XA9847024

FAST REACTOR RESEARCH ACTIVITIES IN BRAZIL

A. MENEZES
Advanced Studies Institute, Aerospace Technical Center,
São Jose dos Campos, São Paulo,
Brazil

Abstract

Fast reactor activities in Brazil have the objective of establishing a consistent knowledge basis which can serve as a support for a future transition to the activities more directly related to design, construction and operation of an experimental fast reactor, although its materialization is still far from being decided. Due to the present economic difficulties and uncertainties, the program is modest and all efforts have been directed towards its consolidation, based on the understanding that this class of reactors will play an important role in the future and Brazil needs to be minimally prepared. The text describes the present status of those activities, emphasizing the main progresses made in 1996.

1- Introduction

In 1996, the total electricity consumption in Brazil was of the order of 260 TWh (1625 kWh per capita), which represents around a 6% increase with respect to the previous year. About 95% of the electricity come from hydric resources, most of them located in the southeastern region of the country. This region, which is highly industrialized, consumes almost 60% of the total electricity produced in Brazil. It is important to point out that about half of the total hydroelectric potential is located in the Amazon Basin and its exploitation will certainly be associated with high financial and environmental costs.

Brazilian uranium resources are presently estimated in 300,000 metric tons and the estimate on the thorium resources is of the order of one million metric tons. The country has presently one reactor (PWR/626 MWe) in operation and a second one (PWR/1300 MWe) has recently received authorization for completion, which is planned for 1999. A third reactor (PWR/1300 MWe), originally planned to be constructed in the same site as the other two is still awaiting for a government decision.

The Brazilian government has kept a low profile on the complete consolidation of an electricity generation program based on nuclear energy. The reason for this resides not only upon the fact that only 25% of the hydroelectric potential is presently being used but also upon the costs involved, which is a central issue of the present discussions related to the privatization of the electric sector. The utilization of nuclear energy for "social applications" is being emphasized, in order to improve its public acceptance. In addition, the nuclear research institutions are being oriented to make their planning with an "eye in the market" , which can put longer-term programs in jeopardy.

Based on the understanding that fast reactors will play an important role in the future and Brazil needs to be minimally prepared, a research program has been initiated with the main objective of establishing a consistent knowledge basis which can serve as a support for an eventual transition to this class of reactors in the future. Although the materialization of an experimental fast reactor is still far from being decided, we felt it was convenient to prepare a reference design which could serve as a focus for several R&D activities. These activities were chosen to fit the existing experiences and were to be conducted within the limitations both in personnel and in financial resources. For this reason, efforts have been concentrated mostly on items related to the primary circuit of an experimental reactor, whose thermal power was chosen to be 60 MW.

2- Reference Design- Main characteristics

The main characteristics for the reference design /1/ were chosen in 1992, in such a way as to benefit from the most recent available literature and also from the already existing experiences. For example, the choice of metallic fuel (U-Zr or U-Pu-Zr) was based not only on the observation that these alloys were receiving great attention due to their high burnup capabilities but also on the fact that the Nuclear Research Institute (IPEN, Sao Paulo) had previous experience with metallic fuel for research reactors and became motivated in engaging in a challenging research towards the development of U-Zr alloys and metallic uranium recovery. The same line of reasoning was used for involving other research groups with HT-9 as a reference for cladding material, electromagnetic pumps, passive safety and so on.

For the reference design, fuel pin dimensions and other data were taken mostly from ALMR (former PRISM) and EBR-II and were used for calculations which led to a general core configuration. The reference design, whose main characteristics are indicated in Table 1, is presently being used for testing our calculational tools, for checking different methodologies for core calculations, etc.

Table 1: Main Design Characteristics

Thermal power (MW)	60
Electric power (expected) (MW)	20
Primary operating pressure (MPa)	0.11
Core inlet temperature (°C)	370
Core outlet temperature (°C)	470
Maximum burnup (MWd/T)	70000
Fuel type	U-10%Zr
Coolant	Sodium
Primary coolant circuit arrangement	pool type
Cladding material	HT-9

The concept of the fuel subassemblies for the REARA-60 reference design was based on the international experience, with the dimensions taken mostly from ALMR. The number of fuel pins in the subassembly is 61, separated by helicoidal wire wraps and arranged in a triangular matrix, forming a hexagonal set. The fuel is a U-10%Zr metallic alloy with active length equal to 62.0 cm and having two (top and bottom) 30.0 cm nickel reflectors.

