Nuclear Power, Safety and Environment

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Recent events have brought energy problems to the fore. In most industrialized countries there is a need for immediate action to take care of shortages to be expected during the next ten years. It is, however, also of interest to study what may happen until the end of this century and even extrapolate to the year 2100. Some observations regarding the long-term global demand and supply of energy are therefore necessary.

This article attempts to give an overall picture of the nuclear energy situation in the world and the problems associated with this new energy source and how they are dealt with. The way an individual country decides to face its energy problems will depend, of course, on its own natural resources, the stage of its industrial development and other factors that cannot be generalized for the whole world.

The world's population in 1900 was 1 600 million, now it is 3 600 million and it is expected to reach 6 100 million at the end of the century. This is not, however, the end of it: a study by the World Bank in 1970 estimated that if zero population growth were attained in developed countries by the year 2000 and the same goal achieved in developing countries by the year 2050 even then a stable situation would only be achieved by 2120 with a world population of 15,000 million.

There is obviously a relationship between the need for energy and the size of the world's population and there is also a relationship between the standard of living and the consumption of energy. To give an idea of the trend in energy consumption, from the beginning of mankind until 1970, total energy consumption is estimated to have been 6 Q (where $Q = 10^{18}$ Btu). In the year 1970 alone, energy consumption was 0.2 Q, and for the period 1971 - 2000, it is estimated to be 13 Q.

At present the power consumption per capita in the US is 10 kW thermal. By the end of the next century, a considerable amount of re-cycling of source material will have to take place, hydrogen may be produced for use both as a reducing agent and as a medium for transfer of energy, water will be desalted, sewage treated, and so on. A greater effort will have to be made to extract raw materials from poor mineral deposits. These considerations make it reasonable to assume, for planning purposes, twice as large a consumption per capita. Assuming that this per capita consumption will apply through the world – an assumption which can, of course, be questioned, but is part of the development goals of the non-industrialized nations – the cumulative consumption of energy by the year 2100 will be 400 Q, which is indeed a very large figure. One then has to ask how large are the present energy resources.

What is the potential of the renewable energy sources? Hydropower represents 0.2 Q/y, photosynthesis half that much, and geothermal springs, tidal power and winds yield between ten to one thousand times less. Total solar influx represents 3 000 Q/y and utilization of thermal gradients in the seas could give 200 Q/y. But it should be pointed out that we don't know the technical and economic limitations associated with the two last energy sources.

The non-renewable energy sources, coal and lignite, as known now and assuming a reasonable recovery cost, represent 200 Q, petroleum 10 Q and natural gas 6 Q. Geothermal energy from hot rock is estimated to be of the order of magnitude of 600 Q and the energy content of oil shale 4 000 Q. However, no methods exist or have been devised to utilize geothermal energy on a large scale and the energy content of the oil shale probably is ficticious, as such vast amounts of earth moving would be required that the large scale use of the shale would not be acceptable.

From the above, it is obvious that under the assumptions made – a population growth up to 15 000 million and a power consumption growth up to 20 kW thermal per capita – the fossil fuels will not suffice to cover the accumulated needs, even up to the end of the next century.

