Automated Practical System Qualification, Validation and Reporting acc. ASTM E2737-10

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Abstract. Today for many users digital X-ray inspection is the method of choice. In order to ensure a constant quality of inspection the ASTM E2737-10 Practice for Digital Detector Array Performance Evaluation and Long-Term Stability has been published in October 2010. It is "intended to be used by the NDT using organization to measure the baseline performance of the DDA and to monitor its performance throughout its service as an NDT imaging system." Since this standard requires extensive support of imaging software functionalities, the paper describes how inspection systems using the best available technology could help an NDT organization to fulfill it.

Terms such as "lag", "burn-in", and "bad pixel" will probably not be familiar to each NDT inspector currently using film for his applications – and even if the terms are understood, the detection of cluster kernel pixels, combined with the correct calculation and determination of image quality parameters like SNR or CNR, are not practical without adequate software tools. To make it as easy as possible for an NDT inspector to qualify and frequently validate the long-term stability of a digital X-ray system, the software must provide more than just the specialized imaging tools - it should at least provide a fully automated sequence to qualify and periodically validate that the DDA performance is in full compliance with ASTM E2737-10. Furthermore it should automatically create system reports as described in the aforementioned standard – at a minimum with a screenshot, or preferably as a PDF.

The ability to conveniently fulfill the ASTM E2737-10 standard and especially being able to take advantage of the qualification and reporting tools, may help reducing one of the most significant barriers for the NDT inspector that is shifting from film to digital technology: "How can I easily and reliably ensure that the system is performing to specification during each inspection shift?". An example video will show how a fully automatic system qualification, validation, and report generation may look on a typical inspection system.

1. Introduction

Besides the earlier published ASTM E2597 - 07e1 „Standard Practice for Manufacturing Characterization of Digital Detector Arrays", which is mainly addressed to manufacturers and integrators of digital detector arrays, the

- ASTM E2698 - 10 „Standard Practice for Radiological Examination Using Digital Detector Arrays"
- ASTM E2736 - 10 „Standard Guide for Digital Detector Array Radiology"
- ASTM E2737 - 10 „Standard Practice for Digital Detector Array Performance Evaluation and Long-Term Stability"

all of them published in 2010, may be relevant standards for NDT using organizations. This paper describes basics of E2737-10 and especially the automated practical system qualification, validation, and reporting.

1.1 Intention of the ASTM E2737-10

To avoid misunderstandings it is first important to know what the intention of E2737 is: E2737 is not a general DDA acceptance test and it is not a general DDA selection advisor.
Its intention is „to be used by the NDT using organization to measure the baseline performance of the DDA and to monitor its performance throughout its service as an NDT imaging system. Though, it supports NDT using organizations to improve their inspection reliability and to support simplifying their quality audits."

1.2 Parameters representing the performance of an NDT imaging system

To evaluate the performance of an NDT imaging system independently of specific inspection items a set of parameters was defined. In general, these parameters can be distinguished in

- „Core image Quality" parameters like spatial resolution, contrast sensitivity, signal-to-noise ratio (SNR) the signal level and the bad pixel distribution. These parameters resp. the ones being a result of further calculation like the contrast-to-noise ratio (CNR) are an indication for the principle defect visibility.
- Inspection part specific: the material thickness range
- Detector specific parameters, like image lag – visible as ghost images –burn-in and degradation. The degradation due to X-ray radiation is indicated by an increase of the offset level of the pixel or by artefacts in the image.

1.3 Defined phantoms to consider application-specific material and its thickness range

Since the performance of an NDT imaging system depends extremely of the wall thickness range within one image,
ASTM E2737-10 describes two different methods to consider it.

1) The 5-groove continuous wedge is being used to quantify the imaging systems' performance. It is defined for light metal or also for heavy metal. To measure the material thickness range various grooves in different shapes and dimensions have to be inserted, which makes the production quite complex. This phantom allows a performance measurement of its material thickness range and thus an indication for the maximum material range of the imaging system.

