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Standard Practice for
Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for X-ray Computed Tomography (CT) Test Methods[1]

This standard is issued under the fixed designation E2767; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice facilitates the interoperability of X-ray computed tomography (CT) imaging equipment by specifying image data transfer and archival storage methods in commonly accepted terms. This document is intended to be used in conjunction with Practice E2339 on Digital Imaging and Communication in Nondestructive Evaluation (DICONDE). Practice E2339 defines an industrial adaptation of the NEMA Standards Publication titled Digital Imaging and Communications in Medicine (DICOM, see http://medical.nema.org), an international standard for image data acquisition, review, storage and archival storage. The goal of Practice E2339, commonly referred to as DICONDE, is to provide a standard that facilitates the display and analysis of NDE test results on any system conforming to the DICONDE standard. Toward that end, Practice E2339 provides a data dictionary and a set of information modules that are applicable to all NDE modalities. This practice supplements Practice E2339 by providing information object definitions, information modules and a data dictionary that are specific to X-ray CT test methods.

1.2 This practice has been developed to overcome the issues that arise when analyzing or archiving data from tomographic test equipment using proprietary data transfer and storage methods. As digital technologies evolve, data must remain decipherable through the use of open, industry-wide methods for data transfer and archival storage. This practice defines a method where all the X-ray CT technique parameters and test results are communicated and stored in a standard manner regardless of changes in digital technology.

1.3 This practice does not specify:

1.3.1 A testing or validation procedure to assess an implementation's conformance to the standard.

1.3.2 The implementation details of any features of the standard on a device claiming conformance.

1.3.3 The overall set of features and functions to be expected from a system implemented by integrating a group of devices each claiming DICONDE conformance.

1.4 *Units*—Although this practice contains no values that require units, it does describe methods to store and communicate data that do require units to be properly interpreted. The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *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.*

1.6 *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]
E1316 Terminology for Nondestructive Examinations
E1441 Guide for Computed Tomography (CT)
E2339 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)

2.2 *Other Standard:*[3]
NEMA PS3 / ISO 12052, Digital Imaging and Communications in Medicine (DICOM) Standard, National Electrical Manufacturers Association, Rosslyn, VA, USA (available free at http://www.dicomstandard.org/)

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3. Terminology

3.1 *Definitions:*

3.1.1 Nondestructive evaluation terms used in this practice can be found in Standard Terminology for Nondestructive Examinations, E1316.

3.1.2 Computed Tomography terms used in this practice can be found in Standard Guide for Computed Tomography (CT) Imaging, E1441.

3.1.3 DICONDE terms used in this practice are defined in Practice E2339.

4. Summary of Practice

4.1 A fundamental principle of DICONDE is the use of standard definitions and attribute formats for data communication and storage. This means all systems that are DICONDE compliant use a common data dictionary and common communication protocols. To further standardization, the elements in the data dictionary are organized into common groups referred to as information modules. The data dictionary and information modules common to all NDE modalities are defined in Practice E2339.

4.2 The data dictionary and information modules specified in Practice E2339 do not cover the information storage requirements for each individual modality (CT, DR, CR, UT, etc.). Additions to the data dictionary and information modules are required to support the individual modalities. This practice contains the additions to the DICONDE data dictionary and information modules necessary to support the X-ray CT inspection.

4.3 The highest organizational level in the DICONDE information model is the information object definition (IOD). An information object definition is a collection of the information modules necessary to represent a set of test results from a specific modality. This practice contains information object definitions for X-ray CT inspection.

5. Significance and Use

5.1 Personnel that are responsible for the creation, transfer, and storage of X-ray tomographic NDE data will use this standard. This practice defines a set of information modules that along with Practice E2339 and the DICOM standard provide a standard means to organize X-ray tomography test parameters and results. The X-ray CT test results may be displayed and analyzed on any device that conforms to this standard. Personnel wishing to view any tomographic inspection data stored according to Practice E2339 may use this document to help them decode and display the data contained in the DICONDE-compliant inspection record.