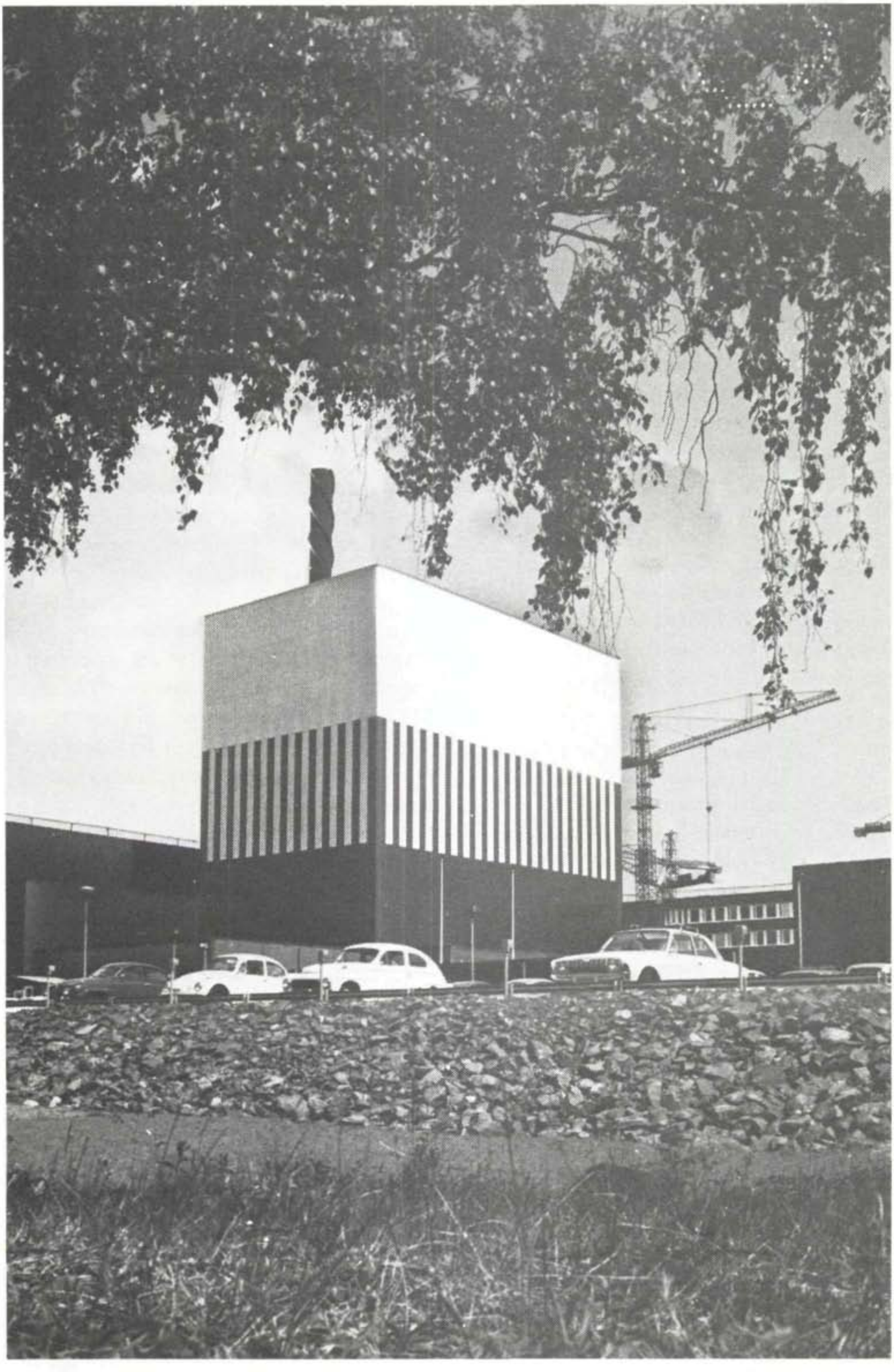
NUCLEAR POWER

What about the potential of nuclear power? Uranium is a very widespread element in the earth's crust; its energy content depends upon what one is willing to pay for its recovery. Considering only the cheap uranium of today, 5 - 10 $/lb of uranium oxide, known resources may represent 0.9 Q if used in light-water reactors, or one hundred times more if used in breeders. Considering more expensive uranium up to the range of 30 - 50 $/lb uranium oxide, its use in light-water reactors would represent 5 Q and in breeders 500 Q – in the former instance, adding a couple of mills (1/1000 of a dollar) to the cost of a kWh, in the latter only 0.2 of a mill. Thorium represents a reserve of the same order of magnitude.

Returning to the global energy situation and its expected development during the next 30 years, it is very important to accept as a fact that no new technological breakthrough can have an immediate impact upon the situation but may have it, at the very earliest, ten years later. Steps can be taken to make better use of the waste heat associated with the thermal cycle and political decisions may have to be made to limit the present almost automatic annual increase in the consumption of energy, decisions however, of a most serious nature and with an almost traumatic impact upon society as a whole.

