6. RADIATION

6.01 Fallout:
Nuclear fallout is the most far reaching of all the weapons effects. Nuclear explosions occurring near the surface of the earth cause huge amounts of debris and dirt to be drawn up into the fireball where they are vaporized and fused with fission products and radioactive residues.

As the fireball cools, the vaporized material begins to condense into liquid droplets, which eventually solidify into glasslike particles.   These particles constitute what we call 'fallout'.

We can see fallout as an accumulation of dust and small particles falling onto the ground and buildings. We cannot, however, see, feel, hear or taste the radiation that is being emitted from the fallout.

6.02 Distribution of Fallout:
Fallout is carried in the nuclear cloud and is moved by winds. The direction of fallout is determined by winds up to at least 80,000 feet and the velocity of the wind governs how far the cloud will travel. The United States has a variety of upper air winds. They are predominantly from west to east during the fall, winter and spring. In the summer, the winds are more variable. Surface winds cannot be used as an indication of direction for the flow of high atmosphere winds.

In addition to the wind, precipitation will affect the radioactive deposition. Rain and snow "wash "or "scrub" the air of the radioactive particles. Contaminated material, which would normally be spread over a much larger area by the dry weather patterns, is rapidly brought down in local rain or snow areas. This is referred to as "rainout".

Terrain features also play a part in deposition. Large mountains or ridges could cause significantly more fallout on the sides facing the surface wind.

Nuclear fallout from areas across the oceans will not pose a large threat to the United States. Small yield weapons deposit most of the fallout locally. The radioactive isotopes from larger yield weapons remain in the stratosphere until the short-lived isotopes decay, and the longer-lived isotopes are significantly reduced.

6.03 Radiation:
The basic building blocks of the atom are protons, neutrons, and electrons. Nuclear radiation is an 'eruption' or' emission' of these particles from the nucleus of the radioactive elements. These high-energy emissions constitute radioactive 'decay'. Fallout from fission type nuclear weapons carries these radioactive particles to the ground where they continue to decay.

Radiation from a nuclear explosion consists of gamma rays, neutrons, beta particles and a small portion of alpha particles.

Alpha particles:

Alpha particles are positively charged and relatively large, consisting of two protons and two neutrons. Alpha particles are completely stopped by a sheet of paper or the outside layers of our skin and are not an external hazard. Internally, however, they will dissipate their entire energy within a small volume of body tissue, causing considerable damage.

Beta Particles:

The beta particle is very small compared to an alpha particle, and is spontaneously emitted from the neutron of certain radioactive elements. It is identical to a high-energy electron and has a negative charge.

Most fission products are beta emitters. Beta will pose a small external hazard if fallout comes into actual contact with the skin and remains for an appreciable time. This causes a burn referred to as "beta burn". Fallout should be brushed or washed from the hair and skin as soon as possible. Beta will, however, do considerable damage if it enters the body.

Certain chemical elements tend to concentrate in specific cells. The body cannot distinguish between the pure element and the radioactive isotope of that element. Radioactive strontium and barium are similar in chemical nature to calcium and will seek the bones. These elements pose a small hazard if inhaled but care should be taken not to eat food contaminated with fallout. Animals that have been exposed to radiation may have significant levels of strontium and barium in their bones. These animals, if healthy appearing, may be slaughtered and eaten if the bones and organs are discarded before the meat is cooked.

Foods contaminated with fallout should not be eaten unless they can be washed or peeled. All cans containing food should be washed before opening. Please see last month's issue of the JCD for additional information on foods and farming in a post war environment.

Iodine 131, which poses the largest threat, will seek the thyroid. Thyroid blocking agents (TBA) are available commercially. They are inexpensive and have a long shelf life. Iodine 131 has a half-life of 8 days and would be a threat for 10 half-lives or approximately 80 days. Enough thyroid-blocking agent should be stored for each person for a 3-month period. Care should be taken to keep fallout contamination from the lungs, eyes, and open wounds and to wash any food that is to be ingested.

