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THE EFFECTS OF HIGH-YIELD NUCLEAR EXPLOSIONS
UNITED STATES ARMY ENERGY COMMISSION

Statement by Lewis J. Semmes, Chairman, USAREC

THE EFFECTS OF
HIGH-YIELD
NUCLEAR EXPLOSIONS

A Report by
The United States Atomic Energy Commission

FALLOUT PATTERN OF 1.4 TEST IN THE PACIFIC

The very large thermonuclear device tested at Bikini Atoll on March 1, 1954, was detonated on a cloud layer and the ensuing fallout terminated an elongated, cigar-shaped area extending approximately 200 statute miles down wind and ranging in width up to 40 miles. In addition, there was a contaminated area upwind and cross-wind extending possibly 30 miles from the point of detonation. Data was collected from 50 points on 4 ships located from 10 to 250 miles down wind from the point of detonation.

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**STATEMENT BY LEWIS L. STRAUSS, CHAIRMAN
UNITED STATES ATOMIC ENERGY COMMISSION**

At a news conference on December 17, 1954, I stated that the staff of the Atomic Energy Commission was studying the subject of fallout and expressed the hope that information about it would be made public at a later date. "Fallout" is the word now applied to a phenomenon that follows the explosion of a nuclear weapon. Such an explosion, if the fireball touches the surface of the earth, draws up large amounts of materials into the bomb cloud. These materials subsequently fall back to earth as radioactive particles over a large area, mostly down-wind and relatively close to the point of explosion—although the lighter particles are carried great distances. The main radioactivity of fallout decreases very rapidly with time—for the most part, within the first hours after the explosion. An in-the-air explosion where the fireball does not touch the earth's surface does not produce any serious radiological fallout hazard.

Since nuclear weapons are in possession of the USSR, the Commission believes the American people wish to be informed regarding the dangers of nuclear explosions and the measures which individuals can take to protect themselves if an atomic attack should ever occur. Therefore, the Commission has condensed in the attached Report the information which can be made public at this time on the effects of the explosions of high-yield nuclear weapons.

The following excerpts and summarized sections contain the highlights of the Report itself.

FALLOUT PATTERN OF 1954 TEST IN THE PACIFIC

The very large thermonuclear device tested at Bikini Atoll on March 1, 1954, was detonated on a coral island and the ensuing fallout contaminated an elongated, cigar-shaped area extending fallout approximately 220 statute miles down-wind and varying in width up to 40 miles. In addition, there was a contaminated area up-wind and cross-wind extending possibly 20 miles from the point of detonation. Data was collected from 25 points on 5 atolls located from 10 to 330 miles down-wind (generally east) from Bikini Atoll. Due to an unexpected shift in the direction of the prevailing winds in the higher altitudes, the fallout missed the observation rafts that had been placed farther north

previent to the test firing. The estimated contour of the pattern of fallout is, therefore, based only in part on data obtained from actual measurements and partly on calculations.

Data from this and other tests permits *estimates* of casualties which would have been suffered within this contaminated area if it had been populated. These *estimates* assume: (1) that the people in the area would ignore even the most elementary precautions; (2) that they would not take shelter but would remain out of doors completely exposed for about 36 hours; and (3) that in consequence they would receive the maximum exposure. Therefore, it will be recognized that the estimates which follow are what might be termed *extreme estimates* since *they assume the worst possible conditions*.

On the basis of our data from this test and other information, it is estimated that, following the March 1, 1954, test explosion, there was sufficient radioactivity in a downwind belt about 140 miles in length and of varying width up to 20 miles to have seriously threatened the lives of nearly all persons in the area *who took no protective measures*. Some distance farther from the point of detonation, at about 160 miles downwind and along the axis of the ellipse, the amount of radioactivity would have seriously threatened the lives of about one-half of the persons in the area who took no protective measures.

Near the outer edge of the ellipse, or approximately 190 miles downwind, it is estimated that the level of radioactivity would have been sufficient to have seriously threatened the lives of 5 to 10 percent of any persons who might have remained exposed out of doors for all of the first 36 hours.