Nuclear power represents – for the next ten years – the only alternative technologically well enough advanced to add significant amounts of new energy to the energy budget. If needs beyond that period are to be satisfied by nuclear power, decisions regarding some actions will have to be taken now. Uranium exploration drilling operations in some developed countries will have to be expanded considerably, as the return in proven reserves per meter drilled has shown a considerable decrease in the last few years. Especially in developing countries new uranium findings must be explored and mining operations initiated. As the overwhelming amount of nuclear energy during the decade will be produced by light-water reactor systems, the availability of enriched uranium must be secured. This means, for example, in the United States both up-grading and uprating of existing enrichment plants even if that country only assumes delivery of a certain fraction of the enriched uranium requirements in the world. The rest of the demand will have to be filled by other enrichment facilities, i.e. in the Soviet Union, or by the co-operative consortia now being organized in Europe.

A general view of the Oskarshamn-I nuclear power station, Sweden. This BWR plant has a capacity of 440 MW(e). Photo: ASEA-ATOM ▶



From the middle of the 1980's experience with breeder reactors should be available from the American, English, French, German and Japanese prototypes. Everything taken into account, it may still be safest to assume that commercial breeders may only be available in the beginning of the 1990's and that their introduction into the market will be slow. An optimistic evaluation is that in the beginning of the 1990's they will constitute 4 to 14 per cent of the nuclear capacity.

As regards fusion, one should recall that it took some 25 years from the establishment of the first sustained chain reaction in 1942 until the first nuclear power reactors became commercially competitive devices. We have still, in spite of enormous progress, not seen the breakthrough experiment in fusion demonstrating an energy output larger than the input. And this is an indication that it may be well into the next century before fusion can be added to the list of energy resources available.

From the foregoing, it is clear that nuclear power from fission is the only alternative available now if mankind is not going to face a real energy shortage within the near future. We will have to wait a considerable time for the results of intensive research and development programmes regarding other alternatives which should start now. During the period 1980 - 1990 there may be some impact from technical developments initiated in the preceding decade. This may include liquification or gasification of coal, further exploitation of shut-down oil wells, use of solar energy in appropriate regions and practical exploitation of geothermal sources, ocean gradients and the use of shales. Without being unduly pessimistic considering the inertia inherent in the utility industry, it may be wise to expect only marginal additions from the latter sources mentioned.

Nuclear power now constitutes about three per cent of the world's electric generating capacity. This three per cent is produced by 128 power reactors in 16 countries generating some 35 000 MW(e). One may add that the number of power reactors in operation this year is expected to be 167 with a generating capacity of 61 000 MW(e), which shows the rapid expansion taking place. By 1980, it is expected that nuclear power will cover 14 per cent of the total electric generating capacity and 50 per cent by the end of the century. It may be interesting to note that there are at present 346 research reactors installed in 45 countries.

SAFETY

Nuclear safety has been under heavy discussion the last few years in spite of the fact that the nuclear industry as a whole has an unprecedented record of being safety-minded with a minimum of casualities as a result. At a recent visit to the Savannah River plant in the US, I was told that the number of accidents was 1/40 of corresponding chemical industry operations. The International Atomic Energy Agency issues a list every year of land-based nuclear power and research reactors in its 104 Member States, and also an annual report on operational experience with nuclear power stations. In 1972 the cumulative reactor/years of operating experience rose to 1004. It is most remarkable that during these 1000 reactor/years of operating experience, there has not been a single incident involving accidental release of harmful amounts of radioactivity from a power reactor to its surroundings.

Some 20 years ago the problems of safety of nuclear reactors were very poorly defined. The situation is different now and the effect of design changes on reactor safety can be analyzed. Nuclear power can be made as safe as anyone could really want it to be, at a cost. This decision is a social one, ultimately to be made by the customers, based upon information given by the specialists. It must be recalled that risk evaluation as a scientific discipline is only in its beginnings. There seems to be a difference of a factor of 1000 between voluntary risks and involuntary risks and there seems also to be a relationship between expected benefits and risks. Generally, people seem to be illogical with regard to risks they know about or can anticipate. Every year in Sweden for example about 1200 people are killed in car accidents and some 20 000 seriously injured. This is accepted as a matter of course and a fatal car accident receives only a short notice in newspapers. A railway accident is in the headlines, even if there are no casualties, and an airplane accident attracts the most attention. The probability of a nuclear reactor accident is so small that it is difficult to give it a meaningful interpretation. Man's natural fear of the unknown, coupled with the thought associated with atomic bomb, is, probably, largely responsible for the emotional reaction regarding the risks of nuclear power.

