CHAPTER 10
RADIOLOGICAL EFFECTS

Learning Objectives: Recall the components of an atom; the different types of nuclear bursts and their effects; and types of personnel injuries that are caused by blast, underwater shock, thermal radiation, and nuclear radiation.

As a Damage Controlman, you will be assigned to a repair party during general quarters (GQ). At GQ, you will participate in Chemical, Biological, and Radiological (CBR) countermeasure activities designed to limit the effects of a CBR attack. Therefore, for you to conduct your duties properly, you must possess knowledge of the basic facts about the types of nuclear bursts and their radiological effects. For more comprehensive and detailed information than can be provided here, you should consult the *Naval Ships' Technical Manual* (*NSTM*), chapter 070, "Nuclear Defense at Sea and Radiological Recovery of Ships After a Nuclear Weapons Explosion," and *Naval Warfare Publication* (*NWP*) 3-20-31, "Surface Ship Survivability."

COMPONENTS OF AN ATOM

Learning Objective: Recall the components of an atom.

Scientists have identified over one hundred substances composed of atoms bearing an identical number of protons in each nucleus that cannot be separated into simpler substances by ordinary chemical means. These substances are called elements, and the smallest quantity of an element is the atom.

An atom is made up of tiny particles known as electrons, protons, and neutrons. The relative number of these small particles determines the attributes of an element. The characteristics of each of these subatomic particles are as follows:

- The electron is an extremely small particle of matter that orbits the nucleus of the atom. It has a negative electrical charge.
- The proton is located in the nucleus of the atom. It is approximately 2,000 times as large as an electron and has a positive electrical charge.
- The neutron is also located in the nucleus of the atom. It is almost as large as a proton but has no electrical charge.

The structure of an atom resembles a solar system with the electrons orbiting around the protons and the neutrons clustered tightly in the center called the nucleus (fig. 10-1). Because the distance between the electrons and the nucleus is so great, the atom is mostly empty space. The number of electrons that orbit the nucleus of a normal atom is equal to the number of protons in the nucleus. Therefore, the electrical charge of the atom is balanced. The number of neutrons in a nucleus can vary from 0 to more than 150.

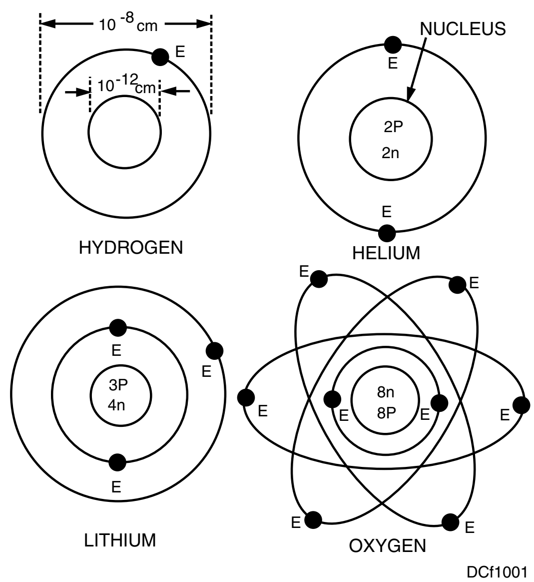

Figure 10-1. Rutherford-Bohr atomic models.

A process known as fission splits the nucleus of a heavy element into nuclei of lighter elements. In this process, an enormous amount of energy is produced. When this energy is released in a short period of time, an enormous explosion takes place. In the process known as fusion, a nuclear reaction occurs causing the nuclei of atoms to combine (fuse together) to form a more massive nuclei. This reaction results in the release of a tremendous amount of nuclear energy. An explosion resulting from a fission or fusion reaction is referred to as a nuclear burst.

REVIEW QUESTIONS

Q1. Electrons, protons, and neutrons are the three subatomic particles that make up an atom.

1. True
2. False

Q2. The electron has what type of electrical charge?

1. Active
2. Positive
3. Neutral
4. Negative

Q3. The nucleus of an atom is composed of what two particles of matter?

1. Electrons and ions
2. Photons and qualms
3. Protons and neutrons
4. Monatomic molecules and quarks

Q4. The proton has what type of an electrical charge?

1. Alternating
2. Positive
3. Neutral
4. Negative

TYPES OF NUCLEAR BURSTS

Learning Objective: Recall the different types of nuclear bursts and their characteristics.

When a nuclear device is detonated in space, in the atmosphere, or at or below the surface of the earth or ocean, many characteristic effects are produced. Some effects, such as nuclear radiations and expanding debris, are common to all of these environments, though varying in degree. Other effects, such as cratering, blast, and water shock, are particular to certain environments. Effects, such as light and heat, are visible or tangible. Others, like nuclear radiations, are not directly apparent and can only be discerned by instruments or secondary effects. Some effects occur in and last only microseconds, whereas others occur in microseconds but linger for days, months, or even years. Meteorological conditions, such as atmospheric pressure, temperature, humidity, winds, and precipitation, can affect some of the observed phenomena. All nuclear detonations, however, produce effects that can damage equipment and injure personnel.

