at Saclay from 6 to 10 July 1959. Twenty-eight papers were presented at the seminar. The authors of these papers as well as those who took part in the discussion on them had had valuable experience in important fields of teaching and research and were, therefore, able to speak from an intimate knowledge not only of the requirements of atomic energy work but also of the specific problems of education, research and training.

The opening session of the seminar was addressed by the Director General of IAEA, Mr. Sterling Cole, the acting Director General of UNESCO, Mr. Malcolm Adiseshiah, and the High Commissioner for Atomic Energy in France, Professor Francis Perrin. There were four main sessions. The first, which dealt with the role of the Universities in nuclear education, was presided over by Professor Glenn Murphy of the Iowa State University, USA. The second was concerned with education in nuclear technology in the engineering colleges; Professor Jack Diamond of Victoria University, Manchester, UK, was chairman of this session. The third session, at which the chairman was Professor Bertrand Goldschmidt, Director of the Departments of Programmes and External Relations, French Atomic Energy Commission, discussed the education and training methods at nuclear research centres. The fourth session, which was devoted to the role of international organizations in this field, was presided over by Professor A. N. Rylov, Deputy Director General of IAEA in charge of the Department of Training and Technical Information.

Panel Discussions

The four main sessions were complemented by panel discussions on (a) nuclear education at the secondary school level, (b) nuclear education at the advanced University level, (c) training in health physics, and (d) special problems. Most of the participants took an active part in these discussions. In the panel on special problems, the subjects discussed included the need for specialization and the stage where specialization should begin. There was almost complete agreement on the need for improving the general scientific background of students and introducing the fundamental principles of nuclear physics in the teaching of general science.

During the seminar, the participants were shown round the Saclay Nuclear Research Centre. They also visited the French National Institute of Nuclear Science and Technology, where the available facilities and training methods were explained by the Director of the Institute and the Research Centre, Professor J. Debiesse.

Those who took part in the Saclay seminar expressed the hope that the work done at the seminar would be continued in some way, possibly through a special committee or by other suitable means, within the framework of IAEA and UNESCO. The papers presented at the seminar as well as the records of discussions will be published jointly by these two organizations.

POWER PROGRAMMES REVIEW

The following is the second in a series of articles on nuclear power programmes in the Member States of IAEA. Each issue of the Bulletin will carry a factual report on the programme of one Member State

NUCLEAR POWER FOR INDIA

India will require a substantial increase in the generation of electrical power to meet the demands of her developing economy. A survey of available resources has been made in the context of development envisaged under the country's five-year plans and it is felt that atomic energy will have to be used in increasing quantities to supplement conventional fuel resources in order to attain the anticipated power targets in the next two decades.

It has, therefore, been decided that a small beginning will be made with the erection and commissioning of an atomic power station of 250 MW (electric) capacity by the end of 1964. The installation of a further 750 MW of nuclear power by the end of the third five-year plan period, i.e. by March 1966, is under consideration. At the IAEA General Conference last year, the Chairman of the Indian Atomic Energy Commission, Dr. Homi J. Bhabha, said: "It is very probable that this minimum (250 MW) will be doubled, and not unlikely that it may be raised to a million kilowatts."

At present, preliminary steps are under way for the selection of a site and preparation of specifications for the first nuclear power station. A decision on additional power stations during the third five-year plan period may be taken in the near future.

This is a programme of considerable dimensions, and it will be the beginning of a much bigger programme for the utilization of India's vast thorium resources for the generation of power. To realize why India is embarking on a programme of this magnitude, one must examine the present pattern of the country's power demands and supply, the likely rates of growth, the extent to which the growing demand can be met by sources other than nuclear energy and the conditions that will make the resort to nuclear power a necessary and feasible proposition for India.

Present Pattern and Future Demand

The Indian economy is still predominantly agrarian and a very large proportion of the energy consumed in the country as a whole is derived from the burning of crude vegetal fuel and agricultural waste. With the rapid industrialization now under way, this pattern, however, is changing. The change involves a correspondingly larger demand for more efficient energy sources like coal and oil. This, in turn, not only helps in the generation of electric power but also leads to an increase in the demand for power. The whole process is both a factor and a feature of industrial growth.

