

Q.A. Collectible

*Sponsored by CRCPD's Committee on Quality Assurance
in Diagnostic X-Ray (H-7)*

Mammography Phantom Image Quality Evaluation

(from the American College of Radiology 1999 Mammography Quality Control Manual)*

Required Test Equipment

- Mammographic phantom (approximately equivalent to a 4.2 cm thick compressed breast consisting of 50% glandular, 50% adipose tissue) containing appropriate details ranging from visible to invisible on the mammographic image. At the time of publication, either the RMI-156 or Nuclear Associates 18-220 mammographic phantom may be used for the ACR Mammography Accreditation Program (MAP). These phantoms have fibers with diameters of 1.56, 1.12, 0.89, 0.75, 0.54, and 0.40 mm; specks with diameters of 0.54, 0.40, 0.32, 0.24, and 0.16 mm; and masses with decreasing diameters and thicknesses of 2.00, 1.00, 0.75, 0.50, and 0.25 mm (Figure 1).
- Acrylic disc (4-mm thick, 1-cm diameter) placed on the top of the phantom in a consistent location in the image area so it will not obscure details in the phantom and where it cannot cast a shadow on any portion of the AEC detector. With current equipment, significant variability in film optical density can result from placing the disc along the central anode-cathode axis, where a varying fraction of the AEC detector area might be covered by the disc's shadow, depending on the exact position of the phantom and the detector. A suitable location is between and slightly below the first and second largest fibers. A glue such as "SuperGlue" may be used to attach the disc permanently to the phantom.
- Cassette and film of the types used clinically for mammography. Use the same cassette used by the facility for their phantom QC to compare results.
- Appropriate masking to eliminate light reaching the viewer's eye from beyond the borders of the exposed phantom image. Images should be viewed on the same viewbox(es) used clinically. If a 14 x 17" viewbox is used, a film mask can be made by exposing a 14 x 17" film to light, processing it, and cutting a hole the size and shape of the phantom being used.
- A magnifying lens of 2X or higher
- Densitometer

Test Procedure Steps

1. Load film from the film bin into the cassette. Be sure to wait an adequate length of time for good screen-film contact to occur.
 2. Place the cassette in the cassette holder.
 3. Place the phantom on the cassette holder, positioning the phantom so that the chest wall edge of the phantom is aligned with the chest wall side of the image receptor. Center the phantom, left to right.
 4. Lower the compression paddle so that it just touches the top of the phantom. Do not compress the phantom since this may damage the compression paddle. (On some units, mild compression is needed to enable exposure.)
 5. Verify that the AEC detector is located beneath the center of the phantom and in the same location as used for previously acquired phantom images.
 6. Make an exposure using the technical factors (target, filter, kVp, grid, density control setting, etc.) currently in use clinically for a 4.2 cm compressed breast of average tissue density.
6. Record all technique factors on the image quality evaluation form.

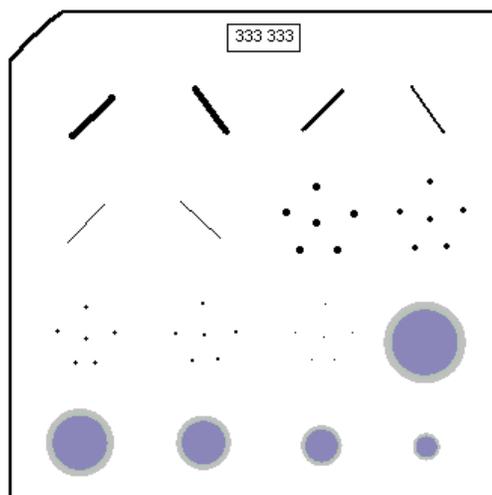


Figure 1. Mammography phantom image diagram: 6 fibers, 5 speck groups, and 5 masses.

8. Process the film in the processor normally used for mammography films.
9. Measure the film optical densities at three locations. The background optical density should be measured at the geometric center of the phantom image. To determine the density difference, measure the optical density inside the disc and directly adjacent to the disc, to its left or right, perpendicular to the anode-cathode axis. The density difference is the difference between the optical density measured inside the disc and that measured outside the disc. For consistent results, these measurements must be made in the same locations each time.
10. Record all measurements on the image quality evaluation form.