A general explanation of the militarily significant effects of nuclear weapons is as follows:

The energy yield of a nuclear weapon is described in terms of the amount of TNT that would be required to release a similar amount of energy. Thus a nuclear weapon capable of releasing an amount of energy equal to the energy released by 20,000 tons of TNT is said to be a 20-kiloton (KT) weapon. A nuclear weapon capable of releasing an amount of energy equal to the energy released by 1 million tons of TNT is said to be a 1-megaton (MT) weapon.

The yield of a nuclear weapon may be a fraction of a kiloton or up to several megatons. Although the total yield of the weapon is not significantly influenced by the environment about the burst point, the relative effect of the weapon depends significantly on the location of the detonation. Therefore, nuclear detonations are classified according to their location as one of the following:

- Airburst
- High-altitude burst
- Surface burst
- Underwater burst
- Underground burst

NOTE

Underwater and underground bursts are often referred to as subsurface bursts.

AIRBURST

An airburst (fig. 10-2) is a burst where the point of detonation is below an altitude of 100,000 feet, and the fireball does not touch the surface of the earth. Air blast, thermal radiation (heat and light), electromagnetic pulse, and initial nuclear radiation (neutron and gamma rays) are produced around the point of detonation. There will be no significant residual nuclear radiation (gamma and beta radiation) from the resulting radioactive material unless rain or snow falls through the radioactive cloud.

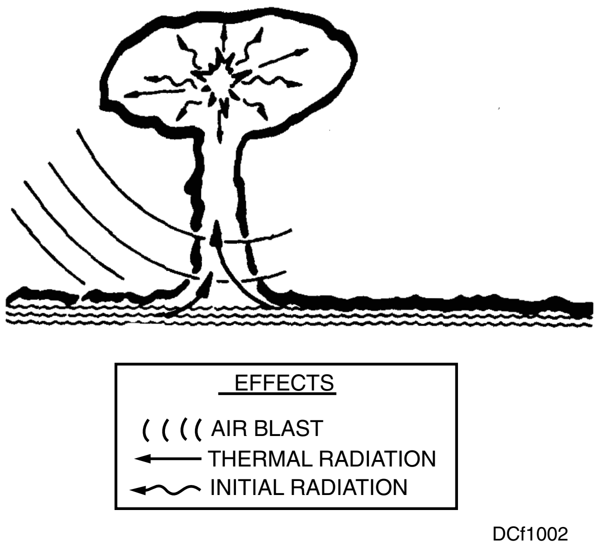

Figure 10-2. Airburst.

The energy released from a nuclear detonation below an altitude of approximately 100,000 feet may be divided into three broad categories. Approximately 50 percent of the energy produces blast and shock, about 35 percent produces thermal radiation, and about 15 percent produces nuclear radiation. Of the nuclear radiation, about 10 percent is referred to as "residual nuclear radiation" and the other 5 percent as "initial nuclear radiation." Initial radiation is delivered simultaneously with the detonation and cannot be avoided by maneuvering or evasive actions. The initial radiation dose received will occur within 1 minute after the explosion, and most of it will occur within a matter of seconds. Residual radiation, on the other hand, may be emitted over a long period of time, extending to days and years. Therefore, maneuvering out of an area contaminated by residual radiation may be an effective countermeasure.

HIGH-ALTITUDE BURST

A high-altitude burst is an airburst where the point of detonation is above 100,000 feet. The high-altitude burst produces air blast, thermal radiation, electromagnetic pulse, initial nuclear radiation, and atmospheric ionization. At such high altitudes, the proportion of energy appearing as blast decreases considerably, and at the same time, the proportion of radiation energy increases. Because of the low density of the atmosphere above 100,000 feet, the range of the initial nuclear radiation increases. In contrast to explosions below 50,000 feet, the attendant atmospheric ionization from a burst above 100,000 feet will last from minutes to hours. The important effects of high-altitude bursts cause damage to weapons systems or satellites operating in the upper atmosphere or in space. There will also be interference with electromagnetic waves from communications or radar systems that pass through or near the region of the burst.

SURFACE BURST

A surface burst (fig. 10-3) is a burst where the point of detonation is on, or above, the surface of the earth and the fireball touches the surface of the earth. The surface burst produces air blast, thermal radiation, and electromagnetic pulse. It produces initial nuclear radiation around surface zero (SZ) and residual (transit and deposit) nuclear radiations around SZ and downwind from SZ. Transit radiation is airborne radioactive material from a base surge and/or fallout. Deposit radiation is radioactive material from a base surge and/or fallout that settles on exposed surfaces. Surface bursts over water will also produce underwater shock and surface water waves, but these effects will be of less importance except to submarines. Over land, earth shock will be produced but will not be an important effect at any significant distance from the point of detonation.

