HANDBOOK
FOR
RADIOLOGICAL DEFENSE EDUCATION

PREPARED FOR INTERIM USE

FOR USE IN SCHOOLS THAT RECEIVED KITS OF
NUCLEAR RADIATION DETECTION INSTRUMENTS

OFFICE OF CIVIL AND DEFENSE MOBILIZATION

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Introduction

Recently a kit of radiological detection instruments was made available to your school by the Office of Civil and Defense Mobilization. These instruments were provided to assist high school science teachers in their nuclear energy and radiological detection instructional programs. Further, this nationwide distribution will enhance local civil defense radiological monitoring capabilities.

These suggested interim instructional materials are furnished to assist teachers further in developing student concepts and understandings in the field of nuclear science and radiological defense. The impossibility of tailoring such materials to the needs of all teachers is clearly recognized. An attempt has been made, however, to present the topics in a logical and usable form. They should be easily adaptable to the techniques and procedures of individual instructors.

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Special Reference Materials Appendix

LESSON PLAN NO. 1

UNIT: Atomic Energy - Knowledge for Action

LESSON TITLE: Atomic Energy and Nuclear Weapons

TEACHING MATERIALS:

Blackboard and Chalk

REFERENCES:

TB 11-22 Radiation Physics and Bomb Phenomenology
TB 8-1 Blast Damage from Nuclear Weapons of Larger Sizes

OBJECTIVES:

To develop an understanding of:

1. The nature of atomic energy
2. Nuclear weapons and their destructive effects
3. Nuclear radiation

MAIN TOPICS — TEACHING POINTS

A. The Nature of Atomic Energy

1. What is atomic energy?
    a. Atomic energy, or more correctly called nuclear energy, is a form of energy released during the rearrangement of the protons and neutrons in atomic nuclei to form nuclei of new atoms.
2. How is matter subdivided?
    a. There are 102 chemical elements known today which are the basic building blocks of nature.
    b. All matter is composed of mixtures and compounds of these various elements which unite chemically.

c. Compounds are of homogenous nature (Na Cl) and cannot be physically separated, while mixtures (iron filings and sawdust) can.

d. Compounds are made up of molecules which are composed of atoms of various elements in fixed and definite proportions.

  (1) The molecule is the smallest subdivision of a compound that can exist and retain the properties of the compound.

e. Molecules are composed of two or more atoms.

  (1) The atom is the smallest unit of matter that retains the properties of an element or can enter into a chemical reaction.

f. An atom is composed of a heavy positively charged nucleus surrounded by a light negatively charged cloud of electrons (orbital electrons). (Fig. 1 TB-11-22).

g. The atomic nucleus contains combinations of protons (positively charged particles) and neutrons (particles with no electrical charge).

h. To be electrically neutral, an atom must contain the same number of electrons in its orbits as protons in the nucleus.

i. The removal of an electron from its orbit produces an ion pair:

  (1) The free electron is the negative ion.

  (2) The remaining portion of the atom is the positive ion.

MAIN TOPICS	TEACHING POINTS

j. Isotopes of an element are forms of the same element containing an equal number of protons but a different number of neutrons.

   (1) Difference in weight.
   (2) Identical chemical properties.

3. What are radioactivity and nuclear radiation?

   a. Nuclear reactions are the rearrangement of protons and neutrons of the nucleus resulting in nuclear changes such as the transmutation of one element into another.

   b. Radioactivity is the spontaneous emission of nuclear particles or rays and is a behavior characteristic of energy changes in the nuclear structure.

   c. Radiation is the conveyance of this emitted energy through space.

   d. A few naturally occurring elements are radioactive and release their excess energy as nuclear radiation.

   e. Many elements can be made radioactive by bombardment with other atomic particles.

   f. The three major forms of nuclear radiation are:

      (1) Alpha particles.
      (2) Beta particles.
      (3) Gamma rays.

4. How is nuclear energy released?

   a. There are two processes by which large amounts of nuclear energy may be released:

(1) Nuclear fission
(2) Nuclear fusion.

b. In both processes the protons and neutrons of atoms rearrange to form nuclei of new atoms.

c. Nuclear fission occurs when the neutron bombardment of a heavy element, such as uranium, results in a reaction in which the nucleus splits into smaller nuclei with the release of a relatively large amount of energy.

d. Fission is accompanied by the release of neutrons. The neutrons in turn may be captured by other fissionable nuclei and cause successive fissioning, sometimes called a chain reaction. This chain reaction makes possible the nuclear reactor and the atomic bomb. (Fig. 5, TB 11-22).

e. The nuclear fusion process, in contrast to the breaking up of a heavy nucleus as is done in fission, combines two nuclei of light elements into a heavier one. The fusion process is the source of solar energy and requires temperatures of millions of degrees.

B. Nuclear Weapons

1. What do we mean by nuclear weapons?

a. The atomic, or nuclear, bomb.

(1) The fissioning of uranium (or plutonium) in an atomic bomb liberates a large amount of energy in a very small period of time.

(2) The energy released from the explosion of the atomic bomb produces the same three effects as an explosion of TNT; light, heat, and blast. In addition, the emission of nuclear radiation occurs.

b. The thermonuclear bomb (H-Bomb).

(1) The thermonuclear bomb, more commonly known as the H-bomb or hydrogen bomb, is a fusion device. The term "hydrogen bomb" has been used because one possibility for the bomb is based on the fusion of isotopes of hydrogen.

(2) Because the fission bomb (A-bomb) produces the high temperature needed for the fusion process, it may serve as a trigger for the fusion device (H-bomb).

C. Energy Yield of Nuclear Weapons

1. How much energy is available from the atom?

a. Energy yield of nuclear fission.

(1) The complete fission of 1 pound of uranium or plutonium can produce as much energy as the explosion of 9,000 tons of TNT.

b. Energy yield of nuclear fusion.

(1) The fusion of all the nuclei present in one pound of the hydrogen isotope deuterium would release roughly the same amount of energy as the explosion of 26,000 tons of TNT.

(2) With the fusion weapon there seems to be no limit to the yield that could be developed except that the weapons now available are capable of destroying most any target assigned.

D. The Physical Effects of Nuclear Weapons

1. What is the blast associated with an explosion?

a. The blast wave and its effects.

(1) When a nuclear device is detonated, all the fission products, bomb casing, and other weapon parts are

converted to the gaseous state due to the extreme heat. These gases are restricted to the region occupied by the original parts of the bomb creating pressures in the order of millions of pounds per square inch.

(2) Most of the material damage caused by the air burst of nuclear bomb is due mainly - directly or indirectly - to the shock (or blast) wave which results from the expansion of the hot gases.

(3) Most structures will suffer some damage from an air blast when the blast wave overpressure (pressure exceeding ambient pressure) is greater than about one-half pound per square inch.

(4) The distance to which a given overpressure level will extend depends on the yield or size of the explosion, and the height of the burst.

(5) The 20 megaton H-bomb (energy yield equivalent to 20 million tons of TNT) is capable of almost absolute destruction of structures within 5 miles of the point of detonation with lighter damage extending out to a radius of 15 miles or more. (Fig. 1, TB 8-1).

b. How do we measure the blast damage of a nuclear explosion?

(1) Civil defense planners have developed a procedure for describing the degrees of blast damage from a nuclear detonation. The damage areas are generally regarded as concentric circular zones around the point of detonation or the point (ground zero) directly under it.

Zone A - The area of almost complete physical destruction.

Zone B - The area of heavy damage.

Zone C - The area of moderate to light damage.

Zone D - The area of partial to light damage.

(2) The size of the zones of damage will vary as the size of the weapon used.

(a) A nuclear bomb with a yield equivalent of 40,000 tons of TNT detonated in the air would produce the following zones of damage (in radius):

Zone A - .65 miles
Zone B - 1.3 miles
Zone C - 1.9 miles
Zone D - 2.5 miles

(b) The air detonation of a nuclear weapon with a yield equivalent of 20,000,000 tons of TNT (20 megatons) would produce the following zones of damage:

Zone A - 5 miles
Zone B - 10 miles
Zone C - 15 miles
Zone D - 20 miles

2. What is the thermal radiation emitted in a nuclear explosion?

a. In a fission bomb (A-bomb) the maximum temperature attained is probably several million degrees or approaching the temperature in the center of the sun.

b. Approximately one-third of the total energy of a nuclear bomb, detonated relatively high in the air, is emitted in the form of thermal (heat) radiation made up of:

  (1) Ultraviolet radiation.
  (2) Visible light.
  (3) Infrared radiation.

c. Radiations from the ball of fire, like the sun rays, are attenuated as they pass through the air so that the amount of thermal radiation from a particular nuclear explosion that will reach a given point depends upon:

  (1) The distance from the burst.
  (2) The condition of the intervening atmosphere.

d. The major thermal effects from a nuclear detonation are:

  (1) Skin burns.
  (2) Ignition of combustible porous organic substances (e.g., wood, fabrics, paper).
  (3) Charring of thick organic material.

3. What is the nuclear radiation that is identified with a nuclear explosion?

a. It is convenient for practical purposes to consider the nuclear radiations as being divided into two categories, namely, initial and residual.

  (1) <u>Initial radiation</u>

    (a) Includes that radiation emitted within one minute of the detonation.
    (b) Consists of gamma rays and neutrons produced during a period of one minute after the explosion.

(c) Both these radiations, though different in nature, can travel considerable distances through the air.

(d) Both gamma rays and neutrons can produce harmful effects in living organisms.

(2) Residual radiation

(a) Includes all nuclear radiation emitted after 1 minute from the time of a nuclear explosion.

(b) Consists of beta and gamma radiation from the fission products and alpha radiation from the unfissioned bomb material.

(c) An additional source of residual radiation may result from the beta and gamma radiations emitted from neutron induced radioactive isotopes.

(d) With surface and subsurface explosions, the demarcation between initial and residual nuclear radiations may merge into one another.

b. Decay rate.

(1) Each isotope of the elements produced in the fission reactions has its own individual rate of decay or half life. However, the radioactivity of the mixed fission products decreases rapidly with time, especially in the first several hours after the explosion.

LESSON PLAN NO. 2

UNIT: Atomic Energy - Knowledge for Action

LESSON TITLE: Radioactive Fallout

TEACHING MATERIALS:

Blackboard and chalk

REFERENCES:

TB 11-1,	Emergency Exposures to Nuclear Radiation
TB 11-8,	Permissible Emergency Levels of Radioactivity in Water and Food
TB 11-9,	Emergency Measurements of Radioactivity in Food and Water
TB 11-19,	Protection Against Fallout Radiation
TB 11-21,	Fallout and the Winds
TB 11-24,	Medical Aspects of Nuclear Radiation

OBJECTIVES:

To acquaint the student with the characteristics of radioactive fallout by presenting its:

1. Nature and origin
2. Methods of protection
3. Scope and effect
4. Medical aspects
5. Hazard in food and water

MAIN TOPICS	TEACHING POINTS
A. Radiation Fallout and its Sources	1. Radioactive fallout from nuclear weapons is the surface deposition of radioactive material explosively distributed in the atmosphere.
	2. Radioactive materials are produced in the explosion of nuclear weapons and consist of: a. Particles produced in the fission reaction (fission products). b. Particles made radioactive by neutrons. c. Unfissioned material of the bomb.

MAIN TOPICS	TEACHING POINTS
B. Formation of Fallout	1. Several factors affect the formation of fallout. First to be considered is the burst itself.
	2. Nuclear explosions can be of various types. The ones of most concern are air, surface, and sub-surface bursts.
	3. Each type has its individual characteristics and resulting fallout peculiarities.
	4. An air burst is the explosion of a nuclear weapon in the air at a height such that the fireball does not touch the ground.
	5. The fireball is so hot that all materials of the bomb are transformed into vapor.
	6. As the fireball cools this vapor condenses forming solid particles and drops of water.
	7. The accumulation of these particles form a cloud known as the radioactive or atomic cloud.
	8. Although the cloud is highly radioactive, little of its radiation reaches the ground because of its height, the dispersal action by wind currents, and normal radioactive decay.
	9. In a surface burst the fireball created by the explosion touches the ground and great masses of pulverized debris are sucked upward into the atomic cloud. The radioactive materials which were vaporized by the heat then condense on these debris particles.

MAIN TOPICS	TEACHING POINTS

10. These tiny particles, now contaminated by the radioactive material fall back to the earth as dust -- this is radioactive fallout.

11. Thus, the major difference between the air and surface burst is the location of the fireball in relation to the ground and the amount of radioactive fallout reaching the ground.

12. The degree and magnitude of radioactive fallout of the surface burst is dependent upon:

    a. Energy yield of the bomb.
    b. Design of the bomb.
    c. Height to which the radioactive cloud rises.
    d. Particle size and distribution.
    e. Nature and chemical composition of the soil around ground zero.
    f. Terrain.
    g. Weather.

13. The surface explosion of a high-yield bomb under certain conditions will contaminate many thousands of square miles of the earth's surface.

14. A sub-surface burst is the explosion of a nuclear weapon underground.

15. This type explosion also creates a fireball which may break through the earth's surface.

16. In this breakthrough the hot gases and residue are released and thrown skyward in a large column, usually in the shape of an inverted cone.

17. When the material falls back to earth, it often produces a thick cloud of dust which spreads outward from ground zero.

18. This cloud of material can produce radioactive contamination over the area on which it settles.

19. The atomic cloud produced by an underground explosion is extremely radioactive and may produce a serious radioactive fallout hazard in the immediate vicinity of the explosion.

20. Methods that may be used to deliver nuclear weapons are:

    a. Manned aircraft
    b. Intermediate range ballistic missiles
    c. Intercontinental ballistic missiles
    d. Submarine launched missiles
    e. Weapons assembled in the United States by clandestine means.

C. Factors Affecting the Dispersion of Fallout

1. Terrain features will cause a variation in amount of fallout deposition. For example, large mountains or ridges could cause significant variation in radiation levels by receiving more fallout on the side facing the surface wind.

2. Precipitation (rain or snow) has definite effect on radiation deposition. Raindrops and snow flakes collect atmospheric impurities as they fall to the earth. Thus radioactive debris may be "washed" or "scrubbed" out of the air by the precipitation causing an increased fallout deposition in that area.

MAIN TOPICS	TEACHING POINTS

3. Wind plays the major role in the distribution of radioactivity.

4. During the winter, spring, and fall seasons, winds in the United States are primarily prevailing westerlies.

5. The speed of these winds will vary with the height of the wind (see Chart TB 11-21, page 4).

6. The deposition of a radioactive particle will thus be determined by the integrated (or combined) wind speed from the particle's maximum height to the surface.

7. To illustrate what the size of fallout areas might be and the radiation doses expected the following figures from a 12 to 15 megaton surface shot are presented:

   a. The area of contamination was 220 miles long and 20-40 wide.
   b. Sufficient radioactivity in the downwind belt was present to seriously threaten the lives of persons who remained in the area 36 hours and did not take protective measures.
   c. The following figures for the estimated total dose for the first 36-hour period were:

      (1) Ten miles downwind - 5000 r.
      (2) 100 miles downwind - 2300 r.
      (3) 110 miles downwind - 2000 r.
      (4) 125 miles downwind - 1000 r.
      (5) 160 miles downwind - 500 r.
      (6) 190 miles downwind - 300 r.

MAIN TOPICS	TEACHING POINTS
	d. Approximate time of fallout arrival at various distances is highly dependent upon the winds. In the pattern just described fallout 160 miles downwind began at about 8 hours after the explosion and continued for several hours.
	e. Estimate of the time that the bulk of the fallout material continued to come down within the area was about 12 hours. However, the size of the area contaminated by fission products usually increases with time for the first day or so.
D. Types of Fallout	1. Local fallout is that which returns to earth within several hours of the detonation and within a few hundred miles of ground zero. With a surface detonation, approximately 80 percent will be in this category. On the water surface the percentage will be somewhat less. Local fallout will be greater than 80 percent for underground detonations and very slight for air bursts.
	2. Tropospheric worldwide fallout, which though not coarse enough to fall of its own weight in the first few hours, remains in the same general latitude of the explosion. Precipitation and other means cause deposition of this material on the earth within a month or two.
	3. Stratospheric worldwide fallout, which does not fall of its own weight within the first few hours, is largely borne in the stratosphere for great lengths of time. An average time may be about 10 years or somewhat less. This is distributed over the earth and contributes mainly to the long-term radiological hazards.

MAIN TOPICS	TEACHING POINTS
	4. For surface bursts of large weapons, the area seriously contaminated with fission products from fallout is much larger and is affected for a much longer time than the area affected by the other hazards.
E. Fallout Prediction	1. Survival of a great number of individuals could be affected by the accuracy and procedures used in predicting possible fallout areas.
	2. High altitude wind observations are taken at many weather stations operated by the US Weather Bureau.
	3. The Weather Bureau issues fallout forecasts daily to all parts of the country to estimate fallout direction, distance and arrival time.
	4. This data provides local, State, and regional areas the necessary information for predicting areas of possible fallout deposition.
F. Monitoring for Fallout	1. When the fallout is complete, areas of deposition need to be monitored in order to determine radiation dose rates at a given time.
	2. This monitoring is accomplished in various areas by coverage such as: a. Mobile monitoring, which may provide a detailed picture of a relatively small area. b. Aerial survey, which enables rapid coverage of large geographical areas but less detail.
	3. The data collected by monitoring teams is reported to the appropriate operating point by the most available means of communication and fallout areas are plotted.

4. The information obtained goes from point of origin to the appropriate levels of responsibility at which summaries are made.

5. At all levels this isolated information is combined with other information collected at each monitoring point, summarized, and is used to advise government officials on operational procedures such as:

   a. Shelter and evacuation

   b. Movement of supplies and forces

   c. Emergency services operation, such as fire, police, communications, rescue and medical

   d. Restoration of normal community facilities and normal living conditions.

G. Medical Aspects of Radiation

1. Radiation sickness is caused by the ionization of the cells in the human body, which destroys some of the constituents essential to their normal functioning.

2. This ionization may form poisons, cause the breakup of chromosomes, cause swelling of the nucleus of the cell, and in many cases cause total destruction of the cell.

3. Varying nuclear radiation exposure doses will produce different effects, but it must be remembered that radiation sickness, even in its most advance stages, is not contagious.

4. The major symptoms of radiation sickness are:

   a. Vomiting
   b. Diarrhea
   c. Hemorrhaging

MAIN TOPICS	TEACHING POINTS
	d. Sore mouth and throat e. Loss of hair f. Loss of weight g. Drop in number of white blood cells
	5. Repeated exposure to radioactivity will result in building up a cumulative amount of radiation damage in the body, unless the biological recovery rate is greater than the exposure rate.
	6. Exposures of 25 roentgens per day at weekly or at longer intervals for a total of 8 exposures (200 r) may be experienced without serious loss of efficiency.
	7. The total cumulative dose and time period in which one is exposed are important in determining whether or not a person may risk further exposure for emergency purposes.
	8. The relationships between total exposure dose, dose rate, and time are similar to the relationships between a car speedometer, a car odometer, and time. Let us assume that a driver maintains a speed of approximately 50 m.p.h., as indicated on the speedometer, for a period of eight hours. At the end of this time, the total distance covered, as indicated by the odometer, will be approximately 400 miles. Similarly if an individual enters a radioactive contaminated area where the dose rate, as measured by a survey meter, is 5 roentgens per hour and remains

in the area for eight hours, his total exposure dose, as measured by a dosimeter (assuming no radioactive decay) would be approximately 40 roentgens. However, in all practical cases allowances must be made for the natural decay of the radioactive material.

9. A quantity called "medium lethal dose" (MLD or LD/50) is commonly used as a reference point for the biological effects of an acute whole-body exposure to ionizing radiation. It is the whole-body dose delivered in a short time (about 2 days or less) which is expected to result in the death within a month after exposure of 50% of the individuals among a large group so exposed. The estimated median lethal dose for man and animals is as follows:

   a. Man -450r
   b. Swine -450r
   c. Mount -590r
   d. Rabbit -790r
   e. Chicken -1000r
   f. Cattle -750r
   g. Sheep -350r
   h. Dog -325r
   i. Rat -800-900r
   j. Horse -450r

H. Danger in Food and Water

1. Individuals should know the maximum contamination levels that can be tolerated in consumption of food and water during the emergency period.

2. Consumption of food and water containing appreciable concentrations of radioactive materials for short periods of time is permissible.

MAIN TOPICS	TEACHING POINTS

3. Maximum levels of beta-gamma and alpha activity for emergency consumption periods are shown in Tables 1 and 2, Technical Bulletin 11-8.

4. Non-perishable foods too contaminated by beta-gamma emitters for immediate consumption need not be destroyed because natural decay of radioactivity will eventually reduce the contamination to safe values.

5. Food that is properly covered or wrapped or stored in closed containers should suffer no contamination provided it is removed properly.

6. This is especially true for canned and bottled foods as well as for any articles industrially wrapped.

7. If the contamination is only external in nature, it can be easily removed by various simple methods of decontamination.

8. If the contamination is internal, it means that the food was unprotected during the fallout time. It should be disposed of by burial unless it can be safely held in storage until the contamination levels decay (Cf. Sec. 5)

9. As for crops grown in contaminated soil there is not sufficient information available to make final determination. However, they should all be regarded with suspicion until their safety can be confirmed by radiological instruments.

MAIN TOPICS	TEACHING POINTS
	10. Most sources of public water supply are located considerable distances from target areas. Nevertheless, contamination might result if the water shed were in the range of heavy fallout from a surface burst or as a result of precipitation through the atomic cloud.
	11. In many cases it is expected that natural decay, dilution by flow, and absorption by soil of the radioactive material will produce water fit for consumption in a reasonable length of time after the exposure.
I. Conclusions	1. Radioactive fallout is a phenomena with which we must become acquainted as a requirement for living in the nuclear age.
	2. It is vitally important that all people understand and/or acquaint themselves with the characteristics of radioactive fallout and the factors affecting its distribution and radiation dose rates.
	3. It is well to know that in an area surrounding a point of radioactive contamination and in a much larger area in the downwind direction, radiation dose rates may be so high that people must take appropriate action in order to survive.
	4. Dangerous areas must be determined by radiological monitoring and action must be taken by concerned agencies to alert the public so that appropriate action may be taken.

MAIN TOPICS	TEACHING POINTS
	5. The threat to many rural areas, especially those that are on the downwind side of large target cities, is real and plans must be made to cope with the situation.
	6. Since fallout deposition takes place over a considerable period of time and its path can usually be predicted within broad limits, counter-measures can be adjusted to the developing situation, thereby greatly increasing survival chances.
	7. As radioactive fallout may affect people, animals, crops and land areas, both in cities and rural areas, certain instructions must be prepared and understood so that the appropriate defensive measures can be carried out.

LESSON PLAN NO. 3

UNIT: Atomic Energy - Knowledge for Action

LESSON TITLE: Introduction to Nuclear Radiation Detection Instruments

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TEACHING MATERIALS:

Blackboard and chalk
CD V-700 Radiological Survey Meter, Geiger Counter, Beta Gamma Discriminating, 0-50 mr/hr
CD V-710 Radiological Survey Meter, Gamma only, 0-50 r/hr.
CD V-720 Radiological Survey Meter, Beta Gamma Discriminating, 0-500 r/hr.
CD V-138 Radiological Dosimeter, self reading, 0-200 mr.
CD V-730 Radiological Dosimeter, self reading, Gamma only, 0-20 r.
CD V-740 Radiological Dosimeter, self reading, Gamma only, 0-100 r.
CD V-750 Radiological Dosimeter Charger
CD V-787 Comparison Standard for Food and Water

REFERENCES:

TB 11-20 Radiological Instruments for Civil Defense
Factory Manuals supplied with Instrument Kits

OBJECTIVES:

To acquaint the students with:

1. The fundamental principles of nuclear radiation detection.
2. The nuclear radiation detection instruments included in the high school kit.
3. Interpreting the readings obtained with radiation detection instruments.

MAIN TOPICS	TEACHING POINTS
A. Detection and Measurement of Nuclear Radiation	1. Nuclear radiation is detected indirectly by detecting the products of the interaction of radiation with matter

MAIN TOPICS	TEACHING POINTS
	2. This interaction results in the formation of ion pairs which occur when the normal electrical balance of atoms is disrupted. As radiation passes through matter it may remove orbital electrons from atoms and leave the atoms electron deficient or positively charged. This combination of the free electron and positively charged atom is referred to as an ion pair.
	3. All radiological instruments included in the kit detect and measure radiation by collecting and measuring these ion pairs.
	4. Civil defense survey meters and self reading dosimeters operate on this principle.
B. Essential Components of Common Radiation Survey Meters	1. Usually a closed tube having an electrically conducting shell and insulated central electrode, containing a definite volume of gas, is used as the radiation sensitive element. Radiation interacts with this gas to produce ion pairs. (Place drawing on board.)
	2. In the presence of an electrical field, the positive ions move in one direction (toward (-) electrode) while the electrons move in the opposite direction (toward (+) electrode). The current thus created is proportional to the radiation level or dose rate. (Review principle of current flow.)
	3. This current is then measured directly with an extremely sensitive electronic circuit. The meter, which measures the amplified current, is calibrated directly in roentgens per hour or milliroentgens per hour.
C. Self Reading Ionization Chambers (Dosimeters)	1. The self reading ionization chamber (dosimeter) operates on the same principle as an electroscope. (Have one of the pupils explain the principle of the electroscope.) (Teacher should demonstrate the electroscope.)

MAIN TOPICS	TEACHING POINTS
	2. The dosimeter consists of a .005 in. electrically conducting quartz-fiber attached to a metal frame. This frame is mounted inside an enclosed air volume, called the ionization chamber.
	3. An electrical charge placed on the quartz-fiber and metal frame system, which is insulated from the outside conducting wall, causes the fiber to diverge by mutual repulsion.
	4. The charge is adjusted until the image of the quartz-fiber rests on the zero of the scale.
	5. Radiation entering the sensitive chamber of the dosimeter produces ions which are collected by the electrodes (quartz-fiber or outside wall) causing a reduction in the charge on the quartz-fiber. This reduction is reflected by an upscale movement of the quartz fiber.
	6. When properly designed the self reading ionization chamber (dosimeter) can be adapted to indicate, in roentgens or milliroentgens, the total accumulated, ionizing-radiation exposure, or <u>total dose</u>.
	7. The dosimeter cannot be used to measure the radiation a person has received unless it is worn by him during exposure.
	8. Civil Defense Dosimeters are designed to measure gamma radiation only.
D. Detecting Nuclear Radiation by Devices other than Ion Chambers. (This topic may be omitted if time does not permit its introduction.)	1. Photographic Emulsions - Interaction of radiation with the silver halide in the emulsion causes ionization which forms a latent image. Development of the film converts this image to black deposits of metallic silver. The degree of darkness is related to the amount of radiation exposure (Mention film badges.).
	2. Phosphate glass (Radiophotoluminescence). The fluorescence of phosphate glass under ultraviolet light is proportional to the amount of radiation exposure.

MAIN TOPICS | TEACHING POINTS

3. Scintillation. Ionization in a crystal produces a flash of light. The light can be converted to electrical current by a photo-multiplier tube. The electrical current can then be amplified, measured, and the meter calibrated in r/hr or mr/hr.

4. Chemical. Chloroform and water and other similar mixtures exhibit acid characteristics which change upon exposure to radiation. Using a suitable indicator to detect this acid change, the radiation exposure of the mixture can be determined.

E. Purpose of Survey Meters

1. Survey meters are used to measure on-th-spot gamma dose rate in roentgens per hour or milliroentgens per hour. (Discuss meaning of prefix "milli".)

2. Some survey meters can be used also to detect the presence of beta radiation.

F. Special Considerations in Selecting a Survey Meter

1. There is no one instrument sufficiently adaptable to all ranges of dose rate to meet the needs for a complete radiation survey.

2. The following general types of survey instruments are in the high school kit distributed by OCDM.

   a. A beta-gamma discriminating Geiger counter for the high sensitivity requirements, for long range follow-up, and for training purposes. (Show CD V-700)

   b. A medium range gamma survey meter for use in the major part of the survey following an explosion. (Show CD V-710.)

   c. A high range beta gamma survey meter for use by highly qualified personnel if it becomes necessary to make measurements in areas where extremely high level radioactive contamination exists. (Show CD V-720.)

MAIN TOPICS	TEACHING POINTS
G. Survey Meter CD V-700 (Instructor should show the instrument as he describes it, pointing out pertinent characteristics.)	1. The CD V-700 is a portable radiological survey meter used to measure gamma fields of low dose rates and detect the presence of beta radiation.
	2. Three ranges provide full scale indication in steps of .5, 5.0 and 50 milliroentgens per hour. (mr/hr)
	3. The meter consists of a probe (Geiger-Mueller tube) earphone and meter assembly. A radioactive sample is provided on the case shell for testing the operation of the instrument.
	4. A movable shield on the probe permits detection of beta and gamma radiation directly by exposing the Geiger-Mueller tube. With the probe window closed, the housing will completely absorb beta radiation of low energy and the instrument measures gamma only.
	5. Earphones when connected to the instrument will provide an audible signal in the presence of a radiation source. Radiation dose rate is indicated by an electrical meter calibrated in mr/hr.
	6. Two types of batteries may be required to power the instrument. a. 1.5V flashlight cells. b. 45V "B" batteries. Series connected for amplifier and Geiger-Mueller tube. (The 45V batteries are not used in the transistorized model 4 CD V-700.)
H. Survey Meter CD V-710 (Instructor should show the instrument as he describes it, pointing out pertinent characteristics.)	1. The CD V-710 is a portable survey meter for detecting and measuring gamma radiation.
	2. There are three ranges 0 to .5, 0 to 5, and 0 to 50 roentgens per hour. (r/hr)

MAIN TOPICS	TEACHING POINTS
	3. The instrument uses an air ionization chamber as the radiation sensitive element. (No probe is associated with this instrument.).
	4. Radiation dose rate is indicated by an electrical meter only.
	5. This instrument is powered by: 1.5V flashlight battery (for filament heaters) 22.5V photo flash type "B" batteries for amplifier plate potential.
I. Survey Meter CD V-720 (Instructor should show the instrument as he describes it, pointing out pertinent characteristics.)	1. The CD V-720 was designed specifically for measuring radiation fields of high dose rates. It can be used to measure gamma radiation as well as <u>detect</u> beta particles.
	2. It has three ranges, 0-5 r/hr, 0-50 r/hr, and 0-500 r/hr.
	3. An air filled ionization chamber serves as the radiation detecting element. The chamber has a thin window which permits the beta particles to act upon the chamber volume. A shutter which covers this window can be closed and thus the instrument will respond only to gamma radiation.
	4. Current produced in the ionization chamber is amplified and indicated on a meter reading directly in r/hr.
	5. The instrument is powered by: 1.5V flashlight batteries and 22.5V batteries.
J. Reading and Interpreting the Scale of Survey Meters	1. Each survey instrument included in the high school RADEF instrument kit has three ranges indicated on the scale of the indicating instrument. This provides needed flexibility in instrument sensitivity, and enables the operator to read the instrument more readily and accurately.

Note to the Instructor

It is recommended that the difficulty in reading a high range meter indicating a low reading be demonstrated.

2. The range in each meter increases in steps of ten units.

Note to Instructor

a. Place this comparison table of each instrument on the blackboard.

