IrisQA, LLC

# CT AutoQA Lite

V3.1 Operators Manual © 2013 www.irisqa.com

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# Revision History

| Revision | Date | Description | Pages | Approval |
|---|---|---|---|---|
| 1 | February 2009 | Changes for V2.4<br>Export to Excel option | 15,17-18 | Steve Dyer |
| 2 | October 2009 | Update Appendix A<br>DICOMPush Instructions | 20 | Steve Dyer |
| 3 | August 2010 | V3.0 Release  QAReports<br>Manual MTF processing | 16,17 | Steve Dyer |
| 4 | November 2010 | SSP Processing Mode | 17 | Steve Dyer |
| 5 | January 2011 | Installation information update<br>Registration and Sample Image location | 6,10,11,13 | Steve Dyer |
| 6 | January 2013 | Changes to support CTP700 Phantom | | SDyer |

# Table of Contents

# Quick Steps for QALite

**Installation Notes**
- An operator's manual is available on the AutoQA Lite Installation CD or provided with the download link
- The AutoQA Lite installation loads the AutoQA Lite program, and the IrisQA Reports program which includes Microsoft .NET and SQL Server software requisites.
- Software registration is required otherwise the application will operate in demo mode only.  Activation of the software license is required for full operation.
    - o You will be provided with a CD-Key and Serial Number typed on the software CD or via an email a software download link in place of the CD.
    - o Upon QALite startup a Demo screen will display information about the option to run QALite in 'Demo' mode or to activate your license if the activation codes are available.
    - o Click 'Ok' to continue in demo mode or click 'Cancel' to start the registration process. **Select 'QALite' for the product to register in the drop down list.**  See page 9 in the operator's manual for detailed instructions on the registration process
    - o When license registration is successful (message displayed) quit the QALite application and restart (icon on Desktop), for full application operation
- The DICOMPush utility is not installed but is available on the AutoQA Lite Installation CD if needed
- A series of phantom images (ACR, Catphan 500, 600, 700 and GE daily QA) have been loaded into the default folder(XP Documents and Settings\All Users\Application Data\AutoQA\Images or Windows7/8/Vista Program Data\AutoQA\Images)
- During QALite initial startup the user is required to enter a facility name (an entry is required) and selects a phantom model for processing

**Scanning Notes**
- Position phantom – centered in the gantry, level and aligned parallel with the table (check phantom manufacturer's instructions)
- **'Patient Orientation' - head first supine (HFS) is recommended for all phantom and required with the Catphan700**
- Scanning modes – axial or spiral modes and
- **Scan protocol should use a field of view slightly larger than the phantom diameter. This ensures that the table will not be in the image field of view (FOV)**
- **Axial scan protocol should scan the first phantom module with a slightly larger FOV than its diameter.  The other modules can be scanned with smaller FOV's than the phantom, resolution sections (MTF), uniformity, low contrast.**

**Processing Notes**
- Start – **Double Click 'QALite'** program icon on Desktop
- Verify Correct phantom – **Click 'Options' / Click 'Select Phantom Model'**
- **Click 'Analyze'/Click 'Select Phantom Image'**
- **Click drop down menu button** next to 'Images'/ navigate to other folders or drives for site images
- **Click on phantom study** in the left window display
- Preview the images in the list in the right window display to determine the center slice of the first phantom module, typically the slice thickness test as in Catphan models (module CTP 401), ACR and GE phantom.  It is important that the order has the images starting with the slice thickness test module.  If not, **Click the check box for 'Reverse Image Order'** to reorder the phantom images
- To enlarge thumbnail image move cursor over thumbnail and the pop up image includes window level controls.  When set correctly the settings will be applied to all the images in the series
- **Click on the image file listing** to identify this as the center slice
- **Click 'Auto Select' button** to identify the correct slices for processing
- **Click 'Begin Analysis'** to process selected images
- **Click on one of the database storage options**; Trend Report, Service or no database storage
- The processed results are presented in the main window
- **Scroll down** to view all image results
- **Double Click on the data results** on the following tests; CT Linearity, MTF, Noise/Uniformity and Low Contrast, to view the graphic data
- **Click on 'Reporting Functions'** to print, save or retrieve reports

# Overview of AutoQA Lite™

This software has been developed as an extension of the standard AutoQA™ programs initially developed and marketed by The IRIS, Inc. for the analysis of CT phantom images. The methodology and algorithms that are used in this package are essentially identical to those currently being used by various service organizations worldwide, as well as in the production QA programs. It has been modified and customized to various phantom specifications. The process of image selection, format conversion, phantom display, and analysis have all been integrated into a single form. This "lite" version provides a Windows development platform with a simple user interface. It has been designed to handle the DICOM 3.0 CT image format. Images can be selected from different folders on the local drive, folders on shared or network drives and from DICOM archived CD's. **It is important to note that with the current version 3.0 can only support DICOM3.0 images in an uncompressed format.** Refer to Appendix A regarding the transfer and storage of the DICOM images to the PC via an Ethernet TCP/IP connection. This describes the DICOMPush utility provided on the QALite installation Disk.

## Phantom Description

The algorithms used with the AutoQA Lite™ program have been designed around the Catphan series of phantoms. However, the software can be adapted to a variety of phantoms including the Catphan Lite phantom developed for the Toshiba InnerVision® program, Catphan CTP503 (Varian OBI), Catphan CTP 504 (Elekta OBI) the ACR Accreditation Phantom, as well as, vendor specific phantoms (GE, Siemens, and Philips). For example, the Catphan Lite phantom consists of three sections and an integrated table-mounting device. The first section contains sub-modules for testing the field size, CT linearity and contrast scale, and slice thickness. The second module contains a small tungsten bead, which is used for the MTF measurements. The last module is a uniformity section of a water equivalent material and is used for the CT number constancy check, noise, and uniformity measurements.

## Test Descriptions

- **Pixel Size**

The pixel size test uses the four 'calibration pins' (3 air holes and 1 Teflon filled) which are approximately 3.2mm in diameter and separated by 50mm. The centroid of each pin is determined by an edge detection algorithm and computed in units of pixels. Based on the known physical locations of these pins, the pixel dimensions can be calculated for the x and y directions. The expected pixel size is extracted from the image header. Table position is also reported by computing the offset in the phantom center with respect to the center of the image matrix. In addition, a rotation of the phantom is calculated based on a least squares estimate of the pin locations relative to the orthogonal image matrix. These results are valid up to rotations of about +/- 5°. The Catphan 700 does not provided these targets for this test.



Measuring spatial linearity in x and y axes.
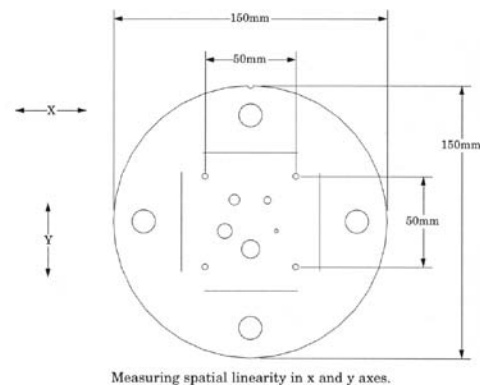
- **Spatial Resolution - Modulation Transfer Function (MTF)**

In this procedure the spatial resolution is measured by calculating the point spread function from the scan of a small tungsten carbide bead (approx. 250 microns in diameter). Line spread functions are determined by integrating the PSF along vertical and horizontal directions. The MTF is calculated from the discrete Fourier Transform of the LSF data after having corrected for the baseline CT value. A cubic roll-off function is also used to force the LSF curve smoothly to the baseline. After calculating the transform, corrections are made for the pixel size and the bead diameter. The 50%, 10%, and 2% MTF values are reported. The 2% parameter is the default value in the phantom description file, and can be adjusted if 2% is not suitable.
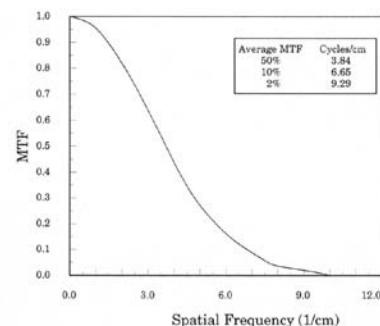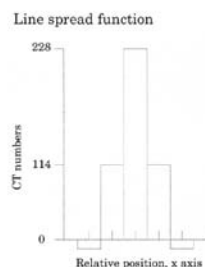
- ### High Contrast Spatial Resolution

This analysis reports the statistics for the high contrast resolution gauges up to the Nyquist cutoff or 11 lp/cm.  This current version supports only the 0 (zero) orientations for the Catphan 700. The reported values are the roi's mean and standard deviation.