Gamma rays:

Gamma rays have no measurable mass or charge. They travel at the speed of light and originate from inside the nucleus. The emission of an alpha or beta particle from the nucleus of an atom will almost invariably be accompanied by the emission of gamma rays.

Gamma radiation will penetrate through the body and does pose an internal danger for two weeks after a nuclear detonation.   In most areas, after two weeks there is no appreciable level of gamma radiation remaining.

Neutrons:
Neutron radiation is part of the 'initial radiation' that occurs in the first moments after the detonation. Neutrons are not contained in fallout. Neutrons have a range of 1-½ miles from the detonation and are very penetrating. The blast levels at that range are fatal if people are not in hardened shelters. All shelter entrances must contain 6 feet of shielding if the shelter is within that range of a target, and the dirt cover on top of the shelter must exceed 6 feet.

6.04 Radioactive Half-Life:
Radioactive elements vary greatly in the frequency with which their atoms erupt. Some have only infrequent emissions (decay) while others are very active and radiate frequently. The rate of radioactive decay is measured in half-lives. The half-life is the time required for the radioactivity of a given amount of a particular material to decrease to half its original value. The half-life of a radioactive material may range from fractions of a second up to millions of years. After 10 half-lives, radioactive elements decay to a level that is no longer considered to be a human hazard. Radioactive Iodine-131 has a half-life of 8 days. After 80 days, Iodine-131 is not longer considered to be a hazard.

6.05 Fallout Protection Factors (PF):
The fallout protection factor (PF) is a ratio of the fallout exposure rate that would be measured by a meter at a height of 3 feet above a surface, to the exposure rate that could be expected in a given location in an area below that surface. A PF 50 would indicate that the radiation level above the surface is fifty times the value of the radiation level below the surface. Protection factors are a function of distance, geometry and shielding, but not of time.

6.06 Principals of Protection:
The three basic principals, which give protection from radioactive fallout, are time, distance and shielding.

Time:
All radiation decays with time. During the fission process in a nuclear detonation, many isotopes with different decay patterns are produced. It has been found that the average decay rate behaves exponentially and can be estimated with the 7 / 10 rule.

Simply stated, this rule says that for every seven-fold increase in time after detonation, there is a ten-fold decrease in the exposure rate.

This rule can be used to roughly estimate the future exposure rates. As an example, if the exposure rate were found to be 1000 R/hr. at 1 hour after the explosion, if there were no other explosions, the forecast for the future would be a rate of 100 R/hr after 7 hours; 10 R/hr after 49 hours (roughly 2 days); and 1 R/hr after 2 weeks. In all but the highest radiation levels, this decrease should allow for activities outside the shelter during much of the day. People should be taught to stay inside the best shelter that can be found for at least two weeks.

Distance:
The dose rate of radiation falls off with increasing distance in air, even though attenuation by air is negligible. The' inverse square law' states that the dose is inversely proportional to the square of the distance in air from a point of a gamma-ray source. The importance of this law will become apparent later in this lesson, in our discussion of sheltering.
This law is not applicable to other than a point source. However, fallout does act as a point source in long, narrow entryways.

Children are more vulnerable to the affects of radiation because of their rapidly dividing cells. Heavy people are somewhat protected by layers of fat. With this fact in mind, it would be wise to put small children and thin adults at the lowest point of the shelter during high radiation levels.

Shielding:
The damaging effect of gamma rays comes from their ability to ionize. Shielding materials containing large numbers of electrons will filter (attenuate) gamma rays. The more massive the material, the greater will be the attenuation factor.

It has been found that certain amounts of shielding material will attenuate half the gamma radiation. This amount is referred to as the "half value thickness" for that particular material. The material is said then to give a protection factor (PF) of 2. The protection factors are multiplicative. Two half-value thicknesses will give a PF of 4. Three half-value thicknesses will give a PF of 8. It takes 10 half-value thicknesses to reach a PF of slightly greater than 1,000.