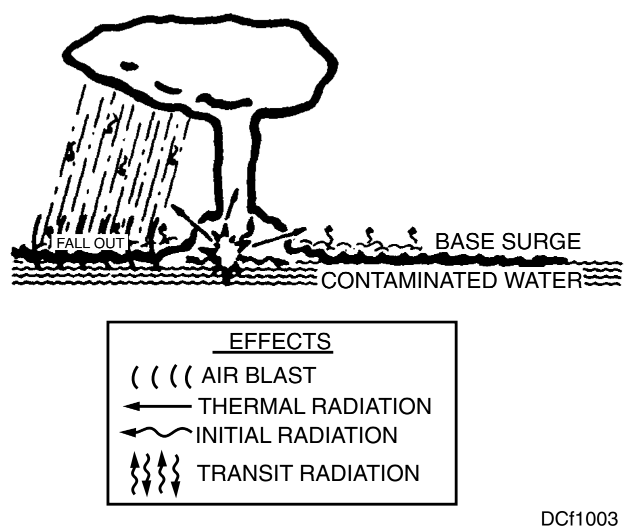

Figure 10-3. Surface burst.

UNDERWATER BURST

An underwater burst (fig. 10-4) is a burst where the point of detonation is below the surface of the water. An underwater burst produces underwater shock and a water plume which then causes a base surge. Bursts with very shallow points of detonation can also produce air blast, initial nuclear radiation, fallout, and possibly some thermal radiation. These effects will be reduced in magnitude from those of a water surface burst and will become rapidly insignificant as the depth of the point of detonation is increased. The range of damage due to shock is increased as the depth of the point of detonation is increased. For a given weapon yield, greater hull and machinery damage will be produced by shock from an underwater burst than by air blast from an airburst or a surface burst. The reverse is true for topside equipment, such as antennas and missile launchers.

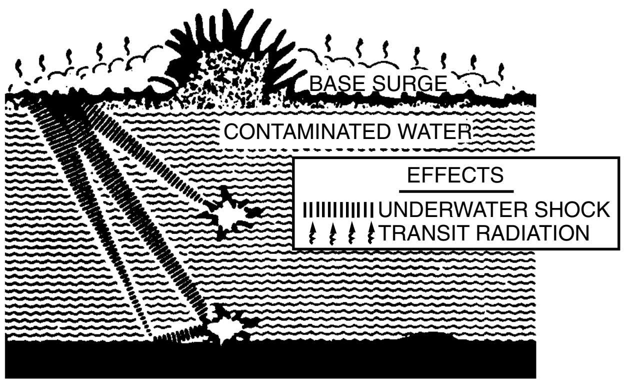

Figure 10-4. Underwater burst.

When a high-yield weapon is detonated in deep water (fig. 10-5) adjacent to a continental shelf, large breaking waves can be generated by the upsurge along the shelf slope. These waves will appear on the shallow-water side of the shelf edge. They are characterized by a long period with a sharp, possibly breaking, crest. They dissipate in amplitude as they progress toward the shore. Calculations and simulation experiments were conducted with the continental shelf off the east coast of the United States. They indicate that in the near vicinity of the shelf edge (shallow-water side only), these waves may be large enough to damage the largest combatant ships and to swamp or capsize smaller ships.

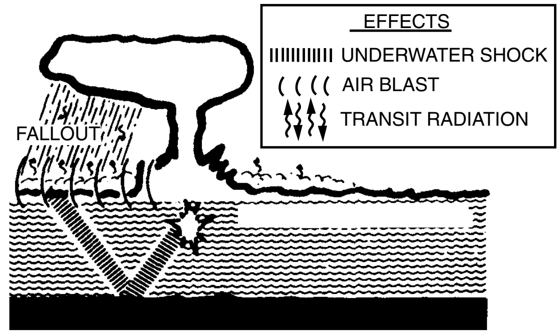

Figure 10-5. Deep underwater burst.

UNDERGROUND BURST

An underground burst (fig. 10-6) is a burst where the point of detonation is below the surface of the ground. An underground burst produces a severe earth shock, especially near the point of detonation. Thermal radiation, air blast, initial nuclear radiation, and fallout will be negligible or absent if the burst is confined below the surface of the earth. For shallow underground bursts, the air blast, thermal radiation, and initial nuclear radiation will be less than for a ground surface burst. Ground shock will cause damage within about three crater radii but little beyond. Early fallout can be significant, and at distances near the explosion base surge (evidenced by a dust cloud) will be an important hazard.

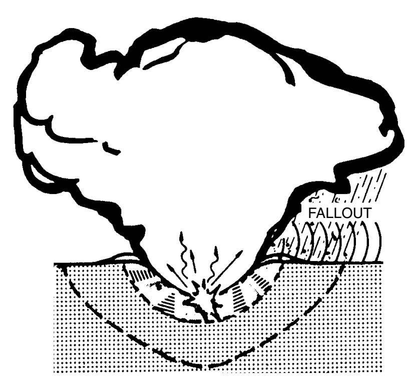

Figure 10-6. Underground burst.

REVIEW QUESTIONS

Q5. An airburst is a nuclear burst where the point of detonation is below what altitude?

1. 50,000 feet
2. 62,00 feet
3. 80,000 feet
4. 100,000 feet

Q6. A surface nuclear burst is a burst where the point of detonation is on or above the surface of the earth and the fireball touches the surface of the earth.