Different types of reactors present different safety problems. The high power density prevailing in the core of a light-water reactor requires that very extensive precautions have to be taken in order to ensure that the consequences of an accident don't become too serious, taking into account both the radioactivity and the toxicity of the irradiated fuel. The difference between the light-water reactors with re-cycled fuel containing plutonium and breeders may from this point of view not be too large.

In this context it is worth recalling, that the present predominance of light-water reactors may not necessarily remain in the long-term future. Both the heavy-water reactor and the high temperature gas-cooled reactor are making in-roads on the market now. They both represent systems which, from a safety point of view, are definitely easier to analze than the breeder, may make use of thorium and in the case of the high temperature reactor, also offers the potential for process heat utilization in industry. The "strategy" of nuclear power reactor system mixes began to be discussed at a meeting of specialists in the IAEA in November 1973.

The public debate on safety precautions necessary has, in my opinion, overshot the target. Why should the general public think that nuclear designers and engineers are less responsible people than, for example, aircraft designers? Has the public anywhere at any time requested a full account for the stability conditions of a jumbo jet in its landing approach? That is as difficult to understand as a detailed description of an emergency core cooling system must be for a layman. We all want to live in balance with nature without at the same time sacrificing the benefits of technology. The general public must be confident that the atomic energy specialists are responsive to this desire.

The stringent requirements which must be fulfilled also with regard to physical surveillance has promoted the idea of building clusters of nuclear plants at convenient sites. Such a cluster may consist of a number of large power reactors and occasionally also a reprocessing plant together with storage facilities for radioactive waste. This idea, when originally launched in the United States, envisaged reactors with power of 5 000 MW(e). Carried further, such a cluster may even contain an industrial or agricultural complex using the power available for industrial purposes, including the production of hydrogen and desalted water. Such a site could be more efficiently protected at a lower cost against sabotage and accidents than individual plants spread over different locations.

In this context, one cannot ignore the possibility of outsiders obtaining access to fissile material with the intention of using it for unauthorized purposes. If we first consider the possibility of stealing irradiated material containing plutonium from a cooling pond where the material may be stored, it must be recalled that such fuel is highly radioactive and can only be transported without fatal consequences for the outlaws themselves if in very heavy and elaborate casks weighing tens of tons. To get hold of the plutonium content the fuel has to be processed in a reprocessing plant, the existence of which could not go unnoticed to its surroundings. If one considers the storage place for separated plutonium concentrate, or plutonium oxide, such places are very well protected by a system of locks and electronic devices which would make it very difficult for an unauthorized person to get access to the material. Furthermore, in Non-Nuclear-Weapon States almost without exception the fissile materials are under a safeguards system designed and implemented by the International Atomic Energy Agency. The recording, reporting and inspection systems required by the IAEA safeguards agreements constitute an additional control of the fissile materials with only minimal quantities unaccounted for. While this system cannot in itself prevent a diversion, it aims to deter it by the risk of early detection.

This international safeguards system, now being applied in 33 States, required some 450 inspections in 1972. Many States have established their own national safeguards system, which assist in accounting for nuclear material. Possibilities for the undetected clandestine disappearance of fissile material for unauthorized purposes are very small.

The enclosures required in most countries as a protection against radioactivity being spread outside the reactor proper could, of course, be substituted by location underground. Investigations in connection with underground nuclear weapon testing have shown that the migration of solid substances in the ground is very slow. For strontium and cesium, which may be released in the case of a reactor accident, the time is 2 500 years/km and 19 000 years/km respectively. Each case has to be judged on its own merits, however, and a full knowledge of the geological conditions is necessary before an underground location can be recommended. The cost aspects, of course, also have to be considered.

Remote location, together with the large requirements for cooling water, has promoted the idea of creating artificial islands on the continental shelf, or even floating islands for this purpose. The thermal effects on the environment could certainly be minimized in this way. On the other hand, a reactor accident could result in the release of radioactivity into the sea and even more strict preventive measures would have to be taken than otherwise necessary.

A point of view which should be kept in mind with regard to the siting of nuclear plants is what should be done after the expiration of their useful lifetime of some 30 years. This is a problem which is now facing the Eurochemic plant in Belgium where the costs for de-contamination and restoration of the site to its original condition is estimated to be comparable to the original investment in the plant. Rational steps for de-commissioning and dismounting of obsolote nuclear plants should form an integral part of the original planning and design. De-commissioning requires not only specialized competence, but also a resources commitment that must be taken into account from the very beginning. At the end of 1973 the IAEA called a meeting between a group of specialists to discuss threse questions and agreement was reached to establish an international working group to co-ordinate future work in this field.