Thus, about 7,000 square miles of territory downwind from the point of burst was so contaminated that survival might have depended upon prompt evacuation of the area or upon taking shelter and other protective measures.

At a distance of 220 miles or more downwind, it is unlikely that any deaths would have occurred from radioactivity even if persons there had remained exposed up to 48 hours and had taken no safety measures.

The estimates cited above do not apply uniformly throughout the contaminated area inasmuch as the intensity of radioactivity within a region of heavy fallout will vary from point to point, due to such factors as air currents, rain, snow, and other atmospheric conditions. Because of this and because most persons, if given sufficient warning, probably would evacuate the area or take shelter and other precautionary measures, the actual percentage of fatalities could reasonably be presumed to be considerably smaller than these extreme estimates.

PROTECTION AGAINST FALLOUT

In an area of heavy fallout the greatest radiological hazard is that of exposure to *external* radiation, which can be greatly reduced by simple precautionary measures. Exposure can be reduced by taking shelter and by simple decontamination measures. Test data indicates that the radiation level, i. e., the rate of exposure, indoors on the first floor of an ordinary frame house in a fallout area would be about one-half the level out of doors. Even greater protection would be afforded by a brick or stone house. Taking shelter in the basement of an average residence would reduce the radiation level to about one-tenth that experienced out of doors. Shelter in an old-fashioned cyclone cellar, with a covering of earth three feet thick, would reduce the radiation level to about 1/5000, or down to a level completely safe, in even the most heavily contaminated area. Designs of shelters of simple yet effective construction have been prepared by the Civil Defense Administration and are available to the public.

Radioactive material deposited during the fallout may or may not be visible but would be revealed by radiation detection instruments such as Geiger counters. Any falling dust or ash that can be seen downwind within a few hours after a nuclear explosion should be regarded as radioactive until measured by a radiation detection instrument.

Care should be taken to avoid the use of solid foods or liquids that may contain fallout particles.

If fallout particles come into contact with the skin, hair, or clothing, prompt decontamination precautions such as have been outlined by the Federal Civil Defense Administration will greatly reduce the danger. These include such simple measures as *thorough bathing of exposed parts of the body and a change of clothing*.

INTERNAL RADIATION EFFECTS

Two other factors must be considered in evaluating possible hazards from radioactive fallout. The first is the effect of internal radiation from fallout particles swallowed in food or liquids. The second is the effect of radiation upon the germ cells which transmit inherited characteristics from one generation to another. It should be noted that in neither case is there reason to believe that weapons testing programs of the United States have resulted in any serious public hazard.

The radioactive forms of strontium and iodine are the constituents of fallout which are of principal concern as internal sources of radiation through ingestion. The concentrations of these substances from

nuclear detonations to date have been monitored at many localities, and the amounts detected have been insignificant, compared to concentrations which would be hazardous.

GENETIC EFFECTS OF RADIATION

There is a wide range of admissible opinion as to the genetic effects which radiation might have upon future generations, and conclusive data is not available at present on which to base an incontrovertible forecast. However, it is important to recognize that the average amount of radiation exposure received by residents of the United States from all nuclear detonations to date has been about the same as the exposure received from one chest X-ray. The Commission's medical and biological advisers do not believe that this small amount of additional exposure is any basis for serious concern at this time.

BLAST AND HEAT EFFECTS

Two important characteristics of any nuclear explosion, other than those from fallout, are the effects of blast and heat, which are of the same nature for a thermonuclear bomb as for the earlier and smaller atomic bombs. The intensity and area of the blast and heat effects increase in relation to the greater energy yield of the explosion. Much information on these two effects has already been published by the Atomic Energy Commission, but it might be recalled that an atomic bomb of the earliest type, equivalent to 20,000 tons of TNT, would produce blast and heat sufficient to destroy, or damage severely, buildings within a radius of more than one mile from the explosion point. The United States has developed fission bombs many times as powerful as the first atomic bombs, and hydrogen weapons in the ranges of millions of tons (megatons) of TNT equivalent.