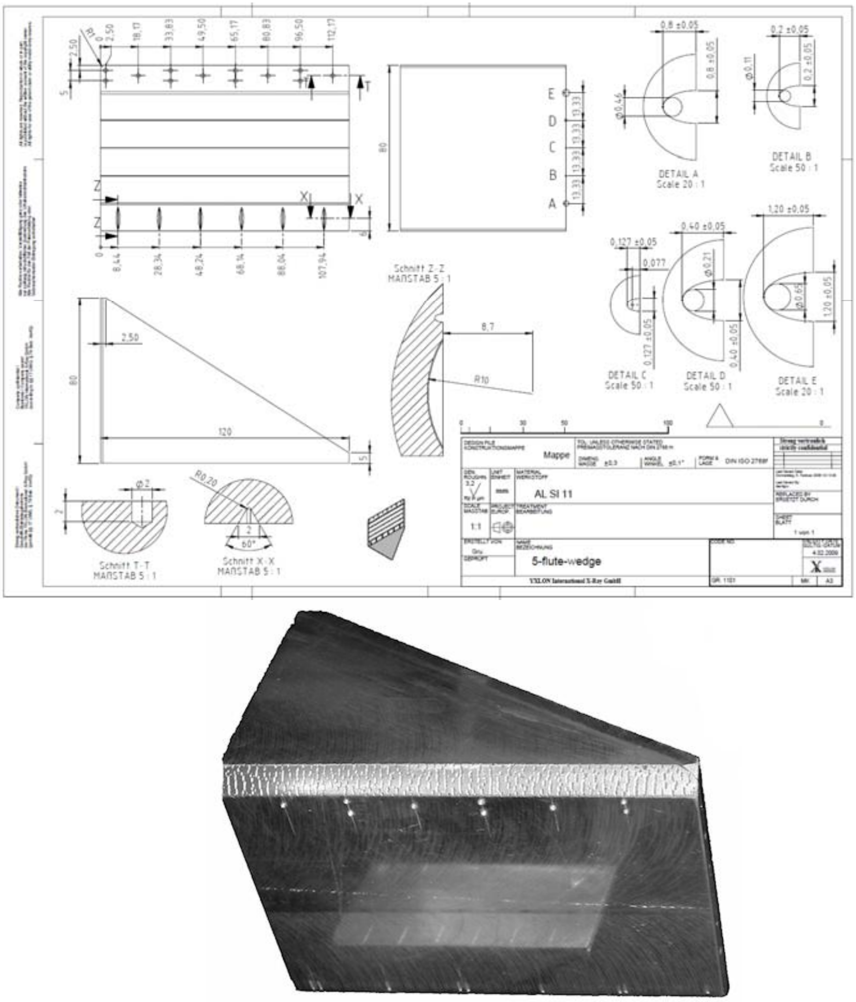


Fig. 1) five groove wedge – CAD drawing and photo (with inner longitudinal holes instead of grooves)

2) The more practical duplex wedge phantom represents with its two plates the thinnest and the thickest wall thickness of the inspection part. It has to be of the same material as the inspection part. Parameters indicating the core image quality are measured with IQI acc. to E1025 resp. E1742 as well as spatial resolution with an ASTM E2002 (resp. EN 462-5) Platinum duplex wire IQI.

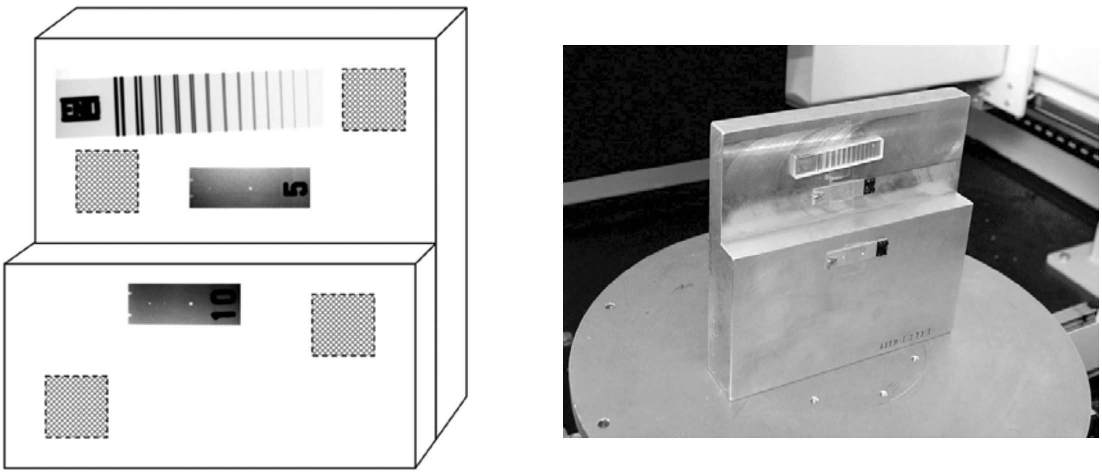


Fig. 2) simple duplex plate phantom, schematic drawing and placed in a typical inspection system with the geometric magnification used in production. For an automated test procedure a duplex wedge specific holder is recommended.