Range	CD V-700	CD V-710	CD V-720
X1	0-.5 mr/hr	0-.5 r/hr	0-5 r/hr
X10	0-5 mr/hr	0-5 r/hr	0-50 r/hr
X100	0-50 mr/hr	0-50 r/hr	0-500 r/hr

b. Discuss advantages of having the scales increase in multiples of ten.

(1) Ease of reading
(2) Tie in with metric system
(3) Simplifies instrument circuitry and calibration.

3. The scales on the survey instruments are either linear or non-linear.

Notes to Instructor

a. Discuss meaning of linear and non-linear scales.

b. Place a diagram of a linear scale and a reproduction of the CD V-700 scale on the board.

c. By means of illustration on the meter panel place a reading of 4 mr/hr. Have a student read this value.

Change the scale indicator on the illustration to indicate range X100 and have the student interpret.

MAIN TOPICS	TEACHING POINTS
	It is suggested that this exercise be expanded to include other readings indicated on the scale. It is also suggested that range indicators be changed on the diagram to include those of the CD V-710, and CD V-720.
	d. It is suggested that readings such as the following be given to the students with instructions to draw a rough sketch of the meter face and indicate the reading and range that is required for each reading. Identify the instrument by CD number. 20 r/hr 0.3 r/hr 0.2 mr/hr 175 r/hr 60 r/hr
K. Purpose of a Dosimeter	1. A dosimeter measures and registers total accumulated ionizing radiation exposure. It must be worn by a person during exposure to perform its function.
	2. Dosimeters are usually self-indicating so the wearer can read directly his accumulated dosage.
	3. Records must be kept of dosimeter readings so that the wearer can determine his total accumulated exposure dose.
L. Characteristics of the Dosimeters included in the High School Kit	1. The three dosimeters included in the high school kit operate on the same principle, discharge by ionization. The chief difference in each is the range. They are carried in the same manner as a fountain pen.
M. CD V-138 (Each pupil should be afforded an opportunity to see one close up.)	1. CD V-138 is a self reading type instrument with a range of 0-200 milliroentgens. Its range makes it particularly adaptable for use in training. It requires an external power source for charging. (CD V-750)

MAIN TOPICS	TEACHING POINTS
N. CD V-730 (Display it)	1. The CD V-730 is a 0-20 r self indicating dosimeter. Except for range its operational characteristics are the same as the CD V-138. It requires an outside source of approximately 180 V to charge it for operational use.
O. CD V-740 (Display it)	1. The CD V-740 is a 0-100 r self indicating dosimeter. Its general description and characteristics are the same as the CD V-730. The major difference is its range. It is designed primarily for use by service specialists in civil defense.
P. Limitation of Dosimeters	1. Civil Defense electrostatic dosimeters are accurate within 10% of true cobalt 60 dose and can be used again and again by recharging. The accumulated dose can be read at any time. Disadvantages of the electrostatic dosimeters are that they may be more expensive than some other types and can give erroneous readings if roughly handled or because of electrical leakage over a very long period of time.
Q. Dosimeter Charger CD V-750	1. A dosimeter charger (Kit contains the CD V-750) is required to charge dosimeters to zero prior to their use.
	2. The CD V-750 provides approximately 180 V required to charge the CD V-138, CD V-730 and CD V-740 dosimeters.
R. Comparison Standard CD V-787	1. This is a comparison standard for food and water, intended for use in determining whether food and water are safe for consumption. FOR DETAILS SEE TB 11-9.)

LESSON PLAN NO. 4

UNIT: Atomic Energy - Knowledge for Action

LESSON TITLE: Use of Nuclear Radiation Detection Instruments

TEACHING MATERIALS:

Blackboard and chalk.

CD V-700 Radiological Survey Meter, Geiger Counter, Probe Type, Beta Gamma Discriminating.
CD V-138 Radiological Dosimeter, Self Reading Type, 0-200 mr.
CD V-750 Radiological Dosimeter Charger
CD V-787 Comparison Standard Source for Food and Water

REFERENCES:

TB 11-20 Radiological Instruments for Civil Defense
CD V-700 Instruction Manual (Available in the high school kit)
CD V-750 Instruction Manual Dosimeter Charger (available in high school kit).

OBJECTIVES:

To acquaint the students with:

1. The importance of nuclear radiation detection instruments to personal safety.

2. The fundamental techniques required to use radiation detection instruments effectively.

3. Some of the common symptoms of a defective radiological instrument.

MAIN TOPICS	TEACHING POINTS
A. Why do we have nuclear radiation detection devices?	1. We cannot see, feel, or smell radiation, so we must have instruments by which radiation hazards can be detected and measured.

MAIN TOPICS	TEACHING POINTS
	2. The value of a nuclear radiation detection instrument is directly related to the skill of the operator. Readings taken by an instrument operator must be taken in a predetermined manner and the reading recorded accurately. Operation techniques and procedures provide accurate data essential to interpret and estimate the total effects of radiation from a source of radioactive contamination. Unless correct techniques are made part of a detailed survey plan, the data collected will be of little value.
B. Consideration in the use of instruments	1. Care must be taken to keep the instrument probe or radiation sensitive chamber clear of any shielding from the source of contamination. (Instructor should review the effects of shielding on types and amount of radiation.)
	2. The distance between the source of radiation and the radiation sensitive chamber of a survey meter affects the instrument reading. When monitoring a surface or a given area the distance the instrument is held from the surface being surveyed should be approximately the same for each reading.
C. When the Dosimeter should be worn	1. Personnel working in the vicinity of a radioactive source should always wear a dosimeter.
	2. The dosimeter or other dosage indicator should be worn exposed and clear of any shielding effect.

MAIN TOPICS	TEACHING POINTS
	3. It must be remembered that the dosimeter indicates only the radiation to which it was subjected. The dosage a person receives must be estimated in terms of total body exposure using the dosimeter as a basis for making this estimate.
D. Records keeping required with a dosimeter	1. Since the dosimeter indicates the radiation a person receives only if he has it on during exposure, it is essential that records be kept on the exposure of the wearer.

Note to Instructor

It is suggested that the following table be placed on the blackboard and explained.

RADIATION EXPOSURE RECORD

NAME

DATE	DOSIMETER SERIAL NO.	FINAL READING	INITIAL READING	DOSE

NOTE TO INSTRUCTOR

Problems involving the calculation of dosage can be given as a student exercise by placing hypothetical readings in the above table.

MAIN TOPICS	TEACHING POINTS
E. How to operate the dosimeter charger CD V-750	1. A dosimeter must be readied for use by charging it with an external voltage. The kit of high school instruments includes a CD V-750 which was designed specifically for this purpose. This instrument includes a lamp arrangement to assist in reading the indicator.
	2. The following steps are taken to charge the CD V-138: a. To read the dosimeter: (1) Remove dust cap from charging contact on the CD V-750. (2) Place dosimeter on charging contact and press lightly to light lamp. (3) Read dosimeter. (4) The dosimeter may also be read by observing the hairline when the charging end is held toward a light source. b. To charge dosimeter: (1) Remove dust cap from charging contact on CD V-750. (2) Place dosimeter on charging contact and press firmly until the dosimeter touches the bottom of the charging well. (3) If hairline is not in sight, <u>hold</u> switch "up scale" to establish fully discharged condition. (4) Operate charger according to instructions on the case until the quartz fiber in the dosimeter is aligned at zero. (5) Replace dust cap. <u>Note to Instructor</u> It is suggested that volunteers be permitted to operate the device.
	3. The same procedure and charger used for CD V-138 is used for CD V-730 and CD V-740.

MAIN TOPICS	TEACHING POINTS
F. Functions the Geiger Counter CD V-700 performs	1. The beta gamma discriminating Geiger counter, CD V-700, is very useful in high sensitivity monitoring, for long range follow-up and training purposes.
	2. The CD V-700 is adapted for use in monitoring food, water, and people for radioactive contamination.
	3. The CD V-700 is particularly adaptable for training since it can be operated in a radiation field of low dose rates, thus minimizing radiation exposures to trainees. The probe containing the Geiger-Mueller tube must be exposed to a source of radiation to obtain a reading on the meter. However the shield on the probe should not be opened when measuring gamma radiation.
G. Checking the operability of the CD V-700	1. The CD V-700 should be given an operation check prior to its use in an exercise. This can be accomplished by performing the following steps: (Details are in the instruction manual in kit.) a. Open the Geiger tube shield and place the probe next to the radioactive source underneath the manufacturer's nameplate on the side of the instrument. (The source is on the bottom of the CD V-700 Model 3) b. Turn the range selector switch to the X10 point, the instrument should read approximately mid scale. c. Placement of the probe against the source is critical. d. If the proper reading is not obtained, the calibration adjustment within the instrument should be adjusted.
	<u>Note to Instructor</u> Review the meaning of the scale range.

H. Using the CD V-700

Note to Instructor

If there are enough instruments available it is suggested that the following be performed by small groups as a field exercise. If instruments are not available, the procedure should be followed as a demonstration:

1. A radiation source should be placed in a fixed spot. The source in the lid of the CD V-787 may be used as a very weak source of beta radiation.
2. Each student should be given an opportunity to attach the headphones to the CD V-700, place the probe near the source and listen to the GM counter.
3. A series of distance markers compatible with the dose rates of the source should be laid out.
4. The following Record Sheet should be prepared for use by the students. (Blackboard is recommended if a demonstration is given).

INSTRUMENT READING
RECORD SHEET

Name Date Time

Inst. Serial Number	Distance	Meter Range	Dial Reading	Inst. Reading

MAIN TOPICS	TEACHING POINTS
	5. Using the probe of the CD V-700 at each of the pre-marked distances record the meter readings on a table similar to that on page 4-6. Note to Instructor Have the class discuss and interpret the results.
I. Interpreting data obtained using a CD V-700	1. Have the students do practical problems, similar to the following: "The range selector is on X10, the CD V-700 dial reading is 0.2, what is the dose rate?"
J. Operator's maintenance on the CD V-700	1. The operator of the CD V-700 should not attempt any maintenance beyond replacement of batteries or the Geiger tube. Details on the procedure to follow are contained in the maintenance manual supplied in the high school kit. 2. Good batteries are essential to the accuracy of all detection instruments. 3. When a detection instrument is to be stored for any period of time the batteries should be removed to prevent damage to the instrument resulting from battery deterioration.
K. CD V-710 and CD V-720	1. The techniques for operation and maintenance of the high range survey instruments included in the high school kit are similar to those just performed with the training instrument CD V-700 and are outlined in the instrument manuals.

LESSON PLAN NO. 5

UNIT: Atomic Energy - Knowledge for Action

LESSON TITLE: Protective Measures Against Radiation

TEACHING MATERIALS:

Blackboard and chalk
Opaque projector

REFERENCES:

TB 5-3, Family Shelters for Protection Against Radioactive Fallout

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OBJECTIVES:

To develop in the students an understanding of:

1. Principles of protection against radiation
2. Standards for fallout shelters
3. Types of fallout shelters
4. Design of fallout shelters
5. Other types of shelters

MAIN TOPICS	TEACHING POINTS
A. Classes of protection	1. There are two tactics of protection against nuclear radiation from nuclear weapons. a. Distance b. Shielding 2. In many cases proper precaution against blast, shock, and fire would also provide protection by decreasing the hazards to personnel from nuclear radiation.

MAIN TOPICS	TEACHING POINTS
B. General principles	1. Radiation is of little importance to personnel inside blast Zone A because the area has been completely destroyed. Outside Zone A, the following actions will provide protection: a. Evacuate from the blast effects. b. Provide a shelter designed to protect from blast and nuclear radiation. 2. Outside the blast Zone A and in the fallout area, shelters would save many people. It may be necessary to remain in shelter for several days. a. Best practical control of radiation dose is shielding. b. Increasing the distance between personnel and the radioactive material may possibly be more advantageous in some cases. For example, at 3 feet above the ground, roughly 50 percent of the dose rate received in the center of a large, flat, uniformly contaminated area comes from distances greater than 25 feet away, and about 25 percent from distances more than 50 feet away. Thus, complete removal of the contaminated surface from a circle 50 feet in radius would reduce the dose rate in the center to about one-fourth of its original value. c. Radioactive decay of fallout contamination is most helpful in the early period after detonation. d. Decontamination of personnel will definitely cut down on beta burns. e. Shortening the time individuals are exposed to high dose rates by taking advantage of shielding and/or distance and personnel decontamination will reduce cumulative dose.

MAIN TOPICS | TEACHING POINTS

f. Prevent intake of radioactively contaminated food and water. Ingestion is mainly a long-term hazard for fallout radiation.

3. The decay of fission products is relatively rapid after detonation. However, this decay rate slows down and radiation from fallout may be a serious hazard for many years.

C. Reduction in radiation by types of materials

1. It is estimated that the following reduction in gamma dose rates is provided by the materials listed below:

Type Structure	% Outside Dose
<u>Frame House</u>	
Top floor (center)	90%
Ground floor (center)	50 to 75%
Basement (center)	5 to 10%
<u>Brick House</u>	
Ground floor (center)	40 to 60%
Basement (center)	2 to 10%
<u>Multi-Story Reinforced Concrete</u>	
Outer rooms on lower floors	90%
Basement	10% or less
Inside rooms on upper floors	10 to 50%
<u>Special Shelters</u>	
In backyard (subsurface) (3 ft. of dirt on top)	.02%

D. Standards for fallout shelters

1. Shelter Dimensions

1. Shelter should provide each occupant at least 12½ square ft. of floor area and 80 cubic ft. of volume.

MAIN TOPICS	TEACHING MATERIALS
	Ceiling heights should be not be less than 6½ ft. Width of entranceway should be kept to a minimum usually not more than 2 feet.
2. Shielding	1. Shielding material must have enough mass to reduce gamma radiation to a relatively harmless level.
	2. As a general rule a high degree of protection against gamma radiation will be afforded by an earth cover of 3 feet or an equivalent mass of other materials. Approximate thicknesses required for other materials to afford protection from fallout radiation equivalent to 3 feet of earth are: concrete, 24 inches; iron and steel, 7½ inches; and lead, 3 inches.
	3. Arrangement of the entranceway is important since harmful amounts of radiation may be scattered around corners. Designs of the entranceway must be such that radiation must make at least two right-angled turns before entering the main chamber. These changes of direction effectively reduce the intensity of radiation.
3. Ventilation	1. In a basement shelter a tolerable and safe environment may be obtained by providing the means for natural ventilation, such as a grilled entrance door. Underground shelters, however, require the use of mechanical blowers or fans.
	2. The shelter ventilation system should be capable of supplying not less than 5 cubic feet of fresh air per minute per person in the main chamber, and means should be provided to exhaust the stale air.

MAIN TOPICS	TEACHING POINTS
	3. Suitable ventilating blowers or fans are commercially available at nominal cost. (See "Family Shelters for Protection Against Radioactive Fallout", Appendix A, page 4.)
	4. Dry-type particulate air filters with cells or canisters containing a filter material made of cellulose-asbestos or fine glass fibers may be used in the ventilating systems (see "Family Shelters for Protection Against Radioactive Fallout", Appendix A, page 4).
4. Radio Equipment	1. A battery-operated radio is necessary equipment for the shelter. If it is to be stored there, precautions should be taken to prevent its deterioration.
	2. A supply of spare batteries is highly desirable. Since batteries deteriorate with time, replacements should be made at least once a year. Transistorized radios give longer battery operating use than radios employing vacuum tubes.
	3. The shielding required for radiation protection also drastically curtails effective radio reception. For this reason, radios used in shelters may require an antenna outside of the shelter itself.
5. Food and Water Supply	1. At least a 2-week supply of food and water should be available. This may be required for survival even though the radiation level permits leaving the shelter in less than two weeks, since food may not be immediately available from normal sources. Foods that can be eaten without cooking are preferred.
	2. At least one-half gallon of water per person per day is needed for

MAIN TOPICS	TEACHING POINTS
	drinking and sanitation purposes, Gallon glass jugs, tightly capped, and carefully packaged to prevent breaking are recommended for long-term storage.
6. Sanitation	1. The sanitary disposal of human wastes is necessary for health protection. A small container, such as a hospital bedpan or other emergency toilet facility, should be provided.
	2. Contents should be disposed of in a covered water-tight container. At least two 5-gallon holding containers are required for the initial shelter period.
	3. These containers should be charged with a small amount of lime and water for odor control. A 10-gallon covered container for food refuse also should be included.
7. Miscellaneous Supplies	1. Other supplies that should be available include: a first aid kit; cots, bunks, or sleeping bags; blankets; flashlight and an extra supply of batteries, or a hand operated generator type of flashlight; can and bottle openers; eating utensils; toilet tissue, towels, and soap; and household tools.
E. Fallout Shelter Types	
1. Outside Underground Shelter	1. Many designs may be developed for an outside family fallout shelter which will provide reasonable adequate protection against radiation.
	a. Concrete, masonry, steel, pressure-treated wood, or other suitable

MAIN TOPICS	TEACHING POINTS
	construction material may be used. (Three different shelter types are illustrated in the drawings in "Family Shelters for Protection Against Radioactive Fallout", Appendices B and C).
	2. A shelter having a 6 inch concrete roof should be covered by an embankment of earth 2 ft. 3 in. high. If desired, the embankment may be eliminated by placing the roof of the shelter 2 ft. 3 in. below ground level.
	3. The basic underground family fallout shelter can be incorporated in the plans of basementless houses, garages, tool houses, or the like. Two structural changes are required. First, the slab thickness of the roof must be increased to 20 inches; second, a "collar" of concrete or masonry must extend above the entranceway opening in the roof slab.
2. Basement Shelter	1. In the construction of a new house with a basement, a family shelter may be incorporated in a corner of the basement. (See "Family Shelters for Protection Against Radioactive Fallout", Appendix B).
3. Above Ground Shelter	1. For areas of the country were underground shelters are not feasible, an above-ground shelter should be built. Any of the materials suggested for construction of underground structures can also be used for the shelter.
	2. The total mass of shielding material, including the material of which the shelter is constructed, should be equivalent to three feet of earth. This may be provided by covering the structure with earth or sand bags.

MAIN TOPICS	TEACHING POINTS
F. Permanent Group Shelters	
1. Existing Structures	1. Some radiation shelter can be provided by existing structures in outlying areas either in their present form or with suitable modification. Such buildings as schools, hospitals, community centers and warehouses can be used.
2. Schools	1. Three types of shelters may be provided in schools: a. Basement b. Separate underground c. Corridors
3. Recreational Developments	1. A promising approach to solution of the problem of providing protection from fallout radiation is the development of designs for facilities that have a peace-time use and a salavage value in addition to their protective characteristics.
4. Parking Garages	1. Underground parking garages in suburban centers provide protection against radiation hazards.
5. Tunnels and Subways	1. Subways, tunnels and underground highways can serve as shelter from radioactive fallout.
6. Natural Caves and Abandoned Mines	1. Large natural caves and abandoned mines are close to a number of cities. These could also provide shelter from fallout.
G. Emergency Shelters	1. The following shelters will provide varying amounts of protection that should be used as an emergency when better shelters are not available: a. Trenches b. Natural Caves and Mines c. Culverts d. Earth or sand bag walls e. Automobiles

LESSON PLAN NO. 6

UNIT: Atomic Energy - Knowledge for Action

LESSON TITLE: Consideration for Living in the Nuclear Age

Section I - Radiation Monitoring
Section II - Decontamination
Section III - Self-Survival Actions

TEACHING MATERIALS:

Blackboard and Chalk
CD V-700 for each laboratory
Pair of rubber gloves (expendable)
1 banana
1 head lettuce or cabbage
1 can orange juice (individual size)
Ash tray, matches, alcohol, can opener
10 microcuries Phosphorus 32 in solution (This is the maximum amount permitted without an AEC license. If the p32 cannot be obtained by arrangement with a local hospital, college or university, quantities up to 10 microcuries may be purchased from companies listed on the attached annex. If p32 cannot be obtained, the demonstration exercise referred to in this lesson cannot be done.)
Sink with abundant running warm water (1 for each 3 students)
A cake of good soap
Paper towels (plenty for all)
Waste can (for paper towels) to be marked and handled for radioactive waste

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REFERENCES: None

OBJECTIVES:

To develop in the students an understanding of:

1. Monitoring systems
2. Decontamination of personnel and materials
3. Self-survival actions
4. Family survival plans and exercises

Section I - Radiation Monitoring

MAIN TOPICS	TEACHING POINTS
A. Introduction	1. Since nuclear radiation cannot be seen or felt, monitoring is necessary to determine if radioactive materials are present and if decontamination is necessary.
B. Need for Nuclear Radiation Data	1. Radiation data are necessary to: a. Determine fallout areas. b. Determine need for shelter and evacuation. c. Determine radiation hazards associated with such operations as fire-fighting, restoration of public services and utilities, and transport of supplies. d. Determine the earliest time feasible for resuming normal living conditions. e. Determine whether decontamination is necessary.
C. Types of Monitoring	1. Aerial survey - this type of survey may be conducted when large areas must be monitored for radioactive fallout. The objectives may be to monitor a broad area such as a ten-mile grid from high altitudes, or evacuation routes at as low an altitude as feasible.
	2. Ground survey - this type of survey is conducted when more detailed and exacting information is necessary. It may be conducted by automobile or truck, or on foot when detailed information for a specific area is needed.

MAIN TOPICS	TEACHING POINTS
	3. In addition, personnel who have worked in areas where radioactive material may have been present, must be monitored for possible contamination.
	4. Monitoring is also done in radiation laboratories with use of specific laboratory equipment to identify specific isotopes, types of radioactivity present, and to evaluate radiation hazards.

Section II - Decontamination

MAIN TOPICS	TEACHING POINTS
A. Principles of Decontamination	1. Since radioactive materials cannot be destroyed, decontamination measures involve transfer of the source of radiation from a location where it is a hazard to one in which it can do little or no harm. 2. In case large areas are contaminated, it will probably be necessary to remove radioactive material from important selected areas to areas which are of lesser importance. 3. All decontamination procedures have two basic aspects: a. Removal of the contamination b. Disposal of the contamination Unless proper consideration is given to the latter aspect, the whole process may do little or no good. 4. Decontamination may be required for certain essential facilities such as communication centers, water pumping stations, vital industrial plants and access routes; and for certain essential equipment such as fire-fighting apparatus and ambulances. 5. Because of its particulate nature, the fallout will tend to collect on horizontal surfaces. These surfaces will in general be more highly contaminated than vertical surfaces.
B. Types of Decontamination	1. Decontamination may be of two types:

MAIN TOPICS	TEACHING POINTS
	a. Gross or rough — this is the rapid, partial removal of contamination on a large scale. Its purpose is to reduce the radiation dose rate as quickly as possible to a point where personnel can use a piece of equipment or remain within an area for a limited period of time.
	b. Detailed — this is almost complete removal of contamination. It is usually a lengthy and difficult process.
C. Methods of Decontamination	1. There are three general methods of decontamination: a. Surface b. Aging and sealing c. Removal and storage
	2. General guidelines for decontamination of materials are as follows: a. Smooth surfaces such as painted and metallic — wet washing. b. Porous materials such as fabrics, brick, stone, and concrete — dry method. c. Dry particles may be removed by: (1) Suction (2) Brushing (3) Adhesive d. Particles embedded on oily surfaces may be removed by: (1) Soap and brushing (2) Detergents (3) Steam cleaning e. Plated or absorbed contamination requires either: (1) Specific solvents (2) Surface removal by: (a) Chemical dissolution (b) Abrasion (c) Excision

f. Broadly speaking, water washing is employed outdoors and on the exterior of vehicles. Vacuum sweeping is used in the interior of buildings and automobiles.

3. Decontamination of specific types of materials are:

Type	Method
Building walls and roof	Hose down with water.
Earth	Remove or cover with sufficient quantity of additional earth. (For example, at 3 feet above the ground, roughly 50 percent of the dose rate received in the center of a large flat, uniformly contaminated area comes from distances greater than 25 feet away, and about 25 percent from distances more than 50 feet away. Thus, complete removal of the contaminated surface from a circle 50 feet in radius would reduce the dose rate in the center to about one-fourth of its original value.)
Clothing, rugs, curtains, upholstered furniture	If radiation dose rate is high, discard or bury. If radioactivity has decayed to a sufficient extent, or initial contamination is low, laundering may be effective in reducing radioactivity of clothing and fabrics to permit their recovery.

Articles with non-porous, non-absorbent surfaces.	Wash with water using a detergent.
Foods in cans or sealed containers	Remove contamination by washing cans or wiping paper wrappers and disposing of outer container.
Foods with skin or leafy covering	Carefully remove skin or outer leaves.
Streets and roads	Hose down with high pressure hoses.
Vehicles	If windows and air vents are closed, only the outside needs decontamination. Use high pressure hose and a detergent on the outside material. To clean the interior, use a vacuum cleaner on fabric and scrub other surfaces with water and a detergent.

4. Fallout material may be removed from water as follows:

Method	Effective Removal (Per Cent)
Coagulation	70
Ion Exchange Column (Mixed bed)	98
Ion Exchange Resin (Mixed ion)	
450 parts per million	80
2700 parts per million	99
Clay Slurry	
1000 parts per million	80
3000 parts per million	90
Distillation	99.99

MAIN TOPICS	TEACHING POINTS
D. Decontamination of Personnel	1. Monitor personnel to determine extent of contamination.
	2. Remove clothing.
	3. Wash body thoroughly with hot water and soap. Give particular attention to washing of hair and recessed areas of the body such as ears, eyes, and nose.
	4. If large number of persons are to be decontaminated, a decontamination station should be set up. Decontamination of persons and handling of decontaminated clothing should be done under controlled conditions.
E. Protection of Operating Crews	1. Personnel engaged in decontamination should wear proper types of clothing.
	2. For dry operations, heavy pants and shoes are recommended as well as a cotton-type of work glove and a tight fitting cap. Open areas of clothing should be tied to prevent entry of contaminated materials.
	3. For wet decontamination operations, water repellent clothing, rubber boots and rubber gloves will be required.
	4. Workers will need protection from excessive exposure to radiation.
	5. After decontamination operations are completed, personnel should bathe and the contaminated clothing decontaminated or discarded.

Section III - Self-Survival Actions

MAIN TOPICS	TEACHING POINTS
A. Individual Self-Survival Actions	1. There are definite actions which individuals can take to protect themselves during a civil defense emergency. These actions may be classified as Prepare and Learn.
	2. Preparation actions include:
	a. Preparing family shelter and equipping with a two-week supply of food and water, first aid kit, and battery radio.
	b. Preparing evacuation kit for the automobile consisting of food, water, first aid kit, battery or car radio, blankets.
	3. Learn actions include learning:
	a. Warning signals and what they mean.
	b. Use of CONELRAD - 640 or 1240 for official directions.
	c. Community plan for emergency action, including evacuation routes and/or location of shelters.
	d. Protection from radioactive fall-out.
	e. First aid and home emergency preparedness.
B. Home Plan and Exercises	
1. Need	1. A home plan should be developed and exercises practiced in order that each member of the family:
	a. Will have appropriate knowledge and understanding.
	b. Will know what to do under various emergency conditions.
	c. Will have drilled until proper actions are automatic.

MAIN TOPICS	TEACHING POINTS
2. Development of Home Plan	1. Using the actions listed above in the "Individual Self-Survival Actions" sub-section as a guide, determine actions which are to be accomplished during preattack, alert, and postattack periods. 2. Determine tasks to be performed in carrying out each action. 3. Assign each task to some member of the family. 4. Practice each action and task.
3. Home Exercises	1. Important family action exercises are: a. Preparing shelter b. Equipping shelter including food and water. c. Preparing automobile evacuation kit. d. Determining and removing fire hazards. e. Learning and practicing first aid and home nursing. f. Learning community plans for emergency actions. g. Learning protective measures for radioactive fallout. h. Turning radio dial to CONELRAD i. What to do when signals sound. j. What to do if someone is trapped. k. Home fire fighting.

DECONTAMINATION EXERCISES

EXERCISE NO. I

Demonstration of Stripping of Fruits and Vegetables to Remove Contamination

Part I

1. Monitor lettuce and banana to show absence of radioactive contamination.
2. Place items in a plastic bag.
3. Place a drop or two of p32 solution on the outside of the plastic bag.
4. Using the probe of the CD V-700, monitor the bag on the outside and on the inside. This demonstrates that the lettuce and banana are exposed to the radiation. (Do not allow probe to become contaminated when monitoring the outside of the bag.)
5. Remove the lettuce and the banana from the bag and monitor them. If correctly done, there should be no contamination. This illustrates that being exposed to radiation and being contaminated by radioactive material are different.

Part II

1. Place a drop of p32 solution on a banana to contaminate it.
2. Monitor the banana.
3. Peel banana carefully (using glove).
4. Confirm absence of radioactive contamination with instrument before eating the banana.

Part III

1. Place a drop of p32 on a head of lettuce to contaminate it.
2. Monitor the lettuce.
3. Strip outer leaves from head of lettuce. (Use gloves where necessary.)
4. With instrument, show contamination to be on removed leaves and not on remaining head.
5. Explain that oranges, apples, potatoes, etc. can be peeled to remove contamination, but care must be used to keep contamination from transferring to freshly peeled surfaces.

PRECAUTIONS:

1. Wear gloves when touching contaminated items.
   (1) Remove glove or gloves aseptically when not needed.
   (2) Have paper ready on which to lay gloves, lettuce leaves, and banana peel.
2. Use GM counter to locate contamination on objects. *
3. Collect all radioactive contaminated paper, etc. and burn it in an incinerator.
4. Rinse thoroughly all reusable utensils, such as ash trays, and flush sink with plenty of water.

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* Placing the microphone of a public address system against the earphone of a GM unit will make the noise audible to a large group.

EXERCISE NO. 2

Demonstration of Use of Foods in Contaminated Cans

1. Exhibit can of orange juice contaminated on one end.
   - a. Contaminate can with p32 solution prior to class.
   - b. Use GM counter to locate contamination.
2. Swab off contamination with tissue soaked in alcohol (methyl alcohol will do) or other combustible solvent.
   - a. Use gloves for protection.
   - b. Place swabs in ash tray.
   - c. Confirm decontamination of can with instrument.
3. Open can aseptically and pour contents into a clean glass.
   - a. After decontamination of can top is complete.
   - b. Check glass contents for radioactivity with instruments before drinking.

EXERCISE NO. 3

Demonstration of Problem of Radioactive Waste Disposal

1. With Geiger-Muller counter show swabs in ash tray to be contaminated.
2. Ignite swabs with a match. (Explaining that alcohol was used instead of soap and water so this could be burned promptly.)
3. With instrument, show that the radioactivity remains in the ash.
    - a. Point out that radioactivity cannot be destroyed.
    - b. Warn that some volatile radioactive compounds (such as iodine) would disperse when heated.

EXERCISE NO. 4

Decontamination Practice for Stude

1. Apply not to exceed 1/2 microcurie p32 solution to glass or chinaware (window-glass or old china which is ready to be discarded.)
    - a. Avoid contaminating skin.
    - b. Daub on with moist swab.
2. Have students wash the object to decontaminate.
    - a. Use soap and brush as necessary.
    - b. Check progress with CD V-700.
3. Explain surgical scrub technique. (Section II 3, National Bureau of Standards handbook 48, Control and Removal of Radioactive Contamination in Laboratories.