APPROXIMATE EFFECTIVE HALF VALUE THICKNESSES

Material	Density (lb / cu ft)	Half Value Thickness (inches)
Steel	490	1
Concrete	146	3.3
Earth	100	4 to 4.8
Water	62.4	7

Good radiation shelters should have a PF of 1000. Ten half-value thicknesses of earth will give a PF of 1,000 and will require about 48 inches of earth cover.

6.07 Biological Effects:
Large exposures to nuclear radiation can cause acute sickness or death, whereas small daily exposure may be tolerated without causing radiation sickness.

An exposure of 600 Roentgens (R) will usually be lethal when received as a brief exposure. The same exposure accumulated over a number of years would have no recognizable effect.

Doses occurring during a 24-hour period are considered 'acute' doses. If the exposure is over longer lengths of time, it is considered 'chronic' exposure.

Ionizing radiation may cause an increase of the permeability of the cell membrane, alter or destroy cells, inhibit the process of cell division ('mitosis') and break chromosomes.

Radiation Sickness:
The symptoms of radiation sickness are nausea, vomiting, headache, dizziness, and a generalized feeling of illness. There is an initial stage of these symptoms that lasts 1 to 2 days, followed by a latent stage with few if any symptoms that lasts between 2 and 4 weeks. The final phase is characterized by a recurrence of the symptoms noted during the initial phase, and in higher doses the individual may experience skin hemorrhages, diarrhea, loss of hair and seizures. The final stage lasts between 1 to 4 weeks and results in either recovery or death.

The symptoms of the initial phase are similar to symptoms of stress and fear. If you have been well shielded, do not assume radiation sickness to be the cause of these symptoms.

Penalty charts have been developed to show the consequences in expected number of deaths of radiation exposure. Most of these deaths will occur from the very young, the frail and the elderly. Survivors will see an increase in cancer deaths, as well as some mutations in progeny.

In a full-scale attack, almost all areas of the country would be affected by high, medium or low levels of radiation. Charts showing required protection factors show very little difference in the number of survivors in these three risk levels. Sheltering indoors in a one level home would provide a PF of about 5. There would be no expected survivors in a medium or high fallout risk area with a PF of 5, and very few in low risk areas. Unexposed basements offer a protection factor between 16 and 20. These charts should impress us for the need of shelters throughout the entire nation with PF's of 500 to 1,000 and more. Acceptable peacetime levels of radiation are set by governing agencies to be less than 1 R per year. Why should we settle for any less during wartime, when the technology is there for our protection?

Shelter design must incorporate protection from all weapons effects-blast; thermal pulse, radiation and EMP. All of these effects will eventually be covered in various chapter lessons.

The main function of fallout shelters is to shield from gamma rays. Alpha and beta particles are not an issue in a sheltered environment. Proper fitting doors and high efficiency particulate air filters will protect the occupants, equipment, food, water and the air you breathe from the alpha and beta particles.

Gamma radiation is attenuated by mass. Most people understand the need to cover the shelter body with at least 4 feet of dirt (or equivalent) to protect the occupants from the effects of gamma radiation. The exposure, therefore, will not come from the top of the shelter—it will come from the entrances. One of the least understood design concepts is the crucial role that proper geometry of entrances plays in radiation attenuation.

The importance of the proper size and geometry of entrances was affirmed by scientists and engineers during early nuclear weapons tests. Underground corrugated-steel shelters were used to prove and document these concepts. The engineers discovered that radiation entering small diameter entrances followed the' inverse square law' that we spoke of earlier, and that every 90-degree turn attenuates (decreases) the gamma radiation by a factor of 10 (PF10). It was their recommendation that entrances should be no more than 48 inches in diameter, and that they should have a length of at least 22 feet, incorporating a 90-degree turn near the half-way mark. Entrances of larger diameter would need to be significantly longer and the design stipulated by an engineer.