1. True
2. False

Q7. An underwater nuclear burst produces underwater shock and a water plume that then causes a base surge.

1. True
2. False

EFFECTS OF NUCLEAR WEAPON BURSTS

Learning Objective: Recall the different types of effects resulting from nuclear bursts.

Specific effects of nuclear detonations depend on the type of nuclear weapon and the type of burst. Also, the effects are influenced considerably by the environment in which the weapon is detonated. A description of the effects of nuclear bursts and the modification of these effects that can be caused by the environment are provided in the following paragraphs.

AIR BLAST

Air blast is the shock wave that is produced in the air by an explosion. The shock wave initially travels outward at a velocity of approximately seven times the speed of sound at high overpressures. It will then gradually slow down to a sonic speed of about 1,000 fps at low overpressures.

An air blast produces a rapid increase in the normal atmospheric (static) pressure and creates high wind (dynamic) overpressures. The high static overpressures produced cause damage by squeezing and crushing targets. The dynamic overpressures cause damage by bending or dragging targets. Ship structures and buildings are primarily vulnerable to static overpressures, whereas aircraft, masts, antennas, and exposed personnel are vulnerable to dynamic overpressures.

UNDERWATER SHOCK

Underwater shock is the shock wave that is produced in the water by an explosion. The shock wave initially travels several times the speed of sound in the water but quickly slows down to a hypersonic speed of approximately 5,000 fps. Underwater shock produces rapid accelerations that can disarrange equipment and machinery, rupture hulls, and/or injure personnel. Both the directly transmitted shock wave and the shock wave reflected from the sea bottom can be damaging. An underwater explosion produces a shock wave similar to that of an airburst. However, underwater shock damage is measured by the peak vertical velocity (for surface ships) and by the peak translational velocity (for submerged submarines), rather than by the water overpressures produced by the shock front. Figure 10-7 shows the direct and reflected shock waves.

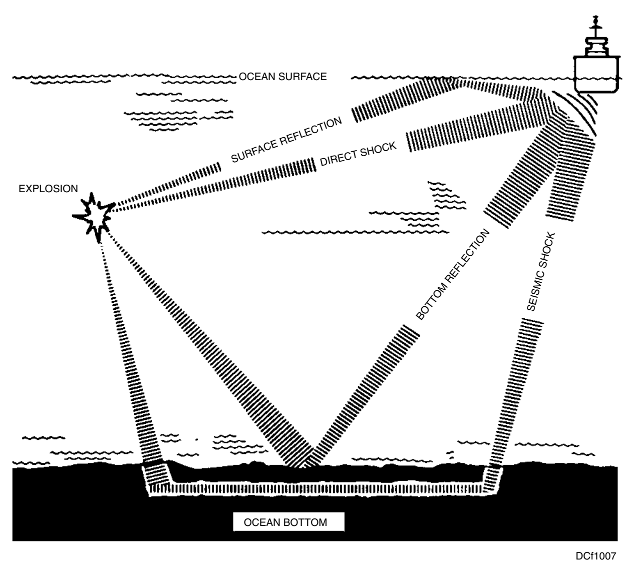

Figure 10-7. Direct and reflected shock waves for an underwater burst.

Four factors determine whether the greater damage will be caused by the direct wave or the reflected wave:

1. Distance from burst

2. Depth of burst
3. Depth of water
4. Bottom configuration and structure

When the point of detonation is above the bottom, the shock wave reflected from the bottom can produce more severe damage to weapon-delivery equipment at a given range than the direct shock wave. Even though the peak pressure of the reflected wave is less than that of the direct wave, the reflected wave will disperse in a more nearly vertical direction. It is, therefore, more effective in producing the vertical motions that control the degree of damage.

The time separation between direct and reflected shock waves decreases as the point of detonation approaches the bottom. When the point of detonation is directly on the bottom, the two waves overlap. For such a burst, the water depth has a direct effect on the range at which the weapon-delivery capability of surface ships will be impaired. However, the water depth has no significant effect on the ranges at which their mobility and seaworthiness will be impaired. Where the sea bottom is sloped, a ship downslope from the point of detonation will tend to receive less damage than a ship an equal distance upslope from the point of detonation. Where the sea bottom is essentially flat, the strength of a reflected wave will depend on the bottom structure. It will be less for mud than for sand, but greater for rock than for sand.

THERMAL RADIATION

Thermal radiation is the radiant energy (heat and light) that is emitted by the fireball. Thermal radiation travels at the speed of light and persists as long as the fireball is luminous. The duration of thermal radiation emission depends on weapon yield. It will last less than 1 second for a weapon yield of l KT and approximately 8 or 9 seconds for a weapon yield of l MT. Thermal radiation is effectively shielded by anything that will cast a shadow (opaque materials). Thermal radiation can incapacitate exposed personnel by causing skin burns, flash blindness, or retinal burns.

Over land, thermal radiation will ignite fires in buildings, vehicles, dry vegetation, and other combustible materials.

Thermal radiation is modified by the height of the point of detonation, weapon yield, atmospheric conditions, cloud cover, and terrain features. As the height of the point of detonation is increased, the area of the surface of the earth exposed to the thermal radiation increases because line-of-sight area increases, and there are fewer shadows from such things as existing structures, vegetation, and terrain features.