ANNEX 1 TO LESSON PLAN NO. 6

A leaflet, ML-14, entitled "Some Suppliers of Generally Licensed Quantities of Byproduct Material (Radioisotopes)" can be obtained from the Isotopes Division, U. S. Atomic Energy Commission, Washington 25, D. C. The following companies have indicated a willingness to furnish generally licensed quantities of phosphorus 32 on request.

Oak Ridge Scientific Developments, Inc.
P.O. Box 124
Oak Ridge, Tennessee

Bio-Rad Laboratories
Radiochemicals Division
800 Delaware Street
Berkeley, California

Atomic Research Laboratory
10717 Venice Blvd.
Los Angeles, California

Abbott Laboratories
Oak Ridge Division
Oak Ridge, Tennessee

Nuclear Consultants, Inc.
3361 Crescent Street
Long Island City, New York

Nuclear Research Corporation
Southampton, Pennsylvania

NUCLEAR SCIENCE SELECTED REFERENCE MATERIALS

This bibliography is designed to be an aid in locating additional material suitable for developing nuclear science concepts and understanding.

The publications listed should be requested from the publisher at the address indicated. They are not available for issue through the Office of Civil and Defense Mobilization.

Books

ATOMIC ENERGY COMMISSION. Major Activities in the Atomic Energy Program. U. S. Government Printing Office, Washington, 1956. 256 pp. $1.25.

A general report covering various political, economic, and scientific activities. The activities include production and application of nuclear material as well as reports on international cooperation and control of atomic energy. The appendix contains a bibliography and a current list of regulations controlling the use of nuclear material.

ATOMIC ENERGY COMMISSION. Progress Report on Atomic Energy Research: Hearings Before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy, Congress of the United States. U. S. Government Printing Office, Washington, 1956.

A collection of illustrated reports describing research using radioactive isotopes in medicine, biology, agriculture and food preservation. The material is clearly written to be understood by those with limited science background. A good book for secondary students and teachers.

ATOMIC ENERGY COMMISSION. The Effects of NUCLEAR WEAPONS. U. S. Government Printing Office, Washington, 1957. 579 pp. $2.00.

This handbook is a comprehensive summary of current knowledge on the effects of nuclear weapons. Within the limitations of national security, the basic phenomena and the most recent data concerning the effects associated with explosions of nuclear weapons are described. In the final chapter some general conclusions are presented upon which protective measures may be based.

BORN, MAX. The Restless Universe. Dover Publications Inc., New York, 1951, 315 pp. $3.95.

This is probably one of the most unusual and helpful books ever written about modern physics. It includes on page 31 an excellent method of demonstrating how the physicist measures the size, weight and number of molecules in a given mass. The last 134 pages are devoted to nuclear physics. It is probably one of the best efforts ever made to translate complicated formulas into words.

BRADLEY, DAVID. No Place to Hide. Little, Brown and Company, Boston, Mass., 1948. 182 pp. $2.00.

"No Place to Hide" is the log of a doctor assigned to the Bikini atom tests. The first of these tests took place in 1946. This day-by-day account is a human, factual, interesting account of one man's experience during several bomb tests on an island in the Pacific.

COMAR, C. L. Radioisotopes in Biology and Agriculture. McGraw-Hill, New York, 1955, 481 pp. $9.00.

This book is written for the college student and the investigator interested in the use of radioisotopes in the solution of biological and agricultural problems. Chapters 1, 3, 5, 6, 8, 9, and 10 should be especially helpful to the high school science teacher who requires a good reference book in basic tracer methodology. In chapter 1 the basic tracer formulas are given with numerical examples.

COMPTON, ARTHUR HOLLY. Atomic Quest. Oxford University Press, New York, 1956, 370 pp. $5.00.

This is a personal story about the release of the atom's energy. It is a story full of dramatic incidents and top-level decisions that is told with sincerity, modesty, and humor. It traces the work on the atom bomb from the presentation of the project to President Roosevelt to its use in Japan. The fifth and last section of the book analyzes the military and social consequences of the release of atomic energy along with its many future peacetime uses.

DE BROGLIE, LOUIS. Physics and Microphysics. Pantheon, New York, 1955, 286 pp. $4.00.

The author presents a series of lectures on the subject of physics, scientific philosophy and the history of the sciences. The first few chapters are of interest to the teacher and general reader. These chapters deal with historical theories as well as present theories in regard to matter, atomic particles, light properties, wave mechanics and corpuscular optics.

FEINBERG, J. G. The Atom Story. Philosophical Library, New York, 1953, 243 pp. $4.75.

A British author traces the history of the atom from the beginning of recorded history down to the present day and even includes some speculation as to the future uses of nuclear radiation. A very readable account for the better high school student and a most satisfying book for the teacher. It is strong on personalities and human interest accounts.

FERENCE, MICHAEL, JR., et al. Analytical Experimental Physics. University of Chicago Press, Chicago, 1956, 623 pp. $8.00.

A first-year college text. It is very helpful to the high school science teacher with a physical science background who desires a thorough summary of the whole field of isotopes and nuclear processes.

FLANOGAN, DENNIS, et al. Atomic Power. Simon and Schuster, Inc., New York, 1955, 180 pp. $1.00.

This is a book that deals with the constructive, beneficial or peacetime uses of energy liberated from the atomic nucleus. The book presents an authoritative account of the information that the layman needs to arrive at intelligent understanding and opinion in this field. The book demonstrates that no single nation has a monopoly on atomic energy and that this energy is no more mysterious than electricity or steam and no less natural.

GAMOW, GEORGE. The Birth and Death of the Sun. The New American Library, New York, 1952. 212 pp. $.50.

A discussion of nuclear physics as it relates to the sun's energy. Suitable for the teacher and the better high school student.

GLASSTONE, SAMUEL. Sourcebook in Atomic Energy. D. Van Nostrand Company, Inc., New York, 1950. $4.40.

This is a standard sourcebook on Atomic and Nuclear Science today. Widely received as a balanced guide to all aspects of atomic energy by countless thousands - scientists, laymen, teachers, and students alike - it brings together the important facts about past history, current status, and possible future in a vital new field.

HABER, HEINZ. Our Friend the Atom. Simon and Schuster, New York, 1956, 165 pp. $4.95.

Traces the historical development of atomic theory from the beginnings of history to the present. The emphasis on people who have contributed to this development helps to stimulate reader interest. The elaborate illustrations by Walt Disney Productions aid in the understanding of the text which is written in a manner sufficiently simple for the high school pupil with average reading ability. Concludes with discussion of peaceful uses of nuclear energy. (Also available as a paper bound booklet: Haber, Heinz. Our Friend the Atom. Dell Publishing Company, Inc., New York, 1956, 128 pp. $.35)

HECHT, SELIG. Explaining the Atom. Viking Press, New York, 1955. 237 pp. $3.75.

An unusual book because it really succeeds in explaining the structure of the atom and the processes by which it can be made to give up its energy, all in terms that the average reader can readily grasp and understand. The revision and the chapters on the recent advances in nuclear study by Professor Rabinowitch have made the book a source of the best knowledge of current studies.

HEISENBERG, W. Nuclear Physics. Philosophical Library, New York, 1953, 224 pp. $4.75.

A book that has proved helpful to the high school science teacher who is making a thorough study of nuclear physics with a time limitation.

HEVESY, GEORGE. Radioactive Indicators. Dober Publications Inc., New York, 1948, 556 pp. $1.98.

This is a survey of work carried out in the fields of animal physiology, pathology and biochemistry with the aid of radioactive isotopes. It is helpful to students or teachers who wish more information on the above topics.

HOFFMAN, M. DAVID, ED. Readings for The Atomic Age. Globe Book Company, New York, 1950, 406 pp. $2.80.

This book is made up of twenty-eight articles about the atomic bomb written by experts in various fields. These twenty-eight articles are divided into four areas. Part I is entitled "The Dramatic Impact of the Atomic Bomb," Part II is "The Development of the Atomic Bomb," Part III is "Science Opens Up a New World," and Part IV "Looking Forward." Also included is a part devoted to "Teaching Aids and Glossary."

HUMPHREYS, RICHARD F. AND BERINGER, ROBERT. First Principles of Atomic Physics. Harper and Brothers, New York, 1950, 380 pp. $4.50.

A college text intended for the student of the humanities or the social sciences. The first half of the text is essentially a review of basic physical principles such as the conservation of momentum, which are essential to understanding atomic and nuclear phenomena. The second part of the book is devoted to atomic and nuclear phenomena. It is an excellent text for the science teacher who isn't a specialist in physics or chemistry.

LAWRENCE, WILLIAM L. The Hell Bomb. Alfred Knopf, New York, 1951, 198 pp. $2.00.

> The material in this book is factual material on the hydrogen bomb. The information was obtained from Los Alamos in 1945. It debates pro and con the subject "shall we renounce the use of the H-Bomb" and briefly outlines international control of atomic weapons.

LIBBY, WILLARD. Radiocarbon Dating. University of Chicago Press, Chicago, 1955, 175 pp.

> This book gives the principles of radiocarbon dating, world-wide distribution of radiocarbon, half life of radiocarbon, how the sample is prepared and measured, and some actual dates established by this method.

NAVPERS. Atomic Warfare Defense. Navy Training Courses. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 1955. 182 pp. $.65.

> Written for the Navy enlisted men, it is complete on atomic defense and will be easily understood by the student.

STOKLEY, JAMES. The New World of the Atom. Ives Washburn, Inc., New York, 1957, 282 pp. $5.50.

> This book is well written in an easy-to-read style for the general reader. It discusses the historical development of the atomic bomb, including the activities of many scientists, and the possible uses of nuclear energy as a fuel. It also lists different reactors now in use in various countries of the world and describes them. The book then goes on to consider uses of the atom in industry, agriculture, medicine, and biology.

TITTERTON, E. W. Facing the Atomic Future. St. Martins Press, 103 Park Avenue, New York, 1956. 379 pp. $5.00.

> This book is aimed at informing the layman about the many problems facing the world because of nuclear energy. It is divided into three major parts with extensive discussion of each. These parts are Atoms for Peace, Atoms for War, and the Social and Political Problems of Atomic Energy.

WENDT, GERALD. You and the Atom. Whiteside Inc., and Wm. Morrow and Company, New York, 1956, 96 pp. $1.95.

> A concise statement on peaceful uses of nuclear energy including essential background information on atomic theory suitable for senior high school pupils with above average reading ability and an interest in the topic. Includes an index with definitions of terms and a brief bibliography.

MISCELLANEOUS PUBLICATIONS

"THE ATOM IN OUR HANDS"
Union Carbide & Carbon Corp., 30 E. 42nd St., N. Y. 17. Free.

"ATOMIC POWER AND SAFETY"
Consolidated Edison Co., 4 Irving Place, N. Y. 11 p. Free.

"101 ATOMIC TERMS"
Eger Murphee, Esso Research & Eng. Co., 1956. Free.

"FREE AND INEXPENSIVE LITERATURE RELATING TO ATOMIC ENERGY"
American Museum of Atomic Energy, P. O. Box 117, Oak Ridge, Tennessee. Free.

"READING LIST - ATOMIC ENERGY FOR ALL AGES"
American Museum of Atomic Energy, P. O. Box 117, Oak Ridge, Tennessee. Annotated. Free.

"A BIBLIOGRAPHY OF CURRENT MATERIALS DEALING WITH ATOMIC POWER AND RELATED ATOMIC ENERGY SUBJECTS FOR NON-SPECIALISTS."
J. and E. Boswell, University of Michigan Fund for Peaceful Atomic Development. 1955. $1.25.

"ANNOTATED CIVIL DEFENSE - BIBLIOGRAPHY FOR TEACHERS"
Federal Civil Defense Administration, U. S. Government Printing Office, 1956. $.35.

"SELECTED READINGS ON ATOMIC ENERGY"
Atomic Energy Commission, Superintendent of Documents, 1954.

"THE BIOLOGICAL EFFECTS OF ATOMIC RADIATION" (Summary Reports)
National Academy of Sciences, National Research Council, Washington, D. C.

"PATHOLOGIC EFFECTS OF ATOMIC RADIATION"
National Academy of Sciences, National Research Council, Washington, D. C.

"CUE FOR SURVIVAL" - A. E. C. Menoda Test Site 1955. Federal Civil Defense Administration, U. S. Government Printing Office, Washington 25, D. C. $.50.

"EDUCATION FOR NATIONAL SURVIVAL" - A Handbook on Civil Defense for Schools. U. S. Dept. of Health, Education and Welfare, U. S. Government Printing Office, Washington 25, D. C. $.65.

"EFFECTS OF ATOMIC EXPLOSIONS ON WEATHER"
Article in Science Magazine, Jan. 21, 1955. Authors: L. Machta and D. L. Harris.

"NUCLIDES AND ISOTOPES"
General Electric Company. Free.

"THE PETRIFIED RIVER" (The Story of Uranium)
Union Carbide and Carbon Corp., 30 E. 42nd St., N. Y. 17, N. Y.
Free.

"RADIATION AND MONITORING FUNDAMENTALS FOR THE FIRE SERVICE"
International Association of Fire Chiefs, Hotel Martinique,
Broadway at 32nd St., N. Y. 1, N. Y. 1955. $1.00.

"THE WORLD WITHIN THE ATOM"
Westinghouse Electric Corp., 401 Liberty, Pittsburgh 30, Pa.,
1953. Free.

"RADIOACTIVE FALLOUT" PA - 7 FCDA
U. S. Government Printing Office, Washington, D. C. $.30.

"FACTS ABOUT FALLOUT PROTECTION" FCDA L-2-18
U. S. Government Printing Office, Washington, D. C. $.05.

"RADIOISOTOPES IN AGRICULTURE"
American Museum of Atomic Energy, Box 117, Oak Ridge, Tennessee.
Free.

"SHOULD YOU BE AN ATOMIC SCIENTIST?"
New York Life Insurance Company. Free.

"SPONSORS HANDBOOK"
Science Clubs of America, Washington, D. C.

"YOU CAN UNDERSTAND THE ATOM"
U. S. Atomic Energy Commission. Free.

"USING ATOMIC ENERGY IN THE SERVICE OF MANKIND"
Metropolitan Life Insurance Co., Free.

Periodicals

Many excellent periodicals publish articles appropriate for use with high school students in the area of nuclear energy. Those listed are suggested and perhaps the most popular.

"Scientific American" - $5.00

Scientific American Inc.
415 Madison Avenue
New York 36, New York

"School Science and Mathematics"	- $4.50

Central Association of Science and
Mathematics Teachers
P. O. Box 408
Oak Park, Illinois

"Science Magazine"	- $7.50

American Association for the
Advancement of Science
1515 Massachusetts Avenue, N. W.
Washington 5, D. C.

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Appendix 1

civil defense
Technical Bulletin
TB - 11 - 1
(Revised August 1956)
(Reprinted October 1958)
A DIGEST OF TECHNICAL INFORMATION

EMERGENCY EXPOSURES TO NUCLEAR RADIATION

Civil defense authorities recognize that exposure to certain amounts of ionizing radiation will be accepted in some operational situations on a calculated risk basis along with other hazards of war. Trained medical personnel (radiological defense medical officers) will be responsible for evaluating the radiological situation in terms of human hazards and for advising the local civil defense director or his representative. The civil defense director must sufficiently appreciate the effects of radiation so that he will be able to utilize this advice in making operational decisions. Material contained in this bulletin is consistent with the thinking of the military and nonmilitary governmental and private authorities in this field.

As with any hazard, the cardinal principle must be: AVOID ALL UNNECESSARY EXPOSURE. Training activities should involve no more than the maximum permissible exposure of 0.3 r (roentgens) per week; most of them can, and should be, carried out at exposures far less than this.

In EMERGENCY operations where appreciable amounts of radiation are present, one should not hesitate to accept an exposure to the whole body of 25 r in a single day.

Operational decisions may be guided by a consideration of the following statements. An acute dosage of 50 r to a group of people will not appreciably affect their efficiency as a working unit. Acute dosage of 100 r will produce nausea and vomiting in occasional individuals, but not to an extent that will render personnel ineffective as groups. People receiving an acute radiation exposure of 100 r or more should be relieved from duty, if possible, and a report made to the staff medical advisor within a week. It should be assumed that if working units receive acute radiation doses substantially above 100 r, they will rapidly become ineffective.

Acute dosage of approximately 150 r or greater can be expected to render personnel as a group ineffective in a few hours through a substantial incidence of nausea, vomiting, weakness, and prostration. Mortality produced by an acute dose of 150 r will be very low, and eventual recovery of physical fitness usually may be expected.

In an emergency it may become necessary to make decisions regarding repeated exposures. The following statement may be used as a "rule of thumb" guide: exposure of 25 r per day at weekly or longer intervals for a total of eight exposures (200 r) may be experienced without serious loss of efficiency due either to illness or significant general deterioration in health and ability. Before each probable re-exposure, the degree of radiation damage already produced and that to be expected should be evaluated. Although not strictly true, to be on the safe side repeated daily exposures should be considered to be directly additive.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF CIVIL AND DEFENSE MOBILIZATION

REFERENCES

Selected OCDM Publications[1]

The following publications can be obtained from the local civil defense organization or purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at nominal cost:

Effects of Nuclear Explosions Upon Drugs, TR-11-1, 1955.
Emergency Measurements of Radioactivity in Food and Water, TB-11-9, Dec. 1952
Fallout and the Winds, TB-11-21, Oct. 1955, Revised Feb. 1956.
Medical Aspects of Nuclear Radiation, TB-11-24, July 1956.
Permissible Emergency Levels of Radioactivity in Water and Food, TB-11-8, Dec. 1952, Reprinted Sept. 1955.
Protection Against Fallout Radiation, TB-11-19, Sept. 1955.
Radiation Physics and Bomb Phenomenology, TB-11-22, Dec. 1955, Revised June 1956.
Radioactive Fallout Problem, The, TB-19-1, June 1955.
Radiological Decontamination in Civil Defense, TM-11-6, 1952, Reprinted July 1955.
Radiological Instruments for Civil Defense, TB-11-20, Sept. 1955.

Other Publications

The Effects of High-Yield Nuclear Explosions, Statement by Lewis L. Strauss, Chairman, and a Report by the U. S. Atomic Energy Commission, Feb. 1955.
The Effects of Nuclear Weapons, U. S. Department of Defense and the U. S. Atomic Energy Commission, June 1957.
Fallout of Radioactive Debris From Atomic Bombs, Circular Letter 16-54, May 27, 1954, Weather Bureau, U. S. Department of Commerce.
Radioactive Fallout, Bulletin of Atomic Scientists, Ralph E. Lapp, Feb. 1955, pp. 45-51.

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[1] The designation "Federal Civil Defense Administration" (FCDA) on these publications will be changed to "Office of Civil and Defense Mobilization" (OCDM) as the publications are reprinted or revised.

Appendix 2

civil defense Technical Bulletin

TB-11-8
December 1952
(Reprinted October, 1958)

A DIGEST OF TECHNICAL INFORMATION

PERMISSIBLE EMERGENCY LEVELS OF RADIOACTIVITY IN WATER AND FOOD

This bulletin, intended for radiological and health officials, describes the maximum permissible levels of radioactivity in water and solid or liquid foods to be consumed in the period immediately following an atomic explosion. These emergency levels are consistent with those being used by the Atomic Energy Commission, the Department of Defense, the U. S. Public Health Service, and the Food and Drug Administration.

Radioactive Contamination

Responsible officials should know the maximum contamination levels that can be tolerated during the emergency period, and should be equipped to monitor foods and water that are suspect. Consumption of food or drinking water containing appreciable concentrations of radioactive material, in terms of peacetime limits, may be permitted for short periods of time under emergency conditions. Table 1 gives the maximum levels of beta-gamma activity, and table 2 the maximum levels of alpha activity that should be tolerated for the stated estimated consumption periods.

Values in table 1 on beta-gamma activity are applicable only during the month immediately following an atomic bomb burst. After 1 month, these values should not be used because a greater portion of the radioactivity will be due to the more hazardous longer-lived fission products and a more complete study which may include a radiochemical analysis is necessary.

During the first month it may be assumed that food and water adjudged safe from a beta-gamma measurement do not contain hazardous quantities of alpha emitters.

TABLE 1.—*Acceptable Beta-Gamma Activity**

Estimated consumption period	µc/cc	dps/cc
10 days	9×10^{-2}	3×10^{3}
30 days	3×10^{-2}	1×10^{3}

* See footnote for Table 2.

Values given in table 2 on alpha activity are not limited to the month immediately following an explosion but apply as emergency values to any 10- or 30-day period.

TABLE 2.—*Acceptable Alpha Activity**

Estimated consumption period	µc/cc	dps/cc
10 days	5×10^{-3}	180
30 days	1.7×10^{-3}	60

*The curie (c) is a unit of radioactivity representing 3.7×10^{10} disintegrations per second (dps). The microcurie (µc), one millionth of a curie, is a more convenient unit and the concentrations of radioactivity are expressed in microcuries per cubic centimeter (µc/cc).

Application of These Emergency Values

These are not peacetime permissible limits of radioactivity in water and food for either long- or short-term consumption. Responsible officials can utilize these values during emergency periods with the conviction that water and food contaminated below these limits can be used with no real hazard.

Nonperishable foods too contaminated by beta-gamma emitters for immediate consumption should not be destroyed because natural decay of radioactivity will reduce the radiation to safe values.

Detecting Contamination in Food and Water

Many standard commercially available instruments are sufficiently sensitive to detect these emergency levels. Almost any instrument with a gamma sensitivity of 0-5 mr/hr (1 milliroentgen per hour equals 0.001 roentgen per hour) and capable of detecting beta radiation is satisfactory.

Bibliography

"Handbook of Atomic Weapons for Medical Officers," issued by the Departments of the Army, Navy, and Air Force under the designations: DA Pamphlet 8-11; NAV MED P-1330; AFM 160-11. June 1951.

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Appendix 3

civil defense Technical Bulletin

TB - 11 - 9
December, 1952
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A DIGEST OF TECHNICAL INFORMATION

EMERGENCY MEASUREMENTS OF RADIOACTIVITY IN FOOD AND WATER

Immediately after a nuclear attack, communities must be in a position to determine quickly if available food and water are sufficiently free of radioactive contamination to permit their consumption. The rapid evaluation of this hazard is essential not only to prevent ingestion of dangerous amounts of radioactive material, but also to avoid the equally serious mistake of denying a stricken community access to drinking water and food which could be used with safety.

This bulletin presents a method of measuring radioactivity in food and drinking water, and describes a method of preparing a radioactive comparison standard designed to provide a check against the following 10- and 30-day acceptable beta-gamma concentrations.

Acceptable Beta-Gamma Activity

Estimated consumption period	μc/cc	dps/cc
10 days	9×10^{-3}	3×10^{2}
30 days	3×10^{-3}	1×10^{2}

Method of Measurement

Almost any convential beta-gamma geiger counter with a scale of 0-20 mr/hr, or OCDM CD V-700, "Radiological Survey Meter, Geiger Counter, Probe Type, Beta-Gamma, Discriminating," may be used with a comparison standard in making the measurements. Although it is preferable to have two standards, one comparable to the 30-day activity and one comparable to the 10-day activity, adequate measurements may be made with only one. If the standard is comparable to the 10-day acceptable limit, the geiger counter reading is divided by three when making the 30-day checks; and conversely, if the standard is for the 30-day check, the reading is multiplied by three for the 10-day measurement. The following procedure should be followed:

(*a*) Turn on the geiger counter, open the beta shield, and observe the reading. If the background gives an appreciable indication on the least sensitive scale (0–20 or 0–50 mr/hr), the area or the instrument is too contaminated, and measurement should be made in another area or with another instrument. If there is no appreciable indication on this scale, the instrument and location are satisfactory.

(*b*) Place the standard face up on a level surface. Turn the geiger counter selector switch to the least sensitive scale and place the probe, with the beta shield open, across the standard with the exposed part of the geiger tube facing the standard. The probe should rest on the edge of the standard container, or a jig should be used so that the exact position of the probe may be reproduced. The instrument reading should be noted.

(*c*) Fill or pack the suspected food or water to a depth of at least 2 mm. in a container the same size as the standard. A greater depth may be used, if necessary, to permit positioning the probe the same distance from the sample's surface as it was from the standard's surface. (If standard 4-oz. ointment tins are used, the container should be filled to the indentation circling the tin.) Place the probe, again with the beta shield open, in exactly the same position with respect to the surface of the sample as it was with respect to the standard. If the reading is less than that of the standard, the food or water may be used for the period indicated.

Other types of instruments that have sufficient sensitivity, such as ionization chamber instruments and scintillization counters, may be used. However, a comparison standard suitable for use with a geiger counter is not necessarily suitable for use with other types of equipment.

Preparation of Comparison Standards

The following applies to preparation of a standard comparable to the 10-day acceptable value and suitable for use in the procedure described above. Each standard should contain 3.0 gm. of finely powdered (60 mesh) uranyl acetate $[UO_2(C_2H_3O_2)_2\ 2H_2C]$ embedded in 5.0 gm. of liquid casting plastic. The standards may be prepared in batches of five by weighing out six times the quantity of each ingredient into a 100 ml. beaker. (The 20 percent excess allows for

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material adhering to the beaker.) After thoroughly mixing with a narrow glass rod, 6 to 8 drops of hardening catalyst should be added, and the mixture stirred for 5 minutes. Standard 4-oz. ointment tins (7.9 x 2.3 cm.) should be used and the inner surfaces should be swabbed with carbon tetrachloride (CCl_4) to remove any adhering film of grease. Eight gm. of the mixture should be weighed into each lid, which should then be rotated by hand to provide a uniform layer. Lids should be heated on a hot plate at a low heat until the plastic begins to harden. The lids should then be removed from the hot plate because overheating will cause the plastic to separate from the lid.

Other uranium compounds might be employed, including oxides as well as salts, in an amount proportional to the desired uranium content. Any plastic embedding material might be used, but the so-called cold setting type is preferred over those that require high temperature polymerization. Both the plastic and catalyst may be obtained in small quantities from hobby shops.

References

"Survey Meters for Water Monitoring," Hursh, J. B., Zizzo, S., and Dahl, A. H. Nucleonics, vol. 9, No. 5, November 1951.

"Permissible Emergency Levels of Radioactivity in Water and Food," TB-11-8, OCDM.

For sale by the Superintendent of Documents, U. S. Government Printing Office Washington 25, D. C. - Price 5 cents

GPO 615708

Appendix 4

civil defense
Technical Bulletin

TB - 11 - 19
September 1955
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RADIOLOGICAL DEFENSE SERIES

A DIGEST OF TECHNICAL INFORMATION

PROTECTION AGAINST FALLOUT RADIATION

This technical bulletin, one of a series on radiological defense, describes the phenomena of radioactive fallout, and gives basic precautions to be taken by people caught in the open or required to remain in contaminated areas.

When an atomic or thermonuclear device is detonated near the ground, great masses of pulverized debris are sucked upward, sometimes to heights of 80,000 feet or more. Radioactive material released by the explosion and vaporized by its heat condenses on the tiny debris particles and is subquently carried back to earth as dust. This is fallout.

Radioactive fallout has a physical behavior and appearance similar to any other dust with the same particle sizes and distribution. The time it takes to fall back to earth after the explosion varies from a few minutes to many hours, depending on the size of the particles and where they were in the cloud. Where it falls depends on the velocity and direction of winds in the altitudes through which it has traveled. The duration of fallout also varies, depending on the same conditions.

In general, fallout descends vertically. However, it will be diffused and if a wind is blowing, will travel in a lateral direction with the wind. Therefore, during fallout, both overhead and side protection are necessary. Since not all dust particles may be visible to the naked eye, the only certain method of determining whether or not fallout is present is detection by radiological instruments. After an atomic attack, dust clouds or unusual dust concentrations in the atmosphere should be assumed to be radioactive until they have been officially surveyed with such instruments.

COMPONENTS OF RADIOACTIVE FALLOUT

Radioactive material released by an atomic explosion consists of: (1) particles created by the fissioning of the material of the bomb, (2) particles made radioactive by the neutrons released at the time of explosion, and (3) the unfissioned material of the bomb itself. The unfissioned material is generally alpha-emitting, while the fission products and the neutron-induced radioactive products are beta-gamma-emitters.

(1) Alpha radiation cannot penetrate the skin. Consequently the alpha-emitters in fallout present no great danger unless taken into the body by ingestion, inhalation, or through open wounds. The relative proportion of alpha-emitters in fallout to beta-gamma-emitters is small.

(2) Beta radiation can be dangerous both internally and externally. The beta particles emitted by fallout are stopped by moderately thick clothing. They are most hazardous when the radioactive dust carrying them comes into direct contact with the skin or is taken internally.

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(3) Gamma rays, like x-rays, are very penetrating. Fallout gives off gamma rays varying in energy from very soft and easily absorbed, to very hard and penetrating. Therefore, even relatively thin shields afford some protection against gamma rays since they absorb the softer components of the radiation. To provide adequate protection against the more energetic gamma rays, considerable thicknesses of materials are required.

PROTECTION FROM FALLOUT

Three basic measures give progressively greater protection against fallout radiation.

(1) *Protection from radioactive dust.* Persons caught in fallout should take any cover available. The dust may descend from the atmosphere or be stirred up by the wind, traffic movement, or other means. It should be kept off the skin and from entering the body. Persons caught in the open should cover their mouths with handkerchiefs and protect all parts of their bodies, so far as possible. The dust should be brushed or washed off immediately.

(2) *Additional protection against beta and low energy gamma rays.* Since the most severe dose from the beta radiation occurs if the radioactive particles are in direct contact with the skin, the primary precaution of keeping it off or washing it off as pointed out in (1) above should be followed. Moderate thicknesses of material, such as heavy shoes and clothing, provide additional protection. After the fallout has settled, the dust, although primarily on the ground, will cling to ledges and to a lesser extent to the sides of buildings. Extreme care should be taken to avoid contact with it either by touching or bringing the unprotected face close to it. When it is necessary to walk through or work in a contaminated area, heavy clothing and heavy shoes or boots should be worn. Beta radiation is rapidly absorbed in the air, thus distance provides good protection—four or five feet will stop most of the beta radiation from fallout.

(3) *Protection against gamma radiation;* The basic requirement for protection against any radiation is to get material between you and the source of the radiation so its energy will be absorbed before it gets to you. The greater the thickness and the denser the material, the better. The concept of "half-thicknesses" is useful in understanding the absorption of gamma radiation. If a particular thickness of material, say one-half inch of lead, reduces the gamma intensity by one-half, the next half inch will not reduce the intensity to zero, but will cut it by another half, giving a total reduction of three quarters. The next "half-thickness" would give a reduction to one-eighth, the next to one-sixteenth, etc. Theoretically, the intensity would never go to zero. However, for practical purposes a reduction to zero is not required.

A reduction of about 5000 will give adequate protection from gamma rays from fallout. This would require about 12 "half-thicknesses", for example, about 36 inches of earth, 24 inches of concrete, or 3 inches of lead. Twelve "half-thicknesses" made up of combinations of materials would give the same protection. A "half-thickness" of air is about 200 feet.

Obviously this third measure, which gives the greatest protection, is the most desirable. However, if this is not possible, the other precautions should be rigorously observed. The degree of protection they afford is significant and could provide the margin of safety that would save lives.

