Federal Working Group on Industrial Digital Radiography

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# Guide for the Qualification of Digital Radiography Systems and Processes

**Revision 1**

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**Federal Working Group on Industrial Digital Radiography (FWGIDR) -** The FWGIDR is a self-chartered organization consisting of federal and government contract employees and endorsed by the Defense Working Group on Nondestructive Testing (DWGNDT). This working group provides a platform for identifying common concerns and critical issues facing the federal industrial radiographic community as it transitions from film to digital radiography (DR). The FWGIDR, utilizing expertise from within the community, organizes and coordinates technical committees that formulate positions, guidance, and/or solutions for the community's common concerns and issues.

**Background –** Recognizing significant difficulties in addressing technical advances in the digital radiographic field, several engineers from the Department of Energy (DOE) and Department of Defense (DoD) organized the FWGIDR in 2007 to address the problems and concerns faced by the industrial radiographic community in transitioning to DR. Digital X-ray systems are revolutionizing medical radiology, as digital cameras revolutionized the photographic community, and similarly have an ever-increasing role in radiographic nondestructive testing. Medical radiology backed by significant development and funding, and digital photography, with rapid public acceptance; have demonstrated the advantages that digital systems offer in image intensive applications. The FWGIDR is focused on a vision for the future radiographic inspection facility, and that vision is digital radiography.

The rapid growth in DR has created transitional issues difficult for the industrial community to assimilate while transitioning from film to digital techniques. These issues include personnel training; data formatting, storage and retrieval; technique development and qualification; equipment qualification and monitoring; process control; and development and acquisition of equipment suitable for industrial applications.

Participants in the FWGIDR are organizations that employ nondestructive testing in support of government contracts. DOE, DoD, prime government contractors, along with other government and contractor personnel are actively contributing to and supporting the efforts of this working group.

## 1. Scope

1.1. This document is intended as a guide to aid activities qualifying Digital Radiography (DR) systems and to assist personnel who are responsible for the qualifying, approving and/or auditing the application of DR systems.

1.2. *Applicability*-- Digital Radiography (DR) is broadly interpreted by the Federal Working Group on Industrial Digital Radiography (FWGIDR) and this document to include any system that converts a radiographic image to a digitized/pixelized computer imaging format. This can include but is not limited to systems using the following detectors: photostimulable luminescence (PSL) plates, amorphous silicon flat panels, amorphous selenium flat panels, complementary metal-oxide-semiconductor (CMOS) flat panels, CMOS cameras, charge-induction device (CID) cameras, charge-coupled device (CCD) cameras, linear diode arrays (LDA), computed tomography (CT), film digitizers (FD), etc. For the purpose of this document, DR systems using flat panel electronic detectors will be referred to as Digital Detector Array (DDA) systems and those using photoluminous plates will be referred to as Computed Radiography (CR) systems respectively.

1.3. This guide does not purport to address all of the safety, quality or contractual concerns, if any, associated with its use. It is the responsibility of the user of this guide to establish appropriate safety, health and quality practices and determine the applicability of regulatory or contractual limitations prior to use.

## 2. Terminology

*2.1.* Unless otherwise specified, terminology in this guide relating to radiographic examination is as defined by ASTM E1316 or other ASTM specifications.

*2.2. Definitions of Terms Specific to This Guide:*

*2.2.1. Customer or Customer's Authorized Representative* – the company, government agency, or other authority responsible for the end use of the system or component for which radiographic examination is required.

2.2.2. *Digital Radiography* –Digital radiography(DR) refers to all systems using that converts ionizing or penetrating radiation into digital information by various means, including computed radiography using photostimulable luminescence (PSL) plates, amorphous silicon flat panels, amorphous selenium flat panels, complementary metal-oxide-semiconductor (CMOS) flat panels, CMOS cameras, charge-coupled device (CCD) cameras, linear diode arrays (LDA), computed tomography (CT), film digitizers (FD), etc.

*2.2.3. Level III Radiographer* – In this document, when the term level III radiographer is used, it is referring to a radiographer employed by the inspecting activity that is responsible for overseeing radiographic operations including but not limited to technique approval and system qualification.

2.2.4. *Long Term Stability Monitoring* – Performance measurements of a DR system over the life-cycle of the devices, used to evaluate relative system performance over time.

2.2.5. *Qualification Plan* – The written agreement between the inspecting activity and the customer that documents how the inspecting activity will demonstrate that they meet the inspection requirements of the customer. This includes documentation of the system configuration, system characterization testing, long term stability testing, the range of items covered by the qualification plan, and technique verification process that will be used for each specific item.

*2.2.6. Representative Quality Indicator (RQI)* – a real part, or a fabrication of similar geometry in radiographically similar material to a real part, that has features of known characteristics that represent all of the features for which the parts to be inspected are being examined. Described in ASTM E1817.

2.2.7. *Sensitivity Demonstration* – The process of verifying that the digital radiography system is capable of detecting all defects required for inspection of a product line over the range of materials and material thicknesses present in that product line.

2.2.8. *System Characterization* – An evaluation of a digital radiographic system to quantify the performance of the system. This is a generic test of system performance and is conducted independent of any particular inspection technique. System characterization tests are essential for monitoring system degradation.

2.2.9. *System Performance Baseline* – The results of system characterization testing done when a system is installed and initially qualified for NDT. These tests results are used as part of a long term stability testing program to monitor any degradation that has occurred in the performance in the system compared to when the system was first put into use.

2.2.10. *Technique Verification* – The process of ensuring that the technique and inspection process are capable of detecting all defects specified in the inspection criteria and meeting all inspection requirements in actual or simulated inspection using inspection procedures, equipment and personnel. Process control methods should also be demonstrated as part of this verification.

## 3. Significance and Use

3.1. The guidance provided by this document addresses the development of qualification plans, sensitivity demonstrations and techniques. Necessary process controls are addressed including approved procedures, system calibration, and the training and certification of personnel.

3.2. The detailed guidance presented in this guide is applicable to CR and DDA systems. Future efforts of the FWGIDR may address computed tomography and film digitizers if there is a clearly identified need and interest from members of the working group.

3.3. This guide is a starting point for development of a user's qualification plan and testing procedures. It does not present specified image quality levels as would be used to address the acceptance or rejection criteria established between two contracting parties, for example, NDT facility or consumer of NDT services, or both. It is not a detailed how-to procedure to be used by the NDT facility or consumer of NDT services, or both.

## 4. Background

4.1. This guide was originally developed by the System Qualification Task Group of the Federal Working Group for Industrial Digital Radiography (FWGIDR) and released on 01 September 2009. The goal of the System Qualification Task Group was to develop a system qualification guideline for the application of industrial digital radiography systems. It will also identify Film to DR transitional issues to support and promote the formulation and adoption of ASTM standards in DR modalities and encourage the adoption of these standards by government agencies and government contractors.

4.2. Since the original guide was published, several ASTM specifications for radiography with Digital Detector Arrays were released including E2698, E2736 and E2737. These specifications rendered parts of this document obsolete. Additionally, it became clear that additional guidance was required for Computed Radiography to ensure a reliable inspection.

