Ontario Breast Screening Program

Digital Mammography Quality Control for the Mammographic Physicist

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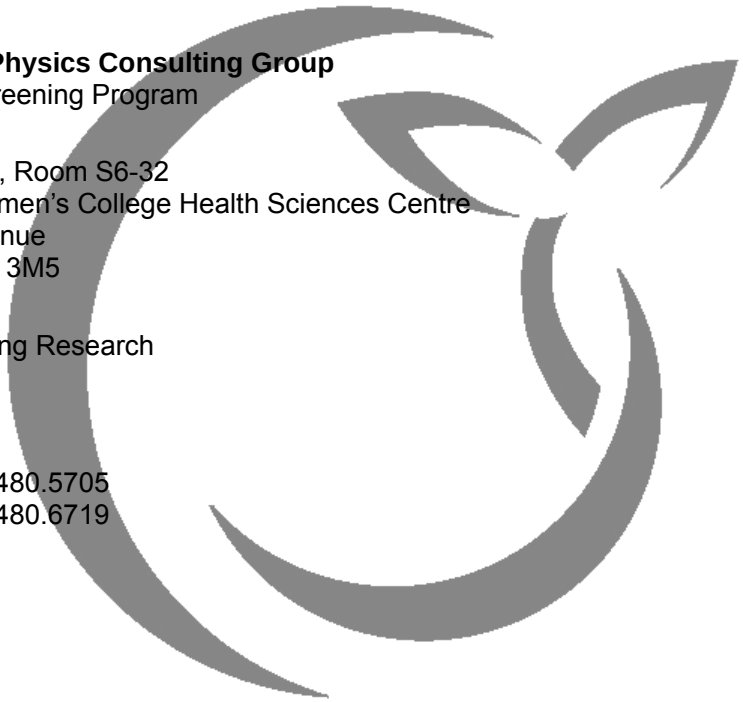

A Program of Cancer Care Ontario / Un programme d'Action

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I. INTRODUCTION

The success of mammography, whether for screening or diagnosis, depends on the production of high-quality images at appropriate doses. Production of such images is a complex and difficult task. Poor quality mammograms lower the detection rate of early breast cancer, reducing the patient's chances of survival and undermining the public's confidence in the value of mammography. Furthermore, substandard mammography generates equivocal examinations leading to increased cost and anxiety to the patient. Achieving high-quality studies at acceptable dose requires vigilant attention to quality control, not only on the part of the radiologist and mammography QC technologist, but also on the part of the medical physicist.

This section of the *Digital Mammography Quality Control Manual* provides detailed procedures for tests to be conducted at least semi-annually by a medical physicist specialized in mammography to help assure proper mammographic system performance. These tests are designed to assess the continuing performance of digital mammography equipment. Similar tests are included for the mammography quality control (QC) technologist, detailing the procedures appropriate for routine QC testing.

The testing has been set up to separately test the acquisition system and display devices, assuming that facilities might have a number of models of acquisition systems, and diagnostic review stations from different vendors, all sharing the same PACS system. We are establishing the principle that if a workstation properly displays test images emulating those from a given acquisition device, that workstation will be a Verified Workstation. This does not validate that image hanging protocols will be properly followed, or that a given manufacturer's image processing will be properly applied. There is no evaluation included for secondary display devices, which are not to be used for interpretation.

An automatic software package called "Gladys" is being evaluated for use by the OBSP. This package was developed for use in the Flemish part of Belgium, and has a number of important features, greatly reducing the effort (recording and plotting) required for the QC program. The mammographic acquisition system automatically sends images of a patient named QC Mammo to this program that performs a complete analysis of the image quality, reporting the results to OBSP Physics through the internet. This greatly reduces the effort involved in regular QC, and enables detection of subtle problems. This will allow the physics group to detect problems quickly, and intervene before a problem becomes critical as well as reduce clerical and technologist time requirements.

The physicist and technologist tests are designed to verify the correct operation of the entire imaging chain, and to serve as a screening tool, rather than as a diagnostic tool. Tests should be performed at technique factors used clinically for digital mammography. When problems are detected, further tests may be required to diagnose and isolate the cause of the problem so that it can be corrected. Depending on the resources available at the site and the nature of the problem, such diagnostic testing may be performed by the

Radiologic Technologist, the site's Medical Physicist, equipment service personnel, or other suitably trained and qualified personnel.

It is the responsibility of the medical physicist conducting or reporting these tests to convey test results accurately to the facility in a written report, to make recommendations to the facility for corrective actions according to the test results, and to review the results with the radiologist and QC technologist. HARP inspectors check the medical physicist's report to determine if the facility is in compliance with the regulations and if the medical physicist's recommendations are acted upon by the facility. Although CAR allows the medical physicist 30 days from the date of the survey to send their report to the facility, a 30-day delay in getting the report to the facility allows the facility no time to take corrective actions. It is essential to note that the CAR requires **immediate** corrective action by the facility for failure of nine of the medical physicist's tests: failure of some aspects of mammographic unit assembly evaluation (Medical Physicist Test # 1), excessive image artifact (Medical Physicist Test # 5), excessive breast dose (Medical Physicist Test # 8), deficient Modulation Transfer Function (Medical Physicist Test # 11), excessive geometric distortion (Medical Physicist Test #13) and problems with the softcopy and/or hardcopy display (Medical Physicist Test #s 14, 15, 16 and 17). If any of the aforementioned tests, excepting tests 14-17, fails, a facility may not conduct mammography with that equipment until the problem is corrected. If any of tests 14-17 fails, the tested display device may not be used to interpret digital mammograms until the problem is corrected. If the monitor being evaluated is on a review workstation, acquisition does not need to be stopped, unless repair cannot be achieved within three working days and no other approved review workstations are available for image interpretation. For a facility to comply with this new requirement, the medical physicist must not only collect test data during the survey, but must also immediately evaluate results and compare them to the pass/fail criteria. Most importantly, the medical physicist must immediately communicate this failure to the facility. It is strongly recommended that failures be immediately communicated to the facility both verbally and in written form. One way to accomplish this is by leaving the facility a preliminary report upon departure.

Communication of test results and recommendation of corrective actions are areas that can be improved in the practices of most medical physicists. Corrective actions should not be limited to repair of x-ray equipment by a qualified service person, but should include recommendations that will improve image quality, including recommendations concerning image receptors, technique factors, viewing conditions, hanging protocols, PACS / image archiving and technologist QC. The medical physicist should periodically review the results of technologist QC tests (at least semi-annually) and make recommendations regarding these tests, if needed. Furthermore, the medical physicist should participate in periodic reviews of the mammography QC program as a whole to assure that the program is meeting its objectives (See Section III).

Note that a new requirement for FFDM QC is that the physicist conducts baseline testing to establish target values for the technologist's quality control program. Target values, action levels, acquisition device specific test images and forms specific to the facility

equipment are to be provided by the Medical Physicist. As such, procedures for establishing QC baselines are included in this document. Baselines should be established at equipment acceptance, and re-established when significant changes or repairs have been made to the unit, when the equipment is known to be operating correctly.

Comment: This is the technologist baselines sheet in the workbook

To assist the medical physicist in communicating test results, recommendations, and target value information, Summary Forms have been included in the physicist's excel spreadsheet. A Preliminary Results form is provided for the medical physicist to leave brief, handwritten results for the facility prior to departure. This immediate communication is particularly essential to allow adequate time for the facility to take corrective action should any tests fail.

Comment: Check that viewing conditions and all baseline QC numbers are available. SDNR OD on steps for laser printer etc.

A list of resources and additional references relevant to digital mammography is included at the end of this manual. There is a Glossary that explains words and acronyms used in this document which are unique to digital mammography, and also some that might not be clear to those new to the field.

An equipment evaluation must be performed on all units and all tests must be passed before the unit is used on patients. This evaluation is to be performed by, or the tests should be reviewed by a medical physicist qualified in digital mammography. Equipment evaluations involve the performance of all technologist's and physicist's QC procedures (except retake analysis) in this manual, ensuring that the basic minimum criteria are met for each test. The values obtained during the initial equipment evaluation are to be used as baseline values, and then referred to during future evaluations to determine if equipment performance is deteriorating.

Images are generally provided to PACS systems in a "For Presentation" form, which assumes that the display device complies with the DICOM gray scale display standard. Most of the tests in this Quality Control program require images in the "For Processing" or "Raw" format. The raw format produces pixel values which are directly related to the radiation interacting in that pixel which enables the evaluation of signal levels and noise without histogram modification or frequency modification which is sometimes performed on "For Presentation" images. It may be important to ensure that the "auto-push" DICOM server is set to the appropriate state to collect these "raw" images at the beginning of a test session, and returned to the original state at the completion of the testing.

Before performing the tests on the unit, open the spreadsheet provided, and save it with the following suggested naming scheme:

YYYYmmmdd_CityOrTown_SiteNameInitials_UnitNameIfNecessary.xls,

where YYYYmmmdd is the year month and day the tests are performed, for example,

2008Apr16_MyTown_ABC.xls or 2008Dec21_ThisCity_ABC_Lorad.xls.

Move the sheets that don't apply to your type of unit to the end of the spread sheet pages

after the worksheet "end of tests" to show the following sheets can be ignored. Deleting sheets may result in the failure of some automatic functions. The original document was designed to make data entry at the test site easier. For the published report, reorder the sheets into numerically increasing order based on the number in the sheet name. Sheets without a number can be moved past the "end of tests" sheet.

Where specific settings are recommended in this document, the closest setting that meets the logical intent of the test should be used.

The physicist is also required to upload test images to the facility PACS system for the evaluation of monitor performance. For sites that are using Gladys, a separate manual will be provided for the installation of the software, and a training manual for the technologist will be supplied.

In addition to the generic tests specified in this manual, manufacturers may also specify tests which they consider must be performed, the results of which should be checked by the medical physicist, but the performance of the tests in the format specified in this document takes precedence. This is essential to allow comparison of equipment across manufacturers, and across medical physicists.

The following table lists the physicist's test procedures and their recommended frequencies.

Table 1: FFDM Medical Physicist's QC Procedures

Procedure #	Procedure Name	FFDM System	Minimum Frequency	Timeframe for Corrective Action	Relevant Forms
1	Mammographic Unit Assembly Evaluation	All	Equipment Evaluation & Semi-Annually	Immediately/ Within 30 days of the test date depending on the problem	Chart 1
2	FFDM Accreditation Phantom Image,	All	Equipment Evaluation, & Semi-Annually	Immediately	Chart 2, Tech. Baselines
3	Missed Tissue	All	Equipment Evaluation, & Semi-Annually	Immediately	Chart 2
4	Technique Chart/AEC Evaluation (SDNR)	All	Equipment Evaluation, Semi-Annually	Within 30 days of the test date	Chart 4
5	Artifact Evaluation	All	Semi-Annually	Within 30 days of the test date or immediately	Chart 5, Tech.

				depending on clinical significance	Baselines
6	Tube output mR/mAs	All	Semi-Annually		
7	Beam Quality Assessment – HVL	All	Semi-Annually	Within 30 days of the test date	Chart 6
8	Breast Entrance Exposure and Average Glandular Dose	All	Semi-Annually	Immediately	Chart 8
9	Ghost and Lag Image Evaluation	All	Equipment Evaluation	Within 30 days of the test date	Chart 9
10	X-Ray Field Evaluation	All	Equipment Evaluation	Within 30 days of the test date	Chart 10
11	Modulation Transfer Function (MTF) Measurement	All	Semi-Annually	Immediately	Chart 11
12	Noise and Linearity	All	Equipment Evaluation	Within 30 days of the test date	Chart 12
13	Spatial Linearity and Geometric Distortion of the Detector	All moving parts	Equipment Evaluation, Semi-Annually	Immediately	Chart 13
14	Monitor Display Quality	All Softcopy	Semi-Annually	Immediately	Chart 14
15	Monitor Luminance Response, Viewing Conditions and Baseline Values	All Softcopy	Semi-Annually	Immediately	Chart 15
16	Viewbox Luminance and Room Illuminance	All Hardcopy	Semi-Annually	Immediately	Chart 16
17	Laser Printer Evaluation and Baseline Values	All Hardcopy	Semi-Annually	Immediately	Chart 17
18	Technologist's QC Program Evaluation	All	Semi-Annually	Within 30 days of the test date	Chart 18

HARP regulations require that quality control records be "maintained for at least six years from the time of their making in the facility in which the x-ray machine to which the records referred is operated". These records must include type and result of test, frequency of testing and actions taken to correct each deficiency identified. In addition, OBSP policy is that QC test images must be retained according to Table 2.

Table 2. OBSP Requirements for Mammography QC Test Image Retention

QC Images	Retention
Daily QC	previous 30 days.
Weekly QC	previous 12 weeks.
Monthly QC	until the next semi-annual inspection has been completed
Quarterly QC	until the next semi-annual inspection has been completed

Semi-annual QC tests	until the next annual inspection has been completed and a Medical Physicist has determined that the facility is in compliance with the quality assurance requirements
Semi-Annual QC tests	the OBSP ***recommends*** that images documenting test failures be provided to the facility to assist them in making corrective actions.
Mammography Equipment Evaluations	the OBSP ***recommends*** that images documenting test failures be provided to the facility to assist them in making corrective actions. See Table 3.

The following table lists the images generated by the physicist's tests which need to be kept for OBSP and archival purposes, along with a suggested patient naming convention. Suggested Patient names are given. "Patient" Ids should be chosen in a manner that aids in identifying the image and does not conflict with actual clinical data in the hospital PACS or HIS/RIS system.

Table 3: Images generated by physicist's tests of digital mammography unit

Procedure #	Procedure Name	Patient Name	Images Required	# of Images Expected
1	Mammographic Unit Assembly Evaluation	NA	No	0
2	ACR FFDM Accreditation Phantom Image	Physics, Phantom	Yes	1 or more
3	Missed Tissue	Physics, Phantom	No – uses images from procedure 2	0
4	Technique Chart/ AEC Evaluation (SDNR)	Physics, Tracking	Yes	4
5	Artifact Evaluation	Physics, Artifacts	Yes	2 or more
6	Tube Output	Physics, Dose	No	0
7	Beam Quality (HVL)	Physics, Dose	No	0
8	Breast Entrance Exposure/Mean Glandular Dose	Physics, Dose	No	0
9	Ghost/Lag Image Evaluation	Physics, Ghosting	Yes	2
10	X-Ray Field	Physics, XRField	Yes	1 or more

Comment: May be we should think of combining 4 and 5 into one test.

Comment: I think it is better to perform the electrical tests in the beginning (ie., before we start the imaging

Comment: Probably this might cause ghosts, but a good idea. How difficult would it be to change?

11	Evaluation System Resolution	Physics, Phantom	No-uses images from procedure 2	0
12	Noise and Linearity	Physics, NLR	Yes	4 or more
13	Geometric Distortion	Physics, Distortion	Yes	1

II. FFDM QUALITY CONTROL TESTS

NOTES:

The following tests are designed to be performed using an excel spreadsheet for data collection. The majority of image acquisition information is initially collected in two tables (Table A – Raw Image Acquisition and Table B – Processed Image Acquisition). The information in these tables populates the various charts where the images are analyzed.

Except where explicitly indicated, images should be acquired in a "Raw"/"For Processing" mode, where any user-selectable post-processing options and/or image enhancements are turned off. This maintains a clearer relationship between pixel values and incident x-ray exposure to the detector.

1. PROCEDURE: MAMMOGRAPHY UNIT ASSEMBLY EVALUATION

OBJECTIVE

To ensure that all locks, detents, angulation indicators, and mechanical support devices for the X-ray tube and breast support assembly are operating properly, and that the DICOM image file headers are correctly populated.

APPLICABILITY

This procedure applies to all full-field digital mammography systems.

TEST FREQUENCY

Equipment evaluations, semi-annually

TEST PROCEDURE STEPS

1. Verify that the freestanding dedicated mammography unit is mechanically stable under normal operating conditions.

2. Verify that all moving parts move smoothly, without undue friction; that cushions or bumpers appropriately limit the range of available motions; and that no obstructions hinder the full range of motions within these limits.

3. Set and test each lock and detent independently to ensure that mechanical motion is prevented when the lock or detent is set.

4. Verify that the image receptor holder assembly is free from wobble or vibration during normal operation.

5. Using the OBSP DMUP phantom, which is 4.0 cm thick, verify that the compressed breast thickness indication is accurate to within ±0.5 cm under conditions of moderate compression (15 to 20 lbs, or 7 to 9 daN) and reproducible to within ±2 mm. This should be done for all sizes of image receptors and for all compression paddles normally used by the facility. If the compressed thickness is printed on the image, or in the DICOM header, the correct value should be verified when images are taken of the FFDM phantom in later tests.

6. Verify that auto-decompression can be overridden to maintain compression (for procedures such as needle localizations) and its status displayed continuously (if auto-decompression is available).

7. Verify that compression can be manually released in the event of a power failure or automatic release failure by turning power off to the equipment with a phantom under compression and using manual controls to release the compression.

8. Verify that, in normal operation, the patient and operator are not exposed to sharp or rough edges or other hazards including electrical hazards.

9. Verify that the operator is protected by adequate radiation shielding during exposure. Ensure that the x-ray switch cannot easily be operated without standing behind the shielding. The switch must require continuous pressure by the operator to produce x-rays.