Gamma radiation travels in straight lines, but like light it can be scattered around corners. The amount of energy scattered will depend on the angle, size of the opening and distance from the point of scatter. For example, if the opening is the size of an ordinary door, the angle of scatter 90°, and point of measurement about three feet along either side of the opening, the radiation would be reduced to about one or two percent. Another 90° angle of scatter would further reduce the dose rate to two percent of two percent or about 4 ten-thousandths (0.0004). Thus, a winding entrance or one of the maze type into a building or cave, would provide significant protection. Of course, the dust must be kept out, since it is the source of the radiation.

As fallout accumulates, the dose rate builds up, since more of the emitting material will be in the immediate vicinity—in the air and on the ground. After the material has settled, however, the dose rate will begin to decrease through natural decay of the radioactive elements.

Studies made to determine the rate at which this decay occurs have indicated that the following equation is generally applicable:

> $I = I_1 t^{-1.2}$ where I is the radiation dose rate at any time t, I_1 the dose rate at unit time, and t the time measured from the instant of detonation.

However, this holds only if the fallout radiation is composed of fission products. It will be changed if neutron-induced activity is present. Weathering also will have a pronounced effect. However, the $t^{-1.2}$ calculation can be used for rough planning purposes and provides a basis for predicting dose rates and doses. To facilitate calculations, charts and slide rules have been developed. (Slide rules are available commercially; charts will be contained in a subsequent bulletin in this series.) In an operational situation, it would be necessary to make periodic measurements to follow the rate of decrease and to use dose measuring devices for determining the doses accumulated by people in the area.

If slide rules and charts are not available, very rough predictions of expected radiological situations can be made, using the rule of thumb that dose rate will vary inversely with time. Time may be expressed in any convenient unit—days, hours, minutes.

As examples:

> If the dose rate is measured 1 hour after burst as 60 r/hr (the roentgen is the unit of radiation measurement) it would reduce to 1/2 (30 r/hr) at 2 hours after burst; to 1/3 (20 r/hr) at 3 hours; and to 1/4 (15 r/hr) at 4 *hours; etc. (If* $t^{-1.2}$ *is used in the calculation and the dose rate is* 60 *r/hr at* 1 *hour, the dose rate would be* 26 *r/hr at* 2 *hours,* 16 *r/hr at* 3 *hours,* 11.5 *r/hr at* 4 *hours, etc.*).
>
> If the dose rate is measured at 16 hours its value at 17 hours would be 16/17 (0.94) of the measured 16-hour value; at 18 hours, 16/18 (0.89) etc. (*Using* $t^{-1.2}$ *the dose rate would be* 0.93 *at* 17 *hours,* 0.87 *at* 18 *hours, etc.*)
>
> If measured at 3 days, the dose rate would be 1/3 that measured at one day; at 4 days, 3/4 (0.75) the measured 3-day value; at 5 days, 3/5 (0.60) etc. (*Using* $t^{-1.2}$ *the dose rate at* 4 *days would be* 0.71 *that measured at one day, at* 5 *days* 0.54; *etc.*)

Doses may be calculated by using the average intensities between the times in question and multiplying by the time of exposure.

> In the first example above, the dose between one and three hours would be $\frac{60 + 20\text{ r/hr}}{2} \times 2$ hours, or 40 r/hr × 2 hours = 80 roentgens. (*Using* $t^{-1.2}$ *the dose would be* 60 *roentgens.*)

Greater mathematical accuracy may be obtained by taking more points for the average. However, mathematical refinement is not necessary since this is an approximation.

This rough method gives answers which are on the safe side as compared with those obtained by using the more complicated formula. Any of these equations, no matter how complex, is good only for estimates. Answers must be obtained through actual measurement.

REFERENCES

The Agency designation "Federal Civil Defense Administration" (FCDA) on publications listed below will be changed to "Office of Civil and Defense Mobilization" (OCDM) as the publications are revised.

Emergency Exposures to Nuclear Radiation. TB-11-1. Revised August 1956.

Emergency Measurements of Radioactivity in Food and Water. TB-11-9, December 1952.

Fallout and the Winds, TB-11-21, October 1955. Revised February 1956.

Family Shelters for Protection Against Radioactive Fallout, TB-5-3, May 1958.

Medical Aspects of Nuclear Radiation, TB-11-24, July 1956.

Permissible Emergency Levels of Radioactivity in Water and Food, TB-11-8, December 1952. Reprinted, September 1955.

Radiation Physics and Bomb Phenomenology, TB-11-22, December 1955. Revised June 1956.

Radioactive Fallout Problem, The, TB-19-1, June 1955.

Radiological Instruments for Civil Defense, TB-11-20, September 1955. Revised September 1958.

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Appendix 5

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Technical Bulletin

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RADIOLOGICAL DEFENSE SERIES

A DIGEST OF TECHNICAL INFORMATION

RADIOLOGICAL INSTRUMENTS FOR CIVIL DEFENSE

This is one of a series of technical bulletins on civil defense against the radiological effects of nuclear weapons.

Nuclear radiation is not detected by any of the five human senses, but instruments have been developed which detect and accurately measure it. Such instruments are necessary equipment in civil defense. Field instruments are required which measure the beta and gamma radiation associated with fallout. Neutrons will be present in the initial radiation and alpha particles will be present in fallout. Their relative importance to the hazard from beta and gamma rays is such that field measurements of alpha and neutron radiation are not required.

There is no equivalent of combat experience upon which to base the requirements for radiological instruments. Test bombs of various yields have been detonated under various conditions. Many variables influence the concentration of residual radiation which might be encountered in civil defense—bomb size, place and height of detonation, type of bomb assembly, and meteorological conditions. This being so, it is not possible to predict accurately the radiation levels that could result from fallout. Moreover, the radiation effects upon people must be radiological defense's major consideration. People will have been in the fallout area, and emergency teams will be entering the area. Hence, for practical consideration of effect of radiation on personnel the gamma instrument must respond accurately to dose rates as high as 500 r/hr. Intense beta radiation fields would probably exist, so detection of beta radiation is required. No definite top limit for beta response has been chosen, but the instrument should read to several thousand rep (roentgen equivalent physical) per hour.[1]

Choosing the maximum sensitivity is much simpler. Rather small increments above background will need to be detected in checking contamination of food and water and personnel, and other circumstances where the early detection of above-normal concentrations of activity is important.

Instruments used in the measurement of radiation dose rate are required to have a direct reading scale. Blinking lights, audible warnings, or "go-no-go" indications are not satisfactory. The radiation dose rate should not be the criterion. Rather, dose rate times time, or dose rate times length of exposure, is the critical factor. Therefore, if a particular dose rate is chosen as the "go-no-go" value, the expected duration of the exposure is also fixed. Exposure time, as well as allowable dose, will depend on the urgency of the situation and cannot be determined beforehand.[2] Radiation dose rate meters are basically reconnaissance instruments. They provide the information required to make maps of contaminated areas which show rough contour lines of dose rates and indicate local hot spots. They provide the information required by civil defense officials in directing civil defense operations.

Estimates of exposures can be made on the basis of dose rate measurements, decay rates, and probable exposure time; but these estimates should be used for planning purposes only—the actual determination of exposures must be made by measurements. The dose measuring devices (dosimeters) must be self-indicating, that is, direct reading, if they are to be used by the wearer to check his accumulated exposure. OCDM recommends the use of two operational dosimeters: 0 to 20 r, and 0 to 100 r for use by the organized civil defense services. (See Fig. 1.) Where expected exposures are small, or where small repeated doses may be received, the lower range dosimeter is used. Dosimeters covering higher ranges are also recommended for these workers to measure exposures received at the time of the bomb burst or accidental or necessary over-exposures during post-explosion activities. Without such information, workers might be asked to undertake duties involving additional exposures which would be dangerous if added to previous substantial over-exposure.

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[1] Another bulletin in this series will contain a section on radiation units.

[2] Another bulletin in this series will cover emergency exposures to nuclear radiation.

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Survey Meters

There is no one simple yet sufficiently accurate instrument to measure all ranges of dose rate required. The extremes of sensitivity are not required in a single operation. OCDM therefore has recommended the use of three survey instruments. They are:

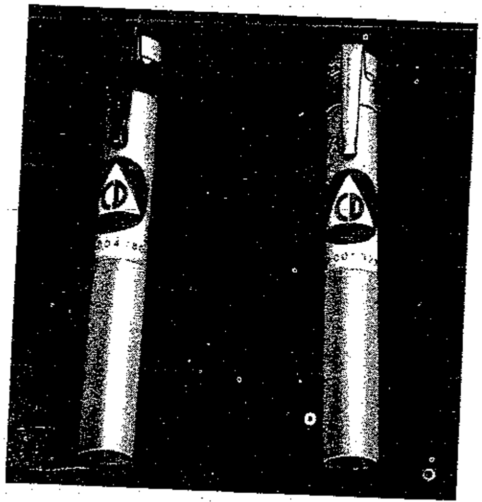

Figure 1.—Civil defense dosimeters.

(a) A beta-gamma discriminating geiger counter for the high sensitivity requirement, for long range follow-up, and for training purposes. (See Fig. 2.) This instrument is also suitable for food and water and personnel monitoring. The ranges are 0-0.5, 0-5 and 0-50 mr/hr, calibrated against gamma rays from cobalt 60 or radium. This instrument, like any other instrument designed for sensitive measurements, would have limited utility in an area of significant contamination since a relatively low background would drive it off scale. In such an event, the instrument would have to be used in an area well shielded from the fallout radiation where food, water, and personnel can be brought for the contamination checks. OCDM Standard Item Specification CD V-700.

Figure 2.—Geiger counter.

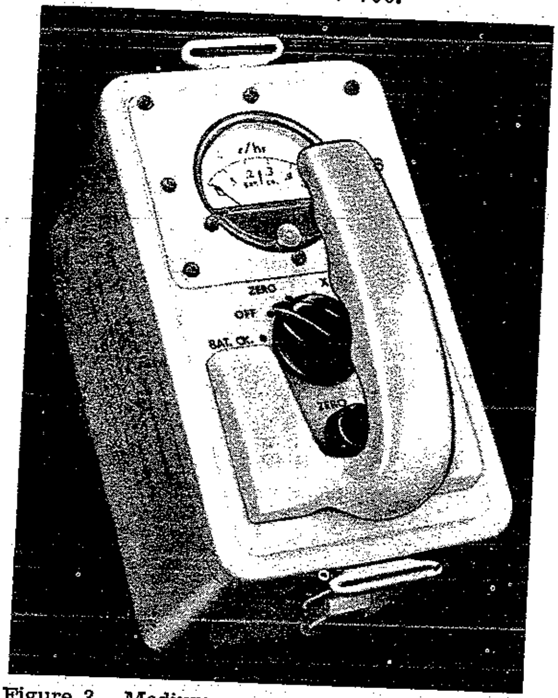

Figure 3.—Medium range gamma survey meter.

(b) A medium range gamma survey meter for use by radiological monitors for the major part of their operation in the period following the attack. (See Fig. 3.) This instrument has three scales: 0-0.5, 0-5 and 0-50 r/hr. This instrument was designed for ground survey where radiation levels would change with relative slowness, but it can serve quite well as interim equipment for aerial measurements. The instrument reading in the airplane should be multiplied by 2 for each 200 feet of altitude for an approximation of the ground reading. For example, a 10 r/hr reading at 600 feet would be multiplied by 2 x 2 x 2 to give as an approximation 80 r/hr on the ground.[3] OCDM Standard Item Specification CD V-710.

Figure 4.—High range beta-gamma survey meter.

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[3] Another bulletin in this series will discuss the techniques and instrumentation for aerial survey.

(c) A high range beta-gamma survey meter is required for use by highly qualified monitors if it becomes necessary to make measurements in areas where extremely high level contamination exists and for making high level beta radiation measurements. (See Fig. 4.) This instrument will have three scales, 0-5, 0-50 and 0-500 r/hr gamma and will have a discriminating slide to permit the measurement of gamma only or of gama and beta radiation. The range of beta sensitivity will be several thousand reps per hour. OCDM Standard Item Specification CD V-720.

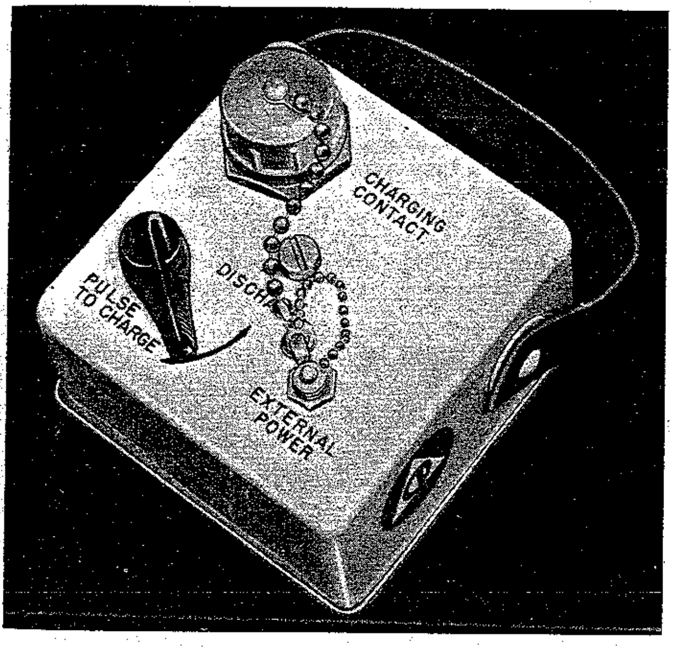

Figure 5.—Dosimeter charger.

Dosimeters

There are requirements for four types of instruments for use in measuring radiation exposures of personnel.

(a) A 0-20 r self-indicating dosimeter. This is an instrument of the quartz fiber type. It is carried in the manner of a fountain pen, which it resembles. Specification is CD V-730. (See Fig. 1.)

(b) An instrument of the type just mentioned, differing only in range, which is 0-100 r. Specification is CD V-740.

(c) An instrument for supplying a source of electric potential for charging (setting to zero) these dosimeters. Specification is CD V-750. (See Fig. 5.)

(d) A high range dosimeter to be used as a back-up instrument to the quartz fiber dosimeters V-730 and V-740. It may or may not be self-reading. An acceptable range is from about 10 r to 600 or 700 r. Dosimeters of the chemical, photographic film, phosphate glass, and electroscope type fall into this category. The instrument may require auxiliary reading equipment such as a fluorophotometer for the phosphate glass dosimeter, or a densitometer for photographic film.

All personnel who may have to execute emergency duties in a contaminated area should be equipped with a self-reading dosimeter. Because of the probabilities of widespread fallout, this now includes all services; rescue, fire, engineering, etc., as well as radiological. Economic reasons make this goal difficult to achieve, at least in the near future. An alternative is to provide at least one member of any working party with the self-reading dosimeter, while the other members of the party carry the less expensive non-self-reading type.

Radiochemical Laboratory Instruments

OCDM requires laboratory equipment to (1) make more refined analysis of decay rates; (2) identify elements in the contaminated material; and (3) analyze samples of contaminated food and water. OCDM has not sponsored the design of specific laboratory equipment or systems for this requirement. Rather, it has encouraged the State and local civil defense organizations to utilize the university, governmental or industrial isotope laboratories which may be in the particular vicinity. These laboratories have the equipment required for the job and people trained in its use. Certain States have decided that specialized laboratory equipment and/or mobile laboratories are required. Where the decision of the individual State has been to procure such equipment, and the quantities and types of instruments seem reasonable, the Federal Government provides matching funds for this purpose.

Ordinary portable equipment such as the CD V-700, or portable electrometer analysis units are suitable for field measurements to determine contamination levels of food and water. Rough determinations of decay rates could be made with the V-710 or V-720, or if the levels are low enough, with the V-700.

Instrument Calibration

The calibration of radiation instruments must be frequently checked. For the medium and high range survey meters CD V-710 and CD V-720, multicurie radiation sources are desirable

Citizens' Instruments

There are two categories of radiation instruments which might be considered for use by a person in his home or on the street: (1) personal dosimeter—a dosimeter to be worn on the person to measure the dose of radiation received at time of the burst and to measure the exposure to fallout radiation, and (2) home survey meter—a rate-meter for measuring the radiation dose rates from fallout.

The Personal Dosimeters.—OCDM believes that the benefits that could be derived from personal dosimeters are not sufficient to justify their use by the general public. The measurement of radiation dosage would be of value if such a measurement could provide information upon which to base medical treatment to those people who have been exposed. The dosage as indicated by radiation dosimeter does not provide an accurate index of the seriousness of the injury. This derives from three factors: (1) the dosimeter does not accurately indicate the total body exposure, (2) it gives no indication of the rate at which the dose was received, and (3) the radiation sensitivity variation from person to person is very broad. Medical authorities have concluded that the treatment of radiation injury must be based primarily on the person's signs and symptoms.

The Home Survey Meters.—The measurement of radioactive fallout resulting from nuclear explosion requires a properly organized and trained monitoring service equipped with instruments which are adequately maintained and periodically calibrated. It is not a job which can be done piece-meal by the individual citizen. The assessment of the radiological hazard must be handled by proper authorities who have access to the overall picture; the degree and extent of fallout; available emergency housing and feeding; and information on chemical, bacteriological, and other hazards. There is no lasting benefit in saving a person from a serious radiation exposure only to have him reexposed or become a victim of biological agents or nerve gases, or to have him freeze or starve to death. A home survey meter could be useful to enable a family to find places of least danger if forced to remain indoors because of fallout. For this requirement, instruments must be easily interpretable, have reasonable accuracy, be highly reliable, and have a "fail safe" characteristic (that is, the instrument indicates when it is not working; otherwise the presence of a radiation hazard might not be detected.) In addition, they must be in the price range to allow procurement by large numbers of people. An instrument meeting these requirements is not available, although some experimental models show some promise.

Instrument Procurement

State and Local.—Primary responsibility for obtaining instruments is considered to be that of the States. Under the Federal Contributions Program, the Federal Government will assume half of the cost—subject to appropriation limitations and providing certain criteria are met. In some instances, the State will match expenditures of the political subdivisions, so that they in turn will expend only one-fourth of the market price of the instruments.

There are several methods by which instruments may be procured:

(a) THROUGH OCDM

States may order instruments through OCDM. Instruments obtained through this procedure will be those listed in the Federal Contributions Manual, and purchased on a bid basis in accordance with OCDM Standard Item Specifications.

(b) BY BIDS

OCDM Standard Item Specifications may be used and bids invited, or negotiations made directly with manufacturers for instruments built in accordance with OCDM specifications. (The States must assure OCDM that the instruments meet specifications either by providing copies of test results or by certifications from the manufacturer.)

(c) DIRECT PURCHASE

States or political subdivisions may buy directly from a manufacturer, instruments which have been tested and found to conform with OCDM specifications.

All transactions must be channeled to OCDM through the State. Political subdivisions are required to make requests of OCDM through State authority.

Federal.—The Federal Government purchases limited quantities of radiation instruments for two purposes: (1) to be available as back-up supplies in the event of emergencies, and (2) to be transferred to the States for use in training radiological defense personnel. Those in the second group include the standard OCDM instruments mentioned earlier and a special kit of instruments and accessories for use in training monitors in the fundamentals of radiation measurement. States must meet established criteria to be eligible for these instruments. The terms and conditions applicable to this program are available through regular civil defense channels. This training program in no way changes the basic philosophy that the procurement of instruments for operational use is the responsibility of the States and political subdivisions. Quantities available under this training program would not be adequate for operational purposes.

Procurement Procedures

The Federal Supply Services of the General Services Administration is the purchasing agent for OCDM. Contracts are awarded as a result of invitations to bid. OCDM Standard Item Specifications are the basis for bid invitation and manufacture of the instruments. National Bureau of Standards conducts tests of conformance to specifications. The Bureau of Standards does not have authority, however, to approve or disapprove instruments for civil defense. OCDM specifies and finances tests which are made in the Bureau's laboratories. Results are reported to OCDM and approval or disapproval given by OCDM.

Development Status of the Instrument Program

A list of manufacturers' instruments, meeting OCDM specifications, may be obtained from OCDM's Regional Offices.

Manufacturers are encouraged to submit instruments for approval under OCDM specifications.

Studies to develop an instrument for aerial survey and a citizen's instrument are now in progress.

BIBLIOGRAPHY

Fallout of Radioactive Debris from Atomic Bombs, **Circular Letter 16-54, May 27, 1954, Weather Bureau, U. S. Department of Commerce.**

Loan of Radiation Detection Instruments and Radiation Sources by the Atomic Energy Commission to States and Communities for Training in Radiological Monitoring, **AB-82, OCDM, 1951**

The Effects of Nuclear Weapons, **U. S. Department of Defense, and the U. S. Atomic Energy Commission, June 1957.**

Radioactive Fallout, **Bulletin of Atomic Scientists, Ralph E. Lapp, Feb. 1955.**

The Effects of High-Yield Nuclear Explosions, **Statement by Lewis L. Strauss, Chairman, and a Report by the U. S. Atomic Energy Commission, Feb. 1955**

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.—Price 5 cents.

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RADIOLOGICAL DEFENSE SERIES

A DIGEST OF TECHNICAL INFORMATION

Appendix 6

FALLOUT AND THE WINDS

This is one of a series of technical bulletins on civil defense against the radiological effects of nuclear weapons.

Radioactive fallout is the surface deposition of radioactive material which has been explosively distributed in the atmosphere by the detonation of a nuclear weapon. When a bomb is detonated at heights which allow the fireball to come in contact with the ground, great quantities of pulverized and vaporized material are carried up in the atmosphere. The cloud then contains a vast amount of radioactive dust particles of all sizes, from submicroscopic specks to visible grains or flakes. The larger particles settle to the ground rapidly, the smaller more slowly. The particles of earth are not in themselves radioactive, but fragments of bomb materials adhere to them and fall to the ground. This is fallout. (See Fig. 1.)

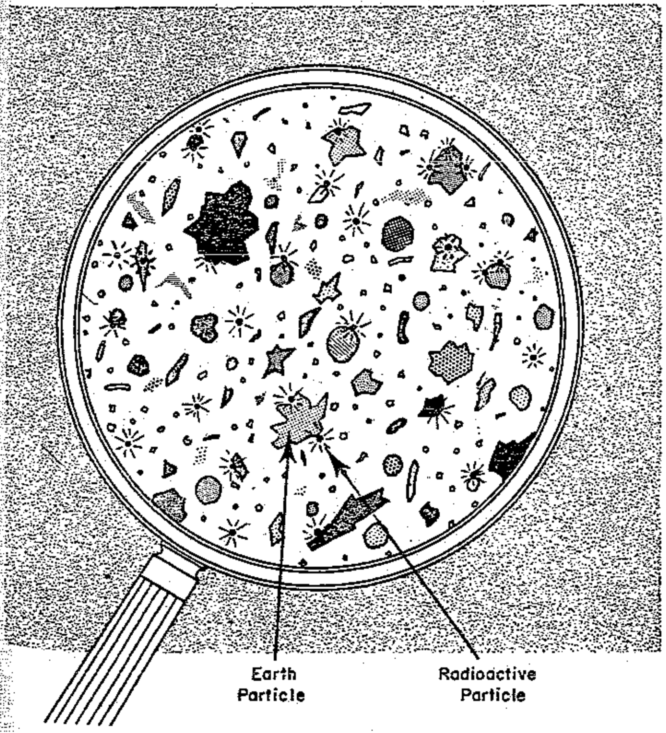

Figure 1. A portion of the mushroom cloud, magnified.

The radioactive particles formed from the bomb materials are themselves very small, and can remain in the air for a long time before settling to the ground. For this reason the cloud from a bomb detonated high in the air so that the fireball does not touch the ground, does not produce dangerous fallout.

Clouds produced by "A-bombs" of the type used in World War II generally do not rise above 50,000 feet. Photographs of the cloud produced by the first thermonuclear bomb at Eniwetok in November 1952 show that it reached a height of 25 miles, or about 130,000 feet. However, this does not mean that dangerous fallout comes from all altitudes up to the top of the cloud. It appears that the uppermost part may not contribute much to the overall hazard. Still, the evidence indicates that debris which rises to altitudes of at least 80,000 feet must be considered in attempting to explain the observed fallout from test detonations of the thermonuclear weapons. Figure 2 shows the comparative size of an A-bomb cloud, H-bomb cloud, and an ordinary thunderstorm cloud.

Rate of Fall of Particles

The particles carried up into the atmosphere by the detonation are acted upon by gravity and are carried by the winds. The wind directions and speeds usually vary from one level to another, so that each particle follows a constantly changing course, with changing speed, during its fall. The rate of fall depends upon the particle's size, shape, and weight, and the characteristics of the air. The stronger the winds in each layer, the farther the particles will be carried in that layer; but the faster the particle falls, the less influence the wind will have on it and the closer to ground zero it will land. The higher the altitude at which its begins to fall, the longer it will be carried by the wind, and under most conditions—when the winds at different altitudes do not oppose one another—the farther it will travel. Figure 3 shows the effects of various combinations of particle size and wind distribution.

Source of Wind Data

High altitude wind observations are taken at many stations in the United States operated by the Weather Bureau, Army, Air Force, and Navy. At these stations, small lightweight radio transmitters attached to helium-filled bal-

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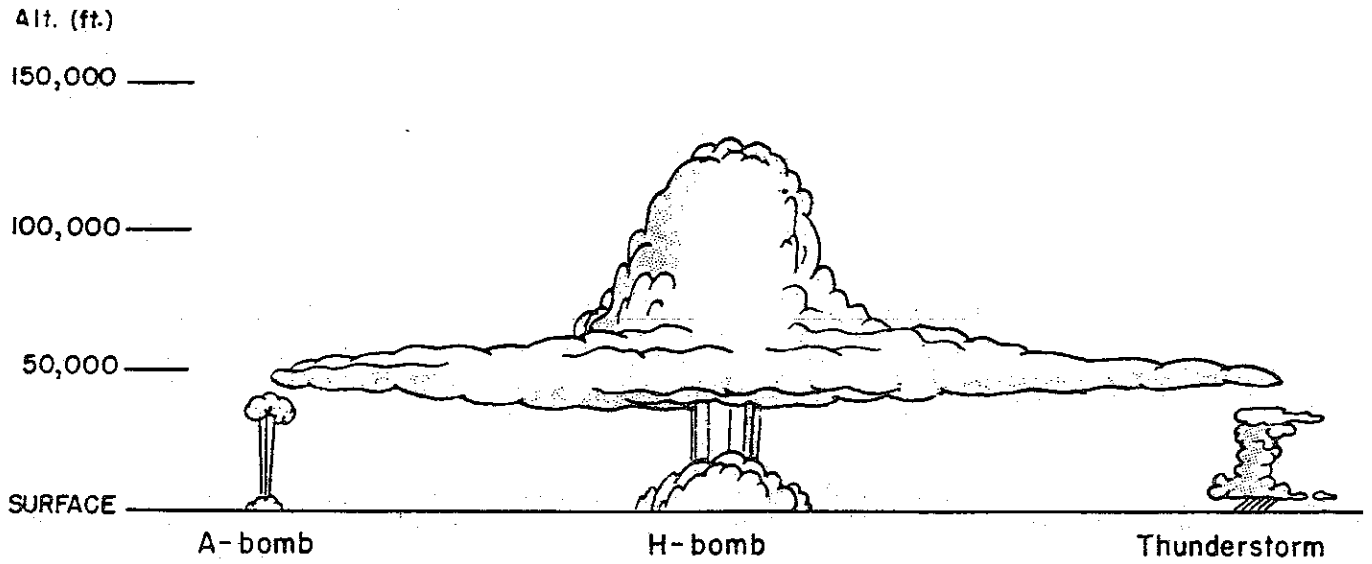

Figure 2. Comparative size of A-bomb mushroom, H-bomb mushroom, and ordinary thunderstorm cloud.

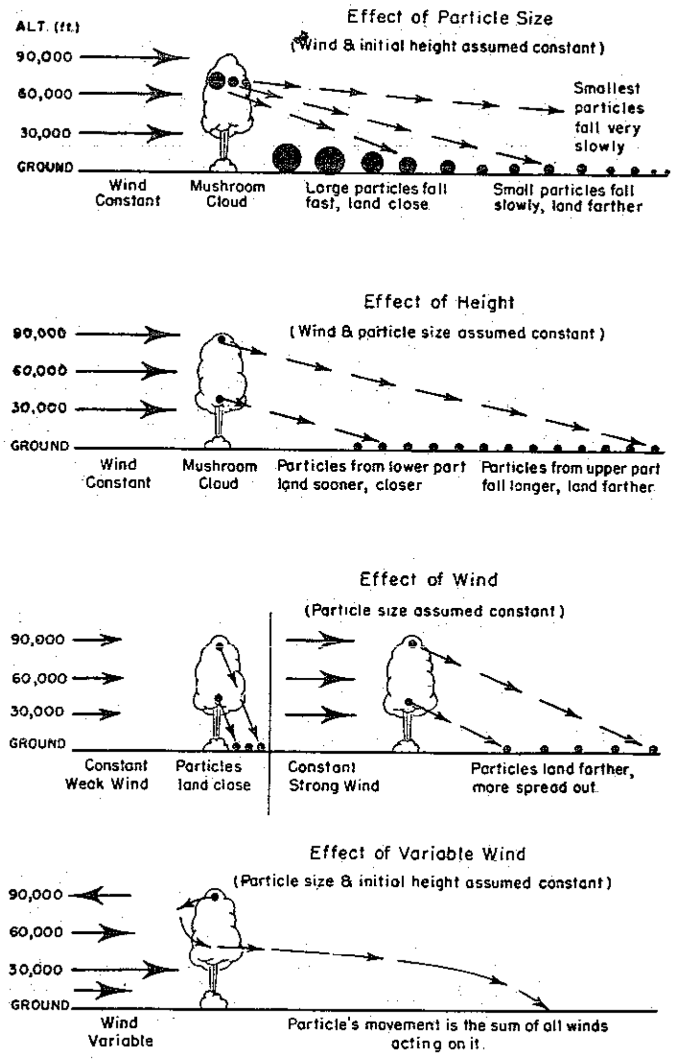

Figure 3. Factors affecting distribution of radioactive particles.

loons are sent aloft several times daily and their positions recorded at frequent intervals by direction-finding receivers. Altitudes of 80,000 feet or more are frequently reached. The wind data for each station at observation time are transmitted by teletype to all weather forecasting offices. Figure 4 indicates the locations of the high altitude wind reporting stations in the United States.

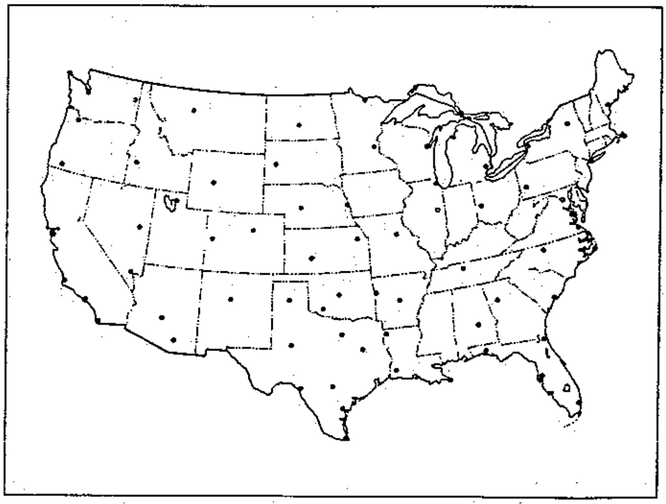

Figure 4. High altitude wind reporting stations in the United States.

