Experiences of users in Digital Radiography

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Computed Radiography Products & Applications

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Content

> Digital Conversion
> Advantages versus Film Radiography
> CR Scanners and Imaging Plates
> CR Standards
> Typical Applications
Digital Conversion
X-Ray Products

• Complete range of Agfa NDT X-ray films, equipment & chemistry
  – Exclusive provider of Agfa NDT X-ray film & associated equipment globally

• Full range of digital solutions
  – Film Digitization
  – Computed Radiography - CR
  – Digital Radiography - DR

• Seifert Source Systems
  – Portable ERESCO System
  – Stationary ISOVOLT HS System
Go digital...improve efficiency & accuracy

Create Digital Images

Film Digitizers scan film into digital images

CR Scanners

Computed Radiography scanners read CR plates to create digital images

DR Detectors

Direct Radiography provides ‘instant’ digital images

DR & Automation create additional efficiencies

Automated Solutions

Manage Digital Images

Rhythm™ Workstation

• Receives digital images from the Image Acquisition Station
• Allows location of defect indications
• Adds inspection results to images
• Saves results on archive media
• Connects to customer network for information storage or transmission
If the world of medical imaging and personal photography can convert to digital, what is delaying the industry?
Film to Digital Conversion

Industry Standards
First ASTM and CEN standards for CR were published in 2005

ASME code case 2476, refers specifically to CR for Film Replacement

Product & Image Quality
Technology innovation coming rapidly. Improvement in SNR, resolution, and speed over the last two years has enabled the use of CR in new applications

The new generation of imaging plates and systems is able to address ASME weld quality requirements

Productivity
Adoption based on productivity…eliminate consumables, environment friendly, reduce processing time, automate

Industry acceptance and knowledge is growing as digital systems are getting cheaper

Users are realizing that total cost savings over the life of the system more than offset the initial cost

Digital Radiography will grow very strongly in the coming years
Computed Radiography

Advantages versus Film Radiography
Computed Radiography
How does it work?

Step 1: The phosphor screen is inserted into a soft or hard cassette (with or without lead)

Step 2: A radiation pattern is exposed on the phosphor screen creating a latent image

Step 3: The phosphor screen is then inserted into a phosphor scanner to be read

Step 4: The phosphor screen is scanned and the digital image is displayed on the workstation monitor for review and evaluation

Step 5: The phosphor screen is then erased and ready to be reused
Film & CR Radiography Process
Set-Up & Exposure Similar: FILM PROCESS

Set Up

Exposure - X-ray or Isotope

Interpretation

Film Processing
Film & CR RT Process Set-Up & Exposure Similar – CR PROCESS

Set Up

Exposure - X-ray or Isotope
Shorter exposure time

Scanning

CR Tower

CR 100i

CR Voyager

Rhythm Software WS
Computed Radiography System Process

*Similarities* between Phosphor & Film

**Step 1:** The phosphor screen is inserted into a soft or hard cassette (with or without lead screens)

*Just like film*

**Step 2:** A radiation pattern is exposed on the phosphor screen creating a latent image

*Shot set-up and technique are basically the same*

**Step 3:** The phosphor screen is then inserted into a phosphor scanner to be read

*Very similar to film being put into a film processor*

**Step 4:** The phosphor screen is scanned and the digital image is displayed on the workstation monitor for review

*Film is put on a lightbox to view*

**Step 5:** The phosphor screen is then erased and ready to be reused
Computed Radiography System Process

**Differences** between Phosphor & Film

**Step 1:** The phosphor screen is inserted into a soft or hard cassette (with or without lead screens)

*Do not need a light-tight darkroom for phosphor imaging*

**Step 2:** A radiation pattern is exposed on the phosphor screen creating a latent image

*Phosphor is faster and much more forgiving (wide latitude)*

**Step 3:** The phosphor screen is then inserted into a phosphor scanner to be read

*No chemical or EPA issues; Film processor (8 minutes) vs. Phosphor (1 to 2 minutes)*

