

Radiographic Sensitivity in Industrial Radiographic Testing With X-Ray Films

By: Tee Kim-Tsew
(Technical Manager, Lott Inspection Sdn. Bhd., Malaysia
ASNT and ACCP Level III)

Abstract.

Radiographic Testing (RT) is widely used in industries, at airport for security checks, medical applications etc. to detect anomalies in materials and human bodies.

Radiographic Testing is the common NDT methods used in the construction and fabrication industries for the oil & gas sectors using welding, gas/liquid transmission pipelines, casting foundries, and condition monitoring in existing oil & gas refineries and facilities.

This paper will discuss radiographic testing sensitivity using industrial X-ray films mainly on welds and castings. No in-depth discussion in related science and physics, merely the perspective of an industrial radiographer based on his experience.

Keywords: IQI, Quantitative, Qualitative, sensitivity, contrast, definition, geometric un-sharpness

INTRODUCTION

The basic principle for the detection of anomalies using radiographic testing method is the difference in radiation absorption coefficients properties exhibits by different materials. The images are captured in a recording medium. The recording medium used may be X-ray film, phosphorous imaging plates, diodes etc. Industrial X-ray films are the common recording medium used for these applications.

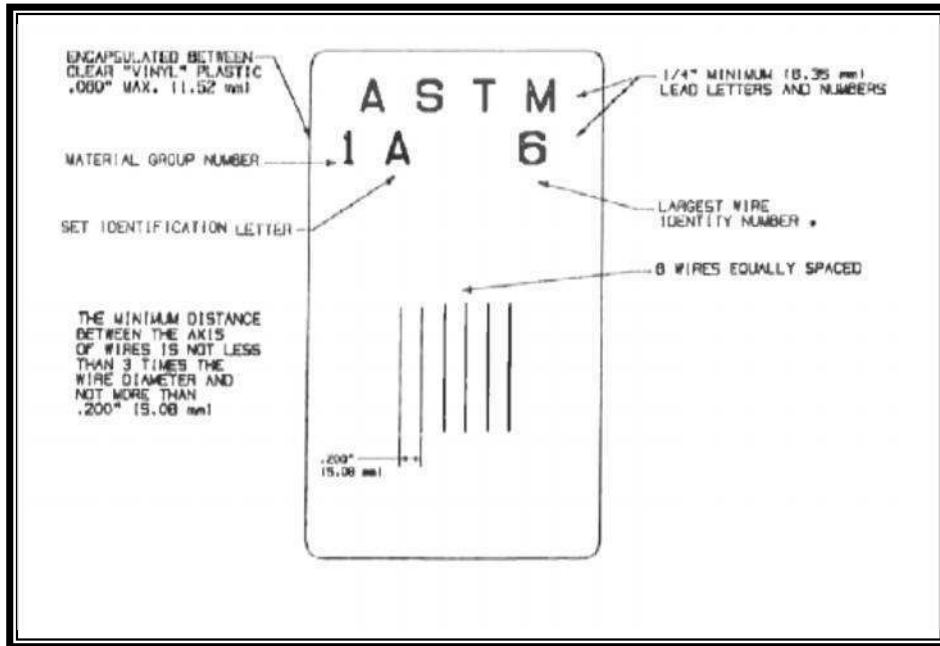
RADIOGRAPHIC TESTING SENSITIVITY

Like all other NDT methods, certain detection sensitivity is required for the technique to ensure detectability of desired anomalies.

In industrial radiography, Radiographic Sensitivity is a **QUALITATIVE** term referring to the size of the smallest detail that can be recorded and discernible on the film/radiograph, or to the ease with which the images of small details can be recorded.

Image Quality Indicator (IQI) which provides **QUANTITATIVE** measurement is used to determine the adequacy of a radiographic technique, but not intended to determine the smallest flaw that can be detected.

Wire type IQI as per ASTM E-747



There are other IQI designs like the Hole/Plaque type and step wedge design.

