safety standards: principles and practice

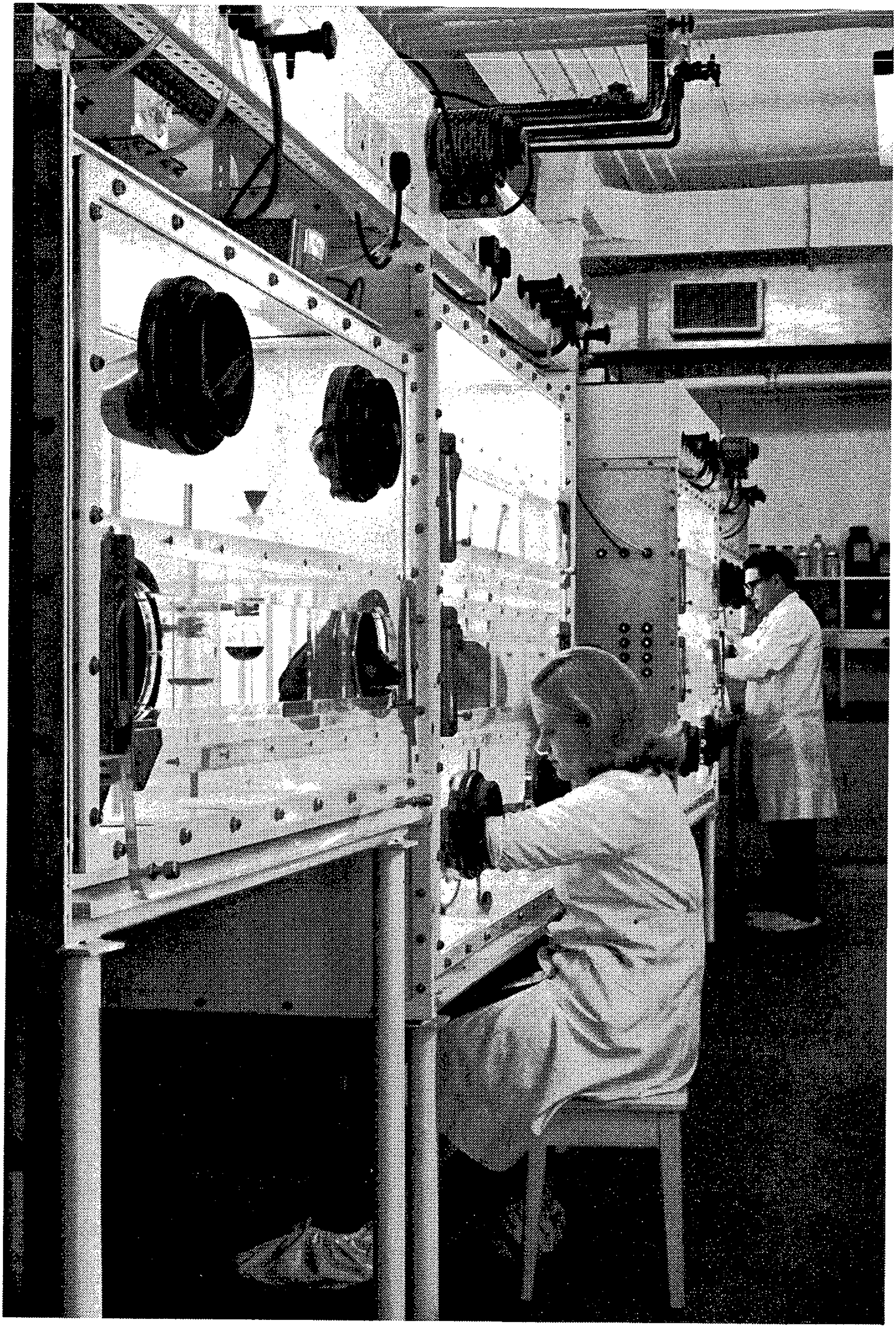
The authors of this article are H.J. Dunster, of the United Kingdom National Radiological Protection Board, Harwell, and A. Preston, of the UK Ministry of Agriculture, Fisheries and Food, Fisheries Radiobiological Laboratory, Lowestoft, Suffolk. In it, they discuss the safety criteria used in the UK for the release of radioactive materials to the environment, and experience gained during the past 25 years.