**Step 4:** The phosphor screen is scanned and the digital image is displayed on the workstation monitor for review

*Digital image can be enhanced increasing POD*

**Step 5:** The phosphor screen is then erased and ready to be reused

*The phosphor screens are reusable*
CR versus Film

- **Feature**
  - **Benefit**
  - **Lower Doses**
    - Smaller Safety perimeters
    - Shorter plant shut-downs
    - Longer life
  - **Easily availability digital images and data**
    - Data and images together on network
    - Easier and faster analysis of defects
    - Lower risk of lost data
  - **Light and robust Phosphor plates & Cassettes**
    - Can keep same workflow the customer is used to
  - **Flexible Imaging Plates**
    - Plates can be bent
CR versus Film

- Feature
  - Benefit
  
  • **Shorter exposure times (10-50% of Film)**
    – Time efficiency for resources, plant shut down, higher throughput
  
  • **Higher Dynamic Range**
    – Less retakes by bad exposure, different thicknesses in one shot…
  
  • **Reusable Phosphor plates**
    - No film needed: consumable cost saving
  
  • **No energy limitations**
    – Wide range of applications
  
  • **No chemicals, no darkroom**
    – Less expensive infrastructure (No EPA issues)
Conclusions

CR is a Workflow Solution that increases productivity

- Less Resources required
- Compact, Small Footprint
- Higher throughput
- Shorter Exposures
- Faster defect evaluation & decision making
- Data Management
- Archiving, Easy retrieval of images
- Networking & Electronic Sharing
- Easy Accessibility
Computed Radiography System consists of the following components:

- WORKSTATION & SOFTWARE
- PHOSPHOR SCANNER
- PHOSPHOR SCREENS
CR Scanners and Imaging Plates
Phosphor Scanners
How is the phosphor screen scanned?

He-Ne laser
rotating mirror
light-guide
PMT
storage phosphor plate
CRx Tower

> Proven reliability
> Automatic cassette handling for long IP life time
  (up to 3000 times reusable plates) 8x10/14x17
> Square root amplification to 12-bit A/D
> If 2X exposure, SNR ~ 2X
> NDT workhorse both Internally & in field
  > Approx 50 14”x17” plates/hr
> Standard Resolution 100 µm pixel pitch
  > Optional 50 micron resolution
> Transportable – On Wheels
CR 50P

Key Features

- 50µm pixel pitch (8 lp/mm)
- Flexible operation: 50µm, 100µm
- All size and shapes of plates up to 14
- Up to 4 plates can be read simultaneously
- High throughput – Fast scan time
- 16 bit dynamic range
  - Allows for different thickness and composite material
- High portability: 18” x 28” x 14”
  22 kg weight
CR50XP

Key Features

- 50µm pixel pitch (8 lp/mm)
- Flexible operation: 50µm, 100µm
- All size and shapes of plates up to 12 inch wide
- High throughput – Fast scan time
- 16 bit dynamic range
- High portability: 17” x 17” x 16,5”
  14 kg weight
- Ideal for field applications
Imaging plates
New developments

Objectives:
• Improved SNR (Signal to Noise ratio)
• Higher sharpness
• A faster ‘High Quality’ Plate
• Reach all classes in ASTM and CEN standards

Results:
• IPS: Superior sharpness and high SNR combined
  Faster exposure times than IPX
• IPC2: Higher image quality and better SNR than IPC,
  similar exposure times as IPC
Overview of GEIT imaging plates
(CRx Tower system)

Relative exposure time and SNR using X ray. Graph shows improvement in speed, SNR and sharpness of the new IPS and IPC2 imaging plates.
Phosphor particle size reduction: SEM image

IP-X and IP-C Phosphor

IP-S Phosphor

All large particles have been removed in the IP-S phosphor.
Computed Radiography Standards
CR Standardization
Overview of the different standards for CR

CEN standards:
EN 14784-1: Industrial CR with storage phosphor imaging plates
  Part 1: Classification of systems
EN 14784-2: Industrial CR with storage phosphor imaging plates
  Part 2: General principles for examination of metals using X-rays and gamma rays

