SOME NATIONAL ATOMIC PROGRAMMES

Statements Made at a Public Discussion Organized by IAEA During the Sixth Session of the General Conference

During the last regular session of the IAEA General Conference, the Agency organized, on 20 September 1962, a public meeting at which leading personalities in the national atomic energy programmes of six Member States described some of the important aspects of these programmes, especially in the field of nuclear power. The speakers were

- Professor V.S. Emelyanov, Deputy Chairman, State Committee for the Utilization of Atomic Energy, USSR;
- Dr. G.C. Laurence, President, Atomic Energy Control Board, Canada;
- Sir Roger Makins, Chairman, Atomic Energy Authority, United Kingdom;
- Professor Francis Perrin, High Commissioner, Atomic Energy Commission, France;
- Dr. Glenn T. Seaborg, Chairman, Atomic Energy Commission, USA;
- Dr. I.H. Usmani, Chairman, Atomic Energy Commission, Pakistan.

The IAEA Director General, Dr. Sigvard Eklund, acted as moderator.

The opening statements by the six speakers, which were followed by some questions and answers, are reproduced below.

Statement by Professor V.S. Emelyanov

Extensive work is being carried out in the Soviet Union on the peaceful uses of atomic energy. It is very difficult, in a brief statement, to give an idea of the great variety of the work in progress, and I shall therefore deal only with the most important trends, which are of practical importance even at the present stage.

Of immediate interest to everyone is the status of work on the use of nuclear processes in electric power production. Construction of two large atomic power stations in the Soviet Union is now nearing completion. One of them, being built near Voronezh, will have an initial output of 210 000 kW, while the second, near Sverdlovsk in the Urals, will have a capacity of 100 000 kW, likewise in its initial phase.

In addition to these two plants, a 150 000 kW station is being built at Bratislava in co-operation with Czechoslovakia and another, with a capacity of 70 000 kW, in the German Democratic Republic.

The erection of these stations will enable us to accumulate experience particularly in the solution of engineering problems associated with the construction of complex equipment, e.g. the design of reliable vessels and housings for reactors and pumps, and the development of fuel element technology and fabrication and of systems for regulating the power of the stations and all their equipment. Meanwhile, Soviet industry has already learned to manufacture completely new types of equipment, together with the materials required for producing them.

Professor V.S. Emelyanov

In addition to building atomic power stations we are studying various types of atomic reactor. We are testing reactors cooled by water, gas, liquid metals and organic liquids and using neutrons of energies ranging from thermal to fast. Not so long ago - last year, in fact - an impulsed reactor of original design was put into operation. I believe this to be the only reactor in the world based on the use of plutonium rods and a disk containing uranium-235 revolving at 5000 rpm. The reactor makes it possible to obtain, 8.3 times per second, a neutron flux of 10^{17} neutrons/cm^2, and is of very great importance for purposes of research, including work on solid state physics.

Reactors have now been developed in the USSR not only for power production but also for use in chemistry, i.e. with a view to the application of ionizing radiations in chemical processes. There are also reactors for driving machinery and, in particular, for ship propulsion.

I should mention that the experience of operating the icebreaker "Lenin", the world's first atomic-powered surface ship, has proved highly satisfactory. Not very long ago, after a prolonged period of operation, the reactor of the "Lenin" underwent an inspection and it was found that no change of any kind had occurred in the fuel rods. No traces of corrosion were found in them: they looked like new, as if they had just been installed. All this inspires confidence that reactors can be used successfully in shipbuilding. It must be borne in mind that the "Lenin" has really undergone very serious testing. Leaving Leningrad and sailing round the Norwegian coast, it ran into a heavy storm; this in itself was a substantial test. Then, its first year of operation was an extremely strenuous one. The winter in the northern regions was very severe, the ice reaching a thickness of 2.5 meters. However, the icebreaker carried out its run very satisfactorily and now, after inspection, everything has been found to be in excellent order. We can therefore state with certainty that there are practical applications for atomic energy in marine engineering. So much has been confirmed by experience.

