HEALTH PHYSICS TECHNICIAN FUNDAMENTALS
Course: RADIATION PROTECTION
Lesson: RADIATION PROTECTION

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INTRODUCTION

ALARA is a management policy of keeping the radiation dose that station workers receive to: As Low As Is Reasonably Achievable. There are three methods that the radiation worker can use to minimize his dose to external radiation. These are: time, distance, and shielding. By using these methods, the worker can protect himself from exposure to external radiation. Protection will be provided by:

- Limiting the duration of exposure time.
- Maximizing the distance between the individual and the radiation source.
- Using shielding between the individual and the source of the radiation.

These concepts along with the use of Radiation Work Permits will be discussed in this section.

OBJECTIVES

TERMINAL OBJECTIVE

The Contractor Health Physics Technician will describe shielding properties for various types of radiation and attenuating materials. The Contractor Health Physics Technician will perform shielding calculations given the variables and the use of a calculator.

ENABLING OBJECTIVES

Upon completion of this lesson, the Contractor Health Physics Technician will be able to:

- Describe the methods used for determining if ALARA.
- Recall the factors that influence the attenuation of radiation in matter.
- Define the following terms:
    a. Bremsstrahlung
    b. Half-Value Layer

c. Tenth-Value Layer

- Recognize the relationship of the atomic number of the shielding material and its ability to attenuate alpha or beta radiation.
- Recall values of Half or Tenth Value Layer (HVL/TVL) for Cobalt-60 gamma rays for lead, steel, concrete and water.
- Solve total dose problems given dose rate or curie content values for various types of radiation.
- Recognize materials useful for shielding neutrons.
- Calculate the exposure rate for a specified radionuclide given the gamma ray constant, the distance from the source, and the source activity in curies.
- Describe situations when Stop Work Authority can be exercised.

1.0 RADIATION PROTECTION

1.1 ALARA

The ALARA concept is built on several factors which can be influenced by the individual on the job. Several methods are employed to provide exposure reduction. These methods include:

* Physical Methods

Decontamination of the work area.
Removal of radiation sources.
Maximizing distance from sources of radiation.
Minimizing time in a radiological area.
Using temporary shielding.
Use of special tools and equipment.

* Preliminary Work Practices

Advanced Planning
job briefing
RWPs are current and available

These are just a few of the methods that all work can be justified in terms of ALARA. It is necessary for all HP Technicians to make suggestions to enhance this program, and thus lower all exposures to plant personnel.

1.2 TIME

The concept of using time to limit radiation dose is easy to understand if we think of what happens when we attempt to get a suntan. Early in the season, we limit the amount of time we spend in the sun to avoid a severe sunburn. The same holds true for radiation exposure. We have learned that radiation measurement is usually specified as a rate, i.e., mrem per hour, disintegrations per minute, etc. These; measurement units explain the concept of time for radiation protection. If we were to enter an area where the radiation dose rate was 200 mrem per hour, we would receive a dose of 200 mrem in one hour. If we limited our time in this same area to only a 1/2 hour, our dose would be 1/2 of 200 mrem or 100 mrem. We can see that the longer a person remains in a radiation area, the large his dose.

Dose is the total amount of radiation absorbed. dose rate is the rate at which the radiation is absorbed. This is usually specified as mrem per hour or depending on the instrument, mrad per hour. If we look at a survey instrument and it reads 50 mrem per hour, we know that we are being exposed to a dose of 50 mrem in one hour, 100 mrem in two hours, and 150 mrem in 3 hours. Limiting our time in the area can limit our radiation dose.

If our survey instrument is sensitive to beta and gamma radiation, its reading in mrem per hour is equivalent to mrem per hour as the quality factor for both of these radiations is 1.

These concepts, dose and dose rate, help control the dose an individual can receive while working in a radiation area. There is a formula that related dose and dose rate:

Dose = Time x Dose Rate

The radiation dose a person receives is equal to the time he spends in the area multiplied by the dose rate within the area.

Example: The Instrumentation Department needs to calibrate an instrument in an area where the dose rate is 50 mrem her hour. They believe it will take 2 hours to calibrate the instrument. What will be the total dose the worker receives?