FACTORS AFFECTING RADIOGRAPHIC SENSITIVITY

Radiographic sensitivity is affected by the combined effects of **inherent un-sharpness** and two sets of factors – radiographic **contrast** and **definition**.

1. INHERENT UN-SHARPNESS

Somethings that cannot be avoided.

1. Film granularity – single or double side coated film, thickness of emulsion, etc.
2. Film processing.
3. Geometry – subject thickness, source size (not point source) and the nature of the flaw and its orientation to radiation beam.
4. Radiation scattering and mottling.

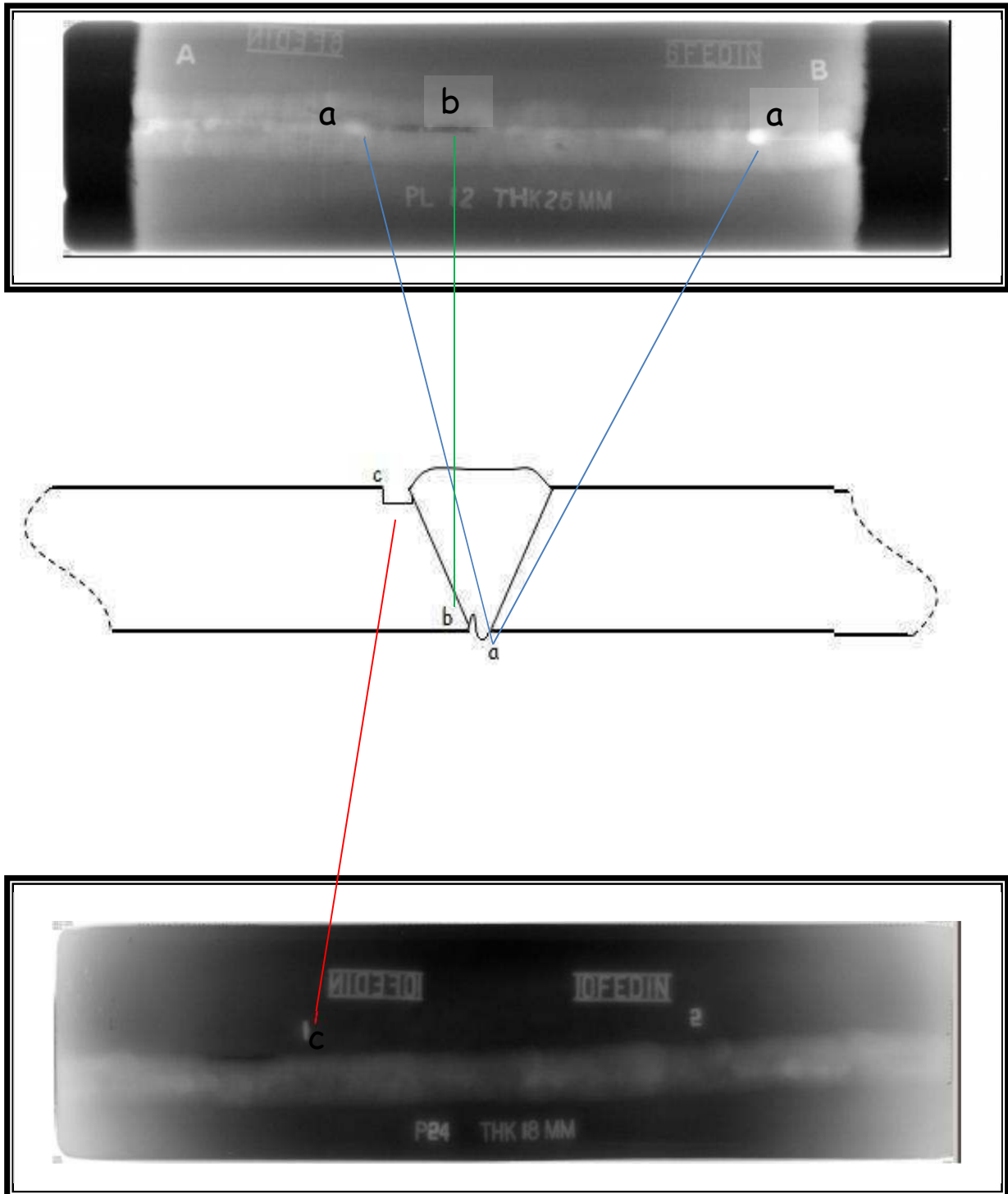
2. CONTRAST

Contrast is the difference in densities between two adjacent areas, and is the product of two distinct factors, i.e. Subject Contrast and Film Contrast.

