# Advanced Digital Radiography for Field NDT

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**Abstract.** The article will show inspections conducted in a laboratory and in a refinery with portable amorphous silicon flat panel combined with iridium (Ir-192) source and a pulsed 270kV X-ray source. The examples will show that exposure time has been shortened ten fold and inspector safety is increased. Plant shut down is reduced and the inspections are conducted in minimum time. Various software tools for immediate analysis on site will be demonstrated with examples from petrochemical and pipes industry.

## Introduction

This article summarizes the results of an experiment commissioned by the French Nuclear Safety Authority and Total Oil, conducted at the Institute De Sudoure NDT services company with a Vidisco portable digital radiography system. The research was commissioned in order to review if digital radiography (DR) can assist in reducing use of Isotope energy for increased safety to NDT technicians and the environment. The research included two phases. The first, laboratory X-ray inspection of pipes with known defects, using a digital radiography amorphous silicon flat panel based system and a pulsed X-ray source. The second, on-site testing in a refinery of known maintenance points using the same portable digital radiography a-Si system with Ir-192 Isotope. The results of this research are detailed below.

## Phase 1: Digital Radiography in a Laboratory

In 2008 a vast project was conducted in order to test the capability of digital radiography systems in the field of pipe NDT. The system used in the test was a Vidisco Ltd. *f*oX-Rayzor portable X-ray inspection system (the previous generation of today's RayzorXPro line), which contains the flat amorphous Silicon (a-Si) 14 bit (16,384 gray levels) panel, with Golden XRS-3 (270kV pulsed X-ray source). Several pipe welding samples with intentional defects such as slag, undercut, corrosion, porosity and cracks were tested. Criteria for the success of the test were the time taken to achieve an image and the visibility of the defects and the IQI wires. 93 images were taken. The inspections were planned for one week (based on time frames known for film) but were concluded in just two days. Shows the sketch of the pipe used in the laboratory for the first phase of the research. A few typical result examples are details below.

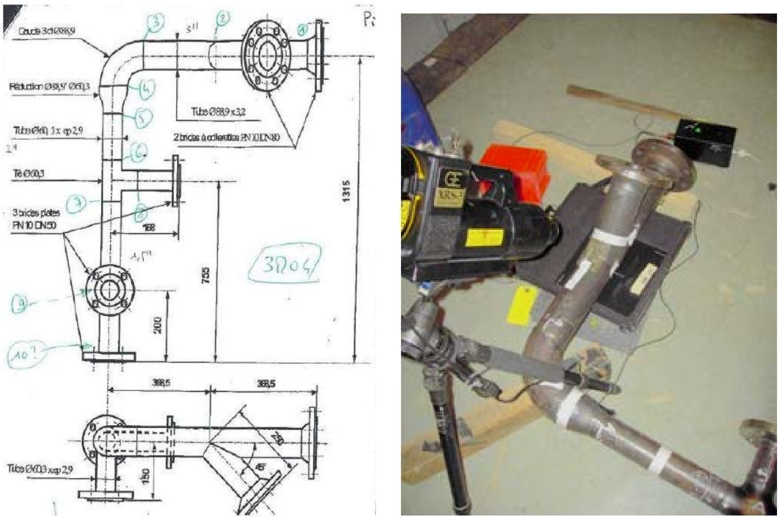

**Figure 1.** Test Pipe Drawing (Left) and Typical Setup (Right)

Figure 2 shows Carbon steel 5355 pipe with 60.3 mm outer diameter and 2.9 mm wall thickness (~6 mm total wall thickness), welded in a V shape. The external setting and the X-ray shot parameters are recorded, as are the conditions and time of X-ray. Measurements of the pipe diameter and wall thickness are also recorded as (removable) annotations on the image. Exposure time was 3.54 seconds (53 pulses). Focal detector distance (FDD) was 50 cm and the “shooting” angle 90 degrees. Wire type IQI EN13FE was used to verify 2% sensitivity. A steel block was placed for this test as a measurement reference. The defects in the weld are clearly visible.