The development of nuclear power and its byproducts has resulted inevitably in the release of some radioactive material to man's environment. Because the dangers of radioactivity were well recognised many years before these developments, the quantities released and the methods of release have been kept under very careful control by national authorities. Nevertheless, there is still a good deal of controversy about the way in which basic radiation safety standards should be applied to the control of such releases. Although the methods used in the United Kingdom represent only one of many possible approaches, it is worth summarizing them because they have proved simple and straightforward in application, and have enabled a very satisfactory standard of control to be maintained over a substantial nuclear power programme.

The United Kingdom has 25 years of experience of the utilization of nuclear energy, and has been using it to generate electricity for more than half this time. Throughout this period, considerable care has been taken in the management of radioactive wastes, and the first decade's experience was used as the basis of government policy and the associated legislation. The government policy [1], published some 12 years ago, included two basic principles. The first was to ensure, irrespective of cost, that exposure of individual members of the public remained within the dose limits recommended by the International Commission on Radiological Protection [2], and that the genetic dose from waste disposal remained below a limit of 1 rem per person in 30 years. The second principle was to do what was reasonably practicable, now taking due account of cost, to reduce doses far below these levels.

Dose limits

The dose limits for members of the public recommended by ICRP are derived by that body from their recommendations for maximum permissible doses for workers. These, in turn, have been obtained partly by a historical process of reviewing of earlier recommendations and partly



by direct comparison with the now substantial amount of human data of the effects of high doses of radiation delivered in short periods. The process of extrapolating this high dose information down to the levels recommended for exposure of members of the public is one requiring considerable judgment, and at present it is usual to make the cautious assumption that the risk of deleterious effects is directly proportional to the dose over the whole of this extrapolated dose range, and is also independent of changes in dose rate or protraction of the dose over many decades. There are sound biological reasons for believing that these assumptions substantially overestimate the risks at the low doses implicit in the control of radioactive wastes. The Commission itself says of these assumptions [3] that they may often "suffice to assess what is considered to be an upper limit of hazard against which the benefit of a practice or the hazard of an alternative practice, not involving radiation exposure, may be based". They add, however, that "in the choice of alternative practices, radiation risk estimates should be used only with great caution, and with explicit recognition of the possibility that the actual risk at low doses may be much lower than that implied by deliberately cautious assumptions".

