THE HYDROGEN BOMB: A SCIENTIST'S DESCRIPTION

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'The heavens will vanish in a whirlwind, the elements will be scorched up and dissolve, earth, and all earth's achievements, will burn away.'—II Peter iii, 10.

THERE are basically two types of process leading to the large-scale liberation of the energy locked in the nucleus of the atom: fission and fusion or, more simply, breaking up large nuclei and sticking together small ones. In the fission process, a nucleus of uranium or plutonium breaks up into two approximately equal parts, with emission of energy. A few neutrons are also emitted, and these can cause more fissions in the surrounding material, thus maintaining the reaction. Energy is also released if two nuclei of very light elements like hydrogen or helium coalesce; this is called fusion. This process will only take place if the combining nuclei have sufficient energy to overcome the powerful electrical repulsion tending to keep them apart, and this means that the hydrogen has to be at a very high temperature before the reaction will begin. The required temperature is many hundred of times greater than the highest attainable by purely chemical means but it can be produced by a nuclear fission reaction. A fission bomb is therefore used to detonate a surrounding mass of hydrogen. The resulting thermonuclear reaction, as it is called, is self-propagating until the reacting mass is blown apart by the force of the explosion.

It is usual to express the power of a nuclear bomb in terms of the weight of T.N.T. that releases the same amount of energy. The fission bombs dropped on Hiroshima and Nagasaki were equivalent to about 20,000 tons of T.N.T. and since then fission bombs of up to about twenty-five times this power have been developed, together with a wide range of smaller weapons for tactical use. The hydrogen bomb tested at Bikini in March 1954 is estimated to be equivalent to some fifteen million tons of T.N.T. and there is no reason to doubt that even more powerful bombs could be made. Indeed, it is one of the main advantages of the hydrogen bomb over the fission bomb that there is no limit to its size apart from that imposed by the need to transport it by air.

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Very little official data on the effects of hydrogen explosions has yet been published, but it is possible to build a reliable picture by multiplying up the well-known effects of fission explosions and checking the results against the scraps of information that are known from analyses of the radioactive content of the atmosphere at large distances from the test explosions. One important conclusion has recently been drawn by Professor Rotblat[1] from such studies. He found that the radioactive contamination was much greater than would be expected from a thermonuclear explosion detonated by a fission process and concluded that the mechanism of the hydrogen bomb is rather more complex than was originally supposed. The main source of the power of the hydrogen bomb is not the thermonuclear reaction itself but fissions of the nuclei of an outer shell of natural uranium caused by the neutrons produced in immense numbers in the thermonuclear reaction. This has an important bearing on the radioactive hazards of these explosions, as it makes them comparable with those of the cobalt bomb. (A nuclear bomb surrounded by cobalt, which is made intensely radioactive by the explosion.)

The effects of hydrogen bombs may be considered under four headings: blast, heat flash, direct radiation and delayed radiation. The extent, both absolute and relative, of the damage under these headings depends in a complex way on a large number of variables: the power of the bomb, the height above ground at which it is exploded, the visibility of the atmosphere, the configuration of the ground, the type of buildings, the prevailing weather, the efficiency of Civil Defence and the nerve of the inhabitants. This makes any precise estimate of the damage quite misleading, but fortunately an indication of its order of magnitude is sufficient for the present purpose.

The blast wave radiating from a thermonuclear explosion is similar to that from a high explosive bomb, but of much greater intensity. When it hits a building it first of all exerts on it a very high pressure for a short time in the direction away from the explosion, and this is followed by a smaller suction towards the centre of the explosion for a rather longer time. Simple brick buildings are easily demolished by these blast waves to a distance of about seven miles from the centre of the explosion. Reinforced

1 'The Hydrogen-Uranium Bomb.' J. Rotblat. *Atomic Scientists' Journal.* Vol. 4. XXX. 1955.

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concrete buildings resist better, though their interiors are shattered. At distances of some fifteen or twenty miles the blast wave causes light damage by bringing down ceilings and shattering windows in a way that will be familiar to many readers. An important secondary effect of the blast wave is the outbreak of numerous fires due to the breakage of gas mains and the scattering of burning material from domestic fires. These fires often destroy many of the buildings only partially damaged by the blast wave and, if the conditions are favourable, the individual fires may unite to form one vast conflagration or fire storm raging unchecked through the shattered city.

The heat flash brilliantly illuminates the area around the explosion and can ignite combustible material up to a distance of some ten miles, thus adding to the fire hazard. It also causes severe burns on the skin of anyone exposed to it.

