77	0,78	0,78	0,77			
60 kV	1,25	1,11	1,04	0,99	0,89	0,85	0,82	0,81	0,80	0,79	0,79	0,79	0,79	0,79	0,79	0,80	0,82
70 kV	1,18	1,06	1,00	0,96	0,88	0,85	0,84	0,83	0,83	0,83	0,84	0,84	0,84	0,85	0,86	0,87	0,89
80 kV	1,13	1,03	0,98	0,95	0,88	0,87	0,87	0,87	0,87	0,88	0,90	0,91	0,91	0,93	0,94	0,96	0,98
90 kV	1,11	1,02	0,97	0,95	0,90	0,89	0,90	0,91	0,92	0,93	0,96	0,97	0,98	1,01	1,03	1,05	1,09
100 kV	1,09	1,01	0,98	0,95	0,92	0,92	0,94	0,96	0,97	0,99	1,02	1,04	1,05	1,09	1,11	1,14	1,21
110 kV	1,07	1,01	0,99	0,96	0,94	0,95	0,97	1,00	1,02	1,05	1,08	1,10	1,12	1,17	1,19	1,24	1,33
120 kV	1,05	1,02	1,00	0,98	0,96	0,98	1,01	1,04	1,06	1,10	1,14	1,17	1,19	1,24	1,27	1,33	1,45
130 kV	1,04	1,02	1,01	0,99	0,99	1,01	1,05	1,09	1,11	1,15	1,20	1,23	1,26	1,31	1,35	1,43	1,56
140 kV	1,04	1,03	1,02	1,00	1,01	1,04	1,09	1,13	1,16	1,21	1,26	1,30	1,33	1,39	1,45	1,52	1,67
150 kV	1,07	1,04	1,02	1,01	1,04	1,07	1,14	1,19	1,21	1,27	1,33	1,38	1,42	1,47	1,56	1,62	1,76

Energy correction factors for Head Phantom (beam quality RQR)

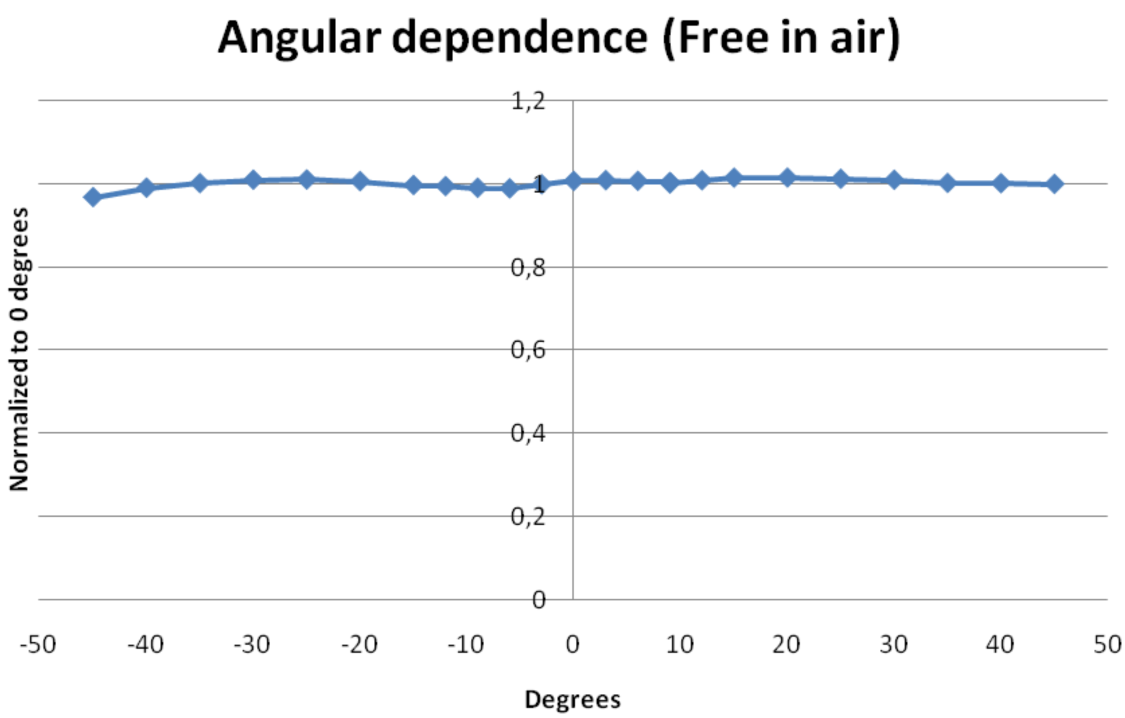
Al (mm)	3	5	7	10	13	19	22	26
55 kV	0,86	0,88	0,88	0,89	0,91	0,92	0,94	
60 kV	0,87	0,88	0,89	0,90	0,92	0,93	0,95	
70 kV	0,88	0,89	0,90	0,91	0,93	0,95	0,97	
80 kV	0,90	0,91	0,92	0,93	0,95	0,98	1,00	
90 kV	0,91	0,93	0,94	0,95	0,97	1,01	1,03	1,07
100 kV	0,93	0,94	0,96	0,97	1,00	1,04	1,06	1,11
110 kV	0,95	0,97	0,98	1,00	1,03	1,07	1,10	1,16
120 kV	0,97	0,99	1,00	1,03	1,06	1,11	1,13	1,20
130 kV	1,00	1,01	1,03	1,06	1,09	1,15	1,17	1,25
140 kV	1,02	1,04	1,06	1,09	1,12	1,19	1,22	
150 kV	1,05	1,07	1,08	1,13	1,16	1,24	1,26	

Energy correction factors for Body Phantom (beam quality RQR)

