Radiography in the Digital Age

Successful transition from film to CR

Sam Tucker
NDT Process Engineering
SFOEP

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A STAR ALLIANCE MEMBER

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Overview

Going digital- a roadmap to the process and progress

Business analysis and justification

Is there opportunity for rapid recovery of investment (ROI)? Typical capital improvements require one year maximum.

Answer- probably not. But there's more to it…

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Digital- what's the difference?

Key difference- film uses a silver emulsion process. Film can only be used once.

Film processors require running water, toxic chemicals and frequent cleaning. All drain water and flushing of chemical waste at SFO must be captured per the Bay Water Quality Control Board.

Computed radiography uses a flexible image plate. Plate is similar in form to film, but uses phosphor to capture latent image. It can be used repeatedly, up to 1000 times or more. Processing is via a digital scanner- no chemicals needed. Stored images only require drive space.

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The need to transition

- Digital systems are a large capital expense- over $100k
- The driving motivations in our case were the increasing costs and environmental liabilities being incurred in operating the film processor. The result was an overriding factor in favor of digital, making the initiative viable despite negligible short term ROI.

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The next step

Once management had indicated the push to go ahead for the project, we had to prove to ourselves that the idea of replacing film with digital imaging was viable.

Key Point:

The question must be answered- is the quality of a digital radiograph equivalent to the results we get with film?

Can we justify the equivalency when applying it to existing film based procedures and work documents?

Will we be able to completely replace film with IP's?

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Finding a system

The number of available system manufacturers is limited (Fuji, Carestream, GE, VMI)

Typically a demo is a sales pitch; the vendor is not necessarily tuned in to the unique and specific needs of a commercial air carrier and/or a repair station, as well as existing OEM maintenance specifics.

Plan ahead for the demo. Be aware of available resources- specifically, ASTM2446 and E2007

Designation: E2446 – 05 (Reapproved 2010)

Standard Practice for Classification of Computed Radiology Systems[1]

This standard is issued under the fixed designation E2446; 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 and classification of a computed radiography (CR) system, a particular phosphor imaging plate (IP), system scanner and software, in combination with specified metal screens for industrial radiography. It is intended to ensure that the evaluation of image quality, as far as this is influenced by the scanner/IP system, meets the needs of users.

1.2 The practice defines system tests to be used to classify the systems of different suppliers and make them comparable for users.

1.3 The CR system performance is described by signal and noise parameters. For film systems, the signal is represented by gradient and the noise by granularity. The signal-to-noise ratio is normalized by the basic spatial resolution of the system and is part of classification. The normalization is given by the scanning aperture of 100 µm diameter for the microphotometer, which is defined in Test Method E1815 for film system classification. This practice describes how the parameters shall be measured for CR systems.

1.4 The values stated in SI are to be regarded as the 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 and health practices and to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E1316 Terminology for Nondestructive Examinations
E1815 Test Method for Classification of Film Systems for Industrial Radiography
E2002 Practice for Determining Total Image Unsharpness in Radiology
E2007 Guide for Computed Radiography
E2033 Practice for Computed Radiology (Photostimulable Luminescence Method)
E2445 Practice for Qualification and Long-Term Stability of Computed Radiology Systems

3. Terminology

3.1 *Definitions*—The definition of terms relating to gamma- and X-radiology, which appear in Terminology E1316, Guide E2007, and Practice E2033, shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *computed radiology system (CR system)*—A complete system of a storage phosphor imaging plate (IP), a corresponding read out unit (scanner or reader) and software, which converts the information of the IP into a digital image (see also Guide E2007).

3.2.2 *computed radiology system class*—A particular group of storage phosphor imaging plate systems, which is characterized by a SNR (signal-to-noise ratio) range shown in Table 1 and by a certain unsharpness range in a specified exposure range.

3.2.3 *ISO speed* S_{IPx}—Defines the speed of a CR system and is calculated from the reciprocal dose value, measured in gray, which is necessary to obtain a specified minimum SNR of a CR system.

3.2.4 *signal-to-noise ratio (SNR)*—Quotient of mean value of the linearized signal intensity and standard deviation of the noise (intensity distribution) at this signal intensity. The SNR depends on the radiation dose and the CR system properties.

3.2.5 *modulation transfer function (MTF)*—The normalized magnitude of the Fourier-transform (FT) of the differentiated edge spread function (ESF) of the linearized PSL (photo stimulated luminescence) intensity, measured perpendicular to a sharp edge. MTF describes the contrast transmission as a function of the object size. In this practice, the MTF characterizes the unsharpness of the CR system. This depends on the scanning system itself and IP-type and cassette employed.

