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Devoted to the discussion of thorium as a future energy resource, and the machine to extract that energy–the liquid-fluoride thorium reactor.

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Thorium Fuel Cycle Development in India

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Homi Jehangir Bhabha, an Indian physicist, who had, during a pre-World War II stay in Europe, made important discoveries about cosmic rays. Upon his returned to India at the start of the war, he began to campaign for Indian research institutions deveoted to physics and nuclear energy. He quickly established himself as a scientist politician who had the ear of Pandit Nerhu, the first Indian Prime Minister. Shortly after Indian independence in 1948, Bhabha was assigned the task of establishing the Indian Atomic Energy Commission, and developing a nuclear research program.

During the first UN Conference on the Peaceful Uses of Atomic Energy (1955), Bhabha, who was the Conference President, presented a paper on Indian Atomic development. He argued that India lacked energy resources, and in order for the Indian people to have a Western standard of living, Indian electricity must be generated by nuclear means. He noted, “the necessity of obtaining enriched or pure nuclear fuel (plutonium- or uranium-233) for use in future atomic power stations of a more advanced design required the setting up during the next decade of a few atomic power stations designed to produce these materials as well as electric power.”

Bhabha once remarked that "No energy is costlier than no energy". He was what Texans use to call a wheeler-dealer. He used his position at the The First Conference to obtain British, Canadian and American assistance for the Indian nuclear program. Soon Indian Scientists were showing up at Chalk River, Harwell, and Oak Ridge for on the job training.

In addition to training, during the 1950's, with American support and Canadian help, India began to construct its first reactor, the heavy water Cirus. What the Americans and Canadians did not notice was that the Cirus was capable of producing weapons grade plutonium.
In early 1957, Bhabha summarized his plan for the Indian nuclear energy future,

"It is likely that in the future more advanced and efficient types of atomic power stations will use concentrated atomic fuel, such as uranium-235, uranium-233, or plutonium, rather than the naturally occurring uranium. If we are not to depend on the import of such fuel from abroad, and not to build a gaseous diffusion plant involving an enormous expenditure and technical effort, it is necessary for us to start producing this fuel now by converting natural uranium into plutonium, and thorium into uranium-233 in atomic reactors. If we are therefore, not to lose further ground in the modern world, it is necessary for us to set up some atomic power stations within the coming five years, which will produce plutonium for our future power reactors, in addition to producing electricity now."

Bhabha believed that nuclear generated electricity would play an important future role in the Indian economy, and that India possessed only limited Uranium resources. However, India possessed large thorium reserves. Thus Bhabha believed that the Indian nuclear research must be directed toward the development of the thorium fuel cycle. During the 1950's Bhabha set out a three stage development program for Indian Nuclear technology.

In the first stage, Heavy water reactors using unenriched uranium derived from India's limited uranium reserve, would be constructed and begin operating. The use of heavy water reactors meant that India did not need to to develop expensive and power demanding uranium enrichment facilities.

During the second stage, India was to construct Fast Breeder Reactors, which burned plutonium reprocessed from the spent fuel of the heavy water reactors as well as their depleted uranium. India needed to develop breeder technology quickly, because it had limited uranium resources. Breeders allowed India's uranium supply to be used much more efficiently.

During the third stage thorium was to be bred, and U-233 would fuel Indian power reactors.

This plan enabled India to boot strap its limited nuclear resources, into a viable nuclear energy program. Of course, along the way, something which Pandit Nehru swore on a stack of Bhagavad Gitas would never happen, did. India used some of Bhabha plutonium to build nuclear weapons. But remarkably fifty years later, India is still following Bhabha's three stage plan for nuclear power development. The plan is now at the beginning of the third stage.

India has 13 heavy water reactors with 4 more under construction. These Indian reactors are smaller than western commercial power reactors. India also has fuel reprocessing facilities, and a developmental breeder reactor. A full scale fast breeder (500,000 MW), which will breed both U-238 and Th-232 in a hybrid fuel cycle, is under construction, and is expected to be completed in 2010. A second large thorium fast breeder, the ATGB is already in the planning stage. The KAMINI test reactor is used to test the use of U-233 produced by the Kalpakkam experimental breeder. A Generation 3+ Thorium fuel cycle Advanced Heavy Water Reactor is also in the planning stage. India plans, by 2020, to have reactors capable of generating 20 GWs of power,

most of it using thorium fuel cycle nuclear fuel. Bu 2050, India plans to produce 30% of its electricity from thorium fuel cycle nuclear generating facilities. The Indians believe that their thorium reserve will last them for at least 350 years.

The Indian nuclear program is remarkable in several respects. First, is the depth of Homi Bhabha's understanding of Indian nuclear resources and the sort of nuclear program that would achieve the maximum benefit from his country. The second, was the reliance on the relatively simple CANDU technology, during the first development stage and its continued development through all three stages. Reactors were kept small, 220 MW's, limiting capitol commitment for each reactor. In addition reactor design was given a chance to develop, successive improvements were made as new reactors were designed. Operational experience gave feedback to reactor designers. During the second stage, the full plutonium – thorium – U233 fuel cycle was tested in two small reactors.

Finally, believing that they had mastered all of the individual components of their thorium fuel cycle program, the Indians have set about to build prototypes of commercial reactors that are intended to go into serial production. They have been faithful to Bhabha's vision. They have found a way to highly efficient technology, a technology that is far more efficient in its use of nuclear fuel, than the French/American nuclear system by ingeniously mastering and organizing relatively old nuclear technologies, and leveraging them into a fuel efficient system. By doing so they will achieve EROIE's many times that achieved by Western fuel/reactor systems. The Indian Thorium fuel cycle system will provide electricity to an enormous country for at least 350 years, from 500,000 tons of fuel. Indian scientists and engineers are on the brink of a significant human accomplishment, the realization of Bhabha vision of bringing nuclear generated electricity to India's vast population. – Charles Barton

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