Session 5C (2) – Applications
Chairman – Mr C Bird

10.25 Digital Radiography for High Energy NDT Applications
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Portable Digital Radiography (DR) surpasses film/film replacements by providing many additional benefits to users. This advanced technology, currently also recognized via new NDT standards, enables super detailed results and provides the basis for high level of NDT analysis. Yet the detectors available with this kind of technology are usually limited to working with limited levels of energy.

Vidisco’s portable amorphous Silicon flat panel systems are especially designed so that one can work with high energy levels and isotopes. The special structure of the thin panel, in which electronic components are not placed behind the imaging area, allows for almost no back scattering and working in high levels of energy with a minimal external shield only. The systems are small, can be conveyed to the inspection site and operated by one person. The systems can operate on batteries for an entire working day, so there is no need for external power (AC) in the inspection area.

As film dyes out and NDT providers must seek a new solution, Vidisco offers cutting edge technology, the thinnest panel in the world and the best portable X-ray inspection tools out there. Fast images upon request for immediate analysis mean there is no compromise on image quality and no repositioning. Vidisco systems enable reduction of working time and costs while enlarging the profits of NDT service providers.

We will present case studies of working with our systems combined with high energy levels from various locations around the world. For applications such as small bore pipes, welding, boilers and shipyard NDT, Vidisco’s systems are a true laboratory in the field, enabling immediate high quality results for analysis on site, and offering mobility and efficient inspection anywhere.

As a loyal member of BINDT, we will be happy to present the newest information regarding Digital Radiography, technical tips for users and the advantages of working with this advanced technology.
Abstract
Portable Digital Radiography (DR) surpasses film/film replacements by providing many additional benefits to users. This advanced technology, currently also recognized via new NDT standards, enables super detailed results and provides the basis for high level of NDT analysis. Yet the detectors available with this kind of technology are usually limited to working with limited levels of energy.

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This article presents case studies of working with Vidisco systems combined with high energy levels from various locations around the world. For applications such as small bore pipes, welding, boilers and shipyard NDT, Vidisco’s systems are a true laboratory in the field, enabling immediate high quality results for analysis on site, and offering mobility and efficient inspection anywhere.

1. Introduction
There is no longer an argument among NDT experts that Digital Radiography (DR) can be a sufficient and even improved replacement for X-ray Film or Film replacement technologies. In fact, when working with DR one can enjoy additional benefits that do not exist with other technologies and that enhance the working experience of the NDT technician.

Among these advantages is the fact that one can produce images in near real time. With just a click of the mouse a high quality image is available on screen on site immediately. A few more simple steps with the software and the images are ready for advanced analysis. The X-ray source can also be controlled by the system, enabling the best
synchronization between the actual shooting of X-rays and the time the digital imager reads the data stored in its amorphous Silicon (a-Si) plate. As this process can be immediate, the data remains unspoiled.

The speedy image acquiring process does not cause any compromise on image quality. The sensitive digital imager can provide the highest image quality available in the market today. At last, the professional user can make the most of the truly amazing capabilities of digital X-ray. By achieving an image immediately, there is no need to be blind to the quality of results. Repeated shots are “cost free” and thus the best position to take an X-ray image is determined on the spot. No repositioning is required. All the testing work in one location can be completed on the same day and even analysis can be immediate.

Despite all the above mentioned advantages, in those applications where high energy is required, the market avoids the transition to the preferred technology of DR. The main problem experienced is the shortening of the producer’s declared life time of the Digital Detector Array (DDA) imager if it is exposed to high levels of energy. This shorter life time makes it difficult to return the investment made in the imager itself, within the stated time frame. This article will review this problem in more detail and suggest a possible solution, which enables a very fast return on investment.

2. The problem: High Energy NDT and DDA imager lifetime
High Energy NDT is defined as tests, which require the use of X-ray energy levels that are higher than 160kV, or tests that involve the use of Isotopes (for example, the relatively popular Ir-192 Isotope, which generates average energy of approximately 450kV).