PROTECTION AGAINST BLAST AND HEAT

The hazard from both burn and blast effects well *outside* the central target area would be reduced greatly by shelter. Clothing or almost any kind of shelter would reduce the danger of direct burns, although there might be danger of clothing and structures becoming ignited. Also, shelter would materially reduce the hazard of blast injury by affording protection against flying or falling debris. As is generally known, the shelter afforded by ordinary city buildings would not suffice within the central area surrounding the point of explosion of a large nuclear weapon. For this reason, the Federal Civil Defense

Administration recommends evacuation of the central areas of target zones on early warning of approaching attack.

FALLOUT FROM NEVADA TESTS

Only relatively small nuclear test explosions are conducted at the Nevada Test Site, in contrast to the tests of high-yield thermonuclear devices at the Pacific Proving Grounds. In Nevada, as well as in the Pacific, all tests are planned for times when forecast weather conditions minimize the possibility of fallout hazard. High air bursts at the Nevada Test Site have produced no significant fallout; heavy fallout from near-surface explosions has extended only a few miles from the point of burst. The hazard has been successfully confined to the controlled area of the Test Site. The highest actual dose of radiation at an off-site community has been estimated to be *less than one-third of the greatest amount of radiation which atomic energy workers are permitted to receive each year under the Atomic Energy Commission's conservative safety standards.*

CONCLUSION

In the event of war involving the use of atomic weapons, the fallout from large nuclear bombs exploded on or near the surface of the earth would create serious hazard to civilian populations in large areas outside the target zones. The Atomic Energy Commission hopes that these dangers will never be experienced by mankind. However, until the possibility of an atomic attack against us is eliminated by a *workable international plan for general disarmament*, the study and evaluation of the effects of weapons which might be used against us and the improvement of our means of self-defense are a paramount duty of our Government.

A REPORT BY THE UNITED STATES ATOMIC ENERGY COMMISSION ON THE EFFECTS OF HIGH-YIELD NUCLEAR EXPLOSIONS

1. Considerable information on the effects of the explosions of atomic weapons has been made public by the Government since the first nuclear detonations in 1945. The handbook, "The Effects of Atomic Weapons", published in 1950, is being revised and brought up to date to include the effects of thermonuclear weapons, as a result of the most recent tests at the Pacific Proving Grounds. References to the effects of thermonuclear explosions have been made in several official statements, beginning with Chairman Strauss' description of the phenomenon of "fallout" at a White House news conference on March 31, 1954. The following statement is designed to condense and correlate information, some of which already has been made public and other portions of which have been of a classified nature until now.

2. The effects of nuclear tests are evaluated for civil defense planning as well as for military and technological purposes. So long as nuclear weapons are in possession of any unfriendly power, the Commission believes the American public will wish to be as fully informed as possible as to the nature and extent of the dangers of nuclear attack and of the protective measures that can be taken by individuals and communities to avoid or minimize those dangers if we should be attacked.

3. Test conditions, which must necessarily form the principal basis of evaluating the effects of nuclear explosions, may differ markedly from those which might be expected if nuclear weapons were used against our population in wartime. It would be difficult to predict the size or kind of bomb an enemy might use against us in event of war, the exact means of its delivery, the height at which it would be exploded, or the number of bombs which might reach a given target. Nevertheless, the facts to follow are the fundamental ones at this time.

FOUR EFFECTS OF DETONATIONS

4. A nuclear detonation produces four major characteristics—blast, heat, immediate nuclear radiation, and residual radioactivity. Of these, the first three are essentially instantaneous, while the fourth has a more protracted effect. The phenomena of blast, heat, and nuclear radiation from the detonation of a thermonuclear bomb are

FALLOUT FROM NEUTRON TESTS

Only relatively small nuclear test explosions are conducted at the Nevada Test Site in contrast to the tests of high-yield thermonuclear weapons at the Pacific Proving Grounds. In Nevada, as well as in the other areas of the United States, the effects of nuclear tests are being studied in order to determine the nature and extent of fallout from these tests. The highest level of fallout from nuclear tests has been estimated to be less than one-tenth of the average amount of radioactive decay atomic energy weapons are expected to receive each year under the Atomic Energy Commission's comprehensive program of radioactive decay atomic energy weapons.

