India Nuclear Program At a Crossroads

by Ramtanu Maitra

Jan. 13—On Dec. 18, Indian media reported an agreement signed by the French industrial giant Areva, for supply of uranium to India. The agreement includes a commitment from Areva to the Indian Department of Atomic Energy to supply 300 tons of uranium to the Nuclear Power Corporation of India (NPCIL) to power its reactors under International Atomic Energy Agency (IAEA) surveillance.

This development may have a deep impact on India's nuclear power program. The three-stage Indian nuclear program, described later in this article, did not have any other options. Since the country has low uranium reserves and is a non-signatory to the nuclear Non-Proliferation Treaty (NPT), India did not have access to nuclear fuel. Now, however, India has options.

These options are: one, to pursue thorium reactor development with added zeal to remove all snags at the earliest point; or two, to ice the thorium reactor "temporarily," and use the imported uranium to build more current-generation reactors, and, in the process, become vulnerable to foreign suppliers of uranium.

Soft Heads Opt for Soft Options

The second one is, by far, the softer option, and, considering the kind of soft-headed leadership in New Delhi at this time, or what might be expected in the coming years, there is a genuine threat that the soft option will be pursued, at the expense of quickly developing thorium reactors.

Although Areva is the first outfit to supply uranium to India since the Nuclear Suppliers Group (NSG), the 45-member-nation body that controls supplies and retransfer of all nuclear-related materials, waived the 34-year-old nuclear ban on India, on Sept. 6, 2008, it is anticipated that a number of other nations are getting ready to sign agreements to supply uranium to India. Kazakstan, Niger, and Australia, among others, are considered likely future suppliers. Signing a deal with Kazakstan is considered close at hand. It is likely to take place when President Nursultan Nazarbayev visits New Delhi as the chief guest at India's Republic Day celebrations on Jan. 26.

One of the primary reasons that India signed a nuclear agreement with the United States in July 2005, was to get the waiver of the NSG, in order to procure uranium from outside. India's present generation of indigenously developed nuclear reactors, pressurized heavy water reactors (PHWRs), uses natural uranium (U-238, with a smattering of U-235), as fuel. India's total established uranium resources (in the form of uranium oxide or yellow cake), so far, are 94,000 tons. However, the low uranium content in the domestic ores makes mined uranium in India expensive, compared to that in Australia, for example, whose ores contain as much as 15% uranium.

Recent media reports, however, indicate that scientists have found uranium in "exceptionally high concentration" in Ladakh, the icy Himalayan region in the northernmost part of the Indian state of Jammu and Kashmir. Samples of rocks analyzed in a German laboratory have revealed uranium content to be as high as 5.36%, compared to around 0.1% or less, in ores present elsewhere in the country. Officials of the atomic minerals division under the Department of Atomic Energy (DAE) have not issued any official statement about the significance of this new find, or whether the Ladakh uranium could augment India's reserves.

The fact remains that despite its great size, India has small uranium reserves. It has been estimated that these modest reserves will suffice to produce no more than approximately 420 gigawatt-years—i.e., 20,000 MW over 21 years—of electric power, if used in the PHWRs currently operating, or those under construction. Thus, importing uranium is fine—as long as India moves ahead to develop its thorium-based program.

India's Three-Stage Program

India's nuclear power program began in the 1950s. On May 10, 1954, Prime Minister Jawaharlal Nehru told the Lok Sabha (the lower house of Parliament): "It is perfectly clear that atomic energy can be used for peaceful purposes; . . . it may take some years before it can be used more or less economically. Experts believe that nuclear power, theoretically, offers India the most potent means to achieve long-term energy security. In practical terms, however, nuclear power may lack the logical preconditions, at least for India, to become their major source of independent energy. . . ."

NPCIL

India's recent agreement with the French firm Areva for supply of uranium is expected to have a significant impact on the country's nuclear power program. Shown: Nuclear Power Corp. of India's Madras plant in Tamil Nadu.

