Radiation Protection and Safety in Industrial Radiography
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Abstract:
Radiography technique is one of the most widely utilized non-destructive methods, used in industry to evaluate the structural integrity or find out the hidden details of an assembled structure. Since this method uses ionizing radiation, it is important to ensure not only the quality of product, but also the safety of the technician and the general public, as well as the protection of the environment. Since the technique deals with very large amounts of radiation during testing periods, improper practice could result in the technician and the public being exposed to a large dose of radiation in just a few seconds. Therefore, a high degree of care and professionalism is required for radiography work. Moreover, contamination from a corroded or damaged source can cause additional radiation hazards to radiography personnel. The radiography procedure for a job is developed in such a way that only a minimum dose is received during practice. This is achieved through the proper design of radiography exposure installation, proper training of radiation workers, strict adherence to radiation safety rules and proper selection and maintenance of radiation sources. This project deals with various aspect of radiation safety norms to be implemented during the practice.

Keywords: Radiography technique, non-destructive methods, radiation hazards, radiation safety.

1. INTRODUCTION
Radiography is an important tool in nondestructive evaluation. The method offers a number of advantages over other nde methods, but one of its disadvantages is the health risk associated with the radiation. Health effects can occur due to either long-term low level exposure or short term high level exposure. The primary risk from occupational radiation exposure is an increased risk of cancer. The amount of risk depends on the amount of radiation dose received, the time over which the dose is received, and the body parts exposed. Although scientists assume low-level radiation exposure increases one's risk of cancer, medical studies have not demonstrated adverse health effects in individuals exposed to small chronic radiation doses (i.e., up to 10,000 mrem above background). The increased risk of cancer from occupational radiation exposure is small when compared to the normal cancer rate in today's society. The current lifetime risk of dying from all types of cancer in the United States is approximately 20 percent (see figure). If a person received a radiation dose of 10 rem to the entire body (above background), his or her risk of dying from cancer would increase by one percent. Complicating matters further is the fact that gamma and x-ray radiation are not detectable by the human body. However, the risks can be minimized when the radiation is handled and managed properly. The law requires that individuals receive training in the safe handling and use of radioactive materials and radiation producing devices.

1.2 MOTIVATION OF PROJECT
There are "n"of shielding methods and materials are available in radiation field like lead, depleted uranium, concrete, but we are making an attempt here go for cheap and economic materials instead of costly and rarely available materials like depleted uranium. Hence we are going to use fly ash, hollow blocks, fire bricks and finding out the radiation by shielding the above materials and analyze with the acceptable level.

2. RADIATION
2.1 WHAT IS RADIATION
Matter is made up of tiny units called atoms; every atom has a nucleus and a surrounding cloud of electrons. The nuclei of some atoms are unstable. They may change their structure and consequently their physical and chemical properties spontaneously. When an unstable nucleus undergoes changes, invisible particles or waves are released. This process is called radioactive decay. The emitted particles or waves are called radiation. The unstable nucleus is said to be radioactive. Radioactive nuclei are called radio nuclides. Radiation can be defined as the propagation of energy through matter or space. It can be In the form of electromagnetic waves or energetic particles.
2.2 TYPES OF RADIATION
Radiation can be classified as non-ionizing and ionizing:

Non-ionizing radiation e.g. visible light, signals from mobile phones, and radio waves; and Ionizing radiation e.g. radiation emissions from uranium ore, and high frequency waves in the electromagnetic spectrum such as x-rays.

2.3 TYPES OF IONISING RADIATION
In general, the most common types of ionizing radiation are:

- Alpha particles have little power of penetration and can be easily stopped by a sheet of paper or the outer layer of the skin. However, alpha emitting materials are harmful to health if they enter the body by inhalation or along with food or water.
- Beta particles are high speed electrons and are more penetrating than alpha particles. A sheet of aluminium a few millimetres thick can stop beta particles.
- X-rays and gamma rays are both very penetrating and can pass right through human body. Dense materials such as lead or concrete are more effective in absorbing these rays.
- Neutrons do not carry any electric and are constituents of atomic nuclei. Hydrogen-rich materials, such as water or paraffin can shield against these highly penetrating particles.

Figure 1. Penetrating power of ionizing radiation

2.4 CHARACTERISTICS OF GAMMA RADIATION AND X-RAYS
Gamma radiation and x-rays are electromagnetic radiation like visible light, radio waves, and ultraviolet light. These electromagnetic radiations differ only in the amount of energy they have. Gamma rays and x-rays are the most energetic of these. Gamma radiation is able to travel many meters in air and many centimetres in human tissue. It readily penetrates most materials and is sometimes called "penetrating radiation." x-rays are like gamma rays. They, too, are penetrating radiation. Radioactive materials that emit gamma radiation and x-rays constitute both an external and internal hazard to humans. Dense materials are needed for shielding from gamma radiation. Clothing and turnout gear provide little shielding from penetrating radiation but will prevent contamination of the skin by radioactive materials. Gamma radiation is detected with survey instruments, including civil defence instruments. Low levels can be measured with a standard geiger counter, such as the cd v-700. High levels can be measured with an ionization chamber, such as a cd v-715. Gamma radiation or x-rays frequently accompany the emission of alpha and beta radiation. Instruments designed solely for alpha detection (such as an alpha scintillation counter) will not detect gamma radiation. Pocket chamber (pencil) dosimeters, film badges, thermo luminescent, and other types of dosimeters can be used to measure accumulated exposure to gamma radiation checking by survey meter.

2.5 RADIOACTIVE “HALF-LIFE”
Radioactive material decays with time. The time taken for half of its original amount to decay is called the “half-life”. For example, radioactive iodine-131 has a half-life of about 8 days. It loses half of its initial radioactivity in 8 days, and half of the remaining radioactivity in another 8 days. The half-lives of various radionuclide’s may vary from millionths of a second to millions of years.

2.6 HALF-VALUE LAYER (SHIELDING)
As was discussed in the radiation theory section, the depth of penetration for a given photon energy is dependent upon the material density (atomic structure). The more subatomic particles in a material (higher Z number), the greater the likelihood that interactions will occur and the radiation will lose its energy. Therefore, the denser a material is the smaller the depth of radiation penetration will be. Materials such as depleted uranium, tungsten and lead have high Z numbers, and are therefore very effective in shielding radiation. Concrete is not as effective in shielding radiation but it is a very common building material and so it is commonly used in the construction of radiation vaults. Since different materials attenuate radiation to different degrees, a convenient method of comparing the shielding performance of materials was needed. The half-value layer (hvl) is commonly used for this purpose and to determine what thickness of a given material is necessary to reduce the exposure rate from a source to some level. At some point in the material, there is a level at which the radiation intensity becomes one half that at the surface of the material. This depth is known as the half-value layer for that material. Another way of looking at this is that the hvl is the amount of material necessary to reduce the exposure rate from a source to one-half its unshielded value. Sometimes shielding is specified as some number of hvl. For example, if a gamma source is producing 369 r/h at one foot and a four hvl shield is placed around it, the intensity would be reduced to 23.0 r/h.