3.2.6 *gain/amplification*—Opto-electrical gain setting of the scanning system.

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[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] 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.

ASTM INTERNATIONAL

Designation: E2007 – 10

Standard Guide for Computed Radiography[1]

This standard is issued under the fixed designation E2007; 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 guide provides general tutorial information regarding the fundamental and physical principles of computed radiography (CR), definitions and terminology required to understand the basic CR process. An introduction to some of the limitations that are typically encountered during the establishment of techniques and basic image processing methods are also provided. This guide does not provide specific techniques or acceptance criteria for specific end-user inspection applications. Information presented within this guide may be useful in conjunction with those standards of 1.2.

1.2 CR techniques for general inspection applications may be found in Practice E2033. Technical qualification attributes for CR systems may be found in Practice E2445. Criteria for classification of CR system technical performance levels may be found in Practice E2446. Reference Images Standards E2422, E2660, and E2669 contain digital reference acceptance illustrations.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.4 *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

E746 Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems

E747 Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology

E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology

E1316 Terminology for Nondestructive Examinations

E1453 Guide for Storage of Magnetic Tape Media that Contains Analog or Digital Radioscopic Data

E2002 Practice for Determining Total Image Unsharpness in Radiology

E2033 Practice for Computed Radiology (Photostimulable Luminescence Method)

E2339 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)

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

E2660 Digital Reference Images for Investment Steel Castings for Aerospace Applications

E2669 Digital Reference Images for Titanium Castings

2.2 *SMPTE Standard:*

RP-133 Specifications for Medical Diagnostic Imaging Test Pattern for Television Monitors and Hard-Copy Recording Cameras[3]

3. Terminology

3.1 Unless otherwise provided within this guide, terminology is in accordance with Terminology E1316.

3.2 *Definitions:*

3.2.1 *aliasing*—artifacts that appear in an image when the spatial frequency of the input is higher than the output is capable of reproducing. This will often appear as jagged or stepped sections in a line or as moiré patterns.

3.2.2 *basic spatial resolution* (SR_b)—terminology used to describe the smallest degree of visible detail within a digital image that is considered the effective pixel size.

[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.

Current edition approved June 1, 2010. Published July 2010. Originally approved in 1999. Last previous edition approved in 2008 as E2007 - 08. DOI: 10.1520/E2007-10.

[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] Available from Society of Motion Picture and Television Engineers (SMPTE), 3 Barker Ave, 5th Floor, White Plains, NY 10601.

Evaluating systems

Digital systems have unique methods for image quality assessment as compared to film, making it difficult to make a direct comparison of the two.

Digital images have a much wider latitude compared to film.

Of greater importance when evaluating are the quality factors for comparing digital systems to each other and not necessarily to film.

New terminology comes into play-

- Signal-to-noise ratio
- Spatial resolution
- Geometrical unsharpness
- Pixel values, gray scale, bit depth
- ISO speed

Cost factors the CR sales rep may not tell you about:

- Necessary process controls will require additional tooling not included in the quote.

  Examples: CR Phantom, EPS plates, display monitor evaluation sensor, duplex wire gauges.
- You will need a variety of image plates based on the techniques you currently use plus future expectations
- Your training and qualification program will need to be reviewed and possibly amended
- In-house trimming of IP's quite possibly will affect their life expectancy
- IP's are available in extended lengths and various sizes, with a cost!
- Higher resolution (25 micron) can be had for a cost if needed, via software upgrade

The big hurdles- getting the funding and implementing the program

- Once you've decided that you can make CR work, have chosen a system and have a reasonable quote to work with, then it's a matter of getting the funds allocated
- There must be an understanding by upper management that the transition from film to CR will not be immediate once the system is in place. Approval basis for each exposure will be on a case by case basis (in our case, by Level III) and will take time.
- Set a goal and expect to allow at least a year for the transition before you can plan to shut down the dark room

Now comes the real work!

- ATA105 does not currently address CR for training and qualification
- Boeing and Airbus do not address CR as an equivalency in their NDT Manuals
- AD compliance must be addressed where applicable
- Fortunately, we have a good statement in the Pratt &Whitney Standard Practices Manual:

> "Filmless electronic imaging X−ray may be used to satisfy requirements, if specific non−film methods are correlated with film techniques. Records that verify this correlation must be established and available for review"

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Training and qualification

- Following NAS410 and TC-1A as templates, formal training and experience will be required to transition from film to CR
- Formal training must be developed or outsourced. Difficult to develop without the necessary experience and expertise!
- X-R-I is a valuable resource for training- www.xritesting.com

- ATA105 revision proposed for addressing how to transition, based on NAS410.

