CPG 2-1A6
June 1973

DCPA ATTACK ENVIRONMENT MANUAL

CHAPTER 6

WHAT THE PLANNER NEEDS TO KNOW ABOUT FALLOUT

DEFENSE CIVIL PREPAREDNESS AGENCY
DEPARTMENT OF DEFENSE

JUNE 1973

DCPA ATTACK ENVIRONMENT MANUAL

WHAT THE EMERGENCY PLANNER NEEDS TO KNOW ABOUT THE NATURE OF NUCLEAR WAR

No one has gone through a nuclear war. This means there aren't any natural experts. But civil defense officials are in the business of preparing against the possibility of nuclear war. Intelligent preparations should be based on a good understanding of the operating conditions that may occur in a war that has never occurred. Lacking such understanding, emergency operating plans probably won't make much sense if they have to be used.

This manual has been prepared to help the emergency planner understand what the next war may be like. It contains information gathered from two decades of study of the effects of nuclear weapons and the feasibility of civil defense actions, numerous operational studies and exercises, nuclear test experience, and limited experience in wartime and peacetime disasters that approximate some of the operating situations that may be experienced in a nuclear attack. In short, it summarizes what the Defense Civil Preparedness Agency now knows about the nuclear attack environment as it may affect operational readiness at the local level.

LIST OF CHAPTER TITLES

PREFACE TO CHAPTER 6

This description of the fallout effects of surface-burst nuclear weapons is intended to provide the operational planner with the basic information needed to plan realistic actions to be taken in fallout areas. It presumes that the reader is familiar with the material in earlier chapters, especially the information on the biological effects of brief exposures to ionizing radiation contained in Chapter 5—"What the Planner Needs to Know about Initial Nuclear Radiation."

Information is presented in the form of "panels," each consisting of a page of text and an associated sketch, photograph, chart, or other visual image. Each panel covers a topic. This preface is like a panel, with the list of topics in Chapter 6 shown opposite. If the graphic portion is converted into slides or vugraphs, the chapter or any part can be used in an illustrated lecture or briefing, should that be desired.

The ordering of topics begins with two introductory panels, followed by four panels on basic aspects of radioactivity in fallout. Five panels summarize the basis for predicting the fallout event from surface-burst nuclear weapons. There follow six panels on what would be observed in the fallout area by eye and with radiation detection instruments. Four panels discuss fallout radiation shielding and two the changes to be expected from winds and various weapon sizes. Contact and internal hazards of fallout radiation and its effects on animals and plants are covered in five panels. The special problems of urgent emergency operations in damaged areas where fallout also is deposited occupy the next five panels. Finally, four panels address the most common questions raised about fallout. A list of suggested additional reading is included for those who are interested in further information on the general subject.

CONTENTS OF CHAPTER 6

WHAT THE PLANNER NEEDS TO KNOW ABOUT FALLOUT

RADIOACTIVITY IN FALLOUT

Nuclear radiation is the major attack effect that is unique to nuclear weapons. The other effects differ from conventional weapons only in degree. Some aspects of the effects of ionizing radiation were considered in Chapter 5. In a real sense, however, it is fallout from nuclear weapons that poses special problems that make civil defense today quite a different thing from civil defense of World War II.

About half the energy produced in the detonation of megaton-yield nuclear weapons results from nuclear fission, a process in which radioactive substances are produced. When detonations occur on or near the earth's surface, these radioactive substances or "fission products" are incorporated into the materials scoured from the crater. Much of this material is carried high into the atmosphere by the rising fireball. The subsequent fall of particles of earth, concrete, and the like has been called "fallout."

In Chapter 1, it was noted that the fallout from a single 5-MT surface burst could produce hazardous radiation exposures several hundred miles downwind of the detonation point. This threat was demonstrated rather dramatically in 1954 when fallout from a test explosion more than a hundred miles away caused injuries among the crew of a Japanese fishing boat and among natives on Rongelap Atoll. The quotation shown here indicates the effect that this incident had on civil defense planning in the mid-1950s.

At first, very little was known about the potential hazards from fallout. Research since that time has reduced the uncertainties involved. But many of the older ideas and assumptions still persist as misconceptions. In this chapter, these misconceptions are dealt with. An attempt is made to present a rather complex subject in simple terms. Even when all useful simplifications are made, the information needed for emergency planning is complex, especially since few are expert in nuclear physics and radiobiology.

The first part of this chapter emphasizes the fallout problems in areas distant from nuclear detonations. Then, the effects of fallout will be described in the area of blast and fire discussed in earlier chapters.

PANEL 1

"The advent of the thermonuclear weapon, with its terrifically augmented power of destruction and dangerous fallout, capable of reaching hundreds of miles from a target area, brought virtually the entire country into the civil defense picture and called for wholesale revision of Federal, State and local civil defense planning. The year 1955 was mainly given to this task."

<u>1955 FCDA Annual Report</u>

TWO KINDS OF NUCLEAR RADIATIONS

At the time of a nuclear detonation, over 200 different radioactive substances are formed by fission. Additional ones are created by neutron irradiation of weapon parts, soil, and other close-by materials. These "fission products" and "induced activities" are potentially harmful because they emit two kinds of nuclear radiation—beta particles and gamma rays. Some emit only one type, but most emit both.

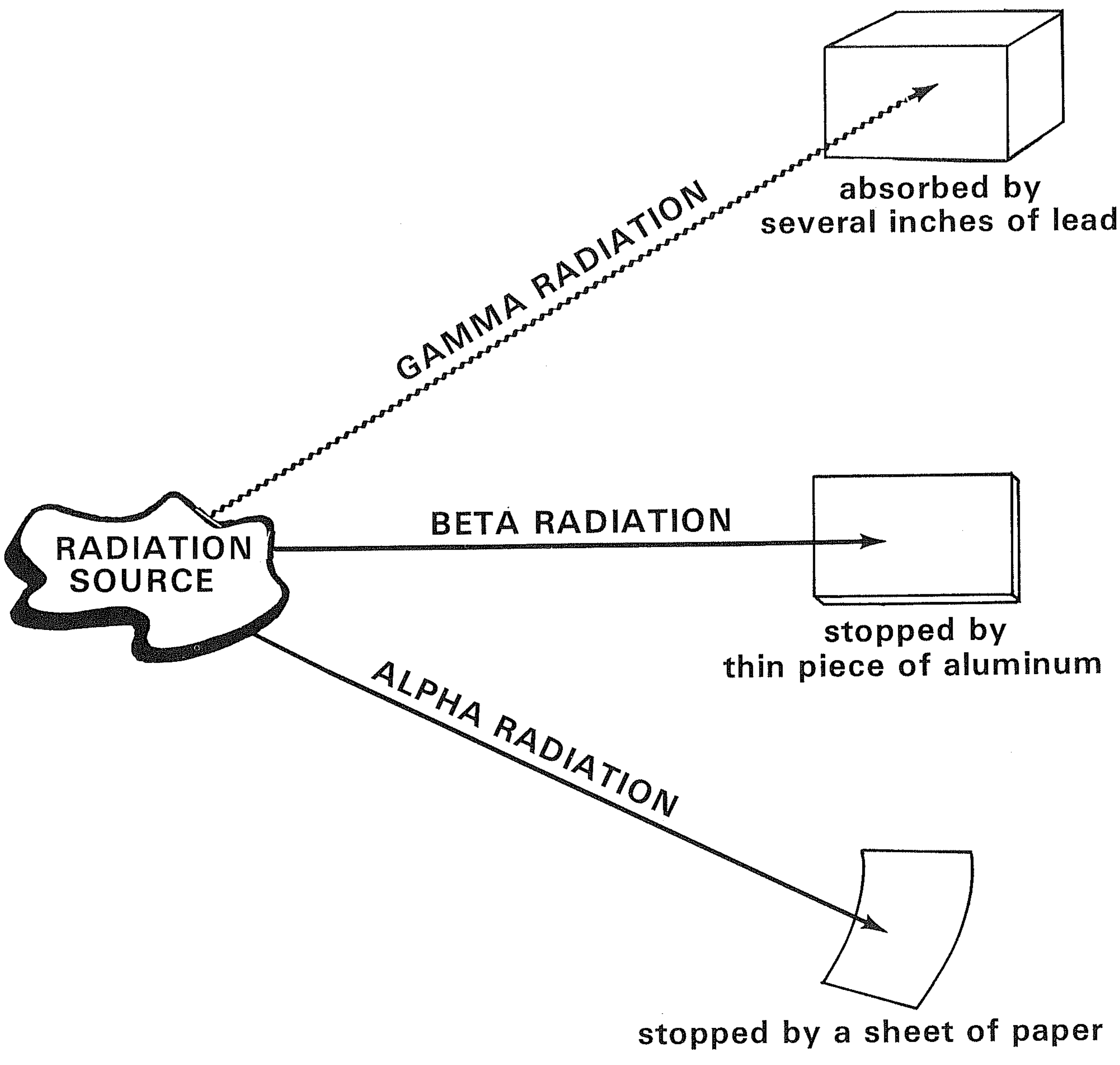
The nature of gamma rays was introduced in Chapter 5. Gamma radiation is electromagnetic radiation like light, radio waves, and X-rays. As such, it travels with the speed of light and spends its energy through interactions with the atoms that make up the atmosphere, materials, structures, or human bodies. Gamma radiation has an effective range in air of many hundreds of feet. It takes a considerable thickness of a heavy material, such as concrete or even lead, to stop this radiation.

Beta particles are electrons ejected by radioactive substances. Although traveling initially at nearly the speed of light, beta radiation is much less penetrating than gamma radiation. The beta particle's energy is expended in air in a few millionths of a second within a distance of about 10 feet from its source. A thin piece of aluminum or heavy clothing stops beta radiation.

It is perhaps unfortunate that nuclear physicists have called beta radiation "particles" to distinguish it from electromagnetic radiation. This has given rise to the misconception that "beta particles" are granules of sensible size and permanence that could be "swallowed" or "brushed off." These radiations cannot be detected by the human senses and should not be confused with the fallout "particles" containing the radioactive material that emits them.

There is a third type of nuclear radiation shown on this chart—alpha radiation. Alpha particles are emitted by the leftover fissionable material—uranium or plutonium—not used up in the fission process. The amount of leftover fissionable material is inconsequential and the alpha hazard will not be discussed further. Only in the immediate neighborhood of an unexploded nuclear weapon would this type of radiation be of significance. Civil defense planning may be undertaken as if it did not exist.

NUCLEAR RADIATION



RADIOACTIVE DECAY

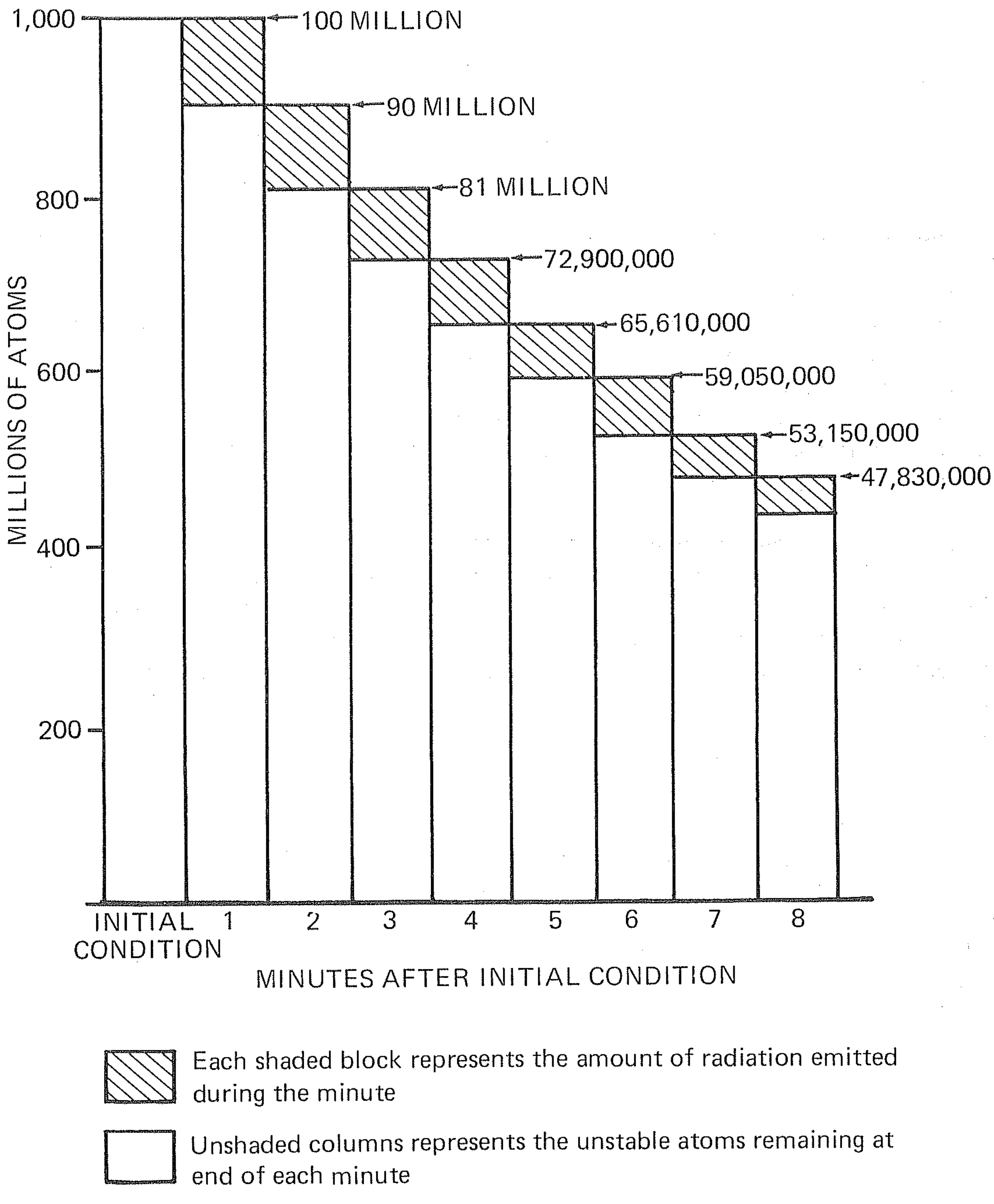
Atoms of the natural element, uranium, and an artificial element, plutonium, when struck by a neutron "projectile," will split in two, releasing energy. Each of the two pieces or "fission fragments" is like the nucleus of an atom of some element of medium weight—except for a surplus of neutrons. Because of this condition, such atoms are unstable and sooner or later they adjust by emitting beta particles and gamma rays. After this adjustment, they have become atoms of still another element. It is this process of adjustment that is called "radioactivity" and the unstable atoms are called "radioactive."

Radioactive atoms have an interesting and important characteristic. The process of adjustment does not occur at a set time or in a set pattern. Rather, some atoms of a particular kind adjust quickly; others of the same kind take a long time. At any point in time, every atom of the group has the same chance of adjusting in the next instant, and this chance does not change as time goes on.

Think of a speck of an imaginary radioactive element consisting of a billion unstable atoms. In any given minute, every atom of this imaginary element has, let us say, a 10 percent chance of adjusting by giving off one beta particle and one gamma ray. Then, during the first minute, 100 million atoms would adjust (10 percent), giving off 100 million beta particles and 100 million gamma rays. There would be only 900 million unstable atoms left. In the second minute, 10 percent of these would adjust, emitting 90 million beta particles and an equal number of gamma rays. In the third minute, 10 percent of the remaining 810 million would adjust and so on. As time passed, there would be fewer and fewer unstable atoms remaining and the number of beta particles or gamma rays emitted each minute would get smaller and smaller. This continuous decrease in the radiation emitted is called radioactive decay.

During the first 7 (more accurately 6.93) minutes, half the atoms of our imaginary element would have adjusted to become atoms of a stable element. The radiation being emitted per minute by the remaining half would be only half as much as in the beginning. In another 7 minutes, only one-quarter would be left and so on. We would say that this imaginary radioactive element has a "half-life" of 7 minutes.

HYPOTHETICAL RADIOACTIVE MATERIAL HAVING 10 PERCENT DECAY PER MINUTE



PANEL 3

DECAY OF THE FISSION-PRODUCT MIXTURE

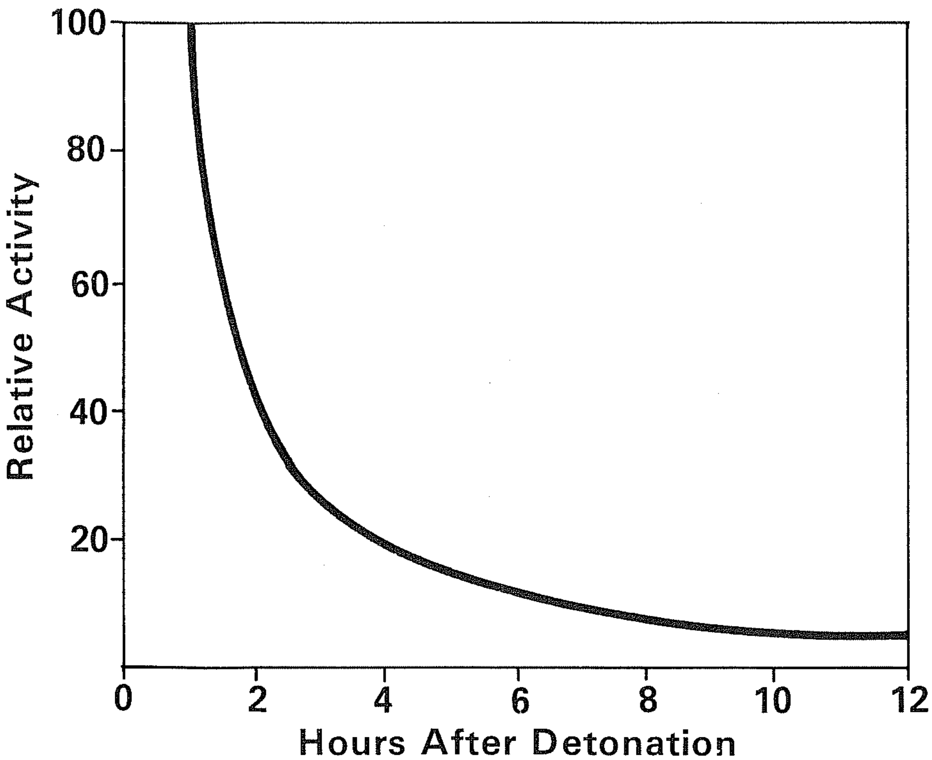
Each of the 200 or so radioactive materials created as the result of nuclear fission has its own characteristic half-life that defines its rate of decay. One substance of special concern that will be discussed later, radioactive iodine, has a half-life of about 8 days. Another that has received much publicity, strontium, has a half-life of about 28 years.

Naturally, at very early times after fission, those radioactive elements with very short half-lives contribute most of the radiation, and the decay of the fission-product mixture is very rapid. As these elements are depleted through the adjustment process, the longer-lived elements become more and more dominant. The overall decay of the mixture becomes slower and slower as time passes. A very rough rule-of-thumb for emergency planners is that the half-life of the fission-product mixture is about equal to the time of measurement. In other words, if a fallout radiation measurement is made at, say, four hours after detonation, the radiation intensity would be reduced by one-half about four hours later. Actually, fallout radiation decay is somewhat faster than this rule-of-thumb would suggest.

A more accurate estimator of radioactive decay of mixed fission products is the "7-10 Rule." This rule says that the radiation intensity is reduced ten-fold for each seven-fold passage of time after detonation. For example, if a fallout radiation measurement is made at four hours after detonation, the intensity would be one-tenth as much at 28 hours after detonation. It would be one-hundredth of the original reading at 7 times 28 hours or a bit over 8 days after detonation. The 7-10 Rule gives reasonably good estimates up to about six months after attack. Subsequently, the dose rate decreases at a much more rapid rate than is predicted by this rule.