- ### Noise

This procedure computes the mean and standard deviation of the CT numbers within several regions of interest over a uniform module.  The number, size, and location of these ROI's are variable, but typically five are defined: one at the phantom center and the other four along the axes at the same radius covering a 15x15 pixel area.  These values are reported along with other relevant header parameters that influence these values.

- ### Slice Width

After locating each wire or ramp, a profile is generated along the orientation of each ramp.  A baseline value is determined and then subtracted from each profile.  The FWHM is then computed for each of the ramps in this test module using linear interpolation.  A trigonometric conversion is then performed based on the known angles of the ramps to yield the slice width in mm.  Since these ramps are always in opposing pairs, a phantom offset can also be calculated.  The expected slice thickness is determined from the image header.  All four wire ramp profiles are reported along with their mean and expected values.  Also based on the opposing ramps a rotation of the phantom about an axis perpendicular to the ramps can also be computed.  Since there are two pairs of ramps oriented along orthogonal directions, then phantom rotations about both the vertical and horizontal axes can be estimated.  The reported values are accurate for rotations up to about +/- 5$^0$ about either axis.

- ### Uniformity

Vertical and horizontal profiles are determined which pass through the center of the uniform module.  A 10 pixel wide area is used and averaged along this width.  The noise value is also determined at the phantom center.  An acceptance range for the vertical and horizontal profile is generated and used to compute fractional uniformity, which is the fraction of points along the profiles, which lie within an acceptable range.  This range is variable and is present in the phantom description file and the default settings are +/- 2$\sigma$ of the mean or 10H whichever is smaller.  Be aware that using "low noise" scans might result in increased values for this parameter due to the integer values for CT numbers.

- ### Coordinate Verification and Slice Alignment

The results from the analysis of the slice width module contain a parameter called the "Table Position Offset".  Verification of the scanner table incrementation accuracy can be checked by incrementing the table by 30mm and then returning the table to the starting position and scanning the module a second time.  The "Table Position Offset" values reported during analysis of these two images should be the same.

- ### Low Contrast Dectectability

This procedure calculates a theoretical Contrast-Detail curve based on the noise value at the center of the low contrast module.  This represents a conservative estimate of the minimum contrast level required so that a cylindrical object of the given diameter should be discernible.  The result screen displays the constant of perceptibility used in the calculation, below the diameter data row; it is listed as "Factor".  Be aware that this constant will influence the predicted low contrast performance with a lower value giving a decreased performance. This factor can be modified by the user to better approximate the calculated CD curve to actual perceived low contrast.  Contact IrisQA for more information. However, particular care needs to be used in interpreting contrast-detail diagrams in which sensitivity, specificity, and the number of target signals may be varying.

- ### Low Contrast – Contrast-Noise-Ratio

This procedure target and background signals from the cylindrical low contrast targets in the CTP515 module. Data is measured from the 3 series of contrast 1.0%, 0.5% and 0.3% .  Not all the targets are measured this number is defined in the configuration file used for the Catphan700 phantom. The report CNR values are calculated using this formula.

$$CNR = \ |(Avg.\,Target - Avg.\,Bkg)|^2 \sqrt{\frac{Target\ StdDev2}{TargetPixels} + \frac{BkgStdDev2}{BkgPixels}}/10$$

- ### CT# Linearity (Sensitometry)

The program computes the average CT value for each reference material contained in the module.  The number, size, description, location, and attenuation coefficients are all specified in the phantom description file.  As shown in the figure above for the first module, there are 4 sample materials present in this phantom.  These include Acrylic, LDPE, TEFLON, and Air to encompass a broad range of CT numbers from approximately -1000H to +1000H.  A linear least squares regression is performed relating CT number and the linear attenuation coefficients as a function of energy.

The energy, which yields the best correlation coefficient, is then used in the final analysis to determine the appropriate linear attenuation coefficients to use. The mean CT numbers for each material and the Contrast Scale are reported in the output. The attenuation coefficients and the electron densities for the materials used in the Catphan phantoms can be found in the operators manuals available at www.phantomlab.com .

## ACR Phantom Processing Features

- **CT Linearity**

Method similar to the method described for the standard processing using 5 materials.

- **Slice thickness**

Measurement is determined from the CT number profile for the pairs of angled series of wires visible in 0.5 mm z-axis increments.

- **Laser Alignment**

Is verified using the central wire in the slice width ramps and determining the location relative to the other wires on a slice less than 2 mm in thickness.

- **Low Contrast**

The contrast is calculated for the for the 25mm target based on the reported mean CT# for the target and the mean CT# for the adjacent background at the same radius, The user also inputs the smallest visible target.

- **Noise/Uniformity**

The mean CT# and standard deviation (SD) is calculated for one central ROI and 4 peripheral ROI's at 3, 6, 9, 12 o'clock locations and displayed as the mean/SD. Uniformity is calculated for each peripheral location based on the difference between the central mean and each peripheral mean values and reported as the 'Diff (HU)'recommendations.

- **Pixel Size**

Is reported as the measured pixel size based on the know distance and the number of pixels between the 2 BB's in module three of the ACR phantom.

- **High Contrast Spatial Resolution**

The measured noise levels of each of the 8 bar resolution patterns are reported as   plus the user inputs the smallest pattern resolved.

- **Table incrementation**

Assessment is based on the detection of the 4 steel BB's at 3, 6, 9, 12 o'clock location in the slice (less than 2 mm) when the table is moved 120mm when the table is moved from the center of the first module to the fourth.

# Operator's Instructions

This section of the manual describes the usage of the AutoQA Lite software.

## Installation

The software is provided on a CD-ROM or available as a software download. The installation will install (1) the QALite software, (2) IrisQA Report applications and (3) Microsoft .NET if not already installed. There is software available for the DICOM transfer utility on the CD and can be installed by the user if necessary see Appendix A. First load the CD. If the auto run feature is turned on then the installation program will be executed. If not, then click on the Start button on the windows task bar. Then click on the Run button. A window will then open requesting the name and location of the program to be executed. Select the Browse button and locate the CD drive in the "look in" option at the top of this form. Click on the file named Setup.exe and then click on the OK button.

## Software Registration

Activation of the software license is required for operation.  You will be provided with a CD-Key and serial number with either the software CD or via an email. Upon QALite startup a screen will display information about the option to run QALite in a 'demo' mode or to activate your license.
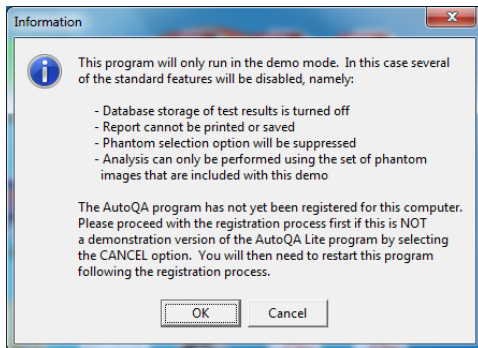




Click 'Ok' to continue in demo mode or click 'Cancel' to start the registration process.

