Quality Control Manual

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Quality Control Personnel

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Location of Records

Performance of the X-ray Unit
- Calibration: Radiology Engineering
- Scheduled Maintenance: Radiology Engineering
- Compliance Testing: Radiology Engineering
- Specialty Areas: Physics Office or Individual Sections
  - Special Procedures
  - Cardiac Cath Labs
  - Computerized Tomography
  - Nuclear Medicine
  - Mammography

Cassettes and Image Plates: Radiology Engineering
- Physical Condition

Repeat Analysis: Team Leaders Office

Radiographic Illuminators: Radiology Engineering

Aprons and Shields: Radiology Engineering

Image Quality
- Routine and R&F: Radiology Engineering
- Specialty Sections: Radiology Engineering or Individual Sections
Introduction and Objectives

Quality Control programs in Diagnostic Radiology are recognized as effective means of managing imaging environments. Quality Control programs insure that all components of the imaging environment perform at optimum; the end result being highest quality images with the lowest possible dose to patient and operator while maintaining high diagnostic content. It is the goal of the Quality Control Program to help contain costs through elimination of unproductive imaging resulting from failure of machines or materials that may occur in the complex chain leading to the finished product. The objective of the Quality Control Program is to detect changes in image quality that may effect diagnosis or cause changes in the radiation exposure to the patient before they become significant and, most frequently, to request service or calibration of the imaging systems before loss of image quality. The Quality Control Program is an integral part of the overall quality assurance program within the Radiology Department and the hospital as a whole.

Quality Control, QC, tests are performed for each x-ray producing device annually. Average or representative x-ray exposures for the most common procedures are measured annually. These records are kept available for use in consultations between patients and physicians or the Diagnostic Physicist when such information is requested by the patient.

Image quality for all modalities in Diagnostic Radiology are monitored at least annually by the Diagnostic Physicist.
Performance Of the X-Ray Unit

1. Background:

   Reproducible, quality, diagnostic radiographic images are dependent upon x-ray equipment functioning correctly and consistently. Exposure of patients to unproductive radiation is a prime concern in establishing proper performance parameters of the x-ray unit. The following procedures are performed to insure compliance with regulations, and to maintain the performance of the equipment to the best of our ability. Calibration and compliance testing are both necessary to ensure proper performance.

2. Calibration

   Introduction:

   Almost all of the x-ray units we have are self-calibrating, either through a phase-locked loop or direct feedback to a regulation circuit for KV and MA. The timers are all digitally controlled. Invasive calibration is only needed in the case of parts replacement or a new tube installation. We verify the calibration during the annual compliance testing.

   Equipment Required: RTI Barracuda MPD
   Kiethley Triad System
   Dynalyzer III
   Digital VOM

   Procedure:

   If QC testing shows a deviation, or in the case of parts replacement or a new tube, invasive calibration is performed using the appropriate test equipment. Calibration procedures for each individual x-ray unit are outlined in their respective service manuals found in the Radiology Engineering area or in the respective rooms.

3. Scheduled Maintenance

   Introduction:

   An effective maintenance program is designed to minimize downtime and maintain equipment in good operating condition. Scheduled maintenance reduces incidence of failure through inspection designed to detect potential problems before they become reality. Scheduled maintenance is performed on an annual or semi-annual basis, according to equipment use or history.

   Equipment Required: Cleaning Supplies
   Vacuum Cleaner
   Test Equipment
   Lubricants
   Tools
4. Routine and R&F Compliance Testing

Introduction:

Compliance testing involves non-invasive testing techniques designed to determine if the system is functioning as specified under particular performance parameters. This testing is performed under the direction of the Section of Medical Physics in conjunction with the Quality Control Section, Department of Radiology. Compliance testing is designed to meet regulatory requirements as specified by JCAH, state, and federal agencies, as well as satisfying the requirements of radiologists in obtaining maximum diagnostic information while minimizing dose to patient and hospital personnel.

