Dose Standards and Methods for Protection Against Radiation and Contamination

This section will discuss the NRC dose standards and the methods used to protect individuals from the harmful effects of radiation and contamination.

NRC Dose Limits

(from 10 CFR Part 20)

For members of the public:

Less than 2 millirems in any one hour from external radiation sources in any unrestricted area

Less than 100 millirems in a calendar year from both external and internal sources of radiation in unrestricted and controlled areas

The NRC limits the handling and use of radioactive materials such that no member of the public will receive a radiation dose of 2 millirems in any one hour from external radiation sources in an unrestricted area, or 100 millirems in a calendar year from both external and internal sources of radiation from each licensee.

Additionally, the NRC has provided design objectives for power reactor licensees to keep offsite doses as far below the 10 CFR Part 20 limits as is reasonably achievable. These guidelines can be found in 10 CFR Part 50.

Permissible dose levels in unrestricted areas during the transport of radioactive material can be found in 10 CFR Part 71.

NRC Dose Limits

(from 10 CFR Part 20)

Occupational Limits:

	Annual Limit
Whole Body (sum of external and internal dose)	5 rems
Extremity	50 rems
Skin of Whole Body	50 rems
Maximum Exposed Organ (sum of external and internal dose)	50 rems
Lens of the Eye	15 rems
Minor	0.5 rem

The dose equivalent to the embryo/fetus of a declared pregnant woman has a limit of 0.5 rem over the gestation period.

Planned Special Exposure (PSE), an infrequent exposure for a special, high-dose job. The yearly limit is equal to the annual limit with a lifetime maximum of 5 times the annual limit. For example, the PSE limit for the whole body is 5 rems in a year, in addition to the above occupation limits, with a lifetime maximum of 25 rems.

The NRC exposure limits shown above apply to all NRC licensees and are designed such that:

1) No worker at a nuclear facility will receive an acute whole body radiation exposure sufficient to trigger the radiation syndrome
2) The risk of cancer (although not zero) will not be higher than the risk of cancer from other occupations.

Licensees are also required by 10 CFR Part 20 to keep radiation exposures as low as reasonably achievable (ALARA).

Note: *The whole body and skin of the whole body includes all of the body except the hands, wrists, forearms, elbows, knees, legs below the knees, feet, and ankles.*

Now that the limits are known, how to protect the body from radiation will be discussed.

Protection Against External Radiation Sources:

Time

Distance

Shielding

The three protective measures listed above (time, distance, and shielding) are primarily utilized to reduce the dose from any external source of radiation. Time and distance are also applicable for reducing the intake of radioactive material (internal dose), although once the radioactive material is inside the body, little can be done to reduce the dose.

However, the total dose (sum of internal and external dose) should be minimized, since overall risk is proportional to the total dose. In some cases, this may mean accepting a small intake of radioactive material to reduce the external dose. The important thing is to keep the total dose as low as reasonably achievable. Recall that the limits for whole body (5 rems/year) and maximum exposed organ (50 rems/year) apply to total dose.

Pages 8-5 to 8-11 will discuss how time, distance, and shielding are used to limit external exposure.

Pages 8-12 and 8-13 will discuss internal exposure control and protection from contamination.

Given:

