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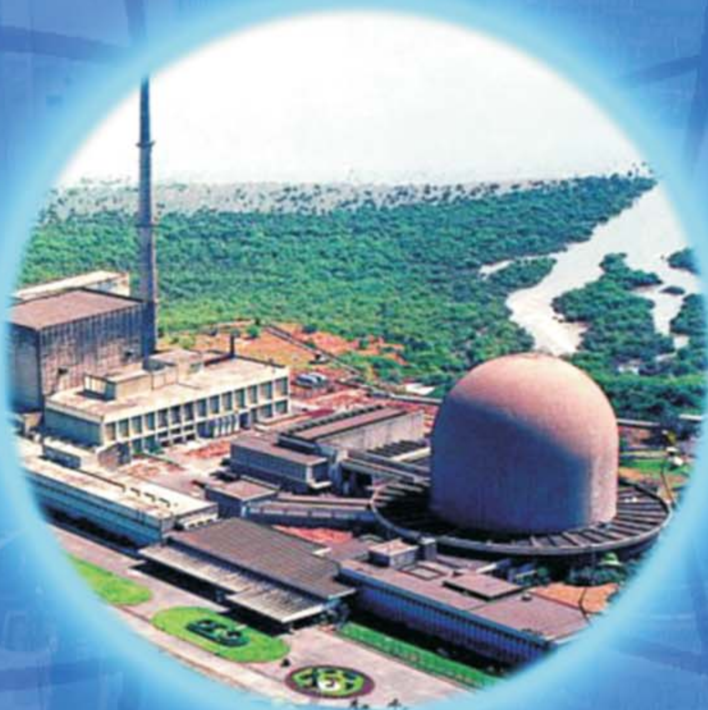

India, Future Global FBR Tech Leader

- Dr. Anil Kakodkar

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In This Issue

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Editorial

Dear Reader,

Greetings from the bimonthly Asian Nuclear Energy and the portal www.asiannuclearenergy.com, both New Media products dedicated to promoting global nuclear commerce. It is heartening to note that a large number of eminent nuclear scientists and industry leaders connected with the peaceful use of nuclear energy are meeting in New Delhi to mark the occasion of the birth centenary of late Homi Bhabha to rededicate themselves to the ideals of the late eminent nuclear scientist. The occasion rightly comes at a time when India is heralding a new era in harnessing nuclear energy for the economic development of the country. We wish the conference a grand success. India's huge energy requirements and its historic deal with the United States on cooperation in civilian nuclear energy has spurred global commerce in this key area. In the current scenario, India's capability and the lead it has taken in building Fast Breeder Reactors (FBRs) stand out. The cover story of the current issue of Asian Nuclear Energy is an exclusive interview with Atomic Energy Commission Chairman Anil Kakodkar, who says confidently that India will be a future global leader in FBR technology. In the focus section, we have a report on the ongoing plans of Nuclear Power Corporation of India Ltd. (NPCIL), which is busy inking deals with both foreign and local corporate entities involved in setting up nuclear reactors. India's entry into the area of nuclear energy in a big way has brought in its wake both challengers and opportunities. Prof. P.M. Kamath discusses these issues in detail in an in-depth article. The German high-technology giant SCHOTT is offering the much needed Electrical Penetration Assemblies (EPAs) to Indian nuclear plants. We carry a write-up. We are also carrying a report on a symposium conducted by SCHOTT on nuclear reactor safety technology. Kazakhstan was once a ground for innumerable nuclear tests. Today the country is celebrating the closure of the Semipalatinsk nuclear testing site. We carry a report. The issue also carries a detailed, up-to-date report of the World Nuclear Association on the overall nuclear energy scenario in India. Besides these, there is a news report about the International Atomic Energy Agency (IAEA) revising upwards the targets for nuclear energy production worldwide, with both India and China launching massive plans to set up nuclear reactors.

Wish you happy reading

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Installed Capacity to Rise to 40,000 MWe by 2020

India, Future Global FBR Tech Leader - Kakodkar

Dr. Anil Kakodkar, *Chairman of India's Atomic Energy Commission (AEC) and Secretary to the Department of the Atomic Energy (DAE)*

Dr. Anil Kakodkar, *Chairman of India's Atomic Energy Commission (AEC) and Secretary to the Department of the Atomic Energy (DAE) is upbeat about the country emerging as a global hub of nuclear energy equipment manufacturing, technology trade and commerce. A key negotiator of the historic Indo-US civilian nuclear energy agreement, culminating in the lifting of the 34-year-long ban on India by the Nuclear Suppliers' Group, Dr. Kakodkar says that India's capability to independently build small sized Pressurized Heavy Water Reactors (PHWRs) and thorium-based Fast Breeder Reactors (FBRs) which will have considerable demand in the future in the developing countries.* **In an exclusive interview to Asian Nuclear Energy,** *Dr. Kakodkar says the lead that India has taken in designing and building FBRs will make the country a global technological leader in this crucial area in the future. Dr. Kakodkar believes that India's nuclear power generation programme, which offers immense potential for technology and equipment suppliers from across the globe through joint ventures will result in an additional installed nuclear power capacity of 40,000 MWe by 2020. He says that India's capabilities in nuclear energy could also provide enhanced export opportunity for the Indian manufacturing sector to tap emerging markets in nuclear business. Following are excerpts from the interview.*

The world is surely moving towards nuclear energy as the best option due to global warming and climate change. What opportunities do you see for India in the emerging scenario?

On short term basis the small size Pressurized Heavy Water Reactors (PHWRs) have a potential to be supplied to some developing countries. With nuclear energy likely to become centre stage, Fast Breeder Reactors (FBRs) are expected to be in considerable demand in future. With India having taken the lead in this crucial area, we could very well be the technological leaders worldwide. Same thing could happen in the context of thorium systems a little later.

India has developed the thorium-based nuclear fast breeder reactor (FBR) to overcome the shortage of uranium supply. What is its role in India's future nuclear power generation programme?

Thorium based reactor technology forms the third stage of the three- stage Indian Nuclear Power Programme. It is envisaged that after about the middle of the country, reactors based on thorium will become commercial not only for electricity generation but also for providing high temperature process heat for industries and hydrogen as a clean fuel as substitute for the petroleum based fuels. Taking into consideration the vast thorium resources in the country, it will provide energy for several centuries.

You are planning to scale up India's installed nuclear power capacity by nearly five times to 20,000 MWe by 2020 from the present 4,120 MWe, which is less than three percent of the country's total power production. Is the policy frame work in place to enable investment to realize a target this high? What incentives the government is expected to announce in order to boost private participation in this industry?

The present installed nuclear power capacity in India is 4,120 MWe. Out of the 20,000 MWe target mentioned in your question and which is likely to be revised upwards, NPCIL can manage about 10,000 MWe through its own financial resources. Atomic Energy Act in its current form does allow investment by private sector up to the extent of 49 percent.

Will there be any amendments to the Atomic Energy Act with regard to facilitating the private sector's entry into the closely guarded nuclear power generation field?

As mentioned above, Atomic Energy Act requires nuclear power generation to be done by a government company in which at least 51 percent shares are held by the Central Government. The private sector can however carry out manufacturing of nuclear equipment and other supply chain activities including construction.

The Indo-US nuclear deal has opened the doors to India for carrying out legitimized nuclear commerce. Please enumerate the immediate and long-term spin-offs.

The nuclear commerce in India has always been legitimate. In fact, India is well known for its responsible behavior in conducting its nuclear business. Immediate benefit of the international civil nuclear commerce with other countries will be an additionality of installed nuclear power capacity (40,000 MWe by 2020) over and above that to be achieved through the indigenous three-stage programme.

There are reports suggesting envisaged collaborations worth $150 billion for setting up a total capacity of 10,000 MWe using equipment and materials from US reactors and companies. Do you expect any significant move or development in this regard during the forthcoming visit to India of US Secretary of State Hillary Clinton?

While the outlay indicated in the question seems highly inflated, discussions are currently taking place between Nuclear Power Corporation of India Ltd. and US vendor companies.

The Economic Survey (2008-09) has suggested allowing Foreign Direct Investment of up to 49 percent in Indian nuclear power plants. Is any policy announcement expected from the government in this regard?

FDI in Indian Nuclear Power Plants is not envisaged.

With multinational companies planning to manufacture nuclear power equipment in India to meet local as well as global demand, do you expect the country to become part of the global supply chain?

Yes, certainly.

Three decades of isolation has also made India realize its capabilities in the nuclear power generation sector. In the light of India's acceptability by the global nuclear community, what are the prospects of outsourcing of equipment/component manufacture to this country?

We certainly expect enhanced export opportunity for the Indian manufacturing sector in nuclear business following appropriate export control regime.

With global nuclear power firms eyeing partnerships with Indian companies, you have recently advised Indian companies to "exercise due diligence and read the fine print" before signing deals. Do you intend to issue any guidelines to Indian companies, defining their priorities in this regard to enable the country to become a supply chain king, as you said recently?

It is important that the Indian industry maintains their technological competence and freedom to support emerging markets both within the country and outside and in so doing they should not allow themselves to be subjected to extraterritorial application of foreign laws that restrict their participation in the domestic development of the three-stage nuclear power programme which is the key to opening up of very large potential of nuclear power. DAE would continue its engagement with the Indian industry in this regard.

How soon will the project for setting up nuclear parks in different States across the country, each providing for six to eight reactors of 1,000-1,650 MW be ready?

Negotiations are already in progress with vendors from France, Russia and USA for this purpose.

You have ambitious plans of meeting 25 percent of power generation from nuclear plants by 2050. What will be the estimated installed nuclear power generation capacity by then?

We expect around 25 percent of power to be realized by nuclear power plants on the basis of further indigenous development of the 2000 MWe programme by 2020. Another nearly 25 percent is expected to come as an additionality based on initial imports of LWRs/uranium to the extent of 40,000 MWe. Thus the proportion of nuclear power by 2050 could well be around 50 percent (~ 600-700 GWe) if we successfully bring to bear the indigenous capability built as part of the three-stage Indian nuclear power programme on the initial additionalities through imports.

What is the overall uranium supply scenario and what will be Uranium Corporation of India's contribution to it in the long run?

UCIL is poised to expand supplies to our expanding nuclear power programme. Further, AMD is aggressively pushing exploration activities by bringing in modern technology. ■

IAEA Hikes Global N-Power Generation Projections for 2030

The International Atomic Energy Agency (IAEA) has elevated its nuclear power projections for 2030 recently, with China, India, Japan and South Korea seen embracing atomic energy more than before.

IAEA
International Atomic Energy Agency

The Vienna-based agency expects installed nuclear power capacity to rise by at least 40 percent worldwide over the next two decades to around 510 gigawatts. It could more than double in one scenario, the agency said.

The projections were 8.0 percent higher than last year's estimates for 2030 and predictions for Asian countries in particular helped to step up the projections.

"The financial crisis that started in late 2008 has affected the prospects of some projects, but its impact has been different in different parts of the world," the IAEA said in a statement.

"The medium- and long-term factors driving rising expectations for nuclear power have not changed substantially."

The IAEA said ongoing concerns about global warming, energy security, and fossil fuel prices meant nuclear power was still seen as a good bet in the medium to long term.

The agency said governments, utilities and vendors were seen firming their commitment to previously-announced projects and this raised confidence in the sector over the longer term, despite the financial turmoil.

A new verification agreement between the IAEA and India in August last year also raised nuclear power prospects for the country which is expected to become one of the biggest users of atomic energy.

Nuclear supplier countries lifted restrictions on nuclear trade with India after the agreement, allowing India to accelerate its planned atomic power expansion.

The IAEA projections are drawn from nuclear experts worldwide who look at operating reactors, licence renewals, planned shutdowns and possible construction projects in their calculations. ■

NPCIL in Deals with Foreign & Local Firms to Meet Target

Nuclear Power Corporation of India Ltd (NPCIL), the State-owned company spearheading the country's nuclear power generation programme, is busy having tie-ups with both foreign and local companies to achieve its target of 40,000 MW by 2020.

NPCIL is currently operating 17 reactors and five are under construction. State-run NPCIL operates 17 plants in India with a total generating capacity of 4,120 megawatts. It is building six more plants with a capacity of 3,160 MW.

