CUTTING EDGE DIGITAL RADIOGRAPHY TECHNOLOGY IN DAILY NDT USE

R. PINCU, E. DAYAN, O. KLEINBERGER
VIDISCO LTD. Or-Yehuda, Israel
Tel: +972-3-533-3001
Email: ndt@vidisco.com

Abstract
Digital Radiography (DR) surpasses film/ film replacements by providing many additional benefits to users. As film dies out and NDT providers seek a new solution, Vidisco offers cutting edge technology and the best portable X-ray inspection tools out there. Producing fast images upon request allows for immediate analysis meaning there is no compromise on image quality and no later repositioning. With our Amorphous Silicon (a-Si) Flat panels, which provide 14 bit dynamic range and excellent resolution, combined with short time to image and using proprietary professional software the NDT operator will achieve high quality images on site.

Vidisco systems enable reduction of working time and costs while enlarging the profits of NDT service providers. This article will present case studies of working with our systems in various locations around the world; we will demonstrate how to utilize this state of the art technology for daily NDT use. Vidisco's systems are a true laboratory in the field, enabling immediate high quality images. Vidisco is the world leader in portable X-ray solutions. Be fast, safe and cost efficient!

1. Speed

Digital Radiography systems offer fast setup and super quick X-ray exposure times, altogether contributing to a significant reduction in working times required for NDT inspections. Even though working hours can be shortened significantly, this does not cause a reduction in image quality – on the contrary – Digital Radiography offers the best image quality available in the market today. The sensitive a-Si detectors, which provide 14 bit dynamic range and 3.5-4 lp/mm resolution, can "capture" information even if a minimal amount of energy (X-ray or Gamma) has indeed reached them. This "recording" ability combined with advanced, but easy to use software tools (such as window leveling, 800% non digitizing zoom and sharpening) enables the NDT operator to extract the information on site for immediate and high quality analysis.

1.1 Environmental Motivation

The necessity of reducing exposure times as part of an effort for environmental improvement through the reduction of the amount of exposure to radiation (and even elimination of the use of radioactive sources altogether) combined with the fact that film X-ray is dying out resulted in a research commissioned by the Environmental Protection Agency (EPA). The research conducted by Dr. Glenn Light (NDT level 3) of the South West Research Institute in the USA was published in 2007 and it clearly shows that Digital Radiography systems with X-ray sources (Vidisco *fo*X-Rayzor and XRS-3 Golden engineering source were used to conduct the research) are a suitable alternative solution to radioactive sources and film X-ray.
The research results obtained using the Digital Radiography technology showed increased defect detection compared to the images obtained with Isotope energy. In fact the DR inspection revealed defects that were not previously known. This increase in quality was

possible even though exposure times were reduced, as shown in Table 1. Dr. Light's research considers factors of time, safety and operational costs and shows that in all these concerns a DR system with X-ray is a valid alternative to radioactive sources and film.

Table 1: Exposure Time Comparison

Criteria for Comparison		**Film (with Isotopic Source)**	***VIDISCO* DR Solution (With Golden XRS-3 Pulsed Source)**
Information Quality		All IQI wires were detected	All IQI wires were detected
Procedure Development		10 minutes for X-raying 30 minutes for film development	10 minutes for X-raying Images available immediately
Exposure Time		60 seconds per shot	3 seconds per shot
Labor Cost		Two radiographers	One operator
Maintenance and operation Costs:	Film Storage Chemicals Disposal of Chemicals Repeated images cost Machine Maintenance	Storage cost and space $200 per week plus disposal cost Source disposal costs $1 per film 3 H labor and $200 in chemicals	None None None None Cost free – imager can be reused Not required
Easy to Use		Similar setup	Similar setup

If one uses X-ray sources instead of radioactive ones, factory shut down can be reduced to a minimum for maintenance and NDT inspections. This translates into a minimal disturbance of production for due to maintenance, which in the long run facilitates better maintenance standards and more frequent testing for the general improvement of factory condition and manufacturer profitability. Shorter working time also increases the profitability of the NDT service provider.

