CarestreamNDT

WHITE PAPER

How to Build Your Own Use Case for a Conformable DR Detector

Part III "The What's":

A Comparison of Conformable Digital Detector Arrays to Film and CR Imaging Plates.

INTRODUCTION

At Carestream NDT we want to share not only our technological developments and product portfolio, but also the knowledge and practical experience that our staff obtains by working shoulder-to-shoulder with customers like you. We aim to share this knowledge and experience in a straightforward fashion so that our readers may find practical applications in their everyday activities.

This series is directed but not limited to NDE professionals in the following industries: Oil & Gas, Nuclear, Construction, Foundry and Castings, Energy Generation, Aerospace, Transportation, Automotive, Military and Defense, Agriculture, Art Restoration & Museum Artifacts, and NDE Services Companies.

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Introduction – On Structured Innovation.

The pace for technological innovations on NDE imaging technologies is influenced not only by the industries where these innovations are deployed but also by how each organization aims to expand, enrich and reinforce at its own pace its imaging capabilities.

As we discussed in the first white paper in this series, technological advancements in imaging media, hardware, and software create a positive syngenetic effect on the rest of the constituents of an organization's imaging ecosystem, reflecting its technology management competencies.

A recent article written by Fernandez and Singh [1] on Structured Innovation provides interesting insights into how innovation can be nurtured and guided: "Innovation in nondestructive evaluation (NDE) is an increasingly important contributor to the safety assurance of high-value assets and operationally critical systems. It enables asset integrity for owner operators and enhances their ability to adapt in a changing world. Novel and innovative ideas give rise to better ways of inspecting, as well as new solutions for reducing costs, generating valuable data, and improving long-term sustainability. However, innovation is not just having a few bright ideas. It is about creating value and helping organizations continuously adapt and evolve. It is closely linked to the resilience of an organization, in that it helps them to understand and respond to challenging contexts, seize the opportunities that that might bring, and leverage the creativity of both its own people and those it deals with."

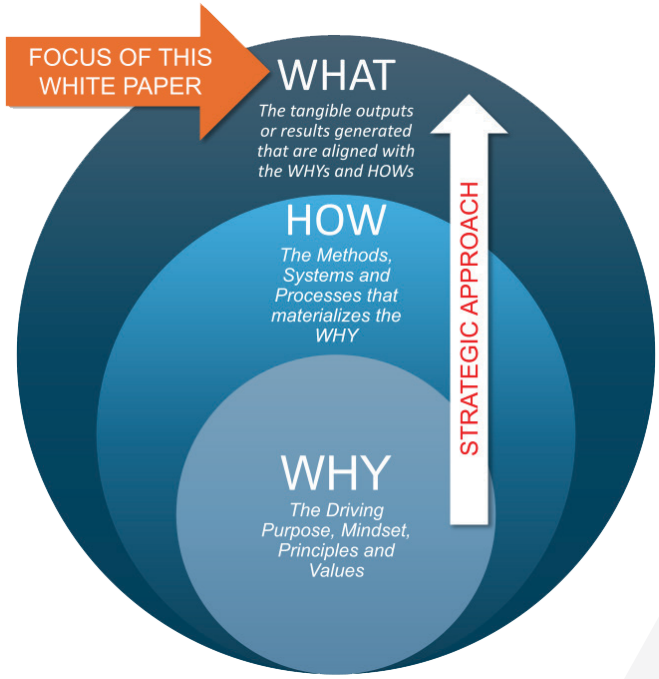

Figure 1: A strategic approach to guide situational analysis, adapted from Simon Sinek's Golden Circle [2]

How a Conformable Digital Radiography Detector is aligned with the Notion of Structured Innovation.

The availability of a conformable digital radiography (DR) detector paired with tailor-made hardware and software support systems out of the shelves constitutes a milestone in digital radiography technology intended to have a substantial positive impact in your productivity, in generating operational savings, in the health and safety conditions in the workspace and in the environmental impact of your imaging processes **(See Table 1).**

Why would you use conformable DR versus film or CR?			
Productivity	**Operational Savings**	**Health and Safety**	**Environmental Impact**
• Instant Images (no processing time associated with film development or IPs Scanning) • Labor flexibility (complete twice as much work in the same time lapse) • Reduce work burden associated with retakes	• Consumables (including films and chemicals or imaging plates) • Inventory carryings costs • Chemical wastes disposal costs • Film scanning and archiving • Isotope replacement costs	• Smaller exclusion zones are possible • Reduce radiographer's fatigue (associated with running films and imaging plates)	• Eliminate impacts associated with chemicals production, distribution and waste disposal. • Eliminate water consumption impact associated with film processing

Table 1: A checklist of key advantage obtained by integrating a conformable DR detector into your imaging process

All the benefits of these Instant Images translate into a transformed imaging workflow that is also respectful of your current imaging skills obtained through the continuous use of film or CR imaging plates and is aligned with our aim to create substantial value for our customers and help them to continually adapt and evolve.