2. General test methods

Since image performance depends on X-Ray tube voltage, tube current, focus detector distance, focus object distance, detector calibration and settings as well the image acquisition and processing software itself, the parameters mentioned above have to be measured and checked for each variation of one of them. If tube energy varies while the inspection, only the highest energy should be used for the settings mentioned above.

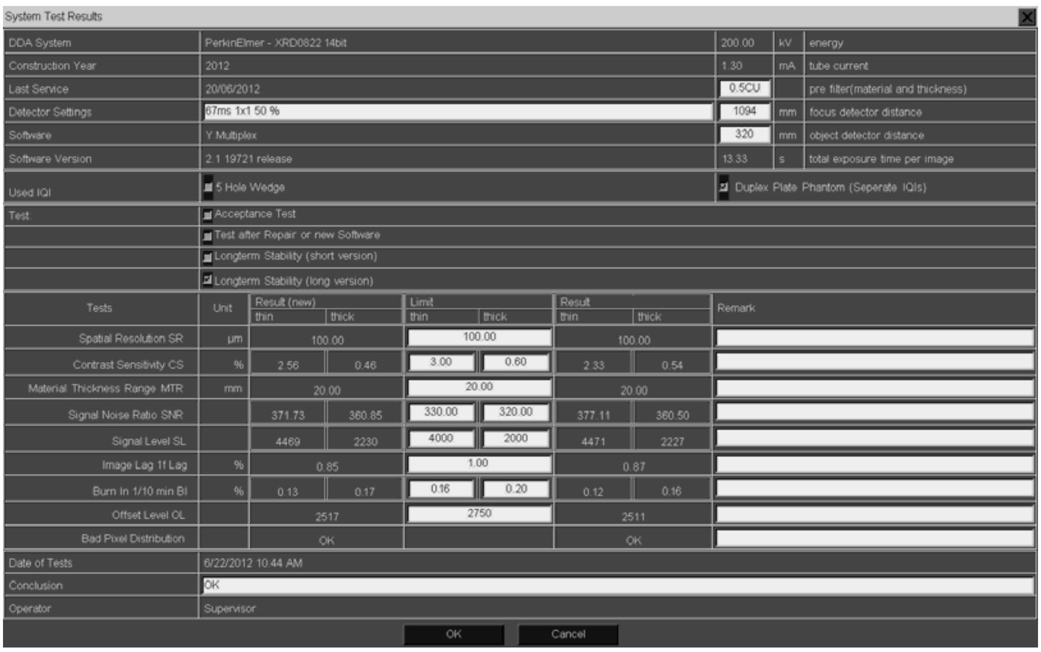
The E2737 distinguishes between an initial „system performance test", which has to be done once to get the 100% performance parameter as reference when the system goes into production, and a periodically done „process check" to measure the degradation of the system during production. All measured parameters plus some more – describing the inspection system, the software release, detector settings etc. – have to be listed in a defined form for further reporting. After the initial system performance test the limits have to be defined by the cognizant engineering organization. Since the acceptable limits for the system performance parameters depends on the application, the E2737-10 itself does not define them. The following matrix illustrates, in which cases all parameters or just a subset of them has to be measured.

Parameters	System performance Test				Process Check	
	Base Line	Software Update	Tube Change	Detector Change/Repair	Short	Long
Spatial Resolution	X		X	X	X	X
Contrast Sensitivity	X	X	X	X	X	X
Material Thickness Range	X	X	X	X	X	X
Signal to Noise Ratio SNR	X	X	X	X	X	X
Signal Level	X	X		X	X	X
*) Image Lag	X			X		X
*) Burn In	X			X		X
*) Offset Level	X	X	X	X		X
Bad Pixel Distribution	X	X	X	X	X	X

*) E2737 defines specific timings for measurement of these parameters

Fig. 3) Matrix of basic parameters, various cases and the proposal to measure them

3. Requirements for the software for automation



System Test Results

DDA System	PerkinElmer - XRD0822 14bit	200.00	kV	energy
Construction Year	2012	1.30	mA	tube current
Last Service	20/06/2012	0.5CU		pre filter(material and thickness)
Detector Settings	67ms 1x1 50 %	1094	mm	focus detector distance
Software	Y Multiplex	320	mm	object detector distance
Software Version	2.1 19721 release	13.33	s	total exposure time per image