Dose Rate X Time = Dose

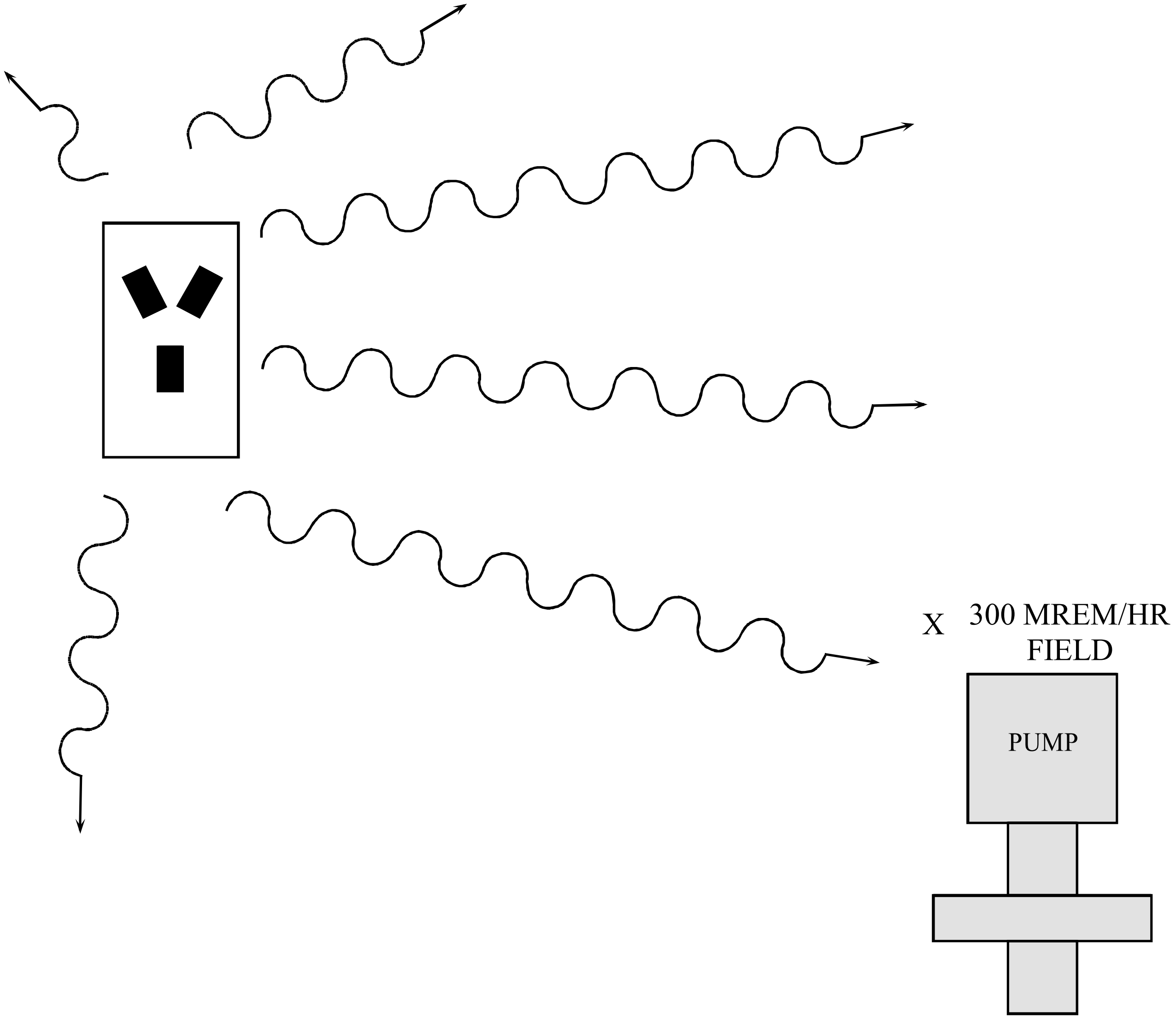
Therefore,

Minimize Exposure Time
to
Minimize Dose

The dose a person receives from external radiation is directly proportional to the length of time spent in a radiation field. Therefore, minimizing the amount of time spent in a radiation field will minimize the dose received. Some methods that can be used to minimize the time spent in a radiation field are:

- Plan and rehearse the job under realistic conditions
- Know the exact location of work prior to entering the radiation area
- Ensure all necessary tools are available at the job location
- Establish good communications
- Do not loiter in the area

