Abstract — Radiography is one of the widely used nondestructive technique. Radiography produces the visual response of the test object on the film. The quality of the radiographic image is influenced by the type of film, source to film distance, exposure time, angle etc. This paper discusses the impact of source to film distance (SFD), voltage on the two types of radiographic film (D4, D7). The test piece considered is a stainless steel metal plate on which a rectangular hole is drilled with different width and depth. The plate is radiographed using X-ray source. The effect of these parameters is analyzed in terms of image grey level intensity on the digitized radiographic film. From the result it was found that higher the SFD and lower the value of KV will cause the gray value high.

Keywords — Source to film distance, Film type, Gray value, Digital radiography.

I. INTRODUCTION

The energy of the X-ray plays an important role in image contrast. The energy of the X-rays is controlled by the electrical potential of the X-ray tube. This potential is generally in the range of thousands of volts. X-ray generators will have a control that allows the voltage to be adjusted and this is generally labeled in kilovolts [1]. The voltage has an effect on the radiographic image because the energy used to produce the X-rays is related to the penetrating power of the X-rays.

Source-to-Film Distance (SFD) is a measure of the distance from the x-ray tube to the film to be exposed. This distance will change for various reasons. The effect of source to film distance will cause a corresponding change in the film density and the exposure time [2][15][16].

The exposure factors selected by the radiographer are Kvp, mA, SFD, time (second) affects the quality of the radiograph produced. The required radiographic density is produced when an adequate beam is penetrates into the material and when sufficient radiation has reached the film [3].

A radiographic image is made up of different shades of gray value, ranging from white gray at one end to black gray at other end. A film that shows very light and very dark areas has high contrast or a short gray scale as there are few shades of gray from one extreme to the other. A radiograph that has many shades of gray is referred to as one with low contrast or long gray scale [5]-[10].

This paper discusses as how X-ray energy (kilovoltage) effects radiograph quality and investigate the effect of how different radiographic films on image contrast. This paper also discusses the effect of source to film distance on the radiographic film.

The paper is organized as follows. Section 2 reviews the materials and methods, Section 3 deals with X-ray radiography. Section 4 discusses the experimental results on the data acquired, and Section 5 concludes the paper.

II. METHODS AND MATERIALS

A stainless steel metal of 3.5 mm thickness is considered. A rectangular notch of different length and breadth is drilled. Each notch is made in such a way that all of different depth. The plate is subjected to X-ray source of different kilovolt and varying source to film distance. The radiation is exposed on D4 and D7 film [16]. Two types of Image Quality Indicator (IQI) are placed on the source side of the material they are the placard, or hole-type and the wire IQI. IQI comes in a variety of material types so that one with radiation absorption characteristics similar to the material being radiographed can be used. After being radiographed, the film is digitized using Array Corporation’s 2905 X-Ray film digitizer of Indira Gandhi Center for Atomic Research, Kalpakkam. It is a Laser film digitizer. The radiographic film was digitized in two different DPI (100,300) and with two file formats (BMP, TIFF). From the digital image acquired the gray level distribution which depends on penetration of the radioactive source is calculated.

III. X-RAY RADIOGRAPHY

X-ray is one of the powerful sources used for the evaluation of radiographic weld material. X-ray sources generate a
continuous range of energies up to a maximum. And that is
dependent on the operating kilo voltage (kV), while gamma-
ray sources produce fixed line spectra at specific photon
Energies [1]. Properly exposing a radiograph is often a trial
and error process, as there are many parameters that affect the
final radiograph. Some of the parameter’s that affect the
density of the radiograph are the spectrum of radiation
produced by the x-ray generator, the voltage potential used to
generate the x-rays (KV), the current used to generate the x-
rays (mA), the exposure time, the distance between the
radiation source and the film, the material of the component
being radiographed, the thickness of the material that the
radiation must travel through, the film being used, the
concentration of the film processing chemicals and the contact
time etc[12]-[14].

The test piece with square notch of varying depth and area
is subjected to X-ray radiography. The different voltages
considered for experimental analysis are 110,130,150 KV
with a source to film distance of 1500, 1000,700,400 mm. The
other specifications include focus size, current, film size
used, screen size are listed in Table 1.

The experiment is done in two methods in one method with
a fixed source to film distance the film is radiographed with
three different voltages (110,130,150 KV) and the effect of
intensity variation is studied. In another method with a fixed
voltage, the film is radiographed with four different sources to
film distance and the effect of intensity variation is studied.

