Electric Power Remains Emphasis of India's Nuclear Energy Program

Bombay. Since August 1964 the plutonium separation plant at Trombay, a few miles northeast of here, has been processing neutron-irradiated fuel elements from a 40-megawatt research reactor. The plant, designed and built entirely by Indian engineers and scientists, has not yet separated the 10 kilograms of plutonium generally said to be desirable for a single atomic bomb, but it soon will.

For the first time, a group of Western correspondents has been allowed inside this plant, which symbolizes India's determination to endow itself with the independent capacity to design, build, and run a complete atomic energy program. The correspondents, four Britons and one American, visited India for 2 weeks in June at the invitation of Homi J. Bhabha, the Parsee physicist and Fellow of the Royal Society who has headed the Indian atomic energy effort from the beginning. Bhabha invited the reporters for at least three basic reasons:

1) To show, in the face of two successive Chinese explosions of nuclear devices in which uranium-235 was used, that India has the technical capacity to obtain the fissionable material for a plutonium nuclear weapon.

2) To emphasize once again, however, that the main push of India's program, which began expanding beyond basic research in 1954, is toward the development of atomic power. Bhabha has consistently asserted that atomic power is vital even at the beginning of India's modern development. Coal from inconveniently located deposits and imported petroleum are so expensive in India that even a "pre-Oyster Creek" enriched-uranium reactor being constructed by International General Electric at Tarapur, 95 kilometers north of here, is economic.

3) To impress Westerners with the range of the effort—from basic research in physics to the development of industrial processes—and its relevance both to education and to industrial expansion. The Indian atomic energy effort embraces not only the Tata Institute of Fundamental Research and the Indian Cancer Research Center in Bombay but also the whole Indian space program, including a rocket base at Thumba, near Trivandrum, and the work of the Physical Research Laboratory of Ahmedabad. To meet its technical needs, the atomic energy program has developed its own electronics industry, which shortly will become an independent company, probably to be located in Hyderabad. No aspect of the program was stressed more repeatedly than these efforts to think out technical issues in India and to develop equipment there wherever possible.

On the whole, the presentation made by scores of confident young engineers and scientists was convincing.

For many years, students of the role of science in the development of poor countries have pointed to the Indian atomic energy program as a prime example of how a nation can direct its resources away from essential problems like agriculture toward a hunt for prestige through imitating advanced, and irrelevant, Western technology.

Personal inspection of the ambitious Indian program leads to exactly the opposite view. Through concentration on a fairly narrow set of aims, the engineers and scientists of the atomic energy program have consistently provided a drive and leadership that has been lacking in the more diffuse structure of India's Council for Scientific and Industrial Research. The program has supported the basic research of important young scientists, even of molecular biologists, who, instead of turning to work on the industrial difficulties of large fertilizer plants, would, in the absence of such a program, have migrated permanently to the West. But, conversely, the industrial experience gained through the program—itself built on work at the Tata Institute of Fundamental Research—does have relevance for other major industrial efforts. There are many Indians who feel that the drives to develop both the steel and the fertilizer industries have been plagued with too much reliance on expensive Western advice and equipment. Bhabha proudly notes that only 10 percent of the nuclear equipment for the power reactors being built in Rajasthan will have to be imported, while 40 percent of the value of such "conventional" equipment as turbogenerators will be imported.

In such discussions nuclear weapons play a very minor role, despite what is, in the popular imagination, the new situation created by the unfolding Chinese test series. It has been assumed, both in India and elsewhere, that the Chinese explosions will require an Indian riposte. This is not at all the way the issue looks at the Trombay Atomic Energy Establishment.

Of course, the 10 kilograms of plutonium which the Trombay plant can produce each year from the long burn-up cycle of the 40-megawatt Canada-India reactor represents a minimum capacity. In an emergency, the reactor's cycle could be changed. The plutonium plant has the capacity to handle spent fuel elements of at least the first three natural-uranium power reactors in India's program, the two being built at Rana Pratap Sagar in Rajasthan and one planned for Kalpakkam, near Madras. The uranium for these reactors, as for the Canada-India reactor, will come from the monazite sands of Kerala and a mine being developed in Bihar.

But these reactors will not begin to operate until about 1970, hence, since plutonium created in the Tarapur plant is governed by safeguards, India will not dispose of significant quantities of plutonium until then. The three reactors will generate about 800 megawatts of electricity and will thus produce something like 500 kilograms of plutonium yearly (enough for about a bomb a week).

