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ASSISTANCE TO LESS DEVELOPED COUNTRIES WITH THE PRODUCTION OF NUCLEAR POWER

Report of the Board of Governors

A. INTRODUCTION

1. The availability of abundant power has proved to be a decisive factor in promoting and sustaining a high rate of growth in industrial output, accumulation of capital and per capita income. The high standard of living prevailing in the industrial areas of the world is linked directly to high rates of power consumption; these areas are therefore rapidly developing their conventional power resources, while at the same time preparing to supplement these resources by other sources of power in order to maintain the high rate of growth. In less developed areas where the increasing pressure of population growth would necessitate an even higher rate of increase in the production of material resources, the development of power production is also considered a vital prerequisite for raising the standards of living. Some of these areas have large, low-cost but still undeveloped hydro-electric reserves, or they may be favourably situated in regard to fossile fuels; others, however, can already foresee that their indigenous conventional power resources will be severely limited in the not too distant future. They may also be faced with specific situations where installation of a new power plant would be of immediate value for developing new or expanding existing industries, but where the cost of producing power by conventional means would be prohibitive due, for instance, to the high cost of fuel transport by a presently inadequate transport system. Interest in nuclear energy as an alternative or supplementary source of power is therefore shared by both the highly industrialized countries and the lesser developed ones.

2. As in all industrial installations requiring large investments, the economics of power production favours large sizes. This is particularly true in the case of nuclear power. In highly industrialized areas, therefore, the first nuclear power plants to be installed will have, for economic reasons, a large power output satisfying the continuous base load demand of an interconnected supply network, and some operating and economic data on such large power reactors is readily obtainable from the large units already in operation. In the case of lesser developed areas, however, the urgent needs for power are often still small and localized, and in some cases may call for power reactors of small and medium output with which relatively little experience as yet exists.

3. In the light of these considerations, the General Conference adopted at its second regular session a resolution on the assistance the Agency might provide to less developed countries in connexion with the development of nuclear power, the operative paragraphs of which read as follows:

- "1. Recommends that the Board of Governors should give earnest and early consideration to:
- (a) Initiating action for a survey of the needs of the less developed countries with their consent, in the matter of nuclear power generation plants suitable for their specific circumstances;
 - (b) Adopting measures so that a continuing study be made of the development of the technology and economics of small and medium scale nuclear power reactors which may be best suited for the economic development of less developed countries;
 - (c) Disseminating to all Member States the information collected by the Agency under sub-paragraphs (a) and (b) above; and
 - (d) Assisting the less developed countries in planning and implementing their training programmes at their request so that they may have, as soon as possible, adequate numbers of scientists, technicians and engineers to take full advantage of the developments in the technology and utilization of small and medium scale power reactors; and
- "2. Requests the Board to report to the General Conference at its third regular session on the steps taken to implement this resolution. [1]"

4. The present document is a progress report, prepared in answer to the request in paragraph 2 of the resolution, and constitutes no more than a review of the steps which had been taken up to 1 August 1959 to implement the resolution. It will be noted that this review does not examine in detail such fundamental questions as the reasons why a less developed country might install nuclear power plants at an early stage. Such questions have only been touched upon in order to provide a better understanding of the type of studies that are called for, and of some of the difficulties which have been encountered in making these studies. Future plans and methods of work for the continuation of the implementation of the resolution are also described.

B. 1959-60 PROGRAMME OF WORK

5. Following the adoption of the resolution, the Board of Governors requested the Secretariat to study the problems raised by the resolution and to submit suggestions for the most effective method of implementing it.

6. In the course of this work, it became apparent that a general investigation of power development in the less developed areas to determine to what extent and at what stages their power needs could be met by nuclear energy would be a far-reaching undertaking which could not be carried out by the Agency alone. In particular, this investigation should be linked with the general economic development studies and the evaluation of power needs which are the responsibility of the United Nations and its regional economic commissions. The progress made in the detailed additional power studies to be undertaken by these organs will thus have an important bearing on the Agency's long-term activities.

7. It was therefore considered that earlier - although more limited - benefits could be gained by initiating a study of potentially promising situations in which the introduction of nuclear power in the near future might prove particularly justified. It was felt that this approach should enable the Agency to make an effective contribution without delay, while still allowing for the preparation of an elaborate, long-term survey of power needs. The broader studies would also benefit from the initial case studies.