10. Verify that current and accurate technique charts for 50/50, dense and fatty breasts are posted and confirmed by consulting with the mammography technologist.

11. Verify that all indicator lights are working properly. Controls, meters, lights and other indicators must be readily recognizable and clearly identifiable as to function. There must be some indication when the machine is energized and ready to produce x-rays (tube spun up) and when x-rays are being produced. The selected technique factor(s) must be visible to the operator before the patient is irradiated in manual mode, and in AEC mode, the kV, mAs, target and filter must be displayed immediately after the exposure.

12. Using a set of scales or a compression test tool, verify that the maximum compression applied under powered drive is less than 20 daN (45 lbs), and that the maximum compression that can be applied by the technologist is no greater than 30 daN (67 lbs).

13. Verify that the unit's AEC or back-up timer terminates exposures before a maximum exposure of 2000 mAs is reached. This is most easily done by putting lead or other highly attenuating material in the beam to ensure the AEC aborts the exposure. An error message or reset light must indicate that the exposure has aborted to avoid exceeding the 2000 mAs limit. On most systems the exposure will be aborted with less than a 5 mAs exposure.

14. Verify that displayed or printed images contain the correct institution name and address, unit number (if more than one at the site), patient name, patient ID number, technologist's initials, projection, laterality and technique factors (kV, mAs, anode, filter), and that the time of image acquisition and the date are correct (Note that after software upgrades, the stored time zone or other data may have changed and be incorrect). This can be accomplished by looking at the information included with the image on the review workstation or on printed films, if available. Record that the values of displayed information are complete **or note necessary changes** on **Chart 1-B.**

15. Verify that the DICOM header *of any randomly selected patient image* is correctly populated with institution name and address, unit number, patient name, patient ID number, technologist's initials, projection, laterality and technique factors (kV, mAs, anode, filter), and that the time of image acquisition and the date are correct (Note that after software upgrades, the stored time zone data may have changed, and patient image times may be incorrect). This can be accomplished either by looking at the information included with the image on the review workstation or by looking at the contents of the DICOM header of an image with appropriate analysis software.

Comment: Is this in the tech man?

Record the presence and correct values of the header tags on **Chart 1-B**.

16. Record the pass or fail of each inspection item on **Chart 1**.

REQUIRED. A permanent identification (ID) label or DICOM header which contains at least the following information: **facility name, facility location** (at a minimum the location shall include the **city, province and postal code**), **patient name (first and last)**, and **additional patient identification number** (e.g., medical record number or social security number; date of birth is less desirable), and the **date of the examination**. .

OBSP REQUIREMENTS:

Mammographic image identification. Each mammographic image shall have the following information on it in a permanent, legible, and unambiguous manner and placed so as not to obscure anatomic structures:

(i) Name of patient and additional patient identifier.
(ii) Date of examination
(iii) View and laterality. This information should be placed on the image near the axilla. Standardized codes specified by the accreditation body shall be used to identify view and laterality.
(iv) Facility name and location. At a minimum, the location shall include the city, province, and postal code of the facility.
(v) Technologist identification
(vi) Cassette/screen identification (for CR systems).
(vii) Mammography unit identification, if there is more than one unit at a facility.

RECOMMENDED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

The digital mammography unit must be safely installed, and present no undue hazards.

Items that are hazardous, inoperative, or operate improperly should be repaired by appropriate service personnel.

TIMEFRAME FOR CORRECTIVE ACTION

Immediately, before any further patients are imaged, for all items except items 2, 5, and 6.

Within 30 days of the test date for items 2, 5, 6 and 13.

Comment: Wasn't improper compression an immediate show stopper? No, there is discretion involved.

2. PROCEDURE: PHANTOM IMAGE QUALITY

OBJECTIVE

To determine if overall image quality is at an acceptable level.

To determine the appropriate window width and level settings to be used for artifact evaluation.

To provide a check of the compression thickness reading in the DICOM header.

To provide images for MTF calculation (Procedure 11).

APPLICABILITY

This procedure applies to all full-field digital mammography systems.

TEST FREQUENCY

Equipment evaluations, after service to the image chain, or modifications to the image acquisition or correction software, or annually.

REQUIRED TEST EQUIPMENT

The ACR FFDM Accreditation Phantom with an MTF tool overlay.

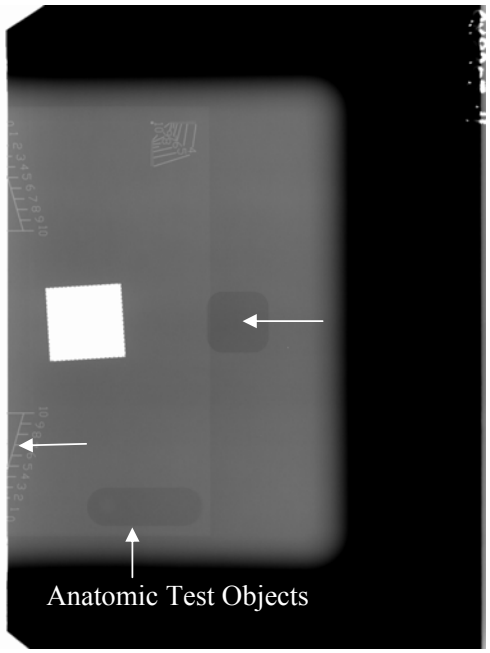

Figure 1: Radiograph of the ACR FFDM Accreditation Phantom, with test objects

identified.

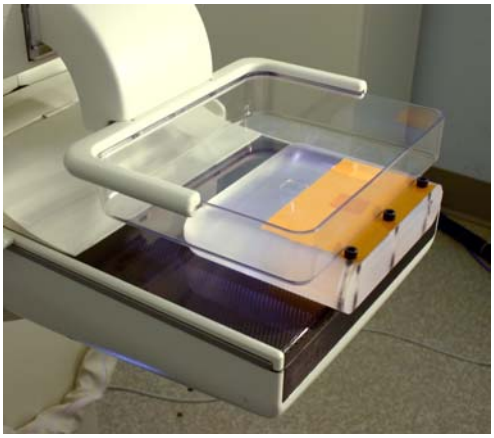

Figure 2: ACR FFDM Accreditation Phantom positioned for imaging

TEST PROCEDURE STEPS

1. Create a patient study with last name "Physics" and first name "Phantom". The patient ID number 9902UYYMMDD may be used, where U is the unit identifier.

2. Position the phantom on the breast support plate with the chest wall edge of the phantom pushed as close to the edge of the table as possible (see Figure 2). The compression paddle should be lowered and compressed to a pressure of 10 daN, while holding the phantom tightly to the table and compressor paddle edges. The phantom should be allowed to be pushed out if the flexing of the compressor paddle forces it to slide against firm pressure from the operator's hand. Ensure that the collimation is opened to the full imaging field. Note that for Lorad systems, the compression thickness displayed should be more than 3.9 cm so that a consistent mA is used.

3. Record the compression pressure, thickness and time of acquisition on **Table A**; this is used to check the correctness of information storage in the DICOM header.

4. Some systems provide only raw or processed images, not both. If that is the case, turn off any user-selectable image enhancements / post-processing.

5. Acquire an image of the phantom using the same settings (AEC preferred) which would be used for a 4.2 cm thick compressed breast consisting of 50% glandular and 50% adipose tissue (standard breast). There should be no pixel values in the uniform regions of the phantom or MTF square that reach the maximum pixel value for the system or fall to the minimum value. If the system has automatic exposure control, use an appropriate mode for the standard breast. If there is a moveable AEC sensor,

the position should be chosen to minimize interference of the overlay with AEC operation. On some systems, the AEC may not perform correctly on the phantom because of the overlay; a manual technique can then be established, which probably will be the technique used for the DMUP phantom images that the technologist takes weekly. For CR, process the imaging plate using a mode suitable for phantoms.

6. Leave the grid on for large-focal spot exposures and the compression paddle in place for all images. Use collimation that allows the full detector area to be imaged.

7. For CR systems, the image should be processed using parameters similar to those used for clinical images, but with image enhancements / post processing turned off. Record the S or EI and L numbers used to process the plate.

8. View the raw image on the acquisition workstation. Check that the phantom image is essentially artifact free before accepting it.

9. Record the acquisition parameters on Table A. This will populate **Chart 2**.

10. If patient images are interpreted in softcopy, view the raw image on the radiologist's softcopy display station.

11. Select a window width and window level that allows the anatomic test objects (see Figure 3) to be clearly visualized and artifact severity assessed, without introducing excessive noise artifacts into the image.

An artifact is considered significant if it is as visible as any of the anatomic test objects (Fibers, Speck Group and Mass, see Figure II2-4) included in the phantom, or obscures a test object, or would obscure a test object if its position were different.

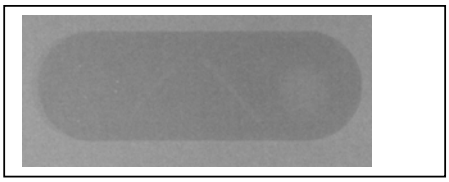

Figure 3: Anatomic test objects in the ACR FFDM Accreditation Phantom

12. If patient images are interpreted on hard-copy, print the image, using the window width and level settings established above. View the image on a mammographic quality viewbox. If the printed image is not suitable (too little or too much contrast, too light or too dark) for artifact evaluation, adjust the window width and level settings slightly and try again.

13. Record the window width and level settings on **Chart 2** and **Technologist Baselines Chart**.

It is not necessary to view the image on all available softcopy monitors. This is a test of image acquisition, not display.

14. Repeat steps 5 through 8 for each target and magnification used clinically. These images will be used to evaluate the modulation transfer function in Test Procedure 10: Evaluation of System Resolution. Record the acquisition parameters on Table A, which will automatically populate cells in chart 10. To obtain images with other anodes, it may be necessary to use manual exposure techniques. If so, ensure that the resulting exposure is reasonable – without 0 pixel values in the area behind the MTF square, and without saturated pixel values

15. For all images, ensure that there is at least 1 cm outside the MTF tool on all four edges within the field of view.

Processed Image performed with most common clinical technique

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16. If the system is using an acquisition mode designed for phantoms which only stores a raw image for each acquisition, repeat the first image acquisition (step 5, the one closest to the clinical technique for a standard breast, using AEC) with the image enhancements /post-processing used clinically turned on. This allows evaluation of any artefacts generated by image processing. Record the image acquisition parameters on **Table B**.

17. View the processed image on the radiologist's review workstation.

18. Select a window width and window level that allows the anatomic test objects (see Figure 3) to be clearly visualized and artifact severity assessed, without introducing excessive noise artifacts into the image.

19. If patient images are interpreted on hard-copy, print the image, using the window width and level settings established above. View the image on a mammographic quality viewbox. If the printed image is not suitable (too little or too much contrast, too light or too dark) for artifact evaluation, adjust the window width and level settings slightly and try again.

20. Record the window width and level settings on **Chart 2**.

DATA INTERPRETATION AND ANALYSIS

1. The images of the phantom should be viewed and inspected for artefacts. Record the window width and level used to display the first phantom image on **Chart 2**. A suitable window width is one which allows good visualization of the anatomic test structures within the phantom without exaggerating image noise.

2. The time and date of acquisition as displayed on the annotated image should be checked for correctness.

3. Examine the image for uniformity of sharpness across the image and for any distortion in the straight lines. Note that on systems with a curved breast support plate the lines will appear distorted/curved. This is normal.

4. The MTF will be evaluated in Procedure 10, "System Resolution".

SUGGESTED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

1. There shall be no artifacts which would interfere with the interpretation of an image, and none which could be confused with or mimic the objects in the phantom.

2. Artifacts should be rated as a failure if they could have clinical significance, and Marginal if they are easily identified, and would not mimic or reduce the ability to interpret pathology in the mammogram.

3. If there is any significant artifact or resolution non-uniformity, move (pan or rotate 90°) the image on the monitor to verify that the artifact is not a software or monitor problem. Seek service from a qualified service engineer to have the problem corrected

4. The Signal Difference-Noise-Ratio (SDNR) calculated for the FFDM Accreditation phantom should be greater than that specified in the table in the excel workbook.

TIMEFRAME FOR CORRECTIVE ACTION

If this test fails Artifact requirements do not image patients until the failure is resolved.

3. PROCEDURE: TECHNIQUE CHART / AEC EVALUATION

OBJECTIVE

To evaluate the ability of the system to image a clinically expected range of breast thicknesses and to ensure that images of adequate penetration and acceptable contrast–to-noise levels are produced.

To provide images for the evaluation of the spatial and electronic noise characteristics of the entire imaging chain.

To establish the imaging technique and viewing parameters to be used by the site for their monthly full-field artifact check.

To provide an imaging technique used in the estimation of mean glandular dose.

APPLICABILITY

This procedure applies to all full-field digital mammography systems.

TEST FREQUENCY

Equipment evaluations, semi-annually.

TEST PHANTOM REQUIREMENTS

Either of two test systems can be used, each including a contrast phantom and a set of attenuators. One system utilizes aluminum (preferred) and the other, PMMA as the uniform phantom material. A 1 mm thick PMMA disc is used as a contrast object. The phantoms must be at least 200 mm along the chest wall dimension, and 175 mm in the direction from the chest wall to the nipple. There should be no radiographically visible structure in the phantom other than the contrast disk, and possibly a serial number or other identification.

4 aluminum sheets, Type 1100, each 1.6 mm thick, free from defects (uniform attenuator).

A 25 mm diameter 1 mm thick PMMA disk to be placed on the top of the stack of aluminum sheets in the middle of the image field (contrast phantom).

Posts or spacers of length 1.84, 3.68, 5.52, and 7.36 cm to set compression paddle position if Al sheets are used.

Or

A set of uniform PMMA slabs, free from defects, to be added to the contrast phantom to form thicknesses of: 4, 6, and 8 cm (uniform attenuator).

A 2 cm uniform PMMA slab with a flat-bottomed well 16 mm in diameter and 1mm deep milled into the top surface and centered (contrast phantom).

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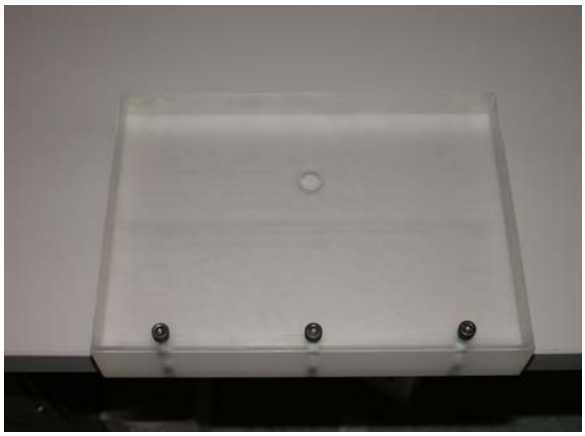

Figure 4: Image of a uniform phantom suitable for artifact evaluation and MGD estimation.

TEST PROCEDURE STEPS

Comment: Add Density step eval for CR (recording mAs only)

1. Create a patient study with last name "Physics" and first name "Thickness". The patient ID number "9903UYYMMDD" may be used.
2. Place the contrast phantom on the tabletop so that the front edge is aligned with the chest-wall edge of the breast support. Use collimation that allows the full detector area to be exposed.
3. For the aluminum sheet, place the 1.84 mm spacer post near the edge of the image area away from the chest wall.

Deleted: 9

4. Lower the compression plate and apply a compression force of 10 daN.
5. Set the AEC or kV, target and filter to the appropriate technique for that thickness of phantom.
6. Expose an image, and record the kV, target, filter and mAs on **Table A**, to populate **Chart 3**.
7. Repeat steps 2 through 6, adding slabs of uniform attenuator under the contrast phantom, and in addition, for the aluminum, inserting the appropriate post to obtain thickness equivalents of 4, 6 and 8 cm (3.2,4.8,6.4 mm Al).

8. Replace the 4 cm equivalent phantom (4 cm PMMA or 3.2 mm Al with 3.68 cm post).

9. For CR systems make exposures using the automatic exposure control's density adjustments, spanning the range of density settings available (typically -5 to +5). Record the mAs used to image the phantom each time. It is not necessary to process the imaging plate after each exposure – the digital image will not be used. The objective is to ensure the density setting adjusts the mAs in a reasonable manner.

10. For CR systems, process the imaging plates with a setting that allows the sensitivity number to vary based on a fixed region of interest, with all post-processing algorithms turned off. Record the resulting sensitivity (S) number or exposure index (EI) for each plate.

11. To evaluate thickness tracking SDNR, use appropriate window-width and window-level settings that allow clear visualization of the contrast area on the raw (unprocessed) images taken of the 2, 4, 6 and 8 cm equivalent phantoms.

12. Choose a region of interest (ROI) on the image completely inside the contrast area and measure the signal level, recording it as A.

13. Choose an ROI located just beside the contrast disk, and measure the background signal level B, and the background standard deviation, C. For CR systems, these measurements must be done using software to convert the pixel values to linear space based on the S and L numbers or EI number.

14. Enter results on **Chart 3**.

DATA INTERPRETATION AND ANALYSIS

1. The signal difference to noise ratio (SDNR) is calculated as:

$$SDNR = (A-B)/C$$

RECOMMENDED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

1. The SNR and SDNR values for images of 2, 4, 6 and 8 cm of material should be within the range shown on Table 2, when the images are acquired using AEC (where applicable) or according to the posted technique chart (where applicable).

