New approach for X-ray weld inspection of pipeline segments

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Overview

- Weld inspection in heavy industries (Pipe and Tank)
- Analogue Film – “The old approach”
- Transition to digital Radiography
  - The international standards
  - Detectors (DDA) – Form factor and Read Out Speed
- New setup with DDA’s
- The next automation level – Feed-thru system
- Commercial Analysis and comparison
- Conclusion
Pipe Manufacturing
Material flow SAW Pipes

Welding

- Tack Weld
- Inseam-welding
- Outer seam-welding

Hydro testing

- Grinding of Weld ends
- Mechanical Expanding
- X-ray Testing
- Ultrasonic testing

Adjustage

- Ultrasonic testing
- X-ray Testing
- Chamfering
- MPI Or UT
- End control
Material flow SAW Pipes

- Ultrasonic testing as an upstream method for weld inspection

- Depending on standards or customer request X-ray test
  - Only at UT indications
  - Inspection of both ends of the welding line
  - Random inspection of a certain percentage of the welding line
  - Inspection of the complete welding line
Setup in reality
Pipe inspection with Film – 1. Setup

1. Xray
2. Xray
3. Xray
4. Xray
5. Xray

Pipe
Boom
Classic X-ray setup: Film

- X-ray Tube
- Device under Test
- Film
## Classic X-ray setup: Film

<table>
<thead>
<tr>
<th>Pro</th>
<th>Contra</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Easy to handle</td>
<td>- Continous cost</td>
</tr>
<tr>
<td>- Less startup investments</td>
<td>- Offline development</td>
</tr>
<tr>
<td></td>
<td>- Needs chemicals (environment, storage)</td>
</tr>
<tr>
<td></td>
<td>- Quality depends on the quality of developing chemicals and human factor</td>
</tr>
<tr>
<td></td>
<td>- Long exposure time</td>
</tr>
</tbody>
</table>
Digital Detector Array (DDA)
Pipe inspection with DDA

**Xray**

Scan along the pipe

**Pipe**

**Boom**
Pipe inspection with DDA

Pipe

Scan along the pipe

Boom

Xray
### Pipe inspection with DDA (flat panel)

#### Pro
- Easy to handle
- Low continuous costs
- No consumables
- Immediate results of the X-ray test
- Live investigations at the weld
- No chemicals
- Short exposure time

#### Contra
- Trained operators are necessary (Digital Radiography qualification)
- X-ray equipment is different to film exposure (focal spot must be smaller)
Transition strategy

The transition from analog to digital is straightforward.

**BUT**

you must take a lot of things in consideration to be successful.
• API 5L takes only the contrast into consideration!
• The so called Wire IQI’s are used to show that you fulfill the standard
Standards for pipe inspection (API 5L/Shell/DNV)

Wire IQI
The newest release of API5L takes DDA´s in consideration:

- Relation to the ISO standard ISO 10893-7:2011

- This standard is now referring to contrast resolution and geometrical resolution

- This standard has 2 different weld classes
  - API5L is classical the lower class A
  - **BUT** most high-end manufacturers are testing according the higher Class B
**Geometrical resolution with Double Wire IQI**

a) Abbildung des Doppeldraht-BPK in einem Durchstrahlungsbild

b) Aus mindestens 21 Zeilen gemitteltes Profil des Doppeldraht-BPK
ISO 10893-7 defines the maximum unsharpness of the system.

Be aware that the critical question is the minimum thickness of the Material!
Geometrical resolution with Double Wire IQI

a) Abbildung des Doppeldraht-BPK in einem Durchstrahlungsbild

b) Aus mindestens 21 Zeilen gemitteltes Profil des Doppeldraht-BPK

d) Calculation of the dip (in %) by: dip = 100 x dip amplitude/background amplitude
Be aware
The dip (2) must be a minimum of 20% of the maximum (1)

This calculation has to be done by Software and not by human eyes
## API 5L – With ISO 10893-7:2011

<table>
<thead>
<tr>
<th>z and t (mm)</th>
<th>API 5L</th>
<th>ISO 10893-7:2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 1,0</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 1,2</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 1,5</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 2,0</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 2,5</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 3,0</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 3,5</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 4,0</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 4,5</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 5,0</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 5,5</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 6,0</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 7,0</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 8,0</td>
<td>A4</td>
<td>W14</td>
</tr>
<tr>
<td>≤ 9,0</td>
<td>A5</td>
<td>W13</td>
</tr>
<tr>
<td>≤ 9,5</td>
<td>A5</td>
<td>W13</td>
</tr>
<tr>
<td>≤ 10</td>
<td>A5</td>
<td>W13</td>
</tr>
<tr>
<td>≤ 11</td>
<td>A5</td>
<td>W13</td>
</tr>
<tr>
<td>≤ 12</td>
<td>A6</td>
<td>W12</td>
</tr>
<tr>
<td>≤ 13</td>
<td>A6</td>
<td>W12</td>
</tr>
</tbody>
</table>
ISO 10893-7:2011 – Flat panel