NPCIL Chairman and Managing Director S.K. Jain the company is also partnering with NTPC Ltd. to build up to eight nuclear power plants. "We have almost finalized the terms and conditions of the joint venture, which we are going to sign very soon," he said in recent newspaper interview. NPCIL will hold a 51 percent stake in the joint venture and NTPC will hold the remaining 49 percent.

Speaking to reporters on the margins of a conference on the energy sector, Jain said NPCIL is signing pacts with two other government firms to fund its new projects. "We are going in for public partnership. We will sign a memorandum of understanding with Indian Oil Corporation and Nalco (National Aluminium Corp)," he said.

Jain also said talks were on to evolve a model that will allow a greater participation of the private sector in owning and operating a nuclear power plant.

The company presently operates 17 nuclear power plants with total installed capacity of 4,120 MM. It also has five reactors under construction with a total capacity of 2,660 MW two each in Tamil Nadu and Rajasthan and one in Karnataka.

In another development, NPCIL is planning to sign a deal with French energy major Areva to set up two new nuclear power reactors in the country's western State of Maharashtra.

NPCIL and Areva had already signed a deal to provide 300 tonnes of Uranium for fuel deficient Indian nuclear reactors. This was a result of the recently signed Indo-French deal to co-operate in nuclear programme.

Jain said, "As a follow up to the Intergovernmental Agreement, we will be signing an MoU with Areva for setting up of two French reactors."

Jain said, "Details of setting up of the plants will take place in due course of time and the projects are expected to begin as soon as formalities with IAEA (International Atomic Energy Agency) is completed on safeguards agreement." Yet more deal with the US energy major Westinghouse Electric may also take place after approval from US authorities.

Meanwhile, NPCIL is planning to raise funds up to Rs 35,000-40,000 crore in next five years. Jain said, "Fund raising will be through a combination of domestic financial institutions and external commercial borrowings (ECBs)."

NPCIL is also in talks with Indian Oil Corp. and National Aluminium Co. for the two state-run companies to invest in the nuclear power monopoly's upcoming energy projects,. Jain has said recently.

"We are in talks with them and, maybe, very soon we will be entering into a memorandum understanding with these companies," he said during an industry event.

Indian Oil is willing to invest Rs10 billion per year, while talks with National Aluminium regarding the size of its investment are on, he said. ■

L&T Emerging as Major Player in N-Equipment Supply

India's engineering giant Larsen & Toubro (L&T) has emerged as a major player on the country's throbbing nuclear energy scene, thanks a surge in demand for equipment for a large number of nuclear plants in the pipeline. The $8.5 billion Technology, Engineering & Construction company has the capability to manufacture a vast range of equipment that goes into nuclear rectors. But it does not design nuclear reactors. In recent months L&T has entered into a number of agreements with foreign companies in order to bridge the know-how that it requires. The historic agreement between India and US on co-operation in the field of civilian nuclear energy signed in October last year opened up new opportunities for global nuclear commerce.

L&T Senior Executive Vice President (Heavy Engineering) M V Kotwal said recently in a newspaper interview that while the company's construction and manufacturing capability has already been established, it is only for design that some tie-ups with a foreign company could become necessary,

"We are already an established manufacturer of the Candu type pressurised heavy-water type reactors. We have the capability to manufacture the main pressure vessels and core equipment for those reactors. But we don't design the reactors. It is only there that we may need to have a tie-up," he said.

Recently, L&T has won a repeat order for design, manufacture and supply of four steam generators for 700 MWe Pressurized Heavy Water Reactors (PHWR) for Rajasthan Atomic Power Plant (RAPP) 7&8 from the Nuclear Power Corporation of India Limited (NPCIL).

These will be the largest steam generators built in India so far. In a nuclear power plant, the steam generators are most critical equipment that require a long lead time.

Further, L&T has won a prestigious "Technology Development" order from Department of Atomic Energy (DAE, MRPU) for Welded Grid plate as per a new design by IGCAR. The grid plate is the core assembly of a Fast Breeder Reactor.

With this, L&T's nuclear power plant equipment business unit has won orders for a total value of Rs.405 crores over the just one week. L&T has played a critical role in the development of technology and capabilities for the Indian nuclear power sector for the last four decades.

L&T is the only Indian manufacturer authorized by the American Society of Mechanical Engineers (ASME) to use N and NPT Stamp for design and manufacture of equipment of nuclear island as per international standards. No wonder, L&T is one of India's most respected private sector companies.

L&T serves the power sector across the entire spectrum from design services to equipment manufacture, erection, construction and commissioning of complete projects on turnkey basis.

A strong customer-focused approach and the constant quest for top-class technology and quality have enabled L&T to attain and sustain leadership position in its major lines of business over the past seven decades.

A number of foreign companies, including – Areva of France, GE & Westinghouse of the US and Atomstroyexport of Russia, are exploring opportunities in the Indian market for supply of not only reactors but fuel as well. ■

Challenges & Opportunities Accompany N-Energy

A Win-Win Situation for India & N-Tech Nations

P M Kamath

India has a great shortage of power. Any one who has lived in any part of India in the last few years would vouchsafe for this fact. I live in an area called Mulund, which is the last suburb in northeast of Mumbai city. Once this was a sleepy town, and a private company called Thane Electricity Co. Ltd provided power. But it was nationalised and Maharashtra State Electricity Board (MSEB) became power provider, and thence onwards began the problems of power cuts and load shedding.

But after the Government of India went on the path of Liberalisation, Privatisation and Globalisation (LPG) in a big way, Mulund became, all of a sudden, Queen of North-eastern suburbs with malls, McDonalds and multiplexes coming up, domestic tourists started pouring in; shootings for films and TV serials became common features. But power cuts - unplanned and planned load shedding - have also become part of Mulund, almost permanently!

This situation has arisen because power generation has not simply kept pace with the LPG and growing demand for power. Of the total power consumed in India, 67 percent comes from coal-fired stations, 20 percent from oil and gas, 10 percent is hydroelectric power, and only 3.0 percent is nuclear.

Coal based power generation is increasingly becoming a matter of international concern as it generates greenhouse effect. Oil based power production is likely to be costly with growing cost of fossil fuel in the international market. The competition to acquire oil resources particularly by China is only growing fierce as days pass by. Hydraulic power is also a dwindling source. Renewable energy like wind or sun has a limited scope. Only hope is in expanding use of environment friendly and clean nuclear energy.

There is the shortage of power production and with the rapid industrialisation gap in the need for power and shortfall is bound to grow. India's need for energy is expected to double by 2025. One major way of meeting this need should be by increasing investment in nuclear energy and getting access to the latest state of the art civilian nuclear technology.

Civil Nuclear Deal: A Major Step

India-US Civil Nuclear Deal (CND) that began in July 2005 and culminated in July 2008 was a major step in moving towards generating nuclear energy. Different policy makers have alluded to different objectives the US and India look forward to achieve. George W. Bush, coming from the energy industry knew that China and India are two rapidly developing economies and as such are competitors to acquire fossil fuel. This will naturally make India along with China to compete with the US for a share of globally dwindling fossil energy resources. The Sino-Indian growing demand for fossil fuel sends up the prices in the US domestic market, which the US would like to prevent. The nuclear deal would help India to diversify its energy development sources.

Second, India switching over gradually to nuclear energy will also help limit the greenhouse effects. The former French President Chirac pleaded that France would like to extend a helping hand within the non-proliferation framework and existing agreements to help India meet its energy needs. He justified French willingness to collaborate with India by relying on its effect in eradicating greenhouse effect when he said: In case developed nations do not "help India to produce electricity using nuclear power, we would let India develop into a chimney "for greenhouse gasses."

Third, to achieve much-needed poverty eradication, economic strength is needed and to maintain tempo in economic growth, energy is essential and the nuclear civil deal enables India to generate economic power by generating clean nuclear energy. Recently, Prime Minister's special envoy on nuclear deal, Sham Saran said that by 2030, India would produce 60,000MW of nuclear energy.

The CND has not only enabled acceptance of India by the major powers as a "responsible" nuclear power but it has also given India access to nuclear technology to generate energy to achieve energy security. President of Confederation of Indian Industry, R. Seshasayee is reported to have said and rightly, that the law for peaceful nuclear cooperation is a vote of confidence in India." Similarly, the President of the US-India Business Council, Ron Somers described the legislation as bringing about a shift in the bilateral relations between the two democracies.

The scope of the 123 agreement on civil nuclear cooperation is fairly wide, covering civil nuclear reactors, fuel and reprocessing for production of nuclear energy. Additionally, it includes "advanced nuclear energy research and development..."; nuclear safety matters; exchange of scientists; "advanced research and development of nuclear sciences."

In many meetings addressed by me on CND, two issue raised by the critics of nuclear energy are: Why the US while trying to sell nuclear reactors in a big way to India, not really doing much to move rapidly enough to generate more nuclear power itself. Second, and related issue is safety-factor in nuclear energy. It should be noted that the US had in the 1970s plans to develop over 1000 nuclear plants and the slogan was: Electricity would be "too cheap to meter." But the 1979 Three Mile Island nuclear accident placed a break on the expansion. Yet, US today have 104 nuclear plants collectively producing one-fifth of total electricity produced in the US. But the Bush administration initiated rebirth of nuclear energy with the submission of a new nuclear power project by NRG Energy and South Texas Project Nuclear Operating Co.

On the safety issue, the Government of India had argued, and rightly, that nuclear cycle is incomplete without the right to reprocess used nuclear fuel. It is not only a storage problem, but also poses a health hazard. Insistence on this right had created maximum heat in negotiations between two countries. The 123 agreement, now provides that India could reprocess the imported nuclear fuel for which it will create a new national facility and would work under the India-specific safeguards agreed between India and IAEA.

There are initial delays and suspicions in implementing the civil nuclear deals and obvious frustrations. Even the Government of India might choose to implement it more cautiously. Sham Saran, for instance, invited private players to participate in the building of nuclear power stations by the Nuclear Power Corporation of India Ltd (NPCIL). "Once the private players gain experience in the nuclear field, the government may consider allowing them nuclear plants of their own."

Opportunities

But CND is a positive development in meeting India's nuclear energy needs. But having won the deal through Lok Sabha last July and Manmohan Singh having won power for a second term, there is the benefit of continuity to negotiate remaining measures needed to complete the CND. Prime Minister has also a unique opportunity to fulfill his several promises advanced in the context of national acceptance of the CND.

Indian government has plans to provide power to every home by 2012. This is possible only by augmenting power generation in the country. In the increase of power output, nuclear energy is the highly suited option. NPCIL has plans to buy eight reactors. Of these, the US is likely to get to build exclusively two reactorsone by the GE and the second by the Westinghouse. After the completion of CND process, the first meeting of the India-US civil nuclear energy working group was held towards the end of April this year to give further momentum to the CND.

Challenges

I am an ardent supporter of the CND. But current regime change in the US with Democrats coming to power, what we see is a return of their inborn tendency to use every economic lever to bring about a change in Indian foreign policy behaviour. And that is a bad omen for Indian efforts to use nuclear energy to fast track economic development. In the specific case of cooperation in civil nuclear technology trade, India expects US to include trade across the full nuclear fuel cycle: nuclear reactors, nuclear fuels and reprocessing the spent fuel.

The 123 agreement also ensures its non-military character when it states, "the purpose of this agreement is to provide for peaceful nuclear cooperation and not to affect the un-safeguarded nuclear activities of either party." Since the agreement is for civil nuclear cooperation for peaceful purposes, it clearly provides that it will be implemented in such a manner "as not to hinder or otherwise interfere with any other activities involving the use of nuclear material, equipment, components, information or technology and military nuclear facilities produced, acquired or developed by them independent of this agreement for their own purposes." In other words, it tries to make it clear that civil nuclear agreement is one for cooperation in civil nuclear energy production and has nothing to do with the military use of nuclear technology by India.

US is also committed to join India in negotiating with the IAEA "an India-specific fuel supply agreement." The US will also support Indian effort "to develop a strategic reserve of nuclear fuel to guard against any disruption" of fuel supply. Further, the agreement also enables India during the operation of the 123 agreement, to build up a reserve of nuclear fuel taking into consideration of any future disruption of fuel supply.

