



**Guide for the
Qualification of Digital
Radiography Systems and
Processes**

1 September 2009

Federal Working Group on Industrial Digital Radiography (FWG-IDR) - The FWG-IDR is a self chartered organization consisting of federal employees and government contract employees and is endorsed by the Defense Working Group on Nondestructive Testing (DWG-NDT). 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 FWG-IDR, 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 - With tremendous advances being made in digital radiography (DR), fueled largely by significant research investments by the medical community, and the acceptance by the general public of digital photography, it became apparent that digital radiography will have an ever increasing role in industrial radiography. Recognizing the value of DR, a good number of Federal Radiographic Facilities embraced the new technology in its earliest developmental stages and implemented DR technology. Spurred by this expanding use of DR and the recognition that a number of technological and process shortcomings existed, several meetings, attended by Department of Energy (DOE), Department of Defense (DOD), and other government and contractor NDT employees, were held to discuss the future vision for industrial digital radiography in the Federal community. Those meetings became the foundation for the Federal Working Group on Industrial Digital Radiography.

The attendees emerged from those first meetings with a consensus that, indeed, DR would be the future of industrial radiography and there were many areas of common concern. They further recognized that a concerted and organized effort needed to be mounted to ensure that all issues concerning transitioning from old to new technology be addressed. An extensive list of issues were discussed among these nondestruction evaluation (NDE) professionals and several topics were determined to be common amongst the attendees. These common issues were prioritized and task teams established to develop recommendations and guidance for the industrial radiographic community.

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 (FWG-IDR) 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 Radiography (DDR) 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 Detector Radiography (DDR)* – Digital radiography that uses an electronic device that converts ionizing or penetrating radiation into a discrete array of analog signals which are subsequently digitized and transferred to a computer for display as a digital imaging corresponding to the radiologic energy pattern imparted upon the input region of the device.

2.2.3. *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.

2.2.4. *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.

2.2.5. *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.

2.2.6. *Qualification Plan* – The written agreement between the inspecting activity and the customer that documents how the inspecting activity will meet the inspection requirements of the customer. This includes documentation of the system configuration, testing that will be done to ensure system performance, the range of items covered by the qualification plan, and technique verification process that will be used for each specific item.

2.2.7. *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.

2.2.8. *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.

2.2.9. *System Characterization* – An evaluation of a digital radiographic system to quantify the performance of the system. The results of this evaluation are used to determine if the system may be capable of meeting NDT requirements and to establish a system performance baseline.

2.2.10. *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.

2.2.11. *Technique Verification* – The process of ensuring that the technique and inspection process for a specific technique are capable of detecting all defects specified in the inspection criteria and meeting all inspection requirements in actual or simulated inspection using all procedures, equipment personnel.

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 DDR systems. Future efforts of the FWG-IDR 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 developed by the System Qualification Task Group of the Federal Working Group for Industrial Digital Radiography (FWG-IDR). The goal of the System Qualification Task Group is to develop a system qualification guideline for the application of industrial digital radiography systems. It will also identify and pursue the resolution of American Society of Testing & Materials (ASTM International) Standards in digital radiographic modalities and promote the adoption of these standards by government agencies and government contractors.

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.

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.

5.2.2. *Characterization for Digital Radiography* - The ASTM specification for Digital Radiography is under development. Appendix X1 has been provided to assist the Level III radiographer in developing their characterization procedure.

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.

5.2.5. *Image Display Performance* – Monitors which display digital radiographic images should be evaluated in accordance with section 8.5 as part of the system characterization.

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 must 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. *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.

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

6.2.5. *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 6.2.4 in the items or families of items specified in 6.2.3. 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.

6.2.6. *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.

6.2.7. *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.

6.2.8. *Qualification Exposure Requirements* – The qualification plan(s) should specify the frequency that qualification exposures must be done and the requirements for the qualification exposures, including specification of the IQIs and/or RQIs.

6.2.9. *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 shall be submitted to the customer or customer's authorized representative for approval. The written technique shall contain, at a minimum, all the requirements specified in ASTM E1742, paragraph 6.1.1 through 6.1.3 and 6.1.5 through 6.1.9. 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 X2.2 & X2.3 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 IQI/RQI should have approximately the same 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.

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.

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 must 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. *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. The level III 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.

8.3. *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 must be documented, including frequency.

8.4. *Requalification Policy* – Digital Radiography systems must be requalified for use after maintenance or repairs that may have affected image quality. These requalification procedures and

policies must be documented. Routine maintenance procedures which do not require requalification should be specified in the requalification policy.

8.5. *Image Display* – The image display should meet the following requirements as a minimum. Alternate image displays or requirements may be used with customer approval. Note: The SMPTE test pattern as defined in RP133 may be used in validation of system requirements.

