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"We are not helpless"

HOW WE CAN DEFEND OURSELVES AGAINST ATOMIC WEAPONS

A series of nontechnical articles reprinted from

The New York Times

Price 10 cents

A note about these articles and the man who wrote them

In August, 1950, the Government published an official guidebook to help in the preparation of civilian defense against atomic attack. This book, "The Effects of Atomic Weapons," is intended as a source of scientific information for technical personnel. Unfortunately, however much he is interested and concerned, the average reader finds it somewhat beyond his depth.

Accordingly, The New York Times, in keeping with its policy of giving readers all the news they have to know, and in terms they can readily understand, assigned William L. Laurence to write a non-technical analysis of the Government's guidebook. This analysis appeared as a series of articles in The New York Times on August 14, 15, 16, 17, 18, 19, 21, and 22. These articles are reprinted in full in this booklet.

William L. Laurence, who wrote these articles, is one of the country's outstanding science reporters, and undoubtedly its foremost newspaper writer on atomic energy. A member of The New York Times staff since 1930, he has twice won the Pulitzer Prize, the highest award in American journalism.

In 1945, the War Department "borrowed" Mr. Laurence for a secret mission. It turned out to be the mission of reporting the birth of the atomic age for all the world, and for history. He was the only reporter to visit the secret war plants and see the production of the atomic bomb. He was the only reporter to witness the first test of the bomb, in New Mexico on July 16, 1945. He was the only reporter to witness the actual use of the bomb, over Nagasaki, on August 9, 1945. The following day, the Japanese sued for peace.

Mr. Laurence, much earlier, had written the first widely circulated newspaper story about the possibilities of atomic energy, in The New York Times of May 5, 1940. His official stories of the development of the atomic bomb were released by the War Department, and were the source from which all news of the atomic bomb and its development was first published to the world.

In 1946, Mr. Laurence published a book, "Dawn Over Zero," which has been acclaimed as the most authoritative and comprehensible account of the development of the atomic bomb.

We Are Not Helpless in Attack

During the five years since the first atomic bomb was exploded over Hiroshima, a frightened world has been led to believe by some of the more articulate atomic scientists that "there is no defense against the atomic bomb" and that "none will ever be devised."

As long as we were the sole possessors of the atomic bomb, with the further assurance that it would take Russia several years to make one, this dictum served largely to generate a sense of security.

The announcement that Russia had tested her first atom bomb at least three years ahead of time, followed by a few months with the Communist attack on South Korea, has changed the picture to the point where many of our people are in danger of succumbing to a sense of helplessness against a potential atomic attack.

The publication by the Defense Department and the Atomic Energy Commission of the most authoritative volume yet to appear on the effects of atomic weapons and the measures that may be taken to counteract, or at least greatly to minimize, their effects, therefore, must be regarded as one of the most important official documents in recent years.

It possibly is more important, in fact, than the hasty publication a few days after Hiroshima of the Smyth Report, which many today believe was a serious mistake that gave Russia much valuable information.

Handbook for Survival

This new volume may properly be given the subtitle "Handbook for Survival Against Atomic Attack," for it gives the basic data essential for the planning and building of an effective civilian defense against potential atomic bomb attacks, whether they come by air or by water.

Unfortunately, the volume has been prepared "as a source of scientific information for technical personnel engaged in civil defense," and as such is not for the average layman. In this, and subsequent articles, the essential data will therefore be presented in non-technical language.

By way of introduction let it be said, first, that there is nothing about atomic energy and atomic weapons that is beyond the grasp of the average layman, and, second, unreasoned fear that might lead to mass hysteria could produce more damage to life and property, and, more important, to spiritual values, than any number of atomic bombs.

In fact, a well-organized civilian defense against a possible atomic attack, added to an efficient military defense, is the best possible deterrent against such an attack.

To understand the fundamental principle underlying the atomic bomb, including also the hydrogen bomb, one must have a general concept of the relationship that exists between what we know as matter and energy, the two aspects in which the material universe manifests itself to our senses.

In his famous relativity theory Albert Einstein demonstrated that matter and energy were two different manifestations of one cosmic entity, that matter was energy in the frozen state, while, conversely, energy was matter in the fluid state, the two states being interchangeable. In a famous mathematical formula he revealed that one gram of matter represented in the frozen state the enormous total of 25,000,000 kilowatt-hours of energy.

From this we learned that whenever energy in any form was liberated, such as, for example, by the burning of coal or oil, a small amount of matter was lost, so small, in fact, that it was not possible to weigh it by any method known to us. We have to burn 3,000 to 7,000 tons of coal to convert the matter of one gram into energy, a ratio of three to seven billion to one.

When energy is obtained by the burning of coal, the atoms of the coal, mostly carbon and hydrogen, remain unchanged, the loss of matter being due to a rearrangement of the electrons on the outside surface of the atom.

In what is known as atomic energy, the energy is obtained by a break up of the atoms used as fuel. When this happens, an amount of matter three to seven million times as great as in the burning of coal is converted into energy. As compared with the amount of matter converted into energy in the explosion of TNT the ratio is 20,000,000 to 1. In other words, the explosion of one kilogram of fissionable material, such as Uranium 235 or plutonium, releases an energy equivalent to 20,000 tons of TNT.

Uranium 235 (U-235) and plutonium are at present the only two substances that can be used for the release of atomic energy, either as an explosive or for power. U-235 is the only one found in nature in sizable quantities. Plutonium is a man-made element, produced from the more abundant form of uranium, known as U-238, in our gigantic plants, known as nuclear reactors, at Hanford, Wash.

U-235 Is the Key

A third fissionable element, known as Uranium 233, can be produced artificially out of the non-fissionable element, thorium, but to do so it is necessary to use either U-235 or plutonium. Uranium 235 is thus the key substance without which no atomic bombs or atomic power could be obtained.

Uranium 235 is found in nature mixed with Uranium 238, each ton of purified uranium metal consisting of 1,986 pounds of U-238 and only fourteen pounds of U-235. To separate the latter required the construction of a billion-dollar plant at Oak Ridge, Tenn.

Plutonium is produced by another method, in which the U-235 in the natural mixed uranium metal is made to split by means of a self-multiplying chain reaction, in which neutrons (fundamental particles without an electric charge) are released. These neutrons enter the Uranium 238 in the mixture and convert it into plutonium.

Just as an ordinary fire needs oxygen to burn, an atomic fire needs neutrons. These neutrons come from the nuclei (cores) of atoms of U-235 or plutonium, each atom split releasing an average of two neutrons, these in turn splitting two atoms which release four neutrons, thus starting a chain reaction. In an atomic bomb these neutrons are released at such an incredible rate that as many as two billion trillion atoms are split in less than one-millionth of a second.

The explosion of an atomic bomb is analogous to spontaneous combustion, the explosion taking place as soon as a minimum amount of fissionable material (either U-235 or plutonium) is assembled in one unit. This minimum amount is known as the critical mass.

Amount a Top Secret

The actual amount is a top secret, but for purposes of illustration let us assume that it is ten kilograms. This would mean that as soon as ten kilograms of either U-235 or plutonium were assembled in one unit, the explosion would take place automatically, the reaction starting with a stray neutron from a cosmic ray coming from outer space. Hence to explode an atomic bomb, the ten kilograms would have to be divided into two parts that were brought together by a timing device after it had been dropped.

The atomic bombs dropped over Japan and tested at Alamogordo, N. M., and at Bikini had a power of 20,000 tons of TNT, which corresponds to the splitting of all the atoms in a kilogram of either U-235 or plutonium.

This does not mean, however, that these bombs contained only one kilogram of the fissionable material, because that would mean an efficiency of 100 per cent, and while the actual efficiency of the bomb is a top secret, the handbook makes it clear that this is less than 100 per cent.

This means that a certain percentage of the atoms remain unsplit after the explosion, going off as part of the great cloud of radioactive vapor that characterized the explosion.

The explosion of an atomic bomb produces several effects, which vary greatly with the manner in which it is exploded.

It is first of all a tremendous blast weapon, concentrating within itself (that is, the "nominal atomic bomb" used over Japan) the blasting power of 2,000 wartime ten-blockbusters. Its temperature after the explosion reaches more than 1,000,000 degrees centigrade, and is thus a tremendous incendiary weapon, setting great fires in buildings and causing severe flash burns in human beings.

Range of Effects

However, and this is very important from the point of view of planning an effective civilian defense, the blast effect and the incendiary effect have an effective range within a rather limited radius from the center of the explosion. So while little can be done for those unfortunates caught in the open within that central area, much can be done to take measures for reducing to a minimum the effects of blast and fire in the region outside this area.

Furthermore, as was the case in Japan, many secondary fires were started in outlying areas by flying debris, from overturned stoves, escaping gas, etc., that efficient planning could eliminate altogether or reduce to a minimum.

Many of those who died from burns that became infected because of lack of first aid can be saved by the training of personnel to give first aid for flash burns. Many others could be saved from burns by training to duck for shelter.

In addition to the blast and incendiary effects the explosion of an atomic bomb gives off large amounts of radiations. The most serious of these are the instantaneous radiations that come off in the form of gamma rays, similar in nature to very powerful X-rays. These last but a very short time, no longer than a flash of lightning, and like lightning kill those they strike. However, these, too, have a rather short effective range, and those who survive it, depending on the dosage they received, may be saved by proper measures.

The second principal form of radiation released in the atomic bomb explosion is that from the fission products, some 200 split fragments of the exploded U-235 or plutonium atoms. If the bomb is exploded some 2,000 feet above the ground, as it was in Japan, and in the air burst (Test "Able") over Bikini, these fragments go up in the great mushroom cloud to some 50,000 feet and are there widely dispersed so that they can cause little harm.

On the other hand, if the bomb is exploded near the ground, as it was in Alamogordo, or under water, as in Test "Baker" at Bikini, these fission fragments may constitute a great hazard for some time.

However, here too we have learned a great deal from the Bikini test as to the nature of the danger and how to avoid it by proper counter-measures.

'Small' Bomb Found Impossible

One of the items that has been causing alarm among the public is the recent talk about "small atomic bombs."

It is known that one kilogram of the explosive material used in the bomb, Uranium 235 (U-235) or plutonium, is equivalent in energy to 20,000 tons of TNT, a ratio of 20,000,000 to 1. So the talk about a "small" atomic bomb is leading to the dangerous impression that such an object or objects weighing a few pounds each, could be easily smuggled into the country and exploded simultaneously in most, if not all, of our important cities.

Nothing can be further from the truth. In the handbook, the American people are given the first official assurance, without any qualifications, that "a 'small' effective atomic bomb cannot be made."

There is a sound technical reason for this. An atomic bomb is exploded with neutrons—atomic bullets released when atoms of U-235 or plutonium are split in a chain reaction in which the neutrons multiply themselves at the incredible rate of two billion trillion in less than a millionth of a second.

Since these neutrons travel with speeds of more than 10,000 miles a second and can penetrate any substance up to a certain thickness, the only way to keep them from escaping to the outside in numbers large enough to stop the chain reaction, which would prevent the explosion, is to have a quantity of explosive (fissionable) material that the neutrons in the interior will be unable to penetrate.

The Critical Size

This quantity is known as the critical mass, or critical size, and puts a definite lower limit below which no atomic explosion can take place.

While the critical size can be diminished to some extent by surrounding the system with a suitable neutron reflector, which reduces the loss of neutrons that escape from the surface, the reduction is not very great.

The inexorable requirement for a minimum amount of material also puts an upper limit on the amount of material that can be used. This is because anything above the critical mass would explode spontaneously.

Let us assume, for purposes of illustration, that the critical mass, the actual amount of which is top secret, is ten kilograms of either U-235 or plutonium. This would mean that anything below this amount would be too small to keep too many neutrons from escaping, so that no explosion could ever take place.

On the other hand, as soon as a quantity totaling ten kilograms is brought together, the neutrons would start multiplying automatically and an explosion would take place in less than a millionth of a second.

Hence, as explained yesterday, to explode an atomic bomb, two pieces, say, of one and nine kilograms, respectively, are made to come together by a timed trigger mechanism after the bomb is released.

Of course, the assembly could consist of two pieces of nine kilograms each, and, theoretically, it should be possible to bring together several such pieces, thus producing a much larger explosion. However, it must be kept in mind that such a large assembly would have to be brought together in less than a millionth of a second, after which the bomb flies apart.

Hence, should two pieces join, while the others lag a fraction of a millionth of a second behind, only the two pieces that came together first would explode while the others would merely go off as hot vapor, without any of their atoms being split.

According to Dr. Louis N. Ridenour, dean of the Graduate College of the University of Illinois, "no amount of ingenuity has yet allowed the design of an efficient fission bomb so much as two or three times critical size."

Now if the atomic bomb consisted only of its explosive material, it would be very small indeed. We know that the so-called "nominal atomic bomb" used on Japan exploded with a power equal to 20,000 tons of TNT, which is the total power of just one kilogram (2.2 pounds) of U-235 or plutonium.

Matter of Timing

Even assuming that the efficiency of the explosion was no more than 1 per cent, the critical mass would be no more than 100 kilograms (220 pounds), while if the efficiency was 10 per cent, the amount of explosive material would be no more than 10 kilograms.

However, to bring about an efficient explosion, in other words, to keep the bomb assembly from flying apart at a stage when the number of atoms split equal only a few blockbusters, and to maintain the assembly long enough until the amount of energy released equals 2,000 blockbusters, very intricate and heavy parts are necessary.

One of these, of course, is a heavy shell, since a light shell would disintegrate too quickly. Another is what is known as a tamper, which must be made of a substance of very high density. Then there are the many intricate devices to bring the assembly together at the instant of the explosion.

All these auxiliary parts of the bomb weigh many times more than the explosive material, so much so that it required the bomb bay of a B-29 to carry it. And the fact that the bomb needs large amounts of material of high density to serve as a tamper and as a reflector of neutrons, together with the other intricate mechanisms to make certain that the explosion is at the highest possible efficiency, makes a "small" atomic bomb than can be successfully hidden and smuggled an absolute impossibility.