Further, India is reassured that despite all these efforts if "a disruption of fuel supply to India occurs," the US will go an additional mile to help India. The agreement clearly provides that in such an event, the US would work with other nuclear states like Russia, United Kingdom and France to see that India will get necessary fuel supply for the working of nuclear reactors.

Despite these positive provisions what is evident is: an effort is being made to reinvent original intent of Democratic lawmakers involved in Hyde act of 2006. It has been a well-established convention that President chooses to implement the law according to his understanding of intent of lawmakers. It is on that basis President Bush had promised India that some provisions of Hyde Act which were not in consonance with the intent of Bush-Singh agreement on CND were in fact overridden in the 123 Executive Agreement signed by the US with India on August 1, 2007. But now no one can prevent President Obama if he chooses to go along with Democrats' intent of denying India technology to reprocess the spent fuelthat was the intent of the Hyde Act, but overlooked by President George Bush in 123 Agreement.

The US is also trying to pressurize India to speed up, under the separation plan, determination of civil nuclear reactors and bring them under international inspection. Under the India-US CND, separation plan is to be implemented in a phased manner by 2014. Though India knows that only the nuclear plants declared under civilian category could get imported nuclear fuel, India cannot be pressurized to implement it before hand. As until signing of the CND, there was a fusion of strategic and civilian activities, material and components and it takes time to separate.

Of course, the US has been repeating at different levels that the CND is going to be implemented by the new administration as it not only received bipartisan support but specifically Senator Obama had also voted for it. Obama's staff aide, Bruce Reidel and US under secretary of state for political affairs, William Burns recently reaffirmed this. However, there is a nagging doubt within the Indian government on the Obama administration's full commitment to implement CND in the same spirit in which the Bush administration had pursued it.

No one can legally object if Obama informally links implementation of certain provisions of the 123 Agreement, by following American policy preferences on Kashmir or asking India to share American perceptions on Pakistan's handling of Taliban or cross borders Terrorism!

Civil nuclear Deal provides economic strength to Indian nuclear weapons programme and general pursuit of great power status. But the US could return to former President Bill Clinton's policy of pressurizing India to sign the NPT or the CTBT thereby slowing down civil nuclear cooperation!

Conclusions

The likely placing of speed breakers by the US in India developing nuclear energy sector, however, need not discourage India. The US behaviour undoubtedly will influence other members of the Nuclear Suppliers Group. But, India has already entered into an agreement with Kazakhstan to buy nuclear fuel for Indian reactors. India has also entered into civil nuclear deal agreements with Russia, France and Canada among others. This is a win-win situation for leading nuclear technological powers and India. NPCIL also ensures that the countries, which supply nuclear reactors also contractually, supply nuclear fuels during the lifetime of reactors provided by them. It should be possible to Indian diplomacy to overcome, if Democratic administration in the US tries to use the civil nuclear deal's logical implementation to subserve its unrelated political or economic goals.

The author, a former Professor of Politics, Department of Civics & Politics, University of Bombay, is currently, Hon. Director, VPM's Centre for International Studies, Mumbai. He has widely lectured and written on India-US Civil Nuclear Deal. His latest book is: India's Policy of No First Use of Nuclear Weapons: Relevance to Peace and Security in South Asia (Anamika Publishers, New Delhi, 2009).

SCHOTT Offers High-Tech EPAs to Indian Nuclear Plants

The German high-technology, international group SCHOTT AG has mastered the glass-to-metal sealing technology for the continued safe and reliable operation of nuclear power plants. For India, which has launched a massive nuclear power generation programme, SCHOTT's technology for building long-lasting and maintenance-free Electrical Penetration Assemblies (EPAs) comes at the right time.

Electrical penetration assemblies (EPAs) permit electrical wirings and instrumentation cables to pass through the containment structure of a nuclear power plant to provide power, control signals and monitoring for the entire sealed-off reactor. EPAs must hence, under all circumstances, be able to maintain the pressure boundary integrity of the containment structure and prevent steam as well as radioactive materials from escaping into the environment. As a leading country in the nuclear renaissance, there is clear potential for SCHOTT's glass-to-metal sealing technology in the Indian nuclear industry.

The SCHOTT name is well-known around the world standing for top-quality optical and specialty glasses in complex and demanding applications such as aerospace and medical industries as well as in consumer goods such as glass-ceramic cooktops. However, few are aware that SCHOTT AG, founded in 1884 and headquartered in Mainz, Germany, is a technology leader in many other fields as well. Technical glasses from SCHOTT specially developed for glass-to-metal seals are used to safely pack electronic components and transmit digital data at high speeds via hermetic (Transistor Outlines, 'TOs' and hybrid or microelectronic) packages and fiber optic cables. SCHOTT Solar has also been manufacturing photovoltaic modules for the last seven years. In addition, the group has more than six hundred scientists and engineers developing new glass technologies and applications at the Otto Schott Research Center in Mainz, one of the most up-to-date glass research centres worldwide.

Hermetically sealed housings with glass-to-metal sealed (GTMS) feedthroughs is one of SCHOTT's key product offerings, a product the company has been manufacturing since 1941. Millions of these are used in the smallest of components, such as the packaging of sensors for the automotive or aerospace industries. However, these feedthroughs, which range in sizes not much larger than the head of a pin (1.2 millimeters) to high voltage feedthroughs with diameters of up to 600 millimeters, are also used in large-scale applications, such as submerged pumps in liquefied natural gas (LNG) tankers.

The functional principle is always the same: multiple electrical lines that supply power, controls, or transmit data must run through a hermetically sealed barrier into the interior of an insulated space containing sensitive electronics. According to Dr. Oliver Fritz, Technical Manager for Large Scale Feedthroughs at SCHOTT Electronic Packaging in Landshut, Germany, the "secret" behind SCHOTT's GTMS technology lies on a technique known as compression sealing. "The glass isolator and the metal conductor are placed inside stainless steel housing and then heated up so that all of the elements melt together. As the assembly cools down, the glass solidifies and the stainless steel housing contracts to a greater degree than the glass. Due to the differences in the coefficients of thermal expansion of the materials used, the glass isolators are subjected to compression and a hermetic joint is created." The seal is so perfect that components packed in this manner work even in the hot oil bath of an engine, in "on-demand" explosive environments such as air bag igniters as well as in LNG vessels which must routinely cycle between temperature and pressure extremes.

A nuclear power plant is an exceptionally demanding environment for any component operating in it. Electrical penetration assemblies (EPA),which create a connection for the equipment within the reactor with the outside environment through the containment barrier, must like the containment walls of the reactor be able to withstand seismic shock, high pressures and temperatures as well as radiation, and in the case of an accident prevent steam, pressure and radioactive materials from leaking out of the containment structure. Hence, EPAs are a critical safety component of a nuclear reactor and calls for a very high standard of quality and reliability. For more than 40 years, SCHOTT has accumulated the experience of producing more than 5,000 pieces of glass-to-metal sealed EPAs for nuclear power plants. Installed in plants worldwide, these EPAs are still performing optimally despite no maintenance no deterioration, radioactive leaks, or leaks of reactive chemical substances have been detected. This is only possible because glass, unlike organic materials, does not degrade as it ages. Hence, its service life is practically infinite. Since SCHOTT's GTMS EPAs is non-aging and call for little, if any maintenance at all, the plants' lifecycle costs are also low. This high safety and performance standard at minimal "costs" advantage is clearly appreciated as can be observed from the use of GTMS EPAs in equally demanding applications like nuclear reactors on ships and submarines.

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Glass-to-metal sealed EPAs are very compact because the cables or contact pins can be packed very tightly. SCHOTT makes round feedthroughs in a modular design with a cross-section of the contacts of up to 1,000 square millimeters for power penetrations or up to 118 lines for control and instrumentation and flange shaped penetrations with over 500 contacts. Depending on the model, these feedthroughs are suitable for voltages of up to 13,000 volts and current up to 1,200 amperes; short-circuit currents up to 120,000 amperes will not damage the seal. Feedthroughs for hermetically glass-sealed fiber optic lines for optical data transmission are also available on request. Furthermore, the plug-in connectors make installation very easy.

With the latest nuclear reactor designs extended to 60 years, GTMS technology is clearly the way to go. This is

why some of the older reactors, which has had no maintenance work carried out on the GTMS feedthroughs, have had their term of service extended from 40 to 60 years. In fact, the operators of 22 nuclear power plants in 7 countries have also replaced their conventional EPAs with GTMS EPAs from SCHOTT.

SCHOTT's glass-to-metal feedthroughs are manufactured according to the German KTA 3403 and 1401 standards and are also compliant with the current IEEE 317 standard. The company also employs continuous quality control procedures in its production facility to ensure that its GTMS EPAs consistently meet stringent requirements. This includes subjecting the EPAs to tests involving high electrical voltages and currents, as well as sudden extreme changes in pressure and temperature that are even more severe than anything that actually occurs at a nuclear power plant. The centerpiece of quality control for SCHOTT is hermeticity testing with a mass spectrometer that can detect extremely minute leaks of test gas through the seal.

As GTMS penetrations are resistant to high pressures of up to 1,000 bars and temperatures of 200°C to +240°C, they are especially well-suited for the future reactor designs such as the European Pressurized Reactor (EPR), Advanced Boiling Water Reactor (ABWR), the Westinghouse AP1000 design as well as the High Temperature Reactors (HTR) both Pebble Bed and Prismatic Reactor (PBR). These reactors reach higher peak temperatures over longer time periods and their radiation intensity is also higher. Glass-to-metal seals are hence the ideal choice for the future generation of nuclear power plants.

With the nuclear renaissance in motion, India is playing a leading role in the construction of new nuclear power plants around the world. To meet the needs of the more than one billion people who live in India, the seventh-largest country in the world must quell an enormous thirst for energy and nourish its growing industrial base. Experts estimate that electricity demand must grow by ten percent a year to keep pace with GDP growth in India. The country is relying on a mix of renewable and traditional energy sources to meet this expected rise in demand. India is currently investing strongly in expanding its network of nuclear power powers, and some new plants are already under construction. As a result, SCHOTT AG expects India to become an increasingly important market for its glass-to-metal sealed feedthroughs. In the fiscal year 2007/2008, SCHOTT AG recorded sales of €2.23 billion, of which, international sales (sales outside Germany) accounted for 74 percent. SCHOTT is no stranger to India, having set up its first sales office in the country in 1998. In fact, India has always been a focus country for the Group. During that same year, the group established its second largest pharmaceutical tubing factory in Vadodara. SCHOTT further intensified its presence in the country more recently with the formation of SCHOTT KAISHA, a joint venture company with Kaisha Manufacturers Private Limited.

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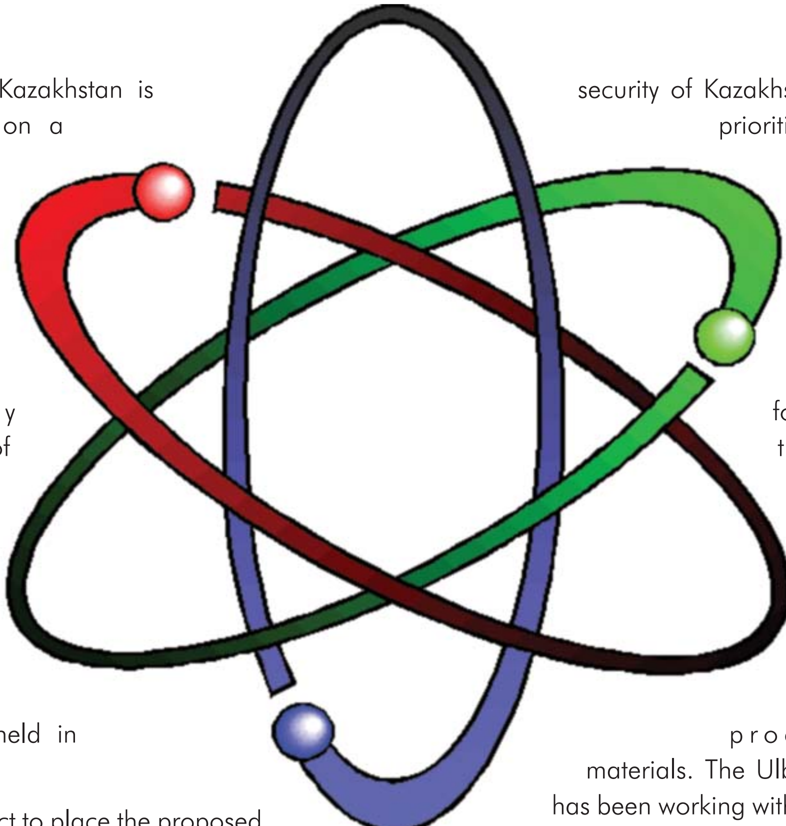
As a business unit of the international technology group SCHOTT, Electronic Packaging (EP) is a leading manufacturer of housings and other components for the reliable, long-term protection for sensitive electronics. The core technologies are glass-to-metal and ceramic-to-metal sealing, thermal sensing components as well as a variety of cutting edge specialty glass competences. SCHOTT EP draws on 125 years of experience in the development, production and reliable supply of specialized solutions for its customers worldwide. With 1,500 employees at five production locations and several competence centers around the world, local customer support and co-developments for individual packaging solutions are at the heart of the business, serving the world's leading manufacturers in the automotive, data- and telecommunication, sensors and semiconductors, consumer electronics, dental care, home appliances, laser as well as security and tracking industries.