Al (mm)	3	5	7	10	13	19	22	26
55 kV	0,83	0,84	0,85	0,86	0,88	0,89	0,90	
60 kV	0,84	0,85	0,86	0,87	0,89	0,90	0,91	
70 kV	0,85	0,86	0,87	0,88	0,90	0,92	0,94	
80 kV	0,87	0,88	0,89	0,90	0,92	0,95	0,96	
90 kV	0,88	0,89	0,91	0,92	0,94	0,97	0,99	1,04
100 kV	0,90	0,91	0,93	0,94	0,96	1,00	1,02	1,08
110 kV	0,92	0,93	0,95	0,96	0,99	1,04	1,06	1,12
120 kV	0,94	0,95	0,97	0,99	1,02	1,07	1,09	1,16
130 kV	0,96	0,98	0,99	1,02	1,05	1,11	1,13	1,20
140 kV	0,98	1,01	1,02	1,05	1,08	1,15	1,17	
150 kV	1,01	1,03	1,05	1,09	1,12	1,20	1,22	

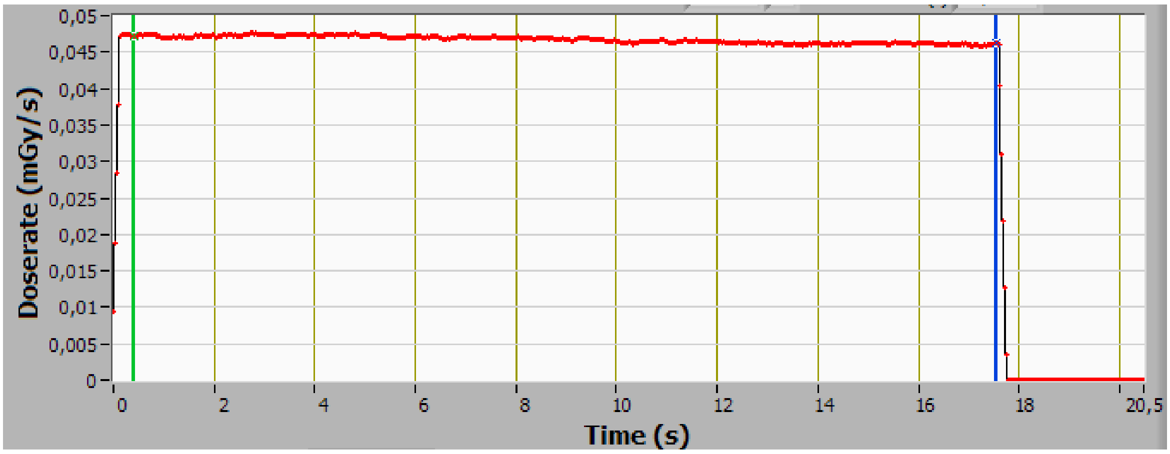
5.3 Angular dependence

This is a graph of the typical angular dependence of the CT Dose Profiler probe measured at 120 kV.



5.4 Rotation symmetry

The rotation symmetry can be measured by rotating the CT Dose Profiler along its longest axis under an irradiating x-ray tube. A typical rotation symmetry for one whole rotation is shown in picture below.

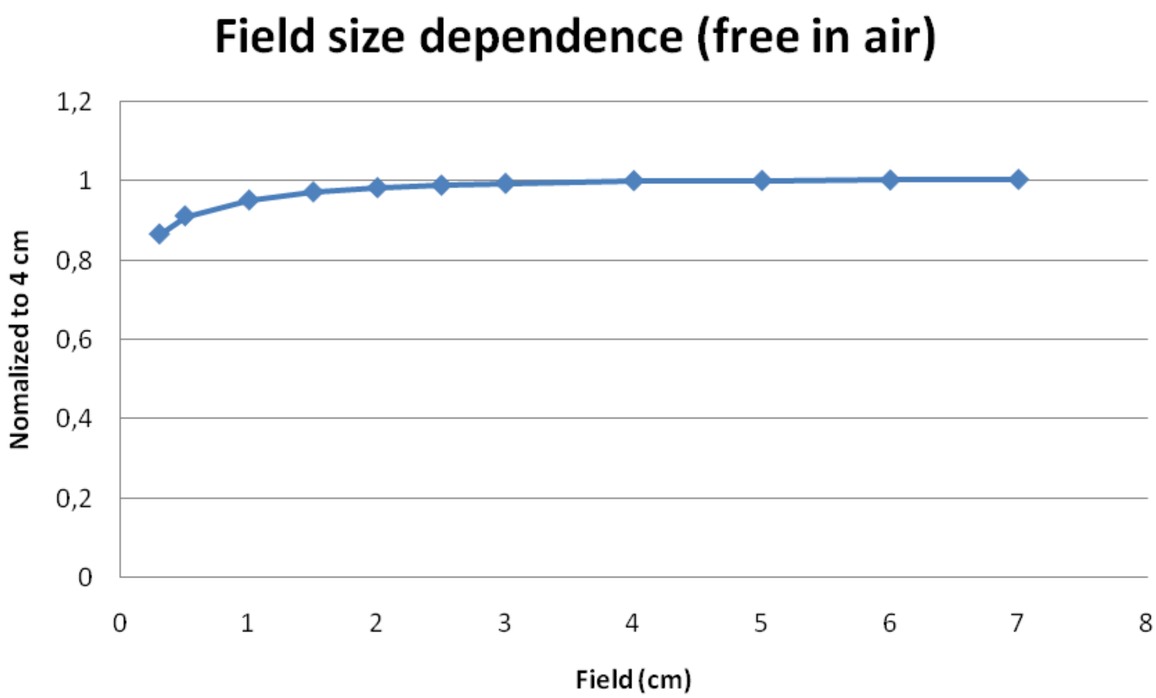


(the output from the tube was going down slightly during the long exposure)

Typical deviation for the CT Dose Profiler probe is about ± 1 %.

