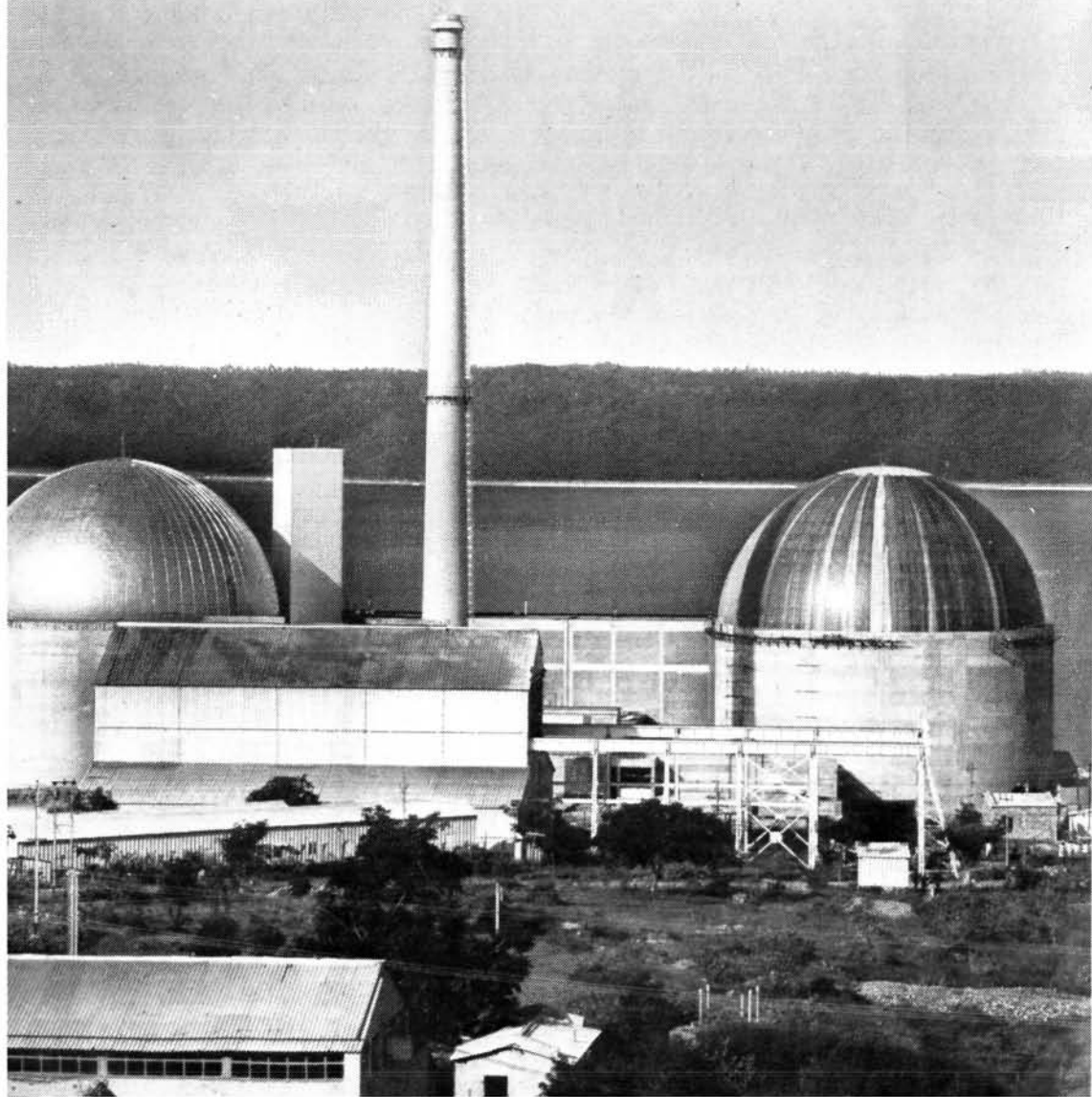


INDIA



PAST ACHIEVEMENTS AND FUTURE PROMISES

by H. N. Sethna, Chairman of the Indian Atomic Energy Commission

It is a well accepted truism that energy is the key to human progress. This has been amply brought home by the experience of the last few centuries, particularly since the advent of the industrial revolution. Inevitably the quest for progress has accentuated the demand for energy, which in turn has forced man to explore and try to exploit all available sources. For centuries energy came mainly from fossil fuel but on December 2, 1942, an altogether new source became available when man learned to tame the atom. Today on the occasion of the thirtieth anniversary of that historic event, it is pertinent to reflect how far the promises held out by nuclear energy have been fulfilled and what prospects the future holds.

