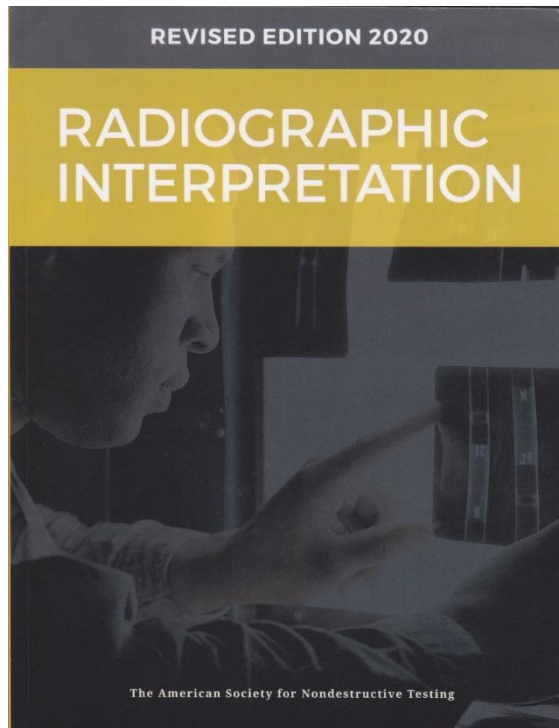


CarestreamNDT

“Uso de diferentes fuentes de radiación y sus implicaciones al aplicarlas en radiografía digital (CR y DR ventajas y desventajas)”

Gabriel Cortés

TOPICS



General

- Digital Radiography Techniques and Technologies
- Difference between CR & DR.

Technical

- Sources (X-Ray, Gamma)
- Image Capture (Film, CR, DR)
- Radiographic Geometry
- Scatter...
- Signal to Noise Ratio
- Contrasts to Noise Ratio

Applications

- Sensitivity of Iridium and Selenium for DDA and CR systems.
- Sensitivity of Xray source with DDA and CR systems
- Sensitivity of Pulse Xray with DDA and CR systems.
- Direct Comparison between Xray and Pulse Xray.

Digital Radiography Techniques and Technologies

Most common;

Computed Radiography (CR)

Digital Detector Array Radiography

- ASNT uses (DR) for digital detector array radiography
- ASTM uses (DDA) for digital detector array radiography

Computed Tomography (CT)

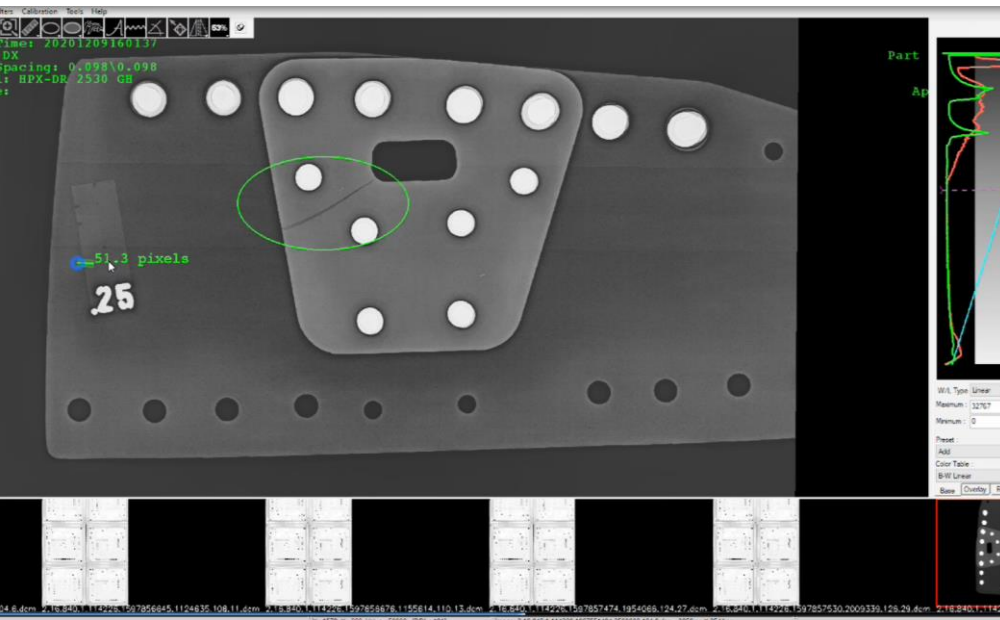
Linear Detector Array Radiography (LDA)

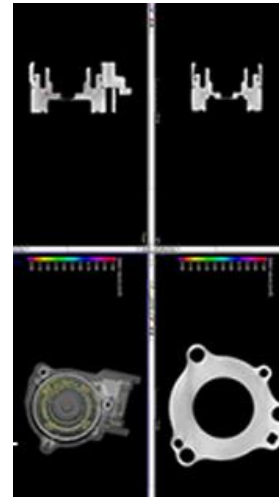
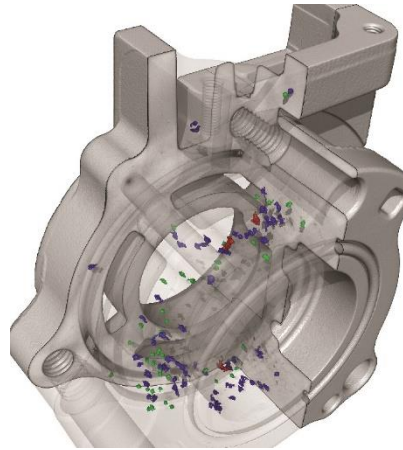
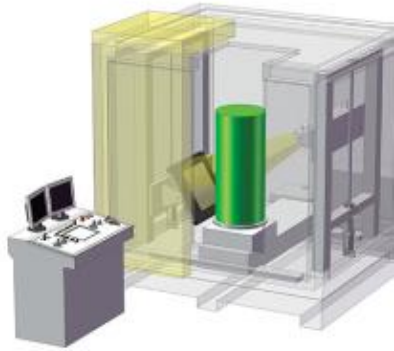
Radioscopy

Real time radiography with DDA's

Digital Radiography Techniques and Technologies

RT – CR – DR : 2D image / no live

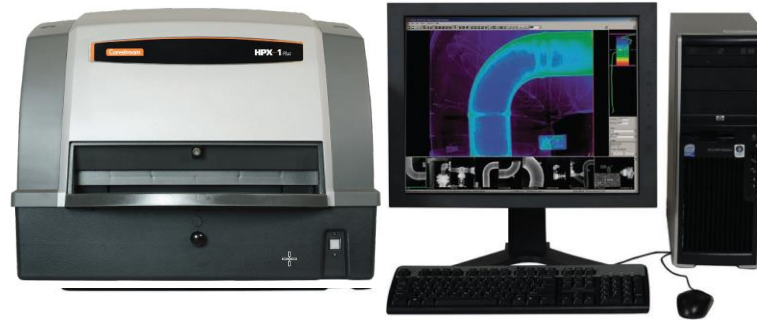
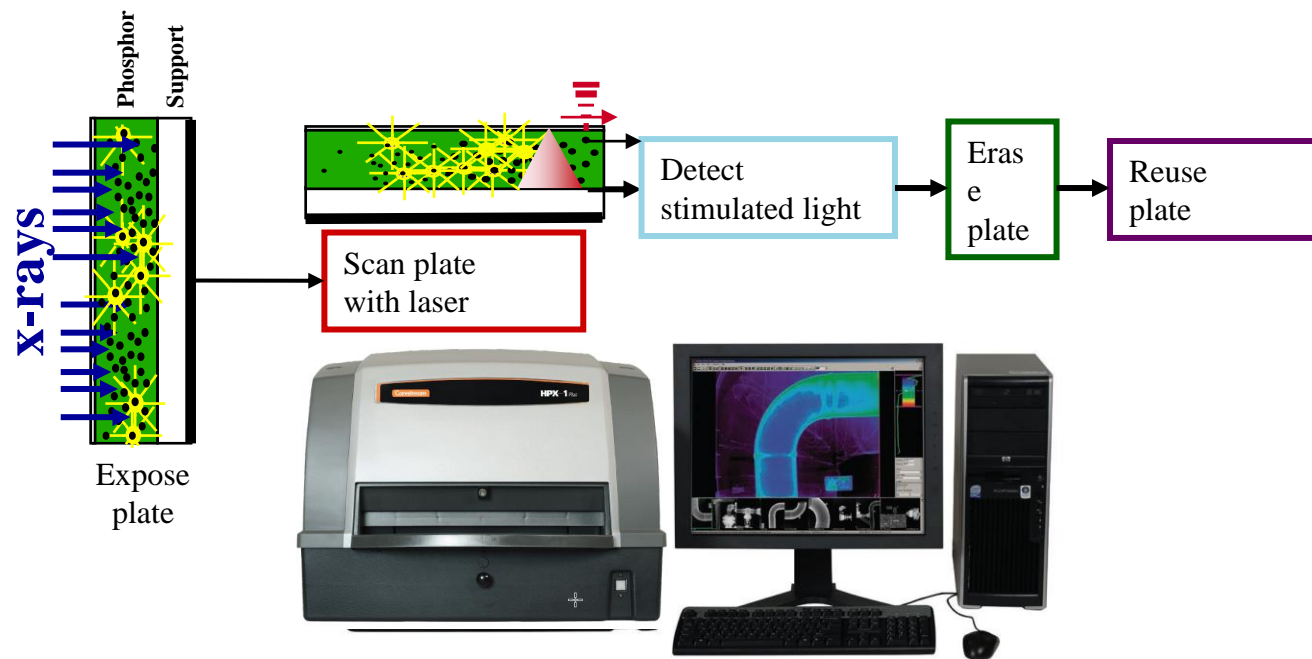