Subject Contrast

1. Subject contrast is a result of difference in attenuation coefficient and absorption of radiation energy by the subject (specimen).
 - Thickness
 - Material densities
 - Flaw densities/nature/orientation Vs. base metal
 - A flat plate or a butt weld with flushed weld reinforcement and flushed root has very little or no subject contrast
 - Weld with high weld reinforcement has high subject contrast

Image formation

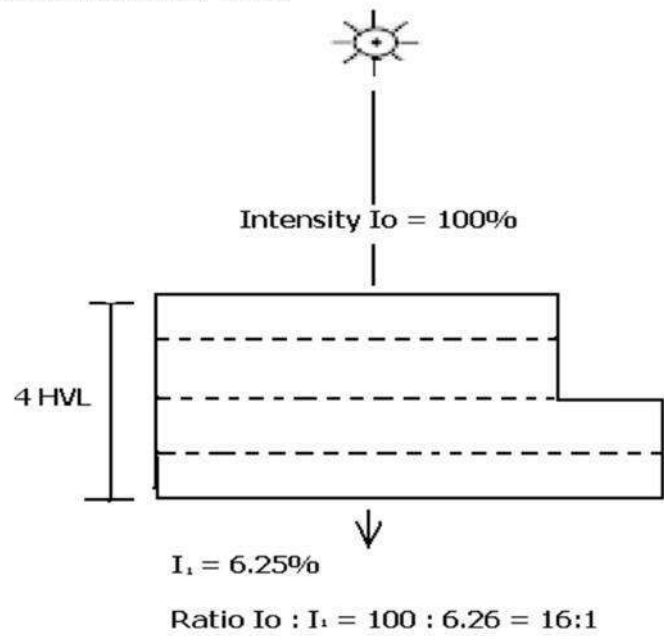


2. Scattered radiation

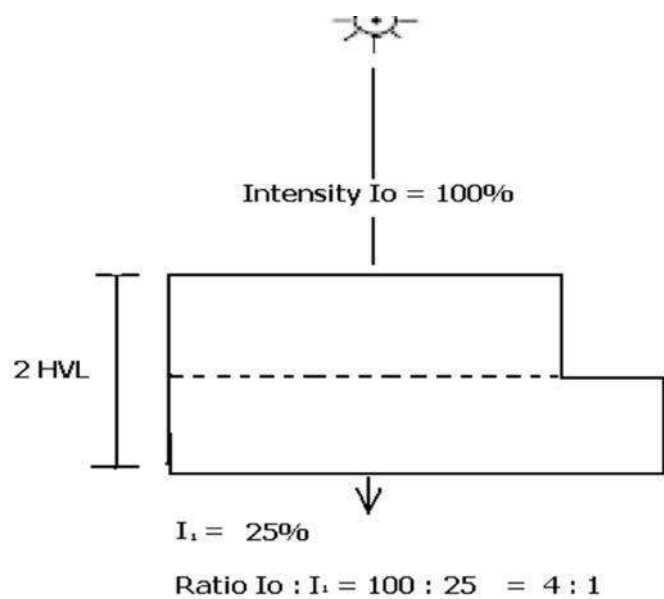
- Back scattering
- Side scattering
- Internal scattering /undercutting/mottling

