A REVIEW OF THE ITALIAN FAST REACTOR PROGRAMME, MARCH 1979

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1. INTRODUCTION

1978 in Italy was marked by a standstill in the nuclear energy field. The decisions previously made for the installation of eight 1000MWe LWR-type reactors could not be acted upon because of the opposition of local authorities and lack of Government power. The construction site at Montalto di Castro (two BWR reactors) was opened with difficulty, whereas the decision to install a plant in Molise equipped with two PWR reactor was postponed.

The new presidents of ENEL and CNEN were appointed in January this year and the appointments of the new Boards of Directors are underway. With regard to CNEN, many political bodies are in agreement on an institutional change which would widen field of activity to include new energy sources, solar energy in particular. This will open a big problem: if CNEN will be no more a "nuclear body, it would be necessary to transerf all the activities connected to the Regulatory Commission to another separate body to be instituted.

In this context, the fast reactor programme has continued to develop under the directives of CIPE, and has concentrated its effort on the following three obiectives:

(i) The PEC Reactor
(ii) The Creys-Malville Power Plant
(iii) Research and development, and industrial promotion.

These obiectives are being pursued with the participation of CNEN, ENEL and Italian industry. CNEN has the role of committing and operating the PEC reactor; it is also charged to perform part of the R&D Italian-French programme and to promote industrial development. ENEL partecipates in the NERSA Company, owner of the Creys-Malville Plant.

Italian industry, with its activities of architect-engineering, designing and manifacturing will partecipate in the construction of the PEC and of the Italian part (33%) of the Creys-Malville Plant.

During the last months of 1978 a consortium (COREV) was set up by CNEN and NIRA which has the purpose of integrating and ensuring the smooth running of Italian efforts in the field of long-term research and development of fast power reactors.

The widening of the NIRA-NOVATOME agreement to include the design of a Superphénix-2-type plant has assumed particular importance for a better programming of Italian fast-reactor research and development activities.

The financial commitment, wich is limited to PEC and research and development activities and does not include the expenses for CNEN staff, was about Lit. 35,000,000,000 in 1978, of which about Lit. 20,000,000,000, was for the PEC.

2. THE PEC REACTOR

The construction design for the civil works and metal structures for the reactor, fuel-handling and control and service buildings has continued, just as has that on the components in the construction stage at the suppliers, such as the tank, plugs, tank-supporting structures, mechanisms and instrumentation.

No further approval of the Detailed Safety Reports by the CNEN Regulating Committee has been given with respect to last year's situation. The construction of the PEC depends on the approval of 21 Detailed Safety Reports which cover all plant parts relating to safety. Ten of these reports, prepared by NIRA and CNEN,

have been submitted to the Regulating Committee, which has approved only three untill now. The approval of the other seven, just as the other remaining and in preparation, depends on the setting-up of an organizational structure for the commitment of plant adeguate to the Regulatory commission standards.

The construction site activities carried out up to now and presently underway are covered by the first three Safety Reports approved, and the progress of the works obviously depends on an adequate rate of approval for the remaining reports.

Inside the reactor building at the site the mounting of the heat shields has been completed, with positive results for the pressure test. The installation of the inserts and metal liner and the casting of the regular and heavy concrete has continued.

The service and emergency air-locks have been delivered and mounted. The foundations for the fuel-handling building have been laid and the excavations for the auxiliary buildings and the creation of the foundation bed for the service and control building have been begun. The work executed to date at the construction site represents about 15 per cent of the total necessary for the completion of the plant. Construction work on the components has continued, In particular, the reactor tank is about 80 per cent complete at BREDA; FIAT has completed construction of the prototypes of the control-rod drives, the core hold-down device and the first test-loop prototype, and has begun acquiring the materials for the rod mechanism series and core hold-down device. The ANSALDO Company has in construction the prototypes of the safety systems and has purchased the central processing units for the data-processing computers.