As the weapon yield is increased, the range at which thermal radiation can cause skin burns and eye injuries to exposed personnel increases. It will extend well beyond the range at which blast and initial nuclear radiation are of significance. The emission rate of thermal radiation from a high-yield weapon is slower than that from a low-yield weapon. Thus the high-yield weapon must deliver more thermal energy to do an equivalent amount of damage because a target has more time to dissipate the heat being received.

The ability of the atmosphere to lessen the effect of thermal radiation depends on such factors as absorption by water vapor, carbon dioxide, ozone, and impurities in the air. On days when fog, haze, and clouds are between the point of detonation and the target, thermal radiation will be decreased. On the other hand, when fog, haze, and clouds are above the burst and the target, a significant amount of thermal radiation will reflect downward and increase the severity of burns received at a given location. Such conditions can also increase the number of personnel who are flash-blinded or dazzled by a burst. The terrain surface cover, such as snow, can also reflect significant thermal radiation. This adds to both the range and severity of the thermal effect.

NUCLEAR RADIATION

The four types of nuclear radiation released as the result of a nuclear explosion are alpha particles, beta particles, gamma rays, and neutrons.

Alpha particles travel only a few centimeters in air before they are stopped. They cannot penetrate even a thin sheet of paper.

Beta particles can travel several feet in air, but they cannot penetrate a sheet of aluminum that is more than a few millimeters in thickness. Beta particles cannot penetrate the normal combat uniform.

Gamma rays are a form of electromagnetic radiation, indistinguishable from X rays.

Neutrons are electrically neutral particles. Both gamma rays and neutrons can travel great distances in air. Gamma rays and neutrons have greater penetrating power than the other forms of nuclear radiation. Their injurious effects on personnel are also quite similar.

Nuclear radiation does not affect most materials in any visible manner. Thus ships, vehicles, electronic equipment (except transistors), and other equipment are not damaged by radiation. However, radioactive contamination does pose a danger to operating personnel. The term *contamination* is used to mean radioactive material that has been deposited where it is not wanted. All radioactive contamination presents a hazard to personnel.

ATMOSPHERIC IONIZATION

Atmospheric ionization is an increase in the density of electrons in the atmosphere around a nuclear burst. These electrons affect radio and radar signals by removing energy from the waves. This decreases the strength of the signals and refracts the wave front, thereby changing the direction of transmission. For detonations below 100,000 feet, this effect disappears in a matter of seconds. At higher altitudes the effect can last up to several hours. The effect can be of considerable importance where communications are over a long range and where radar targets are in or above the ionized layer.

ELECTROMAGNETIC PULSE

An electromagnetic pulse (EMP) will be produced by high-altitude bursts, airbursts, and surface bursts. The initial nuclear ionizing radiation ionizes the atmosphere around the point of detonation. This action produces an EMP, which will contain frequency components in the range from a few to several hundred kilocycles per second. The EMP has magnetic and electric field components that exist for only a fraction of a second. The magnetic field component is significant inside the radius of the ionized atmosphere. It can induce large currents in cables and long-lead wires. These large transient currents can burn out electronic and electrical equipment. The electric field component can also produce transient signal overloads and spurious signals on communication nets and in computer-driven systems. At ranges where ships suffer minor damage from other weapon effects, the major effect of the EMP is expected to be the tripping of circuit breakers and blowing of fuses in protective circuitry. At closer ranges, there is a high probability of permanent damage to the electronic and electrical equipment.

INITIAL NUCLEAR RADIATION

Initial nuclear radiation is defined as the radiation (essentially neutrons and gamma rays) that is emitted by the fireball and the cloud during the first minute after detonation. All significant neutron radiation is emitted in less than 0.1 second and gamma radiation up to 20 or 30 seconds, depending on weapon yield. The l-minute limit is set, somewhat arbitrarily, as the maximum time for the nuclear cloud to rise beyond the range in air at which gamma radiation is a significant hazard. Generally, initial nuclear radiation might not produce significant material damages, but it will incapacitate personnel.

Transient radiation effects on electronics (TREE) is caused by initial gamma and neutron emissions from a nuclear burst. These emissions result in the failure or degraded operation of sophisticated solid-state circuits. Computers and other equipment having solid-state computers are particularly sensitive to TREE and also equipment with semiconductors. Some effects are temporary but some are also permanent.

FALLOUT

Fallout is a major effect of a surface, shallow underground, or underwater burst. It is the radioactive material that falls from the nuclear cloud and is deposited on exposed surfaces. The fallout consists primarily of fission products (gamma and beta emitters) mixed with material that was vaporized by the fireball and drawn up into the nuclear cloud. Fallout, whether airborne or deposited, is a major hazard because it emits gamma radiation. This radiation can penetrate ship structures, buildings, and aircraft, to name a few. It can also reach personnel, causing radiation injury, incapacitation, and even death. Deposited fallout also presents a contamination hazard to personnel. The militarily significant fallout, often called early fallout, is usually deposited in less than 24 hours in an area downwind of SZ.

