# ASTM E545 TUTORIAL ON
# PROPER IMAGE QUALITY INDICATOR USAGE

Neutron radiography is a non-destructive testing method similar to the more familiar x-ray, but which uses neutrons for a radiation source to expose the film. Because of the important differences in neutron radiography from X-Ray, a different kind of penetrameter is needed. The ASTM document E545 describes a pair of image quality indicators that have been accepted internationally as a standard for neutron radiography.

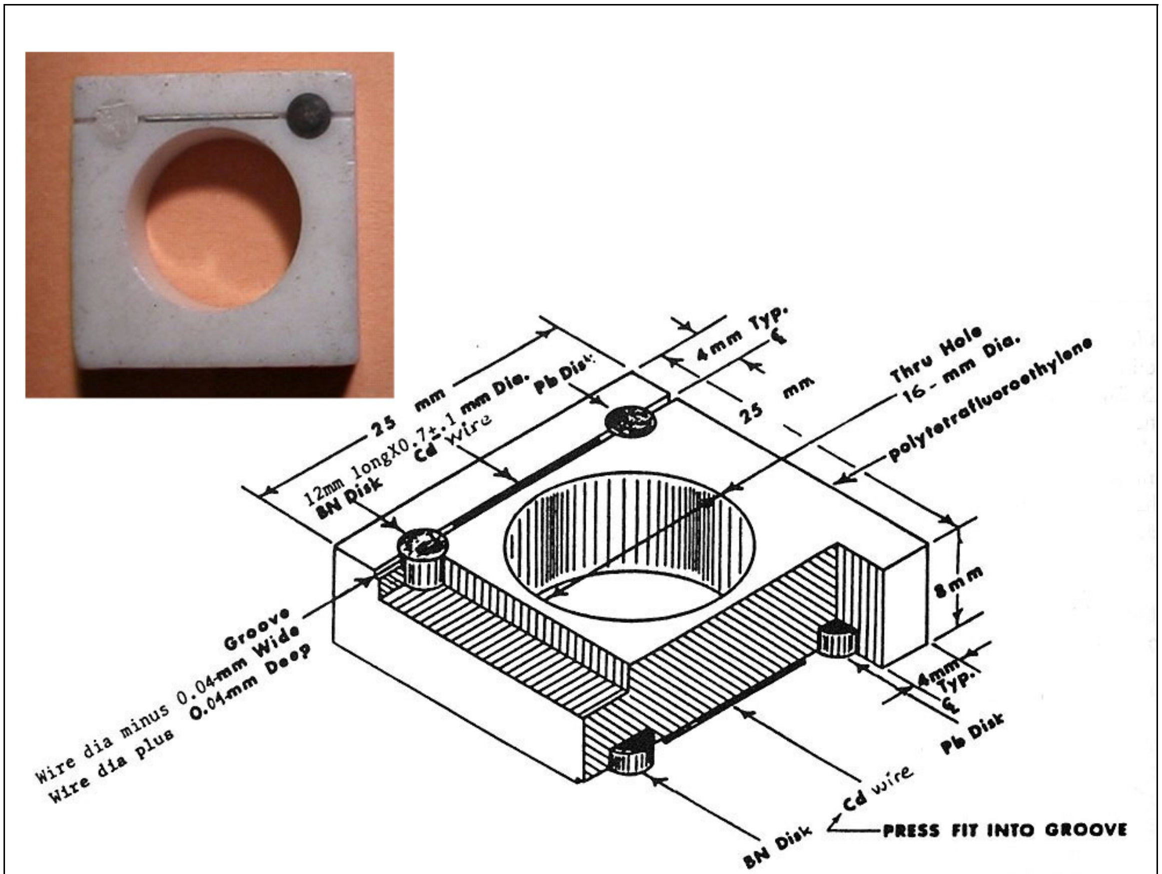



**Figure 17.1: Picture and drawing of Beam Purity Indicator**

The Beam Purity Indicator measures the beam content of the source, whether from a reactor, an isotopic source, or an accelerator. It is constructed of four simple materials so that the image of the BPI on the film can give both a quantitative analysis from measurements using a densitometer, and a qualitative analysis using the human eye for a quick visual check.