3. THE CREYS-MALVILLE PLANT

The Creys-Malville Plant represents the first stage in the programme to introduce commercial-type reactors in Europe. The NERSA Company, made up by EdF, ENEL and SBK, is charged of the Plant's construction and operation. The supplier to NERSA of the Nuclear Steam Supply System is NIRA-NOVATOME, a consortium which was created especially for this purpose. This consortium will also act for further development of the marketing of the Superphénix-type reactor following construction of the Creys-Malville Plant.

In this frame, the italian firm NIRA participates directly with its own personnel in the NSSS construction. The engineering studies are being performed by a mixed design staff called "Project Superphénix" made up of engineers belonging to NIRA and NOVATOME.

Furthermore NIRA has received from the afore mentioned Consortium NIRA-NOVATOME the orders for the design and supply of some important component.

The construction of these components has been assigned to italian manifacturing companies, in some cases in collaboration with french companies: components and companies are reported in the following list:

- main vessel, internal vessel, reactor roof, recator deck (BREDA, in collaboration with the french company NEYRPIC);
- reactor diagrid and core supporting system (BREDA)
- safety vessel (ATB, Fochi, CIMI);
- intermediate heat exchangers (BREDA, TOSI, in collaboration with the french company Stein Industrie);
- secondary pumps (FIAT, Belleli, in collaboration with the french company Jeaumont-Schneider);
- primary pump motors (Ansaldo);
- fuel storage tank (Fochi, ATB, in collaboration with INTERATOOM and NOVATOME);

- primary and secondary storage tanks (D.B. Macchine);
- secondary containment dome (Belleli);
- control rod mechanisms (FIAT, in collaboration with NEYRPIC and NOVATOME);
- fuel handling machine (CMI, in collaboration with NEYRPIC and NOVATOME);
- civil works and conventional metallic structures (CGE, COMEVA, SOMIC);
- primary auxiliary circuits (AMN, in collaboration with Stein Industrie);
- sodium valves (Nuovo Pignone).

NIRA participates also in the design of the core and fuel element; the fabbrication of the italian quota of the core elements has been assigned, through NIRA, to the italian company AGIP Nucleare.

Italian engagement in Superphénis construction is as follows:

- 30% of the total cost of the plant,
- 34% of the main components,
- 42% of the reactor block components.

The status of the works conducted under NIRA responsibility is as follows:

- orders to italian suppliers	100%
- conceptual design	60%
- final design	40%
- manifacturing work	30%
- work at the site	15%

As a logical continuation of the collaboration begun with the construction of the Creys-Malville Nuclear Steam Supply System, one should note the start of NIRA's participation in the design of the Super-Phénix 2 plant, in collaboration with NOVATOME, under the various contracts between NOVATOME and EDF-SEPTEN and between NOVATOME and CEA.

These contracts will run until December 1979, with an average employment of 60 people, 30 per cent of whom are to be provided by NIRA, and have the purpose of carrying out a preliminary project establishing the main technical characteristics of the nuclear steam supply system for the next generation breeder reactors. NIRA will take over the ownership of the project for its use by ENEL. The preliminary project will be followed by the main project, to be carried out by NOVATOME, for the offer to EDF of this type of nuclear steam supply system. A participation in this activity by NIRA is foreseen.

4. RESEARCH AND DEVELOPMENT, AND INDUSTRIAL PROMOTIONAL ACTIVITIES

Our research and development programme is integrated with the French R & D programme.

The programme guidelines comply to the need to conduct an effective promotional effort for Italian industry in given sectors on one hand, and, on the other hand, to acquire and develop the knowledge necessary to evaluate the possible introduction of a Superphénix-type reactor in Italy.

The activities conducted in Italy in this area are aimed at developing national industry in the sectors of sodium circuit and reactor block components (including the auxiliary components and the instrumentation).

