The Phénix Reactor, France

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At 8.15 a.m. on 31 August, 1973, the Phénix fast reactor went critical for the first time. This event, which was hailed as a milestone in development of fast reactors, should be viewed within its historical context.

Preliminary plans were drawn up in 1966, the decision to go ahead with the construction of the power station was taken in 1968 and the work on the site began in 1969.

A reactor capacity of 250 MW(e) was chosen on the grounds that the power station would thereby be large enough to permit study of all the industrial problems associated with fast breeder power generation without excessively high investment; moreover, with this reactor capacity it would be possible to employ a conventional turboalternator of the type normally used at Electricité de France power stations, the characteristics of the steam generated by the reactor being very similar to those of the steam generated at these stations.

The main features of the Phénix reactor are:

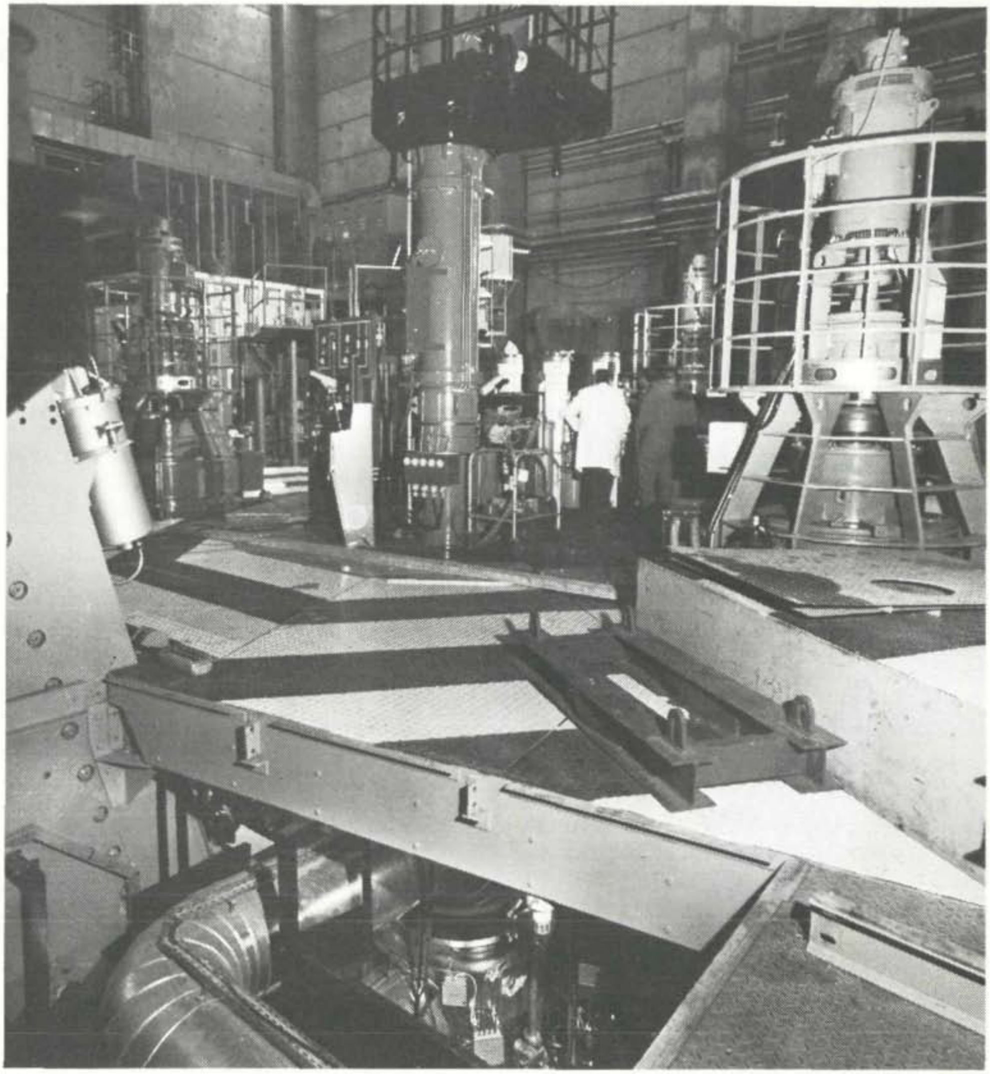
(i) A capacity of 250 MW(e) – 563 MW(th) – with a proven type of turboalternator;
(ii) Sodium coolant and mixed plutonium oxide-uranium oxide fuel with stainless steel cladding;
(iii) Integrated design – the main primary circuit, with its three pumps and six intermediate exchangers arranged around the core, is contained completely within a stainless steel vessel filled with 800 tons of sodium (this design was chosen principally for safety reasons);
(iv) Fuel handling only during reactor shutdowns (one campaign every two months);
(v) Supplier of base-load power to the grid.