2. The techniques chosen shall not result in an image pixel exposure time greater than 5 seconds.

3. If the performance criteria for SDNR are not met, then the AEC should be adjusted or the technique chart should be revised.

TIMEFRAME FOR CORRECTIVE ACTION

Immediately, before any further patients are imaged.

Table 2: SDNR limits for AEC Evaluation

Comment: This should be table 4

System	**cm equivalent material**							
	2		4		6		8	
Lower and Upper SDNR Limits	>	<	>	<	>	<	>	<
Fuji CR								
GE 2000D	3.4	8.1	2.3	6.9	1.8	5.4	1.7	4.0
GE DS (with FineView on)	1.9	6.7	1.6	4.8	1.4	3.6	0.8	3.3
GE Essential with (FineView on)	5.7	6.9	2.2	6.0	2.3	4.5	2.3	3.3
Kodak CR								
Lorad Selenia								
IMS Giotto								
Planmed								
Sectra								
Siemens Novation	1.9	3.3	1.7	2.9	1.5	2.7	0.8	2.4
Siemens Innovation								

4. PROCEDURE: ARTIFACT EVALUATION

OBJECTIVE

To assess the degree and source of artifacts visualized in full-field digital mammograms or phantom images.

To ensure that the flat field image is uniform.

For CR systems, to evaluate the uniformity of system sensitivity of the imaging plates, reader and Printer/Processor.

To establish the baseline values to be used by the site for the weekly SDNR check.

To establish the imaging technique and viewing parameters to be used by the site for their monthly full-field artifact check.

APPLICABILITY

This procedure applies to all full-field digital mammography systems.

TEST FREQUENCY

Equipment evaluations, after service to the tube head, detector or modifications to the image acquisition or correction software, annually.

TEST PHANTOM REQUIREMENTS

The uniform phantom OBSP DMUP used by the site for its weekly QC and monthly full-field artifacts check. This will include a 1 mm thick contrast disk for SDNR measurements

A 2 cm phantom for magnification imaging.

TEST PROCEDURE STEPS

1. Open a patient with the last name “Physics” and the first name “Artefacts”.

2. Place the site’s DMUP phantom (4.0 cm) on the tabletop so that the front edge extends beyond the chest-wall edge of the breast support plate and the phantom is centered left-to-right in the image field. Leave the grid on for large-focal spot exposures and the compression paddle in place for all images. Use collimation that allows the full detector area to be imaged.

3. Apply a compression force of 10 dN to the phantom.

4. Set the exposure mode the site would use for a clinical image of a breast of similar thickness. Turn off any image enhancements or post-processing options.

5. Expose the image, and for CR systems, record the S or EI and L numbers used to process the plate.

6. Enter the imaging parameters on Table A. This will populate **Chart 4**, and the **Technologist Baseline Chart**.

7. For CR systems, after a 2 minute wait, the plate should be processed using a mode suitable for phantom imaging.

8. Move the phantom position slightly to one side before acquiring the next image. This will allow for easy identification of phantom-caused artefacts.

9. Repeat steps 5-8 for all anode and filter combinations used in clinical practice. Use either AEC or manual techniques that result in a reasonably exposed image. For DR systems, the signal level in the raw images should be within 20% of the signal level in the FFDM Accreditation Phantom raw image. For CR systems, the sensitivity (S) number or exposure index (EI) should be within 20% of that obtained for the FFDM Accreditation Phantom raw image. Only one image at a typical clinical kVp is required for any given target/filter combination. At least one image must be taken on each filter available for selection, even if they aren't used clinically.

10. Install the magnification stand (if used clinically).

11. Place the 2 cm equivalent uniform phantom on the magnification stand.

12. Select the AEC mode used clinically for mag-stand imaging of a 2 cm thick breast.

13. Expose the image, and for CR systems record the S or EI and L numbers used to process the plate.

14. Enter the imaging parameters on Table A.

15. Repeat steps 10-14 for other magnification stand positions (magnification factors) and anode-filter combinations. It is not necessary to exhaustively image all possible permutations of magnification stand positions and target/filter combinations, but each mag-stand position should be used at least once, and the most commonly used target/filter combinations should be used at least once with the magnification stand.

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DATA INTERPRETATION AND ANALYSIS.

1. If patient images are evaluated in soft-copy, examine the raw images using the radiologist's review workstation.

2. Select a window width and window level that allows artifact severity assessment, without introducing excessive noise artifacts into the image. Adjust the window width to match that selected for evaluating the ACR FFDM Accreditation phantom and adjust the window level to give a mid-gray.

3. If patient images are interpreted on hard-copy, print the images using the window width and level settings established in step 2. View the image on a mammographic quality viewbox. If the printed image is not suitable (not enough or too little contrast, too light or too dark) for artifact evaluation, adjust the window width and level settings slightly and try again.

4. Record the window width and level settings used on **Chart 4**.

5. Display the unprocessed ("raw" or "for processing") image (if it is possible) of the site's uniform phantom taken in Step 4 on a workstation that provides region of interest analysis. This will be used to provide a baseline for the technologist's routine phantom test.

6. The image should be displayed so that the contrast square or disk is clearly visible (see Figure 4). In order to calculate signal difference to noise ratio (SDNR) place a circular ROI of approximately 1 cm in diameter (approximately 0.8 cm^2) over, and entirely contained within, the 20mm x 20 mm contrast square. Record the mean signal value (or mean ADU) within the contrast square and label this values as "A" on **Chart 4** - it will be used to calculate SDNR.

7. In a region outside, but immediately adjacent to the square or disk, record the mean and standard deviation within a similarly sized ROI as used above as B and C, respectively, on **Chart 4**.

8. The signal difference to noise ratio (SDNR) is calculated as:

9. SDNR = (A-B)/C

10. Examine the images of the uniform phantom(s) carefully for artifacts. These may include: dust or dirt, "ghost" images left over from repeated test or clinical exposures, filter blotchiness, stitching artifacts, clipping/electronic noise, spatial non-uniformities, film handling artifacts, plus or minus signal variations, processing artifacts, grid lines, streaking in the horizontal or vertical directions, bad pixels, and other equipment-induced artifacts. Record any visible artifacts on **Chart 4**.

Comment: Are there more types for artifact mentioned here than elsewhere?

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11. For CR, examine the images for evidence of dirt on the plates (minus density specks) and dirt in the reader (minus density lines across the images).

12. The image should be examined for flat field uniformity to ensure that the image does not have non-uniformities across the field of view. For CR, bear in mind that the heel-effect is not compensated for by the CR reader's processing algorithms, so some non-uniformity due to the x-ray beam is expected.

13. Review the images for all clinically used target/filter combinations.

14. If any artifacts or non-uniformities are present, rotate the phantom 90^o and repeat the exposure and acquisition procedure. For CR systems, the cassette may be placed on

the table top, rotated at a 45 degree angle, to determine if the artifact is filter or x-ray tube generated. Any artifacts or non-uniformities that keep a fixed orientation relative to the image receptor in both images and are deemed significant probably require a re-calibration of the gain file specific to the target/filter combination in question.

15. If the artifact or non-uniformity remains, service by a qualified service engineer should be obtained and the problem fixed.

16. For acceptance testing, ensure that some of the thickness tracking images are also examined to ensure the flat-fielding algorithm works well across the range of 2-6 cm, and not just for the thickness of the site's uniform phantom.

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CALCULATION OF OPERATING POINTS AND LIMITS

1. Calculate the upper and lower mAs control limits. The mAs lower limit is 0.9 x target mAs. The mAs upper limit is 1.1 x target mAs.

2. Calculate the upper and lower ADU control limits. The ADU lower limit is 0.9 x target ADU. The ADU upper limit is 1.1 x target mAs.

Comment: On the tech man chart 3 is the ADU just called Signal?

3. Calculate the SDNR control limits. The SDNR lower limit is 0.90 x target SD NR. The upper limit is 1.1 x the target value.

Record the target values and upper and lower control limits on **Technologists Baselines Worksheet**.

Comment: Currently we are not doing this part!!

Yes, but we should be - Gord

RECOMMENDED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

There will be no visible dead pixels, missing lines or missing columns of data.

There will be no visually distracting structured noise patterns in a uniform phantom image.

There will be no regions of discernibly different density on a raw image of a uniform phantom when viewed on radiologist workstation with a window width setting and a window level setting such that a majority of the image is mid-gray.

Comment: A more specific criterion is needed

If unacceptable artifacts are noted, the service person should be contacted.

Comment: Should we give some examples of artifacts which are unacceptable??

TIMEFRAME FOR CORRECTIVE ACTION

Immediately, before any further patients are imaged.

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5. PROCEDURE: BREAST ENTRANCE EXPOSURE AND BEAM QUALITY ASSESSMENT (H V L)

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OBJECTIVE

To assure that the half-value layer of the x-ray beam is adequate to minimize patient breast dose, while not so excessive that contrast is lost in the resultant image.

To measure the typical entrance exposure rates (mR/mAs) or air kerma of the system for clinically used techniques.

To ensure that the x-ray beam quality is consistent with the target, filter and kV selected.

To enable the calculation of mean glandular dose.

To verify the reproducibility of the x-ray generator.

Deleted: To determine radiation output of the air kerma rate of the system.¶

APPLICABILITY

This procedure applies to all full-field digital mammography systems.

TEST FREQUENCY

Equipment evaluations, semi-annually

REQUIRED TEST EQUIPMENT

Ionization chamber and electrometer calibrated at mammographic x-ray beam energies (the calibration factor should be constant to within ±1% over the HVL range from 0.2 to 0.6 mm Al). A chamber which is not sensitive to backscatter is preferred, otherwise a correction should be made for backscatter.

Sheets of 99.9% pure aluminum (type 1145 aluminum alloy) of length and width sufficient to cover the ionization chamber fully. The stated thicknesses should be accurate to within ±1%. The total thickness of all the aluminum sheets should be at least 0.6 mm. At least one sheet should be 0.1 mm thick or less. One possibility is 6 sheets, all 0.1 mm thick, another possibility is the following combination of thicknesses: 0.05 mm (2 sheets), 0.1 mm (1 sheet) and 0.2 mm (2 sheets)

Lead sheet to protect the image receptor.

NOTE: The use of type 1100 aluminum alloy for HVL measurement can give (depending on specific samples) HVL values up to 7.5% lower than those measured using type 1145 aluminum. If type 1100 aluminum is used, results should be corrected to agree with those obtained using type 1145 aluminum.

TEST PROCEDURE STEPS

1. Create a patient with last name "Physics" and first name "Junk". The patient ID "9905UYYMMDD" may be used. These images will not be viewed or saved. This

Comment: It would be nice to have a table of these with the titles and tests.

same patient study will be used for procedure 8.

2. Place a lead sheet on the breast support surface to protect the image receptor.

3. Place the ionization chamber so its top surface is approximately 4.5 cm above the image receptor holder assembly, centered left to right and 4 cm in from the chest wall edge of the image receptor. The ionization chamber should be fully within the x-ray field.

4. For scanning systems (Fischer Senoscan) ensure that the dosimeter is set to integrating mode rather than pulse mode.

5. Record the temperature and barometric pressure, so any necessary corrections can be applied to the measurements.

6. Select the most commonly used clinical kV and record on **Chart 6**.

7. Set the unit to manual timing, with a time setting sufficiently long to provide an exposure of approximately 500 mR, and record mA and time (or mAs).

8. Make an exposure without any aluminum sheets between the x-ray tube and the ionization chamber. Record the dosimeter reading on **Chart 6**.

9. Add some sheets of aluminum between the x-ray tube and the ionization chamber, by placing the aluminum on top of the compression paddle. Make an exposure and record the ionization chamber reading and thickness of aluminum on **Chart 6**.

10. Repeat step 8 with additional sheets of aluminum between the x-ray tube and ionization chamber, recording the ionization chamber reading each time until the reading is less than one-half the original exposure reading (taken without any added aluminum sheets between the x-ray tube and chamber). Ensure that the incremental increase in aluminum thickness between the measurement where the reading is just greater than one-half the original exposure and the measurement where the reading is just less than one-half the original exposure is no more than 0.1 mm.

11. Remove all aluminum sheets from the top of the compression paddle, make a final exposure and record the chamber reading on **Chart 6.** If the result of this final exposure differs by more than 2% from the exposure in step 7, repeat the measurement sequence.

12. Repeat steps 6–10 for other clinically-used kVp/target /filter settings ranging from the lowest to the highest kVps.

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DATA ANALYSIS AND INTERPRETATION

The HVL is calculated in the spreadsheet by logarithmic interpolation of the aluminum thickness of the points just below and just above 50% of the zero thickness exposure.

RECOMMENDED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

At a given kVp setting in the mammographic kilovoltage range (below 50 kVp), the measured HVL with the compression paddle in place must be equal to or greater than the value:

$$HVL \geq \frac{kVp}{100} + 0.03 \text{ (in units of mm of aluminum)}$$

For example, if the nominal tube potential is 28 kVp, the HVL must equal or exceed 0.31 mm of aluminum. If the measured HVL is below these limits at any kVp setting, service personnel should be contacted to check whether appropriate filtration is in place, or if the kVp has changed.

Excessive HVL should prompt a check by service personnel to assure that the x-ray tube has an appropriate (beryllium) window and that filtration and mirror are correctly installed and that the mirror motor is operational if it exists.

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If the HVL is outside the recommended limits it may be helpful to verify that the kV output of the system is accurate. On scanning systems the desired method of verifying kV is to have a service person connect a volt-meter to the generator. On full-field (non-scanning) systems a calibrated non-invasive kV meter may be used.

Also at any given target, filter and kV combination, the difference in radiation output (mR) between two repeated exposures shall be no more than 2% of the measured output.

TIMEFRAME FOR CORRECTIVE ACTION

Within 30 days of the test date.

6. PROCEDURE: AVERAGE GLANDULAR DOSE

OBJECTIVE

To calculate the associated average glandular dose (AGD) for an "average" patient (approximately 4.2-cm compressed breast thickness—50% adipose, 50% glandular composition).

APPLICABILITY

This procedure applies to all full-field digital mammography systems.

TEST FREQUENCY

Equipment evaluations, semi-annually

REQUIRED TEST EQUIPMENT

TEST PROCEDURE STEPS

1. The parameters for imaging the DMUP phantom are recorded in Table A-Raw Image Acquisition using the AEC setting or technique used clinically for a 4.5 cm breast composed of 50% fatty and 50% fibroglandular tissue.

2. Other techniques used for each of the images from Chart 4 have air kerma rates on **Chart 3**.

DATA INTERPRETATION AND ANALYSIS

1. Multiply the exposure reading from the dosimeter by any correction factors required (Air pressure, temperature, HVL).

2. The mR/mAs for each measurement taken is shown on the HVL page.

3. Using the exposure values for the 4.0 cm PMMA phantom, calculate the mean glandular dose as follows:

4. Determine whether the target is molybdenum, tungsten, or rhodium and find the HVL of the system (see the **Beam Quality Assessment** procedure, **Chart 6**) in the left-hand column of Tables 1 to 3 in the ACR Mammography Quality Control Manual. In the right-hand column of the table appropriate for the target, filter and kV setting, find the factor to convert exposure to average glandular dose for a 4.2-cm compressed breast thickness. Multiply this factor by the entrance exposure value computed above. The product obtained represents the mean dose received by the glandular tissue for that specific energy, breast composition, and compressed thickness and is an approximation of the actual patient dose.

5. Record the dose value on **Chart 7.**

NOTE: The conversion factor and the average glandular dose change

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Lead sheet to protect the image receptor (0.5 mm Pb equivalent minimum)¶
Slabs of PMMA to achieve a thickness of 4 cm¶

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Comment: A bit confusing here – are these tests currently doing by our group?

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substantially for other breast thicknesses; these factors apply only to a 4.2-cm compressed breast thickness. Conversion factors for other breast or phantom thicknesses can be found in papers by Dance and by Wu et al. [Reference]

RECOMMENDED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

The mR/mAs for each target-filter-kV combination should be within the recommended range for that system type.

Comment: Recommended range TBD.

The average glandular dose to a standard breast should not exceed 3 mGy (0.3 rads) per view.

If the values exceed these levels, action should be taken to evaluate and eliminate the cause of excessive dose.

If the AGD determined by the x-ray unit is displayed for an image, or reported in the DICOM header, that value should match the physicist calculated value to within 20%.

TIMEFRAME FOR CORRECTIVE ACTION

Immediately, before any further patients are imaged.

OBSP REQUIREMENTS:

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Dosimetry. The average glandular dose delivered during a single cranio-caudal view of a phantom simulating a standard breast shall not exceed 3.0 mGy (0.3 rad) per exposure. The dose shall be determined with technique factors and conditions used clinically for a standard breast.

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If the results fall outside the action limits, the source of the problem shall be identified and corrective actions shall be taken before any further examinations are performed or any images are processed using the component of the mammography system that failed the test.

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7. PROCEDURE: EVALUATION OF GHOSTING

OBJECTIVE

To evaluate the severity of any artifact due to recent previous exposure to the detector. In this measurement, ghosting (sensitivity variation) or lag (residual signal) from a previous exposure is induced in a manner similar to clinical operation, and the results are quantified. For simplicity, both phenomena will be referred to in this document as "ghosting".