After evaluating and assessing the outcome of the studies made, and once we have at our disposal the results of experience gained in the construction and operation of the new atomic power stations, we intend to undertake a programme of further work on the practical uses of energy from nuclear processes. There are areas in our country where, even now, there would appear to be practical justification for the use of atomic power. However, in order to evaluate the prospects for nuclear power in a given region, it is necessary to make a careful technological and economic analysis taking detailed account of all the power resources of the region in question and of the possibilities of transporting other types of fuel from elsewhere. It can then be decided whether or not it is worth building an atomic power station in the area. There are a number of regions in the Soviet Union where even now atomic power could be used to economic advantage.

Statement by Dr. G.C. Laurence

In Canada, as in most countries, the demand for electric power is increasing year after year. We are interested in nuclear energy to meet this demand, because, and only because, we believe it will become cheaper in some regions than energy from burning coal. Nuclear energy offers the possibility of very low fuel costs. In central Canada coal costs about 3 mills for every kilowatt hour of electricity that it can produce. Our nuclear energy cannot compete with conventional plants unless its fuel costs are substantially less than 3 mills per kilowatt hour. I am talking here about the real cost of the fuel without any subsidy or refund for recovered plutonium, for example. We cannot attach any value to recovered plutonium, because we have neither a use for it nor a market for it.

These considerations rule out of our nuclear power programme reactors that have a poor neutron economy, that is for our large nuclear power stations. Other types of reactors have applications for very small stations, but for the large stations they require enriched fuel which is too expensive.

Dr. G.C. Laurence

This is one of the reasons that led us to the choice of the heavy water reactor. Fuel costs in our first nuclear power station, known as CANDU, being now built at Douglas Point, will be less than 1.2 mills per kilowatt hour and they are expected to decrease. Our first demonstration nuclear power plant, which is called NPD, was not intended to be economical; it is not. It is a pilot plant and a large part of its cost was for research and development, and with a power of only 20 MW it is too small to be economical; but the experience in its construction enables us to estimate fairly accurately the costs of larger plants of the same type. A 50 MW plant of the same type could now be built that would compete with a coal-burning power plant in some regions of Canada.

The cost of power from the CANDU plant at Douglas Point, which is now being built with a capability of 200 MW, will be very slightly higher than the costs of power from coal-fired plants in that part of Canada. We expect that future plants of the same type will cost about the same or slightly less than coal-fired stations.

Our small demonstration nuclear power station NPD has been in operation now only a few weeks. This is too short a time to judge its performance and success fairly. I can only say that so far it has fully justified our confidence in heavy water nuclear power stations.

Meanwhile Canada is continuing to consider variations of the heavy water moderated nuclear power stations. A heavy water reactor cooled with an organic liquid is to be built in our second nuclear development centre at Whiteshell, and a design study is now being made of a heavy water reactor that will be cooled by light water fog. Other studies have been made of other operations in the design of heavy water reactors.

Thus we look forward to economic nuclear power in Canada in a few years. I would like to turn from a description of current events in Canada and speak of another theme, which I think is of interest to this gathering.

We have remarked that our ideas about the cost of power have become much more realistic recently than they were a few years ago. Similarly our thinking about the hazards associated with the operation of nuclear power stations will become more realistic as time goes on. A few years ago a report was prepared for the United States Atomic Energy Commission by a group of experts, who discussed the possible consequences of a bad reactor accident. Many of you know that report, usually referred to as Wash/740. The report described hypothetical accidents resulting in thousands of casualties and thousands of millions of dollars of damage and of financial loss - a rather frightening report.

But the world is beginning to acquire a background of experience in reactor accidents. There have been throughout the world about 20 occasions when a reactor went out of control, but in all these accidents only 6 deaths were caused and in all but one of them - so far as I know - there was no financial loss from damage and contamination outside the plant. In the case of this one exception the financial loss outside the plant was only a few hundred thousand dollars - a very different picture from the conception of the Wash/740 report.