6. Information Object Definitions

6.1 *X-ray CT Image IOD Description:*

6.1.1 The X-ray CT Image Information Object Definition specifies an image that has been created by an X-ray CT imaging device for NDE purposes. To avoid duplication of relevant material from the DICOM standard, the IOD definition will follow that for CT Images found in Part 3, Section A.3 of the DICOM standard except as noted below in Table 1. Table 1 is not stand-alone and must be used in conjunction with

Part 3, Section A.3 of the DICOM standard to have a complete definition of the DICONDE CT information object. In addition to the DICONDE information modules specified in Practice E2339 and this standard, the DICONDE CT IOD utilizes additional DICOM standard information modules as noted in Table 1.

6.1.2 This IOD will use the Service-Object Pair (SOP) Classes for the CT IOD as defined in Part 4, Section B.5 of the DICOM standard.

6.2 *X-ray CT Multi-Frame Image IOD Description:*

6.2.1 The X-ray CT Multi-Frame (CT-MF) Image Information Object Definition specifies a multi-frame image that has been created by an X-ray CT imaging device for NDE purposes. To avoid duplication of relevant material from the DICOM standard, the IOD definition will follow that for Enhanced CT Images found in Part 3, Section A.38 of the DICOM standard except as noted below in Table 2. Table 2 is not stand-alone and must be used in conjunction with Part 3, Section A.38 of the DICOM standard to have a complete definition of the DICONDE CT-MF information object.

6.2.2 This IOD will use the Service-Object Pair (SOP) Classes for the Enhanced CT IOD as defined in Part 4, Section B.5 of the DICOM standard.

7. Information Modules

7.1 *NDE CT Image Module:*

7.1.1 Table 3 specifies the Attributes that describe the NDE X-ray CT image module.

7.2 *NDE X-ray CT Detector Module:*

7.2.1 Table 4 specifies the Attributes that describe NDE X-ray CT Detectors.

7.2.1.1 For X-ray CT Detector module, Detector Type (0018,7004) is specified to use the following defined terms:

DIRECT
SCINTILLATOR

7.2.1.2 For X-ray CT Detector module, Detector Configuration (0018,7005) is specified to use the following defined terms:

AREA
LINEAR

7.3 *NDE X-ray CT Calibration Data Module:*

7.3.1 Table 5 specifies the Attributes that describe NDE X-ray CT calibration data.

7.4 *NDE Multi-Frame Functional Group Attributes:*

7.4.1 Table 6 specifies the Attributes that describe the NDE Multi-Frame Functional Group Elements which are described in DICOM 7.4, DICOM, Part 3, Sections C.8.15.3.2-C8.15.3.13.

7.5 Table 7 specifies the attributes that describe the NDE Enhanced Multi-energy CT Acquisition Data Module which is described in DICOM, Part 3, Section C.8.15.4.

7.6 *NDE CT Multi-Frame Image Module:*

7.6.1 Table 8 specifies the attributes that describe the NDE CT Multi-Frame Image Module.

TABLE 1 X-ray CT-Image Information Object Definition

DICOM Module	DICONDE Module	Reference	Usage[A]
Patient	Component	Practice E2339, Section 7	M
Clinical Trial Subject	Not Applicable		
General Study	Component Study	Practice E2339, Section 7	M
Patient Study	Not Applicable		
Clinical Trial Study	Not Applicable		
General Series	Component Series	Practice E2339, Section 7	M
Clinical Trial Series	Not Applicable		
Frame of Reference	Not Applicable		
General Equipment	NDE Equipment	Practice E2339, Section 7	M
General Image			M
General Reference	Not Applicable		
Image Plane			M
Image Pixel			M
Contrast/bolus	Not Applicable		
Device	Not Applicable		
Specimen	Not Applicable		
CT Image	NDE CT Image	7.1	M
	NDE CT Detector	7.2	U
Multi-energy CT Image			C
Overlay Plane	Not Applicable		
VOI LUT	Not Applicable		
SOP Common	Needed for DICOM compatibility	DICOM, Part 3, Section C.12.1	M
Common Instance Reference	Not Applicable		
X-Ray Collimator	X-Ray Collimator	DICOM Part 3, Section C.8.19.6.12	U
X-Ray Filtration	X-Ray Filtration	DICOM Part 3, Section C.8.7.10	U
X-Ray Grid	X-Ray Grid	DICOM Part 3, Section C.8.7.11	U
	NDE Indication	Practice E2339, Section 7	U
	NDE Geometry	Practice E2339, Section 7	U
	NDE Approval	Practice E2339, Section 7	U
	NDE Embedded Custom Dictionary	Practice E2339, Section 7	U
	NDE CT Calibration Data	7.3	U