The installed capacity of electric power in India is now less than 6 000 MW. By a rough estimate, more than 50 per cent of the total power output is now contributed by coal, more than 40 per cent by hydro sources and five per cent by diesel oil. The present emphasis is on the development of hydro-electric power, partly because of its link with irrigation and flood control. It has been estimated that at the end of the second five-year plan period, i.e. March 1961, hydro power will amount to more than 50 per cent of the total output, about 45 per cent will be contributed by coal and less than five per cent by oil.

The striking fact about the power situation in India is the rapid rate of growth. The generating capacity doubled during the period of the first five-year plan, 1951-56, the actual increase being from 1 700 MW to 3 400 MW. A doubling has also been envisaged for the current Plan period, so that by March 1961 the installed capacity will be nearly 7 000 MW.

While the actual rate of growth over the next few decades cannot be precisely determined in advance, Indian planning experts expect the current rate of compounded growth to continue for the next 20 years. If the generating capacity thus doubles itself every five years, it will be about 30 000 MW in 1971. Working on this estimate, Dr. H.J. Bhabha and Mr. N.B. Prasad, in a paper presented at the 1958 Geneva Conference, showed that even allowing for a gradual tapering off after 1971, the electrical capacity would be of the order of 350 000 MW by the end of the century. On the basis of an earlier conservative estimate, the corresponding figure would be 140 000 MW.

The difference between the two estimates, though striking in itself, is not really important; projections of growth are necessarily tentative, more so in the early stages of democratic economic planning on a very large scale. What is really important is the order of magnitude. Even if one adopts an arbitrary and somewhat simplified mean between the two estimates, one is faced with the prospect that in the course of the next 40 years or so, India's electrical capacity will increase from less than 6 000 MW to about 245 000 MW. In other words, one must reckon with an increase of more than 40 times in about 40 years.

These are, of course, estimates of growth in supply, and they are based on the assumption, first, that the increase in demand will make an increase in supply of this magnitude absolutely necessary and, secondly, that it will be possible to increase the supply to match the increase in demand.

About the first assumption, there is little scope for doubt. The process of industrial and general economic growth that has already been set in motion will call for a rapid and continuing increase in power supply. And a more important factor is the increase in India's population. This is a factor of such immense proportions that even if there were to be no increase in per head power consumption there would have to be a large increase in the total power supply. The present population is about 400 million, and judging by the trend of growth, a population of 500 million in 1985 and 600 million by the end of the century is the least that one can expect. If, therefore, India were to increase her power consumption per head by a significant factor, while allowing for this increase in population, the increase in total electrical capacity would certainly have to be of the order indicated in the estimates given above.

The second assumption needs more detailed examination. The starting-point in such an examination must be a statement of future demand and of the extent of available resources to meet that demand. The estimates of growth quoted earlier may or may not be accurate in regard to the increase in supply that will be actually achieved, but they certainly indicate the order of increase that can be expected in the volume of demand. It would not, therefore, be unreasonable to expect that in a little over a decade India will need nearly 30 000 MW of generating capacity and in 25 years from now the requirements will be of the order of about 100 000 MW.

Available Resources

How much of this increase in demand can be met by conventional sources of power? Oil, which makes a minor contribution now, can be left out of account. The established oil reserves in India are small, and while new reserves may be discovered, they are not likely to be large enough to change the total outlook. Besides, oil is likely to be increasingly used for purposes other than power generation, such as road transport. One must, therefore, primarily consider coal and hydro sources.

India's total hydro-power potential is estimated at between 35 000 and 40 000 MW. Even assuming that the entire potential will have been exploited in 25 years, at least 60 000 MW of generating capacity will have to be based on coal at that time, if the volume of demand estimated above is to be adequately met. That would require an annual consumption of over 200 million tons of coal.

India's total coal reserves are estimated at between 40 000 and 60 000 million tons. Considering the size of the population, this cannot be regarded as large. There is now between 100 and 150 tons of coal per head of the population, which is to be compared with about 15 000 tons per head in the United States, more than 3 000 tons per head in Britain and over 2 000 tons per head in China.