If the above registration screen is not visible minimize the QALite window or click on the QA icon in the taskbar along the bottom. The user will complete the registration form filling in the required information and enter the Serial Number and CD Key that was provided on the CD or via email notification.  Click on the 'Activate' button when all information is entered. It is required that internet access is available. It may take a few seconds or longer to complete the activation process. When the activation process is successful a message is displayed stating this.  The application returns to the QALite screen, however the application is the demo mode operation and the use should click 'Quit' and restart the QALite application for normal mode operation. If unable to successfully register QALite (due to internet access restriction), contact IrisQA via email info@irisqa.com and we'll assist in the 'Activate by Phone' option.

## Scanning the Phantom

This section describes the procedures and methods used in scanning the phantom.  It also provides general guidelines pertaining to phantom acquisition protocols.  It is important to note that although the AutoQA approach is designed to compensate for some degree of scan-to-scan variability, it may not be accurate if the phantom is substantially mis-positioned and/or aligned improperly.  It is also imperative that the user establishes and follows an appropriate quality control program, as well as, the preventative maintenance and testing schedule as recommended by the scanner manufacturer and other regulatory organizations.

## Technique Factors

Since the intention of this QA program is to monitor the CT system for changes in performance relative to some baseline value, we need to specify the conditions under which these measurements are made.  Since different scanners may have a different set of options for their technique factors we must specify these values for each scanner separately, and use these consistently throughout the useful life of the CT scanner.

After reviewing the instruction booklets, please note the following instructions:

- Verify that the modules are loaded into the phantom holder in the appropriate order.  For information regarding other phantoms including those provided by several of the manufacturers and the ACR please refer to the appendix.
- Refer to your vendor's manual regarding specific procedures for positioning the phantom in its holder on the table for proper positioning and alignment.  The table height should be adjusted so that the phantom center is approximately at the center of the field of view.
- Upon completion of the alignment of the phantom, begin scanning the slice width module as positioned.

 IT IS IMPORTANT THAT THE FIRST MODULE MUST BE SCANNED AS THE PART OF THE IMAGE SERIES WITH AN ADEQUATE FOV, and must be centered so as not to clip any of the phantom's edges in the image.  This image is used for determining the absolute center of the phantom within each subsequent module, and hence IT IS IMPERATIVE THAT THE TABLE HEIGHT IS NOT CHANGED DURING A SCANNING SEQUENCE.

There are no restrictions about the number of times each module can be scanned, the order in which they are performed, or that all modules be included in the final image set. **THE ONLY REQUIREMENT IS THAT EACH IMAGE FILE MUST CONTAIN THE FIRST MODULE (USUALLY THE SLICE WIDTH) WITH NO MORE THAN A TOTAL OF 96 IMAGES IN A SET**.

**Important: IT IS IMPERATIVE THAT THE COUCH POSITION IS NOT RESET TO ZERO OR RE-LANDMARKED FOR EACH MODULE THAT IS SCANNED OR THE TABLE HEIGHT CHANGED.** The software determines what tests to perform based on the table position of each image relative to the first module's position.

### Analyzing the Test Data

- Double click the AutoQA Lite icon on the desktop or select the program by clicking on the **Start** button on the taskbar, and then scrolling to the **Programs** option and selecting the IrisQA program group, then CT AutoQALite program from the list. Upon starting the program the screen (right) will be displayed.



If the software was not successfully registered then a warning message will be displayed following the IrisQA splash screen (right), noting that the system will operate in 'Demo' mode. This restricts processing to the Catphan 600 data and disables some reporting and processing functions

If this is the first time the program is executed then the user will be prompted (1) to enter the facility name which will replace the header "Your Facility", and (2) to select a phantom from the currently available list. These selections can always be changed at a later time from the options menu

- Click the 'Analyze' option on the main menu. This will then display three choices: (1) Select Phantom Images, (2) Reprocess Last Selection (3) Show Info on Last Selection
- Click on the menu item 'Select Phantom Images' will open up a directory of all the DICOM 3.0 files located in the default image directory (XP Documents and Settings\All Users\Application Data\AutoQA\Images or Windows6/Vista Program Data\AutoQA\Images) as shown in the left column.
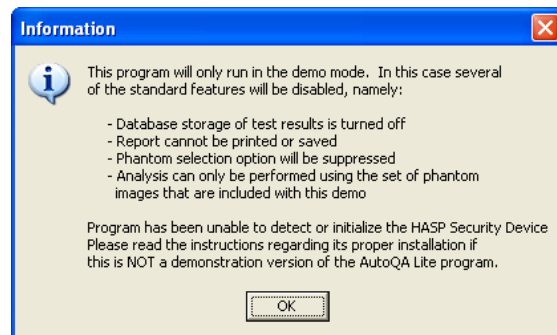


### Image Selection

This window is divided into two sections. The table on the left side is a list of all the study/phantom acquisitions grouped by Facility Name, CT scanner serial number and acquisition date as extracted from the DICOM image header for those studies found in the default \images\ct folder. The user can select folders other than the default by clicking on the drop down menu button next to the '\images\ct' folder. Clicking on one of these studies from the selected folder will then populate or update the table listing to the right, which contains all of the individual images that have been identified as belonging to that acquisition sorted by table position. By default ALL of the images will be included in the analysis. The user can selectively exclude/include individual images by alternately clicking on that row in the list. Those images, which will be excluded from the analysis, are displayed in red. Once a study has been selected the button labeled

Click the *Begin Analysis* button to initiate the processing function

There are also three buttons under the image file window that will *Select All* or *Skip All* or *Auto Select* images. The *Skip All* button is helpful when there are many image files listed. This allows the used to step through the list and select only the appropriate images for processing. The *Select All* is the reverse for this selection.

- *Auto Select* mode for identifying the correctly positioned slices for each phantom module or section in a large series of images. Before clicking the *Auto Select* button the image that represents the center of the first phantom module needs to be identified by either of the following actions;

   Clicking the box left of the image number, which is indicated by a triangle after this action. Or

Click any fields of the image data. This action turns the file selected red.

Once the first image is selected by either method

Click the *Auto Select* button.

The image file list now shows the images selected for processing are white and the excluded image files are red. You can modify the selection by clicking on the individual image file to either include or exclude additional images for processing. When satisfied with the selected images

Click *Begin Analysis* for processing.

The user may also click *Exit* from this window without performing any analysis.

There are also check boxes next to the buttons on this form. One of these *Delete after Processing* can be used to automatically delete the image files from the system upon completion of the analysis. Any images that were excluded from the analysis will, however, not be deleted. The second check box *Reverse Image Order* affects the order in which the images are listed based on the table position. This will also represent the order in which the images are processed. This is important since the first image is used as a reference by which to determine the corresponding module in the phantom for all subsequent images. Some CT scanners will scan using a decreasing table position while others use an increasing table position. Checking or unchecking this box will reverse the image order. The current status of this checkbox is saved for each CT scanner so that the next time that scanner is selected the order will be automatically set. The third check box turns off the image preview function. This screen can also be used to selectively delete studies from the system without performing any analysis. In this case clicking the *Delete* button will remove the currently selected set of images.

