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LECTURE TO THE INSURANCE INSTITUTE ON THE FIRE HAZARDS OF RADIO-ACTIVE MATERIALS

by

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INTRODUCTION

Every year more and more radioactive materials are being used; and the total shipments have grown in this country from 135 in 1947 to over 19,000 last year. This is illustrated in the first slide. By 1965 it is hoped that nuclear power stations will be producing some 2,000 megawatts and this will mean that still larger quantities of radioactive materials will become available. In 1935 the total amount of uranium in the world had an activity of something like 2,000 curies, and this was distributed in small quantities. At present it is not uncommon to manipulate at any one time quantities of 100,000 curies in flammable solvents, and the activities in the materials in the nuclear power stations which are envisaged will amount to tens of millions of curies. It is understandable, therefore, that the population in general, and the Insurance Companies in particular, feel a certain amount of apprehension about these new developments

Radioactive materials are those which undergo transmutation, while at the same time giving off radiation. It is not necessary for us to consider the processes which go on during this transmutation any more than it is necessary for fire insurance assessor to understand the complex chemical changes wood undergoes when it burns. The comparison is, in fact, particularly apposite because the radiations given off by radio-active substances are not changed either in quantity or quality by the application of fire.

Radioactive materials themselves are not more flammable than their non-radioactive counterparts. The only difficulty is that they may be dispersed by fire, and either the materials themselves or the radiations they give off will be absorbed in sufficient quantity to give rise to certain biological effects.

In dealing with this particular fire hazard it is necessary first to deal briefly with the biological effects of radiation and then consider what steps may be taken to avoid dispersing radio-isotopes in fire.

The rays which are emitted if absorbed on the skin produce burns which may be quite superficial, resembling sunburn, or for greater exposures they may be quite deep and resemble the third degree burn caused by intense heating or high pressure steam. The outstanding effects of exposure are loss of hair, altered heredity of offspring, destruction and death of the bones, loss of ability to reproduce, decrease in the number of white blood cells, or cancer.

The effects of radiation have been well known for a long time, for the early workers with X-rays often suffered from the effects of over exposure, and in the past workers employed in the painting of luminous dials on watches have died from bone necrosis, moreover, cancer of the lung is known to be an occupational disease in uranium mines.

Radioactive substances as they give off radiation gradually decay so that the radiation becomes progressively more feeble. The half life of a radioactive substance is the time for the activity to fall to one half and depending on the material this may be reckoned in millions of years or millionths of a second. As a general rule the shorter the half life the more active the material weight for weight. The assessment of the danger associated with any radioactive substance will depend on

its half life (the shorter the half life the less the hazard), the energy and character of its radiation, the selective localisation of the substance in the body, the ability of the body to eliminate the substance, and the quantities and typical modes of handling. Among the most dangerous radioactive substances are carbon ^{14}, calcium ^{45}, iron ^{55}, strontium ^{90} and bismuth ^{210}.

In talking about the effect of radiation on the human body, it is convenient to classify the types of exposure under two heads:- external exposure in which the body is subjected to penetrating radiation from the outside, and internal exposure due to the injestion, or inhalation of radioactive substances. There are at least seven different types of radiation, though only three will be actually met with in practice. The others will be encountered only near to large atomic piles and during atomic explosions. The three most common types are:-

1. Alpha particles. These have a range of not more than 10 cm in air and 0·1 mm in tissue. Radioactive substances emitting Alpha particles are only dangerous if taken into the body by either decontaminated food or by breathing radioactive dusts. The rays themselves are readily stopped by even a thin layer of paper or by the outer layers of the skin. Though radioactive materials emitting this kind of radiation are themselves quite innocuous on the outside of the skin, they must, of course, be removed by thorough washing to prevent them being injested during feeding.

2. Beta particles. These have a range of several centimetres in air and 3 centimetres in tissue. Radioactive substances emitting this type of radiation can constitute an external hazard because of the significant distances that Beta particles can penetrate tissue. Of course, Beta particle emitters taken internally will cause damage to the more deep seated tissues.

3. Gamma rays. Gamma rays have properties identical with X-rays and they usually, though not invariably, accompany Alpha or Beta radiation. Because of their penetrating power they obviously constitute an external as well as an internal hazard. Their penetrating power is such that more than one cm of lead or several feet of concrete may be required to absorb them. In air the intensity of the radiation falls off according to an inverse square law, that is in the same way that the illumination from an electric light bulb decreases with distance.

