Development of gamma exposure chart (Selenium-75) for Industrial Radiography Application

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Abstract

Radiographic exposure can be determined by either trial exposure, reference to previous data or using exposure chart. Without previous data, exposure chart is the easiest and economic way to achieve correct exposure. It will minimize re-shoot and time. This paper presents the development of gamma exposure chart for Selenium-75 source. Film radiography method has been chosen for this development using steel step wedge blocks. Agfa Structurix D7 films have been used during the exposure and the optical density of the films was measured by using X-Rite densitometer. Method of development of the chart is explained. The chart is tested on pipe and welded plate test sample and the results are discussed.

Abstrak

Dedehan radiografi boleh ditentukan sama ada melalui dedahan percubaan, rujukan daripada data terdahulu atau menggunakan rajah dedahan. Tanpa data terdahulu, rajah dedahan adalah cara yang paling mudah dan ekonomi untuk mencapai dedahan yang betul. Hal ini akan meminimumkan masa dan pengulangan dedahan. Kajian ini melibatkan pembangunan rajah dedahan bagi sumber Selenium-75. Keadah radiografi filem telah dipilih untuk pembangunan ini dengan menggunakan blok step wedge. Filem D7 Agfa Structurix telah digunakan semasa dedahan dan ketumapatan optik filem diukur dengan menggunakan densitometer X-Rite. Kaedah pembangunan rajah dijelaskan. Rajah juga diuji terhadap sampel ujikaji plat kimpal dan keputusan dibincangkan.

INTRODUCTION

Industrial radiography is one of the non-destructive testing (NDT) methods that wisely used in detection of volumetric-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 (Hayward & Currie 2006). However, the ability of radiography to detect such planar flaws diminished with unfavorable orientation.

The radiograph images resulted from this technique depends on the ability of the radiation source either gamma or X-ray to penetrate the objects that being inspected. The images should be acceptable in term of contrast and definition on the processed radiograph film, using an acceptable and economic time. In gamma-radiography, several radioisotopes with different energy range have been used for this purpose. Basically, practitioners have used Iridium-192 during the inspection. However, its application is limited to thick wall inspection to achieve requirement as stated in ASME Section V that the radiation energy used shall achieve the density and IQI image requirement given in ASME Section V Article 2.

Selenium 75 is now widely used throughout the world for demanding radiographic applications especially in the working range of 5-30mm steel. Compared with Iridium-192, Selenium-75 has a softer gamma ray spectrum and longer half-life. This also translates to more effective shielding efficiencies for collimators, portable shields, and radiography devices (Shilton, 2000). Furthermore, it provided advantages such as smaller exclusion zone with high image quality and improved practitioner's safety. For these reasons, Selenium-75 can replace X-ray machine for certain case during the inspection and providing much improved radiographic contrast. The details of Selenium 75 have summarized as in table 1. This paper presents the development of exposure chart for Selenium 75 in industrial applications.

Table 1: Selenium 75 properties that used in industrial radiography

Half life, days	120
Gamma energy, keV	66 – 401
Gamma constant	0.203
Dose/exposure rates, μSv/hr/Gbq	55

MATERIALS AND METHOD

The activity of Selenium-75 has been calculated before each exposure to determine the real activity as well as to determine the pre-estimated exposure time as shown in Equation 1 and 2 below:

$$A = \text{Ao}\exp\left[\frac{-0.693(t)}{\mathrm{T}_{\frac{1}{2}}}\right] \qquad (1)$$

$$\mathrm{E_t} = \frac{E}{A} \qquad (2)$$

$$SFD_{min} = t\left[\frac{F}{\mu g_{max}} + 1\right] \qquad (3)$$

where A is the activity, A_o is initial activity, t is elapsed time, $T_{1/2}$ is half-life, E_t is exposure time, Ci-hr, and E is exposure. D7 film has been chosen for this development because it is commercial radiographic film and widely used in industries. The source to film distance (SFD) was measured depending on source size that has been used as in Equation 3 where t is distance from source side of weld or object being radiographed to the film or object to film distance (OFD), μ_{gmax} is geometric unsharpness or penumbra and F is source size. Experimental setup for this exposure as shown in Figure 1 below.