Now we cannot, of course, say, and would not say, that worse accidents are not possible. We must admit their possibility, but it is becoming abundantly clear that their probability is extremely small indeed. The safety record of the nuclear industry is better than that of most other industries.

Statement by Sir Roger Makins

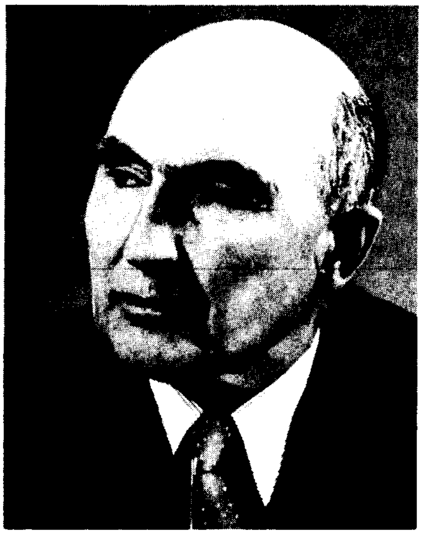
I will say a few words about the progress of British nuclear power and reactor development in the last year. First, the eight plutonium production reactors operated by the Atomic Energy Authority - Calder Hall and Chapelcross - have shown increasing availability for power generation at about 25 per cent above their designed capacity. Although these reactors have to be shut down for refuelling and are extensively used for experiments, they have maintained an overall load factor of over 85 per cent. The earliest of these reactors has now had six years of virtually trouble-free operation and so far no sign of deterioration has been detected in any part of it. Now these reactors are the protoypes of those in the British nuclear power programme. The first two of the civil power reactors - Bradwell and Berkeley - are now supplying electricity and the combined design output of the two stations is 575 MW. Six more stations are being built and two more have been authorized. When all ten stations are finished in 1968, they will have a total capacity of 4 500 MW which, operated at base load, will provide about one eighth of the total usage of electricity in the United Kingdom. About 400 MW will in addition be supplied by the UK Atomic Energy Authority reactors and a 1 000 MW station is planned for 1969.

The cost of power from the latest of the nuclear stations in 1967-68 is, on present assumptions, estimated to be somewhat above that from the best contemporary fossil fuel stations, but these assumptions are now widely thought to be too conservative and that the load factor, the life of the fuel and the life of the reactor itself may be better than is now assumed.

A combination of these improvements and the benefits of operating experience of large reactors could make the cost of electricity competitive with the best conventional power stations. Improvements can still be made to the Magnox reactors, but the nature of the uranium metal fuel and the Magnox cladding limits the temperature to which the gas coolant can be raised and the efficiency of the station.

We are therefore developing more advanced systems. In the gas-cooled type the next step is to move from metal to oxide fuel elements and from Magnox to stainless steel cladding. This leads to higher efficiencies and more compact design. The Authority's prototype advanced gas-cooled reactor at Windscale, which embodies these changes and which will develop about 30 MW of electricity, went critical at the beginning of August and is expected to work up to high power in the next 3 months. An early objective of this reactor will be to prove the reliability of its fuel charge on which the design of the first commercial station can be based. It will also offer a flexible irradiation facility. The system offers the promise of lower capital costs, good safety characteristics and low cost power.

The British nuclear power programme is based on the assumption that it will be possible to make use of the plutonium produced in these large civil stations in fast breeder reactors and the experimental fast reactor at Dounreay in Scotland was built to study the technology of such reactors. It has now been operating for two years. We have had a number of difficulties of secondary importance in raising the power in this reactor, but two months ago the power was raised to 30 MW of heat and it is intended to continue at about this level for a considerable time before bringing the reactor up to still higher power. We are bold enough to hope that the teething troubles that we have had with this reactor have now been overcome.



Sir Roger Makins

Meanwhile work on a design for a prototype fast reactor for power production is being pressed forward. The Authority's work in support of the Magnox system has diminished, now that large-scale power stations are coming into service and resources are available to increase the work of the Authority on hydrogen-moderated systems.