8. Needless to say, when defining the prerequisites for thorough evaluations in given cases, account will also have to be taken of many of the broader economic questions involved. It would be unrealistic, for example, to advise a Government to put reliance on the development of an atomic power programme without first ascertaining the respective costs of nuclear and conventional sources of power, not only per kilowatt hour but also in terms of foreign exchange, of bringing coal or oil to alternative thermal plants and of the general expenditures involved in developing conventional sources of energy; without taking into account unconventional sources of power such as solar, wind or geo-thermic energy, which in less developed countries with localized power demands may become reasonable alternatives in the near future; without measuring the impact of the contemplated nuclear programme on the financial situation of the country; considering the relative importance of such matters as the probable greater flexibility of location of atomic power plants as compared with hydraulic and thermal plants, especially in connexion with present and future location of industries; or without appraising the real significance of relatively high power costs in the context of the vital needs of the country. The United Nations and its regional commissions will doubtless be in a position to provide the Agency with valuable information bearing on such broad economic questions, and it is therefore to be expected that the co-operation between the two organizations will develop significantly as the implementation of the resolution proceeds.

9. In January 1959 the Board approved the programme of work on the resolution for 1959-60 developed by the Secretariat on the foregoing lines, which accordingly aimed at initiating implementation of paragraph 1, sub-paragraphs (a) to (c) of the resolution. As regards sub-paragraph (d), it was decided that specific steps to supplement the Agency's regular training programme should be considered only after a clearer picture had emerged from the studies undertaken under sub-paragraphs (a) and (b).

10. The studies contemplated in 1959-60 can be grouped initially under three main headings, which will finally merge into a fourth one. They are:

- (a) Technical studies. These involve the continuing collection of technical data on reactor systems particularly suitable for small and medium power output. In this connexion it will be noted that a working definition of the general concept "small or medium power unit" has proved to be difficult to make, since in highly industrialized countries large power reactors are steadily increasing in their capacity. In the first phase an arbitrary upper limit of 50 MW(E) has been adopted for working purposes, but no special significance is to be attached to this definition; and it is expected that further studies will include reactors of larger capacity;
- (b) Cost studies. This part of the work also involves the collection and evaluation on a continuing basis of cost data on those reactors considered potentially suitable from the technical viewpoint. The source of information was, as under the first heading, publications and enquiries made to Governments, organizations and industries;
- (c) Searches for promising situations. An enquiry is being made into those situations, either described to the Secretariat by Governments or arising from the analysis of data made available to the Agency, which are potentially promising for specific case studies; and

- (d) Case studies. The last part of the programme of work for 1959-60 will consist of specific case studies of selected situations. These will cover technical-economic evaluations of particular nuclear power plants in particular locations, using all relevant information obtained in the course of the activities outlined in the preceding sub-paragraphs, and include a comparison of the cost of installing and operating a nuclear plant with that of the conventional alternatives available. It is intended by such specific case studies to focus attention on the precise merits which nuclear power might have if applied in a particular situation.

11. It has been agreed that for each section of the work programme of 1959-60, ad hoc groups of consultants will be called in to review the preliminary evaluation and progress made by the Secretariat, as sufficient information has been gathered and processed.

12. It has been proposed by the Secretariat, recommended by the Scientific Advisory Committee and approved by the Board that a technical conference or symposium should be held in 1960 on the subject of small and medium power reactors. This is clearly in line with the desire of the General Conference expressed in paragraph 1(c) of the resolution. It is contemplated that this meeting will be held during the late summer of 1960 and deal with three main topics:

- (a) The technical aspects of small and medium power reactors;
- (b) The cost evaluations; and
- (c) Possible applications of nuclear power to case studies in less developed areas.

It is planned that the Agency will submit a review document on each of these three topics to the meeting.

C. STUDIES OF THE TECHNICAL SUITABILITY OF AVAILABLE POWER REACTORS

13. A study has been initiated by the Secretariat of the design and technology of power reactors of various types, with the special aim of evaluating them as to their suitability for the short-term needs of less developed areas. This study involves a technical analysis of available types of power reactors and nuclear power stations on the one hand, and of the special requirements of such areas on the other. It has also to serve as a technical background for cost studies on nuclear power.

