Designation: E2736 – 10

Standard Guide for
Digital Detector Array Radiology[1]

This standard is issued under the fixed designation E2736; 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 standard is a user guide, which is intended to serve as a tutorial for selection and use of various digital detector array systems nominally composed of the detector array and an imaging system to perform digital radiography. This guide also serves as an in-detail reference for the following standards: Practices E2597, E2698, and E2737.

1.2 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E94 Guide for Radiographic Examination
E155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings
E192 Reference Radiographs of Investment Steel Castings for Aerospace Applications
E747 Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology
E1000 Guide for Radioscopy
E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology
E1316 Terminology for Nondestructive Examinations
E1320 Reference Radiographs for Titanium Castings
E1742 Practice for Radiographic Examination
E1815 Test Method for Classification of Film Systems for Industrial Radiography
E1817 Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)
E2002 Practice for Determining Total Image Unsharpness in Radiology
E2422 Digital Reference Images for Inspection of Aluminum Castings
E2445 Practice for Qualification and Long-Term Stability of Computed Radiology Systems
E2446 Practice for Classification of Computed Radiology Systems
E2597 Practice for Manufacturing Characterization of Digital Detector Arrays
E2660 Digital Reference Images for Investment Steel Castings for Aerospace Applications
E2669 Digital Reference Images for Titanium Castings
E2698 Practice for Radiological Examination Using Digital Detector Arrays
E2737 Practice for Digital Detector Array Performance Evaluation and Long-Term Stability

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *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 radiation 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 minutes per image to many images per second, up to and in excess of real-time radioscopy rates (usually 30 frames per seconds).

3.1.2 *signal-to-noise ratio (SNR)*—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.

3.1.3 *normalized signal-to-noise ratio* (SNR_n)—SNR normalized for basic spatial resolution (see Practice E2445).

[1] This guide 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] 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.

3.1.4 *basic spatial resolution (SRb)*—basic spatial resolution indicates the smallest geometrical detail, which can be resolved using the DDA. It is similar to the effective pixel size.

3.1.5 *efficiency*—$dSNR_n$(see 3.1.6 of Practice E2597) divided by the square root of the dose (in mGy) and is used to measure the response of the detector at different beam energies and qualities.

3.1.6 *achievable contrast sensitivity (CSa)*—optimum contrast sensitivity (see Terminology E1316 for a definition of contrast sensitivity) obtainable using a standard phantom with an X-ray technique that has little contribution from scatter.

3.1.7 *specific material thickness range (SMTR)*—material thickness range within which a given image quality is achieved.

3.1.8 *contrast-to-noise ratio (CNR)*—quotient of the difference of the mean signal levels between two image areas and the standard deviation of the signal levels. The CNR depends on the radiation dose and the DDA system properties.

3.1.9 *lag*—residual signal in the DDA that occurs shortly after the exposure is completed.

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

3.1.11 *internal scatter radiation (ISR)*—scattered radiation within the detector (from scintillator, photodiodes, electronics, shielding, or other detector hardware).

3.1.12 *bad pixel*—a bad pixel is a pixel identified with a performance outside of the specification for a pixel of a DDA as defined in Practice E2597.

3.1.13 *grooved wedge*—a wedge with one groove, that is 5 % of the base material thickness and that is used for achievable contrast sensitivity measurement in Practice E2597.

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

4. Significance and Use

4.1 This standard provides a guide for the other DDA standards (see Practices E2597, E2698, and E2737). It is not intended for use with computed radiography apparatus. Figure 1 describes how this standard is interrelated with the aforementioned standards.

4.2 This guide is intended to assist the user to understand the definitions and corresponding performance parameters used in related standards as stated in 4.1 in order to make an informed decision on how a given DDA can be used in the target application.

4.3 This guide is also intended to assist cognizant engineering officers, prime manufacturers, and the general service and manufacturing customer base that may rely on DDAs to provide advanced radiological results so that these parties may set their own acceptance criteria for use of these DDAs by suppliers and shops to verify that their parts and structures are of sound integrity to enter into service.