As we have seen in Chapter 5, the fission-product radiation is a component of initial nuclear radiation (INR) during the first minute after fission. At one hour after fission, the radioactivity of the fission-product mixture is about 125 times less than it was at one minute. The illustration shows the rate of decay from one hour to 12 hours, using an arbitrary level of 100 at one hour. Note that the level is down to 10 at about 7 hours as the 7-10 rule would predict.

RATE OF DECAY OF FISSION PRODUCTS AFTER A NUCLEAR DETONATION



PANEL 4

WHAT FALLOUT IS

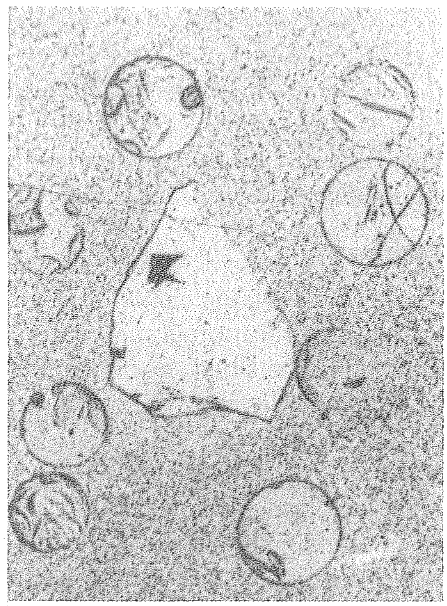
Each megaton of fission yield produces about 100 pounds of fission products. Thus, a 5-MT surface burst of 50 percent fission-50 percent fusion would produce about 250 pounds of fission products. At one minute after fission, each ounce of these products is emitting gamma rays comparable to those from 15,000 tons of radium.

In addition, an explosion of any kind, occurring near the surface of the earth, causes material to be thrown up or drawn into the "chimney" of hot rising gases. A 5-MT surface burst carries aloft about 2 million tons of soil and other surface materials in the stem and mushroom cloud of the detonation. Thus, the material that ultimately returns to earth as "fallout" is almost entirely soil. The radioactive residues incorporated in this soil are actually "trace elements" in a concentration of less than one-tenth part per million.

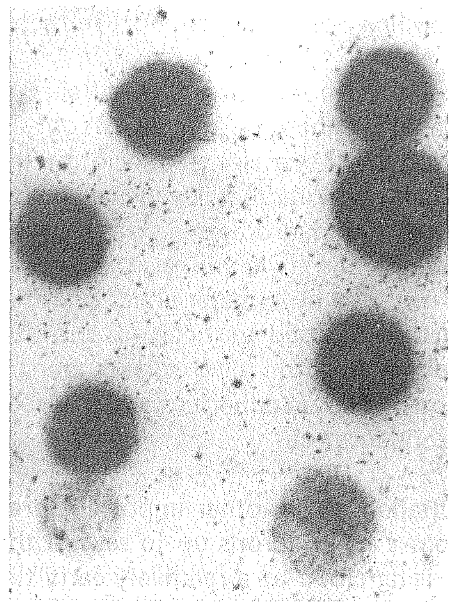
Soil drawn into the very hot fireball is vaporized. As the rising fireball cools, material entering later is only melted, and as the fireball cools further and forms the mushroom cloud, some material reaching the cloud level is virtually unchanged. As the fireball cools below the boiling point of the vaporized soil material, it begins to condense into liquid droplets, which eventually solidify into glass-like particles.

These particles are tiny. The size of fallout particles is generally measured in microns, which is a length equal to one millionth of a meter. To put these sizes in perspective, consider that 1000 microns—a millimeter—is about the thickness of a thin dime. A human hair 100 microns thick can be seen with the naked eye but a spherical particle of the same size is difficult to see without a microscope. Tobacco smoke consists of many very fine particles less than a micron in diameter. Fallout particles deposited in fallout areas defined by a dose rate exceeding 0.5 Roentgens per hour generally range from about 50 microns to several millimeters in size.

The left-hand photograph shows a microscope picture of some fallout particles from a small-yield surface burst at the Nevada Test Site in 1951. The right-hand picture is a "radiograph" of the same particles showing the effect of radioactivity on a photographic film. The radioactive particles are a transparent green-yellow glass with the radioactivity distributed more or less uniformly throughout their volumes. Note that the large irregular particle in the left-hand picture, which does not show up in the right-hand picture, does not seem to contain radioactivity.



PHOTOMICROGRAPH OF
THIN–SECTIONED PARTICLES
(greatly magnified)



RADIOGRAPH OF THE
SAME PARTICLES

From Miller, C.F., **Fallout and Radiological Countermeasures, Vol. I**, Stanford Research Institute, Project No. IMU-4021, January 1963. (AD 410-522)

PANEL 5

WHY ALL FALLOUT IS NOT ALIKE

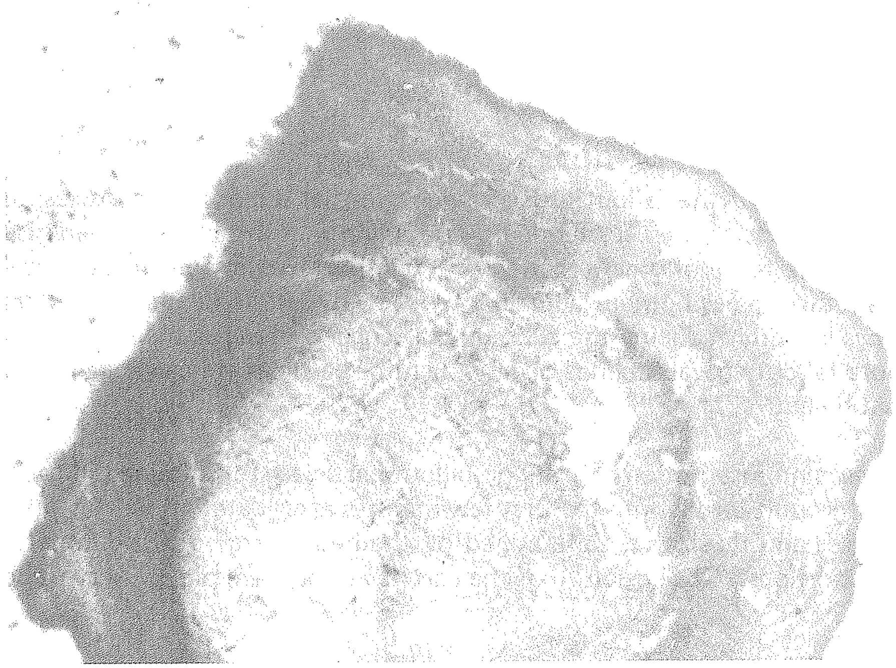
Let us pursue the matter of how fallout is formed a bit further. The formation of fallout is complicated because each of the many elements involved possesses characteristic properties that determine the temperatures at which it changes from a gas to a liquid and from a liquid to a solid. Those with low boiling points are termed, "volatile," whereas those with very high boiling points are termed, "refractory."

In general, entrapment of the radioactive materials, which are present in minute quantities compared to the soil, will occur only after condensation has occurred. Thus, as the fireball cools, the first major step in formation of fallout occurs when the vaporized soil condenses. Then those radioactive elements that have already condensed are readily incorporated into the liquid droplets, as we saw in the previous photograph. The more volatile elements are at this stage still gaseous and not available. Some elements do not interact significantly until the bulk material has solidified. Hence, these volatile elements tend to lodge on the surface of solid particles, as shown in this microscope photograph of a particle of fallout from a megaton-yield surface burst at Eniwetok. The small, black spheres (which are radioactive) shown adhering to the surface of a much larger coral sand grain were formed by vapor condensation.

Simultaneously, another important process is taking place. The particles formed range in size from a few microns up to several thousand microns. The larger particles fall away from the rising cloud at a relatively early time under the influence of gravity and the turbulent motion of the fireball. As a consequence, they are found to be deficient in the more volatile elements and their decay products, such as strontium, while the smaller particles that continue to rise with the nuclear cloud are enriched with the volatile species. Technically, this is known as "fractionation."

In simple terms, it means that all fallout is not alike. The heavier particles that fall to the ground in a matter of hours contain most of the radioactivity produced by the explosion, but they are deficient in the more volatile radioactive elements and, furthermore, most of the radioactive atoms are locked within the glassy particles. The smaller particles, on the other hand, which are enriched in the volatile species, fall to earth very slowly over a period of weeks, months, and even years.

The change in the fission-product mixture with particle size (and, hence, distance from the detonation) is not so great as to invalidate the radiation decay rates we have already discussed but is of great importance to the questions of whether contaminated water can be drunk or whether food can be grown in fallout areas. Many myths have been born from observations made on "worldwide" fallout or at great distances from test explosions, without recognition that "all fallout is not alike."



PHOTOMICROGRAPH OF SECTION OF PART OF A CORAL SAND GRAIN SHOWING ADHERING SMALL SPHERES
(Greatly magnified)

From Miller, C.F., **Fallout and Radiological Countermeasures, Vol. I**, Stanford Research Institute, Project No. IMU-4021, January 1963. (AD 410 522)

PANEL 6

THE MUSHROOM CLOUD

A simple description of the fallout process might be that a cloud of particles, such as just described, is formed as the result of the explosion and that this cloud is then dispersed by the wind and by the force of gravity acting on these particles to return them to earth. Until the particles return to earth, their radioactivity is too remote to be harmful. Moreover, radioactive decay is steadily reducing the subsequent danger so long as they are aloft. This time interval before fallout arrival depends on how high the particles are carried and how fast they fall from that height.

A natural beginning assumption is that the fallout particles are contained in the visible cloud formed over ground zero within the first few minutes after detonation. The height to which this cloud rises and its size are determined by the heat energy of the detonation and the atmospheric conditions. The structure of the earth's atmosphere plays a very important role in this regard.

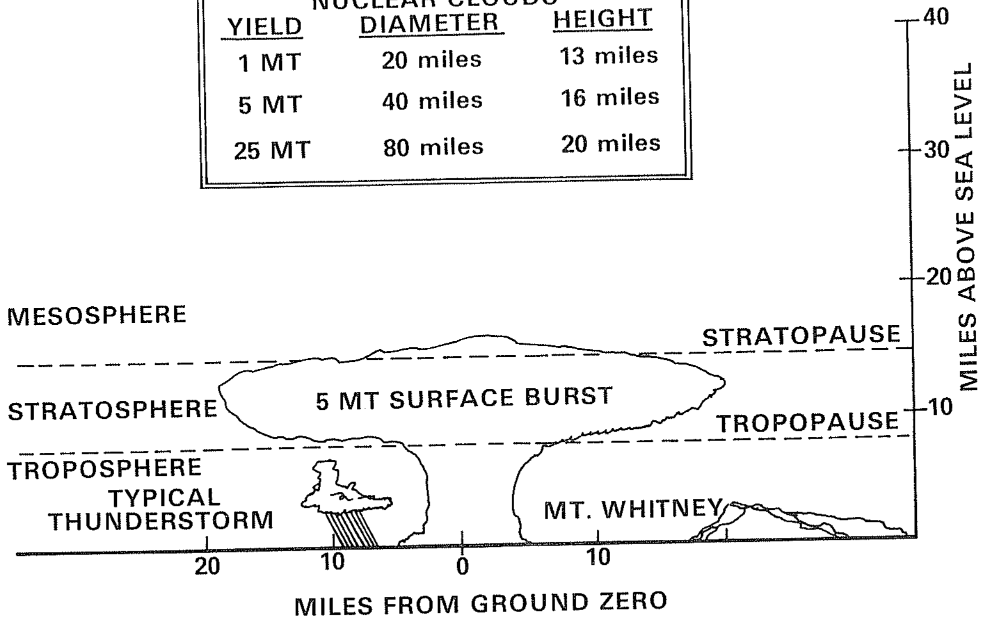
The lowest layer of the earth's atmosphere, known as the "troposphere," is a turbulent layer of winds, clouds, and storms. Over the United States, the troposphere extends up about 8 miles, somewhat higher in the summer than in the winter. A key feature of the troposphere is that the air gets colder with increasing altitude. Thus, the buoyancy of the rising cloud is maintained, even though it is losing its heat energy as it rises. The top of the troposphere, called the "tropopause," is marked by an air temperature minimum, above which temperatures increase in the stratosphere and mesosphere up to an altitude of 30 miles. As the rising cloud penetrates the stratosphere, it rapidly loses buoyancy and spreads laterally to a more-or-less stable size within 5 to 10 minutes after detonation.

Early attempts to explain the subsequent fallout on the ground by assuming that the radioactive particles fell from the visible cloud proved that the fallout near and around the detonation must have come from the region of the stem below the visible cloud. So both the mushroom cap and its stem had to be taken into account. This illustration shows the average dimensions of the visible clouds from explosions in the megaton yield range. The diameter of the mushroom stem is about one-fifth that of the mushroom cloud.

THE VISIBLE CLOUD

NUCLEAR CLOUDS

YIELD	DIAMETER	HEIGHT
1 MT	20 miles	13 miles
5 MT	40 miles	16 miles
25 MT	80 miles	20 miles



FALLOUT PREDICTION MODELS

Measurement of the fallout resulting from nuclear detonations has been done for a relatively few surface detonations during weapon tests in Nevada and in the Pacific. All of the megaton-yield tests were done at Eniwetok and Bikini Atolls where most of the fallout area was open ocean. Fallout researchers have tried to fit various models to these limited data in order to predict what the fallout situation would be for other weapon yields, burst conditions, and wind conditions. One of the key problems has been to assess the size and location of the radioactive cloud from which the fallout particles originate in their fall to earth.

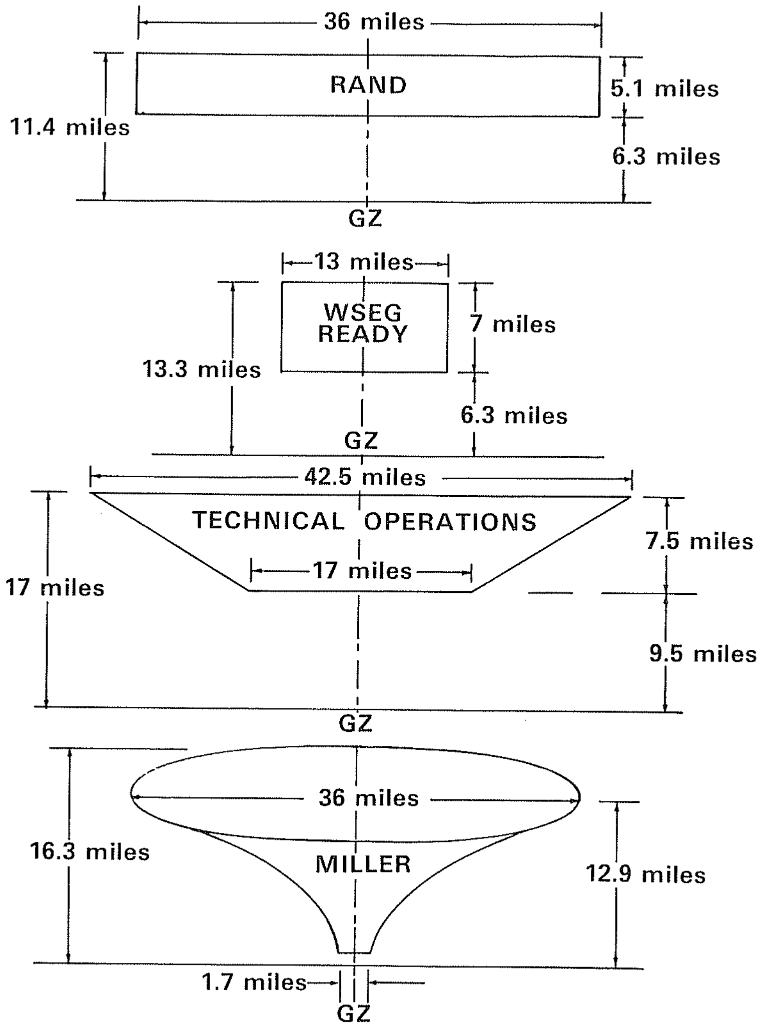
Shown here are the fallout clouds assumed in several of the fallout prediction models that have been developed. It can be seen that they vary considerably. The RAND model was developed in the early 1960s and is still in use at the Rand Corporation. The fallout cloud is seen as a disk having a diameter of 36 miles and a thickness of about 5 miles for a 5-MT detonation, somewhat smaller than the visible cloud dimensions shown in the previous panel. There is no stem in this model. Rather, the whole disk is placed lower in the atmosphere than the visible cloud, with the top at 11.4 miles rather than 16 miles.

The second model shown was developed for the Weapon System Evaluation Group (WSEG) and also forms the basis for the READY I fallout model used by the Office of Emergency Preparedness. It also is a cloud disk without a stem. It has a much smaller diameter, 13 miles, than the RAND model but the disk is thicker. In both models, the bottom of the disk is a little over 6 miles above the ground.

A model developed at Technical Operations, Incorporated, is in the shape of an inverted truncated cone. The height of this cone above the earth corresponds approximately to that of the visible cloud. The final model, the Miller model, was developed for DCPA. The cloud portion is in the shape of an oblate spheroid with dimensions approximating those of the visible cloud. Additionally, there is a horn-shaped "stem," which actually represents the volume swept out by the expanding fireball and cloud as it rises into the stratosphere.

The fallout information in this chapter is based on the Miller model, which is able to match more characteristics of fallout than the other models. It has been used to generate the fallout information used in CDEX-67 and other civil defense exercises.

SEVERAL FALLOUT CLOUD MODELS FOR A 5-MT SURFACE BURST



AN EXAMPLE FALLOUT SITUATION

The Miller fallout model is also called the OCD (DCPA) fallout model because its formulation was first published as an internal OCD research report in June 1962 by Dr. Carl Miller, who was head of the OCD Postattack Research Division at that time. The model grew out of analysis of a great deal of data on the amounts, particle sizes, and chemical and radiological characteristics of fallout collected at nuclear weapons tests.

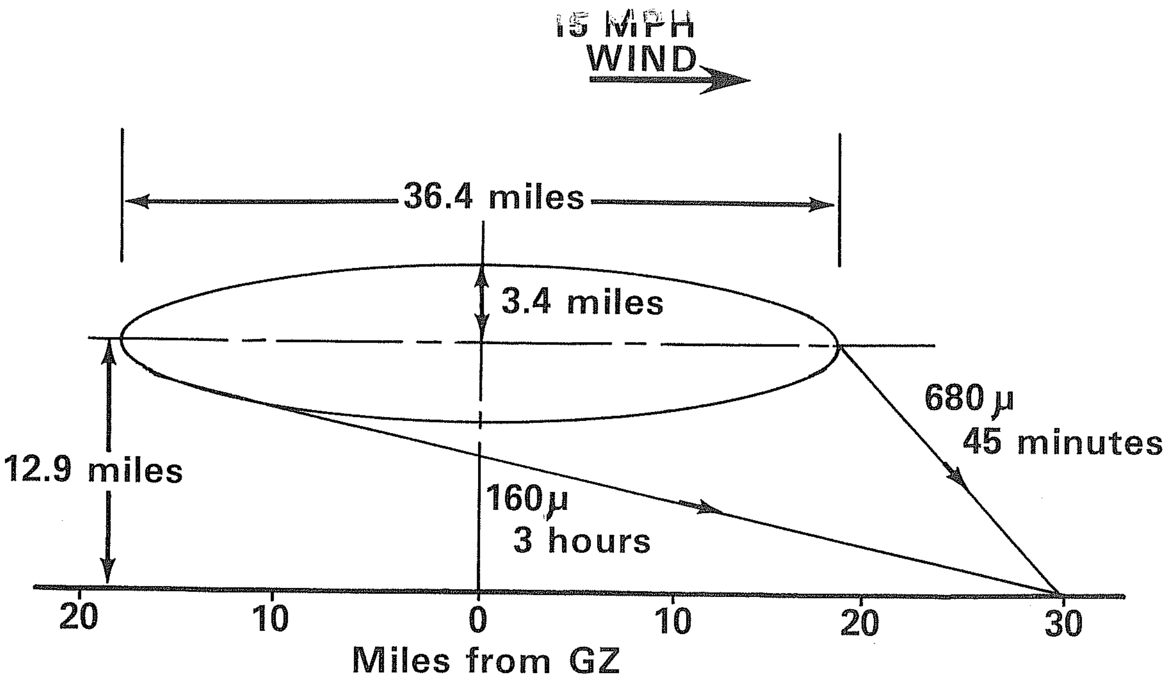
This illustration shows the cloud part of the model for a 5-MT surface detonation. The radiological cloud is about 5 times wider than it is thick. The center of the cloud is nearly 13 miles above the ground, with the bottom 9.5 miles high and the top over 16 miles high. Fallout particles and radioactivity are assumed to be mixed uniformly throughout the cloud volume and the fallout particles are assumed to begin to fall at detonation time. This is a simplified version of a much more complicated actual situation, but it fits the experimental results quite well.