APPLICABILITY

Flat panel detectors (phosphor and direct conversion detectors); does not apply to R systems or on those using photostimulable phosphor plates.

TEST FREQUENCY

Annually, equipment evaluations (new unit, replacement of the detector).

REQUIRED TEST EQUIPMENT

ACR FFDM Accreditation phantom or CAR accreditation phantom (must contain anatomic test objects).

Timer (watch, stopwatch, etc.)

TEST PROCEDURE STEPS

Read through these steps and understand them before starting this test. It is important that the elapsed time between acquisition of the initial image (step 4) and the ghost measurement image (step 5) be either 1 minute, or the shortest time possible between patient images.

1. Create a patient with last name "Physics" and first name "Ghosting". Patient ID "9907UYYMMDD" may be used.

2. Place the ACR FFDM phantom or CAR accreditation phantom on the right half of the breast support plate with the edge placed at the middle of the table, running from chest wall to the anterior edge such that approximately one half of the breast imaging area is covered. See Figure 10.

3. Lower the paddle so that it is 4 cm above the breast support plate. Using the top of the compression paddle (or printed AEC markers) as a reference, note where the edge of the phantom crosses the detector.

4. Acquire an image using a similar technique to that used for imaging the ACR FFDM Accreditation Phantom. This is the ghost creation image. Immediately start timing.

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Comment: Is DR built on a CCD?

Deleted: Uniform attenuator (4.0 cm of PMMA or 2 mm Al sheet large enough to cover the entire image receptor) ¶

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Comment: Why it has to be FFDM phantom?

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5. Place the ACR FFDM phantom or CAR accreditation phantom on the detector so that the middle of the phantom is centered on the location of the edge of the uniform attenuator in the ghost creation image.

6. As soon after one minute from the time that the first image was acquired, that the unit allows another exposure, acquire another image at the same manual technique. This is the ghost measurement image.

7. Use the region of interest tool (ROI, area~ 4 cm^2) to measure the mean following 3 values in the raw version of the ghost measurement image:

   a) A : the mean pixel value in the background of the phantom on the side where no attenuator was present in the first image

   b) B : the mean pixel value in the background of the phantom on the side where the uniform attenuator was present in the first image

   c) C : the standard deviation in the background of the phantom on the side where the uniform attenuator was present in the first image

Comment: This was the phantom right? Don't we use the CAR phantom in this test?

8. Record the results on **Chart 8**.

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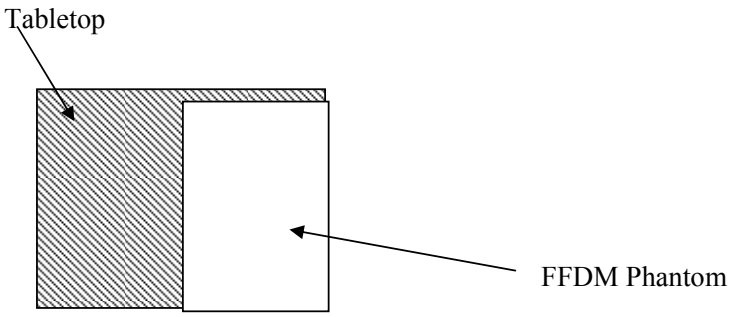

Figure 5: Setup for ghost creation image.

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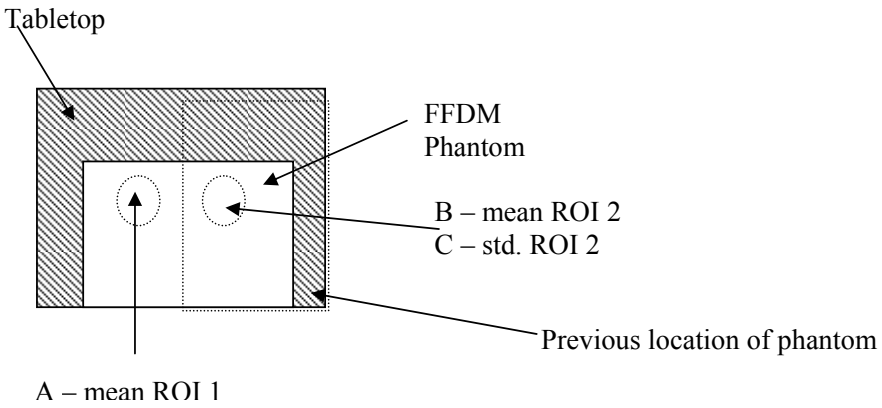

Comment: Maybe use definition or assignment notation here?

Figure 6: Setup for ghost measurement image.

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DATA INTERPRETATION AND ANALYSIS

1. The ghost image SDNR: $\frac{A-B}{C}$

2. View the raw version of the ghost measurement image on the radiologist's review workstation. Adjust the window width and window level to clearly see the anatomic test objects without exaggerating image noise. Record the window-width and window level on **Chart 8**.

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3. If a shadow is visible indicating the location of the attenuator in the ghost creation image, ghosting may be excessive. Record the presence or absence of a shadow on **Chart 8**.

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RECOMMENDED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

If the absolute value of the ghost image SDNR is more than ***, the service person should be contacted.

Comment: TBD

If ghosting is visible at clinically relevant window-width and level settings, the service person should be contacted.

TIMEFRAME FOR CORRECTIVE ACTION.

Within 30 days of the test date.

8. PROCEDURE: COLLIMATION ASSESSMENT

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OBJECTIVES

To assure that the x-ray field aligns with the light field, that the collimator allows for full coverage of the image receptor by the x-ray field but does not allow significant radiation beyond its edges and that the chest wall edge of the compression paddle aligns with the chest wall edge of the image receptor.

To determine the amount of tissue that is not imaged by the mammographic unit when a patient is positioned as close to the unit as possible.

APPLICABILITY

All full-field digital mammography systems.

TEST FREQUENCY

Equipment evaluations (new units, service to x-ray tube or collimator).

REQUIRED TEST EQUIPMENT

Five radiographic rulers (with 5 mm markings or finer) or four radiographic rulers and a coin.

4 phosphorescent screen pieces, 2 cm square, as shown in Figure12.

Tabletop (not mag-stand) image of the FFDM Accreditation Phantom aquired in Procedure 2.

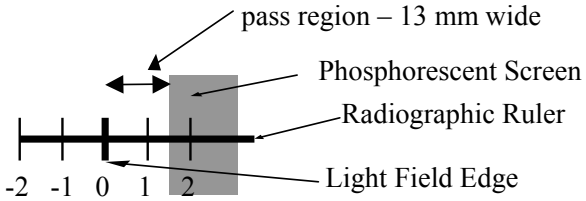

Figure 7: Suggested layout for rulers and phosphorescent screen markers used to evaluate x-ray field and detector alignment.

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The limit for 650 mm SID is 13 mm. If the SID is other than 650 mm, calculate the proper limit as 2% of the SID or 0.02 X SID.

TEST PROCEDURE STEPS

1. Create a patient with last name “Physics” and first name “Collim”. The patient ID number 9908UYYMMDD may be used.

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2. Remove the compression paddle. Tape a ruler to the underside of the compression paddle, with the zero line parallel to and aligned with the patient contact edge of the paddle at the chest wall, or tape the coin to the underside of the paddle with one edge

of the coin tangent to the front edge of the paddle. Diagram illustrating ruler and alignment is shown in figure 7.

3. Place rulers on each of the four borders of the light field such that the "zero line" on the center of the ruler lines up with edge of the light field (point at which light intensity has dropped to approximately one-half of its maximum value). If there is no light field place one ruler on each of the markings on the unit that indicate the x-ray field location. The rulers may be taped to the breast support and the unit may be angulated so that the rulers are easily visible from the operator's console.

4. Place the phosphorescent strips at the 13 mm marks outside the indicated x-ray field for the left, right and anterior edges. For the chest wall edge place the phosphorescent strip 7 mm beyond the tabletop edge. Re-install the compression paddle and adjust the height to be 4.2 cm above the breast support. Place an additional phosphorescent strip in the middle of the x-ray field. This strip will provide a check that at you can perceive the light generated by primary x-ray interaction with the phosphor.

5. Ensure you have a clear view of the tabletop from the control console and darken the room, so that you can watch the markers to see if there is any primary radiation 13 mm beyond the light field, and verify that the phosphorescent strip in the middle of the field glows.

6. Make an exposure using a manual technique, matching the kV, mAs, target and filter used to image the standard breast.

7. For CR, process the imaging plate using the appropriate mode (see Manufacturer Modes in the glossary).

8. Use the resulting image to determine the distance from the edge of the light-field to the active edge of the detector. The active area of the detector is defined as the area visible on the digital image.

9. Enter results on **Chart 9**.

10. Repeat steps 2 through 9 for each image receptor size. If the unit has multiple positions for the small paddle that result in different collimator blade positions (i.e. left and right, to allow better positioning for MLO views), these should be evaluated.

11. Display the image of the FFDM phantom acquired using normal patient imaging technique. Adjust the window width and window level so that the missing tissue rulers are clearly visible (see Figure 1).

12. Record the amount of missing tissue measured by the left and right rulers on **Chart 9**.

DATA INTERPRETATION AND ANALYSIS

1. Calculate the net illuminance of the localizer by subtracting the ambient measurement

Comment: Do we use the coin?

Comment: Is this correct?

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from the illuminance measured at the center of the field.

2. Determine the position of the edges of the detector active area with respect to the rulers from the digital image soft-copy display.

3. From the image, determine the distance from the patient contact chest wall edge of the compression device (Point A in Figure 13) relative to the chest wall side of the detector.

4. If any of the phosphor screens attached to the rulers glow, this implies that the radiation field extends beyond the edge of the active area by more than the limit.

5. The image of the phantom should be viewed, and amount of missing tissue read off the angled scales at the chest wall side of the FFDM phantom.

Comment: Where is this figure?

Comment: We are jumping from figure 7 to figure 13! Figure 13 is missing as well.

RECOMMENDED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

The x-ray field shall cover the entire active (displayed) area and not extend beyond the active area by more than 13 mm in any direction.

For any mammography system with a light beam that passes through the X-ray beam-limiting device, the light shall provide an average illumination of not less than 160 lux (15 foot candles) above background at the maximum source-image receptor distance (SID).

The light field or image field markings shall indicate the active area to within 10 mm in all directions.

Comment: Is this used?

Proper alignment of the edge of the compression paddle with the chest wall edge of the image-receptor holder assembly is necessary for proper positioning and compression of the breast. If the edge of the compression paddle extends too far beyond the image receptor edge, the patient's chest is pushed away from the image receptor and some breast tissue will not be recorded on the image. If the edge of the compression paddle does not extend far enough, the breast tissue will not be properly pulled away from the chest wall and compressed for visualization in the image, and a shadow of the vertical edge of the compression paddle will be visible in the image, possibly obscuring clinical information. The patient-contact chest wall edge of the compression paddle should not extend beyond the chest wall edge of the image receptor by more than 5 mm, and the chest wall edge of the paddle must not be visible in the image. The difference between the diameter of the coin and the amount of the coin seen normal to the chest wall should be between 4 and 6 mm.

No more than 7.0 mm of tissue shall be missed at the chest wall.

TIMEFRAME FOR CORRECTIVE ACTION

Within 30 days of the test date

9. PROCEDURE: EVALUATION OF SYSTEM RESOLUTION/MODULATION TRANSFER FUNCTION (MTF)

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OBJECTIVE

To determine the effective resolution for the entire imaging system including effects from geometric (focal spot) blurring and the detector and allow determination of limiting resolution.

APPLICABILITY

This procedure applies to all full-field digital mammography systems. There are two methods for measuring effective resolution: Method A, an actual measurement of system MTF for those with access to the software; and Method B, an interim method, which is the test specified in the manufacturer's quality control program.

TEST FREQUENCY

Equipment evaluation, after service to detector, tube, bucky or CR plate reader, annually.

METHOD A – MTF DETERMINATION

REQUIRED TEST EQUIPMENT

ACR FFDM Accreditation Phantom with overlay
MTF software

TEST PROCEDURE STEPS

1. Use the images obtained in the ACR FFDM Accreditation phantom test.

DATA INTERPRETATION AND ANALYSIS

1. Use the appropriate software to calculate the MTF from the "for processing" image. It is sufficient to calculate only one MTF in each of the horizontal and vertical directions.

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2. Record the 50% and 10% limits in the x and y directions on **Chart 10.**

RECOMMENDED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

The MTF should at least be equal to the manufacturer's specified values.

The spatial frequency (lp/mm) at which the MTF drops below 50% and 10% should not be lower than the values specified for than model of digital mammogragphy equipment in Table 3.

The MTF at any frequency should not change more than 10 % from the value established at acceptance testing of the equipment.

TIMEFRAME FOR CORRECTIVE ACTION

Immediately, before any further patients are imaged.

METHOD B – MANUFACTURER'S SPECIFIED METHOD

Comment: Other version of document has method using a resolution pattern. Which is correct?

If it is not possible to carry out Method A (i.e. appropriate software is not available), the physicist should use the method for resolution evaluation specified in the manufacturer's quality control manual.

DATA INTERPRETATION AND ANALYSIS

1. Using the manufacturer's test criteria, indicate on **Chart 10** whether the system meets the test specification.

TIMEFRAME FOR CORRECTIVE ACTION

Immediately, before any further patients are imaged.

Table 3: Minimum frequencies at which MTF drops to different values for each system type. If your machine type is not listed, check the ACR web site, www.acr.org for an updated version of this table.

Comment: This table should agree with the previous one.

Comment: This should be table 5

	Minimum Frequency at which MTF drops to:			
	Tabletop		Magnification Stand	
Unit	50 %	10%	50%	10 %
Fuji CR				
GE 2000D	2.6	6.6	3.7	8.4
GE DS	3.4	8.0	4.1	7.6
GE Essential	2.4	7.3	5.6	10
Kodak CR				
Lorad Selenia				
Siemens Novation	5.1	10	3.8	8.1
Siemens Innovation				

Figure 13. MTF reference table. (figure --- table???)

10. PROCEDURE: NOISE AND LINEARITY

OBJECTIVE

To evaluate the spatial and electronic noise characteristics of the entire imaging chain.

APPLICABILITY

This procedure applies to all full-field digital mammography systems.

TEST FREQUENCY

Equipment evaluation, after service. Annually – noise only.

REQUIRED TEST EQUIPMENT

Review workstation with ROI capability or QC software for image analysis.

TEST PROCEDURE STEPS

NOTE: These tests should be performed on flat-fielded, but un-enhanced (raw, i.e. without peripheral or resolution enhancement) images.

1. Open the patient study with last name "Physics" and first name "NLR", used for Procedure 3. The patient ID number 9911UYYMMDD can be used.
2. Place the contrast phantom on the tabletop so that the front edge is aligned with the chest-wall edge of the breast support. Use collimation that allows the full detector area to be exposed.
3. For the aluminum sheet (2mm), place the 3.8 mm spacer post near the edge of the image area away from the chest wall to make it 4 cm equivalent.
4. Lower the compression plate and apply a compression force of 10 daN. Obtain four images that span the range of reasonable mAs settings (1/8, ½, 1x and 4 times the mAs used to image the 4 cm equivalent attenuator for the AEC evaluation). These images along with that of the 4 cm equivalent attenuator will be used to characterize the detector response. The mAs settings should be chosen to approximate an exponential series (doubling or quadrupling each time). For ease of analysis, ensure that the laterality (Left or Right breast) chosen for each image is the same, so the chest wall edge will appear on the same side in all images.
5. Load each of the raw (unprocessed) images of the 4 cm equivalent phantom that span the mAs range.
6. Measure the mean and standard deviation in the regions of interest shown in Figure 8. The ROIs have an area of 4 cm^2, +/- 0.1 cm^2. The ROIs are in the center and in the corners, and at each edge of the field and in the contrast disk, (6 total).
7. Record the values on **Chart 11**, which will automatically calculate the results.

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8. Repeat steps 3 and 4 for all images acquired in procedure 3.

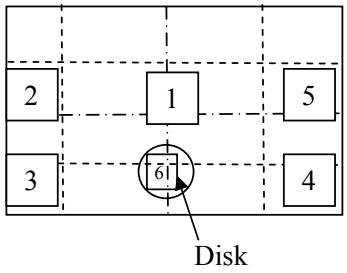

Figure 8: Locations of ROIs for noise and linearity analysis.

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DATA INTERPRETATION AND ANALYSIS

1. ***Detector Linearity***: The mean pixel value/mAs versus mAs is plotted for the center ROI (**Chart 11-B, Signal Linearity**), after correcting for any pixel value offset. For Fuji CR systems which are logarithmically scaled, the product of sensitivity number (S) and mAs is plotted against mAs. For Kodak CR systems, the exposure index (EI)/mAs is plotted against mAs.

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2. ***Raw Noise***: The variance vs. mAs for the different ROI in the images taken at the kV used for imaging the accreditation phantom is plotted (**Chart 11-B, Noise Linearity**). For CR systems, which are logarithmically scaled, the variance is plotted versus the reciprocal of the entrance exposure. The regression coefficient (R^2) for a linear fit to the data is calculated.

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3. ***Signal to Noise Ratio (SNR)***: The signal is divided by the SD (σ) and recorded on **Chart 11-A**.

Comment: May be it is better to move this part to the beginning-before detector linearity – measurements are recorded in Chart 11-A first?