Dose = Time x Dose Rate

Dose = 2 hours x 50 mrem/hour

Dose = 100 mrem

The next step is to determine whether a dose of 100 mrem is a problem. If 100 mrem is below plant administrative limits, then there is no problem. If it is above the administrative limits, then more than one person must be used to perform the work. One person goes into the area, performs the first part of the job, and leaves the are before the administrative limits on absorbed dose are exceeded. Another person performs the next portion of the job, and this sequence continues until the job is completed. this does not limit the collective exposure required to complete the job; it only guarantees that no individual exceeds the administrative limits.

The formula can be used to calculate the length of time a person stays in an area so he does not exceed the administrative or federal limits for the whole-body dose. If both sides of the equation are divided by dose rate, the following formula is used:

$$Time = \frac{Dose}{Dose\,Rate}$$

Now the length of time a person can remain in a specific area without exceeding his allowable dose limit can be calculated.

Example: The maintenance force needs to replace a filter in an area where the dose rate is 100 mrem per hour. The station administrative limits specify that the individuals involved cannot exceed a dose of 300 mrem per week. At least 8 hours will be required to complete the filter changeout. How long can personnel remain in the area and how many people will be required to complete the job?

$$Time = \frac{Dose}{Dose\,Rate}$$

$$Time = \frac{300mrem}{100mrem \quad per\,hour}$$

Time = 3 hours

Each individual assigned to the job could remain in the area for 3 hours without exceeding the administrative limit. If 8 hours are required to complete the job, we need:

- 8 hours/3hours per individual = 2 and 2/3rds people or three people to complete the job.

This assumes that only one individual will be in the area at any one time. If it takes two individuals working together, the total number of individuals required to complete the job doubles.

This example demonstrates that planning is essential to radiation protection. You should know exactly what it is you will do while in the radiation area, so that valuable time is not lost unnecessarily.

If necessary, workers can practice on a mockup in an unrestricted area so that they can work as efficiently as possible when performing the actual work.

1.3 DISTANCE

It is common sense to spend as little time as possible in areas where you are exposed to radiation, it is also common sense to stay as far away from a radiation source as possible. We can demonstrate this by looking at a light bulb. If we are very close to the bulb, the light appears very bright, as we move away, the brightness of the light appears to be reduced. The same holds true for radiation. The farther we are away from the source of radiation, the less our exposure will be. The reduction in dose depends on the type of radiation emitted and on the physical size of the source itself.

There are four types of radiation we are concerned with in a nuclear power station: alpha, beta, gamma, and neutron radiation. Depending on the type of radiation, distance effects can vary dramatically. An alpha particle, because it is a large heavy particle, will interact very quickly, i.e., it has a high specific ionization, and its total path length will be short. This is true in air as well as in any other material medium.

For example, alpha radiation will only travel a few centimeters in air. Beta radiation, because it is 1/1840th the mass of a proton, will travel several meters in air. Gamma radiation can travel up to a thousand meters or more in air. In a nuclear power station we are primarily concerned with gamma radiation and we will limit our discussion to gamma radiation concerns.

Dose rate reduction of gamma radiation depends on the relative physical size of the object emitting the radiation. If the source is physically small, the reduction in dose rate can be very large as the distance increases. If, on the other hand, the source is very large, the dose rate will not decrease as rapidly. A large source such as a tank of radioactive water is called a plane source because the radiation appears to come from a large plane not just a single point.

Another source type is a line source. A pipe carrying radioactive water would be a good example. Dose, as you move away from a line source, reduces directly with the distance. The formula for calculating this decrease is:

$R_1D_1 = R_2D_2$

where: R_1 is the initial rate D_1 is the initial distance
R_2 is the new rate D_2 is the new distance

Example: A pipe passing through a room where some maintenance work is to be done reads 2R/hr on contact. How far away should the workers stay to avoid a dose rate of .2R/hr (200mR/hr)?

Using the formula:

$R_1D_1 = R_2D_2$

therefore: R/hr x 1 = .2 R/hr x D_2

simplifying: x 1 = .2 x D_2

$2/.2 = D_2$

10 inches = D_2

Line and plane sources can appear as point sources if the distance from source to measurement point is great enough. There is a rule of thumb used when considering a source a point source. A source will exhibit the characteristics of a point source if the measurement point to source distance is greater than three times the largest dimension of the source. If a dose rate measurement were taken on a 55 gal. barrel, its dimensions are approximately 2 feet wide by 3.5 feet high, at 10.5 feet the dose rate would decrease as a point source as distance increased.