Consider a point on the ground 30 miles directly downwind from the detonation, assuming that a 15 mile per hour wind is blowing in the same direction at all altitudes. The model predicts that the first fallout particle to arrive will be the largest particle deposited at this location, 680 microns. It will have come from the high forward edge of the cloud, about 13.4 miles up, and will arrive about 45 minutes after the detonation, as shown in the illustration. Larger particles will have fallen more rapidly and so will have been deposited closer in. Particles of the same size elsewhere in the cloud will have followed parallel paths to closer-in locations.

The last particle will arrive about 3 hours after detonation. It will be the smallest particle to arrive, 160 microns, and will have come from the low rear edge of the cloud, about 11 miles altitude, as shown. Smaller particles and particles the same size elsewhere in the cloud will be deposited further downwind. All particles deposited during the 2 hours and 15 minutes between fallout arrival and cessation will be between these two sizes, with the mid-range size about 420 microns, about half the thickness of a dime.

At 30 miles, there will be almost an ounce of fallout particles deposited on each square foot of horizontal surface. If a 40-pound bag of fertilizer intended to cover 5000 square feet was to be spread according to directions, the weight of fertilizer particles per square foot of lawn would be only about one-eighth of an ounce. Of course, fertilizer particles are rather large (about 1000 microns, perhaps) but the more numerous fallout particles would be as readily visible.

CLOUD FALLOUT
(5 MT Surface Detonation)



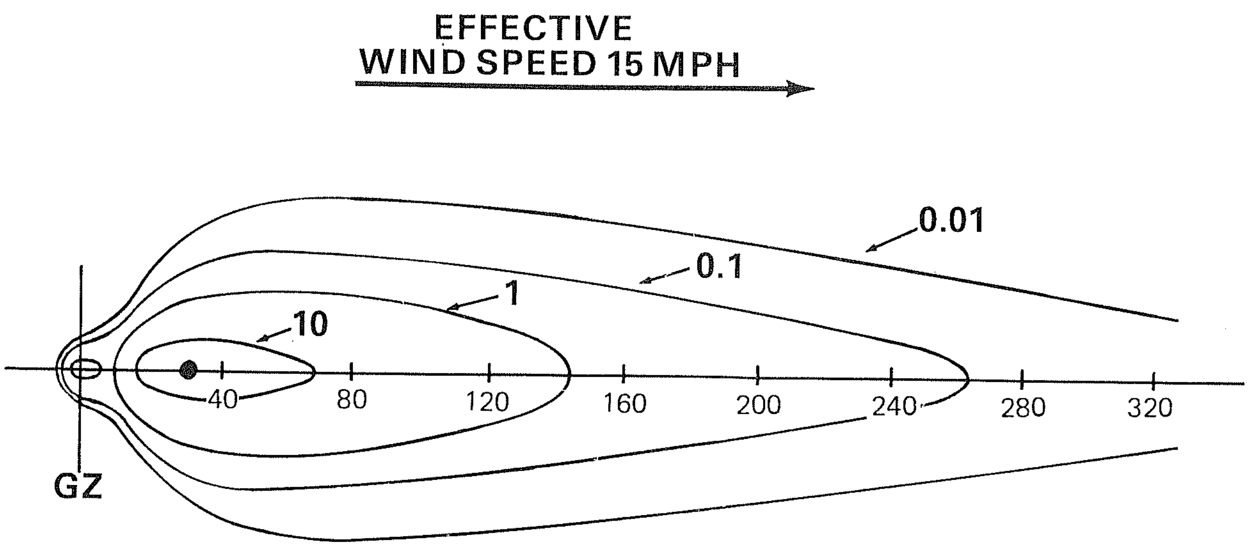
THE FALLOUT PATTERN

Fallout deposition from a 5-MT surface burst is shown here in the form of contours of equal weight of fallout. The unit of measurement is grams of fallout material per square foot of horizontal surface, which is the usual way fallout deposition is expressed. The effective wind speed is a uniform 15 miles per hour. The location 30 miles directly downwind, used in the previous example, is marked by a black dot. A set of contours of equal value, such as shown here, is commonly called a fallout "pattern."

The pattern of the weight of fallout deposited per unit area of ground will be new to most readers, even those who have had RADEF training, because most fallout patterns used in training and exercises show the intensity of the radiation that might be observed as the result of fallout deposition. We chose to show the contours of mass deposition first in order to emphasize that fallout consists mainly of silicacious particles of sensible size. It is these particles that fall through the air and are blown by the wind. They would have fallen and been blown downwind according to their physical nature whether or not they were radioactive. The amount of material deposited is quite substantial and is readily seen with the naked eye. Like desert sand, it can drift into gutters and sift into cracks under the action of wind and rain. It can be vacuumed, brushed off, flushed away, and filtered out just as any particles of the same size range.

The pattern can be thought of as an elongated "shadow" of the mushroom cloud and stem. The relatively small knob around ground zero represents the stem and the much larger "cigar" shapes represent the cloud. Note that the 1 and 10 grams per square foot contours are separate in the stem and cloud fallout regions. The stem fallout pattern is nearly the same width as the visible stem but the cloud fallout pattern is very much wider than the 35- to 40-mile cloud described in Panels 7 and 8. The reason is that atmospheric winds never blow uniformly even though the **effective** wind is in a single direction. Fallout particles follow a more circuitous route in falling to the ground and, hence, are spread more widely. The outermost contour shown here is about 100 miles across at its widest point.

MASS DEPOSITION PATTERN
(5 MT SURFACE BURST)



- Distances in miles
- Contours in grams per square foot

MAXIMUM DOSE RATES

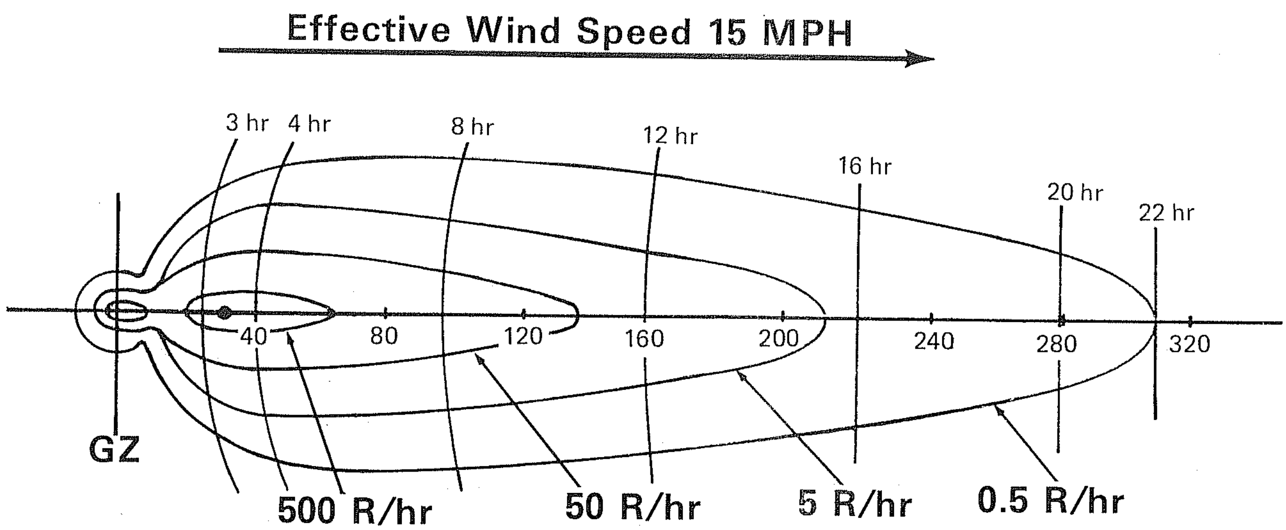
When fallout particles first arrive at a place on the ground and begin to accumulate, the radiation intensity in that area increases. Although radioactive decay is reducing the rate of exposure from those particles that have fallen, additional fallout generally arrives so rapidly that the total intensity continues to increase. Shortly before the time of fallout cessation, a maximum or "peak" dose rate occurs, after which the intensity of radiation begins to decrease through radioactive decay.

If the fallout were deposited rather uniformly on a glassy-smooth surface of a very large extent, the maximum or peak dose rate three feet above the smooth surface following the 5-MT surface detonation would be as shown by these contours. The more-or-less vertical lines across the pattern give the time after detonation at which the peak occurs. This deposition on a glassy-smooth surface would rarely, if ever, occur in reality but, as subsequent panels will show, actual conditions are so variable that the "smooth, infinite plane" situation is used as a base case for fallout models and calculations. Adjustments can be made from this base case to particular conditions that would actually occur.

It can be seen that a peak dose rate of 0.5 R/hr, which is the accepted level above which a fallout threat is recognized, extends to a distance of about 310 miles downwind. The areas of "stem" and "cloud" fallout are clearly evident and these contours are very similar to those shown in Panel 10; for example, the 50 R/hr contour, which delimits the area of severe fallout as defined in Chapter 1, covers almost the same area as the one gram per square foot deposition contour of Panel 10.

There are two contours enclosing areas where the peak dose rate will exceed 500 R/hr, one in the stem region and one in the cloud region. Our example location 30 miles downwind is within the downwind peak area. Here, the "true" dose rate three feet above a smooth, infinite plane would reach a maximum of about 1200 R/hr. This would occur near the time of fallout cessation, about three hours after the detonation.

PEAK DOSE-RATE PATTERN
(5 MT Surface Burst)



- Distances in miles
- Contours in roentgens per hour (true ionization rate at three feet above a smooth infinite plane)
- Vertical curves show peaking time in hours after detonation
- Fission yield 50%.

VISIBLE ASPECTS OF FALLOUT

In weapons tests, personnel were removed to safe distances before firing and kept out of fallout areas until it was safe to enter. Upon reentry the fallout areas were usually marked by a coloration of ground and foliage. Observations of the fallout event itself was often marked by visible fallout and "lowering of the sky" similar to that observed in rain showers.

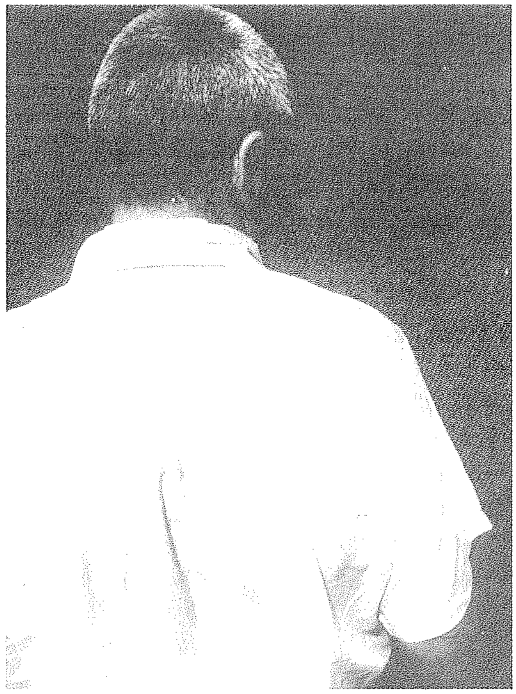
In 1964, the eruption of the volcano Irazu in Costa Rica provided an opportunity to observe fallout that was remarkably similar to fallout from nuclear weapons except that it was not radioactive. This permitted immediate on-site observations not possible in nuclear tests. It was found that deposits of fallout were easily visible when they amounted to 1 to 3 grams per square foot of surface. This level corresponds to the HIRAD fallout area where dose rates may exceed 50 R/hr. (See Chapter 1 for a discussion of fallout situations.)

The upper photograph shows the back of an individual exposed in such a situation. The first sensation when fallout begins arriving is the impact of particles on the nose and forehead. After a few minutes, the second sensation is a gritty feeling on the lips and teeth. (Fallout particles are too large to enter the nose by normal breathing.) On clothes, the particles collect in the folds, in cuffs, and under belts. Women with open-necked blouses feel the particles sifting into underthings. So long as clothes are dry, the particles are readily removed by shaking. They are not so readily removed from damp cloth.

The lower photograph shows a fallout deposit on an automobile. Dry particles are, to a large extent, cleaned by the winds but washing is required to remove all particles from the surfaces.

It may be too strong a statement to say that under all conditions fallout will be readily visible whenever a significant radiation hazard exists. Proper use of radiation instruments will remain the basic tool for control of radiation exposure. But it can be said that, whenever fallout is evident as described here, a significant radiation exposure is in prospect.

WHAT FALLOUT LOOKS LIKE*



* From Miller, C.F., **The Contamination Behavior of Fallout-Like Particles Ejected by Volcano Irazu**, Stanford Research Institute, Project No. MU-5779, April 1966. (AD 634 901)

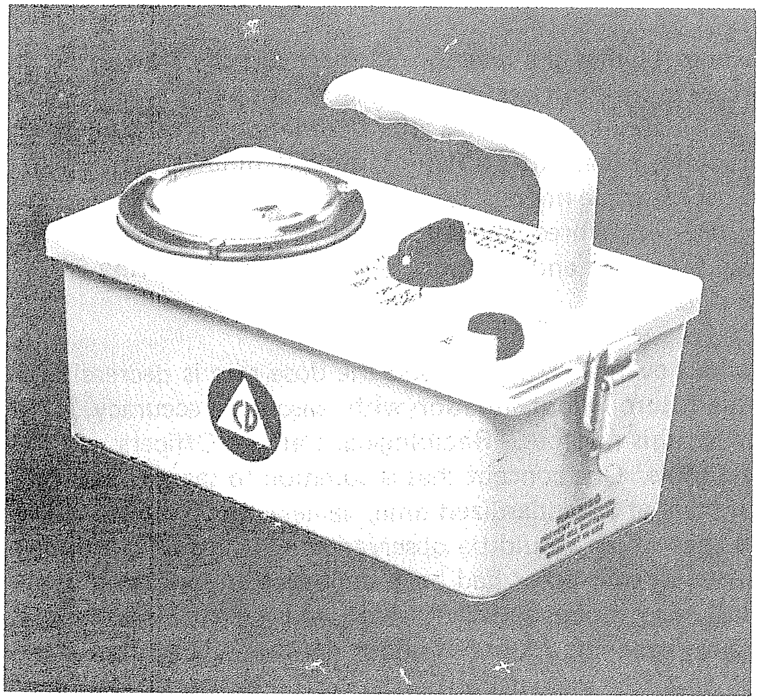
PANEL 12

MEASURING FALLOUT RADIATION

Although the fallout particles themselves will be apparent to the alert observer under most circumstances, the preferred basis for control of radiation exposure is measurement of the radiation itself. Gamma radiation is the chief threat, as outlined in Chapter 5. The dosimeter, used to measure the amount of radiation received, was described in that chapter. Shown here is the CD V-715, which measures the dose rate. This is the "work-horse" instrument for exposure control, since knowledge of the dose rate and radioactive decay permits estimates of current and future radiation exposure, whereas the dosimeter simply records the exposure already received.

For the 5-MT surface detonation, a properly calibrated CD V-715, held at waist height over a glassy-smooth surface of large extent, would measure approximately the peak dose rates shown in Panel 11. The scale on the instrument ranges from 0 to 5. The knob under the handle can be rotated to four scale settings: 0.1, 1, 10, and 100. The full-scale reading when the knob is set to 0.1 is 0.5 R/hr; at a setting of 1, 5 R/hr; at a setting of 10, 50 R/hr; at 100, 500 R/hr. Thus, the contours in Panel 11 are the full-scale readings for the four scale settings on the CD V-715. This means that throughout the area within the 500 R/hr contour, the dose rate would be "off-scale," too high for the instrument to read. This would be true if the real world were a glassy-smooth surface with no obstructions. As will be seen in Panel 16, the real world is quite different. One consequence is that the situations in which the dose rate will exceed the measuring capacity of the CD V-715 will be rare and momentary.

A very similar instrument, the CD V-717, has the sensitive element (that measures the ionization caused by gamma radiation) enclosed in a probe attached to 25 feet of cable. The operating characteristics are the same as the CD V-715, except that the removable probe can be prepositioned outside a shelter so that measurements can be made from within a protected area.



THE OPERATIONAL SURVEY METER, CD V-715

DOSE-RATE MEASUREMENT AND PREDICTION

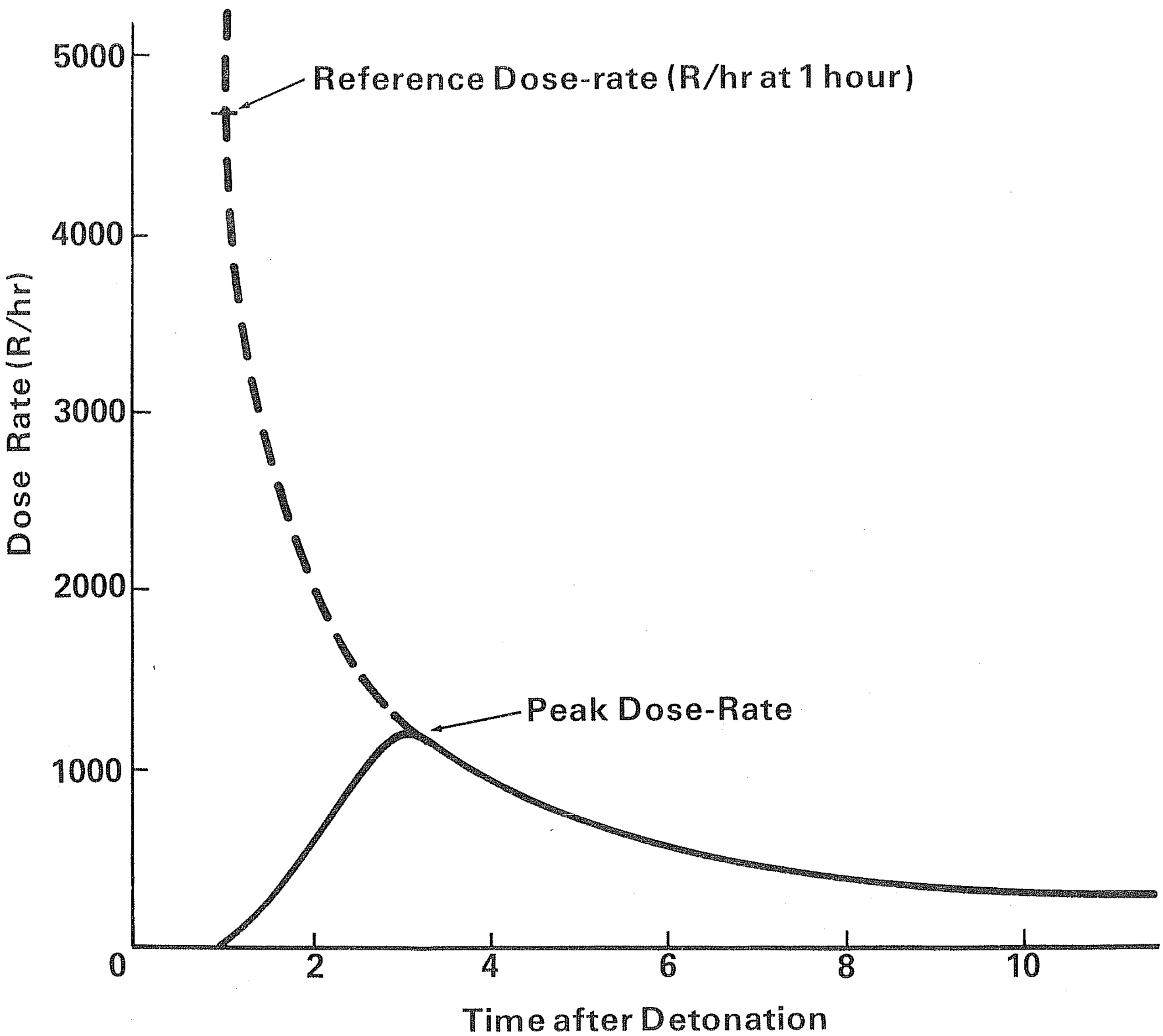
We saw in Panel 11 that the location 30 miles directly downwind from the 5-MT surface detonation was in the "hottest" part of the fallout pattern, and, in Panel 9, that fallout would begin to arrive about 45 minutes after detonation. As shown on this graph, the dose rate would rise rapidly, exceeding 50 R/hr within 10 minutes. The dose rate would peak at about 1200 R/hr, some three hours after detonation and then decrease, quite rapidly at first and more slowly later on. Three hours after peak (six hours after detonation), the dose rate would drop below 500 R/hr and a remote reading instrument (the CD V-717) could again indicate the dose rate.