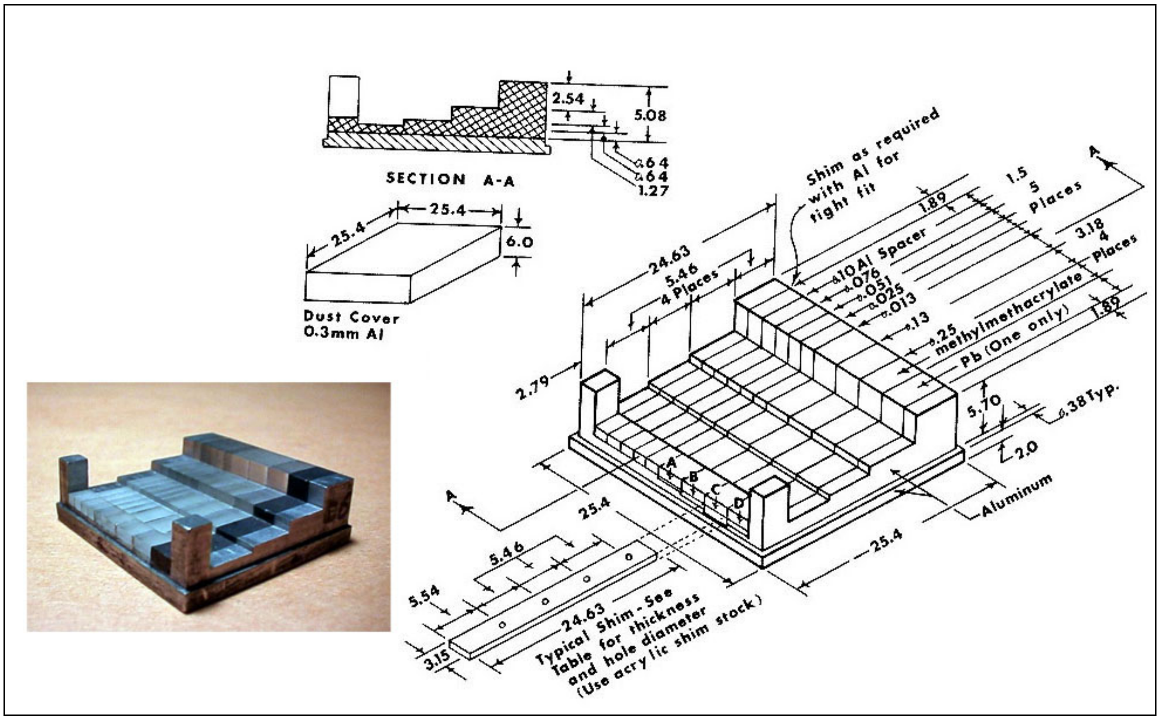



**Figure 17.2: Photo and drawing of Sensitivity Indicator**

The Sensitivity Indicator is a more complex device, consisting of four steps of a plastic material, with holes and gaps built in to examine the resolution available. Its values are based on the film reader's ability to see the smallest size hole or gap that can be resolved by the reader.