Of course, India is not neglecting the production of materials which might go into a thermonuclear weapon. To supply both the Canada-India reactor and a pilot plant, India purchased a heavy-water plant from Linde, a Ger-

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man firm. The plant, which derives its hydrogen enriched in deuterium from the electrolysis section of a fertilizer plant at Nangal near the Bhakra power dam in the Punjab, went into production in 1962. The plant is rated as able to produce 14.5 metric tons of heavy water a year, but so far it has produced only 11 or 12 tons because of insufficient feed from the electrolysis process. Before 1970, however, India will construct a plant which will produce 200 metric tons of heavy water a year. Most, if not all, of the heavy water will be used for power reactors. In the 1970's, it is estimated, one heavy-water-moderated power reactor will be coming into service each year, and each reactor will require about 200 tons of heavy water, according to P. G. Deshpande, an engineer who has worked 10 years on India's heavy-water program.

Indian engineers do not worry much about the difficulties of constructing—in an emergency—a special reactor to irradiate bars of lithium. Such a reactor might be needed to obtain the small quantities of isolated tritium which apparently are necessary in thermonuclear bombs (which obtain most of their tritium for fusion through bombardment of lithium-6 nuclei with fission-derived neutrons inside the weapons themselves).

In delivery systems, India is not advanced. Her air force possesses various Western and Soviet jets whose ability to penetrate an elaborate defense network is limited. This year, India will begin making rockets, but only small French Centaures destined for the program of firings from Thumba into the electrojet associated with the magnetic equator. Nonetheless, the effort to manufacture Centaures under license from Sud Aviation is a prelude to the development of an Indian rocket intended to reach a maximum height of 500 kilometers by the early 1970's.

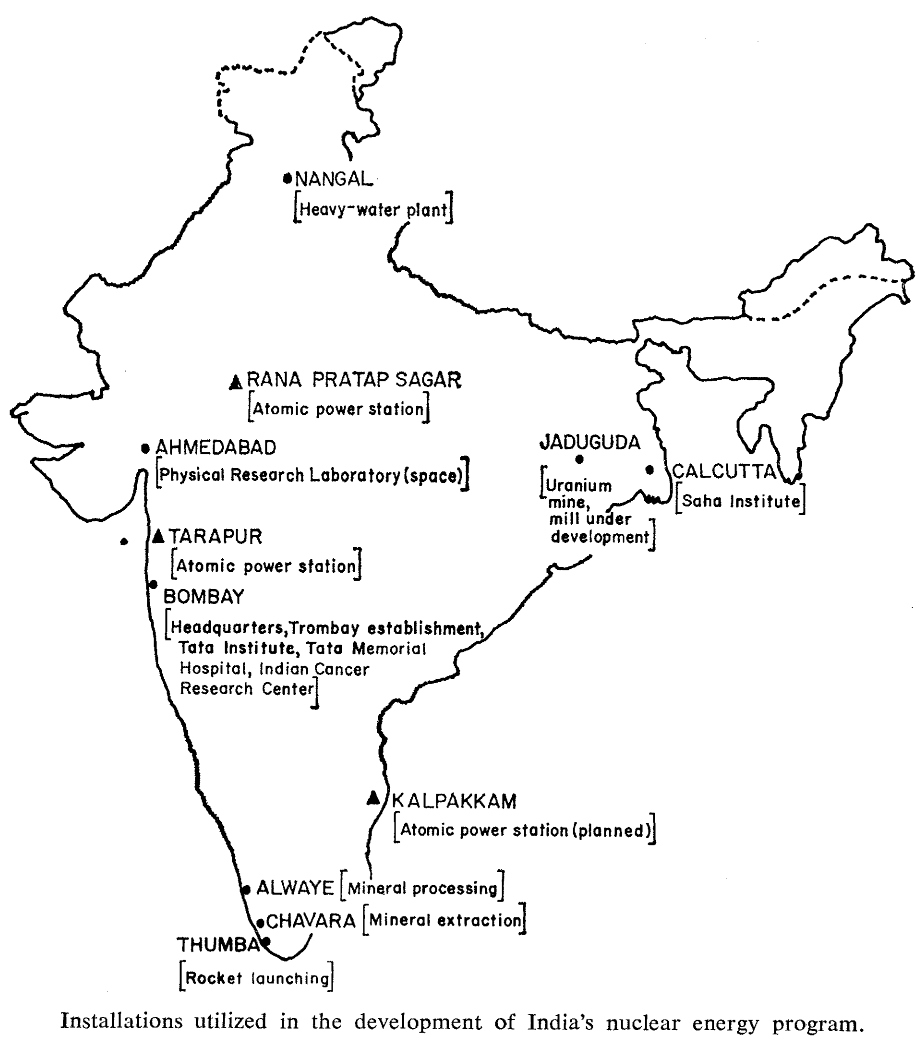
The prevailing attitude at Trombay is that construction of a bomb is possible but diversionary. The prime task is production of atomic power.