But, what about image quality? At Carestream, we conducted a series of tests where we compared the radiographic image quality of conformable DR detectors to the current two-dimensional imaging technologies. Advancing the conclusions obtained from these tests, conformable DR detectors achieved equivalent or improved detectability across a range of conditions relative to film and computed radiography (CR).

The context for our detectability tests – What is in our customers' daily work that require a conformable DR detector.

As we explored in detail in the first two white papers in this series, radiography codes and standards require that we should utilize single wall exposure techniques whenever practical. Single view techniques can now be performed on curved surfaces with conformable digital detector arrays (DDA's), resulting in image quality and workflow time savings and productivity benefits.

DDA's are used for a wide variety of applications within the nondestructive testing (NDT) industry. Single wall viewing is required whenever practical and has substantial advantages relative to double wall viewing.

Film and computed radiography systems can utilize single wall viewing because the detectors are thin and conformable. DDA's that are bent around curved surfaces are new to the industry, and therefore their performance must be compared to the existing technologies.

Images of welded pipes were utilized to contrast detectability performance between a conformable digital radiography (DR) sensor, computed radiography (CR) imaging plates (IPs), and radiographic film. Four pipes were used:

- An eight inch, a six inch, and a four inch pipe were imaged contact double-wall single-view.
- A two inch pipe was imaged double-wall double-view;

The image quality of the weld was assessed with a wire IQI. In addition, the exposure time, time to image, and exposure factors were compared for each technology.

