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## Our first virus structure

With the solving of the structure of *Sesbania* mosaic virus (see **page 655**), India has now joined the exclusive club of virus crystallography (which we are told consists of just 6 to 7 groups in the world). In 1981, just three years after S. C. Harrison and his team solved the structure of tomato bushy virus, one dreamt of establishing a virus group in India. Although many steps were taken, there have been long delays, ups and down. We hope young M. R. N. Murthy, when he is old and grey (and also edits a science journal), will tell us the complete history.

There was a time when we thought that the greatest impediment to virus crystallography in India was the lack of a supercomputer. In spite of the enormous help obtained and funds made available from the highest levels in India the computer did not come. This was due to the sudden drop in temperature that often occurs in the Indo-US relationship. When much later the supercomputer did come to India, Bangalore did not get it! This was a blessing in disguise; for during the intervening years, the philosophy of computation changed. Using their ingenuity, the enthusiastic virus crystallographers of Bangalore processed almost a hundred thousand individual reflections and obtained the 4.7 Å resolution structure of *Sesbania* mosaic virus using a local WIPRO computer! We are told the data up to 2.9 Å are almost ready. We congratulate M. R. N. Murthy, H. S. Subramanya and their team on their magnificent effort and wish them further success.

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## Fast breeder reactors — A background note

This month (December 1992) marks the 'golden jubilee' of the first experimental nuclear reactor that was commissioned by Enrico Fermi, in Chicago, USA during World War II. During the last fifty years, several types of nuclear reactors have been designed, built and operated, and these can be classified depending on their intended function (research, materials testing, power generation), the coolant used (gas, light water, heavy water, liquid metal), or the neutron energies in the reactor core (thermal, fast).

The majority of the reactors presently in operation use a moderator (like water or graphite) to slow down the neutrons to an energy level of about 0.025 eV, to increase the probability of fission of the uranium-235 nuclei in natural or slightly enriched uranium. The fast reactors do not use any moderator, the neutron energies are high in these reactors (> 10 keV), and correspondingly the fuel has to have a higher concentration of the fissionable isotope (20% to > 90% of plutonium-239 or uranium-235), depending on the size of the fast reactor.

From the earliest days, there has been interest in the development of the fast reactor, on account of its attractive characteristics. Plutonium, when it undergoes fast neutron fission, gives the best yield of neutrons — more than 2.5 neutrons (per neutron absorbed), one of which will be required to sustain the chain reaction, another to produce a fresh nucleus of plutonium (form U-238) to replace the one consumed, and the balance to produce surplus plutonium. This favourable balance in a fast reactor allows the possibility of progressively converting U-238 to fissionable plutonium-239, and there is a surplus yield of plutonium (more than what is required for the continuous operation of the same reactor). The process is called 'breeding'. A fast breeder reactor is a fast neutron reactor, using plutonium in adequate concentration in the fuel in admixture with uranium-238 in the core, and uranium-238 in the blanket zones, with the capability to produce more plutonium than it consumes, and this, of course, will be at the expense of uranium-238. As uranium-238 is much more plentifully available in nature than uranium-235, a 60-fold increase in the utilization of the total energy potential in uranium is in principle possible with the operation of fast reactors. At a later stage, the fast reactor can also be used for the conversion of thorium to fissionable U-233, and thorium resources are even more abundant than uranium resources. Enrico Fermi had once stated that the country which masters fast reactor technology would have solved its energy problems.

In the absence of a moderator, the fast reactor core is compact, and the power density in the core is much higher than in moderated reactors. For efficient cooling, liquid sodium has been adopted as the coolant. Sodium metal, which melts at 98°C and boils at a relatively high temperature of 880°C, permits reactor operation at an intermediate temperature of around 550°C without the need to pressurize the system. Radioactivity release and radiation exposure of operating personnel are considerably minimized on this account. The high coolant temperature (> 500°C compared to ~300°C in water-cooled reactors) enables generation of good quality steam, for high thermodynamic efficiency in power generation.

Fast reactors, that use concentrated plutonium as fuel and chemically reactive liquid sodium as coolant, require a high level of sophistication in design, construction and operation. Fast reactor programmes have been in progress mainly in the advanced countries like USA, the erstwhile USSR, France UK, Germany and Japan, over the past four decades. India is the first developing country to have a fast reactor programme.