Historically the DDA imager lifetime is calculated by recording the time to the first dose related failure in the imager. These first faults are typically caused by problems in the electronic components of the imager. Electronic parts are relatively low cost among the components of the imager, and can be easily replaced. The a-Si plate inside the imager can continue to function much longer than the electronics even if it is exposed to high doses of energy. Manufacturer’s however preferred to declare the lifetime of the imager according to these first electronic faults in order to protect themselves. Thus the declared life time of the imager in no way reflects its real abilities. It’s like declaring the lifetime of a car by recording the time to the first flat tire. We all have replaced a tire and continued driving happily and safely.

The first step towards enabling the transition to DR also in High Energy NDT applications is to understand that the true lifetime of an a-Si plate is much longer than the announced lifetime of the imagers. The understanding and acceptance that one can replace faulty electronic parts at a relatively low cost and continue to operate an a-Si panel for periods that are long enough to get a good return on investment is necessary for this technology to acquire its rightful place in the NDT arsenal.
3. The solution: Avoiding high dose exposure of electronics
The major problem when working with DDA imagers in high energy doses is the faults caused to electronic parts. The key to avoiding electronic faults related to dose is to shield the electronics. The solution therefore needs to be found in an early stage of imager planning. Two main technological solutions that must be incorporated into the initial design of the imager present themselves:

3.1 Internal shielding
A layer of shielding material (such as Lead or Tungsten) should be laid inside the imager between the a-Si and the electronic components. Thus the a-Si plate absorbs most of the X-rays and translates them to an image, and any X-rays that go through it are blocked by the internal shield. The electronics are fully protected. The advantage to this solution is that the shield is integrated into the imager.

There are panels that already have internal shielding for the electronic parts, but this shield is only a thin layer of metal that blocks most of the X-rays (but cannot provide complete protection) and which is limited to 160kV and serves to maintain the declared lifetime of the panel (which is calculated as the time to first dose related fault, which typically occurs in the electronic parts). This is not the kind of internal shield that will serve as a solution for High Energy NDT applications. A thicker layer of shielding (which is also heavier) from a suitable metal is required.

3.1.1 Internal shielding disadvantages
There are two main disadvantages to an internal shield:

a. Imager weight
b. Backscattering effect.

The resulting imager weight is significantly increased. The shielding material layer adds a non proportional amount of weight to the imager, compared to its original “native” weight without the internal shield. Also in applications where high energy is not required, the NDT technician has to always work with the heavier resulting panel.

The shield plate throws back many X-rays that reach it, because of its proximity to the a-Si plate, causing a heavy backscattering effect. The scattered X-rays then return and “light up” the a-Si pixels once more. Thus the resulting images may be un-sharp due to this excess of X-rays.

3.2 Electronics on the side
The second solution that enables avoiding high dose on the electronics is moving the Electronics from behind the a-Si plate. When the electronic parts are located to the side of the a-Si plate, they are not directly impacted by the X-rays shot towards the imaging area. An external shield can easily provide full proof protection of the electronic parts of the imager at a low cost (all you need is an adequately cut lead or tungsten plate – see Figure 1). The main advantages to this solution are that the native weight of the imager is maintained and the backscattering effect is reduced to a minimum – it is in fact almost nonexistent. A disadvantage may be found in the increase of the surface area of the panel.
3.2.1 Advantages of placing electronics on the side

A detailed view of the effects caused by this second solution shows that it entails many advantages, from which the NDT technician can profit greatly in adapting to DR:

a. The original weight of the imager is maintained. This makes its placement in various locations remain a simple matter. The portability of the imager is also kept. In most applications where high energy is not required, one continues to work normally, with a lightweight panel and without shielding.

b. When shielding is required, a simple external shield will do. Imaging area is not lost, because only the sides of the imager (where the electronics are located) require protection.

c. The thickness of the external shield can be determined according to the energy level used. This means its weight can be optimized to the kind of work required.

d. The imaging area can start from the edges of the panel (on the corner where the a-Si plate is located). The imaging area of the RayzorX Pro starts just 5 mm from the bottom of the detector and 7 mm from its side.

e. The imager is thin. Because the electronics are located on the side, the entire depth of the imager can be reduced. RayzorX Pro is the thinnest imager known in the market today – with just 13 mm depth (it is even thinner than the original film cassette).

f. An almost “backscattering free” digital panel is created, because there is nothing behind the a-Si plate that will cause radiation to return to it. This reduces the inherent noise in the images, thus Signal to Noise Ration (SNR) is increased and with it the image quality.

g. All the inherent advantages of DR mentioned in the beginning of the article (high quality images upon request, analysis anywhere, no repositioning, and no compromise on quality of results) can all be available in High Energy NDT applications.