Development of the Steam Generators

Research and development activities for the steam generators are divided into:

(i) Development of a modular, straight-tube steam generator of NIRA design;

(ii) Experiments on the sodium-water reaction, whose first stage is planned as a safety study of the steam generator of the Superphénix-1 Plant.

The development plan for the straight-tube modular steam generator of Italian design represents an autonomous initiative of Italian industry for a component for which there still does not exist a joint agreement with the French partners. We are still looking for an agreement between NIRA and a French industry involved in developing steam generators.

Construction of the 50 MWt PGV-1 prototype, designed by NIRA and built by BREDA TERMOMECCANICA is in the completion phase and will be tested at Les Renardières.

The sodium-water reaction experiments, presently under way on Fives Cail Babcock test sections, are a contribution to our French partner, and are limited to a specific phase of experimental activity on the steam generator for the Superphénix-1 reactor.

The first experiment during which secondary failures have been observed were carried out in 1978. The results of the first experiment and the design of successive experiments aimed at checking out the possible systematic occurrence of the phenomenon observed and at checking out the calculation programme for the steam generator safety analysis are in progress.

Development of the Pump

In the pump sector there is a FIAT-NIRA-JEUMONT SCHNEIDER industrial agreement which guarantees a single line of development and, therefore, a precise goal for the experimental support activities. Italian industry is presently constructing the secondary pumps for the Malville Plant and the PEC pumps.

CNEN is involved in building the CPV-1 installation, designed for the test of the rotating parts of the primary pump of the Creys-Malville Plant. The construction of this installation and the relative PIVOTERIE-1 test section has been assigned to FIAT, and is presently being completed. The final commissioning should be completed before the end of this year.

Development of Other Reactor Block and Circuit Components

This line of development includes activities on inflatable joint seals which are developed also taking into account the experimental results and requirements got in the course of analogous activity conducted for the PEC. During 1978, under a contract with the PIRELLI Company, the experimental programme was defined and the construction project completed for two experimental apparatus (one 1.5m in diameter and the other 10m).

With regard to the intermediate exchangers, the trouble encountered with the Phénix intermediate exchanger suggests that we broaden our knowledge and develop design configurations, different from which already studied by the French, which will permit an adequate solution to the problems posed by the temperature distributions in the tube bundle in transitory and stationary conditions.

TECHNOLOGY (MATERIALS)

The exceptional size of the research and development efforts necessary to support the qualification and production of these materials requires the precise identification

and selection of the objectives, and the engagement of the available resources along lines coherent with industrial development.

We are carring on, in collaboration with industry (FIAT, CSM, TERNI, DALMINE), activities related to ferritic alloys and Incoloy 800, in keeping with the choices made in the SPX-2 preliminary project.

CNEN, in collaboration with Italian industry in this sector, is conducting a programme focused mainly on the materials for the steam generator, including their characterization regarding their mechanical properties and their corrosion behaviour in sodium and water-steam.

CORE STUDIES

The theorical-experimental activities supporting Superphènix-1 and those more directly aimed at the reactor series have concentrated on a few high-priority objectives.

In the field of deformed-bundle thermohydraulics, the experimental programme at the Casaccia Laboratories in sodium on seven-rod bundles electrically heated has continued, and the first experiment on a bundle containing a deformed rod has been completed. At the same time, activity for development and completion of the interpretative-type calculation method and of reference-code for the thermohydraulic analyses of the deformed bundles has continued. Activity for the technology needed to construct the heated bundles and deformed rods has also progressed.

Work on the mechanical behaviour of the core has continued, and the apparatus consisting of a grid model of the Superphénix reactor fitted with 100 hexagonal elements installed at Caradache has been completed. During 1978 the first series of mechanical tests aimed at the characterization of the core elements has been completed, and fuel-handling tests have been conducted in support of the Superphénix-1 programme.

The results of the activities on core hydraulics consist in the development of the TERSICORE code which will permit a complete analysis of the fluid dynamics of the coolant flow in the interspace between the core elements.

