**Designation: E2737 – 23**

# Standard Practice for Digital Detector Array Performance Evaluation and Long-Term Stability[1]

This standard is issued under the fixed designation E2737; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice covers the baseline and periodic performance evaluation of Digital Detector Array (DDA) systems used for industrial radiography. It is intended to ensure that the evaluation of image quality, as far as this is influenced by the DDA system, meets the needs of users, and their customers, and enables process control to monitor long-term stability of the DDA system.

1.2 This practice specifies the fundamental parameters of DDA systems to be measured to determine baseline performance, and to track the long-term stability of the DDA system.

1.3 The DDA system tests specified in this practice shall be completed upon acceptance of the system from the manufacturer to baseline the performance of the DDA. Periodic performance testing shall then be used to monitor long-term stability of the system in order to identify when an action needs to be taken due to system degradation beyond a certain defined level.

1.4 Two types of phantoms, the duplex plate and the five-groove wedge, are used for testing as specified herein. The use of these two types of phantoms is not intended to exclude the use of other phantom configurations. In the event the tests or phantoms specified herein are not sufficient or appropriate, the user, in coordination with the cognizant engineering organization (CEO) may develop additional or modified tests, test objects, phantoms, or image quality indicators to evaluate the DDA system performance. Acceptance levels for these ALTERNATE test methods shall be determined by agreement between the user and CEO.

1.5 The user of this practice shall consider that higher energies than 450 keV may require different test methods or modifications to the test methods described here. This practice is not intended for usage with isotopes.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*



## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing
E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiography
E1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging
E1316 Terminology for Nondestructive Examinations
E1742/E1742M Practice for Radiographic Examination
E2002 Practice for Determining Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy
E2446 Practice for Manufacturing Characterization of Computed Radiography Systems
E2597/E2597M Practice for Manufacturing Characterization of Digital Detector Arrays
E2698 Practice for Radiographic Examination Using Digital Detector Arrays
E2736 Guide for Digital Detector Array Radiography

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiology (X and Gamma) Method.

Current edition approved July 1, 2023. Published August 2023. Originally approved in 2010. Last previous edition approved in 2018 as E2737 – 10 (2018). DOI: 10.1520/E2737-23.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E2903 Test Method for Measurement of the Effective Focal Spot Size of Mini and Micro Focus X-ray Tubes

2.2 *Industry Standards:*

ANSI/ASNT CP-189 Standard for Qualification & Certification of Nondestructive Testing Personnel[3]

EN 4179 Qualification & Approval of Personnel for Non-Destructive Testing[4]

ISO 9712 Non-Destructive Testing - Qualification & Certification of NDT Personnel[5]

NAS 410 National Aerospace Standard: Certification & Qualification of Nondestructive Test Personnel[6]

SNT-TC-1A Personnel Qualification & Certification in Non-destructive Testing[7]

## 3. Terminology

3.1 *Definitions*—The definition of terms relating to gamma and X-radiology, which appear in Terminology E1316, Practice E2002, Practice E2597/E2597M, Practice E2698, and Guide E2736, shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *active DDA area*—the active pixelized region of the DDA, which is recommended by the manufacturer as usable.

3.2.2 *burn-in*—change in gain of the scintillator that persists well beyond the exposure.

3.2.3 *duplex plate phantom Type 1*—a phantom manufactured from a single material type and having two thickness made up of either two overlapping plates or a single plate machined to provide two thicknesses with the two thicknesses typically aligning on 3 edges (Fig. 1).

3.2.3.1 *Discussion*—Duplex plate phantom Type 1 was first mentioned in E2737 – 10.

3.2.4 *duplex plate phantom Type 2*—a phantom manufactured from a single material type and having two thickness made up of either two overlapping plates or a single plate machined to provide two thicknesses (Fig. 2).

3.2.5 *five-groove wedge*—a continuous wedge with five long grooves on one side.

3.2.6 *frame rate*—number of frames acquired per second.

3.2.7 *lag*—residual signal in the DDA that occurs shortly after detector read-out and erasure.

3.2.8 *manufacturer*—DDA system manufacturer, supplier for the user of the DDA system.

3.2.9 *material thickness range (MTR)*—the material thickness range within a single DDA image, whereby a minimum specific image quality is achieved throughout the entire thickness range.