4. ***Signal Difference to Noise Ratio (SDNR):*** The difference between the signal in center ROI and the disk, divided by the standard deviation in the center ROI is calculated. The SDNR is normalized by the square root of the mAs and plotted versus mAs. In a quantum-limited system, the resulting plot should show a horizontal line.

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SUGGESTED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

1. Detector Linearity: For "Linear" detectors, the plot of pixel value versus mAs be linear. All (ADU – Pixel Value Offset)/mAs values plotted should be within 10% of the mean ADU/mAs at the kV used for imaging the accreditation phantom. For "Logarithmic" detectors (CR systems) S number multiplied by exposure versus exposure should be constant at the kV used for imaging the accreditation phantom.

2. Raw Noise: For nominally linear systems, a linear least square fit to Variance (SD squared) versus exposure should have $R^2 > 0.95$. For nominally logarithmic systems,

a linear least square fit to Variance versus the reciprocal of exposure should have $R^2 > 0.95$. If one area of the detectors does not have linear response and displays an excess of noise, this region will limit the allowable operating range of the system. Any significant change should be evaluated and corrected.

3. If any ROI mean pixel value differs by more than ± 10% from the center (#1) location, then the source of signal non-uniformity should be identified and corrected unless it is due to heel effect.

4. If the SNR in other ROIs differs by more than ± 20% from the middle (#1) location then the source of SNR non-uniformity should be identified and corrected, excepting the outer corner locations. Limits for the corners will be set based on experience with the units in the field.

5. If the SNR changes by more than ± 10% from the previous SNR measurement made at the same location with the same uniform phantom and target, filter and kV selection, then the source of temporal change in SNR should be identified and corrected.

6. ***The SDNR criteria are To Be Determined***.

TIMEFRAME FOR CORRECTIVE ACTION

Within 30 days of the test date.

11. PROCEDURE: SPATIAL LINEARITY AND GEOMETRIC DISTORTION OF THE DETECTOR

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OBJECTIVE

To determine the absolute image magnification and the fidelity with which straight lines are captured.

APPLICABILITY

This procedure applies to all full-field digital mammography systems with moving parts (e.g. slot-scan & CR).

TEST FREQUENCY

Equipment evaluations and semi-annually for systems with moving parts (e.g. slot-scan & CR)

Deleted: All systems at e

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TEST PHANTOM REQUIREMENTS

Geometric Distortion Test Tool with parallel lines at 20 mm spacing, lines angled at 45 degrees to the edges of the board.

Comment: Is this commercially available?

Figure 9: Geometric Distortion Test Tool

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TEST PROCEDURE STEPS

1. If more than one image size is available, select the largest one and install the appropriate compression paddle.
2. Place the Geometric Distortion Test Tool on the breast support plate, approximately centered left to right.
3. Create a patient with last name “Physics” and first name “Distortion”. The patient ID

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number 9911UYYMMDD may be used.

4. Make an exposure using the technique for the standard breast.

5. Record the target/filtration, kV setting, mAs setting, and grid use on **Table A**, to populate **Chart 12**.

6. For CR, process the imaging plate using the appropriate mode setting (see Glossary for Manufacturers Modes).

DATA INTERPRETATION AND ANALYSIS

1. At the review station, display the image of the distortion phantom, using appropriate window-width and window-level settings. The background of the phantom should be a mid-gray, with the copper tracings clearly visible.

2. Examine the image for uniformity of sharpness across the image and for any distortion in the regular pattern.

3. Using image roam and zoom controls, examine the pattern to ensure that all lines are smooth and straight.

4. Effective pixel size at the support plate should be calculated by measuring the horizontal and vertical distances in pixels between the line intersections in the center of the image. The intersections of the lines are spaced 20 mm x √2 apart = 28.28 mm. Record the results on **Chart 12**.

5. The width and length of the image should be calculated using the breast support plate as the reference position. Multiply the effective pixel size by the numbers of rows and columns in the image matrix. Record the results on **Chart 12**.

SUGGESTED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

The image size should be within 10% of the manufacturer's stated nominal image size.

The effective pixel width and length (x and y) dimensions should be within 5% of each other.

There should be less than 2% deviation from a straight line over a 10 cm length in the center of the field.

If there is any significant resolution non-uniformity or pattern distortion, rotate the image on the monitor 90°. If the resolution non-uniformity or distortion persists there is a detector problem, otherwise it may be a software or monitor problem. Seek service from a qualified service engineer to have the problem corrected.

TIMEFRAME FOR CORRECTIVE ACTION

Immediately, before any further patients are imaged.

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Deleted: Note that on systems with a curved breast support plate the lines will appear distorted/curved. This is normal.

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Deleted: <#>The accuracy of the measuring tool / ruler provided on the radiologist's review workstation should be verified in the horizontal and vertical directions by measuring across a distance of 3 diamonds and comparing the values calculated by the software with the actual value (3 x 2 x √2 cm).¶

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Comment: How do we quantify??

Deleted: The distance measured by the radiologist's review workstation software should be within 5% of the actual distance, in both the horizontal and vertical directions.¶

12. PROCEDURE: MONITOR DISPLAY QUALITY

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OBJECTIVE

To ensure that digital softcopy review workstation and acquisition station monitors have acceptably low artifact levels, with minimal geometric distortion, good contrast and good luminance uniformity.

APPLICABILITY

This procedure should be performed on all primary medical display devices used to interpret digital mammograms (radiologist's workstations).

This procedure (except steps 14-17) should also be performed on the secondary display devices which include the monitor attached to the acquisition workstation that is used to verify patient image quality and/or the monitor(s) used to manipulate and print the images (technologist's workstations).

If the interpreting physicians provide final interpretations from hardcopy ***only***, the tests need only be performed on the secondary display devices.

Test images which mimic the images that are 1) produced by each model of digital mammography unit in the facility, or 2) might be interpreted at that workstation are required to be used.

TEST FREQUENCY

Equipment evaluations, annually

REQUIRED TEST EQUIPMENT

Unit specific TG18-QC pattern with DICOM header and image format the same as that produced by the acquisition system

Unit specific TG18-UNL20 and TG18-UNL 80 images

(These test patterns may be obtained from the manufacturer of the FFDM unit or the workstation.)

Luminance meter (photometer) able to measure luminance between 0.5 and 1000 cd/m^2 with better than 5% accuracy with a precision of at least 10^{-2}, complying with the CIE standard photopic spectral response to within 3%. If the monitors are LCD technology and the photometer is a near-range contact design (not telescopic), the acceptance angle must be less than 5 degrees. The photometer should not be the one attached to the graphics board on the workstation and used to calibrate the monitors – this is to be an independent check of the system (the attached probe could be dirty or out of calibration).

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PROCEDURE

1. This is to be performed for each display station used for diagnosis and a separate **Chart 13B** should be filled out for each review workstation monitor and acquisition

system combination used. In addition, the monitor attached to the acquisition system that is used to verify patient image quality should be tested with the appropriate acquisition system image type and a **Chart 13A** should be completed. Any monitors used to manipulate and print the images should be tested with all image types that will be displayed on that monitor.

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2. Display the specific TG18-QC pattern provided for the acquisition system. Set the window-level to half of maximum and the window-width to full-scale.

3. Set the room lighting as used for image viewing**.**

4. Check that there is no evidence of smearing or bleeding noticeable in the black-to-white and white to black transition areas.

5. Inspect the image for any other artifacts, such as "fluttering" or "shadows".

Comment: NEED TO PROVIDE DEFINITION AND EXAMPLES

6. Inspect the gray-scale ramps to ensure they are smooth and continuous, without noticeable terracing or discontinuities.

7. Visually check that the lines dividing the test pattern into squares are crisp and straight, that the pattern is centered in the active image area of the monitor, and that the squares are indeed square (correct aspect ratio), with right-angled corners.

8. Verify that the 16 gray-level patches labeled 2 through 17 are distinguishable from one another, and that the low-contrast corners in each patch are visible.

9. Examine the text areas below the central region of the pattern (only required for primary display devices/radiologist's workstations). Letters spelling "QUALITY CONTROL" are printed in fainter and fainter text over dark, mid-gray and white backgrounds. Record the number of letters visible over each background for each of the combinations listed in Step 1 on **Chart 13-A or B**.

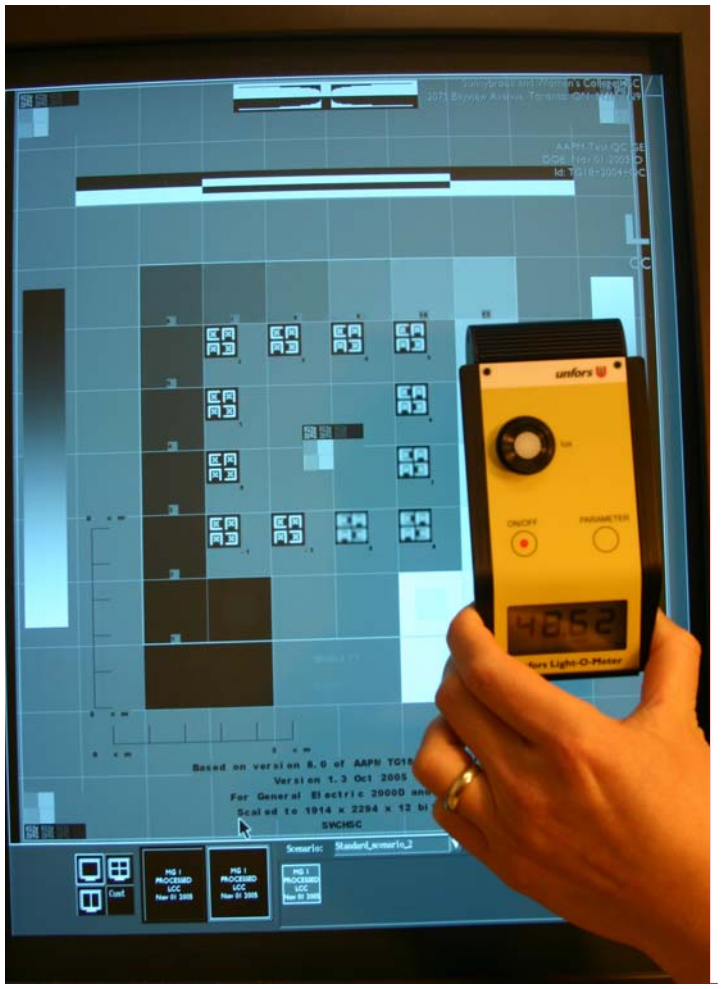
10. Verify that the 0%-5% contrast box is clearly discernible.

11. Verify that the 95%-100% contrast box is clearly discernible.

12. For review workstations, verify that the finest (Nyquist) vertical and horizontal high-contrast patterns are visible in all four corners and record on **Chart 13-B**.

13. If the display system uses two monitors, repeat steps 2 through 12 on the other monitor and ensure that both monitors look the same.

14. For review workstations, measure the lengths of the horizontal and vertical 5 cm rulers using the display software's measurement tool and record the lengths in mm.



Comment: This photo is showing the wrong test pattern – should be ULN or LN pattern

Figure 10: Using the photometer to measure monitor luminance

15. If the monitor is a primary display device, display the TG18-UNL20 image.

16. Measure and record the luminance in the five squares indicated (top left, top right, middle, bottom left and bottom right).

17. Inspect the image for artifacts such as dead or bright pixels (lcd monitors only), scratches or dark or bright areas.

18. Repeat steps 15 through 17 with the TG18-UNL80 image.

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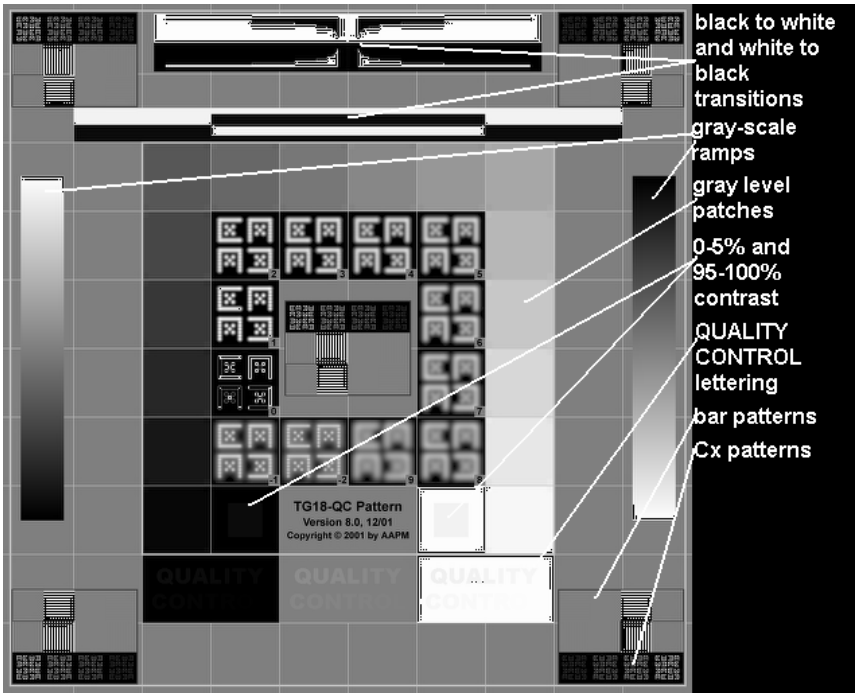

Figure 161: TG18-QC Pattern with components indicated.

Comment: Need up-to-date picture

SUGGESTED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

There should be no smearing or artifacts noticeable. The gray-scale ramps should appear smooth and continuous, without terracing or discontinuities.

Lines should appear straight, and the boxes should be square. The pattern should be centered in the active display area.

At least 11 letters in the phrase "Quality Control" (QUALITY CONT) should be visible and the number should be the same for the dark, mid-gray and light renditions of the low contrast text test strip on the primary display devices (radiologist's workstations).

Comment: This is somewhat different from the tech manual. Needs to be consistent.

If the TG18-QC test pattern luminance squares or low contrast targets are not discernible, the problem should be identified and corrected by a qualified service engineer.

If the same image displayed on both monitors shows distinct visual differences, the two monitors need to be recalibrated.

If any of the horizontal and vertical high-contrast finest line-pair patterns cannot be resolved the problem should be identified and corrected by a qualified service engineer.

The distance measured by the radiologist's review workstation software should be within

5% of the actual distance, in both the horizontal and vertical directions.

The maximum and minimum luminance measurements made on the UNL20 image should be within 30% of their mean.

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The maximum and minimum luminance measurements made on the UNL80 image should be within 30% of their mean.

There should be no bright or dark regions, scratches or bright or dark pixels noticeable when viewing the UNL20 or UNL80 image.

Ambient room lighting is as important as monitor and viewbox luminance for the radiographic reading environment. Ambient illumination should be minimized to improve image contrast and low-contrast object detectability. Illuminance is measured by placing the detector-filter-diffuser combination at the viewbox or monitor surface, pointed away from and parallel to the surface. These measurements can be influenced by the individual making the measurement, especially if one stands between a source of light and the detector-filter-diffuser combination, or wears reflective clothing.

TIMEFRAME FOR CORRECTIVE ACTION

Immediately, before any further patient images are read. If the monitor being evaluated is on a review workstation, acquisition does not need to be stopped, unless repair cannot be achieved within four working days and no other approved review workstations are available for image interpretation.

NOTE: Failure of a review workstation monitor test does not mean that patient image acquisition must cease, only that interpretation of patient images using that monitor must cease until the problem is corrected.

Failure of the acquisition station monitor requires the cessation of patient imaging; unless the review workstation is located close enough to the acquisition station, so that each image can be checked before the next is taken.

INSTALLING TEST IMAGES

1. Install the test images on the primary and secondary display devices.

2. If the device can read DICOM media CDs, simply place the appropriate test image CD in the drive and import the appropriate patients.

3. If the device cannot read DICOM media, work with the hospital PACS people to "C-MOVE" the images to the appropriate DICOM servers.

NOTE: The measurement procedures described here are a modified sub-set of those recommended by the American Association of Physicists in Medicine's Task Group

18 (AAPM TG18). Additional measurements are described in the AAPM TG18 standard that the medical physicist may wish to include.

13. PROCEDURE: MONITOR LUMINANCE RESPONSE AND VIEWING CONDITIONS

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OBJECTIVE

To ensure that digital softcopy review workstation monitors are of adequate brightness and contrast, that the luminance response is perceptually linear and that the brightness and contrast of multiple monitors match one another such that images are displayed and printed consistently.

To ensure that monitors meet the DICOM gray-scale standard to enable the display of mammograms produced by any digital mammography unit adhering to the DICOM gray-scale standard for presentation.

APPLICABILITY

This procedure should be performed on all primary medical display devices used to interpret digital mammograms.

TEST FREQUENCY

All systems with softcopy reading: Equipment evaluations and when display monitors are serviced or changes or upgrades are made to the image display software, annually.

REQUIRED TEST EQUIPMENT

Illuminance meter able to measure illuminance between 1-500 lux (lm/m^2) with better than 5% accuracy, complying with the CIE standard photopic response to within 3%.

