Profile shots on heavy wall pipes with digital radiography (CR/DR) and portable betatrons

Dennis Zaal

GE’s 11th X-Ray Forum in Cologne, July 7th – July 9th 2015
specialized in inspection, repair and maintenance. Pipeline owners bring in IRM Systems when:

- **Looking to minimize overall downtime on their critical lines, including unplanned repairs**
- **Frustrated that inspection, repair and maintenance costs are eating into a business case**
- **Searching for independent, impartial advice and field engineering on integrity (procedures, prices etc.)**

**Services we provide** – *engineering, design, project management, and technical advisory services* on pipeline integrity: from pre-commissioning to end-of-life.
Interest raised by Total E&P NL to perform digital profile radiography on bigger diameter and heavy wall pipes

This by use of a portable 2.5 MeV betatron to replace Co-60

09 & 10th December 2014 tests at JME
Parties involved

- **JME**
  - Provision of the portable betatron and bunker facilities
  - James Denton

- **GE**
  - Provision and operation of digital radiography equipment
  - Stephen Alderton

- **Klift**
  - Manufacturing of test samples and shipment
  - Peter van der Klift

- **Total**
  - Client and witnessing of tests
  - Bas Vrijbergen

- **Applus RTD**
  - NDT company
  - Martijn Hol, Henri van Bavel

- **IRM Systems**
  - Managing project and radiography expertise
  - Dennis Zaal
Equipment: JME 2.5 MeV Betatron

Technical data of the 2.5 MeV betatron:

- Peak energy of accelerated electrons, not less than 2.5 MeV
- Bremsstrahlung dose rate at 1 m distance
  - 7 mSv/min (0.7 R/min)
  - 10 mSv/min (1 R/min)
  - 600 mSv/hr
- Focal spot: 0.2 x 2 mm
- Adjustment range of energy of accelerated electrons: 1.0 – 2.5 MeV
- Penetrated thickness of steel: 30 – 120 mm

Dimensions of betatron units and weight:

- Radiator: 440 x 300 x 150 mm, 31 kg
- Power unit: 445 x 245 x 390 mm, 20 kg
- Control panel: 235 x 200 x 115 mm, 1.5 kg
- Pulse converter: 415 x 205 x 240 mm, 10.5 kg
Equipment: JME 7.5 MeV Betatron

Technical data of the 7.5 MeV betatron:

- Peak energy of accelerated electrons, not less than 7.5 MeV
- Bremsstrahlung dose rate at 1 m distance: 50 mSv/min (5 R/min)
  67 mSv/min (6.7 R/min)
  4020 mSv/hr
- Focal spot: 0.3 x 3 mm
- Adjustment range of energy of accelerated electrons: 2.0 – 7.5 MeV
- Penetrated thickness of steel: 50 - 200 mm

Dimensions of betatron units and weight:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Dimensions (mm)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiator</td>
<td>700 x 430 x 355</td>
<td>110 kg</td>
</tr>
<tr>
<td>Power unit</td>
<td>555 x 370 x 480</td>
<td>69 kg</td>
</tr>
<tr>
<td>Control panel</td>
<td>130 x 200 x 35</td>
<td>1 kg</td>
</tr>
</tbody>
</table>
Equipment: GE DR panel DXR250U-W and CRxVision

Panel GE DXR250U-W

GE CRxVision
Test samples: Heavy wall pipes

16 inch schedule 80 (406.4 mm x 21.4 mm)

12 inch schedule 160 (323.9 mm x 33.3 mm)

50 x 50 mm outside of the pipe with depths of 10%, 20%, 30%, 40% and 50% curved with pipe diameter

50 x 50 mm inside of the pipe with depths of 10%, 20%, 30%, 40% and 50% curved with pipe diameter.

20 mm diameter flat bottom holes from inside of the pipe with depths of 20%, 40%, 60%, 80% and 100% (through hole)
Maximum penetrated thickness

Wmax for 12 inch schedule 160 (323,9 mm x 33,3 mm) is 197 mm
Wmax for 16 inch schedule 80 (406,4 mm x 21,4 mm) is 182 mm

Maximum penetrated thickness of the 2.5 MeV betatron and Co-60 is ~120 mm of steel
Maximum penetrated thickness of the 7.5 MeV betatron is ~200 mm of steel
Typical test set-up

Shots performed both with CR and DR.

