APPLICATION OF THE DIGITAL RADIOGRAPHY IN WELD INSPECTION OF GAS AND OIL PIPELINES

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Abstract

The aim of this work is to evaluate the feasibility of the direct radiography on weld inspection in oil pipelines and gas pipeline during the manufacturing process. To that, 6 specimens with 6 different thickness and varied height of reinforced weld with 5 different kinds of defects were made. All samples were radiographied using Class I films and flat panel. For all specimens the inspection length was 8”. Thus, with the flat panel the detector-to-object distance varied so that it may adequate to several diameters of the tubes.

The detector-to-object distance was calculated based on the physical size of the detector taking into consideration a safe distance between the tube curvature and the flat panel extremities, keeping the lowest possible magnification factor so that it could be obtained the length of the inspection. Images with 6 integration time for each experimental arrangement were obtained.

The images obtained with the Flat Panel/YXLON system were analyzed according to their quality by using the Contrast parameters (essential wire) (DNV 2007/ IS0 12096 – with reinforcement and ISO 10893-7 – basis material), Basic Spatial Resolution – BSR (ISO 10893-7) and normalized signal-to-noise ratio - SNR_N (ISO 10893-7) and by detectability using as reference the conventional radiography.

The results showed that for all thickness, the exposure time used to meet the image quality requirements were below with direct radiography. However the BSR were not reached for thickness of 4.85, 6.40 and 9.67 mm, therefore the compensation principle established by ISO 10893-7 was considered, that is, one more contrast wire for a less wire pair.

The digital technique proved to be more sensitive to real defects found on welds than the conventional technique. Then it can be conclude that the digital radiography utilizing the flat panel can be applicable to the oil and gas segment with advantages over conventional technique as to quality aspects, productivity, environment, safety and health.

1 – Introduction

Radiography today is one of the most important, most versatile, of all the nondestructive test methods used by modern industry. Employing highly penetrating x-rays, gamma rays, and other forms of radiation that do not damage the part itself, radiography provides a permanent visible film record of internal conditions, containing the basic information by which soundness can be determined. In the past decade alone, the evidence from millions of film records, or radiographs, has enabled industry to assure product reliability; it has provided the informational means of preventing accidents and saving lives; and has been beneficial for the user (KODAK, 1980).

Radiography is a method used for non-destructive inspection based on the differential absorption of penetrating radiation through the sample being inspected. Due to differences in density and variations in thickness, or even differences in absorption characteristics caused by variations in material composition, different regions of the same sample will absorb different amounts of radiation. This differential absorption of radiation can be detected through a film or even be measured by electronic detectors. This variation in the amount of absorbed radiation will indicate the existence of an internal defect in the material, so the industrial radiography is used to detect volumetric defects with accuracy (KODAK, 1980).

New digital detectors were developed for medical applications, which have the potential to substitute the X-ray film and revolutionize the radiological technique. Digital Detector Arrays (DDA: Flat Panel Detectors, Line Detectors) allow a fast detection of radiographic images in a shorter time and with higher dynamic than film applications. Companies report a reduction of exposure time down to 5 – 25% in comparison to NDT film exposures (EWERT, 2004). A single detector can replace multiple films and be used with automatic image systems (BUENO et al., 2005). Tests have been conducted and DDA have shown better performance when compared to films to detect small and volumetric defects (BAVENDIEK et al., 2006; PURSCHKE, 2004).

The operating principle of a DDA is the conversion of the incident radiation on an electrical charge which can be read out. Amorphous silicon is used as a semiconductor material for this process (PURSCHKE, 2004). Two conversion methods are used: scintillation method (indirect conversion) and photoconductor method (direct conversion). Each method has advantages and disadvantages, as well as special limits of use in imaging systems.

The flat panel consists of millions of pixels sensitive to light which are arranged in a grid on a rectangular surface (BAVENDIEK et al., 2006), as shown in figure 1.

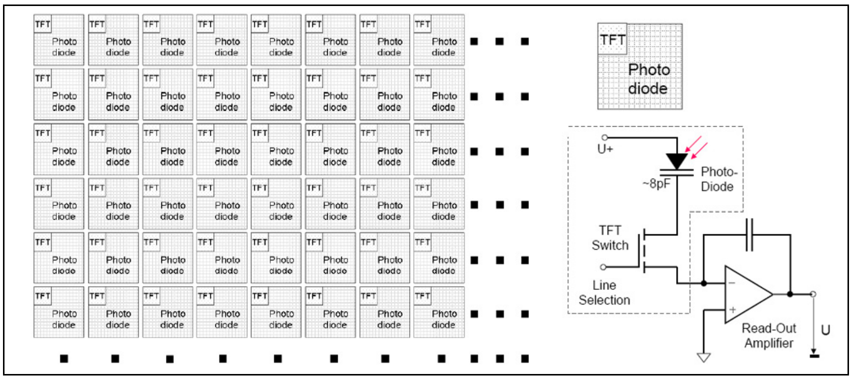

Figure 1 – Flat panel scheme (BAVENDIEK et al., 2006).