CONCLUSION

The Commission's comprehensive program of radioactive decay atomic energy weapons is being carried out under the Atomic Energy Commission's comprehensive program of radioactive decay atomic energy weapons. The Commission's comprehensive program of radioactive decay atomic energy weapons is being carried out under the Atomic Energy Commission's comprehensive program of radioactive decay atomic energy weapons.

PROTECTION AGAINST RADIOACTIVE FALLOUT

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of the same nature as those of earlier and smaller atomic bombs. The nature of the phenomena is, in general terms, standardized whether the bomb be a 20,000-ton (TNT equivalent) atomic weapon or a thermonuclear one of many times that power. The intensity and area of the blast, heat, and nuclear radiation increase in relation to the greater energy yield of the explosion. Information on these effects has been extensively publicized; therefore, the remainder of this report deals principally with effects other than heat and blast.

5. Residual radioactivity, although in no sense exclusive to high yield thermonuclear detonations, does become a matter of major concern when a large thermonuclear device of the type used in the 1954 tests in the Pacific is exploded. The fallout of radioactivity from such an explosion, may, under certain conditions, settle over wide areas. Therefore, the extent and severity of this radioactive fallout has been a subject of continuing study since the first full-scale thermonuclear tests at the Pacific Proving Grounds on November 1, 1952. The results of these studies and of our evaluation of data obtained from the latest tests in the Pacific in March, 1954, are described in subsequent parts of this report.

6. It should be noted that if we had not conducted the full-scale thermonuclear tests mentioned above, we would have been in ignorance of the extent of the effects of radioactive fallout and, therefore, we would have been much more vulnerable to the dangers from fallout in the event an enemy should resort to radiological warfare against us.

BLAST AND HEAT EFFECTS

7. The effects of blast and heat from a nuclear explosion are relatively localized. One A-bomb of the earliest type equivalent to 20,000 tons of TNT (20 kilotons) would produce blast sufficient to destroy or damage severely residences within a radius of more than one mile from the point of burst. Within a radius of about a mile and a half, residences would be so damaged as to be unusable without repairs. A principal hazard to human beings would come from flying and falling debris and from fires due to such causes as broken gas and electric lines or overturned stoves. The area in which injuries to human beings would be caused by blast, therefore, would be about the same as the area of damage to structures.

8. The United States, as announced previously, has developed fission bombs many times as powerful as the first A-bombs, and hydrogen weapons in the ranges of millions of tons (megatons) of TNT equivalent. For these larger weapons, the blast effects can be calculated ap-

proximately by means of a scaling law, namely, the distance at which a given blast intensity is produced varies as the cube roots of the yields of the explosions.

9. Similarly, the heat and burn effects of nuclear explosions can be estimated from accumulated data. These effects, of course, are influenced by prevailing atmospheric conditions. The time element also is a prime factor. Very large weapons deliver heat over an appreciably greater period of time than smaller weapons. A given quantity of heat from a high-yield weapon, delivered over a longer period of time, will produce somewhat less severe burns than the same quantity of heat from a nominal detonation.

PROTECTION AGAINST BLAST AND HEAT

10. The hazard from both burn and blast effects in the *outer* affected areas would be reduced greatly by shelter. Clothing or almost any kind of shelter would reduce the danger of direct burns, although there might be some danger of clothing and structures becoming ignited. Also, shelter would materially reduce the hazard of blast injury by affording protection against flying or falling debris. The Federal Civil Defense Administration has made extensive studies of shelters and has issued plans for several simple and inexpensive types which can be utilized by householders. As is generally known, the shelter afforded by ordinary city buildings would not suffice within the central area surrounding the point of burst of a large nuclear weapon. For this reason, the Federal Civil Defense Administration recommends evacuation of the central areas of target zones on early warning of approaching attack.

RADIATION EFFECTS

11. The immediate nuclear radiation, i. e., the neutrons and gamma rays released instantaneously with the explosion of a large weapon on or near the ground, does not present a serious hazard beyond the area where heat and blast are of great concern.

