Designation: ~~E2737 – 10 (Reapproved 2018)~~ 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 ~~describes the evaluation of DDA systems for industrial radiology.~~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 ~~and long term~~to monitor long-term stability of the DDA system.

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

1.3 The DDA system ~~performance~~ tests specified in this practice shall be completed upon acceptance of the system from the manufacturer ~~and at intervals specified in this practice to monitor long term stability of the system. The intent of these tests is to monitor the system performance for degradation and~~ 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 ~~when the system degrades by a certain~~ 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 ~~the gages provided in this standard is mandatory for each test.~~ these two types of phantoms is not intended to exclude the use of other phantom configurations. In the event ~~these~~the tests or ~~gages are not sufficient,~~ 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, ~~gages,~~phantoms, or image quality indicators to evaluate the DDA ~~system.~~ system performance. Acceptance levels for these ALTERNATE ~~tests~~ test methods shall be determined by agreement between the ~~user, CEO and manufacturer.~~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.*

[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.

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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

E2445/E2445ME2446 Practice for Performance Evaluation and Long-Term Stability 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

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 Nondestructive 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, GuidePractice E2736E2698, and PracticeGuide E2698E2736, shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *digital detector array (DDA) system*—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 image corresponding to the radiologic energy pattern imparted upon the input region of the device. The conversion of the ionizing or penetrating radiation into an electronic signal may transpire by first converting the ionizing or penetrating radiation into visible light through the use of a scintillating material. These devices can range in speed from many seconds per image to many images per second, up to and in excess of real-time radioscopy rates (usually 30 frames per seconds).

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

3.2.2 *signal-to-noise ratio (SNR)*—*burn-in*—quotient of mean value of the intensity (signal) and standard deviation of the intensity (noise). The SNR depends on the radiation dose and the DDA system properties.change in gain of the scintillator that persists well beyond the exposure.

3.2.3 *contrast-to-noise ratio (CNR)*—*duplex plate phantom Type 1*—quotient of the difference of the signal levels between two material thicknesses, and standard deviation of the intensity (noise) of the base material. The CNR depends on the radiation dose

[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.

[3] The saturation gray value is provided by the manufacturer.Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] DDAs can operate in either an extended exposure mode where a single frame may be acquired for 10 s, or multiple frames can be acquired and averaged over the same 10 s. The user is to select the appropriate frame time for the DDA at hand based on manufacturer's recommendations and typical exposure times used for production.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.

~~and the DDA system properties.~~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.

~~3.2.5 *contrast sensitivity*—recognized contrast percentage of the material to examine. It depends on 1/CNR.~~

3.2.4 ~~*spatial resolution (SR)*—~~*duplex plate phantom Type 2—*~~the spatial resolution indicates the smallest geometrical detail, which can be resolved using the DDA with given geometrical magnification. It is the half of the value of the detector unsharpness divided by the magnification factor of the geometrical setup and is similar to the effective pixel size.~~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 ~~*material thickness range (MTR)*—~~*five-groove wedge—*~~the wall thickness range within one image of a DDA, whereby the thinner wall thickness does not saturate the DDA and at the thicker wall thickness, the signal is significantly higher than the noise.~~a continuous wedge with five long grooves on one side.