A more central argument against a weapons effort is the Indian Government's calculation, repeated frequently in private meetings such as those of the Pugwash movement, that construction of a nuclear weapon would add little to India's security. In India's view, not even a West European power like Great Britain possesses "absolute deterrence" against attacks by the United States or the Soviet Union. India cannot envisage either the United States or the Soviet Union permitting an exchange of nuclear weapons between nations like China and India, nor does it believe in the ability of such nations to use a small stock of nuclear weapons to involve larger nations in a thermonuclear war. Hence, what India seeks is an extension of the American and Soviet assistance made available since the 1962 Chinese incursions into Ladakh and Assam—perhaps a U.S.–Soviet guarantee of Indian territorial integrity.

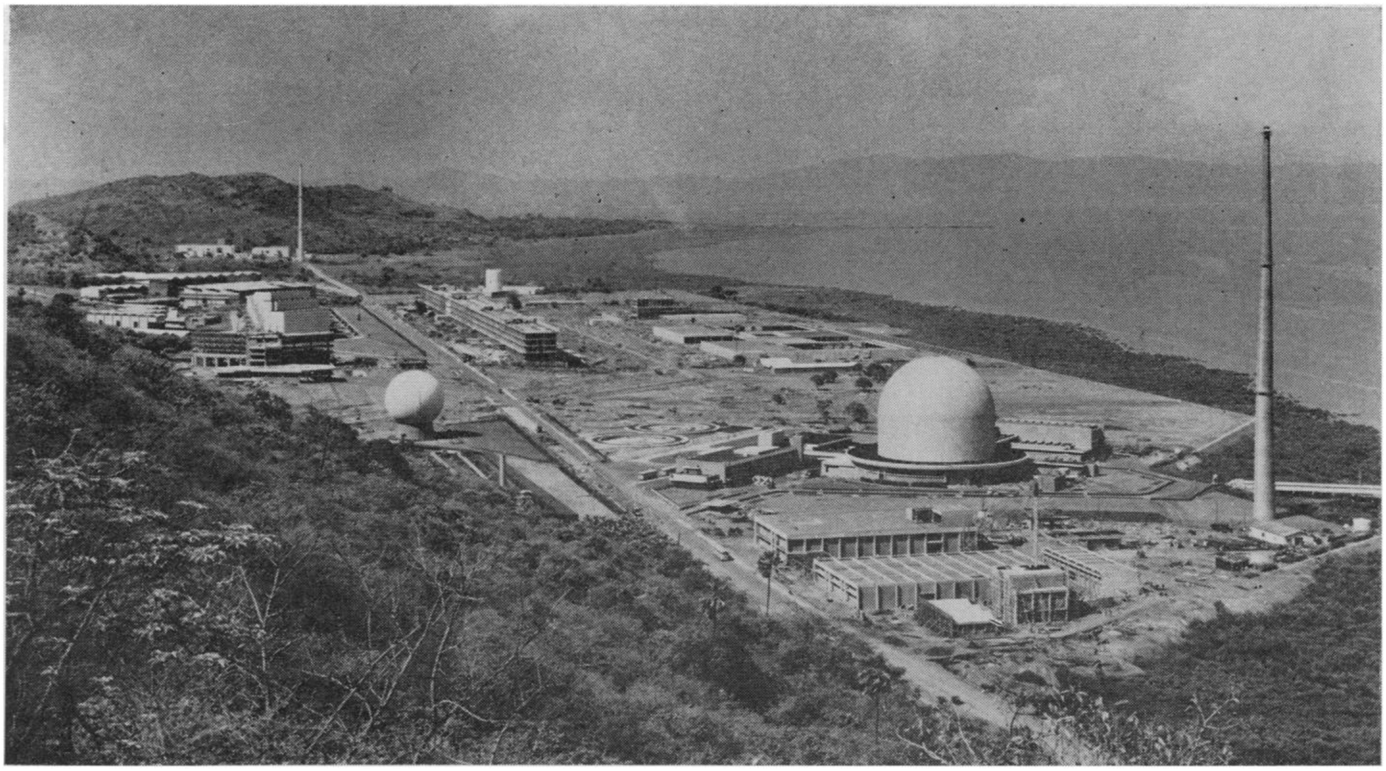
In this climate of opinion, then, the power-oriented nuclear program pushes ahead. It is the same program which Bhabha outlined in 1954, at an Indian conference on peaceful uses of atomic energy, held just after a separate department of atomic energy was created in the Indian Government, with the late Prime Minister Jawaharlal Nehru as its minister.