[A] Definition of usage codes can be found in Part 3, Section A.1.3 of the DICOM standard.

8. Keywords

8.1 CT; computed tomography; database; DICOM; DI-CONDE; digital data storage; digital data transmission; file format; X-ray

TABLE 2 X-ray CT-MF Image Information Object Definition

DICOM Module	DICONDE Module	Reference	Usage[A]
Patient	Component	Practice E2339, Section 7	M
Specimen Identification	Not Applicable		
Clinical Trial Subject	Not Applicable		
General Study	Component Study	Practice E2339, Section 7	M
Patient Study	Not Applicable		
Clinical Trial Study	Not Applicable		
General Series	Component Series	Practice E2339, Section 7	M
CT Series	CT Series	DICOM, Part 3, Section C.8.15.1	M
Clinical Trial Series	Not Applicable		
Frame of Reference	Not Applicable		
Synchronization	Not Applicable		
General Equipment	NDE Equipment	Practice E2339, Section 7	M
Enhanced General Equipment	Enhanced General Equipment	DICOM, Part 3, Section C.7.5.2	M
Image Pixel	Image Pixel	DICOM, Part 3, Section C.7.6.3	M
Multi-frame	Multi-frame	DICOM, Part 3, Section C.7.6.6	M
Frame Pointers	Frame Pointers	DICOM, Part 3, Section C.7.6.9	M
Enhanced Contrast/Bolus	Not Applicable		
Multi-frame Functional Groups	NDE Multi-frame Functional Groups	7.4	M
Cardiac Synchronization	Not Applicable		
Respiratory Synchronization	Not Applicable		
Supplemental Palette Lookup Table	Not Applicable		
Acquisition Context	Needed for DICOM compatibility		M
Device	Not Applicable		
Specimen	Not Applicable		
Enhanced CT Image	NDE CT Multi-Frame Image	7.6	M
Enhanced Multi-Energy CT Acquisition	NDE Enhanced Multi-Energy CT Acquisition	7.5	C – required if Multi-energy CT Acquisition (0018, 9361) is YES.
ICC Profile	Not Applicable		
SOP Common	Needed for DICOM compatibility		M
Common Instance Reference	Not Applicable		
	NDE Indication	Practice E2339, Section 7	U
	NDE Geometry	Practice E2339, Section 7	U
	NDE Approval	Practice E2339, Section 7	U
	NDE Embedded Custom Dictionary	Practice E2339, Section 7	U
	NDE CT Calibration Data	7.3	U
Frame Extraction			C – required if the SOP Instance was created in response to a Frame-Level retrieve request.

[A] Definition of usage codes can be found in Part 3, Section A.1.3 of the DICOM standard.