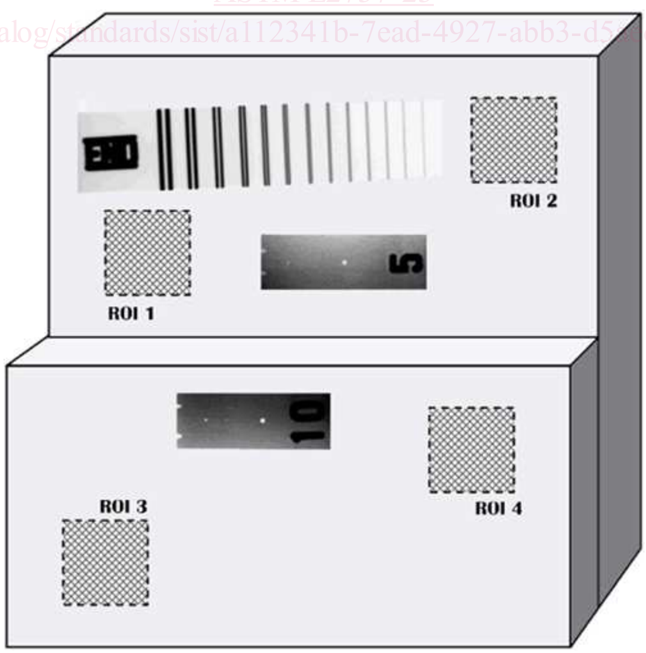
3.2.6 *frame rate*—number of frames acquired per second.

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

~~3.2.10 *burn-in*—change in gain of the scintillator that persists well beyond the exposure.~~

3.2.8 ~~*bad pixel*—~~*manufacturer—*~~a pixel identified with a performance outside of the specification range for a pixel of a DDA as defined in Practice~~ DDA system manufacturer, supplier for the user of the DDA system.~~E2597/E2597M~~.

3.2.9 ~~*five-groove wedge*—~~*material thickness range (MTR)—*~~a continuous wedge with five long grooves on one side (see~~the material thickness range within a single DDA image, whereby a minimum specific image quality is ~~Fig. 1).~~achieved throughout the entire thickness range.



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 ~~5-Groove-Wedge (steel) – see Appendix~~Type 1 Duplex Plate Phantom with IQIs and ROI Positions

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

~~3.2.14 *duplex plate phantom*—two plates of the same material; Plate 2 has same size in x- and half the size in y- direction of Plate 1; the thickness of Plate 1 matches the minimum thickness of the material for inspection; the thickness of Plate 1 plus Plate 2 matches the maximum thickness of the material for inspection (see Fig. 2).~~

~~3.2.15 *DDA offset image*—image of the DDA in the absence of x-rays providing the background signal of all pixels.~~

~~3.2.16 *DDA gain image*—image obtained with no structured object in the x-ray beam to calibrate pixel response in a DDA.~~

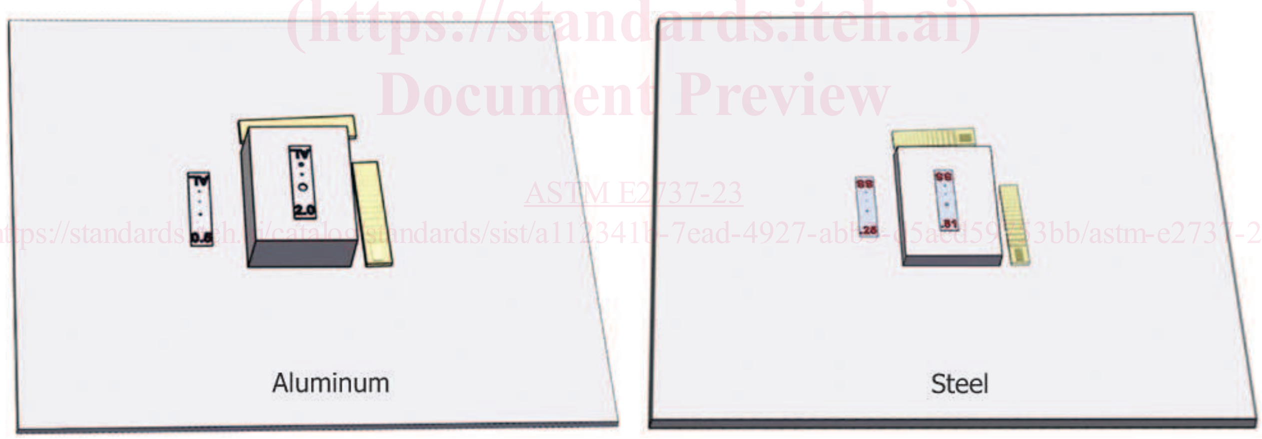
~~3.2.17 *calibration*—correction applied for the offset signal and the non-uniformity of response of any or all of the X-ray beam, scintillator, and the read out structure.~~