The maintenance of peace is a condition *sine qua non* for the widespread use of nuclear power which is foreseen. A situation where power reactors above ground would be the object of warfare from the air would have unthinkable consequences, as would for that matter, fighting action among some of the hundred-odd warships propelled by nuclear power.

THE ENVIRONMENT

There are, of course, some consequences for the environment in the use of nuclear power. It is obvious that any large scale production of power has its impact on the environment. Even hydropower isn't spared criticism by the "environmentalists" who don't like the establishment of big dams any more than they like the disappearance of mighty waterfalls. The conventional thermal stations spread the combustion gases into the atmosphere together with ash particles in no small quantities: a 350 MW(e) coal-fired power station releases some 75 tons of sulphur dioxide, 16 tons nitrogen oxide and 5 tons fly ash each day, not to mention the thermal effects.

Nuclear power represents a solution which is friendly to the environment but there are also some problems associated with extensive use of nuclear power. It is definitely wrong to claim that they all have been solved, but they are manageable at present and later, at the end of the century, techniques will be found which can be applied to the problems which will then be of another magnitude.

It is appropriate to start with the mining of uranium. The element uranium is associated with its decay products which include radium and radon. The mining results in the release of airborne dust with some radon and solid tailings containing uranium oxide plus its decay product radium, however, only in minute quantities. The most serious radiological health problem associated with atomic energy has been the over-exposure of uranium miners. Present levels for working conditions have been established at much lower levels than was the case earlier and future risks for uranium miners should be greatly reduced.

The rest of the procedure to transform uranium to fuel elements does not involve any step affecting the environment.

A consequence of using many energy resources, with the exception of solar energy, is the heating of the earth. Unfortunately, man's knowledge about the long-term global effects to be expected is very unsatisfactory. It is, for example, not quite clear whether the extensive use of fossil fuel would lead to a rise of the temperature of the earth or not. The production of carbon dioxide would certainly increase the so-called greenhouse effect, and thereby the temperature, whereas the production of airborne dust particles may lead to a decreased insolation and thus have the opposite effect.

The relation between man-made energy and the influx of solar energy was in 1860 1 : 1 million. One hundred years later, it had increased to 1 : 10 000 and by the end of the century, the ratio may be 1 : 3 000. This could lead to a temperature rise of a few tenths of a degree centigrade which might have a considerable climatic effect. These problems have, therefore, to be the object of careful analysis in due time.

There are, however, also local and short-term thermal effects from large scale power production and this would be especially pronounced around nuclear parks of the type described above. Individual power stations of the size (1 000 MW(e)) now under construction will have an impact if located along rivers not representing large enough heatsinks. The alternative, cooling towers, eliminates the ecological problem for the aquatic biota only to transfer it to the atmosphere and the countryside which will not be prettier with the large cooling towers and their overhang of vapour clouds, not to mention their micro-climatic effects. With regard to disposal of cooling water to big lakes or oceans in the case of offshore installations, it seems to be quite possible to arrange intakes and outlets in such a way that no damage is caused to the biota present.

The question most intensively discussed in the last few years and of most serious concern to the general public is the production and storage and possible release of radioactive material in nuclear power stations and associated facilities, especially reprocessing plants.

Radioactivity is generated in nuclear power plants in the form of fission products resulting from splitting the uranium nucleus and through induced radioactivity in construction materials. Over 99.9 per cent of all the radioactivity generated in the fuel elements of a nuclear power reactor is contained until the fuel is processed for recovery of unburnt fuel. The coolant used to remove the heat from the nuclear core may cause corrosion and erosion and become radioactive. Radioactive gases, such as tritium and krypton are also produced in the reactor. A fraction of these gases may be released at the reactor, but the bulk of them will be released during fuel reprocessing.