The aim of this work is to evaluate the feasibility of direct radiography on weld inspection in oil and gas pipelines, during the manufacturing process.

2 – Materials and Methods

The digital radiography system was assembled using the following parts:

- X-ray equipment model MG226, manufactured by Yxlon, maximum high voltage of 225 kV and 10 mA, focal spot size of 0.4 and 1.0 mm;
- Flat panel system PaxScan, model 2520V, manufactured by Varian, pixel size of 127 µm, maximum energy of 225 kV;

6 samples were made with 6 different thickness and varied height of reinforced weld with 5 different kinds of defects. Figure 2 shows the experimental setup used.

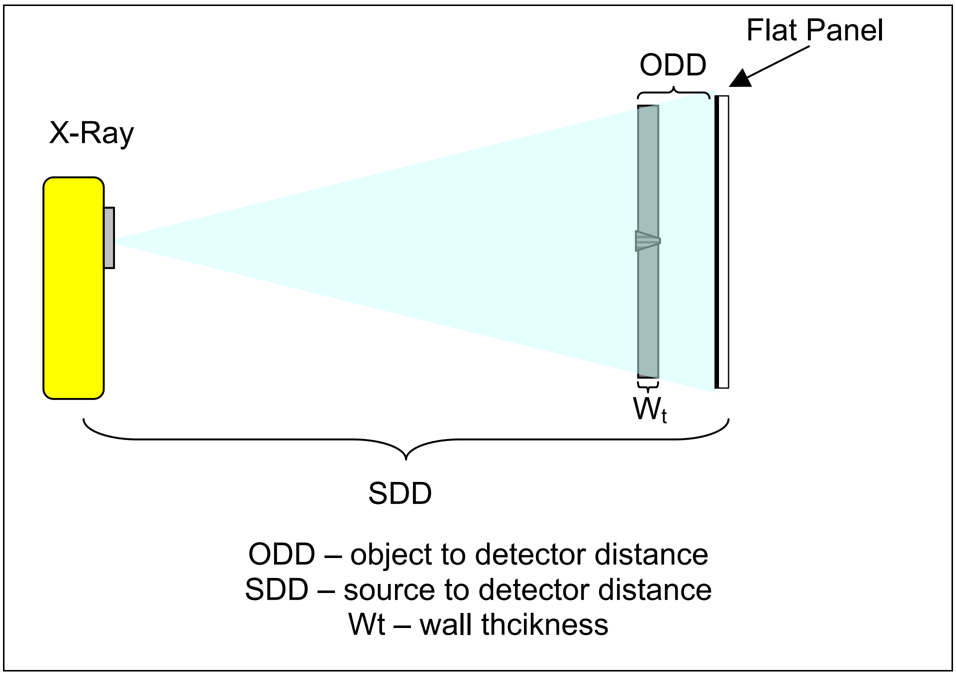

Figure 2 – Exposure setup.

The radiographic technique used was Single Wall Single Image. All samples were inspected using Class I films and flat panel. For all specimens the inspection length was 8”. Thus, because of the flat panel, the detector-to-object distance varied so that it may adequate to several diameters of the tubes. The detector-to-object distance was calculated based on the physical size of the detector, taking into consideration a safe distance between the tube curvature and the flat panel extremities, keeping the lowest possible magnification factor so that the length of the inspection could be obtained. Images with 6 integration times for each experimental arrangement were obtained.

The images obtained with the Flat Panel/YXLON system were analyzed according to their quality by using the Contrast parameters (essential wire) (DNV 2007/ IS0 12096 – with reinforcement and ISO 10893-7 – basis material), Basic Spatial Resolution – BSR (ISO 10893-7) and normalized signal-to-noise ratio - SNR_N (ISO 10893-7) and by detectability using as reference the conventional radiography.

Figure 3 shows the positioning of IQIs on the sample and table 1 shows the quality parameters required for each sample.

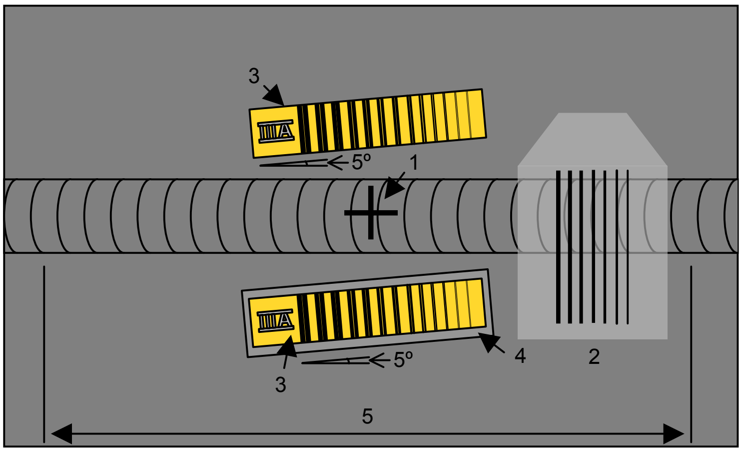

Figure 3 – Positioning of IQIs on the sample - 1 – centre of beam 2 – wire type IQI (source side) 3 – duplex type IQI (source side) 4 - shim stock, to correct height, to be visible 5 - thinnest wire away from the centre of the beam 6 - input screen width (DDA) (8” magnification x1).