If India's annual coal consumption rises to 200 million tons around the year 1984, the total coal reserves will have a further life of a little over 200 years at the then current rate of use. And since the rate will not remain stationary, the point of exhaustion will arrive much sooner. And acute scarcity will arise long before total exhaustion. Dr. Bhabha and Mr. Prasad, in their Geneva conference paper, stated: "We should ..... expect on a conservative estimate that India will have reached the stage by 1986, when increasing the coal production further would become more and more difficult and expensive. India may well have reached this stage by the 70's of this century. The generation of large amounts of electricity from coal-fired stations would then be a burden to be avoided, if possible, and an operation which would give much more expensive electricity than at present. It has been pointed out that coal costs have risen in India by about 50 per cent during the last 12 years, and they may be expected to have increased considerably by 1986 as annual production of coal goes up."

It should be noted that in making this observation, the authors of the paper did not envisage as large an increase in power supply as has been forecast by some others. But even while basing their projections on relatively conservative estimates, they found that by 1986 the total installed capacity would be 50 000 MW, that not more than 60 per cent of it could be expected from hydro sources, and that it would be uneconomic to depend entirely on coal for the remaining 40 per cent. They envisaged, therefore, that by 1986 India would have 10 000 MW of installed nuclear power capacity, while hydro sources and coal would contribute 30 000 MW and 10 000 MW respectively. If the total generating capacity is to be larger than that foreseen by these authors, the contribution to be made by nuclear energy will have to be correspondingly larger.

Immediate Needs

The next question is whether there is need for any immediate installation of nuclear power in India. That the need will arise in less than two decades is obvious, but whether it is necessary to make an immediate beginning towards meeting that need is another question. And to answer that question one must consider some of the specific facts of the power situation in India.

As regards hydro-electric power, full exploitation of the total potential would depend on many complex factors, some of which might make the task rather uneconomic in certain areas. It has, for example, been pointed out that the rivers in central and south India are not fed by melting snow but by monsoon rain. The harnessing of these waters for power generation involves the building of large storage reservoirs. In the immediate context also, hydro-electric schemes may have certain disadvantages. Construction of dams and other large works connected with such projects take a long time to complete, and this may delay the process of industrialization in areas without any existing supply of power. In such areas, it is often found necessary to build thermal power stations in spite of the fact that coal for these stations has to be transported over great distances. This has been done in several industrial centres like Ahmedabad, Bombay and Madras. Despite the fact that these centres can eventually be fed by hydro-electric power, thermal stations have had to be built to meet immediate needs.

As for thermal power, several factors make the dependence on coal an extremely uneconomic system in several parts of India. About 80 per cent of India's coal supplies come from the Damodar Valley in eastern India, and the generation of thermal power in all parts of India except the eastern region has to depend on the transportation of coal over great distances. The problem that arises from this situation is not merely one of availability of coal for the power stations in south, north and western India, but also of a great strain on the country's transport system. Insufficiency of wagons for coal transport has been a difficult problem and the difficulties are likely to increase with further development of thermal power. The railways not only find it difficult to cope with the increasing demand for wagon space, but are faced with a correspondingly larger financial loss as more space is allocated for coal transport, because the freight charges for coal are less than the actual cost of transportation.

In view of these factors, the Indian authorities consider an immediate recourse to nuclear power a feasible and desirable scheme for several parts of the country. Giving one example, Dr. Bhabha told the IAEA General Conference last year: "The present installed capacity of the Bombay grid is over 500 megawatts, and it is expected to reach nearly 800 megawatts by 1963, as a result of hydro-electric and thermal power stations now under construction. A study of the load curve for the grid shows a load factor of over 69 per cent, while due to the cost of coal, the cost of thermal power in this area is about four cents of a rupee, or some nine mills per kilowatt hour. This is clearly an area in which, due to the burden of transporting coal over large distances, a nuclear power station of 150 or even 250 megawatts could be installed without difficulty and operated at a high load factor."