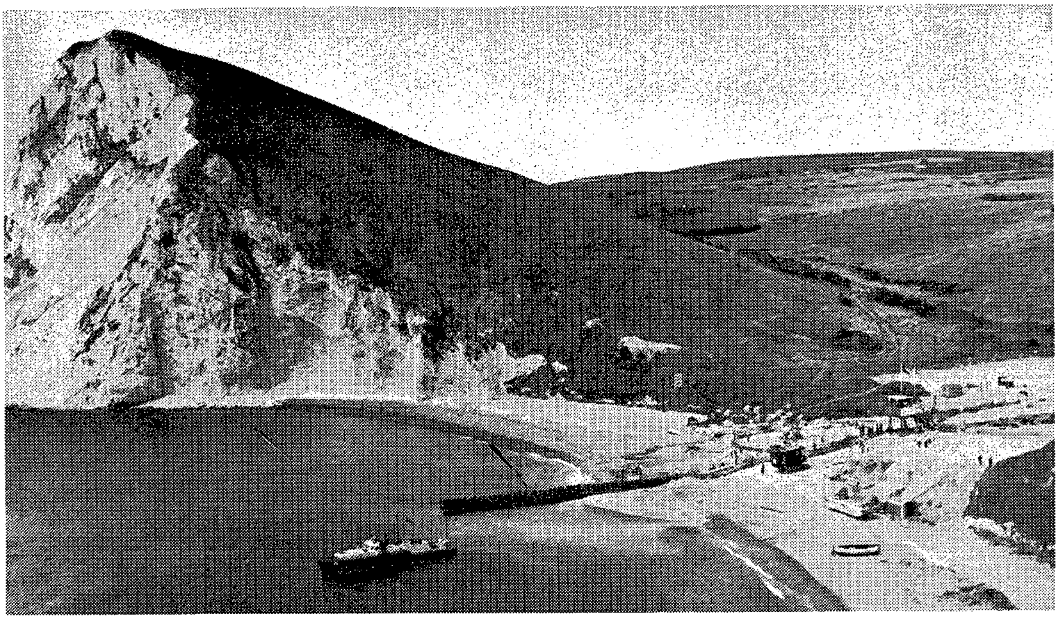
These views have achieved worldwide and almost unanimous acceptance. Nevertheless, there are a few workers who claim that an even more pessimistic interpretation of the facts is possible and claim, as a result, that the dose limits should be reduced. Detailed studies of these suggestions have not indicated that they are well-founded but, nevertheless, it would be wrong to ignore them. This emphasizes the importance of a further recommendation of ICRP to the effect that all exposures should be kept as low as is readily achievable, social and economic aspects being taken into account. This recommendation has an effect very similar to the second principle used in the control of radioactive wastes in Britain, the principle of doing what is reasonably practicable to reduce doses far below the dose limits.

Waste management

The practical application of the waste management principles in Britain requires two distinct procedures. The first is a scientific procedure aimed at forecasting the radiation doses which would result from any proposed release of waste to the environment. The second procedure is a process of discussion aimed at deciding how far the discharges can be reduced by methods which can legitimately be described as "reasonably practicable". When both these procedures are complete the statutory limits for that particular release can be specified.

The scientific studies have been based, since the late 1940s, on the now well-known method of the critical pathway, and the experience gained allows even major releases to be assessed by very simple methods. For most environments, a simple model can be postulated to describe the dispersion mechanisms and enough information is available to superimpose on this the effects of reconcentration processes. The results are quite adequate for planning purposes and, if necessary, can be refined by further studies before and during the initial discharges. For the more common situations where only small amounts of radioactivity are released in waste, these methods show that the resulting doses to man will be literally trivial. Even in these cases, however, the second procedure has also been applied, and releases have not been permitted if they could reasonably have been eliminated or reduced. In assessing what is reasonable in the circumstances the government inspectors take account of the economic and technical feasibility of achieving reductions and also of the expected level of dose and the magnitude of the available reductions of dose, in relation to the dose limits recommended by ICRP.

Workers preparing radiochemicals at Amersham, in the UK: their exposure to radiation is strictly limited.
Photo: UKAEA



A stage in the construction of a pipeline for the discharge of effluents from the UKAEA establishment at Winfrith Heath. Photo: UKAEA

