RADIOGRAPHY OF WELDS USING SELENIUM 75, IR 192 AND X-RAYS

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Abstract

The selection and use of any method to be used for radiography depends on a number of considerations, these in general being:

a) The size, shape, orientation and distribution of imperfection in the weld.

b) The dimensions, geometry and physical properties of the weld and material.

c) The radiographic sensitivity required by the Standard, Code or Specification.

d) Cost of radiography.

e) The location where the radiography will be carried out.

f) When Se 75 can be used to replace X-ray.

Radiography is suitable for the detection of volume-type flaws. Under assured circumstances it is also suitable for the detection of lack of fusion, cracks and crack-like planar flaws which are oriented in the direction of the radiation beam; however, however it needs to be remembered that the ability of radiography to detect such planar flaws diminishes with unfavourable orientation.

The successful use of radiography depends on the ability of the radiation source, be it x-ray or gamma, to provide sufficient radiation to penetrate the material and produce an image of acceptable contrast and definition on the processed radiographic film, using an acceptable and economic time.

This paper presents the results of various techniques used on selected samples. These samples used contained a variety of flaws. The samples were subjected to radiographic inspection using X-rays, Ir 192 and Se 75 and the use of different classes of film.

Introduction

The choice and use of any method used for radiography depends on a number of factors, these in general are:

a) The type, size, shape, orientation and distribution of imperfection predictable in a material.

b) The dimensions, geometry and physical properties of the material.

c) The radiographic sensitivity required by the referencing Code, Standard or Specification.

d) The cost of radiography.

Radiography is suitable for the detection of volume-type flaws. Applying certain conditions it is also suitable for the detection of lack of fusion, cracks and crack-like planar flaws which are oriented parallel to the axis of the radiation beam; however, the ability of radiography to detect such planar flaws diminishes with unfavourable orientation.

The ability of radiography to detect a flaw also reduces with increasing weld thickness, the effect being most pronounced for the detection of fine planar discontinuities. The various NDT methods of inspection are complimentary to each other and consideration is generally given to the use of other appropriate forms of non-destructive testing if the sensitivity of the radiographic method is inadequate.

The successful use of radiography depends on the ability of the radiation source, be it x-ray or gamma, to provide sufficient radiation to penetrate the weld and produce an image of acceptable contrast and definition on the processed radiographic film, using an acceptable and economic time.

The difference between x-ray and gamma-ray radiographs is that while x-rays and gamma-rays are fundamentally the same type of electromagnetic radiation, the quality of radiation produced is based on their origin and their differing energy spectra.

X-ray sources generate a continuous range of energies up to a maximum which is dependent on the operating kilo voltage (kV), while gamma-ray sources produce fixed line spectra at specific photon energies and abundances. The weld being radiographed attenuates the beam of radiation by removing the lower photon energy components in proportion to the material type and thickness.

The quality of a radiograph and its ability to show a flaw is dependant on the procedure used embracing several factors such as set-up, film type/class, radiation energy used, source type and size, source to film distance, object to film distance and the film processing.

The choice of a suitable radiographic technique for a given application in industrial radiography is based on the constraint to reveal any flaw considered unacceptable by the client. In practice this objective may be difficult to measure. Therefore, the chosen radiographic procedure and technique will be a compromise between the quality required and the economic factors such as the set-up and exposure time.

This paper gives the results of various techniques used on selected samples. These samples used because they contain a variety of flaws. The samples were subjected to radiographic inspection using X-rays, Ir 192 and Se 75 and the use of different classes of film.

Gamma Source Considerations

Weld inspection of pipelines has been a typical application use of gamma radiography. The size of the radiation source and low cost and weight of the equipment in comparison to X-ray tubes of comparable power are advantages of gamma radiation equipment. Gamma equipment does not need a power supply and are very useful for mobile inspection and access in space restricted areas.

The more common gamma radiation source used is Iridium 192 (Ir 192) however due to its high radiation energy spectra, its application is limited to thick wall inspections, typically AS 2177 recommends a minimum thickness of 10mm while ASME Section V states that the radiation energy used shall achieve the density and IQI image requirements given in ASME Section V Article 2.