## Processing

At this point the analysis will begin image by image. The progress is displayed in the status bar along the bottom. The test results will then be displayed in the lower "results" window for review. The results window shows the image number, the test(s) performed on that image, and the results of each test. If an error had occurred then a descriptive message will be shown for that test. The bottom status bar will display the CT scanner model and serial number, the name of the health care facility, and the date for which the testing was performed.

The initial phase of processing involves first converting the entire image set into a single file (phant.mti) into a format used by the AutoQA Lite program. The order of conversion is based on the table position so that the modules will be processed consecutively regardless of the acquisition order or file labeling. During the conversion process the program will skip any images that do not match the serial number and scan date as that of the first image in the set. Upon completion of the conversion process individual thumbnail representations of the phantom images will be displayed horizontally along the panel below the menu bar. If there are more images in the set that can be displayed, then a horizontal scroll bar will then be included in-n the area just below the images.

- Double-click on any thumbnail image to enlarge the view with widow/level slider adjusts at the bottom of the window. This image will also include some of the acquisition parameters.

- Click anywhere on the thumb nail image to close the zoomed image

- Click over the thumb nail image of interest. Some of the relevant acquisition parameters can be viewed temporarily on the screen. This information which includes factors such as kV, mA, scan time, table position, study name and ID, and gantry angle will be displayed for approximately 10 seconds. The vertical scroll bar can be used to step through those results, which are not in the current viewing area. **Graphic screens** for the CT linearity contrast scale, MTF, Uniformity and mean CT# and noise can be reviewed by a Double click on the data section for each test (CT linearity, Modulation Transfer Function (MTF), and Noise/Uniformity.
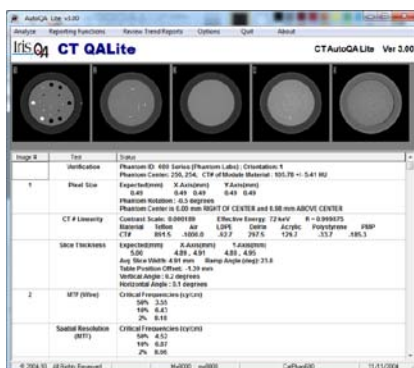


If the analysis was successful, the reporting options under the 'Reporting Functions' menu option will then be enabled.

- Click on 'Reporting Functions' and a list of report functions are listed 'Display Report', 'Print Test Results', 'Export Report to Excel file', 'Save Report as PDF File', 'Dates of Testing Performed' and 'Print Selected Report'

- **'Display Report'**: this option will format a report that can be previewed on the screen. It will include a table of the relevant acquisition parameters for all of the images that were processed along with the test results that are displayed in the results window. There is a button to send the report to the printer. If there is more than one page for the report there are buttons to allow the user to step forward and backward through the report.

- **'Print Test Results'**: this option will send the report directly to the default windows printer. The format will be the same as displayed in the Preview window.

- **'Save Results as a PDF File'**: This option will automatically create a PDF file of the test results. These reports will be stored in 'Test Reports' located 'AutoQA' data folder (XP Documents and Settings\All Users\Application Data\AutoQA\I or Windows&/Vista Program Data\AutoQA\)

- in 'Program Data'. The name of this file will be generated based on a combination of the CT's serial number and the date of the testing. If a file already exists a message will first be displayed asking whether or not to overwrite the previous file. If you need to perform multiple testing on the same scanner on the same date then you will first need to rename the first file. The content of this PDF file is similar to the routine printed report except that it may also contain the phantom images and graphics at the end of the report. However, the user has an option to include or exclude images or graphs. This option is available for selection in the 'Options' menu.

- **'Dates of Testing Performed'**: this option gives the user a report of which tests (e.g. Noise, MTF, etc.) were performed on which date for a given scanner. When this option is selected the user is presented the following window.
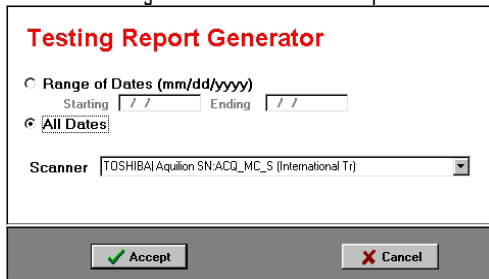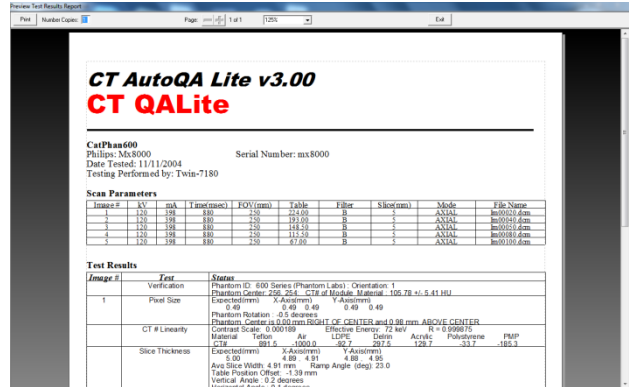
The user can specify either a range of dates or all dates for which this CT scanner was tested. In the scanner field is a drop-down list of all of the CT scanners for which there is test data. This description contains the vendor, the CT model, the serial number, and the medical facility in the description. If the accept button is then selected a report similar to the following will be displayed.
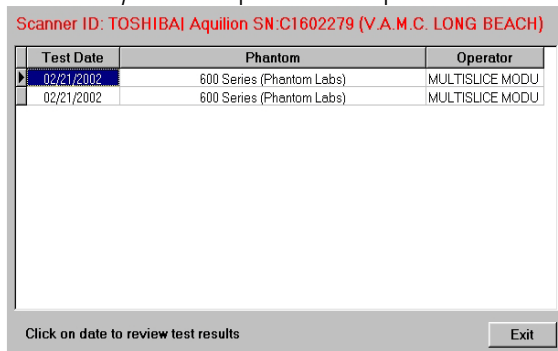
There are options on this preview screen as on the results preview to either print the report to the default printer, page through multiple pages if necessary, change the zoom factor, or exit back to the main menu.

- **'Print Selected Report'**: each time an analysis is performed the raw data is saved in a compressed format within another database file. It is then possible to restore a previous analysis. For this option the user is first presented the same selection option for

dates and scanner as above. After making this choice the window below is displayed.
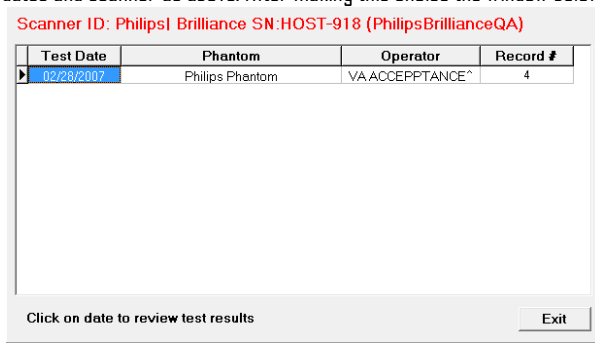


- Clicking on a row in this table will result in that study being restored and reprocessed. However, this requires that the phantom used in the analysis match the currently selected phantom. If this is not the case then the following warning is displayed
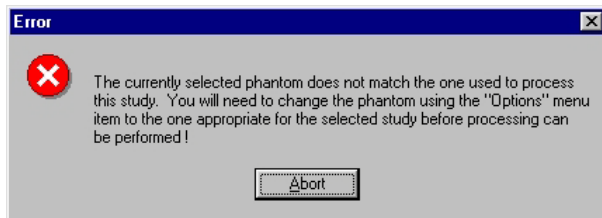


**Note that the phantom parameters used for the analysis are based on the currently selected phantom which was specified by the user. If this doesn't match the actual phantom images, the analysis will FAIL!!** Refer to the *Phantom Selection* section for more information on this.

