with the party having the management of the instrumentality. These are practical considerations. We think the jury should have been permitted to draw an inference of negligence..........from the occurrence of the 150 explosions......" "[*Kleinman* v. *Banner Laundry Co.*, 150 Minn. 515 (1921).]

This somewhat lengthy identification of a problem of civil liability has been presented only to indicate that the questions which arise are substantial and the answers not easily perceived. The facts in any case will predominate and shape the results. Special care should be taken to avoid hasty generalisations concerning the applicable rules, in order to avoid the mistakes that were made, for example, when the automobile first presented novel questions of negligence and liability.

Liability of manufacturers and suppliers

A defect in a component part of a reactor, faulty construction of reactor facilities, and the mishandling or misuse of radioactive products may cause widespread damage and present the problem of the liability of the manufacturer, constructor, or supplier to injured third persons (i.e., persons other than immediate contractors or buyers).

The general rule in the United States is that:

> "A manufacturer who fails to exercise reasonable care in the manufacture of a chattel which, unless carefully made, he should recognise as involving an unreasonable risk of causing substantial bodily harm to those who lawfully use it for a purpose for which it was manufactured and to those whom the supplier should expect to be in the vicinity of its probable use, is subject to liability for bodily harm caused to them by its lawful use in a manner and for a purpose for which it was manufactured."—Restatement of Torts, S. 395.

This principle was originally discussed in terms of "dangerous substances," but has been so extended by recent decisions as to render the concept of "dangerous" practically meaningless. Now, if substantial harm can be foreseen and if the chattel is defective, the rule applies.

An extension of the doctrine in *Moran* v. *Pittsburgh-Des Moines Steel Co.*, 166 F. 2d 908 (3rd Circ. 1948) is of special interest in the atomic energy industry. Defendant, under contract with a public utility company, designed, furnished materials for, and constructed a tank on the utility's land for the storage of liquified natural gas. Thirteen months after completion and acceptance of the tank, it ruptured, releasing large quantities of gas and causing fires and explosions in which more than 100 lives were lost. An employee of the utility company engaged in work unconnected with the storage of gas was killed, and an action for wrongful death was brought against the builder of the tank. The court held the defendant liable for negligent defects in manufacture to one who might reasonably be expected to be in the vicinity of the chattel's use and, also, that the principle applied even though the tank when installed technically became part of the structure and land of the utility company.

The decision is important in that it includes within the rule not only manufacturers of equipment but building contractors as well, and presumably defective design and engineering.

In any case, however, according to prevailing authority there must be proof of negligence. Attempts to extend the doctrine of strict liability to manufacturers of articles or equipment which proves to have a defect that causes injury have not as yet met with much success; but it can be expected that this new principle of liability will be advanced in cases of injury or damage due to reactor break-down. Acceptance will depend upon the courts and circumstances.

The commercial dstribution of radioactive products will also present liability problems. Modern case law holds the manufacturer liable for injury due to inherently dangerous articles marketed without the necessary cautionary statements. A danger is inherent when it derives from the nature of the article itself, as opposed to dangers resulting from a defectively made article that is ordinarily harmless. Negligence attaches not to the manufacturing, but to the distributing and marketing process and is founded on the failure to give proper instructions and warning.

The very good chance that the defenses of contributory negligence and assumption of risk will present recovery in most cases arising out of the distribution of raidoactive products may inspire the argument that strict liability should attach in order to stimulate standards of conduct needed to protect the public. Using as analogy the statutory liability imposed with respect to foods, drugs and cosmetics, it may be advanced that when the distribution of radioactive products is subject to control through licensing and regulations proof of a violation of the regulations and the conditions of the license will constitute conclusive evidence of negligence. Here, again, we merely identify the nature of the problem and do not presume to supply the answers.*

*There are other legal problems which might be mentioned: Since radiation injury may not become apparent for some time, statutes of limitations may have to be changed for special treatment afforded for such injuries. International transportation of materials and a catastrophic incident causing widespread damage over a large geographical area may raise questions of jurisdiction and the choice of law. A "mass" tort may present procedural questions. For problems related to workman's compensation, see Greene, "*Workmen's Compensation Aspects of the Peaceful Use of Atomic Energy*, P/323. Session 4.3, Vol. 13, these Proceedings.