Once the fallout event is complete and the dose rate is decreasing, it is generally possible to predict the future fallout situation with reasonable accuracy. Charts, sliderules, and nomograms exist for this purpose. Radiological Defense Officers and monitors are trained in the use of these tools. One concept that is common to these calculating devices is the use of a reference dose rate at a standardized time; namely, one hour after detonation. This dose rate is defined as that which would be observed at a location if all the fallout which contributes to the dose rate at that point had been deposited by one hour after detonation. The reference dose rate (also variously called "standard intensity" and "dose rate at H + 1") for the location we have been considering is about 4600 R/hr. As shown by the dashed curve, this is a fictitious dose rate since deposition of fallout has barely begun at one hour. This is generally true throughout the fallout area for megaton-yield weapons.

By use of the reference dose rate and the appropriate calculating rules, it can be determined that the dose rate at 30 miles directly downwind at the end of the first day would be about 100 R/hr; at one week, about 10 R/hr; at one month, a little less than 2 R/hr; and at four months after attack, about 3/10 R/hr (or 300 mR/hr, an mR or milliRoentgen being one one-thousandth of a Roentgen).

As we saw in Chapter 5, it is the dose that injures people and, since the dose rate is constantly changing in a fallout situation, special calculations must be made to predict future doses. To get a general idea of how this is done, the emergency planner might read the **Handbook for Radiological Monitors**, or better still, enroll in the home study course, **Introduction to Radiological Monitoring**, available through the DCPA Staff College. The methods taught would tell us that the potential unprotected dose at 30 miles downwind would be about 1200 R at time of peak dose rate, 7500 R at the end of one day, 11,400 R at one week, 13,500 R at one month, and about 15,000 R at four months.

FALLOUT SITUATION AT 30 MILES DIRECTLY DOWNWIND FROM 5 MT SURFACE BURST
(15 MPH WIND SPEED)



PANEL 14

PROTRACTED EXPOSURE AND BIOLOGICAL RECOVERY

In Panel 13 of Chapter 1, we exhibited the dose-penalty table shown opposite. In Chapter 5, we described what is known about the biological consequences of "brief" doses of gamma radiation. The doses shown in the "1-Week" column are consistent with those given in Chapter 5 for the same medical consequences. Therefore, a one-week exposure may be considered "brief," especially as the dose estimates of the previous panel indicate that two-thirds of the one-week dose is received in the first day. The reason why the doses shown in the "1 Month" and "4 Months" columns are larger is because the human body has some capacity to repair the damage caused by ionizing radiation.

In Panel 3 of Chapter 5, it was noted that large single doses can cause acute sickness or death, whereas small daily doses may be tolerated without causing illness. A dose of 600 R will be lethal when received as a brief exposure. The same dose accumulated over a period of 20 years, if delivered in equal daily amounts (less than 0.1 R/day), probably will not cause any recognizable effect. The dose-penalty table recognizes this recovery principle by "allowing" greater exposures, if spread over a period of many weeks or months. It is believed, also, that most of the later signs of radiation injury (Panel 6 of Chapter 5) are also less likely if exposure is protracted.

The lower table shows the situation at 30 miles directly downwind. The doses in the open are those noted in the previous panel. Now imagine a shelter at this location that has the capability of reducing the unprotected dose by a factor of exactly 46. (The characteristics of real shelters are described in Panels 18 to 22.) The column labeled "In Shelter 46" shows the one-week calculated dose to be 248 R, just short of the 250 R shown in the dose-penalty table. Few, if any, deaths would be expected. If one were to remain in "Shelter 46" for a month, the dose would be 294 R and one would have 56 R "to spare," according to the second row in the table. However, since the dose rate over the smooth infinite plane would be nearly 2 R/hr at one month, not much time could have been spent outside in the interim without exceeding the body's repair capability. It might have been wiser, in this circumstance, to have used the "spare" dose during the second week to move out of the heavy fallout area.

It can also be seen that staying in Shelter 46 for four months would have left 174 R to spare (500 R - 326 R). This would appear to be a good deal, but would allow only about an hour a day outside the shelter, on the average.

The final column represents a nearby shelter having the capability of reducing the unprotected dose by a factor of 76. The one-week dose is held to 150 R. The one-month dose leaves 22 R to spare without exceeding the criteria in the first row of the table, and the four-months' dose is 103 R below the penalty dose.

Being in Shelter 76 is better than being in Shelter 46, but, in either case, the table indicates that biological recovery is insufficient to allow much time outside the shelter.

DOSE-PENALTY TABLE

Acute Effects \ Roentgen Exposure Dose in Any	1 Week	1 Month	4 Months
Medical Care Not Needed	150	200	300
Some Need Medical Care Few if Any Deaths	250	350	500
Most Need Medical Care 50% + Deaths	450	600	*

*Little or no practical consideration.

DOSES AT 30 MILES DOWNWIND
(5-MT surface burst; 15 MPH wind)

Time	In Open	In Shelter 46	In Shelter 76
1 Week	11,400	248	150
1 Month	13,500	294	178
4 Months	15,000	326	197

ACTUAL DOSE RATES

Under actual operating conditions, measured dose rates and consequent exposure of people will be generally lower than those implied in previous panels for two main reasons: (1) most real surfaces are not smooth, and (2) many contaminated areas (roofs, streets, and the like) are of limited extent. Typical reductions to be expected are shown in these sketches.

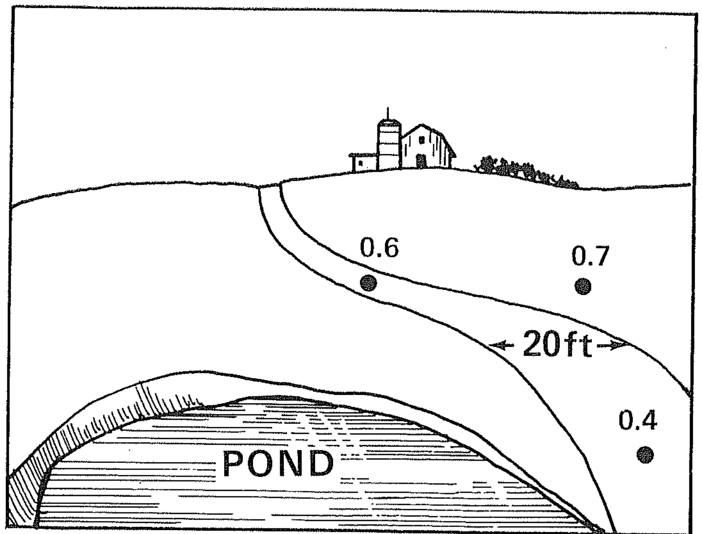
Smooth paved areas, unbroken by curbs, gutters, and the like, offer little reduction due to surface roughness. This is also true of packed snow or ice. Macadam and rough pavement will result in a "reduction factor" of about 0.8. Sand, bare soil, and grassy areas offer a reduction factor of about 0.7. Gravelled roads and roofs will reduce the dose rate about one-half, a reduction factor of 0.5. Fallout on very rough or plowed ground will produce a dose rate only about 0.4 of that on a smooth, infinite plane.

In the sketch of rural America, most of the reduction is due to the roughness of grassy fields and macadam or gravel roads. An exception is the value of 0.4 on the road next to the pond where the fallout has sunk to the bottom of the pond, thereby limiting the extent of the contaminated area at that point.

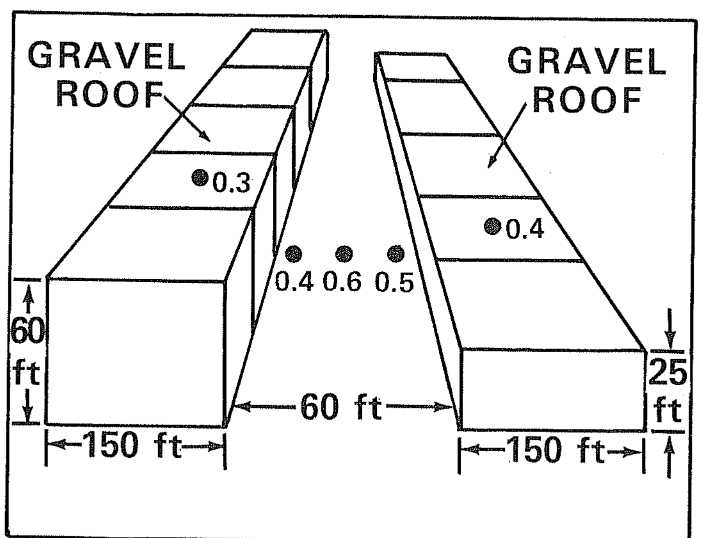
In Main Street USA, the buildings restrict the extent of the area contributing to the dose rate. Here we have assumed that the street is smooth pavement without curbs. The reductions shown in the street are due to the presence of the buildings, being greater near the buildings than in the center of the street. The reduction factors on the roofs are due both to the rough gravel surface and the fact that the height of the buildings reduces the contribution from the surrounding ground.

An operational implication is that measurements reported by radiation monitors are unlikely to allow the drawing of smooth contours, such as those shown in Panel 11, since the measurements will vary considerably depending on the environment in which the measurements are made.

REAL WORLD DOSE RATES
(for 1 R/hr on smooth infinite plane)



RURAL AMERICA



MAIN STREET USA

ANOTHER VARIABILITY—WEATHERING

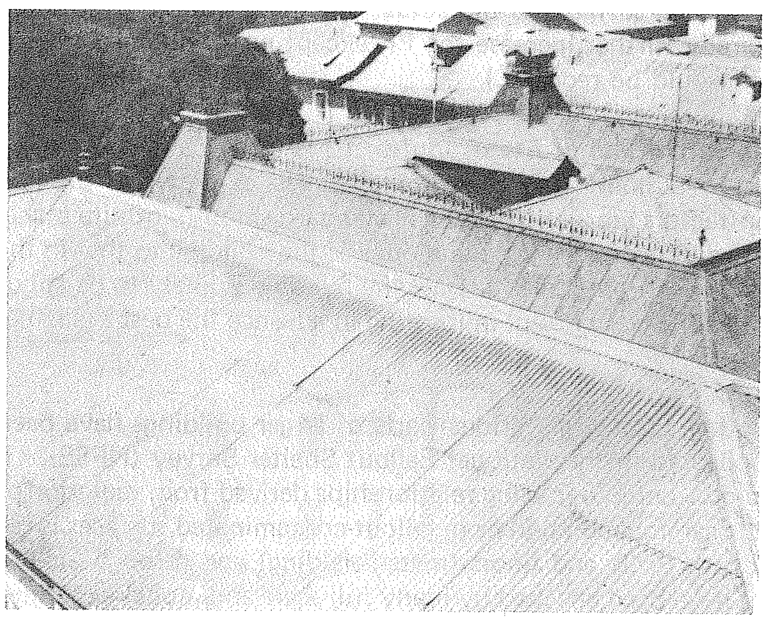
In Panel 16, it was pointed out that measured dose rates would vary according to the roughness of the surfaces upon which fallout had deposited, as well as the unbroken extent of these surfaces. The net result would be measured dose rates generally ranging from 30 to 70 percent of what would have been measured if the same amount of fallout had been deposited uniformly on the "standard" (and imaginary) smooth, infinite, plane surface.

Another variability that will occur in practice results from the movement of fallout particles by the action of wind and rain, generally called "weathering." This effect can be quite marked on smooth surfaces. The upper photograph shows a view of street and sidewalk contamination in San Jose, Costa Rica, after the volcanic fallout particles had been redistributed by wind and passing vehicles. The particles have accumulated near the curb and in cracks and small depressions in the concrete pavement. Often, a concentration of fallout particles will occur at a wind-protected corner, as shown here. If this fallout had been radioactively contaminated, this pedestrian would have been approaching a "hot spot," a limited area of concentrated fallout in which the dose rate could have been considerably higher than average.

The lower photograph shows the distribution of fallout-like particles on roofs. Particles tended to be scoured off the windward sections and to accumulate on the lee side of the roof just below the ridge, as shown. The particles drifted into roof gutters and other wind-protected places. Rain would wash particles toward the drains and ultimately into the storm sewers where they would become shielded from the surface above. Thus, in the long run, weathering acts to further reduce the hazard to people. But, in the process, hot spots are created and great variability introduced into radiation measurements.

Wind and rain do not tend to move fallout particles from natural soil or grassy areas. Consequently, radiation measurements in rural America will be much less variable than in urban areas.

WEATHERING EFFECTS*



*From, Miller, C.F., **The Contamination Behavior of Fallout-Like Particles Ejected by Volcano Irazu**, Stanford Research Institute, Project No. MU-5779, April 1966. (AD 634 901)

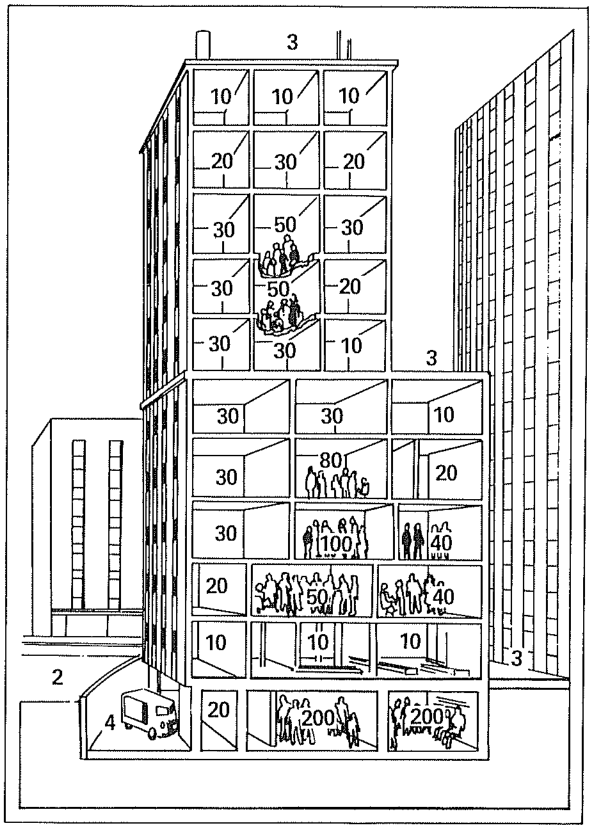
PROTECTION FACTOR

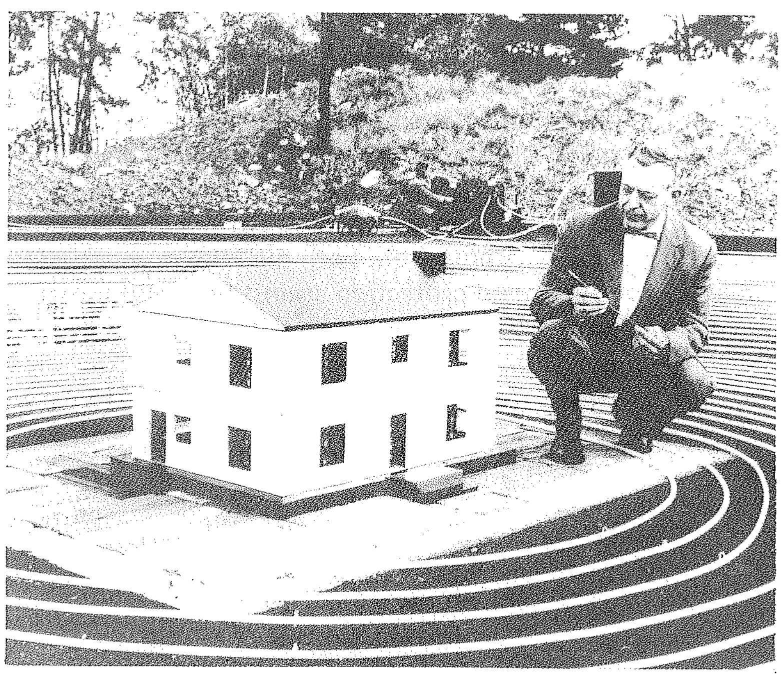
The two previous panels have emphasized that fallout radiation dose rates will vary from place to place within a relatively small area, especially in urban areas, because of the variable roughness of surfaces, the shielding afforded by nearby buildings, and the action of wind and rain. It is for this reason that fallout patterns used in peacetime vulnerability analyses and in training courses are defined for an imaginary standard surface; namely, a mathematically smooth, infinitely large, absolutely plane (flat) surface. Real situations are approximated by what is called a "protection factor" (PF).

The PF is an estimate of the ratio of the dose rate that would be measured at a height of three feet above the imaginary standard surface to the dose rate that could be expected in a given location in the "real world," assuming the uniform deposit of the same amount of fallout in both cases. Thus, when we noted that measured dose rates in the open would be 30 percent to 70 percent of what would have been measured over the standard surface, we were also saying that the outside protection factor would vary from about 1.5 to 3; that is, the hypothetical dose rate over a smooth infinite plane would be 1.5 to 3 times higher than that observed over real surfaces in the actual operating situation. (The action of wind and rain would generally further increase the PF except near "hot spots" or concentrations of fallout, where it would be reduced.)

The most common use of protection factor is to give a measure of the amount of protection afforded by buildings and other shelter areas, as shown in the upper sketch. Since these protection factors are all keyed to the standard smooth infinite plane, the PF does **not** represent the ratio between the dose rate outside the building to that in the shelter area. As we have seen, the PF in the street outside the building is likely to be about 2. Nonetheless, the protection factor is very useful in locating in advance the best available shelter from fallout radiation.

The protection factors in various parts of larger buildings have been calculated from building data collected in the National Fallout Shelter Survey (NFSS). These calculations were performed on a computer using relationships derived from radiation penetration theory that describe how gamma radiation from fallout-contaminated surfaces is reduced in intensity as it passes through walls and floors (mass shielding) and through air (distance shielding). The calculations have been checked by many full-scale and model experiments, of which one is shown in the lower photograph. Here a model building with measuring devices inside was exposed to radiation from a radioactive capsule that traveled around and around through the plastic tubing, thus simulating fallout on the ground. Incidentally, the scientist in the picture is Dr. Eric Clarke, an authority on radiation shielding, who also is an Executive Reservist attached to DCPA Region I.