3. Radiation Quality – **radiation energy selection**

Radiation Source- Soft:



Radiation Source- Hard:

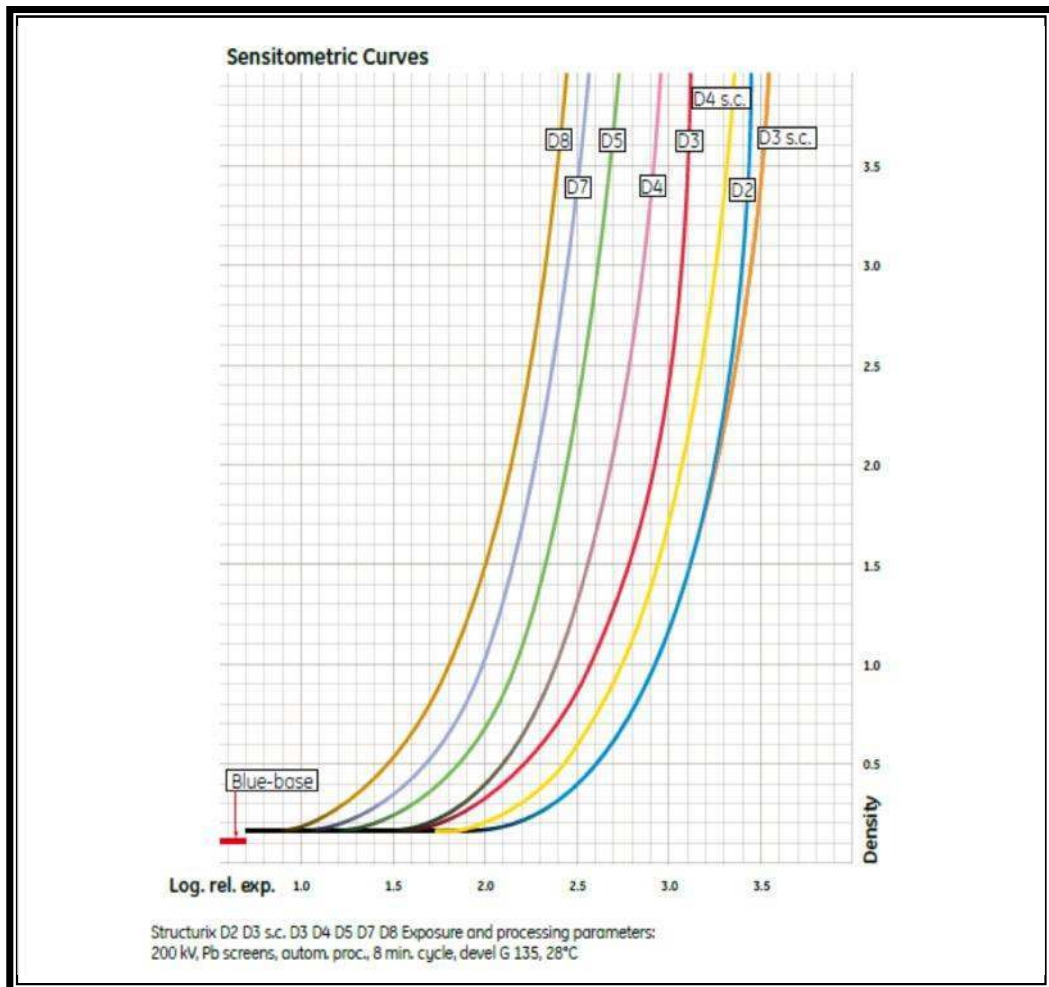


Film Contrast

Film contrast is the difference in the degree of darkness between two adjacent areas of a film.

Film latitude refers to the range of densities that a film is able to record in a single exposure. The H&D or Characteristic Curve of a film provides the relationship of film densities over exposure it received. The curve determines the usable density range of that particular Class of film.