In the heavy water field we have for some little time had collaborative programmes with Canada and with Sweden and we now propose to build, in close collaboration with our industry, a prototype of an advanced type of reactor of the steam generating heavy water type. This appears to have lower capital cost and needs lower enrichment of the fuel than the other systems under study. It is not our purpose to duplicate development work which has been successfully done in other countries, but we think it necessary to broaden our experience of reactor technology. In considering more advanced types of reactor, we are particularly concerned with development potential and to select for development those systems which appear to have the greatest promise in this respect.

Finally, in the field of marine propulsion the Authority is now engaged, again in collaboration with our industry, on an intensive Government-sponsored research programme aimed at developing a reactor which would be competitive with conventional means of marine propulsion.

All in all, therefore, this is an important year for British reactor development.

Statement by Professor Francis Perrin

France is one of the countries which very early recognized the potential importance of the industrial use of atomic energy for the future of their economies. All that was available to us at that time was natural uranium, which we proceeded to use directly for the production of power, and we consider that, in following this course, we succeeded in developing a type of power reactor which is as promising as those using enriched uranium. The fundamental principles involved are the same as those on which nuclear power production in the United Kingdom is based: a natural uranium metal fuel element clad in a magnesium-base alloy can, neutron moderation by means of graphite, and heat extraction by carbon dioxide under pressure. However, the techniques of application are often different in the two countries.

Two prototype reactors working on these principles have been in operation at our Marcoule Centre for over three years and are now delivering a total output of 70 MW to our national grid. On the basis of the experience so acquired, Electricité de France has undertaken the construction of a series of progressively improved reactors, with an interval of 2-3 years between the start of work on each successive reactor. The first three of these units are being built at the same site (Chinon) in the lower Loire valley. The first of them, which went critical for the first time a few days ago, is expected to go into service at the end of this year, with a net power of 70 MW(e). The second, having a capacity of 160 MW(e), should go into operation early in 1964, but it is only with the third unit, the EDF-3 power station, that we hope to approach the goal we have set, namely, the production of electric power of nuclear origin at a price competitive with that of conventional power stations. The EDF-3 plant, which has been under construction for two years, should go into service at the end of 1965. It will have a capacity of 480 MW(e) net, an output of this size being needed to reduce the cost per kWh to something near the conventional level. In any case, it is hardly likely that this figure can be exceeded, say between now and 1970, as far as feeding the French grid is concerned. This output will be made possible by the use of prestressed concrete for construction of the huge vessel which will contain the reactor under a pressure of 25 atm.

Professor Francis Perrin

The prospects opened up by this third EDF station are so favourable that we believe that a slightly different unit, embodying the few improvements which can already be visualized and which could go into construction in 1963 for completion about 1968, would be fully competitive and could serve as prototype for a string of reactors, thereby enabling nuclear energy rapidly to increase the importance of its contribution to electric power production in France.

We know, however, that this first generation of nuclear power stations, regardless of how promising and extensive it may be, cannot be continued over a very long period, since these units and the principles which they embody - and this is also true of the stations operating on slightly enriched uranium, being developed elsewhere - will never be able to utilize more than about 1% of natural uranium. Such a yield is completely inadequate if atomic energy is really to become an important source of power for mankind between now and the end of the century. During the next 15-20 years there is need for the development of plants based on the breeding principle. Breeder reactors use plutonium as a fuel and involve the application of difficult techniques. We have embarked upon an important research and development effort along these lines in France by starting the construction, at our Cadarache Centre, of a reactor which will apply breeding principles. This is the Rhapsodie reactor, which will have a thermal capacity of only 10-20 MW but which will facilitate the development of numerous techniques, especially that of using plutonium as fuel and liquid sodium for heat removal.

The vastness of the breeding undertaking thus begun and the long time that must elapse before it becomes economic have led us, as from this year, to pursue the task in association with EURATOM, an arrangement which will pool the technical and industrial resources of the States of the EURATOM community in an attempt to perfect - within the 15-20 year deadline I have mentioned - this promising but difficult type of reactor.