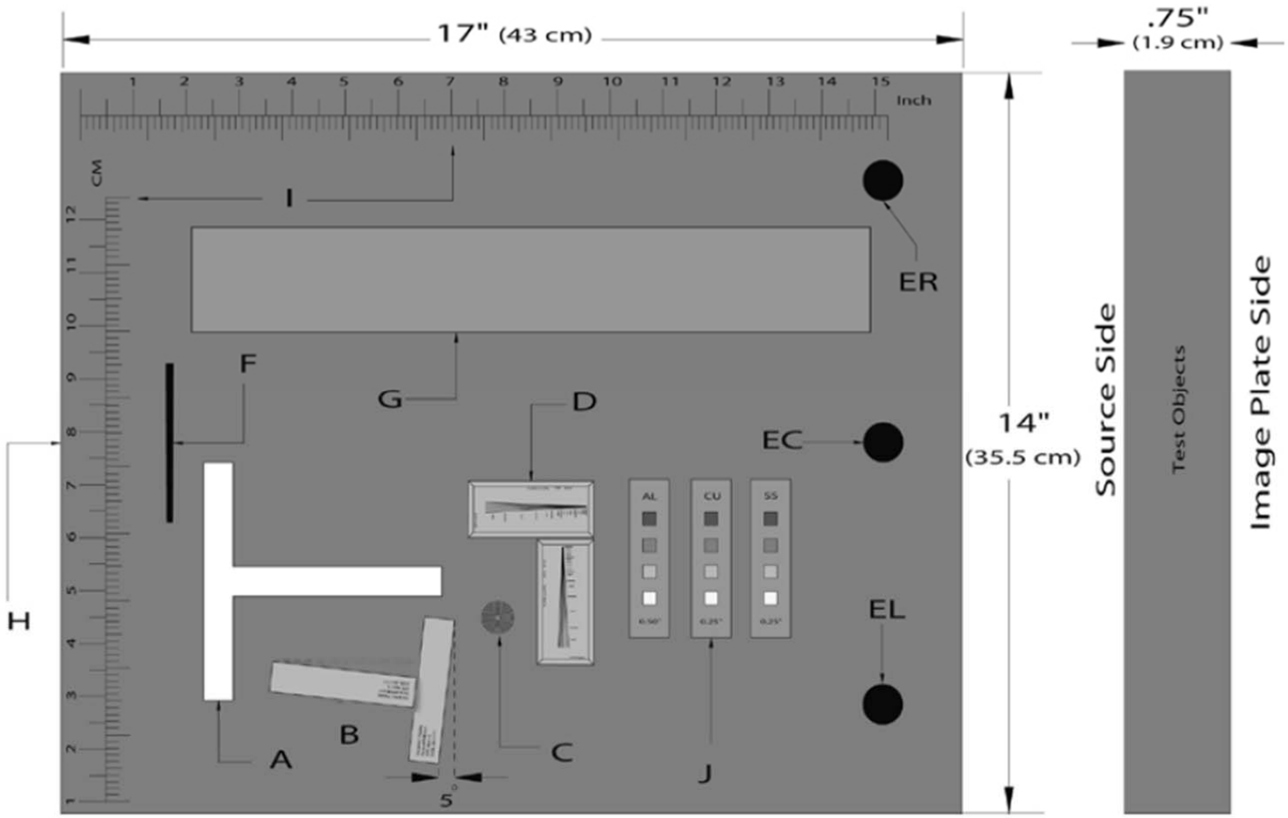
Process Controls

Best resources:

- ASTM2445 Standard Practice for Qualification and Long-Term Stability of Computed Radiology Systems
- FWGIDR Guide for the Qualification of Digital Radiography Systems and Processes
- T.O. 33B-1-2 Technical Procedures- Computed Radiography Process Control