Point source considerations are important because of the dramatic decrease in dose that occurs as we move away from the source. The formula used to calculate the change in exposure as the distance from a point source varies is:

In this equation, R_1 is the exposure rate, or dose rate, at some distance, D_1 away from the object emitting radiation. R_2 is the exposure rate, or dose rate, at a distance, D_2, away from the same object.

Example: consider a point source geometry. If the source is measured from a distance of one foot, the instrument indicates 50 R per hour. What would the exposure rate be at a distance of eight feet from the source?

Using the inverse square law and substituting known values:

$R_1D_1^2 = R_2D_2^2$

$50\ \text{R/hr}\ (1^2) = R_2\ (8^2)$

$50\ \text{R/hr}\ (1) = \text{R}\ (64)$

simplifying:

0/64 = .78 R per hour = R_2

In this example, the dose has been reduced from 50 R per hour at one foot to .78 R per hour at 8 feet.

Besides the inverse square law, the exposure reduction could be calculated using a distance factor. To calculate a distance factor, divide the larger distance by the smaller and square the result. Use this factor and multiply by it if moving toward the source or divide if moving away from the source.

Recalculate the preceding example using the difference factor instead of the inverse square law. The larger distance is 8 ft and the smaller distance is 1 ft. The distance factor is 8 divided by 1, or 8, which is 64 when squared. Because we are moving away from the source, the exposure rate will decrease.

Therefore, the exposure rate of 50 R per hour is divided by the distance factor of 64. The exposure rate at 8 feet from the source is 0.78 R per hour or 780 mR/hr.

Examples: The exposure rate at a distance of 6 ft from a small valve is 10 mR per hour; what will the exposure rate be at a distance of 1 ft from the source? Use the formula:

$R_1D_1^2 = R_2D_2^2$

$10\text{ mR/hr x }(6\text{ft}^2) = D_2\text{ x }(1\text{ft}^2)$

$10\text{ mR/hr x }36 = D_2\text{ x }1$

$10\text{ mR/hr x }36 = D_2\text{ x }1$

$360\text{ mR/hr} = D_2$

With the distance factor method, the larger distance (6 ft) is divided by the smaller distance (1 ft) and the result squared.

$(6/1)^2 = 36$

In this case, by moving closer to the source, the exposure rate increases. Therefore, multiply the distance factor (36) by the known exposure rate (10 mR/hr).6 x 10 mR/hr = 360 mR/hr

Both methods show that the exposure rate at a distance of 1 ft from the source is 360 mR per hour.

These types of calculations are very important to radiation protection. A few feet in distance makes the difference between a low dose and a significant exposure problem. An example of this could be envisioned by considering a radioactive material shipment. If a barrel of spent resin were reading 100 R/hr at 1 foot, a person standing by the barrel for an hour would receive a dose of 100R. An exposure of this magnitude could result in some mild reversible blood changes. This is an injury? Conversely, if the person had to work in the vicinity of this source and could stay 10 feet away from it, the resulting exposure would be only 1 R in an hour. This dose would not exceed federal limits and there would be no injury.

NOTE: Remember to be unit consistent when performing these calculations. Feet or inches, mrem, rem, or rad must all be the same throughout the calculations. Also, measurements are always taken from the source to the point of measurement.

An approximation of the radiation exposure level (R/hr) at one foot from a point source can be made by using the 6 CE_n equation,

where: C is the number of curies, and En is the total effective gamma ray energy (Mev) per disintegration.

Example: Determine the exposure rate from a point source containing 10 curies of cesium-137.

$6\,CE_n$ = exposure rate

C = 10 curies

E_n = .66 Mev (subscript n indicates total gamma energy per disintegration.)

6(10)(.66) = 39.6 R/hr at one foot

Example: Determine the exposure rate from a point source containing 50 curies of cobalt-60.

C = 50 curies

En = 1.17 + 1.33 = 2.5 Mev

6(50)(2.5) = 750 R/hr at one foot

Distance is used as a radiation protection technique many times in the station. The radiation protection staff will quite often rope off areas with yellow and magenta warning rope to make people keep their distance from a radioactive source. The posting of areas is one example of distance being used in radiation protection.

Another example of distance being used in radiation protection is the use of long handled tools in the spent fuel pool area. The tools are required to work on the fuel under many feet of water, so there are two radiation protection techniques in use distance and shielding.