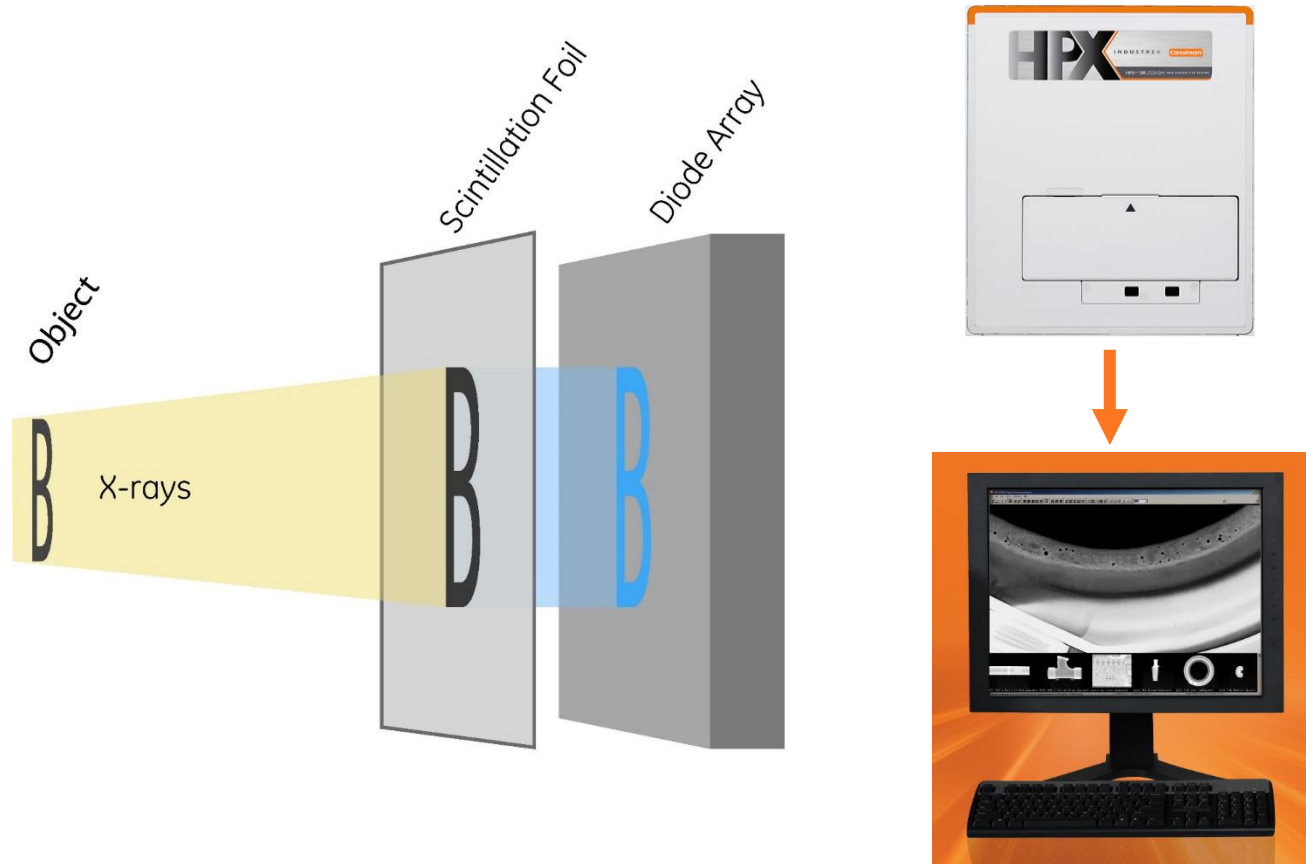
Digital Radiography Techniques and Technologies

CT – LDA – Radioscopy : Live 2D image / Volumetric
Inspection

Computed Radiography

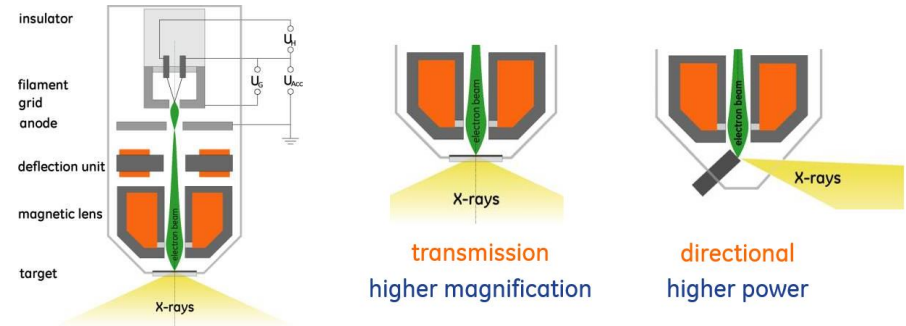


Digital Radiography



Sources

Gamma (Iridium, Selenium) X Ray Generator Pulse X Ray Generator



Performance and Packaging: Pulsed technology generates high output voltage using minimal input voltage. The result is extremely small single package generators with significant penetrating capability.

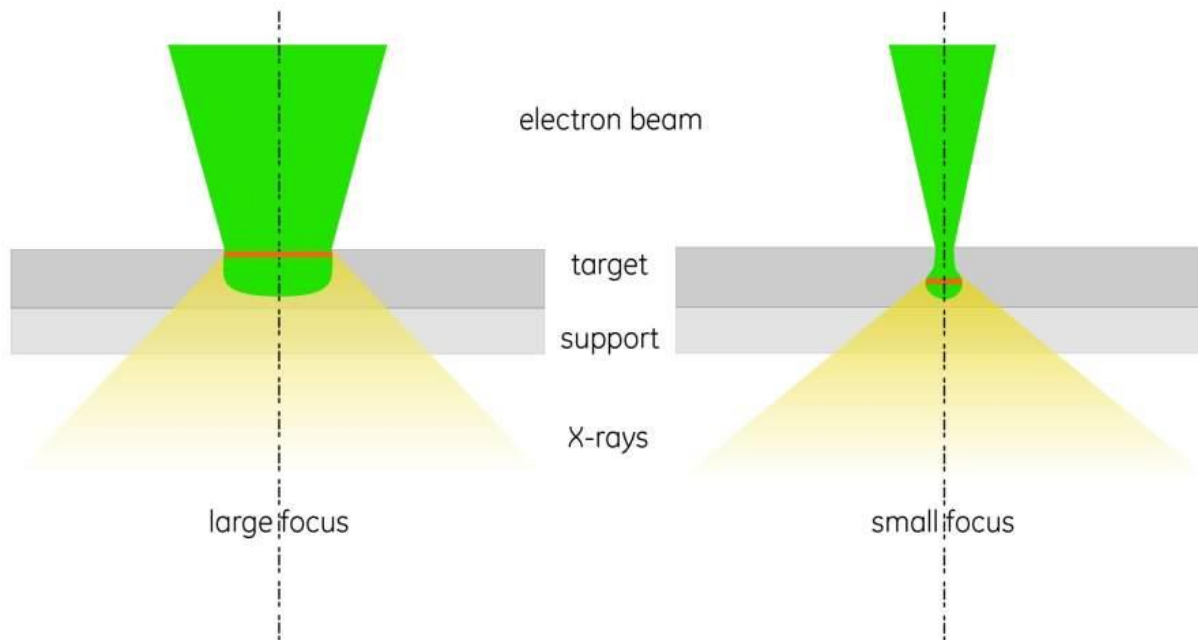
Safety and Simplicity: Minimal side and rear X-ray leakage means the operator safety stand-off distance is 20 feet (6 m) behind the unit. The generators contain no radioactive material. Radiation is only emitted from the generator while it is pulsing. The single package design eliminates the need for connecting cables between tube head, control module, and power supply.