Bhabha argued that the Indian program should be carried out in three stages: construction of (i) natural uranium reactors for producing power and plutonium; (ii) reactors for producing uranium-233 from thorium with the help of plutonium; and (iii) uranium-233–thorium breeder reactors. Such a program is possible because India has the world's largest known reserves of thorium.

India's deposits of thorium and uranium-bearing monazite sands in the southern region that is now the state of Kerala have been known and exploited for half a century. In 1948, both thorium and uranium were declared strategic materials, and their export from India was forbidden. After this, the Indian Government took over the mining and milling of these black sands between the town of Quilon and India's southern tip, Cape Comorin. Extraction activities were concentrated at Chavara, near Quilon, and plants to separate rare earths and thorium and uranium were built at Alwaye, near Cochin, and at Trombay; meanwhile, prospecting was begun in the northeastern state of Bihar. The reserves of uranium and thorium in Bihar are at least as large as those in Kerala. At Jaduguda, near the steel town of Jamshedpur, a mine shaft is



Installations utilized in the development of India's nuclear energy program.



Hawker Siddeley Dynamics Ltd.

North site at Trombay. (Left rear) Main process and waste-evaporation buildings of the plutonium separation plant (with stack); (center rear) 5.5-Mev Van de Graaff accelerator (white cylindrical tower); (left center) engineering halls (at angle to road), which contain variable-lattice zero-energy reactor and heavy-water pilot plant, and, in front of them, administration building and library (under construction); (center) to the right of the road, a long "modular laboratory" which will house many researchers who now work in former jute storehouses on Cadell Road in Bombay and in other scattered buildings; (center right) low square buildings for group working on radiation chemistry; behind them, a food-irradiation building, under construction; (right foreground) Canada-India reactor, with its offices and laboratories; (white sphere to left of road) emergency water supply for reactor. [Atomic Energy Establishment, Trombay]

being sunk to 100 meters and a mill is being built. The mill will cost about $9 million, and construction of a town of 1200 houses for workers' families will cost another $4.5 million.

The department of atomic energy has striven to rely as little as possible on direct know-how from abroad in this development of raw materials. Instead, men who are now experts, like C. R. Das of the Trombay thorium plant, were sent abroad for training in the French firm, Société des Produits Chimiques des Terres Rares, which had been selected to provide the engineering during design and construction of the rare-earths plant in Alwaye and the thorium plant at Trombay. Under the leadership of H. N. Sethna, the plants were built in the early 1950's and staffed with trained men. In future these men would know more than how to buy technology abroad shrewdly; they would be trouble-shooters who could achieve efficient operation. They would learn how to expand the plant's capacity (that of the Trombay thorium plant has been increased more than sixfold) and how to design and build plants at other sites (as at Jaduguda), with help from the large chemical engineering and chemical analysis groups which have grown up over the years, first in former storehouses on Cadell Road in Bombay and later in large new engineering halls at Trombay.

Because they have recently gone through this important process of substituting home-grown expertise for imported technology, everyone, from Bhabha down to the dozens of group leaders the correspondents met, speaks of it constantly. The process does not stop with raw-materials plants. Sethna went on to take over the construction of the plutonium plant; this was accomplished between 1961 and 1964, at a cost of $7.5 million—very much less than the cost of a comparable facility at Mol, Belgium. Sethna is a member not only of the central government's scientific advisory committee (of which Bhabha is chairman) but also of the large government corporation which is rapidly expanding India's fertilizer manufacturing capacity.