## 5. System Characterization

5.1. Prior to the approval of any item specific techniques, the system should be characterized to establish the capabilities of the system and determine the baseline for system performance. If any key components of a system are replaced, such as the CR IP type, CR scanner model, CR scanner settings, DDA panel, software, etc; then this system characterization testing should be repeated.

5.2. *System Performance Baseline* - This system characterization should utilize Image Quality Indicators (IQIs) for quantitative measurement of key system performance parameters. The IQIs and test articles for this testing should be selected based upon materials and geometries that are representative of the system's intended application. The level III radiographer is responsible for developing the testing procedures for determining the system performance baseline.

5.2.1. *Characterization for Computed Radiography* – The level III radiographer should develop the system characterization testing procedure for a CR system based upon ASTM E2445. The level III radiographer may have to tailor this testing procedure for systems that will utilize energy levels that are significantly different from those specified in ASTM E2445.

5.2.1.1. *Equivalent Penetrameter Sensitivity (EPS)* – EPS testing as described in the Metals Affordability Initiative (MAI) guidelines should be done for Computed Radiography systems. A description of this testing can be found in Appendix X3. The purpose of the testing is to determine the exposure levels necessary in order to ensure an adequate signal-to-noise ratio. For systems where a linear relationship exists between pixel value and dosage received, EPS testing will establish the acceptable gray value range for that system. For systems where no linear relationship exists, alternative methods for ensuring adequate exposure level should be established.

5.2.2. *Characterization for Digital Detector Arrays* - The level III radiographer should develop the system characterization testing procedure for a DDA system based upon ASTM E2737 except as noted below.

5.2.2.1. *Bad Pixel Mapping Frequency* – Frequency for checking bad pixels should be agreed upon by the Inspecting Activity and the Cognizant Engineering Organization (CEO).

5.2.2.2. *Duplex Plate Phantom* – The material used for the phantom should be the same as will be inspected. If an alternative IQI material has been approved by the CEO, then this material may be used for the two plates of the phantom as well.

5.2.2.3. *Contrast Sensitivity Measurement* – Contrast to Noise Ratio with the Duplex Plate Phantom should be calculated as specified in ASTM E2737, Paragraph 9.4.2 except for the following: Gray Values for the hole may be measured by calculating the Mean of an area on the shim; Gray Values for the beside squares may be measured by calculating the Mean of an equal size area on the Penetrameter; and the Sigma measured by calculating the Standard Deviation of the same area on the Penetrameter.

5.2.2.4. *High Energy Considerations* - Prior to conducting performance evaluation testing in accordance with E2737 on a high energy system (greater than 320kV), the level III radiographer should discuss the testing with the system manufacturer to determine if any system damage will occur as a result of performing any of the tests, such as the burn-in test. With the concurrence of the CEO, tests should be modified based upon the recommendations of the manufacturer.

5.2.3. *Multiple Focal Spots* - Systems which have multiple focal spots that will be used for inspection should test system performance for each focal spot that will be used.

5.2.4. *Fluctuation in Exposure* – Any testing performed as part of system characterization should be done multiple times and the results compared in order to determine image to image variations which could have an effect on image quality.

5.3. *Long Term Stability Monitoring* - The procedures and test articles developed for the initial system characterization should be developed concurrently with the long term performance monitoring program so that system performance can be tracked over time.

## 6. Qualification Plan(s)

6.1. After system characterization, the level III radiographer is responsible for development and documentation of the qualification plan(s). These qualification plan(s) should be developed based upon the guidance provided in this document and be tailored to the specific needs of the activity, the specific characteristics of the Digital Radiography equipment used, and the items being inspected in addition to the specific requirements of the customer. These qualification plan(s) should be developed with and approved by the customer or the customer's authorized representative in addition to the level III radiographer. Systems that are used for a single product line or family of similar products may only require a single qualification plan. Systems that are used for a variety of items may require multiple qualification plans, particularly if there are significant differences in the inspection criteria for the items.

6.2. *Contents* – The qualification plan(s) should include the following sections at a minimum. Additional information may be included at the discretion of the level III radiographer and the customer or customer's authorized representative.

6.2.1. *System Configuration* – The qualification plan(s) should include a complete and accurate listing of the DR inspection equipment. This should be a detailed listing of the DR system components by manufacturer, model and serial numbers. Guidance for the equipment and software that should be listed is provided in Appendix X5. The software list should include any software that is used as part of the inspection process and its version information. This listing should be updated when key components are replaced or the system is modified. The level III radiographer and customer or customer's authorized representative will make the determination if replacement or modification of system components or software requires requalification.

6.2.2. *Procedures* – The qualification plan(s) should include a listing of the procedures used for operation, calibration and maintenance of the equipment.

6.2.3. Process Controls – The qualification plan(s) should describe the process controls that the customer and inspecting activity have agreed will be used to ensure a repeatable and accurate inspection. This should include any requirements that are above and beyond the ASTM specifications, such as those recommended in Section 8 of this document. This should also include a listing of any ASTM requirements that are being waived by the customer if ASTM standards are referenced in the contractual documentation.

6.2.4. Operator Certification – The qualification plan(s) should specify the required standards for operator certification and training. This should include both theory and equipment training for all radiographers.

6.2.5. *Range of Items* – The qualification plan(s) should specify the items, devices, materials, components, etc. that are covered by the qualification plan. This listing should identify specific items that are covered by the plan or families of items. If families are specified, then a description of the critical characteristics that define the families should be included in the qualification plan.

6.2.6. *Defects Covered* – The qualification plan(s) should specify the types of defects that will be covered by the inspection. Whenever possible, the defects should be described quantitatively such as specifying the minimum dimensions for length, width and depth of cracks for specific materials.

6.2.7. *Sensitivity Demonstration* – The qualification plan(s) should specify the testing that will be done to verify that the DR system is capable of detecting the defects specified in 6.2.6 in the items or families of items specified in 6.2.5. This testing should be done utilizing actual or simulated defects in a controlled environment. The level III radiographer is authorized to participate in this demonstration even if this is outside of their normal role in the inspection process.

6.2.8. *Approach for Meeting Inspection Criteria* – The qualification plan(s) should include a description of the methodology for meeting the inspection requirements as specified by the customer.

This section forms the technical agreement between the inspecting activity and the customer as to how to ensure that defect detectability requirements are met.

6.2.9. *Technique Verification Requirements* – The qualification plan(s) should include a description of how the technique or techniques will be verified and the frequency of the verification. This includes a description and the quantity of the samples used for the technique verification and what IQIs and/or RQIs will be used.

6.2.10. *Qualification Exposure Requirements* – If Qualification Exposures may be used in lieu of using the required IQIs and/or RQIs on every exposure, the qualification plan(s) should specify the frequency and method for monitoring and validating system sensitivity including identification of sensitivity indicators.

6.2.11. *Data Format and Storage* – The qualification plan(s) should include a written policy for data format and storage. This policy should take into account long term data integrity and retrievability and should specifically prohibit the use of lossy data compression.

6.3. *Revision* – A qualification plan should be revised whenever any component specified in 6.2.1 is changed, additional item or family not specified in 6.2.3 is added, additional defect not covered in 6.2.4 or any other change occurs which is outside of the scope of the original qualification plan. Any revision of the qualification plan should be approved by the level III radiographer in addition to the customer or customer's authorized representative.