The Fast Reactor Research Centre (of

the Department of Atomic Energy)—now called the Indira Gandhi Centre for Atomic Research—was set up at Kalpakkam, near Madras in 1971, and the Fast Breeder Test Reactor (FBTR) attained its first criticality in October 1985, using a unique 70% plutonium carbide-30% uranium carbide fuel developed at Trombay. While the design and the technology for building this reactor was obtained from CEA, France, the fabrication of the major reactor components and the assembly of the reactor has been achieved indigenously, and the fuel is totally indigenous. After its first criticality, the Kalpakkam reactor has been operated for short durations, up to a power level of 1 MW (heat) but there has been a delay in commissioning the sodium heated steam generators. The sodium circuits have been in continuous operation for the past eight years.

India has a definite stake in the development of fast reactor technology, in view of its limited uranium resources and abundant thorium resources.

The nuclear industry from its very inception has shown the greatest concern in regard to the safety in design and operation of nuclear reactors. Safety is provided in the inherent characteristics of the reactor, in the elaborate control systems for plant protection, and also the multiple containment philosophy whereby any dispersal of radioactivity is avoided in the unlikely event of an accident. This is even more true in the case of the fast reactors. However, there are a few aspects that have generated added concern to the lay mind, with respect to fast reactors. One relates to the concentrated nature of the plutonium fuel. The question has been raised whether, with loss of flow of coolant, the fuel can assume a more reactive configuration, leading to large energy release and dispersal of the toxic plutonium. The other relates to the chemical reactivity of the sodium. Liquid sodium, if it leaks, will burn freely in contact with air, and can react violently when it comes into contact with water (if there is a leak in the steam generator). These and other aspects have been systematically investigated, over the years, in several programmes, and today the industry has the confidence that large fast reactors can be designed with adequate inbuilt safety features, and operated reliably to deliver power. One of the best examples is the BN 600 (MWe) power reactor that has operated successfully in Russia, for over ten years, with a high capacity factor.

Interest in fast reactor development was at its keenest in the seventies, when the nuclear industry was flourishing and shortages in uranium supply were anticipated with growth in nuclear electricity generation. But with the slowing down of the programme in the eighties, the sense of urgency for fast reactor development appears to have receded in USA, Germany, UK. In 1983, as a result of change in government policy, the 300 MWe Clinch River Breeder reactor project in USA was abandoned, at an advanced stage of construction. In 1990, following the recommendation of a Parliament Committee, the UK government decided to stop funding the operation of the 250 MWe prototype fast reactor (PFR) beyond 1994. In March 1991, the German government decided to abandon the 300 MW(e) SNR 300 fast breeder power plant, after its construction was fully completed in 1985 and it had been waiting for clearance for the loading of the fuel.

After successful operation of the research reactor Rapsodie, and the 250 MWe prototype breeder reactor Phenix, France had gone ahead and built the 1200 MWe *Superphenix* which reached full power in December 1986. But in the subsequent operation of this reactor, there was a long interruption on account of a sodium leak in the fuel storage tank (outside the reactor); and again in June 1990, the reactor had to be shut down for major maintenance following contamination of the sodium circuit. After completion of the maintenance works, Electricite de France is still to obtain Government clearance for re-starting the reactor, as a fresh review of specific safety aspects was considered necessary.

Amidst these set-backs, Japan has been steadily pursuing its fast reactor programme, as (like France) it has seen in it a real potential to achieve energy self-sufficiency. The research reactor Joyo has had an excellent operating record at 100 Mw(t), and the 300 Mw(e) fast power reactor Monju is in advanced stage of completion.

To sum up, while the engineering community has clearly demonstrated the technological feasibility of the sodium-cooled fast breeder reactor and also outlined the strategy for its commercialization in Europe—in a multinational effort—the programme has received set-backs due to government uncertainty and some public opposition. While the eventual need for series construction of fast reactors has been recognized, the date by which commercialization will be realized in Japan, France or Russia is still uncertain.

In this context, the International Atomic Energy Agency (Vienna) has brought out a reasoned report emphasizing that the Fast Reactor Technology option should be adequately sustained during the interim time frame. This message is important for India. (See **page 657** for an article on Fast Breeder Reactor safety.)