One of the remarkable facts about the first harnessing of nuclear energy is that it was achieved barely three years after the discovery of the basic phenomenon of fission. Indeed there is no other known instance where a fundamental discovery has been translated into a major practical application with such rapidity. The demonstration of the feasibility of releasing nuclear energy in a controlled fashion together with a realisation of its vast potential naturally stimulated considerable interest in it during the post-war years, when mankind settled down to the task of reconstruction and of recouping from the ravages of war.

Many nations of the world from both developed and developing areas, have embarked on a nuclear power programme. Almost in every case the evolution of the programme has been influenced by a variety of factors, economic, political and social.

However, the manner in which these factors have operated have naturally tended to vary from country to country. For example, among the advanced countries, those with a weapons programme have experimented with enriched uranium reactors, thanks largely to the availability of U^{235} whose initial production costs were mainly absorbed by a military programme. On the other hand, other countries with a small or no nuclear weapons programme, based their plans on the initial use of natural uranium. In some instances nuclear power programmes appear to have been dictated not so much by an immediate shortage of fossil fuel but essentially by the need to stay at the forefront of technology, and not lose out on potential markets elsewhere.

In recent times, increased ecological awareness on the part of the public has also tended to make an impact of its own. Economic, political and social factors have had a bearing on the programmes of the developing nations also, although the interplay of these factors have been vastly different from that in the case of the developed countries.

The Indian Atomic Energy programme is now nearly two decades old. It represents something of a unique experiment in fostering advanced technology on a large scale in an under-developed country.

The first problem was to convince the national planners that a nuclear energy programme was meaningful and relevant in the context of the development plans of the country. The meagre financial resources on the one hand and relative industrial backwardness on the other had to be considered. Thanks however to the dynamic efforts of the first Chairman of the Indian Atomic Energy Commission, Dr. Homi Bhabha and the sympathetic understanding he received from the Prime Minister, Jawaharlal Nehru, it soon became possible to convince the administrators and the politicians that nuclear energy was necessary, and indeed economic.

Speaking of the relevance of nuclear energy, Jawaharlal Nehru once remarked, "if you have the picture of the future of India that you are trying to build up and of the power that you require you will come to the conclusion of the inevitability of our building up atomic power for peaceful purposes". Having won governmental support, the Atomic Energy

Commission gave considerable thought to the formulation of a strategy for the development of nuclear energy. Generation of nuclear power has been one of the major objectives of the atomic energy programme in India.

One of the early tasks was to establish a firm technological base for the various activities involved in the development of atomic energy. A national research centre then called the Atomic Energy Establishment Trombay and now renamed as Bhabha Atomic Research Centre (BARC) was created at Trombay near Bombay, and a wide range of R & D activities were initiated, ranging from basic studies in nuclear and solid state physics to investigations in metallurgy, engineering, health physics and nuclear medicine.

Viewed especially against the Indian background, the Centre's contributions have been substantial. In addition to building up expertise to take up work in connection with the development, design, and construction of power reactors, it was essential to introduce the manufacturing know-how into industry for the fabrication of all the sophisticated components for these reactors. It was also necessary to establish processes for the fabrication and reprocessing of nuclear fuel and the production of fuel materials and other special materials such as zircalloy and heavy water. Endeavour to be self-sufficient in all aspects of nuclear technology is particularly important for a developing country, so that introduction of a fairly large nuclear power programme does not result in too unfavourable a balance of payment situation.

Based on the experience gained at BARC, it has now become possible to start new production centres concentrating on specific aspects of nuclear technology. The Electronics Corporation of India (ECIL) and the Nuclear Fuel Complex (NFC) represent two examples. Another notable spin-off will be the Reactor Research Centre (RRC) located at Kalpakkam near Madras, where the development of fast reactor technology will be carried out.

Although India was not without a scientific base when the atomic energy programme was launched, organized science was something new to the country. Aside from the chain of National Laboratories set up by the Council of Scientific and Industrial Research in the first years after independence, the atomic energy programme was the only one to involve massive and organized scientific effort. As skilled manpower required for this was not readily available, a training programme was initiated at BARC for new university graduates so that they could be oriented to fit into the atomic energy programme. It is not surprising therefore, that the emphasis in the atomic energy training school is on self-reliance, and the need to work as members of a team for the acquisition and generation of technological skills. This training programme has paid off exceedingly well, and the bulk of the scientists and engineers associated with the atomic energy programme, be it at BARC or at the Power Plants under construction in Rajasthan and Madras, are graduates of the BARC Training School.