A much rarer type of radiation hazard is that of neutrons. These are particles which have the ability to make substances radioactive, and are thus obviously dangerous to human tissue. Some materials such as cadmium and boron readily absorb neutrons, and chemical compounds containing these elements are very often used in neutron shields.

There are four well accepted ways of reducing radiation hazards: first by shielding: second by remote controlled manipulation or handling: third by increasing one's distance from the radioactive substance, and lastly by reducing the time of exposure as far as possible.

In dealing with an emergency such as fire-fighting, it is these latter two measures which are the most important. The range of Alpha and Beta particles in air is very limited, so that at a distance of a foot or so from the source the radiation falls to an insignificant level. The intensity of Gamma radiation falls away at least as rapidly as an inverse square law, so that doubling one's distance from the source reduces the intensity by a factor of 4, etc. The distance factor by itself is very important. The damage sustained by any exposure is a product of the intensity of the radiation and the time of exposure, so that if one is only going to be exposed for a limited time, as in fire-fighting, one can withstand intensities of radiation which would be prohibitive for anyone carrying out continuous work with radioactive substances.

The use of radioactive materials

It is necessary now to say something about uses of radioactive materials, their probable location and the quantities in which they are used. Radioactive materials will be found in four different types of place:-

Government Research Laboratories,
Nuclear Power Stations,
Industrial and Chemical Research Laboratories,

and, of course, during transportation.

Government Research Laboratories

The main concentration of radioactive materials is, of course, in reactors, and every possible safeguard has been taken to avoid any accidents, as quite apart from anything else the apparatus and its fuel are very valuable. Most of these are inherently stable, and any serious overheating would damage the reactor and ultimately lead to a reduction in the power. To prevent this elaborate shut-down systems have been devised should the temperature of the full elements begin to rise.

Careful emergency procedures have been worked out, and the Fire Brigades are well equipped to deal with any incident.

The danger to a reactor from an external fire is quite negligible because of the great thickness of concrete surrounding the radioactive components in order to give adequate biological shielding. Radioactive materials are, or course, used in the laboratories of the nuclear research stations, but in these cases the quantities are very much smaller and the activity is many millions of times less than those found in the reactors. Here again elaborate precautions are taken to avoid accidents, and radioactive materials are always handled inside hoods into which air is being sucked in order to avoid dispersal of the contents. Radioactive materials of higher activities are handled in special compartments by remote handling systems. The Fire Brigades in these Government Departments have special instructions on how to deal with fires in which radioactive materials are involved, and this I will deal with later under the general heading of fire-fighting.

The general working level of radiation in Government Laboratories is kept very low. This is necessary because the same diseases which are caused by over exposure to radiation also occur naturally, and one could only prove that the radiation level was too high by examining the incidence of a particular disease on a statistical basis, this would take a long time. It is possible, however, to estimate the shortening of life associated with any given level of radiation. Of course, many things are held to shorten human life, use of narcotics, indulgence in alcohol, over-feeding to mention only a few. People accept these risks not because they are unavoidable, but in exchange for some other value, real or imaginary. Recently we have been told about the effects of cigarette smoking on the span of human life. It has been estimated that the maximum permissible level of radiation is about as hazardous to human life as smoking four cigarettes a day. The radiation levels at present are being kept down to about 1/30 of this figure.

Perhaps I should end this Section on Government Laboratories by saying that there have been two instances of reactors becoming out of control. In neither case was there any mechanical damage outside the reactor, nor was there any release of fission products to the atmosphere.

The first was an accident at Chalk River in 1952 when the supply of coolant to the reactor was interrupted. In this case the events followed a pattern such as would have been expected. The fuel rods overheated and melted. The reactor was repaired for about 10 per cent of its original cost. The second occurred in Chicago, at the Argonne National Laboratory in 1954, when a reactor was deliberately forced to explode to see what would happen. The explosion was a relatively mild one, as will be seen from Figure 2, comparable to that which would be produced by a few pounds of T.N.T. The catostrophic release of energy characteristic of nuclear devices was prevented by the inherently safe characteristics of the reactor, even though the planned accident was much more severe than might be expected to occur in actual operations.