Statement by Dr. Glenn T. Seaborg

I was not sure just which aspect of the American nuclear energy programme I should emphasize, but it appeared to me that perhaps you would be interested in our programme of nuclear energy in space. There are two broad uses for nuclear energy in space that we are investigating in the United States and I will speak about these in turn.

The first is that of developing the nuclear rocket. This has many advantages compared to rockets which operate on chemicals and these make it possible to perform missions that cannot be performed at all with chemical rockets. They make it possible, for example, to transport high payload missions to the moon and beyond the moon to the near planets. For example, they make it possible to contemplate manned missions to Mars and return. A nuclear rocket on such a mission could transport a spaceship with several men on it to Mars and, allowing about a month or so for exploring Mars and returning, make the roundtrip in about a year. The nuclear rocket has the advantage over the chemical rocket because it has a greater specific impulse, that is, a greater thrust per pound per second of propellant flow. In a nuclear rocket we are investigating specific impulses of the order of twice those possible with a chemical rocket - something like 800 pounds of thrust per pound per second of propellant flow.

The chemical rocket of course depends upon the hot combustion product gases flowing out of the rocket in order to give the thrust. In the nuclear rocket we can choose the propellant that we want to heat, and the most efficient of all at a given temperature is that with the lowest molecular weight, which is hydrogen. The nuclear rocket engine consists of a compact reactor which heats hydrogen transported as liquid hydrogen to very high temperatures to give maximum specific impulse. This, of course, leads to very severe material problems indeed, because we have to have a reactor that will stand up to temperatures all the way from that of liquid hydrogen to the extremely high temperatures of the gaseous hydrogen flow that we are trying to use.

Tests of such a nuclear reactor have been carried out in Nevada at our reactor testing site and the work today indicates success. The first test flight is planned for 1967 in a space vehicle. Long-range missions using nuclear propulsion probably won't come until the 1970's.

Dr. Glenn T. Seaborg

The second application of nuclear power in space is as auxiliary power in space vehicles. We have been developing space power units as a part of our SNAP programme (Systems for Nuclear Auxiliary Power). Here we have two types of units. First there are devices that develop their power from radioactive isotope decay. In this broad programme we are using such radioactive isotopes as the fission products strontium-90, caesium-137 cerium-144 and the isotope plutonium-238. Such conversion of the heat of radioactive decay to electricity - utilizing plutonium-238 - has been used in the Transit satellites, one of which is circling the earth now and sending signals with navigational information back to the earth. There is another transuranium isotope, curium-242, which is scheduled for use as a power source in a lunar probe.

These nuclear power sources involve conversion of heat from isotopic decay to electricity through thermoelectric devices. We are also investigating in connection with most of these devices the more efficient conversion of heat to electric power through the thermionic process. These radioisotopic power sources develop electrical power in a range of watts - tens of watts, hundreds of watts and maybe into the range of kilowatts, but somewhere in that region we probably have a limit as to the amount of power that can be developed from these relatively simple devices due to the extremely high amounts of radioactivity that would be involved.

Of course, such nuclear power sources have very useful applications on earth as well as in space.

The second type of SNAP device uses a compact liquid metal cooled nuclear reactor rather than a radioisotopic source. This makes accessible the energy range from kilowatts up to megawatts and we hope eventually into the multi-megawatt range. We have under investigation a number of systems. One is a 500 watt system that uses thermoelectric conversion and is scheduled for test flight in a year or two. Another system, which would develop 3 kilowatts of electrical power, uses turbogenerator conversion. Another system, similar to the 3 kilowatt system but larger in power and more complicated, develops 30 to 60 kilowatts. Finally, we have under preliminary investigation a reactor system for a SNAP device that will develop electrical power in the range of 100 to 1000 kilowatts or more. This is an extremely difficult undertaking because it must be a reactor that will have a long life to suit the purposes that we have in mind and must have a low weight - something of the order of 10 to 20 pounds per kilowatt. This also is being developed on the liquid metal cooling principle.