TABLE 3 NDE CT Image Module Attributes

Attribute Name	Tag	VR	VM	Type[A]	Description
Image Type	(0008,0008)	CS	1-n	1	Image identification characteristics.
Samples Per Pixel	(0028,0002)	US	1	1	Number of samples per pixel (planes) in this image.
Photometric Interpretation	(0028,0004)	CS	1	1	Specifies the intended interpretation of the pixel data.
Bits Allocated	(0028,0100)	US	1	1	Number of bits allocated for each pixel data.
Bits Stored	(0028,0101)	US	1	1	Number of bits stored for each pixel data.
High Bit	(0028,0102)	US	1	1	Most significant bit for pixel data.
Rescale Intercept	(0028,1052)	DS	1	1	The value b in relationship between stored values (SV) and the output units. Output units = m*SV+b
Rescale Slope	(0028,1053)	DS	1	1	m in the equation specified in Rescale Intercept (0028,1052).
Rescale Type	(0028,1054)	LO	1	1	Specifies the output units of Rescale Slope (0028,1053) and Rescale Intercept (0028,1052).
KVP	(0018,0060)	DS	1	2	Peak kilo voltage output of the X-ray generator used.
Acquisition Number	(0020,0012)	IS	1	2	A number identifying the single continuous gathering of data over a period of time which resulted in this image.
Scan Options	(0018,0022)	CS	1-n	3	Parameters of the scanning sequence.
Data Collection Diameter	(0018,0090)	DS	1	3	The diameter in mm of the region over which data were collected.
Reconstruction Diameter	(0018,1100)	DS	1	3	Diameter in mm of the region from within which data were used in creating the reconstruction of the image. Data may exist outside of this portion of the region and portions of the component may exist outside this region.
Distance Source to Detector	(0018,1110)	DS	1	3	Distance in mm from source to detector center.
Distance Source to Component	(0018,1111)	DS	1	3	Distance in mm from source to isocenter (center of field of view).
Gantry/Detector Tilt	(0018,1120)	DS	1	3	Nominal angle of tilt in degrees of the scanning gantry. Not intended for mathematical calculations.
Table Height	(0018,1130)	DS	1	3	The distance in mm of the top of the part positioner table to the center of rotation; below the center is positive.
Rotation Direction	(0018,1140)	DS	1	3	Direction of rotation of the source when relevant, about nearest principal axis of equipment. Enumerated Values: CW = clockwise CC = counterclockwise
Exposure Time	(0018,1150)	DS	1	3	Time of X-ray exposure in msec.
X-ray Tube Current	(0018,1151)	DS	1	3	X-ray Tube Current in mA.
Exposure	(0018,1152)	DS	1	3	The exposure expressed in mA, for example, calculated from Exposure Time and X-ray Tube Current.
Exposure in µAs	(0018,1153)	DS	1	3	The exposure expressed in mµ, for example, calculated from Exposure Time and X-ray Tube Current.
Filter Type	(0018,1160)	DS	1	3	Label for the type of filter inserted into the X-ray beam.
Generator Power	(0018,1170)	DS	1	3	Power in kW to the X-ray generator.
LINAC Energy	(0014,5002)	IS	1	3	The energy produced by the LINAC expressed in KeV.
LINAC Output	(0014,5004)	IS	1	3	The output of the LINAC expressed in total dose (Gys).
Focal Spot	(0018,1190)	DS	1	3	Size of the focal spot in mm. For devices with variable focal spot or multiple focal spots, small dimension followed by large dimension.
Convolution Kernel	(0018,1210)	DS	1	3	A label describing the convolution kernel or algorithm used to reconstruct the data.
X-ray Tube Current in µA	(0018,8151)	DS	1	3	X-ray Tube Current in µA
Revolution Time	(0018,9305)	FD	1	3	The time in seconds of a complete revolution of the source around the gantry orbit or the complete rotation of a component on a turntable.
Single Collimation Width	(0018,9306)	FD	1	3	The width of a single row of acquired data (in mm).
Total Collimation Width	(0018,9307)	FD	1	3	The width of the total collimation (in mm) over the area of active X-ray detection.
Table Speed	(0018,9309)	FD	1	3	The distance in mm that the table moves in one second during the gathering of data.
Table Feed Per Rotation	(0018,9310)	FD	1	3	Motion of the table (in mm) during a complete revolution of the object being inspected.
CT Pitch Factor	(0018,9311)	FD	1	3	Ratio of the Table Feed per Rotation (0018,9310) to the Total Collimation Width (0018,9307).
Exposure Modulation Type	(0018,9323)	CS	1	3	A label describing the type of exposure modulation used for the purpose of limiting the dose. Defined Terms: NONE
Estimated Dose Savings	(0018,9324)	FD	1	3	A percent value of dose saving due to the use of Exposure Modulation Type (0018,9323). A negative percent value of dose saving reflects an increase in exposure. Required if lossy compression has been performed on the image.
Image Quality Indicator Type	(0014,40A0)	LO	1-n	3	Description of the type of Image Quality Indicator used.
Image Quality Indicator Material	(0014,40A1)	LO	1-n	3	Description of the material used to manufacture the Image Quality Indicator.
Image Quality Indicator Size	(0014,40A2)	LO	1-n	3	Designation of the size of the Image Quality Indicator used. A typical size designation is '2–2T' where the first number indicates that the IQI thickness is two percent of the test material thickness and the second number defines the hole diameter as twice the IQI thickness.