ASTM standards:
ASTM 2007-00: Standard Guide for Computed Radiography
ASTM 2033-99: Standard Practice for Computed Radiography
ASTM 2445-05: Standard Practice for Qualification and Long-Term Stability of CR systems
ASTM 2446-05: Standard Practice for Classification of CR systems
ASTM 2339-04: Digital Imaging and Communication in NDE (DICONDE)

ASME code:
ASME Code Case 2476: Radiography using phosphor imaging plates
CR Stanardization

Characterization by
- SNR
- Spatial resolution
e.g. IP 3/200

**Table 1: CR System classes depending on the minimum SNR**

<table>
<thead>
<tr>
<th>IP System classes</th>
<th>System class CEN</th>
<th>System class ISO</th>
<th>System class ASTM</th>
<th>Minimum Signal-noise ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP 1</td>
<td></td>
<td></td>
<td>IP-AS Special</td>
<td>130</td>
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<tr>
<td>IP 2</td>
<td></td>
<td>IP-T1</td>
<td></td>
<td>117</td>
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<td>IP 3</td>
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<td>IP-AS 1</td>
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<td>65</td>
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<td>IP 5</td>
<td>IP-T3</td>
<td>IP-AS 2</td>
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<tr>
<td>IP 6</td>
<td>IP-T4</td>
<td>IP-AS 3</td>
<td></td>
<td>43</td>
</tr>
</tbody>
</table>

New table with 6 system classes CEN, ASTM, ISO
CR Standarization

Effect of signal to noise ratio (SNR)

Loss of information / perceptibility
Standards Certification : Status
CRx Tower / IPS achieve class IP1/IP-AS Special, the highest class

\[ y = 69,415 \ln(x) + 93,477 \]
\[ R^2 = 0.9922 \]
Case 2476

Radiography Using Phosphor Imaging Plate, Section V

Inquiry: Is it permissible to perform radiography in accordance with Article 2 using a phosphor imaging plate in lieu of film?

Refers to Section V Article 2 (Film radiography)
ASME Section V Article 2

IQI requirements: 2T hole must be displayed

T-283  IQI Sensitivity

T-283.1 Required Sensitivity. Radiography shall be performed with a technique of sufficient sensitivity to display the designated hole IQI image and the 2T hole, or the essential wire of a wire IQI. The radiographs shall also display the IQI identifying numbers and letters. If the designated hole IQI image and 2T hole, or essential wire, do not show on any film in a multiple film technique, but do show in composite film viewing, interpretation shall be permitted only by composite film viewing.
# ASME Section V Article 2

## ASME Hole IQI data

<table>
<thead>
<tr>
<th>Source</th>
<th>WT (mm)</th>
<th>WT (inch)</th>
<th>IPS</th>
<th>Requirement</th>
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</thead>
<tbody>
<tr>
<td>X-Ray</td>
<td>5</td>
<td>0.20</td>
<td>2-1T</td>
<td>2-2T</td>
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<tr>
<td>X-Ray</td>
<td>10</td>
<td>0.39</td>
<td>2-1T</td>
<td>2-2T</td>
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<tr>
<td>X-Ray</td>
<td>15</td>
<td>0.59</td>
<td>2-1T</td>
<td>2-2T</td>
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<td>X-Ray</td>
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<td>0.79</td>
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<td>2-2T</td>
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<tr>
<td>X-Ray</td>
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<td>1.18</td>
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<td>2-2T</td>
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<tr>
<td>Se75</td>
<td>5</td>
<td>0.20</td>
<td>2-2T</td>
<td>2-2T</td>
</tr>
<tr>
<td>Se75</td>
<td>10</td>
<td>0.39</td>
<td>2-2T</td>
<td>2-2T</td>
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<tr>
<td>Se75</td>
<td>15</td>
<td>0.59</td>
<td>2-2T</td>
<td>2-2T</td>
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<tr>
<td>Se75</td>
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<td>0.79</td>
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<td>Se75</td>
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<td>0.98</td>
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<td>Se75</td>
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<td>1.18</td>
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<td>2-2T</td>
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<td>Ir192</td>
<td>15</td>
<td>0.59</td>
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<td>Ir192</td>
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<td>0.98</td>
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<tr>
<td>Ir192</td>
<td>30</td>
<td>1.18</td>
<td>2-2T</td>
<td>2-2T</td>
</tr>
</tbody>
</table>
ASME Section V Article 2