~~3.2.18 *gray value*—the numeric value of a pixel in the DDA image. This is typically interchangeable with the term pixel value, detector response, Analog-to-Digital unit and detector signal.~~

3.2.11 *saturation ~~gray~~pixel value*—the maximum possible usable ~~gray~~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 ~~gray~~pixel values as a function of increasing exposure levels.

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



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 ~~Phantom~~Phantoms with IQIs ~~positioned; one ASTM E1025 or E1742/E1742M Penetrameter on each plate and one ASTM E2002 Duplex Wire IQI on the thinner plate. The boxes ROI 1 to ROI 4 are for evaluation of signal level and SNR.~~

~~3.2.21 *customer*—the company, government agency, or other authority responsible for the design, or end user, of the system or component for which radiologic examination is required, also known as the CEO. In some industries, the customer is frequently referred to as the "Prime".~~

~~3.2.22 *manufacturer*—DDA system manufacturer, supplier for the user 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 ~~NDT using organization~~ DDA user to measure and record the baseline performance of ~~the DDA and~~ an acquired DDA in order to monitor its performance throughout its service as an ~~NDT imaging system.~~imaging system. This practice is not intended to be used as an "acceptance test" of a DDA.

~~4.2 It is to be understood that the DDA has already been selected and purchased by the user from a manufacturer based on the inspection needs at hand. This practice is not intended to be used as an "acceptance test" of the DDA, but rather to establish a performance baseline that will enable periodic performance tracking while in-service.~~

~~4.3 Although many of the properties listed in this standard have similar metrics to those found in Practice E2597/E2597M, data collection methods are not identical, and comparisons among values acquired with each standard should not be made.~~

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 ~~or~~and defined between the user and ~~customer (CEO).~~CEO.

4.3 There are several factors that affect the quality of a DDA image including the basic spatial resolution, ~~geometrical~~geometric unsharpness, scatter, signal to noise ratio, contrast ~~sensitivity (contrast/noise ratio),~~sensitivity, contrast/noise ratio, image lag, and ~~burn in.~~ for some types of DDAs, burn-in. There are several additional factors and settings which can affect these results (for example, integration time, detector ~~parameters or imaging software), which affect these results. Additionally, calibration techniques may also~~ 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. General Testing Procedures**~~

~~5.1 The tests performed herein can be completed either by the use of the five-groove wedge phantom (see Fig. 1) or with separate IQIs on the Duplex Plate Phantom (see Fig. 2).~~

~~5.2 *DDA Calibration Method*—Prior to testing, the DDA shall be calibrated for offset and, or gain to generate corrected images per manufacturer's recommendation. It is important that the calibration procedure be completed as would be done in production during routine calibration procedures, and that these same procedures be used throughout the periodic testing of the DDA after it is in-service.~~

~~5.3 *Bad Pixel Standardization for DDAs*—Images collected for testing shall be corrected for bad pixels as would be done in production during routine bad pixel correction procedures per manufacturer's recommendation wherever required. A standardized nomenclature is presented in Practice E2597/E2597M. The identification and correction of bad pixels in a delivered DDA remain in the purview of agreement between the user and the system manufacturer. The various tests shall be completed under similar conditions as in production. Some parameters to control are listed below. If several different energies are used in production, the complete settings with the highest energy level shall be used for these tests.~~