SCHOTT is an international technology group that sees its core purpose as the lasting improvement of living and working conditions. To this end, the company has been developing special materials, components and systems for 125 years. The main areas of focus are the household appliances industry, pharmaceuticals, solar energy, electronics, optics and the automotive industry. The SCHOTT Group is present in close proximity to its customers with production and sales companies in all its major markets. The Group's approximately 17,300 employees generated worldwide sales of approximately 2.2 billion Euros in the fiscal year 2007/2008. The company's technological and economic expertise is closely linked with its social and ecological responsibility. The SCHOTT AG is an affiliate of the Carl-Zeiss-Stiftung (Foundation). ■

Efforts to House N-Fuel Bank in Kazakhstan at 'Analysis Stage'



The Government of Kazakhstan is making every effort on a project to place the proposed Nuclear Fuel Bank in the country. This was disclosed by Timur Zhantikin, Chairman of the Nuclear Energy Committee, Ministry of Energy & Mineral Resources on 18 May 2009 at an international conference on Remediation of Radioactively Contaminated Sites held in Astana.

He said, that the project to place the proposed Nuclear Fuel Bank in the Kazakhstan territory is "at the stage of analysis. We are now working out technical details and considering the possibilities and location of the Fuel Bank, since at present we have several options. If findings are positive, Kazakhstan will apply to the International Atomic Energy Agency (IAEA) with the official proposal to place the bank on its territory."

Zhantikin said that the Kazakh national company KazAtomProm and the National Nuclear Center are involved in development and the placement of the Fuel Bank. "Why is Kazakhstan so favoured as a place for the Nuclear Fuel Bank?" asked Zhantikin. "Because Kazakhstan has a very positive non-proliferation record. After all, we have a well-developed nuclear industry. There are no direct commercial benefits for the country" he added.

Zhantikin further explained that the environmental security of Kazakhstan is one of the top priorities: "If this project goes ahead, the indispensable condition is to study and evaluate its influence on the environment. If its influence is found to be negative, the project will not be implemented. But we don't expect that [creation of the bank] to entail any ecological problems, because we are already processing similar materials. The Ulba Plant, for example, has been working with such materials for 50 years already" he said.

The Director of the IAEA's Division of Nuclear Fuel Cycle and Waste Technology (NEFW), Hans Forsstrom, said that "We have heard that Kazakhstan has been considering accommodation of this bank in its territory. As of today, Kazakhstan has not officially approached IAEA yet. If Kazakhstan officially makes such an offer, we will accept it," H. Forsstrom said.

In April this year, President Nursultan Nazarbayev of Kazakhstan said that "If a nuclear fuel bank is created, we would consider hosting it here - in a country which has signed the Nuclear Nonproliferation Treaty and voluntarily renounced nuclear weapons."

An international fuel bank under the auspices of the IAEA and supported by the US administration, would provide a global repository which would allow countries to tap into their reserves to fuel their nuclear plants without the need to develop their own nuclear enrichment capability. ■

Celebrating Semipalatinsk N-Testing Site Closure

Towards A World Free From N-Weapons

By **Marat Tazhin**, Secretary, Security Council of Kazakhstan

On the occasion of the Twentieth Anniversary of Termination of Nuclear Tests at the Semipalatinsk Nuclear Testing Site (SNTS) held on 18th June 2009, Kazakhstan President Nursultan Nazarbaev initiated a proposal to declare 29th August as the International Day of Renunciation of Weapons of Mass Destruction. He also made a proposal to work out a new universal "Treaty on Comprehensive Horizontal and Vertical Non-Proliferation of Nuclear Weapons."

The new initiatives of Kazakhstan have been dictated by its aspiration for a more secure world, free from nuclear weapons, and its concern that this process is facing considerable obstacles.

Unfortunately, the global disarmament process has been passing through a very long period of stagnation. Due to lack of consensus and absence of political will, the international community has not been able to move further in deciding the cardinal questions of disarmament and non-proliferation.

In the first place, this concerns the ineffectiveness of the main tool of nuclear non-proliferation - the Nuclear Non-Proliferation Treaty (NPT).

As of today, the NPT is devoid of effective levers to prevent proliferation of nuclear weapons and emergence of new nuclear powers de facto. Inequality which is inherent in NPT is leading to destructive tendencies and a feeling of 'injustice perpetuated by NPT' in some regions of the world. Those countries which are not members of the recognized 'nuclear club' are aspiring to acquire the technology of nuclear weapons and create their own arsenal of such weapons. They consider this as a guarantee of not only their own security, but also as an assurance for safeguarding their foreign policy interests.

This has made the present-day world less predictable, and the problem of use of nuclear weapons has become more complex, as it now depends more on local players rather than global ones.

Our country has got the moral right to come out with new initiatives on this highly sensitive matter. The peoples of Kazakhstan have faced all the horrors of nuclear weapons. Between 1949 and 1991 a total number of 456 nuclear tests were carried out at the Semipalatinsk Nuclear Testing Site. These tests caused diseases and sufferings to several hundred thousands of fellow citizens and led to contamination of a huge territory with radiation.

Kazakhstan has closed down the largest nuclear testing site and has destroyed the entire military nuclear infrastructure. By doing so Kazakhstan has set an example of a very high sense of responsibility before the present and the future generations of mankind which convincingly demonstrates that it is the foreign policy of peace, internal stability, and sustainable economic and political development of the country which are the main components of security rather than any nuclear arsenal.

Realizing that there are serious problems in the implementation of NPT, the President of Kazakhstan Nursultan Nazarbaev, in his address to 62nd Session of the UN General Assembly in the year 2007, had called upon the nuclear powers to move towards a world free from the nuclear weapons, and also to take measures to ensure effectiveness of NPT and to strongly regulate non-proliferation of nuclear weapons. It is necessary to create clear-cut mechanisms to encourage the countries in possession of nuclear weapons to act within the framework the NPT, and to prevent any signatory country to make an exit from the Treaty. It is necessary that all its participants should adhere to unconditional fulfillment of their obligations as embodied in the unity of its three fundamental components - non-proliferation, peaceful use of an atomic energy and disarmament.

The initiative for a new universal Treaty on Comprehensive Horizontal and Vertical Non-Proliferation of Nuclear Weapons is not meant to replace the existing agreements; it is not going to be a mechanical replacement of NPT by something new as a matter of principle. We are interested in strengthening the NPT, to make it really effective, to overcome its fundamental asymmetry and non-obligatory character of some of its provisions. One month or, possibly, even one year may not be sufficient to complete this task. We keep our doors open for a meaningful and fruitful dialogue with anyone interested in strengthening the regime of non-proliferation and disarmament.

Unfortunately, the Comprehensive Nuclear Test Ban Treaty (CTBT) has not yet come into force although it had been passed by the UN General Assembly in September 1996 by majority vote. It is hoped that the example of the new Administration of the United States which has declared that it is committed to the CTBT and is going to place it before the Congress for ratification will be followed by other countries whose participation will decide the fate of this Treaty.

Kazakhstan is making significant contribution to strengthen the regime of verification within the limits of the CTBT, and it is actively cooperating with its Preparatory Committee for setting up of a Global Monitoring Network. In order to strengthen and develop a system of inspection under the Treaty Kazakhstan had supported the initiative to carry out in September 2008 a wide-ranging Integrated Field Experiment in the territory of the former Semipalatinsk Nuclear Testing Site. Implementation of projects connected with CTBT will make it possible to use the infrastructure available in Semipalatinsk in such a manner so that it more and more acquires the role of an international testing site of peace, 'a neutral belt' for solving sensitive issues concerning non-proliferation of nuclear weapons.

Creation of nuclear-free zones can be one of the ways of reducing the threat of a nuclear war. In this direction a Central Asian Nuclear-Free Zone Treaty (CANFZT) was signed in the city of Semipalatinsk on September 8, 2006 which has come into force on March 22, 2009.

The CANFZT is a real substantial contribution of the countries of this region in the direction of achieving the goals of the NPT, and it also helps to strengthen regional and international security. If we compare the Central Asian zone with similar zones we will notice that it has several characteristic features. In particular, the Treaty envisages that all the participant countries must sign an Additional Protocol of the International Atomic Energy Agency (IAEA) to affirm that they do not intend to shift nuclear materials meant for peaceful use to military purpose. This affirmation further proves that the countries of Central Asia have firmly decided that this region should remain nuclear-free in the future also. This is the first and the only zone fully located in the Northern Hemisphere where nuclear weapons had been placed in the past. Another special feature of the Central Asian zone is that it has common borders with two nuclear powers, i.e. Russia and China, and is very close to India and Pakistan who both possess nuclear weapons.

Symbolically, the Central Asian Nuclear-Free Zone Treaty was signed in Semipalatinsk the place which has experienced in full measure the evils of nuclear weapons.

Today Kazakhstan has become a signatory to all the basic international documents on prevention of nuclear, biological, radiological and chemical weapons. We have been rigorously fulfilling the obligations of the UN Security Council Resolution No.1540 on non-proliferation of all kinds of weapons of mass destruction.

In July 2005 Kazakhstan joined the Proliferation Security Initiative which is better known as 'Krakow Initiative'. Kazakhstan is also actively participating in the Global Initiative for Struggle against Acts of Nuclear Terrorism which was put forward by the Presidents of Russia and US in July 2006.

In 2004 Kazakhstan signed an Additional Protocol. All the nuclear objects of Kazakhstan fall under the guarantee of IAEA, and all the nuclear activities of Kazakhstan are being carried out in accordance with the rules and standards of the IAEA.

The day when the historical decision to close down the nuclear testing site at Semipalatinsk was taken marks the beginning of the process of complete liquidation of the fourth largest nuclear potential of the world the nuclear heritage of the erstwhile Soviet Union. The date of 29th August has historical significance not only for Kazakhstan but for the entire mankind too. The fact is that this testing site was closed own not for any technical reasons, but consciously, as a practical contribution to reduction of global nuclear threat. From the point of view of nuclear disarmament this was an unprecedented event of world-wide significance.

On 24th April 2009 the UN General Assembly passed the Resolution "International Cooperation and Coordination of Activities for the Rehabilitation of Peoples and Ecology and Economic Development of the Semipalatinsk Region of Kazakhstan". It has been proposed to the member-countries to formally celebrate the Twentieth Anniversary of closing down of the Semipalatinsk Nuclear Testing Site.

In this connection declaring the 29th August as the International Day of Renunciation of Nuclear Weapons within the format of UN may acquire very special symbolic significance and it may also help to achieve the goal of the world free from nuclear weapons.