## 7. Technique(s)

7.1. It is the responsibility of the NDT facility to develop an examination technique recorded as a written procedure that is capable of consistently producing the desired results and detecting the defects specified by the customer. When required by contract, purchase order or the Qualification Plan, the procedure should be submitted to the customer or customer's authorized representative for approval. The written technique should contain, at a minimum, all the requirements specified in ASTM E1742, paragraph 6.1.1 through 6.1.4 and 6.1.6 through 6.1.10. In addition, the following should be addressed in the written technique.

7.1.1. *Qualification Plan* – All written techniques should be covered by a qualification plan approved by the level III radiographer and the customer or customer's authorized representative; and the qualification plan should be identified in the written technique.

7.1.2. *Filters and Collimators* – The written technique should specify the thickness, material and location of any beam hardening filters. The technique should also specify if a collimator is used to tighten the beam spread and the setting or position of the collimator if adjustable.

7.1.3. *Representative Quality Indicators* - Care must be taken to ensure that the representative quality indicators specified in the technique are adequate to prove that the technique can identify all defects specified in the acceptance criteria. Appendix X1 contains further discussion. Image quality indicators such as hole or wire penetrameters may be used in place of representative quality indicators if allowed by the qualification plan approved by the customer or customer's authorized representative.

7.1.4. *Viewing Adjustments* – Standard digital image viewing software allows adjustment of Window/Level and Zoom. The technique should specify if these parameters may be adjusted during image assessment and the allowable range of adjustment.

7.1.5. *Image Enhancements* – All automated and manually applied image enhancements which manipulate the digital data, including digital filters, contrast or edge enhancements, etc. should be specified in the written technique unless specified in a system's operation procedure that is approved by the level III radiographer. Any manually controlled image enhancements specified in the technique should include the range of adjustment that is allowed.

7.1.6. *Gray Value Range* – Techniques should specify an acceptable gray value range of the area of interest, similar to a film density value used in film radiography. In addition, the gray value on the IQI/RQI should be within +/- 15% of the gray value as the area of interest.

7.1.7. *Image Storage* – The format for file storage should be specified in the written technique unless specified in a systems operation procedure that is approved by the level III radiographer.

7.2. *Technique Verification*– All techniques should be verified prior to approval by the level III radiographer. The verification should simulate the inspection as closely as is practical. This verification should ensure that the technique and inspection process are capable of detecting all defects specified in the inspection criteria and should be witnessed by a customer representative.

7.2.1. *Verification Personnel* – During the validation, the inspection process should be performed by the same personnel who will be performing the inspection once the technique has been approved. The level III radiographer should witness the validation but should not participate in a capacity which is atypical of their normal role in the inspection process.

7.2.2. *Written Technique* – The technique used for the verification should be documented prior to the start of the verification. Changes made to the technique during the verification process may require the verification to be restarted at the discretion of the level III radiographer and/or customer representative.

7.2.3. *Samples for Demonstration* - The preferred method of verification utilizes real or simulated defects (RQIs) in a blind test. At a minimum, the verification should be done using production representative samples.

## 8. Process Controls

8.1. Process controls are required in order to maintain a repeatable and reliable inspection process. The major quality control issues center around personnel, equipment and procedures.

8.2. *Process Controls for Digital Detector Arrays* - Digital Radiography systems using Digital Detector Arrays should meet the following requirements as a supplement to the requirements specified in ASTM E2698. In addition, the supplemental recommendations in Appendix X2 should be considered.

8.2.1. *Software*

8.2.1.1. *Line Profile* - Software for image assessment should be capable of generating a line profile. This should include the ability to generate a line profile of a variable width specified by the user in order to be able to perform the testing specified in ASTM E2737.

8.2.1.2. *Bad Pixel Presentation* – Software for image assessment should be capable of turning on and off the display of bad pixels on demand by the user.

8.2.1.3. *Image Enhancements* – Software should have the capability of display images without image enhancements and then allow the user to apply filters, edge enhancements or contrast enhancements as desired.

8.2.1.4. *Preservation of Original Data* – Software should retain the original data if image enhancements are applied.

8.2.2. *File Format and Storage*

8.2.2.1. *DICONDE* - Software should be capable of saving images in a DICONDE compliant file format in accordance with ASTM E2339. The full bit depth of the image, as read from the DDA, should be retained in the saved image. Images should be saved in a lossless format.

8.2.2.2. *DVD* - Systems should be capable of saving data to DVDs. CDs may be used for smaller inspections; however, any inspection that cannot fit onto a single CD should be

submitted on a DVD. DVDs used for submittal of images to the customer should be write-once (DVD-R or DVD+R).

8.2.2.3. *DICONDE Headers* - Information stored in the DICONDE headers should be agreed upon between the inspecting activity and the CEO, the following data is recommended as a minimum:

- Detector manufacturer and model
- Viewing software and version number
- Pixel pitch (in microns)
- Part Name, such as nomenclature
- Part Identification, such as DODIC or drawing number
- Lot Number
- Date of Inspection
- Inspecting Activity

8.2.2.4. *Data Archival* - Data should be archived in a secure location for the minimum duration specified in the contract.

8.2.2.5. *Digital Annotation* - If digital labeling is used, it should not permanently alter the nature of the image or hinder interpretation of an area within the image.

8.2.3. Exceptions to ASTM E2698

8.2.3.1. Screen Brightness Contrast Testing Frequency – The test for the ratio of screen brightness at the maximum and minimum DDL should be done monthly rather than daily as specified in Table X1.

8.3. *Process Controls for Computed Radiography* - Computed Radiography systems should meet the following requirements as a supplement to the requirements in ASTM E2033. In addition, the supplemental recommendations in Appendix X2 should be considered.

8.3.1. *Facility Considerations*

8.3.1.1. *Temperature & Humidity Control* - The facility should be controlled for temperature and humidity in accordance with the recommendations of the CR manufacturer.

8.3.1.2. *Lighting Requirements for Imaging Plate Handling* - Areas where the imaging plates will be handled should be illuminated with subdued background lighting, free from a high intensity of light in the red spectrum, including conventional darkroom safelights and sodium vapor lights. Time that imaging plates are exposed outside of their cassettes or holders should be minimized.

8.3.1.3. *Interpreter Light Adaptation* - Radiographers should wait sufficient time after entering the viewing area before interpreting the radiographic image.

*8.3.2. Equipment, Hardware and Material*

8.3.2.1. *Source Collimation* - The x-ray source should be equipped with a diaphragm in front of the tube to mask out all radiation which would not penetrate the region of interest in the item to be inspected.

8.3.2.2. *Source Filtration* – The x-ray source should be equipped with a means to install filters at the source to facilitate beam hardening when needed for image quality.

8.3.2.3. *Filter Screens* - Filter screens should be in intimate contact with the imaging plate with the exception of a thin layer or coating to prevent direct contact between the lead and the imaging plate.

8.3.2.4. *Backscatter* - Back filter screens should be used for protection from backscattered radiation. Lead or other suitable material should be used behind the imaging plate to prevent scattered radiation.

8.3.2.5. *Plaque Penetrameter Material* - Plaque penetrameters should be of the same material as the material to be inspected unless otherwise approved by the Cognizant Engineering Organization.