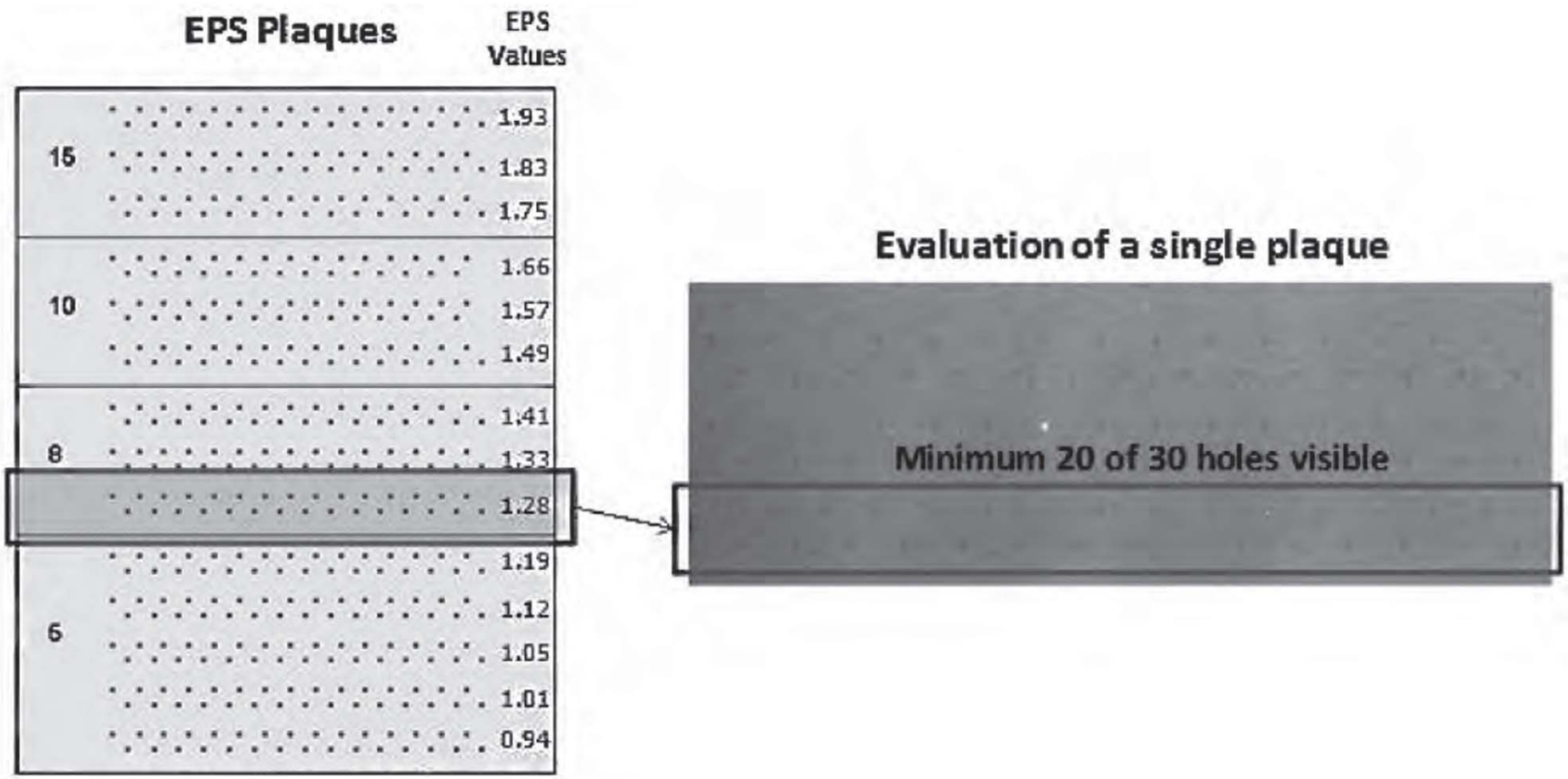
Ultimately it will be up to your Level III to establish the criteria and write the process control document. You may need additional instructions if your system is capable of producing energies greater than 320kV