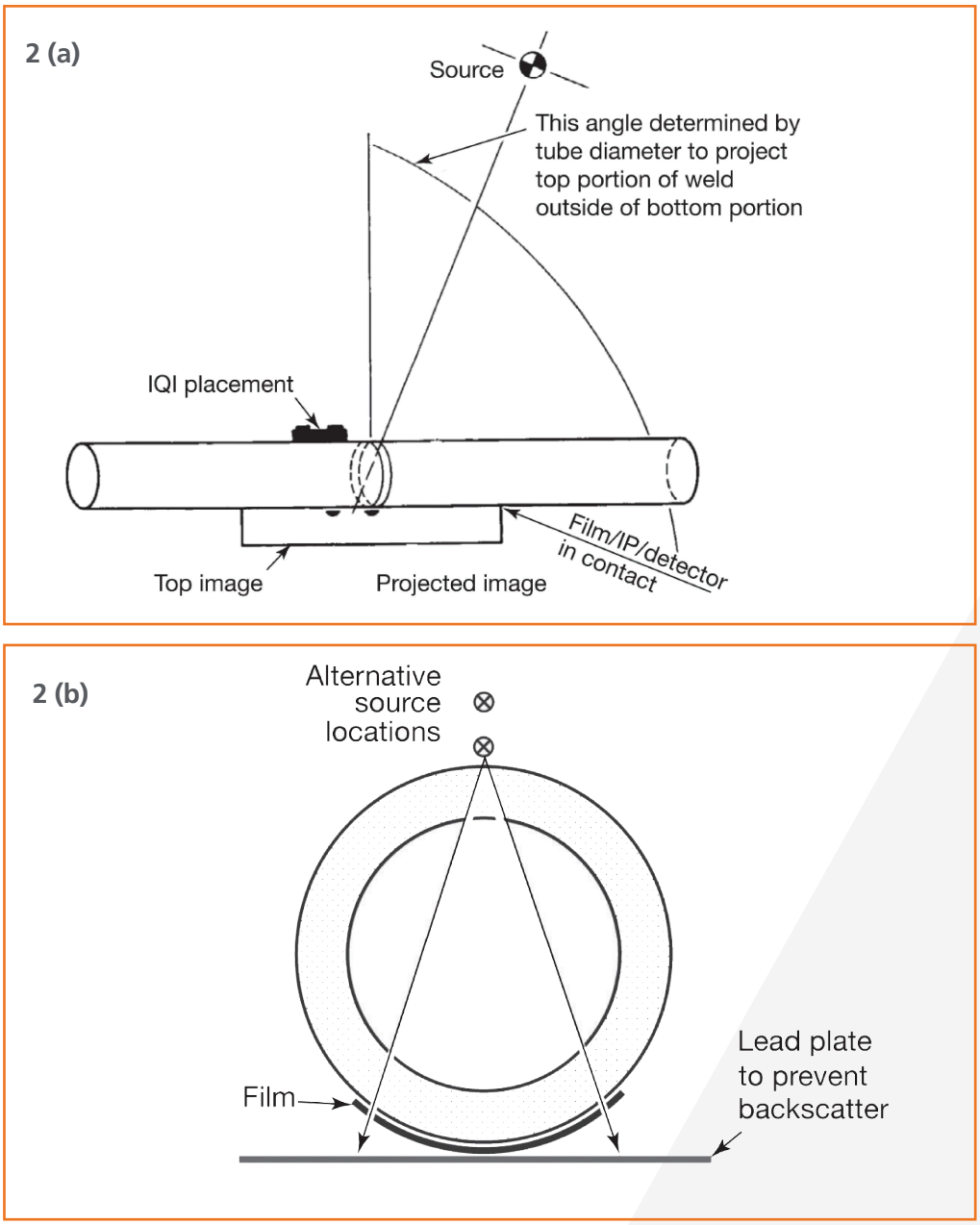

Figure 2: Radiographic Techniques Used in Detectability Tests described in this White Paper.

2(a) double-wall double-view technique, 2(b) double-wall single-view technique,

Adapted from ASNT Nondestructive Testing Handbook, fourth edition: Volume 3, Radiographic Testing [2]

Kicking-off our detectability tests directly on our conformable DR detector up front.

For the first set of tests, we selected a 6 inch steel pipe, and we obtained three sets of radiographic images using our conformable DR detector, CR imaging plates and industrial radiographic film.

In figure 3 we show our conformable DR detector installed around the 6 inch pipe for a double wall single view contact shot. The detector was secured by a bungee cord, with the gamma collimator on the other side of the pipe. The active area of the DDA was 4 x 10 inches, 98 µm pixel pitch, 100 µm image resolution, 1024 x 2560 array size, 2.62 MP. The detector was operated in static mode with 1 x 1 binning. DICONDE images were captured with our DICONDE-Compliant INDUSTREX ® software platform on 16-bit linear scale.

Figure 3: Conformable DR detector installed in 6" pipe test coupon, double-side single-view technique, from White [2]

In figure 4 we show a computed radiography imaging plate (IP) inside a vinyl conformable cassette around a 6 inch pipe for a double wall single view contact shot. The IP was also secured by a bungee cord, with the gamma collimator on the other side. The active area of the IP was 4.5 x 10 inches. An HPX-1+ CR reader was utilized with a HR plate. The IP was scanned at 50 µm pixel size, high laser power, photomultiplier tube setting at 30. 10-mil frontside and backside lead screens were used inside the vinyl cassette. CR DICONDE images were captured with our INDUSTREX ® software on 16-bit linear scale.

Figure 4: HPX-1+ HR imaging plate installed in 6" pipe test coupon, double-side single-view technique, from White [2]

In figure 5 we demonstrate a MX125 CONTAKPAK film around a 6 inch pipe for a double-wall single-view contact shot (CONTAKPAK is a trademark of Carestream Health). The film was against the pipe secured by a bungee cord with the gamma collimator on the other side. The active area film size was 5 x 7 inches. The film was processed in a STRUCTURIX processor with industrial photochemistry (STRUCTURIX is a trademark of GE Waygate Technologies). The duplitized film had 1-mil lead intensifying screens on each side as part of the design. Optical density was measured with a calibrated densitometer.

Figure 5: Film MX125 installed in 6" pipe test coupon, double-side single-view technique, from White [2]

The test methodology that we utilized was to expose the digital systems to the same aim pixel intensity. For DDA imaging, we utilized frame averaging to achieve the required sensitivity. We achieved sensitivity between 16 and 25 averaged frames. For film we exposed it long enough to achieve an optical density of 3.0 or greater via an automatic processor. The images were compared side-by-side for image quality and required sensitivity.

Figure 6 compares side by side the image quality of conformable DR to CR and film for a six inch steel pipe with 0.25 inch wall thickness shot single view contact with a 45.8 Ci Iridium source. The required visible wire was the 6- wire on the steel B set film side.