Initial radiation, as discussed earlier in this lesson, and the prompt neutrons associated with this effect will not follow the same rules and formulas as those for the attenuation of gamma rays. Neutrons have a range of 1 ½ miles and are very penetrating. Shelters near targets that may be within a radius of 1 ½ miles from a potential blast should have at least 8 feet of dirt cover and incorporate additional shielding material into the horizontal runs of their entrances.

Ninety-degree turns provide very little additional protection against neutrons. One entrance should contain a full 6 feet of shielding at all times. Rice, wheat, water and anything with high hydrogen content make good neutron shields. In high-risk areas for initial radiation, we suggest that sacks of rice be left inside the shelter near the entrance, ready to put into place after everyone has entered. If you are within this neutron range, there may be some 'neutron activation' of the shielding materials. Your low-range milliroentgen meter should then be used to test any foods in the entrances that have been used for shielding. If there is a reading above the level found in the shelter, the foods should be discarded and not eaten.

In most areas, after the first two weeks from the time of the detonation, gamma radiation is no longer a threat, and people can leave their shelters. At that point, alpha and beta contamination (though they still persist in small amounts) is only an issue of proper hygiene techniques and careful preparation of food.

THINK:
FEMA documents have stated that hole body exposure must be limited to 175 rems to save more than 50 percent of the population. To attenuate the exposure anticipated in a full scale nuclear attack to this level, a minimum protection factor of 40 would be required. A protection factor (PF) of 40 can be achieved with 24" of dirt cover for shielding. This 50% level of fatalities may be acceptable to FEMA, but it is not acceptable to TACDA. Dirt is 'dirt cheap'. Use 40-inches of cover and you will achieve a PF of 1,000, and expect 'zero' fatalities. Each 4 inches of dirt will provide one doubling. Forty inches of dirt will give the required 10 doublings for a PF of 1,000. Blast becomes a major factor within 5 miles of a target. If you are near a prime target, you will need a shelter with an 'arched' top and dirt cover that is double the diameter of your shelter. We will write more concerning blast in a future lesson.

Most basements with minimum exposure will provide a PF of 16 (four doublings) or better. If you are constructing a fallout shelter in the basement of your home, you will need 6 more doublings, as the mass of your home above will provide the extra 4 doublings required for a total PF of 1,000.

OBSERVE:
Become aware of your surroundings. A nuclear event may occur while you are away from your shelter. Areas such as caves, tunnels and high-rise buildings provide good shielding from radiation.

Contact your state comprehensive emergency office for information on targets in your area. If you are near a prime target you will not be able to survive in a basement shelter.

PREPARE:
We hope you will use the information we have provided to you to further prepare against the effects of radiation. Information becomes 'knowledge' when you put the information to use.

Don't wait until you can afford a deep, underground hardened shelter.   Start now with whatever assets you have at hand. If you live in an apartment, make friends with people in your neighborhood who have a good basement or shelter. Ask them if you can store some of your food, clothing and supplies at their home; and offer to contribute with time or finances in preparing their shelter. If you are able to reach their home in the emergency, you are a helping hand and an asset. If you don't make it to their home, they have extra food. Very few people will turn you down if they think through that scenario.

6.09 Measuring Radiation:
When dealing with exposure levels from fallout, radiation is normally measured in rads or rems. Some dosimeters and meters will measure in Roentgens. Numerically, the rad is very similar to the Roentgen.   We will be using these terms interchangeably in this discussion.

Radiation meters are used to monitor radiation exposure rates. Like the speedometer in a car, which tells how many miles per hour the car is traveling, a survey meter would tell how many roentgens per hour are being received. Dosimeters are used to measure the accumulation of radiation, just as your odometer would measure the accumulation of miles traveled in your car. Both instruments are very helpful in a radioactive environment. Good metering devices are invaluable in a nuclear environment.

Wartime rate meters must measure in rads or (roentgens) up to a level of 500 rads per hour, and wartime dosimeters must measure to a total accumulation of 200 rads (or roentgens).