3.2.10 *phantom*—a part or item being used to quantify DDA characterization metrics.

3.2.11 *saturation pixel value*—the maximum possible usable pixel value of the DDA after offset correction.

NOTE 1—Saturation may occur because of a saturation of the pixel itself, the amplifier, or digitizer, where the DDA encounters saturation pixel values as a function of increasing exposure levels.

3.2.12 *user*—the user and operating organization of the DDA system.

3.3 *Definitions: Abbreviations Specific to This Standard*:

3.3.1 $D_{hole}$—diameter of the IQI hole (in pixels).

3.3.2 *CNC*—Computer Numerical Control.

3.3.3 *GSL*—Groove Sensitivity Level – The smallest long groove which is visible in the image at the first single dot marking.

3.3.4 *MT*—the penetrated material thickness in the ROI under consideration.

3.3.5 $MT_{step}$—material thickness of the plate(s) under the IQI.

3.3.6 $MT_{IQI}$—thickness of hole-type IQI.

3.3.7 $MT_{total}$—total material thickness of plate and hole-type IQI (=$MT_{step}$ + $MT_{IQI}$).

3.3.8 $PV_{median}$*[hole]*—median pixel value of ROI within the IQI hole.

3.3.9 $PV_{mean}$—mean pixel value, for example, of a ROI.

3.3.10 $PV_{mean}$*[beside squares]*—mean pixel value measured inside the area between two boxes.

3.3.11 $PV_{thick}$—mean pixel value of the ROI on the thick area of the five-groove wedge.

3.3.12 $PV_{thin}$—mean pixel value at the thinnest area of the five-groove wedge.

3.3.13 $PV_{mean}$*(Offset)*—mean pixel value of the approximately central 90 % of the area in the offset image.

3.3.14 *Sigma[beside squares]*—standard deviation of the pixel values in the area between two boxes.

## 4. Significance and Use

4.1 This practice is intended to be used by the DDA user to measure and record the baseline performance of an acquired DDA in order to monitor its performance throughout its service as an imaging system. This practice is not intended to be used as an "acceptance test" of a DDA.

4.2 This practice defines the tests to be performed and their required intervals. Also defined are the methods of tabulating results that DDA users will complete following initial baselining of the DDA system. These tests will also be performed periodically at the stated required intervals to evaluate the DDA system to determine if the system remains within acceptable operational limits as established in this practice and defined between the user and CEO.

4.3 There are several factors that affect the quality of a DDA image including the basic spatial resolution, geometric unsharpness, scatter, signal to noise ratio, contrast sensitivity, contrast/noise ratio, image lag, and for some types of DDAs,



[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from British Standards Institution (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., http://www.bsigroup.com.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

[6] Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, http://www.aia-aerospace.org.

[7] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

burn-in. There are several additional factors and settings which can affect these results (for example, integration time, detector parameters, imaging software, and even X-ray radiation quality). Additionally, detector correction techniques may have an impact on the quality of the image. This practice delineates tests for each of the properties listed herein and establishes standard techniques for assuring repeatability throughout the lifecycle testing of the DDA.

## 5. Basis of Application

5.1 The following items are subject to contractual agreement between the parties using or referencing this standard.

5.1.1 *Personnel Qualification*—Personnel performing examinations to this practice shall be qualified in accordance with NAS410, EN 4179, ANSI/ASNT CP 189, ISO 9712, or SNT-TC-1A and certified by the employer or certifying agency as applicable. Other equivalent qualification documents may be used when specified on the contract or purchase order. The applicable revision shall be the latest unless otherwise specified in the contractual agreement between parties.

5.1.2 If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Specification E543. The applicable edition of Specification E543 shall be specified in the contract.

## 6. Apparatus

6.1 *Phantom Types and Selection*—The tests performed herein may be completed either by the use of a Type 1 or Type 2 Duplex Plate Phantom with separate IQIs (See Fig. 1 and Fig. 2), or with a Five-Groove Wedge Phantom (See Fig. 5 and Fig. 6). The phantoms are available for purchase or may be manufactured by the user. A Phantom Record shall be generated providing individual phantom identification, basic material type, basic dimensional data, and traceability to records of any IQIs used with the phantom. Certification of material alloy or dimensions is not required for duplex plate phantoms.

