NUCLEAR POWER PROSPECTS

Expert approach to the prospects of a nuclear power revolution in the world seems to have undergone some change during the past few years. Hopes of atomic energy emerging within a short time as a bountiful source of electric power all over the world have lately been tempered by a critical awareness of the many economic and technical problems involved in such a transformation of the world's energy pattern. As the present and potential role of nuclear power becomes more sharply defined, it also becomes clearer that no concrete program for its introduction can be based upon general notions about the need for its development to supplement the dwindling energy sources of the conventional type.

One of the basic questions is whether the introduction of nuclear power is economically advantageous in a particular situation. That, however, is not always easy to decide. In the first place, the factors that enter into the economics and technology of nuclear power generation are complex and in some respects still uncertain. Secondly, the requirements and existing conditions vary so widely from one situation to another that solutions which seem satisfactory for one are seldom applicable to another.

At the same time, it is a matter of some urgency that the present state and future prospects of nuclear power generation be assessed in as accurate and comprehensive a manner as possible. In many areas which have an inadequate power supply or are faced with the early prospect of one, the introduction of nuclear power may appear to be a promising solution, and many countries are understandably eager to go ahead with nuclear power projects as a means of accelerating industrial activity.

As might well be expected, assistance in this direction is one of the major objectives of the International Atomic Energy Agency. It is also obvious that this assistance will be particularly needed by those of the Agency's Member States which are relatively under-developed in industrial techniques, and at two consecutive sessions the General Conference of the Agency called for efforts to meet that need.

Agency Program

At its session in 1958 the General Conference adopted a resolution calling, among other things, for a survey of the nuclear power needs of the less-developed countries and a continuing study of the technology and economics of small and medium scale power reactors. A report outlining the program of work to give effect to this resolution was submitted to the General Conference last year. After considering the report the General Conference in a further resolution recommended that in carrying out and further developing the program, particular attention be given to the provision of expert advice to Member States in studying the economics and technology of nuclear power, the implications of such studies in terms of the Agency's training and technical assistance programs, the supply of nuclear materials and equipment to Member States, and the possibilities of collective action in this field. The resolution also requested the Agency's Board of Governors to submit a report to this year's session of the General Conference on the progress made and future work. The Board was further requested to submit a general report on the economics of nuclear power. The two reports were accordingly presented to the General Conference which met for its fourth regular session on 20 September 1960.

The Agency's program of work to implement the two resolutions of the General Conference can be divided into two categories. In the first place, the Agency makes its services available to Member States so as to assist them in any way they may need for their future nuclear power plans, and in particular in studying the technical and economic aspects of their power programs. Secondly, the Agency undertakes general studies on the economics of nuclear power, including the collection and analysis of cost data, in order to assist Member States in comparing and forecasting nuclear power costs in relation to their specific situations. Not only is it providing its Members with the latest technical and cost data on nuclear power plants but it is also trying to establish methods for their interpretation and extrapolation. At the same time, it keeps itself ready to assist any Member State that may contemplate the introduction of nuclear power within a well-defined context.

Pattern of Development

It is noted that nuclear power is still in an early stage of development and improvements are being made in its technology and economics. At present only four of the Agency's Member States - France, the USSR, the UK and the USA - are operating nuclear plants for the generation of electricity, while Belgium, Canada, Czechoslovakia, Germany, Italy, Japan and Sweden are actively engaged in building such power reactors. Outside Europe and North America, two

other Member States - India and Brazil - have announced definite plans for installing nuclear power plants.

The possibility of early introduction of nuclear power is closely linked with a fairly high degree of industrialization, not only because the necessary technical knowledge and financial resources are available only in the industrialized countries, but also because of certain technical and economic factors which characterize the present stage of the construction and operation of nuclear plants.

When due allowance has been made for a transitional period when higher costs may be incurred for later gains, the introduction of nuclear power must be justified by an expected saving in the cost of the energy produced or at least a saving in the foreign exchange component of this cost. In comparing the economic merits of nuclear and conventional power, several factors must be taken into account. For instance, in the case of nuclear plants, the investment cost per unit capacity is higher and increases rapidly as the plant size decreases, as a result of which nuclear plants entailing large capital investments have to be operated at high load factors.