1.2 Field Proven

When X-ray sources cannot be used for any reason then Isotope energy can be used with the DR system and there are still benefits to be made. 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 *fo*X-Rayzor DR system. One can clearly see that exposure times have been cut tenfold!

Table 2: Isotope Energy with DR Flat Panel vs. Isotope Energy with Film Results

Item Inspected	Pipe Diameter	Material	Wall Thickness	Liquid Content	Exposure Time	
					***VIDISCO* DR Solution (with Ir-192) Time to Image**	**Film (with Ir-192) Excluding Development Time****
Fire Water Hose	208 mm	St 35	7.2 mm	None	**30 seconds**	3 minutes
Glass Fibre Profile	700 mm	Glass Fibre	approx. 25 mm	None	**70 pulses * (about 4.6 seconds)**	30 seconds
Process Water Pipe	150 mm	ss2343	Total One Wall 6 mm	Water	**20 seconds**	15 minutes
Steam Cooler	250mm+ insulation	10CrMo	Total One Wall 40 mm	None	**50 seconds**	1 hour
Low Pressure Steam Pipe	400mm +insulation	st 35	12 mm	None	**30 seconds**	20 minutes
Fuel Lye Pipe	100 / 80 mm	ss 2343	6 mm	Lye	**15 seconds**	10 minutes

* Test conducted with pulsed XRS-3 source
** Exposure time only, not including film developing

A more specific example from these tests shows a pipe that transfers gasoline to a boiler, with 4-6 mm wall thickness. The pipe is made of SS-2343 (stainless steel) and its external diameter is 80/100 mm. The exposure time required with the conventional Isotope method is 10 minutes. Film development time must also be added when calculating the final time for results. The exposure time required when combining the *f*oX-Rayzor DR system with Isotopes was just 15 seconds and the results were immediate (see Figure 1).

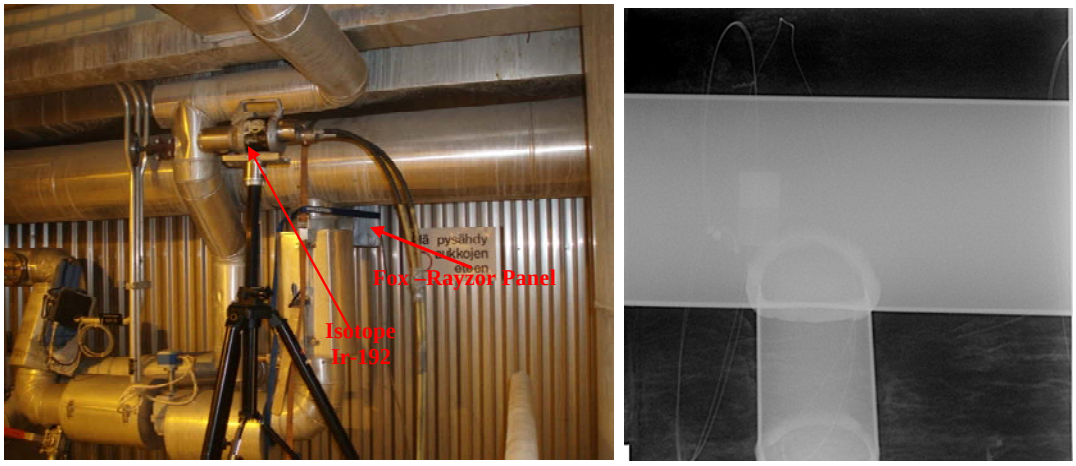

Figure 1: Gasoline Pipe with *f*oX-Rayzor Fine Panel in Position and Corresponding X-ray Image

An insulated SS-2343 (stainless steel) pipe with a 150 mm external diameter and 6 mm walls was inspected full of water. Using the standard Isotope with film method, exposure time is 15 minutes. This does not include the time required to develop the film which must also be added. Combining Isotope energy with *f*oX-Razyor required an exposure time of only 20 seconds and results were available immediately. Figure 2 shows the setup of the DR system and a separation detected in the pipe.