The International Commission on Radiological Protection (ICRP) has issued recommendations about maximum permissable concentrations of different radioactive substances in air and water. These recommendations are aimed at protecting man from harmful effects from radioactive substances, be it through radiation, inhalation or ingestion. We know, as a matter of fact, more about the effects of atomic radiation on man than we do about any other stress to which he is subjected. The current recommendations are based on the results of a prodigious effort mainly in biological research. The purpose of a nuclear waste management system is to ensure the protection of man and his environment and to keep the exposure well below the permissable limits. The methods followed up to now have been either diluting the radioactivity to a state whereby the resulting dose to man is well below the maximum permissable doses recommended, or concentrating it and containing it. There is a definite trend away from the dilution process to concentration followed by containment and isolation from the biosphere. A distinction should also be made between temporary treatment of radioactive waste and long-term storage and ultimate disposal of waste. Different emphases are given to these methods in different countries, but there is a tendency towards long-term storage, at the same time preparing for ultimate disposal.

As indicated, the main release of radioactive substances from the nuclear fuel takes place in the reprocessing plants. The number of reprocessing plants at present is very limited and it is expected that there will be less than one reprocessing plant per 30 000 MW(e) installed nuclear generating capacity, i.e. by 1980 there will probably not be more than 10 sizeable reprocessing plants in operation. At present in the US no such plant for civil purposes is in operation. One is being re-modelled, one is under cold test run, and a third one is under construction. In Western Europe, the biggest capacity plant is the one in Windscale, UK, which is able to receive several different kinds of fuel. Capability for processing oxide fuel is being provided for the full-scale plant in Cap de La Hague in France and a pilot plant is under operation in the Federal Republic of Germany. A full-scale plant is under construction in India, based upon a pilot plant in operation since 1965, and the same situation exists in Japan. All this is mentioned in order to underline the limited number of these plants which will be needed even at the end of the century, with a nuclear generating capacity in the world of 3 000 000 MW(e).

At reprocessing plants there is a release of gaseous radioactive waste in the form of tritium, krypton 85 and iodine 129. Of these gases, krypton 85 may constitute a problem in the long run, but it should be pointed out that methods are already known for the removal and containment of krypton which could be applied to reprocessing plants built towards the end of this century. The waste management technique used for gaseous waste is delay and decay through the storage of the waste for a long enough time to permit some radioactivity to decay before its release to the environment.

Liquid aqueous low and medium level radioactive waste is produced in quantities of several cubic meters per day in reprocessing plants. Different methods are used in different plants in handling these wastes, usually including a storage period for allowing short-lived substances to decay, followed by chemical treatment, dilution or concentration of different fractions.

High level radioactive waste resulting from the concentration procedure may either be stored in liquid form in stainless steel cylinders, cooled and agitated or transformed into solid waste. The first method is used at the plant previously mentioned in Windscale. The second method is used by processing plants in the Federal Republic of Germany, France and the US. The ultimate solid produced may contain the radioactive substance either in a borate or phosphate glass or in a fused alumina silicate.

High level radioactive waste will have to be stored for thousands of years, or periods much longer than stable social systems have existed. One should recall that the half life of the plutonium isotope 239 is 24 000 years. If the long lived so-called actinides (including plutonium) could be removed from the fission products the remaining wastes would remain hazardous for periods of several hundreds of years rather than the many thousands of years required if the actinides remained in the wastes.

At present, there seems to be a general understanding that high level waste should be stored in such a way as to permit its retrieval. If that principle is followed, temporary storage facilities could be devised to take care of these wastes until solutions have been found for their ultimate disposal.

The Windscale reprocessing plant is a multipurpose facility which can process both uranium metal and uranium oxide fuels. As about half of the nuclear power generated in the world up to now has been produced in the UK, their experience in storing highly active waste from some 18 000 tons of fuel they have processed is of special interest.

Highly active waste has been stored at Windscale for over 20 years and amounts now to 500 cubic metres, producing a decay heat of 1.5 MW. This waste, now in smaller tanks, could be contained in four tanks of their newest design of a capacity of 150 m^3, in the form of a vertical cylinder of 6 m in diameter and 6 m height. The tank is contained in a concrete cell with 1 1/2 m thick walls, partly lined with stainless steel, and in this way forming a secondary container. A cooling system ensures the continuous provision of cooling water to remove decay heat from the waste, also in case of complete failure of the electrical mains.