Process Controls



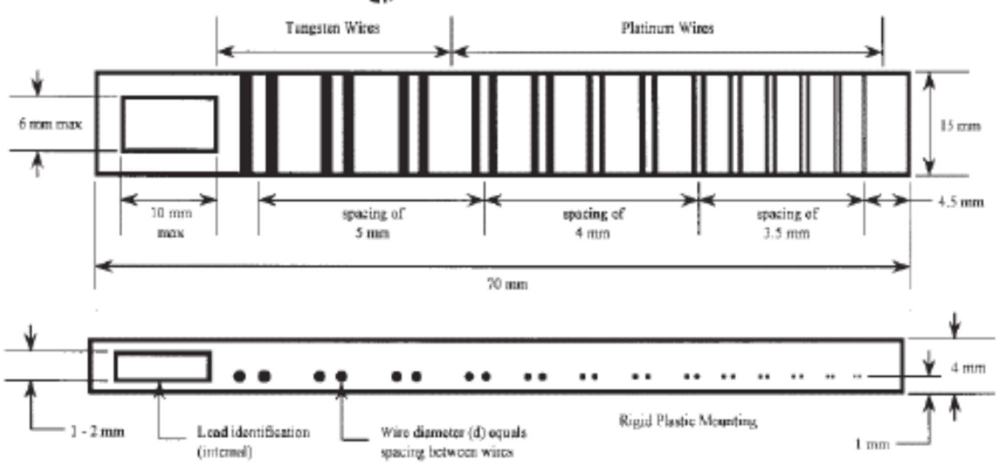
A: T-target for Laser Jitter Test Length 114 by 5 mm H (4.48 by 0.2 in.), Brass
B: Duplex-Wire Image Quality Indicator; in accordance with Practice E2002
C: Central Beam Alignment (BAM-snail)
D: Converging Line Pair Quality Indicators
E: EL, EC, ER: Measuring Points for Shading Correction 19 mm (0.75 in.) Diameter, 0.3 mm (0.1 in.) Acrylic Removed
F: Cassette Positioning Locator (does not appear on radiographic image)
G: Homogeneous Strip: Al, 0.5 mm (0.02 in.)
H: Lucite Plate
I: Inch/cm Ruler for Linearity Check
J: Contrast Sensitivity Quality Indicators
Aluminum: 12.7 mm (0.50 in.)
Copper: 6.35 mm (0.25 in.)
Stainless Steel: 6.35 mm (0.25 in.)