~~5.3.1 X-ray tube voltage [kV]~~

~~5.3.2 tube current [mA]~~

~~5.3.3 focus detector distance (FDD) [mm]~~

~~5.3.4 object detector distance (ODD) [mm]~~

~~5.3.5 total exposure time per image [ms]~~

~~5.3.6 detector corrections (calibration and bad pixel substitution)~~

~~5.3.7 detector settings~~

~~5.3.8 image acquisition software and image processing~~

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. ~~Application of Baseline Tests and Test Methods~~General Procedures Applied to All Phantom Types

7.1 *DDA ~~System Baseline Performance Tests~~ Correction Method—*

~~6.1.1 The user shall accept the DDA system based on manufacturer's results of Practice E2597/E2597M on the specific detector as provided in a data sheet for that serialized DDA or other agreed to acceptance test between the user and manufacturer (not covered in this practice). The user baselines the DDA using the tests defined in Table 1. Additional tests are to be defined in agreement between the CEO and the using organization in terms of the specific tests to perform, how the data is presented, and the frequency of testing. This approach does the following:~~

~~6.1.1.1 Provides a quantitative baseline of performance,~~

~~6.1.1.2 provides results in a defined form that can be reviewed by the CEO and~~

~~6.1.1.3 offers a means to perform process checking of performance on a continuing basis.~~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.

~~6.1.2 Acceptance values, and tolerances thereof obtained from these tests shall also be in agreement between the CEO and the using organization.~~

7.1.1 *Bad Pixel Standardization for DDAs—*~~Acceptance levels for individual bad pixels, bad clusters, relevant bad clusters,~~ 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~~and bad lines, and their statistical distribution within the DDA, as well as proximity to said anomalies is to be determined by agreement~~. The identification and correction of bad pixels in a DDA shall be as agreed upon between the user and the CEO. The ~~user and or CEO may refer to the Guide for DDAs (~~threshold levels used to identify bad ~~E2736), Practice E2597/E2597M, as well as 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.~~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.

~~6.1.4 Given that the other elements of the DDA system are within their tolerances including the x-ray source/generator, the imaging system, and the inspection itself (for example errors with gain/offset mapping are controlled, as is any severe x-ray scatter in the inspection), and the test produces a result below the "agreed to" requirements, the detector is not to be placed in service unless it is repaired, replaced, or some other change is instituted that will assure the quality of the inspection as stated in the agreement between contracting parties.~~

~~6.1.5 The results of the initial test of the new system shall be documented, as delineated in Table 2 and Table 3 and taken as reference values "Result (new)" for further use.~~

TABLE 1 System Performance Tests and Process Check of the DDA System

System Performance Test Parameter		Unit	System Performance Test: Base Line	Software Update	Tube Change	Detector Change/ Repair	Process Check: Short Version			Long Version	Usa Five We
Spatial Resolution	SR	µm	x		x	x	x x		x	x	
Contrast Sensitivity	CS	%	x	x	x	x		x		x	
Material Thickness Range	MTR	mm	x	x	x	x	x		x	x	
Signal to Noise Ratio	SNR		x	x	x	x		x		x	
Signal Level	SL		x	x		x		x		x	
Image Lag	Lag	%	x			x			x		
Burn In	BI	%	x			x			x	x	
Offset Level	OL		x	x	x	x				x	
Bad Pixel Distribution			x	x	x	x		x		x	

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

System Performance Test Parameter		Baseline[F]	System Performance Test: Software Update	Tube Change	Detector Repair		Process Check: Test Intervals[A]	Co
Basic Spatial Resolution (Detector)[E]	$iSR_b^{detector}$	x		x	x	x	6 Months	±3 Sig
Basic Spatial Resolution (Image)	iSR_b^{image}	x	x	x	x		10 Business Days or Before Use	±3 Sig
Contrast Sensitivity in 4T hole	CS_{4T}	x	x	x	x		10 Business Days or Before Use	±3 Sig
Signal to Noise Ratio	SNR		x	x	x	x	10 Business Days or Before Use	±3 Sig
Signal Level	SL	x	x	x		x	10 Business Days or Before Use	±3 Sig
Offset Level[B]	OL		x	x		x	10 Business Days or Before Use	
Bad Pixel Distribution in accordance with E2597/E2597M			x	x	x	x	3 Months	As agreed up
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.