Prediction of Fallout Areas

Weather Bureau reports can be used to predict probable areas of fallout from a nuclear bomb. The observed or predicted wind in each layer of the atmosphere can be translated into a definite horizontal movement for each size of particle. The horizontal movements imparted to the falling particles in all layers of the atmosphere can be added together to predict their total travel. Although particle sizes and altitudes will not be known in advance of an attack, a useful estimate can be made of the direction and rate of spread of the fallout under existing wind conditions. Figure 5 is a simplified drawing indicating the sector of fallout from the stem and top portion of the cloud from all levels 5,000 feet to 80,000 feet.

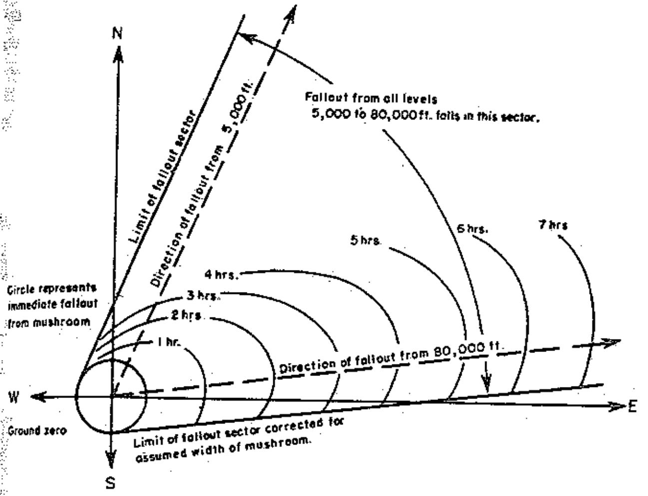

Figure 5. Sector of fallout from stem of cloud.

The U. S. Weather Bureau issues forecasts twice daily for all critical target areas of fallout direction, distance, and arrival time. On February 1, 1956, the service was expanded to cover all areas of the country. This information provides to local, State, regional, and national civil defense, the data necessary for the construction of fallout plots. Details of the program are described in FCDA (OCDM) Advisory Bulletin No. 188, dated May 25, 1955, and Supplements Nos. 1, 2, and 3, dated August 16, September 27, 1955, and January 26, 1956. Instructions are included for constructing fallout plots from the Weather Bureau forecasts.

These fallout predictions are useful for civil defense planning, but limitations must be recognized. Forecasts are released only twice a day. Therefore, at certain times the fallout plots will be based on wind measurements more than 12 hours old.

Prediction of Radiation Levels

Wind data alone, of course, do not indicate the levels of radiation to be expected. Levels would depend on such things as altitude of the burst, amount of energy released, the nature of the ground surface, height to which the cloud rises, and the bomb design. These things could not be known before the attack—making it difficult to predict accurately the radiation levels that would result.

Data for forecasting levels of fallout radiation from a given weapon are limited. However, some information was obtained from the Pacific "H-bomb" tests of the Atomic Energy Commission. According to the AEC, ". . . it is estimated that following the test explosion on March 1, 1954, there was sufficient radioactivity in the downwind belt about 140 miles in length and of varying widths up to 20 miles to have seriously threatened the lives of nearly all persons in the area who did not take protective measures." The device that produced this pattern was in the multimegaton range. However, it cannot be expected that other bombs of the same power would necessarily produce the same fallout pattern or radiation levels. The Bikini "cigar-shaped" pattern is only an example of what is possible. Even with exactly the same type, power, and altitude of detonation, different wind conditions would have produced a different fallout pattern, possibly of irregular shape.

The speed and vertical shear of the upper air winds will affect the concentration of radioactivity on the ground. A fallout pattern under conditions of strong winds aloft would differ from that of weak winds in two ways. The strong wind would spread the material over a larger area, tending to reduce the concentration close to the source, and at a given distance the fallout would arrive sooner and would have had less time to decay. Therefore, the area of dangerous contamination would likely extend farther from the source in stronger winds.

Obviously, the length of time required for the bulk of dangerously radioactive dust to be deposited on the ground will depend on the yield of the bomb and the size of the particles. Referring again to the March 1, 1954, Bikini test, it appears that hazardous material continued to fall in some areas for at least 12 hours after the burst. In some instances, it might continue for 24 hours.

Precipitation in a fallout area will affect the radioactive deposition. Raindrops and snowflakes collect a large proportion of the atmospheric impurities in their paths. Particles of radioactive debris are "washed" or "scrubbed" out of the air by precipitation. The result is that contaminated material, which would be spread over a much larger area by the slower dry weather fallout process, is rapidly brought down in local rain or snow areas. It is conceivable that hazardous concentrations can occur in rain areas where ordinary fallout estimates might indicate a safe condition. This scrubbing reduces the amount of contamination left in the air to fall out farther downwind.

Terrain features will cause a variation in degree of deposition. Hills, valleys, and slopes of a few hundreds of feet would probably not have a great effect on the fallout radiation levels. By receiving more fallout on the side facing the surface wind, large mountains or ridges could cause significant variation in deposition. This is true for both dry weather fallout and "rainout."

Climate and Wind Considerations

It is highly questionable whether the Bikini fallout pattern should be applied to regions not in the tropics. The climate and winds of the United States are generally different from those of Bikini. The United States has a variety of upper air winds. However, wind conditions similar to those accompanying the Bikini test do occur in the United States, particularly in the summer months. During the winter, spring, and fall seasons, the United States winds are primarily the "prevailing westerlies." By this it is meant that the winds over the United States blow more frequently from the western quarter than from any other quarter of the compass. The westerlies in the middle latitudes become increasingly predominant with increasing height up to about 40,000 feet. At 5,000 feet the winds are from the western quadrant about half the time; while at 30 to 40 thousand feet, they are from that quadrant about three-fourths of the time. Above 40,000 feet, the percentage of westerly winds again decreases.

It is implied in the above paragraph that predominance of westerly wind direction changes with the seasons. Upper winds blow from the west more often during winter than during summer. The increase in frequency of other directions in the summer is more pronounced in the southeastern portion of the country, where directions become variable at all levels. Along the Pacific Coast, the winds blow less constantly from the west than in other sections of the country. Southwesterly and northwesterly winds are more common. Above 60,000 feet, easterly winds occur frequently in all seasons and are the rule in summer over most of the United States. Figure 6 indicates the percentage of time that winds blow from the western quadrant at 40,000 feet over the United States in the winter and summer seasons.

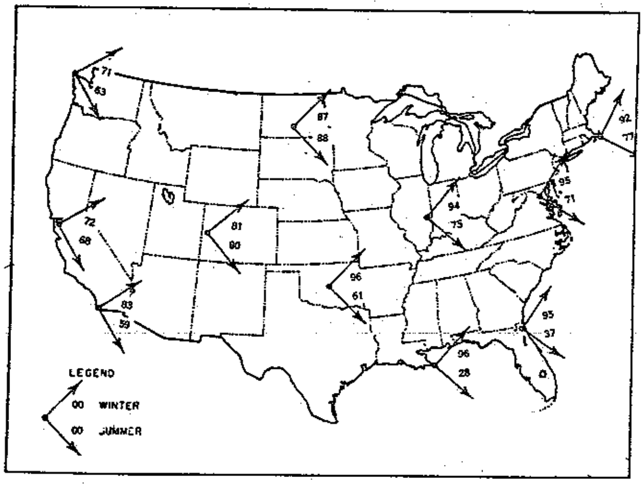

Figure 6. Percentage of time with westerly winds at 40,000 feet.

In describing direction of fallout from the point of detonation (GZ—Ground Zero), the terms "upwind" and "downwind" are often used. The downwind direction is the direction toward which the wind blows. "Upwind" means against the wind, just as "upstream" and "downstream" are related to river currents. When applied to fallout, the terms "upwind" and "downwind" will apply to the resultant or total effect of all the winds through which the particles have fallen. An upwind component results from the very rapid expansion of the cloud in all directions immediately after detonation. The disturbances at the time of the explosion will deposit radioactive material in upwind and crosswind directions for relatively short distances from ground zero.

All civil defense personnel should be cautioned against using surface wind directions as an indication of direction of flow at levels high in the atmosphere. The direction of fallout is determined by winds up to at least 80,000 feet above the surface. Winds in the upper air frequently are different from those at the surface. It is not at all uncommon to have east, south, or north winds at the surface and westerly winds aloft. There is no correlation between the two.

It has been pointed out that, in considering the possible area of fallout, wind speed is as important as wind direction. The direction determines the sector to which particles are carried, and the speed governs how far they will travel before coming to earth. The average wind speed at different heights over the United States is shown in the accompanying table.

Average Wind Speeds Over The United States

Height (ft.)	Winter (mph)	Summer (mph)
5,000	25	15
10,000	35	19
20,000	55	25
40,000	80	45
80,000	30	20

Wind speeds over the United States generally are less in summer than in winter at all heights and above all areas. The only exceptions would be during the passage of hurricanes or tornadoes which produce very strong surface winds in the warm season. This difference between seasons is greatest in the southeastern portion of the country, where winds become particularly light and variable in the summer. During the winter, upper winds along the Pacific Coast generally have lower speed than in any other section of the United States. Winds increase with altitude from the surface up to a level between 30,000 and 40,000 feet. Above this level they usually decrease in speed until, at 60,000 to 80,000 feet they become relatively light. Figure 7 indicates the variation of wind direction and speed in the United States at 40,000, 50,000, 60,000, and 80,000 feet.

The winds of greatest speed usually occur between 30,000 and 40,000 feet, winds exceeding 50 mph being the rule all over the country in winter and in the northeast in summer. In this layer, winds greater than 100 mph are at times experienced over all areas of the United States, but have been observed most often over the northeast, where they are found about 25 percent of the time. In this northeastern area, winds of 200 mph occur frequently and even speeds of 300 mph are observed on rare occasions. The high speed winds usually occur in narrow meandering currents within the broad belt of middle-latitude westerly winds, and are called "jet streams." Figures 8 and 9 indicate the percentage frequency of occurrence of winds greater than 50 knots (58 mph) and greater than 100 knots (115 mph) for the United States by seasons.

The strongest winds encountered by a falling particle have the greatest proportional influence on its total movement. The strongest winds are usually at altitudes in the vicinity of 40,000 feet. These winds would determine largely the general direction and length of the fallout area, although all the winds up to more than twice that height could be effective.

Fallout patterns over the United States, as has been stated, would probably differ in shape and extent from Bikini patterns. In the northern half of the country considerably longer patterns would be expected, spreading toward the east because of the strong upper air westerly winds. The passage of low pressure areas would cause shifts from a more northeasterly to a more southeasterly spread of the fallout pattern from one day to another. In the summer, particularly in the southern part of the country, a great variety of patterns might be expected with a broad irregular spreading in all directions in some cases, and elongated streaks in others. It should be remembered also, that in an area where several target cities are situated within a few hundred miles of one another, fallout from more than one detonation might occur at the same place.

Variation of the winds by day and night has little effect on factors that determine fallout patterns. Winds a few hundred feet above the ground frequently change, from night to day, but those higher up, which have the greatest effect on the fallout pattern, do not follow a daily cycle. Cloudiness or fog alone are not believed to have a marked effect on fallout, although the combination of fallout particles with cloud droplets may result in a faster rate of fall. Some cloud types also have upward and downward air currents. The downward currents might tend to bring some of the radioactive debris down more rapidly than it would otherwise settle.

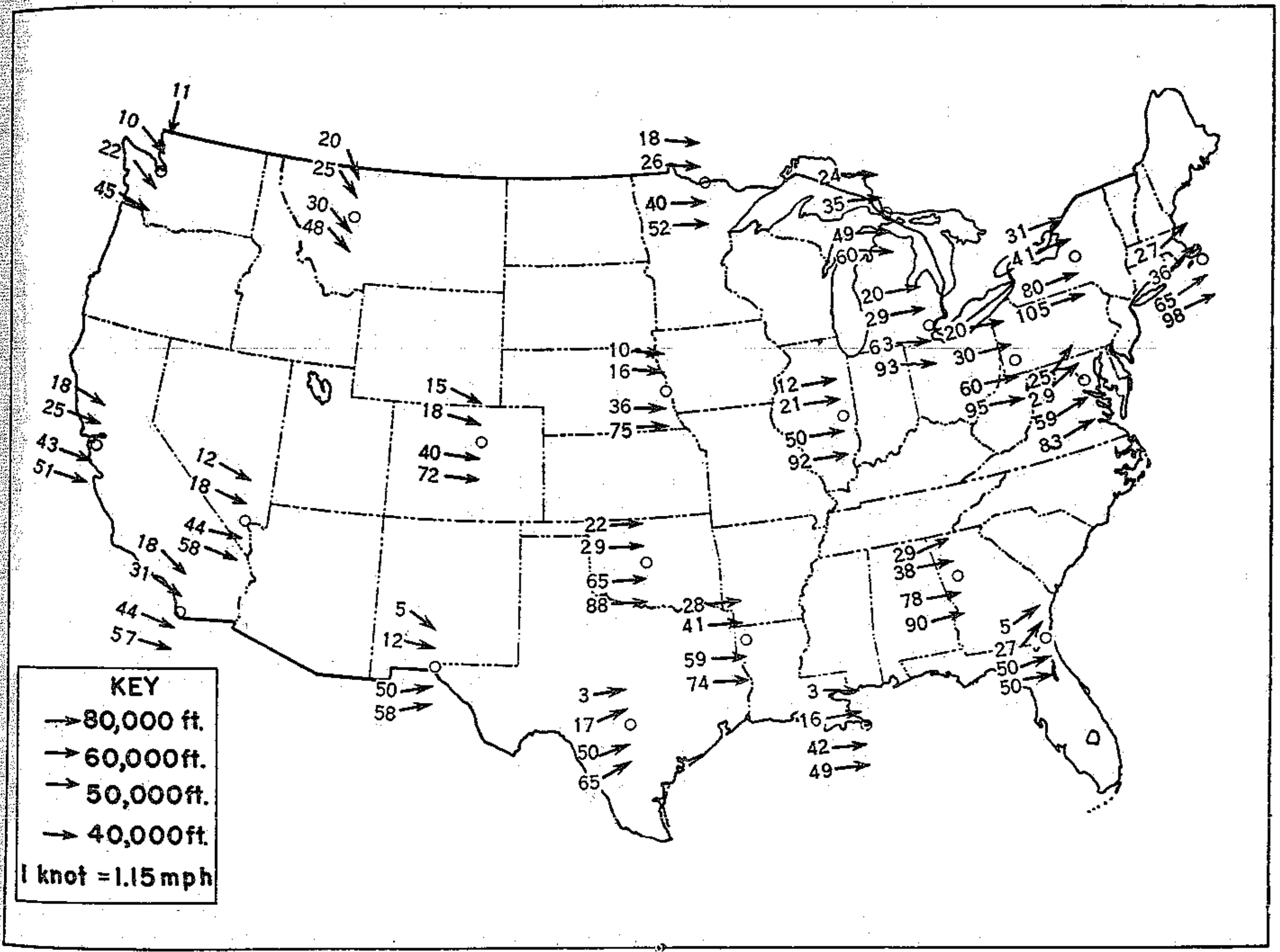

Figure 7.—Average wind direction and velocity for January. (Based on 5 years of data).

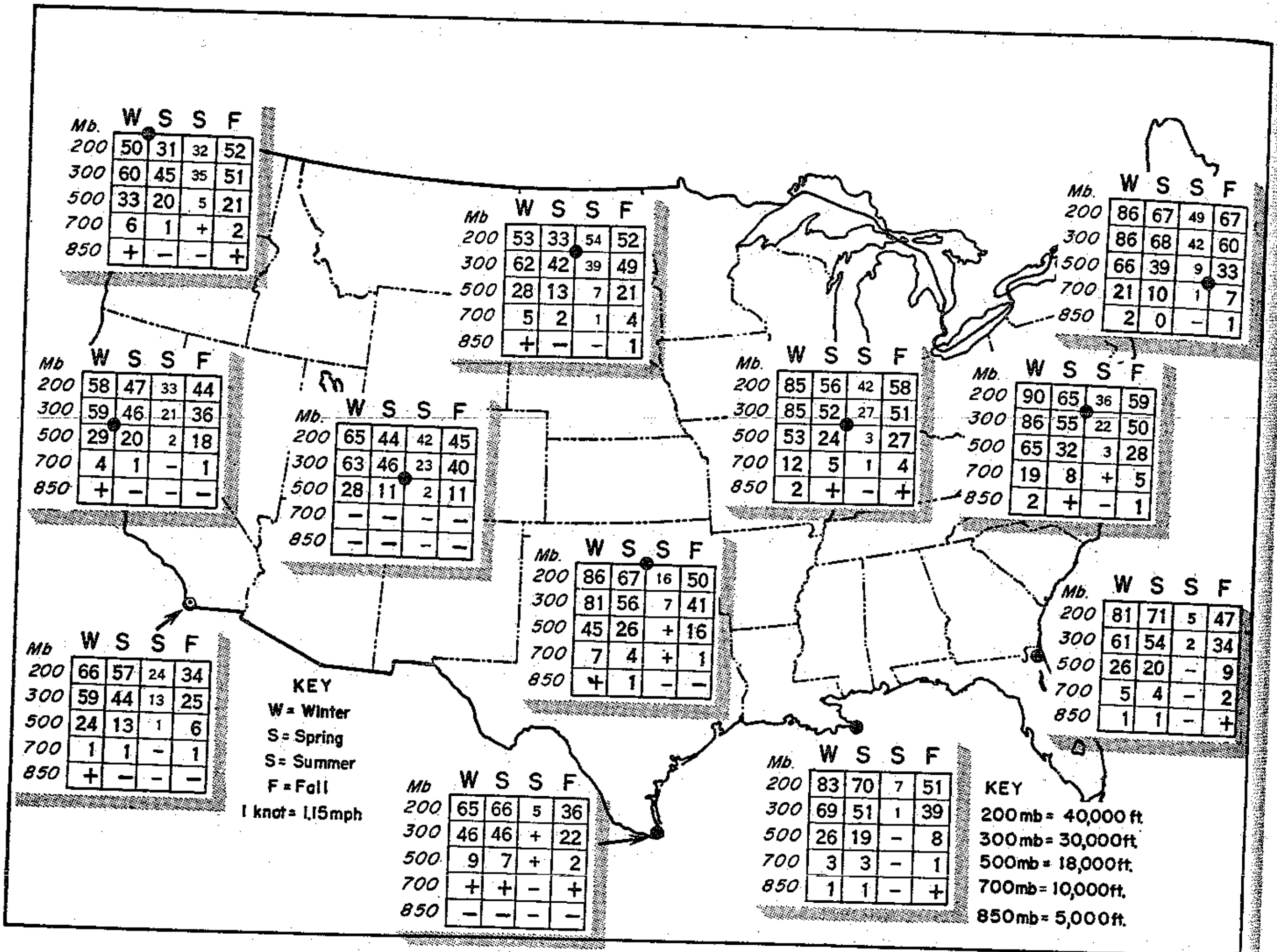

Figure 8. Percentage frequency of winds over 50 knots (58 mph).

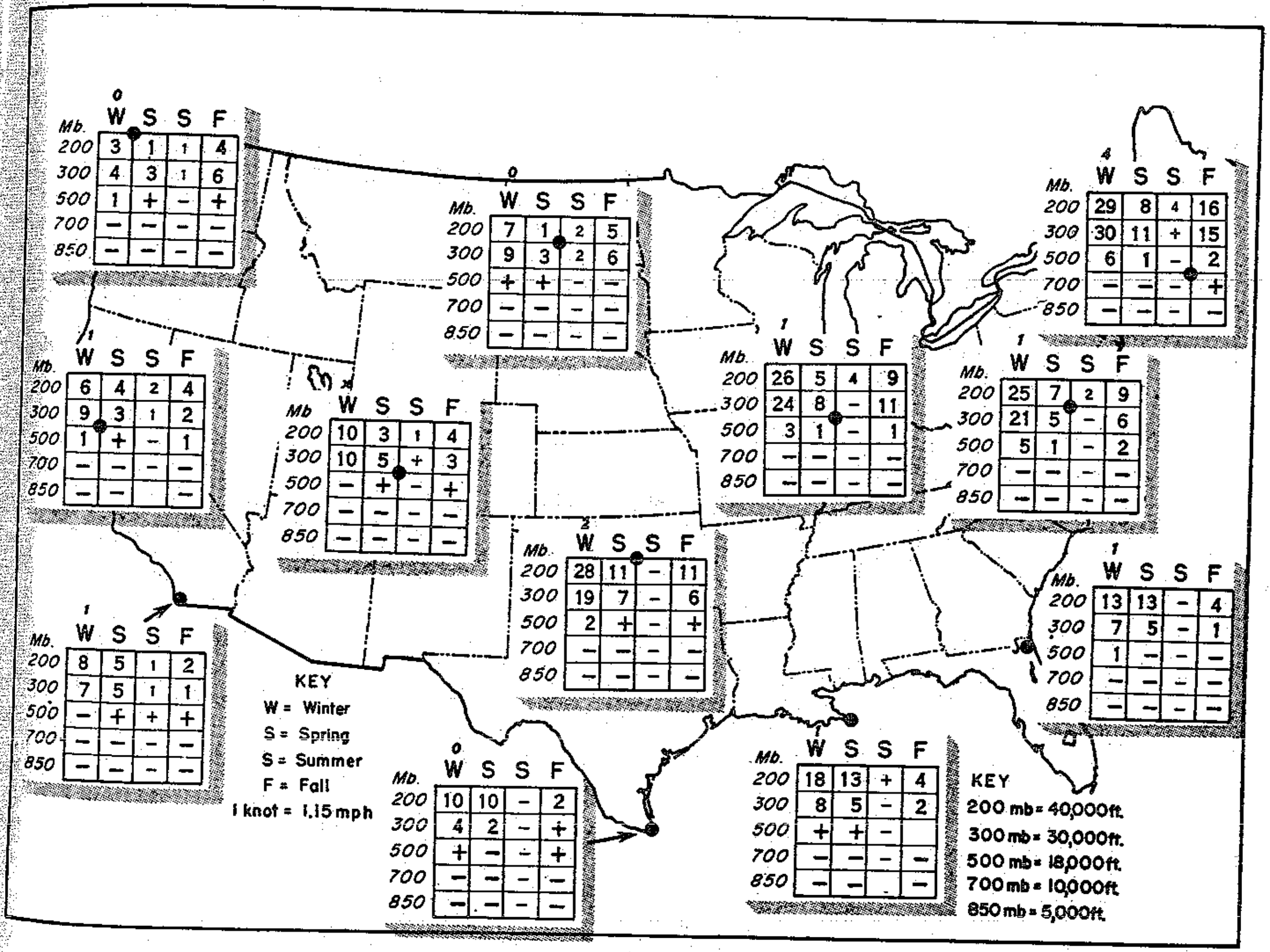

Figure 9. Percentage frequency of winds over 100 knots (115 mph).

REFERENCES[1]

1. *Construction and Use of Area Fallout Plots From Routine U. S. Weather Bureau Coded Forecasts (UF).* FCDA (OCDM) Advisory Bulletin, AB No. 188 (Revised Jan. 24, 1958).
2. *Effects of Nuclear Weapons, The.* AEC, 1957.
3. *Family Shelters for Protection Against Radioactive Fallout.* OCDM Technical Bulletin, TB-5-3, 1958.
4. *Protection Against Fallout Radiation.* OCDM Technical Bulletin, TB-11-19 (Radiological Defense Series), 1955.

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[1] The designation "Federal Civil Defense Administration" (FCDA) will be changed to "Office of Civil and Defense Mobilization" (OCDM) as the publications are reprinted or revised.

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Technical Bulletin

Appendix 7

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Revised June 1956
(Reprinted January 1957)
RADIOLOGICAL DEFENSE SERIES

A DIGEST OF TECHNICAL INFORMATION

RADIATION PHYSICS AND BOMB PHENOMENOLOGY

> **This is one of a series of technical bulletins on civil defense against the radiological effects of nuclear weapons**

This bulletin describes briefly the structure of the atom, how its energy is released in nuclear weapons, and methods of detection and measurement of nuclear radiations.

Structure of Matter

All matter is made up of atoms and combinations of atoms which unite chemically to form molecules. An atom is the smallest unit that retains the properties of an element or can enter into a chemical reaction. For example, common salt, sodium chloride (NaCl), is a combination of one atom of sodium (Na) and one atom of chlorine (Cl). Molecules of single elements may be single atoms or combinations of atoms. For example, one atom of oxygen is represented by O, but the normal oxygen molecule exists as a combination of two atoms, O_2.

Until recently the total number of known elements was thought to be 92, with hydrogen (H) the lightest, and uranium (U), the heaviest. Now, 101 elements have been identified.

All atoms except ordinary hydrogen contain three primary particles, the neutron, proton, and electron. Ordinary hydrogen does not contain a neutron. See Table 1 for characteristics of these particles.

Table 1—Characteristics of Atomic Particles

Name	*Symbol*	*Electrical Charge*		*Mass*
Electron	e	Negative	−1	0.000548 mu*
Proton	p	Positive	+1	1.007575 mu
Neutron	n	None	0	1.00893 mu

*(An atomic mass unit (mu) is 1.6×10^{-24} grams)

The atom may be represented as a solar system consisting of a heavy central mass, the nucleus, with one or more electrons traveling in orbits around it. (Fig. 1). The atomic nucleus contains combinations of protons and neutrons. These combinations and the number of electrons vary with the element. To be electrically neutral, an atom must contain the same number of positively charged particles (protons) in the nucleus as negative particles (electrons) in its orbits. The removal of an electron from the orbit produces an ion pair. The free electron is the negative ion and the remaining portion of the atom, the positive ion. The average radius of an atomic nucleus is about 10^{-12} centimeters, and the atom 10^{-8} centimeters.

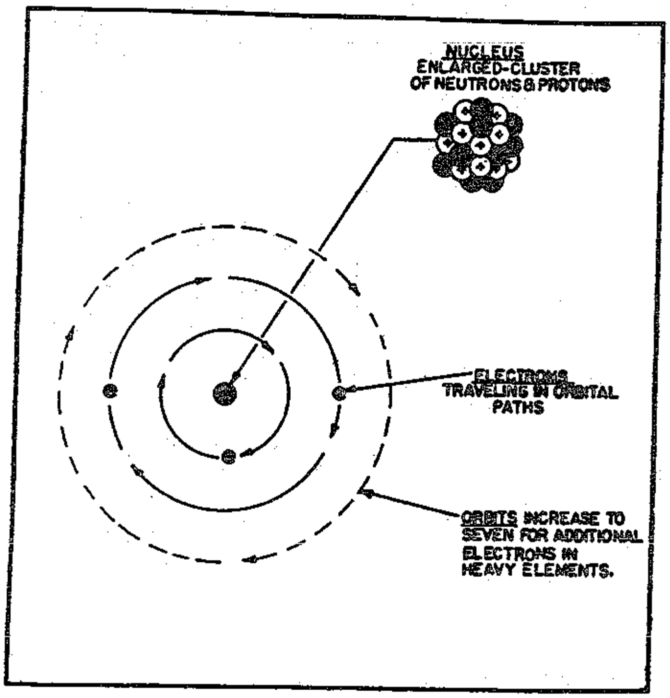

Figure 1—Diagram of an Atom.

Discussion of atomic structure will be simplified by some definitions and symbols that are commonly used.

Z—atomic number. Number of protons in the nucleus of an atom. This number identifies an element. As an example, all atoms of sodium (Na) have a Z number of 11.

A—mass number. Sum of the proton and neutrons in the nucleus of an atom.

N—neutron number. Number of neutrons in the nucleus of an atom.

FEDERAL CIVIL DEFENSE ADMINISTRATION

Isotopes of an element. Forms of the element having the same number of protons in the nuclei, but differing in the number of neutrons. Isotopes of an element have almost identical chemical properties. Any isotope may be represented by the following expression:

$$_{Z}X^{A}$$

where X indicates the element. Examples of 2 isotopes of lithium, $_{3}Li^{6}$ and $_{3}Li^{7}$, are diagrammed in Fig. 2.

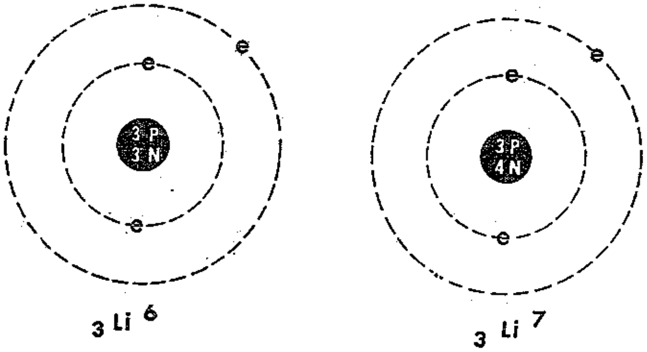

Figure 2—Diagram of Lithium Isotopes.

The difference between these two isotopes is one additional neutron in $_{3}Li^{7}$. Both are stable and are mixed in such proportion in nature that the average atomic weight is 6.94.

Radioactivity

Nuclear radiation is energy spontaneously released by an unstable (radioactive) nucleus to attain a more stable state. In certain cases this will result in transmutation — the changing of one element into another.

Some isotopes are naturally radioactive. Also radioactive isotopes may be artificially produced by subjecting a stable nucleus to bombardment by nuclear missiles such as alpha particles, neutrons, or protons. For example, when stable cobalt is bombarded by neutrons having the proper energy, a radioactive isotope of cobalt is formed as shown in the following nuclear equation:

$$\underset{\text{Stable}}{_{27}Co^{59}} + {_{0}n^{1}} \longrightarrow \underset{\text{Radioactive}}{_{27}Co^{60}}$$

Naturally occurring or artificially produced radioactive isotopes emit one or more of three types of radiation. Two of these are particulate—alpha and beta particles; the third is electromagnetic—gamma rays. Alpha particles are positively charged and consist of two protons and two neutrons. Beta particles are high speed electrons. Gamma rays are similar to light and heat waves, but are more energetic. The five senses are unable to detect the presence of nuclear radiation, therefore, a person can become seriously exposed without being aware of it.

The three types of nuclear radiation can be identified by their behavior in a magnetic field. Those slightly deflected by the field are alpha particles, those more easily deflected in the opposite direction, beta particles, and those unaffected, gamma rays. Table 2 summarizes their characteristics.

Table 2—Characteristics of Nuclear Radiation

Radiation	*Symbol*	*Type*	*Mass*	*Electrical Charge*	*Remarks*
Alpha	α	Particle	4.00276 mu	+ 2	Identical to helium atom stripped of its electrons.
Beta	β	Particle	0.00548 mu	−1	Identical to a high speed electron.
Gamma	γ	Wave	None	None	Electromagnetic wave of energy.

Nuclear stability is determined primarily by the number of neutrons relative to the number of protons in the nucleus. For those isotopes having low atomic numbers, maximum stability is obtained when the n/p ratio is about 1. As the atomic numbers get larger, this ratio increases to about 1.5. When the number of neutrons in the nucleus differs greatly from the optimum ratio, the atom is radioactive. Radioactive elements up to a mass number (A number) of 80 are usually beta and gamma emitters, while those over 210 are alpha emitters. Where the n/p ratio is below the range for maximum stability, a positron ($\beta +$) may be emitted. A positron has the mass of an electron but is positively charged.