Conditions in Less Developed Areas

The less developed areas of the world are characterized by a limited and undiversified industrial base, by low consumption of energy produced by isolated power units, and often by the presence of large conventional energy resources, especially hydro, which may not be fully prospected and evaluated. Nevertheless, this is not meant to imply that there is no case at all for nuclear power generation in the so-called less-developed countries. First, as can be seen in the cases of Brazil and India, there are, in some of these countries, areas with the necessary degree of industrialization. Secondly, there are areas which have a large industrial potential based on adequate supplies of raw materials and the necessary industrial skills, and are located within easy reach of a comparatively large market. Even under such favorable conditions, industrial progress may be hampered by inadequate power supply resulting from a shortage of conventional fuel, high costs of transporting such fuel to the area, or an excessive foreign exchange burden of imported fuel.

In such circumstances, there could well be a case for nuclear power generation - even at a cost which is initially higher than the cost of conventional power generation - if there is a clear indication that in the foreseeable future industrial development will create a substantial base load to make nuclear power economical. When such concrete cases come to light, the Agency will consider the best means to facilitate the introduction of nuclear power - perhaps by installing a small or medium sized reactor as a demonstration project, so that its benefits may be available to a large number of countries.

In the meantime, the Agency's role is necessarily of a somewhat preparatory character. Besides, it has to be different with respect to areas or countries representing different stages of industrialization.

So far as the industrialized and technically advanced countries are concerned, the most useful function of the Agency is to stimulate as thorough and wide an exchange of technical and economic information as possible. This will help in comparing the various lines of development and in detecting the "soft spots" on which attention should be concentrated in order to improve the technology and reduce costs.

As for the relatively industrialized areas in the less-developed countries, the Agency can help by giving expert advice and other technical services for any nuclear power project that may be contemplated. Mention may be made here of the Brazilian project to build a 150/200 MW (electrical) nuclear power station in the Rio de Janeiro-Sao Paulo (Mambucaba) area for which Brazil has requested the Agency to provide experts on third party liability and nuclear safety. For future projects of this nature, the Agency may also be called upon to play a more active role; for instance, in preparing invitations for international tenders.

Joint Study in Finland

In the case of countries which have not yet decided on the installation of their first nuclear plants but which already have a large amount of industrial experience, the Agency can assist by analyzing the conditions under which a first nuclear plant could profitably be installed within an existing power network. Assistance of this kind is being given by the Agency to Finland where a survey is being made to determine the extent to which nuclear power will be needed during the next decade and the steps that will have to be taken to carry out a nuclear power project. At the request of the Finnish Government, the Agency has participated in the survey initiated by the country's Atomic Energy Commission in co-operation with its largest national power undertaking.

Finland has no coal or oil resources and the power system is predominantly hydro-based. At present, thermal power based on imported fuel is utilized only at times of low water, i.e. in winter or dry years. The hydro potential is estimated at 18 000 million kWh per year, about half of which has been exploited so far. Since all of the remaining half may not be economically exploitable, development of hydro power is expected gradually to slow down with an increasing emphasis on thermal stations.

The main question to decide is the place of nuclear power in the total thermal system, which in the first instance needs a study of the character of thermal power in the country's economy. Obviously, nuclear power will be a workable proposition only when thermal power as a whole reaches a high utilization factor, instead of remaining, as it is now, a supplementary source to be drawn upon at times of inadequate water supplies.

The first phase of the study in Finland has therefore consisted in a survey of the power resources of the country and an analysis of estimated power demands in the future. In particular, an attempt has been made to determine the conditions under which a block of thermal power will have a high utilization factor. After this has been determined, the possible role of nuclear power can be assessed on the basis of an analysis of the relative costs of power generation - by nuclear and conventional means.

Survey in the Philippines

In countries that are less advanced, such accurate forecasts of power development may not be possible. Plans for introducing nuclear power into a system can be based only on adequate knowledge of the availability and cost of power from conventional sources and fairly accurate estimates of future power needs. Any investigation of the possible role of nuclear power in the less advanced countries will have to be based on such preliminary power studies.

An investigation of this type is to be carried out in the Philippines at the request of the Government which has asked for the Agency's assistance in studying the potential role of nuclear power over the next decade. Two specialists are to be sent to the Philippines by the end of this year to initiate this study. In the first stage the study will be mainly concerned with the economic and technical aspects of the possible installation of a nuclear power plant in the Manila area which is fed by an integrated supply network. The power demand in the area as well as the economic and industrial factors of the country as a whole will be taken into account. Besides, it may be also possible to initiate an enquiry for a subsequent study of the economic and technical conditions under which nuclear power could contribute to the development of the natural resources of an isolated region in one of the numerous Philippine islands.