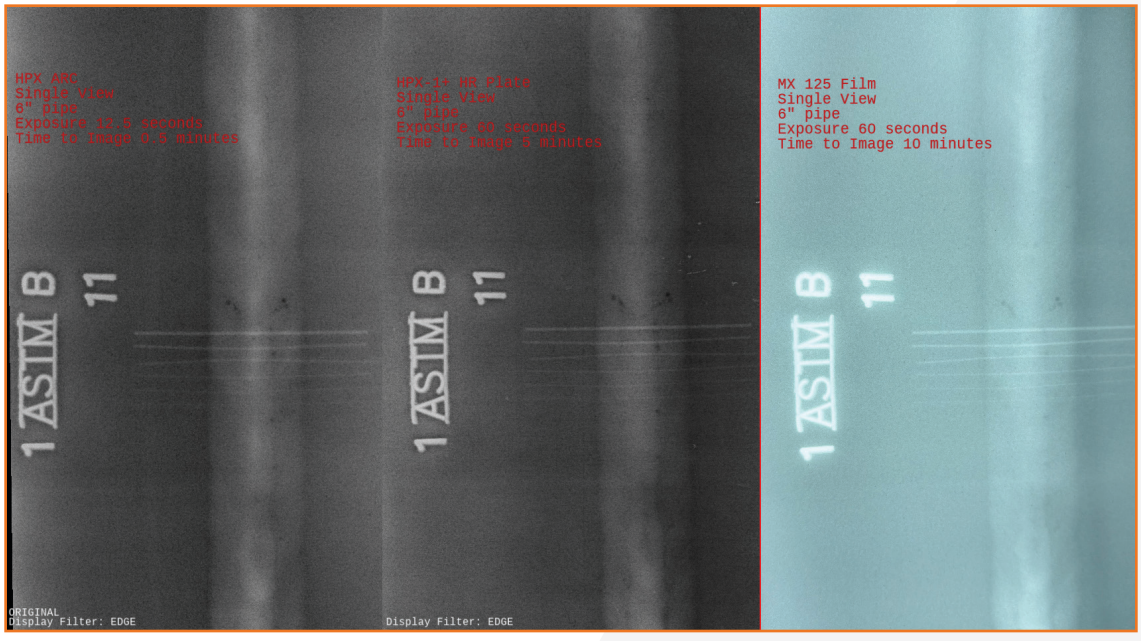

Figure 6: 6" Pipe Conformable DR vs HPX-1+ HR vs MX125 Film, from White [2]

Table 1 provides the exposure parameters to achieve the required sensitivity as shown in the images in Figure 5. The conformable DR achieved the required sensitivity in significatively less time relative to CR and film.

Evaluation Parameters	Imaging Process Options		
	Conformable DR	HPX-1 + CR HR	Industrex MX125 Film
Criteria	6000 pixel intensity	6000 pixel intensity	3.0 optical density
R-Factor per frame	0.030	11	11
Image Acquisition Time	0.5 min. *10 times faster than CR* *20 times faster than film*	5 min.	10 min.

Table 2: Productivity Comparison for Conformable DR to CR to Film with a 6" pipe test coupon, adapted from White [2]

Extending our detectability tests with consistently positive results.

Figures 6a and 6b compare the image quality obtained using a similar set of conformable DR, CR imaging plates and film as described previously, but for our second set of tests they were used in a two inch steel pipe test coupon with 0.154 inch wall thickness shot using a double-side double-view elliptical technique using a 34.6 Ci Iridium source. The required visible wire was the 5-wire on the steel A set when the IQI is placed in the source side.