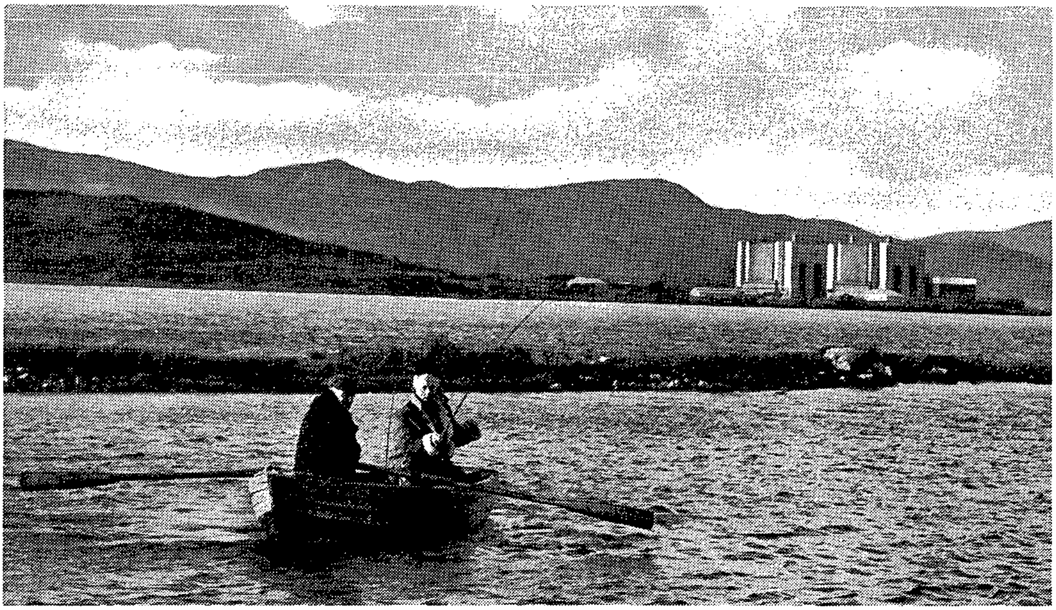
It has sometimes been suggested that these qualitative concepts should be converted to numerical guidance. However, it is part of their strength that they allow the statutory controls to be adjusted to a very wide range of situations. Phrases like "reasonably practicable" and "the best practicable means" occur widely in British Statutory Instruments relating to safety, and attempts to quantify them would be generally disadvantageous.

The final stage is the granting of a statutory authorization, without which any disposal of radioactive waste is illegal. The government departments issuing these authorizations in England are the Department of the Environment and the Ministry of Agriculture, Fisheries and Food.

There is a complex relationship between the basic recommendations of the ICRP and the statutory discharge limits, and there has sometimes been confusion of terminology, especially in the use of the term "radiation standard". In the context of this paper, a radiation standard would be a combination of the numerical dose limits recommended by ICRP and the qualitative procedures, also recommended by ICRP, to ensure that the actual doses received fall well below these numerical limits. Statutory discharge limits derived by the foregoing procedures would not then be called radiation standards. In other contexts, the same broad procedures have been used to arrive at levels of dose which are as low as practicable for a particular type of operation, and these levels of dose have then been called radiation standards. These two uses of the term "standard" can often be distinguished by their context, but the possibility of confusion is obvious.

The present position

The principal source of radiation exposure of the public from waste disposal in the United Kingdom has naturally been from the major users and the most important source in this context is liquid wastes. Gaseous and solid wastes have contributed negligibly by comparison. Most of the nuclear sites in Britain are on the coast, and their liquid wastes are discharged to coastal



Fly fishing trials taking place on the lake at the Trawsfynydd nuclear power station, in the UK.
Photo: Central Electricity Generating Board

or estuarine waters. Of the nuclear power stations only one discharges to fresh water. The research establishments at Harwell and Aldermaston and the Isotope Production Plant at Amersham discharge some radioactive waste to the River Thames.

The radiation doses to individuals resulting from these discharges have been summarized for the year 1970 by Mitchell [4]. For the coastal and estuarine power stations, the radiation doses are generally less than 0.1 per cent of the dose limits for individuals recommended by ICRP. For the one power station on inland waters the figure is about 3 per cent. Only in the case of the Fuel Reprocessing Plant at Windscale does the figure rise as high as 10 per cent. All these figures relate to the most highly exposed or critical groups, and the numbers of people in these groups are, generally speaking, very small. The total contribution to population dose from waste disposal in the United Kingdom is exceedingly small, no more than a few hundred man-rems per year, compared with an annual total background dose of five million man-rems per year. Indeed, it is noteworthy that the principal contribution to the population dose is from occupational exposure and is of the order of some thousands of man-rems per year from the United Kingdom power programme.