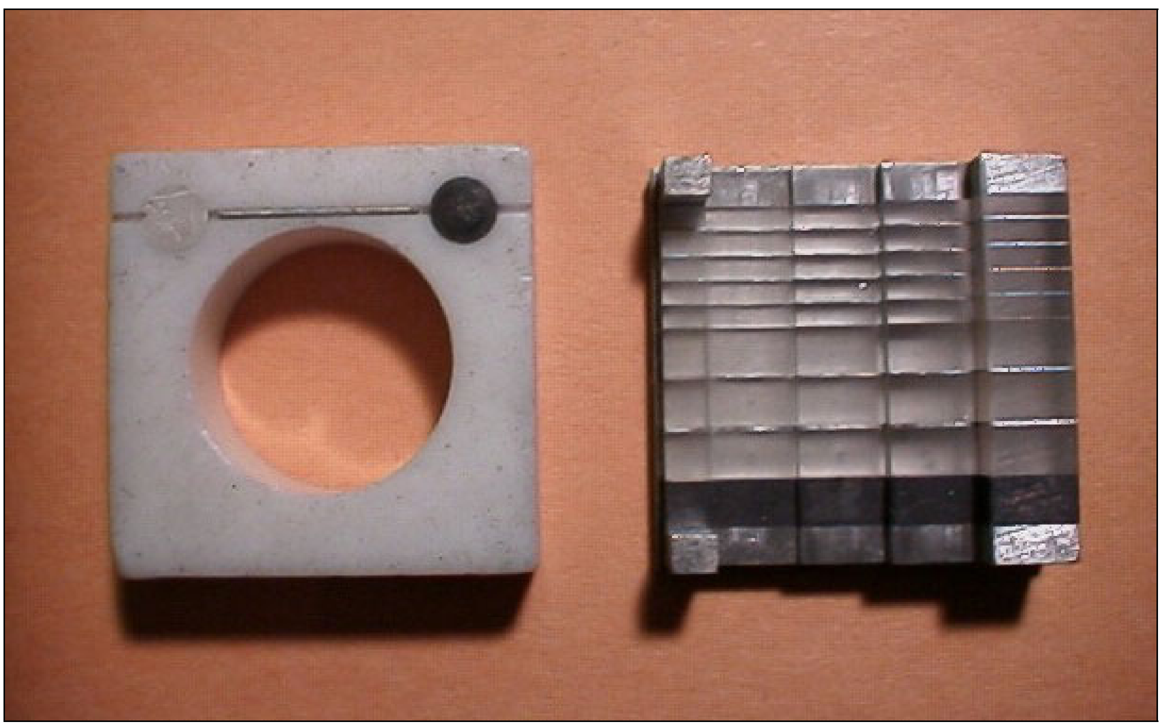


**Figure 17.3: Photo of Beam Purity Indicator (left) and Sensitivity Indicator**

Together this pair of image quality indicators can give the reader a basis for evaluating both the facility at which the film was created, and the resolution of the film itself. Details of construction of these devices can be found in ASTM E2003 and ASTM E2023.

**Figure 17.4: Correct placement of Indicators in part holder**

The BPI and SI should be placed no less than one inch from any edge of the film to avoid the edge effects of captured gamma from the conversion screen. The cadmium rods should be oriented such that their longitudinal axis is perpendicular to the nearest edge of the film, or edge effects will negate or exaggerate the differences between the disks.

**Figure 17.5: Incorrect placement of indicators in part holder (three examples)**

Scattered neutrons are indicated by a simple “reverse collimation” technique. The boron nitride disk adjacent to the cassette is assumed to absorb all thermal neutrons whether primary or scattered. The boron nitride disk that is 6 mm away from the cassette will remove all primary thermal neutrons but permit scattered neutrons to interact with the conversion screen within the boron nitride image area. Low angle scattered neutrons, outside a cone of approximately 33 degrees included angle, will be effective in degrading the contrast, since they have the effect of adding to the background density without providing any meaningful information. An analysis of the difference in density between the two boron disks will give the percentage of neutrons that are scattered in the beam.

Similarly, the lead disk that is against the cassette will absorb all gamma photons while the disk that is 6 mm away from the cassette will allow them to darken the film. An analysis of the difference between the two lead disks will give the percentage of gamma that is in the beam, and low energy gamma is the most detrimental factor in neutron radiography. The relative thicknesses of the lead and the teflon are chosen so that the neutron attenuation for both is the same at those thicknesses.

The cadmium wires should show about the same degree of sharpness at 5/16” apart. A significant difference between them indicates that the L/D ratio is likely too low for general inspection.

Without using a densitometer, a radiographer can now analyze the BPI qualitatively. If there is a significant difference in the density of the two boron disks, the beam has many scattered neutrons. The lead disks should be approximately the same density as the Teflon block. If the lead disks are visibly lighter than the Teflon block, there is a high gamma content. If the lead disks are darker than the Teflon block, the beam has a high pair production content.