Nuclear reactions can transmute one element into another. The bombardment of nitrogen by alpha particles having the proper energy produces a stable isotope of oxygen and a proton and is illustrated by the equation:

$$\underset{\text{Stable}}{_{7}N^{14}} + {_{2}\alpha^{4}} \longrightarrow \underset{\text{Stable}}{_{8}O^{17}} + {_{1}p^{1}}$$

Energy may be imparted to nuclear missiles in particle accelerators such as cyclotrons, synchrocyclotrons, and bevatrons.

Capture or loss of a particle by the nucleus leads to the formation of a new isotope. If this isotope has an excess of nuclear energy, it is radioactive. It becomes stable after this surplus energy is released.

The conversion of mass to energy is explained by Einstein's famous theory of relativity. This relationship is represented by the equation, Energy = Mass times a constant, which is the square of the speed of light, ($E = mc^2$); if E is measured in ergs, m is in grams, then c is the velocity of light in centimeters per second. The following equation shows that an extremely small change in the mass of a system produces a very large amount of energy:

Equation:

Boron 10 + alpha ⟶ Carbon 13 + proton + E
where E represents the energy released

Eq. in Symbols:

$$\underset{\text{Nucleus}}{_{5}B^{10}} + {_{2}\alpha^{4}} \longrightarrow \underset{\text{Nucleus}}{_{6}C^{13}} + {_{1}p^{1}} + E$$

Mass in mu:

$$10.01344^{*} + 4.002764 = 13.004222^{*} + 1.007575 + E$$
$$14.016204 = 14.011797 + E$$
$$0.004407 = E$$

Energy equivalent: $E = 4.1$ Mev.

*The mass of a nucleus is smaller than the combined masses of the individual particles. The difference represents binding energy of the nucleus.

The difference in mass on the two sides of this equation is 0.004407 mass units which is transformed to energy. In this case the energy is equal to about 4.1 million electron volts (Mev). This might be compared to the energy of about 15-20 electron volts obtained from burning a single molecule of gasoline.

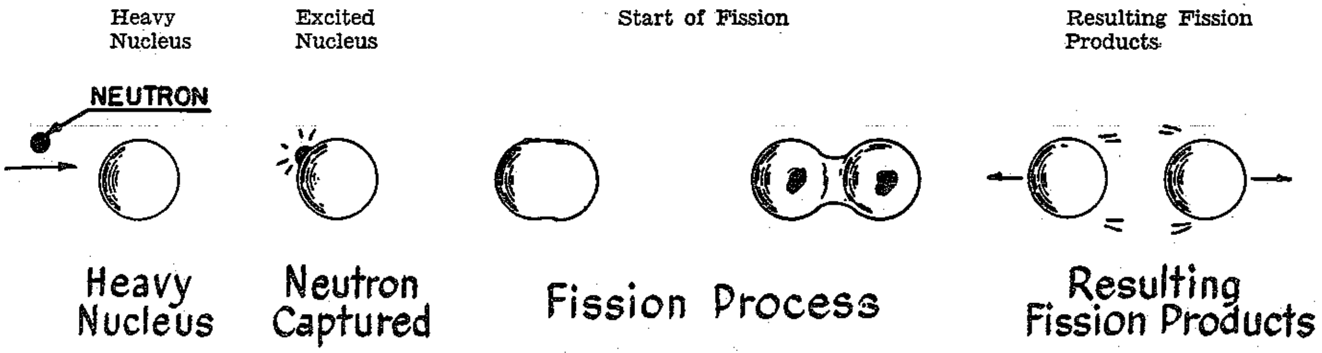

Figure 3—Fission Process.

Fission Process

The neutron is electrically neutral and is not repelled by the electrostatic field surrounding the nucleus. Therefore, it is more easily captured by the nucleus than a charged particle.

The bombardment of a heavy element such as uranium with neutrons may result in a reaction in which the nucleus splits into smaller nuclei with the release of a relatively enormous amount of energy. This is called fission. Although theoretically it is possible to obtain fission energy from all elements heavier than silver, practically, only uranium, plutonium, and thorium are useful for this purpose.

When fission takes place and a heavy nucleus breaks into lighter nuclei—called fission products—the energy released is about 200 Mev. About 0.1% of the mass of the uranium atom is converted into energy. The energy released from fissioning 1 kilogram of U^{235} is about 8 x 10^{20} ergs, equivalent to the energy produced by burning about 3,500 tons of high grade coal. The fission process is illustrated in Figure 3.

The fission process results in random splitting of the nucleus. Usually two, but sometimes three, fission products are produced. More than 200 fission products have been identified. Figure 4 shows the mass distribution of fission products. Most of them are radioactive. The radioactive fission products decay to stable atoms by emitting beta and gamma rays. Fission products are not alpha or neutron emitters.

THE ATOMIC BOMB

Fission is accompanied by the release of neutrons. The neutrons in turn may be captured by other nuclei and cause successive fissioning. This chain reaction (Fig. 5) makes possible the nuclear reactor and atomic bomb. In the reactor or pile, the fission rate is controlled by absorbing some of the neutrons. In the bomb, the reaction is not slowed and the chain reaction is completed in a fraction of a second.

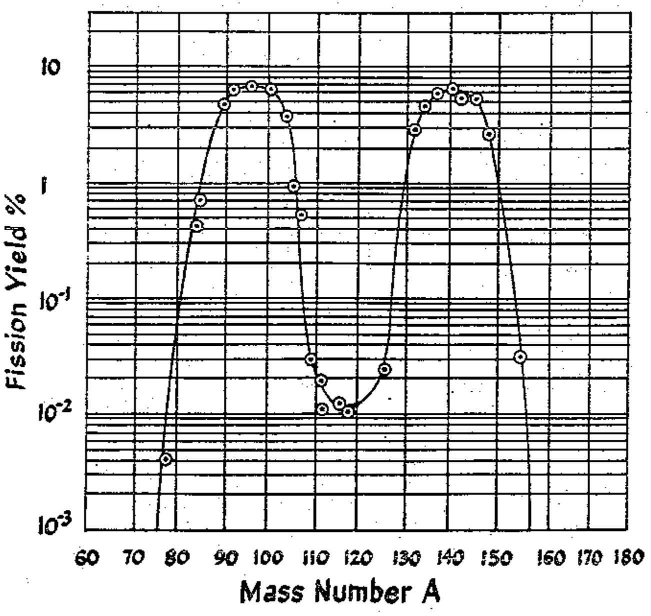

Figure 4—Mass Distribution of Fission Products.

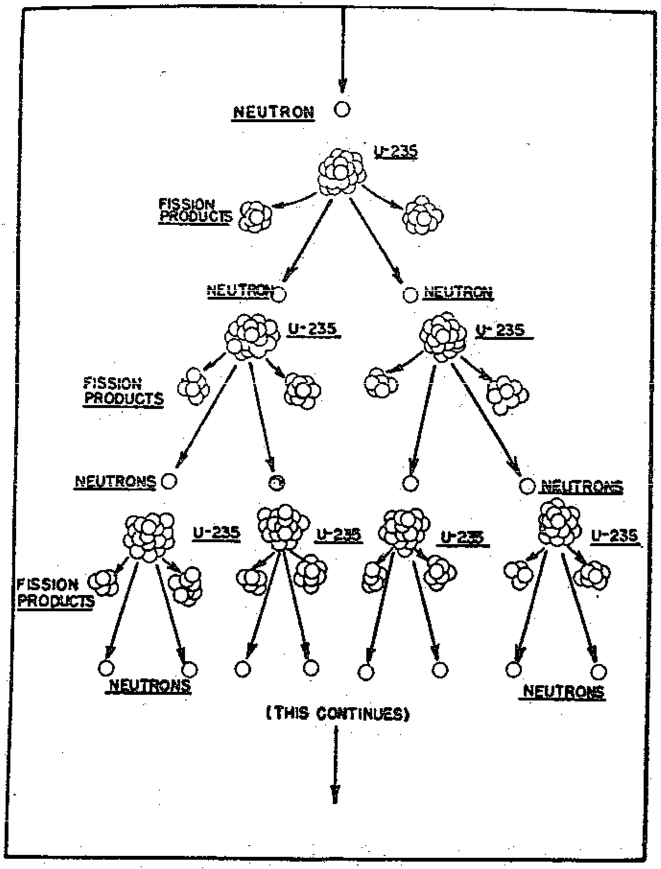

Figure 5—Diagram of Chain Reaction.

Energy released from the explosion of an atomic bomb produces the same three effects as an explosion of TNT; light, heat, and blast. In addition, the emission of nuclear radiation occurs. *Initial* radiation is composed of neutrons, gamma, and beta radiation, and lasts for about one minute after the detonation. The beta radiation, because of its short path length, does not contribute to the hazard. *Residual* radiation is gamma and beta rays from the fission products, alpha particles from the unfissioned uranium or plutonium, and beta and gamma radiation from substances made radioactive by neutrons released at the time of burst.

When a ground burst occurs, debris and dirt are sucked into the ascending cloud. Vaporized fission products, bomb fragments, and neutron-induced radioactive elements condense on this material. These contaminated particles which settle to the ground are called fallout. High air bursts do not produce significant fallout hazard because surface material is not carried into the cloud for the radioactive particles to condense upon.

Fusion

The fusion process, in contrast to the breaking up a heavy nucleus as is done in fission, combines two nuclei of light elements into a heavier one. Such reactions may be used to produce energy. The fusion process is the source of solar energy and requires temperatures of millions of degrees. The following equation is an example of the fusion reaction:

Equation:

Hydrogen 3 + Hydrogen 1 → Helium 4 + Energy

Eq. in Symbols:

$$\underset{\text{Nucleus}}{{}_1H^3} + \underset{\text{Nucleus}}{{}_1H^1} \longrightarrow \underset{\text{Nucleus}}{{}_2He^4} + E$$

Mass in mu:

$$\begin{aligned} 3.016472 + 1.008123 &= 4.002764 + E \\ 4.024595 &= 4.002764 + E \\ 0.02183 &= E \end{aligned}$$

Energy Equivalent:

$$E = 20 \text{ Mev.}$$

THE THERMONUCLEAR BOMB

Because the fission bomb produces the high temperature required for the fusion process, it serves as a trigger for the fusion device. The term "hydrogen bomb" has been used because one possibility for the bomb is based on the fusion of isotopes of hydrogen.

The same type of initial and residual radiation results from the thermonuclear bomb as with the fission weapon, but to a greater degree. A thermonuclear bomb will probably be detonated so that it touches the ground. Great quantities of surface material would be taken up into the cloud for the vaporized fission products and bomb fragments to condense upon. This greatly increases the fallout problem.

Multiple Decay

Each radioactive isotope has a characteristic half-life. These range from a few millionths of a second to millions of years. However, when many elements—in this case the fission products of a bomb—are present, no one half-life applies for the composite. With fission products there is a predominance of short-lived radioisotopes in the period immediately following the burst; hence the radiation level falls off very rapidly. As these expend themselves, the longer half-life isotopes become more dominant and the decay rate of the fission products decreases.

Multiple radioactive decay for fission products may be calculated by using Kaufman's equation for multiple decay, $K = IT^n$, where K = dose rate at unit time; I = dose rate at any time T, measured from the time of burst, and n is the Kaufman exponent. (Fig. 6). Time may be measured in any units—minutes, hours, days, weeks, etc. A more familiar form of this equation is $I = I_1 t^{-n}$. Where I is the activity at any time t, I_1 is the dose rate at unit time, and n is the Kaufman exponent. The value of n is not fixed; it may vary with bomb design, location of burst, and the amount and type of neutron-induced activity. For a particular contaminated area, decay may be affected by weathering and decontamination. For planning purposes, a value of $n = 1.2$ may be used. Accurate information on the radiation levels and rate of decay must depend on radiological surveys. (See table 1, appendix A.)

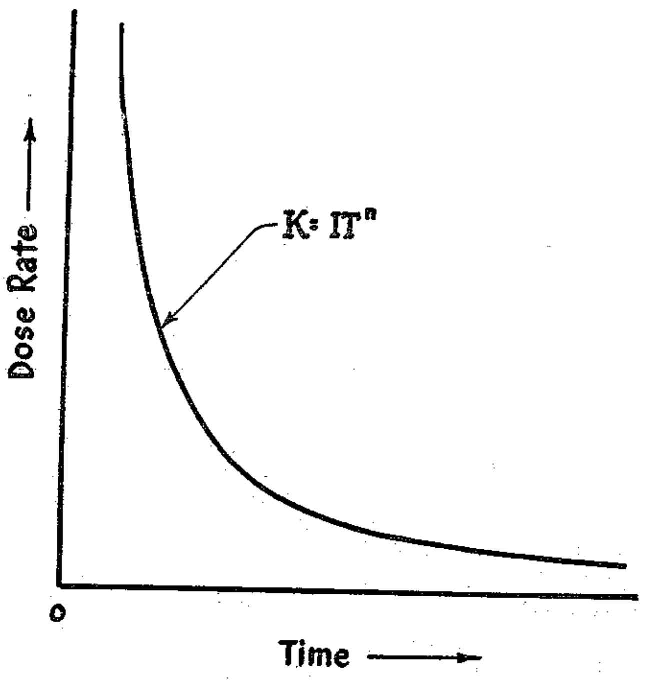

Figure 6—Multiple Decay.

Cumulative Dose

The total cumulative radiation dose and the time period in which it was received by a person is important when deciding if a person should be further exposed in civil defense operations. Dose is equal to the dose rate multiplied by time of exposure. (Dose = Dose rate x Time). This is easy to calculate when the radiation level remains essentially constant over a long period of time, as it does with a long-lived radioactive isotope.

In calculating dose from fallout radiation, the rapid decrease in radiation level must be taken into account. From the equation $D = \frac{K}{n-1}\left[t_1^{1-n} - t_2^{1-n}\right]$, the dose accumulated between the time of entrance (t_1) into a contaminated area and time of exit (t_2) can be calculated. D is the dose received, K = Intensity at unit time, and n is Kaufman's constant. (See appendix A.)

The percentage of total dose accumulated during a portion of the exposure time, is shown in Table 3.

Table 3—Accumulated Dose

Total dose received in:	Percent total dose for following exposure time in hours												
	4	8	12	16	20	24	36	48	72	96	120	336	720
(hours)	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
4	100												
8	78	100											
12	69	88	100										
16	64	82	92	100									
20	60	78	88	95	100								
24	58	74	84	91	96	100							
36	53	69	78	84	89	92	100						
48	51	65	74	80	84	88	95	100					
72 (3 days)	48	61	69	75	79	82	89	94	100				
96 (4 days)	46	59	66	72	76	79	86	90	96	100			
120 (5 days)	45	57	65	70	74	77	83	88	93	97	100		
336 (14 days)	40	51	58	63	66	69	75	79	84	87	90	100	
720 (30 days)	38	48	55	59	62	65	70	74	79	82	84	94	100

(Assuming n = 1.2 and the exposure starts 1 hour after burst)

For example: If the total dose were received in 48 hours, over ½ of it was received in the first 4 hours of exposure. If the total dose were received in 14 days, over half was received in the first 8 hours and about 75% in the first 36 hours.

Detection and Measurement of Radiation

Generally, instruments measure an effect of a phenomenon rather than the phenomenon itself. The sensitivity of radiation instruments depends on the ionizing effect of radiation. Most of these instruments measure the amount of ionization produced in a gas. Ionization of a gas consists of the removal of one or more electrons from one or more of the gas molecules, changing the electrically neutral molecules into positive ions. Civil defense survey meters and self-reading dosimeters are instruments of this type. In the presence of an electrostatic field, these positive ions are moved in one direction while the electrons are moved in the opposite direction. The measurement of the amount of current thus created, provides an indication of radiation level. Usually a closed tube having an electrically conducting shell and insulated central electrode, containing a definite volume of gas, is used as the radiation sensitive element of the instrument. Other instruments such as the phosphate glass and chemical dosimeters depend on ionization phenomena which change their molecular arrangement and consequently their optical characteristics.

GEIGER COUNTER

The geiger tube is filled with inert gas such as neon or argon and small amounts of organic or halogen vapor. The amount of ionization produced inside the tube by the primary radiation is amplified by the inert gas in an avalanche effect producing a pulse of current which activates an electric circuit. The organic or halogen vapor acts to terminate the pulse and restore the tube to its sensitive condition. Geiger counter instruments are useful for many purposes because of their sensitivity. Their primary use in civil defense operations would be for monitoring food, water, and people for radioactive contamination. They are particularly adaptable for training since they can be operated in weak radiation fields minimizing radiation exposures to trainees. Geiger counters do not read true dose rates in roentgens per hour unless measuring a known radiation energy for which the instrument has been previously calibrated. They read numbers of ionizing events without regard to the energy of these events. From a practical standpoint in civil defense, true roentgen readings in the low radiation levels for which a geiger counter is used are not important. The FCDA geiger counter, CD V-700[1], is calibrated against radium or cobalt 60 gamma radiation and will not give a true dose rate in roentgens per hour for the lower energy gamma radiation given off by fallout.

IONIZATION CHAMBER SURVEY METER

Ionization produced in the radiation sensitive chamber of the instrument is measured directly with an extremely sensitive electronic circuit. Electric current produced by this ionization passes through extremely high value resistors developing voltages which are fed into the grid of a special vacuum tube and amplified. Since minute currents are involved, special insulators, large value resistors and "electrometer" tubes are required.

Collecting all of the ions produced becomes a problem especially on the higher ranges. If the batteries are weak, the instrument may calibrate accurately at low readings but indicate less than the actual value in higher fields. For this reason, the batteries supplying the ionization chamber must be up to their rated value, particularly if the instruments are to be used in high radiation fields.

The instruments, CD V-710 and CD V-720[1] are ionization chamber survey meters. CD V-710 measures gamma only; the ionization chamber is protected by sufficient material to completely absorb alpha and beta radiation. CD V-720 may be used to detect gamma radiation only, or with its sliding shield in the open position, it responds to beta radiation as well. The instrument does not indicate beta radiation directly since the contribution from a gamma component will have to be subtracted. Even then a calibration chart must be used for proper interpretation.

DOSIMETER

The self reading ionization chamber dosimeter may be described as an electrical condenser in parallel with a high impedance voltmeter. The condenser is charged to give a

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[1] See TB-11-20, Sept. 1955. Radiological Instruments for Civil Defense.

"zero roentgen" indication on the voltmeter. Radiation entering the sensitive chamber of the dosimeter produces ions which are collected by the electrodes of the chamber causing a reduction in voltage. The amount of this reduction is indicated on the meter as a particular radiation exposure. In the CD V-730 and CD V-740[1], "zero roentgens" correspond to about 170 volts while "full scale" corresponds to about 110 volts. The ionization chamber dosimeter requires exceptionally good insulation, since the instrument must be capable of holding its charge when no radiation is present. This requires insulation many million times better than that required in an ordinary radio. Dosimeters must be capable of accurately indicating the doses received at extremely high rates. Two factors may cause difficulties: (1) not all of the ions are collected or (2) the insulators lose ability to hold the electric charge, resulting in an apparent dose reading. Dosimeters produced in accordance with FCDA specifications do not exhibit these characteristics.

Glossary

Following are terms commonly used in radiological defense:

Absorption—The process by which the energy of radiation is reduced as it passes through matter. Absorbed radiation may be transformed into matter, other radiation, or energy by interaction with the electrons or nuclei of the atoms with which it reacts.

Absorption Coefficient—The fractional decrease in the intensity of a beam of radiation per unit thickness or unit mass of the absorbing material.

Alpha Particle—Nuclear radiation consisting of two protons and two neutrons and having a double positive charge. It is identical to a helium nucleus. Alpha particles can be stopped by a few inches of air, by a sheet of paper, or the dead surface layer of the skin.

Alpha Emitters—Radioactive materials which emit alpha particles. Certain of these substances have an affinity for bone tissue, have long half lives, and tend to remain in the bone for long periods of time. They are therefore dangerous if taken into the body, since the emitted alpha particles can cause cell damage in the immediate area where the substances become located.

Avalanche—A process in which a single charged particle accelerated by a strong electric field produces additional charged particles through collision with neutral gas molecules.

Beta Particle—A negatively charged particle emitted from the nucleus of an atom and having a mass and charge equal in magnitude to an electron. Beta radiation may penetrate about a half a centimeter into the skin producing an effect similar to a burn. Beta particles are more highly ionizing.

Beta Emitters—Radioactive materials which emit beta particles. These substances taken internally can cause serious cell damage.

Curie (c)—The amount of radioactive material which decays at the rate of 3.7×10^{10} disintegrations per second. A millicurie (mc) is one thousandths of a curie; a microcurie (μc) one millionth.

Electron Volt (ev)—The amount of energy gained by an electron in passing through a potential difference of one volt. A million electron volts is abbreviated Mev. 1 Mev equals 1.6×10^{-6} ergs. 931 Mev equals 1 atomic mass unit.

Erg—A unit of work or energy. A million ergs equals 0.1 watt-seconds. A billion ergs equals 24 calories.

Gamma Rays—Short wave length electromagnetic radiations emitted from the nucleus of an atom. They have no mass or electrical charge. They may travel several thousand yards in air, and can completely penetrate the body.

Half-life, Physical—The time required for a radioactive substance to lose 50% of its activity by decay. Each radioactive isotope has its own characteristic half-life; it ranges from a millionth of a second to billions of years.

Ion—An atomic particle, atom, or group of chemically combined atoms that have an electric charge, either positive or negative.

Ionization—The process by which a neutral atom or molecule acquires either a positive or negative charge. A high speed particle passing through matter may cause the atom or molecule to divide into positive and negative parts called ions, destroying the electrical balance. (Fig. 7).

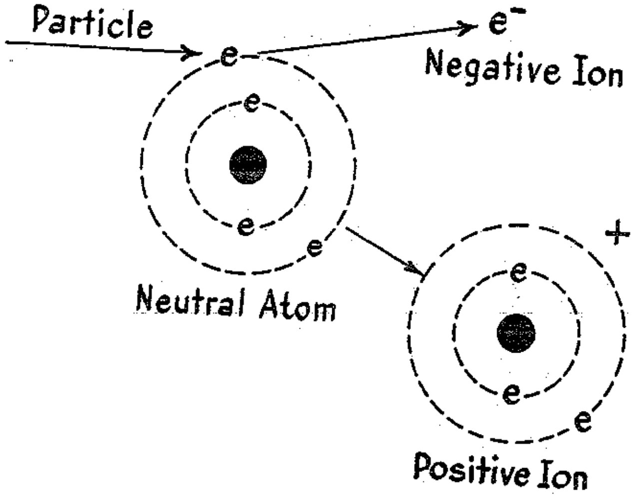

Figure 7—Ionization.

Ionizing Radiation—Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly. Gamma rays, beta and alpha particles, and neutrons are ionizing radiations of concern in radiological defense.

Neutron—Electrically neutral particle having a mass approximately the same as the hydrogen atom. Neutrons are released in the processes of fission and fusion. They are not emitted by radioactive fallout particles.

Residual Radiation—Nuclear radiation emitted by radioactive materials produced by the explosion of a weapon and including unfissioned bomb material.

Rigged Bomb—A nuclear bomb to which an element, such as cobalt, is added to increase neutron-induced radioactivity for the purpose of increasing contamination by fallout. The Department of Defense has called the cobalt bomb "impractical."

Roentgen—A unit of radiation quantity, defined as that amount of X- or gamma radiation which produces one electrostatic unit of charge of either sign in one cubic centimeter of air at standard temperature and pressure.

X-rays—Penetrating electromagnetic radiations identical to gamma rays, but generally less energetic. X-rays originate in the electron structure of an atom and may be produced by the sudden slowing down of high speed electrons as in the X-ray machine, or by the "jumping" of electrons from an outer to an inner orbit.

APPENDIX A

Calculating Dose From Fallout Radiation

Example:

What dose would a civil defense team receive due to a nuclear burst if the team entered a contaminated area 5 hours after the burst and the team stayed for a period of 16 hours. The dose rate at one hour after the burst was 50 r/hr.

Solution:

Using the formula found on page 4.

$$D = \frac{K}{n-1} \left[t_1^{1-n} - t_2^{1-n} \right]$$

$n = 1.2$
$K =$ Intensity at unit time
$t_1 =$ Time of entry
$t_2 =$ Time of exit
$D =$ Dose received in r.

By substituting values in the above formula

$$D = \frac{50}{1.2-1} \left[5^{1-1.2} - 21^{1-1.2} \right]$$

$$= \frac{50}{.2} \left[5^{-0.2} - 21^{-0.2} \right]$$

Referring to table 1 of appendix A, we find that:

$$5^{-0.2} = 0.725$$
$$21^{-0.2} = 0.544$$

Therefore:

$$D = 250 \left[0.725 - 0.544 \right]$$
$$= 250 \text{ x } 0.181$$
$$= 45\text{r}$$

Table 1

t = Time in hours	$t^{1.2}$	$t^{-0.2}$
0.1	0.0631	1.586
0.2	0.1450	1.381
0.3	0.2358	1.273
0.4	0.3330	1.202
0.5	0.4352	1.149
0.6	0.5417	1.110
0.7	0.6518	1.074
0.8	0.7651	1.046
0.9	0.8812	1.023
1.0	1.000	1.000
1.5	1.627	0.921
2.0	2.300	0.871
2.5	3.003	0.826
3.0	3.737	0.803
4.0	5.278	0.756
5.0	6.899	0.725
6.0	8.586	0.697
7.0	10.33	0.679
8.0	12.13	0.660
9.0	13.96	0.644
10.0	15.85	0.631
11.0	17.77	0.619
12.0	19.73	0.608
13.0	21.71	0.599
14.0	23.74	0.590
15.0	25.78	0.582
16.0	27.86	0.574
17.0	29.28	0.567
18.0	32.09	0.560
19.0	34.23	0.555
20.0	36.41	0.550
21.0	38.61	0.544
22.0	40.82	0.539
23.0	43.06	0.534
24.0	45.31	0.530
25.0	47.59	0.525
25.5	48.74	0.523
26.0	49.89	0.521
27.0	52.20	0.518
28.0	54.52	0.514
29.0	56.87	0.510
30.0	59.23	0.505
31.0	61.61	0.503
32.0	64.00	0.500
33.0	66.41	0.497
34.0	68.83	0.494
35.0	71.27	0.491
36.0	73.72	0.488
37.0	76.18	0.486
37.5	77.43	0.484
38.0	78.66	0.483
39.0	81.15	0.480
40.0	83.67	0.478
41.0	86.17	0.476
42.0	88.70	0.474
43.0	91.23	0.472
44.0	93.79	0.470
45.0	96.35	0.467
46.0	98.93	0.465
47.0	101.5	0.463
48.0	104.1	0.461
49.0	106.7	0.459
49.5	108.0	0.458
50.0	109.3	0.457
55.0	122.6	0.449
60.0	136.1	0.441
65.0	149.8	0.434
70.0	163.7	0.427
72.0	169.4	0.425
75.0	177.8	0.422
80.0	192.2	0.417
85.0	206.7	0.412
90.0	226.5	0.407
95.0	236.2	0.402
96.0	239.2	0.401
100.0	251.2	0.399
120.0	312.6	0.384
140.0	376.2	0.372
144.0	389.1	0.370
160.0	442.5	0.362
168.0 (1 wk)	468.1	0.360
180.0	508.5	0.354
200.0	577.1	0.347
250.0	754.3	0.333
300.0	938.7	0.319
336.0 (2 wk)	1075.0	0.313
504.0 (3 wk)	1745.0	0.288
672.0 (4 wk)	2471.0	0.272
720.0 (1 Mo.)	2611.0	0.268
1440.0 (2 Mo.)	6166.0	0.234
2160.0 (3 Mo.)	10031.0	0.216
4320.0 (6 Mo.)	23045.0	0.187
8640.0 (1 Yr.)	52943.0	0.163
17280.0 (2 Yr.)	121640.0	0.143
25920.0 (3 Yr.)	197860.0	0.131
34560.0 (4 Yr.)	279430.0	0.124
43200.0 (5 Yr.)	365240.0	0.118
86400.0 (10 Yr.)	839100.0	0.102
216000.0 (25 Yr.)	2519700.0	0.086

APPENDIX B

Graphical Solution of Dose From Fallout Radiation

Example:

Using the same example as given in appendix A the solution by graph is as follows: See chart 1 of appendix B.

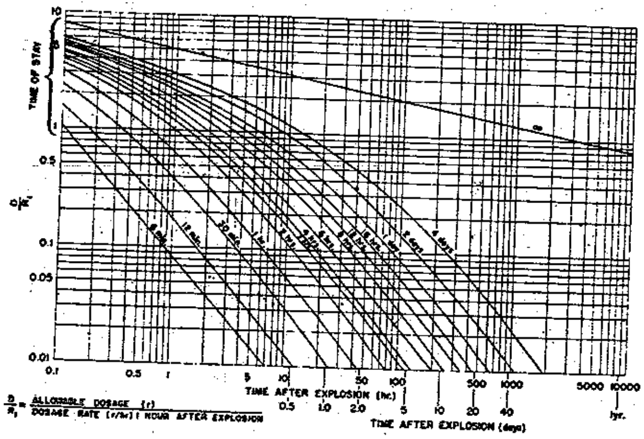

Chart 1

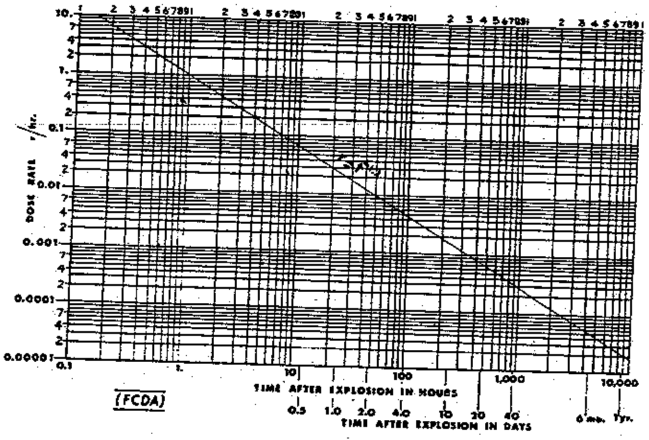

Chart 2

Solution:

The point of intersection of the 5 hour **after the explosion** line and the 16 hour **time of stay** line lies on the $\frac{D}{R_1}$ line and equal to .9

D = Dose (r)

R_1 = Dose rate (r/hr) 1 hour after explosion

$$\frac{D}{R_1} = .9$$

or

$$D = .9 \times R \text{ or } .9 \times 50 = 45 \text{ r}$$

To determine the approximate dose rate at H+1:

1. Determine the time after explosion of your measurement.

2. Locate the point of intersection with time after explosion line (chart 2) and the decay line, $r = t^{-1.2}$. Read the dose rate (r/hr) on the left axis.

Example:

A radiological monitor records a reading of 6.3r/hr at 10 hours. What was the dose rate H+1.