Of course, the bombs could be smuggled into a country in ships and exploded in the harbor, but they could be rather easily discovered if proper measures for searching suspicious vessels were instituted.

It must be mentioned in passing that an unexploded atomic bomb does not give off any sizable amounts of radioactivity, to make possible their detection by means of Geiger counters. This makes necessary a thorough search of the suspected ship before it is allowed to dock.

Not a Larger Bomb

To design a more powerful bomb does not mean the building of a bomb larger in size, or one containing a large amount of fissionable material. What it calls for is to improve the efficiency of the explosion.

For example, if our hypothetical critical mass of ten kilograms explodes with an efficiency of 10 per cent we would have a bomb equal in power to 20,000 tons of TNT. If the efficiency of the explosion were improved to 20 per cent we would have a bomb equal to 40,000 tons.

To improve efficiency would thus mean improved auxiliary mechanisms, such as a better tamper that would make possible the maintenance of the bomb's assembly for a few fractions of a millionth of a second longer before it flew apart, thus making possible the splitting of many more atoms.

This is the incredible thing about the explosion of an atomic bomb, the release of such an enormous amount of energy in such an unbelievably short time. It takes less than a millionth of a second to split one gram of fissionable material, equal to only twenty tons of TNT. It takes only about a tenth of a millionth of a second longer to split a kilogram of the fissionable material, equal to 20,000 tons.

By holding it together for another fraction of a millionth of a second, two kilograms, equal to 40,000 tons of TNT, would be split. It is thus an incredible race against time, measured in fractions of millionths of a second.

While the official handbook deals with what may be called the "Model T" bomb of 1945 vintage, it gives scaling laws to extrapolate on the effects of larger bombs. Here it clears up a general misconception that a bomb twice the power will do twice the damage, which is far from true.

Different Scaling Laws

There are different scaling laws that apply to the different effects of an atomic explosion. The blast effect, for example, increases with the cube root of the power, so that a bomb eight times the power of the 1945 model, one equal to 160,000 tons of TNT, would increase its radius of destruction by the cube root of eight.

This means that a bomb releasing 160,000 tons of TNT would produce damage and casualties to about twice the distance from the center of the explosion as would be caused by a 20,000-ton bomb.

Even the hydrogen bomb, which may reach an explosive power as high as 20,000,000 tons of TNT, 1,000 times the 1945 model, would produce damage and casualties over a radius ten times greater, the cube root of a 1,000.

When it comes to the incendiary effect, the increase in the radius of destructiveness goes by the square root of the power, so that you would need to increase the power of a bomb four, instead of eight, times to produce the incendiary effect over a radius twice as great as that of 20,000-ton models.

The official handbook provides the most detailed description yet to appear anywhere of the immediate visible effects of an atomic detonation, in the air and under water. These effects take place at such an incredibly rapid rate that actually no complete observations of all the phenomena have been made, some eluding even the highest speed cameras.

First come the phenomena of an air burst, an explosion at a distance of about 2,000 feet above the earth's surface. The liberation of such a large amount of energy in a very short period within a limited space results in an extremely high energy density, which causes the fission products to be raised to a temperature of more than 1,000,000 degrees centigrade. The maximum temperature in a conventional high explosive bomb is about 5,000 degrees.

Since this material at the instant of the explosion is restricted to the region occupied by the original constituents of the bomb, the pressure is of the order of hundreds of thousands of atmospheres.

Because of the extremely high temperature, there is an emission of energy by electromagnetic radiations, covering a wide range of wave-lengths, from infra red (heat rays) through the visible to the ultraviolet and beyond. Much of this radiation is absorbed by the air immediately surrounding the bomb, with the result that the air itself becomes heated to incandescence.

In this condition the detonated bomb begins to appear, after a few millionths of a second, as a luminous sphere called the Ball of Fire.

As the energy is radiated into a greater region, raising the temperature of the air through which it passes, the Ball of Fire increases in size, but the temperature, pressure and luminosity decrease correspondingly.

After about one ten-thousandth of a second has elapsed, the radius of the Ball of Fire is some forty-five feet, and the temperature is then in the vicinity of 300,000 degrees centigrade.

At this instant, the luminosity, as observed at a distance of 10,000 yards (5.7 miles), is about 100 times that of the sun as seen at the earth's surface.

The Ball of Fire continues to grow rapidly in size for about fifteen milliseconds (thousandths of a second), by which time its radius has increased to about 300 feet. The surface temperature has by then dropped to around 5,000 degrees centigrade, although the interior is very much hotter.

As the Ball of Fire grows a shock wave develops in the air. At first the shock front coincides with the surface of the Ball of Fire, but as the temperature drops below 300,000 degrees the shock wave advances more rapidly. In other words, transfer of energy by the shock wave is faster than by radiation.

The Shock Front

Although the rate of advance of the shock front, which reaches the vicinity of 15,000 feet per second, decreases with time, it continues to move forward more rapidly than the Ball of Fire. After the lapse of one second the Ball of Fire has essentially attained its maximum radius of 450 feet, and the shock front is then some 600 feet further ahead. After ten seconds the Ball of Fire has risen about 1,500 feet, the shock wave has traveled about 12,000 feet and has passed the region of maximum damage.

If the bomb is detonated at a height of less than 450 feet, the Ball of Fire can actually touch the earth's surface, as it did in the historic "Trinity" test at Alamogordo, N. M. Because of its low density the Ball of Fire rises, like a gas balloon, starting at rest and accelerating within a few seconds to its maximum rate of ascent of 300 feet per second.

After about ten seconds from detonation, when the luminosity of the Ball of Fire has almost died and the excess pressure of the shock wave has decreased to virtually harmless proportions, the immediate effects of the bomb may be regarded as over. The emission of gamma rays and neutrons accompanying fission, the most deadly forms of radiations, will also have ceased by this time.

Soon after the detonation a violet-colored glow is observed, particularly at night or in dim daylight, at some distance from the Ball of Fire. This glow may persist for a considerable length of time, distinctly visible in the column of cloud that forms after the Ball of Fire has disappeared. It is believed to be the ultimate result of a complex series of processes initiated by the action of gamma radiation on the nitrogen and oxygen in the air.

How to Recognize Nuclear Blast

There is a sound reason why the official handbook on the effects of atomic weapons, issued by the Department of Defense and the Atomic Energy Commission as a guide in planning and executing effective civilian defense measures against possible attacks by atomic bombs, describes in detail the various spectacular phenomena accompanying an atomic explosion.

Very few people alive have seen an atomic explosion, and to know what it looks like is an essential for the education of large masses of people, so they would know how to behave in an emergency with calm and precision and, above all, without panic.

The phenomena of an atomic explosion are so spectacular, and they take place in such incredibly short time, measured in split seconds, that individuals surprised by the awe-inspiring, dazzling spectacle may lose precious seconds that might mean the difference between life and death.

Knowledge in advance what the phenomena are, will serve to eliminate the element of surprise. In an effective civilian defense, mental preparation is of equal importance with physical means of defense. The unprepared mind is the one most likely to succumb to panic and hysteria, and, when that happens all physical measures are likely to become disorganized.

Distinction of Explosions

It also is necessary for the average person to learn to distinguish between an atomic and an ordinary explosion. To mistake an atomic explosion for an ordinary one would lead to the needless loss of many lives.

On the other hand, the mistaken identification of the explosion of an ordinary TNT bomb, or an incendiary, as an atomic explosion might lead to needless panic on the part of tens of thousands and to great disorganization in the life of a city.

Depending on the height of the burst of the atomic bomb and on the nature of the terrain, high winds will occur in the immediate vicinity of the explosion. These, together with the air blast from the shock wave, will cause various amounts of dirt and other particles from the earth's surface to be sucked up.

At first the rising Ball of Fire carries the particles upward, but after a time they begin to fall under the influence of gravity at various rates dependent on their size. Consequently, an ascending and expanding column of smoke is observed to form. It consists of water droplets, radioactive oxides of the fission products, and more or less debris, largely determined by the height of the explosion.

The Mushroom Cloud

This is the spectacular mushroom-shaped cloud which rose to 40,000 feet at Alamogordo and to 60,000 feet at Nagasaki.

At the beginning its rate of rise is about 200 miles per hour, reaching 10,000 feet in 48 seconds. It reaches 15,000 feet in 1.5 minutes, when its rate of rise has dropped to 50 miles per hour; goes to 20,000 feet in 2.6 minutes, a rate of rise 33 miles per hour; 25,000 feet in 4.6 minutes, rising at the rate of 20 miles per hour, and to 30,000 feet in 8.5 minutes when its rate of rise has dropped to 12 miles per hour.

The height to which an atomic cloud will rise depends on the thermal energy emitted by the bomb, the temperature of the surrounding air, and the density of the air. The greater the energy liberated as heat, the larger will be the buoyancy thrust on the rising cloud, and hence the greater will be the distance it ascends.

It is believed that the maximum height attainable by an atomic cloud will be limited by the height of the base of the stratosphere.

If the radioactive cloud should pass through a temperature inversion layer, a layer at which the temperature begins to increase again after it had been falling with increasing altitude in the atmosphere, it will tend to "mushroom" to a small extent.

Because the air in the inversion layer is fairly stagnant, some of the particles in the cloud will tend to spread out horizontally instead of continuing to move vertically. Nevertheless, as a result of the enormous heat energy of the hot gas bubble, most of the cloud will usually pass through an inversion layer.

Upon attaining a region where the density of the gas bubble is the same as that of the surrounding air, or upon reaching the base of the stratosphere, at about 40,000 to 60,000 feet, where the temperature of the atmosphere is almost constant and there is practically no motion to convection, the radioactive column will spread out for a distance of several miles and form the characteristic mushroom-shaped cloud.

Having reached the final stage of its development, the cloud remains visible for an hour or more, until it is dispersed by the winds into the surrounding atmosphere.

When the radioactive, metallic oxide particles in the cloud collide with the particles of dirt, which are in general considerably larger, they adhere. Consequently, the dirt particles in the cloud become contaminated with radioactivity. When the violence of the disturbance from the bomb has subsided, the contaminated dirt particles gradually fall back to earth, giving rise to the phenomenon known as the "fall-out."

The extent and nature of the "fall-out" will be determined by the combination of circumstances associated with the height of the explosion, with the nature of the surface beneath, and with the meteorological conditions. If the height of the bomb burst exceeds a certain value, it is possible that there would be no detectable fall-out, since no extraneous particles would be sucked into the cloud.

The importance of the "fall-out," the handbook points out, lies in its radioactivity. Only in exceptional circumstances would the intensity of the activity be great enough to constitute a hazard upon reaching the ground.

The evidence from the Hiroshima and Nagasaki explosions, where the height of the burst was about 2,000 feet, is that casualties ascribable to the radioactive "fall-out" were completely absent.

Hazard of Fall-Out

However, the handbook adds, if the bomb burst occurred relatively close to the ground, a situation that would be uneconomical from the standpoint of the destructive effect, and considerable amounts of dirt and other debris were sucked into the radioactive cloud, the fall-out would have to be considered as a danger.

The fall-out, consisting mostly of water drops, would also be important if the detonation took place at a low level above the surface of the water; and the presence of salt in the water would enhance the hazard.

There was at one time considerable speculation about the possible effects on the weather of an atomic burst, especially one over water, some forecasting violent weather reactions. Actually no such effects have been observed.

The handbook declares that a careful examination of all the available evidence would lead to the conclusion that an atomic bomb burst has a negligible effect on the weather. It would appear that the atom bomb could not be used as a rainmaker.

So far, only one underwater atomic burst, the Bikini "Baker" test, has been reported. The burst was made well below the surface of the lagoon, which was about 200 feet deep. From the results of this test many of the effects of a deep underwater burst can be inferred. Although there are certain characteristic effects, the details would vary with the depth and area of the water and the distance below the surface at which detonation occurred.

The Underwater Blast

In the underwater detonation a Ball of Fire is formed as in an air burst. As the writer can testify from personal observation, the water in the vicinity of the explosion on "Baker Day" was lighted by a luminosity that could have come only from the intense visible spectrum of the Ball of Fire.

The general effect had the appearance of light seen through a ground-glass screen, the distortion from the waves on the surface of the lagoon preventing any clear view of the ball. The luminosity remained for a few thousandths of a second, but it disappeared as soon as the bubble of hot gases constituting the Ball of Fire reached the surface, for then the gases were expelled and cooled.

In the course of its rapid expansion the gas bubble, which now contains steam and its dissociation products, atomic hydrogen and oxygen, in addition to the fission residue, initiates a shock wave.

The trace of this wave, as it moves outward from the burst, is evident, on a reasonably calm surface, as a rapidly advancing ring, apparently darker than the surrounding water.

This ring, sometimes called the "slick," is visible in contrast to the undisturbed water because the ripples or small waves are partially calmed by the reflection of the shock wave as a rarefaction (suction) wave at the surface of the water.

The part of the shock that passes into air through the water surface causes the compression of the moist air. When this is followed by a suction wave, the conditions become favorable to the formation of a spherical cloud of vapor, known as the cloud-chamber effect.

This manifested itself almost immediately after the Bikini underwater burst in a dome-shaped cloud that formed over the lagoon. This great dome, set in the midst of the ring from the shock, looked like a gigantic white derby hat with a huge garland ringing the top of its crown.

After the appearance of the ring, or slick, a mound or column of broken water and spray, called the spray dome, is thrown up directly over the point of the burst by the reflection of the blast wave at the surface. The initial velocity of the water is proportional to the pressure of the incident shock wave, and so it is greatest directly over the explosion.

Consequently, water thrown up over the center rises more rapidly and for a longer time than water farther away. As a result the sides of spray dome become steeper as the water rises. Its upward motion is terminated by the effects of gravity and the resistance of the air.