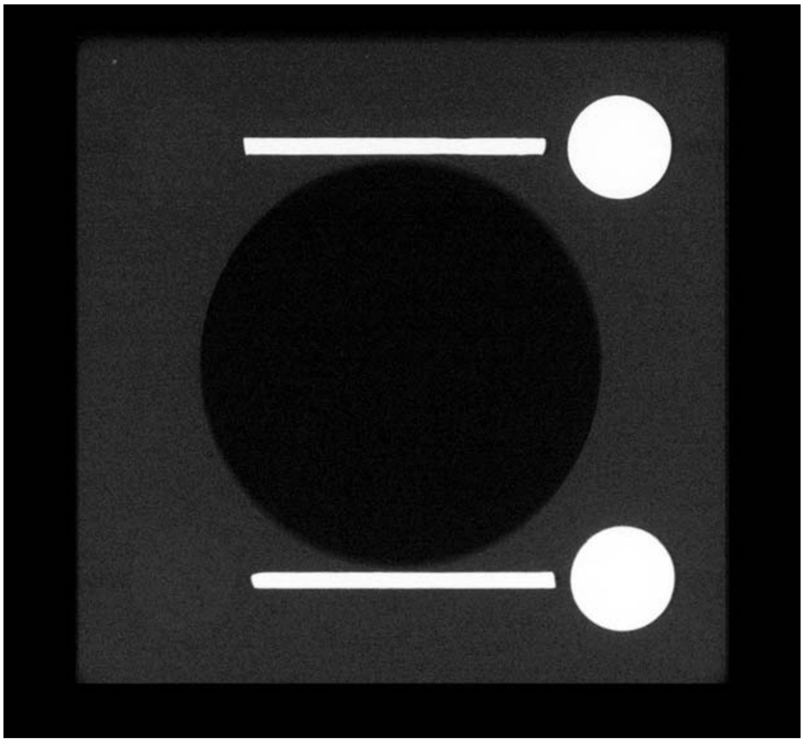


**Figure 17.6: Film image of Beam Purity Indicator**

Visually, the radiographer can quickly determine if the beam contains significantly detrimental elements: scattered neutrons, gamma content, pair production, or low L/D ratio. Any of these observations indicates the need for further image analysis and subsequent determination of the usefulness of the radiograph for that particular inspection.

**Figure 17.7: Light transmission densitometer**

A densitometer that reads the amount of light transmitted through a film can also be used to obtain quantitative information. In this model, high-intensity light is generated in the bottom of the unit and allowed to escape through an aperture to the detector in the top, where it is read and reported logarithmically. Zero is 100% transmission of light, 1 is 10% transmission, etc.

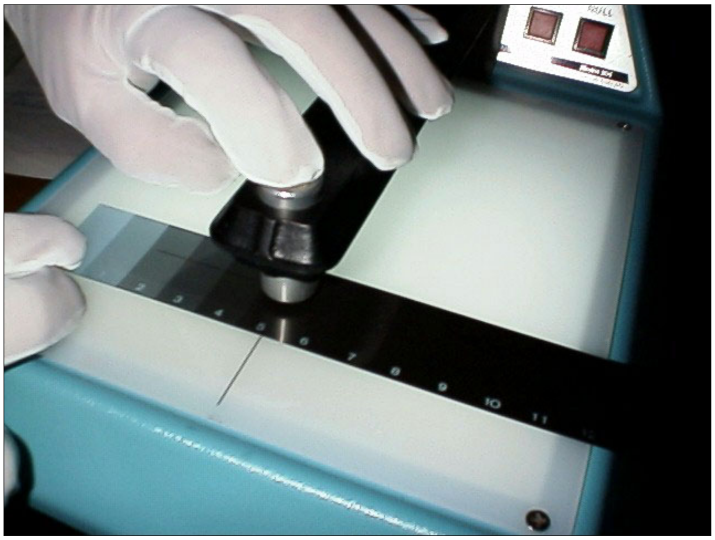


**Figure 17.8: Calibrating densitometer**

The densitometer should be calibrated before use with a step-wedge calibrated to a national standard.

There are six density measurements to be taken from the image of the BPI. The order is not important, as it is the highest, lowest, or difference between the measurements that will determine the results.

Use the densitometer to measure the density of the image of each boron disk, and each lead disk. The lead disks can be difficult to see in the densitometer, so use crosshairs to bisect the opposite corners and find the proper position for the densitometer.