The wind directions up to the top of the cloud determine the area contaminated by fallout. In a complete calm, the fallout pattern is roughly circular. A constant wind direction causes an elongation of the pattern. Complicated wind patterns (wind shear), as well as variations in wind speed and direction, cause complicated ground patterns. The fallout pattern is difficult to predict accurately except under calm and very stable wind conditions.

An airburst or a smaller weapon will reduce fallout. Also, the complete containment of an underground burst will eliminate fallout.

Fallout landing on water will sink and will not be a hazard to ships that pass through the area after the fallout has stopped coming down. Fallout over a land area will remain on the surface and will be a hazard to personnel living in or passing through the area. Eventually all fallout will decay to a militarily insignificant level.

BASE SURGE

Base surge from an underwater burst is a rapidly expanding cloud or mist of water droplets. This cloud is produced by the collapse of the water column that was thrown up by the underwater detonation. After the early, rapid expansion of the visible base surge (2 to 4 minutes), the base surge moves downwind at the speed of the surface wind. The base surge will become invisible in less than one-half hour. The radioactivity initially will occupy about the same volume as the visible base surge. However, as the water droplets evaporate, the radioactive particles and gases will remain in the air and continue to disperse as an invisible radioactive base surge. For approximately 30 minutes after the burst, the base surge is highly contaminated with fission products and is a source of intense transit radiation.

Airborne fallout and base surge contamination can enter a ship or shore installation through the ventilation and combustion-air systems. This could present a radiological hazard. In some instances, hazardous amounts of contamination could concentrate in ventilation ducts, boiler air passages, and interior spaces. High concentrations of radioactive material in these trunks may produce a gamma-radiation hazard to personnel working nearby. Radioactive material deposited in interior spaces may also present radiation hazard to personnel coming into contact with beta particles, even though there may be only a minor penetrating gamma-radiation hazard. For aircraft in flight, the entry of airborne radioactive materials will not be a hazard during the flight but may represent a hazard to maintenance personnel later.

RADIOACTIVE WATER POOL

A surface or underwater nuclear detonation creates a radioactive water pool in the area of the detonation. This pool expands outward rapidly from SZ, for about 2 minutes, and continues to expand more slowly. At 30 minutes, dispersion of the pool and radioactive decay will have reduced the hazard to one of tactical insignificance. During the early expansion phase of this pool, a dose rate of several thousand rad/hr may exist at the water surface.

REVIEW QUESTIONS

Q8. Four basic types of nuclear radiation are given off during a nuclear explosion: alpha particles, beta particles, gamma rays, and neutrons.

1. True
2. False

Q9. Which of the following factors is not considered in determining if greater damage to a ship will be caused by the direct wave or the reflected wave from an underwater nuclear burst?

1. Distance from burst
2. Depth of burst
3. Depth of water
4. Height of wave action at time of burst

Q10. Initial nuclear radiation is defined as the radiation that is emitted by the fireball and the cloud during the first minute after detonation.

1. True
2. False

Q11. A nuclear burst can produce an atomic magnified pulse (AMP) that contains frequency components in the range from a few to several hundred kilocycles per second.

1. True
2. False

PERSONNEL INJURIES

Learning Objective: Recall the different types of personnel injuries that are caused by blast, underwater shock, thermal radiation, and nuclear radiation.

Injuries to personnel can be caused by the blast, by underwater shock, by thermal radiation, and by the nuclear radiation produced by a nuclear burst.

BIOLOGICAL EFFECTS OF NUCLEAR RADIATION

A person receiving a serious injury as a result of a nuclear burst and is man a battle station is described as combat ineffective (CI). The potential for a given nuclear weapon to produce fatalities is fairly well known; however, the potential for CIs is not well known. We have no satisfactory method for estimating the extent to which total injuries relate to the number of CIs. Therefore, for each weapon effect capable of injuring an individual, the noninjury and fatal levels are stated. Only the estimates of the degree of injury are stated for the levels between these injury categories. Table 10-1 outlines the biological effects associated with a variety of dose ranges for both acute (less than 24 hours) and protracted (over 24 hours) doses.

AIR BLAST INJURY

Bodily displacement is the dominant cause of air blast casualties for personnel in the open. Personnel can be picked up and thrown by the blast. They receive their injuries upon landing. The extent of the injuries will depend upon the velocity of the body's movement,