Table 1 – Image quality requirements

Sample Number	Wall Thickness (mm)	Wall Thickness Including Reinf. (mm)	Contrast IQI		Req. SR_b	Req. SNR_N
			Req. DNV 2007 IS0 12096	Req. ISO 10893-7		
11	4.85	7.75	14	16	65	> 70 – Class A> 100 – Class B
6	6.40	9.90	14	15	65	
10	9.67	13.27	13	14	80	
1	19.21	23.21	12	13	100	
3	25.25	30.75	11	12	100	
18	32.30	36.10	10	11	100	

3 – Results

Figure 4 shows the SNR_N values as function of integration time for all samples. At all thicknesses, SNR_N was above the required for Class B (100) with minimal integration time, except for the thickness of 32.30 mm, which only reached this requirement at integration time above 4 seconds.

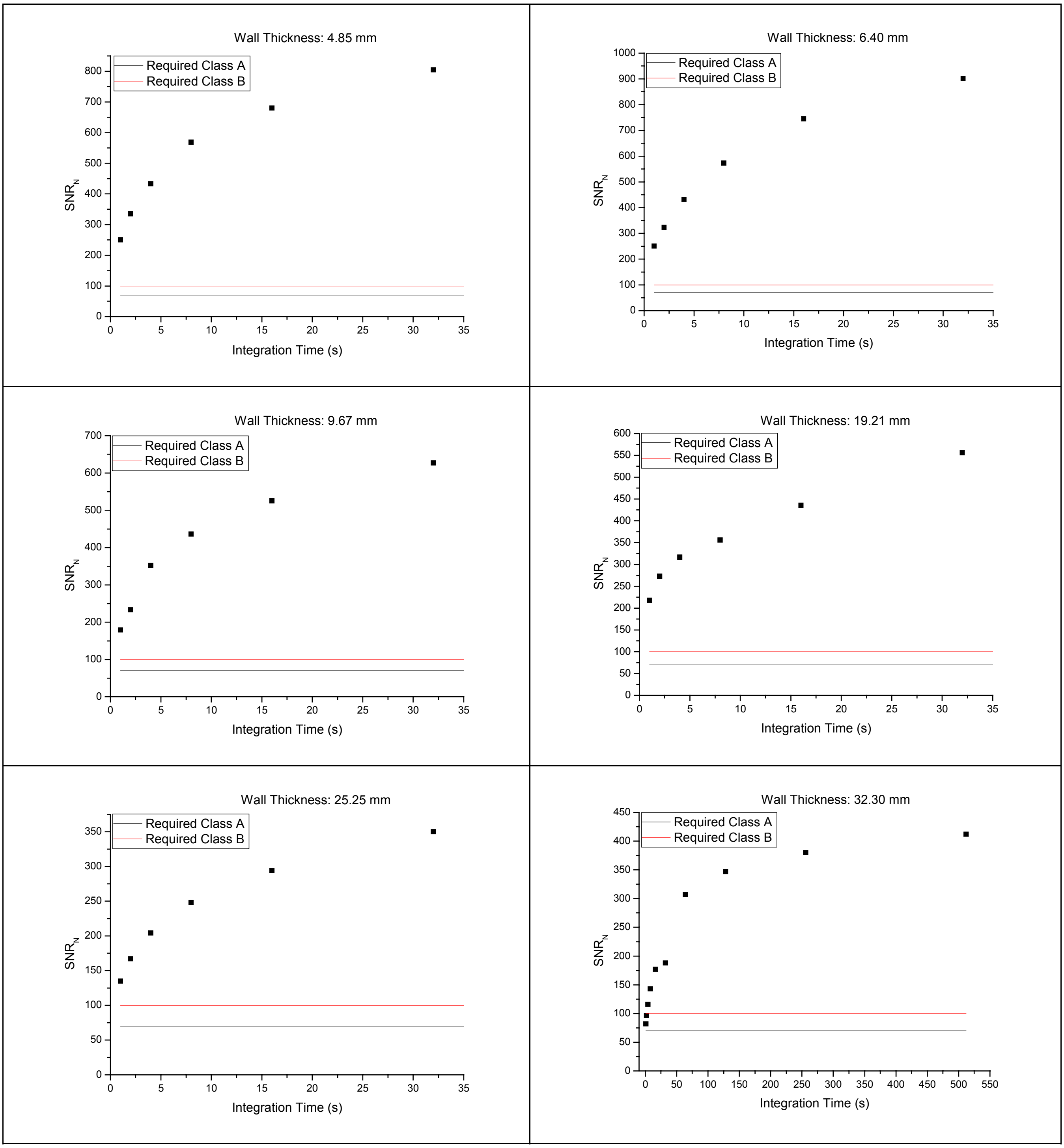

Figure 4 – SNR_N values as function of integration time.