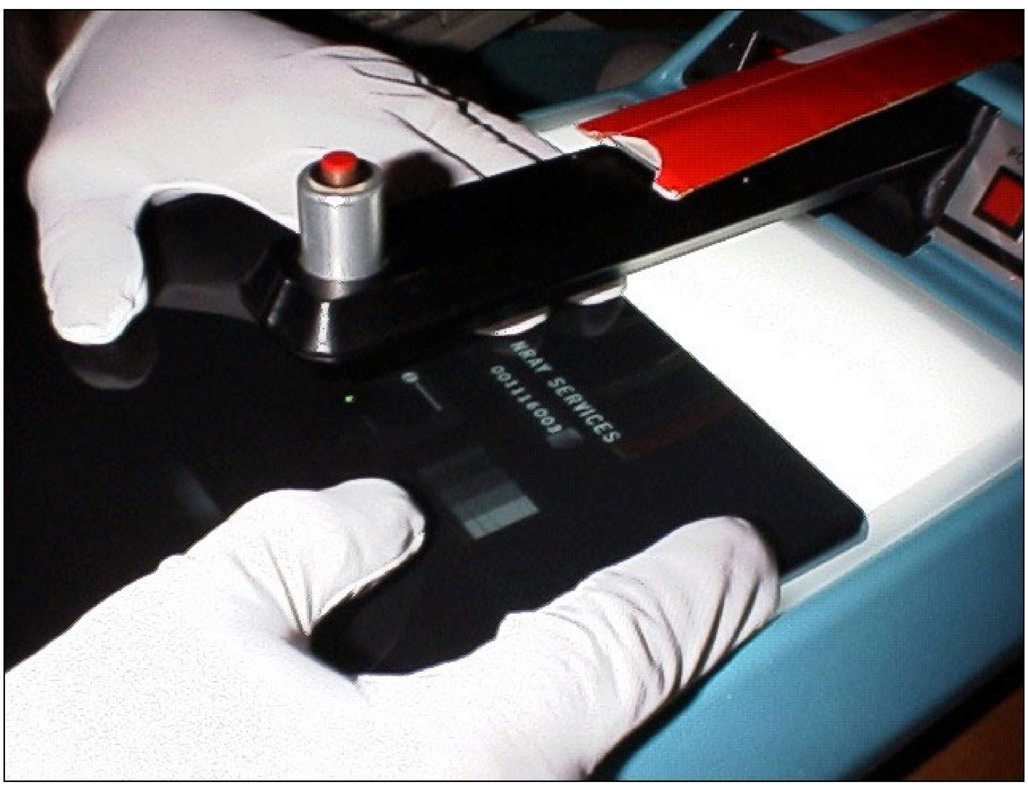



**Figure 17.9: Measuring density of boron disk with densitometer**

Use the densitometer to measure the density of the image of the teflon block. A good place to do this is midway between the lead disks. Then do the same for the center hole. Record all six measurements.