8.3.2.6. *IQI Thickness* - IQIs and shims should represent the area of interest. This is defined as having the area of interest within +/- 15% of the linear pixel value through the body of the IQI. Two IQIs may be used to bound the thickest and thinnest parts of the area of interest.

8.3.3. *Software*

8.3.3.1. *Window/Level* - Software for image assessment should be capable of manual adjustment of the Window and Level.

8.3.3.2. *Zoom* - Software for image assessment should be capable of manual adjustment of the Zoom.

8.3.3.3. *Gray Value Readout* - Software for image assessment should be capable of measuring the gray value of individual pixels.

8.3.3.4. *Histogram* - Software for image assessment should be capable of generating a histogram of an area of interest. Software should be capable of calculating the mean and standard deviation in the area of interest.

8.3.3.5. *Line Profile* - Software for image assessment should be capable of generating a line profile. This should include the ability to generate a line profile of a variable width specified by the user.

8.3.3.6. *Image Enhancements* – Software should have the capability of displaying images without image enhancement as well as providing the capability for filtering, contrast enhancements, etc. if desired.

8.3.3.7. *Preservation of Original Data* – Software should retain the original data if image enhancements are applied.

8.3.4. *File Format and Storage*

8.3.4.1. *DICONDE* - Software should be capable of saving images in a DICONDE compliant file format. The full bit depth of the image, as read from the panel, should be retained in the saved image. Images should be saved in a lossless format.

8.3.4.2. *DVD* - Systems should be capable of saving data to DVDs. CDs may be used for smaller inspections; however, any inspection that cannot fit onto a single CD should be submitted on a DVD. DVDs used for submittal of images to the customer should be write-once (DVD-R or DVD+R).

8.3.4.3. *DICONDE Headers* - Information stored in the DICONDE headers should be agreed upon between the inspecting activity and the CEO, the following data is recommended as a minimum:

- CR system manufacturer and model
- Viewing software and version number
- Imaging plate serial number or other unique identifier
- Pixel pitch (in microns)
- Item Name, such as nomenclature
- Item Identification, such as DODIC or drawing number
- Lot Number
- Date of Inspection
- Inspecting Activity

8.3.4.4. *Data Archival* - Data should be archived in a secure location for the minimum duration specified in the contract.

8.3.4.5. *Digital Annotation* - If digital labeling is used, it should not permanently alter the nature of the image or hinder interpretation of an area within the image.

8.3.5. *Procedures*

8.3.5.1. *Daily Display Testing* - Testing of any monitors used for assessment of images should be done using a SMPTE RP 133 test pattern or equivalent. Processes for performing these tests should be specified in the radiographic procedures. Visual testing with the SMPTE test pattern should be performed daily and include the following:

- The image display should be capable of displaying linear patterns of alternating pixels at full contrast in both the horizontal and vertical directions without aliasing.
- The image display should be capable of displaying linear patterns of alternating pixels at low contrast (1%) in both the horizontal and vertical directions without aliasing.
- The display should be free of discernable geometric distortion.
- The display should be free of screen flicker, characterized by high frequency fluctuations of high contrast image details.
- The image display should be capable of displaying a 5% level against a 0% level background and simultaneously displaying a 95% level against a 100% level background.

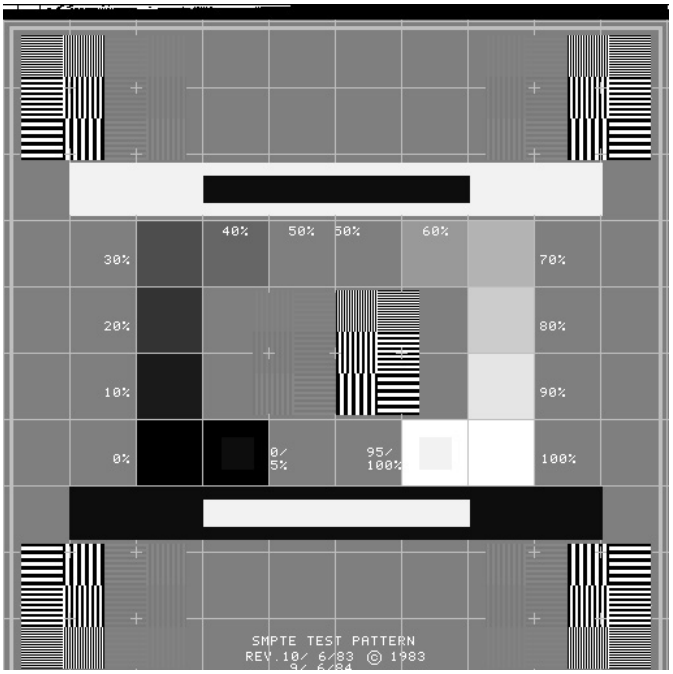


**Figure 1: SMPTE RP133 Test Pattern**

8.3.5.2. *Monthly Display Testing* - The following tests should be performed monthly using a calibrated light meter and the SMPTE RP 133 test pattern. Processes for performing these tests should be specified in the radiographic procedures.

- The minimum brightness as measured off the image display screen at the maximum level should be 250 cd/m2.

- The minimum contrast as determined by the ratio of the screen brightness at the maximum level compared to the screen brightness and the minimum level should be 250:1.

8.3.5.3. *DICONDE Header Data Entry* - Processes for manual entry of data into the DICONDE fields as required in 8.3.4.3 should be specified in the radiographic procedure. Data that is automatically recorded in the DICONDE headers by the software does not need to be addressed in the procedures.

8.3.5.4. *Data Archival and Transfer Processes* - Processes for transfer of data to the archive and preparation of data for submittal to the customer should be specified in the radiographic procedures.

8.3.5.5. *Total Image Unsharpness*- Maximum values for total image unsharpness should be as determined by the Level III, agreed upon by the CEO and specified in the radiographic procedures. Inspections that require the detection of small indications should meet the limits specified in the MAI Guidelines for the Use of Digital Detector Arrays and Computed Radiology for Aerospace Casting Inspections, Section 7.4.

8.3.5.6. *Acceptable Grayscale Range* - Minimum and maximum allowable grayscale values in the area of interest should be specified in the radiographic procedures.

8.3.5.7. *Determination of Adequate Exposure Level* - Processes for verifying that exposure levels are adequate to ensure contrast and minimize noise should be specified in the radiographic procedures.

8.3.5.8. *Handling of Image Artifacts* - Processes for identifying and handling artifacts that might mark or be confused with defects in the material being examined should be specified in the radiographic procedures.

8.3.5.9. *Updating of Artifact Maps* - Processes for updating the artifact map for each imaging plate when a new artifact is located should be specified in the radiographic procedure.

8.3.5.10. *Handling of Residual Images* - Processes for identifying and handling residual images left over from a previous exposure should be specified in the radiographic procedures.

8.3.5.11. *Calibration* - Calibration of computed radiographic systems should be done using the procedures and frequencies recommended by the manufacturer.

8.3.5.12. *Imaging Plate Fading* - Based on the results of the imaging plate fading test, the radiographic procedure should specify a maximum time between exposure and scanning of the imaging plate.

8.4. *Long Term Stability Monitoring* – A process should be in place for monitoring key system performance parameters over time as all Digital Radiography systems degrade over time. This process should be documented, including frequency.