Nuclear Power Stations

The first nuclear power station is scheduled to come into service in this country next year. This is being built at Calder Hall in Cumberland and it will use natural or slightly enriched uranium as a fuel, and in addition to producing electrical power it will produce plutonium as a very useful by-product. This station is the first of twelve such stations which will come into use by 1965, and it is hoped that these will produce some 2,000 megawatts of power. A schematic diagram is shown in Figure 3.

The uranium rods are housed in a block of graphite about 40 ft. in diameter, and the cost of the initial charge of the uranium may amount to £5,000,000, and this will need renewing every three to five years. This reactor is housed in a pressure vessel, which in turn is surrounded by a concrete shield some 5 ft. thick. The coolant in this case is carbon dioxide gas, which is circulated under pressure through the reactor, and this then passes into a heat exchanger where it is used for steam raising. The pressure of the circulating carbon dioxide is 105 lb/in.^{2} and it emerges from the reactor with a temperature of 350°C. The reactor is of the inherently safe type. Any interruption in the coolant would merely result in the uranium rods melting, as the uranium itself is insufficiently enriched to cause an explosion.

From time to time it will be necessary to remove what we might call the ashes from this uranium fire. These will consist of the radioactive fission products of the uranium 235, non-radioactive uranium 238, and a certain amount of plutonium. The chemical processing will consist of removing the plutonium and fission products and re-enriching the uranium 238 with uranium 235.

Every ton of rods discharged from the reactor contains about a pound of plutonium, and a similar weight of radioactive fission products. In the separation process used at Windscale the rods are dissolved in acid and the solution mixed in an organic solvent. The uranium and plutonium pass into the solvent and removed with it, while most of the fission products remain in the acid solution. The plutonium is then separated from the uranium by another similar process. It is ~~rather~~ in these chemical separation processes that the danger of dispersing radioactive materials probably lies rather than in the reactors themselves.

While dealing with chemical separation I might mention two other nuclear chemical plants at present in operation in the United Kingdom. One is at Springfields, and this is concerned with purifying uranium, but the processes used here are no more hazardous than in any ordinary metal refining plant though great care must be taken to avoid the dispersal of uranium in the air as the maximum permissible contamination level for the air is only about two millionths of an ounce per cubic yard. The purpose of the other plant which is at Capenhurst in Cheshire is to treat natural uranium in such a way as to increase its content of uranium 235 to almost any extent, even producing practically pure uranium 235.

This is a gaseous diffusion plant, and its operation is based on the fact that if a gas containing a mixture of molecules, some of which are heavier than others, is pumped through a membrane containing a large number of small holes, the lighter molecules will pass through the membrane more easily than the heavier ones, and so the concentration of the lighter molecules on the gas issuing on the other side of the membrane is greater than that of the gas fed into the system. The uranium is turned into a gas by combining it with fluorine, and the compound uranium hexafluoride which is formed is very reactive, in fact it reacts chemically with nearly all metals. It combines with water to form solid compounds which would block the small pores in the system, so that all traces of water vapour have to be excluded, and to make things even more difficult, this compound is gaseous only at temperatures in excess of 100°F, and the whole processing plant has to be kept at this temperature.

Fast reactors

Another type of reactor is being built in Scotland at Dounreary. This is an experimental plant which may be a forerunner of the power stations in the future. A section of this reactor is shown in Figure 4. The core will consist of a stainless steel pot about 2 ft. in diameter and 2 ft. long. Into this will be placed uranium enriched with uranium 235 or plutonium 239, and the cost of this fissile material is measured in thousands of pounds per pound. This fuel will be surrounded by a blanket of uranium and possibly thorium which in turn will slowly be converted into fuel as the reaction proceeds.

For the operation of the pile it will be necessary to remove some 60 megawatts of heat from this stainless steel pot, and to do this liquid sodium with possibly some addition of potassium will be pumped through stainless steel tubes in the pot and then through a heat exchanger. The pumping is carried out by electromagnetic pumps which have no moving parts, and which are completely sealed. Elaborate precautions can be taken to maintain the flow of coolant, the cooling system being divided into twenty-four separate circuits in practice, twenty feeding the radioactive core and four the blanket. The power supplies to the pumps are separated and these are fed by diesel generators, each of which is connected to only two of the pumps, so that the failure of one generator would only cut out 1/10 of the pumps. The flow through the core would fall by a rather larger fraction because some of the coolant would flow in the wrong direction through the ineffective pumps. Even so the reduction in flow would not be reduced by a dangerously large amount.