Model	Weight Lbs. / Kg	kV	Penetration (steel) in. / cm	Dose mR per pulse*	Pulse Width	Pulse rate per sec.	Rear Standoff Distance Ft / m
XR150 20V	6.0 / 2.73	150	0.75 / 1.91	1.8 - 3.0	50 ns	11	10 / 3
XR200 20V	11 / 5.00	150	0.50 / 1.27	2.0 - 3.4	50 ns	10	10 / 3
XRS3 20V	11.80 / 5.40	270	1.00 / 2.54	2.0 - 4.3	25 ns	21	10 / 3
XRS4 20V	18.30 / 8.30	370	1.75 / 4.46	4.0 - 8.5	10 ns	9	20 / 6

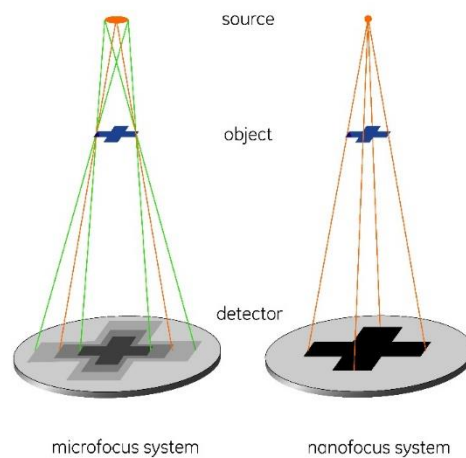
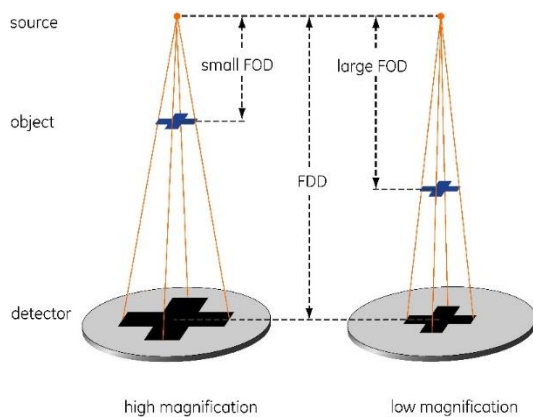
Sources

X Ray Generator

Focal Spot directly impact in image resolution.



Geom Mag & Res/Penumbra



Both have a high impact on image detection.

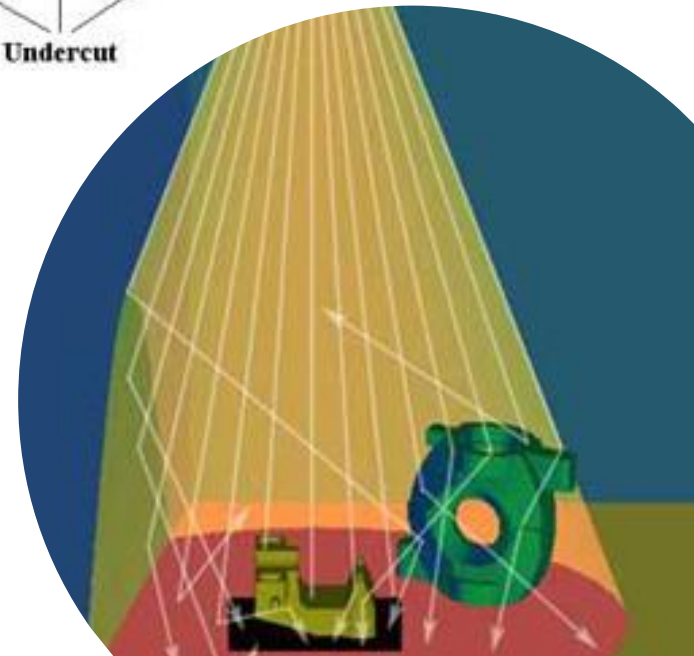
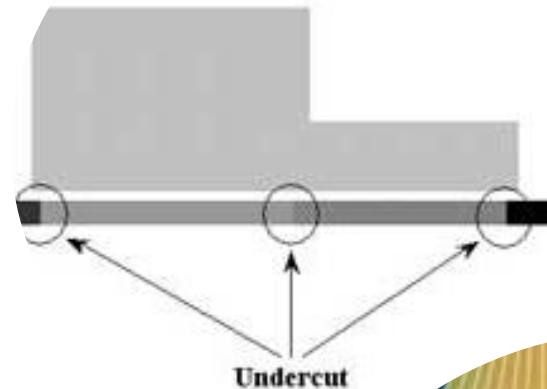
Resolution is always dictated by more than 5 variables.

Scatter & Undercut

Secondary or scatter radiation must often be taken into consideration when producing a radiograph

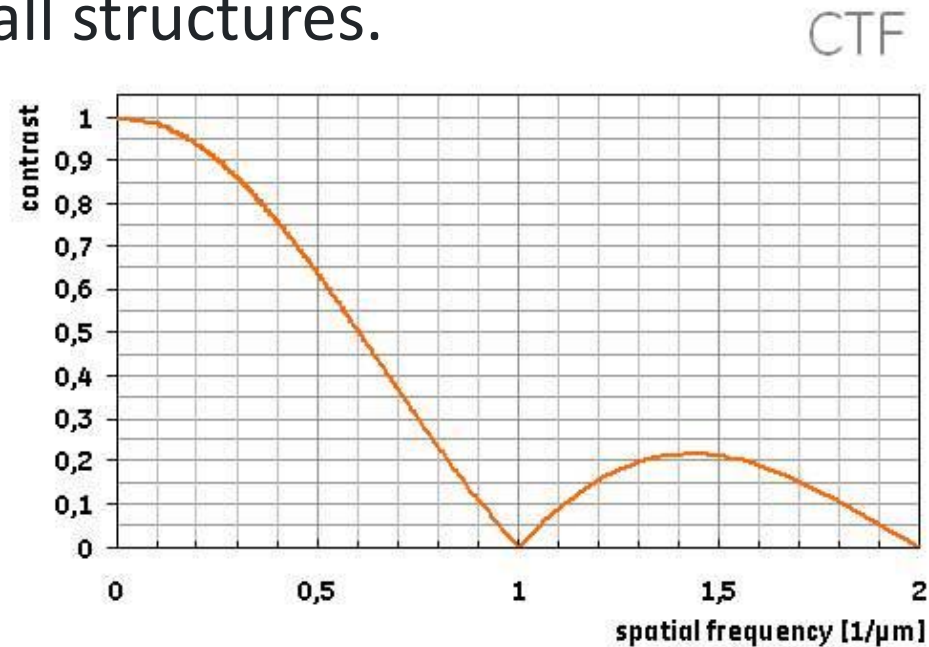
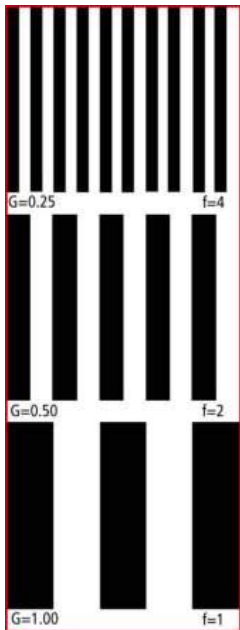
The scattered photons create a loss of contrast and definition

Another condition that must often be controlled when producing a radiograph is called undercut. Parts with holes, hollow areas, or abrupt thickness changes are likely to suffer from undercut if controls are not put in place. Undercut appears as a darkening of the film radiograph in the area of the thickness transition. It appears as a brighter ghosting near the edges in a digital image. This results in a loss of resolution or blurring at the transition area.



Resolution

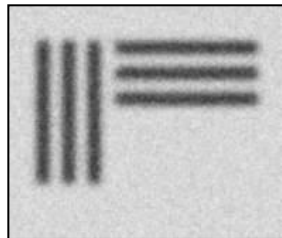
The spatial resolution of an x-ray system is a measure of how the ability of a system to differentiate small structures.