Kazakhstan hopes to get support for this initiative from all the friendly countries when it is put forward before the UN General Assembly. ■

India a Rising Power on the Global Nuclear Horizon

- India has a flourishing and largely indigenous nuclear power program and expects to have 20,000 MWe nuclear capacity on line by 2020 and 63,000 MWe by 2032. It aims to supply 25% of electricity from nuclear power by 2050.
- Because India is outside the Nuclear Non-Proliferation Treaty due to its weapons program, it has been for 34 years largely excluded from trade in nuclear plant or materials, which has hampered its development of civil nuclear energy until 2009.
- Due to these trade bans and lack of indigenous uranium, India has uniquely been developing a nuclear fuel cycle to exploit its reserves of thorium.
- Now, foreign technology and fuel are expected to boost India's nuclear power plans considerably. All plants will have high indigenous engineering content.
- India has a vision of becoming a world leader in nuclear technology due to its expertise in fast reactors and thorium fuel cycle.

Electricity demand in India has been increasing rapidly, and the 534 billion kilowatt hours produced in 2002 was almost double the 1990 output, though still represented only 505 kWh per capita for the year. In 2006, 744 billion kWh gross was produced, but with huge transmission losses this resulted in only 505 billion kWh consumption. The per capita figure is expected to almost triple by 2020, with 6.3% annual growth. Coal provides 68% of the electricity at present, but reserves are limited. Gas provides 8%, hydro 15%.

Nuclear power supplied 15.8 billion kWh (2.5%) of India's electricity in 2007 from 3.7 GWe (of 110 GWe total) capacity and this will increase steadily as imported uranium becomes available and new plants come on line. Some 300 reactor-years of operation had been achieved by mid 2009. India's fuel situation, with shortage of fossil fuels, is driving the nuclear investment for electricity, and 25% nuclear contribution is foreseen by 2050, from one hundred times the 2002 capacity. Almost as much investment in the grid system as in power plants is necessary.

In 2006 almost US$ 9 billion was committed for power projects, including 9354 MWe of new generating capacity, taking forward projects to 43.6 GWe and US$ 51 billion.

A KPMG report in 2007 said that India needed to spend US$ 120-150 billion on power infrastructure over the next five years, including transmission and distribution. It said that distribution losses are currently some 30-40%, worth more than $6 billion per year.

The target since about 2004 has been for nuclear power is to provide 20 GWe by 2020, but in 2007 the prime Minister referred to this as "modest" and capable of being "doubled with the opening up of international cooperation." However, it is evident that on the basis of indigenous fuel supply only, the 20 GWe target is not attainable, or at least not sustainable without uranium imports. However, it is evident that even the 20 GWe target will require uranium imports. Late in 2008 NPCIL projected 22 GWe on line by 2015, and the government was talking about having 50 GWe of nuclear power operating by 2050. Then in June 2009 NPCIL said it aimed for 63 GWe by 2032, including 40 GWe of PWR capacity and 7 GWe of new PHWR capacity, all fuelled by imported uranium. The Atomic Energy Commission however envisages some 500 GWe nuclear on line by

2060, and has since speculated that the amount might be higher still: 600-700 GWe by 2050, providing half of all electricity.

Nuclear power industry development

Nuclear power for civil use is well established in India. Its civil nuclear strategy has been directed towards complete independence in the nuclear fuel cycle, necessary because it is excluded from the 1970 Nuclear Non-Proliferation Treaty (NPT) due to it acquiring nuclear weapons capability after 1970. (Those five countries doing so before 1970 were accorded the status of Nuclear Weapons States under the NPT.)

As a result, India's nuclear power program has proceeded largely without fuel or technological assistance from other countries (but see later section). Its power reactors to the mid 1990s had some of the world's lowest capacity factors, reflecting the technical difficulties of the country's isolation, but rose impressively from 60% in 1995 to 85% in 2001-02.

India's nuclear energy self-sufficiency extended from uranium exploration and mining through fuel fabrication, heavy water production, reactor design and construction, to reprocessing and waste management. It has a small fast breeder reactor and is building a much larger one. It is also developing technology to utilise its abundant resources of thorium as a nuclear fuel.

The Atomic Energy Establishment was set up at Trombay, near Mumbai, in 1957 and renamed as Bhabha Atomic Research Centre (BARC) ten years later. Plans for building the first Pressurised Heavy Water Reactor (PHWR) were finalised in 1964, and this prototype - Rawatbhata-1, which had Canada's Douglas Point reactor as a reference unit, was built as a collaborative venture between Atomic Energy of Canada Ltd (AECL) and NPCIL. It started up in 1972 and was duplicated Subsequent indigenous PHWR development has been based on these units.

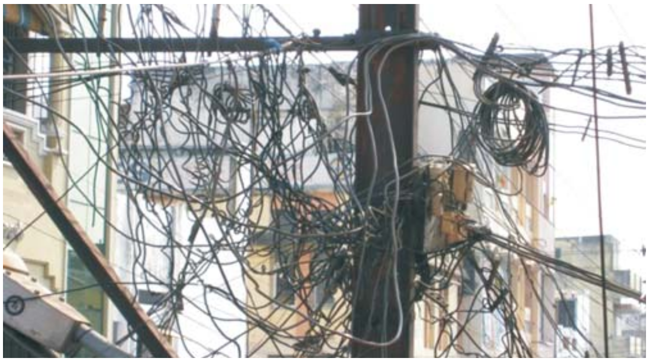
The Nuclear Power Corporation of India Ltd (NPCIL) is responsible for design, construction, commissioning and operation of thermal nuclear power plants.

It has 15 small and two mid-sized nuclear power reactors in commercial operation, six under construction - including two large ones and a fast breeder reactor, and more planned.

India's operating nuclear power reactors:

Reactor	State	Type	MWe net, each	Commercial operation	Safeguards status
Tarapur 1 & 2	Maharashtra	BWR	150	1969	item-specific
Kaiga 1 & 2	Karnataka	PHWR	202	1999-2000	
Kaiga 3	Karnataka	PHWR	202	2007	
Kakrapar 1 & 2	Gujarat	PHWR	202	1993-95	by 2012 under new agreement
Kalpakkam 1 & 2 (MAPS)	Tamil Nadu	PHWR	202	1984-86	
Narora 1 & 2	Uttar Pradesh	PHWR	202	1991-92	by 2014 under new agreement
Rawatbhata 1	Rajasthan	PHWR	90	1973	item-specific
Rawatbhata 2	Rajasthan	PHWR	187	1981	item-specific
Rawatbhata 3 & 4	Rajasthan	PHWR	202	1999-2000	by 2010 under new agreement
Tarapur 3 & 4	Maharashtra	PHWR	490	2006, 05	
Total (17)			3779 Mwe		

Kalpakkam also known as Madras/MAPS
Rawatbhata also known as Rajasthan/RAPS
Kakrapar = KAPS, Narora = NAPS
dates are for start of commercial operation.



The two Tarapur 150 MWe Boiling Water Reactors (BWRs) built by GE on a turnkey contract before the advent of the Nuclear Non-Proliferation Treaty were originally 200 MWe. They were down-rated due to recurrent problems but have run well since. They have been using imported enriched uranium and are under International Atomic Energy Agency (IAEA) safeguards. However, late in 2004 Russia deferred to the Nuclear Suppliers' Group and declined to supply further uranium for them. They underwent six months refurbishment over 2005-06, and in March 2006 Russia agreed to resume fuel supply. In December 2008 a $700 million contract with Rosatom was announced for continued uranium supply to them.

The two small Canadian (Candu) PHWRs at Rawatbhata started up in 1972 & 1980, and are also under safeguards. Rawatbhata-1 was down-rated early in its life and has operated very little since 2002 due to ongoing problems and has been shut down since 2004 as the government considers its future.

The 220 MWe PHWRs (202 MWe net) were indigenously designed and constructed by NPCIL, based on a Canadian design.

The Kalpakkam (MAPS) reactors were refurbished in 2002-03 and 2004-05 and their capacity restored to 220 MWe gross (from 170). Much of the core of each reactor was replaced, and the lifespans extended to 2033/36.

More recent reactor developments

The new series of 540 MWe (gross, 490 MWe net) nuclear reactors are developed indigenously from the 220 MWe (gross) model PHWR. The Tarapur 3&4 units were built by NPCIL.

The first - Tarapur 4 - started up in March 2005, was connected to the grid in June and started commercial operation in September. Tarapur-4's criticality came five years after pouring first concrete and seven months ahead of schedule. Its twin - unit 3 - was about a year behind it and criticality was achieved in May 2006, with grid connection in June and commercial operation in August, five months ahead of schedule.

Russia is supplying the country's first large nuclear power plant, comprising two VVER-1000 (V-392) reactors, under a Russian-financed US$ 3 billion contract. The AES-92 units at Kudankulam in Tamil Nadu state are being built by NPCIL and will be commissioned and operated by NPCIL under IAEA safeguards. The turbines are made by Leningrad Metal Works. Unlike other Atomstroyexport projects such as in Iran there have been only about 80 Russian supervisory staff on the job. Russia will supply all the enriched fuel, though India will reprocess it and keep the plutonium. The first unit was due to start supplying power in March 2008 and go into commercial operation late in 2008, but this schedule has slipped by about two years. The second unit is about 6-8 months behind it.

Under plans for the India-specific safeguards to be administered by the IAEA in relation to the civil-military separation plan, eight further reactors will be safeguarded (beyond Tarapur 1&2, Rawatbhata 1&2, and Kudankulam 1&2): Rawatbhata 3&4 by 2010, Rawatbhata 5&6 by 2008, Kakrapar 1&2 by 2012 and Narora 1&2 by 2014.

India's nuclear power reactors under construction:

Reactor	Type	MWe net, each	Project control	Commercial operation due	Safeguards status
Kaiga 4	PHWR	202 MWe	NPCIL	12/2009	
Rawatbhata 5 & 6	PHWR	202 MWe	NPCIL	7/2009, 10/2009	by 2008 under new agreement
Kudankulam 1 & 2	PWR (VVER)	950 MWe	NPCIL	6/2010, 12/2010	item-specific
Kalpakkam PFBR	FBR	470 MWe	Bhavini	2011	-
Total (6)		2976 Mwe			

Rawatbhata also known as Rajasthan/RAPS dates are for start of commercial operation.

Kaiga 3 started up in February, was connected to the grid in April and went into commercial operation in May 2007. Unit 4 was scheduled about six months behind it, but it and RAPP-5 were to load fuel in late 2007 and are about a year behind original schedule due to shortage of uranium. Though construction is complete, start up of RAPP-5 is now anticipated in 2009.

In mid 2008 Indian nuclear power plants were running at about half of capacity due to a chronic shortage of fuel. The situation was expected to persist for several years if the civil nuclear agreement faltered, though some easing in 2008 was likely due to the new Turamdih mill in Jharkhand state coming on line (the mine there is already operating). Political opposition has delayed new mines in Jharkhand, Meghalaya and Andhra Pradesh.

A 500 MWe prototype fast breeder reactor (FBR) is under construction at Kalpakkam by BHAVINI, a government enterprise set up to focus on FBRs. It is expected to start up in 2010 and produce power in 2011. Four further oxide-fuel fast reactors are envisaged but slightly redesigned by the Indira Gandhi Centre to reduce capital cost. One pair will be at Kalpakkam, two more elsewhere. (See also Thorium cycle section below.)

In contrast to the situation in the 1990s, most reactors under construction are on schedule (apart from fuel shortages 2007-09), and the first two - Tarapur 3 & 4 were slightly increased in capacity. These and future planned ones were 450 (now 490) MWe versions of the 202 MWe domestic products. Beyond them and the last three 202 MWe units, future units will be nominal 700 MWe.

The government envisages setting up about ten PHWRs of 700 MWe capacity to about 2023, fuelled by indigenous uranium, as stage 1 of its nuclear program. Stage 2 - four 500 MWe FBRs - will be concurrent.

Nuclear industry developments beyond the trade restrictions

Following the Nuclear Suppliers' Group agreement which was achieved in September 2008, the scope for supply of both reactors and fuel from suppliers in other countries opened up.

The Russian PWR types were apart from India's three-stage plan for nuclear power and were simply to increase generating capacity more rapidly. Now there are plans for eight 1000 MWe units at the Kudankulam site, and in January 2007 a memorandum of understanding was

signed for Russia to build four more there, as well as others elsewhere in India. The new units will be the larger 1200 MWe AES-2006 versions of the first two.