Figures 5 show the contrast sensitivity as a function of integration time. We can see that in all cases the sensitivity was achieved, except for samples 1 with a time of 1 second and sample 3 with a time of 1 and 2 seconds.

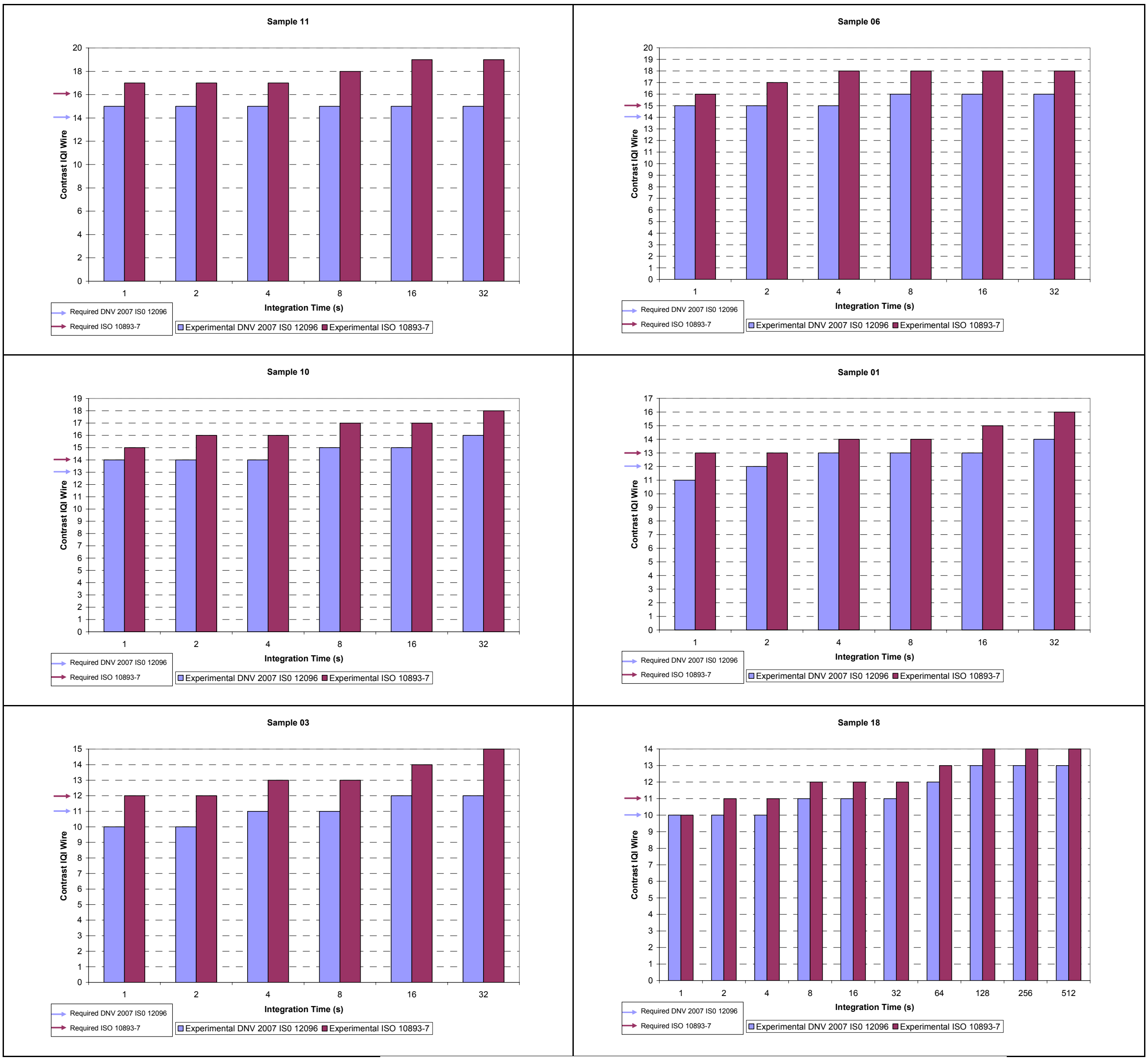

Figure 5 – Contrast sensitivity as a function of integration time for thickness.

In all images, the SR_b was 100 µm. For the cases where this resolution was not sufficient to meet the standard requirements, the principle of compensation established in ISO 10893-7 was taken into account. Table 2 shows the values of image quality parameters for the integration times that the minimum requirements have been achieved.