In the core there are 6 control subassemblies (4 primary+2 secondary). The control material is boron carbide (B_4C) enriched in ^{10}B, with the pellets being clad in stainless steel cylindrical tubes. In the present reference design the control subassembly inserting and withdrawing mechanisms have not been defined.

Consideration has been given to the utilization of some types of special subassemblies distributed in the reactor core, in order to provide means of controlling neutron leakage, protecting against loss of flow accidents, controlling the excess of reactivity and so on. Among them we have the Gas Expansion Modules (GEM), which have been tested in the Fast Flux Test Facility (FFTF) and are to be located (3 subassemblies) in the active core periphery in order to protect against loss of sodium flow.

The core arrangement which has been used for calculations is indicated in Figure 1. The target average burnup is 70 MWd/kg, which will require about 1000 days of full power operation. Using cross section data from the Japanese library JFS-2 (JAERI-Fast Reactor Group Constant Set - Version II, 70 energy groups) and the diffusion theory codes EXPANDA (generates weighting spectrum in 70 groups and uses it to collapse cross sections do 6 groups) and CITATION (RZ ge-

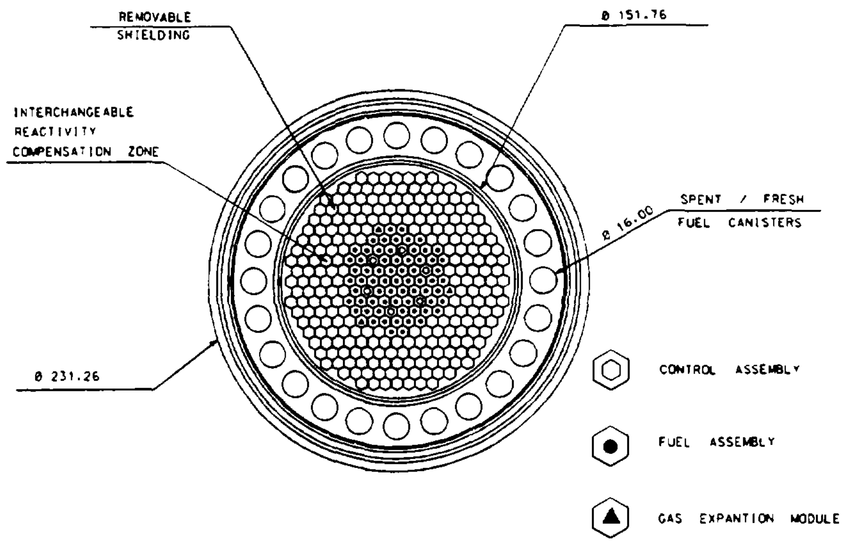

Figure 1: Core arrangement at BOL

ometry, 6 energy groups), evaluation of some reactor parameters have been performed at the Advanced Studies Institute (IEAv, Sao Jose dos Campos) and are indicated in Table 2.

Table 2: Main core parameters

Maximum flux (10^{15} n/cm^2.s)	1.97
Average flux (10^{15} n/cm^2.s)	1.07
Doppler coefficient (-TΔk/ΔT)	7.07×10^{-4}
Sodium void reactivity (-Δk)	3.27×10^{-2}

Also based on data selected from the literature on EBR-II and ALMR, a set of reference values for thermohydraulics calculations have been fixed and used for the reference design of the Intermediate Heat Exchangers (IHX), which are straight shell/tube (primary coolant in shell) and counterflow type. REARA-60 has two identical IHXs, each one associated with two pumps, whose characteristics are not defined yet.

The IHX main characteristics, shown in Table 3, were determined with the computer program TCIPRO /2/, which is written in C-language and runs in PCs.

Table 3: IHX main characteristics

Primary sodium flow rate (kg/s)	226.0
Secondary sodium flow rate (kg/s)	152,0
Number of tubes (#)	1397
Central pipe OD (m)	0.311
Total heat transfer area (m^2)	233.0
Total height (m)	3.859

3- Research and Development Activities

3.1- Reactor physics

Independent core calculations performed at the Nuclear Engineering Institute (IEN, Rio de Janeiro) pointed out to discrepancies -with respect to calculations done at IEAv- which were mainly attributed to the differences in nuclear data sets.

Under a formal cooperation agreement, IEAv and IEN are presently working together on a series of sensitivity analyses with the objective of developing a better understanding of those differences, in order to choose the best route for more refined calculations, if necessary.