This early experience was of value in setting up such now well-established facilities at Trombay as the uranium metal plant and the fuel-element fabrication shop, which turns out elements for the three research reactors at Trombay, provides experimental thorium-bearing elements for studies at Trombay and at the Swedish atomic energy establishment in Studsvik, and is preparing to fabricate elements for the enriched-uranium reactor at Tarapur. The fuel-element shop was designed and built by a team under Brahm Prakash and provided its first lot of ten fuel elements for the Canada-India reactor in February 1960.

The engineers' confidence in undertaking a complex enterprise like construction of the plutonium plant was increased by their experience in designing, building, and running the three research reactors. The first of these, called Apsara, was built in just over a year, under the leadership of A. S. Rao and N. B. Prasad, and went critical in August 1956. Sir John Cockcroft had advised the choice of this 1-megawatt swimming-pool reactor, and the United Kingdom Atomic Energy Authority provided the enriched uranium for it. The second, the Canada-India reactor, is a copy of the NRX reactor at Chalk River, Ontario. About half the money for its construction came from Canada, and Canadian engineers operated it at low power during the early stages after it went critical in July 1960. The cooling system (more complex than that of NRX because of the warmth of the sea water at Trombay) gave considerable trouble and helped prevent operation of the reactor at full power until October 1963. The variable-lattice zero energy reactor known as Zerlina went critical in January 1961. Since then Zerlina has been used to study various core designs for future power reactors.

In India, as elsewhere, engineers and scientists undertake this work with a sense of excitement. An official pamphlet illustrates this in describing how the Apsara reactor was made to go critical: "The efforts to commission the reactor . . . did not lack a sense of drama. . . . The initial loading . . . [began] on the evening of 30 July 1956 and continued until 1 a.m. The first trial run was started the next evening with the loading of more fuel elements. The neutron flux gradually rose, but by 7 a.m. the next morning the reactor had not become critical although all the fuel elements had been loaded. It was then suggested that the central position of the control rods allowed too many neutrons to escape. The disposition of the fuel elements and the control rods was rearranged with the latter spaced out and the second run was started at 5 p.m. on 3 August. The team worked throughout the night, but by 10 a.m. on 4 August no chain reaction had been achieved. It was then decided to eliminate one of the control rods and finally at 3:45 p.m. on Saturday 4 August 1956, the first reactor in Asia became critical."

As the visiting correspondents talked with Sethna about the problems of preventing accidental criticality in the plutonium plant, or with Deshpande about plans to increase the diameter and reduce the number of H_2S-H_2O exchange columns in the projected large heavy-water plant, or with J. Shankar about the chemistry of "zircalloy"-clad fuel elements in an organic coolant, they realized that the Indian program is far from the one-man band that it sometimes appears in the West.

Nonetheless, all acknowledge that Bhabha has provided indispensable leadership. From the first, he has been interested in both applied and fundamental research. It was Bhabha who developed the idea for the Tata Institute of Fundamental Research while he was teaching at the Indian Institute of Science in Bangalore, to which he came during World War II from the Cavendish Laboratory at the University of Cambridge. He became the first chairman of the Indian Atomic Energy Commission in August 1948, and persuaded Prime Minister Nehru to allow the administration of atomic energy to be centered in Bombay, close to the Trombay establishment (and far away from the official tangle of Delhi). Throughout, Bhabha had the unreserved support of Nehru, who served as head not only of the atomic energy department but also of the Council on Scientific and Industrial Research. Such support has allowed Trombay's budget, including investment, to rise from about $8 million in 1957–58 to well over $33 million in the budget year 1965–66 (this sum pays for a total staff of 7500 people, including nearly 1700 scientists and engineers).

Bhabha's interests are wide. He is a painter, and has had the Tata Institute decorate its lobby with the works of Indian painters. He collects exotic plants and has persuaded the central government to turn the top of Trombay hill, which shields the reactors and plutonium plant, into a national botanical garden. He is fond of architecture and works at night on the plans for new Trombay buildings, on a huge tilted table in his top-floor apartment overlooking Malabar Point. He hired Edward D. Stone to design the decorative sheath now being placed around two low, square buildings which are to house hot cells as well as scientists working on radiation chemistry, metallurgy, and isotopes.

Throughout India, scientists testify that Bhabha not only supports them with adequate money, equipment, and supplies, but also, by shrewd questioning about their studies, helps create a vigorous atmosphere for research.

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