8.5.1. The minimum brightness as measured off the image display screen at maximum Digital Driving Level (DDL) should be 250 cd/m².

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

8.5.3. The image display shall be capable of displaying linear patterns of alternating pixels at full contrast in both the horizontal and vertical directions without aliasing.

8.5.4. The display shall be free of discernable geometric distortion.

8.5.5. The display shall be free of screen flicker, characterized by high frequency fluctuation of high contrast image details.

8.5.6. The image display shall be capable of displaying a 5% DDL block against a 0% DDL background and simultaneously displaying a 95% DDL block against a 100% background in a manner clearly perceptible to the user.

8.6. *Image Display Conditions* – The ambient lighting in the image display area should be subdued to facilitate image interpretation and minimize eye strain.

8.7. *DDR Panel Calibration* – Written procedures should specify how panel calibration will be done, including frequency.

8.8. *CR IP Serialization* – All Imaging Plates in inventory should be serialized. Every image captured for inspections should be traceable to the IP serial number or other unique identifier.

8.9. *CR IP Fading* – The images captured on CR Imaging Plates fade from the time they are exposed until they are read. This fading must be considered in developing procedures for CR use. Users must obtain vendor performance data on fading or perform their own measurements to determine the effect of fading on their image quality. Procedures for CR use may require specifying min/max "wait times" between the shot and processing or adjustment of exposure parameters if it is known that the IP will not be processed in the required timeframe.

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:*

CP 189 Standard for Qualification and Certification of Nondestructive Testing Personnel

E 94 Standard Guide for Radiographic Examination

E 543 Standard Specification for Agencies Performing Nondestructive Testing

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 Classification 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 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
- 9.3. *Aerospace Industries Association Document:*
 - NAS 410** NAS Certification and Qualification of Nondestructive Test Personnel
- 9.4. *ASNT Documents:*
 - 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

(Nonmandatory Information)

X1. Characterization for Digital Detector Radiographic Systems

Unlike Computed Radiography, ASTM has not released a specification which covers the characterization testing that should be done for a Digital Detector Radiography (DDR) system using a Digital Detector Array such as an amorphous silicon detector. In order to assist the Level III Radiographer in developing their own test plan for system characterization, the following guidance has been provided.

The manufacturer of the DDA may have provided a baseline data sheet of performance, however, similar tests, outlined in this section, should be conducted in order to establish a baseline for system performance under the conditions that exist at the inspecting activity. In order to evaluate a Digital Detector Radiography system, the following detector properties should be tested:

- Spatial Resolution
- Contrast Sensitivity
- Signal to Noise Ratio
- Shading Consistency
- Latent Image (Ghosting)
- Bad Pixels

These tests may be applicable to other Digital Radiography systems that employ CCD, CID, LDA or CMOS technologies. The level III radiographer may use these tests as a guide in characterizing those systems as well.

X1.1 Spatial Resolution Independent of Contrast

Spatial Resolution for a Digital Detector Array should be measured using a Duplex Wire gage in accordance with **ASTM E2002** using the method described in **ASTM E2597-07, Paragraph 7.7 Measurement Procedure for Basic Spatial Resolution (SRb) and 8.2 Calculations for Basic Spatial Resolution**.

X1.2 Contrast Sensitivity Independent of Spatial Resolution

Contrast Sensitivity for a Digital Detector Array should be measured using a thickness recess gage in accordance with **ASTM E1647** using the method described in **ASTM E2445, Paragraph 6.1.1 Contrast Sensitivity Measurement**.

X1.3 Signal/Noise Ratio (SNR)

Signal to Noise Ratio for a Digital Detector Array can be quantified by the Normalized Signal to Noise test described in the Computed Radiography specification, **ASTM E2445-05, Paragraph**

6.2.8 Measurement of Normalized SNR. Alternatively, if an ionization gage is available, **ASTM E2597-07, Paragraph 7.8.1 Measurement Procedure for Efficiency and 8.3.1 Calculations for Efficiency** can be used.

X1.4 Shading

Shading consistency for a Digital Detector Array can be quantified by the methods described in ASTM E2445, Paragraph 5.1.7 Shading Quality Indicator and ASTM E2445, Paragraph 6.2.5 Shading. This test, as written, is for Computed Radiography that typically does not have a calibration program. Digital Detector Arrays which utilize calibration should be able to easily exceed the performance described in this specification.

X1.5 Latent (ghost) Images

In some cases, a ghosting effect can occur because a particular phosphor or photoconductive material within the Digital Detector Array is prone to instability in response to x-ray dose. Monitoring of ghosting can be achieved as follows with the Digital Detector Array in a typical calibrated state for the examination. When ghosting is observed under typical window/leveling schemes of a DDR image, the following procedure shall be followed for quantification of ghosting.