6.1.6 Maximum deviations from Result (new) as tolerances and limits defined between contracting parties shall also be documented in Table 2 and Table 3 as reference values "Limit" for further use.

6.1.7 If a replacement DDA is placed into service, the reference values from the acceptance test shall be updated, and a new baseline formed.

7.2 *User Tests After Repair, Hardware- or Software Upgrade*—*Procedure for Measurement of the Offset Level*—After modifications, such as repair or upgrade of the DDA system hardware, specialized tests are required to prove the proper performance of the DDA system with the new conditions. With a new DDA the reference values from the acceptance test 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*shall be updated, too. Changes of the functionality of the system (for example, by new software version), which influence the image quality, also need a test to prove the proper performance of the system after changes.). 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 *User Tests for Long-Term Stability*—*Procedure for Evaluation of Bad Pixels*—Quality assurance requires periodic tests of the DDA system to ensure the proper performance of the system.The baseline and performance monitoring evaluation for bad pixels shall be performed in accordance with Practice E2597/E2597M The time interval depends on the degree of usage of the system

TABLE 2 ~~Test Report of DDA SystemReport of Bad Pixels and Clusters~~Content to be Included Within Test Report when using the DUPLEX PLATE

~~Tests~~ ~~Control Limits~~ ~~Test Value~~ ~~Resuls~~ Pass/Fail

DDA System			kV	energy
Construction Year			mA	tube current
Last Service				pre filter (material and thickness)
Detector Settings			mm	focus detector distance
Software			mm	object detector distance
Software Version			s	total exposure time per image
Used IQI	☐	5 Hole Wedge	☐	Duplex Plate Phantom (separate IQIs)

Test:	☐	Acceptance Test
	☐	Test after Repair or new Software
	☐	Longterm Stability (short version)
	☐	Longterm Stability (long version)

Tests	Unit	Result (new)		Limit		Result		Remark
		thin	thick	thin	thick	thin	thick	
Spatial Resolution SR	µm							
Contrast Sensitivity* CS	%							
Material Thickness Range MTR	mm							
Signal to Noise Ratio SNR								
Signal Level SL								
Image Lag 1f Lag	%							
Burn In 1 / 10 min BI	%							
Offset Level OL								
Bad Pixel Distribution		OK						

Date of Tests	
Conclusion	
Operator	

~~* Two columns only needed when using Duplex Plate Phantom~~

Measurement Location		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		

~~and shall be defined~~ unless otherwise agreed upon by the user and CEO. The frequency of evaluation shall be agreed upon by the user ~~with consideration of the DDA system manufacturer's information. There may be two versions of the long version stability tests, the complete program and a short version. The intervals for the performance checks shall not exceed ten days. The check for bad pixel shall be done daily. Details shall be agreed upon between the customer and 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.

TABLE 3 ~~Report of Bad Pixels and Clusters~~System Performance Tests and Process Check of the DDA System using the FIVE-GROOVE WEDGE