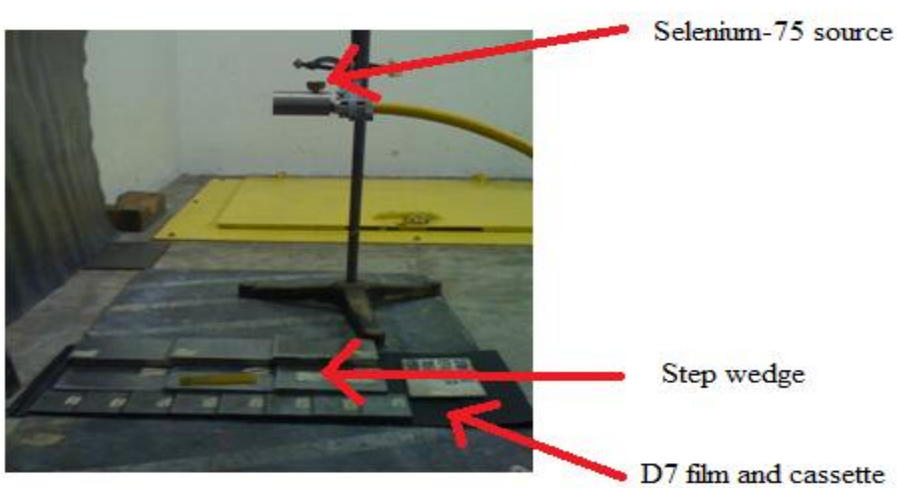

Figure 1: Experimental setup for step wedge exposure using Selenium 75 source

The source-film-distance (SFD) was fixed at 30, 40, 50, 60, 70 and 80 cm and the gamma rays were pointed directly perpendicular to the 8 mm of step wedges thickness. The mild steel step wedge with 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25 and 30 mm were then exposed at the same D7 film with 0.1 mm lead screen at front and back in the film cassette. After exposed the mild steel step wedge and film at certain exposure time, the film have been processed manually based on the film manufacturer's recommendation (Figure 2a).

Figure 2: a) The chemical used for film processing and b) determination of film density using X-RITE.

The density was measured at 8 mm mild steel step wedge which is should be 2.0 ± 0.1 optical density as shown in Fig. 2b. If at this point the film density is in the range 1.8 – 2.3 the optical densities of the other point of thickness were then measured and corrections of exposure were made by using Equation 4 and Table 2 is corrected exposure values at 30 cm source-film-distance.

$$Er = \frac{Ecr}{Ect} Et \quad (4)$$

Table 2: Corrected exposure values for other step wedge thickness depended on 8 mm step wedge optical density at 30 cm SFD.

SFD = 30cm			
Thickness (mm)	Density	Exposure (CiHr)	Corrected Exposure (CiHr)
3	1.8	0.55	0.62
4	1.91	0.55	0.58
5	2.02	0.55	0.55
6	2.07	0.55	0.55
7	2.08	0.55	0.55
8	2.02	0.55	0.55
9	1.87	0.55	0.6
10	1.6	0.55	0.67
15	1.22	0.55	1.04
20	0.59	0.55	2.22
25	0.61	0.55	2.4
30	0.51	0.55	3.12

RESULTS AND DISCUSSIONS

The processed film is shown in Figure 4 where the density for each part of step wedge varied with the thickness. Depending on the density of 8 mm step wedge, the densities of other thickness have calculated using Equation 4. Therefore, the exposure chart developed depending on the step wedge thickness against their exposure as shown in Figure 4. This exposure chart was then tested by two specimens, Plate_SE and Pipe_SE with 9 mm and 14 mm thickness, respectively as shown in Figure 5 and 6. Table 3 has summarized the density range and ASME requirement for each specimen that have been tested.