It is fair to conclude that manpower training must form an important and integral part of the nuclear energy programmes of developing countries. This is in contrast to the advanced countries where trained manpower is readily available, and at best only a small re-orientation is required for adaptation to atomic energy work.

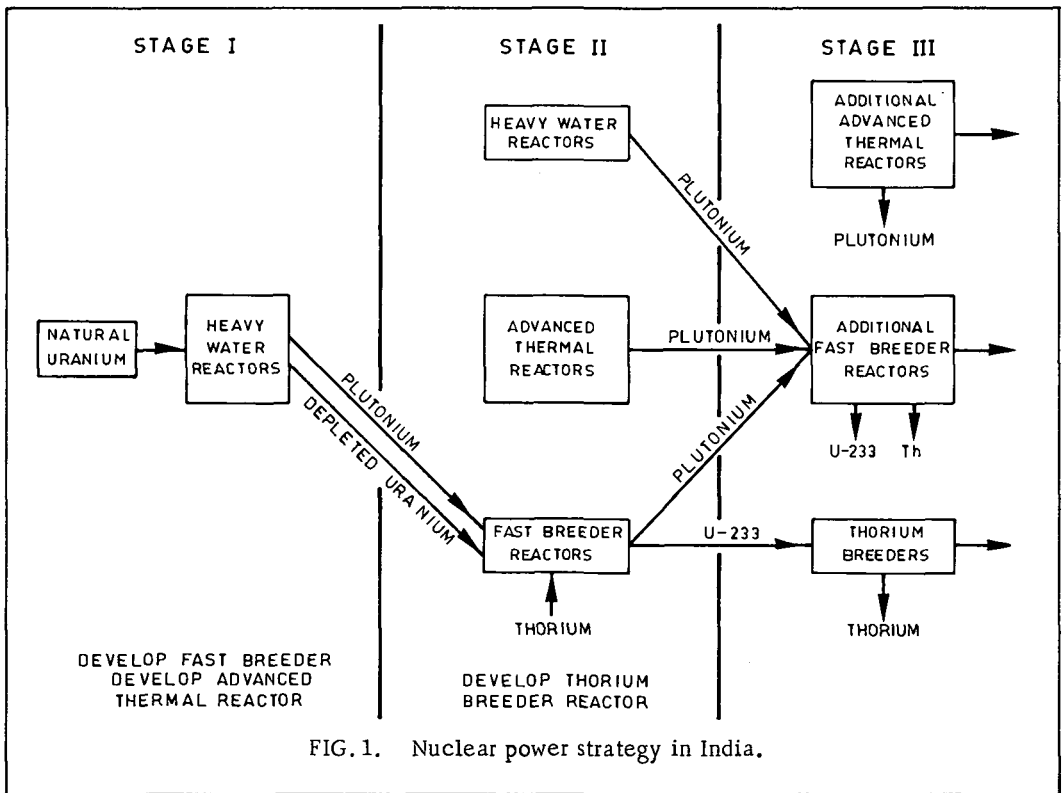
As the research centre at Trombay began to grow, it became clear that one could look forward with confidence to the establishment of a base for nuclear technology, and to the availability of expertise and manpower to launch a large-scale power programme. Accordingly, in 1960 the Atomic Energy Commission submitted its first concrete proposals to the Planning Commission for the setting up of nuclear power stations in India. The basic premise was that nuclear power was essential even at that time for economically supplying energy in large parts of the country, and that it was the only major supply on which the country could fall back by the turn of the century. More specifically it was estimated that even in 1960, nuclear power would be competitive with that generated from Thermal Stations situated more than 800 km. from the coal fields. Since the latter were mainly in Bihar, and since over 35% of the country by area and 30% by population lay beyond the breakeven radius, nuclear power stations with

