7 Control of External Radiation Exposure

In most cases external radiation will be gamma radiation. The four basic methods of providing protection against external radiation exposure are: Time, Decay, Distance, and Shielding. Procedural methods of reducing dose are also available. Examples are the Access Control system and decontamination.

Time

The dose you receive is proportional to the length of the time spent in a radiation area. Therefore, when performing radiation work, keep the time spent to a minimum, while maintaining safe working practices.

$$Max.\,Working\,Time = \frac{Dose\ Limit}{Dose\ Rate}$$

Example:

Assume a work plan says that you should not exceed 1 rem (10 mGy) for a particular job. If the only hazard is found to be external gamma at 10 rem/h (100 mGy/h), how long can you work?

$$Max.\ Working\ Time = \frac{1\ rem}{10\ rem/h} = 0.1\ h = 6\ \text{min.}$$

(5 min work would give a small safety margin.)

One of the most hazardous radiation sources is spent fuel.

Decay

Allowing radioactive material to decay for one half-life will reduce the original activity by one-half and also halve the dose rate. Waiting two half-lives will decrease the original activity to 1/2 x 1/2 = 1/4, or by a factor of 4.

Half-lives of radioactive materials found around a nuclear power station vary from fractions of seconds to millions of years.

By exercising some control and waiting for radioactive decay, where possible, radiation hazards can be greatly reduced and almost eliminated in some areas.

Rules of Thumb

1. Activity will be reduced to less than 1% of its original value after seven half-lives.
2. If the half-life is greater than six days, the change in activity will be less than 10% in 24 hours.

Distance

For point gamma sources (sources concentrated in small areas) radiation intensity varies as the inverse square of the distance from the source. If you double your distance from the source, your exposure is reduced to one-fourth; tripling the distance effects a reduction to one-ninth of the original dose. Remember that reducing the distance increases the dose rate. If you pick up even a very small source, the contact dose rate to your hand will be very high.

The inverse square law is expressed in the following formula:

$$Id^2 = I_o d_o^2$$

where

I	=	intensity
I_o	=	original intensity
d	=	distance
d_o	=	original distance

There are some limitations on the use of the inverse square law.

1. It applies to gamma radiation only.
2. It does not apply to beams.
3. It does not allow for any scattering or shielding effects.
4. The detector must be at least 5 source diameters away from the source.

For line sources (sources such as a resin slurry pipe) radiation intensity varies inversely with the distance from the source. If you double your distance from the source, your exposure is reduced to one-half. Tripling the distance effects a reduction to one-third of the original dose.

Reduction of the radiation with distance from a line source is expressed in the following formula:

$$Id = I_o d_o$$

where:

I	=	intensity
I_o	=	original intensity
d	=	distance
d_o	=	original distance

For plane sources, radiation intensity remains nearly constant with distance from the source. This will change only when you are far enough away so that the source becomes a line or a point source in relation to you.

Shielding

This means putting radiation absorbing material between you and the source of radiation. The purpose is to reduce radiation by means of absorption. Shielding may be placed around the source or around the individual. The effectiveness of the material as a shield depends upon its makeup and the type of radiation being shielded against. In most cases shielding will be used to reduce gamma radiation. The effectiveness of shielding is measured in Half Value Layers (HVL). The HVL of a material is that thickness that will reduce the gamma radiation field by one half.

Important - **Never rely totally on a shielding calculation. Always check the radiation field with a survey instrument after placing shielding.**

Gamma shielding material HVLs are given in Section 16.1. The first HVL reduces the radiation by one-half. The second HVL reduces the remaining radiation by one-half again, i.e., $1/2 \times 1/2 = 1/4$ of the original value. To calculate the dose-reduction factor, n HVLs will reduce the radiation field to $(1/2)^n$ of the original value.

Remember - **You will receive dose while placing shielding. Always bear in mind all four methods of reducing external exposure (TIME, DECAY, DISTANCE, and SHIELDING) to minimize your dose.**

Radiography Hazards

In radiography, the source is remotely driven out of its shielding to expose a photographic film, and then it is driven back in. When the source is in its safe shielded position, the radiation field is relatively harmless (around 200 μGy/h at contact).

However, when the source is exposed (a typical exposure is 2 minutes), the radiation field is far greater than in any other accessible area in the plant. For example, when the 2.8×10^{12} Bq (75 curie) Iridium-192 source is in use, the gamma radiation field at 1 meter is 360 mGy/h. Even 6 meters away, it is still 10 mGy/h.

Radiography areas should be clearly marked.

Beta Radiation

Normally at a nuclear power plant radioactive materials are enclosed in systems which completely shield personnel from beta particles.

However, when materials are released into the station areas, or when systems are opened for maintenance, the shielding is removed from around the beta sources. An external beta hazard may then exist, because beta particles have a considerable range in air. This range depends on the beta energy (3 to 4 meters per MeV). The effective beta energy is approximately 1/3 of the maximum beta energy (E_{max}).

Since beta particles are easily absorbed in shielding, proper work techniques should prevent anyone receiving an appreciable external dose from beta radiation. A practical example of the use of beta shielding is the wearing of safety glasses (90% absorption). Protective clothing will generally reduce beta fields by 30 to 50%.