It is expected that surveys of this nature will serve as useful guides to other Member States as well. They will show the problems which a country may have to face at a given stage of industrialization when contemplating the introduction of nuclear power in future and will give power reactor manufacturers a clearer idea than they now have of the conditions under which they may expect to take part in the installation of nuclear plants abroad. The Agency therefore considers it useful to carry out a limited number of similar studies in the near future. It would, of course, be desirable if the situations to be studied were fairly well diversified and at the same time were such as might yield some conclusions of a general character.

When carrying out these studies, the Agency will also try to meet the related needs for technical assistance and training; it would help if the training requests from Member States are properly timed in relation to their nuclear power programs. In this connexion, the Agency is trying to find out whether it will be possible to send some selected trainees to be associated with the program of development of small and medium power reactors initiated by the United States Atomic Energy Commission.

Technical and Economic Investigations

Apart from these activities which will be of direct benefit to individual Member States, the Agency has undertaken a continuing program of general technical and economic studies concerning nuclear power. In an effort to collect data on a world-wide basis, it has requested Member States to provide technical and economic information on available reactor types that are likely to be suited to the needs of the less-developed countries. Besides, the different power reactor types have been evaluated according to their technological development, operational experience, prospects of future development, and any special requirements for use in the less-developed areas.

Following a United States offer inviting Agency participation in the design, construction and operation of small and medium power reactors in that country, the Agency has established close contact with the USAEC, and arrangements have been made for members of the Agency's scientific staff to follow the development of these projects at first hand. Besides collecting the relevant technical information, the Agency will be able to indicate to the reactor designers some of the specific problems which the less-developed countries may face when building and utilizing such power reactors.

The technical and economic problems of small and medium power reactors were examined at an international conference held by the Agency in Vienna a few weeks ago. * The conference was intended to elicit and review the latest information on the technology, economics and potential utilization of small and medium sized nuclear power plants and dealt with three main topics.

(a) the technical aspects of small and medium power reactors, including the present status and future prospects of various reactor systems and concepts; experience gained in the construction, operation and maintenance of existing plants; safety aspects of nuclear plants; fuel cycling; and requirements and training of technical manpower for nuclear power plants;

(b) cost evaluation and economics of nuclear power with special reference to costing procedures, cost breakdown of different plants, and potential for reduction in nuclear power costs; and

(c) the role of small and medium power reactors in meeting energy problems, particularly in the less-developed countries.

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* *A report on the conference will be published in the next issue of the Bulletin.*

So far as the economic studies are concerned, the Agency intends to prepare a series of documents with particular emphasis on nuclear power costing. The studies are expected to include:

(a) a review of the present methods of presentation and breakdown of the costs of nuclear power plants and of determining unit generating cost in a particular plant;

(b) an investigation of methods of cost comparison between nuclear and conventional power stations, taking into account the future development of the power system in which they will be operated; and

(c) a study of the economic problems involved in comparing the total costs of nuclear and conventional power programs for a given country.

A panel of experts was convened in March this year for going into the first of these problems. The experts agreed on a broad listing of the items of cost likely to be incurred in a less-developed country in making a start with nuclear power and gave their views on costs and costing methods. Attention was drawn to the main uncertainties still associated with nuclear power costs and certain differences of approach were noted as to the methods and costs of construction; the types of load systems into which a first nuclear station would be installed; and the charges of foreign and local capital. The panel will reassemble next November to consider the draft of a first report on "the present methods of nuclear power costing".

Review of Present Costs

In the meantime, the Agency has prepared a report on the present state of the economics of nuclear power on the basis of such information as is available at the present time. The report, submitted to the fourth session of the General Conference by the Agency's Board of Governors, is a first step towards wider investigations and has been restricted to the present costs of nuclear power plants and fuels with some tentative extrapolation of probable future trends.

The reactor types considered for the purposes of this report are those the technology of which is relatively well developed and which have been operated or are about to be operated on an industrial scale. Examples are the pressurized and boiling water, the gas-cooled, the organic-moderated, and the heavy water reactors. Advanced types such as fast breeders or homogeneous reactors have not been dealt with; nor has any attempt been made to compare the economics of the various types. It is, however, noted that the use of enriched fuel provides considerable flexibility in the design of reactors, particularly in smaller sizes since the smaller cores lead to reduced capital costs; enrichment can also be used to increase fuel burn-up and permits a wider choice of materials for the fabrication of the core. But counterbalancing these advantages are the cost of enrichment, the increased cost of fuel fabrication and dependence on the source of fuel enrichment. Hence the interest in the use of reactors which operate on natural uranium, such as the gas-cooled, graphite-moderated and the heavy water reactors. In general, their capital costs are higher but the fuelling costs lower than those of the enriched uranium reactors.