APPENDIX III

The Effects of Radiation and an Assessment of the Hazards of Exposure to Radiation

(Extracts from *The Hazards to Man of Nuclear and Allied Radiations*, Medical Research Council, H.M.S.O., London, 1958)

The future development of civilisation is bound up with the exploitation of nuclear energy. Its use, like that of other sources of energy, entails risk, but the risk is controllable and, within limits, can be accepted. It is the scale and not the nature of the hazard that is new, for human populations have always been exposed to natural radiation of low intensity.

THE NATURE OF RADIATION AND ITS ACTION ON LIVING CELLS

Ionizing radiations are so described because they cause the formation of electrically charged particles, ions, in the matter through which they pass. The common types of penetrating radiation are X-rays, gamma rays, alpha and beta particles, and neutrons. Alpha particles cannot penetrate tissue beyond a fraction of a millimetre but gamma rays, and X-rays produced by extremely high voltages, can traverse the whole body.

The biological effects of radiation are related to the intensity of radiation and to the period of exposure. The basic unit of radiation dosage which has been generally used is the roentgen (r). All living tissue can be killed if exposed to sufficiently high doses of radiation. The effects of dosages below those which damage tissues irretrievably may be modified by processes of healing, so that the response to a dose of radiation which is spread over a long time may be much smaller than, or quite different from, the response which would occur if the same dose were given in a very short time. This does not apply to the important type of genetic effect, called, gene mutation, produced by the irradiation of reproductive cells, the consequences of which are cumulative and irreversible.

THE EFFECTS OF RADIATION ON THE HEALTH OF THE INDIVIDUAL

Sources of information

Our knowledge of the effects of ionizing radiations on human beings comes from four main sources: from the uses of X-rays and radium in the treatment of disease, mainly of cancer ; from a study of the occupational hazards of medical radiologists, workers in the luminising industry, and miners of radioactives ores ; from a study of the victims of atom bomb explosions; and from experiments on animals.

The harmful effects of radiation on man

Almost all the effects of ionizing radiation on tissues are essentially deleterious. The benefits to the individual patient of the eradication of a malignant tumour by radiotherapy result from selective damage to the tumour cells. The nature and severity of radiation injury is determined by the type and dosage of radiation received, the part and extent of the body irradiated, the length of the period of exposure, and the age of the persons exposed. The harmful effects may be classified into those which develop within a few weeks of exposure, and delayed effects which may not make their appearance until many years after exposure.

Effects occurring within a few weeks of exposure

The effect of exposing the whole body to a single dose of gamma radiation of the order of 500 r is such that all the persons so exposed would develop acute illness and at least half would die. In civil life, exposure to such a dosage could occur only under the most exceptional circumstances. With smaller single doses, for example of 100 r, not more than 15 per cent of an exposed population would suffer acute illness and very few, if any, of those affected would die. After a single dose of 50 r, acute illness would be very rare. The relationship between the dose of radiation received and the effects that may be produced within a few weeks of exposure is not one of strict proportionality; with each successive and equal increment of dosage the response increases by a progressively greater amount, at least until very large changes have been produced.

The delayed effects of radiation

Delayed effects of exposure to radiation may occur at any time after the end of the second month. Disorders of the skin and underlying soft tissues and of bone may occur and there may be subsequent development of cancer. Cataracts, severe anaemias and leukaemia have been caused and there is evidence from animal experiments that exposure to radiation may cause death at a prematurely early age.

Leukaemia

Leukaemia is a disease in which there is an uncontrolled overproduction of white blood corpuscles. Experiments on animals have shown that the incidence of leukaemia is increased by irradiation. Clear evidence that the same is true of man comes from two main sources: a study by the Atomic Bomb Casualty Commission of the incidence of leukaemia in Hiroshima and Nagasaki, and a survey under our sponsorhsip of the incidence of leukaemia among patients treated by radiation for ankylosing spondylitis.

Ninety-one proven and fourteen suspected cases of leukaemia have been recorded in Hiroshima and Nagasaki between 1947 and 1954 among those present at the time of the explosion and still resident in the cities; the expected incidence in an unexposed but otherwise comparable population is twenty-five. The difference is greater than would be attributed to chance. Moreover, there was a much higher frequency of occurrence among those who had developed early acute radiation illness and among those who had been nearer to the centre of the explosion. The latent period, that is the average length of the period between the explosion and the first appearance of symptoms of leukaemia, was about six years. The evidence suggests that with this type of exposure to radiation the likelihood of developing leukaemia, after its initial rise, remains approximately constant up to at least the ninth year.