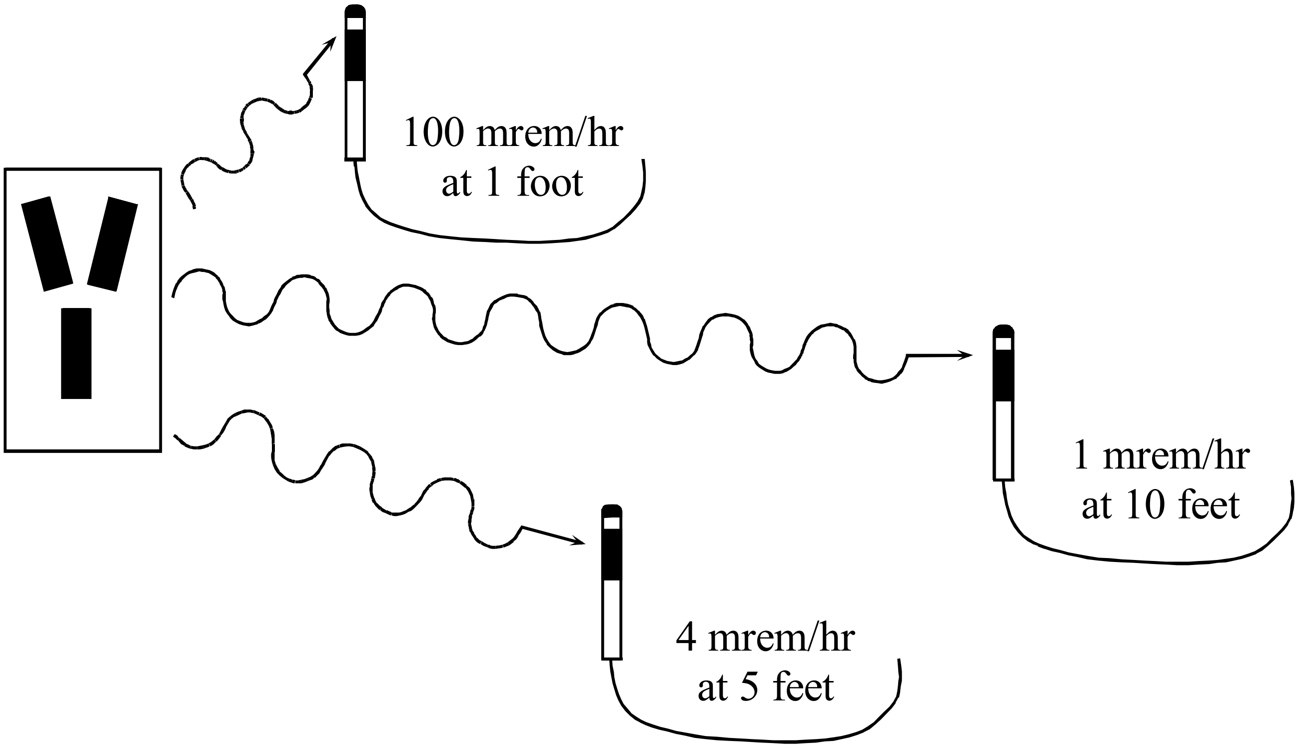
Similarly, minimizing the time spent in an area with airborne radioactivity will minimize the internal dose, since the intake of radioactive material (that being inhaled) is directly proportional to the inhalation time (volume of air being breathed).



Minimize Time

Assuming a radiation field of 300 millirems/hour, an individual working in this area would receive:

- 75 millirems in 15 minutes,
- 150 millirems in 30 minutes,
- 300 millirems in 1 hour, or
- 600 millirems in 2 hours.