Table 3: Analysis results for tested specimens using Se-75 exposure chart.

Samples	Density range	Visible IQI	ASME requirements
Plate SE 9mm SWSI	1.9 – 2.2	6	6
Pipe SE 14mm DWSI	2.0 – 2.1	7	8

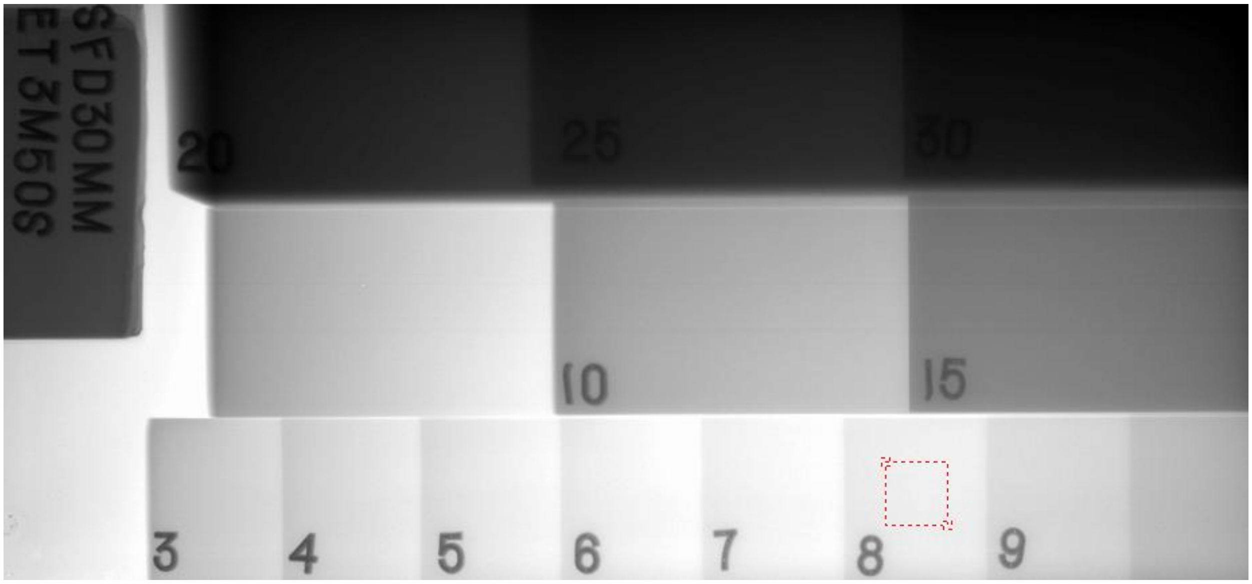