Each material has its own specific hvl thickness. Not only is the hvl material dependent, but it is also radiation energy dependent. This means that for a given material, if the radiation energy changes, the point at which the intensity decreases to half its original value will also change. Below are some hvl values for various materials commonly used in industrial radiography? As can be seen from reviewing the
values, as the energy of the radiation increases the hvf value also increases.

Approximate hvf for various materials when radiation is from a gamma source

<table>
<thead>
<tr>
<th>Source</th>
<th>Concrete</th>
<th>Steel</th>
<th>Lead</th>
<th>Tungsten</th>
<th>Uranium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iridium-192</td>
<td>44.5</td>
<td>12.7</td>
<td>4.8</td>
<td>3.3</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>(1.75)</td>
<td>(0.5)</td>
<td>(0.19)</td>
<td>(0.13)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>Cobalt-60</td>
<td>60.5</td>
<td>21.6</td>
<td>12.5</td>
<td>7.9</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>(2.38)</td>
<td>(0.85)</td>
<td>(0.49)</td>
<td>(0.31)</td>
<td>(0.27)</td>
</tr>
</tbody>
</table>

2.7 IONIZATION AND CELL DAMAGE

As previously discussed, photons that interact with atomic particles can transfer their energy to the material and break chemical bonds in materials. This interaction is known as ionization and involves the dislodging of one or more electrons from an atom of a material. This creates electrons, which carry a negative charge, and atoms without electrons, which carry a positive charge. Ionization in industrial materials is usually not a big concern. In most cases, once the radiation ceases the electrons rejoin the atoms and no damage is done. However, ionization can disturb the atomic structure of some materials to a degree where the atoms enter into chemical reactions with each other. This is the reaction that takes place in the silver bromide of radiographic film to produce a latent image when the film is processed. Ionization may cause unwanted changes in some materials, such as semiconductors, so that they are no longer effective for their intended use.

2.7.1 IONIZATION IN LIVING TISSUE (CELL DAMAGE)

In living tissue, similar interactions occur and ionization can be very detrimental to cells. Ionization of living tissue causes molecules in the cells to be broken apart. This interaction can kill the cell or cause them to reproduce abnormally. Damage to a cell can come from direct action or indirect action of the radiation. Cell damage due to direct action occurs when the radiation interacts directly with a cell’s essential molecules (DNA). The radiation energy may damage cell components such as the cell walls or the deoxyribonucleic acid (DNA). DNA is found in every cell and consists of molecules that determine the function that each cell performs. When radiation interacts with a cell wall or DNA, the cell either dies or becomes a different kind of cell, possibly even a cancerous one. Cell damage due to indirect action occurs when radiation interacts with the water molecules, which are roughly 80% of a cell’s composition. The energy absorbed by the water molecule can result in the formation of free radicals. Free radicals are molecules that are highly reactive due to the presence of unpaired electrons, which result when water molecules are split. Free radicals may form compounds, such as hydrogen peroxide, which may initiate harmful chemical reactions within the cells. As a result of these chemical changes, cells may undergo a variety of structural changes which lead to altered function or cell death. Various possibilities exist for the fate of cells damaged by radiation. Damaged cells can:

- Completely and perfectly repair themselves with the body’s inherent repair mechanisms.
- Die during their attempt to reproduce. Thus, tissues and organs in which there is substantial cell loss may become functionally impaired. There is a “threshold” dose for each organ and tissue above which functional impairment will manifest as a clinically observable adverse outcome. Exceeding the threshold dose increases the level of harm. Such outcomes are called deterministic effects and occur at high doses.
- Repair them imperfectly and replicate this imperfect structure. These cells, with the progression of time, may be transformed by external agents (e.g., chemicals, diet, radiation exposure, lifestyle habits, etc.). Alter a latency period of years; they may develop into leukaemia or a solid tumour (cancer). Such latent effects are called stochastic (or random).

2.8 HARMFUL EFFECTS OF IONISING RADIATION

An individual working with a source of radiation should be familiar with radiation hazards. When ionizing radiation enters the body tissue, it produces ionization and cause the chemical dissociation of the tissue molecules. When chemical dissociation takes place in vital components of the body cell, it may be destroyed by the destruction of DNA chain due to unwanted radiation. The cell production rate may be increased and malignant tumor may be formed. Exposure to ionizing radiation can produce several effects in an individual depending on. The type and amount of radiation producing the exposure the amount of body that is exposed the general health of the exposed individual. The quality of medical care available in the event of are relatively high exposure.

The effects of radiation can be divided into following two types:
1. Stochastic (long term or delayed) radiation effect
2. Non stochastic (short term or immediate or acute) radiation effect

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2.8.1 STOCHASTIC EFFECT
These are effects which show a random process i.e. they can occur at any dose level. The probability of the effect occurring is dose dependent. Higher the dose greater the probability. Stochastic effects are cancer and genetic effects. Of these, most important is cancer. Delayed effects in addition to cancer induction include teratogenesis (the induction of birth effects by irradiation of fetus). And mutagenesis (the induction of genetic disorders in future generation by irradiation of germ cells). Data on stochastic effects are limited. The most important set of data from the survivors of the atom bomb explosion in Japan at Hiroshima and Nagasaki. Cancer birth defects and genetic mutations all occur naturally at relatively high rates in human population and identifying an increase in these rates caused by exposure. Too small amount of ionizing radiation is subject to considerably uncertain.

2.8.2 NON-STOCHASTIC EFFECTS
The short-term effects of radiation are associated with the levels of radiation far above those received by persons working in modern radiation facility. Hair loss, skin burns, sterility etc are the examples of deterministic effects. These effects are a result of loss of functional cells, in tissues or organs i.e. cell killing. The body may lose its ability to combat infection. Following an absorbed dose of sceralgray diarrhea, electrolyte imbalance, dehydration and other gastrointestinal effects may appear within a few days as a sequence of cell damage. Moreover there are some of the serious health hazards caused by heavy exposure to ionizing radiations. These are discussed below

2.8.2.1 GENETIC MUTATION
When the gene in the DNA chain of a cell is distorted or changed, the same effect is reproduced in the subsequent divisions of the cell. If the affected gene belongs to a cell taking part in reproduction, the progeny (offspring) may show some mental or physical disabilities.