Phenomenon of Plume

The total time of rise and maximum height attained depend on the energy of the explosion and on its depth below the surface. For a very deep burst the spray dome may not be visible at all.

If the depth of the detonation of the bomb is not too great the bubble of hot gases will remain essentially intact until it rises to the surface of the water. At this point the gases, in the form of a jet, carrying some water by lateral entrainment, will be vented to the atmosphere.

As the pressure of the bubble is released water rushes into the cavity, and the consequent complex phenomena cause the water to be thrown up as a hollow cylinder, or chimney of spray, known as the Plume. The radioactive contents of the gas bubble are vented through this hollow Plume and form a gigantic mushroom-shaped cloud at the top.

The Plume and its mushroom top are without doubt among the most spectacular and awe-inspiring phenomena to be seen. It was like watching the birth of a new continent rising resplendent out of the sea.

A photograph of the Plume, taken with a super-speed camera, shows a small black smudge on its right edge. It was the 33,000-ton battleship Arkansas, lifted out of the water, suspended vertically in the air for a split second before it plunged to the bottom of the lagoon. A second photograph, taken less than a millisecond later, shows no trace of the Arkansas.

Like a Cauliflower

In the shallow underwater burst at Bikini, the conical spray dome began to form at about four milliseconds (thousandths of a second) after the explosion. Its initial rate of rise was some 2,500 feet per second, but this was rapidly diminished by air resistance.

A few milliseconds later, the hot gas bubble reached the surface of the lagoon and the Plume began to form, rapidly overtaking the spray dome at a height of a few thousand feet.

The maximum height attained by the hollow Plume, through which the gases vented, could not be estimated exactly because the upper part was surrounded by cloud. It was probably some 8,000 feet, and the greatest diameter was about 2,000 feet. It is now estimated that the maximum thickness of the walls of the Plume was about 300 feet, and that about a million tons of water rose in the Plume.

Earlier estimates by scientists on the scene, made soon after the burst, placed the quantity of water raised in the Plume at ten to fifteen million tons.

The cloud, which concealed a large part of the upper portion of the Plume, resembled a cauliflower, rather than a mushroom, in shape. It contained some of the fission products and other bomb constituents, as well as water droplets. In addition, there is evidence that material sucked up from the bottom of the lagoon was also present, for calcarous sediment, which must have been part of the fall-out, was found on the decks of ships some distance from the burst.

The Base Surge

As the column of water and spray constituting the Plume fell back into the lagoon, there developed, on the surface at the base of the column, a gigantic wave of mist about 1,000 feet in height, completely surrounding the neck of the Plume.

This wave began to form within ten seconds of detonation, and traveled rapidly outward, maintaining an ever-expanding doughnut-shaped form. The wave or wall of dense mist, much like the spray of the base of Niagara Falls or another waterfall of considerable height, represents the initiation of what is known as the base surge. It is, in effect, a dense cloud of liquid droplets which has the property of flowing almost as if it were a homogeneous fluid.

As the base surge at Bikini traveled outward at high speed, it gradually lifted from the surface of the lagoon and, after about five minutes, assumed the appearance of a mass of strato-cumulus cloud, which eventually reached a thickness of some thousands of feet.

A moderate to heavy rainfall, moving with the wind and lasting for nearly an hour after the explosion, developed from this cloud mass. In its early stages the rain was augmented by the small water droplets, equivalent in a sense to the fall-out of an air burst, still descending from the cloud.

All Debris Radioactive

Were it not for the fact that base surge is highly radioactive, because of the presence of fission products, it would represent merely a curious phenomenon. Because of its radioactivity, however, which is augmented by that of the water droplets in the fall-out, it may represent a serious hazard for a distance of several miles, especially in the downwind direction.

There are reasons for believing that the base surge can be produced only in fairly deep water. In the event of a sufficiently deep underwater atomic burst, the hot gas bubble would lose its identity in a mass of turbulent water before it reached the surface and vented to the atmosphere. In this case, the spray dome would be relatively insignificant and no Plume would be formed. Hence there would be no formation of a base-surge and no appreciable fall-out.

The disintegration of the gas bubble into a large number of very small bubbles, which are churned up with the water, would produce a radioactive foam or froth. When this reached the surface, a small amount of radioactive mist would be emitted, but most of the activity would be retained in the sea water. The deposition of the highly active foam on a near-by shore might, however, represent a hazard.

It seems possible, the handbook adds, that a base surge, made up of small solid particles, rather than droplets of water, but still behaving like a fluid, might result from an atomic bomb burst below a soft terrain consisting of sand and mud. The debris would, of course, be very radioactive.

Extent and Degree of Nuclear Desolation Are Depicted

The shock wave produced by an air-burst atomic bomb is, from the point of view of weapon delivery and disruptive effect, the most important agent in producing destruction.

This implies that the other characteristics of an atomic bomb that can be employed in warfare, such as heat and visible radiations, neutrons, gamma rays, and fission products, are at present not serious competitors in the production of damage by a bomb that is burst in the air.

There are, of course, other applications, such as the possible use of an atomic weapon as an instrument of radiological warfare by exploding it in a conveniently located body of water, to produce a base surge (described yesterday), or in restricting the escape of fission products by means of a subterranean explosion. The bomb might also be employed to produce earth or water shock through a subsurface explosion.

Such uses, although potent, must, because of the restrictive conditions placed on the delivery problem and the target location and configuration, be regarded as special applications of the varied destructive characteristics of the bomb.

There is an important difference between the effects of an atomic bomb blast and those of a conventional high-explosive bomb.

The Mass Distortion

The great power of the former results in a destruction feature called mass distortion of buildings. An ordinary explosion usually will damage only part of a large structure, but the atomic blast can engulf and flatten whole buildings.

Further, because the shock wave of an atomic explosion is of relatively long duration, of the order of a second as compared with a few milliseconds for a conventional bomb, most structural failures occur during a small part of the positive phase while the pressure is essentially constant.

An examination of the areas in Japan affected by atomic bombing shows that small masonry buildings were engulfed by the oncoming pressure wave and collapsed completely. Light buildings and residences were totally demolished by blast and fire. Manufacturing buildings of steel construction were denuded of roofing and siding, and only the twisted frames remained.

Nearly everything above ground at close range, except reinforced-concrete smoke stacks, was destroyed. Some buildings leaned away from ground zero, the center of damage, as if struck by a hurricane of stupendous proportions. Telephone poles were snapped off to ground level, carrying the wires down with them, and gas containers ruptured and collapsed.

Heat, Fire and Blast

Many buildings that at a distance appeared sound were found on close inspection to be damaged and ruined by fire. Telephone poles were charred and granite surfaces were etched by heat and by sand blasting from the high winds carrying abrasive material.

There were many evidences of the effect of radiant heat in starting fires and in scorching and drying out materials that were not highly combustible. All vehicles at close range were damaged by blast and burned out. Most important, water pressure was lost by the breaking of pipes, mainly as a result of the collapse of buildings, thus greatly increasing the additional destruction by fire.

Certain structures in Japan were designed to be earthquake-resistant, which probably made them stronger than their counterparts in the United States, while other construction undoubtedly was lighter than that in this country.

However, contrary to popular conceptions about the flimsy characteristics of the Japanese residence, it is the considered opinion of a group of highly qualified architects and engineers who surveyed the atomic bomb damage that the resistance to blast of American residences in general would not be markedly different from those in Hiroshima and Nagasaki.

Some Conclusions

From the observations made in Japan it is possible to draw some conclusions about the blast damage to be expected at various distances from ground zero for an air burst of a "nominal atomic bomb," equal to 20,000 tons of TNT. On the assumption that the height of the burst is such as to inflict maximum damage, the various types of damage and the radii within which they may be expected to occur, will be as follows:

1. Virtually complete destruction will occur to a radius of about one-half mile from ground zero, corresponding to an area of destruction of about three-quarters of a square mile.
2. Severe damage, defined as major structural damage that would result in collapse or liability to collapse of the building, will occur to a radial distance slightly in excess of one mile from ground zero. This corresponds to an area of four square miles in which the damage ranges from severe to destructive.
3. Moderate damage short of major structural damage but sufficient to render the structure unusable until repaired, will occur to radius of about 1⅝ miles, giving an area of eight square miles in which the damage ranges from moderate to destructive.
4. Partial damage will be inflicted to a radius of about two miles, adding four square miles of damage area, and making a total of twelve square miles subject to some degree of damage and window destruction.
5. Light damage, which is mostly plaster damage and window breakage, may extend to a radius of eight miles or more, giving a light damage area of 200 square miles. Actually these distances, at which window and light plaster damage will be inflicted, vary appreciably with the meteorological conditions at the time of the detonation and may be considerably greater under conditions that provide a temperature inversion in the lower atmosphere.

In the Report of the British Mission to Japan on "The Effects of the Atomic Bombs at Hiroshima and Nagasaki," it was estimated that in a British city such as London the Nagasaki bomb would have (1) caused complete collapse of normal houses to a distance of 3,000 feet from ground zero; (2) damaged beyond repair out to 5,280 feet; (3) rendered uninhabitable without extensive repair out to 7,920 feet, and (4) rendered uninhabitable without minor repairs out too 13,200 feet.

In Nagasaki there were many steel buildings used for manufacturing. Construction was generally comparable to that in the United States. The first effect of blast was to strip off the siding and roof material, which consisted of corrugated sheet metal or asbestos cement. Since this did not occur instantaneously, a large impulsive force was applied to the frame. Severe damage occurred up to a distance of 6,000 feet.

There were several types of failure of such structures. Close to the explosion the buildings were pushed over, and at greater distances they were in many cases left leaning away from the source of the blast. The long and slender columns offered little resistance to the lateral force.

Sometimes columns failed by a combination of lateral force, causing flexure, at the same time that an increased downward load came from the vertical component of blast on the roof. This caused buckling and collapse. Roof trusses were buckled by compression resulting from blast on the exposed side of the building.

The Public Utilities

In Nagasaki the public utility system was comparable to that in an American city of 30,000 population except that open sewers were used. Damage to the water supply essential for fire fighting was of the greatest significance. This was not caused by failure of the underground mains, but by loss of pressure through breakage of pipes in houses and buildings.

Earth surface depressions up to one foot in depth were observed at scattered points in a filled-in area at a maximum distance of 2,000 feet from ground zero.

This caused a series of failures of 12-inch cast-iron water pipes three feet below grade, the breakage probably caused by an unequal vertical displacement. There was no serious damage to reservoirs and water-treatment plants because they were at too great a distance.

Utility poles were destroyed by blast or fire, and overhead utilities were heavily damaged at distances up to 10,000 feet. Underground electrical conduits were little affected. Switch gear and transformers were not damaged directly by blast but by secondary effects, such as collapse of the structure in which they were, or by debris. Motors and generators were damaged by fire.

Gas containers were heavily damaged by blast at 6,600 feet and the escaping gas was ignited, but there was no explosion. Gas mains suffered no observable damage. Street railway equipment was heavily damaged by fire and blast.

Buses and automobiles were, in general, also damaged by blast and were burned out at shorter distances. As an example, an American made car was heavily damaged and burned at 3,000 feet, while one at 6,000 feet suffered only minor damage.

Damage to Caves

Caves were used to a large extent for shelter, although there were many timber, semi-buried shelters with an earth cover of about eighteen inches. These were not particularly well built, yet in some cases they survived at a distance of 900 feet, and none was damaged beyond half a mile.

Bridges made of wood were burned in most cases, but the steel-girder bridges suffered little damage. One bridge, only 260 feet from ground zero, which was a girder type and had a reinforced concrete deck, showed no sign of any structural damage. It had apparently deflected and rebounded, causing a slight movement.

Other bridges at greater distances suffered more lateral shifting. A reinforced-concrete deck was lifted from the supporting steel girders of one bridge, presumably because of the reflected blast wave from the water below.

While the destructive effects observed in Japan are comparable in general to those to be expected in the United States, there are some differences. There is also the question of damage to the large bridges of many American cities for which there is no direct guide from damage to the small bridges in Japan.

The multi-story buildings in this country are generally designed to withstand a wind load of fifteen pounds per square foot. For an average six-story, reinforced concrete, frame building this would be roughly equivalent to 2 per cent of the vertical load.

On this basis, American reinforced-concrete buildings would be much less resistant to collapse than those designed for earthquake resistance in Japan. However, no firm conclusions can be drawn on this subject, because most American buildings have lateral strength far more than that required to withstand a fifteen pounds per square foot wind load.

Requirements in West

In the eleven Western States of this country, the building codes provide for the design of structures to resist horizontal, earthquake forces varying from 2 to 16 per cent of the vertical load, which is usually taken as dead load plus half the vertical design live load. There are three earthquake zones, the Pacific Coast area having the highest requirements.

The design specifications, as stipulated in the building codes, are similar to those for wind loads, with a 33 per cent increase in the allowable working stresses. These buildings would be proportionately more resistant as the ratio of the horizontal to the vertical load increased.

The effect on steel-frame buildings, such as multiple storied office and hospital structures, should be about the same as that on reinforced concrete buildings, except that steel has a somewhat greater energy absorption capacity than reinforced concrete.

This is because of the fact that, with usual design stresses, the work necessary to produce failure in steel is greater in proportion than in reinforced concrete. Consequently, tall buildings with heavy steel frames, constructed so as to provide good continuity at connections, and a long period of vibration, should withstand the effect of blast quite well.

American steel industrial buildings would probably fare no better than those in Japan, according to expert opinion. The sawtooth roofs designed as rigid frames would be especially vulnerable to blast damage.

Tests made on typical housing of wood-frame construction with conventional bombs up to 500 pounds and at various distances indicate a high degree of resistance against blast beyond thirty feet.

While no direct interpretation of these results can be made with regard to the blast from a large explosion, which would have quite different characteristics, it is believed that the radius of material structural blast damage would not exceed 7,500 feet. This is slightly less than that in Nagasaki where the severe damage to houses extended to 8,500 feet.