FALLOUT RADIATION

12. However, particles with residual radioactivity produced by a detonation (as opposed to the immediate nuclear radiation) may fall out over an area much larger than that affected by blast and heat, and over a longer period of time. All nuclear detonations produce radioactive materials, but the nature and extent of the radioactive fallout

depends on the conditions under which the bomb is fired. The main radioactivity of a bomb's fallout decreases very rapidly with time—for the most part, within the first hours after the detonation.

FALLOUT FROM IN-THE-AIR DETONATIONS

13. In an in-the-air explosion where the fireball does not touch the earth's surface, the radioactivity produced in the bomb condenses only on solid particles from the bomb casing itself and the dust which happens to be in the air. In the absence of material drawn up from the surface, these substances will condense with the vapors from the bomb and air dust to form only the smallest particles. These minute substances may settle to the surface over a very wide area—probably spreading around the world—over a period of days, or even months. But they descend extremely slowly with the result that, by the time they have reached the earth's surface, the major part of their radioactivity has been dissipated harmlessly in the atmosphere, and the residual contamination is widely dispersed.

FALLOUT FROM SURFACE DETONATIONS

14. If, however, the weapon is detonated on the surface or close enough so that the fireball touches the surface, then large amounts of material will be drawn up into the bomb cloud. Many of the particles thus formed are heavy enough to descend rapidly while still intensely radioactive. The result is a comparatively localized area of extreme radioactive contamination and a much larger area of some hazard. Instead of wafting down slowly over a vast area, the larger and heavier particles fall rapidly before there has been an opportunity for them to decay harmlessly in the atmosphere and before the winds have had an opportunity to scatter them.

15. The area of hazard from radioactive fallout from a surface or near-surface explosion of a thermonuclear weapon is much larger than the areas seriously affected by heat and blast. The large radioactive cloud of a thermonuclear explosion rises with great rapidity to the highest levels of the atmosphere and spreads over hundreds of square miles in the first hours. During this time the winds toss the extremely radioactive particles about and the pattern of the radioactive fallout is determined by the size of the particles and by the direction and velocities of the winds, including those up to 80,000 feet and above. The nature of the surface of the earth on which the bomb is fired also must be taken into consideration. Because of these variables, it is impossible to apply a single fallout pattern to

all thermonuclear detonations, even test explosions conducted under selected conditions. However, with adequate knowledge of atmospheric conditions, including wind directions and velocities up to high levels and meteorological reports, the fallout region for any detonation usually can be predicted with considerable accuracy. In general terms, the region of severe fallout contamination from the detonation of a thermonuclear weapon fired on or near the surface can be described as an elongated, cigar-shaped area extending downwind from the point of burst.

FALLOUT PATTERN OF 1954 TEST IN THE PACIFIC

16. The very large thermonuclear device fired at the Bikini Atoll on March 1, 1954, was exploded on a coral island. Coral consists of calcium carbonate, thus the detonation's radioactivity was spread by particles consisting largely of unslaked lime which, during the hours of descent, was slacked by moisture in the atmosphere. These particles ranged between 1/1000th and 1/50th of an inch in diameter and were, on the average, somewhat adhesive. The prevailing winds were westerly so the bomb cloud moved generally to the east and deposited the radioactive particles in varying amounts over an elliptical or cigar-shaped area. About 160 (statute) miles downwind from the point of burst the early fallout was observed in the form of fine particles which looked like snow. Fallout began there about eight hours after the detonation and continued for several hours.

17. The roentgen is the commonly accepted unit of measurement of radiation dosage. A dose of about 25 roentgens of radioactivity received by a person over a brief space of time will produce temporary changes in the blood. A dose of some 100 roentgens received in a short interval may produce nausea and other symptoms of radiation sickness. About 450 roentgens delivered over a day or so might be fatal to approximately half of the persons so exposed. However, because of the body's repair processes, a total radiation dose which would be serious if incurred in a few minutes would produce much less effect if spread over a period of years. These statements may be helpful in understanding the data which follow.