Between 2010 and 2020, further construction is expected to take total gross capacity to 21,180 MWe. The nuclear capacity target is part of national energy policy. This planned increment includes those set out in the Table below including the initial 300 MWe Advanced Heavy Water Reactor (AHWR).

In 2005 four sites were approved for eight new reactors. Two of the sites - Kakrapar and Rawatbhata, would have 700 MWe indigenous PHWR units, Kudankulam would have imported 1000 or 1200 MWe light water reactors alongside the two being built there by Russia, and the fourth site was greenfield for two 1000 MWe LWR units - Jaitapur (Jaithalpur) in the Ratnagiri district of Maharashtra state, on the west coast. The plan has since expanded to six 1600 MWe EPR units here.

NPCIL had exploratory meetings and technical discussions with three major reactor suppliers - Areva of France, GE-Hitachi and Westinghouse Electric Corporation of the USA for supply of reactors for these projects and for new units at Kaiga. These resulted in more formal agreements with each reactor supplier early in 2009, as mentioned below.

In April 2007 the government gave approval for construction of the first four of these eight units, utilising indigenous technology.

In April 2007 the government gave approval for the first four of these eight units (below), using indigenous technology, probably starting construction in 2009. In late 2008 NPCIL announced that as part of the Eleventh Five Year Plan (2007-12), it would start site work for 12 reactors including the rest of the eight PHWRs of 700 MWe each, three or four fast breeder reactors and one 300 MWe advanced heavy water reactor in 2009. NPCIL said that "India is now focusing on capacity addition through indigenisation" with progressively higher local content for imported designs, up to 80%. Looking further ahead its augmentation plan included construction of 25-30 light water reactors of at least 1000 MWe by 2030.

Power reactors planned or firmly proposed

Reactor	State	Type	MWe net, each	Project control	Start construct	Start operation
Kakrapar 3 & 4	Gujarat	PHWR	640	NPCIL	2009?	2012
Rawatbhata 7 & 8	Rajasthan	PHWR	640	NPCIL	2009?	2012
Kudankulam 3 & 4	Tamil Nadu	PWR - VVER	1200	NPCIL	2010?	
Jaitapur 1 & 2	Maharashtra	PWR - EPR	1600	NPCIL	by 2012	2017-18
Kaiga 5 & 6	Karnataka	PWR	1000/1500	NPCIL	by 2012	
Kudankulam 5 & 6	Tamil Nadu	PWR - VVER	1200	NPCIL	2012?	
?		PWR x 2	1000	NTPC	by 2012	2014
Jaitapur 3 & 4	Maharashtra	PWR - EPR	1600	NPCIL	by 2012	
?		PHWR x 4	640	NPCIL	by 2012	
?		FBR x 2	470	Bhavini		2020
?		AHWR	300	NPCIL	by 2012	2020
subtotal		23 units	21,500 MWe			
Jaitapur 5 & 6	Maharashtra	PWR - EPR	1600	NPCIL		
Pati Sonapur	Orissa	PWR 6000 MWe				
Kumaharia	Haryana	PWR 2800 MWe				
Saurashtra	Gujarat	PWR				
Pulivendula	Andhre Pradesh	PWR?	2000	NPCIL 51%, AP Genco 49%		
Kovvada	Andhra Pradesh	PWR				
Haripur	West Bengal	PWR				

For WNA reactor table: first 23 units 'planned', next (estimated) 15 'proposed'.

Longer term, the AEC envisages its fast reactor program being 30 to 40 times bigger than the PHWR program, and initially at least, largely in the military sphere until its "synchronised working" with the reprocessing plant is proven on an 18-24 month cycle. This will be linked with up to 40,000 MWe of light water reactor capacity, the used fuel feeding ten times that fast breeder capacity, thus "deriving much larger benefit out of the external acquisition in terms of light water reactors and their associated fuel". This 40 GWe of imported LWR multiplied to 400 GWe via FBR would complement 200-250 GWe based on the indigenous program of PHWR-FBR-AHWR. Thus AEC is "talking about 500 to 600 GWe nuclear over the next 50 years or so" in India, plus export opportunities.

The AEC also said that India now has "a significant technological capability in PWRs and NPCIL has worked out an Indian PWR design" which will be unveiled soon - perhaps 2009.

In line with past practice such as at Rawatbhata in Rajasthan, NPCIL intends to set up further "Nuclear Parks", each with a capacity for up to eight new-generation reactors of 1,000 MWe, six reactors of 1600 MWe or simply 10,000 MWe at a single location. Preliminary work at Jaitapur in Maharashtra is likely soon with six of Areva's EPR reactors in view, as is further development at Kudankulam in Tamil Nadu for two more pairs of Russian VVER units. The other coastal sites for imported light water reactors are expected to be Saurashtra in Gujarat, and also Kovvada in Andhra Pradesh and Haripur in West Bengal. DAE has also been examining these.

NPCIL is evaluating a site for up to 6000 MWe of PWR nuclear capacity at Pati Sonapur in Orissa state. Major industrial developments are planned in that area and Orissa was the first Indian state to privatise electricity generation and transmission. State demand is expected to reach 20 billion kWh/yr by 2010.

NPCIL is also reported to be planning construction of a 1600 MWe plant in the northern state of Haryana, one of the country's most industrialized, by 2012. The state has a demand of 8900 MWe, but currently generates less than 2000 MWe and imports 4000 MWe. The $2.5 billion plant would be sited at the village of Kumaharia, in Fatehabad district and paid for by the state government or the Haryana Power Generation Corp. In December 2008 Haryana's chief minister said that the AEC had already approved the state's proposal to build a 2800 MWe nuclear power plant at Kumaharia, using imported technology.

India's largest power company, National Thermal Power Corporation (NTPC) in 2007 proposed building a 2000 MWe nuclear power plant to be in operation by 2017. It would be the utility's first nuclear plant and also the first conventional nuclear plant not built by the government-owned NPCIL. This proposal has now become a joint venture with NPCIL holding 51%, and possibly extending to multiple projects utilising imported technology. NTPC says it aims by 2014 to have demonstrated progress in "setting up nuclear power generation capacity", and that the initial "planned nuclear portfolio of 2000 MWe by 2017" may be greater. NTPC, now 89.5% government-owned, is planning to increase its total installed capacity from 30 to 50 GWe by 2012 (72% of it coal) and 75 GWe by 2017. It is also forming joint ventures in heavy engineering.

In February 2009 Areva signed a memorandum of understanding with NPCIL to build two, and later four more, EPR units at Jaitapur. This followed the government signing a nuclear cooperation agreement with France in September 2008. In July 2009 Areva submitted a bid to NPCIL to build the first two EPR units, with a view to commissioning in 2017 and 2018.

In March 2009 GE Hitachi Nuclear Energy signed agreements with NPCIL and Bharat Heavy Electricals (BHEL) to begin planning to build a multi-unit power plant using 1350 MWe Advanced Boiling Water Reactors (ABWR), with discussion continuing regarding the site. In May 2009 L&T was brought into the picture.

In May 2009 Westinghouse signed a memorandum of understanding with NPCIL regarding deployment of its AP1000 reactors, using local components (probably from L&T).

In June 2009 NPCIL said that a further four Russian VVER reactors are planned at another site, after the six at Kudankulam.

After a break of three decades, Atomic Energy of Canada Ltd (AECL) is keen to resume technical cooperation, especially in relation to servicing India's PHWRs. There have been preliminary discussions regarding the sale of an ACR-1000, but this will depend on ratification of a bilateral nuclear cooperation agreement.

In August 2009 NPCIL signed agreements with Korea Electric Power Co (KEPCO) to study the prospects for building Korean APR-1400 reactors in India. This also will depend on establishing a bilateral nuclear cooperation agreement.

The government has announced that it intends to amend the law to allow private companies to be involved in nuclear power generation and possibly other aspects of the fuel cycle, but without direct foreign investment. In anticipation of this, Reliance Power Ltd, GVK Power & Infrastructure Ltd and GMR Energy Ltd are reported to be in discussion with overseas nuclear vendors including Areva, GE-Hitachi, Westinghouse and Atomstroyexport.

NTPC is reported to be establishing a joint venture with NPCIL and BHEL to sell India's largely indigenous 220 MWe heavy water power reactor units abroad, possibly in contra deals involving uranium supply from countries such as Namibia and Mongolia.

In September 2009 the AEC announced a version of its planned Advanced Heavy Water Reactor (AHWR) designed for export.

In August and September 2009 the AEC reaffirmed its commitment to the thorium fuel cycle, particularly thorium-based FBRs, to make the country a technological leader.

Heavy engineering & India's L&T

India's largest engineering group, Larsen & Toubro (L&T) announced in July 2008 that it was preparing to venture into international markets for supply of heavy engineering components for nuclear reactors. It plans to form a 20 billion rupee (US$ 463 million) venture with NPCIL for domestic and export nuclear forgings. In the context of India's trade isolation over three decades L&T has produced heavy components for 17 of India's pressurized heavy water reactors (PHWRs) and has also secured contracts for 80% of the components for the fast breeder reactor at Kalpakkam. It is qualified by the American Society of Mechanical Engineers to fabricate nuclear-grade pressure vessels and core support structures, achieving this internationally recognised quality standard in 2007. It is one of about ten major nuclear-qualified heavy engineering enterprises worldwide.

Early in 2009, L&T signed four agreements with foreign nuclear power reactor vendors. The first, with Westinghouse, sets up L&T to produce component modules for Westinghouse's AP1000 reactor. The second agreement was with Atomic Energy of Canada Ltd (AECL) "to develop a competitive cost/scope model for the ACR-1000." In April it signed an agreement with Atomstroyexport primarily focused on components for the next four VVER reactors at Kudankulam, but extending beyond that to other Russian VVER plants in India and internationally. Then in May it signed an agreement with GE Hitachi to produce major components for ABWRs - the two companies hope to utilize indigenous Indian capabilities for the complete construction of nuclear power plants including the supply of reactor equipment and systems, valves, electrical and instrumentation products for ABWR plants to be built in India. L&T "will collaborate with GEH to engineer, manufacture, construct and provide certain construction management services" for the ABWR project.

Following the 2008 removal of trade restrictions, Indian companies led by Reliance Power (RPower), NPCIL, and BHEL said that they plan to invest over US$ 50 billion in the next five years to expand their manufacturing base in the nuclear energy sector. BHEL plans to spend $7.5 billion in two years building plants to supply components for reactors of 1,600 MWe. It also plans to set up a 50-50 venture with NPCIL that will supply turbines for nuclear plants of 700 MWe, 1,000 MWe and 1,600 MWe and will seek overseas partners to provide technology for these enterprises. In July it announced that it was close to finalising a European partner to take 30-35% of this joint venture. Another joint venture is with NPCIL and a foreign partner to make steam generators for 1000 - 1600 MWe plants.

Areva signed an agreement with Bharat Forge in January 2009 to set up a joint venture in casting and forging nuclear components for both export and the domestic market, by 2012. BHEL expects to join this, and the UK's Sheffield Forgemasters will be a technical partner. The partners have short-listed Dahej in Gujarat, and Krishnapatnam and Visakhapatnam in Andhra Pradesh as possible sites.

Uranium resources

India's uranium resources are modest, with 54,000 tonnes U as reasonably assured resources and 23,500 tonnes as estimated additional resources in situ. Accordingly, from 2009 India is expecting to import an increasing proportion of its uranium fuel needs.

Mining and processing of uranium is carried out by Uranium Corporation of India Ltd, a subsidiary of the Department of Atomic Energy (DAE), at Jaduguda and Bhatin (since 1967), Narwapahar (since 1995) and Turamdih (since 2002) - all in Jharkhand near Calcutta. All are underground, the last two being modern. A common mill is located near Jaduguda, and processes 2090 tonnes per day of ore.

In 2005 and 2006 plans were announced to invest almost US$ 700 million to open further mines in Jharkand at Banduhurang, Bagjata and Mohuldih; in Meghalaya at Domiasiat-Mawthabah (with a mill) and in Andhra Pradesh at Lambapur-Peddagattu (with mill 50km away at Seripally), both in Nalgonda district.