2.8.2.2 CANCER
When there is uncontrolled multiplication of cells whose genes are damaged, a tumour may be formed in any part of the body.

2.8.2.3 LEUCOPENIA
It is caused when the number of white blood cells in the blood becomes low. This reduces the Resistance of the body prone to infections.

2.8.2.4 BONENEROSIS
It results when the bone marrow is damaged by the radiations. The bone marrow is responsible for producing red blood cells in the body.

2.8.2.5 STERILITY
It results when there is severe radiation which damages the goals.

2.8.2.6 EPILATION
With this, the hair start to fall off which is caused by heavy exposure to radiation, vomiting, fever, diarrhea, headache, radiation sickness may result on early effect.

2.9 EXPOSURE SYMPTOMS
Listed below are some of the probable prompt and delayed effects of certain doses of radiation when the doses are received by an individual within a twenty-four hour period.

Dosages are in roentgen equivalent man (rem)

- 0-25 no injury evident. First detectable blood change at 5 rem.
- 25-50 definite blood change at 25 rem. No serious injury.
- 50-100 some injury possible.
- 100-200 injury and possible disability.
- 200-400 injury and disability likely, death possible.
- 400-500 median lethal dose (mld) 50% of exposures are fatal.
- 500-1,000 up to 100% of exposures are fatal.
- 1,000 over 100% likely fatal.

The delayed effects of radiation may be due either to a single large overexposure or continuing low-level overexposure. Example: dosages and resulting symptoms when an individual receives an exposure to the Whole body within a twenty-four hour period.

100 – 200 rem
- First day No definite symptoms
- First week No definite symptoms
- Second week No definite symptoms
- Third week Loss of appetite, malaise, sore throat and diarrhea
- Fourth week Recovery is likely in a few months unless complications
- Develop because of poor health

400 - 500 rem
- First day Nausea, vomiting and diarrhea,
- Usually in the first few Hours
- First week Symptoms may continue
- Second week Depliation, loss of appetite
- Hemorrhage, nosebleeds, inflammation of mouth and throat, diarrhea,
- Third week Emaciation
- Fourth week Rapid emaciation and mortality rate
- Around 50%

2.10 RADIATION DOSE LIMITS

2.10.1 POLICY
Work with sources of ionizing radiation will be conducted so that doses received by individuals do not exceed the applicable limit and doses are maintained as low as reasonably achievable (alara).

2.10.2 DEFINITIONS
Annual limit on intake (ali) the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. Ali is the smaller value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 0.05 Sv (5 rem) or a committed dose equivalent of 0.5 Sv (50 rem) to any individual organ or tissue. Dose equivalent the product of the absorbed dose in tissue and the quality factor (a value that reflects the biological impact of a particular type of ionizing radiation). Measured in rem or sievert (sv). Occupational dose the dose received by an individual in a restricted area or while performing assigned duties that
involve exposure to sources of radiation. Member of the public an individual who is not in a restricted area and who is not performing assigned duties that involve exposure to sources of radiation. Committed dose equivalent (cde) the dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following intake. Committed effective dose equivalent (cede) the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent (cde) to each of these organs or tissues. This is a measure of the overall risk associated with internal deposition of radioactive material. eye dose equivalent (lde) the dose equivalent to the lens of the eye at a tissue depth of 0.3 cm (300 mg/cm²). Shallow dose equivalent (sde) the dose equivalent at a tissue depth of .007 cm (7 mg/cm²) averaged over 1 cm²; applies to external whole body or extremity exposure. deep dose equivalent (dde) for external exposures and the committed effective dose equivalent (cede) for internal exposures. total organ equivalent (tode) the sum of the deep dose equivalent (dde) for external exposures and the committed dose equivalent (cde) to each of these organs or tissues. This is a measure of the overall dose to the organs or tissues. When the dose to the lens of the eye is included, this dose is called eye dose equivalent (lde).

**3. APPLICATION OF RADIATION AND NUCLEAR TECHNOLOGY**

Radiation is part of our daily life, and can be applied in many areas:

- Medical applications
- Industrial applications
- Electricity generation
- Application in consumer products
- Archaeological application

### 3.1 SOURCE OF RADIATION

There are two sources of radiation: natural and artificial (man-made).

#### 3.1.1 NATURAL RADIATION

Natural radiation includes radioactivity in the rocks and soil of the earth’s crust; radon, a radioactive gas given out by many volcanic rocks and uranium ore; cosmic radiation; and radioactivity in food and drinks. Natural radiation accounts for about 80% of the radiation doses to which we are subjected. It may vary from place to place.

#### 3.1.2 ARTIFICIAL (MAN-MADE) RADIATION

Medical use of radiation is the most significant source of man-made radiation. This includes x-ray radiology, nuclear medicine imaging and radiation therapy. Radiation arising from human activities typically accounts for about 20% of public exposure. Exposure due to fallout from past testing of nuclear weapons and generation of electricity in nuclear power plants constitutes less than 0.3%
3.1.3 BACKGROUND RADIATION

Background radiation is the ionizing radiation constantly presents in the natural environment of the earth. Background radiation comes from two primary sources: natural radiation and manmade radiation sources. The annual background radiation is about 3 msv, including 2.4 msv of natural radiation and 0.6 msv of manmade radiation.

3.1.4 RADIATION IN DAILY LIFE

Industrial radiography may be carried out under a variety of exposure conditions further purposes of this code, exposure conditions are classified into one of three types of site: fully enclosed sites (exposure rooms); partially enclosed sites (exposure bays); and open sites (field sites).

3.2 INDUSTRIAL RADIOGRAPHY SITES

A fully enclosed site is designed to keep all direct and scattered radiation arising from radiographic exposures within a totally enclosed volume, and to permit operation of the radiography equipment from outside by remote control. No person shall remain inside a fully enclosed site during exposure. A fully enclosed site shall be so constructed that, with access doors or ports closed, the walls, floor and ceiling surrounding the site form a complete shielding enclosure. The shielding associated with a fully enclosed site shall be sufficient to ensure that at no time during exposure does the dose rate outside the enclosure exceed 25 psv/h measured 5 cm from any accessible surface. The shielding and location of a partially enclosed site shall be such that no member of the public will receive an effective dose equivalent in excess of 1 msv per year from exposures carried out within it.