Fuel Cycles and Cost Estimates

The foregoing analysis and estimates seem to make the conclusion inescapable that in less than two decades there will be a general need for substantial production of nuclear power to maintain the rate of India's economic growth, and that there is a strong case for the immediate installation of nuclear power stations in certain specific locations which are far away from coal mines and where hydro sources are scarce or difficult to exploit.

There is a further technical consideration in favour of the early installation of a few nuclear power stations in India. This arises from the nature of India's resources of nuclear raw materials. India's uranium reserves are not large enough to sustain a very long-term programme of power generation, but the reserves of thorium are. While the total reserves of uranium are estimated at a little over 30 000 tons, the reserves of thorium are known to be about half a million tons. These vast thorium reserves are contained in the monazite deposits on the west coast of south India and in the State of Bihar in eastern India. In both cases, monazite contains eight to ten per cent thorium and above 0. 3 uranium. Uranium is also found in Bihar and in the north Indian State of Rajasthan.

Eventually, India's nuclear power production will have to be based primarily on thorium. But thorium, as is well known, is really a source of nuclear fuel rather than the fuel itself. It has no fissile isotope, but by neutron irradiation thorium 232 can be converted into uranium 233, which is a fissile substance. Such irradiation can be arranged in a reactor fuelled by a fissile substance like plutonium or uranium 235. Separation of uranium 235 from natural uranium is a complicated and extremely expensive process, but plutonium can be produced in a reactor fuelled by natural uranium and the plutonium, in turn, can be used simultaneously for the operation of reactors and the conversion of thorium into uranium 233. And uranium 233 itself can then be used for this dual purpose; it will run a reactor and simultaneously turn more thorium into uranium 233.

The fuel cycles in a thorium-based power programme are, therefore, rather complicated. Before India can make use of her thorium resources for power generation, a series of preliminary stages will have to be gone through in which power reactors will be operated first by natural uranium and then by plutonium. In their Geneva Conference paper, Dr. Bhabha and Mr. Prasad stated: "When an abundance of uranium is available, on which to base a power programme covering several decades, the study of fuel cycles is not so important in the initial stages. In the case of India, the problem is complicated by the need to gradually change the basis of nuclear power production from uranium to thorium within the next 15 years or so. This makes essential the production of new concentrated nuclear fuels as a concomitant of the initial power production. We are, therefore, compelled to consider not only the first generation of atomic power stations, but the second generation to burn the fuel produced in the first, and the third generation to burn the fuel produced in the second."

Estimates of nuclear power costs are complex, more so when the power programme is dependent on the operation of a series of fuel cycles. An added difficulty is that breeder reactors, which can produce more fuel than they consume, are still experimental. Nevertheless, certain broad estimates can and have already been made of the probable costs of nuclear power in India. And these estimates show that in most cases the economic considerations are promising. The Indian authorities are of the view "that the economics of nuclear power are already such as to make it competitive with coal power in most parts of India." The authors of the study presented at the Geneva Conference added: "... with the vast reserves of thorium available in India, an additional investment in nuclear power in the first ten years would repay itself within the following ten years, and, what is more important, hold out the possibility thereafter of an expansion of the power programme at the maximum rate considered reasonable, namely doubling every five years, for an indefinite period."

Progress of Work

The Atomic Energy Establishment Trombay is India's national centre for research in the peaceful uses of atomic energy. India's first reactor, Apsara, which is of the swimming pool type, has been in operation for more than three years now and two other research reactors are under construction. These are the Canada-India Reactor, which is being built under the Colombo Plan in collaboration with Canada, and Zerlina, which is being designed and built by Indian scientists and engineers. The Canada-India Reactor will be a versatile high flux research reactor and will have facilities in which various power reactor concepts can be tried out in the so-called loop experiments. In addition, it will produce considerable quantities of radioisotopes for use in agriculture, biology, industry and medicine. The third reactor, Zerlina, will be a zero energy reactor for lattice investigations in natural uranium fuelled, heavy water moderated systems. Studies and work have begun on the prototype of a natural uranium fuelled, heavy water moderateu, organic cooled power reactor.