8.5. *Requalification Policy* – Digital Radiography systems should be requalified for use after maintenance or repairs that may have affected image quality. These requalification procedures and policies should be documented. Routine maintenance procedures which do not require requalification should be specified in the requalification policy.

8.6. *Personnel* – Personnel should be trained and certified in accordance with an approved certification program. The certification program should follow conventional certification requirements (i.e. as established by ASNT-TC-1A or NAS-410). The certification program should specifically address DR classroom instruction, on-the-job training, experience and testing requirements. Of particular significance is the DR knowledge and experience of the Level III radiographer that approve the certification and training program and the inspection procedures. Level III and Level II radiographers should be knowledgeable and proficient with the particular DR system that they intend to use. The level III proficiency should be supported by documented DR training and/or experience. See Appendix X4.

8.6.1. *Theory Training for Level III Radiographers* - Level III radiographers should receive a minimum of 40 hours of classroom theory training in Digital Radiography. This is above and beyond any equipment specific training provided by the manufacturer.

8.6.2. *Theory Training for Level II Radiographers* - Level II radiographers should receive a minimum of 40 hours of classroom theory training in Digital Radiography. This is above and beyond any equipment specific training provided by the manufacturer.

8.6.3. *Theory Training for Level I Radiographers* - Level I radiographers should receive a minimum of 20 hours of classroom theory training in Digital Radiography. This is above and beyond any equipment specific training provided by the manufacturer.

## 9. Reference Documents

9.1. The following documents are referenced in this guide or may be useful to activities qualifying, approving and/or auditing DR systems.

9.2. *ASTM Standards*:

E 94 Standard Guide for Radiographic Examination
E 543 Standard Specification for Agencies Performing Nondestructive Testing
E 746 Standard Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems
E 747 Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology
E 1000 Guide for Radioscopy
E 1025 Standard Practice for Design, Manufacture and Material Grouping Classificaiton of Hole-Type Image Quality Indicators (IQI) Used for Radiology
E 1255 Standard Practice for Radioscopy
E 1316 Standard Terminology for Nondestructive Examinations
E 1411 Standard Practice for Qualification of Radioscopic Systems
E 1441 Guide for Computed Tomography (CT) Imaging
E 1453 Standard Guide for Storage of Media that Contains Analog or Digital Radioscopic Data
E 1475 Standard Guide for Data Fields for Computerized Transfer of Digital Radiological Examination Data
E 1647 Standard Practice for Determining Contrast Sensitivity in Radiology
E 1695 Standard Test Method for Measurement of Computed Tomography (CT) System Performance
E 1735 Standard Test Method for Determining Relative Image Quality of Industrial Radiographic Film Exposed to X-Radiation from 4 to 25 MeV
E 1742 Standard Practice for Radiography Examination
E 1817 Standard Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)
E 2002 Standard Practice for Determining Total Image Unsharpness in Radiology
E 2007 Standard Guide for Computed Radiology (Photostimulable Luminescence (PSL) Method)
E 2033 Practice for Computed Radiology (PSL Method)
E 2339 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)
E 2445 Standard Practice for Qualification and Long-Term Stability of Computed Radiology Systems
E 2446 Standard Practice for Classification of Computed Radiology Systems
E 2597 Standard Practice for Manufacturing Characterization of Digital Detector Arrays
E 2698 Standard Practice for Radiological Examination Using Digital Detector Arrays

E 2736 Standard Guide for Digital Detector Radiology
E 2737 Standard Practice for Digital Detector Array Performance Evaluation and Long-Term Stability Monitoring

9.3. *Aerospace Industries Association Document*:
NAS 410 NAS Certification and Qualification of Nondestructive Test Personnel

9.4. *ASNT Documents*:
CP 189 Standard for Qualification and Certification of Nondestructive Testing Personnel
SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

9.5. *Government Standard*:
MIL-STD-746 Radiographic Testing Requirements for Cast Explosives

9.6. *Other Government Documents*:
NIST Handbook 114 General Safety Standard for Installations using Non-Medical and Sealed Gamma Ray Sources, Energies up to 10 MeV

9.7. *SMPTE Specification*:
RP 133 Specifications for Medical Diagnostic Imaging Test Pattern for Television Monitors and Hard-Copy Recording Cameras

# APPENDIX

## X1. Considerations for System Selection and Qualification

### X1.1 Image Quality Indicators

Image quality is governed by two factors, image contrast and resolution. These factors are interrelated in a complex manner. Radiographic sensitivity, as indicated by the conventional IQI, measures contrast and resolution. A number of different devices, such as wire penetrameters, hole penetrameters, steps, mesh, etc., have been used to measure image quality. The same principles apply for DR systems as for other radiographic methods. Some DR systems may require several devices, such as IQIs and wire mesh, to assure the proper image quality. In those instances when these IQI devices are inadequate in controlling the quality and repeatability of the DR image, or, when representative criteria levels of the acceptance or rejection of images of discontinuities are important, Representative Quality Indicators (RQIs) should be used.

Image quality indicators must be chosen with care to demonstrate the DR system's ability to detect discontinuities or other features that are of interest. ASTM E 1025 hole-type, ASTM E 747 wire-type IQIs, and ASTM E 1817 RQIs with real or simulated defects, to match the application, are all acceptable unless a particular IQI or RQI is specified in the contractual documents. The selected IQI or RQI should be detailed in the written procedure. An IQI or RQI may not be required for the following DR examinations:

- When performing DR to identify adequate defect removal or grind-out, the final acceptance examination should include an IQI or RQI,
- Examinations to show material details or contrast between two or more dissimilar materials, in component parts, or in assemblies, including honeycomb areas for the detection of fabrication irregularities, the presence or absence of material, or water detection.
- Examinations of electronic components for contamination, loose or missing elements, solder balls, broken or misplaced wires or connectors, and potted assemblies for broken internal components or missing potting compound.

Standard penetrameters such as hole (ASTM E 1025) and wire (ASTM E 747) penetrameters are readily available and have been used successfully for film radiography for years. These standard penetrameters should be only used with the clear understanding of the characteristic performance differences between film and the DR system. Critical imaging performance characteristics for DR systems include: dynamic range, signal to noise ratio, image lag and contrast sensitivity and spatial resolution (Modulation transfer function-MTF). In general when compared with film, DR systems can have better dynamic range, signal to noise ratios and contrast sensitivity. However, film generally has better spatial resolution. (Note: DR system can improve the resolution of the final image by using micro-focus x-ray machines with small spot sizes and geometric magnification. Geometric magnification may also help reduce the negative effects of part scatter.) Film radiography with its higher spatial resolution commonly uses the hole type penetrameters. These penetrameters generally contain three holes of decreasing diameter. A hole, with its low spatial frequency characteristics, does not require a high spatial frequency capability for detection but this is of little concern for film inspection because the

high spatial frequency detection capabilities of film are well known. However, since the spatial frequency responsive capabilities of DR systems can differ significantly based on the specific DR equipment and technique used, it may not be appropriate to assume that if you can see the same hole in a hole type penetrameter with a DR system as you do with film, that you will have the same high spatial frequency detection capability as film and will therefore detect the same crack and separation like indications that film does.