1.4 SHIELDING

Shielding is the third method used for radiation protection. If a shield is placed between a radiation source and an individual, the shield will attenuate or absorb some of the radiation. The radiation will interact within the shield, not within the worker. This results in a reduction of the worker's exposure. There are two things to be considered when designing shielding: type and amount of material used.

Each of the four types of radiation (alpha, beta, gamma and neutron) can be shielded with different types and thicknesses of material. The amount of shielding used can be important simply due to weight restraints. If the wrong type of material is used and it is too heavy, real problems are created.

1.5 RANGE OF RADIATION IN MATTER

The distance that radiation travels is dependent upon a number of factors, such as the type of radiation, the energy of the radiation, and the material that the radiation passes through. In this section, we will discuss in general terms the range of the four primary types of radiation.

Alpha particles, being the largest particles of radiation and having a plus two charge, interact with matter more readily than other types of radiation.

Each interaction results in a loss of energy. This is why the alpha has the shortest range of all the other types of radiation. Alpha particles generally are stopped by a thin sheet of paper. As a comparison, a 4 Mev alpha will travel about 1 inch in air, whereas a 4 Mev beta will travel about 630 inches in air. Because the alpha travels only a short distance, it deposits all of its energy in a very small area. This is one reason why alpha particles are dangerous internally. If a radioactive alpha emitter is swallowed, each alpha will deposit all its energy in the walls of the stomach or the lining of the intestine, which can cause significant damage to these soft tissues.

The beta particle is more penetrating than the alpha. However, because of the -1 charge, the beta particle interacts more readily than a non-charged particle. For this reason, it is less penetrating than uncharged radiation such as the gamma or neutron. The beta particle can generally be stopped by a sheet of aluminum. because the beta travels farther than the alpha, it deposits its energy over a greater area and is, therefore, less harmful than the alpha if taken internally. Shielding betas is complicated by the production of Bremsstrahlung of "braking" radiation. When a high energy electron is in the presence of a nucleus it undergoes acceleration, resulting in the emission of high energy photons (x-rays). Because this photon radiation is uncharged, it has great penetrating power. Bremsstrahlung radiation is favored in heavy materials, whereas light elements interact mostly by ionization. Therefore, beta shielding is better accomplished by aluminum than lead.

Neutrons are best shielded by a material consisting of light elements, such as polyethylene and water. Neutrons lose more energy when interacting with light elements, such as hydrogen, than with heavier elements, such as lead. The highly energetic neutrons in the plant are almost exclusively in the reactor. Because the reactor is shielded with water, neutrons lose their energy in collisions with light atoms in the water and, therefore, are generally contained in or around the reactor.

Gamma radiation is the most difficult to shield against and, therefore, presents the biggest problem in the plant. The penetrating power of the gamma is due, in part, to the fact that it has no charge or mass. Therefore, it does not interact as frequently as do the other types of radiation. The three methods of gamma interaction all involve interactions near the nucleus or interactions with the electrons around the nucleus. For this reason, more gamma interactions occur in a dense material that has many electrons. One such material is lead. Lead is very dense and a lead atom has 82 electrons. Thus, a gamma would interact more times in passing through 8 inches of lead than in passing through the same thickness of a light material, such as water. As with other types of radiation, gamma radiation loses energy as it interacts. When it has lost all of its energy, it disappears and is no longer a problem.

For all different types of radiation, the distance traveled increases as the energy increases. For example, a 10 Mev gamma will travel farther than a 2 MeV gamma. The energy of the radiation emitted from specific nuclides can be obtained from the Chart of the Nuclides. For example, Sb-119 emits gamma radiation of 0.02387 Mev energy. This is the only energy gamma emitted. At time, unknown radioactive nuclides are identified by noting the type and energy of radiation emitted. There is one caution, however. While this specific energy emission is valid for gamma, alpha, and neutron radiation, it is not valid for beta radiation. The beta energy listed in the Chart of the Nuclides is the endpoint energy of all beta particles emitted. As an example, H-3 (commonly called tritium) is the only radioactive isotope of hydrogen. The Chart of the Nuclides indicates that H-3 emits beta radiation and lists an energy of 0.01861 Mev. This indicates that 0.01861 Mev is the highest energy beta emitted from H-3. There are other beta particles of lesser energy emitted from H-3.