Solution:

$$\text{Dose rate (r/hr) at H+1} = \frac{\text{meter reading at specific time}}{\text{Value read from chart 2}} = \frac{6.3}{.07} = \text{Approximately 90 r/hr}$$

To determine the approximate dose rate at any time:

Example:

If the meter reading is 6.3 r/hr at H+10, what will the dose rate be at H+20?

Solution:

$$\frac{\text{Dose rate (r/hr) as measured}}{\text{Dose rate (r/hr) at new time}} = \frac{\text{Dose rate (r/hr) from chart 2 at time of measurement}}{\text{Dose rate (r/hr) from chart 2 at time selected}}$$

By substitution:

$$\frac{6.3}{\text{Dose rate at H+20}} = \frac{.07}{.03}$$

Cross multiplying:

$$\text{Dose rate at H+20} = \frac{.03 \times 6.3}{.07} = 2.7 \text{ r/hr}$$

REFERENCES

Blast Damage from Nuclear Weapons of Larger Sizes, Pub. TB-8-1, Feb. 1955.

Construction of Fallout Plots from Coded Messages Provided by the U. S. Weather Bureau, AB-188, May 25, 1955. Supplement No. 1, August 1955. Supplement No. 2, September 1955.

Emergency Exposures to Nuclear Radiation. Pub. TB-11-1, 1952.

Emergency Measurement of Radioactivity in Food and Water, Pub. TB-11-9, 1952.

Fallout and the Winds, Pub. TB-11-21, Rad. Def. Series, October 1955.

Permissible Emergency Levels of Radioactivity in Water and Food, Pub. TB-11-8, 1952.

Phosphate Glass Dosimetry, Pub. TB-11-15, July, 1954.

Protection Against Fallout Radiation, Pub. TB-11-19, Rad. Def. Series, Sept. 1955.

Radioactive Fallout from Nuclear Explosions, Pub. AB-178, November 1954.

Radiological Decontamination in Civil Defense, Pub. TM-11-6, 1952.

Radiological Instruments for Civil Defense, Pub. TB-11-20, Rad. Def. Series, September 1955.

Residual Radiation in Relation to Civil Defense, AB-179, February 1955.

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.—Price 5 cents.

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Appendix 8

civil defense
Technical Bulletin

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RADIOLOGICAL DEFENSE SERIES

A DIGEST OF TECHNICAL INFORMATION

MEDICAL ASPECTS OF NUCLEAR RADIATION

This is one of a series of technical bulletins on radiological defense. It presents, in general terms, the medical aspects of radiological defense.

The initial radiation hazard from a nuclear weapon detonated high in the air is due to gamma rays and neutrons liberated at the time of the explosion, and gamma rays from the ascending cloud. Casualties from a low yield weapon burst high in the air, will be from blast, heat, and initial nuclear radiation.

With high yield weapons the relative hazard of initial radiation is greatly reduced because the area covered by the blast and heat effects is larger than that covered by initial radiation. These weapons detonated near the surface of the earth cause great amounts of material to be drawn up into the fireball. This material is contaminated by radioactive products of the bomb. The radioactive particles will fall out causing contamination which may be lethal over thousands of square miles. Under these circumstances radiation casualties may equal or exceed those from blast and heat.

The hazards from fallout radiation are whole-body penetrating radiation, skin contamination, and internal absorption of radioactive materials. The whole-body penetration is almost entirely gamma since there are no neutrons present. In skin contamination, the greatest part of the dose is due to the beta component since the beta particles are absorbed almost entirely in the layers of the skin. The internal radiation hazard results from entry of radioactive substances into the body by breathing, swallowing, or through breaks in the skin. These substances may emit beta and gamma radiation from the fission products and alpha particles from unfissioned material. Inhalation will not be significant unless the particle size is very small—0.5 to 5 microns in diameter. Ingestion and entry through wounds is not so dependent on particle size.

Radiation damage from ingested materials results from irradiation of the body—principally the gastrointestinal tract, thyroid gland, and bone—from fallout particles in the intestinal tract, and radioactive materials absorbed and remaining in the body. It is improbable that there would be enough material inhaled or swallowed during the first few days to contribute appreciably to the acute clinical problem. Chronic exposure will be discussed later.

The Acute Radiation Syndrome

The most reliable means of estimating the seriousness of radiation injury is by the physician's evaluation of clinical symptoms, particularly on the day of exposure. The gastrointestinal tract is one of the most radiosensitive organ systems. Observable functional changes occur promptly after the damage has taken place. The incidence, severity, and time of beginning of vomiting and diarrhea have been shown to be a good index of the degree of radiation damage. Information on the distance from the explosion, amount of shielding present, and amount of radiation indicated by dosimeters should be taken into consideration when estimating total exposure.

On the basis of the severity and time of occurrence of gastrointestinal symptoms, casualties may be divided into three groups:

Group I—*Survival improbable.* These will have received supralethal amounts of radiation, probably in excess of 800 r[1] gamma dose of whole body irradiation, in a short period. Severe, and more or less continuous, vomiting will occur within a few hours, and will be followed by diarrhea, producing severe dehydration and apathy. Death may be expected to occur at any time from one day to two weeks.

Group II—*Survival questionable.* These will have received a dose of probably 200 r to 800 r. Vomiting will occur on the first day, but will subside within about 24 hours to be followed by a period of relative well-being from one to three weeks. This quiescent period may be followed by the development of small subcutaneous hemorrhages, sore mouth and throat, loss of hair, bloody diarrhea, loss of weight, and infection of thermal burns and other wounds which had been healing. Most of these symptoms are common to a variety of diseases, but the occurrence of hemorrhagic spots and falling hair are strongly suggestive of severe radiation injury.

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[1] Roentgen (r).—A unit of radiation quantity, defined as that amount of X- or gamma radiation which produces one electrostatic unit of charge of either sign in one cubic centimeter of air at standard temperature and pressure.

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Group III—*Survival probable.* These will have received a dose probably less than 200 r. No symptoms are to be expected on the first day except transient nausea, some vomiting, and fatigue. Later on, from the second to fourth week, there may be a slight feeling of ill health, but no incapacity will occur in most cases.

It is obvious that it is the Group II patients who will benefit most from treatment. If thermal burns or other injuries are present, the prognosis must be looked upon with more concern.

Blood changes provide valuable information on dosage. In Group I cases there will be a profound and prompt drop in the number of white blood cells. Blood concentration may be marked due to excessive fluid loss and lowered fluid intake. However, gastrointestinal symptoms will far overshadow the blood picture.

It is Group II and III cases in which the blood picture is of great medical importance. Doses in the range of 200 r to 800 r will result in profound drop within a day or two in certain of the white blood cells. Other white blood cells are reduced in number within a week or two. The red blood cells and platelets are also depressed, and profound anemia may occur. Examination of the white blood cells soon after exposure in the low dose range is a valuable aid to diagnosis. The platelet count is correlated with the dose, and if made properly is very helpful in making the prognosis.

The acute radiation syndrome presents no new features that are not observed daily in clinical practice. The diarrhea, dehydration, electrolyte imbalance, hemorrhage, anemia, and infection, are all commonplace findings, and the exercise of sound clinical judgment and good nursing care in the treatment of various aspects of the syndrome will save many lives and hasten convalescence.

Gastrointestinal symptoms should receive careful attention. Straining associated with diarrhea may be treated with antispasmodics such as atropine. Dehydration and electrolyte imbalance should be vigorously combatted with intravenous fluids and fluids by rectum if conditions permit. A bland, soft, or liquid high-caloric diet with vitamin supplements and ample fluids should be given as tolerated. Careful attention must be given to oral hygiene.

The treatment of infections associated with radiation injury is one of the most important aspects of handling these cases. The use of antibiotics presents a problem because early prophylactic use may result in development of resistant strains of organisms when at a later time antibiotics are urgently needed. Vigorous use of antibiotics should be started immediately on development of clinical evidence of either localized or generalized infection. It is advisable to use broad spectrum antibiotics with alternating schedules.

Blood transfusions should not be given as a routine measure, but may be lifesaving when clinically indicated.

Many substances have been tested in the hope of developing a specific preventive or therapeutic agent. To date none has been sufficiently established to warrent its inclusion in the physician's armamentarium, but research continues with the hope that a specific therapy will be discovered and developed to allow a greater number of cases to recover, and the illness to be shortened.

Skin Lesions

A wide variety of skin lesions may develop, depending upon variable physical as well as biological factors. The more important physical factors are:

(*a*) The earlier the contamination after the explosion, the greater the dose for a given amount of fallout material.

(*b*) The longer radioactive material remains on the skin, the greater the dose.

(*c*) The greater the proportion of high energy beta radiation, the deeper the effect.

(*d*) The distribution of material on the skin will determine the location of the lesions.

Among the biological factors are:

(*a*) Areas of the body covered by thinner skin will be more severely affected.

(*b*) Where the hair is thicker, the material will tend to remain longer, and the effect will be more pronounced.

(*c*) The material tends to collect and remain in areas of greater perspiration.

Preventive measures such as taking shelter or keeping indoors during the time fallout is taking place, or covering as much of the body as possible followed by removing outer clothing and washing exposed parts of the body, may completely eliminate or greatly reduce incidence and severity of skin lesions.

During the first few weeks after exposure, there may be no indications of skin damage. In more severe exposures, symptoms will occur within the first 24 to 48 hours. These will include: itching, burning or tingling sensations, and burning and watering of the eyes. Areas of redness, swelling, or blanching may be noticed. The greater the exposure, the earlier the symptoms will appear.

Within a few days early symptoms temporarily subside or disappear. The length of time before lesions develop is related roughly to the severity of exposure, and may vary from a few days following severe exposure to a few weeks after a mild exposure.

Following this period of quiescence there is a recurrence or intensification of symptoms. Lesions are usually absent on areas protected by even the scantiest of clothing. They are more likely to appear on areas where the skin is thin, moist, or hairy—head, neck, armpits, and elbows. New lesions may appear over several weeks.

Reddening of the skin, spots, pimples, or raised plaques or tanning of the skin may be the first indication of damage. These lesions may coalesce and form dry, thickened, pigmented areas. Itching, burning, and mild pain may be experienced. Milder lesions may merely show dry scaling from the center outward, leaving a depigmented thinned skin, followed within a few weeks by healing and repigmentation. More severe lesions may show deep destruction with raw, weeping ulcers. Secondary infection may occur especially if there is damage to blood cells incident to gamma radiation and if lesions do not receive proper care. These deeper lesions may be quite painful with resulting limitation of motion. The healing process may be slow or incomplete.

Loss of hair begins 2 to 3 weeks after exposure and usually involves the scalp. Eyebrows, eyelashes, axillary, and pubic hair appear to be more resistant. Unless the exposure has been severe, complete regrowth with normal color and texture within 5 to 6 months, is to be expected.

Treatment during the acute stage is very similar to the treatment of thermal burns. Mild lesions require daily cleansing with soap and water and application of bland ointments or lotions such as calomine lotion with 1% phenol. Ulcerating lesions should be kept cleaned and dressed. Antibiotics orally, locally, or by injection should be used if secondary infection occurs, or prophylactically if there has been a high dose of gamma radiation and severe leukopenia is present. Surgical treatment may be necessary and early skin grafting may be considered in the most severe cases.

Late Effects

Late effects are those harmful results which do not interfere with working efficiency during the first few weeks after exposure. They should never be thought of lightly and may be a major consideration in postattack and recovery periods. During the attack phase, however, we will be much more concerned with problems of our immediate survival and decisions on permissible radiation exposure will be made accordingly. Except for cataract development from neutron exposure and skin cancer from local radiation damage, late results from single exposures are not qualitatively different from those due to chronic exposure.

Chronic Radiation Injury

Chronic injury may result from one or a combination of the following types of exposure:

(*a*) Continuous low level exposure to external sources.

(*b*) Intermittent exposure to external sources.

(*c*) Prolonged exposure to internal sources.

There is no human and very little animal experience in continuous low level exposure to radiation from external sources. There is, however, much information on long continued intermittent exposure, and little reason to doubt that the clinical picture would be indistinguishable, one from the other. The principal findings are blood changes with leukemia predominating, skin cancer, as noted on the hands and face of radiologists, and shortening the life span—statistically demonstrable in animals and man. There will also be some genetic changes.

Prolonged exposure to internal sources may occur through continued inhalation or ingestion of radioactive substances or the fixation of long lived radioisotopes in the body. Certain substances, such as radium, plutonium, and strontium, have a tendency to become a part of the chemical structure of bones and remain in the body for many years. It is with these substances—principally radium—that we have had most of our experience with chronic internal source radiation injury. The principal results are bone destruction and bone cancer occurring some 20 years after deposition of the radioactive substance. Anemia may occur within a few years after rather large amounts of radium have gained access to the body, but in lower doses—10 to 30 micrograms—it is not a prominent finding.

REFERENCES

Blast Damage from Nuclear Weapons of Larger Sizes, TB-8-1, Feb. 1955.

Construction of Fallout Plots from Coded Messages, Provided by the U. S. Weather Bureau, AB-188, May 25, 1955, Supplement No. 1, August 1955, Supplement No. 2, September 1955.

Effects of Atomic Weapons (Revised September 1950), A. E. C.

Emergency Exposures to Nuclear Radiation, TB-11-1, 1952.

Fallout and the Winds, TB-11-21, Rad. Def. Series, revised Feb. 1956.

Permissible Emergency Levels of Radioactivity in Water and Food, TB-11-8, 1952.

Protection Against Fallout Radiation, TB-11-19, 1955, Radiological Defense Series.

Radiation Physics and Bomb Phenomenology, TB-11-22, revised July 1956.

Radiological Decontamination in Civil Defense, TM-11-6, 1952.

Radiological Instruments for Civil Defense, TB-11-20, Rad. Def. Series, September 1955.

Report by the U. S. Atomic Energy Commission on the Effects of High-Yield Nuclear Explosions, AEC, 1955.

Family Shelters For Protection Against Radioactive Fallout, TB-5-3, 1958.

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.—Price 5 cents.

Appendix 9

civil defense
Technical Bulletin

TB–8–1
February 1955
(Reprinted October 1958)

A DIGEST OF TECHNICAL INFORMATION

BLAST DAMAGE FROM NUCLEAR WEAPONS OF LARGER SIZES

This bulletin makes available to State and local civil defense directors, without the necessity of detailed calculations, rough estimates of the blast damage from larger nuclear weapons at various distances from ground zero. These blast damage radii vary roughly with the cube-root of the energy release of the bomb.

The graph in figure 1, with a horizontal scale of "bomb size" and a vertical scale of "GZ (ground zero) distance," shows the limits of the blast damage zones for A-, B-, C- and D-damage as defined in table 1.[1]

Determining the Blast Damage Zone

To estimate the damage at a particular distance from a bomb burst of any size, mark on the graph a point horizontally across from its "GZ distance" on the vertical scale and vertically above the "bomb size" on the horizontal scale. This will show the blast damage zone, in terms of A-, B-, C-, or D-damage in which the point lies.

Estimates of Damage

With this information one can refer to the blast damage zone columns in the table showing the degrees of damage which may be expected for each of the 17 items. Principal among these is item (1), which is a typical urban complex of buildings. With A-damage the buildings are virtually destroyed, with B-damage they have to be demolished, with C-damage they have to be vacated for repairs, whereas with D-damage the repairs can be accomplished while the buildings are in use.

The Scales in the Graph

To give about the same reading accuracy on a percentage basis for bombs of all sizes, as well as to reduce the curves

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[1] See Civil Defense Urban Analysis, TM—8—1, FCDA, (OCDM), pp. 14, 15.

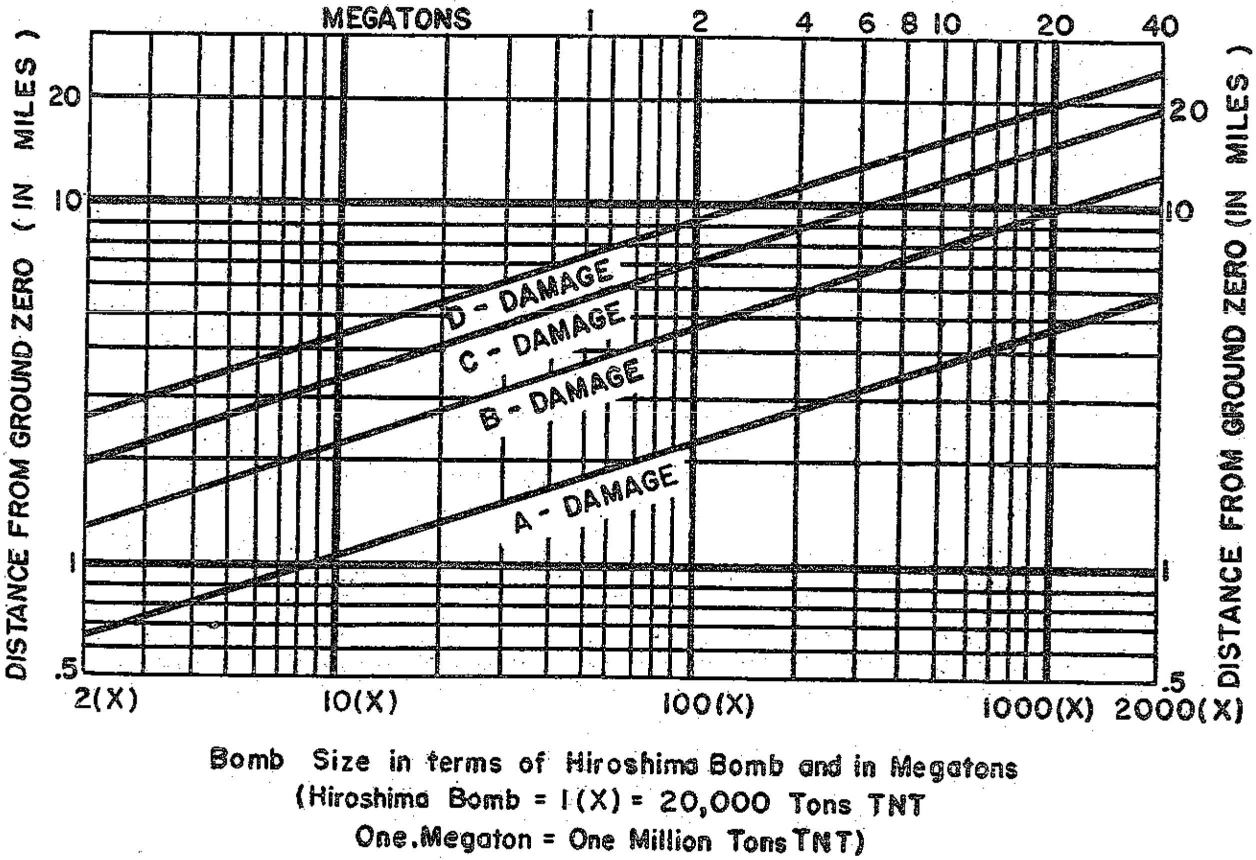

Figure 1.—Blast damage radii for nuclear weapons.

of blast damage zone limits to the form of simple straight lines, the scales of GZ distance and of bomb size have been suitably adjusted. The divisions of the scales are not all of uniform length, but this imposes no difficulty in their use. To get the 700(X) point on the bomb size scale count off 6 spaces from 100(X) in the 100(X) to 1000(X) interval. To get the megaton equivalent, count off 6 spaces of 2 MT each from 2 MT for a 14 MT or 700(X) bomb. Similarly, to fix a GZ distance of 9 miles, count up 8 spaces in the 1 mile to 10 mile interval on the vertical scale.

Limitations

A bomb burst height of 2,000 feet was assumed for the 1(X) bomb with scaling by the simple cube-root law. In theory this would require burst heights to be similarly scaled, but this probably would indicate unreasonably great burst heights for bombs in the metagon range. Damage depends not only on blast pressure but also upon blast duration (which also scales with the cube-root law), although no allowance is included here for blast duration effect. Because

Table 1.—*Blast damage by nuclear bomb—air burst*

No.	Item	Zone of A-damage	Zone of B-damage	Zone of C-damage	Zone of D-damage
1	(*a*) Ordinary buildings—typical urban complex for American cities.	Virtually completely destroyed.	Severely damaged or destroyed; buildings must be torn down.	Moderately or severely damaged; moderately damaged buildings must be vacated for repairs.	Partially damaged; buildings need not be vacated during repairs.
	(*b*) Reinforced-concrete or steel-frame buildings.	Buildings standing but most masonry panel walls and non-load-bearing partitions probably destroyed or displaced.	Buildings standing but many masonry panel walls and non-load-bearing partitions probably destroyed or displaced.	Interiors moderately damaged.	Interiors slightly damaged.
2	Highways and streets	Impassable	Impassable	Many parts blocked by rubble and require clearing before use.	Some parts blocked by rubble and require clearing before use.
3	Elevated roads and short span bridges.	Some destroyed; approaches blocked; decks of steel-plate girder bridges may shift laterally.	Some severely damaged; bridge approaches blocked by rubble and disabled vehicles.	Moderately damaged; approaches blocked; generally usable.	Partially damaged but probably usable.
4	Vehicles: aubomobiles, busses, trolleys, trucks, etc.	Vehicles unusable	Vehicles generally unusable.	Some vehicles unusable	Most vehicles usable.
5	Railroad yards and tracks.	Some tracks blocked by damaged rolling stock and rubble.	Some tracks blocked by damaged rolling stock and rubble.	Some tracks blocked by damaged rolling stock and rubble.	Some tracks blocked by damaged rolling stock and rubble.
6	Water mains	Some mains broken especially at ground zero and on bridges.	Not damaged except on bridges.	Not damaged	Not damaged.
7	Water pipes in buildings.	Numerous breaks causing loss of pressure.	Numerous breaks causing loss of pressure.	A few breaks causing loss of pressure	No breaks.
8	Elevated water tanks and towers.	Mostly destroyed or damaged beyond use, some substantial water towers may be usable.	Mostly destroyed or damaged beyond use; some substantial water towers may be usable.	Tanks supported by frames may fall.	Partially damaged but probably usable.
9	Sewers and storm sewers.	Some mains broken especially at ground zero.	Not damaged	Not damaged	Not damaged.
10	Large fuel gas storage tanks.	Destroyed	Probably destroyed	Possibly destroyed	Not damaged.
11	Gas mains	Some mains broken especially at ground zero and on bridges.	Not damaged except on bridges.	Not damaged	Not damaged.
12	Gas pipe in buildings	Numerous breaks	Numerous breaks	A few breaks	Probably no breaks.
13	Above ground oil storage tanks.	Mostly destroyed or damaged beyond use.	Mostly destroyed or damaged beyond use.	Partially damaged; not ruptured.	Partially damaged; not ruptured.
14	Overhead electric power lines-poles, wire, and transformers.	Destroyed	Destroyed or severely damaged	Poles, mostly usable; wires, broken by falling or flying objects; transformers, short-circuited.	Poles, mostly intact; wires, broken by falling or flying objects; transformers, may be short-circuited.
15	Underground electric power lines.	Intact except where join overhead lines or enter transformer or power stations; some may be short-circuited if conduits flood.	Intact except where join overhead lines or enter transformer or power stations; some may be short-circuited if conduits flood.	Not damaged; some may be short circuited if conduits flood.	Not damaged; some may be short circuited if conduits flood.
16	Telephone poles and overhead wires.	Destroyed	Destroyed or severely damaged.	Poles, mostly usable; wires, broken by falling or flying objects.	Poles, mostly intact; wires, broken by falling or flying objects.
17	Radio and TV towers	Destroyed	Some destroyed	Some destroyed	Partially damaged but may be operable.

we do not know what size bomb an enemy might use, these errors do not seem critical to civil defense planning. With these errors in it the making of the graph much larger and more finely subdivided would be undesirable and unjustified because such a larger graph would appear to be much more accurate than it actually is and would probably be misleading.

The graph refers simply to blast damage and does not include effects of thermal or of nuclear radiation of any sort. It also disregards the effect of distant radioactive fallout. While the graph covers a range of bomb sizes between 2(X) and 2,000(X), this is no indication that bombs which may be dropped will be of sizes between those limits, nor even that this upper limit will be closely approached, nor that any particular burst-height relation will be used by the enemy.

Recommended Policy

Although various other bomb size estimates have been made by individual writers, State and local civil defense officials should base their planning on the bomb size estimates consistent with current OCDM planning assumptions.

Familiarization

Each civil defense director should familiarize himself with the use of this graph by working out practical examples. By applying the information in it to selected points in critical target areas, he can estimate the damage which would be caused by a nuclear bombing attack of types described in OCDM planning assumptions. (See FCDA (OCDM) Advisory Bulletin 204.)

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Appendix 10

civil defense Technical Bulletin

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A DIGEST OF TECHNICAL INFORMATION

FAMILY SHELTERS FOR PROTECTION AGAINST RADIOACTIVE FALLOUT

PURPOSE

This bulletin provides guidance to engineers, architects, contractors, and the general public in planning family shelters for protection against the effects of radioactive fallout.

FALLOUT

General

Whenever a nuclear bomb is exploded near the ground, large amounts of earth and debris are drawn upwards by the ascending fireball. The resulting cloud may rise to a height of 80,000 feet or more. Radioactively contaminated particles which fall back to earth from this cloud are termed "fallout." Some of these radioactive particles are deposited close to the point of burst soon after the explosion, while others may be carried several hundred miles by the winds before they settle to earth.

Period of Shelter Occupancy

In any locality in the United States, fallout could require occupants to remain in shelter for two weeks or more. In many areas, radiation levels may permit leaving shelter, for intermittent periods or permanently, after 2 or 3 days. However, since the intensity of fallout at any specific place is impossible to predict prior to an attack, it is advisable to plan for a 2-week occupancy.

Radiation Hazard

There are several types of radiation associated with fallout. From the standpoint of shelter, however, the most significant hazard is from gamma radiation. Gamma rays, like X-rays, are highly penetrating, and to secure adequate protection from them special standards for shelter are required.

STANDARDS FOR FALLOUT SHELTERS

Shelter Dimensions

The shelter should provide for each occupant at least 12½ square feet of floor area and 80 cubic feet of volume. In general, ceiling heights should not be less than 6½ feet. The width of the entranceway should be kept to an absolute minimum, usually not more than 2 feet.

Shielding

(a) The shielding must have enough mass to reduce gamma radiation to a relatively harmless level. The less dense the material used, the greater the thickness required for a given degree of protection.

(b) As a general rule, a high degree of protection against gamma radiation will be afforded by an earth cover of 3 feet or an equivalent mass of other material or combination of materials. Approximate thicknesses required for other materials to afford protection equivalent to 3 feet of earth are: concrete, 24 inches; iron and steel, 7½ inches; and lead, 3 inches.

(c) The arrangement of the entranceway is important since harmful amounts of radiation may be scattered around corners. Therefore, the designs of the entranceways, shown on the attached drawings, should not be altered. It may be noted from the drawings that the radiation must make at least two right-angled turns before entering the main chamber. These changes of direction effectively reduce the intensity of radiation.

Ventilation

(a) In a basement shelter a tolerable and safe environment may be obtained by providing the means for natural ventilation, such as a grilled entrance door. Under-

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ground shelters, however, require the use of mechanical blowers or fans.

(*b*) The shelter ventilation system should be capable of supplying not less than 5 cubic feet of fresh air per minute per person in the main chamber, and means should be provided to exhaust the stale air. The actual intake of air which should be supplied to the shelter at any given time depends to a large extent on outside temperature conditions. For warmer temperatures, 5 cubic feet per minute per person is desirable. However, colder outside air may require a reduction in the amount delivered to the shelter, but this should never be less than 3 cubic feet of fresh air per minute per person. If practicable, the ventilating system should create a slight overpressure inside the shelter to prevent the infiltration of contaminated particles. The use of fuel-burning apparatus in the shelter area should be avoided.

(*c*) Suitable ventilating blowers or fans are commercially available at nominal cost (see Appendix A, page 4). Hand-operated centrifugal blowers of the type used in blacksmith forges have appropriate pressure-capacity characteristics. At a somewhat higher cost, small positive-displacement rotary blowers may be obtained with alternative hand-crank and electric motor drives, the latter feature being optional. While continuous operation of the ventilating blower at peak capacity would be best, intermittent operation on a short time cycle may be satisfactory. However, if the blower in a closed shelter is not operated for periods exceeding two hours, hazardous air conditions may result.

(*d*) Dry-type particulate air filters with cells or canisters containing a pleated filter material made of cellulose-asbestos or fine glass fibers are preferred for use in the ventilating systems (see Appendix A, page 4).

Radio Equipment

A battery-operated radio is necessary equipment for the shelter. If it is to be stored there, precautions should be taken to prevent its deterioration. A supply of spare batteries is highly desirable. Since batteries also deteriorate with time, replacements should be made at least once a year. The shielding required for radiation protection also dractically curtails effective radio reception. For this reason, radios used in shelters may require an antenna outside of the shelter itself. Since portable radios are made with widely differing circuit characteristics, it is impracticable to describe a single type antenna system suitable for all radios. However, two methods that have proven satisfactory with the radios tested are:

(*a*) Placing the radio near the underside of the entrance door.

(*b*) Running a lead-in wire from an outside antenna into the shelter, wrapping it several times around the radio in the direction that gives the best reception, and then grounding the end of the lead-in wire.

If neither of these methods proves successful, a local radio serviceman should be contacted for information on the most appropriate antenna system.

Food and Water Supply

At least a 2-week supply of food and water should be available. This may be required for survival even though the radiation level permits leaving the shelter in less than two weeks, since food may not be immediately available from normal sources. Foods that can be eaten without cooking are preferred. Packages of food should be in sizes which will meet the needs of one meal only. At least one-half gallon of water per person per day is needed for drinking and sanitation purposes. Gallon glass jugs, tightly capped, and carefully packaged to prevent breaking are recommended for long-term storage.

Sanitation

The sanitary disposal of human wastes is necessary for health protection. A small container, such as a hospital bedpan or other emergency toilet facility, should be provided. Contents should be disposed of in a covered watertight container. At least two 5-gallon holding containers are required for the initial shelter period. Following this period it may be possible to leave the shelter for short periods for disposal. These containers should be charged with a small amount of lime and water for odor control. A 10-gallon covered container for food refuse also should be included.

Miscellaneous Supplies

Other supplies that should be available include: a first aid kit; cots, bunks, or sleeping bags; blankets; flashlight and an extra supply of batteries, or a hand operated generator type of flashlight; can and bottle openers; eating utensils; toilet tissue, towels, and soap; and household tools.

Continuous low level lighting may be provided in the shelter by means of a 4-cell hot shot battery to which is wired a 150 milliampere flashlight-type bulb. Tests have shown that such a device, with a fresh battery, will furnish light continuously for at least 10 days. With a spare battery, a source of light for 2 weeks or more would be assured. A flashlight or electric lantern also should be available for those periods when a brighter light is needed.

FALLOUT SHELTER TYPES

Outside Underground Shelter

Many designs may be developed for an outside, underground, family fallout shelter which will provide reasonably adequate protection from radiation. Concrete, masonry, steel, pressure-treated wood, or other suitable construction material may be used. Three different shelter types are illustrated in the attached drawings (Appendixes B and C). It will be noted that all of these shelters are modifications of the basic underground family fallout shelter.

Basement Shelter

(*a*) In the construction of a new house with a basement, a family shelter may be incorporated in a corner of the basement in the manner illustrated in the attached drawing (Appendix D).