~~System Performance Test~~ ~~Process Check~~ ~~Control Limits~~

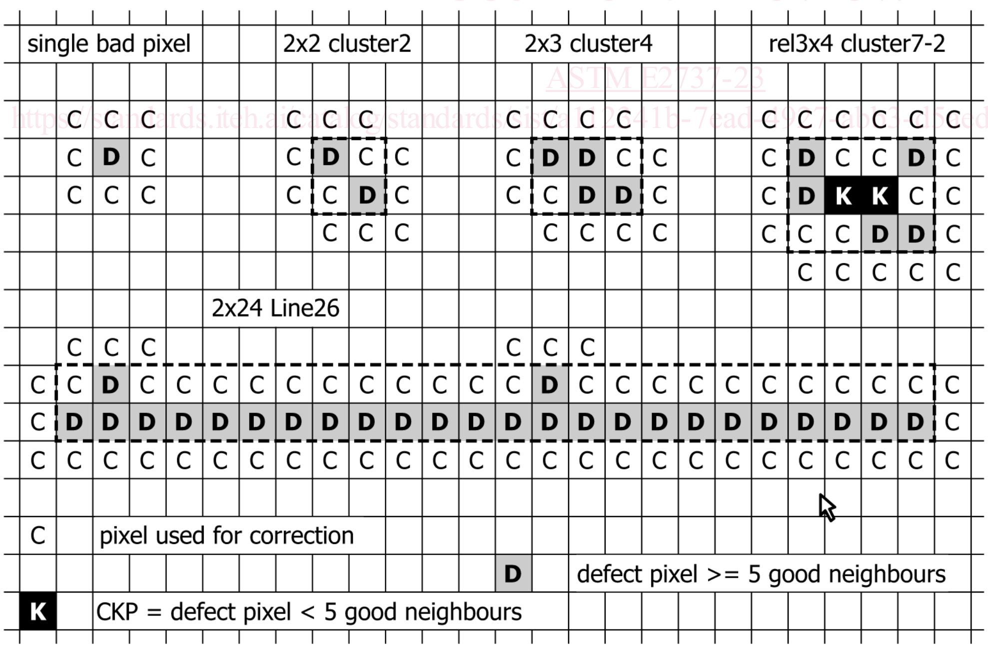
Bad Pixel Definition Thresholds:			
Underperforming Low Threshold	=		%
Underperforming High Threshold	=		%

Name of the Bad Pixel Image: ______________________________

Bad Pixel Summary:		Result (new)	Limit	Result	Okay/Not Okay	Remark
No Total Bad Pixels	=					
No of relevant Cluster	=					
No of remaining irrelevant Cluster	=					
No of Bad Lines	=					

Size / Name of relevant Cluster #1				No of ClusterKernelPixel =					
Position of relevant Cluster #1		X1		X2		Y1		Y2	
Size / Name of relevant Cluster #2				No of ClusterKernelPixel =					
Position of relevant Cluster #2		X1		X2		Y1		Y2	
Size / Name of relevant Cluster #3				No of ClusterKernelPixel =					
Position of relevant Cluster #3		X1		X2		Y1		Y2	

Date of Tests	
Conclusion	
Operator	



Definition of Cluster, relevant Cluster and Line with size and name.

~~System Performance Test~~

Parameter		Baseline[G]	Software Update	Tube Change	Detector Repair	Test Intervals[A]	Method[C]
Basic Spatial Resolution (Detector)[F]	$iSR_b^{detector}$	x	x	x	x	6 Months	±3 Sigma, or ±20 percent
Groove Sensitivity Level[E]	GSL	x		x	x	10 Business Days or Before Use	±3 Sigma, or ±20 percent

Contrast Sensitivity (groove)	CS_{4T}	x	x	x	x	10 Business Days or Before Use	±3 Sigma, or ±20 percent
Signal to Noise Ratio	SNR	x	x	x	x	10 Business Days or Before Use	±3 Sigma, or ±20 percent
Signal Level	SL	x	x	x	x	10 Business Days or Before Use	±3 Sigma, or ±20 percent
Material Thickness Range	MTR	x	x	x	x	10 Business Days or Before Use	±3 Sigma, or ±20 percent
Offset Level[B]	OL	x	x		x	10 Business Days or Before Use	+50 percent
Bad Pixel Distribution Per 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 15.2.3, *Control Limits Values*. It is understood that one previously applied method of establishing control Limits was ±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]Groove Sensitivity Level: The smallest visible groove shall be taken as the Groove Sensitivity Level.
[F]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.
[G]Baseline: See Section 15 for Application of Baseline Tests and Test Methods.

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 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.