In the field of noise analysis, we have completed a general-use code for analyzing in the time domain the noise of different kinds (neutron, thermal, acoustic), originating from experimental apparatus or from reactors.

PHYSICS

Activities in the sector of fast reactor physics are conducted under the CNEN-CEA agreement.

The main lines of development are:

(i) Acquisition, analysis and comparison of calculation methods for the core's neutron design and for the dimensioning of the neutron and gamma-ray shields.
(ii) Completion of increasingly flexible and accurate nuclear data sheets.

During 1978 activities which were previously begun were continued. In the area of nuclear data evaluation, a review was made of four fission products which had demonstrated large discrepancies with the integral data; the evaluation of the nuclear data for Am^{241} over the entire energy range was also begun.

Experimental work continued on the RB-2 reactor for determining the cross section of Fe, Cr, Ni, Mo, Mn, Ti and various types of steel. Work on modifying the RB-2 reactor to conduct measurements with faster spectra is in the final stage.

With regard to the shielding studies, along with the activities for developing the calculation methods, the design of fertile zone experiments to be conducted on the TAPIRO reactor has been completed. In support of the optimization studies for the Superphénix-2 reactor, the work of interpreting the measurements made with the PRE-RACINE programme on heterogeneous configurations has been continued.

FUEL

Activities for the development of the fuel element for the reactor series are grouped into two basic developmental areas:

(i) Oxide fuels
(ii) Advanced fuels (carbides, fuels for heterogeneous cores).

For the oxide fuels, the COMPERE L5, L6 and L7 experiments, irradiated in the SILOE' reactor, were completed. They showed a less marked dependence of the conductivity integral on the O/M ratio than was thought. The FLORUM V3 irradiation experiment (in the SILOE' reactor) on the creep of in-pile fuel was halted because of a defect in the capsule. The results, although obviously incomplete, nonetheless furnished some significant data for the study of this phenomenon.

The construction of the irradiation samples for the X-8 experiment which will be conducted in the RAPSODIE reactor for the study of the fuel-clad mechanical interaction as a function of the gap size and the density has been completed. Post-irradiation examination of the irradiated pins in the DFR reactor at high clad temperature has begun. There are also underway activities for perfecting the manufacturing processes and techniques for the oxide fuels and for the structural parts. Promising results have been obtained for the gel-supported precipitation hybrid process as well as in the field of plug-clad welding.

In the advanced fuel sector, the irradiation programme with the OSIRIS and RAPSODIE reactors, aimed at studying the clad-carbide fuel interaction as a function of the gap size, the density and the clad type, continued. Off-pile studies continued on the fragmentability and the plastic creep of uranium carbide as a function of composition and manufacturing parameters. Activity has been started to support the development of heterogeneous-core fuels consisting in experiments that simulate the irradiation conditions that the fertile rods of a heterogeneous-core will undergo (the CONDIA experiment to be conducted in the SILOE' reactor).

SAFETY

Research and development activity in this areas, which are directly connected with the basic objectives in the National Energy Plan, are aimed at investigating the problems of safety and environmental impact, in order to make an overall assessment of the feasibility and acceptability of the fast reactor series in Italy, and at the same time at optimizing technology for appropriate prevention and protection.

The activities underway under the CNEN-CEA agreement are in line with the basic objective described above; they have been planned and worked out so as to cover some fundamentally important safety areas in which CNEN has the ready know-

ledge and actual possibilities of working and in which, in any case, a large developmental effort is indispensable.

In the field of dynamic behaviour of the coolant, experimental and theoretical research on load and flow transients which involve the boiling of sodium have continued. The experimental tests are conducted on the ENA-2 circuit at Casaccia, and the study of the effect of an obstruction of a fuel element has also been started; the experiments are conducted on a 19-rod bundle using the CEF-1 water circuit at Brasimone. The results are used for confirming the calculation methods developed at the same time as the experimental activity.