Gamma radiation is the largest contributor to radiation exposure due to the inherent shielding provided by the plant systems. Alpha radiation, of course, cannot even penetrate a thin sheet of paper; beta radiation could be shielded by a thin piece of wood or aluminum; neutron radiation is shielded by water and is a local problem only near the operating reactor. Since alpha, beta, and neutron radiation either cannot penetrate the plant systems, pipes, etc., or are a local concern, only (neutron radiation) gamma radiation is our primary exposure concern.

The section on radiation interaction showed us that gamma radiation primarily interacts with orbital electrons. If we construct a shield with a material whose atoms have many electrons, it should make an effective material. A material with many orbital electrons is also a heavy, dense material. Lead is an example. Water is also used for gamma shielding, but there are not as many orbital electrons available, so it is not as efficient as a shield of lead.

1.6 BASIC SHIELDING

In nuclear plants, alpha and beta radiation are shielded by piping or other enclosure material. Neutrons are shielded by the water around the reactor. However, gamma radiation, at time, requires the construction of shields to protect personnel. For example, if a tank contains a gamma emitter and the tank is located where personnel frequently walk it may be necessary to erect a shield to protect the personnel. To determine the thickness of shield required, it is necessary to discuss some basic shielding principles.

If a beam of gamma rays is projected at a lead wall, we find that the intensity of the beam decreases exponentially over the width of the wall. This is due to the gamma interactions occurring in the wall. However, some gamma interactions, such as pair production and Compton scattering, result in other gamma rays of lower energy being given off. For this reason, the actual decrease in the intensity of a beam of gamma rays passing through a wall is less than the theoretical decrease (Figure RP-4-1).

The difference between the actual decrease and the theoretical decrease is called buildup. So, in any calculations involving a thickness of material required to reduce gamma intensity, we need to add a little additional material to account for the build up.

In determining the thickness of material needed to shield against radiation, we frequently use helpful rules based on half value thickness and tenth value thickness. On half value thickness is the thickness of material required to reduce the photon intensity to 1/2 the initial value (assuming no buildup). One tenth value thickness is the thickness of material required to reduce the photon intensity to 1/10 the initial value (assuming no buildup). Both the tenth and half value thicknesses are dependent upon the energy of the photon and the material it passes through. Table 1 lists tenth and half value thickness of 1 Mev gamma rays for various materials.

Table 1

Tenth and Half Value Thicknesses for 1 Mev Gamma Rays

Material	1/10 Value	1/2 Value

Lead	1.5 inches	0.5 inches
Steel		
Concrete	12 inches	4 inches
Water	24 inches	8 inches

Many types of lead shielding are available: lead sheets, lead bricks, lead blankets, and even lead shot. Different types are appropriate for different circumstances. To shield a small gamma check source to ship it to another site, we might place it in a can filled with lead shot. On the other hand, if we wanted to shield a large valve in the station, we may build a lead brick wall around it, or we could shield detectors with brick "caves". Lead cannot always be used as a gamma shield however. If we want to shield the gamma radiation from spent nuclear fuel, we could not do so with lead and still be able to work on the fuel. In this case, water would be the logical choice for gamma shielding.

How much shielding is appropriate for a particular application? The amount of shielding used is a very important consideration. This is particularly true when a heavy dense material is used to shield gamma radiation. If too much is used, time will be wasted in installing the material and weight restrictions may be exceeded that could possible cause structural damage. An estimate of the proper amount of shielding to use can be made using tenth-value and half-value thicknesses.

Another consideration in designing shielding is the energy of the incident photon. It takes more shielding to attenuate a 5 Mev gamma photon that it would to attenuate a 1 Mev gamma photon. Most of the shielding required in a nuclear station is for energy levels around 1 Mev or less. At times we are concerned with a higher energy gamma photon emitted by nitrogen-16. N-16's gamma photon has an energy of approximately 6 Mev.

Table 2 shows two sets of tenth-value thicknesses for specific shielding materials. The 6 Mev set should be used for lines and equipment containing reactor water or primary steam with hold-up times of less than 5 minutes. The 1 Mev set should be used for irradiated fuel, isolated equipment, and all equipment during a plant shutdown.