6.2 *Phantom Materials*—The phantoms may be manufactured from any material group, however Aluminum is recommended for light metal applications (material group 02 of equal or lower atomic number and density as listed in Practice E1025) and Stainless Steel is recommended for more dense material applications (material group 1 of equal or higher atomic number and density as listed in Practice E1025). It is not necessary to make use of other materials that more closely represent a given product being evaluated. If a facility evaluates materials from more than one material group, a phantom from only one material group needs to be processed. Radiographically homogeneous material alloys are preferred. 7022 Aluminum and 316L Stainless Steel are strongly recommended. Other materials may be used when approved by the CEO. Materials displaying grain structure mottling or visible scatter artifacts, reduce the ability to effectively measure DDA system performance and variability. When required, the selected material shall be agreed upon between the user and CEO. Previously established baseline test materials are not required to be modified to align with the above material recommendations.

## 7. General Procedures Applied to All Phantom Types

7.1 *DDA Correction Method*—As part of the baseline testing, the DDA offset, gain corrections shall be acquired in accordance with the manufacturer's recommendation, using a typical process as applied during production product evaluations. These same correction procedures shall be used at normal production intervals throughout the periodic testing of the in-service DDA. Additionally, the DDA corrections shall be re-acquired when the periodic test results fall out of the established control limits. Reference Annex A1.

7.1.1 *Bad Pixel Standardization for DDAs*—Baseline Images shall also be corrected for bad pixels as would be done in production using routine bad pixel correction procedures. A standardized nomenclature is presented in Practice E2597/E2597M. The identification and correction of bad pixels in a DDA shall be as agreed upon between the user and the CEO. The threshold levels used to identify bad pixels shall be recorded in the test report in full or in reference. The bad pixel data shall be presented as an image or as a report containing specific parameters for bad pixels, cluster kernel pixels, relevant clusters, non-relevant clusters, and lines.

7.2 *Procedure for Measurement of the Offset Level*—Before measurement of the Offset Level, the DDA should be powered-on and not exposed for approximately ten minutes. One image with 30 s acquisition time (for example 1 s frames and averaging all 30 frames) shall be captured without radiation (*Offset Image*). Bad Pixel Correction is active, no gain or offset correction shall be done. The Offset Level is the mean pixel value of the approximate central 90 % of area in the offset image. An ROI of greater than 90 % may be used providing consideration is made for defective or underperforming pixels in the border of the detector.

7.3 *Procedure for Evaluation of Bad Pixels*—The baseline and performance monitoring evaluation for bad pixels shall be performed in accordance with Practice E2597/E2597M unless otherwise agreed upon by the user and CEO. The frequency of evaluation shall be agreed upon by the user and CEO. The documentation of bad pixels shall be performed by evaluating an acquired image for any individual nonconforming pixels, clusters, or lines that display a pixel intensity value that is outside of tolerance compared to the mean surrounding pixels. This can be completed by selecting one of several secondary evaluation methods: visual examination, ASTM procedure, or manufacturers recommended procedure. An example of a Secondary Evaluation for Bad Pixels would be a simple visual screening for bad pixels during normal viewing of a production image. Newly identified bad pixels shall be added to an existing bad pixel map, or a completely new map may be utilized. Any relevant cluster or line shall be clearly noted and added to the bad pixel map, as non-correctable pixels could hide relevant indications. The location of correctable and non-correctable bad pixels shall be documented. In addition, a report may contain the number of bad pixels, cluster kernel pixels, total clusters, relevant clusters, non-relevant clusters, and lines.

7.4 *Technique Parameters*—The various tests shall be completed using documented baseline technique parameters. It is not required that these technique parameters represent conditions used in production. Both the Detector and X-ray Source may degrade over time and impact image quality, therefore at a minimum, the following parameters shall be recorded and used in acquiring the baseline images as well as the long-term stability data. These technique parameters shall be recorded as part of the baseline and ongoing tests reports in full or in reference.

7.4.1 *X-ray System Identification:*

7.4.1.1 Detector Model Number and Serial Number.

7.4.1.2 X-ray Tube Model Number and Serial Number.

7.4.2 *X-ray Tube Settings/Configuration:*

7.4.2.1 X-ray tube voltage (kV).

7.4.2.2 Tube current (mA).

7.4.2.3 Focal spot size. (As measured according to Test Methods E1165 or E2903, or another standard. The recorded focal spot may be taken from the manufactures documentation.)