Air Bursts Over Water

From the data obtained in the Bikini "Able" air burst, it may be concluded that the general nature of the damage to houses and other buildings and installations on shore by air burst over water would be much the same as air burst over land.

Destruction of ships and their contents would be almost entirely from the shock wave in air. From the results observed at Bikini, it appears that, up to about 2,500 to 3,000 feet of horizontal distance from the explosion, vessels of all types would suffer serious damage or would be sunk. Moderate damage would be inflicted out to 4,000 feet, and minor damage would be expected to occur within a radius of 6,000 feet.

Because of the shock wave transmitted through the air, exposed structures, such as masts, spars, radar antennae, etc., would be expected to suffer damage. This would be severe up to 3,000 or 3,500 feet from the explosion.

With the same radius, vehicles and airplanes on the ships, and other light structures and electronic equipment would be seriously damaged. Boilers would be expected to suffer heavy damage up to 2,700 feet, moderate damage to 4,000 feet and light damage to nearly 5,000 feet. This would account for most cases of immobilization.

The damage to be expected from an underground detonation appears to be less than from an air burst. It has been estimated that a bomb dropped from the air, which penetrated to a depth of forty to fifty feet below the surface before exploding, would cause blast damage over radii of about one-half to two-thirds of the radii for corresponding damage due to an air burst.

However, the reflection of the shock wave from rock strata, at depths of less than 200 to 300 feet beneath the point of detonation, would probably result in an appreciable increase in the area of damage.

If a nominal atomic bomb were dropped in such a manner as to explode at a depth of about fifty feet in ordinary soil, a crater of about 800 feet in diameter and 100 feet in depth would be produced. Tests indicate distributions of appreciable quantities of crater material to a radius of one mile downwind and 0.2 mile upwind. The material expelled from the crater would be highly radioactive, because of the presence of trapped fission products and of material activated by neutrons.

The major portion of the shock from a shallow underwater explosion is propagated through the water. The sinking range of all types of surface vessels would be in the neighborhood of 1,200 to 1,800 feet, from surface zero, center of damage on the surface, for burst of a nominal atomic bomb. Some ships would probably be sunk out to 2,700 feet, but others in this range would suffer considerable structural damage.

Serious loss of efficiency is to be anticipated within a radius of 3,600 feet from surface zero. Even at this distance the peak pressure of the underwater shock wave would be over 500 pounds per square inch. Submerged submarines would probably be lost out to 2,700 feet from the explosion.

A not inconsiderable amount of the shock from a shallow underwater explosion is transmitted as a shock wave in the air. The data obtained at Bikini indicate that the energy of the air shock for a nominal atomic bomb is roughly equivalent to 4,000 tons of TNT. Such a shock would, of course, be capable of producing extensive destruction.

The data indicate that a shallow underwater atomic bomb burst within something like half a mile from shore would cause serious damage to harbor facilities and to warehouses and other structures near the water. Partial damage would extend to somewhat over one mile. Light damage, mainly cracking of plaster and window breakage, would occur for a distance up to four miles.

This means that if the bomb were detonated under water more than one mile from shore, the structural damage on land would not be serious.

At one mile from surface zero at Bikini, the maximum height of the wave formed in the water, from trough to crest, was about twenty feet. Even at a distance of two miles, the wave height reached a maximum of ten feet. The water at Bikini was moderately deep, so that for an explosion in shallow water the waves at the same distance would be twice as high. Such waves breaking over the shore could do serious harm to port facilities and warehouses.

The general type of damage ensuing from a deep underwater burst would approximate those following from a shallow one, since the effects would be from the shock wave transmitted through the water. Shock damage to machinery in ships, resulting in immobilization, would extend to 4,500 feet.

Apart from damage caused by waves, it is believed that, with the possible exception of piers and breakwaters, little harm would result to harbor and shore installations as a consequence of a deep underwater explosion of an atomic bomb.

Damage From an Atomic Bomb

Following is a table of the air-blast damage of an atomic bomb as charted from the explosion at Hiroshima and Nagasaki:

0 Feet ("Ground Zero,' Center of Damage)

Air burst of an atomic bomb.

1,000 Feet

Decks of steel plate girder bridge shift laterally.

2,000 Feet

Limit of severe structural damage to earthquake-resistant reinforced concrete buildings.

Reinforced concrete buildings collapse, 10-inch walls, 6-inch floors.

Mass distortion of heavy steel frame buildings.

Loss of roofs and panels.

3,000 Feet

Virtually complete destruction of all buildings, other than reinforced concrete aseismic design.

4,000 Feet

Reinforced concrete smoke stack with 8-inch walls overturned.

Roof tiles bubbled (melted by heat).

Eighteen-inch brick walls completely destroyed.

5,000 Feet

Twelve-inch brick walls severely cracked.

Steel frame building destroyed (mass destruction of frame).

Light concrete buildings collapse.

6,000 Feet

Severe damage to entire area.

Severe structural damage to steel frame building.

Nine-inch brick walls moderately cracked.

Electrical installations and trolley cars destroyed.

Multi-story brick buildings completely destroyed.

7,000 Feet

Structural damage to multi-story brick buildings.

8,000 Feet

Severe damage to homes, heavy damage to window frames and doors, foliage scorched by radiant heat.

9,000 Feet

Heavy plaster damage.

Moderate damage to area.

10,000 Feet

Blast damage to majority of homes.

Severe fire damage expected.

Flash ignition of dry combustible materials.

11,000 Feet

Flash charring of telegraph poles.

Roof and wall covering on steel frame building damaged.

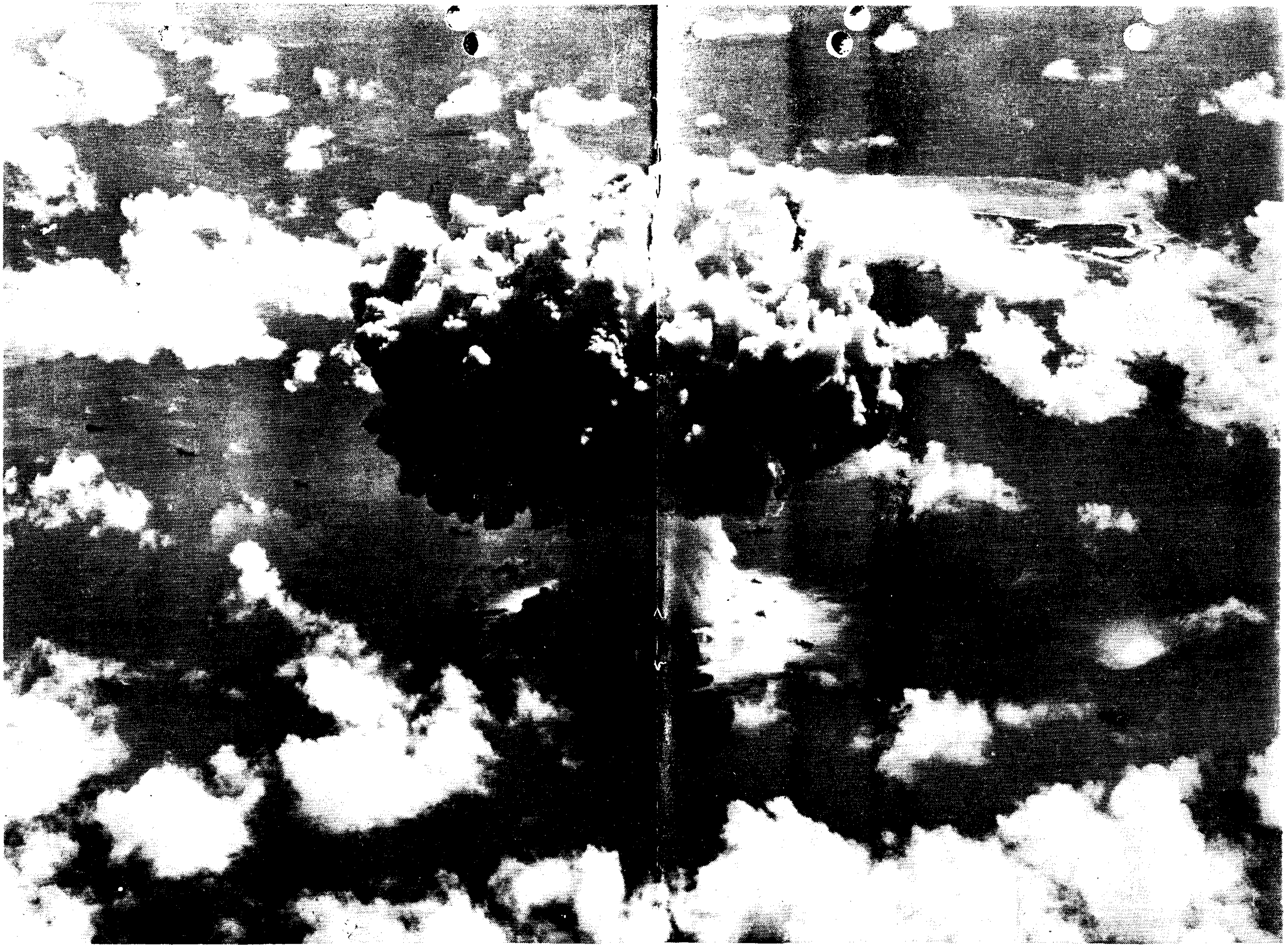
Partial damage to structures in area.

12,000 Feet

Light damage to window frames and doors, moderate plaster damage, complete window damage.

8 Miles

Limit of light damage.



Underwater explosion of atomic bomb at Bikini on July 25, 1946, lifts gigantic "mushroom" of water and steam 5,500 feet, more than a mile, above the test fleet.

Nuclear Blast Triple Threat

The explosion of an atomic bomb produces three major effects, which make it three major weapons in one.

It devastates by blast, by heat and by radioactivity. It has been estimated that the blast wave, in an air burst, is responsible for 50 to 60 per cent of the deaths; the heat-flash for 20 to 30 per cent, and radioactivity for 15 to 20 per cent.

An important difference between an atomic and a conventional explosion is that the energy liberated per unit mass is much greater in the atomic blast. As a consequence, the temperature attained is much higher, with the result that a larger proportion of the energy is emitted as thermal radiation (heat) at the time of the explosion.

An atomic bomb, for example, releases roughly one third of its total energy in the form of this radiation. For the nominal atomic bomb, equal to 20,000 tons of TNT, the energy emitted in this manner would be about 6.7 trillion calories, which is equivalent to about 8,000,000 kilowatt hours.

It is evident that such an enormous amount of radiant energy would produce considerable damage to living organisms and to combustible materials.

When the radiation falls on matter, part may be reflected, part will be absorbed, and the remainder, if any, will pass through, ultimately to fall on other portions of matter. It is the radiation absorbed that is important for the present purpose.

The extent of this absorption depends on the nature of matter and also upon its color. A black material will absorb a much larger proportion of the thermal radiation falling upon it than will the same material when colored white. Most of the absorbed thermal radiation is converted directly into heat.

Some High Temperatures

It has been estimated that in the atomic explosions in Japan, which took place some 2,000 feet above the ground, the temperature at ground zero, from thermal radiation, was probably between 3,000 and 4,000 degrees Centigrade, 5,400 to 7,200 degrees Fahrenheit. It is true that the temperature fell off rapidly with increasing distance from the burst, but the effects were definitely noticeable as far as two miles away or more.

An important point in connection with the thermal radiation from an atomic bomb is not only the amount of energy in this radiation, but also the fact that nearly the whole of it is emitted in an extremely short time, about three seconds from the initiation of the explosion. In other words, the intensity of the radiation, which is a measure of the rate at which it reaches a particular surface, is very high.

Because of this high intensity, the heat accompanying the absorption of thermal radiation is produced rapidly, most of it on the surface of the body upon which it falls. Since only a small proportion of the heat is dissipated by conduction during the short interval, high surface temperatures are attained.

A set of data have led to the conclusion that exposure to thermal radiation from a nominal atomic bomb, on a fairly clear day, would lead to more or less serious skin burns within a radius of 10,000 feet from ground zero. This is in general agreement with the experiences in Japan.

However, in spite of its great range, protection from thermal radiation is easily achieved. The rays travel in straight lines, and so only direct exposure, in the open or through windows, would lead to harmful consequences. Shelter behind almost any object, such as anywhere in the interior of a house, away from windows, of course, or behind a tree, or even protection of one part of the body by another so as to avoid direct exposure to the atomic Ball of Fire, would be effective.

Only fairly close to ground zero would the thermal radiation be expected to penetrate clothing, and so parts of the body covered in this way are generally safe from thermal radiation burns.

The "Flash-Burns"

One of the striking facts connected with the atomic bombing of Japan was the large number of casualties attributed to what have been called "flash-burns," caused by the instantaneous thermal radiation. It has been estimated that 20 to 30 per cent of fatal casualties at Hiroshima and Nagasaki were from such burns, as distinct from those who suffered the more familiar flame burns.

Thermal radiation burns were recorded at a distance of 7,500 feet from ground zero at Hiroshima and as far as 13,000 feet at Nagasaki. The incidence of these burns, as might have been expected, was inversely related to the distance from the explosion.

A very distinctive feature of the thermal radiation burns was their sharp limitation to exposed areas of the skin facing the center of the explosion. They were consequently sometimes referred to as "profile burns." This is because of the fact mentioned above that radiation travels in straight lines and so only regions directly exposed to it will be affected.

A striking illustration of this behavior was that of a man writing before a window. His hands were seriously burned, but his face and neck, which were not covered, suffered only slight burns because the angle of entry of the radiation was such as to place them in partial shadow.

Although thermal radiation burns were largely confined to exposed parts of the body, there were a few cases in which such burns occurred through one, and very occasionally more, layers of clothing. Instances of this kind were observed only near the center of the explosion.

Where burns did occur through clothing, these tended to involve regions where the clothes were tightly drawn over the skin, at the elbows or shoulders, for example, while areas where the clothing fitted loosely were unharmed.