Figure 3: Processed film at 30 mm SFD

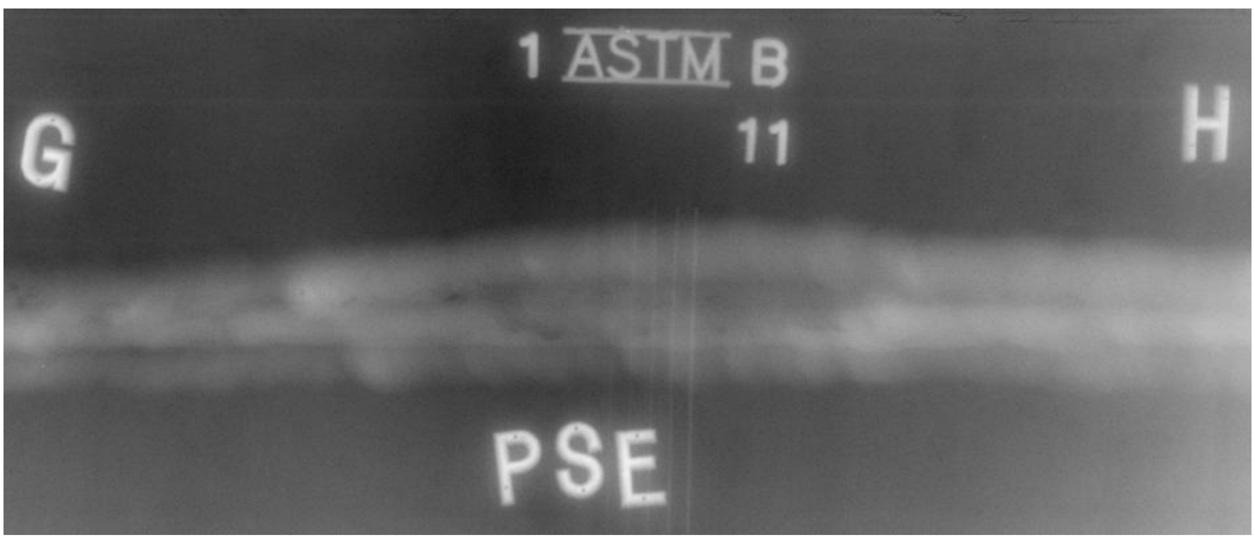

Figure 5: The film image of the pipe specimen (PIPE_SE)

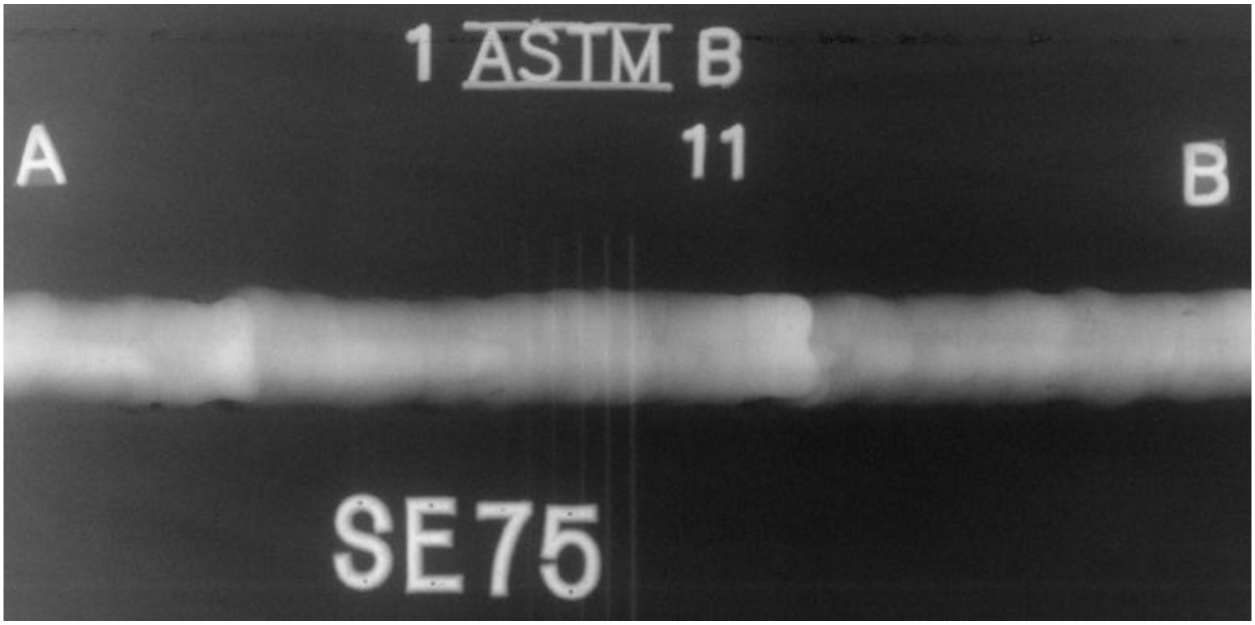

Figure 6: The film image of the plate specimen (PLATE_SE).