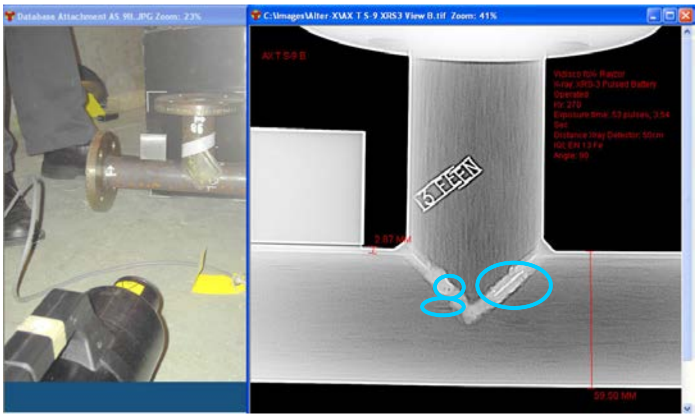

**Figure 2.** Set-up and Test X-ray of Carbon Steel 60.3 mm Pipe

**Figure 3.** Set-up and Test X-ray of Weld Ellipse in Pipe

In Figure 3 lack of root penetration is clearly seen on the top of the weld. On the bottom left of the weld one can discern porosity and on the lower right slag and undercut are visible. The pipe is made of Carbon Steel 5355 and has 88.9 mm outer diameter with 3.2 mm wall thickness (total wall thickness 6.4 mm).

Figure 4 shows a T shaped Carbon Steel 5355 pipe with 60mm outer diameter and 2.9 mm wall thickness (total wall thickness to penetrate in X-ray, ~6 mm). The exposure was just 4.3 seconds and the distance between the detector and the source 50 cm. The angle was 90 degrees and the IQI used was EN10FE, to verify 2% sensitivity. Slag and lack of root penetration are clearly visible in the top left welding, as are the IQI wires in the center.

**Figure 4.** Set-up and Test X-ray of Carbon Steel 60mm Pipe

The results of the first phase prove that a digital radiography system with a flat a-Si panel used in combination with a 270kV pulsed x-ray source can be a valid replacement for the use of film and Isotope energy. Due to the focus of X-rays and the sensitivity of the panel, the digital images produced in this part of the research were of higher quality than typical Isotope images. Orderly data archiving in a digital database improves analysis and documentation. The cost of labor for operating the Isotopes is more expensive than digital X-ray which is considerably faster.

### Phase 2: Digital Radiography in the Field

A test of the efficiency of digital radiography was conducted in one of the TOTAL refineries in France. The test set out to understand the advantages of working with a digital radiography inspection system using a gamma ray source. The system used in the test was the Vidisco *f*oX-Rayzor portable inspection system (the previous generation of today's RayzorXPro line), with the 13 mm thin amorphous Silicon flat panel. The source used was an Ir192, 16Ci gamma source. The distance between the detector and the source was 50 cm – the same distance used when conducting inspections with film. Exposure time ranged between 8 to 16 seconds. Criteria for the success of the test were, 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.

The images appeared on the screen in real time, without the need for development or scanning. Typically an image that takes minutes with Isotope and film, takes only seconds with Isotope and a digital radiography a-Si panel. If an image was not good enough, it was immediately repeated and a new image was once again available in seconds. There was no need to compromise on image quality as good images were achieved on site. 33 images were taken in just 3 hours.

The system is portable and carried in one ruggedized case to any location in the refinery. Setup of the imager was conducted with the help of a tripod and cables. Figure 5 shows the capability of working with the portable DR system in the refinery site.


**Figure 5.** Working in the Refinery with the Portable DR System

The Vidisco DR system offers a combination of the highest quality images, shortest time to image and superior software for analysis of results on site. The software tools most commonly used for on-site analysis were: Window leveling, Sharpening, Emboss, Overlay, Wall Thickness Measurement and Averaging. With these tools the level of analysis the operator can conduct on site is significantly increased. This gives the operator the tools to make a correct and immediate decision regarding the quality of the image and the information obtained.