3.2.1 REQUIREMENTS FOR A FULLY ENCLOSED SITE

A fully enclosed site shall be identified as such through the use of warning notices at access points. A warning light or lights shall be provided to be illuminated during exposure and to be clearly visible from outside the enclosure. Interlocks shall be fitted to all access points of a fully enclosed site which will activate a visible and audible alarm if any interlock is opened during exposure. In the case of x-radiography equipment, the opening of an interlock during exposure shall automatically cause the interruption of the power supply to the x-ray equipment or to the x-ray tube, and subsequent closing of this interlock shall not automatically re-energise the x-ray tube. A fully enclosed site shall be provided with visible and audible warning devices inside the enclosure which shall be activated during exposure, and with a suitable means of exit which may be the main or only exit-to enable any person who is accidentally shut in to leave the enclosure without delay. Opening of this exit during exposure shall activate an alarm as specified and subsequent closing of the exit shall not automatically reset the alarm or re-energises an x-ray tube. Doors and panels covering access apertures into a fully enclosed site shall overlap those apertures by a sufficient margin to prevent the leakage of scattered radiation from the enclosure. Where a maze is used for access of persons, a lockable door or barrier shall be incorporated and connected to an interlock complying. Conduits for feeding cabling, including without cables, electrical power or other services through the walls of a fully enclosed site, shall incorporate a dog-leg or baffle that leaves no line-of-sight aperture through the walls to the radiation source, so that the radiation shielding integrity of the walls is not impaired. Before constructing a fully enclosed site, plans and details of construction and of proposed operations shall be provided to the statutory authority for approval.

3.2.2 REQUIREMENTS FOR A PARTIALLY ENCLOSED SITE

A partially enclosed site is designed to keep all direct radiation arising from radiographic exposures within the area enclosed and to limit any radiation scattered outside the enclosure to a low level. A partially enclosed site is typically an area of a building or room which is partitioned off with shielding walls and floor such that the partitioned area is closed on all sides that adjoin occupied areas, but which may be open at the top or on one side to permit the transfer in and out of the items to be radio graphed, and such that the radiography equipment can be operated from outside by remote control. No person shall remain inside a partially enclosed site during exposure. A partially enclosed site shall be constructed with walls at least 2.1 m high and affording sufficient shielding such that, while exposures are being carried out, the dose rate measured outside the area defined by the enclosure shall not exceed 25 ps/h measured 5 cm from any accessible surface. The shielding and location of a partially enclosed site shall be such that no member of the public will receive an effective dose equivalent in excess of 1 msv per year from exposures carried out within the enclosure. A partially enclosed site shall be identified as such through the use of warning notices at its perimeter and at access points. A warning light or lights shall be provided to be illuminated during exposure and to be clearly visible from outside the enclosure. Interlocks shall be fitted to all entrances to a partially enclosed site to activate a visible and audible alarm should any interlock be opened during exposure. In the case of x-radiography equipment, the opening of an interlock during exposure shall automatically cause the interruption of the power supply to the x-ray equipment or x-ray tube, and subsequent closing of this interlock shall not automatically re-energises the x-ray tube. A partially enclosed site shall be provided with visible and audible warning devices which shall be activated during exposure and which can be seen and heard from both inside and outside the enclosure. A partially enclosed site shall be provided with a suitable means of exit which may be the main or only exit to enable any person who is accidentally shut in to leave the enclosure without delay. Opening of this exit during exposure shall activate an alarm as specified and subsequent closing of the exit shall not automatically reset the alarm or reenergise an x-ray tube. Doors or panels covering
access apertures into a partially enclosed site shall overlap those apertures by a sufficient margin to prevent leakage of scattered radiation through the boundary of the partially enclosed site. Where a maze is used for access of persons, a lockable door or barriers shall be incorporated and connected to an interlock complying particular attention shall be given in the design of a partially enclosed site to limit scattered radiation passing through the no enclosed parts of the site boundary to occupied areas outside. For example, a partially enclosed site that is open at the top shall not be located such that radiation scattered from the roof of the building or room in which it is constructed can present a radiation hazard in occupied areas outside the enclosure. If cabling, including wind out cables, electrical power or other services, is taken through the walls of a partially enclosed site, it shall be fed through conduits that incorporate a dog-leg or baffle that leaves no line-of-sight aperture through the walls to the radiation source, so that the radiation shielding integrity of the walls is not impaired. Before constructing a partially enclosed site, plans and details of construction and of proposed operations shall be provided to the statutory authority for approval.

3.2.3 REQUIREMENTS FOR AN OPEN SITE

For reasons of economy, convenience or practical necessity, a great deal of industrial radiography takes place without any shielding enclosure. This is especially the case where radiography of structures is required in situ. Particular care shall be exercised at an open site to avoid unnecessary exposure of persons and to keep all radiation exposures as low as reasonably achievable. Collimators should be used to restrict the spread of the beam to the region to be radiograph. Before undertaking any field radiography work, appropriate working rules shall be established. If a general set of open site working rules is available, the operator shall ensure that he or she is familiar with those rules that apply to the planned circumstances of exposure, and that any modifications or additional rules to meet the particular circumstances are developed in cooperation with the radiation safety officer. If no such working rules are available, the radiation safety officer shall ensure that a set that is acceptable to the statutory authority is prepared. Before commencing radiography operations at an open site, a well defined and clearly visible boundary shall be erected using warning signs and devices such as barriers, flagged rope, etc, around, above and below the site as appropriate. An example of a suitable warning sign to be used during exposure is given in annexed iii. The boundary shall be located such that the calculated dose rates at the boundary during exposure shall not exceed 25 psv/h. The actual dose rates at the boundary shall be measured during exposure using a survey meter and the location of the boundary shall be rectified as necessary before subsequent exposures. The boundaries of adjacent sites should not overlap. If overlap is unavoidable, close liaison shall be maintained between operators responsible for the overlapping sites to avoid accidental exposure. The source control position shall be located such that the dose rate there is as low as practicable. During exposure the operator should, whenever possible, move quickly to and remain in a location where the dose rate does not exceed 25 psv/h. The dose rate at the source control position, if occupied, or at the position taken up by the operator during exposure shall be checked regularly by means of a survey meter. The immediate environment of the exposure position shall be clearly visible from the source control position and from the position taken up by the operator during exposure. The area inside the delineated boundary of an open site shall be inspected prior to exposure to ensure that no person is within it and shall be kept under observation at all times during exposure to ensure that no person enters it. One or more warning lights and an audible alarm located immediately adjacent to the exposure position shall be used to indicate when an exposure is underway. The working rules developed according to 6.3.1 shall be adhered to at all times.