Considerable progress has also been made in the setting up of plants producing materials for a large atomic power programme and of special laboratories for radiochemical work. A plant for the production of thorium from monazite sands has been working for a number of years, and a plant for the production of uranium metal of atomic purity has been in operation since the beginning of this year. A fuel element fabrication facility has been completed and prototype fuel elements for the research reactors have already been produced. Investigations on the setting up of a large mill for treating uranium ores in Bihar are under way.

In the field of moderators, a heavy water plant with an annual capacity of over 14 tons is being built at Nangal, as part of large fertilizer complex. The possibility of producing heavy water at other fertilizer plants under construction in the country is also being considered. Besides, studies have been made for the production of nuclear graphite from indigenous raw materials, and a decision on a plant is likely to be taken soon.

SAFEGUARDS FOR THE ATOM

The reason why the development of atomic energy should be regulated by a system of appropriate safeguards hardly needs any elaboration today. Concern over the destructive potentialities of nuclear energy has grown all over the world. In fact, it was this concern, coupled with an awareness of the equally great potentialities for peaceful prosperity, that led to the establishment of the International Atomic Energy Agency.

That nuclear energy should be used solely for peaceful purposes is an ideal to which all people would subscribe. Realization of this ideal, however, is dependent on many complex factors which are outside the scope of the Agency. In its own limited sphere, however, the Agency has the responsibility to ensure that in its efforts to promote the peaceful uses it does not in any way increase the potentiality of military use.

Need for Agency Safeguards

Why it should be necessary for the Agency to be concerned with this problem will be clear if it is remembered that the basic science and technology of nuclear energy is the same for both peaceful and military applications. Essentially, the release of energy follows the same principle in a reactor as in a nuclear weapon; the difference is in the technical arrangements and consequently in the manner of release. It is, therefore, not impossible to divert some of the basic installations or materials from peaceful to military use.

The purpose for which the Agency was set up would be defeated if the development of atomic energy brought about by its assistance or under its auspices were to be used to further any military purpose, and the Agency must do whatever it can to prevent misuse of its assistance. The importance of this function was clearly recognized when the Agency was set up, as can be seen from the statement of its objectives in its Statute, which says that the Agency "shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose".

The possibility of military application is not the only danger that the Agency must guard against, it has a further function arising from the nature of the materials needed in atomic energy work. Since the basic materials are radioactive and since all ionizing radiation is potentially dangerous, the Agency must ensure that in helping its Member States to develop the peaceful uses of atomic energy it does not increase the hazards of nuclear radiation or radioactive contamination. It must establish standards of safe practice for activities carried out under its auspices or with its assistance. The Statute, therefore, authorizes the Agency to establish, adopt and provide for the application of standards and measures for the "protection of health and minimization of danger to life and property". If requested, the Agency may also apply safeguards and the health and safety measures to a State's own nuclear activities or to any bilateral or multilateral arrangement.

Since its inception the Agency has been engaged in a careful examination of all aspects of the problem, and after many months of expert study and consultation certain draft regulations have been worked out. These regulations, which embody the principles and procedures, for the application of Agency safeguards are being considered by the Agency's Board of Governors.

Two Types

Since the safeguards will have two distinct objectives, a distinction can be made between those which will be designed to prevent the diversion of Agency assistance to military use and those against health and safety hazards. So far as the health and safety measures are concerned, a good deal of work has already been done in determining the standards of safe practice which will be the basis for the relevant rules. The Agency has published the first in its series of safety manuals, "Safe Handling of Radioisotopes", which deals with such standards.

Safeguards against the diversion or loss of nuclear materials and facilities are more difficult to devise. It is not considered feasible for the Agency to set up a system of safeguards that would guarantee that no nuclear material at all could be diverted to unauthorized use. What the Agency intends is to apply its safeguards in such a manner as to achieve a high probability of detecting the diversion of even small quantities of materials, and when larger quantities are involved, to make detection almost certain.

Not all types of materials and facilities needed in peaceful atomic energy work can be of much use for military purposes, and the safeguards against diversion need not be applied to all projects with which the Agency may be concerned. The need for safeguards would obviously arise in the case of fissile materials, because of their possible use in the production of weapons. Materials ordinarily used as fuel