X-ray data

Wire sensitivity, ASME (X ray)

Object thickness (inch)

Equivalent wire sensitivity (inch)

CR50P / IPS

ASME compliance

ASME V requirement
ASME Section V Article 2

Selenium data

Wire sensitivity, ASME (Selenium)

Object thickness (inch)

Equivalent wire sensitivity (inch)

CR50P / IPS

ASME compliance

ASME V requirement
ASME Section V Article 2

Iridium data

Wire sensitivity, ASME (Iridium)

Object thickness (inch)

Equivalent wire sensitivity (inch)

CR50P / IPS

ASME compliance

ASME V requirement
Computed Radiography
Typical Applications
Applications 1

On Stream Inspection

> Problem
  – Leaking pipes expensive if detected too late
  – Plant shut downs are costly & time consuming

> Solution
  – IPC2
  – Rhythm + Wall thickness Measurement Tool
  – CUI inspection – no need to remove insulation
  – Faster exposures resulting in shorter plant shutdowns, allowing more inspection and smaller security areas
  – On-site scanning giving immediate results
  – High Dynamic range avoiding retakes
  – Automatic wall thickness measurement giving fast, repeatable and accurate status of the pipes
  – Lower energy needed (Ir192 instead of Co60)
Applications 2

Weld Inspection

> Problem
  » Inspection of welds (X Ray AND Isotopes)
  » Reaching sensitivity
  » Standards

> Solution
  » **IPS**
  » Shorter exposures resulting in faster inspection
  » On-site scanning give immediate results
  » High Dynamic range avoids retakes
Applications 3

Aerospace: composite materials

> Solution:
  – **IPS**
  – High Dynamic range of CR captures the whole range in one image.
  – Short exposure times gives up to 6 times faster result.
  – Rhythm with bi- or tri-pack solution
Applications 4

Casting Inspection

> Solution:
  - IPS
  - Automated workflow avoids human error and increases throughput

- High dynamic range gives all thickness in one image
Applications 5

Security - Inspection of suspicious objects left in public places

> Solution :
  – Portable total solution: CR50XP & IPC2
Corrosion monitoring

Weld inspection
Wall Thickness measurement

Overview

• 2 techniques for wall thickness evaluation in digital radiography
  • Tangential Projection technique (edge detection), absolute method
  • Double Wall technique (calibration with 2 known wall thicknesses), relative method

• Insulation and media tolerable, on-stream inspection

• Computer based evaluation algorithms:
  • higher precision of measurement
  • digital archiving, direct inclusion into reports, data base access to inspection results
  • reduction of exposure time with digital detectors
Wall Thickness measurement - Tangential

Workflow for corrosion inspection

Tangential wall thickness measurement

Calculates thickness from line profile

- Measurements are indicated
- Wall thickness is calculated
- Results are reported