Case of the Kimono

Because white or light colors reflected the thermal radiations, they generally afforded better protection than dark clothing. Thus it was not unusual to find burns through black clothing, but not through white material worn by the same individual.

This was strikingly shown in the case of a woman clad in a kimono at the time of the explosion. Her back and arms were badly burned in a pattern corresponding to the dark portions of the kimono, while the skin under the light portions was unaffected.

Studies on the part played by the ultra-violet range of the thermal radiations have led to the conclusion that the ultra-violet radiations from an atomic bomb do not make the major contribution to skin injuries. This means, therefore, that the infra-red radiation is the main factor in causing the flash-burns.

This is a subject of more than mere scientific interest. If it is the infra-red that is the most important, then there is the possibility that a person caught in the open by the explosion of an atomic bomb might have sufficient time to take cover, or other appropriate evasive action, thus reducing the thermal radiation damage.

This would be possible because most of the infra-red radiation is emitted by the Ball of Fire in its later stages, following the second temperature maximum, 7,000 degrees Centigrade; that is to say, from about 0.3 to three seconds after the explosion.

Thus, if protection could be found within one second of the explosion, the exposure to infra-red radiation would be very roughly one-third of the total amount received at that distance. Under many circumstances this difference would be very significant.

Blast Kills Fire

At distances close enough to the explosion to cause actual ignition of wood, etc., the blast wind, coming within a few seconds, generally would be strong enough to blow out the flame.

For this reason it would appear that relatively few of the numerous fires, which developed almost instantaneously after the atomic bombings of Japan out to distances of 4,000 to 5,000 feet from ground zero, that is, almost to the limit of severe blast damage, were directly caused by thermal radiations from the bombs.

It is probable that most of the fires originated from secondary causes, such as upsetting of charcoal or wood stoves, which were common in Japanese homes; electrical short circuits; broken gas lines, and so on, which were a direct effect of the blast wave. In several cases, fires in industrial plants were started by the overturning of furnaces and boilers, and by the collapse of buildings upon them.

It is true that fire-fighting services and equipment were poor by American standards, but it is doubtful if much could have been achieved, under the circumstances, by more efficient fire departments. At Hiroshima, for example, 70 per cent of the fire-fighting equipment was crushed in the collapse of firehouses, and 80 per cent of the personnel were unable to respond. Even if men and machines had survived the blast, many fires would have been inaccessible because of the streets being blocked with debris.

Another contributory factor to the destruction by fire was the failure of the water supply in both Hiroshima and Nagasaki. The pumping stations were not largely affected, but serious damage was sustained by distributing pipes and mains. Most of the lines above ground were broken by collapsing buildings and by heat from the fires that melted the pipes.

The Fire Storm

About twenty minutes after the detonation of the atomic bomb at Hiroshima there developed the phenomenon known as fire storm. This consisted of a wind that blew toward the burning area of the city from all directions, reaching a maximum velocity of 30 to 40 miles per hour, two to three hours after the explosion, decreasing to light or moderate and variable in direction about six hours later.

It should be noted, however, that the fire storm was by no means a special characteristic of the atomic bomb. Similar fire storms have been reported as accompanying large conflagrations in the United States, and especially after incendiary bomb attacks in both Germany and Japan during World War II.

The nigh winds are produced largely by the updraft of the heated air over an extensive burning area. They are thus the equivalent, on a very large scale, of the draft that sucks air up a chimney under which a fire is burning.

In addition to the flash-burns, many of the casualties from the atomic bomb explosions were caused by flame burns. In buildings collapsed by the blast, many persons who might otherwise have survived their injuries were trapped and burned. The burns suffered were of the kind that might accompany any fire and were not especially characteristic of an atomic explosion.

Burns of both types, flash and flame, were believed to be responsible for more than half of the fatal casualties and probably at least three quarters of all the casualties at Hiroshima and Nagasaki.

The magnitude of the problem, therefore, points to the necessity for making adequate preparations for dealing with large numbers of burned patients in the event of an emergency. This means the training of great numbers in giving the most rudimentary first aid for burns, because a sufficient number of doctors and nurses could not be provided.

The explosion of an atomic bomb is accompanied by the emission of nuclear radiations, consisting of gamma rays, similar in nature to X-rays, neutrons, beta particles (electrons) and a small proportion of alpha particles (nuclei

of helium atoms). Radiations emitted within a minute of the detonation are referred to as initial nuclear radiations. Those emitted after more than a minute are known as residual.

The initial radiations of importance to us are the gamma rays and the neutrons Both have considerable penetrating power, so that they can reach the earth even when liberated at appreciable distances away. Both can produce harmful effects on living organisms.

The energy of the gamma rays present in the instantaneous, or prompt nuclear radiation is about 3 per cent of the total energy liberated by the bomb, but only a small proportion of this, perhaps 1 per cent, succeeds in penetrating any great distance from the bomb. A somewhat similar amount is present in the gamma rays emitted by the fission products in the first minute after an atomic explosion.

Nevertheless, in spite of the energy being considerably smaller than that appearing in the form of thermal radiation, the gamma radiation can cause an appreciable proportion of the atomic bomb casualties. On the other hand, nuclear radiations do not have any incendiary effect.

Shielding from gamma rays or neutrons is not the simple matter of shielding against thermal radiation. For example, at a distance of 3,000 feet from the explosion of a nominal atomic bomb, the initial nuclear radiation would probably prove fatal to 50 per cent of human beings, even if protected by twelve inches of concrete.

However, beyond about 7,000 feet the nuclear radiations would be virtually harmless, without protective shielding, whereas exposure to thermal radiation at this distance could produce serious skin burns.

Radiation Dosage

Radiation dosage is measured in terms of a unit called the roentgen, or the r. It is usually accepted that a dose of 400 r of radiation over the whole body in the course of a few minutes represents the median lethal dose that would be fatal to about 50 per cent of human beings. The median lethal range of the gamma radiation from a nominal atomic bomb is about 4,200 feet.

Thus a large proportion of human beings exposed to the initial gamma rays within 4,200 feet of an atomic explosion would die from radiation sickness. If part of the body were protected by a suitable shield, it is probable that a larger dose than 400 r would not prove fatal. Ordinary clothing can in no sense be regarded as protective.

At less than 2,100 feet from the explosion, physical and thermal destruction are so serious in unprotected regions that radiological injury does not need consideration. At distances greater than 9,000 feet, the dosage is, in general, too small to be of serious consequences, unless it is repeated at short intervals.

At the minimum distance of 2,100 feet from the explosion, the dosage of gamma rays in an unprotected location would be 10,000 r. To reduce this to below the median lethal dose of 400 r would require something like twenty inches of concrete or about three inches of lead. A layer of some thirty inches of soil would be equally effective. Underground shelters could thus provide adequate protection agianst the radiation hazard.

Outside Shelters

An outside shelter of the type used in World War II as a protection against blast bombs, covered with about twenty inches of packed soil, would decrease the radiation dosage below the median lethal value at distances greater than about 3,000 feet from the explosion. For a height of burst of 2,000 feet, this would represent 2,250 feet or more from ground zero. The thickness of concrete that would produce the same effect is roughly twelve inches, that of iron four inches, and that of lead about two inches.

The statement that an unprotected person within 4,200 feet of an atomic explosion would receive a median lethal dose of 400 r is based on the supposition that the exposure lasts for the whole minute of the period of initial radiation. It has been determined that at this distance about a half of the gamma ray dosage is received during the first second.

Taking shelter quickly behind a convenient building or in a slit trench, an act that is conceivable within a second of seeing the bomb flash, might thus mean the difference between life and death to a human being at a point where the unprotected dosage would be near the median lethal value.

If the energy release of the bomb were doubled from 20 to 40 kiloton TNT equivalent, the median lethal range, at which the dosage is 400 r, would be increased from 4,200 feet to 4,750 feet. This means that the lethal area of the initial gamma radiation would be much less than double.

Consequently, the thickness of shielding necessary to attenuate the radiation to less than the lethal value at any point would not have to be increased greatly. For a forty kiloton TNT equivalent bomb the dosage at 2,100 feet would be 20,000 r and about twenty-five inches of concrete would reduce it to 400 r, the median lethal dose. This may be compared with twenty inches required at the same distance for the nominal twenty kiloton TNT energy equivalent bomb.

Effect of Neutrons

The neutrons emitted in the fission process carry about 3 per cent of the energy of the atomic explosion. Of this amount, perhaps less than 1 per cent appears outside because of the loss of energy to the components of the exploding bomb. Like the gamma rays neutrons can penetrate considerable distances through air, and since they are a physiological hazard, they are a significant aspect of an atomic explosion.

More than 99 per cent of the total number of neutrons accompanying the fission of Uranium 235 or plutonium are released almost immediately, probably within one hundred-millionth second of the explosion. These are referred to as the prompt neutrons. In addition, somewhat less than 1 per cent, called the delayed neutrons, are emitted subsequently. The latter are actually expelled from some of the fission products.

It is estimated that the lethal range of neutrons from a nominal atomic bomb would be 1,800 feet for fast and slow neutrons, while for neutrons of intermediate energy the distance would probably be increased to 2,400 feet. In other words, neutrons from an atomic bomb would be lethal to unshielded persons at distances not greater than half a mile from ground zero.

All the neutrons from the bomb would reach a point 2,000 feet distant within less than a second. It would appear, therefore, that most of the neutrons reaching the earth would do so within such a short period of time after the explosion that evasive action would not be possible.

Increasing the energy of the bomb by two would lead to an increase of less than 400 feet in the lethal distance of the neutrons.

In general, concrete may represent a fair compromise for neutron shielding. However, unless used in considerable thickness, the main function of concrete is to slow down the fast neutrons and so make them less of a biological hazard. Better results would be obtained by using a modified concete made by adding a considerable proportion of iron (oxide) ore, such as limonite or magnetite, to the cement. Small pieces of iron, such as steel punchings, may also be incorporated.

World-Wide Ruin by Contamination Held Doubtful

The nuclear radiations emitted after one minute from the instant of an atomic explosion, namely the residual radiations, arise mainly from the fission products. To a lesser extent they also come from the uranium 235 or plutonium atoms that had escaped fission, and, in certain circumstances, from activity induced by neutrons in various elements present in the earth and in the sea.

Any of the radioactive material reaching the inhabited surface of the earth in appreciable amounts may represent a serious physiological hazard. In addition, there is the possibility, which, although not highly probable, must nevertheless not be ignored, that radioactive material might be used deliberately, apart from an atomic explosion, for the purpose of making certain areas uninhabitable.

The problem of dosage emitted in a very short period of time, namely, the "one-shot" dose, described yesterday, is quite different from that arising in the case of the residual nuclear radiations which might persist for days, weeks or months. A human being receiving a total of 400 r (roentgen units of radiation) of the initial nuclear radiation, that is, over a period of a minute or so, would have a 50 per cent chance of survival, but, if the same amount of radiation was absorbed over a period of a month, the probability of death would be considerably less.

Human Tolerance Doses Set

The United States Committee on X-rays and Radium Protection concluded in 1936 that the maximum human tolerance dose of X-rays or nuclear radiation, which could be taken up on successive days was 0.1 r per day over the whole body. In other words, it was thought that the whole body could absorb up to 0.1 of radiation per working day for long periods without permanent harm.

This rate of absorption was accepted as the tolerance dose or permissible dose of nuclear radiation. However, in order to insure an adequate factor of safety for personnel exposed to radiations every working day for many years the accepted permissible dose rate in the United States has now been reduced to 0.3 r per week.

Among X-ray technicians regularly exposed to radiations analogous to gamma rays there is no authenticated case of injury where the exposure has been kept down to 0.1 r per day over extended periods.

It should be understood that this safe dose applies to absorption over the whole body and for repeated and protracted exposures over long periods of time. Small areas can be exposed to very much larger quantities of radiation with no more than local injury being experienced. In addition, there is a difference between acute, that is, brief and occasional, exposure and the chronic exposure to which the tolerance limit applies.

Thus, a dose of 5,000 r can be used to treat a small skin cancer, leaving a scar but no other permanent effect. Even the whole body may absorb 50 r in one day without any apparent harm. Somewhat larger single doses may have unpleasant consequences, but will not prove fatal unless repeated on successive days.

Fission Brings Sixty Fragments

The fission of uranium 235 or plutonium (they very seldom split in equal parts) results in the formation of at least sixty atomic fragments, representing isotopes (twins) of probably thirty-four different elements. All of these are radioactive, decaying by the emission of electrons, accompanied by one or more gamma rays.

It has been calculated that at one minute after the detonation of a 20-kiloton TNT equivalent atomic bomb, when the residual nuclear radiation begins, the fission products will be emitting gamma radiation at the enormous rate of 934.5 kilowatt-hours of energy per second. Even after an hour, the rate of emission of gamma radiation will be nearly 7.12 kilowatt-hours per second, so that, although the gamma activity has decreased by a factor of about 130, it is still extremely large.

A widely used method of expressing rates at which radioactive atoms decay is in terms of a unit called the curie, named after the discoverers of radium. A curie is defined as a quantity of radioactive material undergoing 37 billion disintegrations per second, which is equal to the rate of disintegration of one gram (1/28th ounce) of pure radium. A megacurie is a million curies, corresponding to disintegrations at the rate of 37 quadrillion atoms per second, namely, that of 1,000 kilograms (2,200 pounds) of radium.

The gamma activity of the fission products one minute after the explosion of the nominal 20-kiloton TNT equivalent atomic bomb, is equal to the gamma radiation emitted by 1,804,000,000 pounds (902,000 tons) of radium. This, as we have seen, is at rate of 934.5 kilowatt-hours of energy per second. After one hour the gamma radiation from the fission products equals those that would be given off by 13,200,000 pounds (6,600 tons) of radium, an energy equal of 7.12 kilowatt-hours per second.