14. The preliminary analysis indicates that the most important technical requirements for power reactors in less developed areas are:

- (a) Proven system. The power reactor system must be of established design with proven characteristics. Sufficient operating experience should have been gained with it to reduce uncertainties to a minimum;
- (b) Reliability and safety. The reliability and safety of nuclear and non-nuclear parts are a major consideration. The design should aim at the highest degree of safety. The operation and maintenance should also be simple and safe;
- (c) Design in small sizes. Certain reactor systems are particularly sensitive in their economy and efficiency to a reduction of size. To merit consideration a system must be susceptible of efficient and economic operation with the range of required power levels. The possibility of building and operating a given reactor system economically in small or medium sizes (up to 50-60 MW(E)) must therefore be taken into account; and

- (d) Good response to power demand changes. This is especially important for the operation of power plants in remote areas where an inter-connected network does not exist.

Considerable interest exists in the possibilities offered by small transportable power reactors that can be built from pre-fabricated parts which can be transported by air, water or road to remote locations for installation. This feature, however desirable in certain cases, has not been mentioned as one of the general requirements since reactors which can be installed in this manner are at present limited to very small power units, and since in some cases it may prove more economical to install a nuclear power plant which will not be of the "package" type.

15. A technical evaluation of power reactor installations already in existence or planned has been started, with special reference to the state of technological development reached or operational experience acquired with particular types and to the above mentioned requirements of less developed areas. In this analysis power reactor systems have been divided into three groups:

- (a) Group 1. Power reactor systems the state of development of which is not sufficiently advanced to recommend them at present because of difficult technology, lack of operating experience, safety, reliability or other reasons. Extensive research and development are necessary before these types will be ready for construction as commercial installations, even in the highly industrialized countries. Among them are fast neutron reactors, aqueous homogeneous reactors, liquid-metal cooled reactors and pebble-bed reactors. In order to limit the studies, the power reactors in this group are not being considered in the short-term programme of 1959-60. The work on this group of reactors during this period is being limited to collecting information on the state and progress of their development;
- (b) Group 2. Power reactor systems which are promising from technological, safety and other points of view, but with which the experience gained so far does not appear sufficient to recommend them for use in any initial nuclear power programme in a less developed area. However, such experience will probably be gained in the next two or three years with the help of power reactors now under construction. Among reactors in this group are heavy water reactors and organic moderated and cooled reactors. There are no power stations with such types of reactors in operation. Power reactors in this group are being covered in the work programme for 1959-60 only so far as their general characteristics are concerned. However, their development and experience gained with them is being constantly followed with a view to including some types in this group in the long-term programme; and
- (c) Group 3. This group includes power reactor systems with relatively simple and proven technology, with which some operating experience has been gained. Four types of power reactors may be included in this group:
- (i) Pressurized water reactors;
 - (ii) Boiling water reactors;
 - (iii) Graphite-moderated, gas-cooled reactors; and
 - (iv) Graphite-moderated, pressurized water-cooled reactors.

Several nuclear power stations with reactors of each of these four types are now in operation in the atomically advanced countries, and more are under construction or in the planning stage in various countries.

16. Power reactors of types (i), (ii) and (iv) require enriched uranium and may be constructed in a wide range of capacities from package power plants to large central

power stations. Those of type (iii) may be constructed with natural uranium but in this case the design becomes suitable only in medium or big sizes. It is not possible at present, and will hardly be possible in the near future, to decide whether one of these types will emerge as the best type from the technical point of view.

17. The technical evaluation of power reactors in Group 3 will be continued and expanded during 1959 and 1960. Studies are now in progress with special reference to the safety, reliability, maintenance and operation problems, transportability, fuel technology and fuel cycling.

18. In order to accomplish this task the Secretariat has been collecting all relevant technical and economic information concerning the power reactors which have been or are being built in different countries. The published literature, including technical periodicals, technical reports of various laboratories and firms, papers of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy and data already supplied to the Agency for the preparation of the Directory of Nuclear Reactors, Volume I - Power Reactors, [2] is being carefully studied.

19. Consultations with scientists and nuclear engineers and also with manufacturing organizations have been an important source of information for the study. More information is needed before a sound technical evaluation can be achieved for all the reactor systems involved, and this information is being solicited from Member States.

D. STUDIES OF NUCLEAR POWER COSTS

20. Preliminary studies of nuclear power costs with special reference to small and medium power units have been undertaken by the Secretariat, and the Board considers it useful at this stage to draw attention to a few points which have emerged from this work.