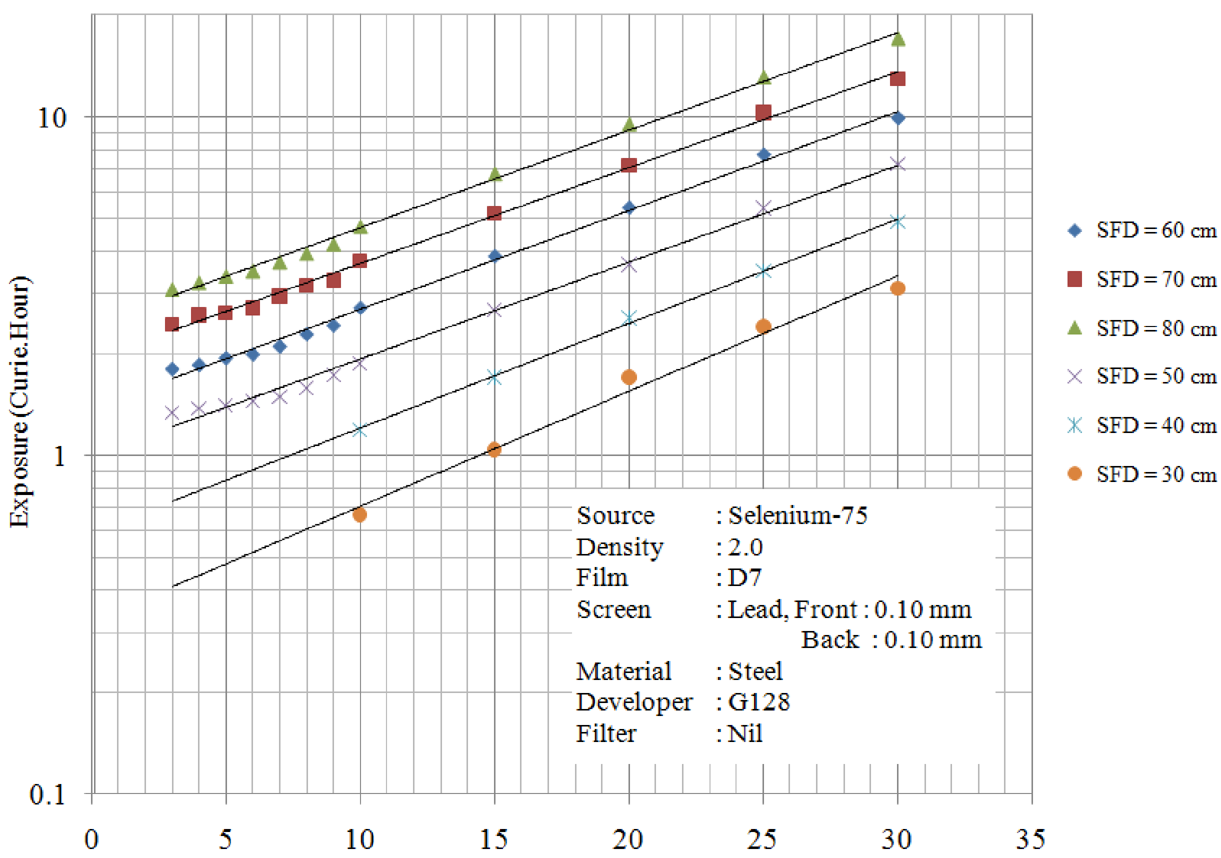

Figure 4: Exposure chart that have been developed at various source-film-side (SFD)

CONCLUSION

From this experiment it is found that the exposure chart provided density accuracy of 0.02%. The film density and IQI image were within the limit specified in ASME Section V Article 2. The results shown that this exposure chart has successful developed and can be used for further experimental needed.

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