Characteristic Curves of AGFA films



1. Classification of Industrial X-ray films as per ASTM E1815

- Class I: low speed, very high contrast, very low graininess.
- Class II: medium speed, high contrast, low graininess.

When the objective is to detect “very small” defect in weld, it is a common practice in the industry that Class I films (Agfa D4 and Fuji IX 50) or slower speed films (D2) are used carbon and stainless steel welds and casting.

The film manufacturers do not recommend these Classes of films to be used on thick and high densities materials like carbon and stainless steels. These Classes of films are recommended to be used on light materials, composite and electronic components. Agfa D5 and Fuji IX80 films, being Class 1 films, are more suitable.

Independent of how sharp (definition) the radiographic image is achieved, the film contrast may deteriorate without noticeable effects when such films are used on dense materials.

When there is subject contrast issue like incomplete root fusion due to high-low in pipe girth butt weld, or planar defects in joint of carbon steel pipes welded with INCONEL electrodes, these flaws may not be detected.

The exposure time for D4 and IX 50 films is about 4 times longer than the exposure time D7 or IX 100 films (Class 2, commonly used).

2. Film processing

- Temperature of processing chemicals
- Concentration of chemicals
- Stop bath, washing and wetting agent
- Degree of agitation
- Safe light
- Dark room conditions – water source, tank etc.

3. Film densities

Higher films densities has better film contrast provided the film density is within the usable density range of that class of film (Characteristic Curve) The film viewer must be sufficient bright to view the films.

The availability of viewing facilities at Client premises has to be taken into consideration when high densities films are submitted for review and acceptance.

4. Exposure time

Exposure time is the time required for sufficient radiation energy to ionize the film emulsion to the desire density after processing.

Over exposure or under exposure and compensated by film development time in manual processing will affect the film contrast. This is related to film graininess and densities.

5. Type of intensifying screens used.

Intensifying screens are used to intensify the image and reduce the exposure time. The image quality will be improved under suitable conditions.

- No intensifying screen is used
- Lead oxide or lead foil screens.
- Fluorescence screen
- Fluoro-metallic screens
- Copper, iron, INOX or other material
- Thickness of screen depends energy of radiation used
- Cleanliness, aging and quality deterioration/oxidation causing loss of intensification.