Equipment Required: RTI Barracuda MPD
Keithley 35050 Dosimeter
Keithley 35080A KVP Meter
Keithley Quality Control Kit

Procedure:

The tests performed on each x-ray unit are designed to test the entire imaging chain. The following tests are performed when appropriate for the particular unit: tube and generator performance, image intensifiers, cameras, monitors, and tomographic devices. These tests include evaluation of the following to the extent possible with each unit: linearity, reproducibility, kVp, half value layer, timer function, phototimer function, output, light field radiation field coincidence, positive beam limitation function, tomographic depth of cut, tomographic resolution, fluoroscopic maximum exposure rate, fluoroscopic low contrast and high contrast resolution, automatic brightness control. When a specific unit is dedicated in a specific mode of operation that mode is tested. For example, C-arms have no manual exposure mode so only tests that are appropriate are conducted. Another example is a chest unit where only one kVp and focal spot size is used; only those settings need be tested.

The Barracuda QC system used has the specific sequence of exposures programmed in for most rooms; the necessary calculations are made by the computer and compared to standards stored in the computer. The printout from the computer is used as the record of QC testing. When programmed sequences are not present for a room, the testing sheets at the end of this section are followed. The following tests are always made without the computer system: collimator-light field alignment, Bucky operation, PBL (positive beam limitation) operation, phototimer operation, tomographic cut thickness and position, fluorographic low contrast resolution, fluorographic high contrast resolution and fluoroscopic automatic brightness control. Procedures are in the next section. Quality Control in Diagnostic Imaging by J.E. Gray, et. al. located in the Quality Control Office or the Medical Physics Office can be used as a reference. Compliance testing is performed on an annual basis.

Procedures:

X-ray light field alignment:

Use the round plexiglass column centered on top of the brass plate with the scale scribed in it on top of a CR cassette. Make sure the bead on top of the column shows on the dot on the bottom of the column when the collimator beam is on. Move the copper plate and cassette and/or the tube so that the light from the collimator ends at the square scribed into the copper plate. Expose the cassette and record where the x-ray field ends on the processed image.
PBL (positive beam limitation):
   Place a cassette of the most commonly used size in the Bucky. Allow the PBL to set the collimators. Check to make sure the light field is slightly smaller (to account for beam divergence) than the cassette size. Record the size of cassette used and the size of the light beam. Rotate the cassette by 90 degrees and make sure the light field adjusts properly.

Phototimer and Bucky operation:
   Place 5 to 10 cm of plexiglass over the collimator. Place a cassette of the largest size used in the Bucky. Set a 40 inch SID and allow the PBL to set the collimators. Expose the cassette using all three phototimer cells. Make sure the image is uniformly dark. The optical density of the image should be between 1.0 and 1.3. There should be no light or dark corners or spots. No lines should be visible. Repeat the procedure after adding 1/32 inch and 1/16 inch of Cu to the plexiglass.

Tomographic cut thickness and position:
   On systems that have tomographic capabilities use the tomographic test kit to check the tomographic cut thickness and depth. Screw the shorter legs into the plexiglass plate with the lead numbers and copper meshes in it. Make sure the legs are snug. Place the plate with the legs on the table. Set the depth 11cm above the table top and take an exposure using an appropriate technique and a typical sweep. Record the number that is sharpest and the range of numbers that are sharp.

Fluoroscopic low contrast resolution:
   Place the two 1 inch thick plates of aluminum in the beam with the aluminum sheet with holes drilled in it. Record the number of holes that can be seen; this is the 2% resolution. Remove one of the inch thick aluminum plates and again record the number of holes that can be seen; this is the 4% resolution.

Fluoroscopic high contrast resolution:
   Tape the line pair phantom to the center of the image intensifier. If the image is not good, place enough copper in the beam to produce a good image. Record the number of line pairs that be resolved at each image intensifier field size.

Fluoroscopic automatic brightness control:
   Place the 1/32 inch copper plate over the image intensifier. Adjust the monitor if necessary. Place the 1/16 inch copper plate over the image intensifier and make sure there is no change in the brightness of the image on the monitor. If the image changes perceptibly, record the mA and kVp with and without the extra copper plate. If the image brightness does not change, record the fact that the image brightness did not change. Move the edge of the 1/16 inch copper plate across the image intensifier while the beam is on and make sure the image lag is not too long.