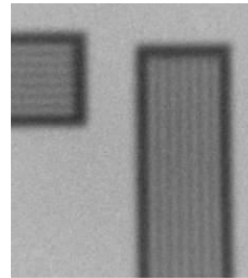
Resolution

Contrast transfer function / Focal Spot Size

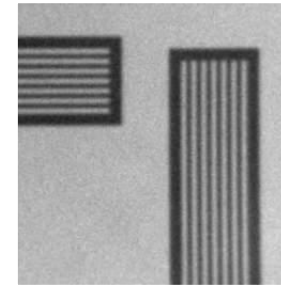
$$CTF = \frac{\left| \sin \left[\pi G^{-1} \left(\frac{M-1}{M} \right) \right] \right|}{\left[\pi G^{-1} \left(\frac{M-1}{M} \right) \right]} = 0 \rightarrow$$



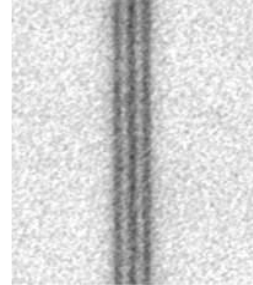
$$\text{for } G = F \left(\frac{M-1}{M} \right) \cong F$$



2 μm bars
F < 2.5 μm



2 μm bars
F < 1.5 μm



0.6 μm bars
F < 0.8 μm

Image Quality

Traditional FILM

Densitometry is the quantitative measurement of optical density in light-sensitive materials.

Digital Imaging

Dynamic Range (bit)
Signal to Noise Ratio
Contrast to Noise Ratio
Spatial Resolution

Sensitivity

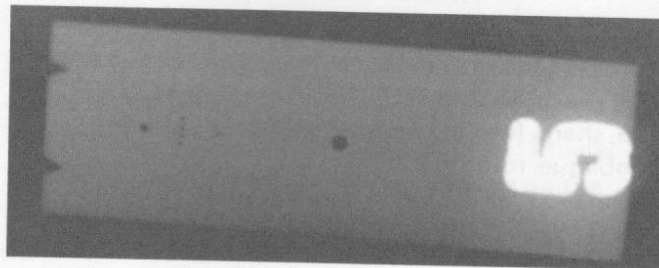
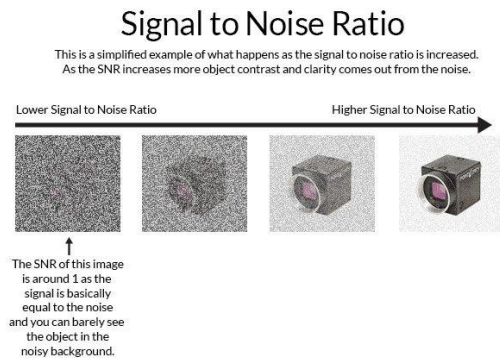


Figure 17. Radiograph of a penetrameter used in radiography.

SnR vs CnR

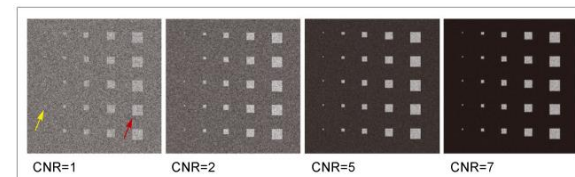
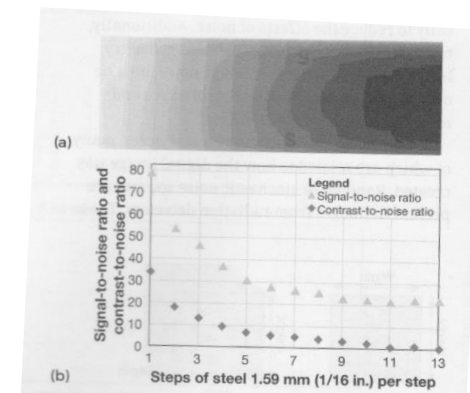
Signal to Noise

Attempts to quantify a signal or image element value compared to the background noise.



Contrast to Noise

Difference in the image element values for adjacent image region. Capacity to differentiate from background.



SnR vs CnR

Signal to Noise

$SNR = N / \sigma$ N = pixel value; σ = standard deviation

Signal –desirable part of image: increases with dose

Noise –undesirable part of image: influenced by

- Scatter

- Statistical noise variation

Guideline is SNR > 100:1

DR can be > 1000:1 with frame averaging

Contrast to Noise

Difference between pixel values of adjacent areas inside and outside the hole

Divided by standard deviation of pixel value outside the hole

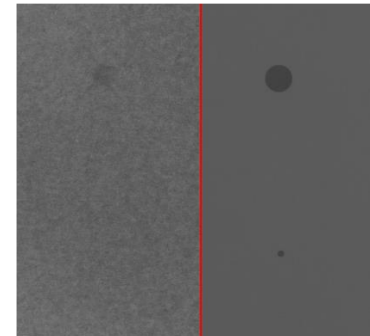
$(N2 - N1) / \sigma$

N = pixel value

σ = standard deviation

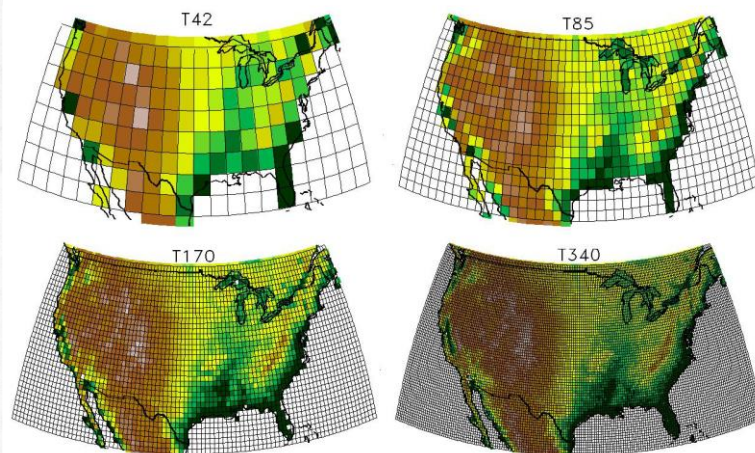
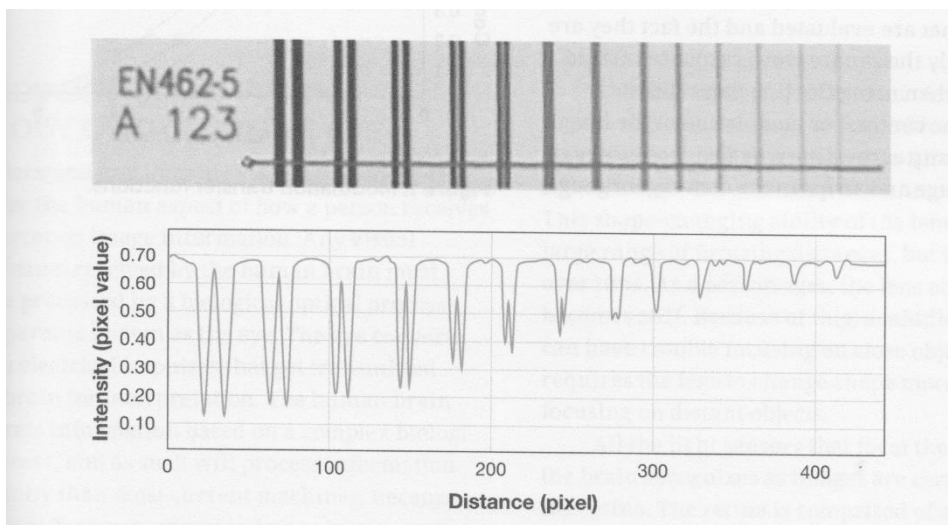
Standards specify this contrast is measured inside the 4T hole, and adjacent to it