In Jharkand, Banduhurang is India's first open cut mine and was commissioned in 2007. Bagjata is underground and was opened in December 2008, though there had been earlier small operations 1986-91. The Mohuldih underground mine is expected to operate from 2010. A new mill at Turamdih in Jharkhand, with 3000 t/day capacity, was commissioned in 2008.

In Andhra Pradesh the Lambapur-Peddagattu project in Nalgonda district has environmental clearance for one open cut and three small underground mines but faces local opposition. In August 2007 the government approved a new US$ 270 million underground mine and mill at Tummalapalle near Pulivendula in Kadapa (Cuddapa) district, for commissioning in 2010.

In Meghalaya, close to the Bangladesh border, the Domiasiat-Mawthabah mine project (also called Nongbah-Jynrin) is in a high rainfall area and also faces longstanding local opposition. UCIL does not yet have approval from the state government for the open cut mine at Kylleng-Pyndeng-Shahiong, though pre-project development has been authorised. However, federal environmental approval in December 2007 for a proposed uranium mine and processing plant at Kylleng-Pyndeng-Shahiong in the West Khasi Hills of Meghalaya and the Nongstin mine has been reported, along with opposition to other development in the West Khasi Hills, including at Domiasiat and Wakhyn, which have estimated resources of 9500 tU and 4000 tU respectively. The status and geography of all these is not known.

India's uranium mines and mills - existing and announced

State, district	Mine	Mill	Operating from	tU per year
Jharkhand	Jaduguda	Jaduguda	1967 (mine) 1968 (mill)	175 tota from mill
	Bhatin	Jaduguda	1967	
	Narwapahar	Jaduguda	1995	
	Bagjata	Jaduguda	2008	
	Turamdih	Turamdih	2003 (mine) 2008 (mill)	190 total from mill
	Banduhurang	Turamdih	2007	
	Mohuldih	Turamdih	2011	
Meghalaya	Kylleng-Pyndengsohiong (Domiasiat), Wakhyn, Mawthabah	Mawthabah	2012	340
Andhra Pradesh, Nalgonda	Lambapur-Peddagattu	Seripally	2012	130
Andhra Pradesh, Kadapa	Tummalapalle	Tummalapalle	2010	220

However, India has reserves of 290,000 tonnes of thorium - about one quarter of the world total, and these are intended to fuel its nuclear power program longer-term (see below).

By December 2008, Russia's Rosatom and Areva from France had contracted to supply uranium for power generation, while Kazakhstan, Brazil and South Africa were preparing to do so. The Russian agreement was to provide fuel for PHWRs as well as the two small Tarapur reactors, the Areva agreement was to supply 300 tU. In February 2009 the actual Russian contract was signed with TVEL to supply 2000 tonnes of natural uranium fuel pellets for PHWRs over ten years, costing $780 million, and 60 tonnes of low-enriched fuel pellets for the Tarapur reactors. The Areva shipment arrived in June 2009. RAPS-2 became the first PHWR to be fuelled with imported uranium.

In January 2009 NPCIL signed a memorandum of understanding with Kazatomprom for supply of uranium to India and a feasibility study on building Indian PHWR reactors in Kazakhstan. NPCIL said that it represented "a mutual commitment to begin thorough discussions on long-term strategic relationship."

In September 2009 India signed uranium supply and nuclear cooperation agreements with Namibia and Mongolia.

Uranium fuel cycle

DAE's Nuclear Fuel Complex at Hyderabad undertakes refining and conversion of uranium, which is received as magnesium diuranate (yellowcake) and refined. The main 400 t/yr plant fabricates PHWR fuel (which is unenriched). A small (25 t/yr) fabrication plant makes fuel for the Tarapur BWRs from imported enriched (2.66% U-235) uranium. Depleted uranium oxide fuel pellets (from reprocessed uranium) and thorium oxide pellets are also made for PHWR fuel bundles. Mixed carbide fuel for FBTR was first fabricated by Bhabha Atomic Research Centre (BARC) in 1979.

Heavy water is supplied by DAE's Heavy Water Board, and the seven plants are working at capacity due to the current building program.

A very small enrichment plant - insufficient even for the Tarapur reactors - is operated by DAE's Rare Materials Plant at Ratnahalli near Mysore. Some centrifuge R&D is undertaken by BARC.

Reprocessing: Used fuel from the civil PHWRs is reprocessed by Bhabha Atomic Research Centre (BARC) at Trombay, Tarapur and Kalpakkam to extract reactor-grade plutonium for use in the fast breeder reactors. Small plants at each site were supplemented by a new Kalpakkam plant of some 100 t/yr commissioned in 1998, and this is being extended to reprocess FBTR carbide fuel. Apart from this all reprocessing uses the Purex process. Further capacity is being built at Tarapur and Kalpakkam, to come on line by about 2010.

In 2003 a facility was commissioned at Kalpakkam to reprocess mixed carbide fuel using an advanced Purex process. Future FBRs will also have these facilities co-located.

The PFBR and the next four FBRs to be commissioned by 2020 will use oxide fuel. After that it is expected that metal fuel with higher breeding capability will be introduced and burn-up is intended to increase from 100 to 200 GWd/t.

To close the FBR fuel cycle a fast reactor fuel cycle facility is planned, with construction to begin in 2008 and operation to coincide with the need to reprocess the first PFBR fuel.

Under plans for the India-specific safeguards to be administered by the IAEA in relation to the civil-military separation plan several fuel fabrication facilities will come under safeguards.

Thorium fuel cycle development

The long-term goal of India's nuclear program has been to develop an advanced heavy-water thorium cycle. The first stage of this employs the PHWRs fuelled by natural uranium, and light water reactors, to produce plutonium.

Stage 2 uses fast neutron reactors burning the plutonium to breed U-233 from thorium. The blanket around the core will have uranium as well as thorium, so that further plutonium (ideally high-fissile Pu) is produced as well as the U-233.

Then in stage 3, Advanced Heavy Water Reactors (AHWRs) burn the U-233 from stage 2 and this plutonium with thorium, getting about two thirds of their power from the thorium.

In 2002 the regulatory authority issued approval to start construction of a 500 MWe prototype fast breeder reactor at Kalpakkam and this is now under construction by BHAVINI. The unit is expected to be operating in 2011, fuelled with uranium-plutonium oxide (the reactor-grade Pu being from its existing PHWRs). It will have a blanket with thorium and uranium to breed fissile U-233 and plutonium respectively. This will take India's ambitious thorium program to stage 2, and set the scene for eventual full utilisation of the country's abundant thorium to fuel reactors. Four more such fast reactors have been announced for construction by 2020.

Initial FBRs will be have mixed oxide fuel but these will be followed by metallic-fuelled ones to enable shorter doubling time.

So far about one tonne of thorium oxide fuel has been irradiated experimentally in PHWR reactors and has reprocessed and some of this has been reprocessed, according to BARC. A reprocessing centre for thorium fuels is being set up at Kalpakkam.

Design is largely complete for the first 300 MWe AHWR, intended to be built in the 11th plan period to 2012, though no site has yet been announced. It will have vertical pressure tubes in which the light water coolant under high pressure will boil, circulation being by convection. A large heat sink - "Gravity-driven water pool" - with 7000 cubic metres of water is near the top of the reactor building. In April 2008 an AHWR critical facility was commissioned at BARC "to conduct a wide range of experiments, to help validate the reactor physics of the AHWR through computer codes and in generating nuclear data about materials, such as thorium-uranium 233 based fuel, which have not been extensively used in the past." It has all the components of the AHWR's core including fuel and moderator, and can be operated in different modes with various kinds of fuel in different configurations.

In 2009 the AEC announced some features of the 300 MWe AHWR: It is mainly a thorium-fuelled reactor with several advanced passive safety features to enable meeting next generation safety requirements such as three days grace period for operator response, elimination of the need for exclusion zone beyond the plant boundary, 100-year design life, and high level of fault tolerance. The advanced safety characteristics have been verified in a series of experiments carried out in full-scale test facilities. Also, per unit of energy produced, the amount of long-lived minor actinides generated is nearly half of that produced in current generation Light Water Reactors. Importantly, a high level of radioactivity in the fissile and fertile materials recovered from the used fuel of AHWR, and their isotopic composition, preclude the use of these materials for nuclear weapons.

At the same time the AEC announced an LEU version of the AHWR. This will use low-enriched uranium plus thorium as a fuel, dispensing with the plutonium input. About 39% of the power will come from thorium (via in situ conversion to U-233, cf two thirds in AHWR), and burn-up will be 64 GWd/t. Uranium enrichment level will be 19.75%, giving 4.21% average fissile content of the U-Th fuel. While designed for closed fuel cycle, this is not required. Plutonium production will be less than in light water reactors, and the fissile proportion will be less and the Pu-238 portion three times as high, giving inherent proliferation resistance. The design is intended for overseas sales, and the AEC says that "the reactor is manageable with modest industrial infrastructure within the reach of developing countries".

Radioactive Waste Management

Radioactive wastes from the nuclear reactors and reprocessing plants are treated and stored at each site. Waste immobilisation plants are in operation at Tarapur and Trombay and another is being constructed at Kalpakkam. Research on final disposal of high-level and long-lived wastes in a geological repository is in progress at BARC.

Regulation and safety

The Atomic Energy Commission (AEC) was established in 1948 under the Atomic Energy Act as a policy body. Then in 1954 the Department of Atomic Energy (DAE) was set up to encompass research, technology development and commercial reactor operation. The current Atomic Energy Act is 1962, and it permits only government-owned enterprises to be involved in nuclear power.

The DAE includes NPCIL, Uranium Corporation of India (mining and processing), Electronics Corporation of India Ltd (reactor control and instrumentation) and BHAVIN* (for setting up fast reactors). The government also controls the Heavy Water Board for production of heavy water and the Nuclear Fuel Complex for fuel and component manufacture.

* Bhartiya Nabhikiya Vidyut Nigam Ltd

The Atomic Energy Regulatory Board (AERB) was formed in 1983 and comes under the AEC but is independent of DAE. It is responsible for the regulation and licensing of all nuclear facilities, and their safety and carries authority conferred by the Atomic Energy Act for radiation safety and by the Factories Act for industrial safety in nuclear plants.

NPCIL is an active participant in the programmes of the World Association of Nuclear Operators (WANO).

Research & Development

An early AEC decision was to set up the Bhabha Atomic Research Centre (BARC) at Trombay near Mumbai. A series of 'research' reactors and critical facilities was built here: APSARA (1 MW, operating from 1956) was the first research reactor in Asia, Cirus (40 MW, 1960) and Dhruva (100 MW, 1985) followed it along with fuel cycle facilities. The Cirus and Dhruva units are assumed to be for military purposes, as is the plutonium plant

commissioned in 1965.

BARC is also responsible for the transition to thorium-based systems and in particular is developing the 300 MWe AHWR as a technology demonstration project. This will be a vertical pressure tube design with heavy water moderator, boiling light water cooling with passive safety design and thorium-plutonium based fuel. A large critical facility to validate the reactor physics of the AHWR core has been commissioned at BARC.

A series of three Purnima research reactors have explored the thorium cycle, the first (1971) running on plutonium fuel fabricated at BARC, the second and third (1984 & 1990) on U-233 fuel made from thorium - U-233 having been first separated in 1970.

In 1998 a 500 keV accelerator was commissioned at BARC for research on accelerator-driven subcritical systems as an option for stage three of the thorium cycle.

There are plans for a new 30 MWt multi-purpose research reactor for radioisotope production, testing nuclear fuel and reactor materials, and basic research. It is to be capable of conversion to an accelerator-driven system later.

Two civil research reactors at the Indira Gandhi Centre for Atomic Research at Kalpakkam are preparing for stage two of the thorium cycle. The 40 MWt fast breeder test reactor (FBTR) has been operating since 1985, and has achieved 165 GWday/tonne burnup with its carbide fuel (70% PuC + 30% UC) without any fuel failure. In 2005 the FBTR fuel cycle was closed, with the reprocessing of 100 GWd/t fuel - claimed as a world first. This has been made into new mixed carbide fuel for FBTR. Prototype FBR fuel which is under irradiation testing in FBTR has reached a burnup of 90 GWd/tonne. FBTR is based on the French Rapsodie FBR design. Also the tiny Kamini (Kalpakkam mini) reactor is exploring the use of thorium as nuclear fuel, by breeding fissile U-233. BHAVINI is located here and draws upon the centre's expertise and that of NPCIL in establishing the fast reactor program.