The sodium in this cooling circuit becomes very radioactive, and so it would not be prudent to use this in a heat exchanger for steam raising immediately. The heat exchanger is therefore used to heat a secondary liquid metal circuit also containing sodium, and this in turn passes into a second heat exchanger where the heat is used for steam raising.

The stainless steel pot in which the reaction takes place is surrounded by 4 ft. of borated graphite, the function of this is to absorb the neutrons from the reaction, and this in turn, together with the primary heat exchangers is contained in a huge concrete bowl 5 ft. thick. In the event of a total failure of the electrical supplies, the reactor would be shut-down, and the heat from the core would be dissipated in an emergency air-cooled circuit. The whole reactor and its concrete bowl is encased in a sphere 135 ft. in diameter. This would not be sufficiently strong to contain an explosion should it occur, but it is confidently believed, however, that the danger of this can be eliminated by the suitable design of the control system, and of the core itself. The function of the sphere is to contain any fission products which might escape; with something like one hundred million curies in the core, an escape of more than a few per cent would be a very substantial hazard over a wide area. The liquid metal coolant brings with it the risk

of fire, and to reduce this risk, no significant quantity of water will be allowed in the sphere. It is possible, though improbable, that if a leak occurred the sodium from the coolant circuit could burn in the oxygen contained in the air in the containing sphere. Sodium, however, is not a very good fuel because it requires one-half the heat it gives out in burning, to vaporise an equal quantity of fresh sodium so that the burning process can continue. It has been calculated that if the sodium in the coolant circuit burned completely, then the temperature of the air in the sphere might reach 340°C. This would produce a maximum pressure of 16 lb/in.$^{-2}$ some fifteen minutes after the fire started. The sphere itself has been designed for a maximum internal working pressure of 15 lb/in.$^{-2}$.

Of course, if the sodium burned completely it would remove the oxygen from the air, and when this cooled down in the sphere a partial vacuum would be created. It has been estimated that the external excess pressure would be about 3 lb/in.$^{-2}$. The pressure which the sphere would stand in this way would depend on its uniformity, and the most pessimistic estimate is that at 5 lb/in.$^{-2}$ excess external pressure, a shallow dimple some 18 ft. in diameter would appear at the top. This would not cause stresses in the steel greater than 1 ton/in.$^{-2}$.

In order to assist in cooling the sphere should any accident occur, it has been arranged for water to be piped over the top, so that you will see that most eventualities seem to have been taken care of.

Radioactive materials in industry

Radioactive materials are now so widely used in industry that it would be impossible to give any guidance as to where they might be found. They are used in industrial radiography, in the petroleum industry for tracing the flow of oil in pipes, in the motor industry for lubrication studies on cylinders, and metallurgical laboratories use them whenever infinitesimally small quantities of metal have to be measured. They may be used in production lines for the routine measurement of the thickness of materials, and for the dissipation of static electricity.

Chemical research laboratories use radioactive materials for labelling atoms in order to keep track of any one particular element in a chemical reaction. They are used in plant and animal nutrition experiments, and also in medicine, in studies of circulation, gland physiology, and the location of brain tumours not to mention the deep ray therapy that is now being carried out with radioactive cobalt.

This does not pretend to be a complete catalogue of the many diverse uses of radioactive materials at present, and no doubt their use will be further extended in the future when cheap supplies of radioactive materials become available from atomic power plants. Possible future uses involving large quantities of radioactive materials would be the sterilisation of food, the promotion of polymerization in plastics, and the possible use of radioactive isotopes in the cracking of petroleum oils to increase the yields of the lighter factions.

It may well be that these future applications will turn on whether the large amounts of radioactive materials, which need to be used, can be handled with safety.

The quantities of radioactive substances in use in industry at present are small, the most common one being iodine, and this is followed by phosphorus and caesium, which are much less frequently used.

There are at present no factory regulations dealing with the general use of radioactive isotopes in industry, but both the Factory Department of the Ministry of Labour and National Service, and the Industrial Section of the Atomic Research Establishment at Harwell are always pleased to give any advice to potential users.

The most powerful sources in use at present are employed in industrial radiography, and it is these which have first claim on our attention. The safe storage of these Gamma ray sources whether they are for use in the factory or on site by contractors is a matter of importance. It is preferable to store them well away from normal working areas. If these are to be stored within a building then they should be placed in a conventional type of safe housing made of lead or iron, this will stop any dangerous radiations, and this should then be kept in either a brick or concrete compartment 9 in. thick. This will prevent the radioactive materials being dispersed in the event of a fire. Alternatively, radioactive materials should be kept outside the factory in a lined borehole of suitable depth provided with a padlocked cover.