7.4.3 *X-ray Tube/Detector – Beam Filtration:*

7.4.3.1 Material Type.

7.4.3.2 Material Thickness.

7.4.4 *Beam Collimation:*

7.4.4.1 Collimation Location (Tube/Detector/Part).

7.4.4.2 Blade Positioning or Collimation Opening Values.

7.4.4.3 Collimation Material.

7.4.5 *Geometry:*

7.4.5.1 Source to Detector Distance (SDD).

7.4.5.2 Object to Detector Distance (ODD) or Source to Object Distance (SOD).

7.4.6 *Detector Settings:*

7.4.6.1 Detector Gain Setting.

7.4.6.2 Binning Mode.

7.4.6.3 Orientation (Landscape/Portrait/N/A).

7.4.7 *Exposure Time Per Image:*

7.4.7.1 Frame Rate or Integration Time.

7.4.7.2 Frame Averaging.

7.4.7.3 Total Exposure Time.

7.4.8 *Detector Corrections (correction and bad pixel substitution). Detector correction technique parameters may be recorded on a separate technique:*

7.4.8.1 Frame rate.

7.4.8.2 Number of frames averaged.

7.4.8.3 Number of Gain corrections (including each Gain's Approximate Mean Pixel Intensity Value or Percent of Saturation Pixel Value).

7.4.9 *Image Acquisition Software and Image Processing:*

7.4.9.1 Software Revision.

7.5 *Technique Energy Selection*—The energy used shall be appropriate for the Phantom material and thickness range to provide the required image quality in imaging the selected phantom and associated IQIs.

## 8. General Tests Required for all Phantom Types

8.1 *User Tests for Baseline and Long-Term Stability*—Quality assurance requires periodic tests of the DDA system to ensure the proper performance of the system. The time interval depends on the degree of usage of the system and shall be defined by the user with consideration of the DDA system manufacturer's information. If no time intervals are established by the contracting parties, the intervals for the performance checks shall be as defined within Table 1.

8.1.1 *Offset level Test*—Degradation of the DDA may reduce the system sensitivity after extensive usage. For this reason, the DDA system shall be checked for increasing offset value. The Offset value is the mean DDA response with no DDA corrections and without radiation. Offset values can be influenced by



**TABLE 1 System Performance Tests and Process Check of the DDA System using the DUPLEX PLATE**

| System Performance Test | | | System Performance Test | | | Process Check | Control Limits |
|---|---|---|---|---|---|---|---|
| Parameter | | Baseline[F] | Software Update | Tube Change | Detector Repair | Test Intervals[A] | Method[C] |
| Basic Spatial Resolution (Detector)[E] | $iSR_b^{detector}$ | x | x | x | x | 6 Months | ±3 Sigma, or ±20 % |
| Basic Spatial Resolution (Image) | $iSR_b^{image}$ | x | x | x | x | 10 Business Days or Before Use | ±3 Sigma, or ±20 % |
| Contrast Sensitivity in 4T hole | $CS_{4T}$ | x | x | x | x | 10 Business Days or Before Use | ±3 Sigma, or ±20 % |
| Signal to Noise Ratio | SNR | x | x | x | x | 10 Business Days or Before Use | ±3 Sigma, or ±20 % |
| Signal Level | SL | x | x | x | x | 10 Business Days or Before Use | ±3 Sigma, or ±20 % |
| Offset Level[B] | OL | x | x | | x | 10 Business Days or Before Use | +50 % |
| Bad Pixel Distribution in accordance with E2597/E2597M | | x | x | x | x | 3 Months | As agreed upon by user and CEO |
| Bad Pixel Distribution Secondary Evaluation (7.3)[D] | | x | | | | Daily or Before Use | |

[A]Test Intervals: Unless other intervals are defined and agreed upon by user and CEO.

[B]Offset Level: A recorded mean pixel value of a standard offset correction fulfills this requirement 7.2). The baseline for the offset level measurement can be a single measurement; it is not required to collect 30 days of test data.

[C]Control Limits Method: See 10.2.3, *Control Limits Values*. It is understood that one method of control limits being used is ±20 %. Some industries are now transitioning to ±3 Sigma. Either is acceptable unless otherwise specified by the CEO.