Used IQI: 5 Hole Wedge; ☑ Duplex Plate Phantom (Seperate IQIs)

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

Tests	Unit	Result (new) thin	Result (new) thick	Limit thin	Limit thick	Result thin	Result thick	Remark
Spatial Resolution SR	µm	100.00		100.00		100.00		
Contrast Sensitivity CS	%	2.56	0.46	3.00	0.60	2.33	0.54	
Material Thickness Range MTR	mm	20.00		20.00		20.00		
Signal Noise Ratio SNR		371.73	360.85	330.00	320.00	377.11	360.50	
Signal Level SL		4469	2230	4000	2000	4471	2227	
Image Lag 1f Lag	%	0.85		1.00		0.87		
Burn In 1/10 min BI	%	0.13	0.17	0.16	0.20	0.12	0.16	
Offset Level OL		2517		2750		2511		
Bad Pixel Distribution		OK				OK		

Date of Tests: 6/22/2012 10:44 AM

Conclusion: OK

Operator: Supervisor

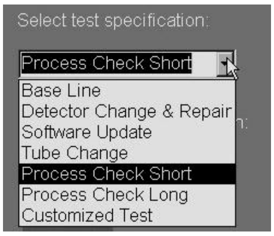
OK Cancel

Fig. 4) Software test report form as described in E2737 after long version of process check. Results and limits listed in the figure above only for illustration purposes.

For the NDT organizations convenience, these forms should be stored automatically as a screenshot or as a PDF. Since the test(s) shall be completed under similar conditions as in production and variation of e.g. mA, FDD, FOD etc. will be typical during inspection of real inspection parts the software should be able to store numerous settings to consider various inspection conditions.

Besides being able to measure the required parameters themselves, the software has to list them automatically in the forms defined in the E2737 and enables the responsible engineering organization entering their limits:

Furthermore it has to allow a selection of the measured parameters, at least acc. to the table in fig. 3).



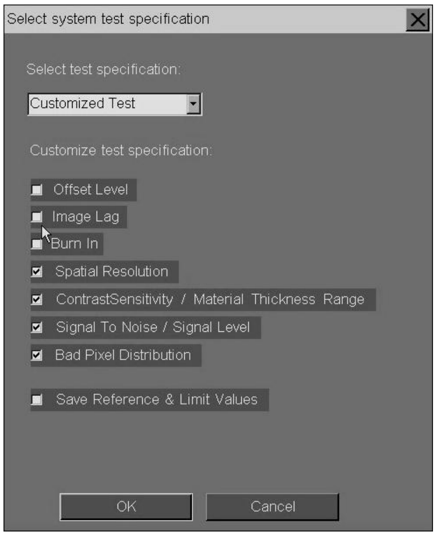


Fig. 5) Selection of the test case resp. defining a customized test

A customized set of performance analysis will allow the NDT organization to evaluate critical parameters several times during the inspection shift Thus, a re-inspection without spending too much time for a complete process check can be avoided.

If various phantoms are needed due to different applications and/or it is not possible to place phantoms in the inspection system permanently, accurate „phantom holders" are recommended. In addition due to these positioning tolerances, the ones of an automatic NC positioning have to be added. Especially while measuring the contrast sensitivity using a duplex phantom and its E1025 / E1742 IQIs, these tolerances may cause, that the 1T or 2T hole cannot be recognized. The latter will be avoided, if the software performs shape recognition or an image registration.