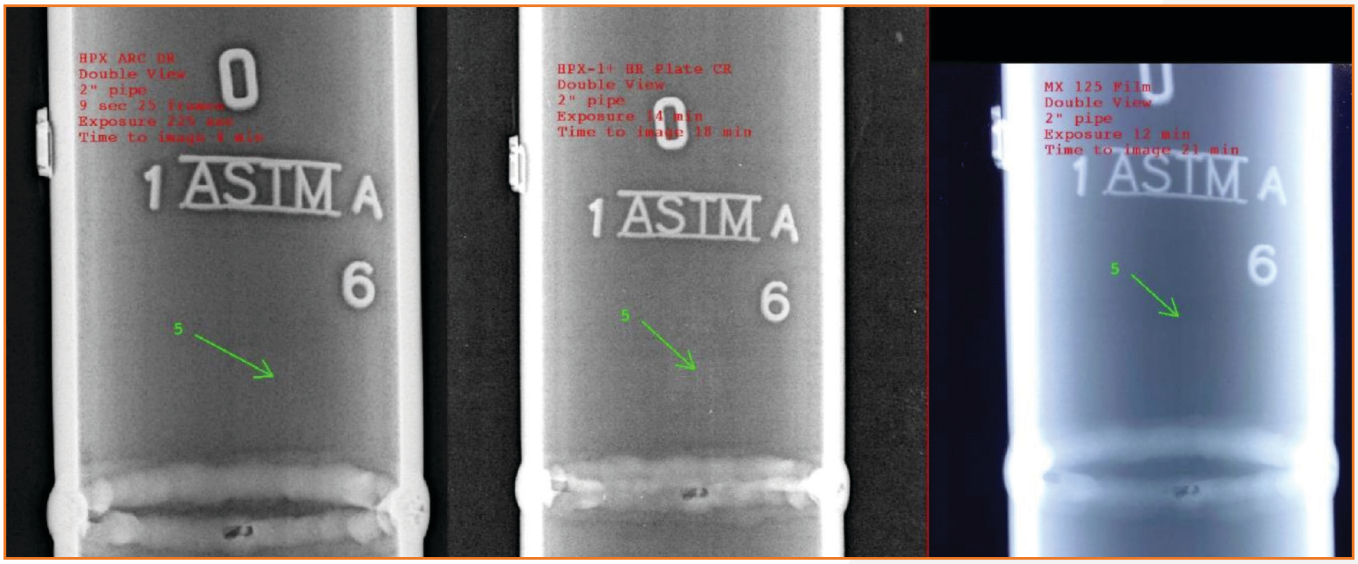

Figure 6a: Image Quality Comparison of Conformable DR vs HPX-1+ HR vs MX125 Film in a 2" Pipe Test Coupon, from White [2]

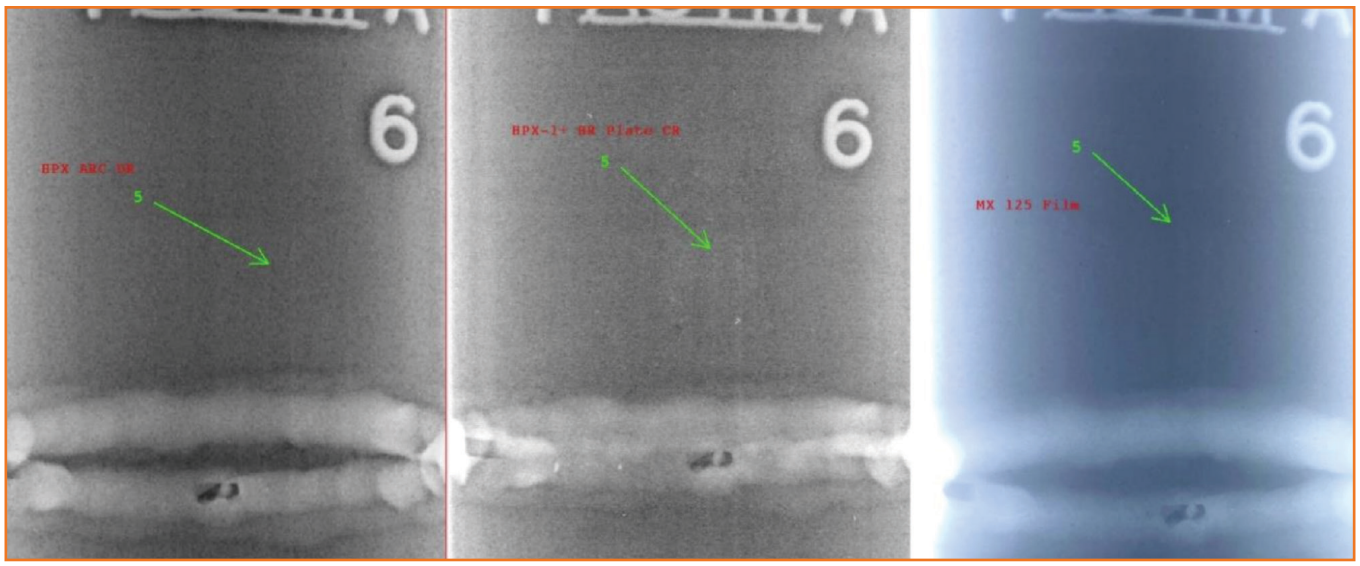

Figure 6b: A Magnified Image Quality Comparison of Conformable DR vs HPX-1+ HR vs MX125 Film in a 2" Pipe Test Coupon, from White [2]

Table 3 provides the exposure parameters to achieve the required sensitivity as shown in the images in Figures 6a and 6b above. Similarly to the prior set of tests, the conformable DR detector again achieved the required sensitivity in less time relative to CR and film.