Ankylosing spondylitis is a disease in which the joints, particularly those of the spine, progressively lose their freedom of movement. In the treatment of this condition very extensive areas of the body are exposed to irradiation. The records of between 13,000 and 14,000 patients, who had been treated with X-rays between 1933 and 1954, have been studied. Up to 1955, thirty-eight of these patients developed leukaemia, an incidence which, although only about one-third of one per cent, is about ten times greater than the normal expectation. No increased incidence of leukaemia was found among 400 patients who had not been treated for irradiation, but the number is too small to exclude completely the possibility that ankylosing spondylitis may of itself predispose its sufferers to leukaemia ; nor can the possibility be excluded that these patients are more liable than the average person to develop leukaemia after irradiation. Nevertheless, there is clear evidence of a correspondence between the dosage of radiation received and the incidence of leukaemia. The average length of the latent period between the first exposure to X-rays and the diagnosis of leukaemia was about six years.

The conditions of exposure to radiation in Hiroshima and Nagasaki, and in the treatment of ankylosing spondylitis, are not comparable with the irradiation in small doses over long periods which might be received by persons engaged in work with a possible radiation hazard. Some evidence has been presented suggesting an increased death rate due to leukaemia among radiologists but our knowledge of the occurrence of leukaemia under conditions of chronic exposure is too scanty to allow any reliable conclusions to be drawn.

Cancers

Two characteristics of cancers induced by radiation are noteworthy: the tendency of tumours to arise in tissues already severely damaged by radiation, and the long latent period, twenty years or more, before they appear.

A study of the pitchblende miners of Schneeberg and Joachimsthal suggests strongly that inhalation of the radioactive gas radon may lead to cancer of the lung. The latent period has been put at seventeen years and the dosage to the lungs over that period at about 1000 r and in some parts of the lung much higher. In theory, the inhalation of radioactive particles in the fall-out from atomic explosions or in the vicinity of nuclear reactors could also lead to cancer of the lung, but the former hazard is extremely unlikely in peacetime, and steps are always taken to ensure that the latter does not occur.

Radium, mesothorium, plutonium and radioactive forms of strontium are accumulated by and retained in bone. Until the enforcement of stringent controls, cancer of bone occurred among workers in the luminising industry as a result of swallowing radium-containing paint. The latent period was more than fifteen years.

Cancer of the skin was the earliest form of radiation-induced tumour to be described in man. By 1911, before the adoption of modern safeguards, fifty-four cases had been described among the

pioneers of radiology. The doses of radiation which have led to the formation of skin cancers must have been several thousand r.

Cancer of the thyroid gland in children has been a sequel to irradiation of the neck for enlargement of the thymus gland. This form of cancer is distinguished by its short latent period (about 7 years) and the comparatively low dosage of radiation required to induce it. However, it is not unlikely that other factors are involved here in addition to the direct effect of irradiation.

Other delayed effects

A fall in the number of red cells and white cells in the blood may follow exposure of the whole body to even moderate doses of gamma radiation. If not detected in time a condition known as aplastic anaemia may occur.

Cataract formation is known to have been caused by neutron irradiation, but for all practical purposes the production of cataract by X-rays is not an occupational hazard.

Delayed effects of radiation on the skin extend from a temporary loss of hair after local dosages of 300r-400r to severe and permanent damage after local exposure to single dosages of 1550r or more, or to repeated doses totalling 4000r or more in a number of weeks. It is in the skin damaged by these higher doses of radiation that tumours, when they occur, are most likely to develop.

Miscarriage and stillbirth may be a consequence of irradiation during pregnancy, but they do not constitute a problem unless the dose of radiation is large. A number of different developmental abnormalities have been described in the children of women treated by irradiation during pregnancy, the most conspicuous defect being microcephaly, a partial failure of the development of the brain. Eleven cases so classified are recorded in children irradiated before birth in Hiroshima and Nagasaki.

THE GENETIC EFFTCES OF RADIATION

The assessment of the genetic effects of ionizing radiations is subject to special difficulties. We believe that we have formed as fair an assessment as is possible in the light of present knowledge, but our conclusions must be regarded as provisional.

The material basis of heredity

The physical determinants of heredity are genes, carried on chromosomes in the nuclei of cells. Chromosomes are present in pairs; one member of the pair is of maternal origin, the other of paternal origin. There are twenty-four pairs of chromosomes in human beings; the number of genes is not known, but may well be many thousands.