Luminance meter (photometer) able to measure luminance between 0.5 and 1000 cd/m^2 with better than 5% accuracy with a precision of at least 10-2, complying with the CIE standard photopic spectral response to within 3%. If the monitors are LCD technology and the photometer is a near-range contact design (not telescopic), the acceptance angle must be less than 5 degrees. The photometer should not be the one attached to the graphics board on the workstation and used to calibrate the monitors – this is to be an independent check of the system (the attached probe could be dirty or out of calibration).

TG18-LN image set with DICOM header exactly matching the modality produced by the Acquisition system (provided)

Note: The unit candela per square meter is sometimes referred to as the "nit".

PROCEDURE

1. This is to be performed for each display station used for diagnosis and a separate **Chart 14** should be filled out for each workstation.

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2. Set the room lighting as used for viewing.

3. Display the first TG18-LN pattern provided for your system (patient name "AAPM^Test^Patterns, Series "TG18-LN"). Set the window-level to half of maximum and the window-width to full-scale. Ensure the image is scaled to fill the monitor (1 image per monitor).

4. If the photometer used is the telescopic type, point the sensitive region of the meter at the center of the square. If the photometer used is the near-range contact type, place the sensitive region against the monitor in the center of the square. Measure the intensity of the square. Record this value on **Chart 14-A** and compare to previous measurements.

5. Repeat steps 3-4 for each luminance level.

6. Turn off the monitors and measure the amount of ambient light falling on the monitor face with the illuminance meter. If the ambient light measured is more than 10 lux, adjust the lighting until ambient light level is low enough. Record the viewing conditions that result in sufficiently low ambient light levels on **Chart 14-C** and leave a copy on site to be posted in the room.

7. If the photometer used is the near-range contact type (not telescopic) the ambient luminance must be measured. With the monitor turned off, hold the photometer a distance from the monitor such that the acceptance angle includes the majority of the monitor face but excludes the monitor surroundings. This distance will vary depending on the photometer design and monitor dimensions. ***Care must be taken to ensure that the measurement is not affected by direct luminance sources outside the monitor face.*** Record the luminance reflected from the monitor face on **Chart 14-A**.

8. The Observed Contrast/ just noticable difference (JND) difference $((\Delta L/L)/(JND_n-JND_{n-1}))$ versus average JND indice $((JND_n+JND_{n-1})/2)$ is plotted on **Chart 14-B**.

9. Repeat steps 2 through 7 for the other monitor if this is a two-monitor workstation.

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Comment: Need to get terminology and units right. TG18 uses nits for all. We use lux for ambient light!

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Comment: This could be clarified.

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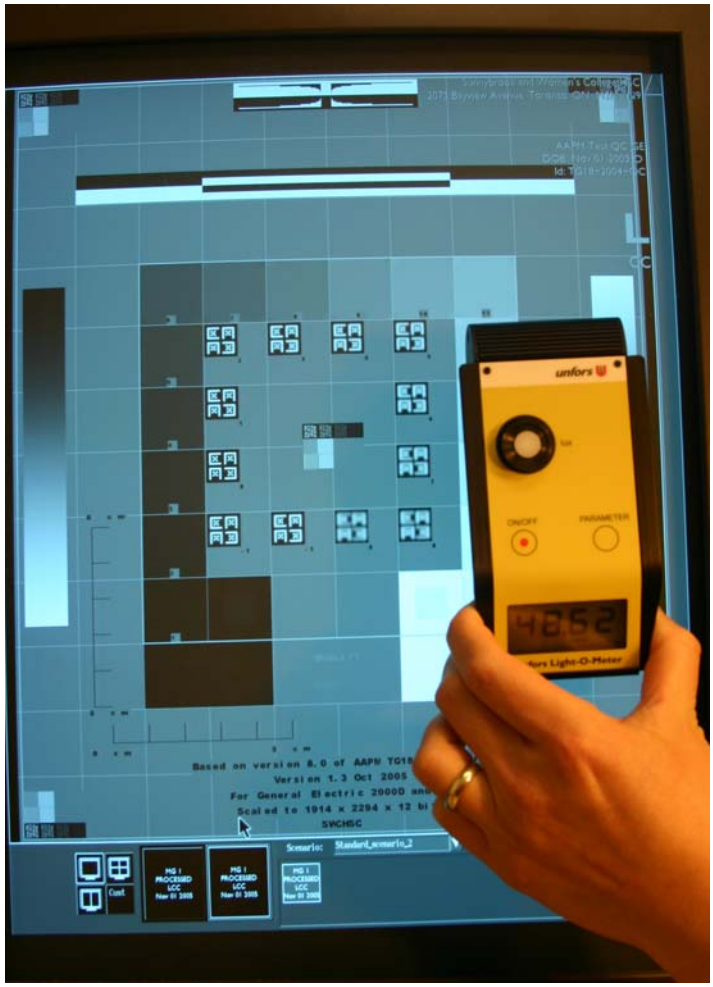

Figure 12: Using the photometer to measure monitor luminance.

Comment: This picture should show TG18-LN pattern, not QC Pattern?

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SUGGESTED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

The maximum intensities of monitors attached to the same workstation (including ambient light) should be within 5% of each other.

The dynamic range, or ratio between white target intensity and black target intensity including ambient light shall meet the TG18 requirement for a primary medical display device of at least 250:1.

The Observed Contrast/JND difference $((\Delta L/L)/(JND_n-JND_{n-1}))$ versus average JND indice $((JND_n+JND_{n-1})/2)$ shall be within 10 % of the response described by the DICOM softcopy display gray-scale function.

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The average number of JNDs per luminance interval shall be less than 3.

The maximum deviation from the average number of JNDs per luminance interval shall be less than 2.

The root mean square deviation from the average number of JNDs per luminance interval shall be less than 1.

The ambient light level must be less than 10 lux, and should be less than 3 lux.

If the monitor luminance response is unacceptable, the monitor should be recalibrated. If recalibration does not correct the problem, the monitor may need servicing or replacement.

TIMEFRAME FOR CORRECTIVE ACTION

Immediately, before any further patient images are read.

NOTE: Failure of a review workstation monitor test does not mean that patient image acquisition must cease, only that interpretation of patient images using that monitor must cease until the problem is corrected.

PRECAUTIONS AND CAVEATS

The accuracy of the diagnosis and the efficiency of the radiologist are influenced by the conditions under which the mammograms are viewed. Viewing conditions may affect the diagnostic potential of even the best quality mammograms. These conditions are determined by the luminance and calibration of the monitors used for softcopy interpretation, the luminance of the viewboxes used for hardcopy interpretation, the ambient room illumination or the amount of light falling on the monitor and/or viewbox surface, and good masking of films on the viewbox.

Contrast is extremely important in the mammography image and is degraded by extraneous light. Consequently, monitors and viewboxes should be positioned to avoid light from windows, other monitors or viewboxes, and other sources of bright light, either direct or reflected. General lighting in the room should be at a low level and diffuse.

Ambient room lighting is as important as monitor and viewbox luminance for the radiographic reading environment. Ambient illumination should be minimized to improve image contrast and low-contrast object detectability. Illuminance is measured by placing the detector-filter-diffuser combination at the viewbox or monitor surface, pointed away from and parallel to the surface. These measurements can be influenced by the individual making the measurement, especially if one stands between a source of light and the detector-filter-diffuser combination, or wears reflective clothing.

ADDITIONAL INFORMATION

Photometric Measurements

Luminance is the amount of light either scattered or emitted by a surface, measured in cd/m^2 (nit).

Illuminance is the amount of light falling on a surface, measured in lux (1 lux = 1 $lumen/m^2$).

One lux falling on a perfectly diffusing (Lambertian) surface with 100% reflectance produces a luminance of $1/\pi$ cd/m^2.

Other units often used for luminance and illuminance are footlamberts and footcandles, respectively. To convert footlamberts to cd/m^2, multiply the numerical value by $10.76/\pi$ (3.425). To convert footcandles to lux, multiply the numerical value by 10.8.

Viewbox and monitor luminance measurements are made with a photometric system. The detector-filter-optics combination is placed near the viewbox surface, taking care to exclude any extraneous room light. Typical viewbox luminance values range from 1,500 to 3,500 cd/m^2 and monitors can range from .1 to 400cd/m^2.

Comment: Aili- please check this

Table 4: Equipment for Basic Photometric Measurements

Purpose	Description
Luminance and Illuminance	Autoranging handheld power meter
Luminance	CRT luminance sensor** with photometric filter, lens, and ambient light shade
Illuminance	Illuminance sensor** with photometric filter and cosine diffuser

Suggested Acceptable Viewing Conditions

This is an incomplete list – we would appreciate every physicist providing their final form to generate a template.

1. The room lights will be off.
2. All curtains and hall-way doors will be closed.
3. All viewboxes in the vicinity (define) will be off, or fully masked, if used for previous cases.
4. The ambient light falling on the diagnostic and screening (primary interpretation) monitors shall be less than 10 lux.
5. The resulting ambient luminance of the monitors will not degrade the monitors' luminance response functions to the point where they do not comply with the

DICOM GSDF.

14. PROCEDURE: VIEWBOX LUMINANCE AND ROOM ILLUMINANCE

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OBJECTIVE

To assure that the luminance of the viewboxes for interpretation or quality control of mammography images meet or exceed minimum levels, that the room illuminance levels are below prescribed levels, and that viewing conditions have been optimized.

APPLICABILITY

This procedure should be performed on all viewboxes interpretation of screen-film mammograms or hard-copy digital mammograms are viewed.

TEST FREQUENCY

Equipment evaluation & annually

REQUIRED EQUIPMENT

Photometer designed to measure both luminance and illuminance that meets or exceeds the NAPM recommendations.

TEST PROCEDURE STEPS

NOTE: The measurement procedures described follow, as closely as possible, those recommended by the National Association of Photographic Manufacturers (NAPM). Additional measurements are described in the NAPM standard that the medical physicist may wish to include, e.g., luminance uniformity.

1. Reproduce the typical ambient lighting conditions for the reading room including overhead and task lighting which is used when mammograms are typically interpreted. Doors and window coverings shall be in their normal (open or closed) position. If light from other viewboxes can fall on the surface of the viewbox being evaluated, these viewboxes shall be on, but the viewing surface shall be covered with radiographs.

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Comment: This contrasts with the list above.

2. With the light-level set for film reading and the viewbox turned off, measure the ambient luminance of the viewbox with film on it, by pointing the photometer at the viewbox. If the photometer used is a near-range contact type (not telescopic), the distance that the meter is held away from the viewbox surface should be chosen based on the meter's acceptance angle. A large amount of the viewbox should be included in the measurement without any surrounding objects.

3. For each viewbox that is used for mammographic interpretation, turn on the lights in the viewbox at least 30 minutes before making the following measurements.

4. Place the luminance meter with its detector parallel to and facing the viewbox surface. The detector should be centered in a hole (which is centered in an opaque

mask) just slightly larger than the detector itself, and in contact with the viewbox surface (see Figure **).

Comment: Add this figure

5. Make the measurement and record the result as the viewbox luminance on **Chart 15**.

Comment: No mention of the averaging process or the max and min values?

6. Visually inspect each viewbox for uniformity of luminance and for uniformity of color of the lighting. Note non-uniformities (see Figure **). Also evaluate viewboxes for proper function of masking devices, and the presence of dirt or marks as described in the "Viewboxes and Viewing Conditions" procedure of the "Radiologic Technologist's Section".

Comment: Add this figure

7. Make the following illuminance measurements with the viewbox lights turned off.

8. Place the illuminance meter so that its detector is parallel to and facing away from the viewbox surface, with the rear side of the detector in contact with the viewbox surface. The meter shall be held so that the medical physicist is not within the angle of acceptance.

9. Make the measurement and record the result of the illuminance falling on the viewbox surface on **Chart 15**.

10. Place the illuminance meter 50 cm from the viewbox with its detector parallel to and facing towards the viewbox surface, centered on the viewbox (see Figure **).

Comment: Add this figure

11. Make the measurement and record the result of the illuminance seen by the observer on **Chart 15**.

12. Repeat the tests for all viewboxes used for interpreting printed mammograms and for the viewboxes used by the technologist to check the printed mammograms during the examination.

RECOMMENDED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

Viewboxes used for interpreting mammograms and clinical quality review by the technologist should be capable of producing a luminance of at least 3,000 candela per square meter (cd/m^2). The room illumination levels should be 10 lux, or preferably less than 3 lux. All viewboxes used for mammographic interpretation must be masked to the exposed area of the film.

In addition to the measurement procedure described, the "Viewboxes and Viewing Conditions" procedure of the "Radiologic Technologist's Section" should be followed. It is essential to mask the area around the mammograms to exclude extraneous light, which reduces image contrast and low contrast perceptibility and also limits the maximum densities that can be seen without "bright-lighting" each image. Viewboxes should be positioned to avoid light from windows, monitors, other viewboxes, and other sources of bright light, either direct or reflected. Visually check the viewboxes to assure that all of the bulbs are producing light of the same color and luminance level.

If the luminance level of the viewbox is less than 3,000 cd/m^2, or if the luminance or the color of light of the individual lamps appears significantly different from others in the same viewbox, then all bulbs in the viewbox should be replaced at the same time.

Comment: This would be better as a table.

15. PROCEDURE: LASER PRINTER EVALUATION AND BASELINE VALUES

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OBJECTIVE

To ensure that high quality, uniform, artifact-free images are produced.

To determine the normal operating levels to be used by the technologist for their laser printer sensitometry test.

APPLICABILITY

This procedure should be performed on all printers used to print digital mammograms.

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TEST FREQUENCY

Equipment evaluations, yearly, after service to the printer or modifications to the image display and/or printing software.

Comment: What about redoing the ww and wl settings after changes to the RWS or printer?

REQUIRED EQUIPMENT

Unit specific TG18-QC pattern with DICOM header and image size exactly matching the modality produced by each Acquisition system (provided)
Uniform image AAPM^Test^ImageType^UNL80 (provided)
Densitometer
Jewelers loupe
Transparent Ruler showing mm
Radiologist's viewbox

PROCEDURE

Where possible, printing should be conducted directly from the radiologist's review station to evaluate the entire printing chain integrity.

1. Turn on the radiologist's viewbox and allow it to warm up for 20 minutes to allow the light output from the bulbs to stabilize.

2. Place a vertical and a horizontal 5 cm line or ruler on the TG 18 QC image using an annotation tool, located near the existing rulers on the pattern.

3. Print the annotated TG18-QC Pattern from the review work-station, ensuring that the window-width is set 100 % of full scale and window-level is set to 50% of full scale.

Comment: Does this agree with the tech man?

4. Place the film on the radiologist's viewbox for the visual verification steps.

5. Verify that all density steps are visible. Measure the optical density at each step and record on **Chart 16-A**. The luminance response as Observed Contrast/JND

difference values is plotted automatically on **Chart 16-B**.

6. Verify that the low contrast squares are visible in the corners of the density steps and record on **Chart 16-A**.

7. Verify that the 0-5% and 95-100% low contrast targets are visible.

8. Using the loupe verify that the line pair patterns are visible in both directions for half nyquist and full nyquist frequencies at high and low contrast. Record the pattern visibility on **Chart 16-B**.

9. Display the uniform image provided. Set the window-width to 100 % of full scale and the window-level to to give a printed optical density between 1.5 and 2.0. Print the image. Record the window and level settings and use the same settings each time the test is performed.

10. Measure the optical density in the middle of the resulting uniform film and record on **Chart 16-A**.

11. Examine the uniform phantom film for artifacts.

12. Measure TG18-QC rulers, as well as length of annotation lines. Calculate the scaling factor of the printed image (1cm on detector = ? cm on film)

13. Record the results on **Chart 16-A.**

14. Print (and process if a wet processor is being used) a TG18-QC image or a gray-scale step wedge.

15. If a TG18-QC image is printed, use the appropriate window-width and level settings, Record these values on **Chart 16-B -Wet** or **Chart 16-B-Dry**, as appropriate.

16. If a wet processor is being used, obtain 5 films, spaced out over at least 2 hours, but preferably over 5 days. The films could be printed by the site technologist provided they are shown how it should be done. Ensure that the window and level settings are the same each time.

Comment: Comments on frequency?

17. If using the TG18-QC pattern, read and record the densities for the max OD area (D_{max}, border of 0-5% contrast square), the mid–density (MD) box (box 8, 47.06%), upper density (DD1, box 4 (21.96%)), lower density (DD2, box 13 (78.43%), and the base+fog (BF, border of 95-100% contrast square).

18. If using a gray-scale step wedge, choose step numbers as follows:

    a) Base+Fog (BF) – the lightest step

    b) Mid-Density (MD) – the step closest to but not below an optical density of

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1.20 or your working optical density

c) Upper Density (DD1) – the the step closest to 2.20 minus

d) Lower Density (DD2) - the step closest to but not less than 0.45

e) Maximum Density (D_{max}) – the darkest step

19. If using a wet process printer, record the density values on **Daily Wet Process Printer Sensitometry Target Values**. If using a dry process printer, record the density values on **Monthly Dry Process Sensitometry Target Values.**

20. Calculate the Density Difference by subtracting the Lower Density value from the Upper Density value (DD = DD1-DD2).

21. If a wet-process printer is being used, determine the averages for these four values (base+fog, mid-density, density difference, and D_{max}) over the five films.