[D]Secondary Evaluation for Bad Pixels: Example—One method of performing this evaluation would be a simple visual screening for bad pixels during normal viewing of a production image.

[E]Basic Spatial Resolution (Detector): The baseline for this measurement can be a single measurement; it is not required to collect 30 days of test data.

[F]Baseline: See Section 10 for Application of Baseline Tests and Test Methods.

temperature, therefore, where operational temperatures vary, it is important to understand the impact on offset measurement values.

8.1.2 *Bad Pixel Distribution*—Newly identified bad pixels shall be added to the Bad Pixel Map. Any relevant cluster shall be clearly noted and added to the Bad Pixel Map.

8.1.3 *Image Lag and Burn-In (Nonmandatory)*—The test for Image Lag and Burn-In are tests typically performed by detector manufactures for a given model number detector. These tests shall be performed only if required by the CEO. If required, the tests shall be performed in accordance with Practice E2597/E2597M at a frequency defined by the CEO.

## 9. Duplex Plate Phantom Requirements

9.1 *Duplex Plate Phantom Configuration—*

9.1.1 *Phantom Material Thicknesses/Dimensions*—Either Type 1 or Type 2 phantom shall made of a single material type consisting of two thicknesses (see Fig. 1 and Fig. 2. The thickness of step 2 shall be minimum of 2 times the thickness of step.

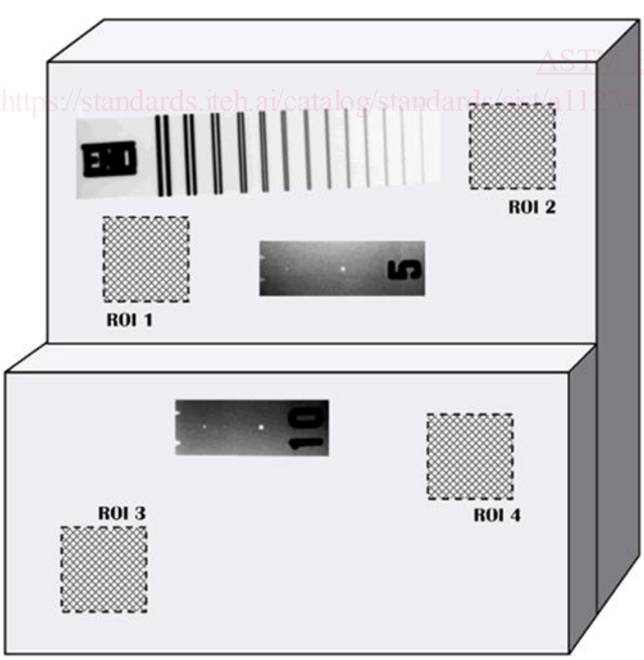
9.1.1.1 Other thicknesses may be used if agreed between user and CEO. It is not required that the phantom thicknesses represent the thickness range of product being evaluated. It is recommended that the outside dimensions of the phantom be sufficient in size that when imaged, the phantom is projected across the entire detector for the geometric magnification used. The phantom may be manufactured by overlapping two or more plates or by manufacturing from a single plate of material. An advantage of Type 2 Phantom is that it can be manufactured with the thinner plate being much larger than the thick plate, thereby reducing the phantom's weight. This is especially true when dealing with phantoms for large DDAs and lower geometric magnification imaging techniques. The thicker plate shall be large enough in width and length to provide clear separation from the IQI and the plate edge to reduce influence from edge gradient within the image.

9.1.2 *Image Quality Indicators*—IQIs used in combination with the Duplex Phantom provide an initial evaluation of the quality of a DDA system as well as a method for monitoring system performance. Practice E2002 duplex wire IQIs along with Practice E1025 or Practice E1742/E1742M hole-type IQIs shall be used along with the Duplex Plate Phantom.

9.1.2.1 *IQI Selection*—Each hole type IQI shall be 2 % of the specific plate thickness unless otherwise agreed upon between the user and the CEO. The Practice E2002 Duplex Gauge model shall be selected based on the spatial resolution range common to the majority of techniques being used.