*2.1 Sharpening*

The **Sharpening** Tool is a sophisticated algorithm, which sharpens the image with minimum added noise. The **Sharpening** tool comes in handy especially when using the Ir-192 source, which shoots its rays in every direction and therefore has a large focal spot that causes unsharpness in the images. This feature can help bring out details of defects in an image.

*2.2 Emboss*

The **Emboss** Algorithm translates the gray-level scale into depth, creating a 3-D effect and making the image appear as if stamped in metal. This makes it easier to detect defects such as corrosion and porosity in pipes.

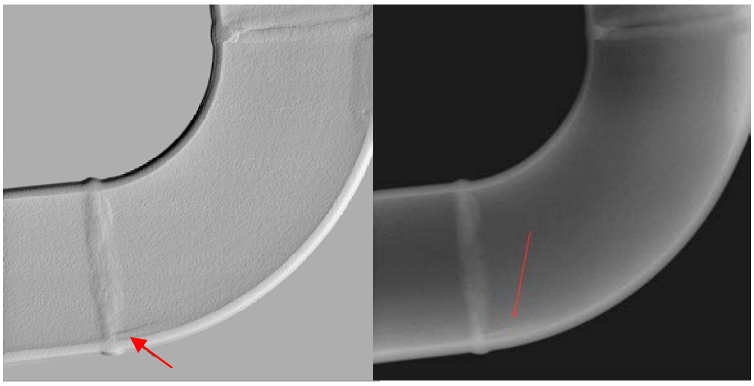

**Figure 6.** Emboss Effect Compared to Original X-ray

Figure 6 illustrates how the **Emboss** effect brings out the sunken materials in a 3.5” outer diameter Carbon Steel pipe and makes it much easier to see. With a click of a button the image is transformed on the screen immediately for convenient analysis.

*2.3 Window Leveling*

The **Window Leveling** Tool is a software feature that allows the NDT operator to make the most of the information created by the DR system. The Portable Flat imager offers a 14 bit dynamic range image, which means 16,384 grey levels of information. A computer screen normally shows only 256 Grey levels. The **Window Leveling** Tool allows the operator to lighten up or darken an image, examining a particular spectrum of grey levels each time, allowing visibility of more specific information on an 8 bit screen.

*2.4 Overlay*

**Overlay** Mode combines two images one on top of the other. This mode is most useful when different parts of the X-rayed object require different exposure times. This allows viewing different thicknesses and materials in one image.

In Figure 7 the differences between the materials of the pipe and its insulation make it difficult to see all the details with just one exposure. The first exposure is 10 seconds long and the second just 3 seconds. Then the images are laid automatically exactly on top of each other using the **Overlay** Mode. Now all the details can be viewed in one image for clear analysis.

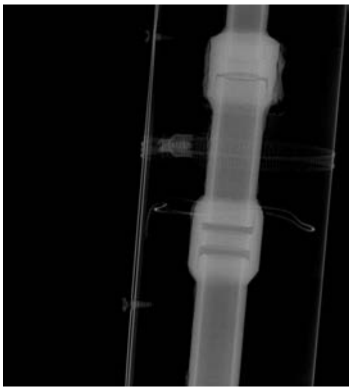

**Figure 7.** Insulated Pipe in Overlay Mode

In Figure 8 the **Overlay** Mode assists in differentiating between the horizontal pipe and the perpendicular one. A crack can be clearly determined (red arrow). The external setup is recorded with the corresponding X-ray in the data base, making future tests for the same location easy.