Guideline is CNR > 2.5

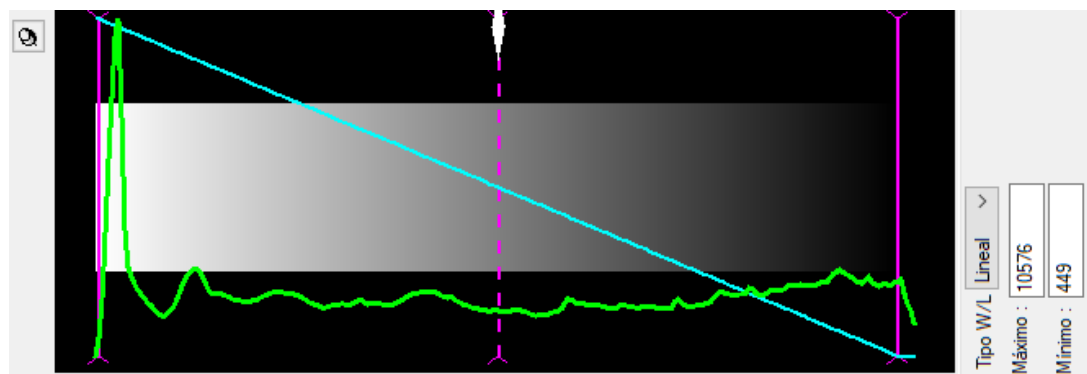
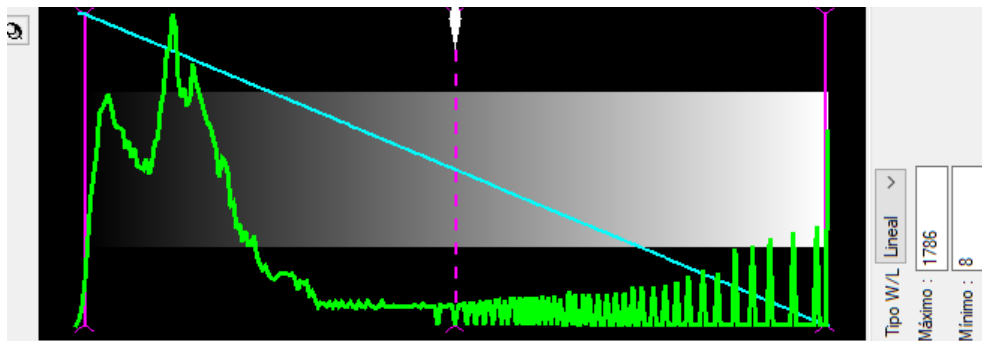


Spatial Resolution

Is the reference to the smallest detectable feature in the image. UnSharpness is the parameter measured.



HISTOGRAM – Key Feature



Main additional - Points to Qualify a System

Scanning Vibration (CR)

Pixel Pitch (DR)

Contrast Sensibility

Digital Shadows

Ghost Image

Dead Pixels (DR)

ATTRIBUTE	CR	DR
Flexible	Yes	No
Reusable Media	1,000 – 5,000	10,000-1,000,000
Capture Speed (vs film)	.20–30 % faster	50-90% faster
Process Speed (vs film)	0.5	0.1
Exp. Latitude	10,000:1	10,000:1
Spatial Resolution	25 – 150 micron	50 – 200 micron
SNR	100 - 250	250 - 2000
ROI	Moderate	High
Environmental Tolerance	Excellent	Moderate / High
Darkroom/Chemicals	No	No
Size Range	2"x2" – 35"x60"	Various sizes
Image Sharing	CD, DVD, E-Mail, Cloud	CD, DVD, E-Mail, Cloud
Accessibility	Immediate	Immediate

Se - 75 vs Ir - 192

Source Type	Gamma Energy	Half-life and Activity Range	Average Emission Energy	Working range with steel	Emissivity rate
Selenium-75	97 to 401 keV	120 days 10 – 120 Ci	~215-230 keV	~0.118 to 1.14 inches ~3 to 29 mm	2.18 R/hr/Ci at 1 foot 5.4 × 10 ⁻⁵ mSv/h/MBq at 1 m
Iridium-192	206 to 612 keV	74 days 10 – 150 Ci	~370-380 keV	~0.47 to 2.48 inches ~12 – 63 mm	5.2 R/hr/Ci at 1 foot 1.3 × 10 ⁻⁴ mSv/h/MBq at 1 m

Two sets of experiments with Se-75 and Ir-192 gamma sources were conducted; the first set comprehends obtaining images from a ½-inch stainless steel plate and from a 3/8-inch aluminum plate using both DDAs for DR images and IPs for CR images.

Equipment

For computed radiography, the source-to-detector distance was 20-inches.

HPX-PRO radiography system was utilized in conjunction with **INDUSTREX Version 5.1 Software** for image capture. Exposures were done at 7 R with an aim pixel intensity of 6000 through the base metal on a 16 bit linear scale. An HR type imaging plate was used. Images were captured at 50 mm pixel size with a photomultiplier tube setting of 10.

For digital detector array radiography, the source-to-detector distance was 29-inches. A **139 mm pixel pitch HPX-DR 3543 Non Glass** radiography system was utilized in conjunction with **INDUSTREX Version 5.1 Software** for image capture. Exposures were done at 0.08 R for Iridium and 0.04 R for Selenium with an aim pixel intensity of 20,000 through the base metal on a 16 bit linear scale. Integration times were typically 5 seconds for Iridium and 14 seconds for Selenium, with 25 averaged frames.

Se-75

62.3Ci Se-75 2.75mm Φ focal Shot time: 6m 50s

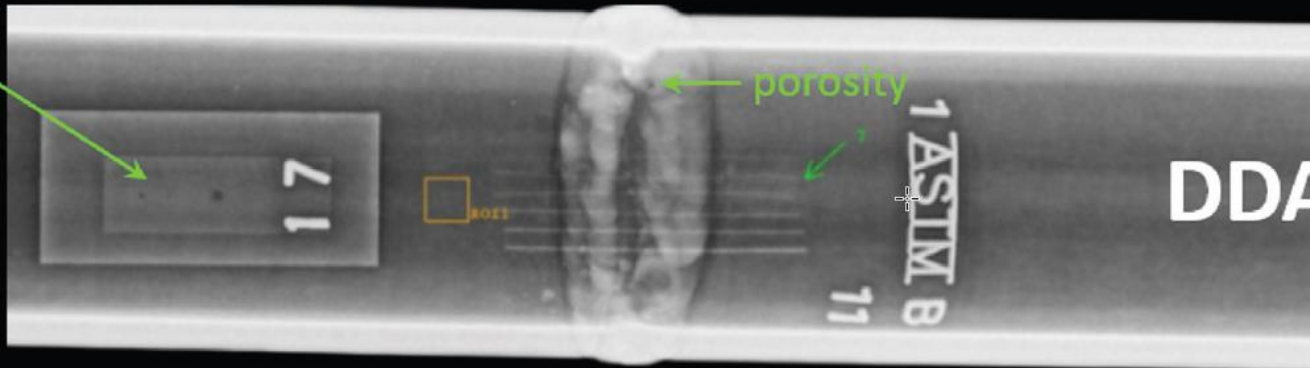
2T visible



CR PANEL

62.3Ci Se-75 2.75mm Φ focal Shot time: 15m 32s

1T & 2T visible

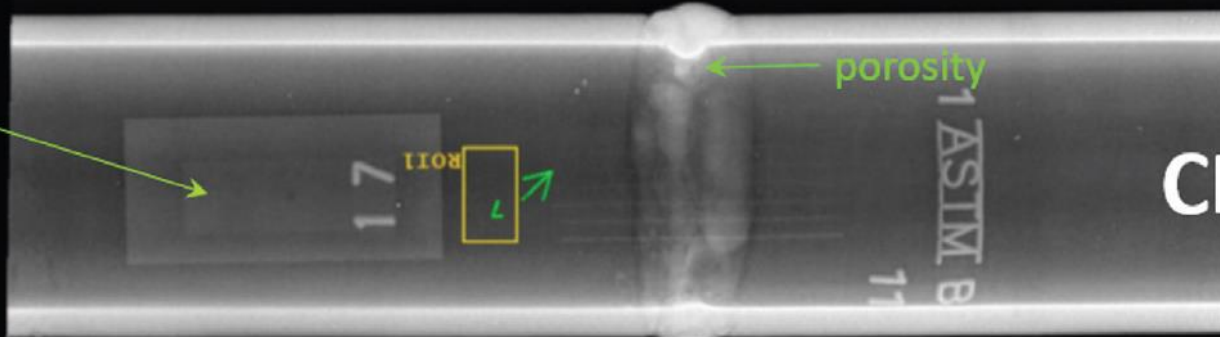


DDA PANEL

IR-192

120Ci Ir-192 2.7mm Φ focal (axial emission)