## Storage of Test Results

As each test module is processed the results are saved in a Dbase IV compatible file that is specific to the test. There are actually two sets of database files: one for the purpose of a monitoring QC program Trend Analysis Database, and the other to store more extensive tests results that are primarily intended for service and acceptance testing purposes Service Database. Program execution stops until the user selects an option. At this point the processing will immediately continue so it is important to select the correct option.
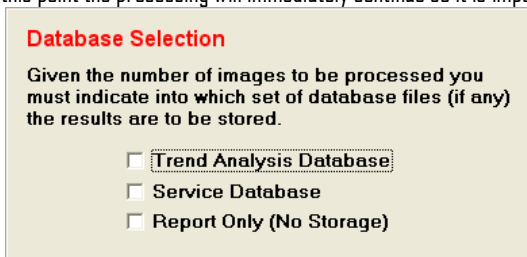


In order to try to avoid unintentional duplicate records several checks are first performed. First if the user had selected the option to simple reprocess the last data set, the database is automatically turned off. In addition, before any processing begins, the program examines all of the tests to be performed for that CT scanner (based on serial number) and test date, and scan parameters. If any records are found to match then the user is presented the following warning form.



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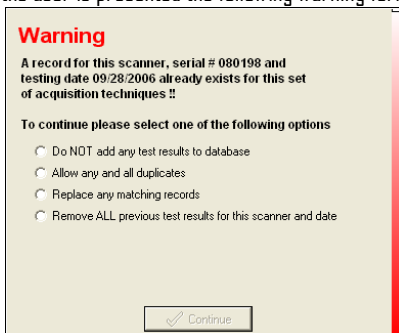
The operator MUST select one of these options in order to proceed. The first option disables the database. The second option will save all of the test results including any that might be duplicates. The third option will replace the first record that matches. If there were duplicates already in the database or there were other records that the user wished to replace, then select the last option. In this case the program will first remove ALL previous test results for that CT scanner on that testing date. This will include any duplicates, as well as, those tests, which are not included in the current data set. Due to the effect of this option the user is presented with another dialog box to confirm that this operation should be performed. Once the records have been replaced or removed they cannot be restored. It is good practice to perform periodic backups of all of these database files. (*.dbf files stored in the folder ProgramData/AutoQA).

## Options (Menu)

The following is the list of available menu items under the Options selection;

- o Enter Facility Name
- o Select Phantom Model
- o Sort Results by Test
- o Include Images in PDF report
- o Include Graphs in DPF report
- o Display ROI on Images
- o Automated Processing

- **Enter Facility Name** – At the first time startup the user is requested to enter a name used to identify the medical facility. This name will be displayed on the main screen below the menu and on any printed test report. This can be changed at any time by selecting the 'Options' item and then 'Enter Facility Name'. The following dialog box will be displayed.



- **Select Phantom Model** - In order to perform the analysis the AutoQA Lite program needs to know what phantom model is being processed. There are sets of predefined information and instructions for a number of commercially available phantoms. However, it is the user's responsibility that the phantom selection matches the image data acquired. The choice is made from this menu item, by choosing the *Select Phantom Model* option the following window is displayed.



The *Accept* button is not enabled until the user has made a selection. The currently selected phantom is displayed on the status bar of the main screen prior to any processing. The tests performed on the phantom images will depend on the particular phantom undergoing processing. The table shown below lists several different commercial and/or vendor supplied phantoms for which the analysis has been configured to work with (or under development).

| Table of CT Tests (AutoQA Lite) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Phantom | Noise | Uniformity | Low Contrast* | MTF | Slice Width | Resolution | Linearity | Pixel Size |
| Catphan® 412 | • | • | • | • | • |  | • | • |
| Catphan® 424 | • | • | • | • | • |  | • | • |
| Catphan® 440 | • | • | • | • | • |  | • | • |
| Catphan® 500 | • | • | • | • | • |  | • | • |
| Catphan® 503 | • | • | • | • | • |  | • | • |
| Catphan® 504 | • | • | • | • | • |  | • | • |
| Catphan® 600 | • | • | • | • | • |  | • | • |
| Catphan® 700 | • | • | • | • | • |  | • |  |
| InnerVision® | • | • | • | • | • |  | • | • |
| ACR | • | • | • | • | • | • | • | • |
| Siemens | • | • | • | • | • |  |  | • |
| GE | • | • | • |  | • | • | • |  |
| Philips | • | • | • | • | • |  | • |  |

It is important to note that the program itself cannot determine which phantom has been acquired.  It is the responsibility of the user to have selected the appropriate phantom prior to the analysis; otherwise erroneous results may be reported. In most cases the program will fail or individual tests will not be performed.

- **Sort Results by Test**
  This option provides a sorted report based on the test whereas the standard report lists results of all the tests for each image in order of image number (image number is based on decreasing or increasing table position).

- **Include Images in PDF Report and Include Graphs in PDF Report** - When the option has the check mark, that option is enabled to save either images, graphs or ROI's in the PDF report. The available graphs are shown below.
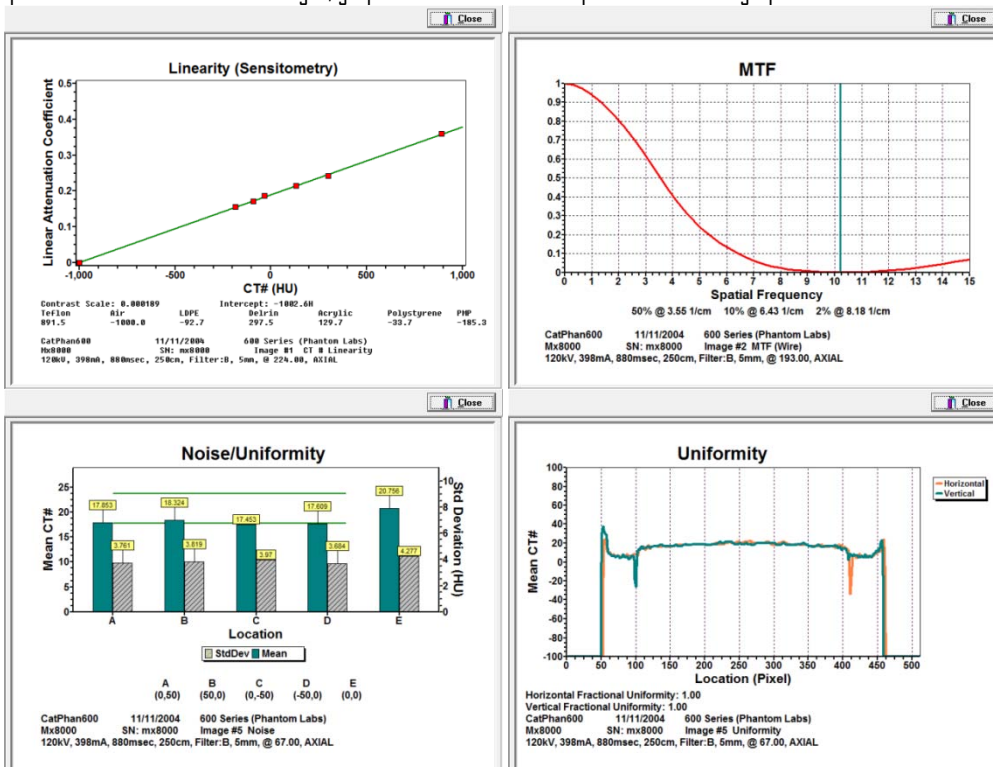
- **Automated Processing** - When this option is checked the all images selected are processed according the phantom configuration selected. When 'Automated Processing' is turned off when one of the tow 'Manual Processing' options are selected.
- **Manual Processing** -When either MTF Only or SSP Only options are selected Automated Processing (normal mode) is disabled. When *Automated Processing* is turned off the message (right) is displayed and a response is required to continue.
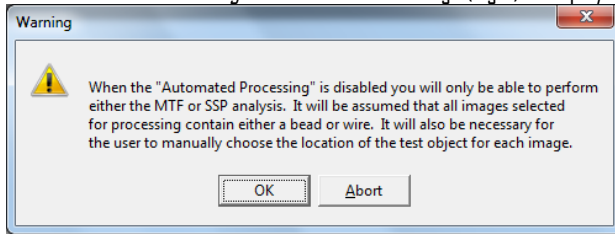


o MTF Only - QALite will only execute the MTF – spatial resolution analysis. The user will be required to select those MTF images and skip non MTF images. For each MTF image to be processed the user is required to click on the location of the MTF bead or wire then click *Accept* to execute processing of this image (shown below). This processed needs to be repeated for each MTF image. When the last image in the set is reviewed processing will begin.