Viewing Conditions

Phantom images should be read under optimal viewing conditions. General lighting should be at a low level and diffuse. Viewboxes should be positioned to avoid light from windows, other viewboxes, and other sources of bright light, either direct or reflected. Images should be masked to eliminate extraneous light. Use a magnifying glass of 2X or higher for scoring speck groups as well as any other appropriate test objects.

Data Analysis and Interpretation

1. When scoring the image of one of the ACR-approved accreditation phantoms, each object type is scored separately. Always count the number of visible objects from the largest object of a given type (i.e., fiber, speck group, or mass) downward until a score of 0 or 0.5 is reached, then stop counting for that object type.
2. Count each fiber as one point if the full length of the fiber is visible and the location and orientation of the fiber are correct. Count a fiber as 0.5 point if not all, but more than half, of the fiber is visible, and its location and orientation are correct. Add each full or partial fiber score to the total fiber score, from the largest down to the smallest visible, until a score of 0 or 0.5 is reached. Record the “raw” fiber scores before artifact deduction.
3. After determining the last fiber to be counted, look at the overall background for artifacts. If a fiber-like artifact appears anywhere in the wax insert area of the image, but not in an appropriate location or orientation, deduct the “artifactual” fiber from the last “real” half or whole fiber scored if the artifactual fiber is equally or more apparent. Deduct only from the last real fiber, not from additional fibers. Record the final score after artifact deduction in the appropriate space on the form.

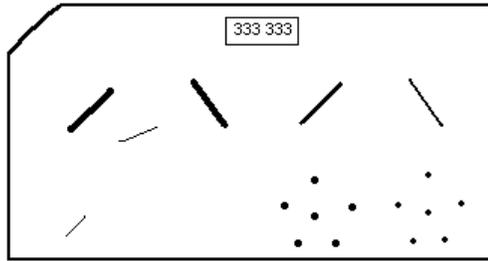


Figure 2. Fibers: 4.0 (4.5 – 0.5)
(the fiber-like artifact between the 1st and 2nd fiber must be subtracted from the last real fiber scored)

4. Use a large field-of-view magnifying lens (approximately 2X or higher) to assist in the visualization of specks. Starting with the largest speck group, count each speck group as 1 point if four or more of the six specks in the group are visible in the proper locations. Count a speck group as 0.5 if 2 or 3 of the six specks in the group are visible in the proper locations. Add each full or partial speck group score to the total speck group score, from the largest down to the smallest visible group, until a score of 0 or 0.5 is reached. Record this “raw” speck score before artifact deduction.

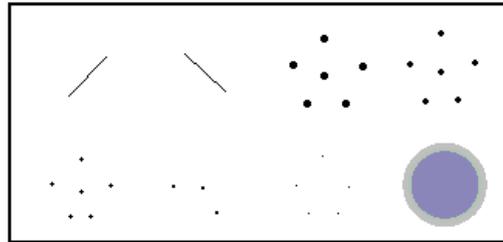


Figure 3. Speck groups: 3.5 (although 5 specks in the 5th speck group are visible, only 3 are visible in the 4th group)

5. After determining the last speck group to be counted, look at the overall background for artifacts. If noise or speck-like artifacts are visible in the wrong locations within the area of the wax insert, and are as apparent as the “real” specks, deduct them one for one from the individual specks counted in the last whole or half speck group scored, and adjust the score of the last group appropriately. Record the final score after artifact deduction in the appropriate space on the form.
6. Count each mass as 1 point if a minus density object is visible in the correct location and the mass appears to be generally circular against the background (i.e., greater than $\frac{3}{4}$ of the perimeter is visible). A mass is counted as 0.5 point if a minus density object is visible in the correct location, but the mass does not have a generally circular appearance.

Add each full or partial mass to the total mass score, from the largest mass down and until a score of 0 or 0.5 is reached. Record the “raw” mass score before artifact deduction.

7. After determining the last mass to be counted, look at the overall background for artifacts. If a mass-like artifact is seen in the wrong location within the area of the wax insert, deduct the “artifactual” mass from only the last “real” whole or half mass scored if the artifactual mass is equally or more apparent. Record the final score after artifact deduction on the appropriate space on the form.