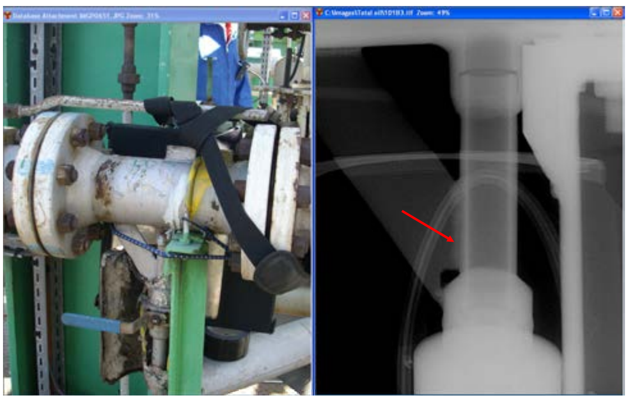

**Figure 8.** External Setup and X-ray Recorded in Digital Data Base (Overlay Mode)

*2.5 Averaging*

The **Averaging** Function combines two or more images by averaging their values at every pixel. The **Automatic Averaging** Function averages a number of images (as set by the user) by taking consecutive images one after another and then displaying one image that is the result of averaging the consecutive images. The result is a cleaner image due to reduction of noise, which will show finer details.

In Figure 9 the Averaging was based on 6 exposures of 9 seconds. The total time to acquire the averaged image was just 54 seconds. The X-ray image on the right is the result of the **Automatic Averaging** Process. It is much cleaner and shows details more clearly than the image on the left, which is just one exposure of 9 seconds. A crack in the center of the image is much clearer. The process is automatic and controlled by the software.

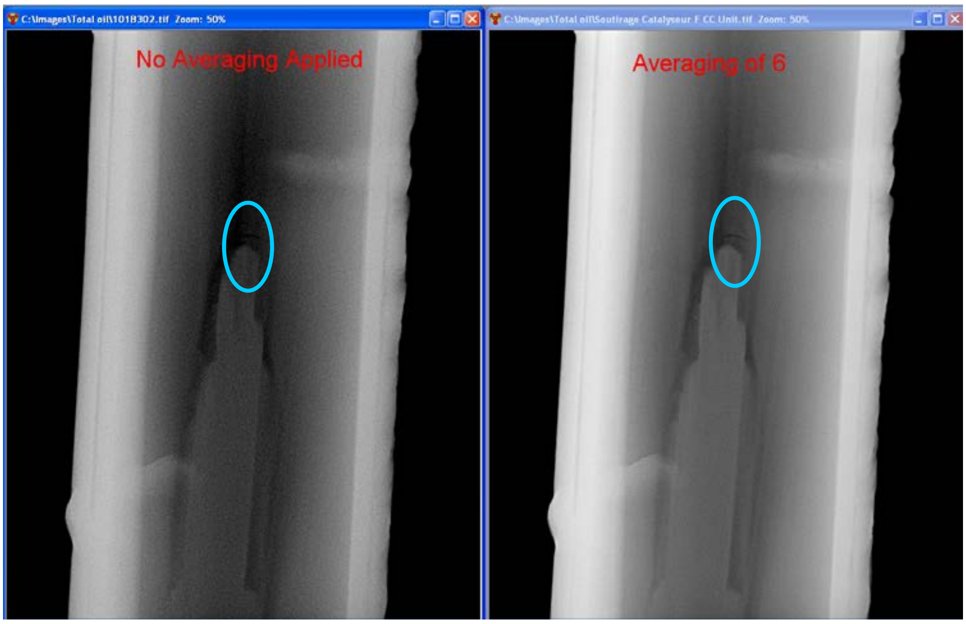


**Figure 9.** Soutirage Catalyseur FCC Unit Averaging with Ir-192

*2.6 A combined Test*

A cut of a pipe was brought to the laboratory from the refinery for a comparison between the pulsed X-ray source and the gamma ray source.
Figure 10 shows that the pulsed X-ray source was able to achieve sharper results in minimal exposure time. Just one exposure with XRS-3 270kV source (c) gave a high quality image that surpassed even the image created by averaging 6 images with Ir192 (b) and was most certainly better that a single exposure with Ir-192 (a).

The **Emboss** effect shows that new defects can be detected in the image created with the pulsed X-ray source (c). The image on the left (a) was created with 9 seconds exposure with Ir-192, the middle image (b) is an averaging of 6 such images (9X6=54 seconds exposure with Ir-192) and the image on the left (c) is an image taken with XRS-3 pulsed X-ray source, with 2.03 seconds of exposure only. Not only is X-ray less dangerous that the radioactive Iridium, its rays are more focused and directional and the exposure time is shortened.