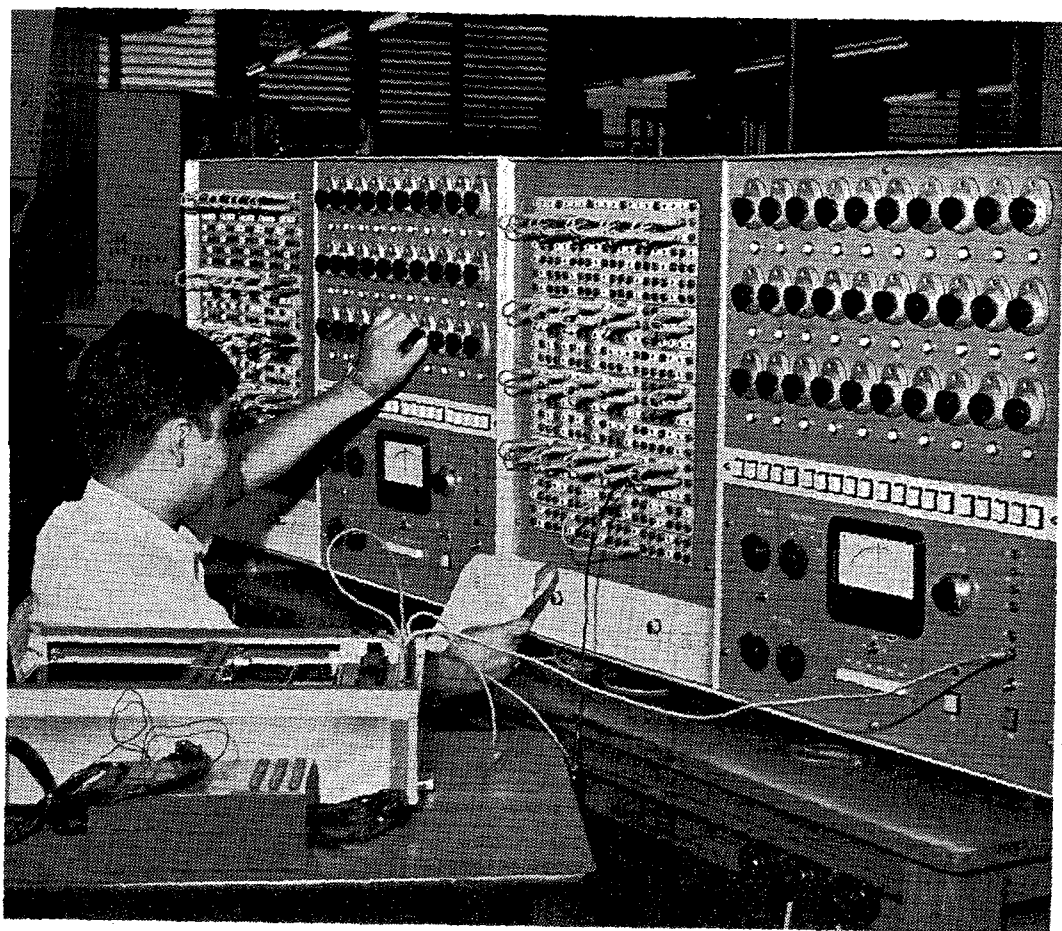
even single units of 200 MWe offered an advantageous solution to the power demands of areas far removed from the coal fields.

To quote from the memorandum submitted by Bhabha to the Planning Commission, "The major fraction of the nuclear power capacity will be installed in natural uranium power stations which are dual purpose stations producing power on the one hand, and plutonium on the other. This plutonium is a concentrated fuel, which is not available from outside as a commercial commodity, and its production is essential in order to enable the country to set up breeder power stations using thorium or depleted uranium for the second stage of its nuclear power programme. Such power stations will also be much cheaper in capital cost than the present one, and the indications are that power from these may even be competitive with power from conventional thermal power stations near the coal fields. It will not be possible for India to take advantage of these developments later, unless steps are taken now to set up dual purpose power stations for producing plutonium".

For the nuclear power programme in India the strategy as presented in Fig. 1 has been planned to lead to a sustained growth of power. In the first stage of the programme, natural uranium fuelled and heavy water moderated and cooled reactors of the CANDU-PHW type are being set up. At present 200 MWe size units are being installed, but as soon as manufacturing capability and electrical grid capacity as well as transport problems make it feasible, 500 to 600 MWe size units will be installed.

At the same time development work on the sodium cooled fast breeders has been initiated. A 40 MWt Fast Breeder Test Reactor is being set up at the Reactor Research Centre at Kalpakam. Development work on advanced thermal reactors (which would be second generation heavy water reactors and which may have specific advantage over the CANDU-PHW design) is proposed. Studies are being made at present to assess the potential of boiling light water as the coolant in a heavy water moderated reactor.