The transition to DR (regardless of the imager architecture) encompasses one more advantage, namely that the amorphous Silicon based DDA imager is sensitive enough to enable great results in low doses. Sometimes when working with DR one may not need to use the energy level one is used to from working with Film. High energy dose levels can be avoided and operator safety is increased.
4. Relevant Applications
Applications that require high energy levels usually require penetration of thick metallic components. Such NDT inspections include pipe welding and pipe erosion tests, welding in boilers or ship hulls and quality control inspections in casting facilities. The following case studies contain various High Energy NDT examples in which a RayzorX Pro portable Digital Radiography (DR) system was used.

The major advantages of the use of DR in High Energy NDT applications include shortening of exposure times, lower dose levels, increasing the quantity of work one can achieve in the lifetime period of an Isotope Gamma ray source. These advantages translate into improved operator safety and better working efficiency. These mean reduced shut down of factories (time and space) and increased profitability for the NDI provider.

4.1 Pipe inspection: Reducing dose
A test recently conducted in Texas, USA by an NDT service company, using the RayzorX imager with Ir-192 (Iridium) and Se-75 (Selenium) sources alternatively, show two interesting results:
1. Tests that are usually conducted with Ir-192 at a certain level of activity can be also conducted with a lower level of activity when using the digital panel. This means longer usage of the same source is achieved and good results are maintained.
2. Inspection that is usually conducted with Ir-192 can be done with the weaker Se-75 source and the digital panel, yet producing images of higher quality (due to the better focal spot and lower radiation energy spectra of the Se-75 Isotope).

A more specific example from these tests can be seen in Figure 2. X-ray images of an 8” diameter pipe with 3/4” wall thickness (total wall thickness 1.5”) were taken with Iridium (a) and Selenium (b) Isotopes.
Table 1 organizes the condition details of the images in Figure 2.

Table 1: Imaging conditions in Texas

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Image a (Left)</th>
<th>Image b (Right)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotope</td>
<td>Ir-192</td>
<td>SE-75</td>
</tr>
<tr>
<td>Ci (average energy in kV)</td>
<td>56Ci (353kV)</td>
<td>27.2 Ci (265kV)</td>
</tr>
<tr>
<td>Exposure time (per image)</td>
<td>0.6 Seconds</td>
<td>10 seconds</td>
</tr>
<tr>
<td>Averaging (to improve SNR)</td>
<td>20 images</td>
<td>20 images</td>
</tr>
<tr>
<td>Total exposure time for averaged final image</td>
<td>12 seconds</td>
<td>200 seconds</td>
</tr>
<tr>
<td>Focal spot</td>
<td>0.146”</td>
<td>0.139</td>
</tr>
<tr>
<td>Distance between source and detector</td>
<td>Contact Method Approximately 9”</td>
<td>Contact Method Approximately 9”</td>
</tr>
</tbody>
</table>
In the image taken with Selenium Isotope (b) an extra 5th wire is clearly visible. Both images were taken under the same setup conditions, except the Isotope type and exposure times.

### 4.2 Pipe inspections: Reducing exposure time

Table 2 contains results of tests that were conducted by a large NDT service provider on pipes on site (in the field), using Isotope Ir-192 combined with the Vidisco RayzorX Pro DR system and/or Film. The comparison shows clearly that exposure times have been cut tenfold!