5.5 Field size dependence

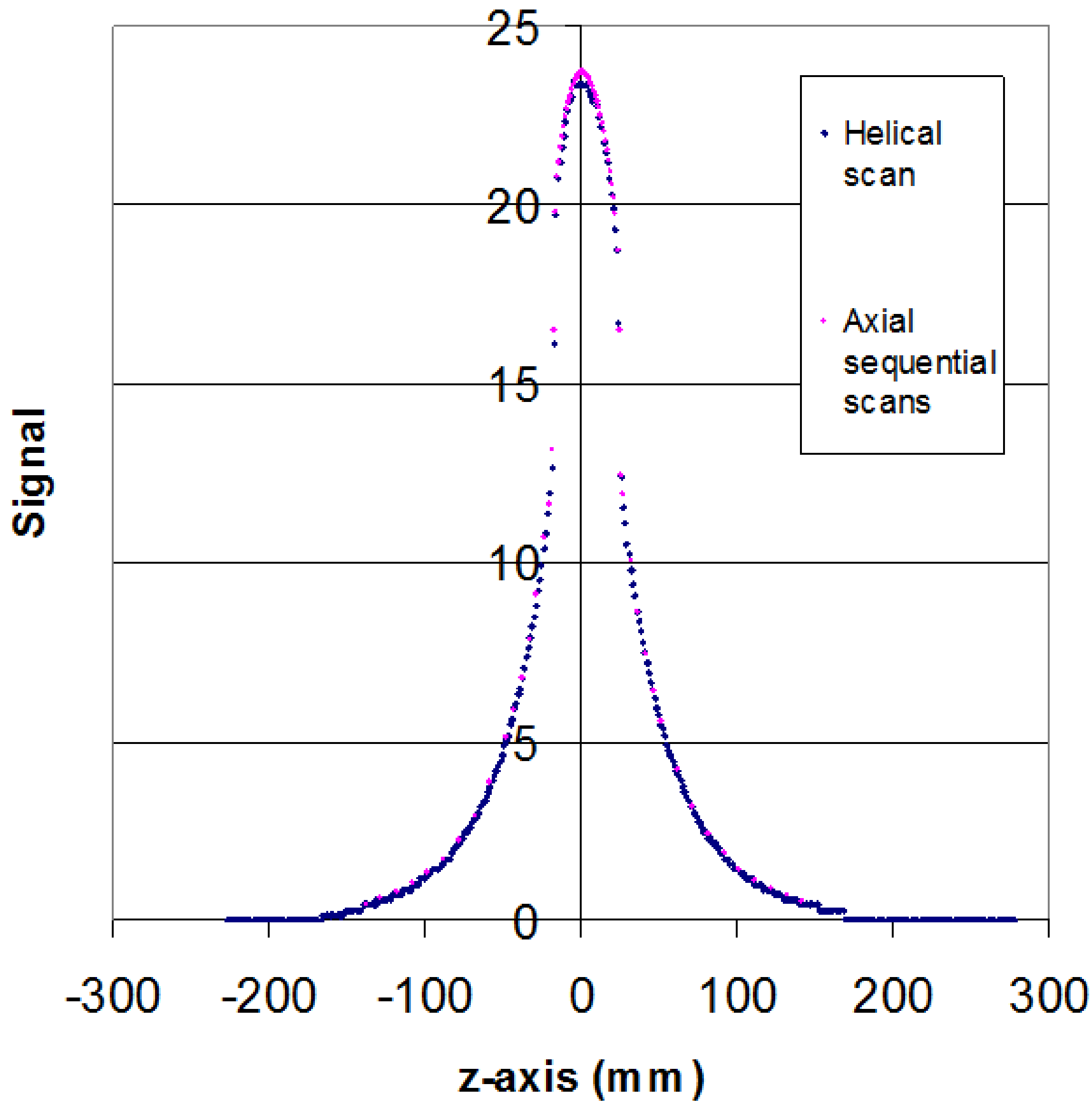
The CT Dose Profiler probe is calibrated with a 5 cm wide field. When measurements are performed free in air with small fields (< 4 cm and down to 3 mm) the calibration factor is no longer accurate and must be corrected, see picture below. This is automatically done in Ocean Next when you measure free-in-air and the FWHM lower then 4 cm.



No correction is needed in a phantom due to the large amount of scattering material.

5.6 Axial sequential scans vs. helical scans

The two methods to receive a dose profile, axial sequential scans and helical scans, have been compared and two dose profiles from the two methods are shown in the picture below. The measurement with the axial sequential scans took a long time to perform and the helical scan took a couple of seconds. The measurements were made in a phantom (without the couch in the beam).



Chapter 6

Appendix

6 Appendix

6.1 k-factors

The table below shows the k-factors Ocean Next uses. There is one factor for head and body, respectively. The k-factors are based on data from impactctscan.org and from measurements.