An analog computer being manufactured by the Electronics Corporation of India Ltd., Hyderabad.

In the second stage of the programme, it is proposed to build fast breeder reactors using plutonium as the fuel, which would have been generated in the heavy water reactors. However, since the doubling time for installing nuclear power will be shorter than the doubling time for the most optimistic type of fast breeder, it would be necessary to continue construction of heavy water reactors even after the fast breeders have been commercially accepted as economic power reactors. The total installed nuclear capacity which may double every 5 years has been shown in Fig. 2. The relative contribution to the total installed capacity by the heavy water reactors and by the fast breeders will depend on the type of breeders developed, and the performance characteristics that would be achieved. Assuming that only heavy water reactors and plutonium fuelled fast breeders would be available as fully developed commercial reactors, the contribution by each of these two to the total generating capacity has also been shown in Fig. 2.

Two types of fast breeders have been considered for this presentation - one with a specific fissile inventory of 2.5 kilograms per MWe and a doubling time of 7 years, and the other with a specific fissile inventory of 3.0 kilograms per MWe and a doubling time of 13 years - the rate of introduction of fast breeders being controlled by the availability of plutonium from the heavy water reactors, and the plutonium generated by the fast reactors themselves. It may be noted that out of the total nuclear installed capacity of 43 million kilowatts by the end of this century, about 50 to 75 per cent may be from fast breeder reactors and the rest from heavy water reactors.

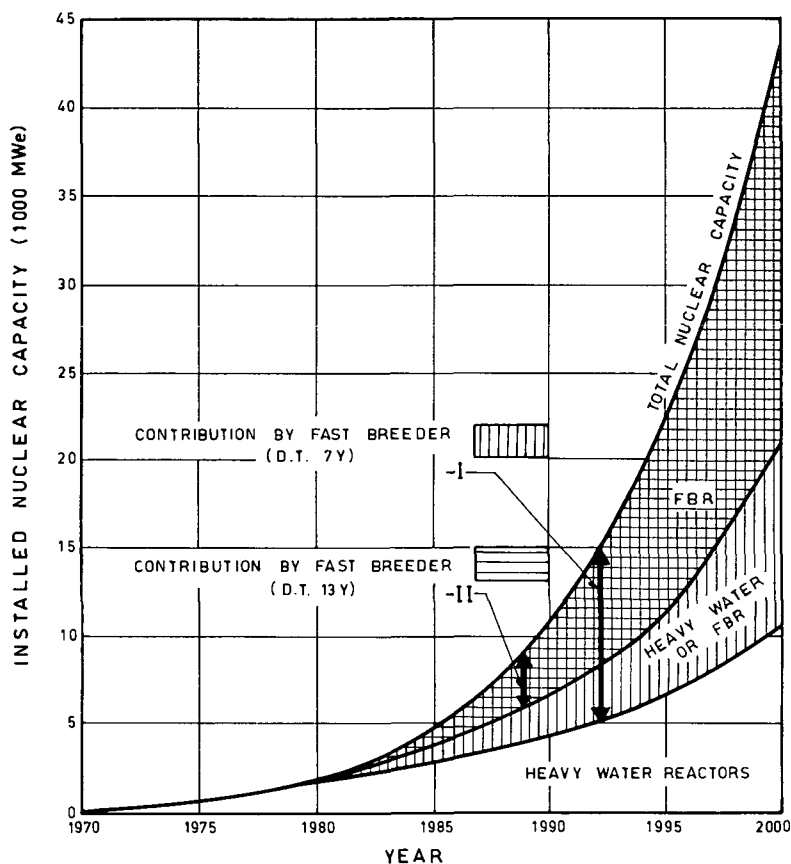


FIG. 2. Growth of installed nuclear capacity.

As the natural uranium resources in India are limited, it would be necessary to minimise the total quantum of power generated by heavy water reactors and maximise the contribution of the fast breeders. Hence, during the following two decades a major effort will be made towards the development of efficient and economic fast breeders.

Because of the limited resources of natural uranium, studies are being carried out on the use of thorium in fast as well as in thermal breeder reactors. It is proposed to initiate development effort on the thorium breeder reactors during the second stage of the programme, so that thorium breeders would be available in the third stage. Hence, in the third stage it is quite possible that there would be four types of reactors simultaneously in operation, viz natural uranium fuelled heavy water reactors, advanced thermal reactors, plutonium fuelled fast breeders, and breeders using the thorium cycle.