(*b*) The provision of fallout shelter equivalent to the basement shelter described above presents serious construction difficulties in existing houses. Placement of the large mass of shielding material for the roof of the structure in the restricted space, and the possibility of additional footings being required for the extra weight are the primary problems. A shelter of this type could be built into the basement of an existing house using lesser thicknesses of material, but a lesser degree of protection must be accepted by the occupants.

Aboveground Shelter

For areas of the country where underground shelters are not feasible, an aboveground shelter should be built. Any of the materials suggested for construction of an underground structure can also be used for this shelter. The total mass of shielding material, including the material of which the shelter is constructed, should be equivalent to three feet of earth. This may be provided by covering the structure with earth or sandbags. If the arrangement of the entranceway cannot meet the standards of paragraph c (p. 1) under "Shielding," the entrance door will require sandbagging from the inside.

The basic underground shelter, shown in Appendix B, with the entrance modified, could be placed aboveground and mounded over as described above.

Appendix A

A GUIDE TO CONTRACTS AND SPECIFICATIONS FOR USE IN FAMILY FALLOUT SHELTER CONSTRUCTION

If the services of a contractor are to be used in the building of a family shelter, it is generally advisable to have a written contract and technical specifications to supplement the drawings. A widely used and convenient contract form for construction of this size is the "AIA Short Form for Small Construction Contracts," which is available from the American Institute of Architects, the Octagon, Washington, D. C., for 25 cents. It would be impractical to write technical specifications to suit every local condition; however, the following summary of generally accepted construction materials and practices should be a useful guide:

EARTHWORK

The excavation should have side slopes gradual enough to prevent caving, or appropriate shoring should be provided. The soil from the excavation should be stockpiled near the site for later use as backfill if suitable for the purpose.

Material used for backfill and embankment should have debris, roots, and large stones removed before placement.

Backfill and embankment should be placed in horizontal lifts 12 inches thick or less and thoroughly tamped or rolled while in a damp condition.

The subgrade for the floor slab should be leveled and tamped to provide uniform bearing conditions for the structure.

The area surrounding the embankment should be sloped away at a minimum grade of 2 inches per 25 feet to provide good drainage.

CONCRETE WORK

The required compressive strength of the concrete in the attached OCDM designs is 3,000 pounds per square inch.

For details of concrete construction, the "Building Code Requirements for Reinforced Concrete (ACI 318–56)" should be followed. This publication may be obtained from the American Concrete Institute, P. O. Box 4754, Redford Station, Detroit 19, Mich., for one dollar.

DAMPPROOFING AND WATERPROOFING

Dampproofing and waterproofing specifications may be obtained from the nearest Federal Housing Administration Office, or any commercially acceptable specification may be used.

METAL WORK

The OCDM family fallout shelters were designed using deformed intermediate grade billet steel reinforcing bars. However, the shelters may be designed using other types of deformed steel bars. It is important that the builder insure that the bars to be used conform to the ACI Building Code referred to under "Concrete Work" above.

There are many types of commercially produced metal roof hatches that will adequately serve as shelter doors. However, as long as the door is weatherproof and durable, a job-made wooden door would be suitable.

piping in the shelter should be installed in accordance with the practices outlined in the "National Plumbing Code (ASA A40.8–1955)." This publication may be obtained from the American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N. Y., for $3.50. All piping should be galvanized.

The rungs in the entrance hatch are standard ¾-inch deformed reinforcing bars. The unembedded portion should be painted to prevent rusting.

VENTILATING EQUIPMENT

Suitable ventilating blowers, air filters, and roof ventilators are available from many sources of supply, although fabrication details, and consequently the installation requirements, will differ for equipment furnished by the various manufacturers.

Positive-displacement blowers having both electric motor and geared hand-crank drives are manufactured by Roots-Connersville Blower Division, Connersville, Ind. Small centrifugal blowers having a geared hand-crank drive are made by the following manufacturers:

Buffalo Forge Co.,
450 Broadway,
Buffalo, N. Y.

Champion Blower and Forge Co.,
Harrisburg Ave. and Charlotte St.,
Lancaster, Pa.

Air filters of the type used for engine or compressor intake pipes are manufactured by the following concerns:

Dollinger Corp.
6 Centre Park,
Rochester 3, N. Y.

Fram Corp.,
Providence 16, R. I.

Purolator Products, Inc.,
970 New Brunswick Ave.,
Rahway, N. J.

Roof ventilators are made by the following manufacturers:

Air Devices, Inc.,
185 Madison Ave.,
New York City 16, N. Y.

G. C. Breidert Co.,
P. O. Box 1190,
San Fernando, Calif.

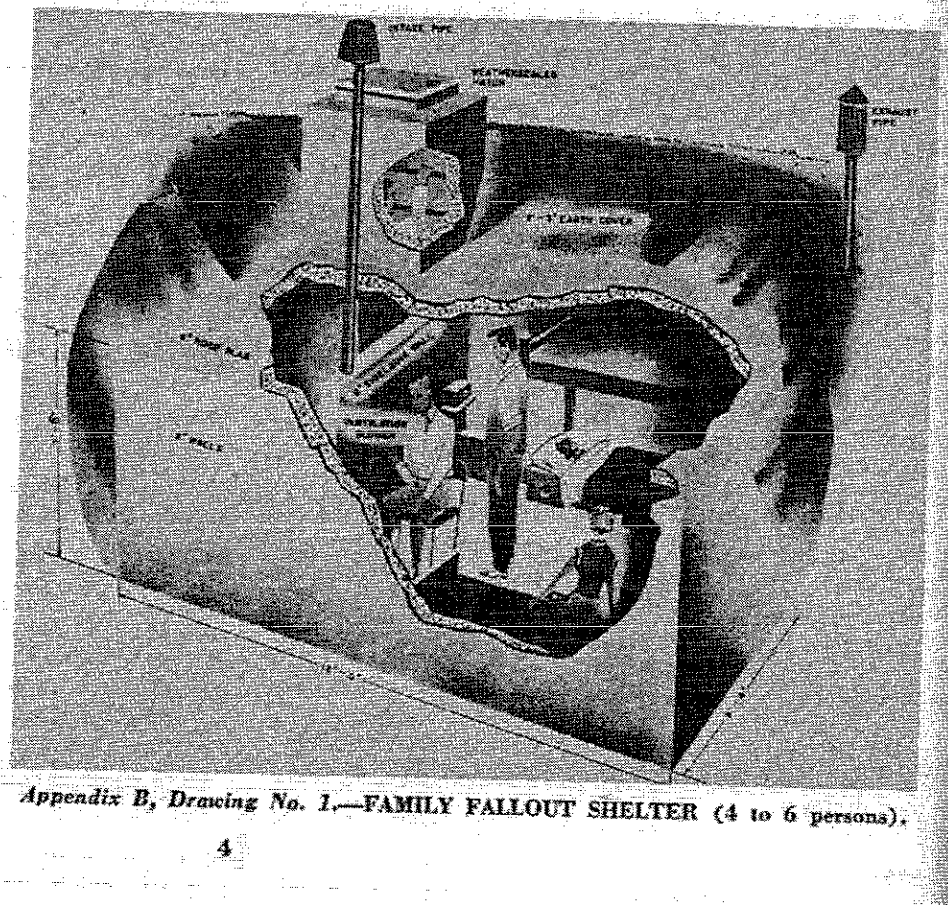
Penn Ventilator Co.,
3252 Goodman Ave.,
Philadelphia 40, Pa.

The names of specific manufacturers of blowers, filters, and roof ventilators are given only as examples, and do not denote a preference for their products. Local contractors, dealers, or distributors of heating, ventilating, and air conditioning equipment may be consulted when selecting equipment for a protective shelter.

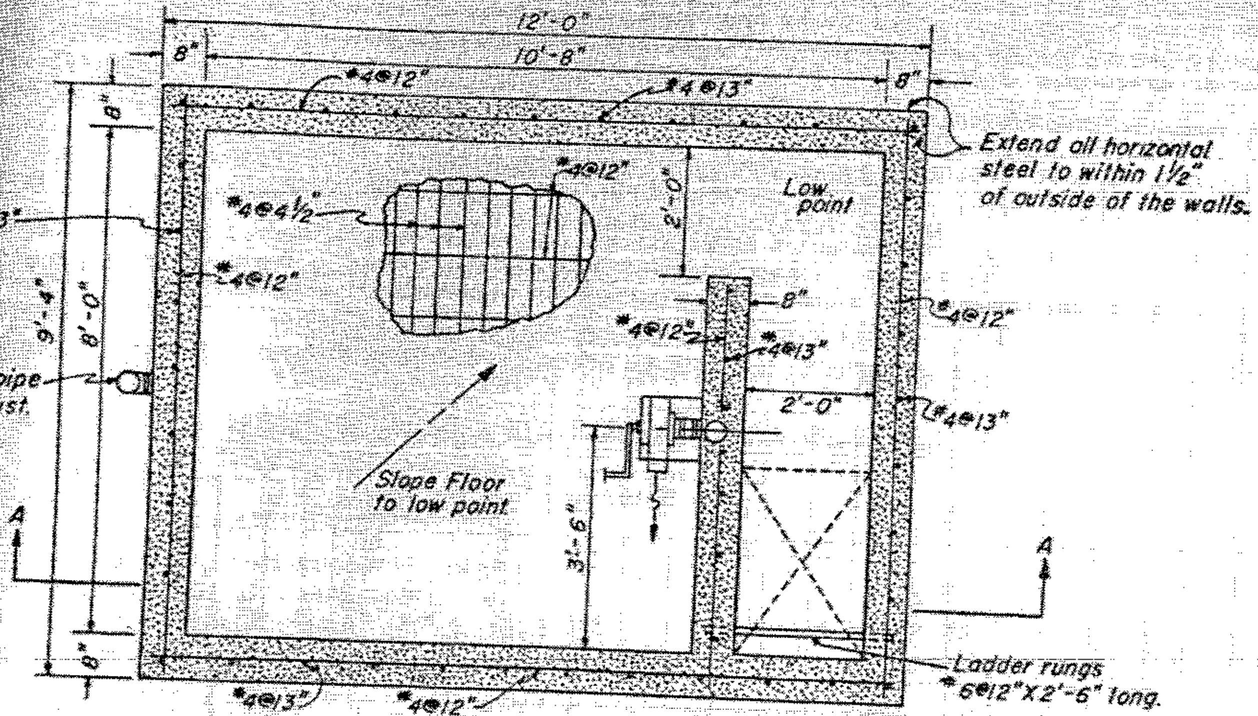
Appendix B

THE BASIC UNDERGROUND FAMILY FALLOUT SHELTER

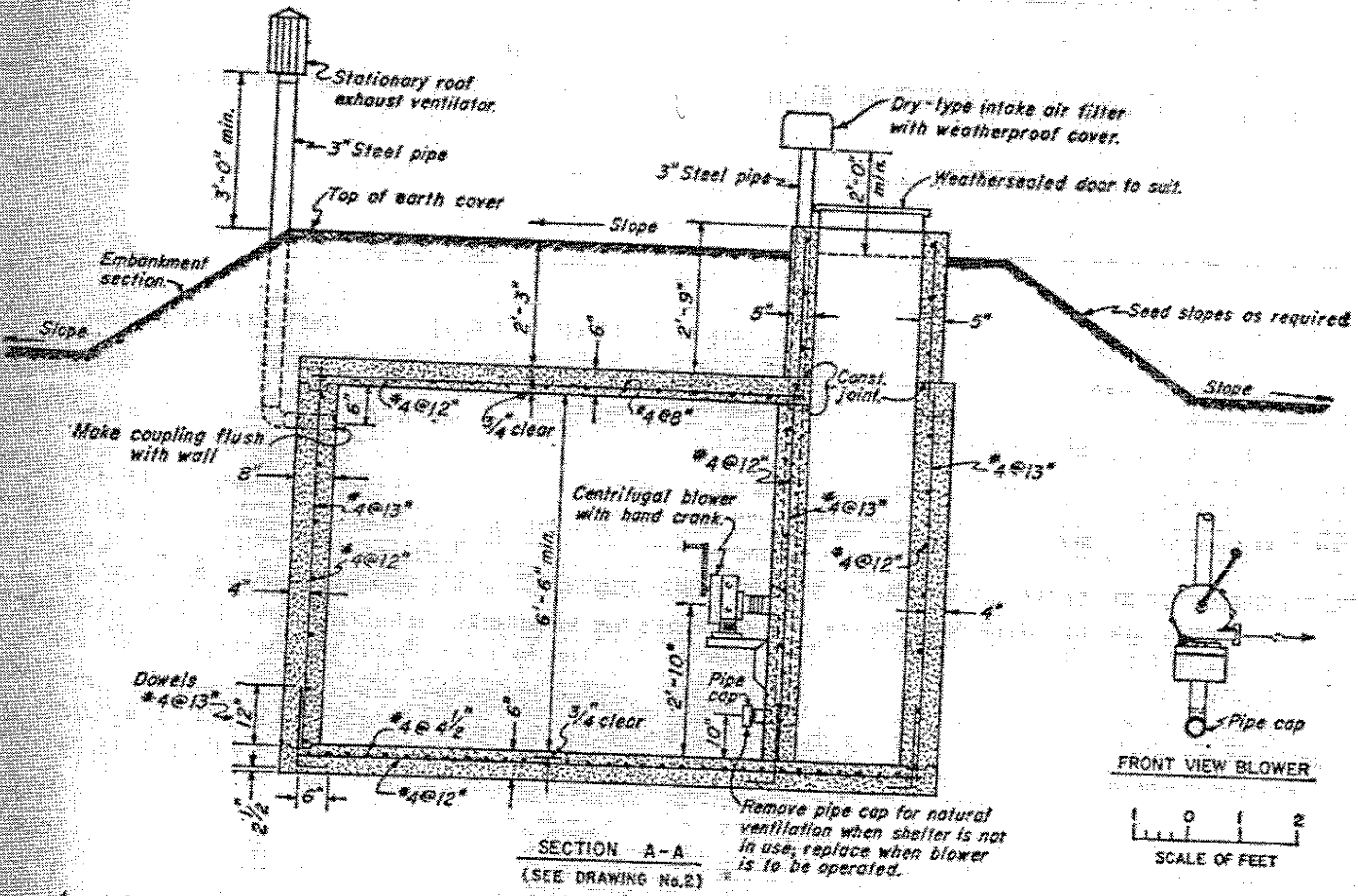
This reinforced concrete shelter has been designed to provide a high degree of protection from radioactive fallout for up to six adult occupants. The drawings show the shelter covered by an embankment 2 feet 3 inches high. If desired, the embankment may be eliminated by placing the roof of the shelter 2 feet 3 inches below ground level. The selection of which type of earth cover to use is optional since there is no significant difference in the amount of protection afforded. If the embankment is used, however, its slopes should be seeded or treated to prevent erosion.



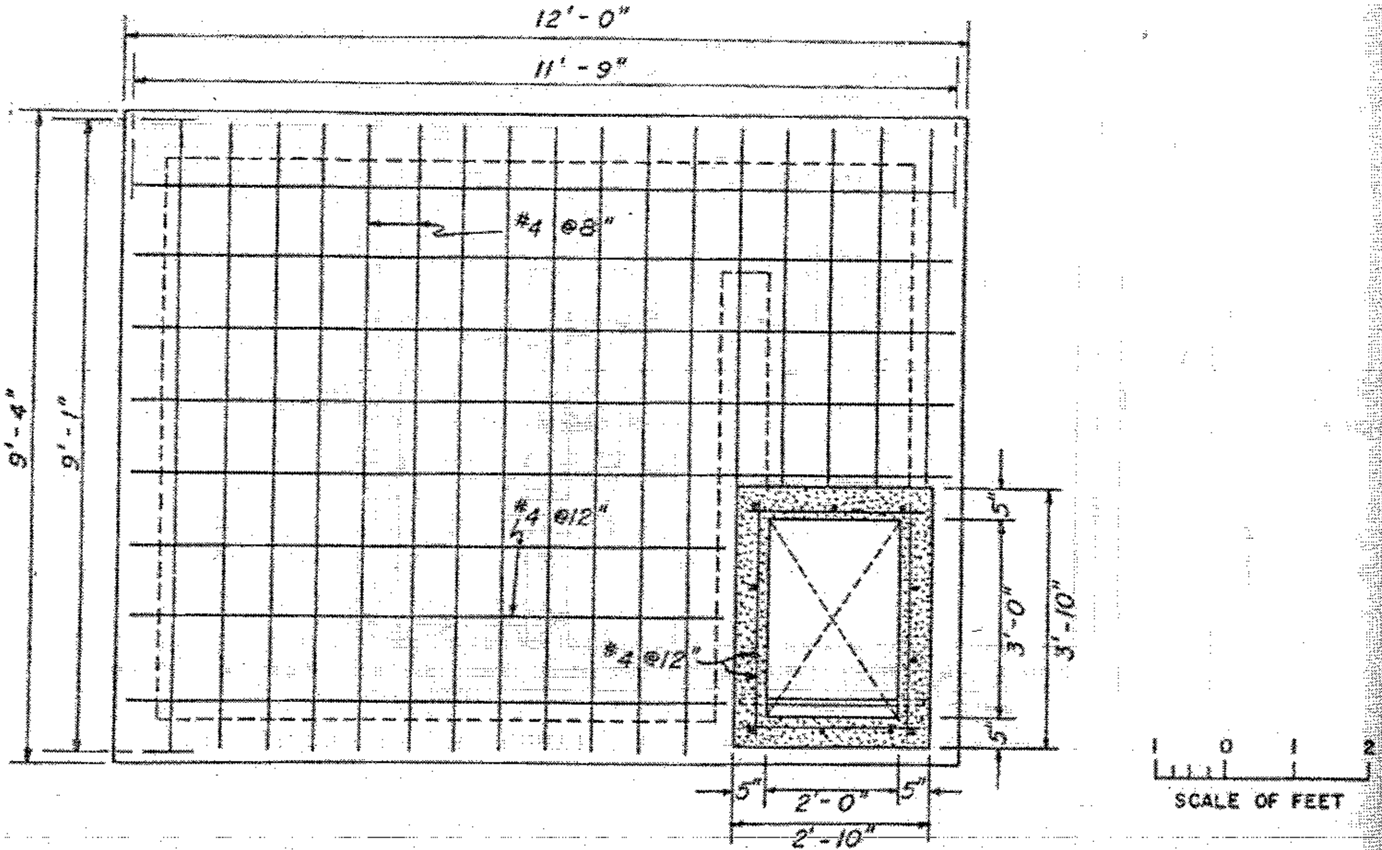
Appendix B, Drawing No. 1.—FAMILY FALLOUT SHELTER (4 to 6 persons).



Appendix B, Drawing No. 2.—BASIC UNDERGROUND FAMILY FALLOUT SHELTER—Plan.



Appendix B, Drawing No. 3.—BASIC UNDERGROUND FAMILY FALLOUT SHELTER—Longitudinal Section.



Appendix B, Drawing No. 4.—BASIC UNDERGROUND FAMILY FALLOUT SHELTER—Roof Slab and Entranceway.

Appendix C

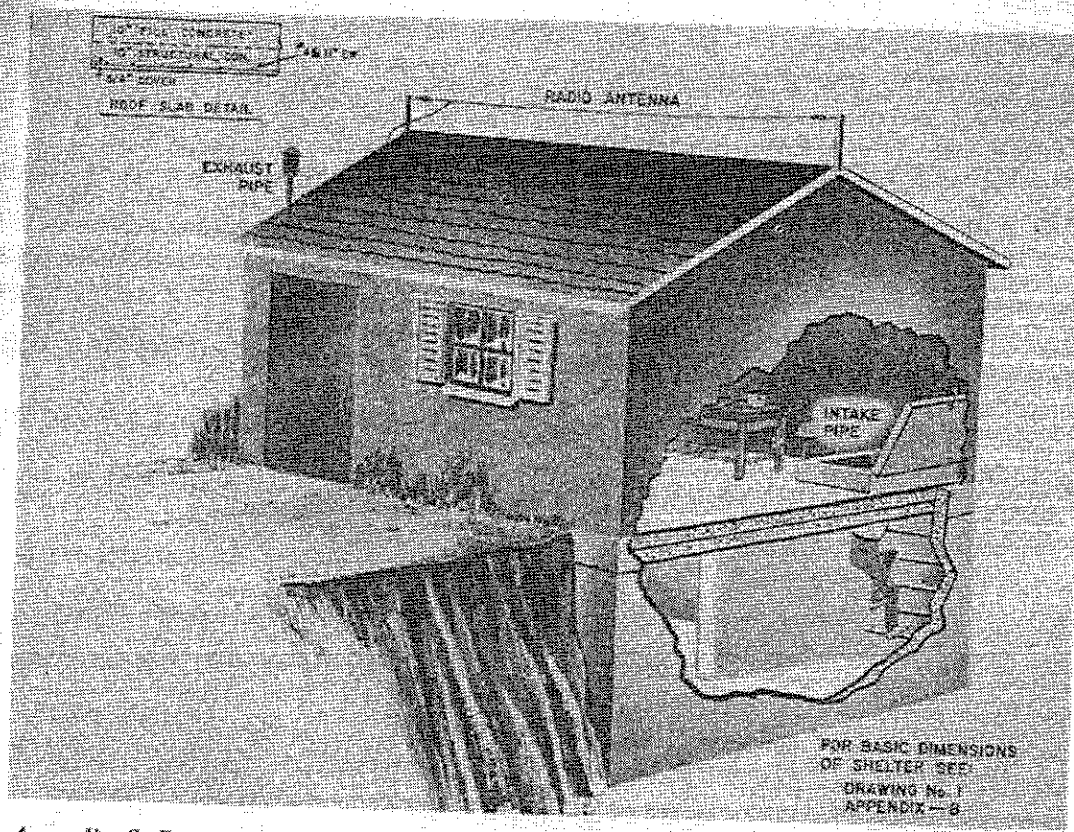
THE BASIC UNDERGROUND FAMILY FALLOUT SHELTER INCORPORATED INTO SMALL BUILDINGS

The basic underground family fallout shelter can be incorporated into the plans of basementless houses, garages, garden or tool houses, and the like (see drawings 1 and 2). There are only two structural modifications required. First, the slab thickness of the roof must be increased to 20 inches, and second, a "collar" of concrete or masonry must extend above the entranceway opening in the roof slab. The reinforcing bars of the walls and floor slab must be the same as in the basic shelter.

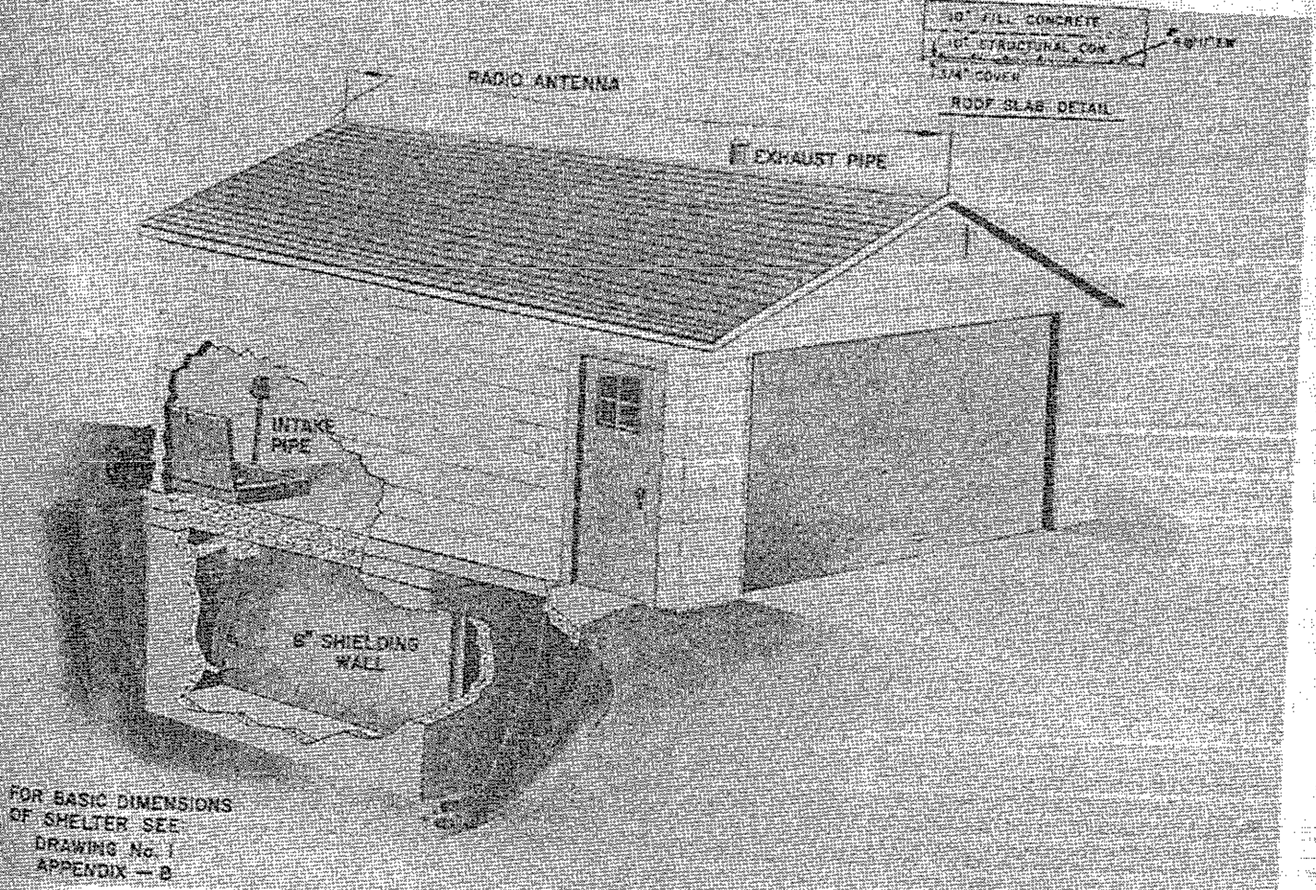
To meet recognized code requirements economically, the roof slabs should be placed in two 10-inch layers. The lower layer should contain the minimum amount of reinforcing steel required by code. The upper layer is for radiation protection only, and it should be placed and compacted with the same care as the structural concrete.

The "collar" should have a minimum height of 12 inches and width of 12 inches. These dimensions are based on radiation considerations. Since most commercially available door hatches have minimum inside dimensions of 2 feet 6 inches x 3 feet, the collar is of ample size to accommodate them, even though the actual opening is narrower.

The ventilation system should contain the same components as the basic shelter; however, the intake may be located within the small building and the exhaust outside, as shown on the drawings.



Appendix C, Drawing No. 1.—FAMILY FALLOUT SHELTER—Incorporated into Garden House.



Appendix C, Drawing No. 2.—FAMILY FALLOUT SHELTER—Incorporated into Garage.

THE BASEMENT CORNER ROOM FAMILY FALLOUT SHELTER INCORPORATED INTO NEW CONSTRUCTION

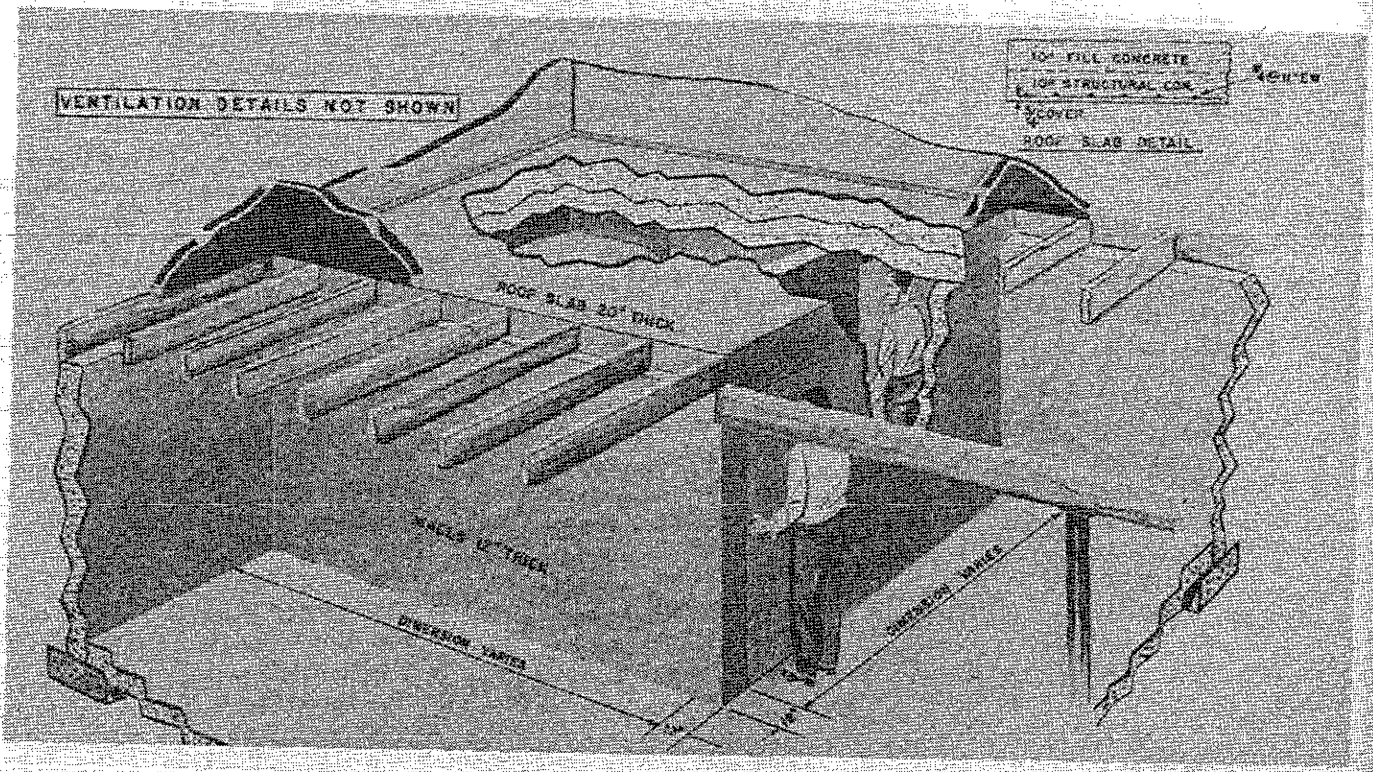
In this design (drawing No. 1) the two exterior walls of the shelter also serve as house foundation walls and the top of the roof slab is used as the floor for a room above.

Any contractor should be able to construct the basement corner room shelter without difficulty. Special care, however, should be taken in shoring the formwork for the heavy roof slab. Although not shown on the drawing, conventional wall footings should be added under the interior walls of the shelter.

To meet recognized code requirements economically, the roof slab should be placed in two 10-inch layers. The lower layer should contain the minimum amount of reinforcing steel required by code. The upper layer is for radiatio protection only, and should be placed and compacted wit the same care as the structural concrete.

The shelter may be built with either a natural or mechanical ventilation system. Natural ventilation may be achieved by having two grilles or louvers about 1 foot square in the entrance door. One grille should be near the top and the other near the bottom of the door.

If a mechanical system is used, it should contain the same components as the basic underground family fallout shelter except that a grille in the door may be substituted for the exhaust pipe.



Appendix D, Drawing No. 1.—BASEMENT FAMILY FALLOUT SHELTER (4 to 6 persons).

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