Table 2 – Minimum integration time to achieve the image quality requirements.

Sample Number	kV	mA	SDD (mm)	ODD (mm)	Focal Spot Size (mm)	Frames/ sec	t_T(s)	IQI Contrast		SR_b (μm)		SNR_N
								DNV 2007 IS0 12096	ISO 10893-7	Base Mat.	Reinf.	
11	180	4	700	100	0.4	10	8	15	18	100	100	569
6	200	4	700	103	0.4	10	8	16	18	100	100	573
10	225	3.55	700	108	0.4	10	4	14	16	100	100	352
1	225	8	700	66	1.0	1	8	13	14	100	100	356
3	225	8	700	73	1.0	1	16	12	14	100	100	294
18	225	8	700	80	1.0	1	32	11	12	100	100	188

The figures 6 to 11 show the comparison between conventional and digital radiography for the minimum integration times, as shown in table 2.

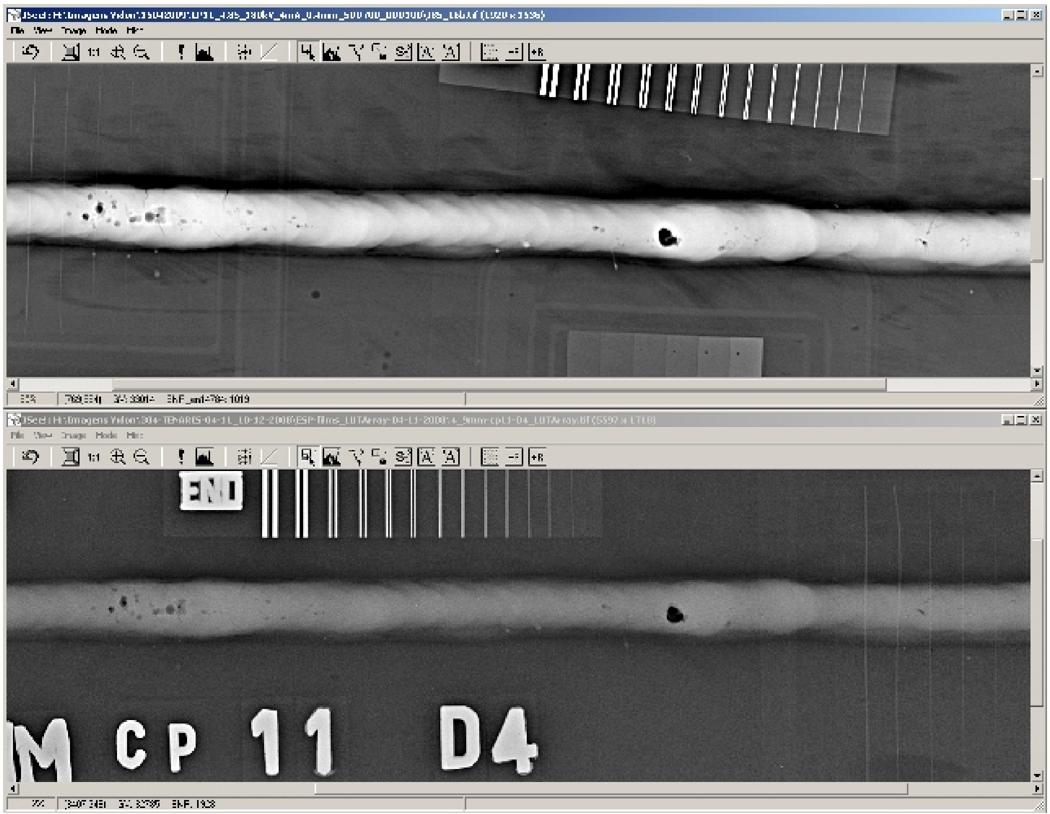

Figure 6 – Sample 11 – Comparison of digital radiography with total time of 8 seconds (top) and conventional radiography with film D4 (bottom).