o SSP Only – In this mode the slice sensitivity profile of a series of sequential images scanned through a high density 'bead' target will be measured. The FWHM and FWTM of a background corrected profile of the peak 'bead' signal through the series of images are calculated. A minimum of 20 images are required. This screen is similar to the 'MTF Only' processing but including buttons to move through the series of images to pick the image that approximates the central slice through the bead. The image spin buttons are positioned to the right of the window and center display settings. . For each SSP series to be processed the user is required to click on the location of the bead after selecting the approximate central bead slice then click *Accept* to initiate processing of the data.



Manual MTF
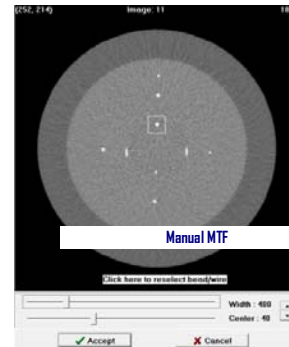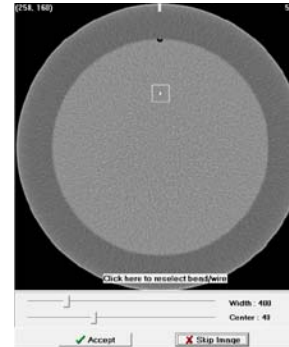
# Trend Analysis IrisQA Reports

This function provides the user the ability to view the results of CT Linearity, Noise and Mean CT#'s, Spatial resolution (MTF) and Slice thickness using the following database files; **Linearity.dbf, Noise.dbf, Resolut.dbf, Slicethk.dbf and the latest added report for low contrast LC-CNR.dbf**. This analysis provides trend analysis using user defined baseline and acceptance limits in graphical formats.

Startup of IrisQA Reports for the first time.

## Enter Database Setup
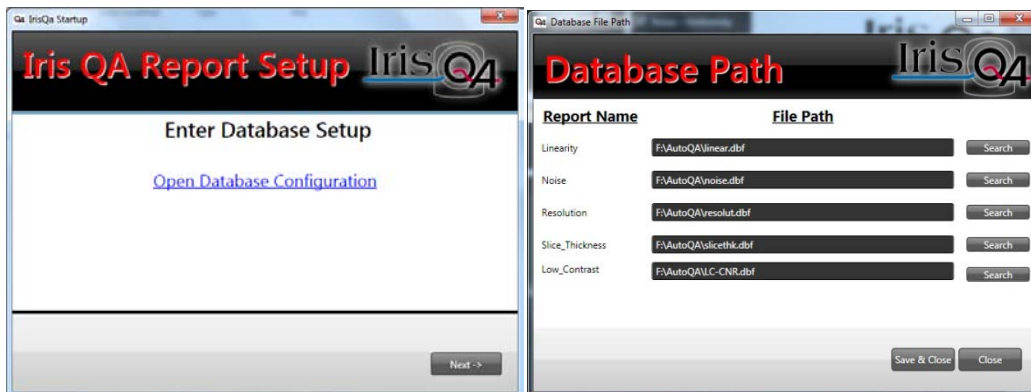


The user selects the path for the database file locations (typically ProgramData/AutoQA). . When all four selections have been completed Click *Save* and *Close* to continue.

## Search Database –

The main Reports screen now opens (showed below).  The window contains three search field sections; Date Range, Reports (Linearity, Noise, Resolution and Slice thickness) and Equipment Selection (Hospital and Serial number). **At least one report and either the Hospital or CT Serial Number are required to perform a database search**, when these items are selected click the *Submit* button.





After clicking *Submit*

a series of thumbnails images for each unique set of matching scan techniques is displayed as (above right).  Select a report by clicking on a thumbnail.

## Setting Baseline Criteria

The linearity report is shown (right) which contains 4 main functions;



- Export - exports report into Excel format
- Settings – Allows the user to select the parameters for the baseline acceptance criteria.
  - o List of Trend parameters for the five (5) databases reviewed;
    - ▪ Linearity – CT#'s of all materials found in the phantom
    - ▪ Noise – Central Mean (HU), Uniformity (absolute value of the maximum difference between the central ROI mean CT# and the four peripheral ROI's mean CT#'s), Central Noise (SD)
    - ▪ Slice Thickness – Measured slice thickness (mm) and table offset (mm)
    - ▪ Resolution – MTF cy/cm values calculated at 50%, 10% and at cutoff (default is 2%)
    - ▪ Low Contrast – CNR values for 1% targets 15-6mm, 0,5% targets 15-7mm and 0.3% targets 15-8mm



    The user selects the Field Name (test parameter) in the example for Linearity there is Teflon, Air, LDPE and Acrylic.  The baseline value is entered next then the operator (for the operators that require a %, enter this value as a fractional value.  The options are available in a drop down list. When the three screen fields are complete click *Add* then *Save & Close*. **The baseline settings are saved to the related CT scanner serial number listed in the drop down in the lower left corner.  This is a new feature for V3.1.01 that a system specific set of baseline values can be used.**  Click *Update* to view the baseline settings just completed.  The user can modify the baseline value with a number of different options.  Click right on the data column (not the data column header) there are the following baseline selection options; Selected Average Rows, Selected Top 5 rows, Selected Top 10 Rows, Average all Rows, Clear Baseline, Settings.  When any of these options are selected the screen values are automatically updated.

  - o The trend plots for the test parameter can be expanded by clicking on the individual curve.  In the expanded view the user can modify the date range for the trend plot located in the top toolbar of that window.
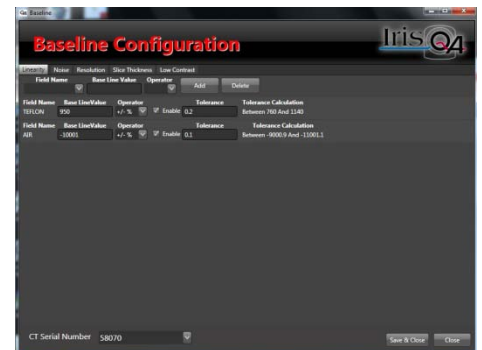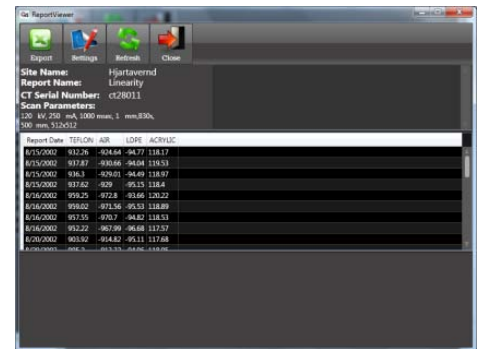
- Refresh – when the baseline value is modified this will update any out of range values
- Close – returns to main reports screen.