Process Controls

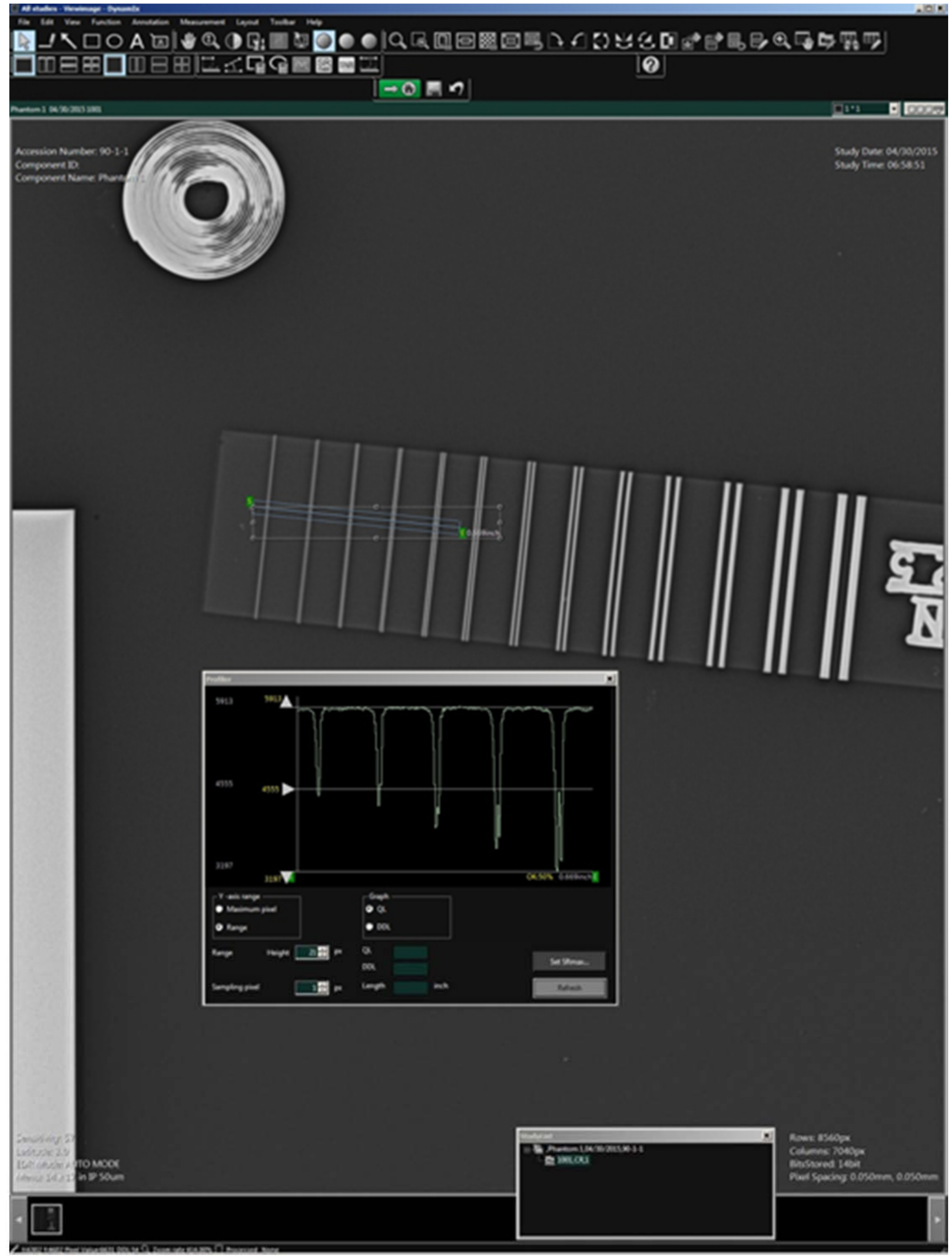


Process Controls

E 2002 – 98 (2003)$^{\epsilon 1}$



Element No D: =Duplex	Corresponding Unsharpness	Wire diameter And spacing, mm
13D	0.10	0.050
12D	0.13	0.063
11D	0.16	0.080
10D	0.20	0.100
9D	0.26	0.130
8D	0.32	0.160
7D	0.40	0.200
6D	0.50	0.250
5D	0.64	0.320
4D	0.80	0.400
3D	1.00	0.500
2D	1.26	0.630
1D	1.60	0.800



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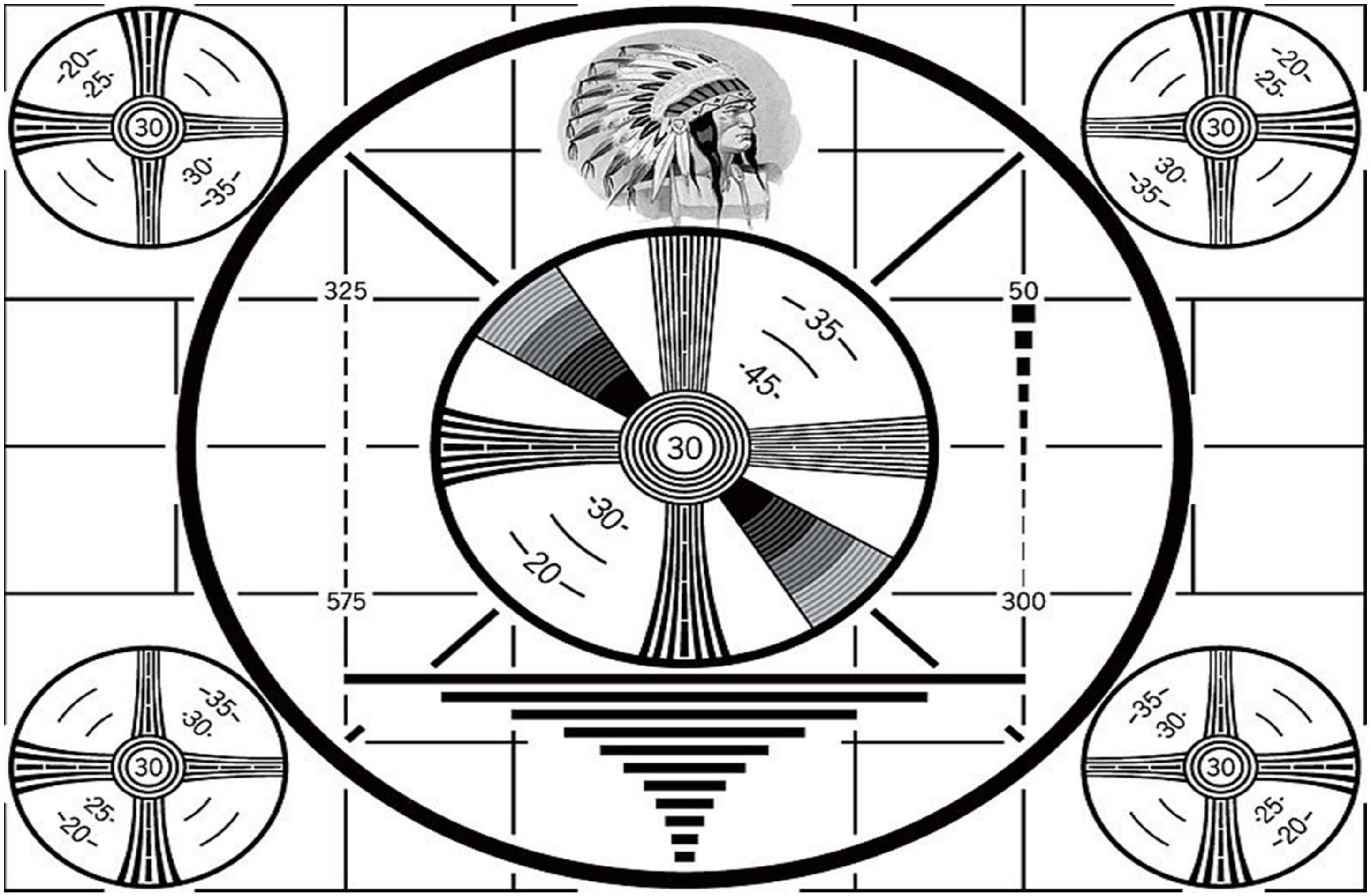
Additional Process Controls