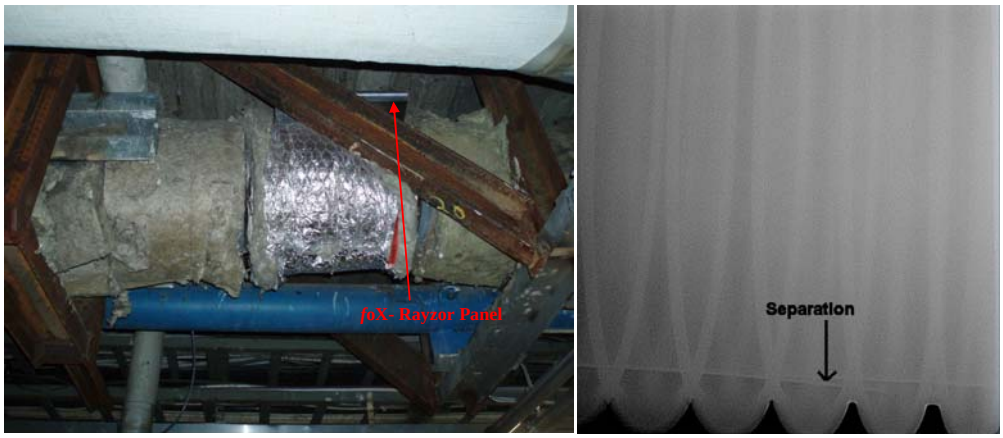

Figure 2 : Insulated Pipe full of Water and Corresponding X-ray Image

Shortening the exposure time when using radioactive sources means increased safety for the operator combined with faster working times. These factors translate into increased profitability for the NDT service provider.

1.3 In the Service of Art

Another example of speed achieved without compromising image quality comes from the field of art X-ray and museums. Figure 3 shows a digital scan of film X-ray (a) and an X-ray image taken with Flat *f*oX-17 a-Si flat panel (b) of a tin bronze statue, taken at the Metropolitan museum, NY. Table 3 contains the imaging conditions of the images in Figure 3.

Table 3: Metropolitan Museum Imaging Conditions

Conditions	Image a (Left) Film	Image b (Right) *VIDISCO* DR Solution
X-ray source	Unknown	Seifert Eresco
mA of X-ray source	3 mA	4.10 mA
X-ray source Energy in kV	320 kV	230kV
Exposure time (per image)	90 seconds	6 seconds
Averaging (to improve SNR)	none	10 images
Total exposure time for averaged final image	90 seconds	60 seconds
Filter	0.5-1mm Sn	0.5-1mm Sn
Distance between source and detector	1.27m	1.27m