In the event of a capsule containing a radioactive dust being broken or involved in a localised fire, the capsule should be covered with a wet towel. Workers should be excluded and ventilation fans be switched off, the area should then be left until expert helpers equipped with respirators and suitable protective clothing can be called to clear up the contamination. It need hardly be said that an immediate check should be made for possible contamination on the clothes and person of any worker immediately involved in the capsule breakage.

Radioactive materials are also used on industrial production lines as static eliminators, and thickness gauges, but the radioactive materials here are firmly bonded within noble metals in the foils, plaques and wires supplied by the Radio Chemical Centre at Amersham, so that they cannot become dispersed into the surrounding work room either suddenly by accident, or as a result of fire.

It is sometimes necessary to use unsealed radioactive components, as for example in work on nutrition and on work on lubrication. When unsealed radioactive materials are being used it is necessary to take extreme care to avoid any accident. It is perhaps fortunate that it is not usually necessary to handle any but the smallest quantities of radioactive materials in this unsealed condition. This subject has been dealt with at length for the Medical Research Council by the Atomic Energy Research Establishment in a publication, "Introductory Manual on the Control of Health Hazards from Radioactive Materials", a copy of this can be obtained gratis on application to the Secretary of the Medical Research Council, 38 Old Queen Street, London, S.W.1.

At present the Ministry of Labour and National Service are informed of all deliveries of radioactive materials, and in all cases the appropriate District Staff are notified. Visits are made to where it is thought that advice may be necessary, or where some definite query has been raised by the firm.

The transportation of radioactive materials

Radioactive materials are most frequently used as sources of Gamma rays, and for this purpose the radioactive materials can be sealed in aluminium containers which the Gamma rays readily penetrate. The Gamma capsule itself for purposes of shipment is contained in a lead or iron container, which forms an effective screen against the radiation. Some of the shipments are used as Beta particle emitters, and here it is not possible to enclose the material in an aluminium capsule In these cases the radioactive substance is covered with a thin foil which is penetrated by the Beta rays, but the foil, of course, prevents the materials being dispersed.

Radioactive materials may be sent through the post provided the radiation which they emit is weak enough, the limit is set by whether they would be liable to "fog" unexposed photographic material, which may also be in course of transmission through the mails.

Radioactive materials may also be sent by rail in any one of three categories. In category A transport a special van is made available for transporting the radioactive substances. This method of transportation, however, is rarely used and it is inconvenient and costly.

In the other two methods of rail transport the radioactive materials are sent as ordinary goods, the difference being in the allowable amounts of radiation in the two cases. This again is based on possible damage to consignments of photographic materials which might be near to the radioactive substances. In one type of consignment the radiation level must be so low as to cause no damage to photographic materials placed close to the radioactive material. In the other type photographic materials are kept 6 ft. away. No special fire precautions are taken.

Cars are sometimes used for the delivery of radioactive materials, the criterion here is that the external radiation from the cargo must be safe for the driver. Sometimes the activity of the radioactive materials transported in this way is rather higher than those sent by rail, but largely this form of transport is used primarily as a matter of convenience. Instructions are posted inside the driver's cab on the vehicle indicating what steps should be taken if an accident occurs.

There is also transport of radioactive materials by road between Government Atomic Research Establishments. This would, among other things, consist of waste products from reactors. The radioactive materials are in a liquid form and have an activity higher than any of the others mentioned so far. Such shipments are always accompanied by a capable officer who should be able to give information as to what action should be taken in the event of an emergency. The Fire Brigades are not at present warned when these shipments take place, though these generally proceed along well recognized routes.

Firefighting and radioactive materials

It is important when dealing with fires in which radioactive materials are involved, to keep a sense of perspective. I suppose that radioactive materials in most people's minds are linked with such things as the atomic bomb, cancer and the after-math of such explosions as occurred at Hiroshima and Nagasaki. There is a feeling also that these mysterious substances are giving off radiations which cannot be seen, and therefore one is never quite sure what actual hazard exists.