The future

The present position is highly satisfactory, but it is important to see whether it is likely to remain satisfactory as nuclear power in Britain increases by a factor of 10, or perhaps 30, over the next few decades [5]. There should be no difficulty in limiting the doses from the wastes from nuclear power stations; the critical groups are small in size, and the interaction even of adjacent power stations will be only marginal in its effect on their doses. The use of inland sites for nuclear generating stations may increase the individual doses somewhat, and may also increase the size of the exposed groups. Nevertheless, the total genetic dose will remain far below the figure specified in government policy. It is expected that the existing factories concerned with the fuel cycle, that is, the fabrication and reprocessing of nuclear fuel, will continue to handle the increasing load of the next few years. Past experience shows that the effectiveness of processing and waste management in these plants has increased progressively over the years so that there has been no proportional increase in the level of radioactive discharges to the environment. For all nuclides except tritium and krypton-85 this situation is expected to be maintained during the next few decades. The arisings of tritium and krypton-85 increase roughly in proportion to the power programme, and neither can be easily removed from the waste systems. The bulk of the tritium appears in liquid systems and is therefore discharged to sea. This is by far the best way of disposal of tritium because of the large isotopic dilution and the small transfer of water from a localized region of the sea back to man. Over the next two decades the discharges of tritium to sea from the British reprocessing plant will rise to about 1 megacurie per year, which is no more than about 1/10 000 of the capacity of the local environment to receive tritium without resulting in unacceptable doses to man. It is also clear that these quantities of tritium will not cause any ecological changes.

Krypton-85 appears in the gaseous wastes from the early stages of chemical reprocessing. This gives rise to some beta radiation of skin in people adjacent to the plant, and to a very much smaller level of gamma radiation to the whole body and to the gonads. A review of the krypton problem [6] concluded that by the end of this century there would still be no appreciable problem from these radiation doses, either in the vicinity of the reprocessing plant or averaged over the whole of the United Kingdom population, or resulting from the world-wide production of krypton from the world nuclear power programmes. Nevertheless, the review concluded that it would be prudent to make provision for the later addition of krypton removal equipment in any plant built after 1990.

The principal fission product wastes

Although the principal fission product wastes from a nuclear power programme are not released to the environment, these wastes have been the subject of considerable publicity. In the United Kingdom they are at present stored in high integrity, stainless steel tanks in concrete vaults. By 1971 the total activity contained in these stores was about 250 megacuries in a volume of about 500 cubic metres [5]. The present system has been in operation for some 15 years and is considered both satisfactory and safe. Spare tanks are available to deal with unexpected failures, though these have not yet occurred, and an adequate policy of tank replacement is instituted. The programme of tank replacement and the associated commitment to provide maintenance services of a chemical engineering character will have to be continued for several hundred years. This is one of the reasons why it is recognised that storage in the liquid form will probably have to be replaced by a solidification process which will make continued surveillance less vital, and will reduce requirements for the replacement of storage facilities. If the safety aspects of the solidification process are included, and if it is remembered that an initial period of storage as liquid will still be required, there is no decisive safety benefit in going to long-term storage in solid form. Nevertheless, it may be much easier to demonstrate publicly the overall safety provisions if the fission products are in solid rather than in liquid form.

Flexibility for expansion

The United Kingdom's policies for controlling the release of radioactive materials to the environment have proved straightforward in application and extremely effective. They provide the necessary flexibility for dealing with the future expansion of nuclear power, at least over the next few decades. Their continued effectiveness over this period depends on an adequate understanding by the public of the principles involved, and a continued high quality of professional judgement on the part of those concerned with administering the policy. Given these conditions, the policies form a model which could usefully be taken as a guide in the handling of the releases of other toxic materials to the natural environment.

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