**Table 2: Isotope energy with DR flat panel vs. Isotope energy with Film: Results**

<table>
<thead>
<tr>
<th>Item Inspected</th>
<th>Pipe Diameter</th>
<th>Material</th>
<th>Wall Thickness</th>
<th>Liquid Content</th>
<th>Exposure Time VIDISCO DR Solution ***</th>
<th>Film**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Water Hose</td>
<td>208 mm</td>
<td>St 35</td>
<td>7.2 mm</td>
<td>None</td>
<td>30 seconds</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Glass Fibre Profile</td>
<td>700 mm</td>
<td>Glass Fibre</td>
<td>approx. 25 mm</td>
<td>None</td>
<td>70 pulses <em>(about 4.6 seconds)</em></td>
<td>30 seconds</td>
</tr>
<tr>
<td>Process Water Pipe</td>
<td>150 mm</td>
<td>ss2343</td>
<td>Total One Wall 6 mm</td>
<td>Water</td>
<td>20 seconds</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Steam Cooler</td>
<td>250mm+insulation</td>
<td>10CrMo</td>
<td>Total One Wall 40 mm</td>
<td>None</td>
<td>50 seconds</td>
<td>1 hour</td>
</tr>
<tr>
<td>Low Pressure Steam Pipe</td>
<td>400mm+insulation</td>
<td>st 35</td>
<td>12 mm</td>
<td>None</td>
<td>30 seconds</td>
<td>20 minutes</td>
</tr>
<tr>
<td>Fuel Lye Pipe</td>
<td>100 / 80 mm</td>
<td>ss 2343</td>
<td>6 mm</td>
<td>Lye</td>
<td>15 seconds</td>
<td>10 minutes</td>
</tr>
</tbody>
</table>

* Test conducted with pulsed XRS-3 source
** Film and Ir-192. Exposure time only, not including film developing
*** a-Si panel and Ir-192. Time to Image
In a large test conducted in cooperation with a refinery in France, several pipe welding samples with intentional defects such as slag, undercut, corrosion, porosity and cracks were tested with High Energy NDT compatible RayzorX Pro a-Si panel in the laboratory with a portable pulsed X-ray source. Criteria for the success of the tests were the time taken to achieve an image and the visibility of the defects and the IQI wires. Table 3 organizes typical tested items and time to results.

<table>
<thead>
<tr>
<th>Material</th>
<th>Outer Diameter</th>
<th>Wall Thickness (mm)</th>
<th>Total Wall Thickness (mm)</th>
<th>Energy</th>
<th>Exposure Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel</td>
<td>60 mm</td>
<td>2.9 mm</td>
<td>~6 mm</td>
<td>270kV</td>
<td>4.3 sec</td>
</tr>
<tr>
<td>5355</td>
<td>60.3 mm</td>
<td>2.9 mm</td>
<td>~6 mm</td>
<td>270kV</td>
<td>3.54 sec</td>
</tr>
<tr>
<td></td>
<td>88.9 mm</td>
<td>3.62 mm</td>
<td>~6.4 mm</td>
<td>270kV</td>
<td>2.3 sec</td>
</tr>
</tbody>
</table>

Further tests were conducted in the refinery itself with an Ir-192, 16Ci gamma ray source (real piping in the field – see setup example in Figure 3). Criteria for the success of the tests were the time to set up the detector and source on site, time to take a good image, the quality of images in comparison with known images of the tested object, and analysis tools available on site.

![Figure 3: Setup of a-Si panel in refinery and corresponding X-ray image](image)

The tests in the refinery proved a reduction of exposure time from an average of 4-5 minutes to 8-16 seconds! The X-ray conditions were the same (X-ray / Gamma ray source, 50 cm distance between imager/ Film to the source, sample or pipe inspected) only the Film was replaced with a DDA imager. 33 images were taken in just 3 hours! Reducing exposure times from minutes to mere seconds means a significantly faster rate of inspection that translates to shorter refinery shut down periods and increased inspection efficiency. Costs of inspections to the refinery are reduced tenfold!
5. Summary
It is possible to use Digital Radiography also with high energy levels. Providing one has a suitable imager like the RayzorX Pro, which is designed so that its electronic components are located to the side of the imaging area, one can achieve excellent images upon request and enable high level of analysis results. Such an imager can also contribute to shortening exposure times and even reducing dose levels, so that many NDT applications which are considered “High Energy” traditionally may no longer be captivated in such requirements.

Additional inherent advantages to working with DR technology are improved operator safety due to lower exposure (time and dose) and increased NDT provider profitability caused by the shortening of time to results (cost and time are considerably saved because one can take many images per day with a DR imager). The true lifetime of the amorphous Silicon based DDA imager is long enough to allow very fast return of investment even if one conducts many tests, which are defined as High Energy NDT.