Selenium 75 (Se 75) has been commercially available for several years. The source containers are of similar size as those used for Ir 192, but their weight is less.

The gamma constant of Se75 (0.200) is almost half that of Ir-192 (0.48); and the Se 75 half life is 120 days as against 74 days for Ir-192. From the gamma spectrum of Se-75 its range of application regards material thickness is between Ir-192 and Ytterbium 169 (Yb-169).

The radiographic characteristics of Se 75 such as specific contrast and image quality were measured and compared with Ir-192 and X-ray to determine the suitable wall thickness range. The characteristics were measured with different class of films with lead screens. Test measurements of welds were compared to demonstrate the potential use of Se 75. It should be noted that due to measurements carried out by others the international standard ISO 5579, and the European EN 1435 (weld inspection) include the use of Se 75 for radiography.

Properties of Gamma Sources

The practical application and use of gamma radiography depends on the basic properties of the gamma sources as well as the availability of the working source containers and accessories. The table below gives the values for Yb 169, Se 75 and Ir 192 gamma sources which are considered in the standard EN 1435, and ISO 5579. With respect to the gamma constant and half-life, only three sources are of major practical importance for industrial radiography, these are: Selenium 75 (Se 75), Iridium 192 (Ir 192), and Yb 169. The application range as a function of the wall thickness depends on the gamma spectrum. Se-75 should be applied to examination of components with thinner wall thicknesses than are suitable for Ir 192. The intent of this paper is the description of the quantitative estimation of the suitable wall thickness ranges for Se 75 and Ir 192 in comparison to X-ray radiography.

Table 1 Gamma ray spectrum of sources used in industrial radiography

	Ytterbium Yb-169	**Selenium Se-75**	**Iridium Ir-192**
Gamma energy (kVp)	008-308	66-401	206-612
Half life (days)	32	120	74
Gamma constant	0.125	0.203	0.48

Wall Thickness Ranges
Using Se 75 a minimum wall thickness of 5 mm steel can be applied along with a maximum economical steel thickness of 30mm.

Gamma sources generally exceed the contrast for the X-ray sources for heavy wall thicknesses only. However, the practical and economical advantages of gamma sources need to be considered in comparison to X-rays. A reduced contrast has been accepted for the use of Ir 192 when isotopes are used for low wall thicknesses. Se 75 can provide the same contrast at lower wall thicknesses when compared to Ir 192, or provide improved values for the same material thickness.

Geometric Unsharpness
Measurements using the Se 75 show that the geometric unsharpness (fuzziness or lack of definition resulting from the source size) meets the requirements of AS 2177 and ASME V.

Inherent Unsharpness
Measurements with Se 75 and wire image quality indicators (IQI) corresponding to AS 2314 confirm the results of the contrast measurements. Moreover, these results show an over-proportional advantage of Se 75 in comparison to Ir 192 in the range of lower wall thicknesses. This can be explained with the reduced inherent film unsharpness of the Se 75 radiation due to its lower spectral energy compared to Ir 192.

Results of Trial Radiographs
Table 2 below show a sample of results of radiography tests carried out on pipes and plate using X-rays, Ir 192 and Se 75 that contained typical welding imperfections. A tick √ shows the imperfections were observed in the radiograph of the item.

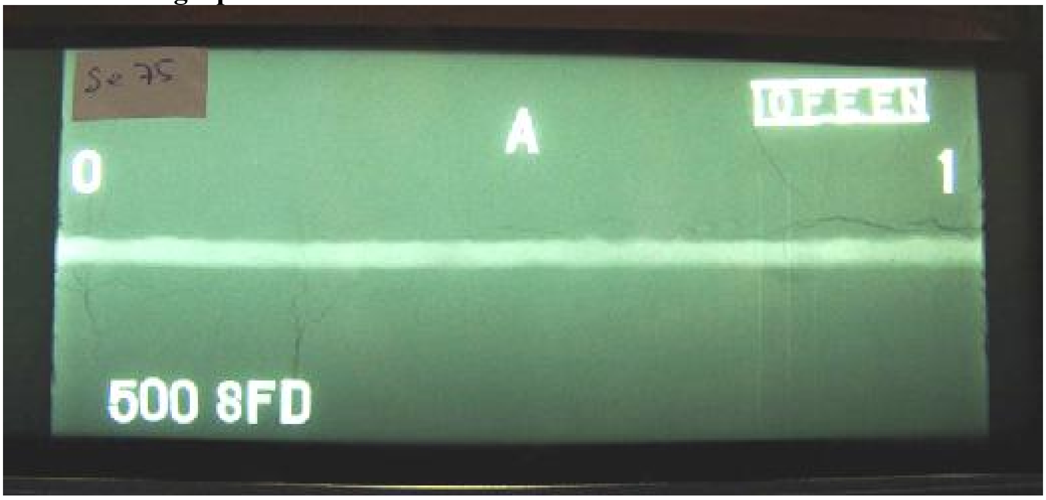
Item 1 – Stainless Steel Plate, WT = 3.4mm.
Item 2 – Steel plate, WT = 15.5mm
Item 3 – 200mm NB Steel Test Pipe, WT = 7.0mm.
Item 4 – Steel Plate, WT = 10.0mm