Manufacturer	Name	kVp	Head	Body	Filtration
Canon	Aquilion One / Genesis Edition	80	1,070	1,640	7
Canon	Aquilion One / Genesis Edition	100	1,050	1,520	7
Canon	Aquilion One / Genesis Edition	120	1,040	1,480	7
Canon	Aquilion One / Genesis Edition	135	1,040	1,460	7
Canon	Aquilion Silver (Ag) filtration	120	1,020	1,448	26
Canon	Aquilion Lightning (SP)	80	1,090	1,820	7
Canon	Aquilion Lightning (SP)	100	1,070	1,720	7
Canon	Aquilion Lightning (SP)	120	1,067	1,620	7
Canon	Aquilion Lightning (SP)	135	1,073	1,570	7
Canon	Aquilion Multi/4	80	1,117	2,072	7
Canon	Aquilion Multi/4	100	1,079	1,846	7
Canon	Aquilion Multi/4	120	1,057	1,728	7
Canon	Aquilion Multi/4	135	1,034	1,672	7
Canon	Aquilion 16	80	1,147	2,206	7
Canon	Aquilion 16	100	1,070	1,959	7
Canon	Aquilion 16	120	1,056	1,779	7
Canon	Aquilion 16	135	1,051	1,728	7
Canon	Generic scanner	80	1,140	2,140	7
Canon	Generic scanner	100	1,090	1,970	7
Canon	Generic scanner	120	1,030	1,580	7
Canon	Generic scanner	130	1,020	1,470	7
Canon	Generic scanner	135	1,020	1,450	7
Elscint	Exel 2400 Elect	120	1,069	1,527	7
Elscint	Exel 2400 Elect	140		1,430	7
Elscint	CT Twin	120	1,047	1,466	7
Elscint	Helicat	120	1,047	1,466	7
Elscint	Generic scanner	120	1,050	1,490	7
Elscint	Generic scanner	140	1,030	1,430	7
FujiFilm	Scenaria View (Normal Bow-tie)	80	1,103	1,948	7
FujiFilm	Scenaria View (Normal Bow-tie)	100	1,072	1,792	7
FujiFilm	Scenaria View (Normal Bow-tie)	120	1,058	1,718	7
FujiFilm	Scenaria View (Normal Bow-tie)	140	1,050	1,671	7
FujiFilm	Scenaria View (Small Bow-tie)	80	1,038	1,676	7
FujiFilm	Scenaria View (Small Bow-tie)	100	1,020	1,560	7
FujiFilm	Scenaria View (Small Bow-tie)	120	1,012	1,494	7
FujiFilm	Scenaria View (Small Bow-tie)	140	1,009	1,471	7
GE	8800/9000 Series	120	0,962	1,680	7
GE	9800 Series	120	1,038	1,585	7
GE	9800 Series	140	1,020	1,503	7
GE	CT Max	120	0,961	1,505	7
GE	Discovery 670 (SPECT-CT)	80	1,065	1,985	7
GE	Discovery 670 (SPECT-CT)	100	1,035	1,765	7
GE	Discovery 670 (SPECT-CT)	120	1,015	1,660	7
GE	Discovery 670 (SPECT-CT)	140	1,005	1,595	7

GE	Discovery 690 (PET-CT)	80	1,000	1,930	7
GE	Discovery 690 (PET-CT)	100	1,090	1,700	7
GE	Discovery 690 (PET-CT)	120	1,070	1,590	7
GE	Discovery 690 (PET-CT)	140	1,050	1,530	7
GE	Discovery CT750	80	0,965	2,100	7
GE	Discovery CT750	100	1,111	1,850	7
GE	Discovery CT750	120	1,090	1,730	7
GE	Discovery CT750	140	1,084	1,670	7
GE	Discovery CT750 (small, bd)	120		1,560	7
GE	FX/i	80	1,145	2,213	7
GE	FX/i	120	1,058	1,692	7
GE	FX/i	140	1,037	1,605	7
GE	HiLight	80	1,047	1,600	7
GE	HiLight	100	1,008	1,636	7
GE	HiLight	120	1,030	1,605	7
GE	HiLight	140	1,015	1,571	7
GE	HiSpeed CT/i no SmartBeam	80	1,047	1,600	7
GE	HiSpeed CT/i no SmartBeam	100	1,008	1,636	7
GE	HiSpeed CT/i no SmartBeam	120	1,030	1,605	7
GE	HiSpeed CT/i no SmartBeam	140	1,015	1,571	7
GE	HiSpeed CT/i with SmartBeam	80	1,047	2,093	7
GE	HiSpeed CT/i with SmartBeam	100	1,008	1,827	7
GE	HiSpeed CT/i with SmartBeam	120	1,030	1,607	7
GE	HiSpeed CT/i with SmartBeam	140	1,015	1,568	7
GE	HiSpeed NX/i	80	1,027	1,810	7
GE	HiSpeed NX/i	120	0,993	1,500	7
GE	HiSpeed NX/i	140	0,968	1,480	7
GE	HiSpeed ZX/i	80	1,027	1,810	7
GE	HiSpeed ZX/i	120	0,993	1,500	7
GE	HiSpeed ZX/i	140	0,968	1,480	7
GE	LightSpeed	80	1,032	1,927	7
GE	LightSpeed	100	0,999	1,730	7
GE	LightSpeed	120	0,987	1,633	7
GE	LightSpeed	140	0,977	1,570	7
GE	LightSpeed 16;Optima 520; Revolution GSI	80	1,046	1,819	7
GE	LightSpeed 16;Optima 520; Revolution GSI	100	1,010	1,627	7
GE	LightSpeed 16;Optima 520; Revolution GSI	120	0,993	1,611	7
GE	LightSpeed 16;Optima 520; Revolution GSI	140	0,984	1,483	7
GE	LightSpeed Plus	80	1,032	1,927	7
GE	LightSpeed Plus	100	0,999	1,730	7
GE	LightSpeed Plus	120	0,987	1,633	7
GE	LightSpeed Plus	140	0,977	1,570	7
GE	LightSpeed Pro 16;Optima 540	80	1,057	1,996	7
GE	LightSpeed Pro 16;Optima 540	100	1,013	1,771	7
GE	LightSpeed Pro 16;Optima 540	120	0,994	1,652	7
GE	LightSpeed Pro 16;Optima 540	140	0,983	1,577	7
GE	LightSpeed RT;Optima 580	80	1,093	2,140	7
GE	LightSpeed RT;Optima 580	100	1,052	1,897	7
GE	LightSpeed RT;Optima 580	120	1,028	1,770	7
GE	LightSpeed RT;Optima 580	140	1,015	1,694	7
GE	LightSpeed Ultra	80	1,042	2,009	7