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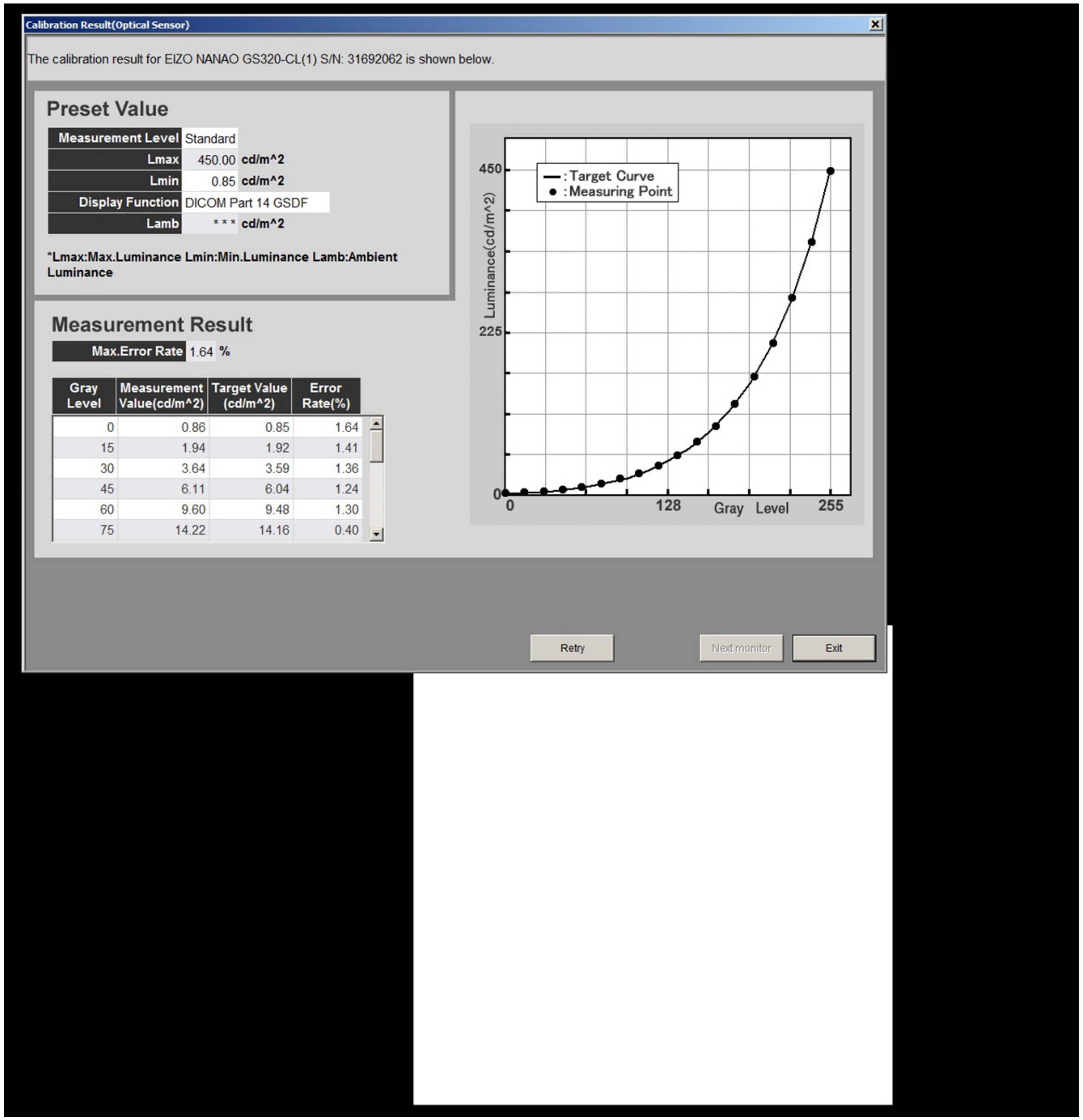
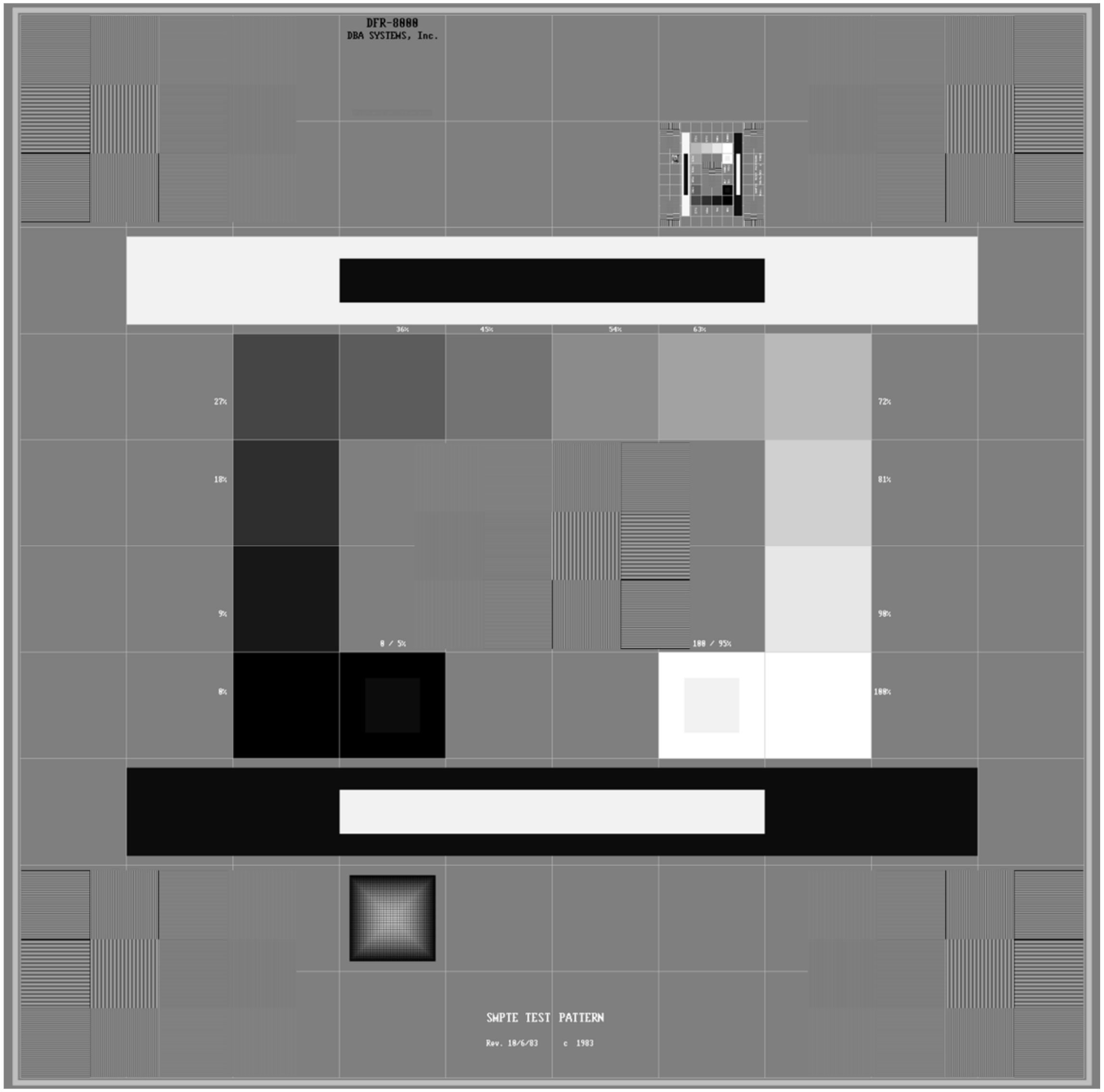
Additional Process Controls

- What about the display?
- Air Force T.O. checks SMPTE only
- ASTM E2446 does not have display checks
- 14 bit means 16,384 shades of gray. Human eye can detect about 900.
- Industrial Displays are medical grade.
- Better to check gray scale through its range than just brightness
- Software solution and optical sensor- a good solution

Additional Process Controls



Additional Process Controls



What now?

- Pending requests to Boeing, Airbus
- Evaluation of current procedures to determine AMOC requirements, if any
- Establish parameters and build database of technique sheets cross referenced to film exposures

Conclusion

- CR is a viable equivalency for film radiography
- Because it is still an emerging technology, OEM's have some catching up to do
- Be aware of the differences; the end results are equivalent but the two media types are apples and oranges!

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Questions?

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