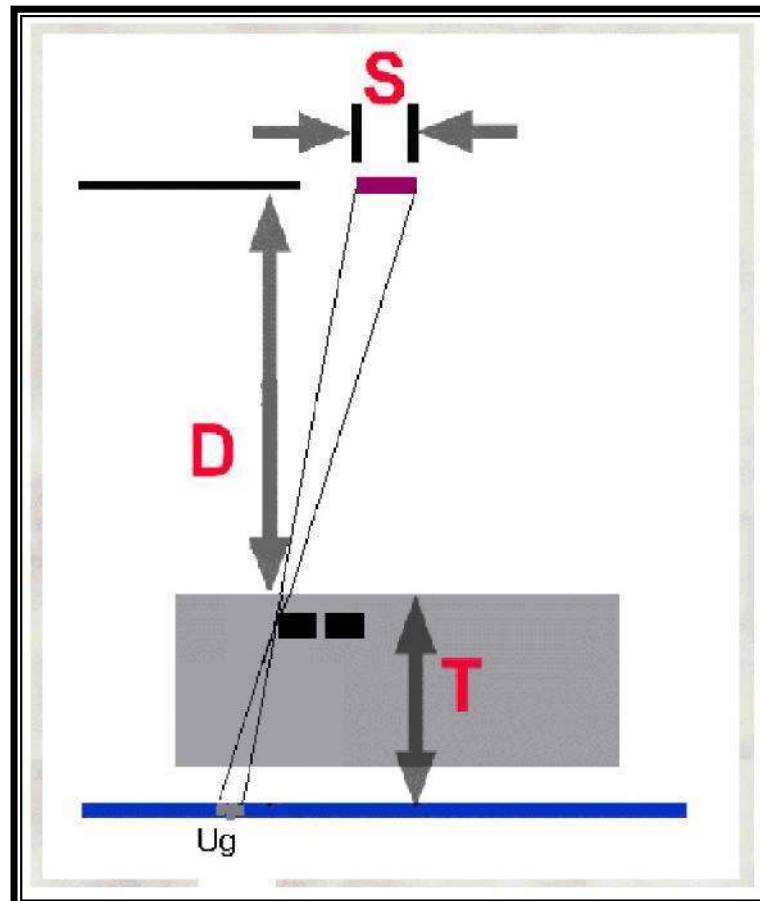
3. DEFINITION

Definition refers to the degree of sharpness of the outline of the radiographic image.

Geometry Factors

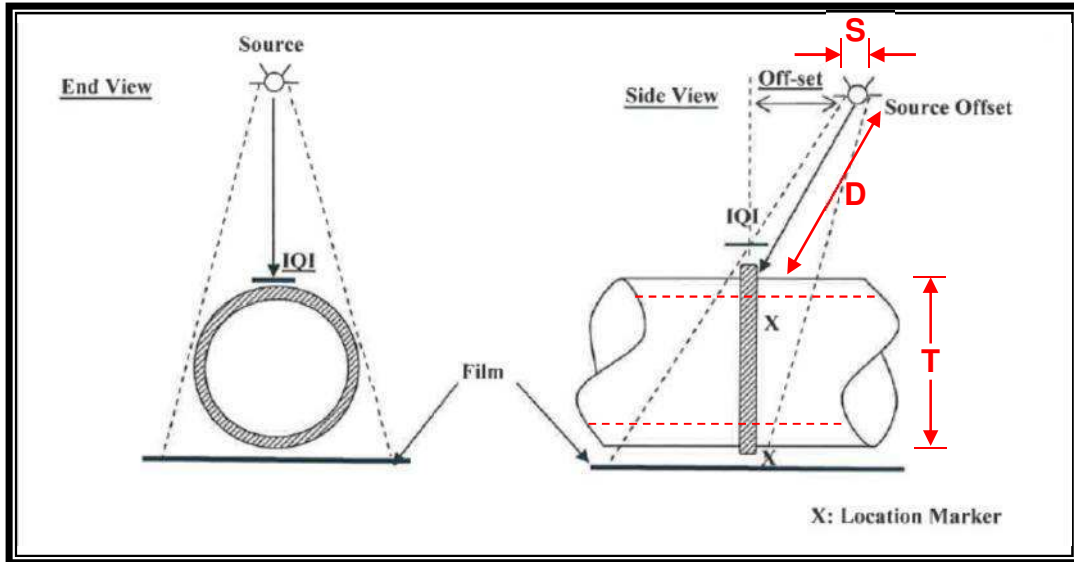
1. Geometric Un-sharpness (ASME Section V) $U_g = \frac{ST}{D}$

- S - effective focal-spot or source size (**Not point source**)
- D - source-to-subject distance
- T – source side of subject to film distance



This U_g computation is based on similar triangle formula.

Example: Elliptical exposure technique – double wall exposure, double wall image viewing