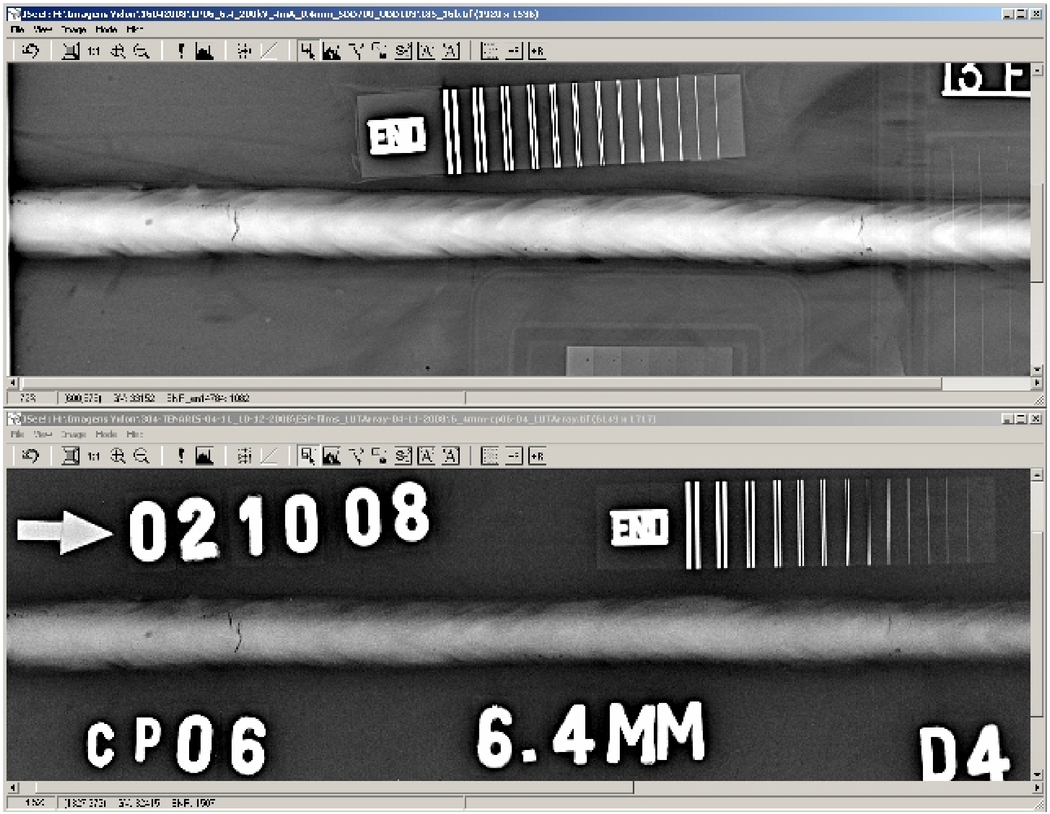

Figure 7 – Sample 06 – Comparison of digital radiography with total time of 8 seconds (top) and conventional radiography with film D4 (bottom).

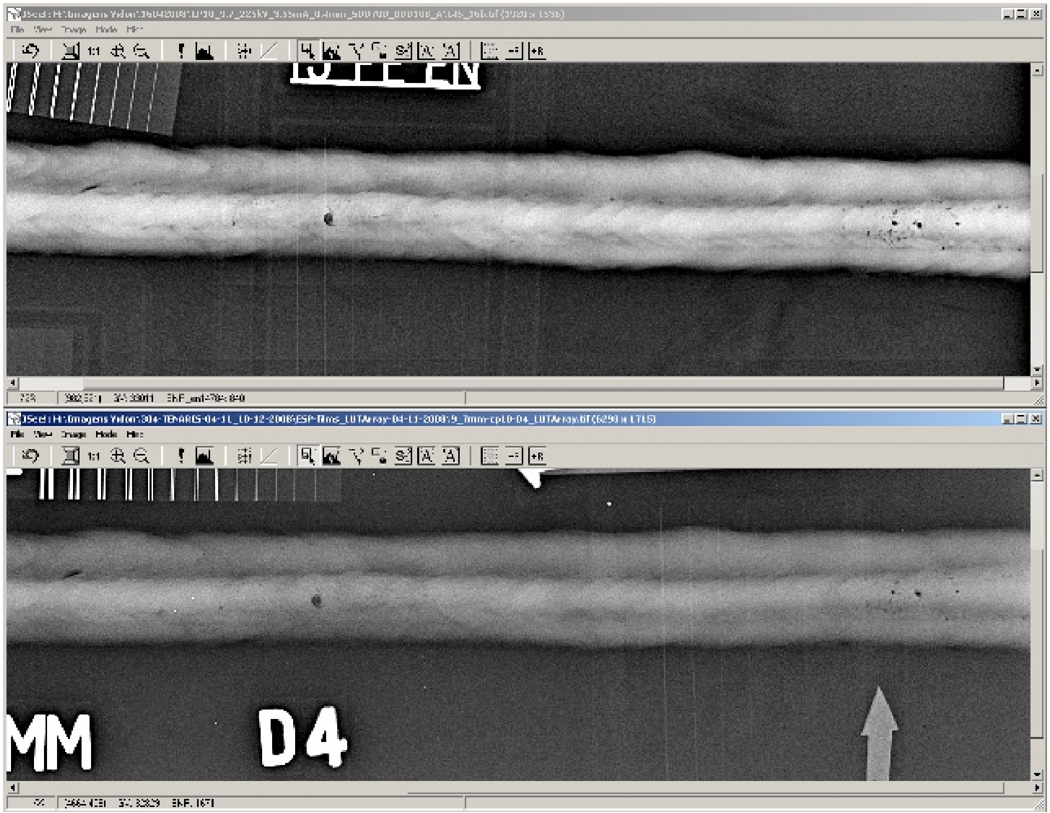

Figure 8 – Sample 10 – Comparison of digital radiography with total time of 4 seconds (top) and conventional radiography with film D4 (bottom).