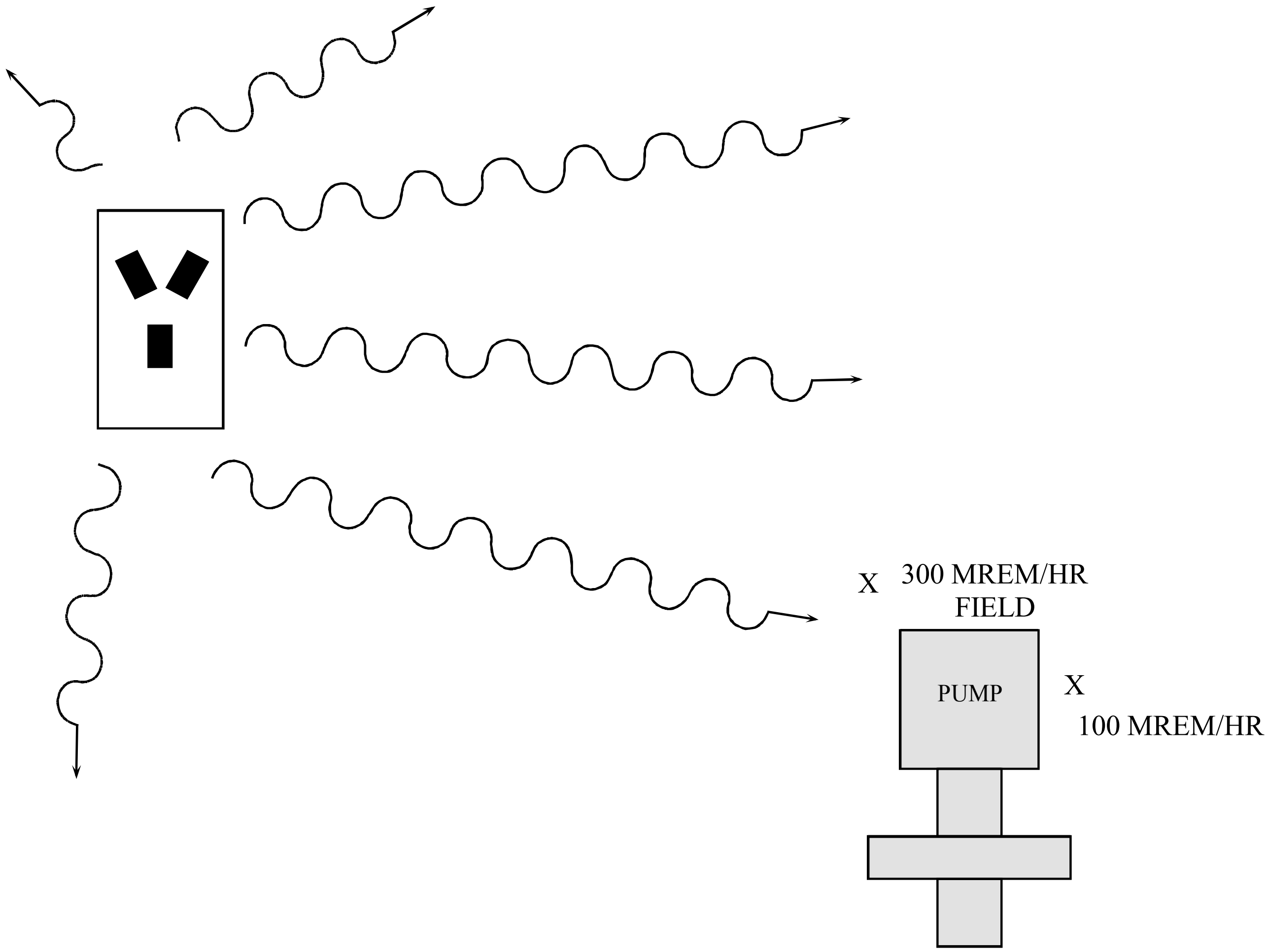


Maximize Distance to Minimize Dose

Many radiation sources are “point sources” (the radiation appears to emit from one spot some distance away). The radiation dose from these sources can be significantly reduced by applying the protective measure of “distance” as demonstrated above. The dose a person receives from an external radiation source is inversely proportional to the square of the distance from the source ($1/d^2$). Therefore, if the dose rate at one foot is 100 millirems/hour, the dose rate at 10 feet would be $1/10^2$ of that, or 1 millirem/hour. Some ways to increase the distance on a job are:

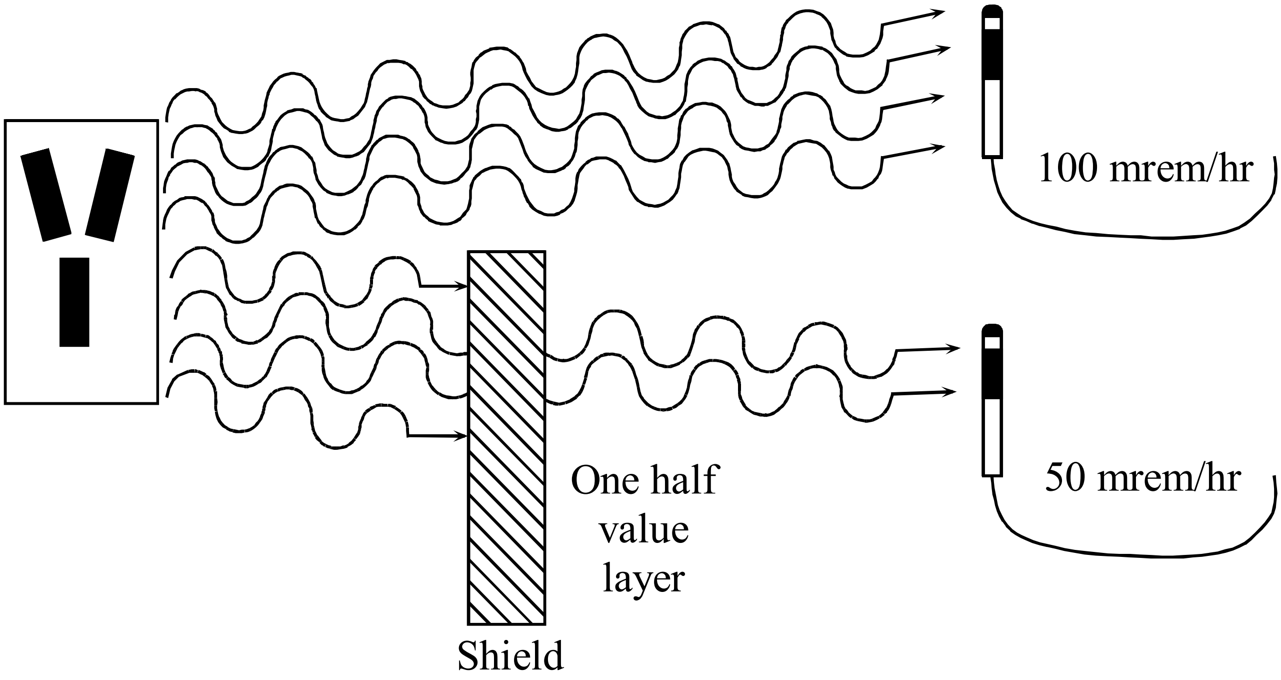
- Using extension tools,
- Utilizing remote operating stations, and
- Staying away from hot spots.

Staying as far away as possible from a source of airborne radioactivity will minimize the intake of radioactivity, because the activity will disperse and become less concentrated (in most cases) as it moves away from the point of release.