Evaluation Parameters	Imaging Process Options		
	Conformable DR	**HPX-1 + CR HR**	**Industrex MX125 Film**
Criteria	7500 pixel intensity	7500 pixel intensity	3.0 optical density
R-Factor per frame	0.010	10	8
Image Acquisition Time	4 min. *4.5 times faster than CR* *5.25 times faster than film*	18 min.	21 min.

Table 3: Productivity Comparison for Conformable DR to CR to Film with a 2" pipe test coupon, adapted from White [2]

Figure 7 compares the image quality of our third set of tests using our conformable DR to CR and film in a four inch steel pipe with 0.337 inch wall thickness using a single-side single-view technique using a 34.6 Ci Iridium source. The required visible wire was the 5-wire on the steel A when the IQI is placed in the film side.

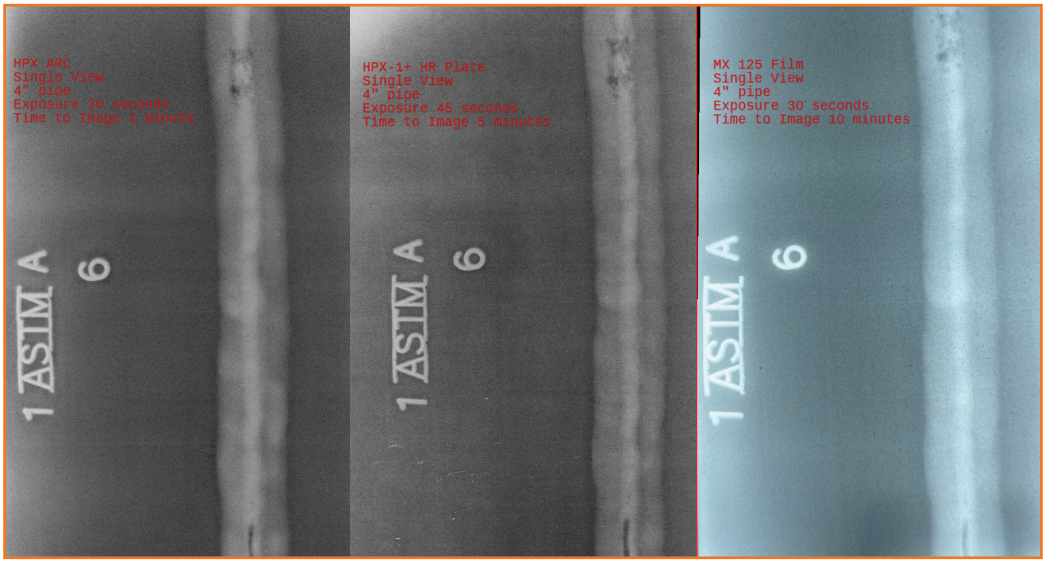

Figure 7: Image Quality Comparison of Conformable DR vs HPX-1+ HR vs MX125 Film in a 4" Pipe Test Coupon, from White [2]

Table 4 provides the exposure parameters to achieve the required sensitivity in our third setoff tests as shown in the images of Figure 7 above. The conformable DR achieved the required sensitivity in less time relative to CR and similar or less time relative to film.

Evaluation Parameters	Imaging Process Options		
	Conformable DR	**HPX-1 + CR HR**	**Industrex MX125 Film**
Criteria	7000 pixel intensity	7000 pixel intensity	3.0 optical density
R-Factor per frame	0.010	10	7
Image Acquisition Time	4 min. *1.25 times faster than CR* *2.5 times faster than film*	5 min.	10 min.

Table 4: Productivity Comparison for Conformable DR to CR to Film with a 4" pipe test coupon, adapted from White [2]

Figure 8 compares the image quality of conformable DR to CR and film for our fourth set of tests. In this case, an eight inch steel pipe test coupon with 0.375 inch wall thickness was evaluated using a double-wall single-view technique using a 34.6 Ci Iridium source. The required visible wire was the 6-wire on the steel B set when the IQI is placed in the film side.