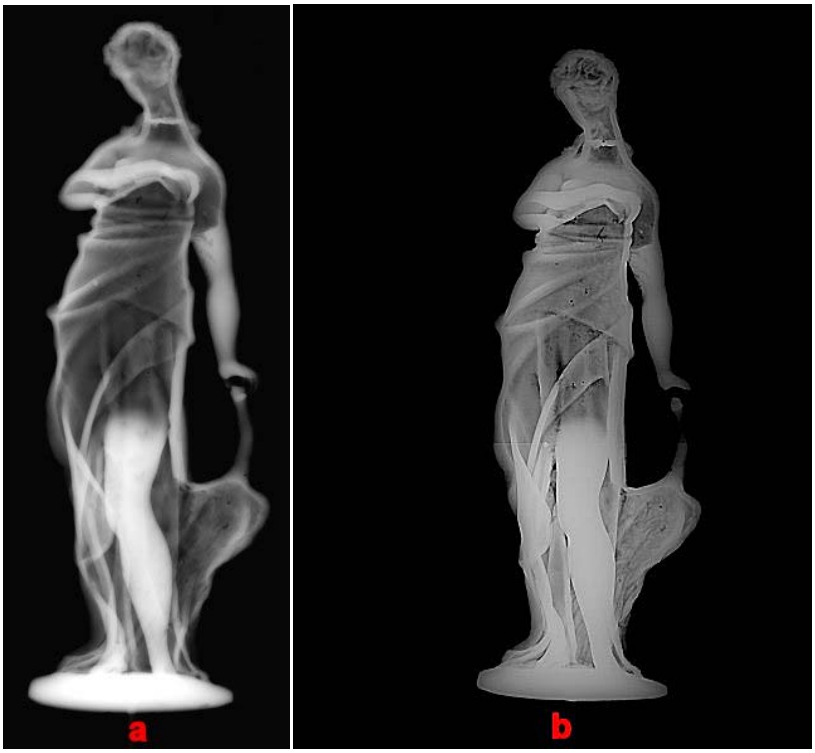

Figure 3: Tin Statue X-ray Images

Although the energy level was lower with DR, the exposure time is shorter. The image is sharper and contains more elaborate details of the statue structure. Figure 4 shows the setup for taking the image with DR.

Figure 4: Setup for Status X-ray

2. Safety

A test recently conducted in Texas, USA by an NDT service company, using DR and Isotope energy has been able to prove that exposure times are significantly shortened in comparison to exposure times that are familiar to NDT operators today.

With eyes on increased safety, the tests in Texas continued to search for even less exposure to radiation. The tests, which were conducted with *f*oX-Rayzor DR system, IR-192 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. 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, yet producing images of higher quality (due to the better focal spot and lower radiation energy spectra).

A more specific example from these tests can be seen in Figure 5.
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 4 organizes the condition details of the images in Figure 5.

Table 4: Imaging Conditions in Texas

Conditions	Image a (Left)	Image b (Right)
Isotope	Ir-192	SE-75
Ci (average energy in kV)	56Ci (353kV)	27.2 Ci (265kV)
Exposure time (per image)	0.6 Seconds	10 seconds
Averaging (to improve SNR)	20 images	20 images
Total exposure time for averaged final image	12 seconds	200 seconds
Focal spot	0.146”	0.139
Distance between source and detector	Contact Method Approximately 9”	Contact Method Approximately 9”

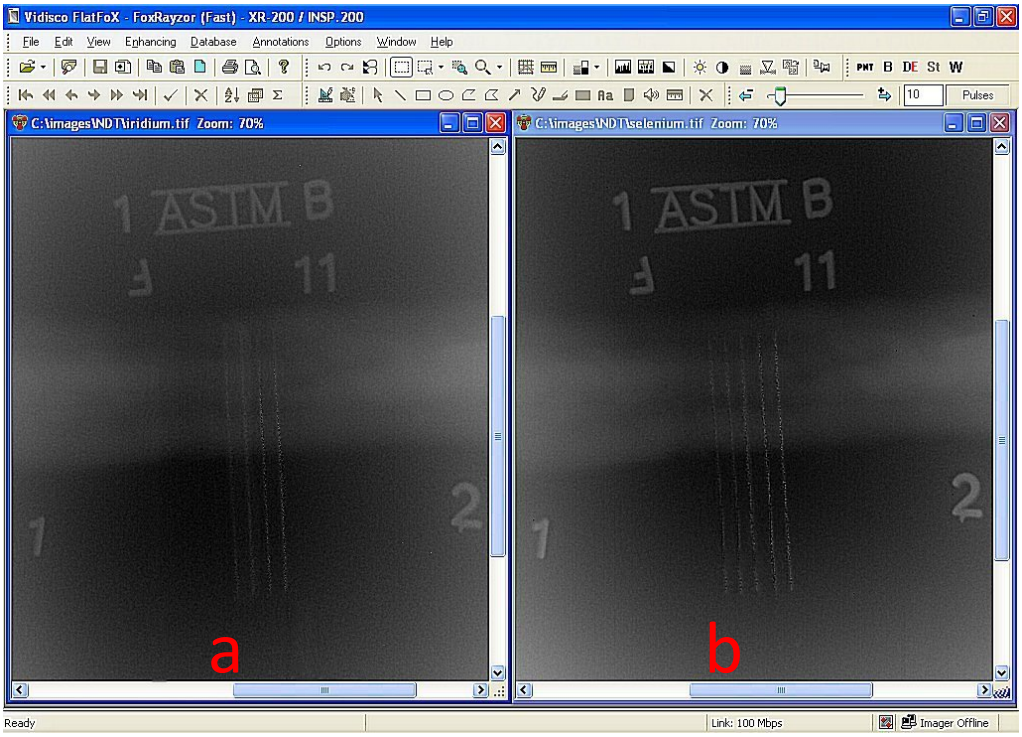

Figure 5: X-ray Images of 8" Diameter Steel Pipe, 3/4” Wall Thickness

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. The setup of the DR system and Isotope is shown in Figure 6.