3.2- Heat transfer/removal

A small natural circulation circuit using water as the circulating fluid has been recently built in the Department of Mechanical Engineering of the Aeronautics Technological Institute (ITA, Sao Jose dos Campos), as part of a formal agreement between IEAv and ITA. Using an 8 kWt heat source, the circuit will be used for studying basic phenomena associated with natural convection, for experimental validation of theoretical models and so on. For being installed in an engineering school, the circuit will also be useful for academic purposes.

Also in the area of heat removal, an exchange with researchers from the Indira Gandhi Centre for Atomic Research (IGCAR, India) has been recently initiated in order to identify topics of common interest for an eventual cooperation. This exchange has been facilitated by the visit to Brazil of Dr. Placid Rodriguez, Director of IGCAR.

3.3- Structural materials

In the area of structural materials, experimental research is underway with the objective of understanding the basic processes involved in the production and characterization of HT-9, which has been taken as a reference for cladding material. A first sample has shown a slight deviation with respect to the composition used as a reference and a second sample, produced in improved conditions, is presently being analyzed.

3.4- Uranium recovery by electrorefining

Under a formal cooperation agreement with IPEN, uranium recovery by electrorefining techniques is being investigated, also to understand the basic processes involved.

In a first experiment, which has been useful for identifying some critical items which are part of the processes, a basket containing almost 100 grams of metallic uranium was introduced in a five liter cylindrical electrolytic cell. Temperature has been raised to 500 °C and the basket was immersed in a mixture composed by the electrolyte (59mol%LiCl+41mol%KCl) and the anode (metallic cadmium). The uranium dissolution process has been maintained for 72 hours, under an argon atmosphere, and resulted in 94,45 grams of dissolved uranium. For the U-electrodeposition the cathode was maintained rotating at 50 rpm, but the experiment was forced to terminate after about two hours due to unexpected operational problems. For this reason, the mass of uranium electrodeposited (in dendritic form) was only a few grams.

In spite of the problems, for our purposes this experiment has been useful for an initial understanding the role of parameters involved in the process, in order to optimize the conditions in which the next experiments are to be performed.

3.5- Electromagnetic pumps (EMP)

The acquisition of experiences in modeling and designing of electromagnetic pumps (EMP) is one of the objectives of present activities. Experimental research has led to a first EMP which was successfully tested -using mercury as working fluid- at IEAv. This pump used an Iron C-type magnet with a continuous-current coil to obtain the required magnetic induction. A second pump, using rare-earth permanent magnets (Sm-Co) in place of the C- magnets in order to reduce the geometric dimensions is also finalized and is being prepared for evaluation of its characteristic curves. R&D work on alternating current EMPs is planned to be initiated in 1997.

3.6- Sodium technology

In 1981, a contract with ANSALDO/NIRA (Italy) was signed to design and construct three sodium loops and auxiliary systems. Due to insufficient funding the loops were never constructed. In 1996 funding has been finally provided for assembling the first loop (named SS-10), which is to be used as a test bed for experiments related to sodium purification and transferring. The loop will be constructed in IEN and completion is expected by mid-97.

3.7- Heat pipes

An investigation on the substitution of the heat exchanger internal tubes by heat pipes has been initiated based on theoretical modeling, with the objective of evaluating if there are gains which could be achieved. The first discussions have resulted in the basic concept showed in Figure 2, which