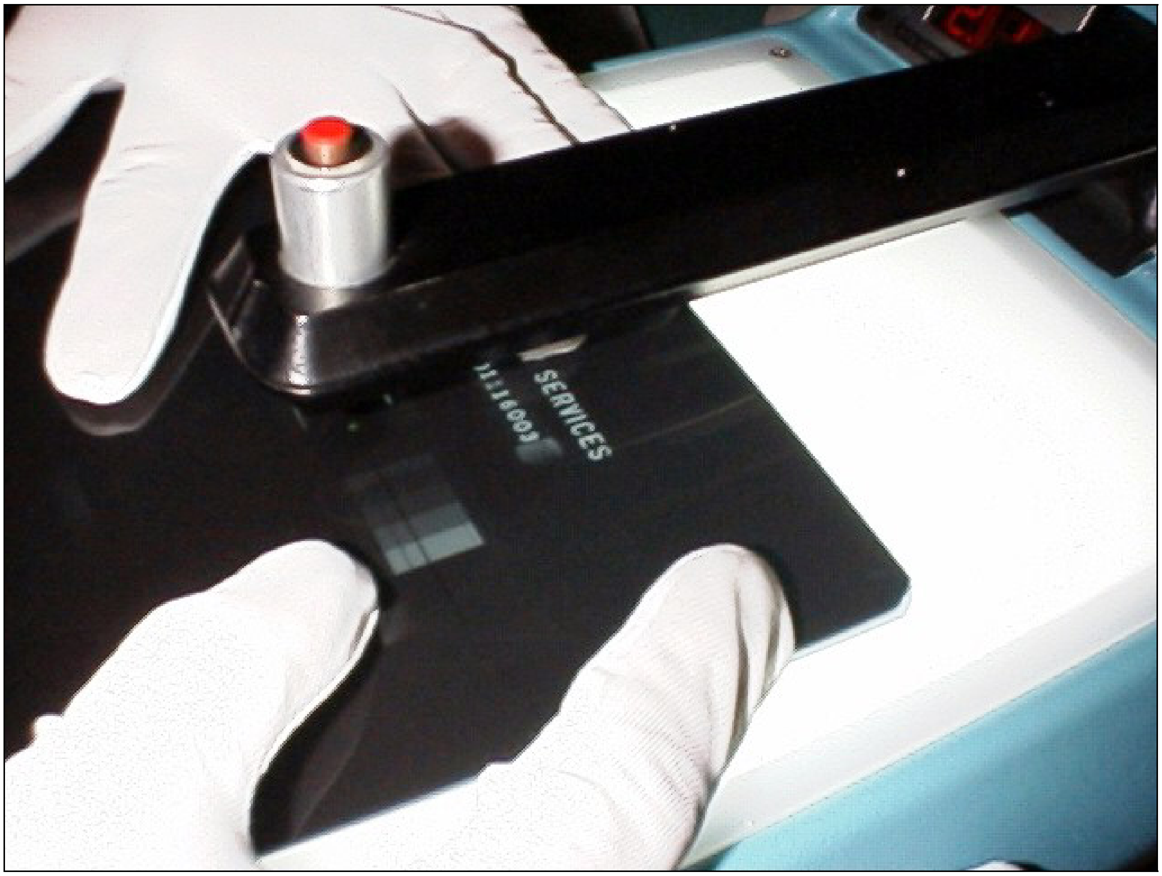



**Figure 17.10: Measuring the density of the Teflon with densitometer**

Consult a copy of ASTM document E545. The formulas are printed in paragraph 10.

To calculate the effective thermal neutron content, add the value of the higher of the two boron disks to the *difference* between the two lead values. Subtract this value from the hole, then divide by the value for the hole. Multiply by 100 to make it into a percentage.

To calculate the effective scattered neutron content, divide the difference between the boron disks by the value for the hole, then multiply this quantity by 100.

To calculate the effective gamma content, subtract the lowest of the two lead values from the value for the teflon block, divide by the value for the hole, and multiply by 100.

To calculate the effective pair production content, divide the difference between the lead values by the value for the hole, then multiply by 100.

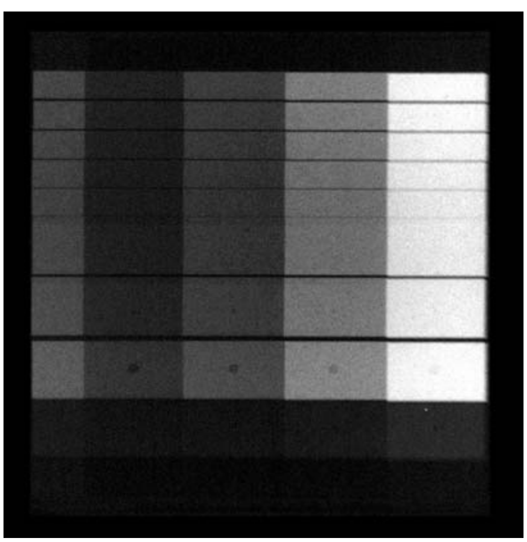
These results can then be compared to the figures in Table 4 of E545 to categorize the quality of the radiograph. For example, a neutron radiograph that has a BPI on it that yields a thermal neutron content of 62%, a scatter content of 5%, a gamma content of 3%, and a pair production of 0.5% would qualify as a Category II radiograph. A neutron radiograph that yields a neutron content of 67%, a scatter content of 4%, a gamma content of 4%, and a pair production of 1% would also only qualify as a Category II radiograph because the gamma content did not meet Category I requirements.