Sample 10 mm Steel – Weld Class B

**API 5L**

- Asks for:
  - Wire: W13
  - Double wire: Not defined

**ISO 10893-7**

- Asks for:
  - Wire: W14
  - Double wire: D11

**Perkin Elmer XRD822**

- 200 µm Pixel size

- Wire: W15
- Doublewire IQI: D7

Is OK!

Is NOK!
ISO 10893-7:2011 – Flat panel

Sample 10 mm Steel – Weld Class B

API 5L

Asks for:
Wire : W13
Double wire : Not defined

Is OK!

Varian Panel
127 μm Pixelsize

Wire : W16
Doublewire IQI : D9

ISO 10893-7

Asks for:
Wire : W14
Double wire : D11

Is OK!
ISO 10893-7:2011 – Flat panel

Sample 10 mm Steel – Weld Class B

API 5L
Asks for:
Wire : W13
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ISO 10893-7
Asks for:
Wire : W14
Double wire : D11

Varian Panel
127 µm Pixelsize

Wire : W16
Doublewire IQI : D9

Is OK!

Why it is ok?
ISO 10893-7:2011 — Compensation

Varian Panel
127 µm Pixel size

ISO 10893-7

Asks for:

Wire : W16
Doublewire IQI : D9

Compensation:

When you have too less resolution you can compensate with higher contrast sensitivity!

D9 is two stages too low (D11 required)
W16 are two stages too high (W14 required)
Signal to Noise Ratio

Beside the visibility of defects you must guarantee that you’re your noise level is low enough – Or your signal has a minimum ratio compared to the noise

<table>
<thead>
<tr>
<th>Strahlenquelle</th>
<th>Durchstrahlte Werkstoffdicke ( \bar{v} ) mm</th>
<th>Mindest-SNR(_N) ( ^{\circ} )</th>
<th>Klasse A</th>
<th>Klasse B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spannung des Röntgenstrahlers ( \leq 50 \text{ kV} )</td>
<td>100</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spannung des Röntgenstrahlers ( &gt; 50 \text{ kV bis 150 kV} )</td>
<td>70</td>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spannung des Röntgenstrahlers ( &gt; 150 \text{ kV bis 250 kV} )</td>
<td>70</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spannung des Röntgenstrahlers ( &gt; 250 \text{ kV bis 360 kV} )</td>
<td>( \leq 50 )</td>
<td>70</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Spannung des Röntgenstrahlers ( &gt; 350 \text{ kV bis 1000 kV} )</td>
<td>( &gt; 50 )</td>
<td>70</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

Min SNR required
From the image

\[
\text{SNR}_N = \frac{\text{SNR}_{\text{measured}}}{\text{SR}_b} \\
\text{SNR}_{\text{measured}} = \frac{88.6 \mu m}{\text{SR}_b}
\]

Meanvalue
Standard deviation

Tabelle D.1 — Erforderliche \( \text{SNR}_{\text{measured}} \)-Werte für ausgewählte CR-Systeme mit unterschiedlichen \( \text{SR}_b \), die den jeweiligen \( \text{SNR}_N \)-Werten äquivalent sind

<table>
<thead>
<tr>
<th>Systemparameter</th>
<th>Hochauflösendes System</th>
<th>Standardsystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doppeldraht-BPK-Qualifizierung</td>
<td>13+ 13 12 11 10 9</td>
<td>8 7 6</td>
</tr>
<tr>
<td>Basis-Ortsauflösung ( \text{SR}_b )</td>
<td>40 ( \mu m ) 50 ( \mu m ) 63 ( \mu m ) 80 ( \mu m ) 100 ( \mu m ) 130 ( \mu m )</td>
<td>160 ( \mu m ) 200 ( \mu m ) 250 ( \mu m )</td>
</tr>
</tbody>
</table>
ISO 10893-7:2011 – SNR
Choice of the detector

Which DDA for which wall thickness and Class B?