## Equipment Selection

*File* button on main screen provides three selections



- Database – the user can re-select different database file locations (Database Path Screen shown above)
- Equipment – Equipment Selection screen (right). On first time use after the database path is selected the application automatically auto populates the list of scanners contained in the database. If the user needs to change database files updating this screen is required. The operation searches the databases and extracts all unique facility names and scanner serial numbers. The user can use the *Auto Populate* function or manually enter the two fields; Hospital and CT serial number. If the *Auto Populate* function is selected the screen is populated with the hospital and serial numbers, the user then clicks *Close*. The *Delete* is used to remove any devices not longer being monitored from the current list.
- Close – Returns to the main reports screen.

# Appendix A

## Evaluation and Routine Testing of CT Scanners as Described by IEC

The International Electrotechnical Commission (IEC) has established evaluation and routine testing guidelines for various medical imaging devices. In particular, the publication IEC 61223-2-6 (2006-11) describes a series of tests and protocols designed to track the "constancy" of the performance of CT scanners. The objective of these standards is to assist the radiological installation or health care facility in the establishment and operation of an ongoing Quality Assurance Program for medical imaging devices. The intent is not to establish methods and techniques, which are both sufficient and comprehensive enough to meet the demands of acceptance testing. Rather they are based on simple measurements using appropriate test equipment or assessments of other information, which should be capable of detecting any significant variation in the level of performance with respect to some reference levels. These reference levels are determined once the system has been deemed to meet performance specifications as assessed through more rigorous acceptance testing. Guidance is provided in this document to indicate the degree of variation in any variable at which remedial action should be taken. Furthermore, it clearly states that this standard is not intended to address:

 - Aspects of mechanical or electrical safety
 - Optimization of imaging performance
 - Special applications of CT, e.g. Calcium Scoring or QCT

For the results of the constancy tests to be valid, it is essential to ensure that they are not significantly influenced by anything other than changes in the parameters under test. All equipment under test or used for testing shall be marked in order to permit easy identification as those items are used in the initial CONSTANCY TEST and to assist in ensuring that the same items are used subsequently in related constancy tests. Prior to testing the constancy of all equipment that is used for the constancy tests shall be checked.

## Establishment of Baseline Values

An initial constancy test (using the same methods, analysis, and test equipment as in subsequent monitoring) will be performed to establish baseline values for each of these tests. This initial test shall be carried out immediately following the indication that the CT scanner is performing satisfactorily based on passing acceptance testing. Whenever new x-ray equipment is added or replaced, including the test equipment, then additional constancy tests need to be performed to verify that this has not resulted in any significant changes from the baseline values.

## CT Constancy Tests and Frequency

In order to establish a set of tests and protocols that were not overly burdensome and which would be conducive to a regular QA program, a limited number of tests have been identified by the IEC along with the recommended frequency of measurement. This information is listed in the table below.

| Test | Frequency* |
|---|---|
| Noise | Monthly |
| Mean CT# | Monthly |
| Uniformity | Monthly |
| Slice Width | Monthly |
| Patient Positioning | Quarterly |
| Spatial Resolution | Quarterly |
| Dose | Semi-Annual (and after major maintenance) |

*In addition to the frequencies listed in the table above, the tests should also be performed or repeated:
-    whenever a malfunction is suspected,   Or
-    immediately after the equipment has undergone maintenance  that could affect the performance parameter under test,   Or

- Whenever the CONSTANCY TEST leads to results that are outside the established criteria, to confirm the test result.

The AutoQA Lite™ program has been developed to provide a simple, automated phantom analysis and trend analysis to address all of these tests with the exception of radiation dose and table positioning. Both of these tests require additional test equipment and direct user involvement in the measurements and cannot be extracted from the CT images directly. Results from testing the radiation dose and table positioning accuracy are therefore not incorporated into this version of the software.

## IEC Evaluation Criteria

This section summarizes in the table below, the criteria proposed by the IEC for the various tests listed below the table. These criteria are primarily based on objective measurements of the deviations of the test results from the established baseline values, and could be obtained using standard image analysis programs directly from the CT scanner. These tests and criteria are listed in the table below.

| Parameter | Evaluation ( ACCEPTABLE DEVIATIONS ) |
|---|---|
| Noise | Deviations from BASELINE VALUE < +/- 10% OR < +/- 0.2H, whichever is larger |
| Mean CT# | Central Average CT# <= +/-4H of BASELINE VALUE |
| Uniformity | Difference between mean CT# at central ROI and outer ROI's <= +/- 2H of BASELINE VALUES |
| Spatial Resolution | The 50% and 10%Modulation values shall be within 0.5 lp/cm or +/-15% of BASELINE whichever is greater |
| Slice Width | Comparison made with BASELINE VALUES<br>    If slice width > 2mm then   +/- 1.0mm<br>                2mm to 1mm +/- 50%<br>                < 1 mm then   +/- 0.5mm |
| Dose | CTDI <= +/-20% of BASELINE VALUES |
| Patient Positioning | The distance moved forward and backward shall not deviate by more than +/- 1mm from indicated values. The backlash value shall not exceed +/- 1mm. |

## General Description of CT Test Phantoms

In order to perform the tests required for the CT quality assurance program defined by the IEC certain test equipment and phantoms will be required. Furthermore it will be necessary to select two sets of scan parameters for constancy testing which are typical of the clinical applications of the CT scanner undergoing evaluation. If appropriate, one set of scan parameters should reflect head scan techniques, and the other body scan techniques. The radiation dose is based on the measurement of the CTDI (computed tomography dose index) at various locations within a scattering media. Therefore, an ionization chamber and associated electronics will be required in which the sensitive volume of the radiation detector is at least 10cm in length and fits snugly within the scattering phantom. In addition, the response of the sensitive volume shall not vary by more than ± 3% over the length when measured with a 2mm wide radiation field.

The phantoms shall consist of PMMA (polyethylmethacrylate) cylinders with holes of appropriate diameter and location into which the radiation probe can be inserted snugly, and which are parallel to the axis of the cylinder. The diameter shall be 16cm for the head mode, and 32cm for the body mode. These phantom requirements are illustrated in the figure below. This version of AutoQA Lite™ has been developed to function with a variety of CT phantoms including all of the models of Catphan®, including Catphan Lite (used by Toshiba InnerVision®), the ACR CT Accreditation Phantom, and other vendors as well. The measurement of the MTF a wire or bead sources is now the recommended option for spatial resolution. The measurement of the modulation of a square wave is s discussed in IEC 61223-2-6 as an alternative method by which to quantitate and monitor the spatial resolution.

## Evaluation Procedures

For each of the CT scanner tests identified by the IEC in document IEC 61223-2-6 there is a description on how to perform the test and how to analyze the results. The analysis procedures associated with the various tests are summarized in the table below. The user should refer to this IEC document for more detailed information about each of these tests. Information regarding the testing which the AutoQA Lite™ program performs

can be found in 'Test Description' section of this manual.  It should be noted that all of the analysis is consistent with the guidelines specified by the IEC.