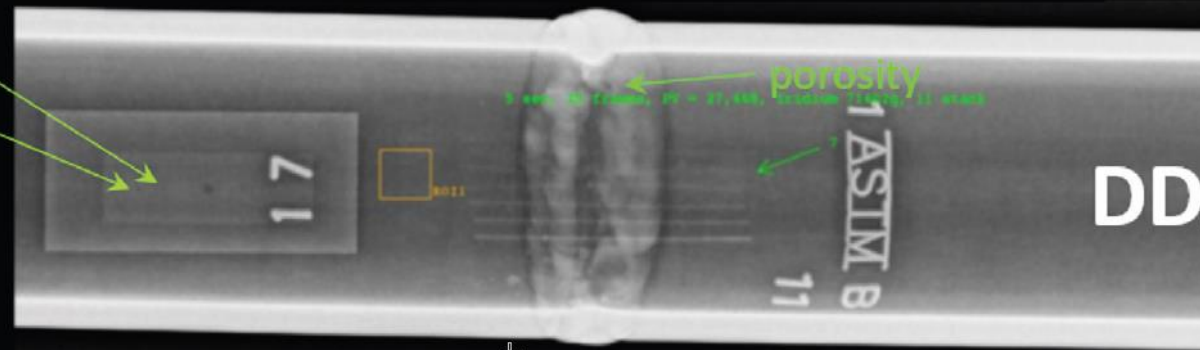
2T
barely
visible



CR PANEL

120 Ci Ir-192 2.7mm Φ focal (axial emission)

1T
2T



DDA PANEL



Conclusions

System	Gamma Source in Use	Observed Hole	Observed Wire
HPX-PRO	Se-75	2T	7
HPX-DR		1T	6
HPX-PRO	Ir-192	4T	7
HPX-DR		1T	7

Radiographic detectability was best for Selenium radioisotopes used in conjunction with digital detector array systems because Selenium produced images with less noise.

Likewise, digital detector array radiography systems produced images with reduced noise, which resulted in higher contrast-to-noise ratios and improved detectability. This can reduce shot time and extends the practical working life of sources.

X-ray vs Pulse Xray

For Xray was used a ECO 200DS Comet tube at 160KV and 5ma in all cases.

For pulse generator a XRS3 model with 195KV pulse with 15ns. For CR 650 pulses were used. For DR 90 pulses.

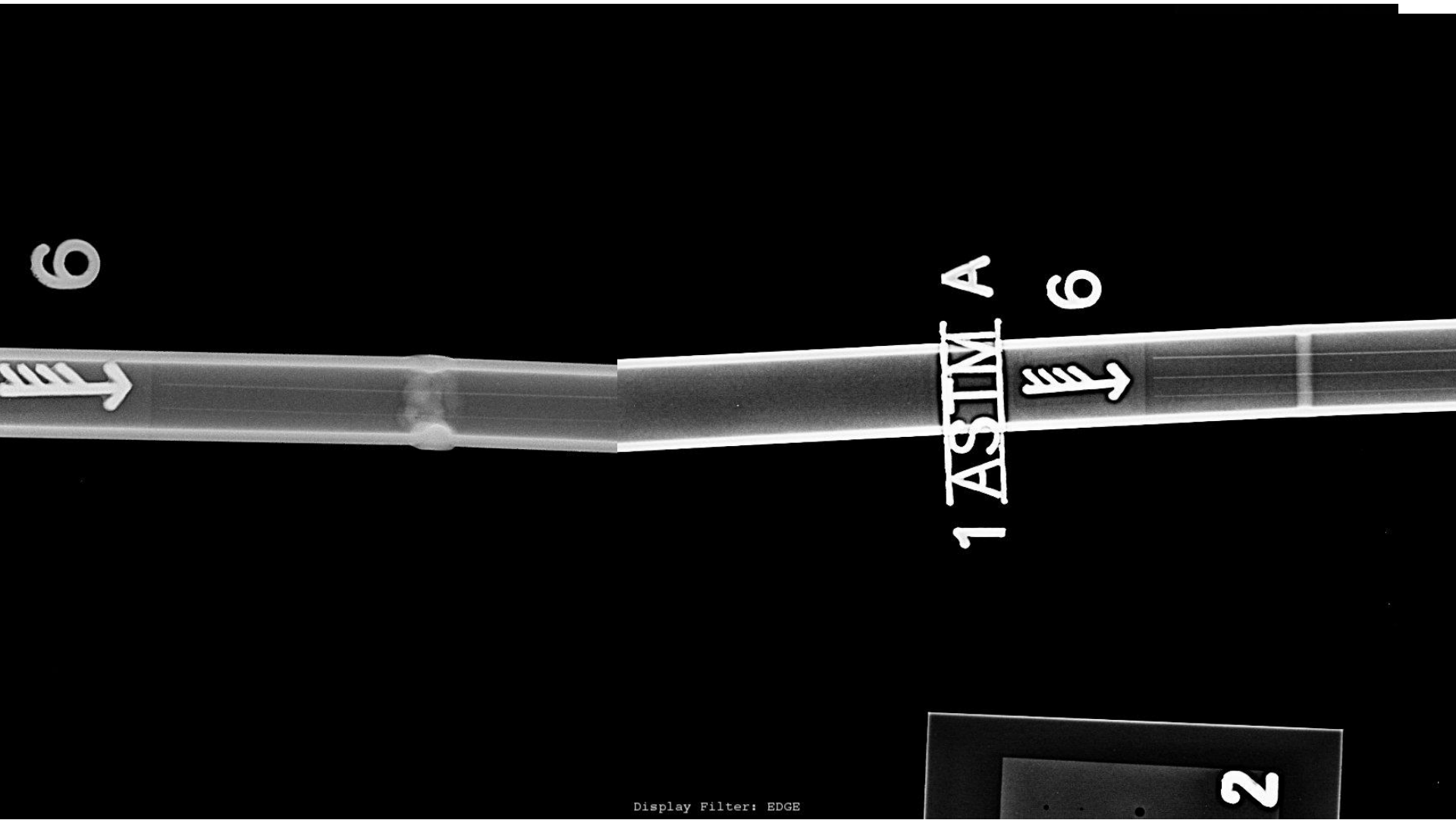
Equipment

For computed radiography, the source-to-detector distance was 20-inches.

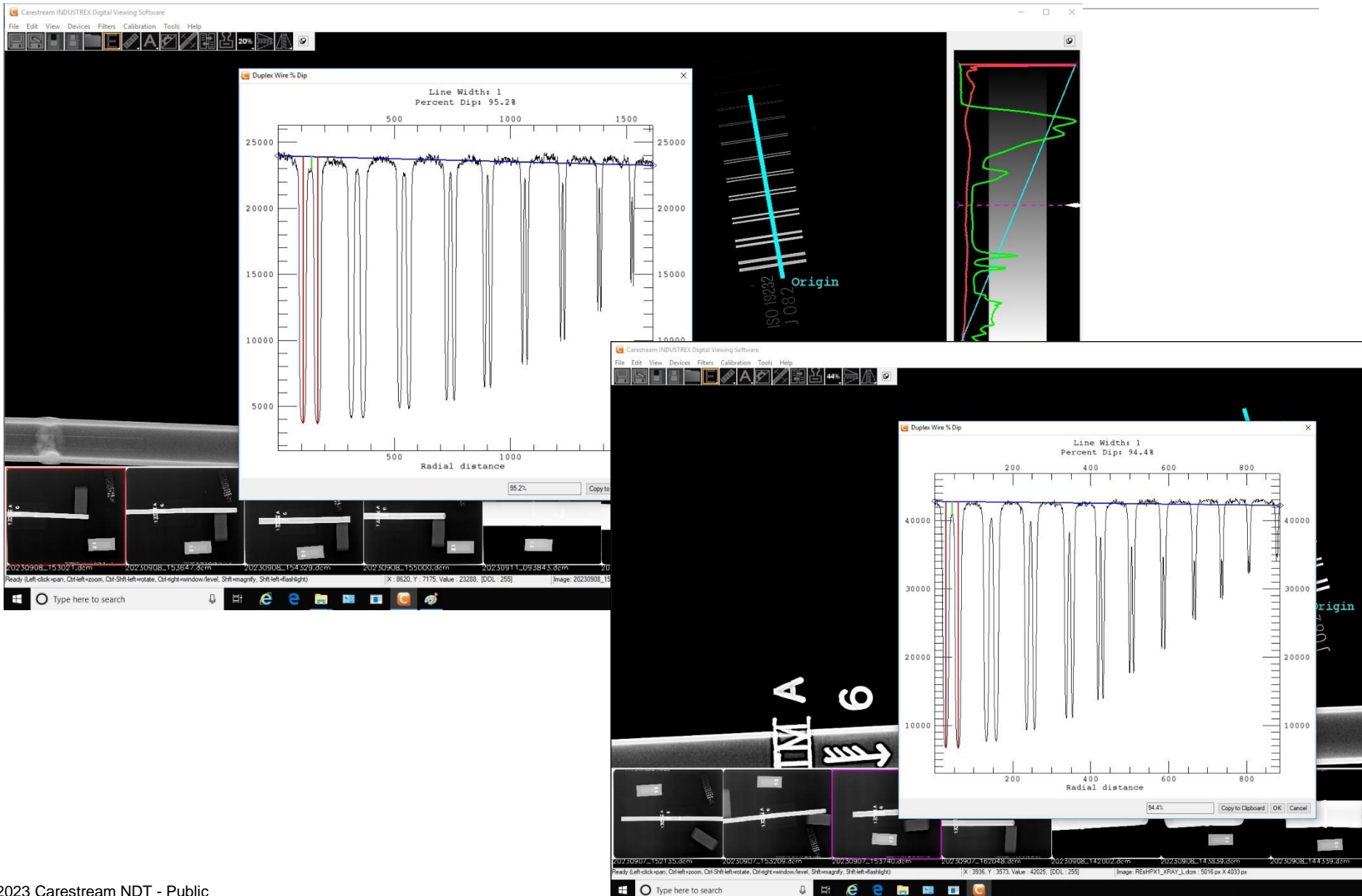
HPX-HPX1plus radiography system was utilized in conjunction with **INDUSTREX Version 5.4 Software** for image capture. Exposures An HR type imaging plate was used. Images were captured at 50 mm pixel size.