18. The test explosion, at ground surface, contaminated a cigar-shaped area extending approximately 220 statute miles downwind and varying in width up to 40 miles. In addition, there was a contaminated area upwind and cross-wind extending possibly 20 miles from the point of detonation. Data was collected from 25 points on 5 atolls located from 10 to 330 miles downwind (generally east) from

Bikini Atoll. Due to an unexpected shift in the direction of the prevailing winds in the higher altitudes, the fallout missed the observation rafts that had been placed farther north previous to the test firing. The estimated contour of the pattern of fallout is, therefore, based only in part on data obtained from actual measurements and partly on extrapolation, i. e., calculations based on known data, including factual information obtained during previous tests of smaller devices.

19. Data from this test permits *estimates* of casualties which would have been suffered within this contaminated area if it had been populated. These estimates assume: (1) that the people in the area would ignore even the most elementary precautions; (2) that they would not take shelter but would remain out of doors completely exposed for about 36 hours; and (3) that in consequence they would receive the maximum exposure. Therefore, it will be recognized that the estimates which follow are what might be termed *extreme estimates* since they assume the *worst possible* conditions.

20. On the basis of our data from this and other tests, it is estimated that, following the test explosion on March 1, 1954 there was sufficient radioactivity in a down-wind belt about 140 miles in length and of varying width up to 20 miles to have seriously threatened the lives of nearly all persons in the area who *did not take protective measures*. During the actual tests, of course, there were no people in this zone. Inside Bikini Atoll at a point 10 miles downwind from the explosion it is estimated that the radiation dosage was about 5000 roentgens for the first 36 hour period after the fallout. The highest radiation measurement outside of Bikini Atoll indicated a dosage of 2300 roentgens for the same period. This was in the northwestern part of the Rongelap Atoll, about 100 miles from the point of detonation. Additional measurements in Rongelap Atoll indicated dosages, for the first 36 hour period, of 2000 roentgens at 110 miles, 1000 roentgens at 125 miles, and, farther south, only 150 roentgens at 115 miles from Bikini.

21. Some distance farther from the point of detonation, at about 160 miles down-wind and along the axis of the ellipse, the amount of radioactivity would have seriously threatened the lives of about one-half of the persons in the area who *failed to take protective measures*. It is estimated that the radiation dosage at that point was about 500 roentgens for the first 36 hour period.

22. Near the outer edge of the cigar-shaped area, or approximately 190 miles down-wind, it is estimated that the level of radioactivity would have been sufficient to have seriously threatened the lives of 5 to 10 percent of any persons who might have remained exposed out of doors for the first 36 hours. In this area the radiation dosage is estimated at about 300 roentgens for the first 36 hour period.

23. Thus, about 7,000 square miles of territory down-wind from the point of burst was so contaminated that survival *might* have depended upon prompt evacuation of the area or upon taking shelter and other protective measures.

24. At a distance of 220 miles or more down-wind, it is unlikely that any deaths would have occurred from radioactivity even if persons there had remained exposed up to 48 hours and had taken no safety measures.

25. The estimates cited above do not apply uniformly throughout the contaminated area inasmuch as the intensity of radioactivity within a region of heavy fallout will vary from point to point due to such factors as air currents, rain, snow, and other atmospheric conditions. Because of this and because most persons, if given sufficient warning, probably would evacuate the area or take shelter and other precautionary measures, the actual percentage of deaths could reasonably be presumed to be considerably *smaller* than these extreme estimates.

PROTECTION AGAINST FALLOUT

26. In an area of heavy fallout the greatest radiological hazard is that of exposure to *external* radiation. Simple precautionary measures can greatly reduce the hazard to life. Exposure can be reduced by taking shelter and by utilizing simple decontamination measures until such times as persons can leave the area. Test data indicate that the radiation level, i. e., the rate of exposure, indoors on the first floor of an ordinary frame house in a fallout area would be about one-half the level out of doors. Even greater protection would be afforded by a brick or stone house. Taking shelter in the basement of an average residence would reduce the radiation level to about one-tenth that experienced out of doors. Shelter in an old-fashioned cyclone cellar, with a covering of earth three feet thick, would reduce the radiation level to about 1/5000, or down to a level completely safe, in even the most heavily contaminated area. Designs of shelters of simple yet effective construction have been prepared by the Civil Defense Administration and are available to the public.