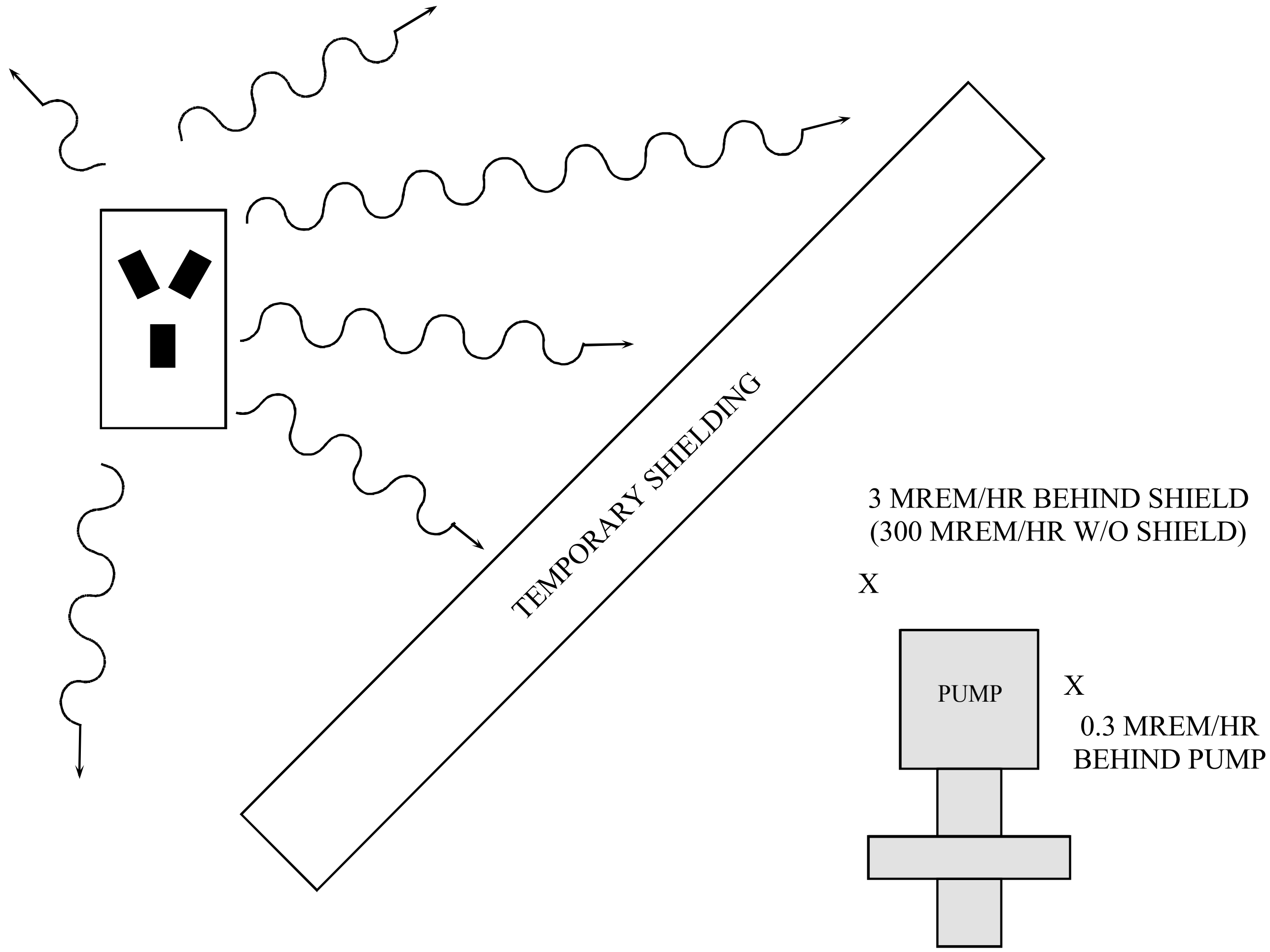
Maximize Distance

By moving a few feet away from a nearby source of radiation, the dose rate can be significantly reduced. Therefore, a person performing a job can have a longer stay time to perform the needed task.



Maximize Shielding to Minimize Dose

Shielding is one of the most effective means of reducing radiation exposure. The example above shows that the installation of one half-value layer (half-thickness) of shielding will reduce the dose rate by a factor of two at a set distance from the source of radiation. By locating the shielding as close as possible to the source, dose rates can be reduced in a large area, and thus reduce the dose to many workers (some of which, perhaps, could not reduce their exposure time or work further from the source).