3
10
10
10
20
30
20
30
50
30
30
50
20
30
30
10
3
30
30
10
30
80
20
30
100
40
20
50
40
10
10
10
3
2
4
20
200
200



PANEL 18

PROTECTION AGAINST FALLOUT RADIATION

Once more we show the table of relative blast protection given in Chapter 2. We used this table in Chapter 5 to show how the protection afforded against initial nuclear radiation compared with the relative blast protection. Here we have added in parentheses the typical range of fallout protection factors that could be expected in the locations described. As before, a high protection factor means good radiation protection.

The lower of the numbers in each parentheses relates to locations near entrances, windows and the outer portions of aboveground floors; the higher number pertains to locations remote from openings and in core areas. In aboveground locations, the topmost floor will also offer lesser protection because of fallout deposited on the roof. Plans of each floor, showing protection factors and shelter areas, are available for NFSS buildings that have been surveyed for fallout protection.

Recall that protection factor calculations for buildings assume that fallout is deposited uniformly on ground and roof surfaces. The shielding effect of nearby buildings is taken into account, but the movement of fallout by wind and rain is not. The effect of building damage by blast also is not considered. These effects are highly variable. This is an important reason why radiation measuring kits should be provided in large shelters to permit the occupants to locate those areas having the lowest dose rates in the actual fallout situation.

One point to note in this table is that the middle floors of tall buildings offer good fallout protection mainly because they are remote from both the fallout on the ground and that on the roof. These areas do not offer good protection against blast and initial nuclear radiation. In localities that are unlikely to experience direct effects, this fallout protection is a valuable resource for planners.

PANEL 19

TYPICAL FALLOUT PROTECTION FACTOR RANGES RELATIVE TO BLAST PROTECTION

Blast Preference	Description
A	Subway stations, tunnels, mines, and caves with large volume relative to entrances. (1000 - 10,000)
B	Basements ans sub-basements of massive (monumental) masonry buildings. (100 - 1000)
C	Basements and sub-basements of steel and reinforced-concrete framed buildings having flat slab or slab and beam ground floor construction. (100 - 1000)
D	First three floors of buildings with "strong" walls. (20 - 80)
E	Basements of wood-frame and brick-veneer residences. (10 - 50)
F	Fourth and higher floors of buildings with "strong" walls. (20 - 100)
G	Basements of steel and reinforced-concrete framed buildings with flat plate ground floor. (100 - 200)
H	First three floors of buildings with weak walls, brick buildings and residences. (20 - 80)
I	Fourth and higher floors of buildings with weak walls. (20 - 100)

HOW MUCH PROTECTION IS NEEDED?

In Panel 15, we showed how much protection shelters having protection factors of 46 and 76 gave in the "hot area" 30 miles directly downwind of the 5-MT surface burst. To measure the usefulness of the protection factors shown in the previous panel, we need to consider the needs in the areas of more moderate fallout as well. We should also consider how fallout patterns might overlap and build up when many weapons are detonated in an area. The results shown on this chart consider the doses resulting from a major attack with the enemy arsenal described in Chapter 1.

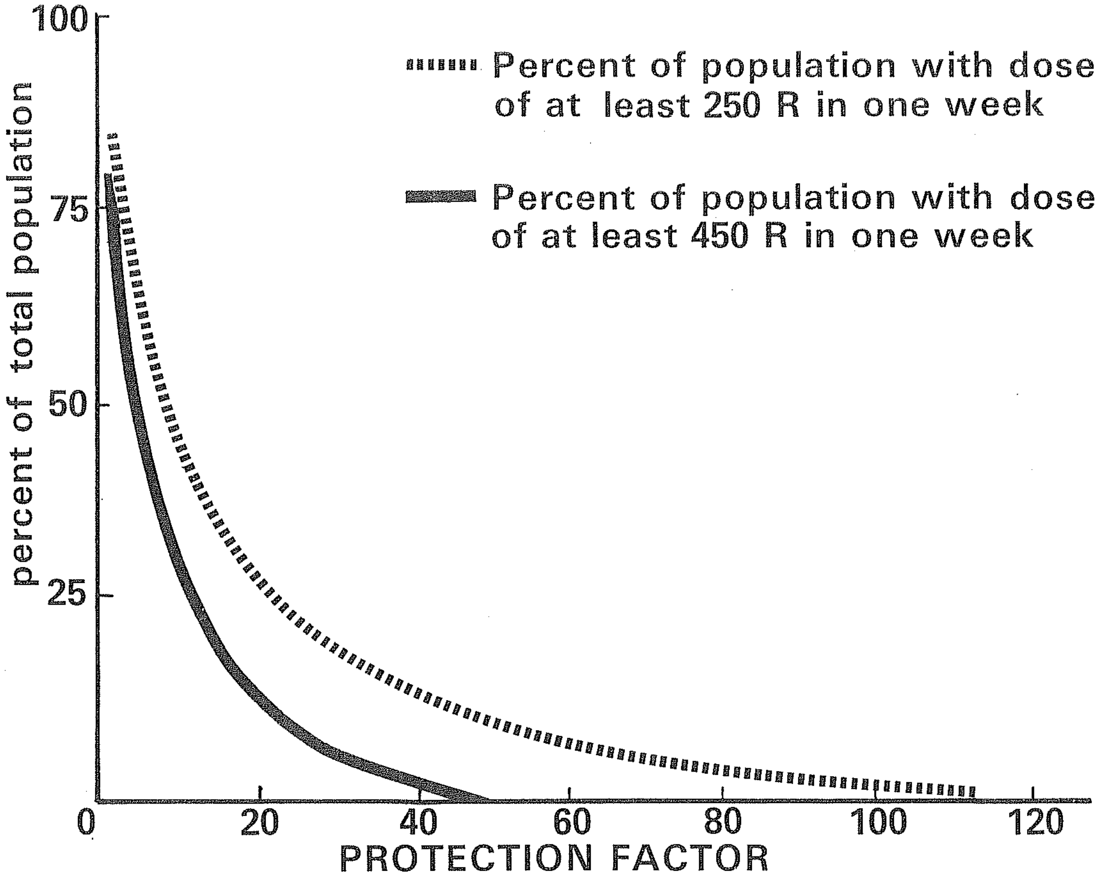
As a starting point, consider the population as if they were all located outside (or in small wood-frame residences) during the first week after attack. We found in Panel 16 that the "real world" outside dose rate was about half of the smooth-infinite-plane dose rate, or equivalent to having a PF of 2. For this condition, the dashed curve indicates that about 80 percent of the population of the U.S. would receive a one-week dose in excess of 250R; alternatively, only 20 percent would have received a dose less than 250R. Only 25 percent of the population would have a better than even chance of surviving, since 75 percent would have received a dose in excess of 450R.

The efficacy of higher protection factors is dramatic. At a PF of 20, 75 percent of the population would receive less than 250R and all but 10 percent would receive a dose less than 450R. At PF 40, less than 2 percent would receive a dose of at least 450R; over 85 percent would receive less than 250R. At PF 100, less than 2 percent would receive as much as 250R.

These percentages account for the whole preattack population, even those that would most probably have been killed by blast. You can find similar curves, for blast survivors only, in Appendix 1 to Part A, Chapter 1, of the Federal Civil Defense Guide. The message you find there will be the same. Appendix 1 is titled, "Policy on the National Goal for a Minimum Protection Factor of 40 for Public Fallout Shelters." When one is attempting to build and improve protection capabilities, **goals** are important. When one is an emergency planner, such goals are meaningless. One needs to plan to use the best shelter available, even if it offers less protection than the goal. The data shown here demonstrate that protection factors of 20, or even 10, are greatly to be preferred over leaving some part of the population unsheltered.

One final point—the very best protection is really better than the next best. If a PF of 100 keeps most doses below 250R, a PF of 1000 will keep them below 25R. Refer to Panels 3 through 5 in Chapter 5 for reasons why exposures should be kept as low as possible.

ONE-WEEK DOSE AFTER LARGE ATTACK FOR VARIOUS PROTECTION FACTORS



PANEL 20

PROTECTION IN RESIDENTIAL BASEMENTS

We noted in Chapter 2 that home basements could play an important role in improving survival from blast effects. They can also play an important role in providing protection against fallout radiation. In most parts of the country outside of the downtown areas of cities, the amount of fallout shelter identified in the National Fallout Shelter Survey (NFSS), which is located in large buildings, is insufficient for the population that needs shelter.

About half the homes in the United States have basements, but, as shown on this map, they tend to be concentrated in the northern part of the country. A small proportion of homes have basements in the South, Southwest, and Far West sections. Even these could be of great value if neighbors shared with neighbors. The average residential basement has an area greater than 1000 square feet. The standard shelter space in the NFSS buildings is 10 square feet. The usual emergency housing space allotment in peacetime natural disasters is 40 square feet. Thus, from 25 to 100 persons could be sheltered in the average home basement, if necessary.

The fallout protection afforded by home basements can be estimated in the following way:

(1) Single-story homes with average basement wall exposures (i.e., above ground) less than 2 feet will provide at least PF 20 throughout the basement.

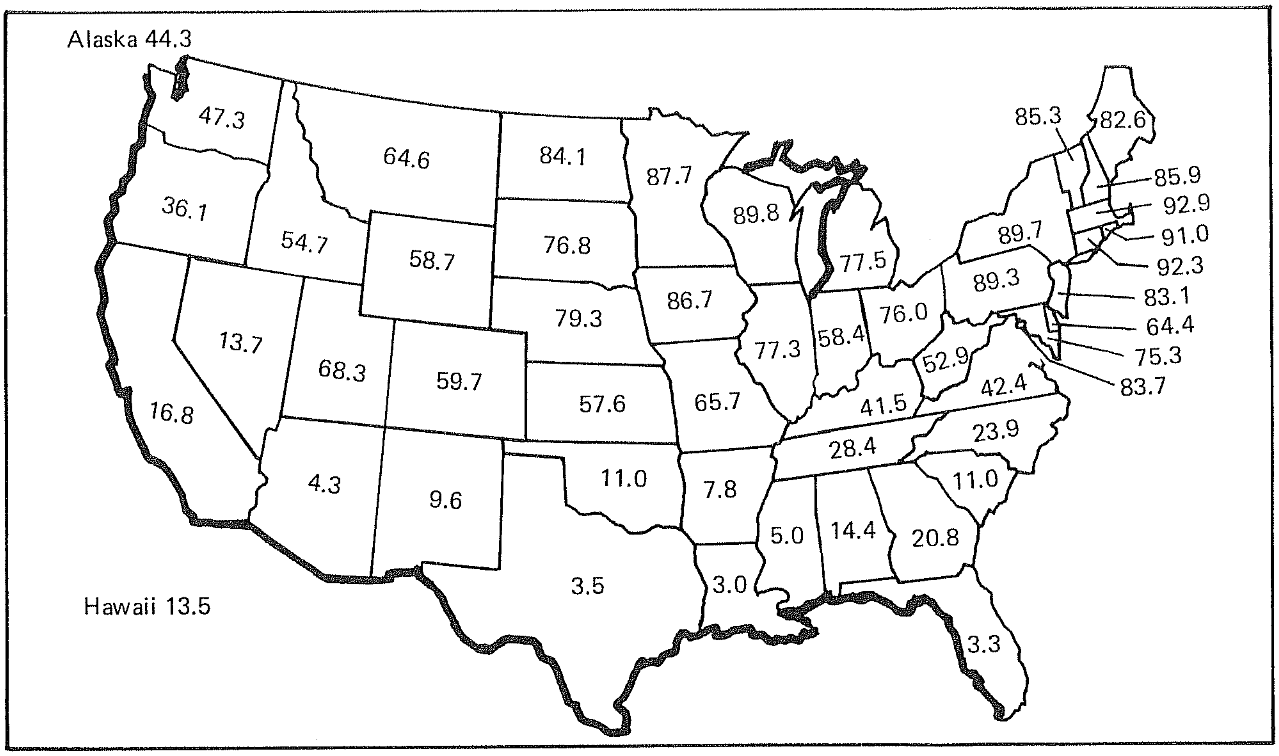
(2) Homes with 2 or more stories and 2 feet or less average basement wall exposure will provide at least PF 40 throughout the basement.

(3) Single-story homes with average basement wall exposure greater than 2 feet can be improved to PF 20 by sandbagging the exposed walls or mounding earth against them.

(4) Similarly, multi-story homes with basement wall exposure greater than 2 feet can be improved to PF 40 by sandbagging or mounding earth.

Generally, fallout protection in home basements is least in the center of the basement and greatest in the corners and along the walls.

PERCENTAGE OF HOMES WITH BASEMENTS



EFFECT OF SIZE OF WEAPON

Throughout this manual, effects have been described mainly for a 5-MT nuclear weapon because it represents the middle range of the current Soviet arsenal. For comparison, we show here the general character of the fallout patterns from 1-MT and 25-MT surface bursts as well. This covers the yield range of current Soviet missile warheads. (See Chapter 1.)

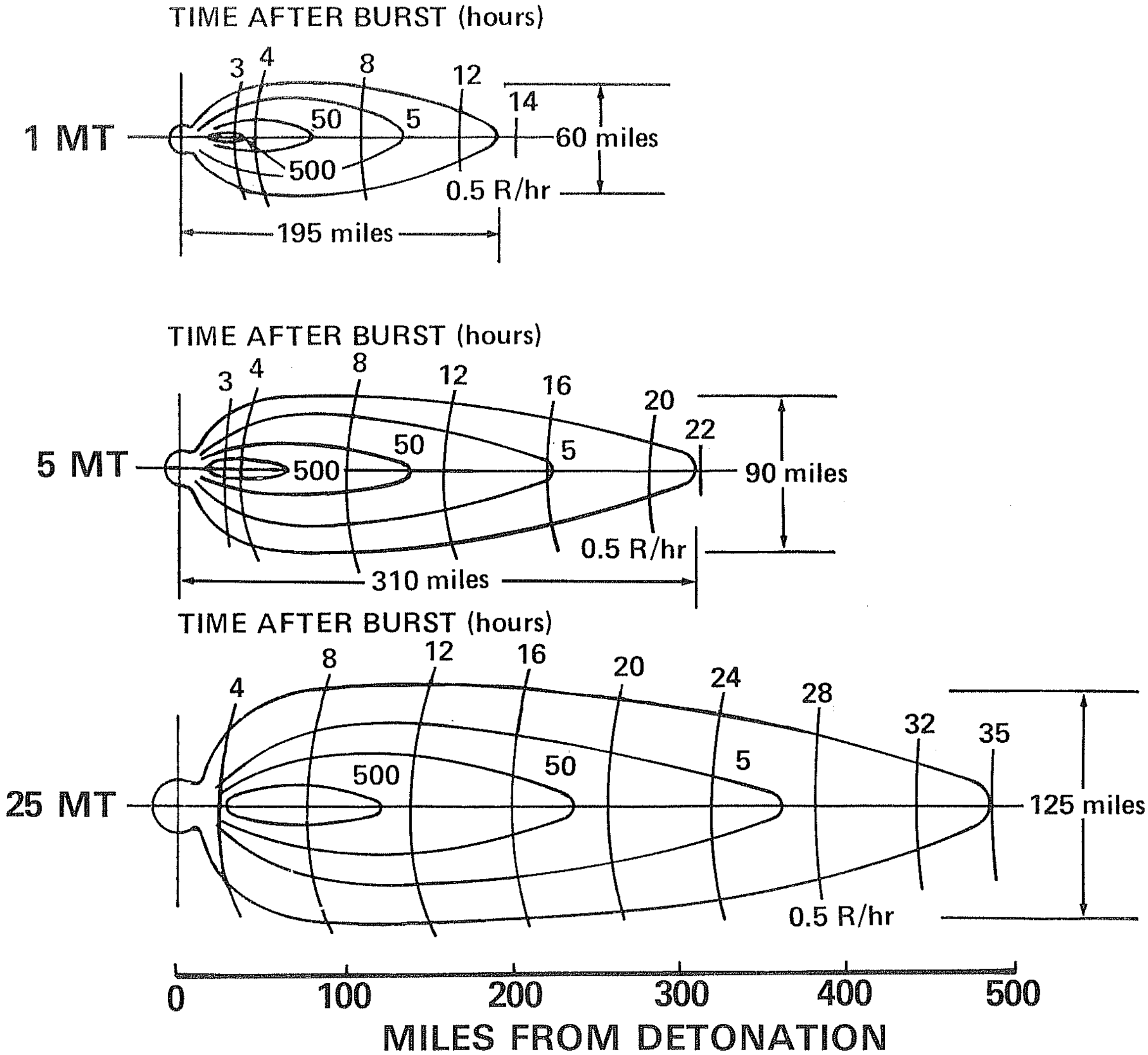
Shown are the maximum dose rates that would be observed by measurements taken at three feet above a smooth, infinite plane. As we saw in Panel 16, the actual dose rates would be less than shown here by a factor of 2 or perhaps more because of the roughness of the surfaces on which fallout had deposited, as well as the limited extent of these surfaces. Also shown, by curved vertical lines, is the time after detonation, in hours, at which the dose rate would attain its maximum.

The fallout pattern for a 25-MT surface burst is about twice as wide as that for a 1-MT detonation. It is about 2½ times as long. The 5-MT pattern is intermediate in size. The highest dose rate in the downwind area (within the 500 R/hr contour) varies by about the same factor. For a 1-MT burst, the most severe fallout situation in this area has a maximum dose rate in the neighborhood of 1000 R/hr. For the 25-MT burst, it is over 2000 R/hr. As we have seen, the maximum for a 5-MT burst is about 1500 R/hr.

The fallout process occurs most rapidly for the smallest weapon yield. Fallout deposited later than about 14 hours after detonation of a 1-MT weapon will not produce a dose rate exceeding 0.5 R/hr on a smooth, infinite plane. In contrast, dose rates will peak above 0.5 R/hr as late as a day and a half after the detonation of a 25-MT weapon. Significant fallout from a 5-MT weapon may continue to arrive for about a day.

Note that the point 30 miles downwind, used as an example in previous panels, is always in the heaviest fallout area. As the weapon size increases, fallout arrives earlier and ceases later. Shown here are the times of fallout cessation (peak dose rate). At 1-MT, the peak at 30 miles occurs less than three hours after detonation. At 5-MT, the peak occurs at about three hours. At 25-MT, four hours elapse before the maximum dose rate occurs at 30 miles downwind.

FALLOUT PATTERNS
(PEAK DOSE RATES AND TIME OF PEAK) FOR 15 MPH EFFECTIVE WIND



EFFECT OF WINDS

To this point, we have presented fallout patterns for a very simple wind condition; namely, winds at all altitudes blowing from west to east at an effective velocity of 15 miles per hour. Shown here is an actual fallout pattern from a test detonation of about 5 megatons in the South Pacific (Eniwetok Proving Grounds). Shown are the contours for "dose rate at H + 1." As discussed in Panel 14, these are therefore "fictitious dose rates" because fallout deposition is not complete for many hours after the detonation in most of the area.

The winds in this case were quite variable, blowing in differing directions and speeds at various altitudes up to the top of the mushroom cloud. Nonetheless, the features we have described are still discernible. One can note the stem fallout area around the burst point and the down-wind peak area about 35 to 60 miles north. The heavier fallout particles appear to be influenced mainly by lower altitude winds blowing from south to north, while smaller particles also appear to be influenced by winds from east to west at higher altitudes.