Interpretation of Results:
   Testing results are reviewed by the medical physicist and passed onto the Quality Control Section. The medical physicist will inform Quality Control of any problems so corrective action may be taken. The worksheet or the compliance report is returned to service if there is a failure to meet required standards. The final compliance reports are then filed with Medical Physics. Retesting of failed system is recorded on original worksheet or compliance report.
5. Compliance Testing of the Specialty Units

The special imaging units usually are engineered to do specific tasks. For example, in many cases they cannot be placed in manual mode to do reproducibility. In general the tests outlined for routine and R&F rooms are followed to the extent possible where appropriate. Compliance Testing of the special procedures rooms, the cardiac catheterization labs, computed tomography (CT), Nuclear Medicine imagers and mammographic units are performed annually.

5.1 Special Procedures Rooms

Introduction:

Manual measurements are made when ever possible. The measurements are modified appropriately when manual measurements are not possible. Specials rooms have digital capabilities that should be evaluated for patient exposure.

Equipment Required: RTI Barracuda MPD
Keithley 35050 Dosimeter
Keithley 35080A KVP Meter
Keithley Quality Control Kit
Copper (Cu) sheets

Procedure:

When manual exposures can not be made, a specific kVp is obtained by adding appropriate attenuators in the beam. For example, the half value layer can be measured in fluoroscopic mode by placing Cu and aluminum in the beam until 80 kVp is reached. The aluminum can be moved from the image intensifier side of the exposure probe to the x-ray tube side of the probe to increase the aluminum filtration of the beam while maintaining the total attenuation so the kVp remains constant. The reproducibility can be done by using a given thickness of Cu in the beam and taking repeated measurements when the automatic exposure control has settled to a constant value. The reproducibility, output, kVp, linearity, focal spot size, half value layer, and collimation are measured as well as the standard fluoroscopy tests: high and low contrast resolution, maximum exposure rates, average exposure rates and x-ray beam collimation. In addition, the digital and film exposures used in angiography are measured with 2.5 inches of plexiglas and 1/16 inch of Cu or other appropriate attenuators in the beam.

5.2 Cardiac Catheterization Rooms

Introduction:

Cath labs generally can not be placed in manual mode. All exposures are made with fluoroscopy, digital and film cine. The kVp and mA are adjusted by the unit to obtain an optimal image. The standard tests used on R&F rooms are adjusted appropriately often in the same way as in specials rooms.

Equipment Required: RTI Barracuda MPD
Keithley 35050 Dosimeter
Keithley 35080A KVP Meter
Keithley Quality Control Kit
Copper (Cu) sheets
Procedure:

The following tests are performed with cine. The exposure is measured at the entrance to the Cu absorber. The output and kVp are measured at the entrance of three thicknesses of Cu. The kVp, mA on the generator is recorded as well as the mR/min and kVp from the Barracuda meter. The input exposure to the image intensifier is measured with two thicknesses of Cu in the beam. The image lag and automatic exposure control are evaluated by pushing an additional sheet of Cu across the image intensifier face. The focal spot is measured with a star pattern; the dimensions of the star pattern are measured on the video monitor. The standard fluoroscopy tests are performed testing: half value layer, high and low contrast resolution, maximum exposure rates, average exposure rates and x-ray beam collimation.

5.3 Computerized Tomography
Introduction:

With the increased use of computerized tomography as a diagnostic tool, the need has arisen for an efficient means of evaluating the performance of CT scanners. The image quality is measured with a procedure established by the manufacturer of the CT scanner. It permits the quantification of resolution, linearity, contrast, and noise. This procedure is listed in the Image Quality section of the manual. In addition to the use of CT phantoms, the patient dose for an average patient for each of the three most common examinations and the kVp at each station is measured.