As part of developing higher-burnup fuel for PHWRs mixed oxide (MOX) fuel is being used experimentally in FBTR, which is now operating with a hybrid core of mixed carbide and mixed oxide fuel (the high-Pu MOX forming 20% of the core).

A Compact High-Temperature Reactor (CHTR) is being designed to have long (15 year) core life and employ liquid metal (Pb-Bi) coolant. There are also designs for HTRs up to 600 MWt for hydrogen production and a 5 MWt multi-purpose nuclear power pack.

The Board of Radiation & Isotope Technology was separated from BARC in 1989 and is responsible for radioisotope production. The research reactors APSARA, CIRUS and Dhruva are used, along with RAPS for cobalt-60.

BARC has used nuclear techniques to develop 37 genetically-modified crop varieties for commercial cultivation. A total of 15 sterilising facilities, particularly for preserving food, are now operational with more under construction. Radiation technology has also helped India increase its exports of food items, including to the most developed markets in the world.

India's hybrid Nuclear Desalination Demonstration Plant (NDDP) at Kalpakkam, comprising of Reverse Osmosis (RO) based unit of 1.8 million litres per day commissioned in 2002 and a Multi Stage Flash (MSF) desalination plant of 4.5 million litres per day, as well as a barge-mounted RO desalination unit commissioned recently, help address the shortage of water in water-stressed coastal areas.

Non-proliferation, US-India Agreement & NSG

India's nuclear industry has been largely without IAEA safeguards, though four nuclear power plants (see above) have been under facility-specific arrangements related to India's INFCIRC/66 safeguards agreement with IAEA.

India's situation as a nuclear-armed country excluded it from the Nuclear Non-Proliferation Treaty (NPT)* so this and the related lack of full-scope IAEA safeguards meant that India was isolated from world trade by the Nuclear Suppliers' Group. A clean waiver to the trade embargo was agreed in September 2008 in recognition of the country's impeccable non-proliferation credentials. India has always been scrupulous in ensuring that its weapons material and technology are guarded against commercial or illicit export to other countries.

NPT - A Political Issue

India could only join the NPT if it disarmed and joined as a Non Nuclear Weapons State, which is politically impossible.

Following the 2005 agreement between US and Indian heads of state on nuclear energy cooperation, the UK indicated its strong support for greater cooperation and France then Canada then moved in the same direction. The US Department of Commerce, the UK and Canada relaxed controls on export of technology to India, though staying within the Nuclear Suppliers Group guidelines. The French government said it would seek a nuclear cooperation agreement, and Canada agreed to "pursue further opportunities for the development of the peaceful uses of atomic energy" with India.

In December 2006 the US Congress passed legislation to enable nuclear trade with India. Then in July 2007 a nuclear cooperation agreement with India was finalized, opening the way for India's participation in international commerce in nuclear fuel and equipment and requiring India to put most of the country's nuclear power reactors under IAEA safeguards and close down the Cirus research reactor by 2010. It would allow India to reprocess US-origin and other foreign-sourced nuclear fuel at a new national plant under IAEA safeguards. This would be used for fuel arising from those 14 reactors designated as unambiguously civilian and under full IAEA safeguards.

The IAEA greeted the deal as being "a creative break with the past" - where India was excluded from the NPT. After much delay in India's parliament, it then set up a new and comprehensive safeguards agreement with the IAEA, plus an Additional Protocol. The IAEA board approved this in July 2008, after the agreement had threatened to bring down the Indian government. The agreement is similar to those between IAEA and non nuclear weapons states, notably Infcirc-66, the IAEA's information circular that lays out procedures for applying facility-specific safeguards, hence much more restrictive than many in India's parliament wanted.

The next step in bringing India into the fold was the consensus resolution of the 45-member Nuclear Suppliers Group (NSG) in September 2008 to exempt India from its rule of prohibiting trade with non members of the NPT. A bilateral trade agreement then went to US Congress for final approval. Similar agreements will apply with Russia and France. The ultimate objective is to put India on the same footing as China in respect to responsibilities and trade opportunities, though it has had to accept much tighter international controls than other nuclear-armed countries.

The introduction to India's safeguards agreement says that India's access to assured supplies of fresh fuel is an "essential basis" for New Delhi's acceptance of IAEA safeguards on some of its reactors and that India has a right to take "corrective measures to ensure uninterrupted operation of its civilian nuclear reactors in the event of disruption of foreign fuel supplies." But the introduction also says that India will "provide assurance against withdrawal of safeguarded nuclear material from civilian use at any time." In the course of NSG deliberations India also gave assurances regarding weapons testing.

In October 2008 US Congress passed the bill allowing civil nuclear trade with India, and a nuclear trade agreement was signed with France. The 2008 agreements ended 34 years of trade isolation on nuclear materials and technology.

India's safeguards agreement was signed early in 2009, though the time frame for bringing the eight extra reactors (beyond Tarapur, Rawatbhata and Kudankulam) under safeguards still has to be finalised. The Additional Protocol to the safeguards agreement was agreed by the IAEA Board in March 2009, but needs to be ratified by India. ■

(Source: World Nuclear Association)

SCHOTT's Symposium on Safety Tech for Future Indian N-Reactors

Leading companies and experts involved in India's ambitious nuclear power development programme and German International Technology Group SCHOTT, a key player in the worldwide nuclear industry got together at a symposium recently in Mumbai to discuss about 'Safety Technologies for Future Reactors' and various other aspects of India's nuclear energy development programme.

The objective of the symposium, organized by SCHOTT, a leading provider of secure and reliable electrical penetrations for safety-critical applications in nuclear power plants worldwide, was to discuss about current and future technologies for the safe operation of nuclear power plants across the globe, including India. Leading scientists and technologists from top organizations, including Nuclear Power Corporation of India Ltd (NPCIL), Bhabha Atomic Research Centre (BARC), Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI) and Larsen & Toubro, were present at the symposium which also dwelt on expectations from the industry about future partners to India's civilian nuclear programme.

"This symposium aims to bring together authoritative figures in the Indian nuclear industry to discuss vital developments and build greater understanding of the availability of international technology driven products for the Indian nuclear industry. The symposium will also provide an opportunity to review the cutting-edge technology developed for the continued safe operation of nuclear power plants", said SCHOTT Electronics Chief Executive Officer GmbH Hermann Ditz.

SCHOTT is a key player in the worldwide nuclear industry, having supplied more than 5,000 Electrical Penetration Assemblies (EPAs) for more than 50 nuclear power plants in the last 40 years.

Chairman & Managing Director of the Nuclear Power Corporation of India Limited (NPCIL) S.K. Jain said the country's economy is growing at a rate of more than 7.0 percent per annum. "In order to meet the country's rising energy requirements, all energy sources have to be developed and deployed to support the sustainability of long-term economic growth", he said.

Executive Director (Engineering & Procurement) NPCIL, K.B. Dixit said that India had over the past 35 years demonstrated full capability in all facets of building a commercial nuclear power plant.

Sharing his views on the theme, the 'Future of the Indian Nuclear Industry', Dixit said India is well versed in all areas of reactor building, such as siting, designing, manufacturing, construction, operation and maintenance, renovation and modernization, waste management and decommissioning.

He said India has planned an ambitious nuclear program to add 20,000 MW or more by 2020. This large scale deployment scenario in a densely populated country like India lends utmost importance to safety features.

Dixit said, "The sustainability of our long-term economic growth is critically dependent on our ability to meet our energy requirements of the future. When our country grows at a rate of above 7.0 percent per annum, energy becomes a critical issue. All energy sources have to be developed to meet the energy requirements of the country since we do not have the choice. The energy that we generate has to be cost effective and affordable, not only in terms of its first cost, but also in terms of the cost to our environment. Nuclear power is recognized as an important and environmentally benign constituent of the overall energy mix. The future of the Indian nuclear industry is therefore a bright and glowing one. It would be a realistic estimate that India could add more than 20,000 MW of power by 2020."

"India is committed to the three-stage nuclear power development program involving the use of pressurized heavy water reactors, the fast breeder reactors and the thorium reactors. The country is also focused on capacity addition through imported designs, with indigenous content progressively increasing up to 80 percent," he added.

Dixit further said, "With a large thorium reserve and accumulated technological and operational expertise over the last 35 years, India is well poised to become a world leader in the nuclear industry. Nonetheless, to support the growth of this industry, there are some challenges that the nation must overcome. These include developing skilled manpower, nurturing a culture of safety and security, coming up with ways to optimize new builds and achieving cost-competitive supply of power to the grid."

L&T Deputy General Manager Hari Ravindran said, "Collaborative efforts and consolidation of the Indian industry based on domain expertise will help leverage the Indian industry's strength to meet the scale and speed required by India's Nuclear Power Programme. This approach will help realize the country's potential to be a global hub for equipment and services in the ensuing nuclear renaissance." His speech touched on the opportunities and challenges for the Indian nuclear power sector supply chain. L&T is a major contributor to the success of the Indian nuclear power programme.

Dr. Oliver Fritz, a Technology Expert from SCHOTT Electronic Packaging in Germany talked about the latest technical developments regarding glass-to-metal sealed (GTMS) feedthroughs. "Glass-to-metal sealed penetrations provide pass-through for power, control and instrumentation cables to the thousands of instruments, control panels, electric motors and many other electric and electronic devices within a nuclear power plant", Dr. Fritz said. "They maintain the pressure boundary integrity of the containment structure for periods far above 60 years design lifetime and will enhance the safety levels of the new generation of reactor designs", he added.

Developing skills for the Advanced Reactor Program

As with all countries initiating nuclear programs, developing skilled manpower and nurturing a culture of safety and security is a big challenge. Another vital topic at the symposium was the development of ways to optimize new builds and overcome the absence of experience with new designs in order to achieve cost-competitive supply of power to the grid.

Dr. R. K. Sinha, Director (Reactor Design and Development Group) at BARC, dwelt on the current status and future plans of the Indian Advanced Reactor Programme.

Prabhat Kumar, Project Director at BHAVINI provided an insight into the expectations towards the industries involved in the construction of the first 500 MWe Fast Breeder Reactor (FBR) at Kalpakkam in Tamil Nadu.

He said, "India is committed to a three-stage nuclear power development program involving the use of pressurized heavy water reactors, the fast breeder reactors and the thorium reactors. The country is also focused on capacity addition through indigenization with progressively higher local content for imported designs, up to 80 percent. With a large thorium reserve and accumulated technological and operational expertise over the last 35 years, India is well-poised to become a world leader in the nuclear industry."

SCHOTT Glass India Private Ltd, is an international technology group headed by Mohan Joshi. It is a 100 percent subsidiary of SCHOTT with sales offices in Mumbai and Pune and 400 employees at the manufacturing unit for glass tubing in Vadodara. SCHOTT KAISHA Private Ltd., a 50:50 joint venture of SCHOTT AG and KAISHA Manufacturers Private Ltd., is the leading manufacturer of primary pharmaceutical packaging made of glass in India.

SCHOTT Glass India President Joshi talked about the company's operations in India. "SCHOTT set up its sales office in Mumbai in 1998. We enhanced our commitment to India with the acquisition of Bharat Glass Tube Ltd during the same year and a subsequent joint venture with KAISHA Manufacturers Private Ltd. in 2008", he said.

SCHOTT Glass India Private Limited sees its core purpose as the lasting improvement of living and working conditions of the people. The company has been developing special materials, components and systems for 125 years. The main areas of focus are the household appliances industry, pharmaceuticals, solar energy, electronics, optics and the automotive industry. The SCHOTT Group is present in close proximity to its customers with production and sales companies in all its major markets. The Group has approximately 17,300 employees. The company's technological and economic expertise is closely linked with its social and ecological responsibility. The SCHOTT AG is an affiliate of the Carl-Zeiss-Stiftung (Foundation). ■

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