[A] Definition of type codes can be found in Part 5, Section 7.4 of the DICOM standard.

TABLE 4 NDE X-ray CT Detector Module Attributes

Attribute Name	Tag	VR	VM	Type[A]	Description
Detector Type	(0018,7004)	CS	1	2	The type of detector used to acquire projection data.
Detector Configuration	(0018,7005)	CS	1	3	The physical configuration of the detector.
Detector Description	(0018,7006)	LT	1	3	Free-text description of the detector.
Detector Mode	(0018,700A)	LT	1	3	Text description of the operating mode of the detector.
Detector ID	(0018,7008)	SH	1	3	The ID or serial number of the detector used to acquire projection data.
Date of Last Detector Calibration	(0018,700C)	DA	1-n	3	Date of the last calibration for the detector.
Time of Last Detector Calibration	(0018,700E)	TM	1-n	3	Time of the last calibration for the equipment used to pulse the transducer.
Detector Active Time	(0018,7014)	DS	1	3	Time in msec that the detector is active during acquisition of this data.
Detector Activation Offset from Exposure	(0018,7016)	DS	1	3	Offset time in msec that the detector becomes active after the X-ray beam is turned on during the acquisition of this data. May be negative.
Detector Binning	(0018,701A)	DS	2	3	Number of active detectors used to generate a single pixel. Specified as the number of row detectors per pixel followed by the number of column detectors.
Internal Detector Frame Time	(0014,3011)	DS	1	3	The time in msec that the detector is acquiring an image.
Number of Frames Integrated	(0014,3012)	DS	1	3	The number of frames to form an image.
Detector Manufacturer's Name	(0018,702A)	LO	1	3	Name of the manufacturer of the detector component of the acquisition system.
Detector Manufacturer's Model Number	(0018,702B)	LO	1	3	Model number of the detector component of the acquisition system.
Detector Conditions Nominal Flag	(0018,7000)	CS	1	3	A flag that indicates whether or not the detector is operating within normal tolerances during data acquisition. This flag is intended to indicate whether there has been some compromise of the diagnostic quality of the data due to some operating condition (for example, overheating).
Sensitivity	(0018,6000)	DS	1	3	Detector sensitivity in manufacturer specific units.[B]
Field of View Shape	(0018,1147)	CS	1	3	Shape of the Field of View, that is, the image pixels.
Field of View Dimension(s)	(0018,1149)	IS	1-2	3	Dimensions in mm of the Field of View.
Field of View Origin	(0018,7030)	DS	2	1C	Required if the Field of View has been rotated. Offset of the Top Left Hand Corner (TLHC) of a rectangle circumscribing the Field of View before rotation or flipping, from the TLHC of the physical detector area measured in physical detector pixels as a row offset followed by a column offset.
Field of View Rotation	(0018,7032)	DS	1	1C	Required if the Field of View has been rotated Clockwise rotation in degrees of the Field of View relative to the physical detector.
Field of View Horizontal Flip	(0018,7034)	CS	1	1C	Required if the Field of View has been rotated Whether or not a horizontal flip has been applied to the Field of View after rotation relative to the physical detector as described in the Field of View Rotation.
Imager Pixel Spacing	(0018,1164)	DS	2	1	Physical distance measured at the front plane of the detector housing between the center of each image pixel specified by a numeric pair – row spacing value followed by a column spacing value in mm.
Detector Element Physical Size	(0018,7020)	DS	2	3	Physical dimensions of each detector element in mm that comprises the detector matrix. Expressed as the row dimension followed by the column dimension.
Detector Element Spacing	(0018,7022)	DS	2	3	Physical distance between the center of each detector element, specified by a numeric pair – row spacing value in mm followed by column spacing value in mm.
Detector Active Shape	(0018,7024)	CS	1	3	Shape of the active area.
Detector Active Dimension(s)	(0018,7026)	DS	1-2	3	Dimension(s) in mm of the active area.
Detector Active Origin	(0018,7028)	DS	2	3	Offset of the TLHC of a rectangle circumscribing the active detector area from the TLHC of a rectangle circumscribing the physical detector area, measures in physical detector pixels as a row offset followed by a column offset.
Detector Temperature Sequence	(0014,3020)	SQ	1	3	Sequence that contains detector temperature information.
> Sensor Name	(0014,3022)	ST	1	3	The name of the sensor.
> Horizontal Offset	(0014,3024)	DS	1	3	The horizontal offset in mm from the left position of the detector.
> Vertical Offset	(0014,3026)	DS	1	3	The horizontal offset in mm from the top position of the detector.
> Temperature	(0014,3028)	DS	1	3	Temperature in Celsius of the sensor.