These higher power devices will be useful for electric propulsion. This is a system of propulsion whereby the ions to be used as a propellant are accelerated through the use of electro-magnetic fields out of the back of the rocket, giving low thrust but high specific impulse, and making it possible to have perhaps the most efficient ultimate system of nuclear propulsion.

These devices also make it possible to contemplate worldwide television, that is, the use of satellites of fixed relative position up some 22 000 miles above the earth. This would permit transmission of television directly to the home receivers, as contrasted, for example, to Telstar television, where the signal is intercepted on earth by a very sensitive receiver and then re-broadcast to the home.

Statement by Dr. I.H. Usmani

I am glad to have this opportunity of presenting the point of view of a number of under-developed countries in regard to the prospects of nuclear power in these countries, with particular reference to Pakistan.

You may be surprised to know that in Asia outside the People's Republic of China the per capita availability of fossil fuels is only one-fiftieth of that of the United States and Canada, and one-tenth of Western Europe. Thus in Asia, and I am sure in some countries of Africa, nuclear energy appears to be the only alternative for the generation of power to meet the growing demand for the programmes of their economic development. Of course the paradox is that nuclear power technology is at present confined to those countries which do not need nuclear power as much as those where the know-how is absent. In the former there are large reserves of conventional fuels, which they can tap. We just do not have them. Fortunately many types of nuclear power reactors, thanks to the researches done in the developed countries, have proved very successful in operation and can be installed anywhere in the world with a modest infrastructure of industry and trained manpower, which I think most developing countries with the help of the Agency would have before 1970.

Dr. I.H. Usmani

One often hears the argument that because nuclear power is not yet competitive in advanced countries, how can it be competitive in underdeveloped countries. This, of course, in my opinion is a puerile argument, in that the word "competitive" is relative and has different meanings in different situations. There are many countries, such as mine, where economic development is suffering because of the high cost of fuel and an enormous bill of foreign exchange for imported fuel. We have therefore decided to launch upon a very modest nuclear power programme in East and West Pakistan.

Now let me give you some facts and figures. I am sure all experts would agree that if there is any single yardstick to measure the economic development of a country, it is the per capita consumption of power in that country. I will give you the figures for some of the countries which I just recall from memory. In Norway the per capita consumption of power is 7 000 units per person per year; in the United States and Canada it is of the order of 5 000; in the United Kingdom and France 2 000; and in Japan of the order of about 900.

Taking my country as a typical under-developed country, I am sorry to say that at the time of independence in 1947, nearly 15 years ago, our per capita consumption of power in Pakistan was 2 units. It went up to 18 units in 1957 and today it stands at 34 units per person - in 1962. The question is, where do we go from here? Even if we accept the very slow rate of growth, namely doubling this per capita consumption of power in ten years, which is incidentally the world average, we have calculated that in the next 40 years or so we would require in West Pakistan alone generating capacity to the tune of about 23 million kW and in East Pakistan about 7 million kW.

The population of Pakistan today is about 94 million, and it is growing at a rate of about 2.34 per cent, which is extraordinarily high. This is typical of many Asian countries. If we have to maintain a steady growth of economic development and sustain the present tempo during the next decade, it is absolutely necessary for us to augment our power generating capacity. The question is, what are the resources to generate power available to us.

We have in West Pakistan a hydro potential which is estimated to be of the order of about 15 to 20 million kW, but this hydro potential is confined to the very inaccessible hilly regions of the Northern Himalayas, so inaccessible that if you go there to survey the potential you would probably go to your ultimate destination!

