Atomic energy in India – 50 years

Haridas Banerjee has recently reviewed a book[1] and in addition to the book under review, he has quoted from a few papers by Meghnad Saha and also added his own perception about the Atomic Energy Programme in India. In this connection, I would like to place certain facts before the readers to enable them to arrive at their own conclusions.

At present, India has ten nuclear power reactors in commercial operation. The designs of its new reactors have progressively evolved to incorporate advanced features to further improve safety, reliability and economics. It has successfully developed the technologies for in-service inspection, maintenance and refurbishment of the older plants. As India gains experience and masters various aspects of nuclear technology including repair technology, the performance of the Indian nuclear plants is improving. In spite of sanctions imposed by some countries following nuclear tests in May 1998 at Pokhran, the *average capacity factor of Indian plants in 1998–99 was 75%, an increase of 4% over the previous year. It has further improved to over 78% in the first nine months of the year 1999–2000. So far they have produced more than 140 billion units of electricity.*

On 24 September 1999, one PHWR at Kaiga in Karnataka attained first criticality and has been since connected to the grid. It will achieve commercial status in a few weeks. One reactor at Rawatbhata in Rajasthan attained first criticality on 24 December 1999 and will be connected to the grid in a few days. Two more PHWRs are nearing completion and will attain first criticality in the year 2000. Reactors under construction include the 500 MWe PHWRs, fully designed and developed in India. *The PHWR programme of the DAE is now in industrial domain and the rate of addition of the nuclear generation capacity will be determined only by the availability of capital.* At the same time, it is clear that we must use every possible means to augment the electricity generation in the country, as electrical energy is the vehicle for acceleration of the development process in the country. In particular, at locations away from coal mines, it is necessary to look for alternate fuel sources for the generation of electricity. The rail infrastructure is under severe pressure and is not in a position to meet the increasing demands of coal transportation[2]. Therefore, it is necessary to look at ways and means to augment electricity generation based on fuels other than coal and nuclear electricity is one viable option. There is also a need to set up a large enough nuclear electricity generation capacity to enable the Nuclear Power Corporation of India Ltd (NPCIL) to generate enough surplus funds to finance further expansion. In view of this, in parallel to the indigenous nuclear programme based on setting up of PHWRs in the first stage, it is contemplated to build a few light water reactor based plants with foreign collaboration. The deal with the Russian Federation to set up two 1000 MWe light water reactors at Kudankulam in Tamil Nadu is a part of this strategy. *The medium term objective is to achieve 20,000 MWe of nuclear generation capacity by the year 2020. This would include about 7000 MWe of capacity based on foreign technology.*

NPCIL has gained an operating experience of over 160 reactor-years with a good record of safety of the operating personnel, public and the environment. Safety measures in all its activities are in conformity with the norms stipulated by an independent regulatory body, the Atomic Energy Regulatory Board (AERB). These norms are also in line with the international standards. To give non-experts a realistic idea of the potential hazards of nuclear events, an international safety significance scale, the International Nuclear Event Scale (INES) was introduced a few years ago by the International Atomic Energy Agency[3]. In the INES, nuclear events are numbered according to safety significance of the event from 0 (no safety significance) to 7 (serious or major accident). The events having low severity (0 to 3) are termed incidents, while the events of higher severity (4 to 7) are termed accidents. The classification is done by the International Atomic Energy Agency based on a set of guidelines. *Till date, the nuclear facilities in India have not reported any event beyond the level 3.* NPCIL is a member of the World Association of Nuclear Operators (WANO) and the reactors at Kakrapar have already been subjected to a peer review by WANO and reactors at Narora are scheduled to be peer reviewed by WANO in January/February this year. The basic motive of this exercise is to ensure that all our plants operate safely and we learn from the operating experience of other countries.

The improvement in performance of nuclear plants is also reflected in the financial position of NPCIL. It is a profit-making public sector undertaking and has recently given a dividend of Rs 50.4 crores to the Government of India. Given these facts, should we call nuclear power programme as the Achilles heel of the DAE or lament about the capacity factors of our nuclear power plants or describe PHWRs as accident-prone?