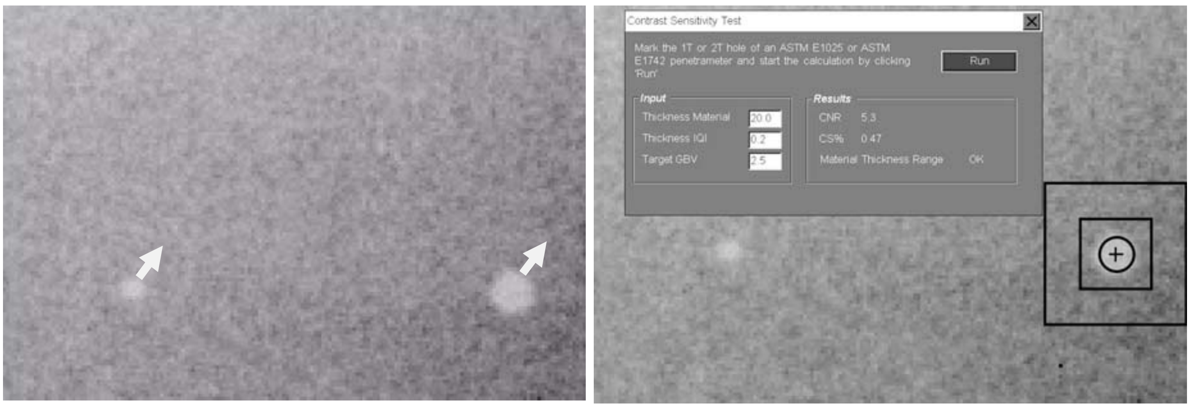


Fig. 6) The left image of E1025 / E1742 IQI (acquired while system performance test or process check) will be transformed laterally to fit in the „contrast sensitivity processing mask" as stored in the test set up procedure.

To increase reproducibility of all of these tests and process checks, it is an advantage if the software performs a shape recognition / image registration for all tests.

Some parameters require a defined sequence of actions before they are measured. In the perfect world the software provides a clear feedback, if all required actions are processed accurately. Otherwise a warning message should appear.

Since some measurements take several seconds to minutes, progress bars should give feedback about the current status.

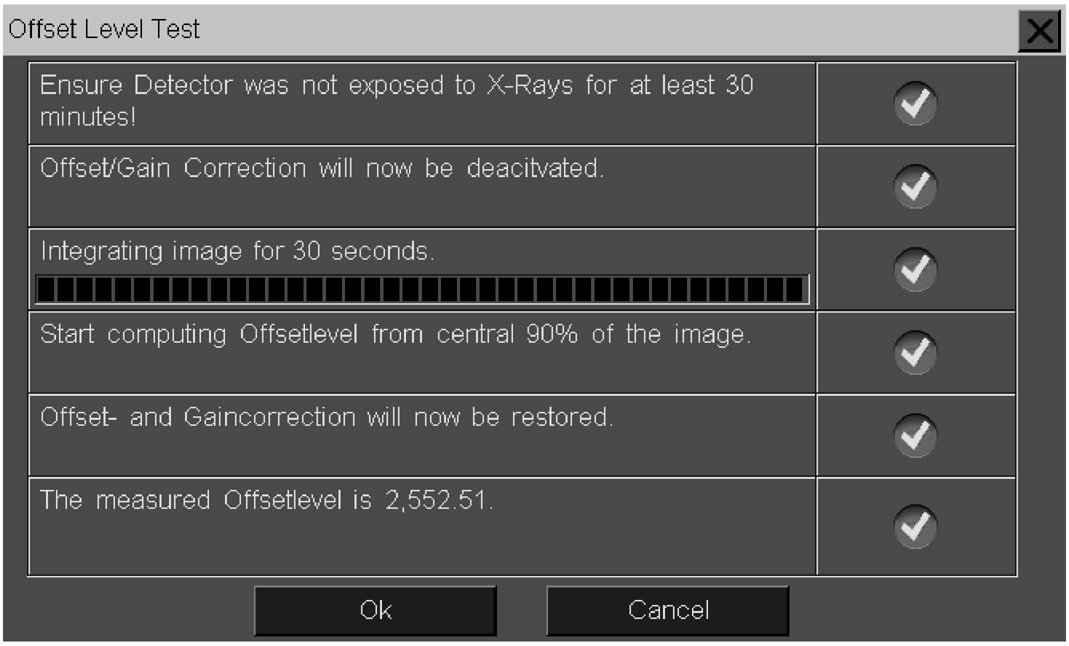


Fig. 8) Screenshot of offset-level test dialog

4. Conclusion

The majority of inspectors changing from film to digital may have been waiting for a standard which helps them to ensure and to record their DR system performance. With the ASTM E2737-10 a standard is available, but its approach requires specific support of software, especially for automation. Therefore suppliers of DR systems shall provide convenient and reliable solutions to enable NDT organizations to do the tests.

MAI (Metals Affordability Initiative), Nadcap (National Aerospace and Defense Contractors Accreditation Program) drafts, and various company specific specifications do refer to E2737. For NDT organizations moving from film to DR technology it may be wise to consult ASTM E2636 and consider E2737 functionalities in the software before they purchase NDT equipment.