As far as gas is concerned, we have discovered quite large reserves of gas to the tune of about 9 million million cubic feet of gas. We find that using gas requires transmission over long distances through pipelines (which we do not produce) with the result that by the time we tap the gas for the generation of power it costs us as much as imported oil - in the neighbourhood of about 38 to 40 cents per million BTU. However, we are going ahead with the utilization of gas, and I am glad to say that for power generation we have gone up to about 35 per cent of the total quantity now used. Natural gas, as you know, is a basic chemical which happens to burn, but there are many uses to which gas can be put. The most important use for our country is the manufacture of chemical fertilizers. Now the total actual consumption of fertilizer in Pakistan is of the order of about 3 kg. per acre per year, as compared to 56 kg. per acre per year in Japan. No wonder her yield of paddy and wheat, etc. is about 3 to 4 times higher than our yield. We could not therefore burn all the gas for the generation of power. But even if we were to burn this gas for power, the total reserves of gas in West Pakistan, as discovered up to date, although there may be more, would be equivalent to about 365 million tons of coal, which is about two years' consumption of the United Kingdom at the present rate. We do not have very large reserves of gas as is commonly believed. In any case, I for one in Pakistan can never advise my Government in such a way that by the time my son, who is 4 years old, grows up to my age and becomes a petrochemical or a chemical engineer and asks "where is the gas of Pakistan", he is told "your daddy has burnt it for power generation". We do not want to be in that situation.

In East Pakistan unfortunately there is no hydro potential at all. We have about 120 MW for a population of about 51 million, an area peopled with the highest density of population in the world. There is no major discovery of gas comparable to the big deposits found in West Pakistan; there is no oil and no coal. In East Pakistan we are importing about 80 000 tons of coal per month from South Africa, China, Poland, India and everywhere to keep the economy going. We have to break the ice somewhere as far as power is concerned and in East Pakistan we have already decided to start with a modest nuclear power programme. We are thinking of establishing a water-moderated 50 MW reactor in East Pakistan to be operative some time in 1967-68 and about a 100 MW reactor in West Pakistan in the Karachi area where the load factor is fairly high.

HIGH-LEVEL RADIOACTIVE WASTES

Methods of Treatment and Storage Discussed at IAEA Symposium

Management of radioactive wastes produced in reactor operations is one of the important problems in the atomic energy industry, and since the expansion of the industry involves an increase in the volume of the wastes produced, it is also a problem of growing magnitude. While the hazards from the radioactive by-products of atomic operations must be reduced to the minimum possible in a given state of technology, there should be a simultaneous effort to ensure that the measures to achieve safety are sufficiently practical and economical for application on a large scale.

Safety, of course, must remain the primary consideration, and attempts are being made at atomic energy centres all over the world to devise the safest and most effective methods of dealing with radioactive wastes. From the beginning, the International Atomic Energy Agency has considered it one of its main tasks to stimulate and co-ordinate this effort; in fact, work in this field has constituted one of the Agency's most comprehensive programmes. An important part of this programme has been the organization of scientific meetings to discuss different aspects of radioactive waste management.

Certain aspects of the subject have been, and are being, examined by small groups of experts convened by the Agency, while common scientific and technical problems are discussed at larger meetings. In organizing these discussions, the Agency has divided the problems into two broad groups: those relating to wastes of large volume but with a low level of activity and those of a relatively small volume but with a very high level of activity. Although the distinction between high and low levels of activity is largely a matter of convenient definition, current usage of the two terms puts the wastes from the operation of small research reactors or from radioisotope applications into the low-level category, while wastes generated from the reprocessing of spent reactor fuel - such as from nuclear power plants - are placed in the high-level category. Apart from being intensely radioactive, the latter, in many cases, retain their radioactivity for very long periods, often for thousands or hundreds of thousands of years. It is the combination of these two characteristics which makes these substances especially difficult to deal with. If the level of activity is very low, it may be possible to disperse the wastes into the environment, but substances with a high level of activity must be kept isolated. If the radioactive products are short-lived, the isolation need only be temporary, but high-level wastes with a long radioactive life may have to be isolated from the human environment for thousands or more years. In other words, they must be stored in such a way that they cannot escape into the environment so long as they remain a potential source of radiation hazards; and before storing them, it is usually necessary to treat the wastes by various chemical processes so as to make them suitable for storage.