27. Radioactive material deposited during fallout may or may not be visible but would be revealed by radiation detection instruments such as Geiger counters. Any falling dust or ash that can be seen down-wind within a few hours after a nuclear explosion should be regarded as radioactive until measured by a radiation detection instrument and found to be harmless.

28. Care should be taken to avoid the use of solid foods or liquids that may contain fallout particles.

29. If fallout particles come into contact with the skin, hair or clothing, prompt decontamination precautions such as have been outlined by the Federal Civil Defense Administration will greatly reduce the danger. These include such simple measures as *thorough bathing of exposed parts of the body and a change of clothing.*

30. If persons in a heavy fallout area heeded warning or notification of an attack and evacuated the area or availed themselves of adequate protective measures, the percentage of fatalities would be greatly reduced even in the zone of heaviest fallout.

FALLOUT FROM NEVADA TESTS

31. Only relatively small nuclear test explosions are conducted at the Nevada Test Site, in contrast to the tests of high-yield thermonuclear devices at the Pacific Proving Grounds. In Nevada, as well as in the Pacific, all tests are planned for times when forecast weather conditions minimize the possibility of fallout hazard. Methods of forecasting weather patterns in these areas are improving steadily. High air bursts at the Nevada Test Site have produced no significant fallout; heavy fallout from near-surface explosions has extended only a few miles from the point of burst. The hazard has been successfully confined to the controlled area of the Test Site. The highest actual dose of radiation at an off-site community has been estimated to be *less than one-third of the greatest amount of radiation which atomic energy workers are permitted to receive each year under the Atomic Energy Commission's conservative safety standards.*

INTERNAL RADIATION EFFECTS

32. Several basic facts should be kept in mind in evaluating the hazard from fallout radiation. First, radiation is not a new phenomenon created by the explosions of fission and thermonuclear weapons. Since the beginning of life, living things have been exposed constantly to radiation from natural sources. Cosmic rays from space constantly pass through our bodies. We are exposed to "background" radiation from radium and radon in the soil, water and air. Our bodies have always contained naturally radioactive potassium and carbon.

33. As pointed out earlier, detonations of all atomic weapons produce radioactivity, a portion of which is carried to high altitudes and over great distances in the form of fine particles. The percentage of this radioactivity which travels beyond the relatively near area of the explosion depends largely on the conditions under which the bomb

is fired, the percentage being higher for in-the-air bursts where the fireball does not touch the earth's surface. The most widespread radioactivity is produced only by the longer-lived fission products, since the radioactivity of the shorter-lived products decays and disappears before the particles come down to earth in a matter of days, weeks, months, and even years. The longer-lived radioactive products may be distributed over the entire earth. However, as the particles are carried farther and farther to remote areas, the possibility of significant amounts of fallout decreases.

RADIOSTRONTIUM FALLOUT

34. One of the most biologically important radioactive substances found in fallout is strontium-90. It has a long lifetime—nearly 30 years on the average. Radiostrontium has a chemical similarity to calcium and, therefore, when taken into the body it has a tendency to collect in the bones. Radiostrontium can enter the body in two ways—by inhaling or by swallowing. Normally, the amount inhaled would be small compared with the amount one might swallow. Fallout material deposited directly on edible parts of plants may be eaten along with the plants, but washing the plants before they are eaten would remove most of this radioactive material. However, rainfall carrying the radiostrontium down to earth may deposit it in the soil where it can be taken up, in part, by plants and incorporated into plant tissues, later to be eaten by humans or by grazing animals which, in turn, provide food for humans.