The role that nuclear power could play in the future in starting agro-industrial complexes in the different regions of the country has been well brought out in the recent studies carried out with respect to Western Uttar Pradesh and Saurashtra regions in India. The impact that the supply of cheap energy and water could make on the countryside is so striking that it would be rewarding to initiate the necessary development programme towards the establishment of such agro-industrial complexes.

Apart from power production, the multifarious applications of radioactive isotopes and radiation constitute the most important use of atomic energy, and will play a significant role in the future.

Radioisotopes have been widely introduced in India to serve industry, agriculture and medicine, and their role in these areas is expected to increase vastly both in quantitative and qualitative terms.

The current level of diagnosis using radionuclides in India is only 0.05 per thousand population per year. Our plans envisage a twenty-fold increase within this decade. This ambitious programme would require the setting up of zonal radiation medicine centres and smaller radio-isotopic laboratories in over a 100 medical college hospitals throughout the country.

To sustain the vastly increased variety and quantity of radiopharmaceuticals that this programme would require, various specific steps are being taken. These include the construction of a new high flux reactor with substantial irradiation volume and a variable energy cyclotron of 60 MeV. Production facilities for the manufacture of end products will also be enlarged.

High specific activity Co-60 will be available in substantial quantities from our new power reactors. This will enable us to widen the coverage of teletherapy in the country. As a major back-up, a manufacturing programme for indigenous teletherapy units is being implemented by private industry with the assistance of BARC.

The wellknown industrial applications, such as nucleonic gauging, industrial isotope radiography and radioactive tracer studies are fast becoming commonplace.

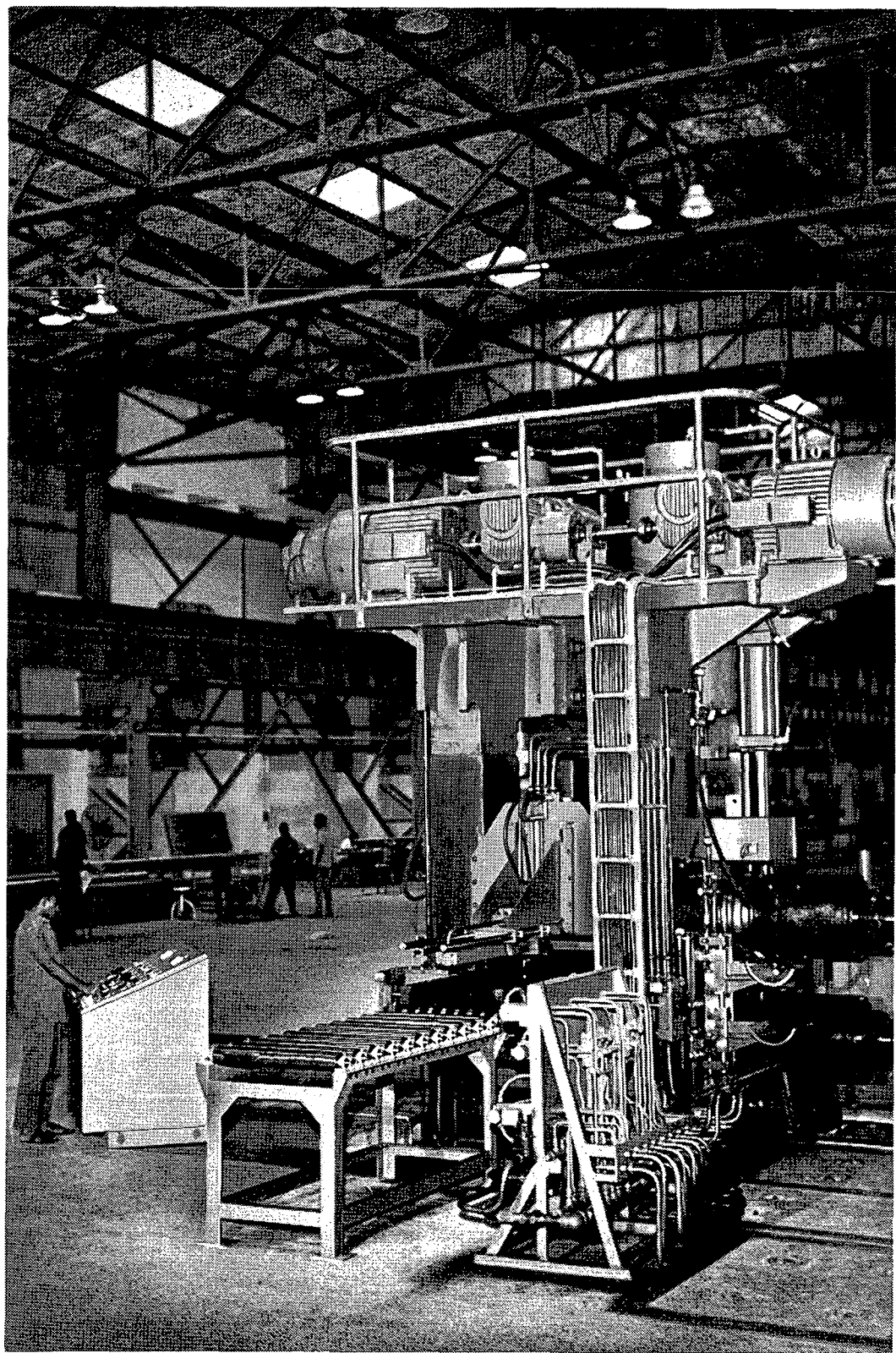
In the future, however, isotopic power sources with their potential applications in remote and inaccessible areas, as satellite power sources and for use in cardiac pacemakers, will receive greater attention. The development of suitable radioactive sources and of conversion systems for these devices will be taken up shortly.