The second stage of the three-stage programme involving setting up of Fast Breeder Reactors (FBR) programme is also underway. After the Fast Breeder Test Reactor (FBTR) attained criticality in October 1985, a lot of improvements have been carried out in the various systems for improving the plant performance. Many physics and engineering experiments have been conducted in the recent years and the results have compared well with the analytical predictions. In July 1997, the FBTR was synchronized to the grid. As a logical follow-up of the FBTR, it was decided to build a Prototype Fast Breeder Reactor (PFBR). The 500 MWe PFBR has been designed and technology development is in progress in cooperation with industry. Construction of PFBR is scheduled to start in the last year of the 9th Plan (2001–2002).

India is emerging as a leader in the deployment of technologies for thorium utilization. Research reactor KAMINI is presently the only reactor in the world operating with uranium-233 based

nuclear fuel. India is developing an Advanced Heavy Water Reactor (AHWR), which would employ thorium-based fuel. We expect to complete the detailed project report of the AHWR in the 9th Plan and would like to launch its construction thereafter. AHWR is a unique concept because of the use of thorium fuel and incorporation of passive safety features.

1. Sundaram, C. V., Krishnan, L. V. and Iyengar, T. S., *Curr. Sci.*, 1999, **77**.
2. *Fuel Map of India*, Central Electricity Authority, August 1998.
3. IAEA Publication, *Radiation, Health and Society*, November 1997.

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Academia–industry collaboration

The editorial on 'Conflicts of interest' (*Curr. Sci.*, 10 December 1999) typically reflects the cat on the wall position of scientists in India. Indian scientists are all happy publishing papers and collecting awards including for technology, while all the time criticizing every move to make science relevant. This is nothing but *hypocricy*. The world over, academic institutions are adapting to the demands of industry and it has only helped basic science. In fact many industries have better facilities to do basic research. There are many examples where scientists have admirably partitioned their time for consultancy and academic responsibility and often the two commitments have complemented each other. Industries setting up research laboratories on campuses is a welcome sign and I do not believe that MOUs can be one-sided favouring the industry. But, please remember that no MOU can be made public since these are privileged documents and one company does not want another to know the details. Academic institutions will lose credibility if they make MOUs with individual industries public. The editorial seems to find fault with every initiative taken by government to promote academia–industry collaboration and if it has been subverted to produce nothing, the responsibility lies squarely on the scientist and not on the establishment. It is not true that every aspect of industry research is shrouded in secrecy and many findings form part of publications with joint authorship. To make money is not a dirty word, so long as it is done by honest means and I do not believe that academics need to sacrifice their academic commitments to teach commercial courses. I understand that in India college teachers teach commercial courses to their own students and you cannot blame industry for this attitude! I wish the editor had thought more deeply before he wielded the pen.

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Researching a Ph D in USA

There has been a lot of discussion about the status and quality of Indian science in general in the recent issues of *Current Science*. I would like to share my experience of doing a Ph D in the US, to try and provide an inside view on teaching and research there, so that the readers may decide on the good and the evil in the American system and may find some useful ideas which may help towards improving the quality of teaching and researching science in India.

I started my Ph D after completing a Master's degree in Applied Geology from Indian School of Mines in 1990. One of the first conversations I had with my American advisor was about teaching a senior undergraduate class in two days and I remember being surprised at the level of responsibility that was given to me at the very outset. We also had a very general conversation on what was expected of me if I were to make it to the end of the programme and get my degree. First, my definition of a good student underwent an instant transformation. I was told that good grades in courses I would take would be assumed. Any grade below B would land me in trouble as far as my scholarship was concerned. More important for a good graduate (M S and Ph D) student was to do 'new stuff' with the knowledge gained during the courses. A natural caveat of this was that diversity of content in the courses taken would lead to different perspectives and view points on the subject and help in doing 'new stuff' and cutting-edge research. Given this, it also followed that I would not be expected to do my Ph D 'under' my advisor but 'with' him. This meant that he not only expected to teach me but also expected me to pick up things which he could learn from me; a real give-and-take relationship. He said that this was essential because otherwise he would only be creating clones of himself in his students and that would be bad for all concerned and science in general and cloning was best left to the biologists. He urged me to develop a niche for myself as a researcher on the long run and said that the Ph D would just be the first stepping stone in that process. In keeping with this, he urged