Some meters and dosimeters measure only in milliroentgens (mr). A milliroentgen is 1,000th of a roentgen. These meters and dosimeters are useful in a post-war situation to monitor contamination of food and equipment. The most useful of these low-rate meters will have a 'wand' capable of reading beta contamination.

RADIATION DETECTION INSTRUMENTS

Survey Meters

Survey meters are used to monitor radiation exposure rates. Like the speedometer in your car, which tells you how fast you are going, the survey meter tells you how fast you are receiving radiation.

a. **Geiger meuler tubes**. The geiger meuler tubes are normally used for low range radiation detection. They are quite sensitive, but not very accurate. We sometimes call them geiger counters and they were widely used for hunting uranium ore. They are also used for training purposes where low radiation exposure rates will be encountered.

   On the outside of the box you often find a probe about 3/4 inch in diameter and 4 inches long connected to the box with a cord. When opened, the probe gives the meter the capability of reading beta radiation. Sometimes there is a headphone supplied with this instrument.

   Inside the box, you will find a tube. Typically this tube is about the diameter of a pencil and 3 or 4 inches long; or the size of the diameter of a dime and about 3 inches long.

   There are a number of the ANTONE 106-101 CDV-700 around that have been declared surplus by the government. They are a highly sensitive, low range instrument. They can measure gamma radiation and discriminate between beta and gamma radiations.

   They have the larger (dime size) meuler tube. They have a range (full scale deflection) of only 0 to 50 miliroentgens. Don't believe anyone who says they can be adjusted to read roentgens. The tube will saturate at 1000 milliroentgens (one roentgen). This means the reading on the scale will reach the full length of its range and stick at the far end of the scale until turned off. We then say that it has "pegged out" or "jammed". It will recover shortly after being turned off.

   To increase the range of this unit, a smaller diameter tube or a lead shield probe must be installed. This is very expensive, and the reliability is questionable. In a war time situation, we must have a reliable unit.

   By using a potengeometer, you can adjust the scale to read as much as 3 X scale (150 milliroentgens). Even this, however, is not large enough a reading for war time purposes. You could use this unit for checking food, clothing, etc. for beta contamination, but I believe your money would be better spent on a unit with a wider range capability.

   I would not recommend this unit. You need the capability to read 50 or even 500 roentgens per hour for war time purposes.

b. **Ion Chambers**. The other basic detecting instrument for a survey meter is an ion chamber. With the lid of the meter opened, the ion chamber looks like and is about the size of a can of chewing tobacco-- approx. 2 inches in diameter and 1 inch thick. An ion chamber has the capability of reading roentgens, and is the meter we want for our shelters.

This unit only reads gamma radiation, and is designed for post attack operational use. It typically has a full scale deflection of 0 to 500 roentgens. To reach these levels of detection there would probably be four multiplying scales of .1, 1, 10 and 100.

Currently, the government is using the CD V-715. There are a few of these for sale, but the government, in some cases, may claim them as stolen property. Question where this meter was obtained before buying it.

The CD V-710 is now obsolete and can be bought legally. If in doubt about any meter offered for sale call the state Comprehensive Emergency Management Office.

Always question whether the meter for sale has been hardened against EMP and if it will function in an electromagnetic field.

Dosimeters

Dosimeters come in many sizes and shapes. The dosimeters used by the government look like a short, fat yellow pen. They are designed to tell you your continual exposure. Like the odometer on your car, which tells you how many miles you have driven, the dosimeter tells you how much radiation you have accumulated.

Dosimeters measure gamma radiation.

For post attack use, don't purchase a dosimeter that has a range in milliroentgens. It would be useless to you. The dosimeters in that range are used for training purposes, only. A dosimeter in the range of from 0 to 200 Roentgens would be the most desirable in the eventuality of a nuclear attack.

Dosimeters do not need to be commercially calibrated. Purchase a charger with your dosimeter, and store extra batteries for the charger.