Of course, the fireman has been dealing with unseen hazards for a long time, and he now knows the proper precautions to take with such invisible hazards as electricity, carbon monoxide and flammable vapours. The level of radiation can, of course, be measured equally as accurately as these hazards I have just mentioned, but the truth of the matter is that apart from such apparatus as reactors and atomic power stations and their chemical separation plants, the level of radiation is very small. Indeed we are all being exposed to radioactive radiations all the time. The luminous dial of a watch gives off far more radiation than the average worker in an atomic energy plant receives, and the taking of an X-ray picture of the chest exposes us to fifty times as much radiation as the daily tolerance permitted in nuclear research establishments.

The fireman will always be exposed to dangers by the very nature of his job. He may become trapped in a burning building, injured by falling debris, or he may himself fall into a void in a smoke-logged building. It will never be possible to eliminate completely accidents due to exposure to radioactive materials, it can only be hoped that they can be kept within the same bounds as the other hazards to which the fireman is accustomed. One thing must be remembered, the fireman during firefighting has only a relatively brief contact with radiation, and therefore can withstand many, many times the level of radiation that would be tolerable for a worker engaged in the continuous handling of radioactive materials.

I can do no better than close this section with some advice to firefighters, given by Mr. Edward J. Keyhoe of the United States Atomic Energy Commission:-

(1) Consult and comply with the on-the-spot recommendations of the trained personnel associated with the project. Where any extra hazardous radioactive materials are being handled, such personnel will be available at all times.

(2) Wear breathing apparatus in any serious fire; the self-contained type is preferable. Remember that these materials are most frequently found in chemical plants and laboratories where, fortunately, modern firefighting practice now utilizes breathing apparatus as standard equipment.

(3) Avoid unnecessarily disturbing or stirring-up any materials and smashing any laboratory glasswear and apparatus. Firefighting operations should be conducted as carefully as possible. The use of water should be minimised to prevent the washing away and running-off the radioactive materials.

(4) Avoid smoking, eating or drinking in a fire area, this will practically eliminate the possibility of swallowing radioactive materials.

(5) Avoid handling materials with the bare hands. If the presence of radioactive materials is suspected use shovels or gloves.

(6) Avoid remaining in the fire area longer than necessary. However, remember the radiation tolerance level used for employees in nuclear plants is extremely low because it is expected that the men may be exposed day after day, year after year, for his entire working life, and the fireman, who is exposed on rare occasions, can take many, many times the daily tolerance limit without ill effects.

(7) Co-operate with trained technicians on the scene and their application of whatever routine health and safety precautions they deem necessary.

(8) Personnel who have operated at a fire should take a shower as soon as possible thereafter.

You will note that these precautions are not particularised to radioactive material, they are the ordinary precautions that one would take in dealing with a fire in any chemical plant.

Insurance for atomic projects

I suppose that the question of insuring an atomic plant is one that comes nearest to your hearts, but I am, however, no expert in insurance matters, nor, as far as I know, has any settled policy been formulated in this country. The current belief in America at present

is that reactors are insurable at commercial rates, and they will be considered in the category of the more hazardous types of chemical reactions.

Physical damage to reactors is handled up to a prescribed limit in the same way as boiler and machinery coverage on extra hazardous machinery. The belief is that a nuclear explosion, although more serious than anything now known in industry, is likely to be remote, and that the precautions made in developing controls, and the steps that are taken to contain any radioactive materials, will make the chance of a serious incident very small. The most serious problem may be the Third Party Liability Insurance, where the insurer, faced with a catastrophe, might be called upon to meet the claims of extreme magnitude for property losses in the immediate surroundings, decontamination and workmen's compensation, losses from other plants in the general area adjacent to the reactor site.

It has been suggested that it would be desirable to form eventually special pools of underwriting groups for handling direct coverage on the plants. The insurance experts feel that an agreeable maximum limit or primary liability can be worked out, but as a matter of public policy, they say it should be the Government's decision and responsibility whether or not to create a special fund which would provide a means of insurance in excess of the capacity of the commercial market.

The accident record so far in Government Establishments is very good indeed, only two people have died from radiation since the beginning of modern atomic energy operations, and these were in the United States. This, of course, was two too many, but it is a level which compares very favourably with other industries. Of the accidents occurring, these are the normal accidents which would occur in any industry. The only person who has been killed on the Atomic Energy Authority's Station at Harwell fell off scaffolding!

The tolerance levels which have been set at present have often been criticised as being unduly low, and therefore unnecessarily costly, but this is surely a correct policy in dealing with a subject which is so young and about which we have so much to learn.

PC.