Table 10-1. Biological Effects of Nuclear Radiation

Dose Range (rads)	Onset and Duration of Initial Symptoms	Performance (Mid–Range Dose)	Medical Care and Disposition
0 to 70	From 6 to 12 hours: none to slight incidence of transient headache and nausea; vomiting in up to 5 percent of personnel in upper part of dose range.	Combat–effective.	No medical care; return to duty.
70 to 150	From 2 to 20 hours: transient mild nausea and vomiting in 5 to 30 percent of personnel.	Combat–effective.	No medical care; return to duty; no deaths anticipated.
150 to 300	From 2 hours to 2 days: transient mild to moderate nausea and vomiting in 20 to 70 percent, mild to moderate fatigability and weakness in 25 to 60 percent of personnel.	DT: PD from 4 hours until recovery. UT: PD from 6 to 19 hours. PD from 6 weeks until recovery.	At 3 to 5 weeks: medical care for 10 to 50 percent. At low end of range less than 5 percent deaths; at high end, death may occur for more than 50 percent; survivors return to duty.
300 to 530	From 2 hours to 3 days: transient moderate nausea and vomiting in 50 to 90 percent; moderate fatigability in 50 to 90 percent of personnel.	DT: PD from 3 hours until death or recovery. UT: PD from 4 to 40 hours and from 2 weeks until death or recovery	At 2 to 5 weeks: medical care for 10 to 80 percent. At low end of range less than 10 percent deaths; at high end, death may occur for more than 50 percent; survivors return to duty.
530 to 830	From 2 hours to 2 days: moderate to severe nausea and vomiting in 80 to 100 percent of personnel. From 2 hours to 6 weeks: moderate to severe fatigability and weakness in 90 to 100 percent of personnel.	DT: PD from 2 hours to 3 weeks; CI from 3 weeks until death. UT: PD from 2 hours to 2 days and from 7 days to 4 weeks; CI from 4 weeks until death.	At 10 days to 5 weeks: medical care for 50 to 100 percent. At low end of range, death may occur for more than 50 percent at 6 weeks; at high end, death may occur for 99 percent at 3 1/2 weeks.
830 to 3,000	From 30 minutes to 2 days: severe nausea, vomiting, fatigability, weakness, dizziness and disorientation; moderate to severe fluid imbalance and headache.	DT: PD from 45 minutes to 3 hours; CI from 3 hours until death. UT: PD from 1 to 7 hours; CI from 7 hours to 1 day; PD from 1 to 4 days; CI until death.	1000 rads: at 4 to 6 days, medical care for 100 percent; 100 percent deaths at 2 to 3 weeks. 3000 rads: at 3 to 4 days, medical care for 100 percent; 100 percent deaths at 5 to 10 days.
3,000 to 8,000	From 30 minutes to 5 days: severe nausea, vomiting, fatigability, weakness, dizziness, disorientation, fluid imbalance, and headache.	DT and UT: CI from 3 to 30 minutes. PD from 30 to 90 minutes; CI from 90 minutes until death.	4500 rads: at 6 hours to 1 to 2 days, medical care for 100 percent; 100 percent deaths at 2 to 3 days.
Greater than 8,000	From 30 minutes to 1 day: severe and prolonged nausea, vomiting, fatigability, weakness, dizziness, disorientation, fluid imbalance, and headache.	DT and UT: CI from 3 minutes until death.	8000 rads: medical care needed immediately to 1 day; 100 percent deaths at 1 day.
LEGEND:	CI – combat–ineffective (less than 25 percent performance) PD – performance–degraded (25 to 75 percent performance)		DT – demanding task UT – undemanding task
WARNINGS:	1. This data is based on accumulated whole body acute exposure to neutron and gamma radiation over a 24 hour period. The skin dose from beta radiation on unprotected skin is not included. 2. This information is provided for planning. It shall not be used for the management of health care for individual patients.		

the nature of the object with which the body collides, and the nature of impact, whether glancing or solid.

Primary blast effects are associated with injuries from static overpressure. Eardrums can rupture at about 5 pounds per square inch (psi), lung injuries occur at approximately 15 psi, and fatalities begin at 30 psi. Personnel standing in the open will be picked up and thrown by gust winds at overpressures of approximately 6 psi. Personnel prone in the open will be picked up and thrown at overpressures of approximately 12 psi.

UNDERWATER SHOCK INJURY

Underwater shock produces injury among topside and below-deck personnel by the rapid upward movement of the deck. Table 10-2 shows the estimated peak vertical velocity, in feet per second, which will produce certain injuries from underwater shock. It should be noted that the peak vertical velocities are the same as those required to produce damage to the ship.

Table 10-2. Combat Ineffectives from Underwater Shock

EFFECT	PEAK VERTICAL VELOCITY feet/second
Broken ankles or heel bones	10
Seated or supine man, collision with adjacent objects	15
Standing man, skull injuries	20

THERMAL RADIATION INJURY

Thermal radiation can cause burn injuries directly when the skin absorbs radiant energy. It can also cause burn injuries indirectly as a result of fires started by the radiation. The flash of thermal radiation from the fireball produces direct burns, called flash burns. The indirect, or secondary, burns are called flame burns. These burns are like the skin burns that are caused by any large fire, no matter what its origin.

Because thermal radiation can burn the retina of the eye, it can cause permanent eye damage to personnel looking directly at the burst. For example, a 1-MT burst 25 miles high could produce retinal burns out to the horizon on clear nights. A more frequent occurrence is the temporary loss of visual acuity (flash blindness or dazzle). This is caused by exposure to the extreme brightness of a nuclear burst, particularly at night, when the eyes have adapted to the dark. This may happen regardless of the direction you are facing. Flash blindness or dazzle occurs at ranges beyond those for retinal burns. Little data on the ranges at which flash blindness will occur is available.