Active After Ten Years

After one day it equals 292,600 pounds of radium; 28,600 pounds after a week, 5,060 pounds after a month, and less than four ounces after a year. Even after ten years the gamma activity of the fission products will still equal the gamma energy given off by eight grams of radium, while after the lapse of 100 years the gamma activity will be the equal of 600 milligrams of radium. This is an energy corresponding to about 67 billionths of a kilowatt-hour.

The total energy of the electrons (beta particles) produced in the fission process is similar in magnitude to that of the gamma radiation. However, because the electrons do not penetrate to such great distances as do the gamma rays, the energy of the former would, as a general rule, be of significance only in borderline cases.

Data show that a person who has remained in a region in which the dosage rate after one hour from the explosion is one r per hour, will have received a total of 23.8 r of residual radiation within two hours from the explosion, and 24.9 r after three hours from the detonation.

Neutrons from an atomic explosion which reach the earth's surface may interact with elements there and make them radioactive. Radioactivity induced by the neutrons may persist for some time, contributing to the residual radiation activity. As the neutron's intensity at the earth's surface decreases rapidly with increasing distance from the bomb, the induced activity would probably be significant only for relatively low air burst, and then at distances not too great from ground zero. Underwater and underground explosions present special problems.

Third Source of Radiation

A third possible source of residual nuclear radiation is the uranium 235 or plutonium which may have escaped fission. Their radioactivity, measured in curies, is very small compared with that of the fission products.

For a contamination of one megacurie per square mile due to fission products, the dosage rate at about three feet above the ground, calculations show, is approximately 4 r per hour, which is equivalent to about 100 r per day. An activity of one megacurie per square mile would be attained if at the end of one day these products were spread uniformly over 133 square miles. In a normal air burst only a portion of the fission products would have descended by the end of one day, and the area covered would probably be greater than 133 square miles.

It is of interest to note that even under normal circumstances long before X-rays or atomic bombs were even dreamed of, all living organisms were continually being exposed to radiations. This "background radiation" is due partly to the high energy particles, known as cosmic rays, originating in outer space, and partly to radium and its disintegration products which are present in the earth and in the air. In addition, it is not generally realized that the human body contains not insignificant amounts of radioisotopes of carbon and potassium. These radioactive species are also present in plants and in the soil

Absorption of Average Human

It has been estimated that at sea level a human being absorbs, from all the aforementioned background sources, something like 0.003 r of radiation per week throughout his life. This is about one-hundredth part of the accepted tolerance dose believed to be harmless. At high altitudes, where the intensity of the cosmic rays is increased three-fold at 15,000 feet, the total background radiation is appreciably higher.

It appears that during the average lifetime every individual receives from 10 to 15 r or more of radiation over the whole body, in addition to amounts that may be absorbed as a result of X-ray or similar treatment. The same state of affairs has undoubtedly persisted during the whole period of man's existence on earth, although the total radiation absorbed in a lifetime has increased as the average lifespan has lengthened.

Fears have been expressed in some quarters concerning the danger of world-wide contamination by radioactivity resulting from atomic explosions. That such fears are groundless can be shown by estimating the number of bombs which would have to be detonated to produce enough activity to cover the earth. Such calculations may be made for external gamma radiation from the fission products, on the one hand, and for the internal hazard due to plutonium which has escaped fission.

If the whole surface of the earth is to be contaminated, with a minimum number of bombs, they would have to be exploded within a very short period of time. Further, since contamination from fission products would be due essentially to the fall-out, sufficient time must be allowed for all the particles to settle out. On the basis of these postulates, it has been calculated that in order to constitute a world-wide hazard something like a million atomic bombs, of the nominal size, would have to be detonated, roughly one to each 200 square miles of the earth's surface.

Estimates on Plutonium

An estimate of the possibility of world-wide contamination by plutonium is more difficult, because of the uncertainty concerning the proportion which escapes fission. In order to take the extreme case it is supposed that the whole of the plutonium originally present in the bomb is uniformly distributed in the top centimeter of soil. This plutonium may then be presumed to be absorbed by plants and thus find its way into the human body in the form of food. Inhalation of dust represents another possibility. It appears from the calculations that for plutonium to constitute a world-wide hazard millions of atomic bombs would have to be exploded.

World-wide radioactive contamination would thus appear to be extremely unlikely, but local contamination due to a relatively small number of bombs might be a serious problem over a large area. The fact that the fall-out may be so widely dispersed means that radioactive particles will descend hundreds and even thousands of miles from the point of detonation. Although they may not necessarily do any physiological harm, the particles may cause trouble. An illustration is the case of radioactive dust from the test explosion at Alamogordo appearing in strawboard manufactured over a thousand miles away and spoiling sensitive photographic film wrapped in this material.

When an atomic bomb is detonated at a high altitude, as it was in Japan, so as to cause maximum blast damage to a city, the hazard due to radioactivity on the ground after the explosion is small.

Tests at Low Altitudes

Atomic bombs were exploded experimentally at low altitudes at Alamogordo and Eniwetok. Radioactive contamination of the ground was many times greater than for the high altitude bursts, due to the fact that the Ball of Fire touched the earth's surface. The radioactivity near the center of the explosion resulted partly from condensation of fission products upon contact with the ground, and partly from radioactivity induced by neutrons.

The approximate radiation dosage rates, in roentgens per hour, measured on the ground at Alamogordo one hour after the detonation had taken place at a height of 100 feet was 8,000 r at ground zero, 5,000 r at a distance of 300 feet from ground zero, 600 r at 600 feet, 150 r at 900 feet, 30 r at 1,200, 10 r at 1,500 feet, 5 at 2,250, 0.3 r at 3,000 and 0.07 at 3,750 feet.

It can thus be seen that near the explosion center an area subjected to a low altitude airburst, small compared with the damage area due to the bomb, would be uninhabitable because of the radiation hazard. Nevertheless, calculations show that a vehicle traveling at a moderately high speed could cross the contaminated ground about 15 minutes after the explosion without the occupants being greatly harmed.

It would probably be six hours or more before it would be safe to walk across the area; but to stay for any length of time would, of course, be out of the question, unless proper shielding were available. The great amount of radioactive dust remaining in the air after a low-altitude explosion would require special precautions to prevent entry of the active material into the system. Masks such as used in chemical warfare protection are suitable for this purpose.

The disturbance of large quantities of earth and other material in the formation of a crater, which accompanies an air burst at low altitude, results in the deposition of contaminated debris at some distance away. In addition, much of the dust is carried aloft into the atomic cloud, but it eventually settles to the earth as the fall-out, after picking up fission product particles, to contaminate areas much further from the center of the explosion.

After the Alamogordo test, for example, high concentrations of radioactivity were detected on the ground several miles north and east of the site of the explosion. The integrated dose was, however, not dangerous to human life.

Dust's Effects on Animals

A number of cattle, about ten to fifteen miles from the Alamogordo explosion, were inadvertently exposed to the radioactive dust from the fall-out. In the course of a few weeks, loss of hair and blisterlike lesions were apparent. The latter soon healed, however, and the hair, originally red, grew again, although it was white or gray.

Continued observation of the animals has shown that the cows have produced normal calves, irrespective of whether they were mated with bulls which had, or had not, been exposed to the radioactive dust. By the end of 1949 there was no evidence of any effects of the radiation, other than the graying of the hair.

Of various types of atomic explosion the underwater burst at Bikini produced by far the greatest degree of radioactive contamination. It is estimated that almost all of the fission-product activity either remained in the water immediately following the detonation, or fell back into the lagoon in the form of the radioactive base surge and rain. The total dosage due to the base surge and contamination from the underwater burst ranged from 8,000 r down to a 100 r to a distance of about four and one-half miles.

There is the possibility that after an underwater burst of an atomic bomb, the radioactivity might be spread over a large area due to the action of marine life. It is well known that land plants absorb and so concentrate mineral elements from the soil, and that these are further concentrated in animals feeding on the plants. Similar circumstances arise in water environments; the simple plants, i.e., plankton and algae, absorb the nutritive salts from the water, and they are then accumulated in the large aquatic forms, namely, fish, which directly or indirectly consume the simple plants.

Radioactivity In Water

In water containing radioactive materials, the latter are concentrated by the fish in the same manner and for the same length of time as are the stable forms of the corresponding elements. If the fish die, the radioactive istopes are not lost, but they return to the water, as do the stable isotopes, to take part once again in the life cycle.

Because of the landlocked nature of the Bikini lagoon there is evidently little or no outward migration of the larger aquatic organisms, so that there is no appreciable tendency for the radioactivity to spread. However, due to the behavior of the anadromous migratory fishes, namely, salmon, shad, etc., which feed in the sea and then migrate upstream to die, or of birds that concentrate the minerals of the sea in guano, there might be some distribution of radioactivity in other cases following an underwater atomic explosion. The extent of such dispersion and its effect would depend greatly on circumstances and appears difficult to estimate.

The possibility must also be considered of an underwater explosion so near to the shore that significant amounts of the fall-out and the base surge will reach the adjacent land areas, and possibly affect dock facilities, warehouses, etc.

The general consensus at the present time is that the size of an area highly contaminated by an underground explosion would be less than in the case of an underwater burst. One reason is that the density of the soil is greater than that of water and so a smaller mass would be thrown into the air to descend at a distance from the explosion. However, although the area covered may be less, the radiation intensity may be correspondingly greater at small distances from the bomb burst.

How Radiological War Works

The possibility exists of contaminating persons, objects or areas with radioactive materials not produced in an atomic explosion.

This deliberate use of radioactive isotopes as an offensive military weapon is known as radiological warfare. The materials to be used can be either fission products, obtained in a nuclear reactor, or artificially made radioactive isotopes, produced from stable elements by exposing them to neutron bombardment. Such warfare would present many difficulties, both in the production of the materials and in delivering them to the target. Perhaps its most important application would be its psychological effect as a mystery weapon.

If gamma ray emitters were to be used as radiological warfare agents, and these seem to be the only ones likely to be effective, the problem would arise of shielding personnel from the radiations during manufacture, storage and delivery of the weapon. The use of adequate shields, presumably of concrete, iron or lead, would add greatly to the weight of the munition and would complicate the mechanism of dissemination on the target. The uniform distribution of a relatively small amount of material over a large area would itself present a difficult problem, the solution of which might nullify the advantage of compactness.

While it is impossible to predict, as in the case of chemical warfare, whether radiological warfare will be used or not, it is necessary to understand and be prepared for it.

Only in the event of being unprepared are the consequences likely to be as serious as the destruction caused by an atomic bomb.

How Decontamination Works

Radioactive contamination, as explained earlier, may come from four sources. It may be caused by the fission products formed in the explosion of an atomic bomb; by activity induced from neutrons in soil and water, and by the deliberate use of radioactive materials in radiological warfare as a particularly vicious form of poison gas attack. There also is the possibility that plutonium that has escaped fission may act as a contaminant representing an internal hazard.

There are essentially three ways whereby the hazard associated with radioactive contamination may be minimized:

1. Disposing completely of the material by deep burial in the ground or at sea.
2. Keeping it at a distance for a sufficient time to permit the radioactivity to decay to a reasonably safe level.
3. Attempting to remove the contaminant, that is, to decontaminate the material.

These three procedures were used in radioactive contamination suffered by ships and their equipment in the Bikini underwater ("Baker") test.

At Bikini, the Independence, a small aircraft carrier, received such a large radiation dosage that, had there been any one on the hangar deck at the time, he would have died from external radiation, apart from the effects of the blast.

Yet two weeks after the detonation, the dosage rate was about three r (radiation dosage units) per day, permitting short-time access. About a year later, the average dosage rate was only 0.3 r per day. Three years after the original contamination, the Independence was in use at the San Francisco Naval Shipyard, where she housed the experimental engineering group of the Naval Radiological Defense Laboratory.

It was difficult at that time to find any areas on the ship in which the radiation dosage would have exceeded the limit of 0.3 r per week adopted at the installations of the Atomic Energy Commission.

Vessels Are Reclaimed

No decontamination of the Independence was attempted because the vessel was in a battered condition, and it seemed unlikely that she could be returned to service as an aircraft carrier. However, some of the other vessels at Bikini were decontaminated and reclaimed much sooner.

Two submarines thus decontaminated were used soon afterward in the Naval Reserve with no risk to the operating personnel. Most of the other target vessels were destroyed, not because decontamination was not feasible, but mainly because they were damaged in other ways and decontamination would not have been economical.

Except where radioactive solutions, such as were present after the underwater burst at Bikini, soak into porous materials, such as rope, textiles, unpainted or unvarnished wood, etc., or where neutrons have penetrated and induced radioactivity to some depth, the decontamination will be largely restricted to the surfaces of materials, objects and structures. An outstanding exception would, of course, be the radioactive contamination of water supplies for drinking purposes.

The problem of decontamination is thus, to a considerable degree, a problem of removing sufficient of the surface material to reduce the activity to the extent that it is no longer a hazard. The methods of surface removal may be divided into two main categories, chemical and physical.

In the first case, the contamination is eliminated by making use of chemical reagents which, if sufficiently mild, will have a minor effect on the underlying material. In the second case, an appreciable thickness of the actual surface is removed.

Use of Detergents

It should be understood that the activity of a particular radioisotope is not changed in any way by chemical reaction. All that chemistry can do is to convert the active isotope into a soluble compound, so that it can be detached and washed off as a solution. Certain processes of decontamination, involving the use of detergents, represent a category intermediate between the chemical and physical.

The actual process of decontaminating material and equipment can be resolved into two stages: first, immediate emergency measures, to permit continued operation; and second, final more thorough decontamination operations.

Although the degree of decontamination achieved by the initial treatment may not be large, it at least reduces the physiological hazard to an extent that will make possible, probably with changing personnel, an operation that otherwise would have been impractical. A more complete decontamination can then be carried out, if necessary or desirable, at a later time.