Table 2 Results showing weld imperfections found in radiographs comparing Se 75, X-ray and Ir 192.

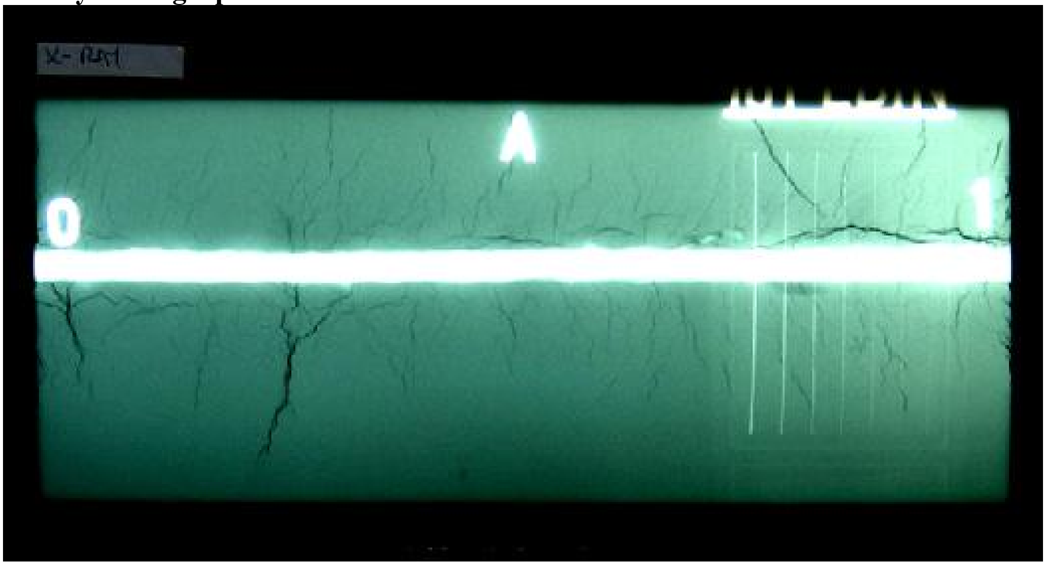
Imperfection Type – Yes = contained in item												
Sample ID	**GP**	**PG PU, PL**	**LP**	**LR**	**KT**	**KL**	**BT**	**SUC**	**SRC**	**SSP**	**IQI %**	**Method (AS 2177)**
Item 1					**Yes**	**Yes**						
Se 75					√**	√**					6.0	XR1/S & GR1/S
X-ray					√	√					3.2	XR1/S & GR1/S
Ir 192					√**	√**					8.0	XR1/S & GR1/S
Item 2		**Yes – PU, PL**				**Yes**						
Se 75	√	√				√					1.6	XR1/S & GR1/S
X-ray	√	√				√					1.2	XR1/S & GR1/S
Ir 192	√	√				√					2.0	XR1/S & GR1/S
Item 3					**Yes**	**Yes**						
Se 75					√*	√*					2.7	XR2/S & GR2/S
X-ray					√*	√*					2.7	XR2/S & GR2/S
Ir 192					√	√					5.4	XR2/S & GR2/S
Item 4	**Yes**	**Yes - PG**	**Yes**	**Yes**			**Yes**	**Yes**	**Yes**	**Yes**		
Se 75	√	√	√	√			√	√	√	√	2.0	XR2/S & GR2/S
X-ray	√	√	√	√			√	√	√	√	1.8	XR2/S & GR2/S
Ir 192		√	√				√	√		√	3.4	XR2/S & GR2/S