Besides demonstrating power generation, the role of Phénix as an experimental plant will remain important for at least the first few years of operation.

When construction work got under way in 1968, it was envisaged that general trials would start in 1972 and that the reactor would begin supplying power to the grid in 1973. Despite certain delays, which are to be expected in the construction of such a prototype, this overall schedule was adhered to.

In order to minimize the risks inherent in a prototype while extracting the maximum of information, the trials were made as comprehensive and exhaustive as possible, all parts of the plant being tested systematically in four successive stages:

(i) Trials before exposure of the main circuits to sodium (completed in 1972);
(ii) Trials with sodium coolant before loading of the fuel, beginning with exposure of the reactor and the secondary circuits to the sodium (completed in January 1973) and continuing until the end of July. During this very important stage, all circuits were tested under conditions (flow rates and temperatures) as similar as possible to those of operation at rated power. At the same time, the turboalternator was tested in February 1973 with auxiliary steam;



Inside view of the Phenix reactor building at the 8.50 floor level. The picture shows the upper part of the revolving plug and the fuel handling arm drives. On the right is the pony and pump motor. Below the floor is seen the sodium secondary loop piping . . . . . P. Jahan

(iii) Fuel assembly loading starting on 3 August and criticality on 31 August;

(iv) Increase of the reaction rate until, if all goes well, full power is reached during the early months of 1974.

An initial assessment can already be made of what has been learned during the construction of Phénix and what may be expected from its operation:

(i) During the basic conception and design stage, it was possible to gauge and subsequently master the problems inherent in the integrated nature of the reactor block (hydraulic behaviour; distribution of thermal gradients and associated stresses) and in the operation of the station as a whole;

(ii) *During the construction stage proper, the inherent advantages of this reactor type were confirmed (no particular civil engineering difficulties; through the absence of high pressures in the circuits, the possibility of fabricating at the site components — such as the reactor vessel — which are thin but otherwise have large dimensions);*

(iii) *The trials with sodium have demonstrated how one can best reach components for maintenance and repair purposes, and the operating teams are capable of overcoming the special problems associated with active sodium.*

The question of fuel is a particularly interesting one.

During fabrication of the fuel for the initial core of Phénix, irradiation was carried out frequently in the Rapsodie reactor, yielding very valuable information about the behaviour of the fuel pins at high fluxes — especially as regards deformation through radiation-induced swelling of the mixed plutonium oxide-uranium oxide fuel and of the steel cladding.

It is clear, however, that only a study of the general behaviour of the first Phénix core will provide the comprehensive statistical information necessary for determining what mean flux level can be achieved and indicate what changes will have to be made in the fuel of subsequent cores.

Phénix thus has two roles: that of a demonstration plant and that of a large experimental reactor in which irradiation operations contribute significantly to the development of breeder fuels.

As far as the nuclear industry is concerned, the component manufacturers have learned to deal with the problems inherent in fast breeders and now know what construction methods to use and what kinds of manpower and equipment are needed.

In this connection it should be emphasized that, from the very outset, the Commissariat à l'énergie atomique and Electricité de France have worked in close association with the nuclear industry, so as to promote the creation of the infrastructure necessary for fast breeder development. This has been particularly so with regard to project studies for the power station, the construction and start-up of Phénix having been followed through under the overall direction of the Commissariat à l'énergie atomique by an "integrated" team comprising representatives of the Commissariat à l'énergie atomique and Electricité de France and staff of the Groupement Atomique Alsacienne Atlantique, a private company which has for a long time been associated with the work being done by the Commissariat à l'énergie atomique in the field of fast breeders.

One cannot stress too much the importance of having teams capable of pooling their efforts and their experience in order to overcome the special problems presented by a new product.

Thus, the increase of the reaction rate in the coming weeks and the linking of Phénix to the grid will mark the beginning of a further important stage. It should be possible to make immediate use of the experience gained during construction and the first year of operation in the further development of fast breeders in France — in the first place in designing and building the 1200 MW(e) Super-Phénix. The Commissariat à l'énergie atomique is looking ahead with reasonable optimism along the road to the commercialization of sodium-cooled fast breeders.