3.3 CONTROLLING RADIATION EXPOSURE

When working with radiation, there is a concern for two types of exposure: acute and chronic. An acute exposure is a single accidental exposure to a high dose of radiation during a short period of time. An acute exposure has the potential for producing both no stochastic and stochastic effects. Chronic exposure, which is also sometimes called "continuous exposure," is long-term, low level overexposure. Chronic exposure may result in stochastic health effects and is likely to be the result of improper or inadequate protective measures. The three basic ways of controlling exposure to harmful radiation are: 1) limiting the time Spent near a source of radiation, 2) increasing the distance away from the source, 3) and using shielding to stop or reduce the level of radiation.

3.3.1 TIME

The radiation dose is directly proportional to the time spent in the radiation. Therefore, a person should not stay near a source of radiation any longer than necessary. If a survey meter reads 4 mR/h at a particular location, a total dose of 4 mR will be received if a person remains at that location for one hour. In a two hour span of time, a dose of 8 mR would be received. The following equation can be used to make a simple calculation to determine the dose that will be or has been received in a radiation area.

\[
Dose = \text{dose rate} \times t
\]

When using a gamma camera, it is important to get the source from the shielded camera to the collimator as quickly as possible to limit the time of exposure to the unshielded source. Devices that shield radiation in some directions but allow it pass in one or more other directions are known as collimators. This is illustrated in the images at the bottom of this page.
3.3.2 DISTANCE

Increasing distance from the source of radiation will reduce the amount of radiation received. As radiation travels from the source, it spreads out becoming less intense. This is analogous to Standing near a line. The closer a person stands to the fire, the more intense the heat feels from the lire. This phenomenon can be expressed by an equation known as the inverse square law, which states that as the radiation travels out from the source, the dosage decreases inversely with the square of the distance.

Inverse square law: \( i_1 / i_2 = d_1^2 / d_2^2 \)

3.3.3 SHIELDING

The third way to reduce exposure to radiation is to place something between the radiographer and the source of radiation. In general, the more dense the material the more shielding it will provide. The most effective shielding is provided by depleted uranium metal. It is used primarily in gamma ray cameras like the one shown below. The circle of dark material in the plastic see through camera (below right) would actually be a sphere of depleted uranium in a real gamma ray camera. Depleted uranium and other heavy metals, like tungsten, are very effective in shielding radiation because their tightly packed atoms make it hard for radiation to move through the material without interacting with the atoms. Lead and concrete are the most commonly used radiation shielding materials primarily because they are easy to work with and are readily available materials. Concrete is commonly used in the construction of radiation vaults. Some vaults will also be lined with lead sheeting to help reduce the radiation to acceptable levels on the outside.

3.4 SAFETY CONTROLS

Since x-ray and gamma radiation are not detectable by the human senses and the resulting damage to the body is not immediately apparent, a variety of safety controls are used to limit exposure. The two basic types of radiation safety controls used to provide a safe working environment are engineered and administrative controls. Engineered controls include shielding, interlocks, alarms, warning signals, and material containment; Administrative controls include postings, procedures, dissymmetry, and training.

3.4.1 ENGINEERED CONTROLS

Engineered controls such as shielding and door interlocks are used to contain the radiation in a cabinet or a "radiation vault." Fixed shielding materials are commonly high density concrete and/or lead. Door interlocks are used to immediately cut the power to x-ray generating equipment if a door is accidentally opened when x-rays are being produced. Warning lights are used to alert workers and the public that radiation is being used. Sensors and warning alarms are often used to signal that a predetermined amount of radiation is present. Safety controls should never be tampered with or bypassed.

When portable radiography is performed, it is most often not practical to place alarms or warning lights in the exposure area. Ropes and signs are used to block the enhance to radiation areas and to alert the public to the presence of radiation. Occasionally, radiographers will use battery operated flashing lights to alert the public to the presence of radiation. Portable or temporary shielding devices may be fabricated from materials or equipment located in the area of the inspection. Sheets of steel, steel beams or other equipment may be used for temporary shielding. It is the responsibility of the radiographer to know and understand the absorption value of various materials. More information on absorption values and material properties can be found in the radiography section of this site.
3.4.2 ADMINISTRATIVE CONTROLS

As mentioned above, administrative controls supplement the engineered controls. These controls include postings, procedures, dissymmetry, and training. It is commonly required that all areas containing x-ray producing equipment or radioactive materials have signs posted bearing the radiation symbol and a notice explaining the dangers of radiation. Normal operating procedures and emergency procedures must also be prepared and followed. In the US, federal law requires that any individual who is likely to receive more than 10% of any annual occupational dose limit be monitored for radiation exposure. This monitoring is accomplished with the use of dosimeters, which are discussed in the radiation safety equipment section of this material. Proper training with accompanying documentation is also a very important administrative control.

3.5 RESPONSIBILITIES

Working safely with radiation is the responsibility of everyone involved in the use and management of radiation producing equipment and materials. Depending on the size of the organization, specific responsibilities may be assigned to various individuals and/or committees.

3.6 RADIATION SAFETY OFFICER

All organizations that are licensed to use ionizing radiation must have a radiation safety officer. The rso is the individual authorized by the company to serve as point of contact for all activities conducted under the scope of the authorization. The rso is ensures that radiation safety activities are being performed in accordance with approved procedures and regulatory requirements. Some of the common responsibilities for the rso include:

- Ensuring that all individuals using radiation equipment are appropriately trained and supervised.
- Ensuring that all individuals using the equipment have been formally authorized to use the equipment.
- Ensuring that all rules, regulations, and procedures for the safe use of radioactive sources and x-ray systems are observed.
- Ensuring that proper operating, emergency, and alara procedures have been developed and are available to all system users.

Figure: The minimum qualifications, training, and experience for industrial radiography are as follows: (1) completion of the training and testing requirements of sec. 34.43(a) of part 10 of the federal code of regulations, (2) 2000 hours of hands-on experience as a qualified radiographer in industrial radiographic operations, and (3) formal training in the establishment and maintenance of a radiation protection program.

4.6.1 RADIATION SAFETY COMMITTEE

Some organizations may have a radiation safety committee (rsc) to assist the rso. The rso often provides oversight of the policies, procedures and responsibilities of an organization's radiation safety program.

3.6.2 SYSTEM USERS

The individuals authorized to use the x-ray producing system 01' gamma sources are responsible for ensuring that:

All rules, regulations, and procedures for the safe use of the x-ray system are followed. 0 An accurate record of the use of the system is maintained.

All safety problems with the system are reported to the rso and corrected before further use.