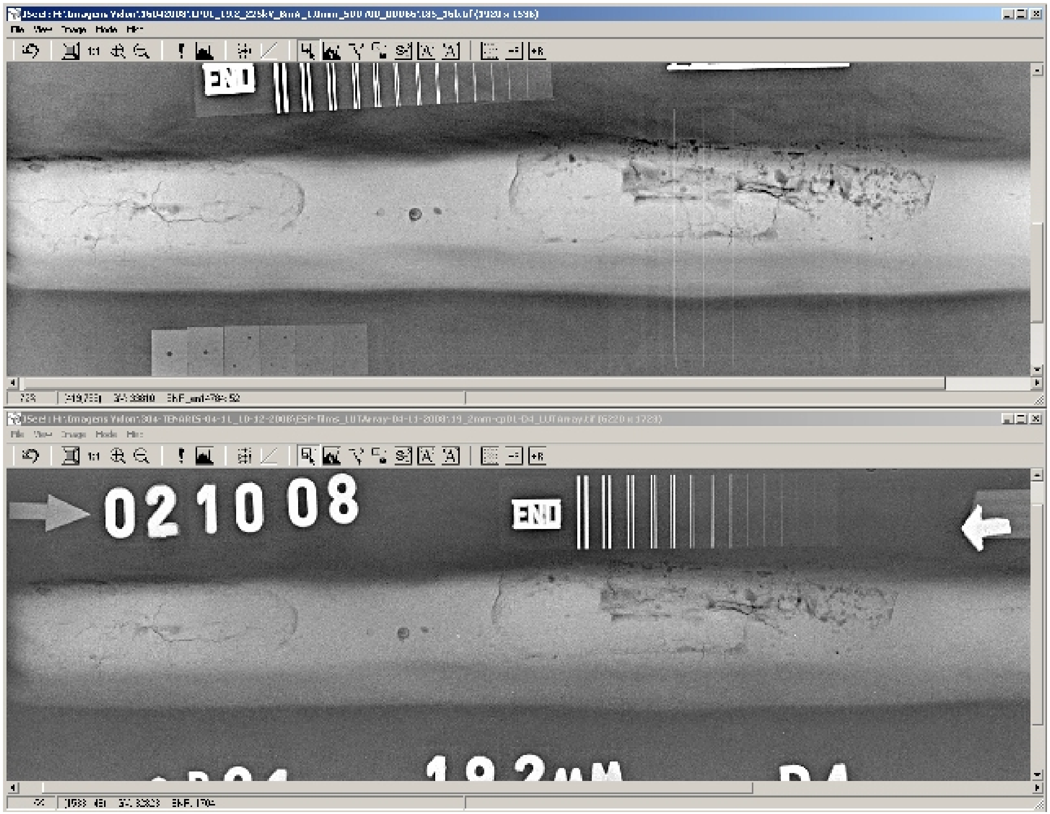

Figure 9 – Sample 01 – Comparison of digital radiography with total time of 8 seconds (top) and conventional radiography with film D4 (bottom).