It should be recognized that these categories favour contrast factors because the sensitivity indicators do not permit accurate determination of sharpness alone; all such determinations are subjective. It may, therefore, be advantageous to use a lower number category when sharpness is a more important factor than contrast.

Using these methods, the radiographer can now use the BPI to qualitatively analyze the radiograph through visual means, or quantitative analyze the radiograph through mathematical means. The BPI can also be used to verify the day-to-day consistency of the neutron radiographic quality in a facility. Metallic conversion screens and single-emulsion silver halide films, exposed together in the neutron imaging beam, were used in the development and testing of the BPI. Use of alternative detection systems may result in densitometric readings which are not directly comparable to the formulas mentioned above.

Now we will examine the Sensitivity Indicator, or SI.

The design goal for the ASTM sensitivity indicator was to provide the maximum information regarding sensitivity in an easy to manufacture and easy to interpret configuration. It combined into a single device the best elements of the four previously used devices. It is generally accepted that the only truly valid sensitivity indicator is a reference standard comparison part, of a material or component equivalent to the part being radiographed with a known standard discontinuity. Making a standard for every configuration being radiographed may not be practical for the manufacturer, however, so the SI may be used instead.



The SI consists of a step wedge containing gaps and holes of known dimensions. Visual inspection of the image of the SI provides subjective information regarding total radiographic sensitivity with respect to the step-block material as well as subjective data regarding detrimental levels of gamma exposure.

**Figure 17.11: Film image of Sensitivity Indicator**

The SI device is constructed of nine step-wedge strips of methylmethacrylate, which is also known by the trademark, “Lucite.” Aluminum shims are placed in between the strips to simulate gaps in the neutron radiographic image. Three or an optional four shims with various sized holes are slipped under the strips. In the option, there may be a fourth shim slipped under a strip of lead, which is useful in detecting gamma, but the shim holes under the lead should not be used in figuring the sensitivity of the device for categorizing. The holes in the three regulation shims cover the range of what can be seen in most facilities. The smallest holes, 0.005”, are smaller than what can be seen by conventional neutron radiography when covered by methylmethacrylate. Keep in mind that many neutron radiography facilities may see holes much smaller than this in other applications. The larger holes are obvious even when radiographed by a relatively crude facility. Thus, the holes as well as the gaps in the gage cover a sensitivity range for all conditions.

The purpose of the methylmethacrylate is to scatter off some of the neutrons, such as may occur in many applications. It is a good thermal neutron attenuator. Because it attenuates by scattering, it is a harsh test of combined facility and object contrast and sharpness, again covering a wide range of objects that might be radiographed. For this reason, the SI should always be used in one orientation, with the shims and holes on the bottom of the SI toward the source. For protection, a dust cover may be used on the unit, but care should be taken so that the SI is oriented correctly. The thickest step in the wedge should be placed away from the part or BPI.

The resolution of the film may now be subjectively interpreted by the radiographer. Begin with an examination of the holes. Remember that the holes under the lead are only for the purpose of determining the detrimental effect of the gamma in the beam, and should not be counted as part of the resolution examination.

The easiest hole to see will be the largest (0.51 mm) hole in the thinnest stepwedge. Count this hole as number one. From there, continue to the thicker wedges, staying in the same hole size. If you can count all four of these holes, go on to the next set of holes (0.25 mm), again starting with the thinnest step. This step will now be number five. Count the holes until you come to a spot where you cannot see the hole. The last hole that you can definitively resolve is the number that you should assign as the H value. If you have to skip a step, but can see the next hole after that, you must assign the H value of the last consecutive hole that you can resolve. The best facilities typically have a value of 7 or 8 out of 12.

The G value is the smallest gap that can be seen at all absorber thicknesses. Because of the linear axis of the gap, most facilities can see much smaller gaps than holes.

These values can also be compared against table 4 of ASTM E545 in order to categorize the quality of the radiograph.