4.4 The manufacturer characterization standard for DDA (see Practice E2597) serves as a starting point for the end user to select a DDA for the specific application at hand. DDA manufacturers and system integrators will provide DDA performance data using standardized geometry, X-ray beam spectra, and phantoms as prescribed in Practice E2597. The end user will look at these performance results and compare DDA metrics from various manufacturers and will decide on a DDA that can meet the specification required for inspection by the end user. See Sections 5 and 8 for a discussion on the characterization tests and guidelines for selection of DDAs for specific applications.

4.5 Practice E2698 is designed to assist the end user to set up the DDA with minimum requirements for radiological examinations. This standard will also help the user to get the required SNR, to set up the required magnification, and provides guidance for viewing and storage of radiographs. Discussion is also added to help the user with marking and identification of parts during radiological examinations.

4.6 Practice E2737 is designed to help the end user with a set of tests so that the stability of the performance of the DDA can be confirmed. Additional guidance is provided in this document to support this standard.

4.7 Figure 1 provides a summary of the interconnectivity of these four DDA standards.

5. DDA Technology Description

5.1 *General Discussion*:

5.1.1 DDAs are seeing increased use in industries to enhance productivity and quality of nondestructive testing. DDAs are being used for in-service nondestructive testing, as a diagnostic tool in the manufacturing process, and for inline testing on production lines. DDAs are also being used as hand held, or scanned devices for pipeline inspections, in industrial computed tomography systems, and as part of large robotic scanning systems for imaging of large or complex structures. Because of the digital nature of the data, a variety of new applications and techniques have emerged recently, enabling quantitative inspection and automatic defect recognition.

5.1.2 DDAs can be used to detect various forms of electromagnetic radiation, or particles, including gamma rays, X-rays, neutrons, or other forms of penetrating radiation. This standard focuses on X-rays and gamma rays.

5.2 *DDA architecture*:

5.2.1 A common aspect of the different forms of this technology is the use of discrete sensors (position-sensitive) where, the data from each discrete location is read out into a file structure to form pixels of a digital image file. In all its simplicity, the device has an X-ray capture material as its primary means for detecting X-rays, which is then coupled to a solid-state pixelized structure, where such a structure is similar to the imaging chips used in visible-wavelength digital photography and videography devices. Figure 2 shows a block diagram of a typical digital X-ray imaging system.

5.2.2 An important difference between X-ray imaging and visible-light imaging is the size of the read-out device. The imagers found in cameras and for visible-light are typically on the order of 1 to 2 cm^2 in area. Since X-rays are not easily focused, as is the case for visible light, the imaging medium must be the size of the object. Hence, the challenge lies in meeting the requirement of a large uniform imaging area without loss of spatial information. This in turn requires high pixel densities of the read-out device over the object under examination, as well a primary sensing medium that also retains the radiologic pattern in its structure. Therefore, each DDA consists of a primary X-ray or gamma ray capture