These effects of hydrogen bombs are of a familiar type, though of unprecedented intensity. The radioactive effects are quite unfamiliar, and are probably even more serious and widespread than the familiar ones. Accompanying the heat flash is an intense burst of neutrons and gamma rays. These pass right through the body without any directly perceptible effects, but the damage they cause to the cells and tissues of the body results in radiation sickness. Those who have received a lethal dose of radiation experience no immediate ill-effects, but nausea is soon experienced, followed by vomiting. The cells in the bone marrow that produce white blood corpuscles are particularly sensitive, and soon no more of these corpuscles are being made. Since their function is to fight bacteria, increased susceptibility to infection ensues. Small wounds do not heal, and haemorrhages become more frequent. Diarrhoea and vomiting increase, and this is followed by fever, emaciation and death. However, deaths due to radiation sickness from the direct radiation form only a small proportion of the casualties because those near enough to receive a lethal dose are usually killed by blast and heat flash.[2]

The residual pieces of the split nuclei, or fission fragments as they are called, are carried high into the air by the cloud of hot gases forming the familiar mushroom. This cloud is gradually dispersed by the winds in the upper atmosphere and the fission fragments slowly descend to the ground. These fission fragments

[2] 'The Biological Effects of Atomic Radiations.' P. E. Hodgson. *The Month*. Vol. 10. 1953.

are intensely radioactive and they continually emit nuclear radiations capable of damaging the human body in the way described above. The Japanese fishermen in the *Fukuryu Maru* were showered with these radioactive particles, although they were about eighty or ninety miles from the explosion. All of them suffered from radiation sickness, and one of them died six months later.[3] It is estimated that an area of seven thousand square miles was covered by a lethal quantity of radioactive dust.[4]

These radioactive particles from the test explosions are scattered over the whole of the surface of the earth. Although they are then so diluted that they cannot cause radiation sickness, their genetic effects cannot be ignored. Nuclear radiations can cause mutations in the reproductive cells of the body and these may result in defective children. Most of these mutations are recessive and so the deformities produced by them may not appear for several generations. Very little is known about the amount of radiation necessary to increase the number of deformed children by a given fraction, as the necessary experiments would take many decades to complete. Our present knowledge is based on an extrapolation from experiments on fruit flies and mice and is consequently rather uncertain. Nevertheless, although geneticists are unable to make precise estimates of the genetic effects of radiation, they do understand the question sufficiently to be able to say that the danger is a very real one. Quite recently Dr Sturtevant, a distinguished American geneticist, estimated that the tests that have already been made will ultimately cause about two thousand abnormal births. This is clearly of the greatest importance for the future of mankind, and it is essential that available data should be published and an extensive series of researches initiated.

There is one important consideration that provides a rough indication of the amount of radiation that can be tolerated by the human race. We are all continually exposed to nuclear radiations from radioactive rocks and from outer space (the cosmic rays), without any catastrophic ill-effects, although they are probably responsible for some of the small number of abnormal births that always occur. If a test explosion, or the waste gases from an atomic factory, or the radiation used in

[3] 'Bikini Ash.' Y. Nishiwaki. *Atomic Scientists' Journal.* Vol. 4. 1954.
[4] U.S.A.E.C. Report. February 15th, 1955.

medical diagnosis and treatment gives the population a dose of radiation small compared with the ever-present background dose, then there is little cause for alarm. But if it becomes of comparable magnitude to the background dose serious consequences may well follow. It is always possible by suitable precautions to reduce the dose due to atomic factories and medical work to negligible proportions, but recent calculations indicate that the world-wide radiation from hydrogen bomb test explosions, if they are continued at their present rate, will be quite comparable with that of the natural background. Over many millenia the human race has established a delicate genetic balance with this radiation and no one can predict the consequences if it is upset. These genetic effects are certainly very serious, but it is important to keep them in perspective. It can hardly be maintained, for example, that it is wrong to increase the dose received by the population by any amount however small, because this would compel the human race to live at sea level as the intensity of the cosmic radiation increases with altitude.

Such then are some of the effects of hydrogen bomb explosions, so far as we know them at present. It is hardly necessary to enlarge on the vast chaos and human suffering that would be caused if even one were to be exploded in a modern industrial city. Millions would be killed immediately and many more millions rendered homeless; millions again in neighbouring cities up to a hundred or more miles away would die a lingering painful death from radiation sickness; and perhaps millions again in the decades and centuries to come would be born defective. These bombs are not prohibitively difficult to make; in a few years the stocks held by the major powers will be numbered in hundreds, if not in thousands.

It is important to consider in what sense hydrogen bomb explosions may be said to be out of control. It seems that the only reasonable meaning of 'control' when applied to an explosive process is that the effects of the explosion are known, within reasonable limits, to those who initiate it. Furthermore, they should understand the process sufficiently to be able to say with some confidence that no other deleterious effects occur. These conditions are satisfied by chemical explosions, may be satisfied by small tactical atomic weapons, but it is difficult to see how they are satisfied by large hydrogen bomb explosions.