The decontamination of personnel who have come into contact with radioactive material is, of course, a primary requirement. Normally clothing will prevent access of the material to the skin. When contaminated, clothing should be removed and disposed of, by burial, for example, in such a manner as to prevent the spread of the radioactivity into uncontaminated areas, like the interiors of buildings.

A fair degree of decontamination of the exposed skin can be achieved by vigorous rubbing with soap and water, paying particular attention to the hair, nails, skin folds and areas surrounding body openings, with due care to avoid abrasion. Certain synthetic detergents, of which many are now on the market, soapless household cleansers, have been found to be especially effective.

In the event of serious radioactive contamination of a large part of a city, steps would have to be taken to make the locality habitable within a reasonable time. Most important would appear to be removal or coverage of loose material that might form dust that would be inhaled or ingested with food.

For paved streets, flushing, perhaps with the aid of detergents, street cleaning or vacuum sweeping, if feasible, might be the first steps.

Concrete, stone and brick buildings, if the contaminant is on the surface, or has not penetrated too deeply, perhaps would have to be wet-sandblasted and reroofed. Stucco buildings might have to be removed. The same would well apply to roofs, which would collect considerable amounts of radioactive material, but could not be easily decontaminated.

Properly covered foods should undergo little or no contamination. The same would be true for

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Bomb Results Compared

Following is a comparison of the effects of atomic and conventional bombs. The Tokyo attack was the huge fire raid of March 9, 1945. *Final column covers other bombings.*

	Hiroshima	Nagasaki	Tokyo	93 Attacks
	Weapon			
	Atomic Bomb	Atomic Bomb	1,667 Tons TNT, Incendiary	1,129 Tons TNT, Incendiary
Population per square mile	35,000	65.000	130.000	....
Square miles destroyed	4.7	1.8	15.8	1.8
Killed and Missing	70,000	36.000	83,000	1,850
Injured	70.000	40.000	102,000	1.830
Mortality per square mile destroyed	15.000	20,000	5,200	1,000
Casualties per square mile destroyed	30,000	42.000	11,800	2,000

canned goods or any materials in impervious, dustproof wrappings. There appears to be no feasible means of salvaging unprotected food, either in the home, the store, or in the fields.

In surface waters, radioactive contaminants will tend to be adsorbed by the suspended and colloidal matter that invariably is present. In urban water systems, radioactive material that has escaped adsorption in a reservoir itself may be picked up by the surface of the distribution system.

When, in addition, the purification process includes coagulation, sedimentation and filtration stages, it is expected that very little radioactive material would normally reach the consumer.

Wells and Reservoirs

Underground sources of water are generally safe from contamination. So are moderately deep wells, even under contaminated ground, provided surface drainage of contaminated material is prevented.

If a reservoir or river is seriously contaminated, and the water is not subjected to coagulation or filtration, the water might be unfit for consumption for several days. However, because of dilution and natural decay of radioactivity, the degree of contamination will decrease with time.

In some cities water is taken directly from a river and merely chlorinated before being supplied for domestic consumption. If no alternative source of water is available in case of emergency, consideration should be given to the provision of positive and negative ion exchange columns or beds (purifying agencies) to be used if the regular supply should become contaminated.

Home water softeners might serve the same purpose. In hospitals and on ships sufficient water for emergency purposes could be obtained by distillation. It was found at Bikini, for example, that contaminated water, when distilled, was perfectly safe for drinking.

It should be emphasized, however, that mere boiling of water contaminated with radioactivity is of no value.

The ideal defense against radioactive contamination is the use, wherever possible, of surfaces that either are resistant to such contamination or from which the active material can be readily removed.

It has been found, for example, that surfaces coated with certain plastic paints are relatively easily decontaminated. At the present time it appears that well-maintained paint or other sealer is the only means of protecting structural material, such as concrete, brick and soft woods, against radioactive contamination. This should be borne in mind especially in new construction near bodies of water where an underwater explosion is possible.

Another possibility is to use coatings that can be easily removed and replaced with new ones.

Where these procedures are not possible, vital equipment may be kept under cover by means of tarpaulins or other movable protection.

Personal Injuries Vary

The types of injuries suffered by personnel in an atomic explosion will vary with the manner in which the bomb is used. In a high air burst, such as at Hiroshima and Nagasaki, most of the casualties will be from burns and blast effects.

There will be a small proportion of radiation injuries resulting from exposure to the initial nuclear radiations, emitted within the first minute after the burst, but the effect of contamination by the residual radiations, emitted after the first minute, will be negligible.

An explosion at low altitude or at ground level would produce somewhat fewer casualties from blast or burns, but a small area would be highly contaminated with radioactive material. If proper precautions are taken, the casualities from this residual radiation should be a very small fraction of the total.

After a shallow underwater burst, the number of casualties from blast and burns also will be diminished. However, some casualties might arise from exposure to radiation from fission products and, to a lesser extent, material that has escaped fission, spread over an appreciable area by the base-surge and the fall-out.

During the first two months or more the primary danger would be from the gamma rays, in particular, and the beta particles (electrons) from fission products. Subsequently, the ingestion of plutonium might in exceptional circumstances become a hazard. In the event of serious contamination of this kind, it would be necessary to evacuate the population from the affected areas until they could be adequately decontaminated.

Injuries by blast are of two kinds, direct and indirect. Direct blast injuries result from the positive pressure phase of the shock wave acting on the body to cause injury of the lungs, stomach, intestines and eardrums, and internal hemorrhage. Such injuries occurred in World War II after large-scale air raids with conventional high explosive bombs.

At Hiroshima and Nagasaki, however, the direct blast effect was not a significant primary cause of fatality, because those near enough to the explosion to suffer injury in this manner were burned or crushed to death. A pressure of about thirty-five pounds per square inch or more is required to cause direct harm to a human being. The peak pressure of the shock wave from a nominal atomic bomb would attain such values only at distances of 1,000 feet or less from ground zero, assuming a height of burst at 2,000 feet.

More important than the primary blast injuries in the Japanese bombings were the indirect or secondary effects from collapsing buildings, and from timber and other debris flying about in the blast wave. Persons were injured by flying objects, crushed or buried under buildings, and thrown against fixed structures. Glass fragments penetrated up to an inch beneath the skin, and the light summer clothing worn at the time offered little protection. Unless proper precautions are taken, to be described later, glass is a considerable hazard.

For practical purposes of diagnosis and treatment, it is not necessary to distinguish among burns caused by thermal radiation (flash-burns), by flame, or by contact burns, a form of flash-burn caused by dark-clothing materials becoming hot and burning the skin with which they are in contact.

Although there are differences in body surface involved, depth of the injury to the skin, and general reactions of the individual to burns of different types, the indicated treatment for burns from an atomic explosion appears to be the same as for those encountered in large-scale incendiary raids and in civil disasters.

Sudden Casualties

The unique feature of atomic bomb burns is the great number of casualties produced in a brief period, the variety of burns encountered, and the wide range of severity, depending on the distance from the explosion.

A great deal was learned during World War II about the treatment of burns, but the subject is still under investigation and has not yet become stabilized. It is recommended, therefore, that until there is more general agreement, the medical men in each community employ the treatment for severe burns they have found most efficacious.

Because of their importance in relation to the effects of an atomic explosion, a comprehensive study of flash burns is being sponsored by the Atomic Energy Commission.

The effect of thermal radiation on the eyes was surprisingly small. Even those who looked directly at the explosions at Hiroshima and Nagasaki, from some distance, of course, reported only temporary loss of vision. One patient was so blinded by the flash that he was unable to distinguish light from dark for two days, but eventually his recovery was complete.

The effects of nuclear radiations, as distinguished from thermal, on living organisms depend not only on the total amount absorbed, but also on the rate of absorption; on whether it is chronic or acute, and on the area of the body exposed.

Amount of Dosage

Some radiation phenomena, such as genetic effects, are apparently independent of the rate of delivery of the radiation, and depend only on the total dosage. In the majority of instances, however, the biological effect of a given dose of radiation decreases as the rate of exposure decreases.

Thus, to cite an extreme case, 600r would certainly be fatal if absorbed by the whole body in one day, but it would probably have no noticeable consequences if spread over thirty years. The most reasonable explanation of this fact is that if the dosage rate, that is, the amount of radiation taken per day, is very small, the damaged tissues have a chance to recover. If the intensity or rate of delivery of the radiation is increased, recovery cannot keep up with the damage.

It is apparently the recovery factor that makes it possible for human beings to accept limited doses of radiation, at least 0.3 r per week for long periods without any apparent harmful consequences.

While little of a specific nature can be done in the treatment of radiation sickness where the acute dose is 600r or more, there is a possibility that where the dose is smaller, particularly 400r, or less, many lives can be saved with proper treatment. Immediate hospitalization, to insure complete rest, and avoidance of chills and fatigue, is an essential first step.

Whole blood transfusion should be given, as required, until the bone marrow, the blood-forming tissue quickly damaged by radiation, has had time to regenerate and produce blood cells. Adequate nourishment could be provided by intravenous feeding to supply the necessary sugars, proteins, vitamins, etc.

The danger of infection, from destruction of the germ-fighting white blood cells, may be controlled by the use of penicillin and other antibiotics. The whole subject of radiation sickness, a rare occurrence before the bombings of Hiroshima and Nagasaki, is intensively studied, and important advances in its treatment may be expected.

Hereditary Factors

Because of the possible importance of the subject for the future of the human race, no discussion of radiation injury would be complete without consideration of the genetic (hereditary) effects. These effects differ from most other changes produced by radiation in that they appear to be cumulative and, within limits, independent of the dosage rate of the energy of the radiation.

The mechanism of heredity is essentially similar in all sexually reproducing plants and animals, including man. The material responsible for inheritance is organized into discrete structures, the chromosomes, which are visible microscopically in the nuclei of dividing cells.

The chromosomes, rod-shaped bodies, are considered to be fine threads of nucleoproteins (group of proteins combined with nucleic acid, the latter a constituent of the nuclei of living cells), which are differentiated along their length into thousands of distinctive but submicroscopic units, the genes.

The development of inherited characteristics is controlled by the action of the genes. Chromosomes, and hence the genes, occur in pairs in the nuclei of the cells of individuals, one member of each pair contributed by each parent through the sperm or egg.

Mutations, defined as changes in inherited characteristics, may be classified roughly into two categories. Microscopically detectable changes in chromosome structure are called chromosomal mutations or aberrations. They may be responsible for visible changes in inherited characteristics, may cause reduced fertility, and frequently may be lethal, preventing development of the embryos.

The Gene Mutations

The second category, gene mutations, include those cases in which sudden changes in inherited characteristics are not the result of demonstrable changes in chromosome structure but rather are believed to be from changes in the chemical composition of the normal gene. The possibility remains, however, that many so-called gene mutations may actually be ultramicroscopic changes in chromosome structure.

Mutated genes are commonly classified as either dominant over the normal genes, in which case the individual will show the particular characteristic if he receives the mutated gene from either parent, or recessive, in which case an individual must receive the mutated gene from both parents before exhibiting the characteristic.

While most gene mutations appear to be recessive, recent evidence indicates that many so-called recessives are partially dominant. Almost all mutations are deleterious, the occurrence of beneficial mutations being very rare.

There is a large body of data which indicates that any dose of radiation, no matter how small, increases the probability of genetic changes. Until recently the risk would have been thought to apply mainly to distant descendants, when the probability of two recessives mating would be greater. New information on the frequency of partial dominants indicates that the risk may not be negligible even to the first generation.

A Matter of Time

Incomplete experimental work on mice leads to the important practical conclusion that the probability of passing on chromosome aberrations to the next generation will be greatly reduced if individuals exposed to doses of radiation refrain from begetting offspring for two to three months after exposure.

It should, however, be stressed that, according to the evidence available, this practice would cause little or no reduction in the risk of transmitting gene mutations.

Many of the basic data necessary for a reliable estimate of the genetic effects of radiation in human populations have not yet been obtained. We are not yet able to calculate the exact magnitude of the risk. It is obvious, therefore, that until more basic knowledge is available, exposures of personnel should be kept to a minimum.

It may be mentioned, however, that the possibility of the production of a race of monsters in Japan as a result of radiation emitted by the atomic bombs is extremely improbable in the opinion of geneticists who have made careful study of the subject.

Protection Requires Planning

Adequate protection against the effects of an atomic bomb attack would require comprehensive and detailed planning. Such planning would be necessary to avoid panic, for mass hysteria could convert a minor incident into a major disaster.

The purpose of the Government handbook, "The Effects of Atomic Weapons," is to provide the essential scientific and technical information that would permit necessary plans to be made for dealing with the new and unusual situations that would arise as the result of the explosion of an atomic bomb.

The organization, preparation and techniques designed to deal with these situations involve considerations beyond the book's scope. Their precise nature depends on many factors that must be evaluated nationally, and their application would vary with the patterns of regional and community development.

Any planning and organization against a possible atomic attack must be designed to meet the various destructive effects that an atomic explosion is likely to produce. These, as we have seen, include damage caused by air blast, ground and water shock, thermal radiation, initial nuclear radiations, and residual nuclear radiations. In addition, extensive fires from various secondary causes would follow an atomic explosion.

Fortunately, protection from these hazards, although by no means simple, is not as complex as the existence of so many danger factors would imply. In general, it appears that proper protection against blast, shock and fire damage could also minimize the danger to personnel from thermal radiation and initial nuclear radiations.

Thermal Radiation

As far as burning caused by thermal radiation is concerned, the essential points are protection from direct exposure for human beings and the avoidance of easily combustible materials, especially near windows.

The only known defense against the gamma rays and neutrons constituting the initial nuclear radiation is the interposition of a sufficient mass of material between the individual and the atomic bomb, including the rising Ball of Fire. The use of concrete as a construction material, which is necessary to reduce air-blast and ground shock damage, would, to a great extent, decrease the initial radiation hazard.