Table 2

Approximate Tenth - Value Thicknesses

Material	1/10 Value 1 Mev	1/10 Value 6 Mev
Lead	1.5 inches	2.0 inches
Steel	3.0 inches	4.0 inches
Concrete	12 inches	24 inches
Water	24 inches	48 inches

Lead and water are the most important ones to remember.

Note that the half-value thickness (HVT) for any material is about one third of the tenth-value thickness. For example, the tenth-value thickness for 1 Mev gammas in lead is 1.5 inches; the half-value thickness is 0.5 inches.

Example: The radiation protection department takes a reading on an isolated pump and finds readings of 1000 mR per hour. How thick should a shield be to reduce this level to 50 mR per hour?000 mR/hr to 50 mR/hr

Half or Tenth Value Thickness	Inches	Reading
0	0	1000 mR/hr
1 TVT	1.5	100 mR/hr
1 HVT	.5	50 mR/hr
Total	2.0 inches of lead needed	

Example: What is the lead thickness required to reduce the levels from a reactor vessel wall from 2000 mR/hr to 20 mR/hr?000 mR/hr to 20 mR/hr

Half or Tenth Value Thickness	Inches	Reading
0	0	2000 mR/hr
1 TVT	1.5	200 mR/hr
1 TVT	1.5	20 mR/hr
Total	3.0 inches of lead needed	

Besides the type and amount of shielding, the placement of the shield is also a concern.

Example: Assume that the radiation level from a pump is 30 mR/hr one foot from the pump. If a shield of lead 1.5 inches thick is placed so that the outside edge of the lead is one foot from the pump, calculate the readings at a distance of 10 feet from the pump.

Step 1: Calculate the reading through the shield: 1.5 inches of lead is 1 TVT, so the reading is 3 mR/hr through the shield.

Step 2: Calculate the readings 10 feet from source.

$$\text{Distance factor} = \frac{10^2}{1} = 100$$

$$\text{Reading} = \frac{3\ \text{mR / hr}}{100} = 0.03\ \text{mR/hr}$$

As the example and question show, the location does not affect the thickness of the shield because a given thickness always provides the same fraction of reduction. However, the farther away from a source we get, the more the radiation diverges. Although the shield thickness is the same, the height and width of the shield have to be larger. As shown in Figure RP-4-2, it is usually best to place the shield as close to the source as possible to keep the shield as small as possible and thus minimize its cost.

Scattering of radiation is a final consideration of shielding. As the radiation interacts with the shield material some of it may be deflected or scattered out of the shield and into the work area. Generally, scattering is not a problem as the exit levels are 100 to 1000 times less than the incident levels. The problem arises when dealing with very high radiation levels. Scattering needs to be considered when designing specific shields for specific areas.

Some jobs require the use of temporary shielding while work is being performed. Temporary shielding usually consists of workers placing lead blankets over piping or valve that would significantly contribute to the dose receive while working in the area. The installation time required should be considered. If more exposure is received installing the shield than doing the job, the shield is not a good method of reducing exposure. This is an ALARA consideration usually considered by the ALARA engineer before he approves the installation of temporary shielding.

2.0 RADIATION WORK PERMIT

As you approach a radiation area, you will note the warning signs placed there by radiation protection personnel. The signs may require that you have a Radiation Work Permit (RWP) to enter the area. The RWP is a control method. It provides a place for indicating all the things that need to be considered before you enter the area. An RWP provides information on job location, job description, names of personnel, allowable exposures, dose rate and contamination levels in the area. In addition, types of monitoring, protective equipment needed, and special instructions are indicated.

The RWP is a very important document. Besides the above, the RWP also acts as an exposure recording and exposure history record. It will be used in the future for re planning the same job with the intent of reducing exposure on future jobs. The RWP is the primary method of controlling work in radiation areas.

Figure RP-4-3 is a typical Radiation Work Permit. Actual RWPs vary from station to station but they generally look like the one in the figure.

The RWP also contains space for the signatures of various station personnel needed to approve the permit. Space is provided for the job supervisor, health physics/radiation protection supervisor, and shift supervisor. The job supervisor assigns the personnel to the job, so his name is on the permit; the HP/RP people do the surveys and indicate the requirements for entry into the area, so their names are on the permit and finally, the shift supervisor is responsible for what goes on in the plant so his name is the final approval signature on the RWP.