21. It became clear at the start that such cost studies would progress rather slowly and would have to be made very carefully in order to avoid misleading generalizations, in particular since the construction of power reactors in less developed areas would be subject to certain conditions widely different from those under which the very few prototype units have been built and are being operated.

22. It was thought at first that before discussing any cost estimates, an endeavour should be made to set up a universally applicable method of calculating nuclear power costs. It is well known, for instance, that in certain countries it is customary to include the first nuclear fuel inventory in the capital cost, whereas in others the fuel is accounted for separately and included in the operating costs. Similarly, differences exist between the methods of calculating amortization of the plant. In seeking to harmonize existing methods, great care would have to be taken to avoid introducing one that would artificially favour one type of nuclear power system rather than another. It became apparent, however, that although efforts to standardize these costing methods should be continued, it would take a long time and much effort before such a standardization was achieved; and in the meantime reliance would have to be placed on the costing methods already in existence. The decision as to which method would be adopted would probably vary from case to case, due account being taken of the usual practice for conventional power units in the interested country as well as in the country most likely to supply the reactor system and that of eventual external sources of finance.

23. The costing parameters to be applied, such as the annual financing charges (cost of money, taxes, rate of depreciation), would also vary greatly from situation to situation. Existing cost data on nuclear power have only been obtained in the advanced countries and in most cases apply to a specific nuclear plant planned, built and operated in the same country, and therefore the calculated power costs of existing units cannot be directly compared or correlated. It has been decided, therefore, to apply for each situation the exact set of costing parameters prevailing in that situation, and that the underlying hypotheses would always be thoroughly described in order to avoid any misinterpretations of the results. It is also obvious that the comparison of the economic merits of a nuclear power plant with the conventional alternatives available for any particular situation can only be achieved by using the same method of accounting as well as the same set of cost parameters for all alternatives compared.

24. Special emphasis has had to be placed on the collection of data on construction costs of nuclear power plants because of their overwhelming impact, in comparison with costs, on the cost of nuclear power. Here the main difficulties have proved to be the scarcity of data based on actual experience. The most reliable are, of course, those on nuclear plants actually built and operating, but, as is well known, no more than a dozen plants in only four countries are in existence. Reference has therefore also had to be made to construction cost estimates for nuclear plants in construction or at an advanced stage of planning. Information on costs provided by industrial firms which have acquired experience in designing and building nuclear power units is of considerable help and such information is being actively sought.

25. Data on the construction costs of nuclear plants made available to the Agency by Member States should be sufficiently detailed to allow for the three following types of extrapolation:

- (a) Extrapolation from the cost of a prototype unit to that of a "second generation" unit. Although it can be argued in this connexion that mass-production of small or medium nuclear power plants would obviously lead to a lowering of costs, this view will have to be balanced against the opposite view that such a concept may be somewhat premature in the present early stage of rapidly evolving techniques in nuclear power development; a certain degree of standardization should, however, be attainable in some of the reactor components;
- (b) Extrapolation of the construction cost of a unit in a highly industrialized country to that of the same plant in a less developed area. It is realized that the conditions under which the plant will be built (local labour, local industries, transport to the site, etc.) will vary greatly from case to case and have some bearing on the construction costs of the plant itself. In some cases it will appear cheaper or simpler to build as much of the power station as possible on the spot and to make maximum use of local construction services; in others it may be considered preferable to install transportable units in which local construction requirements will be limited to a minimum. In all cases the reactor manufacturers should provide the Agency with as much information as possible as to what parts of the power system could, in their opinion, be built locally and which ones could be prefabricated, taking into account the reactor types involved and various possible degrees of industrialization of the recipient countries. Different breakdowns of the construction costs have to be provided under these various hypotheses; and
- (c) Extrapolation of costs for various sizes of reactors. In very few of the contemplated reactor systems is there any construction experience over a wide range of size or of net electric output, and consequently an evaluation of the

variation of construction costs with size remains difficult at the present stage. Among the existing power reactors some large units, such as the natural uranium graphite reactors, would have to be extensively redesigned to operate with enriched uranium in order to produce such smaller units, and a straightforward extrapolation of costs to units of reduced size would be misleading. Other reactors, such as those for naval propulsion, have been built to meet such special technical requirements that the inclusion of their costs in a general pattern would not lead to useful results. Still others, such as various boiling water reactors presently in operation, have been built essentially for experimental purposes and were conservatively designed to assure good performance; a considerable increase in the initial thermal power output of some of them has been possible and it is difficult to make proper use of cost data on them. Semi-empirical laws on size factors for certain reactor types are, however, being devised but they should only be considered for the time being as rough guesses. The importance of acquiring a clearer view on that question is considered essential.