√* Crack image/definition observed more apparent, interpretation easier compared to Ir 192 but not as well defined and observable as x-ray radiographs.
√** Cracking (SCC) observed but much inferior and reduced to the x-ray radiographs of the plate. Se 75 radiographic contrast improved to the Ir192 radiograph.

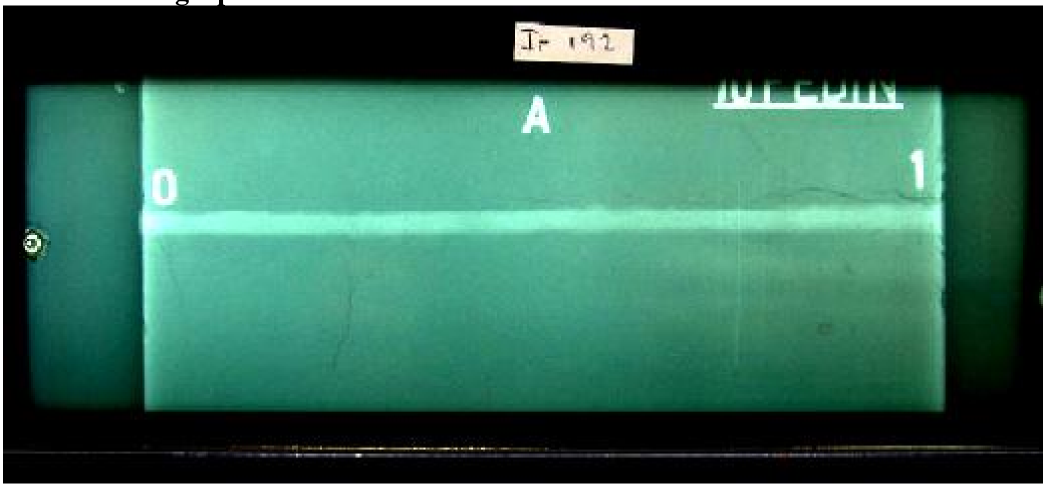
Item 1 – Se 75 Radiograph



Item 1 – X-ray Radiograph



Item 1 – Ir 192 Radiograph



The results show the improved detection of welding flaws using Se 75 compared to Ir 192. It can be seen that the Se 75 radiographic results are superior to Ir 192 for the radiography of thin (5mm) materials. X-ray radiography is superior for the detection of cracking compared to both Se 75 and Ir 192.

Additional radiography was also carried out on various samples. The result of these also illustrates an increased radiographic sensitivity and contrast of Se 75 compared to Ir 192.

References:

(1) AS 2177.1 – 2006 Non-destructive testing – Radiography of welded butt joints in metal.

(2) AS 2314 – 2006 Radiography of metals-Image quality indicators and recommendations for their use.

(3) ISO 5579 Non-Destructive Testing: Radiographic Examination of Metallic Materials by X- and Gamma Rays, Basic Rules, 1997.

(4) EN 1435, 1997 Non-destructive Examination of Welds: Radiographic Examination of Welded Joints.

(5) ASME Section V, 2004 Non Destructive Examination.

(6) Uwe Ewert and Jurgen Stade – Comparative Analysis of Image Quality from X-ray Radiography and Gamma Radiography Using Selenium 75 and Iridium 192.

Conclusions

- The application and use of Se 75 for industrial radiography is applicable for steel thicknesses over 5mm.
- The relative contrast of Se 75 is improved compared to Ir 192.
- The geometric unsharpness meets the requirements of AS 2177.1 and ASME V, Article 2.
- The results show that the typical welding flaws can be detected using Se 75. However, it should be noted that fine cracks in thin materials may be missed when compared to x-ray.
- The half life of Se 75 is 120 days compared to 74 days for Ir 192.
- Technicians have reported that the radiation area is reduced when using Se 75 compared to Ir 192.

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