9.1.2.2 *IQI Placement*—Either two Practice E1025 or two Practice E1742/E1742M hole-type IQIs shall be placed on either side of the phantom. Placing the IQIs on the flat side will provide the same geometric conditions for all IQIs. The hole type IQIs shall be placed on an area of the plate corresponding to the IQI's thickness (Fig. 1 and Fig. 2). A minimum of one Practice E2002 Duplex Wire IQI shall be placed on the thinner area as shown in Fig. 1 and Fig. 2 with an angle of 2° to 5° to the DDA pixel matrix directions. If required by the CEO, the spatial system resolution shall be measured in two perpendicular directions. This requirement may be met by either use of two Practice E2002 IQIs or by use of a single IQI providing images from two separate positions are acquired during the test. Other IQI placement may be used if agreed upon between user and CEO.






NOTE 1—Fig. 1 plate sizes and thicknesses are only examples and not meant to be restrictive.

NOTE 2—See 9.3.2 for placement of phantom for exposure.

NOTE 3—ROI locations are only examples and not meant to be restrictive.

**FIG. 1 Type 1 Duplex Plate Phantom with IQIs and ROI Positions**

9.2 *Duplex Phantom Tests:*

9.2.1 The tests listed in 9.2.2 – 9.2.6 and Table 1 shall be performed with the selected duplex phantom and corresponding IQIs. The tests shall be performed initially to establish the baseline and at specified intervals.

9.2.2 *Basic Spatial Resolution – Detector ($iSR_b^{detector}$)*—In accordance with Practice E2002 method using the duplex-wire gage at the detector.

9.2.3 *Basic Spatial Resolution – Image ($iSR_b^{image}$)*—In accordance with Practice E2002 method using the duplex-wire gage and duplex plate phantom positioned at a specific exposure geometry.

9.2.4 *Contrast Sensitivity – In 4T Hole*—Measured on the two separate IQIs located on the thin and thick step of the duplex plate phantom.

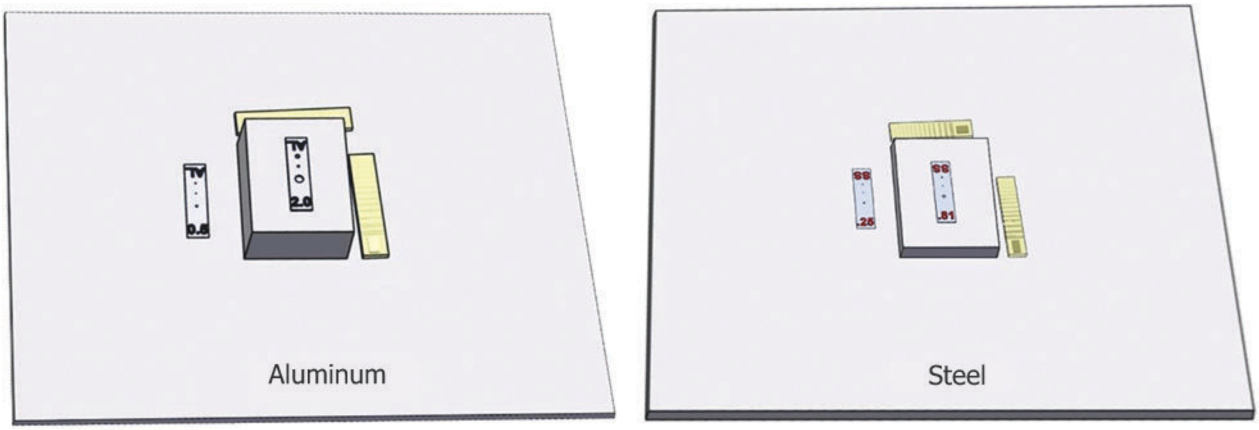
9.2.5 *Signal to Noise Ratio*—Measured on the thin and thick step of the duplex plate phantom.

9.2.6 *Signal Level*—Measured on the thin and thick step of the duplex plate phantom.

9.3 *Duplex Plate Phantom Exposure Procedures:*

9.3.1 For tracking performance of a DDA, all of the same technique parameters which were used to establish the system baseline shall be used during long-term stability or process checking.

9.3.2 *Exposure of the Duplex Plate Phantom Assembly*—The side with the IQIs shall face the radiation source and an




NOTE 1—Fig. 2 plate sizes and thicknesses are only examples and not meant to be restrictive. Examples of standardized dimensions for manufacturing Type 2 duplex plate phantoms within the requirements of this Practice are listed below.