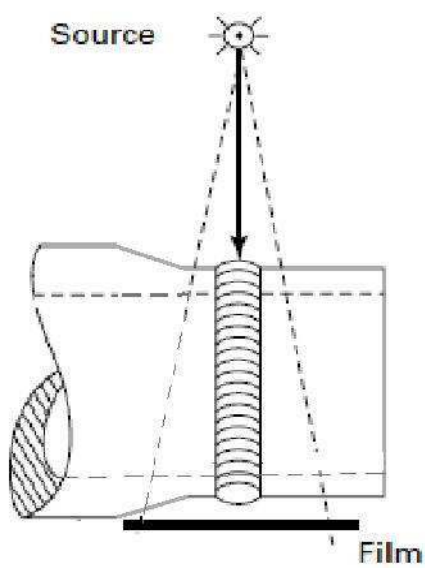
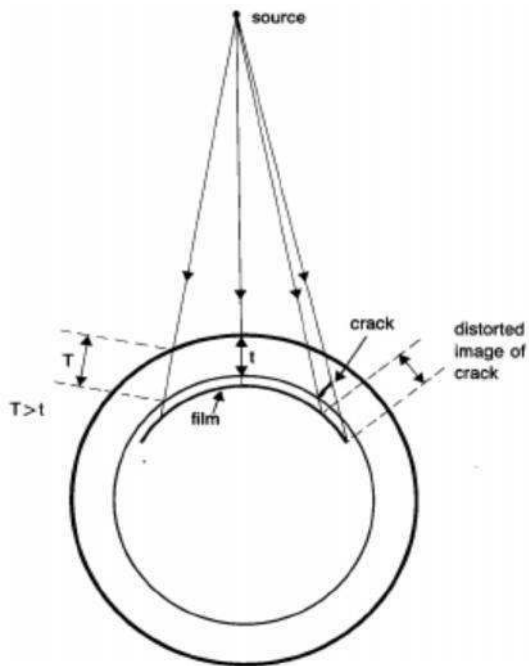
Exposure set-up for 2" Ø Wall Thickness 5.6 mm.

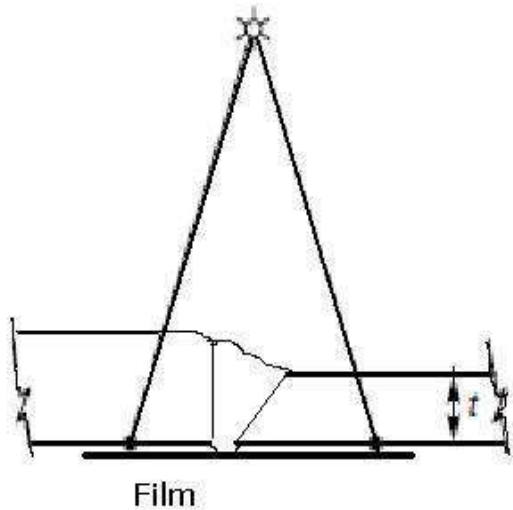
$$Ug = \frac{S.T}{D};$$

$$0.51 \text{ mm} = \frac{3.6 \text{ mm} \times 60.3 \text{ mm}}{D}; \quad D = 426 \text{ mm} = \mathbf{16.7 \text{ inches.}}$$

2. Abruptness of thickness changes in subject and its geometry

- Geometry causing image distortion
- Diagnostic film length, related to Ug formula above





3. Intensifying Screen to film contact

- Free electrons are emitted when lead screen is exposed to X- ray or Gamma-ray.
- Image's definition and contrast will deteriorate if there is a gap between the film and screen during exposure due to "stray" electrons.

4. Motion of subject, source and/or film during exposure

- Double image
- Image distortion

4. FILM GRANULARITY

This is the appearance of film graininess on the processed radiographs.

- i) This is directly related to the grain sizes / granularity of the film emulsion, Classification of films.
- ii) Exposure time. Over exposed or under exposed may affect image quality which is also related to contrast.
- iii) Dark room practices.

RADIOGRAPHIC SENSITIVITY / IMAGE QUALITY

Inherent un-sharpness

Contrast

Definition

Subject Contrast	Film contrast
Affected by:	Affected by:
1. Absorption difference in subject	1. Class of film
2. Scattered radiations	2. Film processing and dark room practices
3. Radiation quality	3. Film Density
	4. Exposure time
	5. Intensifying screens

Geometry	Film Granularity
Affected by:	Affected by:
1. Geometric un-sharpness $U_g = FT/D$	1. Class of film
2. Abruptness of thickness changes in subject.	2. Exposure time
3. Screen to film contact	3. Film processing and dark room practices
4. Movement of film or source during exposure	