26. Methods of evaluating the running costs arising from nuclear fuel burn-up appear to be well agreed upon, although the calculation may be quite complex if complicated nuclear fuel cycles are involved. There are available, however, limited data on actual costs of fabrication of nuclear fuel and also of the re-processing of irradiated fuel. Very little has been published on the costs of transportation of irradiated fuel elements, especially outside countries equipped with modern transportation networks.

27. Experience is also limited of the burn-ups of the fuel which can be obtained, but it is believed that recent technological developments allow for some optimism and that long life-times of the nuclear fuel in the reactor core will be a current achievement within a few years. This longer life-time should lower substantially that part of power costs accounted for by the nuclear fuel cycle, provided it does not disproportionately increase the fuel cycle charges.

28. As regards operating and maintenance costs, all of the existing nuclear power plants are being operated in highly industrialized countries, and the experimental power units are in most cases located in specialized nuclear centres. The experience acquired with these power plants cannot be directly used for extrapolating these costs to similar plants to be installed in less developed areas.

29. In spite of the difficulties described which prevent the calculation of firm and generally valid cost figures at the present stage, some basic trends have become clearly apparent since the beginning of the economic studies. Three factors in particular seem to have an important bearing on the power costs wherever and in whatever conditions a nuclear power plant is being built. For any given reactor type these are the power-capacity of the plant, its utilization factor and the financing charges (taxes, cost of money and depreciation).

30. As an illustration, it may be of interest to note that for one particular nuclear power system, planned and built in a highly industrialized country, studies carried out so far indicate that the cost of the KWh produced varies roughly by a factor of:

- (a) 2.3 for a variation of the size of the unit from 50 MW to 5 MW;
- (b) 3.0 for a variation of the load factor from 80 to 20 per cent; and
- (c) 0.7 if the total financing charges are 7 instead of 14 per cent per year,

which may mean that, for that type of plant, there could be in the order of a ten-fold difference in the electric generating cost from the best conditions considered (a 50 MW

plant operating at 80 per cent load factor, and with 7 per cent annual charges) to the worst (5 MW, 20 per cent load factor, and 14 per cent annual charges). The graphs in annex I give further indication of the possible variation in the relative cost of electric power generation due to a variation in the power output, load factor and annual financing charges. It is true that these figures will vary somewhat with different reactor systems, and in the present state of knowledge can be considered only as educated guesses; nevertheless they do indicate that the figures commonly quoted for rather large units operating with high load factors may be extremely misleading under less favourable conditions.

31. It is well known that the same general trends exist in conventional thermal power plants but, owing to the fact that their construction costs are generally lower, the resulting variations in the cost of power will be somewhat smaller. Considerable attention will consequently need to be given, when selecting a promising situation and comparing conventional power costs with nuclear, to obtaining a precise evaluation of the three factors listed above for both the conventional as well as the nuclear alternatives.

32. The Agency's studies of the costing of nuclear power installations must rely heavily on the provision of detailed cost data by manufacturers and constructors; and in order to allow for some extrapolation to be made, it is essential that the conditions under which these costs have been calculated should be precisely specified. A continuous flow of information from Member States must be maintained, as well as close contacts with all sources of information on nuclear power station costs. It is planned to continue the systematic collection of cost data which has been started and to develop the studies initiated, with particular emphasis on the extrapolation of data to the costing of nuclear power plants to be constructed in less developed areas. Costing engineers will be called in from time to time as consultants to review the studies in progress.

E. SEARCH FOR POTENTIALLY PROMISING SITUATIONS

33. As the Secretariat proceeded with the work of collecting and analyzing data concerning power development in interested Member States, with a view to selecting situations which may be particularly promising for the introduction of nuclear power at an early stage, it became apparent:

- (a) That inasmuch as the introduction of nuclear energy is only a part of the problem of power development in a given area, which is in turn a part of the more general industrial, economic and social development, the short-term and long-term problems are closely inter-linked, both from the standpoint of the less developed countries and from that of the Agency. No investigation of the immediate advantages of the introduction of nuclear power into a particular area could be divorced from a general examination of the power prospects in the country as a whole;
- (b) That although the final evaluation of the most promising cases could only be effected with the help of "on-the-spot" surveys by specialized teams, it was desirable to obtain from the beginning such detailed information on conventional power costs as would permit a preliminary classification of areas of potential interest. Of particular importance were data on conventional fuel costs; there is no hope as yet for nuclear power to compete on the grounds of capital costs (the construction costs of a nuclear power unit are still much higher than those of a conventional thermal power plant of the same capacity) and it is only because of lower fuel costs that nuclear power plants

may become competitive. A very close examination of the local cost structure for conventional fuel was therefore necessary, taking as a starting point the costs of local production or import of that fuel; and

- (c) That it was highly desirable to avoid new and detailed questionnaires and any duplication of work already done elsewhere. Consequently, full use should be made of existing sources of information and close contact established with all organizations already working on related questions.

34. As an initial step a circular letter was addressed to all Member States to ascertain their desire to participate in a survey of their power needs. By 1 August 1959, 35 replies had been received, of which 20 expressed a positive interest in the survey and the intention to participate, six indicated that the matter was under study and nine were negative. The 20 positive replies emanated from Argentina, Burma, Ceylon, China, Finland, Greece, Iran, Italy, the Republic of Korea, Mexico, Pakistan, the Philippines, Portugal, Thailand, Tunisia, Turkey, the Union of South Africa, the United Arab Republic, Venezuela and Yugoslavia. Several of these States expressed their interest in small and medium size reactors as an initial step in familiarizing themselves with the problems of nuclear units in the future. Furthermore, some of the replies which indicated no desire to participate in the survey contained offers of assistance to the Agency in the discharge of its task under the resolution of the General Conference.

35. Data on the power situation in the interested countries are at present being classified and studied. It will be noted that the countries which have shown interest in the resolution represent a great variation in stages of industrial development, and consequently their early needs for nuclear power will differ somewhat one from another. The more industrialized among these countries already have a well developed electric grid network and, although they are willing to follow the studies undertaken by the Agency, their special interest is directed towards nuclear power units of a larger size than could be included in the term "small and medium power reactors". The same situation prevails in specific areas in large countries which may be considered as less developed in toto but which have some regions in an advanced stage of industrialization. On the other hand, outside those limited, highly industrialized areas, and in some of the smaller countries, the total installed power is as yet so limited that these countries judge it premature and imprudent to meet the increase in their power demand by installing a rather large nuclear power plant. It is in these cases that interest is expressed for small and medium power reactors, but the same countries also consider the prospects of larger nuclear power units when they refer to their long-term needs, when they will be equipped with an inter-connected network. Some interest in installing a nuclear power unit of small or medium power output in a highly industrialized area has also been expressed, but in that case the main reason put forward is to acquire practical experience at the cost of a smaller total investment. The preliminary answers to the circular letter thus received tend therefore to lead to the conclusion that the concept of "small and medium power reactors" should not be interpreted too strictly and that, at a later stage, it may also prove useful to consider larger units.

36. The Secretariat has also prepared an outline of the minimum information required by the Agency ranging from general, readily available data to answers to somewhat more detailed questions, such as the costs of conventional power in a country according to area and mode of generation, typical construction and fuel costs, utilization factors for recently erected power plants, load factors, fuel transportation and power transmission costs. Copies of this outline have been sent to all Governments that have expressed an interest in participating in the studies under the resolution.

37. Contact was also established at the outset with the Secretariat of the United Nations as well as with the International Bank for Reconstruction and Development. The Agency despatched to them the outline referred to in the previous paragraph and laid the foundations for co-operation which have already begun to bear fruit. The United Nations Secretariat has declared its willingness to extend, within its available means, full assistance to the Agency.

38. As a result of the collaboration of the Secretariat of the Economic Commission for Europe, much data on European countries participating in the survey, the collection of which would have called for extensive research, were obtained in a short time, and additional information is still being received. The Secretariat of the Economic Commission for Latin America has expressed its full readiness to supply the information required and has already made available some economic data. The Economic Commission for Asia and the Far East lent its assistance to the Agency's preliminary missions to Asia, and has informed the Secretariat of its intention to expand its programme of collection of information in the power field; in addition, it has already sent some preliminary data. The co-operation of the Economic Commission for Africa, which held its first session in December 1958, also promises to be useful since the Commission counts several participants among its Members.