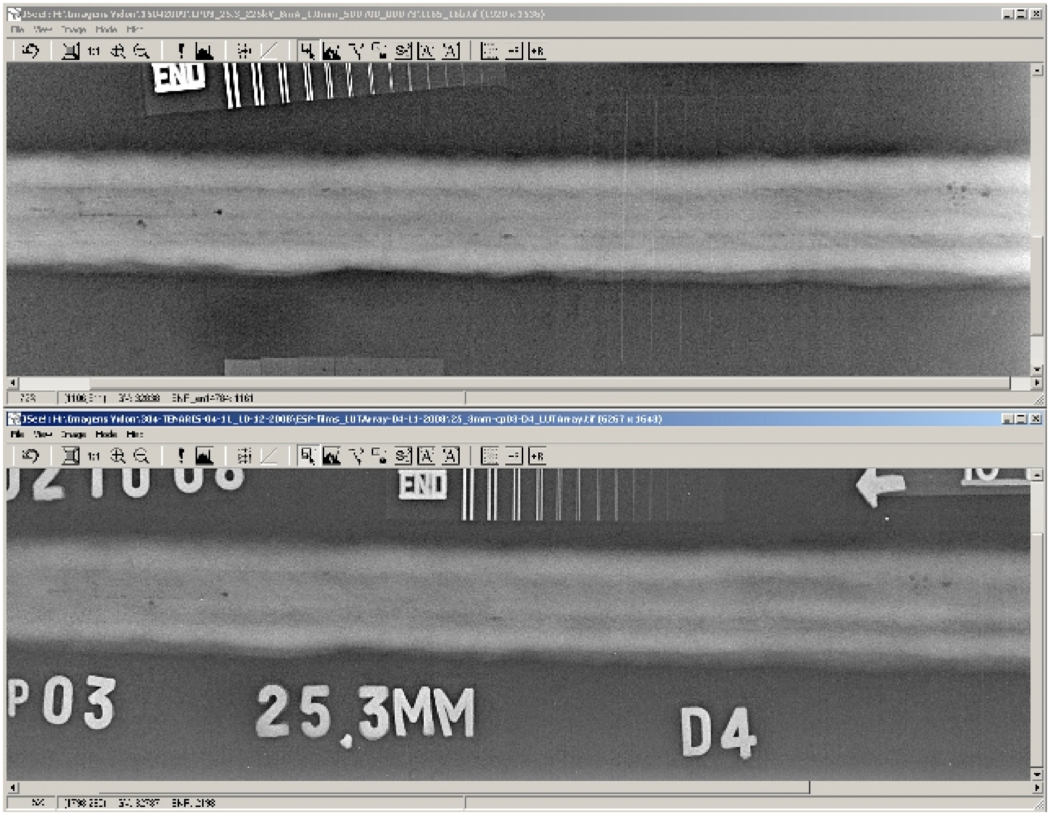

Figure 10 – Sample 03 – Comparison of digital radiography with total time of 16 seconds (top) and conventional radiography with film D4 (bottom).

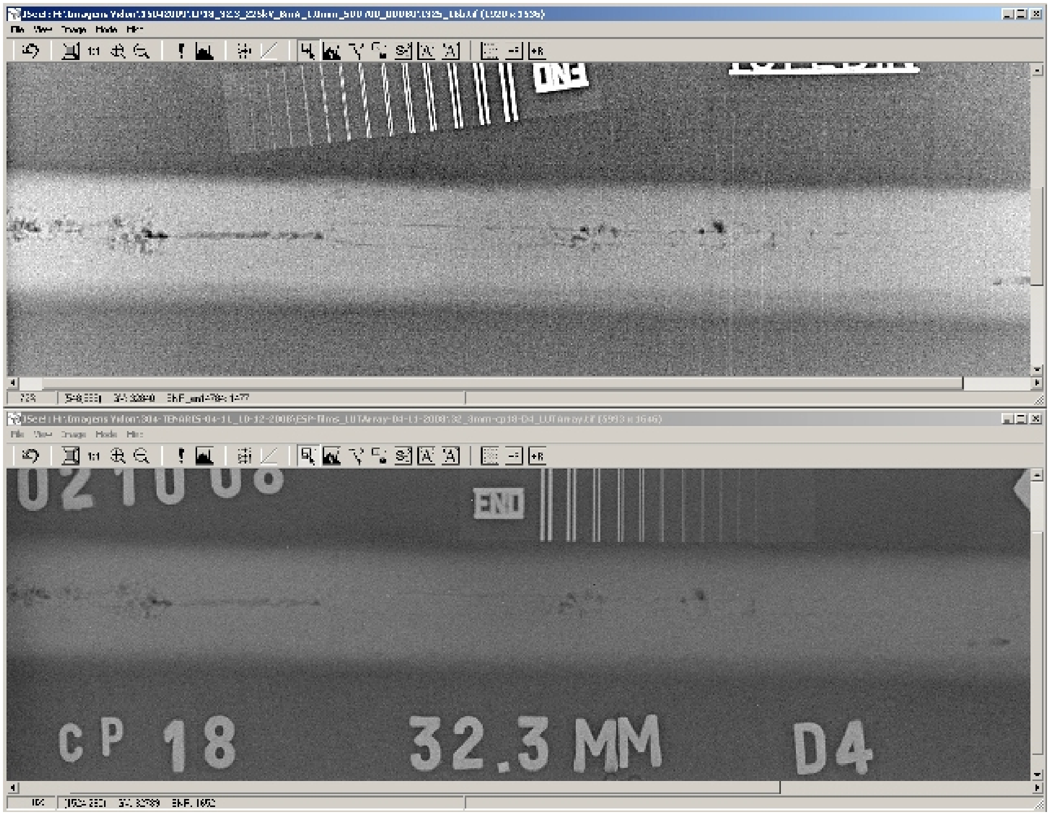

Figure 11 – Sample 18 – Comparison of digital radiography with total time of 32 seconds (top) and conventional radiography with film D4 (bottom).

4 – Conclusions

The results showed that, for all thicknesses, the exposure time used to meet the image quality requirements were below the usual time needed for direct radiography. However the SR_b were not reached for thickness of 4.85, 6.40 and 9.67 mm, therefore the compensation principle established by ISO 10893-7 was considered.

The digital technique proved to be more sensitive to real defects found on welds than the conventional technique. We can therefore conclude that the digital radiography using the flat panel can be applicable to the oil and gas segment with advantages over conventional technique as to quality aspects, productivity, environment, safety and health.

5 – References

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