[A] Definition of type codes can be found in Part 5, Section 7.4 of the DICOM standard.
[B] This value is intended to provide a single location where the manufacturer specific information can be found for annotation on a display or film that has meaning to a knowledgeable observer.

TABLE 5 NDE X-ray CT Calibration Data Module Attributes

Attribute Name	Tag	VR	VM	Type[A]	Description
Dark Current Sequence	(0014,3040)	SQ	1	2	
> Photometric Interpretation	(0028,0103)	US	1	1C	Required if Dark Current sequence is non-zero. Pixel representation.
> Bits allocated	(0028,0100)	US	1	1	Required if Dark Current sequence is non-zero. Number of bits allocated.
> Bits stored	(0028,0101)	US	1	1C	Required if Dark Current sequence is non-zero. Number of bits stored.
> High bit	(0028,0102)	US	1	1C	Required if Dark Current sequence is non-zero. Most significant bit.
> Dark Current counts	(0014,3050)	OW or OB	1	1C	Required if Dark Current sequence is non-zero. A data stream of the pixel samples which comprise the dark current counts.
Gain Correction Reference Sequence	(0014,3060)	SQ	1	2	
> Photometric Interpretation	(0028,0103)	US	1	1C	Pixel representation.
> Bits allocated	(0028,0100))	US	1	1C	Number of bits allocated.
> Bits stored	(0028,0101)	US	1	1C	Number of bits stored.
> High bit	(0028,0102)	US	1	1C	Most significant bit.
> Air counts	(0014,3070)	OW or OB	1	1C	A data stream of the pixel samples which comprise the air counts.
> kV Used in Gain Calibration	(0014,3071)	DS	1	3	Kilovoltage Used in Gain Calibration.
> mA Used in Gain Calibration	(0014,3072)	DS	1	3	mA * Sec Used in Gain Calibration.
> Number of Frame Integrations	(0014,3073)	DS	1	3	Number of Frames Used for Integration.
> Filter Material Used in Gain Calibration	(0014,3074)	LO	1	3	Filter Material Used in Gain Calibration.
> Filter Thickness Used in Gain Calibration	(0014,3075)	DS	1	3	Filter Material Used in Gain Calibration.
> Date of Gain Calibration	(0014,3076)	DA	1	3	Date of Gain Calibration.
> Time of Gain Calibration	(0014,3077)	TM	1	3	Time of Gain Calibration.
Bad Pixel Image	(0014,3080)	OB	1	3	Byte image with the same number of rows and columns as the Pixel Data (7FE0,0010). The pixel data of this image will contain a ″1″ for a good pixel and a ″0″ for a bad pixel.
Calibration notes	(0014,3099)	LT	1	3	User-generated notes on the calibration data.

[A] Definition of type codes can be found in Part 5, Section 7.4 of the DICOM standard.