Figure 6: External Setup; *f*oX-Rayzor mounted on Tripod and Radioactive Source (Contact Method)

The results show that an Isotope can be used for longer periods, even if it is already low on activity. This translates into longer life cycles for sources and slower replacement requirements, thus contributing to reduction of operation costs.

In order to penetrate the above mentioned pipe with Ir-192 and D5 film, one needs an exposure time of approximately 1.2 minutes. Comparing this to 12 seconds that were required with Ir-192 and a digital flat panel, as shown above, it is clear that DR facilitates dramatically shorter exposure times. Even though the exposure time with Se-75 is slightly longer than with Iridium, Selenium produces an image of higher quality and higher contrast.

3. Cost Effectiveness

The two below tables examine the cost effectiveness of using a DR system.

3.1 South West Research Institute (for EPA)

In the first case, taken from Dr. Glenn Lights research already mentioned above, shows comparison factors that have been reviewed from a cost point of view.
Table 5* shows the results of this evaluation.
* The prices are taken from the research data as published in 2007.

Table 5: Comparison Factors Costs (2007 Prices)

Comparison Factor	**Isotope Radioactive Source (Ir-192) and Film**	**X-ray Source and Digital Panel**
X-ray Source Cost	$ 5000.00	$ 5000.00 cost required for 5 years and more
Film Development Field Kit	$ 20,000.00	No need: Image immediately available on computer screen
Film Costs	$1.00 per film	No need
Chemicals Cost	$ 200.00 per week	No need
*f*oX-Rayzor System Cost	No need	$75,000.00 - unlimited repeated shots
Time for results (16" pipe)	10 minutes for positioning and exposure, 20 minutes film development	12 seconds exposure, 8 seconds repositioning. For 4 images - 50 seconds
External Power Supply	No need	5 hours with batteries, no need for external power. With DC inverter the system can be operated on a vehicle battery for unlimited time.
Image Quality	Detection according to ASME B thread standard is possible	Detection of threads is higher than Isotope image. Compliant with ASME standards.
X-ray Source Life Span	For IR-192: 4-6 months	4000 pulses per 1 hour charge and 150,000 pulses per tube
Size of X-ray Source	Approx. 30 cm	Approx. 30 cm, 5 Kg
Number of Images Required to Cover 10" of Pipe Circumference	3	12
Time Required to Cover 10" of Pipe Circumference	70 seconds exposure and 8 seconds repositioning per image. 3 images. 25 minutes developing = **28 minutes and 54 seconds**	3 seconds exposure and 8 seconds for repositioning per image. 12 images = **132 seconds** (2 minutes and 12 seconds)
Technology Acceptance	Isotopes are in use for over 50 years	Portable DR systems are available in the market for 7 years
Staff Required for Inspection	2 people - certified to work with Isotopes	1 person - certified to work with X-ray

Dr. Light's research shows that in the long run, DR systems with a pulsed X-ray source is conductive to operational savings due to the following reasons:

- Efficiency: The image is available within seconds on a laptop screen. There is no need to collect the film after every image and there is no loss of developing time. Working hours are shortened significantly and costs are proportionately reduced.
- Image Quality: is excellent. The DR panels have a wide dynamic range of 16,384 grey levels (14 bit). The operator is not blind to the result (like in film, when one has to wait

for developing to see what has been achieved). Reshoots are done immediately if needed and image quality is never compromised.