Tolerance < 0.2-0.5 mm
## Third Party Validation by BAM - Scope

<table>
<thead>
<tr>
<th>DN 50, outer diameter Ø 60,3 mm</th>
</tr>
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<tbody>
<tr>
<td>step number (wall thickness):</td>
</tr>
<tr>
<td>1 (1,0 mm)</td>
</tr>
<tr>
<td>2 (2,0 mm)</td>
</tr>
<tr>
<td>3 (2,9 mm)</td>
</tr>
<tr>
<td>4 (3,8 mm)</td>
</tr>
<tr>
<td>5 (4,5 mm)</td>
</tr>
<tr>
<td>6 (5,6 mm)</td>
</tr>
<tr>
<td>7 (6,3 mm)</td>
</tr>
<tr>
<td>- empty</td>
</tr>
<tr>
<td>- empty with insulation Ø 180 mm</td>
</tr>
<tr>
<td>- filled with H₂O</td>
</tr>
<tr>
<td>- filled with H₂O and with insulation Ø 180 mm</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>DN 100, outer diameter Ø 114 mm</th>
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</thead>
<tbody>
<tr>
<td>step number (wall thickness):</td>
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<tr>
<td>2 (2,0 mm)</td>
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<tr>
<td>3 (2,9 mm)</td>
</tr>
<tr>
<td>4 (4,5 mm)</td>
</tr>
<tr>
<td>5 (5,6 mm)</td>
</tr>
<tr>
<td>6 (6,3 mm)</td>
</tr>
<tr>
<td>7 (8,0 mm)</td>
</tr>
<tr>
<td>- empty</td>
</tr>
<tr>
<td>- empty with insulation Ø 320 mm</td>
</tr>
<tr>
<td>- filled with H₂O</td>
</tr>
<tr>
<td>- filled with H₂O and with insulation Ø 320 mm</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>DN 200, outer diameter Ø 219 mm</th>
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<td>step number (wall thickness):</td>
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<td>1 (1,0 mm)</td>
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<td>2 (2,0 mm)</td>
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<td>3 (2,9 mm)</td>
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<tr>
<td>4 (4,5 mm)</td>
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<td>5 (5,6 mm)</td>
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<tr>
<td>6 (6,3 mm)</td>
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<tr>
<td>7 (8,0 mm)</td>
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<tr>
<td>- empty</td>
</tr>
<tr>
<td>- empty with insulation Ø 470 mm (ISO 470)</td>
</tr>
<tr>
<td>- filled with H₂O</td>
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<tr>
<td>- filled with H₂O and with insulation Ø 470 mm</td>
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<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
<tr>
<td>25%, 100%, 400% and 800% exposure time</td>
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</table>

<table>
<thead>
<tr>
<th>DN 300, outer diameter Ø 320 mm</th>
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</thead>
<tbody>
<tr>
<td>step number (wall thickness):</td>
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<td>1 (4 mm)</td>
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<tr>
<td>2 (8 mm)</td>
</tr>
<tr>
<td>3 (10 mm)</td>
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<tr>
<td>4 (12 mm)</td>
</tr>
<tr>
<td>empty</td>
</tr>
<tr>
<td>25%, 100%, 400% exposure time</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DN 400, outer diameter Ø 405 mm</th>
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<tbody>
<tr>
<td>step number (wall thickness):</td>
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<tr>
<td>1 (5 mm)</td>
</tr>
<tr>
<td>empty</td>
</tr>
<tr>
<td>55 s, 200 s, 280 s exposure time</td>
</tr>
<tr>
<td>15 s, 55 s, 280 s exposure time</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DN 500, outer diameter Ø 510 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>step number (wall thickness):</td>
</tr>
<tr>
<td>1 (6 mm)</td>
</tr>
<tr>
<td>empty</td>
</tr>
<tr>
<td>15 s, 70 s, 260 s exposure time</td>
</tr>
</tbody>
</table>
Validation - Results

- **Maximum deviation of 0.2 mm**
  - DN 50: up to 6 mm wall thickness for all conditions (empty, filled with water or additional insulation)
  - DN 100: up to 5 mm wall thickness for all conditions (empty, filled with water or additional insulation)
  - DN 200: up to 4 mm wall thickness for all conditions (empty, filled with water or additionally insulation)
  - DN 300: below 4 mm wall thickness

- **Maximum deviation of 0.5 mm**
  - DN 100: from 5 to over 8 mm wall thickness for all conditions (empty, filled with water or additional insulation)
  - DN 200: from 4 to 8 mm wall thickness for empty pipe and up to 6 mm for water filled pipe
  - DN 300: up to 6 mm for empty pipe

- **Application limit of projection technique with Ir-192 : \( L_{\text{max}} = 80\text{mm} \)**
  - Contrast and SNR decrease with increasing wall thickness
  - Sufficient contrast and SNR are required to detect the point with maximum thickness
Weld inspection with CR

10"x11mm C/S weld
160kV 2mA CP Pan 5s
No Pb screens Medium Gain

1.5% sensitivity
10 mm Steel Weld_160kV_5mA_180s_FFD700

Gas Porosities/Slag Inclusions

Undercut
Thank you for your attention