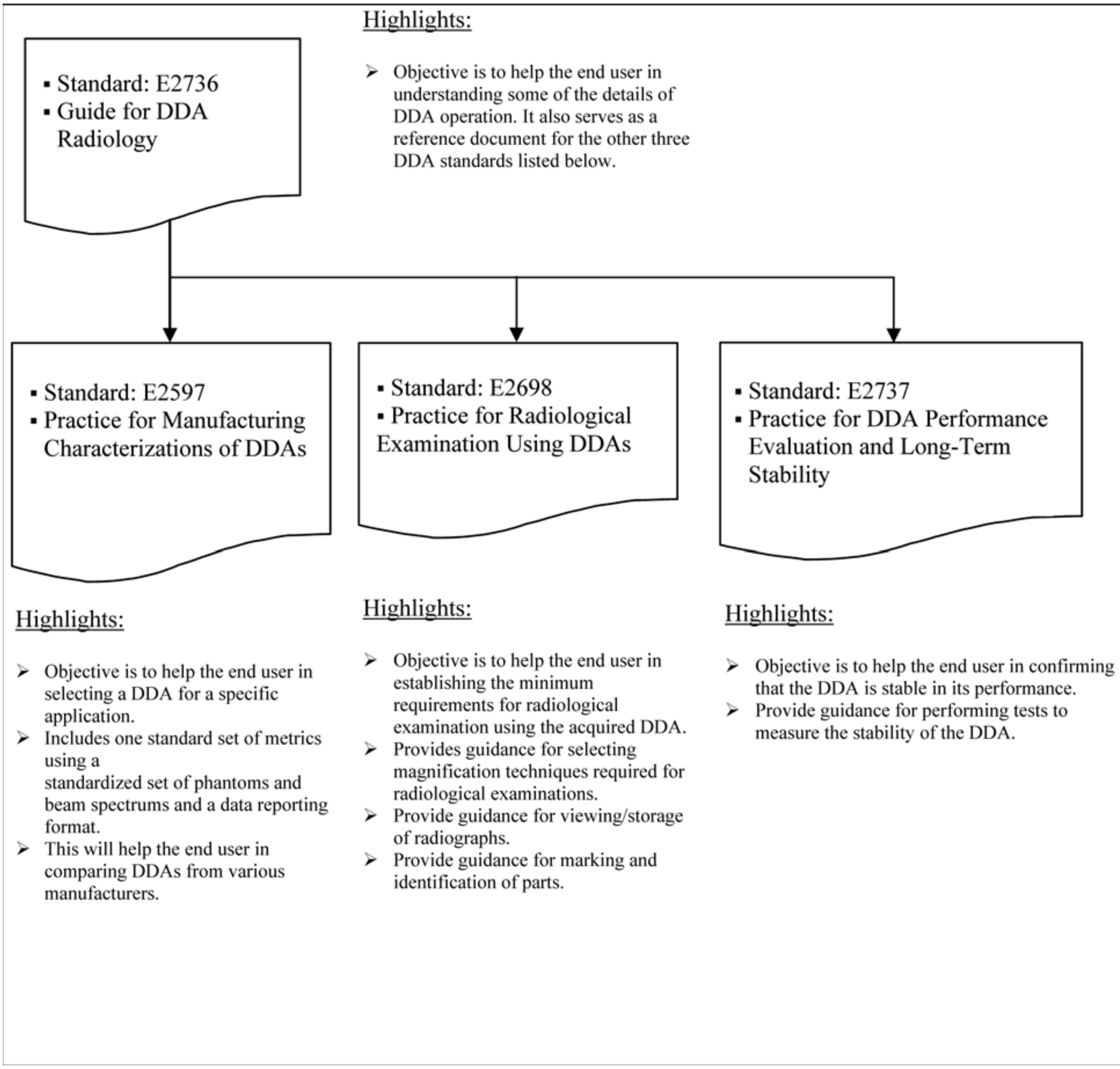

FIG. 1 Flow Diagram Representing the Connection Between the Four DDA Standards

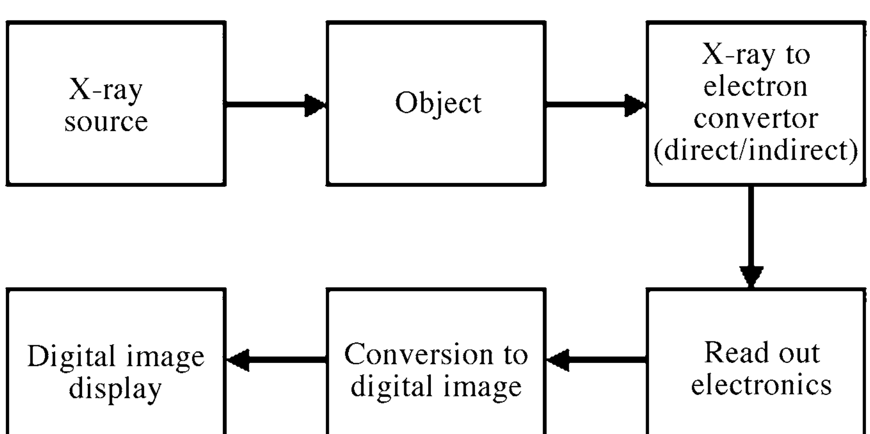

FIG. 2 Block Diagram of a Typical Digital X-Ray Imaging System

medium followed by a pixelized read structure, with various means of transferring the above said captured pattern. For each