The system is protected from unauthorized access or removal.

4. PROCEDURES

Written operating procedures must be developed and made available to anyone that will be working with radiation sources or x-ray producing equipment. These procedures must be specific to the equipment and its use in a particular application. Simply making the equipment manufacturers operating instructions available to workers does not satisfy this requirement. The operating procedure must be followed at all times unless written permission to deviate is received from the radiation safety officer.

4.1 STANDARD OPERATING PROCEDURES

As a minimum, operating procedures must include instructions for the following:

- Appropriate handling and use of licensed sealed sources and radiographic exposure devices so that no person is likely to be exposed to radiation doses in excess of the established exposure limits.
- Methods and occasions for conducting radiation surveys.
- Methods for controlling access to radiographic areas.
- Methods and occasions for locking and securing radiographic exposure devices, transport and storage containers and sealed sources.
- Personnel monitoring and the use of personnel monitoring equipment.
- Transporting sealed sources to field locations, including packing of radiographic exposure devices and storage containers in the vehicles, placarding of vehicles when needed, and control of the sealed sources during transportation.
- The inspection, maintenance, and operability checks of radiographic exposure devices, survey instruments, transport containers, and storage containers.
- The procedure(s) for identifying and reporting defects and noncompliance.

IJESC, June 2021

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• Maintenance of records.

4.2 EMERGENCY PROCEDURES

Procedures must also be developed that guide workers in the event of an emergency. A few of the items that could be covered include:

• Steps that must be taken immediately by radiography personnel in the event a pocket dosimeter is found to be off-scale or an alaramtemeter alarms unexpectedly.
• Steps for minimizing exposure of persons in the event of an accident.
• The procedure for notifying proper persons in the event of an accident.
• Radioactive source recovery procedure if licensee will perform the recovery.

4.3 SURVEY TECHNIQUE

The majority of over exposures in industrial radiography are the result of the radiographer not knowing the location of a gamma emitter and failing to conduct a proper radiation survey. Exposure vaults are equipped with warning lights and safety interlock switches which provide a margin of safety for workers. A survey must be performed occasionally to verify that vaults are not "leaking" radiation and that the safety devices are performing properly. However, when conducting radiography with gamma emitters in the field, the radiographer must rely heavily on measurements with a survey meter since other safety devices are uncommon. A series of surveys must be taken and some of the results from these surveys must be documented when transporting and working with gamma emitters in the field.

Figure 4.1. Approaching the Exposure Device

A technician should be thoroughly familiar with the operation of a survey meter since proper use of the device is essential. Before removing the exposure device (camera) from storage, the calibration of the survey meter must be verified and the battery level must be checked. When approaching the exposure device to remove it from the storage location, the survey meter should be in hand and operational. The survey meter should be placed next to the exposure device to verify that the source is contained inside the projector, and to verify that the survey meter is working properly. Survey meter readings should be compared to previous readings and recorded.

4.3.1 TRANSPORTING THE EXPOSURE DEVICE

When transporting the exposure device, it must be stowed securely in the vehicle. A lockable metal box is often bolted in the rear of the vehicle. A survey of the over pack, the outside of the vehicle, and the drivers compartment is then conducted and documented.

4.3.2 PREPARING FOR AN EXPOSURE

Once on the job site, the exposure area will be assessed, distance calculations made for restricted area boundaries, and ropes and signs placed appropriately. Once this is complete, the radiographer is ready to remove the exposure device from its storage compartment in the vehicle. The survey meter should be monitored as the storage compartment is approached and when removing the exposure device from the compartment. Daily safety checks should then be made. Once these checks are completed, the radiographer and assistant may then move the exposure device to the exposure location. As the cranks and guide tubes are attached in preparation for the first exposure, the survey meter should be monitored. Before the source is exposed, the assistant should check the area for persons who may have crossed into the restricted area, and then move outside the rope boundary.

4.3.4 MAKING AN EXPOSURE

The radiographer should be at the maximum distance from the exposure device that the guide tube will allow as he or she quickly cracks the source out of the exposure device and into place. As the source moves out of the exposure device, the survey meter will increase to a very high level and then reduce once the source is inside the collimator. During the exposure, the assistant will survey the established boundary to determine the levels of radiation present. If the survey meter indicates levels are higher than calculated, the boundary must be extended.

4.3.5 RETRACTING THE SOURCE

On retraction of the source, the radiographers will see a rise in readings as the source moves from the collimator and is retracted into the projector. When the source is inside the exposure device, the radiographer should approach it while monitoring the survey meter. If the source is properly retracted, no increase in the survey meter reading should be seen when approaching the exposure device.

4.4 RADIATION DETECTORS

Instruments used for radiation measurement fall into two broad categories:
Rate measuring instruments

Personal dose measuring instruments.

Rate measuring instruments measure the rate at which exposure is received (more commonly called the radiation intensity). Survey meters, audible alarms and area monitors fall into this category. These instruments present a radiation intensity reading relative to time, such as r/hr or mR/hr. An analogy can be made between these instruments and the speedometer of a car because both are measuring units relative to time. Dose measuring instruments are those that measure the total amount of exposure received during a measuring period. The dose measuring instruments, or dosimeters, that are commonly used in industrial radiography are small devices which are designed to be worn by an individual to measure the exposure received by the individual. An analogy can be made between these instruments and the odometer of a car because both are measuring accumulated units. The radiation measuring instruments commonly used in industrial radiography are described in more detail in the following pages.

4.4.1 SURVEY METERS

The survey meter is the most important resource a radiographer has to determine the presence and intensity of radiation. A review of incident and overexposure reports indicates that a majority of these types of events occurred when a technician did not have or did not use a survey meter. There are many different models of survey meters available to measure radiation in the field. They all basically consist of a detector and a readout display. Analog and digital displays are available. Most of the survey meters used for industrial radiography use a gas filled detector. Gas filled detectors consist of a gas filled cylinder with two electrodes. Sometimes, the cylinder itself acts as one electrode, and a needle or thin taut wire along the axis of the cylinder acts as the other electrode. A voltage is applied to the device so that the central needle or wire becomes an anode (+ charge) and the other electrode or cylinder wall becomes the cathode (charge). The gas becomes ionized whenever the counter is brought near radioactive substances. The electric field created by the potential difference between the anode and cathode causes the electrons of each ion pair to move to the anode while the positively charged gas atom is drawn to the cathode. These results in an electrical signal that is amplified correlated to exposure and displayed as a value. Depending on the voltage applied between the anode and the cathode; the detector may be considered an ion chamber, a proportional counter, or a geiger-müller (gm) detector. Each of these types of detectors has its advantages and disadvantages. A brief summary of each of these detectors follows.