35. Since the start of nuclear tests, careful measurements have been made of the distribution of radiostrontium over the earth's surface, in the soils, in plants and animal tissues, in the oceans, in rain, in the atmosphere and in all forms in which it might be expected to occur. The results of this study are reassuring. The amount of radiostrontium now present in the soil as a result of all nuclear explosions to date would have to be increased many thousand times before any effect on humans would be noticeable.

RADIOIODINE FALLOUT

36. Among the shorter-lived fission products involved in the study of internal radiation, the most biologically important is radioiodine-131 with an average life of only 11.5 days. Even though this product may be widely spread after a nuclear explosion, the possibility of serious hazard is limited by its relatively short life. Like the non-

radioactive form of the element, it concentrates in the thyroid gland and, in excessive quantity, conceivably could damage the thyroid cells.

37. Scientists of the Atomic Energy Commission have estimated that the average exposure of people in the United States from radioiodine in the fallout from the entire series of tests in the spring of 1954 was only a few percent of the annual dose that can be received year after year and still have no noticeable effects.

38. These two isotopes—radiostrontium and radioiodine—constitute the principal internal hazards from the radioactivities produced by the detonations of atomic weapons, both fission and thermonuclear. The Atomic Energy Commission has been engaged for three years in a broad study of the radioactive forms of these isotopes and conducts year-round monitoring of these radioactivities in many localities. Any accumulation of these materials can be detected with great sensitivity so that ample warning of potential hazard could be given long before any actual danger occurred from test detonations. The amounts of radiostrontium and radioiodine which have fallen outside the areas near the test sites as a result of all atomic tests up to now are insignificant compared to concentrations that would be considered hazardous to health.

GENETIC EFFECTS OF RADIATION

39. One other effect of radiation must be considered in evaluating the long-range possibilities of hazard from nuclear detonations. This is the possible genetic effect upon the germ cells which transmit inherited characteristics from one generation to another. At our present stage of genetic knowledge, there is a rather wide range of admissible opinion on this subject.

40. In general, the total amount of radiation received by residents of the United States from all nuclear detonations to date, *including the Russian and British tests* and all of our own tests in the United States and the Pacific, has been about one-tenth of one roentgen. This is only about 1/100th of the average radiation exposure inevitably received from natural causes by a person during his or her reproductive lifetime. It is about the same as the exposure received from one chest X-ray.

41. The medical and biological advisers of the Atomic Energy Commission believe that the small amount of additional exposure of the general population of the United States from our nuclear weapons testing program will not seriously affect the genetic constitution of human beings. Nevertheless, we are continuing our thorough study of the entire question and will continue to report our findings to the American people.

SUMMARY

42. The Atomic Energy Commission hopes that the information on nuclear weapons effects contained in the foregoing report will never be reflected in human experience as the result of war. However, until the possibility of an atomic attack is eliminated by a workable international plan for general disarmament, the study and evaluation of weapons effects and civil defense protection measures must be a necessary duty of our government.

43. Inevitably, a certain element of risk is involved in the testing of nuclear weapons, just as there is some risk in manufacturing conventional explosives or in transporting inflammable substances such as oil or gasoline on our streets and highways. The degree of risk must be balanced against the great importance of the test programs to the security of the nation and of the free world. However, the degree of hazard can be evaluated with considerable accuracy and test conditions can be controlled to hold it to a minimum. None of the extensive data collected from all tests shows that residual radioactivity is being concentrated in dangerous amounts anywhere in the world outside the testing areas.

44. In the event of war involving the use of atomic weapons, the fallout from large nuclear bombs exploded on or near the surface would create serious hazards to civilian populations in large areas outside the target zones. However, as mentioned in the foregoing Report, there are many simple and highly effective precautionary measures which must be taken by individuals to reduce casualties to a minimum outside the immediate area of complete or near-complete destruction by blast and heat. Many of these protective measures, such as shelter and decontamination procedures, have been detailed by the Federal Civil Defense Administration.

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BY ORDER OF THE SECRETARY OF THE ARMY :

M. B. RIDGWAY,
General, United States Army,
Chief of Staff.

JOHN A. KLEIN,
Major General, United States Army,
The Adjutant General.

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For explanation of abbreviations used, see SR 320-50-1.