Equipment Required: Plexiglas body phantom
Plexiglas head phantom
Keithley 35050 dosimeter
CT chambers for the dosimeter
Keithley 35080A KVP meter

Procedure:

The plexiglas phantoms is centered in the gantry. The one scan is performed with the exposure chamber in each of the five holes. The exposure readings are recorded and converted to exposure per slice. The five exposures per slice are recorded for each of the three common examinations: head, body and spine. The average techniques are obtained from the current protocol used by the technologists. The kVp meter is placed on the gantry and a scout view is taken at each of the kVp stations. The kVp is only required at the 120 kVp setting.

5.4 Nuclear Medicine
Introduction:

Nuclear Medicine imaging systems depend upon the integration of many components to produce quality diagnostic images. Detector crystals, photomultiplier tubes, amplification circuitry, video systems, and hard copy imaging systems, all contribute to the Nuclear Medicine image. Like other diagnostic tools, it is necessary to insure proper operation of the system through quality control measures. Also, it is extremely important to verify that patients receive the correct dose for the procedure to the performed. Dose calibrators must be checked routinely to confirm the reliability of the instrument.

The procedures for quality assurance are closely monitored by the State of New Hampshire. They are listed in the Nuclear Medicine section.
5.5 Mammography

Introduction:

Mammographic image quality is monitored by the American College of Radiology. The procedure and required performance criteria are given by ACR and is located in the Mammography section.
**GENERATOR:**

Room Number _______________  Date ___/___/___

Done at 80 kVp, 200 mA, 100 ms, at 40 inches

Reproducibility:

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Linearity:

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<td>mA (s)</td>
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kVp:

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Timer:

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<td>Set</td>
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**Tube:**

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<th>Room Number</th>
<th>Date</th>
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<td>____________</td>
<td><em><strong>/</strong></em>/___</td>
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</table>

**Output:** 20 mAs at 40 inches

<table>
<thead>
<tr>
<th>Voltage (kVp)</th>
<th>Small Focal Spot</th>
<th>Large Focal Spot</th>
</tr>
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<tbody>
<tr>
<td>50</td>
<td>______ mR</td>
<td>______ mR</td>
</tr>
<tr>
<td>60</td>
<td>______ mR</td>
<td>______ mR</td>
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<tr>
<td>80</td>
<td>______ mR</td>
<td>______ mR</td>
</tr>
<tr>
<td>100</td>
<td>______ mR</td>
<td>______ mR</td>
</tr>
<tr>
<td>120</td>
<td>______ mR</td>
<td>______ mR</td>
</tr>
</tbody>
</table>

**Half Value Layer:**

<table>
<thead>
<tr>
<th>Voltage (kVp)</th>
<th>Thickness (mm Al)</th>
<th>______ mR</th>
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<tbody>
<tr>
<td>80</td>
<td>2.0</td>
<td>______ mR</td>
</tr>
<tr>
<td>80</td>
<td>3.5</td>
<td>______ mR</td>
</tr>
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</table>

**Focal Spot Size:**

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<tr>
<th></th>
<th>Small Focal Spot</th>
<th>Large Focal Spot</th>
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<tbody>
<tr>
<td>Specified</td>
<td>______ mm</td>
<td>______ mm</td>
</tr>
<tr>
<td>Star Diameter</td>
<td>______ mm</td>
<td>______ mm</td>
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<tr>
<td>Blur Diameter</td>
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**Collimator Light Field Alignment:** Pass Fail

**Tomography:** (if applicable)

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<th>Measured</th>
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<td>Cut Thickness</td>
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<td>______</td>
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<tr>
<td>Cut Depth</td>
<td>______</td>
<td>______</td>
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</tbody>
</table>
Fluoroscopy:

Room Number _______________ Date ___/___/____

Maximum Fluoroscopic Exposure Rate: _______ R/min

For 12 sheets of 1/4 inch Plexiglass and 1/16 inch Cu:

Average Fluoroscopic Exposure Rate: _______ R/min

Average 100mm/PPR Exposure: _______ R/min

Average Spot film Exposure: _______ R/min

Spot Film Alignment: Pass / Fail

ABS Function:
1/32 inch Cu _______ kVp _______ mA
1/16 inch Cu _______ kVp _______ mA
3/32 inch Cu _______ kVp _______ mA

Phototimer Function:
1/32 inch Cu _______ Film Density
1/16 inch Cu _______ Film Density
3/32 inch Cu _______ Film Density

Image Quality:
II Mode: _______ inch _______ inch _______ inch

Low Contrast Resolution: (at Table top or II ?)