Once a RWP has been filled out and approved, the responsibility rests with the individual worker to read it and adhere to all of its provisions. If the RWP requires full protective clothing, the worker is responsible for wearing the required equipment. As was discussed earlier, radiation protection is everyone's responsibility and following the RWP is one good way of meeting this responsibility.

When entering an area where a RWP is required, you have to sign in and out of the area on an access control and exposure recording sheet which is attached to the RWP. This information provides an estimate of the dose the person received while in the area. We say "estimate" because the film badge or TLD is the legal record of exposure. The access and exposure control form makes the RWP a complete record of the job and the exposures received on the job. It is a legal record of the job.

Every RWP should specify the time for which it is valid. Most RWPs are valid for one 8 hour shift. If the job extends beyond eight ours, a new RWP is usually issued.

For jobs that are done repeatedly, some plants use a blanket RWP. The blanket RWP is filled out and used the same way as a standard RWP. The only difference is that the record of personnel exposure is kept on a separate sheet.

Radiation Work Permits (RWPs) are used anytime personnel need to enter:

- High Radiation Areas
- Contaminated Areas
- Airborne Radioactivity Areas
- Neutron Radiation Areas
- Reactor Containment
- Any area where radiation dose rates are likely to exceed 100 mR/hr or where a whole body dose of 100 mrem a week on the performance or duration of a specific job is likely.
- Any area posted with an "RWP Required" sign or areas deemed necessary by HP supervision.

An RWP is designed to specify radiation safety and control requirements in areas where a significant exposure to personnel is possible. It also provides an exposure recording system and a system for recording sources, job types and functions where personnel exposures occur.

Occasionally an RWP may be issued for an extended period of time, covering a specific area, that will allow operations personnel to perform routine operations, surveillance and inspections in the area. This type of RWP is termed a "Blanket RWP".

Most nuclear power stations have some type of administrative procedure that specifies responsibilities and actions required by the various individuals involved with the issue, use and processing of Radiation Work Permits. Some of these various groups or individuals and the responsibilities are:

1. Health Physics is responsible for:

   Survey measurements

   Available exposure for personnel listed on RWP

   Radiological safety in areas denoted by the RWP

   Establishment of control point monitors if required

   Providing RWP compliance checks.

   HP signatures and approvals.

   Short term filing of RWPs.

   The ALARA Coordinator is responsible for completion of ALARA codes.

2. Shift Supervisor/Senior Control Operator is responsible for:

   Approval and signature of the RWP indicating that no plant evolutions are planned which could change the radiological conditions in the area listed on the RWP.

   Notifying HP whenever any plant evolution has taken place or is to take place that would change the radiological conditions in the area listed on the RWP.

   Approval and signature of the RWP indicating that the plant is not jeopardized by the work indicated on the RWP.

3. Work Supervisor is responsible for assuring that worker sections of the RWP are filled out completely.

4. RWP Initiator is responsible for:

Providing an accurate description of the job and location.

Listing workers names (preferably in alphabetical order) and social security number of each.

5. Workers are responsible for:

   Reading, understanding, initialing and following RWP instructions.

   Recording dosimeter readings in and out and time in and out of an area in the RWP area.

6. There are two prerequisites required prior to individuals being issued RWPs or entering areas that require an RWP. They are:

   Individuals shall have been issued appropriate personnel monitoring devices.

   Individuals listed on blanket RWPs are responsible for reviewing and understanding the latest airborne, contamination and radiation surveys prior to any entry in those areas.

   Some applicable precautions to this procedure include:

7. All blanket and other RWPs shall require either a dose rate meter required for entry into high radiation areas or one of the following:

   An individual qualified in radiation protection procedures equipped with a radiation dose rate monitoring device.

   This individual shall be responsible for providing positive control over the activities within the area and shall perform periodic radiation surveillance at the frequency specified in the Radiation Work Permit.

   The surveillance frequency shall be established by the

   Health Physics Supervisor.

   A continuously, integrating radiation monitoring device which alarms when a preset integrated dose is received. Entry into such areas with this monitoring device may be made after the dose rate in the area has been established and personnel have been made knowledgeable of them.

8. Health Physics approvals on RWPs shall be made by supervisory Health Physics personnel (Health Physics Operations Foreman, Radiation Protection Supervisor or Health Physics Supervisor) or their designees only.