For digital detector array radiography, the source-to-detector distance was 29-inches. A **98 mm pixel pitch HPX-DR 2530 Non Glass** radiography system was utilized in conjunction with **INDUSTREX Version 5.4 Software** for image capture. Exposures were done at Integration times were typically 1 second for both sources, with 50 averaged frames.

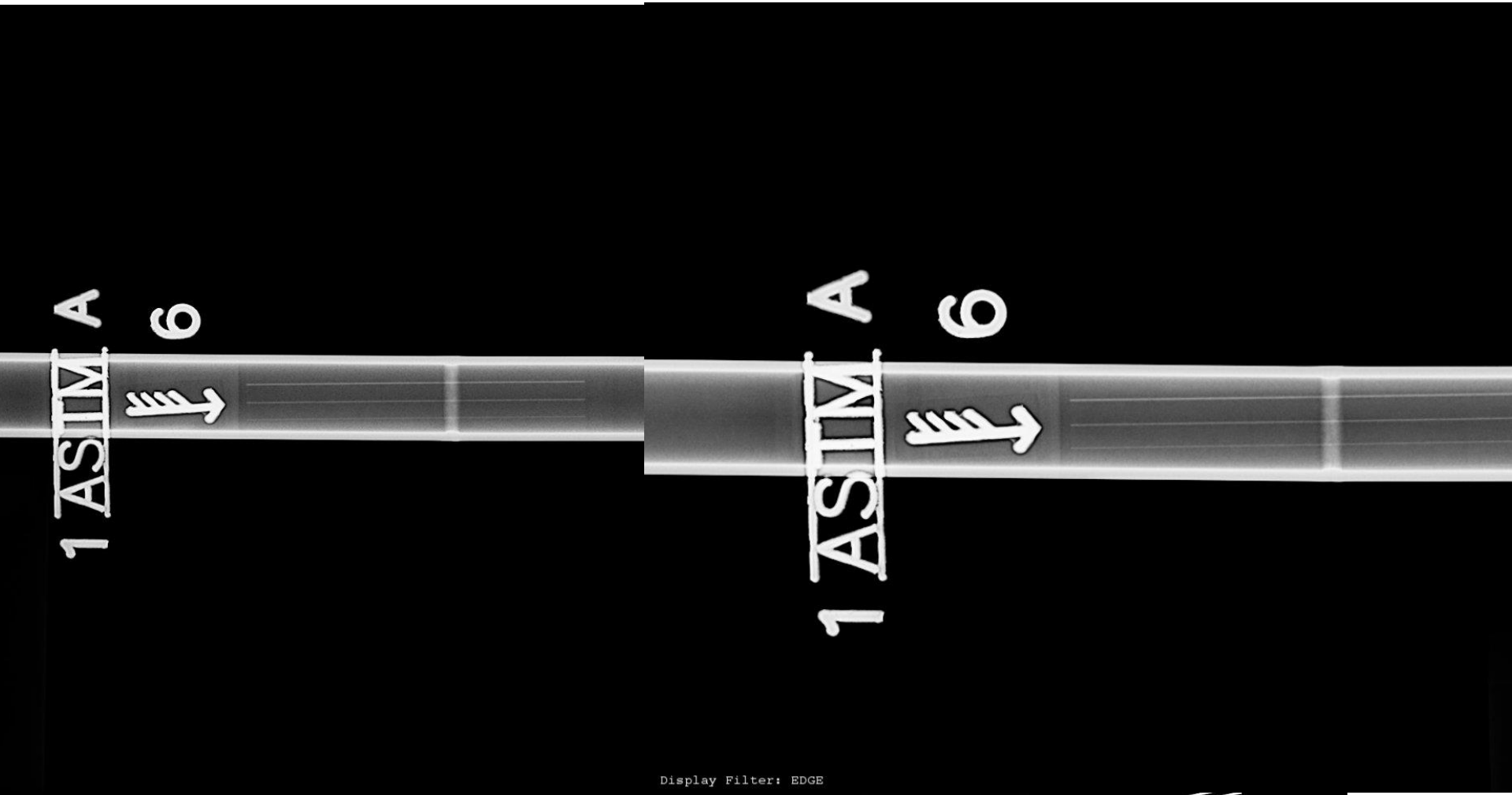
CR Comparison



CR Spatial Resolution



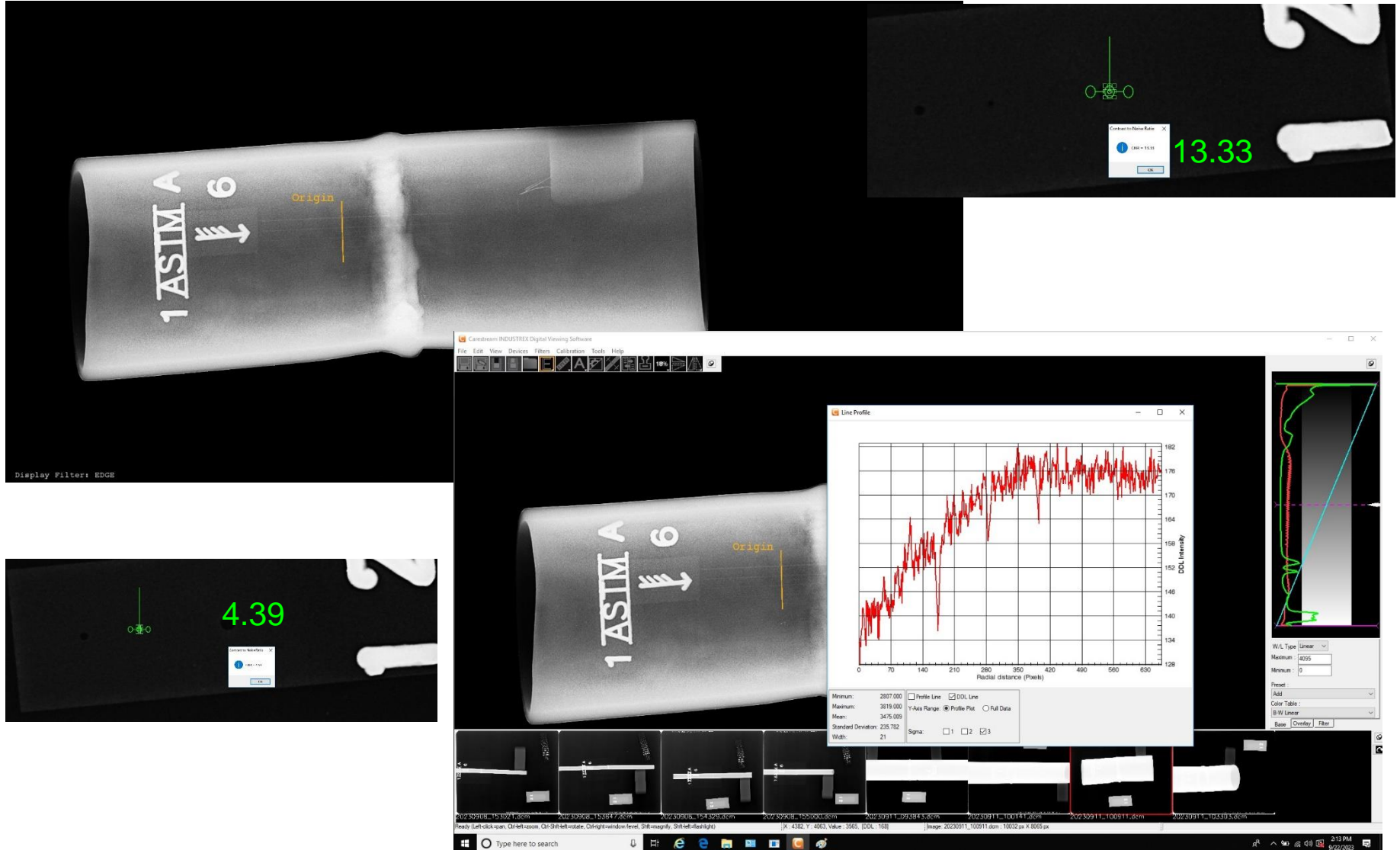
DR Comparison



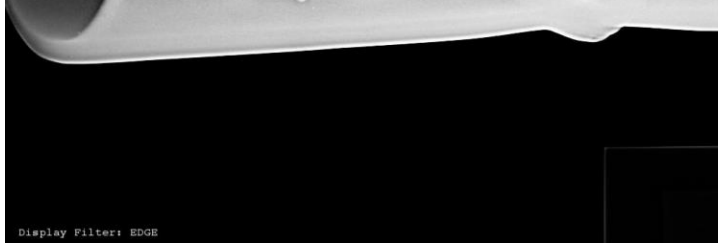
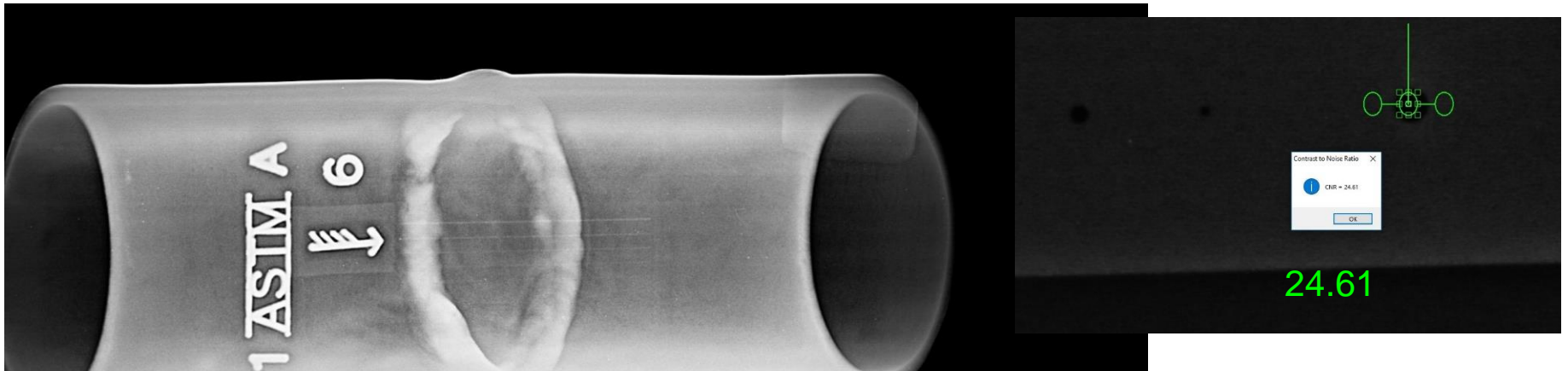
DR Spatial Resolution

The image displays two software windows for wire dip analysis. The left window, titled "Duplex Wire % Dip", shows a graph with a "Line Width: 1" and "Percent Dip: 93.5%". The x-axis is labeled "Radial distance" and ranges from 0 to 400. The y-axis ranges from 0 to 40000. A graph shows a series of peaks and valleys. A red vertical line is at approximately x=20, and a green vertical line is at approximately x=30. A blue horizontal line is at y=40000. The right window, also titled "Duplex Wire % Dip", shows a graph with a "Line Width: 1" and "Percent Dip: 91.8%". The x-axis is labeled "Radial distance" and ranges from 0 to 400. The y-axis ranges from 0 to 14000. A graph shows a series of peaks and valleys. A red vertical line is at approximately x=20, and a green vertical line is at approximately x=30. A blue horizontal line is at y=14000. A settings panel on the right shows "Despeckle: EDGE", "Image Class: HPX DR 1", "Brightness: -0.1", "Global Contrast: 1.0", and "Detail Contrast: 1.2". A "Sharpness" slider is also visible. The software interface includes a menu bar (File, Edit, View, Devices, Filters, Calibration, Tools, Help) and a toolbar. The Windows taskbar at the bottom shows various icons and the search bar.

CR CNR Pulse



CR CNR Xray



This is a screenshot of the Carestream INDUSTRIEX Digital Viewing Software interface. The main window displays the X-ray of the pipe. A "Line Profile" window is open, showing a graph of "DDL Intensity" versus "Radial distance (Pixels)". The graph shows a red line fluctuating between approximately 118 and 158 intensity units. The software interface includes a menu bar (File, Edit, View, Devices, Filters, Calibration, Tools, Help), a toolbar, and a status bar at the bottom with various parameters and file names.

Parameter	Value
Minimum	3554.000
Maximum	3801.000
Mean	3558.285
Standard Deviation	177.882
Width	21

DR CNR Pulse