In general, winds over the United States are not as complex as those affecting the fallout pattern shown here. Nonetheless, simple, regular, "cigar-shaped" patterns would be unlikely. Very generally, wind speeds increase with altitude up to the upper troposphere, where a "jet stream" having wind speeds of 50 to 150 or 200 miles per hour often exists over parts of the country. Average wind speeds from the surface to the top of the mushroom cloud vary widely but can range from around 5 miles per hour in the summer to around 40 miles per hour in the wintertime. The effective wind speed used in this chapter, 15 miles per hour, can be considered near the average. Higher wind speeds elongate the fallout pattern, with a corresponding reduction in width.

Because of the thinness of the atmosphere, fallout particles fall faster in the upper altitudes than they do near the earth's surface. Winds from the surface to, say, 5000 feet thus play an important role in the spread of fallout. These winds are affected by terrain and surface temperatures. For example, near-surface winds tend to flow up valleys in daytime and down valleys at night. Onshore and offshore winds in coastal areas are another case in point.

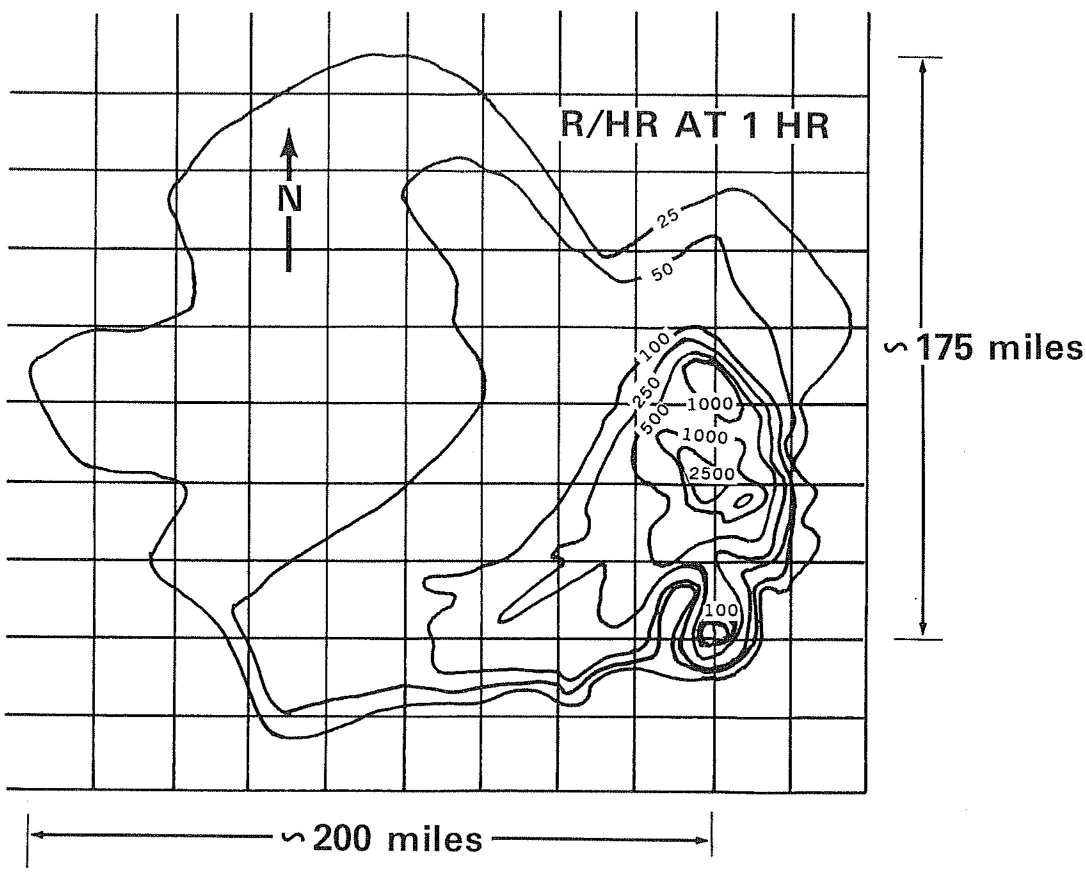
The implications for planning are:

(1) Fallout predictions based solely on wind data are not likely to be accurate in the early hours after detonations. The most reliable indicators of potential fallout arrival are actual fallout measurements reported from locations 20 to 40 miles away.

(2) The fallout "front" will move relatively slowly, from 5 to 40 miles each hour.

(3) Plans to move people from the presumed path of fallout are not practical.

FALLOUT PATTERN FROM A WEAPON TEST OF ABOUT 5 MT



From: **Congressional Hearings**, "Biological and Environmental Effects of Nuclear War," p 80, June 1959.

SKIN BURNS FROM FALLOUT

The fallout discussion thus far has emphasized the gamma radiation emanating from deposited fallout particles, which is the chief threat to survival outside the direct effects area. Another potential source of injury is from the beta radiation also given off by the fallout particles. Beta radiation was described in Panel 2. Because it is not very penetrating, beta radiation becomes a potential hazard when fallout is lodged on the skin or light-weight clothing. In close proximity to the skin, the beta radiations are absorbed in growing layers, causing burnlike lesions if present in sufficient quantity for a sufficient interval of time.

In 1954, residents of Rongelap Atoll in the Marshall Islands were exposed to fallout that arrived four to 6 hours after a test detonation on Bikini Atoll about 100 miles to the west. Fortunately, they were located near the edge of the fallout pattern, where they received only about 175R (gamma) during the two days before they were evacuated. About two-thirds of the people experienced nausea and loss of appetite and a few vomited and had diarrhea. Otherwise, the signs of injury from gamma radiation exposure were only disclosed by blood tests, which showed a gradual return to normal.

Nearly all of the people experienced itching and burning of the skin during and after the time fallout was deposited. They were, of course, lightly dressed. About two weeks after exposure, beta burns appeared on the skin, largely on parts of the body not covered by clothing. One such case is shown here. About 90 percent of the people exposed on Rongelap had these burns, and a smaller number developed spotty loss of hair from the scalp. Most of the burns were superficial. Rapid healing occurred in these cases. Some burns were deeper and more painful. A few burns became infected and had to be treated with antibiotics. For the most part, burns had healed and hair grown back by six months after exposure.

Experiments and calculations show that beta burns are likely only if fallout is deposited on the skin during the first day or two following detonation and mainly during the fallout event itself. Emergency operations after cessation of fallout (peak dose rate) do not generally result in significant contamination of people. Handling of contaminated objects without gloves would be the principal hazard.

An implication for operational planning is that to delay sending people to shelter until fallout is first detected is unwise. A person traveling on foot to shelter at our example point 30 miles downwind of a 5-MT detonation would receive about 175 roentgens in the first 15 minutes after fallout arrival. He would also have accumulated fallout particles on the scalp, collar or neck area, belt and shoe-top area that could cause painful burns and possible infection if not removed promptly.

BURN FROM BETA RADIATION *

* From Cronkite, E.P., et al., **Some Effects of Ionizing Radiation on Human Beings**, U.S. Atomic Energy Commission, July 1956.

CONTAMINATION OF WATER AND MILK

The 64 Marshallese on Rongelap Atoll were not aware that they were being exposed to fallout radiation, nor of its significance. They remained out of doors and took no special precautions. They continued to drink water from cisterns that received rain water from roofs. Analysis of urine samples taken after the people were removed from the island showed internal absorption of radioactive materials. The body levels were most serious for two radioactive materials, **strontium and iodine**. At the time, the estimated concentrations were believed to be too low to result in any serious effects. Body levels fell rapidly; by six months radioactivity in the urine was barely detectable. To this day, some 19 years later, the general health of the exposed adults has been good and about the same as that of the unexposed population, but nearly all children have suffered serious thyroid injury.

Radioactive elements follow the same metabolic processes in the body as chemically similar stable elements. Thus, strontium, which is chemically like calcium, is deposited in the bone, where it can irradiate the blood-forming cells of the bone marrow. Young growing bones incorporate calcium more rapidly than adult bones. Iodine, on the other hand, is absorbed in the thyroid gland. It is estimated the thyroids of adults received about 160 rads from the absorbed radio-iodine. (The **rad** is a unit of absorbed dose used for both beta and gamma radiation.) The smaller thyroid glands of the young children, however, received an estimated 525 to 1225 rads from the radio-iodine.

In 1963, nine years after exposure, a thyroid nodule was first detected in a 12-year-old girl (who was 3 at the time of exposure). Since then, thyroid abnormalities, many requiring surgery, have appeared in nearly all of those who were less than 10 years of age when exposed. Retardation in growth of the children has also been observed, which has been corrected by thyroid hormone treatment. One example is shown here. These findings indicate the seriousness of ingestion of radioactive iodine. Because of its short half-life, the iodine hazard would exist, at most, for a month postattack. It is an important hazard as a contaminant in water and milk, especially to the very young.

The implications for operational planning are:

(1) Water from sources other than open reservoirs should be used during the first month postattack, if possible.

(2) Young children should not be fed milk from cows that have grazed on contaminated pasture during the first month, and

(3) Stocking shelters with "pre-war" water can help avoid the iodine hazard.

One of the two boys showing most retardation of growth with development of hypothyroidism. Left: near the beginning of thyroid hormone treatment (1966, age 13); right: after 3 years of treatment (1969), showing remarkable spurt in growth and development with disappearance of hypothyroid symptoms.

From Conard, R.A., et al., **Medical Survey of the People of Rongelap and Utirik Islands Thirteen, Fourteen, and Fifteen Years after Exposure to Fallout Radiation**, Brookhaven National Laboratory BNL 50220 (T-562), June 1970.

EFFECTS ON LIVESTOCK

The survival of livestock is an important element of an assured food supply, as is the ability to grow crops, treated in the next panel. The contamination of food, other than fresh milk, by fallout represents, on the other hand, a relatively unimportant problem. The grains of fallout are readily removed from cans, food packages, and the surfaces of fruits and vegetables by wiping or rinsing. Besides, fallout is gritty and no one likes "sand in his spinach." In other words, fallout contamination of food is readily recognized and dealt with.

Fallout radiation affects livestock much as it does people. Shown here are the gamma radiation exposures to the main food-producing animals that would result in about 50 percent deaths over a period of 60 days following exposure. The first column (In Barn) represents the effects of gamma radiation only. Most animals are about as vulnerable as people. Poultry are much more resistant than other animals.

Animals in open pens would receive not only gamma radiation but also skin burns from fallout deposited on their backs. The combined effect has been accounted for (second column) by a modest reduction in the amount of gamma exposure required to kill half the animals.

Finally, animals on pasture are subjected to the combined effects not only of gamma radiation and beta burns to the skin but also the internal injury resulting from eating contaminated grass. The ingested fallout can cause damage to the stomach and intestines. As a result, lethality occurs at much lower doses than otherwise.

The Department of Agriculture, Atomic Energy Commission, and DCPA have joined in sponsoring research on livestock effects and protection for a number of years. The information shown here suggests the sort of actions that should be planned to preserve this valuable food resource. Local planners can get more details from their USDA County Emergency Board Chairman and the county extension agent.

DOSE IN ROENTGENS TO KILL HALF THE ANIMALS IN BARNS, PENS, OR PASTURE*

Animal	In Barn (R)	In Open Pen (R)	On Pasture (R)
Cattle	500	400	170
Sheep	400	320	240
Pigs	660	(550)**	(400)
Horses	670	(600)	(350)
Poultry	850	(780)	(730)

*From current Department of Agriculture estimates.

**Parentheses indicate no experimental data available.

EFFECTS ON CROPS AND CROPLAND

Not too many years ago, it was believed that, following a nuclear attack, large areas of valuable farmland would have to be abandoned for generations because of fallout contamination. This view was based on early estimates of the availability of radioactive strontium in soluble form and the amount that would be taken up by the roots of growing plants. As explained in Panel 6, we now know that radioactive strontium is depleted in heavy fallout areas and, moreover, most of the radioactive material is locked within the glassy particles. In addition, it has been found that crops in the open field do not take up strontium as readily as was assumed. Thus, even though radioactive strontium has a long half-life (about 28 years), crops grown the year following an attack are expected to be fit for human consumption. Moreover, by a year after attack, radiation exposure to farm workers would no longer be of consequence.

On the other hand, the yield of growing crops can be severely reduced or the plants killed by the levels of gamma radiation to be expected over wide areas following nuclear attack. Gamma doses that would reduce crop yield by 50 percent on the average are shown here for some important food and forage crops. Beta radiation from fallout particles adhering to various parts of the plant or on the ground will add to the dose, amounting to from one to twenty times the gamma dose depending on the crop and stage of growth. Young, actively-growing plants are most vulnerable; those near maturity are least vulnerable. Severe damage to crops may therefore be expected where the gamma one-week dose is only a few hundred to a thousand or so roentgens.

Much more is known about the effects of gamma radiation on plants than about the effects of beta radiation. Consequently, the ability to predict injury to plants from fallout is highly unsatisfactory. It will probably remain so for some years to come. This situation is of operational significance in agricultural areas if one is to avoid committing manpower and scarce fuel and fertilizer to the growth of crops that have already been injured beyond the point of economic yield. As information in this area is gained by experiment, it will be made available through the County Emergency Boards of the Department of Agriculture and the county extension agents.

GAMMA DOSE IN ROENTGENS TO REDUCE CROP YIELD BY 50 PERCENT*

Crops	YD-50 Dose
Peas, Broadbeans	less than 1000R
Rye, Barley, Onion	1000 to 2000R
Wheat, Corn, Oats, Cucumber	2000 to 4000R
Peanut, Alfalfa, Fescue, Sorghum	4000 to 6000R
Cotton, Sugar Cane, Melons, Celery	6000 to 8000R
Soybeans, Beets, Broccoli, Red Clover	8000 to 12, 000R
Rice, Turnips, Sweet Potatoes, Strawberries	12, 000 to 16, 000R
Squash	16, 000 to 24, 000R

*Based on estimates in NATO document AC/25-WP/79, **The Effects of Radioactive Fallout on Food and Agriculture**, November 1972.

EFFECTS ON THE HUMAN ECOSYSTEM

The study of the interrelationships among members of a community of animals and plants is called **ecology** and the community itself is usually referred to as an **ecosystem.** Today's environmentalists tend to call the human ecosystem, the "ecology." Concern has been expressed since the development of nuclear weapons that a nuclear war might have a catastrophic effect on the biological environment insofar as it affects humans. The concerns have stemmed mainly from the perceived characteristics of fallout and the radiations emanating from it.

In his novel, **On the Beach**, Neville Shute had to invent an impossible kind of fallout, one that did not settle out or undergo significant radiological decay, in order to cause the end of mankind. Others, not intending fiction, have forecast a new Ice Age or, alternatively, the melting of the polar ice caps, raising the level of the oceans to flood the eastern United States—and most of the populated part of the rest of the world. Which should occur depends on the presumed particle size and shape of that part of the fallout that is injected into the stratosphere and mesosphere (Panel 7). Particle clouds circling the earth could upset the earth's heat balance. Whether the earth would cool off or heat up would depend on whether the dust particles interfered with the sunlight striking the earth more or less than it interfered with the heat loss to outer space. Large volcanic eruptions offer the closest natural analogy. It is said that the huge eruptions of 1815, involving quantities of volcanic dust equivalent to the detonation of 50,000 MT or more, may have been responsible for an unusually cool summer the following year, some 13 degrees below normal. Indeed, the three major historic volcanic eruptions were all followed by exceptionally cold years. But only one year was affected. It has been concluded that the earth's climate is exceptionally stable despite severe temporarily imbalancing effects. Continued pressure of change over decades and centuries are required to produce an Ice Age.

Similarly, observation that insect predators, such as birds, are more vulnerable to fallout radiation has led to predictions that the insects will inherit the earth after a nuclear war. Analysis shows, however, that heavy fallout areas are rarely more than 50 to 100 miles from areas of negligible fallout. Since the population of the various species is controlled largely by food supply, there would be a rapid invasion of predators into the temporarily insect-rich areas. In sum, no nuclear attack can induce gross and permanent changes in the "balance of nature" anything like those that human civilization has already produced through agriculture and urbanization.

On the other hand, there could be ecological changes that might require governmental control action in the early postwar years. World-wide fallout could increase rainfall over normal amounts by acting as a "cloud-seeding" mechanism. This would have adverse effects in flood-plain areas but would delay the onset of fire hazard from radiation-killed trees in areas of moderate-to-heavy fallout. Failure to log dead trees (which would be useful for housing and firewood) would sooner or later result in forest fires and erosion damage. Over a period of several years, silting could destroy the usefulness of reservoirs and irrigation works. Finally, degraded sanitation and public health measures in damaged urban areas could create conditions favorable to outbreaks of disease-carrying insect and rodent populations. All these consequences are subject to human planning, intervention, and control.

IMPLAUSIBLE CATASTROPHES

1. End of all life on the planet Earth.
2. A new Ice Age.
3. Melting of the polar ice caps.
4. Insects inherit the Earth.

MORE LIKELY ECOLOGICAL CONSEQUENCES

1. Temporarily increased rainfall.
2. Fire hazard in dead pine forests.
3. Longer-term threat of increased erosion and silting.
4. Outbreaks of disease-carrying insects and rodents in damaged urban areas.

FALLOUT IN THE DAMAGED AREA

Most of the fallout from megaton-yield nuclear detonations is carried tens to hundreds of miles by the wind before it is deposited on the ground. For this reason, we have emphasized the fallout environment outside the area of blast damage and fire. Fallout from surface bursts will also occur in the direct-effects area, making firefighting, rescue, and medical aid more difficult and urgent. The next six panels describe the fallout threat in the damaged area, as defined by the Miller fallout model. Weapons test data supporting these estimates are quite limited.

Fallout does not arrive immediately in the damaged area. Particles begin to fall from the rising fireball when the rate of cloud rise decreases to less than the falling velocity of the particles. The time of arrival of first fallout from the mushroom stem is shown in the table for 1-, 5-, and 25-MT detonations.

The somewhat complex pattern below the table shows the time of arrival of close-in fallout for the example 5-MT surface burst used previously. Fallout arrives almost simultaneously at 22 minutes after burst over nearly all of the direct effects area. (For reference, the extent of 2-psi blast overpressure is shown as a dotted circle.) Thereafter, fallout progresses downwind at the assumed effective wind speed of 15 miles per hour, reaching a distance of about 16 miles at one hour after detonation. For other wind speeds, the distances shown would obviously be different.