From the standpoint of physical damage, the problems of construction and protection from atomic bombs are not fundamentally different from those associated with bombs of the conventional type. It should not be forgotten, however, that atomic bombs are enormously more powerful. The damage would cover an extensive area, probably several square miles. These facts are important in planning for control of fire-fighting and rescue operations.

Protection from the effects of radioactive contamination presents a problem that has not previously been encountered. The results of blast and fire are visible and can generally be controlled in a relatively short period after an explosion. But nuclear radiation cannot be detected by the senses without the use of instruments, and, unless the contamination is removed, the deleterious effects may continue for weeks, months or longer.

Even though the dangers from radioactivity after an atomic explosion are uncertain and perhaps exaggerated, nevertheless some consideration must be given to possible contamination of areas, structures and equipment.

Monitoring of regions close to, and especially downwind from, the explosion should be undertaken soon after the detonation for the guidance of fire fighters and rescue teams. Subsequently, more detailed monitoring may be required to find which areas are safe for occupation.

Many steps can be taken to reduce both the personal casualties and the physical damage effects of an atomic explosion. The planning of new construction affords the best opportunity for the inclusion of protective measures at a minimum cost. But existing structures can, in many cases, be strengthened to make them more resistant to blast, fire and radiation, thus increasing the protection afforded to personnel and equipment.

For example, blast damage can be reduced by strengthening structures, particularly against lateral and downward forces. It is desirable to keep to a minimum fixtures, ornamental plaster, or other interior treatments that might be dislodged when the buildings are subjected to violent forces.

The fire hazard may be decreased by avoidance of exposed inflammable material. General protection against gamma radiation may be achieved by a sufficient thickness of structural material.

Question of Distance

In taking protective measures, how far away may it be supposed that the atomic explosion will occur? Of course, it is impossible to supply a definite answer, but a decision must be made on the distance from the explosion at which protection becomes practical. Steps can then be taken to provide protection appropriate to this distance.

Taking various factors into consideration it seems that a distance of about half a mile from ground zero would be a reasonable compromise for the planning of general protective measures. The assumption is made that the bomb is exploded in the air at such a height as would provide maximum physical damage.

It must be admitted, however, that the choice of distance involves an element of risk, for there may be accidental or deliberate bursts of several bombs in proximity at the same time. Further, there is the possibility that these bombs might have different energies and be detonated at different heights.

On the other hand, there is some justification for the choice of half a mile from ground zero, from a nominal (20 kiloton TNT equivalent) atomic bomb, as the point from which protection should be considered.

In the first place, the evidence from the Japanese bombings indicated that within this distance the chances of survival, from one cause or another, were very poor. It is only beyond 3,000 feet or so that the proportion of persons killed begins to fall off at an appreciable rate. Suitable protective measures would result in an even sharper drop.

No Closer Protection

Further, protection against blast, initial radiation, and thermal radiation becomes practical at a half mile from ground zero, while at closer distances it would not generally be feasible. In certain cases, however, stronger construction may be desirable on the ground of the essential nature of the operations carried out in a particular building.

One of the most important lessons learned from the atomic bomb attacks on Japan is the necessity for the provision of an adequate water supply for the control of fires.

In Nagasaki the water pressure was only thirty pounds per square inch at the time of the explosion and because of breaks in mains and house service lines it soon dropped to ten pounds per square inch. On the following day the pressure was almost zero. This drop in the water pressure contributed greatly to the extensive destruction caused by fire.

The experience at Hiroshima was similiar.

A large proportion of the fire devastation in Japan after the atomic bomb attacks was because the fire-fighting services were incapacitated. It would seem to be advisable that fire departments of strategic cities and industrial plants should be housed in structures capable of withstanding the blast at about half a mile from the explosion. Underground construction of concrete walls two feet thick would provide this degree of blast protection.

Facilities for the direction of disaster-relief activities, and provision of first aid in a city, require a protected area on one of the lower floors of a well-constructed, fireproof, reinforced-concrete or steel-frame building. To avoid the hazard of general conflagration, the building should not be among others that are not fireproof.

Facilities required for rescue and damage control operations, in addition to the measures found necessary on the basis of World War II experience with conventional explosives, must be given special treatment in view of some of the novel effects of atomic weapons.

The problem of radiological hazard control requires more elaborate facilities, and this hazard, as well as the mechanical damage effects, requires that careful consideration be given to the communications networks, probable need for duplicate facilities, special storage requirements, emergency medical services, evacuation procedures and immediate debris clearance.

Shelters inside buildings should be in fireproof, reinforced-concrete or steel-frame structures that are resistant to collapse. The areas chosen should be on the lower floors and in halls, or in the interior portions of the buildings, since these seem to offer the most reasonable possibilities for protection. Secondary hazards, such as those from falling plaster or fixtures, or from fire, should, of course, be avoided.

Outside Shelters

Shelters outside the larger structures should, in general, be designed to resist the effects of blast and radiation from an atomic burst at a reasonable distance, say one-half mile. They should be well clear of buildings to avoid hazards from debris and fire.

A buried, or semi-buried, shelter will usually be the best choice for protection from an air burst, because the earth cover will act as protection against radiation. In addition, blast effects will be less than on a surface shelter. Such buried shelters would, of course, be useless in the event of a near-by underground detonation of an atomic bomb.

It might be advisable to construct shelters so that they would provide protection in case of surface or subsurface bursts, in which the spread of radiation through the air might be a hazard. Hence, special consideration should be given to the problem of insuring suitable ventilation for shelters.

The most effective method for providing adequate ventilation is to use a pressurized installation in which the air is forced through special air filters that would remove radioactively contaminated particles. The practicability of such extreme measures, however, is open to question.

Basements of homes, especially if they were extended beyond the main structure of the house, would offer reasonable protection against blast damage, provided they were not too near the center of the explosion.

However, care must be taken to provide escapes to be used in case the house catches fire or collapses. A shallow rampart of soil or of sand bags outside the house would probably be advantageous. Semi-buried shelters for individual families, of the type used in Europe during the last war for protection against conventional bombs, would also provide worth-while protection against atomic explosions.

In cities like New York, the subways would make good shelters, though they probably would collapse in case of a near-by underground explosion.

The discussion of shelters is, of course, based on the assumption that there has been sufficient warning to permit people to take shelter. In the event of a surprise atomic explosion, immediate action would mean the difference between life and death.

The first indication of an unexpected atomic burst would be a sudden increase of the general illumination. It would then be imperative to avoid the instinctive tendency to look at the source of this light, but rather to do everything possible to cover all exposed parts of the body.

Personal Protection

If a person is in the open when the sudden illumination is apparent, the best plan is to drop instantaneously to the ground, curling up so as to shade bare arms and hands, neck and face with the clothed body. Although this will not protect against gamma rays, it might help in reducing flash-burns.

This is important because disabling burns can be suffered well beyond the lethal range for gamma rays. The curled-up position should be held for at least ten seconds. The immediate danger is then over, and it is permissible to stand up and look around to see what action appears advisable.

If in the street, and some sort of protection, such as a doorway, a corner or a tree is within a step or two, then shelter may be taken there with the back to the light, and in a crouched position to provide maximum protection, as described above. No attempt should be made to reach a shelter if it is several steps off.

The best plan then is to crouch on the ground, as if completely in the open. After ten seconds, at least, a standing position may be resumed, but it is strongly advisable to press the body tightly against the side of a building to avoid breaking glass, or falling missiles, as far as possible.

A person who is inside a building or a home when a sudden atomic attack occurs should drop to the floor, with his back to the window, or crawl behind or beneath a table, desk, counter, etc. This would also provide a shield against splintered glass from the blast wave.

Windows to be Avoided

The blast wave might reach the building some time after the danger from radiation had passed, and so windows should be avoided for about a minute, because the shock wave continues for some time after the explosion. The safest places inside a building are the interior partitions, and it is desirable to keep as close to these as possible.

In considering the practical problems of a radiological hazard it may be supposed that there would be three stages, the duration and severity of which would depend on circumstances. These are as follows:

1. Complete disorganization stage: In the event of heavy and widespread physical damage, it may be presumed that roads would be blocked for some distance from the explosion, and that all normal communication systems would be out of commission. Emergency transportation and communication, except perhaps for self-contained radio equipment, would not be immediately in effect.
2. Emergency control stage: This phase would begin as soon as margin roads had been cleared, and transportation and communication had been re-established, at least on an emergency scale, so that information could be transmitted to a control room. In the case of moderate physical disaster, the emergency control phase would start immediately, and might last a week or more.
3. Recovery stage: The final phase would be reached when most persons were out of immediate danger of injury, and there was time to start more thorough decontamination operations where necessary.

In the emergency control phase, an important factor in the operation of radiological defense would be rapid gathering of data on contamination. The radiations that may be encountered are gamma rays and beta particles (electrons) from fission products, neutron-induced activity or other radioactive material, and alpha particles (nuclei of helium) from plutonium or uranium.

Of these, the gamma radiation can be measured most readily. This is perhaps the greatest immediate hazard because of its considerable penetrating power. Beta particles as such are not a serious menace unless the source enters the system or remains on the skin for some time.

Monitoring of Areas

Monitoring of suspected contaminated areas for gamma radiation should be carried out at the earliest possible moment. Initially, this might even be done by means of low-flying aircraft. From the gamma radiation dosage measured at a known height above the ground it would be possible to obtain an approximate indication of the area and intensity of the contamination.

However, ground monitoring for gamma radiation, with portable instruments, would be necessary at the first opportunity. The monitoring for beta radiation would, in general, be an auxiliary measurement, made in the later stages after the immediate emergency had passed.

The question of the amount of exposure to the residual nuclear radiation that would be permissible for control and rescue personnel would depend a great deal on circumstances and the risks that inevitably would have to be taken. In the initial disorganization phase, when the radioactivity was also most intense, it would be important for emergency personnel to avoid overexposure to radiation except where is was necessary to carry out missions of the greatest importance.

It may be noted in this connection, however, that because of the rapid initial decay of the fission products, a person who is exposed to the radiation from this mixture for the first hour after an explosion would not suffer any further appreciable injury by staying for several hours more. A situation of this kind might arise because of the immediate fall-cut from an underground or an underwater burst.

During the emergency control phase the radiological defense system should be fully operable. Every effort should be made to minimize the dose of gamma activity received by the general population.

Protective Clothing

Personnel entering a contaminated area, whether to perform monitoring or other emergency work, should wear protective clothing of some kind. Actually ordinary clothing is adequate protection against alpha and beta radiation, but since it is likely to become contaminated it would have to be destroyed.

Soon after an atomic explosion there is likely to be a large amount of dust in the air, especially in the regions of appreciable damage. There is practically no danger of this dust being contaminated after a high air burst. However, other types of deliveries could spread radioactivity on the ground.

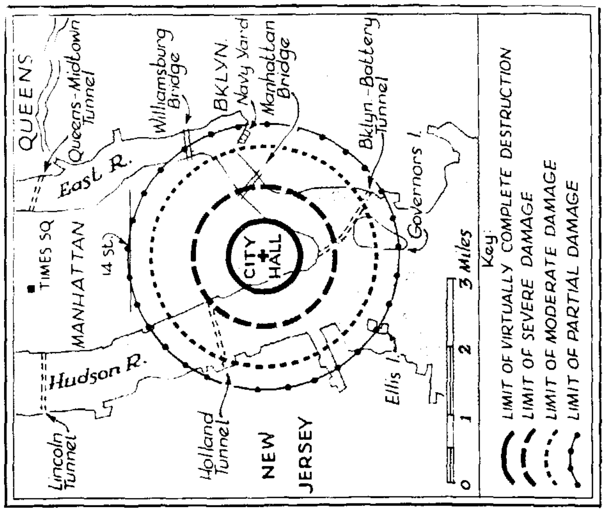
Consequently, all members of emergency teams entering a contaminated area should wear respirators. Masks covering the nose and mouth, of the type developed as a protection against chemical warfare agents, have been found to be satisfactory in preventing inhalation of dust particles. Where the amount of dust is very large, it might be necessary to use a respirator hood to give complete protection of the head.

In planning defenses against the atomic bomb, it is essential to remember that in addition to its multiple physical effects, it is also a weapon calculated to arouse terror in a population. One of the essential defenses against it, along with those outlined, must therefore be psychological preparedness.

Without minimizing the seriousness of a possible atomic attack, intelligent planning based on the known facts could make it much less serious, while a state of mind accepting as true the notion that "there can be no defense against the atomic bomb" will most certainly make its effects much more serious than they otherwise would be.

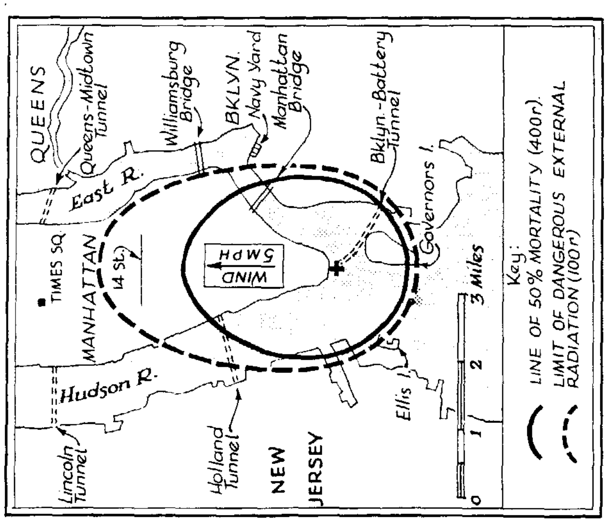
Had the people in Hiroshima and Nagasaki known and put into practice the defense measures outlined in the official handbook on how to prepare against atomic attack, there can be no question that their casualties would have been but a fraction of what they actually were.

HOW ATOM AIR AND UNDERWATER BLASTS WOULD AFFECT CITY



The New York Times

Approximate limits of damage from atom bomb exploding 2,000 feet above City Hall.



Aug. 22, 1950

Approximate limits of residual radiation from shallow underwater blast off the Battery here.