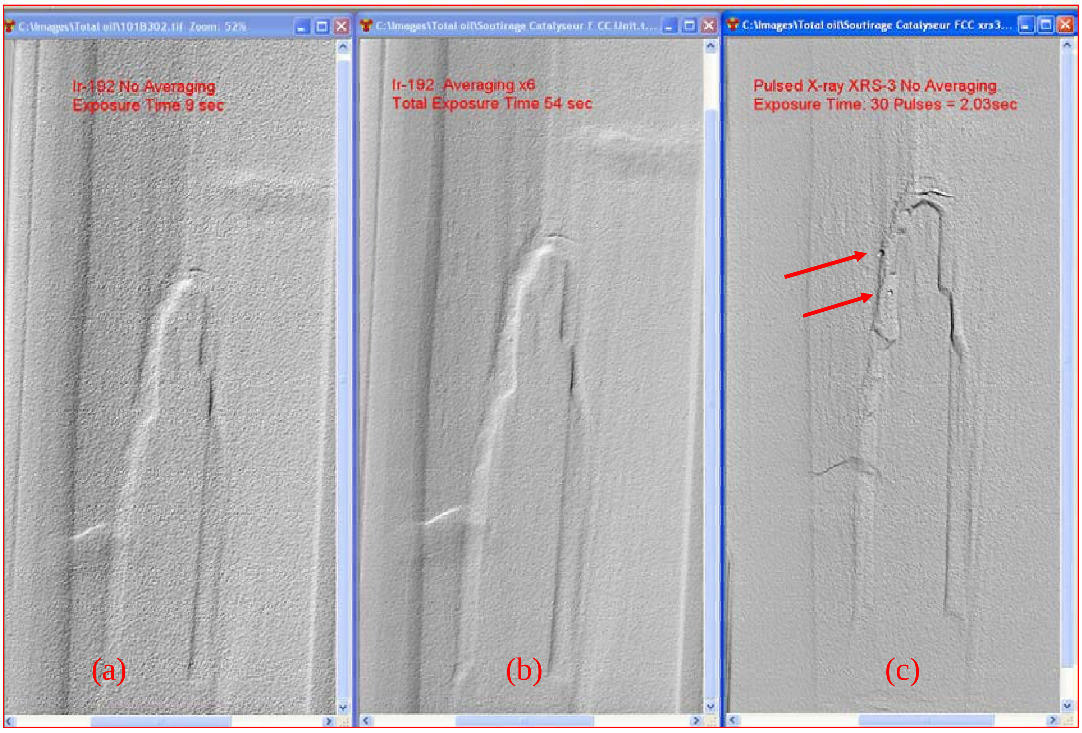

**Figure10.** Soutirage Catalyseur FCC Unit, Comparison with XRS-3 – Emboss Tool

## Conclusion

The portable amorphous Silicon DR system has proven itself to be efficient because it offers practical solutions to both laboratory uses of NDT and also to conducting inspections on site. In the refinery it took just 3 hours for the operators of the portable DR system to conduct inspection in 10 locations. A similar inspection when using film or film replacement technologies that require scanning and development can take more than one day (including film development but excluding analysis, which adds more time to end result of the test). The use of the Isotope was shortened significantly and the NDT technicians' safety was improved by reducing the time of their exposure to radiation.

Not only was the inspection time shortened, there was minimal need to shut down the plant and the quality of the images was known immediately. There was no need to return to conduct further inspections with repeated shut down, because if a location mistake had been made, the operator could tell at once (because images are seen immediately on screen) and correct it immediately – thus always achieving good images in an on site inspection.

In laboratories and in field NDT portable X-ray systems make analysis easier due to sophisticated enhancement software. Results are immediate and images are of the highest quality.

To conclude: DR systems offer the NDT provider an opportunity to achieve good results in a shorter time and to increase the quality of analysis. The service provided can therefore be improved and its cost reduced. Profitability and operator safety are increased significantly.