Flash! filter used and fine tuning
12 inch schedule 160 tests results: 2.5 MeV

12 inch schedule 160 outside steps 2.5 MeV DR panel (4 frames 120 s)

12 inch schedule 160 inside steps 2.5 MeV CR (1200 s)

12 inch schedule 160 inside holes 2.5 MeV DR panel (1 frame 120 s)
12 inch schedule 160 tests results: 7.5 MeV

12 inch schedule 160 inside inside steps 7.5 MeV DR panel (4 frames 30 s)
16 inch schedule 80 tests results

16 inch schedule 80 outside steps 2.5 MeV DR panel (4 frames 60 s)

16 inch schedule 80 inner steps 2.5 MeV DR panel (4 frames 60 s)

16 inch schedule 80 inner steps and holes 2.5 MeV CR (600 s)
Pipe in pipe: 7.5 MeV

Pipe in pipe 12 inch pipe inside 16 inch with 12 inch outside steps 7.5 MeV DR panel (4 frames 30 s)
Pipe in pipe: 7.5 MeV

Pipe in pipe 12 inch pipe inside 16 inch with 12 inch inside steps 7.5 MeV DR panel (4 frames 30 s)
6 inch JME piece with WT ~17 mm: 2.5 MeV DR panel (4 frames 60 s)
Penetrated thickness ~102 mm
12 JME sample WT ~16.5 mm

12 inch JME piece 2.5 MeV DR panel (4 frames 60 s)
Penetrated thickness ~143 mm
<table>
<thead>
<tr>
<th></th>
<th>Barrier distance [m]</th>
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<tr>
<td></td>
<td>Direct in bundle</td>
</tr>
<tr>
<td></td>
<td>7.5 $\mu$Sv/hr 10 $\mu$Sv/hr</td>
</tr>
<tr>
<td>Co-60</td>
<td>42 36</td>
</tr>
<tr>
<td>2.5 MeV betatron</td>
<td>283 245</td>
</tr>
<tr>
<td>7.5 MeV betatron</td>
<td>732 634</td>
</tr>
<tr>
<td>Absorbtion material needed</td>
<td>Direct in bundle</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>7.5 µSv/hr</td>
<td>10 µSv/hr</td>
</tr>
<tr>
<td>HVT</td>
<td>Steel [mm]</td>
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<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Co-60 [0.5 Ci]</td>
<td>9.8x</td>
</tr>
<tr>
<td>Co-60 [1.0 Ci]</td>
<td>10.8x</td>
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<tr>
<td>2.5 MeV betatron</td>
<td>16.3x</td>
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<tr>
<td>7.5 MeV betatron</td>
<td>19x</td>
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<table>
<thead>
<tr>
<th>Absorbtion material needed</th>
<th>Behind betatron</th>
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<tbody>
<tr>
<td>7.5 µSv/hr</td>
<td>10 µSv/hr</td>
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<tr>
<td>HVT</td>
<td>Steel [mm]</td>
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<tr>
<td>2.5 MeV betatron</td>
<td>13.6x</td>
</tr>
<tr>
<td>7.5 MeV betatron</td>
<td>14.5x</td>
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</table>
Conclusion and recommendations

Conclusion
• Good image quality with portable betatrons

2.5 MeV
• 120 mm penetrated thickness is good reference for 2.5 MeV for profile radiography
• Barrier of ~100 meters or >150 mm lead is not feasible for offshore platforms

7.5 MeV
• 200 mm penetrated thickness was able to penetrate pipe in pipe situations
• Too heavy for offshore purposes
• Ideal for specific projects

CR and DR
• Difference in image quality of the CR and DR systems was hardly visible.
• DR 10 times faster then CR

Recommendations
• For heavy wall pipes recommendation is contact shots and C-scan
• Perform tests with Co-60 for comparisation