9. Weekly blanket RWPs shall be terminated by HP or work supervision at the end of a calendar quarter or calendar year rather than the end of the week if the RWP will span two calendar quarters or years (i.e., write two weekly blanket RWPs if the first RWP will start 12/28/79 and end 1/4/80).

10. HP and work supervision shall brief all workers on radiological and other work conditions prior to entry of RWP areas. The RWP should clearly state high dose rate areas to avoid.

11. The description of work specified on the RWP shall precisely describe all the work activities which may occur. Work activities not described shall not be allowed on that RWP.

There is no acceptance criteria required to complete this procedure. The procedure itself gives general instructions, a flow diagram of RWP issuance and examples of forms used. They are as follows:

General Instructions

* All prerequisites and precautions have been read and understood.

* A different RWP should be written or clearly distinct tasks of the job which may contribute a major portion of the total man-rem for that job.

* All work to be performed shall be clearly specified under description of work. Work not specified will not be allowed on that RWP.

* RWPs when signed by Health Physics (HP) signify adequate radiation controls have been specified and are (or will be) in effect for the RWP. At this point, the RWP only grants approval for radiation exposure to the individuals specified.

* RWPs when signed by the Shift Supervisor/Supervising Control Operator, indicates the Shift Supervisor/Supervising Control Operator is aware of the presence of on going work and that plant conditions are suitable for the worker(s). Also he will not deliberately change plant conditions which would have any radiological consequences to the personnel listed on the RWP.

* Continuous HP personnel coverage may be substituted for an RWP when an emergency exists which threatens personnel or plant safety.

* Any exposures received during entries into RWP areas without direct health physics coverage should be recorded on the Weekly Dosimeter Record Form.

* Personnel may be issued a blanket RWP for routine work with the HP Supervisor approval. Specific jobs or work identified during surveillance tours and inspections shall not be done on the Blanket RWP. Separate RWPs shall be initiated for such work.

* No further work shall be performed under an RWP once it is terminated or expired except for the following:

For weekly blanket RWPs, a deterioration of radiological conditions in a work area will terminate the work in that area only.

Work may be resumed when HP supervision determines that favorable conditions have been reestablished. Routine activities being performed in other areas under the blanket RWP will not need to be terminated.

Should a job necessitate continuance beyond its designated terminated time or date, appropriate changes shall be made, to the RWP, or HP prior to such extension. The shift Supervisor shall be notified when such changes are made.

* Each RWP has two main parts. The first part, Part 1 Radiation Work Permit, is common to all RWPs written. This portion of the RWP provides approvals for HP and the Shift Supervisor, and ALARA information on the job. (Figure RP-4-1 shows the RWP flow paths.)

The second part of the RWP may be either a "daily log" or "weekly blanket" for access and exposure control (Part 2 or Part 2a, respectively). These portions of the RWP are used to record personnel exposures. Part 2 also includes a "time in" and a "time out" of an area. The RWP from Parts 2 or 2a shall be routed with the RWP and be treated as part of the RWP.

* Prior to use, individuals will read and initial the RWP indicating understanding of work conditions, radiation and contamination controls, the Control Point Monitor logs the workers dosimeter readings and times in and out of RWP area(s) on the Daily Log Access and Exposure Control sheet, RWP Part 2. If there is no Control Point Monitor established, the individuals entering the RWP area(s) shall assume the responsibility of recording their individual dosimeter readings and times in and out of RWP area(s).

* It is important for the Health Physics Technicians to understand when a Stop Work Authority may be exercised in the course of duties. Situations which may arise which may result in the HP Technician declaring a stop to radiological work include:

- Violations of the RWP.
- Dose rates changing.
- Contamination levels rising.
- Unsafe conditions existing in the work area

3.0 <u>SUMMARY</u>

We have learned in this section that time, distance and shielding are major methods used to protect use from radiation exposure. If our time spent in a radiation area is reduced through planning and training experience, then our radiation exposure will be reduced. If we increase the distance between the radioactive material and ourselves, the dose of radiation we receive will be reduced by a factor of 4 each time we double the distance. This is the Inverse Square Law, i.e., "Double the Distance, Quarter the Dose". Shielding can also reduce our exposure. Many things need to be considered prior to shielding a source, however. Some of these include: structural support, space limitations, cost, installation time and exposure. These are not the only methods used for radiation protection; work permits, design features, station procedures and common sense are all additional concepts we may use in radiation protection.