India's DAE under the direct control of Prime Minister Nehru, and the guidance of India's leading nuclear scientist Dr. Homi Bhabha, formulated a three-stage approach to make nuclear power a major source of India's power requirements. Their three-stage nuclear program called for setting up of natural uranium-fuelled pressurized heavy water reactors in the first stage; fast breeder reactors (FBRs) utilizing a uranium-plutonium fuel cycle in the second stage; and breeder reactors utilizing thorium fuel in the third stage.

In the first stage, natural uranium (U-238) was used in the PHWRs. In the second stage, the plutonium extracted from the used fuel of the PHWRs was scheduled to be used to run FBRs. The plutonium was used in the FBRs, in 70% mixed oxide (MOX) fuel, to breed U-233 in a thorium-232 blanket around the core. In the final stage, power generation will be based on the thorium-uranium-233 cycle. Fissile U-233 is obtained by irradiation of thorium in PHWRs and FBRs.

This three-stage program was designed not only to produce nuclear power, but to move away from uranium dependence, given India's very low reserves. It was also understood, as far back as in 1950s, that India, being a nation with a population comparable only to China's in size, could not base its future generation of vast amounts of electrical power, perhaps the most important ingredient needed to build and sustain an agro-industrial society, and provide opportunities to the hundreds of millions waiting to be born, on imported uranium, a highly sensitive mineral ore.

For Nuclear Power Independence

The potential for long-term independence in India's nuclear power generation was vested in a fissionable material, not a fissile material, thorium. That is, thorium is not fissile like U-235; thorium-232 (Th-232) absorbs slow neutrons to produce U-233, which is fissile. In other words, Th-232 is fertile like U-238, which absorbs neutrons to produce fissile plutonium (Pu-239).

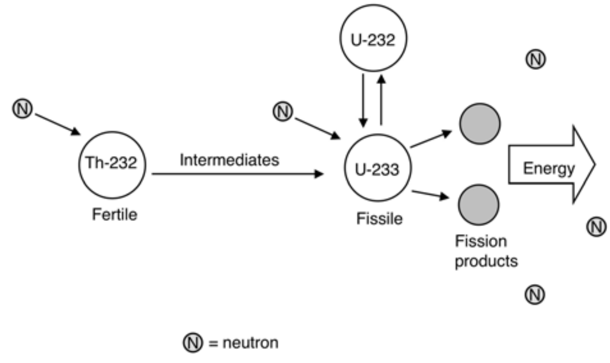
According to an estimate by analysts based in India's premier nuclear research and development facility, the Bhabha Atomic Research Center (BARC), India's thorium reserves can amount to a staggering 358,000 GWe-yr (Gigawatt electrical-year) of energy. In other words, India's thorium reserves could last for as long 1,000 years, at a rate of generation of 358 GW every year, even without using breeder reactors. India's total power-generation capacity at this point in time is close to 146 GW, of which, nuclear power's contribution is a paltry 4.12 GW.

Thorium reserves have been estimated by Indian authorities to be between 360,000 and 518,000 tons. The U.S. estimates the "economically extractable" reserves to be 290,000 tons, among the largest in the world.

Another important aspect of the Nehru/Bhabha-designed three-stage nuclear power program is the requirement of plutonium (Pu-239). In stage one, PHWRs use natural uranium, which contains about 99.3% of fissionable U-238, as the primary fuel. The process produces some Pu-239.