39. In response to an invitation extended by the Director of the International Bank for Reconstruction and Development, a senior member of the Secretariat has spent a few weeks discussing with various members of the Bank's staff the power problems of different regions, and informal discussions have also taken place with the Bank's specialist in atomic energy matters.

40. The Director General has also discussed with the Managing Director of the United Nations Special Fund the question of assisting less developed countries to develop nuclear power, and is maintaining contact with him by correspondence. The Agency will co-operate closely with the Special Fund to provide possibilities of using it to carry out the resolution, a fact which the Governments of interested Member States may wish to bear in mind.

41. It will be realized that the kind of studies called for by the resolution makes it impossible to separate arbitrarily some of the conventional power aspects from the nuclear aspects of the problem. For instance, in those areas where a grid system is either in existence or planned, part of the electricity supplied to the grid will be of conventional origin and part of it of nuclear origin, and to undertake a separate evaluation of the costs of both parts would be meaningless. In other cases where the installation of a nuclear power plant at a particular place is contemplated, it will be necessary to evaluate and compare the costs of conventional and nuclear power production at that location. This will require a very careful choice and adjustment of the pattern of hypotheses on both types of plant in order to allow for a just comparison, and it would appear unwise to arrange for the two types of studies to be carried out by different bodies. Although, therefore, the maximum of help and advice will be sought from the most competent international bodies dealing with conventional power and economic development such as the United Nations and its regional economic commissions, it is indispensable for the specific central tasks of comparison of costs and evaluation of situations to be carried out continuously within the Agency itself.

42. While thus organizing a systematic collection of all relevant published information, the Secretariat has remained aware that the task the Agency has undertaken calls for up-to-date, specific and detailed technical data which can best be secured by direct contact with specialists in the countries themselves. Consequently, full use is being made of the preliminary assistance missions and of teams which the Agency is

despatching to various areas, and these missions are being instructed to seek as detailed direct information as possible on all matters covered by the outline referred to in paragraph 36 above. The importance of such first hand information can hardly be over-emphasized. Delays of several years in publishing statistics, widely divergent forecasts of future power consumption and different costing procedures for power projects, often not mentioned in the published material, all give rise to ambiguities in the interpretation of data which only on-the-spot investigation can help to clarify. The experience of the missions to South East Asia and Eastern Asia were particularly fruitful and illuminating in this regard.

F. TRAINING OF SCIENTISTS, ENGINEERS AND TECHNICIANS

43. As regards the provision of assistance to less developed countries in planning and implementing their programmes for training reactor scientists, engineers and technicians (paragraph 1 (d) of the resolution), the Agency is fully prepared to initiate special action when needed. It will be recalled, however, that in 1958 and 1959 a great number of requests have been made by the Governments of Member States under the Agency's regular training programme for the training of reactor specialists. In 1958 out of a total of 279 requests for fellowships, 113 were in the domain of reactors and nuclear power; so far this year the figure has amounted to 161 out of a total of 491 requests. These requests for fellowships were made by the Governments of many different Member States, including the less developed ones. In awarding reactor fellowships to nationals of less developed countries, particular attention has been paid to the date when the requesting Government would have a reactor in operation, and also in some instances when these countries would need specialists to develop their reactor programmes. It seems clearly desirable for Governments to time their reactor training programmes in relation to their reactor development, with perhaps the first programme advanced over the second by one or two years, since such a time-table will permit reactor specialists to be employed shortly after having been trained.

44. As long as definite indications have not been obtained from the studies undertaken under the General Conference's resolution, that such or such a situation within a given country is promising for the early introduction of nuclear power, the Government concerned would conform to the normal pattern in submitting requests for training under the regular training programme of the Agency. If it turns out that a number of cases studied will lead to the early development of nuclear power plants, a special training programme might be introduced to cover those needs; but it is already apparent that a special programme of this kind cannot be initiated before the end of 1960 at the earliest.

G. SUMMARY OF PROGRESS AND OF FUTURE PLANS

45. The work that has so far been done to give effect to the wishes of the General Conference has followed the general lines of the resolution itself and the initial programme approved by the Board of Governors in January 1959. This work is conceived as having a continuing nature, in view of the long-term implication of the introduction of nuclear energy as one of the potential sources of power for the less developed areas of the world and their intimate connexion with the studies of general economic development and the evaluation of the power needs and potentials of the world by the United Nations. In this connexion, the resolutions adopted by the Economic and Social Council at its twenty-seventh session are of particular importance. [3] These activities are receiving, in some instances, valuable financial support from the Special Fund and other international sources.