Wire type penetrameters have relatively small diameters and therefore have a higher spatial frequency content than the hole-type penetrameters. As a result, these may be more appropriate for DR sensitivity tests. However, the wires are quite long. Inspection criteria often call for detection of crack and separation type indications that are far shorter than the wire penetrameters. Two of the characteristics that determine the detectability of an indication are its subject contrast and its area. If the wires are longer than the inspection criteria, they will be easier to detect due to their larger area. This should be considered prior to the implementation of standard wire penetrameters.

#### X1.1.1 Wire-Type Image Quality Indicator

This IQI consists of a graded set of wires where the diameter size increases by a factor of 1.26 as described in Practice E 747. The visibility of the essential wire determines the sensitivity of the system. The smallest wire is 0.005 in., thereby limiting their usefulness for thin materials. Since the cross section of the wire is round, it is not affected by position.

| | |
|---|---|
| **Reference:** | **ASTM E747-04** |
| **Notes:** | **Specification covers the design, material grouping classification and manufacture of gauge** |
| **Caveats:** | **None** |

#### X1.1.2 Hole-Type Image Quality Indicator

This IQI is described in Test Method E 1742 and Practice E 1025. It consists of a plaque with three drilled holes with diameter equal to one, two, and four times the plaque thickness (1T, 2T, and 4T). The minimum plaque thickness is 0.127 mm (0.005 in.) and the minimum hole diameters are 0.25 mm (0.010 in.), 0.5 mm (0.020 in.) and 1 mm (0.040 in.) for the 1T, 2T, and 4T holes. Most codes require the detection of the 2T hole in a plaque that is 2 % of the object thickness.

| | |
|---|---|
| **Reference:** | **ASTM 1025-05** |
| **Notes:** | **Specification covers the design, material grouping classification and manufacture of gauge** |
| **Caveats:** | **None** |

### X1.2 Process Control Standards (Phantoms)

Process Control Standards or Phantoms are a collection of targets that can be used to evaluate various aspects of digital radiography system performance. Targets can be either a standard type of IQI or a customized IQI developed to meet the specific requirements of Digital

Radiography. The following CR phantoms are used for system characterization and/or system degradation monitoring. They are not used to validate a particular technique.

### X1.2.1 CR Phantom

The CR Phantom was developed specifically for the evaluation of CR systems for industrial radiography and it incorporates a variety of gauges covered by ASTM Standards. Since this device was developed by ASTM for general use, it contains a few test targets that are somewhat redundant, as well as some targets that are unnecessary for specific users. For example, two types of spatial resolution gauges are included, and contrast gauges for three material types. Some users may find that additional test targets or gauges are necessary, such as additional contrast gauge materials, or that other types of test targets provide more pertinent data for their specific inspection applications.

| | |
|---|---|
| **Reference:** | **ASTM E2445-05** |
| **Notes:** | **Specification covers the design, material grouping classification and manufacture of gauge** |
| **Caveats:** | **Several of the incorporated gauges are applicable only to CR.**<br>**High cost may be a problem for smaller organizations.**<br>**Developed for low energy. May not be suitable for high energy.** |

### X1.2.2 USAF Computed Radiography Process Control Standard (CRPCS)

Based loosely on the ASTM Phantom, the USAF CRPCS was developed by AFRL/RXS specifically for CR systems used for USAF inspection applications. The design approach was to provide a low cost standard that could be evaluated in a timely manner with minimal use of software tools to interpret image data.

| | |
|---|---|
| **Reference:** | **USAF T.O. 33B-1-2; AFRL report AFRL-RX-WP-TR-2009-4069** |
| **Notes:** | **Some tests are identical to ASTM E2445, while others are unique. Procedures for use of the CRPCS documented in USAF T.O. 33B-1-2.**<br>**About 1/3 of the cost of the ASTM Phantom at the time of this writing.**<br>**Covers nearly all ASTM tests to some extent. Design rationale provided in AFRL report AFRL-RX-WP-TR-2009-4069. Available from www.ARINC.com** |
| **Caveats:** | **None** |

## X1.3 Automatic Imaging Processing for Panel Calibration and Bad Pixel Correction

Radiography with Digital Detector Arrays allows for fast, automatic correction of problems, however, this capability can only be used if the radiographer fully understands how these corrections work and what their potential problems may be.

### X1.3.1 Bad Pixel Mapping and Correction for DDA

There is no such thing as a perfect DDA panel; bad pixels and/or lines are created in the manufacturing process and may increase over time. Manufacturers of these panels

have developed automatic programs to correct for these defect pixels and/or lines, however, a radiographer must be aware that the data which is generated by these automatic programs is simulated based upon surrounding values and is not real. For this reason, some radiographers may choose to disable this bad pixel correction in order to ensure that decisions are made based on valid data. The use of bad pixel correction should only be done with customer approval. Radiographers should develop tools and procedures to ensure that bad pixel clusters or lines are not in the area of interest.

## X1.4 Backscattered Radiation

Digital Radiography is no different for film radiography in that it can be negatively affected by back scattered radiation. The traditional method for testing back scattered radiation as described in ASTM E1742 Section 6.22 involves placing a letter B behind the film holder and checking for the presence of this letter on the processed film. This test may be insufficient to detect back scattered radiation at levels which may decrease the performance of a Digital Radiography System. This is particularly true in the case of Digital Detector Arrays which use a calibration program. This calibration may correct for the back scattered radiation, however, at the expense of dynamic range. An alternate testing for back scattered radiation is provided here:

### X1.4.1 Backscatter Test using a Lead Sheet

Using typical values for kV, mA, etc, expose the digital detector panel or computed radiography imaging plate with a piece of 0.20 lead sheet covering half of the back of the detector or imaging plate. Repeat the exposure, moving the lead sheet to the other half. View the two images, adjusting the window/level controls to view the noise. Visually apparent differences between the two images are the result of back scattered radiation.

## X1.5 Physical Identifiers (Lead letters/numbers)

Unlike film radiography, digital radiography systems provide additional options for identification of the components being inspected, NDT facility, date of examination, etc. These options include data fields incorporated into the DICONDE standard and text added digitally to the processed images. These options bring additional risks. Images stored in DICONDE or similar formats may be exported to TIFF or JPG formats for distribution to users who lack the ability to view DICONDE images. The exported images may be lacking the data fields that provide the required information, resulting in distribution of an image with no identifiers if an alternative method of marking (such as Lead letters/numbers) is not also used. In addition, if text is added digitally to the processed images, it may destroy information contained on the original image or may cause problems during post-processing. The level III radiographer should consider these concerns prior to discontinuing the use of lead letters/numbers.

| | |
|---|---|
| **Reference:** | **ASTM 1742-06, Paragraph 6.4 Radiographic Identification** |
| **Notes:** | **Section describes the requirement for identification of the components being inspected, NDT facility, date of examination, etc.** |
| **Caveats:** | **Specification does not specify how this information must be stored. This implies that any method is acceptable; lead, digital annotation, file headers, etc.** |

## X2. Recommendations for Digital Radiography Process Controls

Conversion to Digital Radiography requires a number of additional considerations that should be taken into account when developing process controls. These considerations can have a significant impact on the repeatability of the process and the degradation which is inherent to Digital Radiography equipment. These recommendations may not be applicable to all systems and should not be viewed as requirements.