1. A monolithic slab of similar thickness and material to that under examination with an area of approximately 50 x 50mm (2 x 2in) is placed on the detector in a manner that will simulate a real examination. No masking of the object, or collimation of the beam shall be done unless this is common protocol.
2. An exposure is obtained under conditions similar to the actual examination including beam filtration,
3. The slab is shifted at least 25mm (1in) in either the X or Y direction in the plane of the detector.
4. A second exposure of the same intensity shall then be acquired immediately following the movement of the slab. A new calibration file shall not be obtained between these exposures.
5. The % GHOST is computed by the following formula:

$$\% \text{ GHOST} = \frac{(S2 - S1) \times 100}{S1}$$

Where:

S1 is the mean gray value measured using a Region of Interest of at least 20x55 rectangle in the center of the slab of material

S2 is the mean gray value measured using a Region of Interest of at least 20x55 rectangle in the center of the location previously occupied by the slab of material

If the % GHOST is greater than 1%, then the DDA suffers from ghosting for the intended examination and practical procedures must be instituted to continually maintain this level under 1% for examination. This procedure change can be accomplished by increasing the time between images. Recalibration of the panel may also reduce or eliminate ghosting.

X1.6 Bad Pixels

Bad pixel maps should be generated in accordance with the manufacturer instructions when the system is initially deployed. The criteria used to define if a pixel is bad or acceptable for inspection shall be established based upon manufacturer guidance with the concurrence of the customer.

X2. Considerations for System Selection and Qualification

X2.1 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. Practices E 1025 hole-type, E 747 wire-type IQIs, and 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 contract documents. The selected IQI or RQI shall 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 shall 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 E1025) and wire (ASTM E747) 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 contrast to noise ratio (CNR) 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.

X2.1.1 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

X2.1.2 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

X2.2 Reference Standards (Phantoms)

Reference 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 for a specific application.

X2.2.1 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.
High cost may be a problem for smaller organizations.
Developed for low energy. May not be suitable for high energy.

X2.2.2 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.
Caveats: About 1/3 of the cost of the ASTM Phantom at the time of this writing.
Covers nearly all ASTM tests to some extent. Design rationale provided in AFRL report AFRL-RX-WP-TR-2009-4069.

X2.3 Automatic Imaging Processing for Panel Calibration and Bad Pixel Correction

Digital Detector Radiography 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.

X2.3.1 Bad Pixel Mapping and Correction for DDR

There is no such thing as a perfect DDR 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.

X2.4 Back scattered Radiation

Digital Radiography is no different for film radiographer 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:

X2.4.1 Backscatter Test using a Lead Sheet

Using typical values for kV, mA, etc, exposing the digital detector panel or computed radiography imaging plate with a piece of 0.20 lead sheet covered 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.

X3. Process Controls

Conversion to Digital Radiography requires a number of additional considerations that must 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.

X3.1 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.

X3.1.1 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.

X3.1.2 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.

X3.1.3 Protector of Imaging Plates and Detectors from Overexposure

Inadvertent overexposure of a CR imaging plate or DDR detector can cause permanent damage. Digital Radiography typically requires lower dosages than film so initial technique development should be conservative when selecting dose rate to avoid damage. DDR detectors may require additional lead shielding for the electronics of the detector, particularly in applications greater than 160kV.

X3.2 Storage and Handling of CR Imaging Plates

Storage, handling and cleaning of Computed Radiography Imaging plates should be done in accordance with manufacturer recommendations. With proper handling, imaging plates can last indefinitely, however, improper handling will reduce the life expectancy of the plates considerably. Direct contact with lead has been known to cause damage to some imaging plates; users should consult with the manufacturer as to whether precautions should be taken such as leaving the plastic on the lead or using wax paper.

X3.3 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, text added digitally to the processed images 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.

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. ASNT-TC-1A 2006 Table 6.3.1 C provides Initial Training and Experience Levels for Level II Limited Certifications. (The key term here is limited certification.) Included in this table is a limited certification for DR. The training noted is 32 hours of formal training and 175 minimum hours of work experience. When compared with those required for both Levels I and II radiographers, this training and experience is significantly less. DR inspections can be far more complex than film radiography. It is recommended the ASNT's Table 6.3.1 C recommendations for limited certification Level II DR personnel be restricted for those inspectors operating fixed DR systems where inspectors primarily turn the system on and off, follow a written detailed inspection procedure and receive specific training and examination for each item or category of item inspected. Personnel with limited certification should not be making manual adjustments to DR systems. (Note: The FWG-IDR has developed a suggested training guide for Level III DR personnel.)

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