[3] Particularly 709(XXVII) and 710(XXVII).

46. In the meantime, however, it is felt necessary to evaluate the current possibilities of introducing nuclear energy in a few particularly favourable cases in some less developed areas. Where power requirements are localized and limited, small and medium power reactors may be needed. However, it is well known that small sizes of power units and low utilization factors have adverse effects on the cost of power production. The short-term 1959-60 programme is therefore aimed at providing answers to the following questions:

- (a) Which types of power reactors among those known today would meet the requirements of construction and operation in a less developed area, and in particular would lend themselves to an optimization of design within the range of small and medium power units?
- (b) What are the known cost data and the current trends in the cost of nuclear power plants, and how could cost data obtained for reactors constructed in highly industrialized countries be used for less developed areas?
- (c) Are there specific locations in less developed areas where power needs could be met in the near future by nuclear energy at costs competitive with those of conventional power? If not, are there determining factors other than costs which would justify the installation of nuclear power units at an early stage?

47. The answer to the last question will naturally depend on those given to the first two. These in turn require the collection and analysis of a considerable amount of information. At the time of writing this report, the collection of this information is far from complete and the analysis of some of the data could only be started recently. This first phase of the work should take the great part of the year 1959. A preliminary analysis of particular situations, to be carried out by the end of 1959 or in early 1960 should indicate a number of cases where prospects appear promising, from the viewpoint of comparative power costs among others; it is intended to evaluate more specifically some of those promising cases and to bring the results of those evaluations to the attention of the General Conference during its fourth regular session in 1960.

48. In the meantime, the technical and cost studies of small and medium power reactors will lead to the technical conference or symposium referred to in paragraph 12 above. This meeting should be of great value in helping all Member States, whether highly industrialized or less developed, to acquire the most up-to-date view of the situation. On the one hand, the incentives that may exist for the manufacturing organizations in industrialized countries may be more clearly brought to light; on the other, all Member States could apply the results obtained to the particular conditions prevailing in their respective countries.

49. It is impossible at the present stage to anticipate the results which may emerge from the short-term studies undertaken by the Agency, especially with regard to any specific area of the world. However, it may be opportune to consider the possible range of situations that may emerge. In some instances situations may be found where nuclear energy can, for a specific power need, compete almost immediately with conventional power resources. Other cases may be found where the situation may be only marginally unfavourable for nuclear energy. These marginally unfavourable cases should not, it is considered, be overlooked, especially if they relate to areas where it is believed that nuclear power will be needed in the future, or if they represent good examples of typical situations (arid location, process heat, water desalting, etc.). In those cases, the power production cost in excess of that of the conventional power alternative should be considered as the price of acquiring experience, and it would be for the country or group of countries interested to judge whether they could afford to

pay that price. The studies could also provide indications as to the most appropriate type of power reactor system and the nuclear fuel to be used.

50. Finally, the problem of financing would have to be solved. In cases where the interested Government wished to seek further assistance in this sector, it would have to be seen whether some international partnership scheme could be worked out. Several possibilities could be considered, such as the wish of neighbouring countries to participate in the project in order to benefit from the operating experience and the possibility of providing training opportunities on a regional basis. The Agency might well be in a position to stimulate such arrangements or to give its support to the undertaking by advanced countries of technical development work on power reactors in partnership with less developed countries. Such a partnership would provide first hand experience with the construction and operation of a nuclear plant in a less developed area. Still another possibility might be for the interested Government to apply for support from the Special Fund, stressing the "pilot" character of a project aiming at installing a small or medium nuclear power plant in a less developed area, which could bring valuable knowledge to all countries on the operation of such a plant under some typical conditions.

51. Independent of the possibilities of such favourable or near favourable situations being brought to light, an objective evaluation of both the availability of and the demands for power reactors, especially of small and medium power output, within the near future will prove extremely useful in providing a sound basis for any further programme to be undertaken by the Agency. With this information at its disposal the General Conference will no doubt be in a position at its fourth regular session in 1960 to make recommendations as to the next stage in the continuing effort of the Agency to render assistance to the less developed countries with the development of nuclear energy as part of their power programme.

A N N E X I

PRELIMINARY INDICATION OF THE RELATIVE COST OF NUCLEAR POWER GENERATION

Variation with Reactor Output, Load Factor and Annual Capital Charge