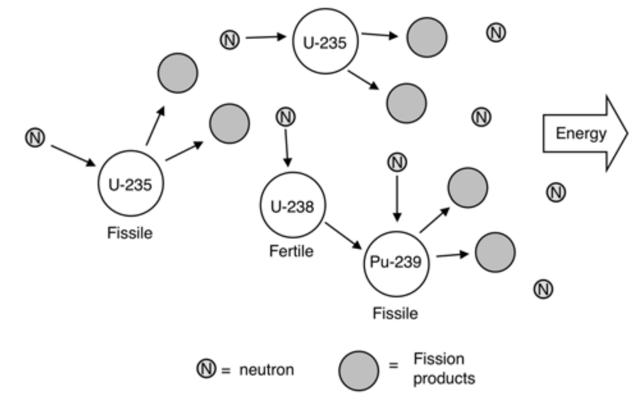
India's second stage of nuclear power generation envisages the use of Pu-239 obtained from the first stage reactor operation, as the fuel core in fast breeder reactors. The main features of India's fast breeder test reactor (FBTR) are: Pu-239 serves as the main fissile

FIGURE 1
Simplified Diagram of the Thorium Fuel Cycle



The neutron trigger to start the thorium cycle can come from the fissioning of conventional nuclear fuels (uranium or plutonium) or an accelerator. When neutrons hit the fertile thorium-232 it decays to the fissile U-233 plus fission fragments (lighter elements) and more neutrons.

FIGURE 2
Simplified Diagram of the Uranium Fuel Cycle



In the conventional uranium fuel cycle, the fuel mix contains fissioniable U-235 and fertile U-238. A few fast neutrons are released into the reactor core (for example, from a beryllium source), and when a neutron hits a U-235 nucleus, it splits apart, producing two fission fragmets (lighter elements) and two or three new neutrons. Once the fission process is initiated, it can continue by itself in a chain reaction, as the neutrons from each fissioned uranium nucleus trigger new fissions in nearby nuclei. Some of the U-238, when hit by a neutron, decays to plutonium-239, which is also fissionable.

element in the reactor; the blanket of U-238 surrounding the fuel core will undergo nuclear transmutation to produce fresh Pu-239, as more and more Pu-239 is consumed during the operation; in addition, a blanket of Th-232 around the FBTR core undergoes neutron-capture reactions, leading to the formation of U-233. U-233 is the nuclear reactor fuel for the third stage of India's nuclear power program.

Pu-239 then becomes the main fissile element: the fuel core in the FBRs. India's FBTR is in operation in Kalpakkam, and the construction for a 500 MWe prototype FBR was initiated recently by Prime Minister Dr. Manmohan Singh. Concurrently, the FBR is designed to use thorium-based fuel, along with a small feed of plutonium-based fuel in advanced heavy water reactors (AHWRs). The AHWRs are expected to shorten the period for reaching the stage of large-scale thorium utilization.

In other words, India's first stage was not only designed to produce a sufficient amount of power, but also P-239, which could then act as the "trigger" in the FBRs that use Th-232 and produce U-233 for power generation in the third-stage reactors, and some Pu-239. A small 40 MWe test reactor, the Kamini, at Kalpakkam became critical in September 1996, using U-233 fuel, and has demonstrated some of India's technological successes in developing the thorium reactor.

India began construction of the advanced heavy water reactor last year. The AHWR will use thorium, the "fuel of the future" to generate 300 MW of electricity up from its original design output of 235 MW. The reactor, which will use plutonium-based fuel, will have a life of 100 years and may be built on the campus of the Bhabha Atomic Research Centre at Trombay. The AHWR is thus the first element of the third stage.

It is evident that in order to begin the third stage of country's nuclear power program, and to make the country independent of outside pressures on such a vital item as nuclear fuel, India's earlier leaders had focussed on developing thorium reactors. The basic research and development of thorium-based fuel cycles has been conducted in Germany, India, Japan, Russia, the U.K., and the U.S.A. However, other than in India, the subject was studied on a much smaller scale than uranium, or uranium/plutonium cycles.

India is by far the most committed nation as far as the use of thorium fuel is concerned, and no other country has done as much neutron physics work vis-à-vis thorium as Indian nuclear scientists have done. The positive results obtained in the neutron physics work have motivated Indian nuclear engineers with their current plans to use thorium-based fuels in more advanced reactors now under construction.