NUCLEAR RADIATION INJURY

Radiological hazards described in this section are those that might be of significance for the military effectiveness of naval personnel in combat operations. Injuries to personnel can be caused by exposure to initial or residual radiation or a combination of the two. Unlike injuries from other weapon effects, nuclear ionizing radiation injuries may not become evident immediately unless a high enough dose is received. Nuclear radiation, even in very small doses, has some harmful effects on the body. It should be avoided whenever possible without interfering with military operations.

FACTORS INFLUENCING RADIATION INJURIES.—An injury to an individual who has received nuclear radiation will depend on many factors. Some of these factors are as follows:

- Radiation dose received
- Partial or whole-body exposure
- Period over which the dose is received
- Variations in the body's resistance to radiation injury, including those due to physical condition, sex, and age
- Previous radiation exposure
- Presence or absence of other injuries
- Periods of recuperation between periods of radiological exposure

The time required for a previously unexposed individual in good health to get sick or die after exposure will vary. It depends primarily on the total dose received, the period of time over which it was received, and variations in individual physical makeup. Some individuals have greater resistance to radiation injury than others have, and some may have had partial body shielding when exposed. For those personnel, a larger dose is required to produce a given biological effect. Individuals previously exposed may require less radiation to make them combat ineffective than those who were not previously exposed. The human body can repair some of the radiation injury but not all of it.

Generally, a given dose received in a short period of time will be more harmful than the same dose received over a longer period of time. For practical purposes, the types of radiation exposures are as follows:

- Acute. Those in which doses are received in a short time, normally less than 24 hours, as a result of exposure to initial radiation, base surge, or fallout, or combinations thereof.

- Protracted. Those in which doses are received over a longer period of time, normally greater than 24 hours, as a result of exposure to fallout.

CHARACTERISTICS OF RADIATION SICKNESS.—Radiation sickness is the complex of symptoms characterizing an excessive exposure of the entire body or a large part of it to nuclear radiation. The onset of radiation sickness depends primarily on the dose received. Early symptoms are nausea, vomiting, and diarrhea, which may be followed by hemorrhage, inflammation of the mouth and throat, and general loss of energy. At lower dose levels that will cause sickness, several hours might elapse before the severity of the symptoms will make anyone a CI. After the initial period of sickness, a variable latent period is likely during which the individual shows few outward symptoms other than a general lack of well being. During this middle period, personnel should be able to perform most light tasks. After a week or so, the second and more serious phase of their sickness occurs and lasts several weeks until the person either recovers or dies. As dose levels increase, the pace of illness quickens—the onset occurs sooner and the latent period becomes shorter. Also, the probability of death increases, and the time between exposure and death shortens.

REVIEW QUESTIONS

Q12. Burn injuries to personnel can result when their skin directly absorbs radiant energy from thermal radiation.

1. True
2. False

Q13. What type of nuclear blast causes bodily displacement casualties for personnel caught in the open?

1. Undewater
2. Airblast
3. Underground
4. Stratospheric

Q14. Underwater shock produces injury among topside and below-deck personnel by the rapid upward movement of the deck.

1. True
2. False

SUMMARY

In this chapter you have been introduced to nuclear bursts and their effects. Your knowledge of these effects and bursts will better prepare you to train personnel to protect themselves from the effects of nuclear bursts. In the following chapter you will be introduced to personnel defense, shipboard defense, and recovery.

REVIEW ANSWERS

A1. Electrons, protons, and neutrons are the three subatomic particles that make up an atom. **(1) True**

A2. The electron has what type of electrical charge? **(4) Negative**

A3. The nucleus of an atom is composed of what two particles of matter? **(3) Neutrons and protons**

A4. The proton has what type of an electrical charge? **(2) Positive**

A5. An airburst is a nuclear burst where the point of detonation is below what altitude? **(4) 100,000 feet**

A6. A nuclear surface burst is a burst where the point of detonation is on or above the surface of the earth and the fireball touches the surface of the earth. **(1) True**

A7. An underwater burst produces underwater shock and a water plume that then causes a base surge. **(1) True**

A8. Four basic types of nuclear radiation are given off during a nuclear explosion: alpha particles, beta particles, gamma rays, and neutrons. **(1) True**

A9. Which of the following factors is not considered in determining if greater damage to a ship will be caused by the direct wave or the reflected wave from an underwater nuclear burst? **(4) Height of wave action at time of burst**

A10. "Initial nuclear radiation" is defined as the radiation that is emitted by the fireball and the cloud during the first minute after detonation. **(1) True**

A11. A nuclear burst can produce an MMP that contains frequency components in the range from a few to several hundred kilocycles per second. **(2) False. A nuclear burst produces an electromagnetic pulse (EMP) that contains frequency components in the range from a few to several hundred kilocycles per second**

A12. Thermal radiation can cause burn injuries when the skin directly absorbs radiant energy. **(1) True**

A13. What type of blast causes bodily displacement casualties for personnel in the open? **(2) Airblast**

A14. Underwater shock produces injury among topside and below-deck personnel by the rapid upward movement of the deck. **(1) True**