The report deals in detail with construction costs, fuel costs and operation and maintenance costs, summarizing and interpreting the available data and commenting upon their significance and applicability.

Expected Reductions

In conclusion, the report points out that nuclear power is still in its early phase of development and substantial cost reductions can be expected from technical improvements that are likely to emerge from the continuous research and development that are going on in several fields. It is noted that current designs of relatively developed systems will be further improved upon to incorporate the experience being gained with the first and second generation plants. Some other reactor concepts now at the experimental stage may emerge as particularly promising. Especially significant will be the possible reductions in fuel cycle costs, resulting from lower fabrication and re-processing charges, higher burn-ups and a fall in uranium prices. A great deal of work is being done to develop low cost reactor materials with good nuclear properties and capable of standing up to high temperatures. Sizeable savings can also be expected from the standardization and development of reactor components such as pumps, valves and heat exchangers, which represent a large fraction of total investment. Again, lack of extensive experience in the field of reactor safety has led to conservative and costly designs for containment shells, control mechanisms and instrumentation. With better understanding of essential safety requirements and through the use of improved techniques, containment and control of reactors will become simplified and less expensive. Finally, most of the nuclear power plants now in operation have very few duplicates; when several plants of essentially the same design are built, the engineering development expenses will be spread out and the cost per unit will decrease.

According to USAEC evaluations which assume a 14 per cent annual capital charge, an 80 per cent plant utilization factor, no changes in the Commission's present schedule of uranium prices and in the purchase price of plutonium, the generating cost of power produced from a 200 MW (electrical) reactor fuelled by slightly enriched uranium, which on the basis of present technology would fall between 11 and 14 mills per kWh, is expected to decrease later to 9 to 10 mills per kWh. Under these conditions and assuming that efficiency improvements of conventional thermal power plants are levelling off, the cost of power generated in a large nuclear power plant to be

installed towards the end of the next decade would become competitive with that of conventional thermal power in areas where conventional fuel costs are above 55 cents per million BTU * (US $2.20 per million kilocalories).

Inevitably the report is primarily concerned with moderate and large size power reactors. Technical data for power reactors in the small and medium range are at present insufficient to permit cost estimates of comparable reliability, but it is noted that engineering studies on these types of reactors are being made in several countries. The report itself contains some cost data and indicates certain possible extrapolations in regard to small and medium reactors. The exchange and review of information that took place at the recent Agency conference on small and medium power reactors may fill some of the existing gaps in knowledge. Useful information will also be obtained from the Agency's participation in the United States program for the development of small and medium power reactors. Eventually, all these efforts will provide a firmer basis than now exists for dependable cost estimates for the whole range of power reactor sizes.

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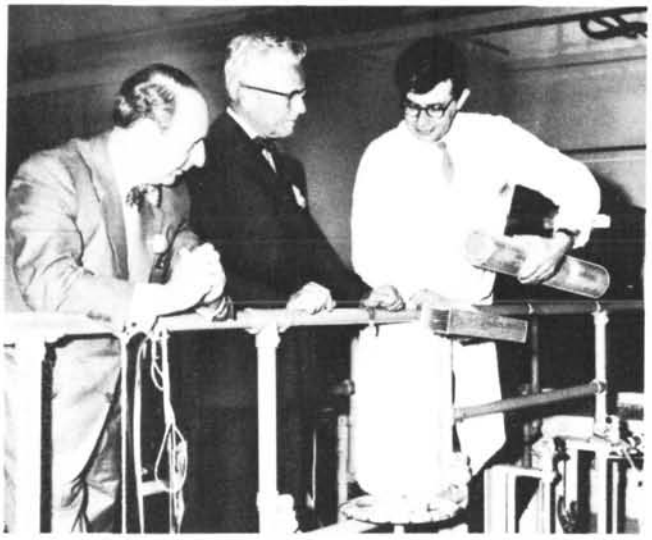
* *British thermal units. One kilogram of coal contains about 30 000 BTU of energy.*



Mr. Sterling Cole, Director General of IAEA, accompanied by Dr. Henry Seligman, Deputy Director General (Research and Isotopes), visited the Atomic Energy Research Establishment at Harwell, United Kingdom, on 12 July 1960. Mr. R.W. Clarke of the Isotope Research Division of the Establishment showing cropped fuel elements to Mr. Cole (center) and Dr. Seligman (left) (Photo: UK AEA)

Mr. V. M. Molotov (left) paid a courtesy visit to the Director General of the International Atomic Energy Agency (IAEA), Mr. Sterling Cole, on taking up his appointment as Resident Representative of the U.S.S.R. to the Agency