22. Record the target values on **Daily Wet Process Printer Sensitometry Target Values** or **Monthly Dry Process Printer Sensitometry Target Values**, as appropriate**.**

RECOMMENDED PERFORMANCE CRITERIA AND CORRECTIVE ACTION

All density steps should be distinct and all low-contrast squares in the corners of the gray scale patches should be visible. If the density steps are not distinct and/or low-contrast squares are not visible, the printer should be recalibrated to work with the current viewbox and ambient illuminance levels.

The 5% squares at both bright and dark levels must be visible when the film is placed on the radiologist's mammographic viewbox. If a 5% square is not visible, the printer should be recalibrated.

The printer shall be calibrated to match the DICOM softcopy gray-scale display function when the films are read on the radiologist's mammographic viewbox. The Observed Contrast/JND difference $((\Delta L/L)/(JND_n-JND_{n-1}))$ versus average JND $((JND_n+JND_{n-1})/2)$ shall be within 20 % of the response described by the DICOM gray-scale display function.

Comment: This is just a guess at how tight it should be. Our printer still fails at 20 % right now!

The dynamic range of the film on the radiologist's mammographic viewbox shall be at least 250:1.

The average number of JNDs per luminance interval shall be less than 3.

The maximum deviation from the average number of JNDs per luminance interval shall be less than 2.

The root mean square deviation from the average number of JNDs per luminance interval shall be less than 1.

All line-pair patterns should be distinguishable. If not all line-pair patterns are distinct, the service person should be consulted.

Measured lengths of the horizontal and vertical rulers on the TG18-QC pattern need to be within 5%.

Measured lengths of the horizontal and vertical annotation lines on the film need to be within 5%.

The average length of the TG18-QC rulers needs to be within 5% of the average length of the annotation lines.

NOTE: New operating levels should not need to be set except when major changes are made to equipment. The printer should be re-calibrated to meet the expected operating levels when film or chemistry is changed.

If there are noticeable artifacts, the source should be identified and corrected.

TIMEFRAME FOR CORRECTIVE ACTION

Immediately, before any further patient films are printed.

III. EVALUATION OF THE MAMMOGRAPHY SITE'S TECHNOLOGIST QC PROGRAM

The medical physicist can provide a valuable service to mammography sites by assessing the sites' quality control programs and identifying areas where quality and quality control testing can be improved. At most sites, the visit by the medical physicist can serve as an external assessment of quality and a comparison of quality and quality control practices with those of other mammography sites. This review provides an opportunity for valuable feedback to the site on methods of quality improvement.

For this opportunity to be realized, the medical physicist must be familiar with the quality control practices that are performed by the QC technologist. In addition, the physicist should check that QC tests are properly performed and documented and that appropriate actions are being taken to correct problems when they occur.

Each mammography site should have a QC or QA Procedures Manual that documents the individuals responsible for QC testing, the testing performed, and the results of that testing. The manual should also document the on-site training of technologists on equipment operation, positioning, compression, mammography technique selection, and patient and operator safety, including radiation safety. (See a more complete listing of the items that should be contained in a procedures manual in the "Radiologist's Section".) The medical physicist should review the Procedures Manual on each visit to a site, reviewing contents to ensure that the manual is up-to-date and contains at least summary results of the last year's QC tests. A checklist to aid the medical physicist in reviewing the site's QC procedures is provided in Section IV.

The medical physicist can also provide a useful independent check of film viewing conditions.

Problems with the mammography site's quality and QC program and recommendations to the site for improvement should be clearly communicated in a cover letter or summary sheet of Problems and Recommendations. Too often, communications back to mammography sites are ignored by the site because they lack clarity or are too obscure to interpret. The Medical Physicist's Mammography QC Test Summary forms in Section IV have been included to aid in communicating the results of physics tests to the mammography site. A Preliminary Results form is also provided in Section IV for the medical physicist to leave brief, handwritten results for the facility prior to departure. This immediate communication is particularly essential to allow adequate time for the facility to take corrective action should any tests fail.

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IV. SUMMARY REPORTING FORMS

All Technologist Baseline Worksheet results should be left on site for use in the daily Quality Control Program.

Comment: Where are the forms?

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V. GLOSSARY

A

Active display area. The part of the softcopy viewer used for showing images, applications and the desktop.

Acquisition workstation (AWS). The computer, display, and associated equipment used to collect and verify image data. There is a graphical interface, which permits patient identification, includes a viewer for displaying either the single image or multiple images, and provides a connection to the radiology information system (RIS) and picture archiving and communication system (PACS). The viewer provides functions for adjusting window width and level, zooming, scrolling, adding text and graphical annotations, and permits validation of positioning and image quality. It is not used for diagnostic interpretation.

Acquisition time. The date, hour, minute, and second at which collection of data to form an image began. It could also be the duration of image acquisition.

ADU. Analog to digital unit. The signal or pixel value in the raw image.

Air kerma. The energy deposited per unit mass in air. The unit used to measure air kerma is the Gray (Gy). For x-rays with energies less than 300 kilo-electron volts (keV), 1 Gy = 100 rad. In air, 1 Gy of absorbed dose is delivered by 114 roentgens (R) of exposure.

Algorithm. A set of well-defined instructions for accomplishing a task. It is often a step-by-step procedure, performed by a computer. From a given set of initial information, the same result will always occur.

Aliasing. An effect that causes different continuous signals to become indistinguishable from one another when sampled. In images, it gives rise to image artifacts such as superimposed image data, moiré patterns (when the original image is finely textured) or jagged outlines. (See Figure xx in Effective Resolution of the Technologist's Section)

Array. A rectangular arrangement of data in rows and columns, as in a matrix, or an arrangement of detector or memory elements in one or more planes.

Artifact. Any structure or pattern visible in the image that is not part of the object being imaged.

Assistant. A trainee or un-certified person who performs tests under the supervision of a certified medical physicist.

Automatic optimization of parameters (AOP) mode. An automatic exposure control mode whereby the kVp, target material, and filtration material are determined to give an

appropriate signal-to-noise ratio with an adequately short exposure time. A short pre-exposure is used to determine the attenuation in the breast.

Automatic exposure control (AEC) systems. A device designed to determine the spectrum (target material, filtration material, and kVp) and/or the exposure (mAs) needed to produce an adequately penetrated x-ray image. This is typically done by sampling the x-ray intensity after it passes through the patient and image receptor.

Average glandular dose (AGD). The energy deposited per unit mass of glandular tissue (the most radiosensitive tissue in the breast) averaged over all the glandular tissue in the breast. The average glandular dose delivered during a single craniocaudal view of an FDA-accepted phantom simulating a standard breast shall not exceed 3.0 milligray (mGy) (0.3 rad or 300 millirad) per exposure. The dose shall be determined with technique factors and conditions used clinically for a standard breast. The AGD is calculated from values of entrance exposure in air, the x-ray beam quality (half-value layer), and compressed breast thickness. See also: dose. As opposed to the entrance exposure, AGD or mean glandular dose can be used to estimate the risk of cancer induction from the exposure.

B

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Bad pixel map. A specification which describes which array elements in the detector are defective.

Banding. A pattern of subtle stripes on an image.

Bar pattern. A tool for determining the limiting spatial resolution of an imaging system. It is composed of groups of highly x-ray attenuating strips spaced by an equal length of non-attenuating material. Each group of strips is smaller than the previous. The last group in which each bar is visible as a distinct line indicates the limiting spatial resolution of the system.

Bit-depth. Number of values that can be assigned to a pixel in a certain digital system, expressed in powers of two.

Black. The lowest light level displayed on a monitor. In normal mammographic viewing, this represents the maximum x-ray transmission. Photometric Interpretation Monochrome 1 represents images with highest x-ray intensity being black, while Monochrome 2 represents images with the maximum x-ray intensity being white.

Brick. An outboard power transformer of the kind associated with laptops, modems, routers and other small computing appliances, especially one of the modern type with cords on both ends. In the SELENIA system, the x-ray generator, detector, and acquisition computer communicate with each other through a device called a "brick".

Broker. A device or application that provides a software interface between systems that do not comply with a particular specification. Messages to or from a system are instead sent to the broker, which translates between the system and the required specification.

C

Cassette. A light-tight case usually made of thin, low x-ray absorption plastic, for holding CR plates or intensifying screens and film. Both types of image receptors store the latent image and require further processing to produce a visible image.

Clipping. The truncation of a signal because one of the stages in the system has saturated or gone beyond the maximum (or minimum) numerical value. Further increases (or decreases) in signal cannot be recorded. The system is not linear at levels when clipping occurs, and often is not linear *near* the clipping level.

Compression device. A plastic paddle used to flatten and immobilize the breast. Compression helps reduce motion blurring in the breast, separate structures within the breast, and to decrease the thickness of breast tissue, minimizing the amount of radiation used and the amount of scattered radiation reaching the image receptor. Ideally, the compression device is made of rigid, thin plastic and has a flat bottom surface that is parallel to the plane of the image receptor and with edges perpendicular to the plane of the image receptor to assist in moving breast tissue away from the chest wall and into the field of view.

Computer aided detection or diagnosis (CAD). Software for the computer-aided analysis of mammograms, marking suspicious areas to increase the sensitivity of the radiologist.

Computed radiography (CR). Digital radiology technology using photostimulable phosphor plates.

Conformance Statement. A formal statement that describes a specific product implementation that uses the DICOM Standard. It specifies the Service Classes, Information Objects, and Communication Protocols supported by the implementation.

Contrast to noise ratio (CNR). A measure of image quality defined as the signal difference between two known structures divided by the system noise within one or both of those structures. The CNR represents the ability to distinguish subtle lesions on a uniform background in which only image noise is present.

Control chart. A graphical means of displaying data in which the variable of interest is plotted on the vertical axis as a function of time on the horizontal axis. The control chart allows for easy and rapid review of the data to determine whether the process is within the desired control limits ("in control").

Control limit. The upper and lower values indicating that the process is "out of control" and requiring that corrective action be taken. It is prudent to immediately repeat the measurement to verify that the system is "out of control" before taking corrective action. If the repeated measurement is "out of control," then corrective action is required immediately (or in some cases within 30 days). Synonym for Action Limit

Consistent Presentation of Images (CPI). [IHE] The CPI profile ensures that image views are consistent throughout the enterprise, regardless of the monitor or printer used. It prevents confusion about patient orientation and enables display calibration or exchange of specific print settings.

Craniocaudal (CC) view. One of two routine views for mammography. The image receptor is placed caudad to (below) the breast and the vertical x-ray beam is directed from cranial to caudal (downward) through the breast.

D

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D_{max}, D_{min}. The maximum and minimum optical density on a film. Dmax is the darkest area of the film, where the highest exposure of x-rays occurs. D_{min} is the base plus fog optical density of the film.

Del. Discrete element in a digital detector. The del spacing specifies the smallest possible sampling pitch of an imaging system. This would also be the nominal sampling pitch in a storage phosphor system.

Dekanewton or Decanewton (daN). A unit of force equal to 10 Newtons. The spelling deka (rather than deca) is recommended by NIST to reduce confusion with deci (1/10).

Densitometer. An instrument for measuring the optical density or degree of blackening of film.

Detective quantum efficiency (DQE). The fraction of incident photons that would have to be detected without additional noise to yield the same SNR as is actually observed by the detector. The DQE gives the efficiency with which the device uses the available quanta.

Detector. A device that converts incident x-rays into an electrical representation of that image.

Detector defect cluster. A grouping of detector elements that do not respond correctly (approximately linearly with exposure), as do other detector elements.

Detents. Mechanical settings that limit or prevent the motion, rotation, or exposure of an x-ray tube, cassette assembly, or image receptor system.

DICOM. Digital Imaging and Communications in Medicine. The established standard for the exchange of digital information between medical imaging equipment and other systems.

Diagnostic mammography. Mammography performed on patients who, by virtue of symptoms, physical findings, or a prior screening examination, are considered to have some likelihood of having breast cancer.

DICOM grayscale standard. Part 14 of the DICOM standard that describes the charactistics of a display monitor to enable consistent display of images (see GSDF).

DICOM header. The initial block of data associated with an image that describes the patient, facility, and image format information. The DICOM header uses tagged fields to convey information about the modality, image format, acquisition time, patient demographics, and technical factors. In a mammographic image, a number of fields are compulsory. Digital Mammography images are either MG, DR, CR or DX modality types.

Digitization. The process of turning an analog signal into a digital representation of that signal. The term is also used for the scanning of radiographic films into a data format that can be stored by computer or a PACS system.

Digitized / Digital image. A data file or structure normally representing a rectangular grid of pixels, also referred to as a raster graphics image, or bitmap. Often people make the distinction between a "digitized image" and a "digital image": Digitized images are generally acquired in analog form and then "recaptured" by digitization, while a digital image is originally acquired by a digital detector.

Direct radiography (DR). Digital radiology technology using sealed units mounted on a radiography system, which captures x-rays and produces a digital image.

Dose. The amount of energy per unit mass deposited in tissue due to x-ray exposure. The S.I. unit of absorbed dose is the gray (Gy) representing 1 J/kg. One gray is equal to 100 rads; 1 milligray (mGy) is equal to 0.1 rad or 100 millirad.

Dose indicator. A manufacturer-provided value indicated on each image which is derived from the digital image receptor system and indicates the amount of x-ray exposure used to form the image.

Dose optimization. An attempt to balance the contrast, noise and dose while obtaining the highest amount of information from the exposure.

Dry processing. Laser film printers that use thermal processes to produce and fix the blackness on the transparency film. They use a heat-sensitive development process rather

than chemicals, and normally have frequent self re-calibration to ensure stability of images.

Dynamic Range. The difference between, or ratio of, the highest and lowest signals in an electronic circuit or image.

E

Effective resolution. The limiting spatial resolution measured with a line pair test pattern located at the level of the top surface of the average breast. It is affected by both focal spot size and detector resolution. The effective resolution is typically measured in the orthogonal directions parallel to and perpendicular to the anode-cathode axis.

Equipment Evaluation. Inspection to verify compliance with CFR21 – 900 and MQSA regulations.

Exposure. The amount of x-irradiation, quantitated by measuring the amount of ionization in air caused by the radiation.

Exposure indicator (index). Number ascribed to an image related to the exposure.

Exposure time. The duration of primary x-rays striking the breast and image receptor.

F

Full field digital mammography (FFDM). An x-ray imaging system dedicated to providing an image of the entire breast that is stored by computer, as opposed to screen-film mammography or a digital biopsy unit that acquires small field-of-view images of a segment of the breast.

Fill factor. The fraction of the area of a detector element that is actively sensitive to the incident x-rays.

Flat fielding. Correction of a digital image for non-uniform detector response and x-ray beam non-uniformities. Flat-fielding helps reduce artifacts and structured noise in DR images.

Focal spot. The area of the target or anode that is bombarded by electrons from the cathode of the x-ray tube to produce x-rays. The smaller the focal spot, the better the limiting spatial resolution of the x-ray system, especially in magnification mammography.

Fog. The unwanted signal added to an image by the exposure of the image receptor to light, radiation, or heat between patient exposures.

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Format. A particular way to encode information for storage in a computer file. Each digital image has its own headers, codes, and rules for laying out image content. There are many different file structures for each kind of file, including executable programs, word processing documents, image, graphics files and databases.

For Presentation. Images that are appropriate for diagnostic interpretation. They may or may not have had image processing performed to alter their characteristics.

For Processing. Images that have been corrected to account for characteristics of the detector but which are intended to be further processed before being used for interpretation. These are also called "raw" images.

Full-field digital mammography system. A digital mammography system designed to produce digital mammograms of the entire breast.

G

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Ghost image. An image whose intensity is related to previous exposures. As used here, ghosting includes two phenomena: 1) "lag", which is a residual image from previous exposures to the image receptor. This is caused by incomplete readout of the previous image, or incomplete erasure of prior images, 2) true ghosting, which is a change of detector sensitivity related to previous detector exposure and may be caused by incomplete erasure of prior images. In both cases, an artifactual image pattern is superimposed on subsequent images.

Gigabyte. A unit of computer memory or data storage capacity equal to 1,024 megabytes (2^{30} bytes).

Gray scale display function (GSDF). A DICOM standard established to ensure that images are displayed with similar grayscale perception and basic appearance on display systems of different luminance. It is linearly related to human perceptual response, allowing applications to know *apriori* how image values are transformed to viewed luminance values by a display system.

Gray-scale ramp. A region on the TG-18 or other test pattern in which the pixel intensity is increased by one unit at a time to cover the entire display range. The gray-scale ramp is used to test display system software and hardware.

Grid. A set of thin, closely spaced strips of highly attenuating material, such as lead , interspaced by a radiolucent support material, such as carbon fiber. In mammography the grid is placed between the breast and image receptor to reduce scattered radiation reaching the image receptor. Scattered radiation reduces image contrast in mammography and limits the detection of low-contrast structures such as fibers and masses. Grids improve the contrast of radiographic images at the price of increased dose to the patient.

H

Half-value layer (HVL). The thickness of a specified substance which, when introduced into the path of a beam of radiation, reduces the exposure rate by one-half. HVL is a measure of beam quality and is usually specified in millimeters of aluminum for diagnostic x-ray equipment. The higher the HVL, the more penetrating the x-ray beam.

Hanging protocol. A description of the way a series of mammograms is presented to a radiologist on the workstation, since the entire case cannot be viewed in its entirety at full resolution in a single view presentation.

Hard Copy. The display of digital mammograms on film.

Health Level 7 (HL7). The established standard for the exchange, management and integration of data that support clinical patient care and the management, delivery and evaluation of healthcare services.