GE	LightSpeed Ultra	100	1,009	1,787	7
GE	LightSpeed Ultra	120	0,994	1,656	7
GE	LightSpeed Ultra	140	0,985	1,614	7
GE	LightSpeed VCT	80	1,136	2,046	7
GE	LightSpeed VCT	100	1,088	1,778	7
GE	LightSpeed VCT	120	1,066	1,648	7
GE	LightSpeed VCT	140	1,048	1,566	7
GE	LightSpeed VCT (small hd, large bd)	80	1,061	2,041	7
GE	LightSpeed VCT (small hd, large bd)	100	1,022	1,802	7
GE	LightSpeed VCT (small hd, large bd)	120	1,004	1,684	7
GE	LightSpeed VCT (small hd, large bd)	140	0,993	1,614	7
GE	LX/i	80	1,145	2,213	7
GE	LX/i	120	1,058	1,692	7
GE	LX/i	140	1,037	1,605	7
GE	Optima 660;Revolution EVO;Revolution Apex;Revolution Ascend	80	1,037	1,958	7
GE	Optima 660;Revolution EVO;Revolution Apex;Revolution Ascend	100	1,006	1,764	7
GE	Optima 660;Revolution EVO;Revolution Apex;Revolution Ascend	120	0,996	1,643	7
GE	Optima 660;Revolution EVO;Revolution Apex;Revolution Ascend	140	0,996	1,580	7
GE	Pace	80	1,162	2,164	7
GE	Pace	120	1,053	1,734	7
GE	Pace	135	1,041	1,627	7
GE	Pace	140	1,061	1,636	7
GE	Prospeed	120	1,052	1,713	7
GE	Prospeed	140	1,040	1,610	7
GE	QX/i	80	1,032	1,927	7
GE	QX/i	100	0,999	1,730	7
GE	QX/i	120	0,987	1,633	7
GE	QX/i	140	0,977	1,570	7
GE	Revolution	80	1,110		7
GE	Revolution	100	1,100	1,760	7
GE	Revolution	120	1,080	1,690	7
GE	Revolution	140	1,061	1,630	7
GE	Sytec	80	1,162	2,164	7
GE	Sytec	120	1,053	1,734	7
GE	Sytec	135	1,041	1,627	7
GE	Sytec	140	1,061	1,636	7
GE	Generic scanner	80	1,070	1,980	7
GE	Generic scanner	100	1,030	1,800	7
GE	Generic scanner	120	1,020	1,750	7
GE	Generic scanner	135	1,010	1,630	7
GE	Generic scanner	140	1,010	1,580	7
Hitachi	Generic scanner	80	1,010	2,018	7
Hitachi	Generic scanner	90	1,095	1,885	7
Hitachi	Generic scanner	100	1,066	1,888	7
Hitachi	Generic scanner	120	1,049	1,771	7

Hitachi	Generic scanner	130	1,045	1,763	7
Hitachi	Generic scanner	140	1,033	1,638	7
Philips	Philips 310 (GE2, no Cu)	120	1,089		7
Philips	Philips 350 (GE2, no Cu)	120	1,089		7
Philips	Philips 310 (GE2, w. Cu)	120	1,025		7
Philips	Philips 350 (GE2, w. Cu)	120	1,025		7
Philips	Philips 310 (GE3, no Cu)	120		1,956	7
Philips	Philips 350 (GE3, no Cu)	120		1,956	7
Philips	Philips 310 (GE3, w. Cu)	120			7
Philips	Philips 350 (GE3, w. Cu)	120			7
Philips	Philips AV	80	1,120	2,034	7
Philips	Philips AV	100	1,061	1,795	7
Philips	Philips AV	120	1,061	1,718	7
Philips	Philips AV	130	1,066	1,739	7
Philips	Philips AV	140	1,048	1,666	7
Philips	Philips LX	80	1,120	2,034	7
Philips	Philips LX	100	1,061	1,795	7
Philips	Philips LX	120	1,061	1,718	7
Philips	Philips LX	130	1,066	1,739	7
Philips	Philips LX	140	1,048	1,666	7
Philips	Philips SR7000	80	1,120	2,034	7
Philips	Philips SR7000	100	1,061	1,795	7
Philips	Philips SR7000	120	1,061	1,718	7
Philips	Philips SR7000	130	1,066	1,739	7
Philips	Philips SR7000	140	1,048	1,666	7
Philips	Philips CX	120	1,059	1,572	7
Philips	Philips CX/S	120	1,059	1,572	7
Philips	Philips SR4000	120	1,053	1,724	7
Philips	Philips SR 5000	120	1,065	1,768	7
Philips	Philips SR 5000	130	1,052	1,886	7
Philips	Philips M/EG	120	1,199	2,640	7
Philips	Philips M/EG	130	1,196	2,631	7
Philips	Philips TX	100			7
Philips	Philips TX	120	1,038		7
Philips	Philips TX	130			7
Philips	Philips CT Secura	120	1,060	1,688	7
Philips	Philips CT Secura	140	1,052	1,638	7
Philips	Philips Mx8000	90	1,096	1,888	7
Philips	Philips Mx8000	120	1,061	1,683	7
Philips	Philips Mx8000	140		1,653	7
Philips	Philips AcQSim	120	1,130	2,057	7
Philips	Philips AcQSim	130	1,114	1,983	7
Philips	Mx8000 IDT/Brilliance 16 (& Power)	90	1,072	1,765	7
Philips	Mx8000 IDT/Brilliance 16 (& Power)	120	1,059	1,623	7
Philips	Mx8000 IDT/Brilliance 16 (& Power)	140	1,062	1,554	7
Philips	Aura	120	1,114	1,667	7
Philips	Big Bore	90	1,113	1,996	7
Philips	Big Bore	120	1,083	1,778	7
Philips	Big Bore	140	1,063	1,718	7
Philips	Brilliance 16	90	1,080	1,785	7
Philips	Brilliance 16	120	1,060	1,625	7