Although the operating experience of both the evaporating concentrating plant and the storage system has been entirely satisfactory and gives confidence that it could continue to be used for several decades, it is recognized as only a temporary and preparatory step. It is considered that solidification of the waste offers greater assurance of long-term containment. Ultimate disposal of the waste cannot be visualized whilst it remains in liquid form.

Ultimate disposal implies relinquishment of control over the waste without the ability to retrieve it. Inevitably, therefore, there should be an absolute guarantee that the waste should remain remote from man for an indefinite period of time.

In the UK the waste will be immobilized in a solid of low leachability followed by storage in such a way that it is retrievable for eventual ultimate disposal. The aim is to have all highly active waste at the Windscale site converted to solids by 1995.

According to new regulations by the US Atomic Energy Commission, solidification has to be made within five years after the liquid radioactive waste has been produced and this solidified waste has to be deposited to a storage yard assigned by the US Government within another five years.

The solidified waste at Windscale will be kept in ponds which can be monitored to give a continuous check on the integrity of the containers. In the Federal Republic of Germany the disposal of radioactive wastes deep underground in salt cavities has been chosen as the most promising method, and an abandoned salt mine, Asse, in Harz, has been adopted for this purpose and is expected to have capacity enough for all the radioactive waste generated by the Federal Republic of Germany's nuclear programme up to the year 2000. For the time being only solidified low level and intermediate level waste is stored in Asse but preparations are being made to also dispose of high level waste by 1976.

At Oak Ridge in the US a method for non-retrievable disposal of radioactive waste has been developed, using injection under high pressure of low level or intermediate level waste together with concrete in red shale layers 300 metres below ground. Since 1966, 5 000 m^3 containing 5 million curies have been disposed of in this way.

Other ultimate disposal methods suggested will have to await technical developments: the use of rockets to shoot waste into interplanetary space or the use of accelerators or fission or fusion reactors to transmute long lived substances into isotopes with shorter half lives. An overview of high level radioactive management studies published three months ago on behalf of the US Atomic Energy Commission doesn't exclude that these methods might be used in the future, but emphasizes the need for more detailed analyses of the problems involved.

A few words should be said about tritium — a hydrogen isotope with a half life of 12 years. Tritium is produced in the upper atmosphere by the bombardment of nitrogen with cosmic rays, giving a steady state global inventory of natural tritium of some 70 - 140 megacuries. It is estimated that as a result of bomb testing before the Moscow Treaty of 1963 some 7 700 megacuries were released to the atmosphere. Assuming that the present rate of growth of the nuclear programme continues, it is estimated that the accumulation of fission-produced tritium will be about 600 megacuries in the year 2000.

It is, therefore, expected that for the next two decades most tritium in the environment will be that which resulted from nuclear weapons testing, and that the total inventory will decline during this period.

In the US the average annual radiation dose from nature is 130 millirems. To this should be added 114 millirems per year per capita from man-made exposure, 90 per cent of which are of medical origin, diagnosis, therapy, etc. Operation of nuclear power stations in the year 1971 resulted in the minute exposure to the total population of 0.003 millirems. Even an increase with a factor of one hundred in the use of nuclear power reactors would thus not lead to a significant contribution to the total radiation exposure.

To summarize briefly:

- Large additional amounts of energy will be needed to maintain the quality of life both because of the population increase and the necessity of using more energy to extract the indispensible raw materials.
- Out of different alternatives, only nuclear power through fission is ready at present from a technological and economic point of view to make an immediate contribution to the world's supply of energy. In the balance of alternative sources, nuclear power will play an increasing role.
- Present commercially available nuclear power reactors have shown operational safety and remarkable reliability. It is to be expected that with increased operational experience future power reactors of these types will be still safer and more reliable.
- Known and proven methods will keep radioactive waste generated during the next ten years safely isolated from the environment, at a cost which will be less than one per cent of the cost per kilowatt hour. The larger quantities of radioactive wastes which will be produced from the middle of the 1980's can be stored under conditions permitting retrieval at a few (perhaps 30) selected places in the world using techniques well under development now. Some discussions have already taken place, under the auspices of the IAEA, regarding the establishment of international storage sites. Results of further development work may limit the necessary storage time to hundreds, instead of thousands, of years.
- Nuclear power provides a means of bridging the energy gap until new sources of power are developed and does not, if carefully planned and controlled, face mankind with unacceptable environmental consequences.