- Latitude and Contrast: DR provides high latitude images while maintaining high contrast. This is known as a contradiction when working with film, but with DR one can enjoy both worlds (mainly due to the wide dynamic range).
- Detection: Sensitive digital panels provide an image quality that enables increased detection capabilities. More defects can be sighted and the analysis is improved.
- Environmentally friendly: there is no need for the use of chemicals. Costs of chemical storage and waste procedures as well as the chemicals themselves are saved.
- Safety: Exposure times are substantially reduced. Operator and environment safety are increased.
- Convenience: Digital X-ray inspection systems enable transferring from dangerous and cumbersome equipment to the easily transported and operated pulsed X-ray source. This translates into increased efficiency.
- Customer Satisfaction: Immediate high quality results and shorter working times increase the service quality provided to the client by the service company. By reducing inspection time and safety distance/ shut down, the commissioner of the inspection endures reduced operational losses.
- Simplification: With high end software tools such as "Window Leveling", which enables viewing a selected scale/spectrum of grays for improved detection, an 800% non digitizing zoom, and measurement tools the analysis process becomes simpler and more effective.
- Data Storage and Management: A computerized data base is provided with the digital systems. All images are stored in an organized fashion for easy retrieval, analysis and information sharing. The commissioner of the tests can review the results easily. Film storage is also no longer required thus storage costs are saved.

3.2 Aerospace Laboratory

As part of a modernizing and saving effort, an Israeli Aerospace lab purchased a DR system after conducting a comparison of costs between film X-ray and DR. The X-ray source type and all other laboratory conditions remained the same. The only difference in the test was, instead of film an amorphous Silicon Flat panel was used (Vidisco Flat foX-17). The setup of the panel in the laboratory is shown in Figure 7. The expenditure was compared over a period of one year (spending with DR was compared to the spending of the previous year with film).

Figure 7: Flat *f*oX-17 in Aerospace Laboratory

Table 6 shows the annual savings in USD accumulated with the Digital Radiography system.

Table 6: Aerospace Laboratory Comparison

	Film X-ray		**DR**		
X-ray Procedure / Stage	**Cost of 1 film Image**	**Annual Cost (7250 Film Images)**	**Cost of 1 DR image**	**Annual Cost (7250 DR Images)**	**Annual Savings with DR**
Exposure	$6.00	$ 43,500.00	$3.00	$21,750.00	$21,750.00
Developing Time (Film only)	$4.50	$32,625.00	N/A	$0.00	$32,625.00
Film & Chemicals (Film only)	$2.50	$18,125.00	N/A	$0.00	$18,125.00
CD (for DR only)	N/A	$0.00	$0.03	$218.00	-$218.00
Analysis Report	$3.00	$21,750.00	$3.00	$21,750.00	$0.00
Management Costs	$1.00	$7,250.00	$1.00	$7,250.00	$0.00
Equipment Depreciation and Maintenance Costs	$1.00	$7,250.00	$2.20	$15,950.00	-8,700.00
Documentation Costs and Storage Space	$0.20	$1,450.00	S0.10 (network, no space)	$363.00	$1,088.00
Annual Cost	**$18.00**	**$131,950.00**	**$9.00**	**$67,280.00**	**$ 64,670.00**

The laboratory returned its investment on the DR system in less than two years and has been enjoying further annual savings since. The cost effectiveness of the system is combined with the additional benefits of higher X-ray speed (time to image is much faster), increased operator safety and modern database of images and documentation.

Summary

Digital radiography is a leading X-ray NDT inspection technology that brings with it not only innovation but also speed, safety and cost effectiveness. Amorphous Silicon Flat panels, with 14 bit dynamic range and excellent resolution provide highest quality images immediately on site with no need for repositioning. These images are available on a laptop screen and can be immediately analyzed with user friendly and yet advanced software, to provide high end analysis and results. The detection capabilities of the panels enable NDT operators to shorten exposure times and reduce the level of energy they use to conduct the tests. These factors translate into increased efficiency of testing.

Shortening exposure times enables NDT operators to shorten their working time; this combined with working with lower energy levels increase operator safety and prolong the life of the radioactive or X-ray source. All these factors combined with high quality results and minimal shut down on site; translate into increased customer satisfaction and higher profitability for the NDT service provider.