The two genes which occupy corresponding positions on the two chromosomes of a pair are spoken of as alleles of each other. Alleles of different kinds arise by the process of mutation and are thereafter reproduced faithfully in their altered form.

Some genes produce the same effect whether they are paired with like or with unlike alleles. Such genes, and the characters they determine, are described as dominant. Other genes produce a noticeable effect only when paired with similar alleles; these, and the characters they determine, are described as recessive. There is every gradation between these two extremes. A recessive gene can be transmitted in a family by an individual who gives no signs of carrying it.

Sex difference is determined by a special pair of chromosomes, and the genes carried on these chromosomes are said to be sex-linked.

So far as is known, all genes are subject to mutation, and mutation occurs spontaneously all the time at a very low rate. Factors influencing mutation appear to affect only the frequency with which it happens. New alleles of harmful effect are eliminated by natural selection until equilibrium is reached with the rate at which they are introduced by fresh mutation. Recessive allecles are eliminated much more slowly than dominant alleles.

Basic principles of the genetic effects of radiation

There is little direct knowledge of the genetic effects of ionizing radiations on man, but with certain reservations it is justifiable to draw upon our knowledge of the effects of radiation on other organisms.

Ionizing radiations have genetic consequences only in so far as they affect the reproductive cells or the cells ancestral to them

in the reproductive organs (gonads). Two kinds of effect may have genetic consequences; the chromosomes may be damaged or the genes may be caused to mutate more frequently. Chromosome changes of the kind that can persist are only rarely produced by long continued exposure to X-rays or gamma rays of low intensity. They are likely to be a comparatively unimportant radiation hazard.

It is the frequency of gene mutation that is increased by radiation; there is no evidence and little likelihood that radiation produces entirely new kinds of genes. The rise in mutation rate is probably directly proportional to the amount of additional exposure to radiation, and any additional exposure, however small, must be expected to raise the mutation rate, if only by a minute amount.

Damage to genetic material is cumulative and irreparable. Long continued exposure to radiation of low intensity induces as much gene mutation as a single exposure to an equal dosage of radiation of higher intensity.

The age-distribution of those exposed to radiation has an important bearing on the future consequences of its effects. The genetic consequences of the irradiation of individuals beyond the age of reproduction are of course nil.

Effect of increased mutation on the incidence of disease in human populations

The rule of heredity in the production of disease range from that of a predisposing to that of a preponderating cause. The effects which might be expected to result from an increase in mutation rates can most easily be calculated for diseases known to be caused by single genes, but for relatively few such diseases have we sufficient evidence of the kind upon which such a calculation must be based.

Achondroplasia, haemophilia, and phenylketonuria have been taken as examples of diseases believed to be caused by single genes. If the mutation rates of these genes were to rise to, and remain at, twice their present values, the incidence of the disease for which they are responsible would ultimately, though at very different rates, rise to nearly twice their present frequencies. Calculations suggest that the incidence of achondroplasia, a dominant form of dwarfism, would rise 80 per cent above its present value in a single generation; haemophilia, a sex-linked disease, would take about six generations to rise by 90 per cent in frequency; and phenylketonuria, a recessive disease associated with severe mental deficiency, would take more than fifty generations to increase its frequency by one half.

Mental diseases, the most important single category in which hereditary causes are known to be important, account in all for nearly half the hospital beds provided in this country. There are grounds for believing that a doubling of the mutation rates of the genes concerned with their causation would, in one generation, increase the frequency of low-grade mental deficiency by three per cent, and of the two principal types of mental illness, schizophrenia and manic depressive reaction, by about one per cent. If the mutation rates were to remain at twice their present values, the incidence of mental diseases might on the most pessimistic assumption double also, but would only attain this value after very many generations.

When all serious illnesses with a hereditary element in their causation are taken into account, it is unlikely that the burden put upon society by a doubling of mutation rates would exceed by more than a few times the contribution made by the increase of mental disease.

It must be remembered that a harmful recessive gene gives no outward evidence of its presence until chance brings it together with another of its kind. The crop of newly mutated recessive genes caused by an increase of mutation rates could cause suffering over many generations.

Hereditary traits showing continuous variation about the normal

Most of the variation between human beings is not of the sharp kind that can be traced to the action of single genes. Characters such as physique, intelligence and length of life vary over a wide range by imperceptible gradations, and the hereditary portion of this variation is believed to be due to the combined action of many genes.