TABLE 6.07.1 RADIATION PENALTY TABLE

Acute Effects	Accum. Exposure 1 Week	Accum. Exposure 1 Month	Accum. Exposure 4 Months
Medical Care Not Needed	150 Roentgens	200 Roentgens	300 Roentgens
Some Need Medical Care Few if Any Deaths	250 Roentgens	350 Roentgens	500 Roentgens
Most Need Medical Care 50% + may die	450 Roentgens	600 Roentgens	600 Roentgens
Lethal Dose	600 Roentgens		

The accumulated exposure should not exceed those in the first row. If radiation levels reach 10/R/hr in the sheltered area, the doses in the first row will probably be exceeded.   In this eventuality, the shielding in the sheltered area should be increased. In a full scale attack, about 35% of our population would be expected to exceed the above doses.

EXPOSURE AT 30 MILES DOWNWIND
(500 KT surface burst, 15 mph wind)

Time	In Open	In Shelter PF 15	In Shelter PF 40
1 Week	3450 Roentgens	230 Roentgens	86 Roentgens
1 Month	4100 Roentgens	273 Roentgens	103 Roentgens
4 Months	4500 Roentgens	300 Roentgens	113 Roentgens

6.08.3 RISK AREAS

One-Week Dose Range in Rads

Protection Factor Using Shelter	High Fallout Risk Area	Med. Fallout Risk Area	Low Fallout Risk Area
PF 5	1200-3000	600-1200	600 rads or less
PF 10	600-1500	300-600	300 rads or less
PF 20	300-750	150-300	150 rads or less
PF 30	200-500	100-200	100 rads or less
PF 40	150-375	75-150	75 rads or less
PF 60	100-250	50-100	50 rads or less
PF 80	75-188	38-75	38 rads or less
PF 100	60-100	30-60	30 rads or less
PF 200	30-75	15-30	15 rads or less
PF 500	12-30	6-12	6 rads or less

**Estimate the Risk Levels in each of your surrounding counties
by potential prime and secondary targets.**

County	Risk Level	County	Risk Level

Individual Radiation Exposure Record

Name of individual _____ Local _____

Low range (m/R) dosimeter # _____ High range (R) dosimeter # _____

Name of person or agency maintaining record _____

low range (m/R)					high range (R)				
date	time (circle am or pm)	dosage (m/R)	total m/R	daily total	date	time (circle am or pm)	dosage (R)	total R	daily total
	am pm	start				am pm	start		
	am pm	final				am pm	final		
	am pm	start				am pm	start		
	am pm	final				am pm	final		
	am pm	start				am pm	start		
	am pm	final				am pm	final		
	am pm	start				am pm	start		
	am pm	final				am pm	final		
	am pm	start				am pm	start		
	am pm	final				am pm	final		
	am pm	start				am pm	start		
	am pm	final				am pm	final		
accumulated weekly dose					accumulated weekly dose				

Use the back of the form for notes and comments.

RADIATION GLOSSARY

- **Acute Doses:** Radiation Doses occurring during the first 24 hours of exposure.

- **Attenuation:** Decrease in radiation level

- **Alpha particle:** Positively charged radiation particle emitted from the nuclei of a radioactive element, consisting of 2 protons and 2 neutrons.

- **Beta particle:** Negatively charged radiation particle identical to an electron, but originating from the nucleus.

- **Chronic Doses:** Radiation doses occurring over extend lengths of time.

- **Decay:** Decrease of activity of radioactive material due to the emission of an alpha or beta particle from the nuclei.

- **Gamma Rays:** Radiation with no measurable mass accompanying alpha and beta emissions. Identical to an x-ray, but originating from the nucleus.

- **Half-Life:** The time required for the activity of a radioactive species to decrease to half of its initial value due to decay.

- **Half-Value Thickness:** The thickness of a certain material that will absorb half the gamma radiation incident upon it.

- **Protection Factor:** Ratio of measured radiation levels 3 ft, above surface to the radiation level below the surface.