Heel effect. Non-uniformity of the radiation field striking the image receptor caused by the geometry of the x-ray target. X-ray intensity is higher toward the chest wall than nipple, due to the increased path length through the target and filter of x-rays striking the nipple side of the image receptor.

I

Illuminance. A photometric quantity describing the light intensity per unit area falling on a surface. The SI unit for illuminance is lux (candela-steradians per square meter). In mammography it is important that the illuminance in the reading room be low.

Image blur. The spatial spread or unsharpness of distinct edges in a image, caused by the finite size of the focal spot, light spread in a phosphor, or motion of the object, resulting in reduced perception of detail and indistinct edges in the image.

Image compression, Lossless and Lossy. The process by which data is reduced to minimize storage space. Lossless data compression allows the exact original data to be reconstructed from the reduced data. Lossy compression provides high degrees of compression, but result in a certain amount of information loss when the image is restored.

Image contrast. The pixel value difference between adjacent areas in an x-ray image resulting from an attenuation difference in the imaged object.

Image manipulation. The action of changing the appearance of the image by modifying the underlying data. It might involve changing the spatial frequency information by smoothing or edge-enhancement, or adjusting the contrast by histogram manipulation.

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Image noise. See radiographic noise.

Image quality. The overall clarity of a radiographic image. Image sharpness, image contrast and image noise are three common measures of image quality.

Image receptor. A device that detects and records the distribution of x-rays to form an image.

Image sharpness. The overall impression of detail in a radiographic image.

Integrating the Healthcare Enterprise (IHE). An initiative by healthcare professionals and industry to improve the way computer systems in healthcare share information.

J

Just noticable differences (JND). A measurement of the difference in signal level which may just be reliably discerned on the monitor at different intensity levels. See DICOM grayscale standard.

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K

Kilovoltage, peak (kVp). The maximum value of the potential difference (kVp) between anode and cathode in an x-ray tube. The kVp determines the maximum energy of x-rays emitted by the x-ray tube, usually measured in kilo-electron volts (keV).

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L

Lag. A phenomenon related to the temporal characteristics of the signal from a detector. If the detector is "read-out" before the entire signal has been collected, the left over signal may show up the next time that detector element is read. This may cause the blurring of moving objects, or a shadow image.

L-number. For CR systems, the latitude index which indicates the dynamic range of the system. See S-number.

Linearity. System response where the output increases in direct proportion to the input signal.

Luminance. A photometric quantity describing the light power per unit area per unit solid angle emitted by a light source. The SI unit for luminance is candelas per square meter (nits). In mammography it is important that the display devices used for viewing mammograms have high luminance.

Lux. The SI unit of illuminance. One lux equals one lumen per square meter. The lumen is derived from the candela and is the luminous flux emitted into unit solid angle (1 steradian) by an isotropic point source having a luminous intensity of 1 candela.

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Matrix. An arrangement of objects in rows and columns. Pixel signal values in this arrangement are used to represent an image in the computer.

Matrix, active. A set of transistors used to sample a set of discrete detector elements.

Mean glandular dose. See Average glandular dose.

Mediolateral view. One of the more common diagnostic views for mammography, which has been replaced by the mediolateral oblique view as a standard screening view. The image receptor is placed lateral to the breast, and the horizontal x-ray beam is directed from medial to lateral aspect through the breast.

Mediolateral oblique view. Now one of the standard two views of the breast. The image receptor is angled 30^{o}-60^{o} from horizontal so that the cassette assembly is parallel to the pectoral muscle and the corner of the cassette holder fits comfortably into the axilla. The x-ray beam is directed from the superomedial to the inferolateral aspect of the breast.

Megabyte. A unit of computer memory or data storage capacity equal to 1,048,576 (2^{20}) bytes.

Milliampere (mA) setting. The electron current passing from the cathode to the anode in an x-ray tube. For a fixed kVp, the output of x-rays per unit time from the tube is linearly proportional to the mA setting.

Milliampere-seconds (mAs). The product of electron current (mA) and the exposure time (in seconds). For a fixed kVp, total x-ray output is linearly proportional to mAs.

Modulation transfer function (MTF). A parameter that describes the contrast captured by the imaging system at each spatial frequency.

Modality. The DICOM classification of a diagnostic device, such as computed tomography (CT), magnetic resonance imaging (MRI), nuclear medicine (NM), ultrasound (US), computed or direct radiography (CR), secondary capture (SC) or digital mammography (MG).

MG. The DICOM modality type for digital mammography which ensures that the acquired images contain all relevant information that is necessary for further processing and usage. This profile is absolutely necessary for generating correct mammography image content and for proper display on the review workstation.

Mammography Quality Standards Act (MQSA). A United States law that went into effect in 1994, with the final rules promulgated in 1997. MQSA requires all mammography facilities in the United States to be accredited by an approved body and undergo annual inspections by state or federal inspectors. The Food and Drug Administration (FDA) is responsible for implementing MQSA and developing national

mammography regulations. The latest guidelines can be found at: www.fda.gov/cdrh/mammography/

N

Noise. Fluctuations of the signal that are not associated with the imaged object. Elevated levels of noise can be caused by the use of too few x-ray photons, random electronic pulses, and non-uniformities in the detector. In mammography systems, quantum noise (or quantum mottle) should be the dominant noise source. The standard deviation in a region-of-interest (ROI) in the output image is taken as a measure of noise.

Noise power spectrum (NPS). Function which describes image noise as a function of spatial frequency, also known as the Wiener spectrum.

nit. The SI unit of luminance. One nit equals one candela per square meter, or one lumen per steradian per square meter.

O

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Operating level. The central value about which we expect day-to-day measurements to fluctuate, for example, the empirically determined mid-density on a sensitometric film.

P

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Picture archiving and communication system (PACS). The local image storage and transfer system within the facility. It is comprised of a communications backbone with acquisition devices (digital mammography units as well as other modalities), workstations (both mammographic quality as well as those not of high enough quality for primary diagnosis), output devices (printers or CD writers), and an archive. All of these communicate using DICOM, and patient studies and images can be stored, queried and displayed at a number of locations.

P-value. See presentation value.

Phantom. A test object that simulates some aspect of human anatomy. A breast phantom simulates a typical breast in terms of size, composition, and x-ray attenuation and may contain test objects that simulate anatomy in the breast.

Pixel. One picture element of an acquired or displayed image. On a presentation device, in some cases, not every pixel is displayed unless there is a 1:1 or “full” display mode. without which information may be lost.

Pixel pitch. The physical distance between the centers of adjacent pixels on the digital detector or display. In the DICOM tags, pixel pitch is called imager pixel spacing and is generally equal to detector element spacing.

Pixel value. Numeric value assigned to a pixel. In current FFDM systems pixel values can range from 1 to 1024 (for 10-bit storage), 1 to 4096 (12-bit storage), or 1 to 16384 (14-bit storage), depending on the detector. Most systems provide linear scales for pixel values, but some present the data in logarithmic form. (see ADU)

Pixel value offset. A constant value is added to the measured signal values of all pixels. Only some manufacturer's systems use a pixel value offset.

Polymethyl methacrylate (PMMA). Also known by the generic name acrylic, and trade names Plexiglas (Rohm and Haas) and Acrlyate (General Electric).

Portable Data for Imaging. [IHE] Enables creating DICOM-compliant image CDs on the modality.

Presentation value. Pixel value after a value of interest (VOI) look-up table (LUT) or window width and window level settings have been applied.

Primary class display device. A display device used for the interpretation of medical images (also referred to in the text as 'diagnostic display device').

Processed image. The image after image processing, ready for presentation on the monitor or print-out. In the DICOM file, the value of tag Pixel Intensity Relationship (0028,1040) is 'for presentation'. In digital mammography, processed images have typically been thickness-equalized to make the image visible with approximately uniform background densities out to the skin line without re-windowing.

Processor artifact. Any unwanted or artificial image feature appearing on an image due to malfunction or misuse of the film processor or laser imager.

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Qualified Workstation. A workstation which has passed all tests of resolution and GSDF compliance with images from a particular manufacturers acquisition device. A workstation which has not passed all of the tests must not be used as a primary diagnostic display device.

Quality assurance (QA). A management tool that includes policies and procedures (including quality control tests and tasks) designed to optimize the performance of facility personnel, equipment, and procedures.

Quality control (QC). The routine performance of tests and tasks and the interpretation of data from those tests to characterize equipment and personnel function. QC includes the corrective actions taken when systems are found to be "out of control".

Quality control technologist. The technologist assigned the task of QC testing and maintaining QC records for radiographic imaging systems.

R

Radiographic noise. Fluctuations in signal values from pixel to pixel due to the discrete nature of x-ray photons and the resulting random fluctuations in the number of photons contributing to the image at each location. Also called quantum noise or quantum mottle, radiographic noise increases with increasing x-ray fluence, but less rapidly than the radiographic signal.

Radiographic sharpness. The distinctness or perceptibility of the boundary or edge of a structure in the x-ray image.

Raw image. See "unprocessed image" and "for processing".

Raw noise. The noise in an unprocessed, but flat-fielded image. See noise.

Repeat analysis. A systematic approach to determine the number of and causes for images being repeated or re-taken. Analysis of data on repeats helps identify technical problems and/or operational difficulties and suggests ways to improve mammography quality.

Review workstation (RWS). A computer with high-resolution monitors designed for the interpretation of digital mammograms. There is often a graphical interface, which incorporates a DICOM browser, a viewer with hanging protocols for displaying multiple images at a time, and a connection to the radiology information system (RIS). The viewer provides functions for adjusting window width and level, zooming, scrolling, adding text and graphical annotations, and performing measurements.

Resolution. The fineness of detail that can be distinguished by an imaging system, often described by the MTF and measured by a bar pattern.

RIS. Radiology information system. A system used by radiology departments to maintain a record of patients, their demographics, and their imaging results.

S

Sampling aperture. The linear dimension of an area over which a single sample of a spatially varying quantity is measured. Spatial variations finer than the sampling aperture are integrated to produce a single measurement.

Sampling pitch. The distance between the centers of adjacent sampling apertures.

SC. The DICOM modality representing "Secondary Capture" images, normally digitized screen-film mammograms. Depending on the vendor, the acquired images may or may not contain all relevant information that is necessary for further processing and usage.

Scanning systems. Units that either have a moving detector, or use a scanning laser beam to read the signal off the detector.

Scatter fraction. The ratio of the x-ray exposure due to scattered radiation to the x-ray exposure due to both scattered and primary radiation detected by an image receptor.

Screen-film mammography. Radiographic images of the breast performed with high-detail intensifying screen(s) that are in close contact with the film in the cassette.

Screening mammography. X-ray breast examination of asymptomatic women in an attempt to detect breast cancer when it is small, nonpalpable, and confined to the breast.

Screen processing. Image processing applied in a CR system during readout of the imaging plate.

Secondary class display device. A display device used for viewing the images, but not acceptable for diagnostic purposes. This can include the acquisition workstation or operator's console.

Server. A computer system or program that performs specific tasks, such as access to files or shared peripheral devices, and constantly listens to machines on the network for requests to perform those tasks. Permissions may need to be granted to certain machines or users to enable it to perform the task.

Service class. [DICOM] A function, such as storage or printing, specified by DICOM and implemented by a device, which may provide or use the service.

Service class provider (SCP). [DICOM] A system or application that provides a DICOM Service (often viewed as the "server" of a service).

Service class user (SCU). [DICOM] A system or application that uses a DICOM Service (often viewed as the "client" of a service).

S - Nominal sensitivity setting. Indication of the sensitivity setting of the system, comparable to the speed class in screen-film systems. A speed class 100 corresponds to a mean absorbed dose to the detector of 10 microGray.

Sharpness (or unsharpness). The subjective impression of the distinctness of the edge of a structure in an image. It is related to the magnitude and width of the object, that is, the abruptness of the signal level change across the boundary.

Signal. In digital mammography, the signal is considered to be the pixel value. Normally, the image values are highest with the most x-ray transmission, and in the raw image, are either linear or logarithmic with increasing exposure.

Signal to noise ratio (SNR). The ratio of the signal content to the noise content of an image. The SNR is calculated as the mean signal value in an area divided by the standard deviation of signal in that area, assuming the object was uniform.

Signal Difference to Noise Ratio (SDNR). SDNR is a measure of the ability of a system to differentiate an object of low contrast from its background. For digital mammography, the reference contrast is 1.0 mm PMMA on a 4.0 cm PMMA background.

Soft copy. An image displayed on a high-resolution computer monitor rather than printed on a film.

Standard breast. A 4.2 centimeter (cm) thick compressed breast consisting of 50 percent glandular and 50 percent adipose tissue used as the "average" breast for dosimetry calculations. This may be represented by 4.0 cm of PMMA, a thickness which attenuates approximately the same amount as the standard breast.

Standard Deviation. A mathematical representation of the degree of fluctuation in a set of values. In mammography, the standard deviation is used to quantify noise. It is defined as $\sigma = \frac{1}{N-1}\sqrt{\sum_i \left[P_i - \bar{P}\right]^2}$ where N is the number of pixels whose standard deviation is to be calculated, P_i is the value of the ith pixel, and $\bar{P}$ is the average pixel value. The summation is taken from i = 1 to N of the difference between each pixel's signal value and the mean pixel value squared.

Standard test block. A PMMA test object representing the attenuation of the average breast (although not an exact tissue-substitute) so that the x-ray machine operates correctly under automatic exposure control and the dosimeter readings may be converted from exposure to average glandular tissue. The thickness is 40 ± 0.5 mm. The standard test block covers the whole detector.

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Standard region-of-interest. The region of interest (typically 4 cm², but always > 1 cm²) in which mean pixel **(ROI)** values and standard deviation are measured. The center of the region-of-interest is positioned 60 mm perpendicular to the chest wall edge of the image, and centered laterally.

Stitching. The method to join and re-align images from smaller sized detectors to form a full-sized image. It is sometimes used to mask the presence of dead columns in detectors.

Structured noise. A background pattern in a radiograph that often adds visual clutter and degrades or masks the detection of a lesion. In a clinical image, normal anatomy can provide structured noise. In phantom images, structure noise is typically the result of systematic artifacts such as roller marks in screen-film images, grid lines, or poor flat-fielding of digital images.

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Test Pattern. Artificially produced image for the evaluation of gray tone rendition, contrast, resolution, or the geometric characteristics of image display equipment.

TG 18. American Association of Physicists in Medicine Task Group 18 - Acceptance Testing & Quality Control of Electronic Devices for Soft-copy Display http://deckard.mc.duke.edu/~samei/tg18

Thermoluminescent dosimeter (TLD). A radiation exposure measurement device using a chip or powder that absorbs radiation and when subsequently heated produces light whose intensity is proportional to the amount of radiation absorbed.

Threshold contrast. The smallest detectable contrast for a given detail size and x-ray exposure that can be shown by the imaging system over its whole dynamic range. The threshold contrast is a measure for imaging of low-contrast structures, and is determined largely by the DQE of the detector.

Trainee. An individual who is in the process of becoming certified, and performs testing under the direct supervision of a certified mammographic medical physicist.

U

Uncorrected image. The image from a digital imaging system before any image processing, including detector corrections and flat-fielding, is performed.

Unprocessed image. The image from a digital imaging system after flat-fielding and detector corrections (corrections for individual pixel sensitivity variations and electronic gain of the readout) but before other image processing (such as thickness equalization) has been applied. The pixel value is in general linearly related to exposure in the unprocessed image. The international standard IEC MT 31 refers to the unprocessed image as ‘raw data’.

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Viewbox. A device providing a relatively uniform surface luminance for viewing mammographic films. Mammographic viewboxes should have a luminance level of at least 3,500 nit.

Variation. The change in intensity or pixel value across an image of a uniform object.

Value of interest lookup table (VOI LUT). The VOI LUT defines the (non-linear) transformation of pixel signal values into values meaningful for presentation (presentation values).

W

Window center or level. The signal setting at which a median gray scale is displayed.

Window width. The range of signal values over which gray scales ranging from black to white are displayed. The window center or level is at the center of that range.

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If there are techniques (target, filter, kV combinations) desired that have already not been measured in Procedure 7, then the same patient "Physics" and first name "Junk" that was used for the HVL test procedure should be used. These images will not be viewed or saved. Prepare the mammographic imaging system for operation in the imaging mode to be evaluated (e.g., contact mammography with grid). Use appropriate field limitation for this imaging mode.

Place a lead sheet (to protect the image receptor) on the breast support surface. Tape the ionization chamber to the underside of the compression paddle or use an appropriate holder to position the chamber. The ionization chamber should be centered left to right and 20 mm in from the chest wall edge of the image receptor. The mid-line of the chamber should be 4.5 cm above the breast support plate. The chamber should be fully within the X-ray field. If the chamber is sensitive to backscatter, there should be no more than 1 mm of low density material between the back side of the chamber and the lead sheet.

For scanning systems (Fischer Senoscan) ensure that the dosimeter is set to integrating mode rather than pulse mode.

Record the temperature and barometric pressure, so any necessary corrections can be applied to the measurements.

Set the kV, mAs, and target/filter as close as possible to the values used for each of the images from Chart 4 and record the dosimeter readings on **Chart**

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If desired for future reference, the entrance exposure can be measured at other kV settings that might be used clinically.

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