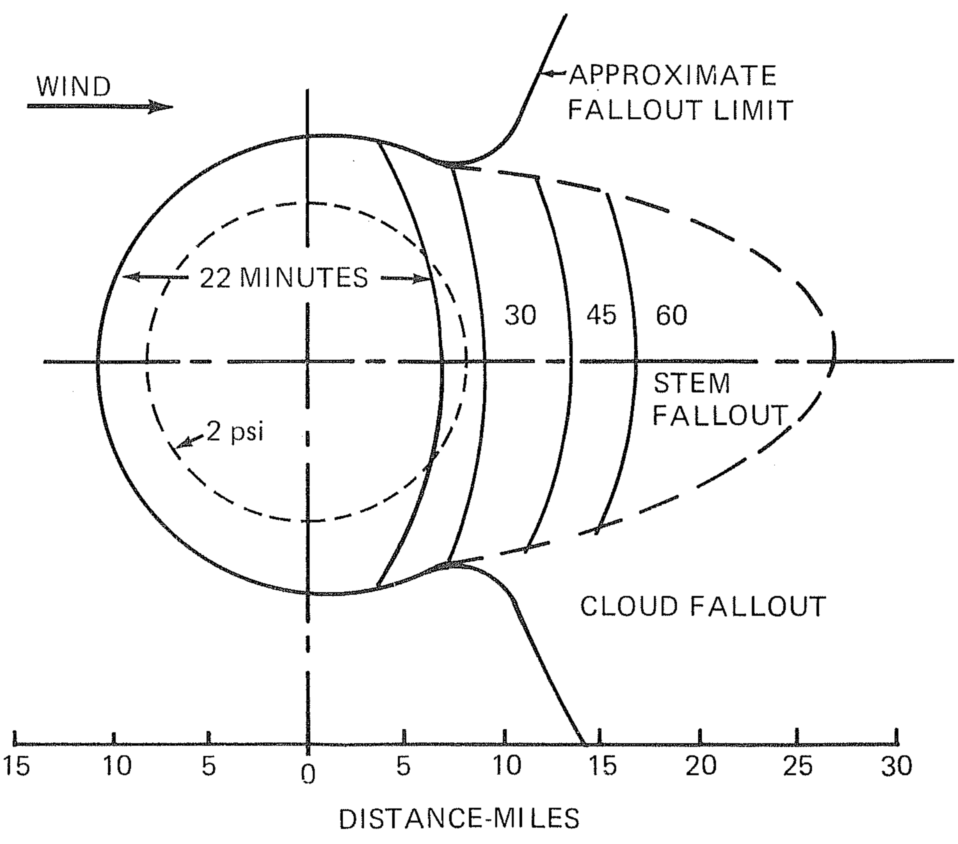
One might ask how it could be that fallout would not arrive at 16 miles downwind until one hour after detonation when, in Panel 9, we saw that fallout arrived 30 miles downwind at 45 minutes after burst. The reason is that the point at 30 miles, shown by a black dot, is in the cloud fallout region, not the stem fallout region. In the upwind portion of the cloud fallout region, fallout from the bottom of the cloud arrives before that from the main portion of the cloud. The earliest arrival of cloud fallout is beyond 30 miles and arrival times increase toward ground zero. Fallout arrival at 25 miles is later than at 30 miles, increasing to about one hour inside 20 miles where cloud and stem fallout arrive almost simultaneously. Therefore, stem fallout arrival times are not shown beyond one hour.

EARLIEST FALLOUT ARRIVAL

Weapon Yield	Fallout Arrival Time
1 MT	16 Minutes
5 MT	22 Minutes
25 MT	30 Minutes

FALLOUT ARRIVAL FOR 5 MT BURST

(15 MPH WIND SPEED)



EARLY OPERATIONAL DOSES

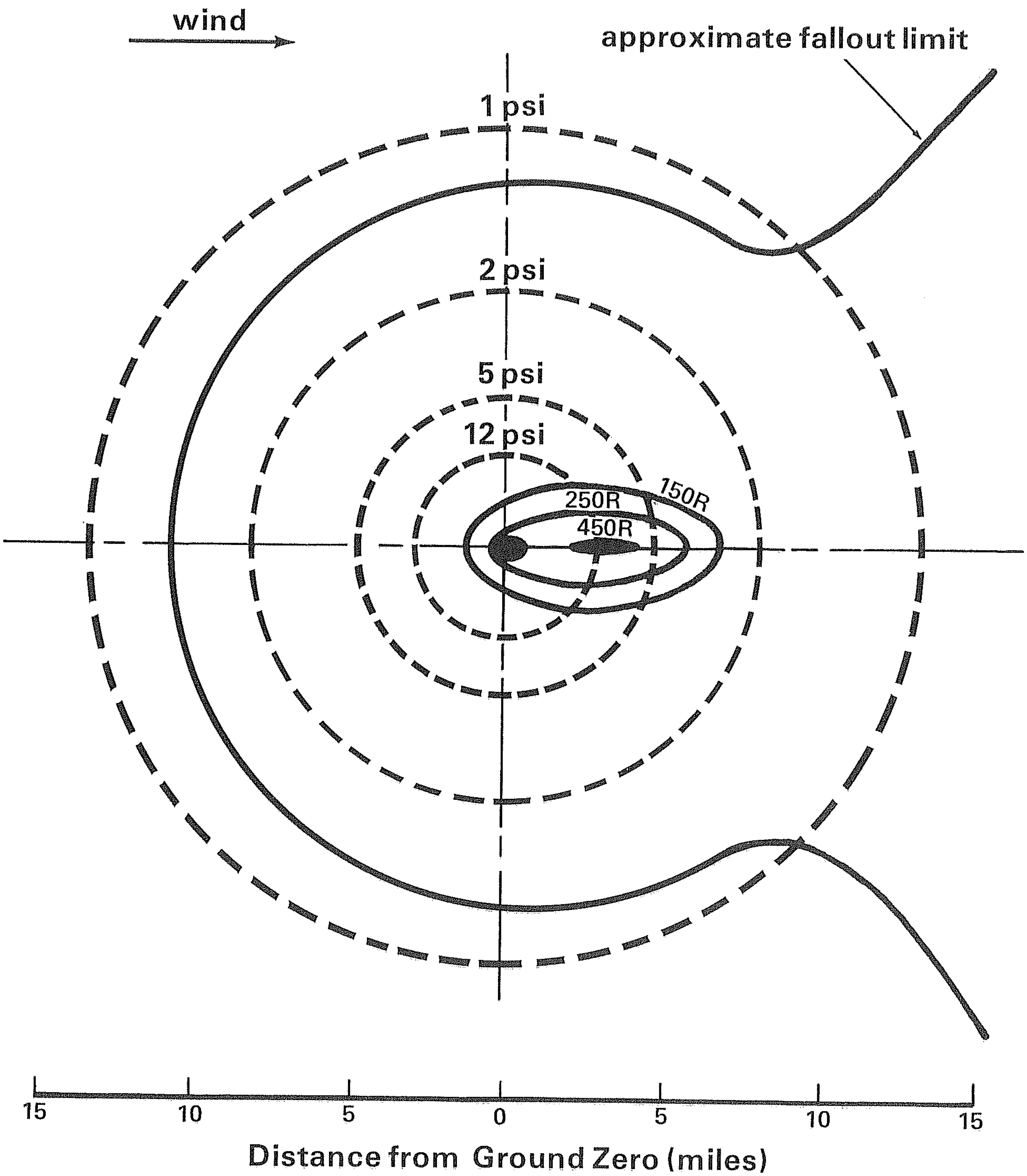
Although fallout will arrive in the damaged area within 15 to 30 minutes after detonation, fallout radiation exposures during the critical first hour will generally be nominal. The region affected by the doses defined in the Dose Penalty Table of Panel 15 is shown here. This region is confined to a small downwind area in the moderate and severe damage areas. There is a small area astride the 12-psi circle where exposures in the first hour would be in excess of 450R. Practically all of the area where suppression of smouldering ignitions, fire-fighting, rescue, and medical aid would be urgent tasks would experience outside doses of less than 150R during the first hour.

The doses shown are not those that would be received over a smooth, infinite plane. As we saw in Panel 16, exposures under actual operating conditions would be lower than the smooth, infinite-plane case because real surfaces are rough and of limited extent. Debris caused by blast damage would make most of the damaged area quite "rough." How "rough" these areas might be can be appreciated by reviewing Panels 35 and 36 of Chapter 2.

For this example, it has been assumed that the "real world" exposures would be about one-third those predicted for the smooth, infinite-plane situation. This is probably a conservative estimate of the effect of blast damage, and actual exposures would likely be even lower. Radiation exposures would vary even more widely than suggested by Panel 16. To aid in control of such exposures, at least one member of each emergency team should be equipped with a dosimeter.

One additional point to be considered is that, although gamma radiation exposures might be nominal during the first hour, fallout would be occurring during most of this period. Emergency teams should be dressed to avoid accumulation of fallout particles on the skin. A "Man-from-Mars" suit is not necessary. A coat with hood or hat and gloves are desirable. The usual fireman's "running gear" is excellent for the purpose.

DOSE DURING THE FIRST HOUR
(5MT SURFACE BURST -15 MPH WIND)



LATER OPERATIONAL DOSES

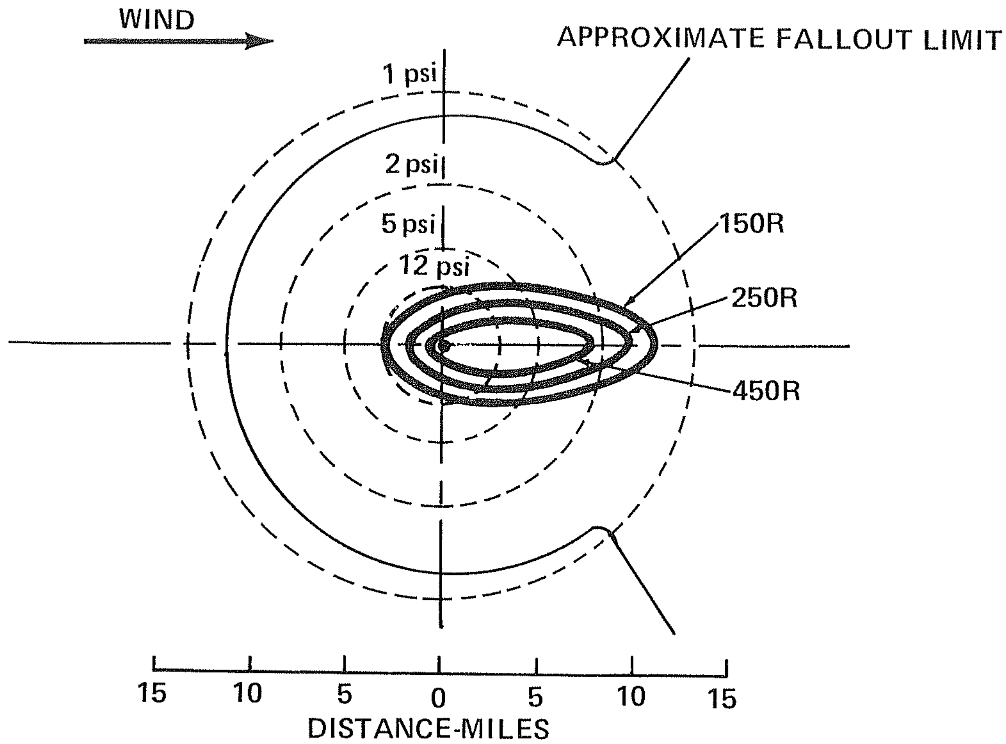
Urgent tasks of fire defense, rescue, medical aid, and remedial movement of people from threatened shelters may require continued operations beyond the first hour after a detonation. Shown here are the areas in which 150R, 250R, and 450R doses might be expected during the first two hours (upper sketch) and first four hours (lower sketch). The assumption as to the roughness of the debris-strewn area is the same as in the previous panel.

At two hours, the area enclosed by the 450R dose contour extends from about 1 mile upwind to about 8½ miles downwind and is about 4 miles wide at its widest. By the end of four hours, this area extends from 1½ miles upwind to 10 miles downwind and is 5 miles wide. As can be seen, doses above 150R are likely only in the downwind sector of the damaged area and affect less than one-third of the potential fire area.

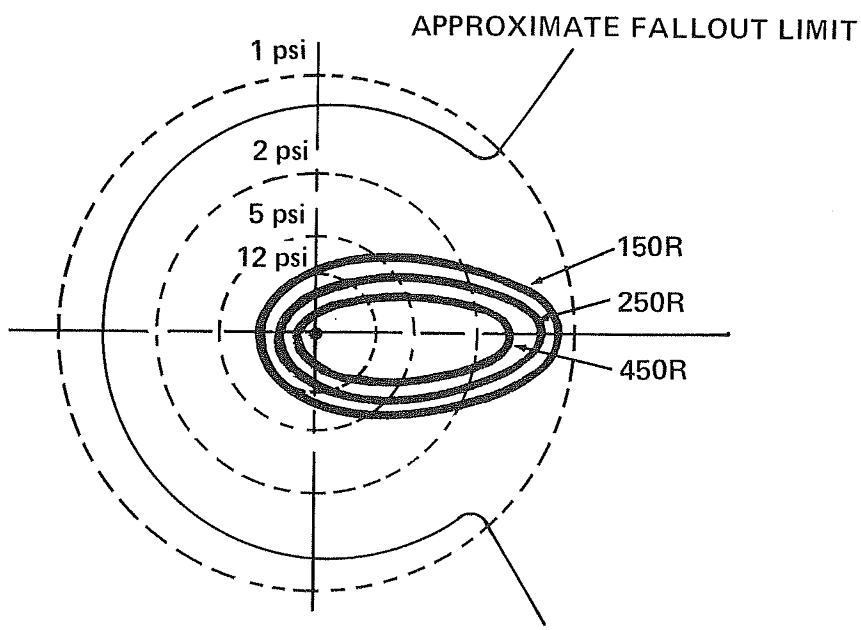
In contrast to the situation in the cloud fallout area further downwind, the dose rate in the stem fallout area will peak well before the cessation of fallout. This is because of the rapid decay of radioactivity at early times. The dose rate can be expected to peak within the first hour throughout most of the damaged area. Only a small part of the subsequent dose is received during the "buildup period." Hence, the observed peak dose rate can be used to guide emergency operations. For example, where the dose rate peaks at, say, 125 R/hr, the anticipated dose in the first two to four hours is predicted to be about 125R. Similarly, if the CD V-715 goes off-scale on the high range (greater than 500 R/hr), potentially lethal outside exposures are to be anticipated. Since the direction of down-wind fallout may not be related to the observed surface winds, use of radiation measurements is to be preferred in operational planning.

DOSE DURING FIRST TWO HOURS

(5 MT SURFACE BURST-15 MPH WIND)



DOSE DURING FIRST FOUR HOURS



PANEL 31

EFFECT OF FIRES ON FALLOUT DEPOSITION

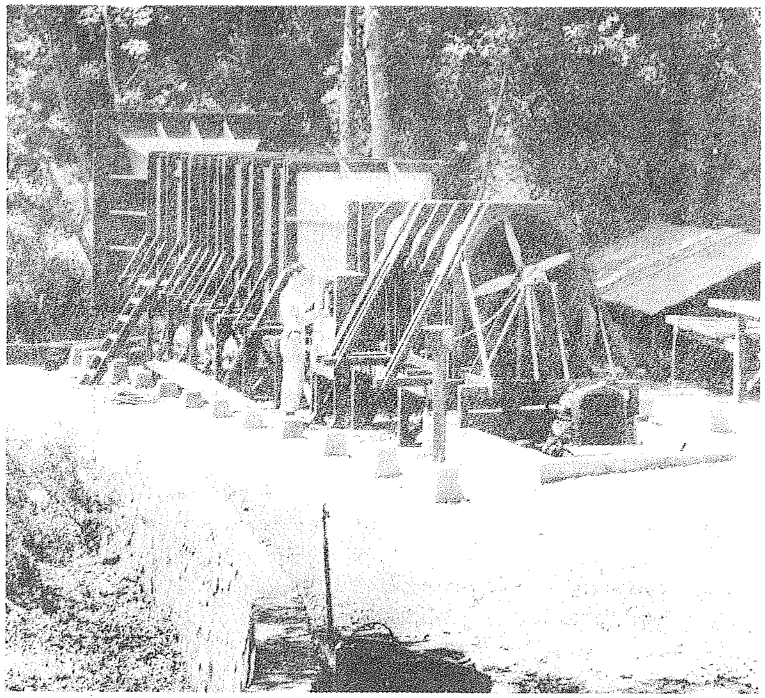
In Chapter 3, the fire environment in the damaged area was described. Mass fires are marked by "in-rush" winds and a rising "convection column" above the fires. Theoretical analyses of convection columns above large-scale fires indicate that the updraft from even moderate rates of heat output exceeds the falling velocities of most fallout particles. It would appear, then, that convection columns induced by fires set by the detonation could have an effect on the fallout pattern.

A time lapse occurs between the time of ignitions and the time when massive fires can be burning. Experience from World War II incendiary raids indicates this time period may vary from 25 to 45 minutes. The effect of the nuclear blast wave in suppressing ignitions to a smouldering condition would increase this time delay substantially. Thus, it is unlikely that the fires resulting from a megaton-yield surface burst would alter significantly the deposition of stem fallout in the damaged area.

Analyses and experiments have been done to assess the effect of well-established fires on fallout deposition from the cloud or from later fallout from upwind detonations. The main experiments were conducted in the low-velocity wind tunnel shown here. Gas burners were used to simulate the fire area and simulated fallout was introduced upwind of the fire near the top of the wind tunnel. As predicted by theory, the fire updraft buoyed up the fallout, causing it to fall much further downwind than otherwise would be the case. There was also much lateral dispersion of the fallout so the effect would be to lower markedly the high dose rates in the downwind area and increase somewhat the lower dose rates over a much larger area.

Other experiments conducted in the mid-1950s showed that rapidly burning fires in already contaminated areas as small as one tenth of an acre resulted in removal of perhaps a third of the deposited fallout, and the removed material was dispersed so that there was no significant concentration in any other region. This process may have some effect in further reducing radiation hazards during firefighting operations.

LOW-VELOCITY WIND TUNNEL USED IN FIRE-FALLOUT EXPERIMENTS*



* From Broido, A., and McMasters, A.W., **The Influence of a Fire-Induced Convection Column on Radiological Fallout Patterns**, California Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, February 1959. (Library of Congress PB 149923)

PANEL 32

EFFECT OF DAMAGE ON FALLOUT PROTECTION

The fallout protection afforded by buildings (Panel 18) is estimated on the basis that the roof and surrounding ground areas are uniformly contaminated with fallout and that fallout does not lodge on the sides of the buildings nor do fallout particles penetrate into the interior of the building. In effect, the calculation is made as if the fallout fell vertically onto the surfaces below. In the real world, winds or breezes are blowing near the ground most of the time. If windows were broken or walls blown in, some fallout could penetrate into the interior of buildings.

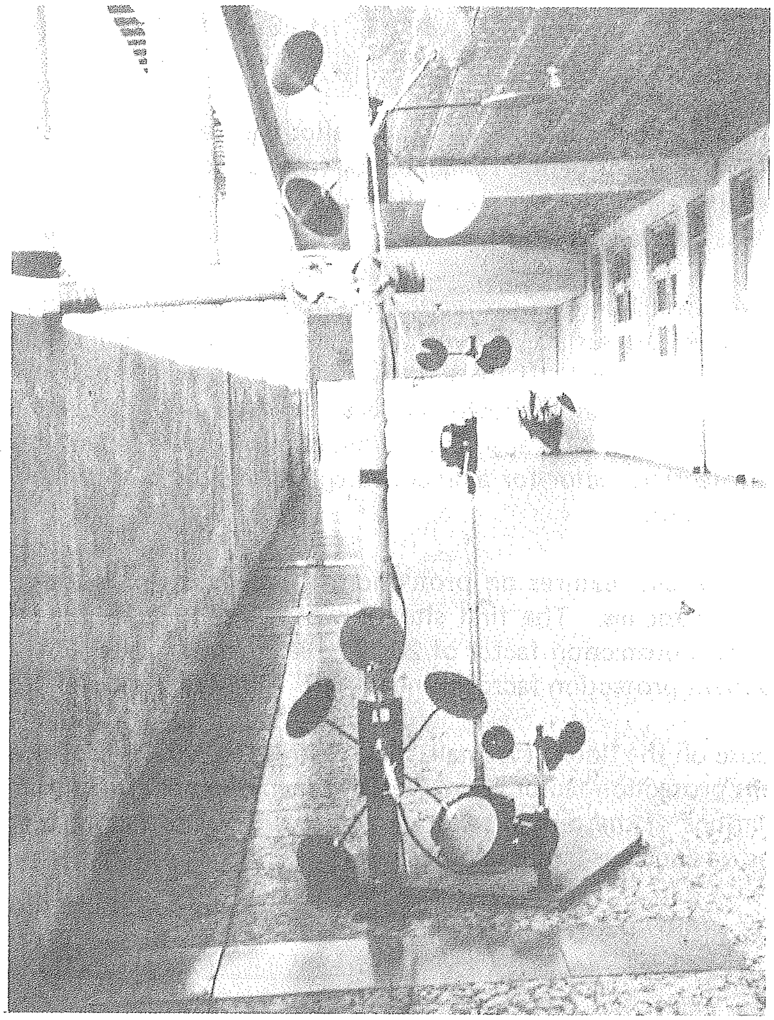
A number of calculations have been made of the effect of "fallout ingress" on the protection afforded by buildings. These estimates have been necessarily highly idealized and are not very useful. The small amount of experimental evidence available does indicate, however, that large reductions in fallout protection are not to be expected in most instances.