### X2.1 Protection of Detectors and Imaging Plates from Unnecessary Exposure

The performance of DDR panels and CR imaging plates degrade over time based on the amount of radiation that they are exposed to. The degradation of a DDR panel will occur regardless of whether the data from the detector is currently being processed or even if the detector is not turned on. For this reason, it is important to minimize the exposure of the detector or imaging plate to radiation.

#### X2.1.1 Protection of Detector in a Multi-Use Cabinet or Bay

If an x-ray cabinet or room is not exclusively used for a specific DDR panel and the panel cannot be easily removed when not in use, lead shielding should be placed around the detector when x-rays are being generated for the exposure of film or other DDR, CR or real time systems.

#### X2.1.2 Protection of Detector during Warm-up

If the detector cannot be easily removed when not in use, lead shielding should be placed between the detector and the x-ray source when x-rays are being generated during x-ray source warm-up.

#### X2.1.3 Protection of Imaging Plates and Detectors from Overexposure

Inadvertent overexposure of a DDR detector can cause permanent damage. Initial technique development should be conservative when selecting dose rate to avoid damage. CR imaging plates exposed to high energies or doses may develop a residual image that is difficult or impossible to remove. Removal of residual images on imaging plates may be possible by exposing the IP to a uniform exposure and performing several erasure cycles. DDR detectors may require additional lead shielding for the electronics of the detector, particularly in applications greater than 160kV.

## X3. Equivalent Penetrameter Sensitivity (EPS) Testing for Computed Radiography

EPS plates are used to establish acceptable exposure ranges for CR imaging plates. Traditional film based techniques had acceptable film density ranges. The EPS plates provide a means for establishing a range of acceptable pixel values similar to the acceptable range requirements for film density. There are EPS plates for low and high energy CR. The EPS plates are used to ensure that the exposure levels are sufficient.

For low energy Computed Radiography Systems, the EPS performance and qualified pixel value range of the system should be established by visual evaluation of Computed Radiography images of the ASTM E 746 Relative Image Quality Indicators placed on a 0.75 inch absorber (see figure X3.1). EPS plaques are used because they allow the radiographer to discern subtle differences in image quality as radiographic parameters are changed. Materials other than mild steel, as called out in ASTM E 746, may be used, but the EPS plaques and absorber should be made of the same material. The surface finish of the absorber should be a maximum of 6.3 µm (250 µin) Ra ground finish, both faces.

For high energy Computed Radiography systems, such as used for linear accelerators, testing can be conducted using the quality indicators described in ASTM E1735. These gauges are used on a thicker absorber plate, typically 3 to 6 inches thick depending on the energy level of the system. In the case of linear accelerators, RADs will be used in place of mA-seconds to quantify exposure level. The methodology for the testing at high energy is otherwise the same as described here for low energy.

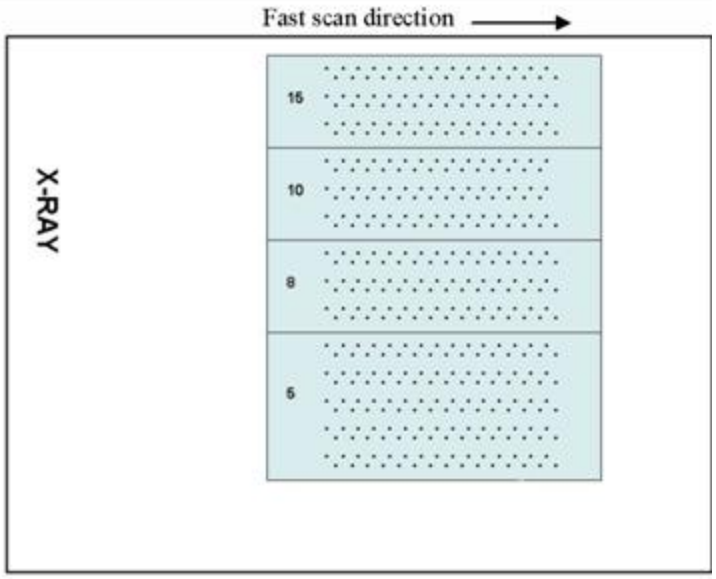


**Figure X3.1: ASTM E 746 EPS plaques placed on 0.75 inch thick absorber.**

Align the X-radiation source in the approximate center of the plate between the #8 and #10 EPS plaques (plates may be slightly separated for this purpose). Focal Detector Distance (FFD) should be a minimum of 36 inches (or 1 meter) from X-ray source. General radiographic technique parameters should be consistent with how the system will be used for inspections. Radiograph the plate series with a minimum of 10 exposures using similar technique parameters for the desired range of pixel values from minimum to maximum of the specific scanner operational parameters employed (i.e. the only technique variable is exposure time). Exposures should range from at least 10% max pixel value (MPV) to 90% MPV and be approximately distributed within the qualified PV range. Determine the pixel value (PV) in the approximate center of the computed radiograph on the base plate between the #8 and #10 EPS plaques in an area free of any holes or alternatively, within a central area of the base plate alongside the EPS plaques. All

CR system processing parameters, energy level and exposure data for each exposure should be recorded and maintained.

For each exposure, record the EPS performance by determining the duplex row where a minimum of 20 holes (out of 30 holes in each duplex row) are clearly visible. Table X3.1 provides EPS values per ASTM E 1025 for each duplex row on the standard shown in Figure X3.1. Table X3.2 provides the calculated EPS values for the high energy EPS plaques when used with a 3-inch absorber.

| step thickness (inches) | hole dia (inches) | plate thickness (inches) | EPS % |
|---|---|---|---|
| 0.015 | 0.028 | 0.750 | 1.93 |
| 0.015 | 0.025 | 0.750 | 1.83 |
| 0.015 | 0.023 | 0.750 | 1.75 |
| 0.010 | 0.031 | 0.750 | 1.66 |
| 0.010 | 0.028 | 0.750 | 1.58 |
| 0.010 | 0.025 | 0.750 | 1.49 |
| 0.008 | 0.028 | 0.750 | 1.41 |
| 0.008 | 0.025 | 0.750 | 1.33 |
| 0.008 | 0.023 | 0.750 | 1.28 |
| 0.005 | 0.032 | 0.750 | 1.19 |
| 0.005 | 0.028 | 0.750 | 1.12 |
| 0.005 | 0.025 | 0.750 | 1.05 |
| 0.005 | 0.023 | 0.750 | 1.01 |
| 0.005 | 0.020 | 0.750 | 0.94 |

**Table X3.1: Table of EPS Values – Low Energy**

| step thickness (inches) | hole dia (inches) | plate thickness (inches) | EPS % |
|---|---|---|---|
| 0.063 | 0.118 | 3.000 | 2.02 |
| 0.063 | 0.072 | 3.000 | 1.58 |
| 0.050 | 0.072 | 3.000 | 1.41 |
| 0.050 | 0.060 | 3.000 | 1.29 |
| 0.038 | 0.060 | 3.000 | 1.13 |
| 0.038 | 0.048 | 3.000 | 1.01 |
| 0.025 | 0.056 | 3.000 | 0.88 |
| 0.025 | 0.046 | 3.000 | 0.80 |
| 0.025 | 0.037 | 3.000 | 0.72 |

**Table X3.2: Table of EPS Values – High Energy**

Generate a graph of the pixel value versus exposure level and determine if the system exhibits a linear relationship between pixel value and exposure level for any exposure level range as shown in Figure X3.2.