Co-60, in view of its versatility, ease of production, long half-life and low cost, occupies pride of place as the most important radiation source. With the commissioning of the new power reactors, up to 3 MCi per year of Co-60 will be progressively available within the next 5 years. The infrastructure for handling and processing such large quantities and for fabricating sources, is nearing completion. The indigenous availability of Co-60 will give a boost to our programme for setting up large irradiators for sterilization of medical supplies, food preservation, wood-plastic composites manufacture, chemical synthesis and plastics modification processes, within the decade. Large-scale sewage treatment and manufacture of concrete polymer composites, are some of the other promising possibilities using Co-60 in the not-too-distant future.

The first plant in this series for sterilization of medical supplies will be completed by the end of 1973. Apart from fulfilling a long-felt need for ensuring sterility in medical products, it will give an impetus to the development of the single-use medical products industry and other ancillary industries in the country. Within the next 20 years, it is expected that there will be similar plants in each of the major regions of the country to satisfy the domestic demand.

Food preservation by irradiation should gain wide acceptance in the near future in view of its distinct benefits. The Indian programme envisages large demonstration plants within this decade for preserving commodities such as onions, potatoes, grains, fruits and sea-foods. The demonstration plants are expected to be followed by a number of fully commercial food irradiators in the country.

Applications of radioactive isotopes are of great importance to developing countries whose economies are based primarily on agriculture. The estimation, using tritiated water, of underground water resources and the rate of their replenishment in areas such as the Gangetic Plain, where extensive lift irrigation is proposed, is of great practical importance. India has recently witnessed the dramatic economic impact of new strains of seeds. Use of irradiation for enhancing the capability of the plant breeder is of major significance. Similarly, a study



The rolling mill at the nuclear fuel complex, Hyderabad.

of the intake of fertilizers and of water by plants using labelled chemicals can lead to the adoption of procedures for the efficient utilization of both.

The applications of isotopes and radiation are in the process of becoming an established industry in India. Plans for major programmes outlined above would, however, infuse into this industry an order of growth hitherto unmatched, requiring major commitments of material and human resources and a pronounced commercial orientation.

Considering the importance of the nuclear programme to India, the pace of research and development in nuclear technology is being stepped up. The construction of a 100 MW research reactor at Trombay and the rapid expansion of the programme of the Reactor Research Centre bear testimony to this.

In the words of the Prime Minister, Mrs. Indira Gandhi, "to those who made remarks about a cow-dung economy wishing to go in for nuclear energy, Dr. Bhabha convincingly explained the technological fall-out which results from atomic energy and the impact it has on other fields of economic and scientific activity. In the last 20 years we have been engaged in building our infrastructure..... If the building of the infrastructure itself incorporates higher technology, future progress will be accelerated. It is this point of view which gives significance to the work of the Atomic Energy Department."