The best evidence comes from the volcano fallout in Costa Rica described in Panel 12. Shown here is a fallout situation where most of the wall is open. Visible fallout is concentrated in a band about 20 inches wide below the sill. (The devices shown are for collecting fallout and measuring air movement.) Measurements indicated that the deposition near the sill was about 5 percent of that on the ground in the open and about 1 percent elsewhere in the corridor. Other measurements near smaller open windows indicated deposition near the windows of about 1 percent of the exterior amounts. Calculation of the effect of this amount of ingress on the mid-floors of tall buildings indicate a reduction of about 5 percent in the protection factor (e.g., 38 PF rather than 40 PF). Measurements under covered walkways where both sides were completely open indicated that as much as one-tenth of the outside deposit level could be deposited. Thus, where walls are completely blown in as shown in the upper sketch of Panel 14 in Chapter 2, the protection factor in the middle floors could be reduced by perhaps 10 percent or more (e.g., 35 PF rather than 40 PF).

The deposition of building debris on the floor above basements would tend to increase the protection below in most cases.

The most serious degradation of fallout protection due to blast damage would occur in residential basements and the basements of other lightly constructed buildings under the circumstance where the building is blown clear of the basement (lower sketch in Panel 12 of Chapter 2). Fallout would be deposited in the basement, reducing the protection factor from 20 to 40 down to about 4 or 5. It would be necessary for basement occupants to prop sections of flooring or walls against the basement wall, lean-to fashion, and to cover the lean-to with nearby pieces of masonry for fallout protection. This need is another reason why it may be desirable to plan for group occupancy of residential basements in urban areas rather than single families.

OPEN CORRRIDOR ON THIRD FLOOR OF SCHOOL CONTAMINATED BY FALLOUT-LIKE VOLCANIC DEPOSIT IN COSTA RICA*



* From Clark, D.E., Jr., and Sartor, J.D., **Operation Ceniza-Arena: Techniques for the Measurement of Deposition and Redistribution of Fallout Around Structures**, Stanford Research Institute Project No. MU-5779, December 1966. (AD 647 242)

PANEL 33

WHAT ABOUT HILLS?

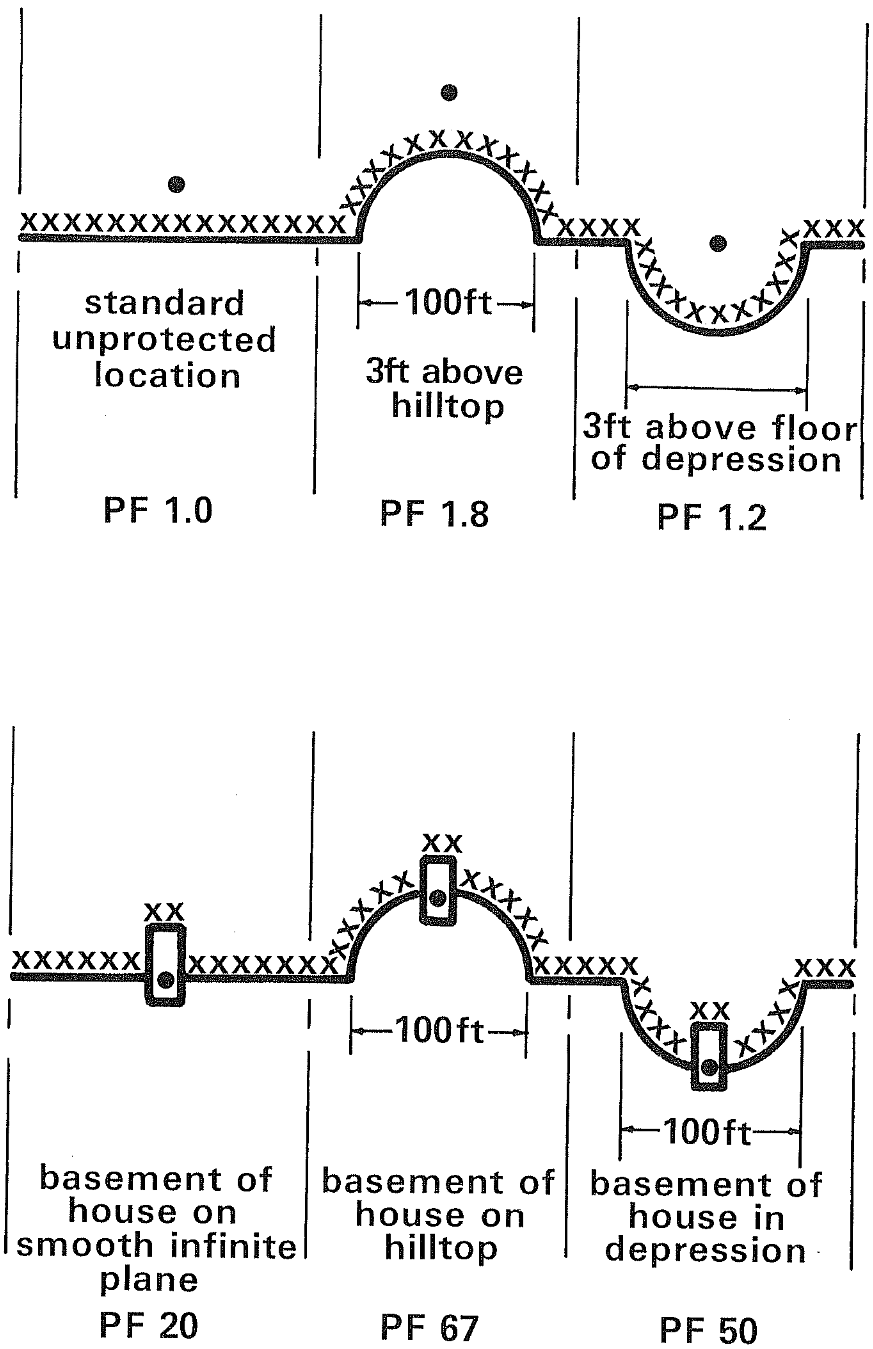
Protection factor calculations assume that fallout is deposited on smooth plane surfaces. In Panel 16, the effect of the roughness of real surfaces was discussed, but again in terms of level terrain. The question might be raised as to the effect of prominent terrain features, such as hills and valleys.

The upper sketches show the protection afforded a person standing in the open on smooth surfaces. When the surface is level, we have the standard unprotected location for which the protection factor is 1. If the person were on top of a small, steep hill that falls away in all directions (the example shown here is a hemisphere with a diameter of 100 feet), the PF is increased to nearly 2 because the hill hides much of the fallout beyond the immediate area. The protection factor for a small, steep depression is not much improved over the infinite-plane situation.

The effect of terrain features on protection in basements is much more marked, as shown in the lower sketches. The first situation shows a home basement on a smooth, infinite plane having a protection factor of 20. The same house on top of a small, steep hill would have a basement protection factor of nearly 70. Many rural houses are built on hills.

The same house on the floor of a small, steep depression would also have a substantially increased basement protection factor. However, not many homes are built in such locations. In general, undulations of the terrain tend to restrict the area of fallout that can contribute to radiation exposure and thus improve protection.

EFFECT OF TERRAIN FEATURES



A NOTE ON DECONTAMINATION

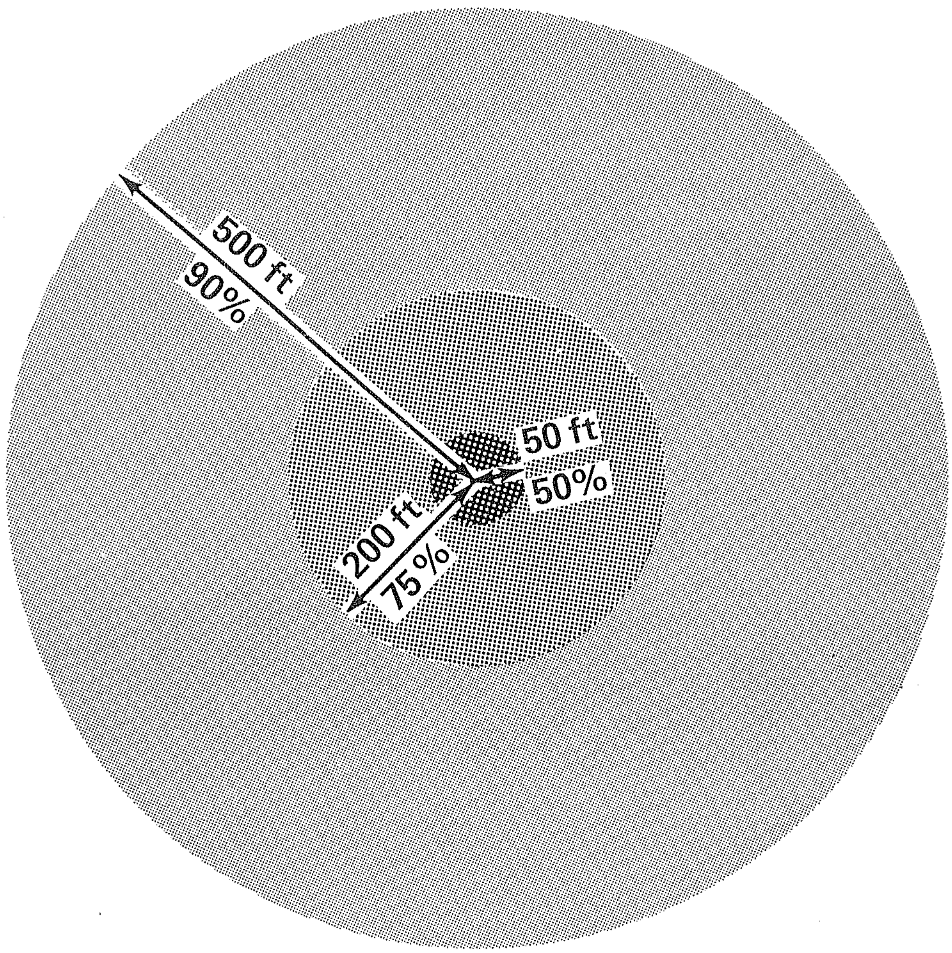
Surfaces on which fallout particles have fallen are called **contaminated** surfaces. Being sand-like material, fallout can be cleaned from most surfaces by readily available means. The process of removing fallout particles from exposed surfaces and disposing them where they cannot harm people is called **radiological decontamination**. Paved areas can be decontaminated with firehoses, street flushers, or with street sweepers. Roofs can be decontaminated with firehoses. Unpaved areas can be decontaminated by scraping off or plowing under the top layer of soil.

As shown in this sketch, half of the radiation received at a point 3 feet above a large, smooth, unbroken surface comes from fallout within 50 feet. On rough surfaces, the area contributing half the exposure is much less. In an area covered with 6 inches of debris, a depth indicated in Chapter 2 as quite common, half the radiation comes from fallout within about 10 feet.

The sketch shows that three-quarters of the radiation comes from fallout within 200 feet on smooth surfaces (100 feet or less on rough or debris-strewn surfaces). But at least 10 percent of the exposure comes from fallout radiation originating many hundreds of feet away. This suggests that, if large reductions of exposure are desired, not only must the work or living area be decontaminated but also a "buffer zone" around it to a distance of several hundred feet in most instances.

For this reason, decontamination as a measure to improve the fallout protection of people in shelter is not generally practical except, possibly, for the sweeping up of visible fallout near broken windows or near entrances to a shelter area. Decontamination can be important, however, in speeding postattack recovery in fallout areas. Hence, decontamination is covered in more detail in Chapter 8.

DOSE CONTRIBUTION vs DISTANCE



PANEL 35

WHAT ABOUT BOATS?

The fact that a large part of the radiation from fallout comes from contaminated areas a considerable distance away has suggested that boats and ships located on bodies of water (lakes, rivers, and bays) might provide good fallout protection. Fallout particles will settle rather quickly to the bottom. Three to five feet of water will provide ample shielding from this fallout. Thus, if a boat is anchored or lying at least several hundred feet offshore, nearly all of the radiation exposure will come from fallout actually deposited on the boat. Most fishing and pleasure boats are quite small, and the protection factor from being on the water would be about 4 or 5, better than in a house but not as good as most home basements.

The protection can be greatly improved by rigging a tarpaulin or awning over cockpit areas and shaking or sluicing the canvas to dislodge the fallout particles when visible deposits appear. Exposed decks can also be sluiced by hose or bucket. Thus, a combination of lying offshore and early decontamination can generally result in an equivalent protection factor of 20 to 40. If no better fallout protection is available, boats may be considered in localities where they are plentiful.

Ships may also be useful in many circumstances. They can carry large numbers of people. Because they are larger than boats, the radiation levels from fallout deposited on the decks more nearly approaches the level that would occur on shore. The steel construction will offer significant shielding but prompt decontamination is also necessary to achieve a reasonable amount of fallout protection. The topside areas of ships are readily flushed off. Most naval ships and some merchant ships have washdown equipment to accomplish rapid decontamination. A washdown system in action is shown here.

PHOTOGRAPH OF USS KITTY HAWK UNDER WASHDOWN
(Courtesy of Office of Chief of Naval Operations)

PANEL 36

FACTS ABOUT RADIATION AND FALLOUT

During the average lifetime, every person receives about 10 Roentgens of ionizing radiation from nature and about an equal amount additionally from dental and chest X-rays and even the luminous dials of wrist watches. Yet radiation effects and fallout remain mysterious and misunderstood threats to both the average citizen and government employee. Emergency planning should include informing the public on the basic facts shown here if an unwarranted paralysis of action during a fallout emergency is to be avoided. The basis for these statements is contained in the panels of this chapter and those of Chapter 5.

SOME BASIC FACTS

1. Everyone receives some radiation exposure in peacetime. It is when large doses are absorbed in a short period that sickness or death results.
2. Radiation sickness is neither contagious nor infectious. But people made sick by radiation are temporarily more susceptible to infection.
3. Radiation exposures that cause sickness are much lower than those that cause death. Being sick does NOT indicate that one is necessarily going to die.
4. Fallout radiation cannot make anything radioactive. Fallout itself consists of sand-like particles too large to be inhaled.
5. Dangerous amounts of fallout can generally be seen but special instruments are needed to measure the danger of radiation exposure.
6. Radiation exposure can be kept below sickness levels by using good fallout shelter; by delaying outside activities until decay has reduced the exposure rate; and by limiting the time of exposure on urgent tasks.
7. No one should thirst or starve for fear of contaminated water or food. Illness can be caused as readily by malnutrition and poor sanitation as by radiation injury.

SUGGESTED ADDITIONAL READING

The following sources provide additional background on the material in this chapter:

Effects of Nuclear Weapons, Revised Edition 1964, Glasstone, S., (editor), Chapters 1, 2, 6, 9, 10, and 11, Superintendent of Documents, GPO.

National Committee on Radiation Protection, **Exposure to Radiation in an Emergency**, Report No. 29, January 1962.

Miller, C.F., **Fallout and Radiological Countermeasures, Volumes I and II**, Stanford Research Institute, January 1963. (Vol. I—AD 410 522, Vol. II—AD 410 521)

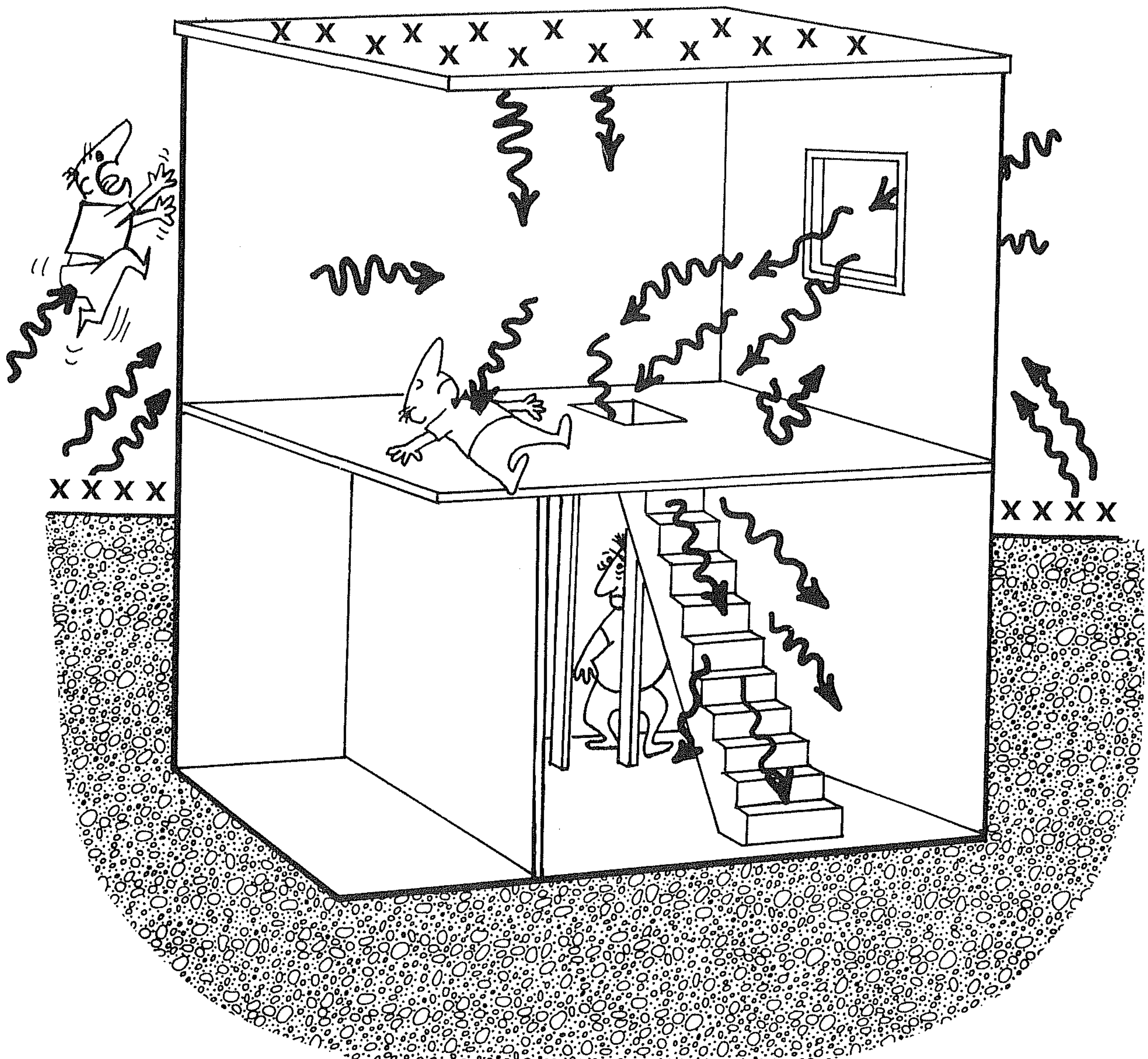
Casarett, A.P., **Radiation Biology**, Prentice-Hall, 1968.

Upton, A.C., **Radiation Injury: Effects, Principles, and Perspectives**, University of Chicago Press, 1969.

Bensen, D.W., and Sparrow, A.H.,(editors), **Survival of Food Crops and Livestock in the Event of Nuclear War**, No. 24 of AEC Symposium Series, CONF-700909, December 1971.

Radiological Defense Textbook, SM-11.22.2, Office of Civil Defense, June 1968.

Radiological Health Handbook, U.S. Department of Health, Education and Welfare, Public Health Service, Rockville, Maryland 20852, January 1970.



PANEL 38