Note that the last two tests listed in this table require additional test equipment and operator interactions in order to perform these measurements.

| Parameter | Phantom | Procedure |
|---|---|---|
| Noise | Uniform cylinder (preferably water) | ROI's at center of phantom and 4 locations approximately 1cm from the edge at the top, bottom, left, and right positions.  Each ROI > 100 pixels, does not overlap the edge, and < 10% of the diameter of the test device.   NOTE: Phantom diameter is not specified. |
| Mean CT# | " | Average CT # from the central ROI. |
| Uniformity | " | Average CT #'s from outer ROI's compared to the central ROI. |
| Spatial Resolution | High density wire or bead by which to perform MTF | In this procedure the spatial resolution is measured by calculating the point spread function from the scan of a small tungsten carbide bead |
| Slice Width | One or more angles ramps with an attenuation coefficient not less than aluminum | Scan with the technique used for noise, as well as, for max and min slice thicknesses.  Analysis is based on visual inspection and measurements performed on the scanner using vendor software.  First the CT # of the background material is determined by adjusting the window until the background is at zero intensity.  This level is recorded.  The maximum CT # for each ramp is determined using the same technique and the value recorded.  These two values are added and then divided by 2.  The window is then set to its narrowest value and the center set to the CT # just calculated.  The length of each ramp is then measured using the distance measuring program which is in units of distance (mm).  The true slice thickness must be calculated from this value based on the angle of the ramp. |
| Dose | Measurement performed at center and 1 cm within test device edge.  PMMA cylinder 16cm diameter for head and 32cm for body, and longer than the sensitive volume of the probe.  Holes large enough for the probe and plugs in the holes not used @ $90^0$ intervals.  Sensitive volume of probe > 10 cm. | Center phantom within +/- 2mm of axis with scan plane through center of test device.  Place detector in either the 12 o'clock hole or the hole at which the maximum dose occurs.  Measure the CTDI using the detector's protocol.  Repeat measurement at the center. |
| Patient Positioning | A ruler is used with a patient load on the table. | Mark ruler and patient support.  Drive patient support a fixed distance and measure.  Return patient support back to original position and measure difference.  Repeat in opposite direction.  Repeat this cycle in 8mm increments up to a total distance of about 30cm in both directions. |

## Radiation Dose

This test involves the measurement of the radiation dose in terms of the CTDI, which is measured using a calibrated ion chamber probe.  The value is measured at five locations within a uniform scattering medium.  One of these locations is at the phantom center, and the other four are at the compass corners near the edge of the phantom.  Two different diameter phantoms are to be used in accordance with either a head or a body scanning protocol.

## Patient Positioning System

The accuracy of the motion of the patient support system is tested by moving the table forward and backward under specific test conditions.  This test needs to be made while the table is under a typical patient load condition.  A measuring device is attached to a fixed portion of the table.  The table is moved a programmed distance in the forward direction which is at least 30 cm from a central location in 10mm increments.  Subsequent testing will involve moving the table this same distance.  A mark is first placed on the table and the difference between the expected movement and the measured movement is recorded as Lforward.  The table is then sent back to the starting location and the difference between where the mark lines up with its initial position is recorded as a "backlash" factor, Cforward.  The process is repeated in the backward direction with the values recorded as Lbackward and Cbackward, respectively.  The series of measurements are repeated except in this case the table is moved in increments of 8mm so that it will require about 40 incremental steps in each direction to reach the target displacements.  The programmed distance is the planned motion which should be at least 30cm.

## Baseline Performance

AS discussed in section 1.2, the purpose of this program as defined by the IEC is to monitor the general performance of CT scanners relative to baseline values established at the time of acceptance and/or following any major service or upgrade. As such, the IEC has identified a subset of important test conditions and a testing schedule, which is both practical and meets the objectives of a quality assurance program. A summary of the evaluation criteria was presented in the first table. The user should refer to IEC 61223-2-6 for more details. For the spatial resolution test, there are two approaches that can be used to monitor the CT performance; (1) the MTF calculated from a bead or wire (2) an appropriate square wave pattern. The MTF calculation requires more sophisticated approaches and is not as general. A resolution gauge, however, is the simpler of these two since the data necessary for the calculation can be extracted from the image of this module using standard image analysis commands available on most if not all CT scanners

## Appendix B

## DICOM Push

### DICOM 3.0 Image Transfer
The simplest way in which to transfer the phantom images to the PC for any of the IrisQA software packages is through an Ethernet connection to the CT scanner. To facilitate this transfer we have provided a simple DICOM communications program, which will allow images to be **pushed** from the scanner workstation or console to the PC as described below.

### DICOM (Storage Class Provider) Installation and Set Up
It will be necessary to interface the PC to the CT network using the appropriate cable and connections (not included as part of this package). Check with your CT manufacturer or IS department regarding these instructions. The CT manufacturer will require the AE Title (Default: QALITE_SCP) and the Port Number (Default: 104) in order to configure the DICOM/PC network node. Available on the software CD is the installation program for the DICOMPush software. Double click the icon for DICOMPushInstall program (DICOMPushInstall.exe) to begin the installation process. Please follow the installation instructions. The installation process will provide an option to launch the DICOMPush program at the completion of the installation.

When the DICOMPush program is launched the screen shown below is displayed:
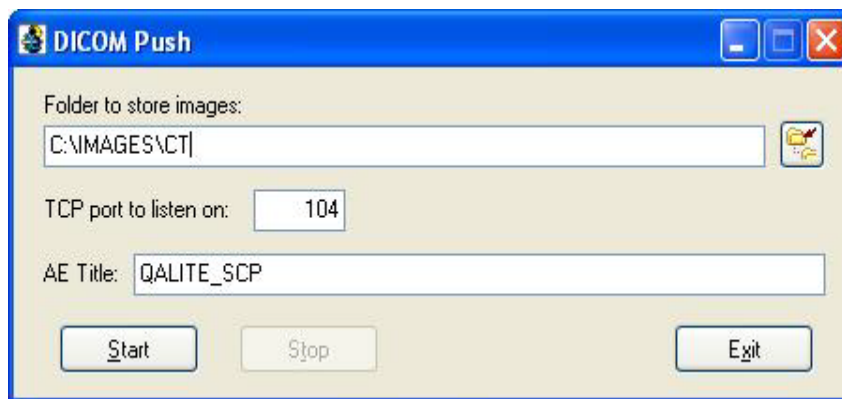


There are three fields that need to be verified before 'Start' is initiated.
1. Folder to store images: A user defined field however a suggested folder CT AutoQALite is XP Documents and Settings\All Users\Application Data\AutoQA\Images or Windows&/Vista Program Data\AutoQA\Images for NMToolKit is Program Data\NMTooKitData\Images. Other folder locations are acceptable as well.
2. TCP port: 104
3. AE Title: QALITE_SCP

Fields 2 and 3 can be changed but MUST match the settings for this device as it is configured on the CT scanner. When these fields are set and verified click the 'Start' button then click the minimize button in the upper right corner. The icon will be in the system tray and can be restored when you double click. The 'Stop' button will stop the activity and allow the user to change the setting or the exit the program. The 'Exit' icon will terminate and close the DICOMPush application.

# Appendix C

## Processing Error Messages

This is a list of messages reported in the processed data report along with an explanation and the possible causes.

1. Verification
2. Pixel Size
3. CT# Linearity
   a. CT# of the following material(s) outside the expected range: - the CT#'s of the listed materials listed exceed an expected range.  This range can be modified by editing the configuration file for this phantom
4. Slice thickness
   a. 'Slice width measurements are not within expected range'  - if the measured slice thickness exceeds the expected by more than 1 mm that data is considered corrupted or unreliable for this test measurement
   b. '------' reported for an individual slice width measurement – indicates that the wire was not detected or located in the expected location
   c.
5. MTF
   a. *Warning: exceeds Nyquist frequency of x.xx cy/cm – the result is probably unreliable given the measurement exceeds the maximum frequency for the sampling provided by the reconstructed matrix
   b. 'Bead not located for PSF – Signal too Low' – The PSF source was found but the peak value did not exceed a processing threshold (80)
   c. 'Bead not located for PSF' -