Philips	Brilliance 16	140	1,050	1,560	7
Philips	Brilliance 64	80	1,100	1,897	7
Philips	Brilliance 64	100	1,060	1,750	7
Philips	Brilliance 64	120	1,058	1,690	7
Philips	Brilliance 64	140	1,050	1,570	7
Philips	Brilliance iCT	80	1,105	1,865	7
Philips	Brilliance iCT	100	1,100	1,740	7
Philips	Brilliance iCT	120	1,085	1,625	7
Philips	Brilliance iCT	140	1,060	1,585	7
Philips	Ingenuity	80	1,095	1,875	7
Philips	Ingenuity	100	1,070	1,720	7
Philips	Ingenuity	120	1,055	1,630	7
Philips	Ingenuity	140	1,050	1,565	7
Philips	Iqon	80	1,160	2,115	7
Philips	Iqon	100	1,120	1,865	7
Philips	Iqon	120	1,095	1,760	7
Philips	Iqon	140	1,085	1,745	7
Philips	Generic scanner	80	1,120	2,030	7
Philips	Generic scanner	90	1,090	1,880	7
Philips	Generic scanner	100	1,070	1,800	7
Philips	Generic scanner	120	1,070	1,800	7
Philips	Generic scanner	130	1,060	1,750	7
Philips	Generic scanner	140	1,050	1,650	7
Picker	Picker 1200SX	80		3,008	7
Picker	Picker 1200SX	120	0,950	2,087	7
Picker	Picker 1200SX	130	1,018	2,053	7
Picker	Picker 1200SX	140	0,895	1,938	7
Picker	Picker PQ Series	120	0,966	1,960	7
Picker	Picker PQ Series	130	0,950	2,053	7
Picker	Picker PQ Series	140	0,950	1,937	7
Picker	Picker UltraZ	80	1,076	3,328	7
Picker	Picker UltraZ	100	1,047	2,185	7
Picker	Picker UltraZ	120	0,977	1,955	7
Picker	Picker UltraZ	130	0,965	1,926	7
Picker	Picker UltraZ	140	0,960	1,868	7
Picker	Generic scanner	80	1,080	2,500	7
Picker	Generic scanner	100	1,050	2,190	7
Picker	Generic scanner	120	0,960	2,000	7
Picker	Generic scanner	130	0,950	2,010	7
Picker	Generic scanner	140	0,940	1,910	7
Philips	Philips/Marconi Mx8000	90	1,096	1,888	7
Marconi	Marconi Mx8000	90	1,096	1,888	7
Marconi	Marconi Mx8000	120	1,061	1,683	7
Marconi	Marconi Mx8000	140		1,653	7
Marconi	Marconi AcQSim	120	1,130	2,057	7
Marconi	Marconi AcQSim	130	1,114	1,983	7
Marconi	Generic scanner	90	1,100	1,890	7
Marconi	Generic scanner	120	1,100	1,870	7
Marconi	Generic scanner	130	1,110	1,700	7
Marconi	Generic scanner	140	1,100	1,650	7
Shimadzu	Shimadzu SCT	80	1,134	2,470	7
Shimadzu	Shimadzu SCT	120	1,079	1,992	7
Shimadzu	Shimadzu SCT	130	1,070	1,984	7

Shimadzu	Generic scanner	80	1,130	2,470	7
Shimadzu	Generic scanner	120	1,080	1,990	7
Shimadzu	Generic scanner	130	1,070	1,980	7
Siemens	Naeotom Alpha	70	1,050	1,840	7
Siemens	Naeotom Alpha	80	1,020	1.69	7
Siemens	Naeotom Alpha	90	1,010	1,590	7
Siemens	Naeotom Alpha	100	1,010	1,580	7
Siemens	Naeotom Alpha	110	1,010	1,530	7
Siemens	Naeotom Alpha	120	1,000	1,550	7
Siemens	Naeotom Alpha	130	1,000	1,500	7
Siemens	Naeotom Alpha	140	1,010	1,500	7
Siemens	Siemens CR	125	1,121	2,164	7
Siemens	Siemens CR512	125	1,121	2,164	7
Siemens	Siemens DR1/2/3	125	1,117	2,190	7
Siemens	Siemens DRG	125			7
Siemens	Siemens DRG1	125			7
Siemens	Siemens DRH	125	1,121	2,164	7
Siemens	SOMATOM 2	125	1,117	2,190	7
Siemens	SOMATOM Access	80	1,201	2,135	7
Siemens	SOMATOM Access	120	1,124	1,750	7
Siemens	SOMATOM Access	140	1,107	1,696	7
Siemens	SOMATOM AR.SP	110	1,076	1,817	7
Siemens	SOMATOM AR.SP	130	1,067	1,736	7
Siemens	SOMATOM AR/HP	130	1,036	1,565	7
Siemens	SOMATOM AR-C	110	1,076	1,817	7
Siemens	SOMATOM AR-C	130	1,067	1,736	7
Siemens	SOMATOM AR-T	110	1,076	1,817	7
Siemens	SOMATOM AR-T	130	1,067	1,736	7
Siemens	SOMATOM Balance	110	1,085	1,806	7
Siemens	SOMATOM Balance	130	1,074	1,729	7
Siemens	SOMATOM Definition AS plus	70	1,086	1,790	7
Siemens	SOMATOM Definition AS plus	80	1,067	1,670	7
Siemens	SOMATOM Definition AS plus	100	1,040	1,560	7
Siemens	SOMATOM Definition AS plus	120	1,035	1,520	7
Siemens	SOMATOM Definition AS plus	140	1,030	1,470	7
Siemens	SOMATOM Definition AS;Biograph	80	1,054	1,851	7
Siemens	SOMATOM Definition AS;Biograph	100	1,036	1,680	7
Siemens	SOMATOM Definition AS;Biograph	120	1,031	1,587	7
Siemens	SOMATOM Definition AS;Biograph	140	1,027	1,525	7
Siemens	SOMATOM Definition Flash	70	1,132	1,934	7
Siemens	SOMATOM Definition Flash	80	1,103	1,801	7
Siemens	SOMATOM Definition Flash	100	1,064	1,632	7
Siemens	SOMATOM Definition Flash	120	1,052	1,573	7
Siemens	SOMATOM Definition Flash	125	0,815	1,625	7
Siemens	SOMATOM Definition Flash	130	0,543	1,612	7
Siemens	SOMATOM Definition Flash	133	0,380	1,603	7
Siemens	SOMATOM Definition Flash	137	0,163	1,593	7
Siemens	SOMATOM Definition Flash	140	1,045	1,521	7
Siemens	SOMATOM Drive;SOMATOM Force	70	1,050	1,840	7
Siemens	SOMATOM Drive;SOMATOM Force	80	1,020	1.69	7