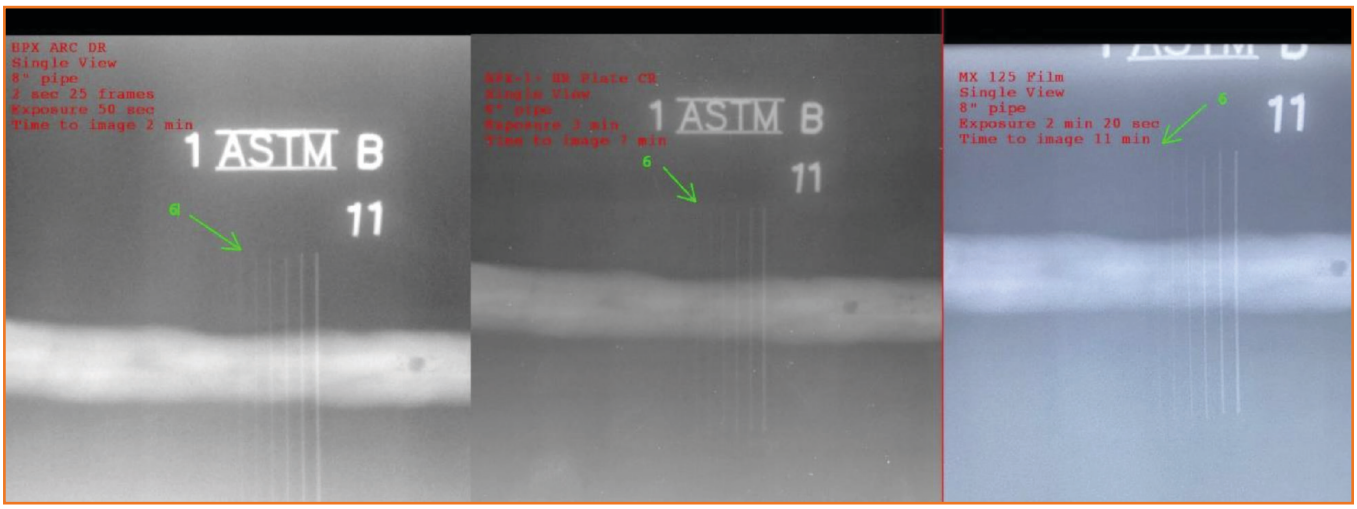

Figure 8: Image Quality Comparison of Conformable DR vs HPX-1+ HR vs MX125 Film in a 8" Pipe Test Coupon, from White [2]

Table 5 provides the exposure parameters to achieve the required sensitivity in the images of Figure 8 above. The conformable DR again achieved the required sensitivity in sensibly less time relative to CR and film.

Evaluation Parameters	Imaging Process Options		
	Conformable DR	**HPX-1 + CR HR**	**Industrex MX125 Film**
Criteria	7500 pixel intensity	7500 pixel intensity	3.0 optical density
R-Factor	0.010	10	9
Image Acquisition Time	4 min. *1.75 times faster than CR* *2.75 times faster than film*	7 min.	11 min.

Table 5: Productivity Comparison for Conformable DR to CR to Film with a 8" pipe, adapted from White [3]

Summary of insights derived from these test results.

The essential wire was seen for all pipes for flexible DR, CR, Film. The comparative increase in detectability obtained with the use of our conformable DR detector compared with CR and Film are graphically evident in Figure 5 for the 6" pipe, in Figure 6a and 6b for the 2" pipe, in Figure 7 for the 4" pipe and in Figure 8 for the 8" pipe.

Related with productivity comparison, Table 6 compiles the results for both Exposure Time and Image Acquisition Time compared with the use of CR Imaging Plates and Film. This means that radiographers will be able to obtain images with increased quality at a faster image acquisition time, both using a wireless or a tethered connection.

Evaluation Parameters		Test Coupon			
		8" Pipe	6" Pipe	4" Pipe	2" Pipe
Image Acquisition Time	Compared with CR	1.75 times faster	10 times faster	1.25 times faster	4.5 times faster
	Compared with Film	2.75 times faster	20 times faster	2.5 times faster	5.25 times faster

Table 6: Consolidated Productivity Comparison Results for Conformable DR to CR to Film, adapted from White [3]

Brian White, Research Scientist and Level III Radiographer at Carestream NDT, explains the practical implications of the notions discussed in the present white paper in the following terms [8]:
"Conformable DR detectors bent repeatedly around an object enable both a significant productivity advantage and an image quality advantage relative to CR and film. (For business decision-makers), The primary advantage of conformable DR detectors is productivity, the ability to get the inspection done quicker, which results in cost saving. (For radiographers), Equivalent or better contrast sensitivity was achieved with the result dependent on the actual exposure and the number of averaged frames."