### Table 1. Specification for X-ray Radiography

<table>
<thead>
<tr>
<th>Specification of the sources</th>
<th>X-Ray</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>110,130,150 Kv</td>
</tr>
<tr>
<td>Focus size</td>
<td>2.6 mm</td>
</tr>
<tr>
<td>Current</td>
<td>5 mA</td>
</tr>
<tr>
<td>Source to film distance(SFD)</td>
<td>1500,1000,700,400mm</td>
</tr>
<tr>
<td>Source size</td>
<td>Ø2.7mm×2.1mm HT</td>
</tr>
<tr>
<td>Film type</td>
<td>D4 ,D7</td>
</tr>
<tr>
<td>Intensifying screen lead foil type</td>
<td>Front size 0.1mm</td>
</tr>
<tr>
<td></td>
<td>Back screen 0.1mm</td>
</tr>
<tr>
<td>Film size used</td>
<td>8” x 6”</td>
</tr>
</tbody>
</table>

IV. DATA ANALYSIS AND RESULTS

In the first phase of experiment the test piece of different
length and breadth is subjected to different voltage of X-ray
energy ie (150,130,110 KV) with a constant current of 5ma,
and a source to film distance of 700mm. This procedure is
carried out for two film type D4, D7[16]. The experimental
work is done on Scan Ray Private India Limited, Chennai.
The radiographic film is digitized using array 2905 laser film
digitizer. In the digital image the intensity value of the pixel
is calculated for different positions. Figure 2 shows the intensity
value distribution for different X-ray Voltage (KV) and a fixed
Source to Film Distance of 700mm on a D4 film

![Comparison of different Kv with constant Source to Film Distance on a D4 film](image1)

Fig 2. shows the gray value variation on a D4 film for different X-ray voltage when the Source to film Distance is kept constant.

![Comparison of different Kv with constant Source to Film Distance on D7 film](image2)

Fig 3. shows the gray value variation on a D7 film for different X-ray voltage when the Source to film Distance is kept constant.

![Comparison of different source to Film Distance with constant Kv in D4 film](image3)

Fig 4. Shows the gray value variation on a D4 film for different Source to Film Distance when X-Ray voltage is kept constant.
From the result it was found that the film digitized with 110kV is having the maximum intensity value. This is because of low penetration of X-ray source. Increase in voltage (KV) will cause too many photons strike the film and in the digital image it appears to be darker which causes the intensity value approach to zero. The same effect is absorbed for D7 film. Figure 3 shows the intensity value distribution for different X-ray Voltage (KV) and with a fixed Source to Film Distance of 1000mm on a D7 film.

Figure 4 shows the intensity value distribution for different Source to Film Distance and constant X-ray Voltage (KV) of 150KV on a D4 film. From the result it was found that film placed with 1500 mm distance from the source is having high intensity value. This is because the penetrating power of X-ray is less and in the digital image it appears to be lighter which causes the gray value to approach a maximum. The same effect is adsorbed for D7 film. Figure 5 shows the intensity value distribution for different Source to Film Distance and constant X-ray Voltage (Kv) of 150Kv on a D7 film.

Figure 1 shows the digital Radiographed image of the test piece. The image has seven rectangular notches along the horizontal direction which is of same length and with different depths. In position 1 the depth is maximum and the penetration of x-ray in this region is high and the image acquired is darker for this region. In position 7 the depth is minimum and the penetration of x-ray in this region is low and the image acquired is lighter for this region. The gray value distribution for the test image is shown in Figure 6. The depth orientation along the x-axis and y-axis direction is obtained by surface plot which is shown in figure 8 and figure 9. Along the y-axis direction the depth is same but with different lengths so that the peaks are of same height and different length which is shown in Figure 8. Along the x-direction of the test piece, the length is same but has different depths which are shown in surface plot of Figure 9.
V. CONCLUSION

The effect of source to film distance and voltage on the image contrast is analyzed in this paper. From the result it was analyzed that higher the voltage, the greater the speed of the electrons striking the focal spot. This results in decrease in the wavelength of the x-rays emitted and an increase in their penetrating power and intensity. The higher the source to film distance will cause the gray value to be increased in the digital radiographic image. Further quality of the digital radiographic image is analyzed using many image quality parameters in particular the gray value of the image is analyzed in this paper. Generally, the selection of an appropriate imaging system to a specific application task, involves a component specific characteristics, setup and application specific considerations.

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REFERENCES