The work done by Indian nuclear scientists to advance the production of thorium reactors, was pointed out in a press conference Oct. 3, 2004, by Dr. Anil Kakodkar, chairman of the AEC, and Secretary of the Department of Atomic Energy, who said, "The AHWR will be one of the first elements in the third stage. Its design is complete. We have prepared the project report. We have completed a peer review by knowledgeable people other than those who designed it. A fairly large amount of R&D work has been completed. There is more R&D work to be done. . . ."

Plutonium Shortfall

On the other hand, fast-breeder reactors constitute the second stage of India's program. The second stage is the key to ushering in the third stage. But long-term growth of the third stage depends upon the production of Pu-239. Since Pu-239 is a highly fissile material that is used for making nuclear weapons, Pu-239 is not available to India.

The Manmohan Singh government pushed the India-U.S. nuclear deal, not only to get access to nuclear reactors available abroad, but also to get access to uranium fuel. India wanted uranium fuel desperately because of the policy failures in the earlier days.

The real challenge that India's nuclear industry faces is the fuel constraint. If the capacity factor of the indigenous PHWRs was at a high of 90% in 2002-03, it has declined to 65%. This reflects the serious shortage in the supply of natural uranium to fuel the PHWRs, a senior journalist, T.S. Subramanian, wrote in the Indian daily *The Hindu*, last year.

He pointed out that the opening of new uranium mines and mills has lagged behind the demand for the metal. There are uranium mines at Jaduguda, Turamdih, Bhatin, and Narwapahar, all in the state of Jharkhand. A mill is operating at Jaduguda for processing the natural uranium into yellow cake, which is sent to the Nuclear Fuel Complex at Hyderabad to be fabricated into the fuel bundles that power the PHWRs.

What all that meant is that India does not has enough uranium reserves to fuel a large number of PHWRs, which produce Pu-239, besides generating power, and is not in a position to move on to the second stage of the program. According to K. Santhanam, a nuclear scientist who has been associated with India's science, technology, and security for the last 43 years, "without adequate plutonium, India cannot successfully transit to its second stage. And to transit there requires uranium, imported or otherwise."

In addition, some of India's DAE scientists believe that the Indo-U.S. deal would pave the way for India acquiring the plutonium it needs for its long-term energy security based on thorium. They point out that there are at least 3,000 tons of plutonium waiting to be reprocessed from spent fuel discharged globally from uranium-based reactors. For the first time, after 30 years of freeze, the U.S. is reconsidering plutonium use for energy generation and, together with Russia, wants to set up the GNEP (Global Nuclear Energy Partnership) for plutonium recovery. It has invited India to become a partner.

Notwithstanding the genuine shortfall of India's uranium requirements, the key to India's energy independence is its ability to develop indigenous thorium reactors at the earliest possible time. At this stage, when India has only 15 active nuclear reactors producing a meager 4,120 MW of power, the issue of importation of uranium fuel can be ignored. However, over the years, as India pushes forward with its nuclear program, there is a danger that India will be depending on the fuel supply from abroad for as many as 150 reactors, producing 80 MW to 100 GW. This is a dangerous situation for a nation as populous and important as India; such a situation would develop only if the powers-that-be in the coming years, undermine the thorium reactor development for the exigency of generating power from the proven first generation natural uranium-fuelled reactors.

That would not only be a betrayal of Nehru and Bhabha, but also would endanger the nation. On May 8, 2007, the-then Indian President A.P.J. Abdul Kalam, a rocket scientist of international repute, told scientists and academicians at the National Centre for Scientific Research at Demokritos, Athens, that "energy independence is India's first and highest priority." Kalam said that India is determined to achieve energy independence by the year 2030, and for this, "India has to go for nuclear power generation in a big way using thorium-based reactors." He acknowledged that "Energy independence throws very important technological challenges to the entire world."

He added, "India has to go for nuclear power generation in a big way using thorium-based reactors. Thorium, a non-fissile material, is available in abundance in our country."