Siemens	SOMATOM Drive;SOMATOM Force	90	1,010	1,590	7
Siemens	SOMATOM Drive;SOMATOM Force	100	1,010	1,580	7
Siemens	SOMATOM Drive;SOMATOM Force	110	1,010	1,530	7
Siemens	SOMATOM Drive;SOMATOM Force	120	1,000	1,550	7
Siemens	SOMATOM Drive;SOMATOM Force	130	1,000	1,500	7
Siemens	SOMATOM Drive;SOMATOM Force	140	1,010	1,500	7
Siemens	SOMATOM DXP	120	1,102	1,789	7
Siemens	SOMATOM DXP	137	1,068	1,749	7
Siemens	SOMATOM Emotion	110	1,085	1,806	7
Siemens	SOMATOM Emotion	130	1,074	1,729	7
Siemens	SOMATOM Emotion 6	80	0,821	1,751	7
Siemens	SOMATOM Emotion 6	110	0,854	1,584	7
Siemens	SOMATOM Emotion 6	130	1,024	1,526	7
Siemens	SOMATOM Emotion Duo	80	1,108	1,951	7
Siemens	SOMATOM Emotion Duo	110	1,055	1,666	7
Siemens	SOMATOM Emotion Duo	130	1,039	1,606	7
Siemens	SOMATOM Go All	70	1,070	1,930	7
Siemens	SOMATOM Go All	80	1,050	1,760	7
Siemens	SOMATOM Go All	100	1,030	1,640	7
Siemens	SOMATOM Go All	110	1,020	1,610	7
Siemens	SOMATOM Go All	120	1,020	1,580	7
Siemens	SOMATOM Go All	130	1,020	1,570	7
Siemens	SOMATOM Go All	140	1,010	1,550	7
Siemens	SOMATOM Hi Q	133	1,079	2,027	7
Siemens	SOMATOM Perspective	80	1,060	1,840	7
Siemens	SOMATOM Perspective	110	1,040	1,640	7
Siemens	SOMATOM Perspective	130	1,020	1,550	7
Siemens	SOMATOM Plus	120	1,102	1,789	7
Siemens	SOMATOM Plus	137	1,068	1,749	7
Siemens	SOMATOM Plus 4 Series	80	1,100	2,047	7
Siemens	SOMATOM Plus 4 Series	120	1,075	1,782	7
Siemens	SOMATOM Plus 4 Series	140	1,062	1,738	7
Siemens	SOMATOM Plus-S	120	1,102	1,789	7
Siemens	SOMATOM Plus-S	137	1,068	1,749	7
Siemens	SOMATOM Sensation 10	80	1,155	1,893	7
Siemens	SOMATOM Sensation 10	100	1,111	1,743	7
Siemens	SOMATOM Sensation 10	120	1,086	1,639	7
Siemens	SOMATOM Sensation 10	140		1,584	7
Siemens	SOMATOM Sensation 16	80	1,142	1,893	7
Siemens	SOMATOM Sensation 16	100	1,103	1,743	7
Siemens	SOMATOM Sensation 16	120	1,079	1,639	7
Siemens	SOMATOM Sensation 16	140		1,584	7
Siemens	SOMATOM Sensation 16 Straton	80	1,258	1,893	7
Siemens	SOMATOM Sensation 16 Straton	100	1,209	1,663	7
Siemens	SOMATOM Sensation 16 Straton	120	1,088	1,629	7
Siemens	SOMATOM Sensation 16 Straton	140		1,571	7
Siemens	SOMATOM Sensation 4	80	1,156	1,939	7
Siemens	SOMATOM Sensation 4	120	1,086	1,656	7
Siemens	SOMATOM Sensation 4	140		1,602	7
Siemens	SOMATOM Sensation 64	80	1,042	1,684	7