The basic effect of an increase in mutation rates upon such characters, here exemplified by scores in intelligence tests, will be

to increase the numbers of the more extreme types at the expense of the more average individuals. A doubling of the mutation rates for a few generations would be expected to have only the most trivial effect upon their variation. The effect of a permanent doubling of the mutation rate would be, at most, to double the variation, and this would take hundreds of generations to achieve.

Observations on populations exposed to radiation

Three direct studies have been made on the children of human beings who have been exposed to ionizing radiations. Two, on the children of American radiologists, were for a variety of reasons inconclusive; the third is the extensive study made by the atomic Bomb Casualty Commission on the children of those who were in Hiroshima and Nagasaki when the atomic bombs exploded. All three studies are limited to observations on the first generation, so that little genetic effect would yet have become manifest even if the mutation rate had increased.

The evidence assembled in the report of the Atomic Bomb Casualty Commission is beset by many difficulties of interpretation, but we believe that it reveals, in the children of those who were the more heavily exposed, a slight but significant change in the sex ratio at birth which might be due to genetic damage. From the nature of the evidence a doubling of the rate of incidence of congenital malformations, or a 50 per cent rise in the stillbirth rates, might have escaped detection if either had occurred. The evidence does not allow us to make any useful estimate of the radiation dose which doubles the mutation rate in man.

The 'doubling dose' in man

An assessment of the sensitivity of human genes to radiation is particularly difficult. Any such estimate should be based upon a sample of genes large enough to be representative of all the effects they exercise, for it cannot be assumed that all genes are equally radio-sensitive, nor that the proportion of the spontaneous mutation rate which can be attributed to natural radiations is the same for different genes.

If all mutations were indeed due to radiation, then the dosage which doubled their frequency would be expected to be equal to that received from natural sources, namely, a dosage to the gonads of about 3 r in thirty years. The available evidence suggests, however, that the percentage of human mutations that are caused by natural radiation might lie between 2 per cent and 20 per cent, and if this is so the doubling dose will lie between 15 r and 150 r.

The direct estimates which have been made of the doubling doses for a variety of plants and animals mostly run from 24 r upwards. It is true that none of the more fully investigated organisms has a lifetime comparable with man's, but there are theoretical grounds for believing that the organisms with the longer pre-reproductive periods might be expected to have the less radiosensitive genes.

The evidence at our disposal, though far from adequate, leads us, to conclude that there is rather little likelihood that the real value for the doubling dose for human genes lies between 3 r and 15 r; and that, although we cannot exclude the possibility that for some human genes the doubling dose may be less than 30 r and for others more than 80 r, the best estimate that we can make in the light of present knowledge, is that the value in general lies somewhere between 30 r and 80 r.

Even if the doubling dose were as low as the minimum we can reasonably entertain, namely 15 r, it is extremely improbable that in times of peace more than a small fraction of the population could receive an extra dose of this size. The prevalence of naturally-occurring hereditary abnormalities is such that, if comparatively few individuals received such a dose, there would be no noticeable effect on their immediate offspring or on their descendants even over several centuries. For levels of radiation up to the doubling dose, and even some way beyond, the genetic effects of radiation are only appreciable when reckoned over the population as a whole, and need not cause alarm to the individual on his own account.

Existing and Foreseeable Levels of Exposure to Radiation

Doses of radiation which are of no known significance to the individual may have genetic consequences. Exposure levels must therefore be expressed in terms of the total dosage to the gonads received by the population as a whole during the period of reproductive life.

Radiation from natural sources

The natural sources of radiation are cosmic rays and the naturally-occurring radioactive elements. From all such sources an individual in this country receives, on the average, a total gonad dose of about 3 r over a priod of thirty years.

Radiation from the appurtenances of civilisation

Over the past sixty years man has made increasing use of X-rays and radioactive materials in medicine, industry, and ordinary civil life. The additional gonad doses received from these sources by poeple of this country are expressed as percentages of the gonad dose which they already receive from natural sources.

We have conducted a limited survey which suggests that the additional dose received from the various forms of diagnostic radiology may well be higher than 22 per cent, the major amount of which is accounted for by examination of a relatively few sites of the body. The contribution made by the use of radiation in medical treatment cannot be accurately estimated; it is probably much less than that made by diagnostic radiology but greater than that received from any other artificial source.

Watches and clocks with radioactively luminous dials contribute about one per cent of additional radiation. X-rays from television sets account for much less than one per cent. The contribution from X-ray apparatus used in shoe-fitting is not likely to exceed 0.1 per cent.