The image displays a series of screenshots from the Carestream INDUSTRIEX Digital Viewing Software, illustrating the process of measuring Contrast to Noise Ratio (CNR) on a Digital Radiograph (DR) image. The primary image is an ASTM A661 radiograph, which includes a scale and the text "ASTM A 661".

Key elements shown in the screenshots include:

- Contrast to Noise Ratio (CNR) Measurement:** Two windows show the CNR value. One window displays a CNR of 23.30, and another displays a CNR of 10.33. The measurement is performed on a specific region of interest (ROI) within the radiograph.
- Line Profile Graph:** A graph titled "Line Profile" plots "DDL Intensity" (Y-axis, ranging from 130 to 170) against "Radial distance (Pixels)" (X-axis, ranging from 0 to 180). The graph shows a red line representing the intensity profile across the ROI. Below the graph, statistical data is provided:
 - Minimum: 6704.000
 - Maximum: 9025.000
 - Mean: 8357.089
 - Standard Deviation: 552.335
 - Width: 21
- Software Interface:** The screenshots show the software's menu bar (File, Edit, View, Devices, Filters, Calibration, Tools, Help) and various toolbars. The "Despeckle" and "EDGE" settings are visible on the right side of the interface.

DR CNR Xray

The image is a collage illustrating DR X-ray processing. It features a main X-ray of a forearm with a '12' marker and '1 ASIM' text. Two inset images show a 'Contrast to Noise Ratio' dialog box with values 46.81 and 27.63. A 'Line Profile' graph shows DDL Intensity vs Radial distance (Pixel). A software interface on the right shows various image processing parameters like Brightness, Contrast, and Sharpness.

Contrast to Noise Ratio

CNR = 46.81

CNR = 27.63

Line Profile

DDL Intensity

Radial distance (Pixel)

Maximum: 3062.000
Minimum: 6281.000
Mean: 3083.739
Standard Deviation: 301.090
Width: 21

Image Processing Parameters

Despeckle: EDGE
Image Class: SPX DR 2
Brightness: 0.1
Global Contrast: 0.9
Detail Contrast: 0.9
Sharpness: 1.0
Noise Reduction: 0.0
Segmentation:

Apply Current Setting
Revert To Previous
Save Current Setting As

EDGE
Apply filter setting
 Use display filter

Edge: Despeckle Filter

Conclusions

Pulse Xray in CR, represents a high use of the number of pulses and the consequence of rapidly consuming interchangeable tubes. At the same time, quality was downgrade to a limit of not pass CNR standards.

In both cases (Pulse- Xray) digital detector array radiography systems produced images with reduced noise, which resulted in higher contrast-to-noise ratios and improved detectability. This can minimize shot time and extend the practical working life of sources.

Carestream**NDT**