4.4.2 ION CHAMBER COUNTER

Ion chambers have a relatively low voltage between the anode and cathode, which results in a collection of only the charges produced in the initial ionization event. This type of detector produces a weak output signal that corresponds to the number of ionization events. Higher energies and intensities of radiation will produce more ionization, which will result in a stronger output voltage. Collection of only primary ions provides information on true radiation exposure (energy and intensity). However, the meters require sensitive electronics to amplify the signal, which makes them fairly expensive and delicate. The additional expense and required care is justified when it is necessary to make accurate radiation exposure measurements over a range of radiation energies. This might be necessary when measuring the bremsstrahlung radiation produced by an x-ray generator. An ion chamber survey meter is sometimes used in the field when performing gamma radiography because it will provide accurate exposure measurements regardless of the radioactive isotope being used.

4.4.3 PROPORTIONAL COUNTER

Proportional counter detectors use a slightly higher voltage between the anode and cathode. Due to the strong electrical field, the charges produced in the initial ionization are accelerated fast enough to ionize other electrons in the gas. The electrons produced in these secondary ion pairs, along with the primary electrons, continue to gain energy as they move towards the anode, and as they do, they produce more and more ionizations. The result is that each electron from a primary ion pair produces a cascade of ion pairs. This effect is known as gas multiplication or amplification. In this voltage
regime, the number of particles liberated by secondary interactions is proportional to the number of ions produced by the passing ionizing particle. Hence, these gas ionization detectors are called proportional counters. Like ion chamber detectors, proportional detectors discriminate between types of radiation. However, they require very stable electronics which are expensive and fragile. Proportional detectors are usually only used in a laboratory setting.

4.4.4 GEIGER-MULLER (GM) COUNTER

Geiger-miller counters operate under even higher voltages between the anode and the cathode, usually in the 800 to 1200 volt range. Like the proportional counter, the high voltage accelerates the charges produced in the initial ionization to where they have enough energy to ionize other electrons in the gas. However, this cascading of ion pairs occurs to a much larger degree and continues until the counter is saturated with ions. This all happens in a fraction of a second and results in an electrical current pulse of constant voltage. The collection of the large number of secondary ions in the gm region is known as an avalanche and produces a large voltage pulse. In other words, the size of the current pulse is independent of the size of the ionization event that produced it. The electronic circuit of a gm counter counts and records the .5 gm counter W number of pulses and the information is often displayed in counts per minute. Again, Muller who collaborated this only takes a fraction of a second, but this process slightly limits with Geiger in rate at which individual events can be detected. Because they can develop it further in display individual ionizing events, gm counters are generally more 1928, sensitive to low levels of radiation than ion chamber instruments. By means of calibration, the count rate can be displayed as the exposure rate over a specified energy range. When used for gamma radiography, gm meters are typically calibrated for the energy of the gamma radiation being used. Most often, gamma radiation from cs-137 at 0.662 mev provides the calibration. Only small errors occur when the radiographer uses ir-192 (average energy about 0.34 mev) or co-60 (average energy about 1.25 mev).Since the geiger-miller counter produces many more electrons than a ion chamber counter or a proportional counter, it does not require the same level of electronic sophistication as other survey meters. This results in a meter that is relatively low cost and rugged. The disadvantages of gm survey meters are the lack of ability to account for different amounts of ionization caused by different energy photons and noncontiguous measurement (need to discharge).

4.4.5 COMPARISON OF GAS FILLED DETECTORS

The graph to the right shows the relationship of ion collection in a gas filled detector versus the applied voltage. In the ion chamber region, the voltage between the anode and cathode is relatively low and only primary ions are collected. In the proportional region, the voltage is higher, and primary ions and a number of secondary ions (proportional to the primary ions originally formed) are collected. In the gm region, a maximum number of secondary ions are collected when the gas around the anode is completely ionized. Note that discrimination between kinds of radiation (e1 and e2) is possible in the ion chamber and proportional regions.

4.4.6 POCKET DOSIMETER

Pocket dosimeters are used to provide the wearer with an immediate reading of his or her exposure to x-rays and gamma rays. As the name implies, they are commonly worn in the pocket. The two types commonly used in industrial radiography are the direct read pocket dosimeter and the digital electronic dosimeter.

4.4.7 DIRECT READ POCKET DOSIMETER

A direct reading pocket ionization dosimeter is generally of the size and shape of a fountain pen. The dosimeter contains a small ionization chamber with a volume of approximately two milliliters. Inside the ionization chamber is a central wire anode, and attached to this wire anode is a metal coated quartz fiber. When the anode is charged to a positive potential, the charge is distributed between the wire anode and quartz fiber. Electrostatic repulsion deflects the quartz fiber, and the greater the charge, the greater the deflection of the quartz fiber. Radiation incident on the chamber produces ionization inside the active volume of the chamber. The electrons produced by ionization are attracted to, and collected by, the positively charged central anode. This collection of electrons reduces the net positive charge and allows the quartz fiber to return in the direction of the original position. The amount of movement is directly proportional to the amount of ionization which occurs.

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By pointing the instrument at a light source, the position of the fiber may be observed through a system of built-in lenses. The fiber is viewed on a translucent scale which is graduated in units of exposure. Typical industrial radiography pocket dosimeters have a full scale reading of 200 milli roentgens but there are designs that will record higher amounts. During the shift, the dosimeter reading should be checked frequently. The measured exposure should be recorded at the end of each shift. The principal advantage of a pocket dosimeter is its ability to provide the wearer an immediate reading of his or her radiation exposure. It also has the advantage of being reusable. The limited range, inability to provide a permanent record, and the potential for discharging and reading loss due to dropping or bumping are a few of the main disadvantages of a pocket dosimeter. The dosimeters must be recharged and recorded at the start of each working shift. Charge leakage, or drift, can also affect the reading of a dosimeter. Leakage should be no greater than 2 percent of full scale in a 24 hour period.

4.4.8 DIGITAL ELECTRONIC DOSIMETER

Another type of pocket dosimeter is the digital electronic dosimeter. These dosimeters record dose information and dose rate. These dosimeters most often use geiger-müller counters. The output of the radiation detector is collected and, when a predetermined exposure has been reached, the collected charge is discharged to trigger an electronic counter. The counter then displays the accumulated exposure and dose rate in digital form.