The contribution arising from the work of the Atomic Energy Authority is the most accurately known, and is about 0.1 per cent. A study of the records of the National Radiological Protection Service has put the contribution from other occupational sources at about 1.6 per cent.

Contamination of the world by fall-out from the explosion of nuclear weapons

Continual watch is kept by the Atomic Energy Authority on the radioactive fall-out reaching this country from nuclear devices exploded in other parts of the world. From the bombs exploded up to the present time, the population of this country may expect to receive, over the next fifty years, additional radiation amounting to between 0.02 per cent and 0.04 per cent of the radiation which will be received over the same period from natural sources.

If the firing of bombs were to continue indefinitely at the same rate as over the past few years, radioactivity would gradually accumulate to a level at which an inhabitant of this country would receive an average dose of 0.026 r over a period of thirty years, or about one per cent of that which he would receive in the same period from natural sources.

The contribution of this figure from thermonuclear explosions, relative to their numbers, is very great. If the rate of firing of weapons of this type increases, exposure to radiation will be significantly raised.

Special hazards of radioactive fission products

It is unlikely that the inhalation of radioactive particles present in the air as a result of fall-out would constitute a problem in ordinary civil life.

The deposition of radioactive strontium is probably a greater hazard, because it is soluble and, if ingested, is deposited and retained in bone. Measurements which have been made of radioactive strontium in bone show that the highest levels are at present about a thousand times less than is considered permissible for those who are occupationally exposed.

Atomic war

Atomic bombs were developed for their capacity to create blast, but for persons exposed in the open that heat flash is equally to be feared. The ionizing radiations produced immediately after explosions have a much greater penetrating power than the heat rays, but the range at which they cause death or immediate injury is somewhat less. The hazard from radiations is therefore only one of the immediate effects of atomic explosions. Their peculiar danger lies in their distant and delayed effects.

Assessment of the Hazards of Exposure to Radiation

An attempt is made to assess the medical and genetic consequences of exposure to radiation at the levels of dosage which occur now or which might conceivably come about. The naturally occurring level of radiation can be accepted as a standard of reference, because it is a level to which mankind has long been adjusted.

In considering the genetic effects of radiation, we are concerned with the sum, over the whole population, of the total gonad dose received by its members from conception until the end of reproductive life.

In considering the effects of radiation upon the individual, we are concerned with his whole span of life, and with the rate at which the radiation is received as well as with its total dosage; and we must have regard to the possibility that the severity of the effects produced by radiation may increase in more than equal proportion to the dosage that is received.

Dosage and effects on the individual

The acute effects of radiation which appear within two months of exposure to a single dose or a few heavy doses do not enter into ordinary civil calculations; nor is it feared that they may be produced by repeated exposures to doses that do not exceed 0.3 r per week.

Of the delayed effects of irradiation of the whole body, leukaemia is probably the most easily induced. We consider that an individual could, without feeling undue concern about developing any of the delayed effects, accept a total dose of 200 r in his lifetime, additional to that received from the natural background, provided that this dose is distributed over tens of years and that the maximum weekly exposure, averaged over any period of 13 consecutive weeks, does not exceed 0.3 r. We recommend, however, that the aim should always be to keep the level of exposure as low as possible.

Dosage and genetic effects

The genetic effects of radiation are essentially problems concerning the future welfare of the population as a whole.

It follows from the nature of the genetic effects of radiation that a small fraction of population without harm to its members, receives dosages of radiation which would be likely to have serious genetic effects if applied to the population as a whole. We feel that an individual, considered as such, can accept a total gonad dose of not more than 50 r , from conception until the age of thirty, additional to that received from the natural background, without undue concern for himself or his offspring, but that the number of such individuals should not exceed one-fiftieth of the population as a whole.

Our present knowledge does not justify us in naming any specific figure as a limit for the average dose of radiation which might be received by the population as a whole. It is highly desirable that such a figure should be named as soon as possible; and we understand that the International Commission on Radiological Protection has this matter under consideration. In the meantime, we feel bound to state our opinion that it is unlikely that any authoritative recommendation will name a figure for permissible radiation dose to the whole population, additional to that received from the natural background, which is more than twice that of the general value for natural background radiation. The recommended value may, indeed, be appreciably lower than this.