With regard to the dynamic behaviour of the fuel, off-pile experimental activities for the study of the molten sodium-fuel thermal interaction (AF2 and AF4 Casaccia plants) have continued with a view to studying the evolution of the processes and determining the energy yield; Italy is still actively participating with CEA in the in-pile CABRI-SCARABEE experimental programme.

The experimental activity in this sector also is accompanied by a theoretical-type activity having the purpose of perfecting experimentally-tested interpretative-type codes and calculation methods.

Regarding the activity for the dynamic behaviour of the core, the development and verification of an essential core dynamics code for safety analysis has continued taking the NADYP code developed by CNEN as the starting point.

The studies on the dynamic behaviour of the structures continue in collaboration with CCR-Euratom ISPRA and the University of Bologna, with the aim of carrying out the analysis of the consequences on the plant of an accident originating in the core.

Considerable effort on sodium-air reaction will be made through the participation in the ESMERALDA programme of CEA on large sodium fires in scale on the Superphénix reactor. That will make it possible to obtain the indispensable knowledge of the evolution and consequences of accidents arising from sodium fires, both for the correct design of the plant and for the perfection of preventive and fire-fighting techniques. Lastly, a full-scale experiment on the large reactor will remove doubts about the consequences inside and outside the plant caused by accidents of this nature which only with difficulty could be resolved by extrapolating the effect of small losses.

TECHNICAL AND ECONOMIC STUDIES

An activity has been underway for some time at CNEN for studying the strategy of electronuclear systems and the optimization of fast reactors to be gradually inserted into the context of conventional-type thermal reactors. With the agreement reached between CNEN and CEA this activity has been aimed at studying the penetration of the electronuclear system of Superphénix-type fast reactors and at making a technical and economic comparison between the different reference strategies. This activity, which until now has been limited to studies of a general nature or in support of the French reactor series, assumes a considerable importance in the light of the initiatives for the Superphénix-2 and, the prospective of a reference study for a reactor of this type in the Italian context.

Italy participating in the work of INFCE.

CODES AND STANDARDS

This sector is probably that with the great est need for a close coordination between all the organizations involved and that where the deficiency and dispersion of personnel for the proposed projects is most acute. The interests involved, the objective complexity of the activities and the continuous evolution of our knowledge make it necessary to proceed with caution in organizing an Italian programme for standards. At the same time the need to proceed rapidly in order to strengthen the ties between the different national organizations is evident, in order to create a correct frame of reference for programming future actions and with the immediate objective of perfecting the initiatives in progress, with particular reference to the criteria of the high-temperature structural project.

Classification and Control of Standards

The first analysis of the standards for the main components of the fast reactors applied in Italy and in the United States has been completed.

On the basis of this initial examination, the standards applied in the two countries have been studied and a comparison has been started in order to identify the most critical areas. A data file for standards is also in preparation.

A National Commission for Fast Reactor Standards (CNRV) has been set up on the initiative of the president of CNEN with the participation of the companies and organizations working in this sector. The sectors in which this commission will be involved are the controls, structural analyses, the relative experimental checks and the structural materials.

Experimental Activity

Thermal fatigue tests on thick tubes (I.D.= 100mm, t = 10mm) in SS316 at the JRC Laboratories at Ispra (in collaboration with CEA) have continued. 60,000 Runs have been reached without observing cracks or fissures. A test programme on the effect of thermal shocks on models of piping with small thicknesses is underway at the Casaccia Laboratories. The present equipment will be transformed into a sodium circuit for ratchetting tests.

In the field of structural materials (AISI 316 used for the PEC reactor), characterization tests have been conducted in collaboration with the Consiglio Nazionale delle Ricerche (CNR) and oligocyclic fatigue testing is in progress.

Calculation Codes

The structural calculation codes for the thick pipe tested at Casaccia during the 1977 test programme have been made. Acquisition and application of the elastic, viscous and plastic codes continue.