<table>
<thead>
<tr>
<th>Min. Wallthickness</th>
<th>Pixelsize</th>
<th>DDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mm</td>
<td>75µm</td>
<td>Dexela (CsI) 1512</td>
</tr>
<tr>
<td>10 mm (Comp)</td>
<td>127 µm</td>
<td>Varex Imaging PaxScan 2520DX</td>
</tr>
<tr>
<td>60 mm</td>
<td>200 µm</td>
<td>Perkin Elmer XRD822</td>
</tr>
</tbody>
</table>

Besides the choice of the detector the system design plays a big factor
Old design

A heavy boom is carrying the film or DDA (1000 kg)

Pipes feed in and out is always in the same direction
New design – The boom

- Carbon
- Less than 100 kg
- Panel is inside the boom
- Panel is protected
- Easy cooling

- Min. inner diameter : 190 mm
New design – Termination type
New design – Feed thru type
The change from film to digital technique is mainly driven by reducing the cycle time, eliminating the film with its wet development area and at least also human resources.

**Sample calculation with 3 different setups:**
We assume that we have 12m LSAW pipe with 15 mm wall thickness.
The gate is opened.
The bunker is empty.
100% test of the weld.
300 working days per year.
50 € per hour labour costs per employee
5 € per 48 cm film incl. development.
## Costs

<table>
<thead>
<tr>
<th>Step</th>
<th>Film 6*48 cm</th>
<th>2520 panel – terminus mode</th>
<th>2520 panel feed thru mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move pipe in</td>
<td>60 sec</td>
<td>60 sec</td>
<td>60 sec</td>
</tr>
<tr>
<td>Close Gate</td>
<td>25 sec</td>
<td>25 sec</td>
<td>25 sec</td>
</tr>
<tr>
<td>Placing the film</td>
<td>120 sec</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>X-ray On</td>
<td>3 sec</td>
<td>3 sec</td>
<td>3 sec</td>
</tr>
<tr>
<td>Expose</td>
<td>(1200/40) * 30 sec</td>
<td>(1200/23) * 4 sec</td>
<td>(1200/23) * 4 sec</td>
</tr>
<tr>
<td>Move to Position</td>
<td>((1200/40)-1) * 3 sec</td>
<td>((1200/23)-1) * 2 sec</td>
<td>((1200/23)-1) * 2 sec</td>
</tr>
<tr>
<td>X-ray Off</td>
<td>3 sec</td>
<td>3 sec</td>
<td>3 sec</td>
</tr>
<tr>
<td>Open Gate</td>
<td>25 sec</td>
<td>25 sec</td>
<td>25 sec</td>
</tr>
<tr>
<td>Move pipe Out</td>
<td>60 sec</td>
<td>60 sec</td>
<td>60 sec</td>
</tr>
<tr>
<td>Move pipe to Wait position</td>
<td>60</td>
<td>60 sec</td>
<td>60 sec</td>
</tr>
<tr>
<td>Sum</td>
<td>22 min</td>
<td>9 min</td>
<td>8 min</td>
</tr>
<tr>
<td>2.5 pipes/ hour</td>
<td></td>
<td>6 pipes/hour</td>
<td>7.8 pipes/ hour</td>
</tr>
<tr>
<td>20 pipes/ shift</td>
<td></td>
<td>48 pipes/ shift</td>
<td>60 pipes/ shift</td>
</tr>
<tr>
<td>Cost’s of Material</td>
<td>(1200/40)<em>2</em>5 € = 3000 €</td>
<td>0 €</td>
<td>0 €</td>
</tr>
<tr>
<td>Costs HR</td>
<td>2<em>8</em>50 € = 800 €</td>
<td>1<em>8</em>50 € = 400 €</td>
<td>1<em>8</em>50 € = 400 €</td>
</tr>
<tr>
<td>Per shift</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost’s per year with one shift</td>
<td>1.140.000 € per year</td>
<td>120.000 € Per year</td>
<td>120.000 € Per year</td>
</tr>
<tr>
<td>Cost’s per year with 2 shifts</td>
<td>2.280.000 € per year</td>
<td>120.000 € Per year</td>
<td>120.000 € Per year</td>
</tr>
</tbody>
</table>
Conclusion

Change over from an existing film setup to a brand new digital bunker will bring a Return on Invest in less than 2 years!

Beside the commercial facts there are several soft facts:

- Higher test quality
- Faster feedback of identified defect inside the weld
- Protection of the environment
- Better reputation on the market because of better results.
- Access to other “high-end demanding” customers, because of improved inspection quality
- Higher prices for sold products.
Thanks for your attention

Any questions or feedback?

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