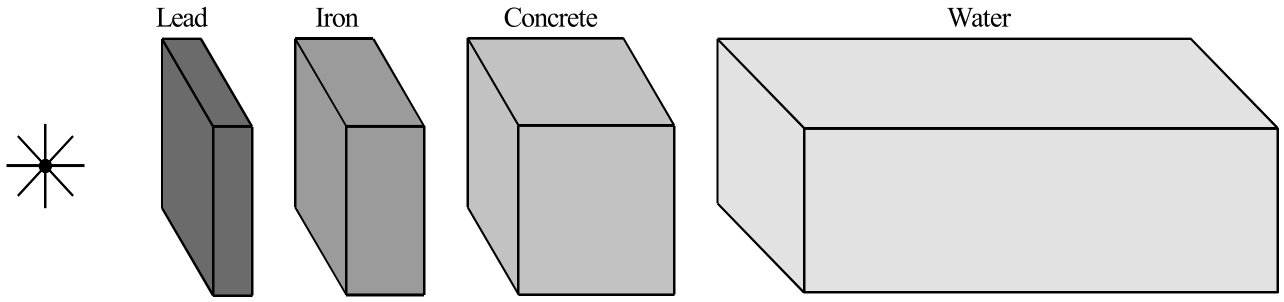
Temporary and Installed Shielding

The two major types of shielding at the plant are installed shielding and temporary shielding. Installed shielding is permanent shielding installed at the plant for the purpose of reducing the radiation levels in some areas. An example of permanent shielding is the concrete shield walls located in the containment.

Temporary shielding can take the form of lead sheets, lead bricks, or bags filled with lead shot. This type of shielding can be placed near the source to reduce the radiation levels in large areas. It can also be shaped as needed to provide the maximum shielding effectiveness.

Installed equipment can also be used as shielding material. In the drawing above, the dose rate without the temporary shielding would be 300 millirems/hour. The installation of the temporary shielding reduces the dose rate to 3 millirems/hour. However, if the worker can perform the job from the far side of the pump, the dose rate can be reduced to 0.3 millirem/hour due to the effectiveness of the pump acting as a shield.

Relative Effectiveness of Various Shielding Materials



Materials differ in their ability to shield (absorb) radiation. The figure above shows the relative effectiveness of four common shield materials (lead, iron, concrete, and water) for gamma radiation. To have the same gamma radiation exposure level at the outside of each material, it takes about twice as much iron as lead, about twice as much concrete as iron, and about three times as much water as concrete.

A thumb rule that can be used is that it takes 2 inches of lead to reduce the dose rate by a factor of 10. Therefore, if a radiation detector measured the dose rate at a certain distance to be 100 millirems/hour, 2 inches of lead would reduce the dose rate to 10 millirems/hour. This value is called a tenth-value thickness of lead. To accomplish the same reduction using the other materials would require 4 inches of iron/steel, 8 inches of concrete, or 24 inches of water. These values are only thumb rules. The exact amount of material required depends upon the energy of the radiation (gamma ray) that is being shielded against.

Internal Exposure Control

$$1\ ALI = 2000\ DAC\text{-}hr = 5\ Rems$$

Intakes of radioactive material are controlled by the Annual Limit on Intake (ALI), expressed in units of microcuries. The ALI is the primary limit for internal exposure control, and in the absence of any external radiation, a worker may intake one ALI in a year. One ALI equals 5 rems internal dose.

Concentrations of radioactive materials in air are limited by the Derived Air Concentrations (DACs), which are derived from the ALI. The DACs are derived assuming a worker breathes 1.2 cubic meters of air per hour for 2000 hours per year. Therefore:

$$DAC\ (microcuries\ /\ ml)\ =\ \frac{ALI\ (microcuries)}{2.4\ X\ 10^{9}\ ml}$$

If a worker breathes air containing radioactive material at a concentration of 1 DAC for one hour, then the worker has been exposed to 1 DAC-hr. Therefore:

$$1\ ALI\ =\ 2000\ DAC\ -\ hr\ =\ 5\ rems$$

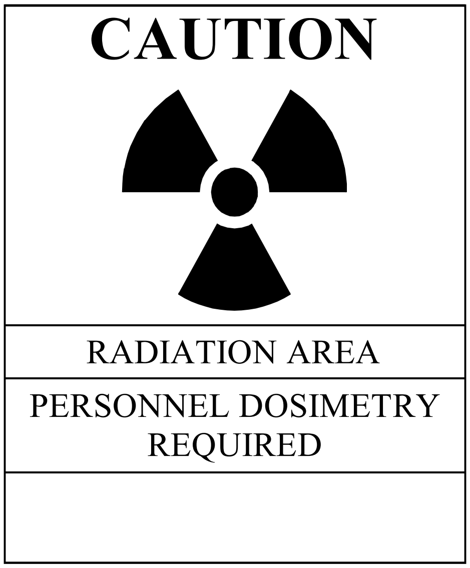
Since the operational limit of 5 rems applies to the sum of the internal and external exposures, if a worker has some external dose, the ALI must be modified or offset to account for the external dose. For example, assume the worker has 2 rems from external sources of radiation. Only 3 more rems are allowed from internal radiation before the worker reaches the occupational whole body limit. Expressed in DAC-hr, this would be:

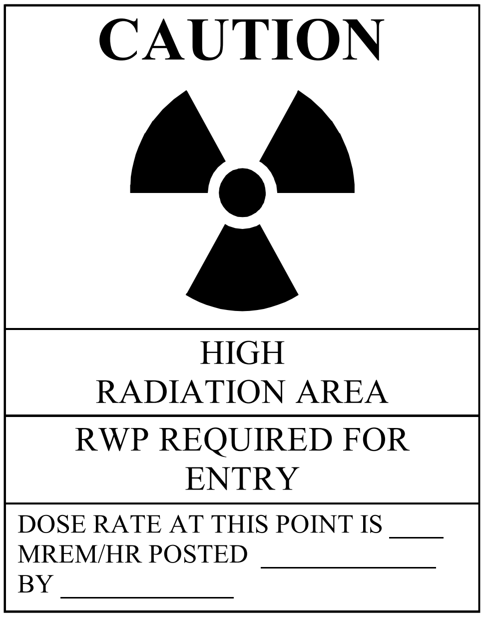
$$\tfrac{3}{5}\ X\ 2000\ DAC\ -\ hr\ =\ 1200\ DAC\ -\ hr$$

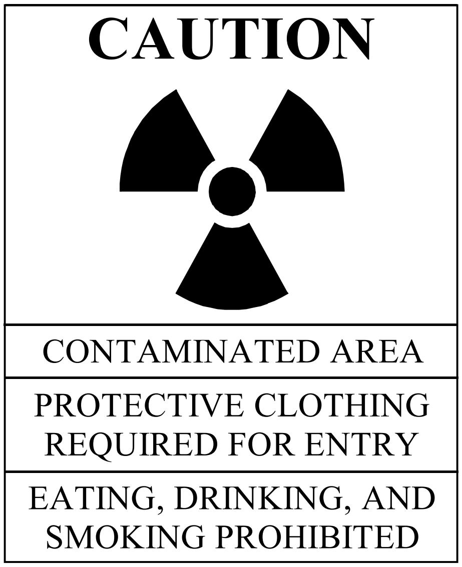
Protection Against Contamination

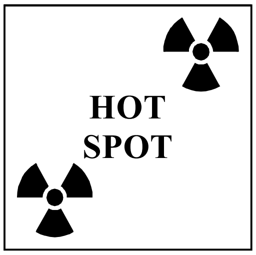
Utilize containments
Maintain access control
Conduct frequent surveys
Utilize protective clothing
Wear respiratory protection
Practice good housekeeping
Conduct follow up bioassays
Minimize radioactive leakage

The protective measures listed above are used to prevent, detect, and/or contain radioactive contamination. Since radioactive contamination can be inhaled and/or ingested, the above measures are also considered to be methods of protection against internal doses.









Above are some common radiation signs and labels. These are commonly used to warn people of radiation areas, contaminated areas, and locations where radioactive material is found. The international symbol for radioactive material and radiation is a magenta or black three-bladed design on a yellow background.