Siemens	SOMATOM Sensation 64	100	1,027	1,581	7
Siemens	SOMATOM Sensation 64	120	1,022	1,532	7
Siemens	SOMATOM Sensation 64	140		1,538	7
Siemens	SOMATOM Sensation Open	80	1,071	1,812	7
Siemens	SOMATOM Sensation Open	100	1,046	1,674	7
Siemens	SOMATOM Sensation Open	120	1,037	1,601	7
Siemens	SOMATOM Sensation Open	140		1,558	7
Siemens	SOMATOM Volume Zoom	80	1,201	2,135	7
Siemens	SOMATOM Volume Zoom	120	1,124	1,750	7
Siemens	SOMATOM Volume Zoom	140	1,107	1,696	7
Siemens	Symbia Intevo 16	80	1,050	1,810	7
Siemens	Symbia Intevo 16	110	1,010	1,620	7
Siemens	Symbia Intevo 16	130	1.02	1,550	7
Siemens	Symbia T2	80	1,090	1,830	7
Siemens	Symbia T2	110	1,050	1,630	7
Siemens	Symbia T2	130	1,040	1,530	7
Siemens	Symbia T6	80	1,050	1,830	7
Siemens	Symbia T6	110	1,040	1,580	7
Siemens	Symbia T6	130	1,020	1,560	7
Siemens	Generic scanner	80	1,110	1,920	7
Siemens	Generic scanner	100	1,090	1,680	7
Siemens	Generic scanner	120	1,080	1,690	7
Siemens	Generic scanner	125	1,070	1,680	7
Siemens	Generic scanner	130	1,060	1,670	7
Siemens	Generic scanner	133	1,080	1,650	7
Siemens	Generic scanner	137	1,070	1,650	7
Siemens	Generic scanner	140	1,070	1,610	7
Toshiba	Toshiba TCT 600	120	0,987	1,527	7
Toshiba	Xspeed II	120	0,995	1,598	7
Toshiba	Xpress GX (Pre '98)	120	1,035		7
Toshiba	Xvision/EX	120	0,952	1,354	7
Toshiba	Xpress HS1	120	1,039	1,369	7
Toshiba	Xpress HS	120	1,000	1,359	7
Toshiba	Xpress GX (Post '98), Asteion	120	1,035	1,501	7
Toshiba	Xpress GX (Post '98), Asteion	130	1,017	1,472	7
Toshiba	Asteion	120	1,035	1,501	7
Toshiba	Asteion	130	1,017	1,472	7
Toshiba	Aquilion One / Genesis Edition	80	1,070	1,640	7
Toshiba	Aquilion One / Genesis Edition	100	1,050	1,520	7
Toshiba	Aquilion One / Genesis Edition	120	1,040	1,480	7
Toshiba	Aquilion One / Genesis Edition	135	1,040	1,460	7
Toshiba	Aquilion Lightning (SP)	80	1,090	1,820	7
Toshiba	Aquilion Lightning (SP)	100	1,070	1,720	7
Toshiba	Aquilion Lightning (SP)	120	1,067	1,620	7
Toshiba	Aquilion Lightning (SP)	135	1,073	1,570	7
Toshiba	Aquilion Multi/4	80	1,117	2,072	7
Toshiba	Aquilion Multi/4	100	1,079	1,846	7
Toshiba	Aquilion Multi/4	120	1,057	1,728	7
Toshiba	Aquilion Multi/4	135	1,034	1,672	7
Toshiba	Auklet	120	1,019	1,470	7
Toshiba	Asteion Multi (older tube)	80	1,141	2,131	7
Toshiba	Asteion Multi (older tube)	100	1,099	2,039	7
Toshiba	Asteion Multi (older tube)	120	1,076	1,731	7

Toshiba	Asteion Multi (older tube)	135	1,062	1,841	7
Toshiba	Asteion Multi (CXB-400C tube)	80	1,141	2,131	7
Toshiba	Asteion Multi (CXB-400C tube)	100	1,099	2,039	7
Toshiba	Asteion Multi (CXB-400C tube)	120	1,076	1,731	7
Toshiba	Asteion Multi (CXB-400C tube)	135	1,062	1,841	7
Toshiba	Asteion Dual	120	1,117	1,857	7
Toshiba	Asteion Dual	135	1,070	1,685	7
Toshiba	Aquilion 16	80	1,147	2,206	7
Toshiba	Aquilion 16	100	1,070	1,959	7
Toshiba	Aquilion 16	120	1,056	1,779	7
Toshiba	Aquilion 16	135	1,051	1,728	7
Toshiba	Generic scanner	80	1,140	2,140	7
Toshiba	Generic scanner	100	1,090	1,970	7
Toshiba	Generic scanner	120	1,030	1,580	7
Toshiba	Generic scanner	130	1,020	1,470	7
Toshiba	Generic scanner	135	1,020	1,450	7
Generic Manufacturer	Generic scanner	80	1,010	2,018	7
Generic Manufacturer	Generic scanner	90	1,095	1,885	7
Generic Manufacturer	Generic scanner	100	1,066	1,888	7
Generic Manufacturer	Generic scanner	120	1,049	1,771	7
Generic Manufacturer	Generic scanner	130	1,045	1,763	7
Generic Manufacturer	Generic scanner	140	1,033	1,638	7
United Imaging	uCT 760 & 780 (SFOV 300)	70	1,082	2,021	7
United Imaging	uCT 760 & 780 (SFOV 300)	80	1,081	1,695	7
United Imaging	uCT 760 & 780 (SFOV 300)	100	1,047	1,595	7
United Imaging	uCT 760 & 780 (SFOV 300)	120	1,036	1,509	7
United Imaging	uCT 760 & 780 (SFOV 300)	140	1,032	1,482	7
United Imaging	uCT 760 & 780 (SFOV 500)	70	1,178	2,264	7
United Imaging	uCT 760 & 780 (SFOV 500)	80	1,109	2,004	7
United Imaging	uCT 760 & 780 (SFOV 500)	100	1,097	1,828	7
United Imaging	uCT 760 & 780 (SFOV 500)	120	1,085	1,727	7
United Imaging	uCT 760 & 780 (SFOV 500)	140	1,085	1,674	7

Chapter 7

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Please find more information about the basis of the dose profile detector in these thesis works:

”Development and evaluation of a new detector and software for measuring CT dose profile, CTDI and CT tube current variation”

“Evaluation of two thin CT dose profile detectors and a new way to perform QA in a CTDI head phantom”

You can download these papers and other application notes as a PDF file from our website at www.rti.se

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