4%: _______ Holes _______ Holes _______ Holes

2%: _______ Holes _______ Holes _______ Holes

High Contrast Resolution: (Table top or II ?)

_______ Mesh _______ Mesh _______ Mesh
Cassettes and Image Plates

Introduction:
Warped cassettes, worn closures, dirt, light leaks, etc., frequently produce unsharp or fogged radiographic images. In order to minimize these problems, it is necessary to inspect the condition of each cassette and image plate quarterly.

Equipment Required: 99.5% Ethanol
Lint free cleaning clothes

1. Physical Condition:
   A. Observe cassettes for defects of closures, hinges etc..
   B. Clean the cassette body and image plate

Evaluation of Results:
Physical Inspection - Any defects found should be recorded in the inspection column of the master cassette inventory list. Cassettes with defects affecting image quality should be removed from service until repaired or image plate replaced.

Any negative findings should be brought to the attention of the Asset Manager so appropriate action may be taken.
Reject Analysis

Background:
The digital imaging equipment provides an efficient, accurate, and objective method of obtaining image reject (repeat) information as well as Exposure Index/Sensitivity Number statistics. This information is used to evaluate training and orientation needs for the routine radiology section and helps improve staff performance and patient care.

Equipment Required:
- Thumb Drive
- Calculator

Standard Reject Reasons:
- Positioning Error
- Exposure Error
- Patient Motion
- Image Artifact
- Student Reject
- Service Testing
- Equipment Problem

A. Reject Analysis:

Procedure:
Within the first week of the month, the previous month’s reject information is taken from all DR and CR units in the diagnostic section and stored to a department thumb drive. When software changes are made to the digital equipment, this information is taken at that time in order to maintain accurate reject rate data for the month. The data retrieved includes: overall reject rate, exam/view reject rate, and Exposure Index statistics (where possible). This information is emailed to the Diagnostic Team leaders, the Radiology Coordinator, the Clinical Operations Manager and Administrative Director and stored on the department ‘I’ Drive directory.

Interpretation of Results:
Student and Service Testing rejects are subtracted from the overall reject rate from each unit. The individual rates are averaged to determine the overall rate. Individual CR and DR rates as well as any outstanding data at the exam level are also reviewed and reported for training/orientation needs. Where possible, Exposure Index and Sensitivity Number data is recorded.

Reject Rate: A reject rate below 8% is targeted for the combined CR/DR rate.
Radiographic Illuminators & Monitors

Introduction:

The conditions under which a radiologist, clinician, etc., views radiographic images may influence diagnostic accuracy and stamina. Viewing conditions include the brightness of the illuminators/monitors as well as the ambient room light level. Undesirable radiographic viewing conditions include:

A. Low intensity illuminators or monitors.
B. High ambient room light levels.
C. Gross mismatch between viewing conditions used by the radiologist and viewing conditions used by the technologists to check images.
D. Illuminators in the same viewing area having grossly mismatched intensities and/or color.

Non-uniformity of radiographic illuminator brightness most commonly occurs when bulbs are replaced without regard to matching their color or intensity and when the output of the lamps changes with age.

Equipment Required: GE or Philips Lamps
Cleaning Supplies

Procedure:

Inspect all view boxes for burnt or blackened bulbs. If bulbs need to be replaced, use only GE or Philips cool white fluorescent tubes. Viewboxes are cleaned and checked to insure adequate light output. The switches are inspected. Any mar's or artifacts are removed from the illuminators. Illuminators are inspected annually.
Aprons and Shields

Introduction:
Aprons and shields are an integral part of protection of both patient and operator. Therefore, it is necessary to insure that aprons and shields are free from defects that might reduce the effectiveness of their use. Aprons and shields are inventoried and tested on an annual basis.