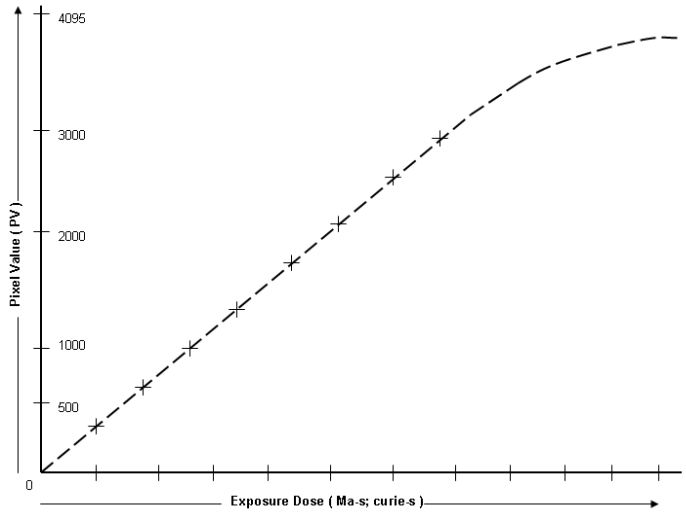


**Figure X3.2: Graph of Pixel value vs Exposure Level**

If the pixel value response was determined to be linear, generate a graph of the EPS value versus pixel value shown in Figure X3.3. Establish the qualified minimum-to-maximum pixel value range as the pixel value range that exhibits a relatively low and consistent EPS value. If there is no evidence of degraded (higher) EPS at greater than 85% MPV, the max PV may be assumed to be 100% (e.g. in Figure X3.3, the qualified pixel value range would be approximately 15-100% MPV).

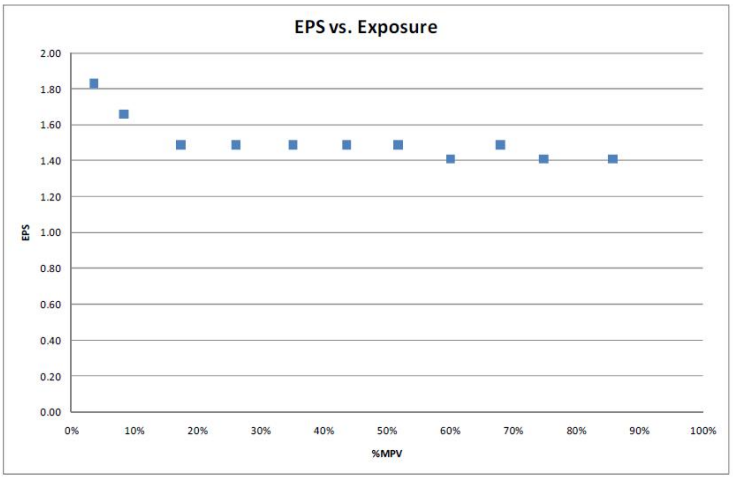


**Figure X3.3: Graph of EPS vs Gray Value**

Record the EPS performance as the maximum EPS value in the EPS "plateau". For long-term stability tests, EPS only needs to be verified at a single point at the beginning of this EPS "plateau" (i.e. only one exposure required, corresponding to the minimum pixel value required to be on this EPS "plateau").

For systems that do not exhibit a linear response to exposure level, this methodology cannot be used to establish an acceptable pixel value range and pixel value cannot be used to ensure adequate exposure level. It is possible to ensure adequate exposure levels in other ways. One example is to determine if correlations exists between Signal-to-Noise ratio and EPS value in addition to between Signal-to-Noise ratio and exposure level. As exposure level increases, Signal-to-Noise ratio will increase up to a certain point and level off. For these systems, minimum SNR can be determined and specified in procedures. Procedures can then be written to check for minimum SNR in the area of interest for each technique. To verify that this methodology is performing as expected, it will be necessary to test new techniques at different exposure levels and verify that the SNR responds as expected.

## X4. Personnel Training and Certification

Within the industrial radiographic community, there is a lack of DR training opportunities. The majority of the training classes offered to date have been offered by hardware manufacturers (OEMs) and may have been limited more to equipment operation than to application. Given this situation, personnel knowledge and experience may be a considerable concern. A careful review of personnel knowledge and experience, specifically that of the Level III, is recommended. The Federal Working Group on Industrial Digital Radiography has developed a training curriculum for Level III radiographers that is intended to be given as a 40-hour classroom class. This is an overview of the knowledge that is necessary for setting up a Digital Radiography operation. Several providers now offer courses that have been developed based upon this curriculum. Additionally, the FWGIDR has developed training curriculums for Level I and Level II radiographers that can be used as a basis for developing classroom training for users of Digital Radiography systems.

## X5. Suggested Listing of Hardware and Software for Configuration Management Control

### X5.1 System Information

System Manufacturer _____ System Model Number_____

Serial Number_____ Date of Manufacturer ___ /___ /_____

System Configuration: Cabinet _____ or Walk-in Room _____

Scan Plan: Manual Control Y/N Program Control Y/N

Accept/Reject Decision: Manual Y/N Computed Aided Y/N Automatic Y/N

Source to Detector Distance _____ inch to _____inch

Target to Detector Distance _____ inch to _____inch

### X5.2 X-Ray Generating System

Controller Manufacturer _____ Model _____ Under System Control Y/N

Tube Manufacturer _____ Model _____

Generator Manufacturer _____ Model _____

Conventional_____; Minifocus_____; Microfocus_____; kV Range _____ to _____

Minimum mA _____; Maximum mA _____; Ripple at highest mA _____kV;

kV measurement: Primary _____ or Voltage Divider _____;

Large Focal Spot ____ mm x ____ mm, ____ watts; Small Focal Spot ____ mm x ____ mm, ____ watts;

Inherent filtration _____; Additional filtration _____;

### X5.3 Primary Beam Source Collimator

Manufacturer _____ Model _____ Under System Control Y/N

Variable Opening from _____ mm X _____ mm to _____ mm X _____ mm

Fixed Opening _____ mm X _____ mm

### X5.4 Computed Radiography

Manufacturer _____ Model _____

Software and Version _____

Image Dimensions _____ mm x _____ mm; Pixel Dimensions _____ pixels x _____ pixels

Bit Depth _____ bits

Imaging Plate Type _____

### X5.5 Digital Detector Array

Manufacturer _____ Model _____

Software and Version _____

Image Dimensions _____ mm x _____ mm; Pixel Dimensions _____ pixels x _____ pixels

Bit Depth _____ bits Frame Averaging _____ to _____ frames;

### X5.6 System Software

System Control Software and Version _____

_____

System Calibration Software and Version _____

_____

Image Processing/Enhancement Software and Version _____

_____

### X5.7 Image Storage Device

Manufacturer _____ Model _____

Software and Version _____

Capacity _____ Gb; Redundancy _____

## X5.8 Image Format

Internal File Type _____; Bit Depth _____ bits

Exportable File Type(s) _____; Bit Depth _____ bits

_____; Bit Depth _____ bits

_____; Bit Depth _____ bits

_____; Bit Depth _____ bits