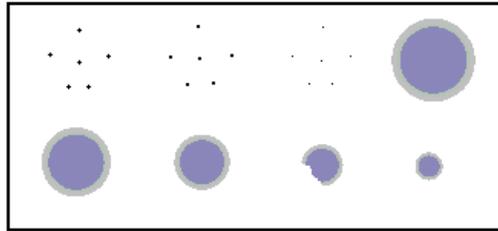


Figure 4. Masses: 3.5 (greater than $\frac{3}{4}$ of the round perimeter should be visible for a full point)

Recommended Performance Criteria and Corrective Action

The present criteria for the number of objects to pass the ACR Mammography Accreditation is **a minimum of the four largest fibers, the three largest speck groups, and the three largest masses**. Furthermore, the number of test objects of each group type (fibers, specks, and masses) visible in the phantom image should not decrease by more than one half, assuming the same individual is viewing the images under identical conditions. If a greater change in the number of test objects is noted, then the present image should be compared with the original image and the previous image to determine whether the change is real or if the individual viewing the film has changed his or her criteria.

The phantom image background optical density should never be less than 1.20, and the control limits for the phantom image background density should be ± 0.20 . Thus, in order to have the full ± 0.20 density control limits available, the **operating level for phantom image background optical density should be at least 1.40**. Substantially higher phantom image background optical density operating levels may provide improved mammographic image quality and avoid underpenetration of dense tissue. However, increasing mAs to achieve higher film optical density will increase the mean glandular dose and higher average film optical densities may require higher-luminance viewing conditions to see important diagnostic detail.

Generally, the operating level for density difference due to the 4.0-mm acrylic disc should be at least 0.40. The density difference will vary depending on disc thickness, the choice of film, kVp, processing conditions, and background image optical density. Higher mAs and background optical density may result in significant increases in density difference even when using the same film, kVp, and processing conditions. Once an operating level for density

difference is established, control limits are ± 0.05 for subsequent phantom images. The density difference control limits are only applicable when the 4.0-mm acrylic disc is used. If a new operating level for background optical density is chosen, then a new operating level for density difference must be established as well.

In addition to assuring that each mammographic imaging system produces similar film optical density and density difference over time, it is also essential that all mammographic units and mammographic processors at one facility produce similar film optical densities. It is not acceptable to have one unit or processor producing film optical densities of 1.40 and another producing optical densities of 1.80. Likewise, one should expect each mammographic unit and mammographic processor at a facility to produce images with similar density differences and images of similar image quality.

The mAs noted on the generator read-out should not change by more than $\pm 15\%$ for a given density control setting. It might be helpful to check that the QC technologist has set mAs control limits correctly and is plotting mAs correctly on the control chart.

If the recommended performance criteria and corrective action for this test are not met, a second phantom image should be taken and evaluated. If the criteria are still not met, the reasons for this failure should be investigated; corrective action taken, and the results documented before patients are examined with this system. Other testing methodologies may exist to help isolate the source of system change (e.g., processing versus X-ray unit) that could be applied in addition to the phantom and the 4.0-mm disc.

NOTE:

- **At a minimum, the four largest fibers, the three largest speck groups, and the three largest masses must be visible.**
- **The phantom image background optical density should be at least 1.40.**
- **The density difference due to the 4.0-mm acrylic disc should be at least 0.40.**

Possible causes for changes in phantom image background optical density or density differences are the processor, film emulsion batch, x-ray generator, etc. If the change in film optical density is confirmed to be due to a change in the film emulsion batch, and if the magnitude of the change is within the expected batch-to-batch variation for that film type, then an adjustment of the density control setting to bring the phantom background optical density back into control is appropriate. The film manufacturer should be consulted for guidance on expected batch-to-batch variation. If the change in film optical density due to the film batch change is greater than should be expected, then the non-compliant batch should be replaced by a new batch. The 1995 ACR Publication, *Recommended Specifications for New Mammography Equipment*, suggests that a difference in film optical density of 0.30 is a reasonable maximum to expect between any two films of the same type when given the same mammographic exposure and processed together.

All sources of significant artifacts should be eliminated. This may require careful cleaning and readjustment of the processor or cleaning of the screens and cassettes, as an example. Slow grid motion may introduce a structured pattern, especially with higher speed screen-film mammography image receptors, for which the times are relatively short. The grid may move only a few millimeters during the exposure and this may result in an image that includes grid lines. This can be corrected by service to the grid drive mechanism by a qualified service person.

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