Equipment Required: Fluoroscopic X-Ray Unit

Procedure:
Inspect each area for the presence of aprons and shields. Only shields that have a number should be in use. Remove all unnumbered pieces of lead shielding from service. All aprons are numbered with an inventory number. After testing, insure all aprons and shields are returned to their designated area.

Using the fluoroscopic x-ray unit on automatic brightness, collimated to the appropriate size, scan the apron or shield. Look for any signs of tears or rips and mark them with a felt pen on the apron. Any slight defects may be acceptable if not located in a vital area.

Interpretation of Results:
Note the condition of the apron and record the fluoroscopy results in the apron and shields section of the Quality Control records. Defective aprons and shields must be removed from service and reported to the Asset Manager for appropriate action.
Image Quality

Image quality for all modalities in Diagnostic Radiology are monitored as appropriate and to meet all state and federal requirements and at least annually by the Diagnostic Physicist.

1. Routine and R&F Equipment:
   Image quality for x-ray and fluoroscopic systems is measured with the compliance procedures described in previous section. The compliance requirements are intended to assure good image quality with minimum patient exposure. The compliance measurements are sufficient to assure diagnostic image quality.
   For routine radiographic equipment, the kVp and automatic exposure control must be measured. The procedures for measuring the above are found in the Compliance section of this manual. The kVp will be within 10% of the set value. The automatic exposure control will produce no more than 0.5 changes in mR/mAs taken of different thicknesses of plexiglas.
   For fluoroscopic systems, automatic brightness control, kVp, fluoroscopic exposure for an average phantom, high contrast resolution and low contrast resolution must be measured. The procedures for measuring the above are found in the Compliance section of this manual. Two holes on the 4% low contrast resolution phantom and one hole on the 2% low contrast resolution phantom will be visualized. At least one line pair per millimeter will be visualized.

2. Nuclear Medicine Equipment:
   Image quality tests for gamma cameras includes flood phantoms and bar phantoms for all imagers. There should be no apparent variation in intensity across the computer corrected flood phantom. The NEMA uniformity tests will be the standard. Center and full field of view uniformity will be no larger than 10%. Two sets of bars will be visualized on the bar phantom images for all systems.

3. Ultrasound Equipment:
   Image quality in Ultrasound is tested with the a multipurpose ultrasound phantom. The vertical and horizontal position linearity, low contrast resolution and high contrast resolution will be estimated. Errors in the vertical and horizontal position will be less than 5mm and 8mm, respectively. The high contrast resolution will be sufficient to resolve the 16/(MHz) mm lines. The low contrast resolution will be able to resolve three large disks.

4. Mammography Equipment:
   The numbers of contrast objects resolved in images of the American College of Radiology phantom measures image quality very accurately. The procedures and performance criteria are kept in the section of mammography.

5. Special Procedures and Cardiac Catheterization Laboratories:
   The compliance testing for these rooms includes image quality testing. The high and low contrast resolution for the imaging chain are recorded. The procedures are given in the compliance testing section of this manual. The kVp will be within 10% of the set value. On fluoroscopy, two holes on the 4% low contrast resolution phantom and one hole on the 2% low contrast resolution phantom will be visualized. At least one line pair per millimeter will be visualized in all image intensifier modes.
6. Magnetic Resonance Imaging Equipment:
   The homogenous ball phantom will be imaged. The body SNR will be between 100 and 140. The head SNR will be between 80 and 130. The head and body T2 will be between 60ms and 90ms.

7. Computed Tomography Equipment:
   The GE QC phantom will be imaged. The CT number scale will show a difference between water and polyethelene of 120 ± 20 CT numbers. The slice thickness will be with in 20% of the set value. The low contrast will show standard deviations of 3.5 ± 0.5.