The peacetime hazards from nuclear radiation

Nuclear energy may become the principal source of power. So far as its use affects the small numbers likely to be employed in its production, we believe that nuclear energy might make power available at a lower cost in accidents, illness and disability than that incurred in connexion with other sources of power. What is novel in the use of nuclear energy and the other, increasing, uses of processes producing radiations is the genetic risk to the community as a whole. The risk from civil usage is at present small, and seems unlikely ever to be large; but from the point of view of population genetics all possible extra radiation should be avoided, and it is not now too early to suggest where we might restrain its use.

With regard to occupational exposure we consider that the record of the Atomic Energy Authority shows the standard that is attainable and the practicability of being satisfied with nothing less.

We consider that the time has come for a review of present practice in diagnostic radiology, and of certain uses of radiation in the treatment of non-malignant conditions, particularly in children.

Among the less important sources of radiation, we hope that the use of X-rays in shoe-fitting, will be abandoned except when prescribed for orthopaedic reasons; that watches and clocks with radioactively luminous dials will be confined to necessary uses; and that the X-ray hazard from television tubes, at present negligible, will be borne in mind if special types of high voltage equipment come to be widely used.

Test explosions of nuclear weapons

The genetic effects to be expected from present or future radioactive fall-out from bombs fired at the present rate and in the present proportion of the different kinds are insignificant. They might not be so, if present rates of firing were increased and particularly if a greater number of thermonuclear weapons were tested.

So far as radioactive fall-out may affect the individual, we believe that immediate consideration would be required if the concentration of radioactive strontium in bone showed signs or rising greatly beyond that corresponding to one-hundredth of the maximum permissible occupational level.

Wartime hazards

361. The area in which a greater or lesser proportion of those exposed would be at serious risk from the radioactivity released by the ground burst of a thermonuclear weapon is measured in thousands of square miles. If a sufficient number of nuclear weapons were exploded, no part of the world would escape biologically significant degrees of exposure of the load of distress and suffering to individuals and society which such exposure would entail.

Report of the Physics Department, Faculty of Science, Alexandria University

RADIOACTIVE FALL-OUT IN ALEXANDRIA FROM NUCLEAR TESTS

Our measurements of radioactive fall-out, due to nuclear tests over Alexandria (around 3200 kms far from nuclear test site) began early in 1960. Air filtration is carried out at ground level with the aid of an air pump and a continuous air monitor. In this report we concern only with the variation of radioactive contamination of air as well as the fall-out deposited as a result of the nuclear tests. We have disregarded the measurements of radio-contamination of food and drinking water.

Figure (I) shows the air-born activity diagram. The French nuclear tests, mainly the second, the third and the fourth tests are clearly observed as peaks.

The background activity prior to the second French test was 0.1 millimicrocurie per cubic meter of air. No obvious increase in the activity of the collected samples was detected till April 11, 1960, when a pronounced increase in air contamination occurred. The radio-active 'cloud' stayed over Alexandria till May 8. During this period the activity was fluctuating, according to the meteorological conditions, and reached a peak on April 15, of about 8.5 uuc/m^3. The third French test took place on December 27, 1960. The increase of activity due to this explosion reached Alexandria on January 8, 1961. A peak of 2.62 uuc/m^3 was registered on January 16. The fourth French test contributed less activity, about 1.5 uuc/m^3 on April 30, 1961. It was worth noting that the air-born activity curve shows a real increase of air contamination just before the third and fourth French tests. These two registered excesses of contamination are of 'unknown' origin(s).

Figure (II) shows the deposited activity diagram. It is a measure of the deposited activity after the fourth French test.

As a result of these tests, the estimated activity uptake by the normal human body due to breathing during the last year is 2.5.

millimicrocurie. Moreover, the human body was exposed to an external radiation of the contaminated air estimated to be 0.04 millimicrocurie during the last year. Rough estimates show that the overall effects of contamination gave rise to an integrated radiation dosage of the order of one milli-rem unit in the last year. Fortunately, it is a small amount far beyond the maximum permissible dose of radiation.

Although the measured amount of these radiations exposed to human beings in Alexandria are really small, yet there might be very good reasons to expect some genetic effects of radiation after a long time, especially for nearer regions, but these are extremely difficult to be evaluated.

NOTE : The graphs referred to in the report—(Figures I and II)—are not reproduced.

* This report is contained in the M. Sc. thesis of Mr. E.A. Ammar to be submitted to the Physics Department. Faculty of Science, Alexandria University.