NOTE 2— See 9.3.2 for placement of phantom for exposure.

NOTE 3—When required to measure the spatial resolution in two perpendicular directions, it is optional to use two Practice E2002 duplex wire gages. See 9.1.2.2.

NOTE 4—Examples of ROI locations are included in Fig. 4.

| Examples of Standardized Dimensions for Manufacturing Type 2 Duplex Plate Phantoms | | |
|---|---|---|
| Stainless Steel Duplex Plate: Min. Thickness: 5 mm (0.12 in.), Max. Thickness: 20 mm (0.79 in.) | | |
| Base Plate | 400 mm by 300 mm (15.75 in. by 11.81 in.) | 5 mm Thick (0.12 in.) |
| Top Plate | 100 mm by 80 mm (3.94 in. by 3.15 in.) | 15 mm Thick (0.59 in.) |
| Aluminum Duplex Plate: Min. Thickness: 12 mm (0.47 in.), Max. Thickness: 50 mm (1.97 in.) | | |
| Base Plate | 400 mm by 300 mm (15.75 in. by 11.81 in.) | 12 mm Thick (0.47 in.) |
| Top Plate | 100 mm by 80 mm (3.94 in. by 3.15 in.) | 38 mm Thick (1.5 in.) |

**FIG. 2 Type 2 Duplex Plate Phantoms with IQIs**



image shall be acquired with the technique parameters outlined in 7.4 recorded along with the energy setting as described in 7.5. When establishing the Phantom Technique, it is recommended that the projected image of the phantom cover the entire active area of the detector. This helps to avoid a substantial gradient in the image which can negatively influence the ability to provide quality contrast sensitivity measurements. In the event the projected image of the phantom does not cover the entire detector active area, it is acceptable to use masking around the phantom or to employ beam collimation. It is recommended that the masking be of a similar material density of the phantom and be permanently attached to the phantom to provide more repeatable results. Inconsistent placement of the phantom within the system increases the potential for additional image and data variability. Therefore, it is recommended that actions be taken to provide for repeatable placement of the phantom during imaging. In systems where computer numerical control (CNC) type positioning is provided, it is recommended that a motion program be used for performing performance tests.

## 10. Application of Baseline Tests and Test Methods When Using the Duplex Plate Phantom

10.1 *DDA System Baseline Performance Tests*—The user shall baseline the DDA using the tests delineated in 9.2.2 – 9.2.6 and Table 1. Any additional tests or requirements agreed upon between the user and the CEO should address the specific tests to perform, the data presentation, and the frequency of testing and any required approvals.

10.2 *Establishing Control Limits*—Unless otherwise specified by the CEO, the baseline performance upper and lower control limits shall be established through the following process:

10.2.1 *Acquisition Interval*—System performance test data shall be acquired daily and recorded for the first 30 days the equipment is in use. Evaluation of product is allowed within these 30 days providing the established image quality requirements are consistently met and any required technique approvals have been received. Multiple daily measurements may be taken and included in establishing the system baseline, however 30 data points captured over a minimum of 30 days of operation shall be used in establishing the baseline.

10.2.2 *Calculations*—Calculate the mean and the standard deviation for each test performed during the first 30 days.

10.2.3 *Control Limits Values*—Unless otherwise specified by the CEO, the baseline upper and lower control limits for tests shall be as stated in Table 1 and as follows:

10.2.3.1 $iSR_b^{image}$, $CS_{4T}$, *SNR, and SL*—Either ±3 Sigma, or ±20 % of the mean value from the first 30 days of test results.

10.2.3.2 *Offset Level*—Is +50 % of the mean value from when the detector is originally placed into production use. The baseline for this measurement can be a single measurement; it is not required to collect 30 days of test data.

10.2.3.3 $iSR_b^{detector}$—Either ±3 Sigma, or ±20 % of the mean value from when the detector is originally placed into production use. The baseline for this measurement can be a single measurement; it is not required to collect 30 days of test data.

10.2.3.4 *Bad Pixels*—Acceptance levels for individual bad pixels, bad clusters, relevant bad clusters, and bad lines, and their statistical distribution within the DDA, as well as proximity to each other is to be determined by agreement between the user and the CEO. The user and or CEO may refer to the Guide for DDAs (Guide E2736), Practice E2597/E2597M, and may consult with the manufacturer on how the prevalence of these anomalous pixels might impact a specific application. This practice does not set limits but does offer a means for tracking such anomalous pixels in the table templates provided herein.