An actionable approach for radiographic imaging professionals and business decision-makers - Building your own use case for a conformable DR detector (Part III of III)

Following the guidelines provided in the first two white papers of this series, you should proceed to compare alternative radiographic techniques:

H. After completing stages I and II of the use case, for each component or assembly include in this column the imaging acquisition time using your current radiographic technique. This includes not only the exposure time from column F but also the IPs scanning time for CR or the chemical development time in the case of film.

I. Then, for each component or assembly, include in this column the estimated imaging acquisition time using our conformable DR detector. This should include not only the exposure time of column G but also the time required for image transmission after exposure, either through a wireless or a tethered connection, and for display in the viewing device. For the tests described in this white paper this time ranged from 15 to 70 seconds. You can estimate this time according with this guideline or see it for yourself by evaluating our conformable DR detector in your facilities.

J. Finally, based on the number of similar components or assemblies where you perform radiographic inspection per week, you can estimate the substantial positive impact on the efficiency of your radiographic imaging process. As we discussed in the first white paper of this series, you should focus this use case on those components that constitute your largest volume of radiographic imaging process.

A. Component / Assembly	B. Applicable Codes	C. Is DR allowed?	D. Applicable Exposure	E. Number of Images per exposure	F. Exposure Time (with your current radiographic technique)	G. Exposure Time Using a conformable DDA	H. Image Acquisition Time (with your current radiographic technique)	I. Image Acquisition Time Using a conformable DDA	J. Efficiency increase based on Number of Exposures per week
Circumferential Weld in a Pressure Vessel	ASME BPVC, Section VIII-1 UW-51 and Section V Article 2.	Yes, ASME BPVC, Section V, Article 2, Mandatory Appendix IX.	Panoramic	25 images in one exposure	32:28 minutes (51 Ci Cobalt Source, 3" thick steel, 40" Source to Film Distance, using radiographic film,2.5 intended density)	1:22 minutes (51 Ci Cobalt Source, 3" thick steel, 40" Source to Film Distance, 9000 Pixel Density intended)	42 minutes	1:55 minutes 21.9 times faster	5 Exposures. 3.5 hours using your current radiographic technique 9:35 minutes using our conformable DR detector with increased detectability capabilities.

At this stage, you should have consolidated into a single document not only a comprehensive list of the most common components or assembles where you need to perform radiographic imaging processes, which of those radiographic imaging applications have the option to be performed with DR and which are suitable to use a conformable DR detector, but comparative data on both exposure time and image acquisition time that will be invaluable for your business decision based on this use case.

We want to conclude this guide to help you build your own use case for a conformable DR detector with a few quotes that were insightful while we were developing and evaluating this new exciting new product category and that we hope can generate in you a wider perspective on how radiographic imaging processes can be expanded, enriched and reinforced.

To move forward in the construction of your business case, we advise you to review other White Papers in this series:

Building Your Own Use Case for a Conformable DR Detector

Part I – "The Why's" Expanding, Enriching and Reinforcing Your Imaging Capabilities

Part II – "The How's" Proposing an actionable approach to a new set of imaging capabilities

Part III – "The What's" An Insightful Comparison of Conformable DDAs to Film and CR Imaging Plates (This White Paper)

- **For readers interested in exploring how digital radiography (DR) can be integrated into your processes:**

  https://www.carestream.com/en/us/nondestructive-testing-ndt-solutions

- **For readers interested in exploring supplementary white papers on practical application and innovation on imaging processes:**

  https://www.carestream.com/en/us/nondestructive-testing-ndt-solutions/ndt-white-papers

Here are some supplementary information resources from Carestream NDT's products and services portfolio:

Products

- HPX ARC 1025 PH
- HPX ARC 1043 PH
- INDUSTREX Fieldview, Tablet
- INDUSTREX Digital Viewing Software
- Advanced Industrial Radiographic Training Academy
- ayData NDT Archive Solution
- Virtual NDT Showcase
- Resource Center
- NDT White Papers

Services - Training and Supplementary Resources:

- Digital Detector Array Radiography - 40 Hour Online Course
- Digital Imaging - 40 Hour Classroom Training

Resources from ASNT

- Nondestructive Testing Handbook, fourth edition: Volume 3, Radiographic Testing

References:

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