Some digital electronic dosimeters include an audible alarm feature which emits an audible signal or chirp with each recorded increment of exposure. Some models can also be set to provide a continuous audible signal when a preset exposure has been reached. This format helps to minimize the reading errors associated with direct reading pocket ionization chamber dosimeters and allows the instrument to achieve a higher maximum readout before resetting is necessary.

4.4.9 AUDIBLE ALARM RATE METERS AND DIGITAL ELECTRONIC DOSIMETERS

Audible alarms are devices that emit a short "beep" or "chirp" when a predetermined exposure has been received. It is required that these electronic devices be worn by an individual working with gamma emitters. These devices reduce the likelihood of accidental exposures in industrial radiography by alerting the radiographer to dosages of radiation above a preset amount. Typical alarm rate meters will begin sounding in areas of 450-500 mrix hr. It is important to note that audible alarms are not intended to be and should not be used as replacements for survey meters.

Most audible alarms use a geiger-müller detector. The output of the detector is collected, and when a predetermined exposure has been reached, this collected charge is discharged through a speaker. Hence, an audible "chirp" is emitted. Consequently, the frequency or chirp rate of the alarm is proportional to the radiation intensity. The chirp rate varies among different alarms from one chirp per milli roentgen to more than 100 chirps per milli roentgen.

4.4.10 FILM BADGES

Personnel dosimeter film badges are commonly used to measure and record radiation exposure due to gamma rays, x-rays and beta particles. The detector is, as the name implies, a piece of radiation sensitive film. The film is packaged in a light proof, vapor proof envelope preventing light, moisture or chemical vapors’ from affecting the film. A special film is used which is coated with two different emulsions. One side is coated with a large grain, fast emulsion that is sensitive to low levels of exposure. The other side of the film is coated with a fine grain, slow emulsion that is less sensitive to exposure. If the radiation exposure causes the fast emulsion in the processed film to be darkened to a degree that it cannot be interpreted, the fast emulsion is removed and the dose is computed using the slow emulsion. The film is contained inside a film holder or badge. The badge incorporates a series of filters to determine the quality of the radiation. Radiation of a given energy is attenuated to a different extent by various types of absorbers. Therefore, the same quantity of radiation incident on the ‘badge will produce a different degree of darkening under each filter. By comparing these results, the energy of the radiation can be determined and the dose can be calculated knowing the film response for that energy. The badge holder also contains an open window to determine radiation exposure due to beta particles. Beta particles are effectively shielded by a thin amount of material.

The major advantages of a film badge as a personnel monitoring device are that it provides a permanent record, it is able to distinguish between different energies of photons, and it can measure doses due to different types of radiation. It is quite accurate for exposures greater than 100 milli rem. The major disadvantages are that it must be developed and read by a processor (which is time consuming), prolonged heat
exposure can affect the film, and exposures of less than 20 milli rem of gamma radiation cannot be accurately measured.

A badges need to be worn correctly so that the dose they receive accurately represents the dose the wearer receives. Whole body badges are worn on the body between the neck and the waist, often on the belt or a shirt pocket. The clip-on badge is worn most often when performing x-ray or gamma radiography. The film badge may also be worn when working around a low cutie source. Ring badges are worn on a finger of the hand most likely to be exposed to ionizing radiation. A lixi system with its culminated and directional beam would be one example where monitoring the hands would be more important than the whole body.

4.4.11 THERMOLUMINESCENT DOSIMETER

Thermo luminescent dosimeters (tld) are often used instead of the film badge. Like a film badge, it is worn for a period of time (usually 3 months or less) and then must be processed to determine the dose received, if any. Thermo luminescent dosimeters can measure doses as low as 1 milligram, but under routine conditions their low-dose capability is approximately the same as for film badges. Tlds have a precision of approximately 15% for low doses. This precision improves to approximately 3% for high doses. The advantages of a tld over other personnel monitors are its linearity of response to dose, its relative energy independence, and its sensitivity to low doses. It is also reusable, which is an advantage over film badges. However, no permanent record or re-readability is provided and on the job readout is not possible.

How it works

A told is a phosphor, such as lithium fluoride (lit) or calcium fluoride (caf), in a solid crystal structure. When a tld is exposed to ionizing radiation at ambient temperatures, the radiation interacts with the phosphor crystal and deposits all or part of the incident energy in that material. Some of the atoms in the material that absorb that energy become ionized, producing free electrons and areas lacking one or more electrons, called holes. Imperfections in the crystal lattice structure act as sites where free electrons can become trapped and locked into place. Heating the crystal causes the crystal lattice to vibrate, releasing the trapped electrons in the process. Released electrons return to the original ground state, releasing the captured energy from ionization as light, hence the name thermo luminescent. Released light is counted using photomultiplier tubes and the number of photons counted is proportional to the quantity of radiation striking the phosphor instead of reading the optical density (blackness) of a film, as is done with film badges, the amount of light released versus the heating of the individual pieces of thermo luminescent material is measured. The “glow curve” produced by this process is then related to the radiation exposure. The process can be repeated many times.

5. EXPERIMENTATION

We are going to make an attempt by shielding the industrial radiography using in fly ash, fire brick, hollow blocks and comparing the minimum acceptable levels to have a safer radiation working environment.

Figure: Radiation measuring from fly ash brick

Figure: Radiation measuring from fire bricks

5.1 CONSTRUCT ION OF OPERATING ROOM WITH FLY ASH BRICK-FIRE BRICK, HOLLOW BLOCKS

Here we are going to construct the 10 feet each size operating rooms using the shielding materials of fly ash, hollow blocks, Fire bricks and source will be kept inside of the blocks, object and source we kept inside it will be positioned using crank unit. The radiation can be measured inside the room and also outer side of the room using survey meter.

Figure: Radiation measuring from hollow blocks
5.2 EVALUATION OF SOURCE RADIATION IN SIDE OF THE ROOM

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6. CONCLUSION

There are three basic ways to controlling exposure to harmful radiation are 1. time 2. distance 3. shielding out of which the 3rd one shielding to step or reduce the level of radiations lot of materials like, depleted uranium (du), concrete, lead etc.. Used. Now a days we are introducing a cheaply available materials like, Fly ash, fire brick, hollow block in such a way that improvements that to be made, both commercially and technically so as to have a safe radiation zone with a minimum investments and if it’s successful it can be easily implemented in remote sites, shops, yards etc., in a economic and minimum time for construction taking to account of radiation safety. In mass production the commercial value is less and the profit ratio is increased without affecting safety.

7. REFERENCES

[9].’Dienes’ 3’ J’; and vineyard, .H ~ radiation eff t ‘ l’ Co. (new york), 1957’ g 60 S in so ldS.Intersciences pub.