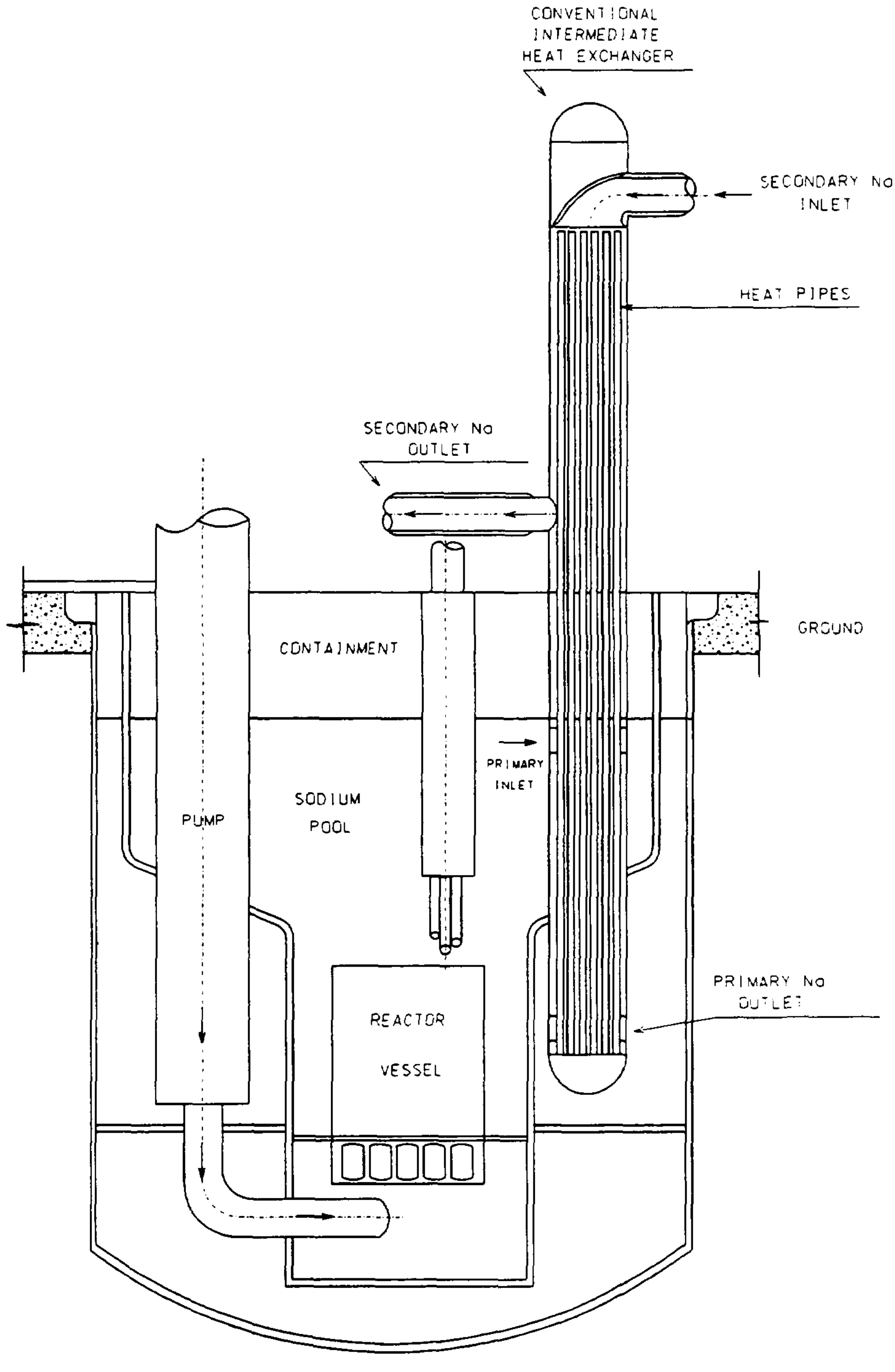

Figure 2: Schemactic view showing IHW with heat pipes replacing internal tubes

is to be used for the initial calculations. This concept indicates, among other things, that safety levels can be increased because the chances of accidental contact between primary and secondary sodium are drastically minimized. As a result, the elimination of the intermediate heat exchanger from the primary circuit could, at least in principle, be possible. This and other possibilities will have to be supported by calculations and further discussions, which are planned to be continued during 1997.

Along with these research activities, there are others involving studies on shielding analysis and actinide burning calculations.

4- Final Remarks

As previously mentioned, REARA-60 is being used as a reference for R&D activities in a few areas. Considering that there is no decision as to its materialization, yet for some time in the future the reference design will be our "experimental installation". The present priority is the consolidation of this research program and all efforts are being made for showing that a long-term program will not only result in the materialization of the reactor, but can also generate, along its way, relevant expertise which can also be useful for other sectors or programs.

Discussions on the "optimization" of our activities have also occupied part of our time. How can we effectively contribute to the international efforts in the fast reactor field, given the fact that brain power and investments for small installations and experiments are the only assets easily available at the present? Is it enough to be involved with research activities which are compatible with our investment capability, for reporting them in the IWGFR annual meetings? Or should we take part in tasks which are either part of an international fast reactor project or of a broader international cooperation?

In our viewpoint, the consolidation of our program depends not only upon convincing Brazilian decision-makers about the importance fast reactors may have in the future, but also upon showing that the results we produce can be useful to the fast reactor field, on a broader scale.

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