## 11. Test Reports

11.1 The results of the baseline and ongoing tests shall be documented. At a minimum the test report shall include in full or in reference the content of Table 2 and 1-8 below. The technique parameters as identified in 7.4 shall also be included in the report in full or in reference. The Maximum deviation Control Limits shall be documented in Table 2. The bad pixel report should include the content as described in Practice E2597/E2597M or as agreed upon between the user and CEO.

*(1)* Date of Test.

*(2)* Operator.

*(3)* System Identification.

*(4)* Duplex Phantom Identification.

*(5)* Material and Thicknesses (It is acceptable to reference Phantom Record with Material and Dimensional Data).

*(6)* Separate IQI's Standard and Identification for thick and thin plates (for example, Practice E1742/E1742M, AL, 1.5 in. and 0.5 in.) Practice E2002 Duplex Wire Gage.

*(7)* Identification of the IQI hole used for measuring Contrast Sensitivity. (It is acceptable to reference procedurally.)

*(8)* Conclusion of Tests.

11.2 *Test Logs*—A log can be used to record part of the test data, such as when tests have been performed and the operator performing the tests. If maintenance, repair, or a software change has occurred, these events shall also be recorded or logged documenting a description of the event as well as the date it was performed.

## 12. Monitoring Performance to Control Limits

12.1 The subsequent ongoing test results shall be within the established upper and lower control limits. If test results exceed the established baseline control limits, refer to Annex A1 Test Phantom Processing Steps Flowchart. The user's level 3 shall perform an investigation to assess the cause and impact to the current condition. Production evaluations can resume providing image quality requirements are met. If an out of specification (as agreed between CEO and user) condition occurs, the DDA or X-ray Source, as applicable, is to be repaired or replaced or an action has to be taken as agreed between user and CEO.

12.2 *Events Requiring Removal of DDA from Service*—Due to accumulated exposure or other unforeseen equipment malfunctions, DDA replacement or repair shall be required when one or more of the tolerance metrics applied cannot be maintained. Prior to replacement, the user should consult the DDA manufacture and/or system provider to explore the root cause and any potential equipment repair or replacement.

12.3 *Conditions requiring a new 30 day Baseline:*

12.3.1 *Detector Repair or Replacement*—In the event that a systems detector is repaired or replaced, a new 30 day baseline shall be established in accordance with this practice.

12.3.2 *X-ray Tube Repair or Replacement*—If an X-ray tube is replaced a new 30 day baseline shall be established. In the case of an x-ray tube repair, if the phantom test can be performed using the current technique and provide results within the current control limits then a new baseline is not required providing user level 3 approval is attained.

12.3.3 *Software Changes or Upgrades*—Software changes that may influence image quality and measurements shall be identified by the manufacturer and communicated to the user. These software changes as well as those listed in Table 1 require that a new 30 day baseline be established.

12.3.4 *Normal System Degradation*—In the event system degradation occurs from normal operational use which causes the system to fall out of the established control limits, yet the image quality requirements continue to be met, the user may



**TABLE 2 Content to be Included Within Test Report when using the DUPLEX PLATE**

| Measurement Location | Tests | Control Limits | | Test Value | Resuls Pass/Fail |
|---|---|---|---|---|---|
| | | Min | Max | | |
| DP-Thin - Position 1 | Basic Spatial Resolution ($iSR_b^{image}$) | | | | |
| DP-Thin - Position 2 | Basic Spatial Resolution ($iSR_b^{image}$) | | | | |
| DP-Thin | Contrast Sensitivity in 4T hole ($CS_{4T}$) [%] | | | | |
| DP-Thick | Contrast Sensitivity in 4T hole ($CS_{4T}$) [%] | | | | |
| DP-Thin | Signal to Noise Ratio | | | | |
| DP-Thick | Signal to Noise Ratio | | | | |
| DP-Thick | Signal Level | | | | |
| DP-Thin | Signal Level | | | | |
| N/A | Offset Level | | | | |
| Face of Detector | Basic Spatial Resolution ($iSR_b^{detector}$) | | | | |
| N/A | Bad Pixel Distribution | | | | |