



**STATUS OF THE R&D ACTIVITIES ON
FAST REACTORS AND ADS IN BRAZIL**

By

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1.INTRODUCTION/1/

The total electric power installed in Brazil, as 12/2000, is 68,533 Mwe, being 87.82% hydro, 9.29% thermal, 2.83% nuclear, and other sources 0.02%. These plants generates a total of 305 TWh, from each 2% are Nuclear. The Nuclear Energy is generated by 2 LWR, ANGRA I, a Westinghouse 657Mwe, and ANGRAII, a SIEMENS-KWU, 1,309 MWe recently inaugurated. Besides these 2 units, it is under construction, a third unity (ANGRA III), with the same design and power as ANGRA II. All these units are operated by a State Utility (ELETRONUCLEAR) In the Nuclear Material Resources, Brazil has estimated reserves of 309,000 tons of Uranium (6th World Reserve), and together with India the biggest world Thorium reserves. The industrial activities in the Fuel Cycle are conducted by a State Company (INB), which operates a mine (Caetité), with a capability of production of 400 tons/y, and factories for UO₂ Powder (140 ton/y) and Pellet (120 ton/y) production, and a fuel assembly with Westinghouse and Siemens technology. Besides INB is foreseen in a near future (2008) an enrichment facility with Brazilian Technology (Centrifuge).

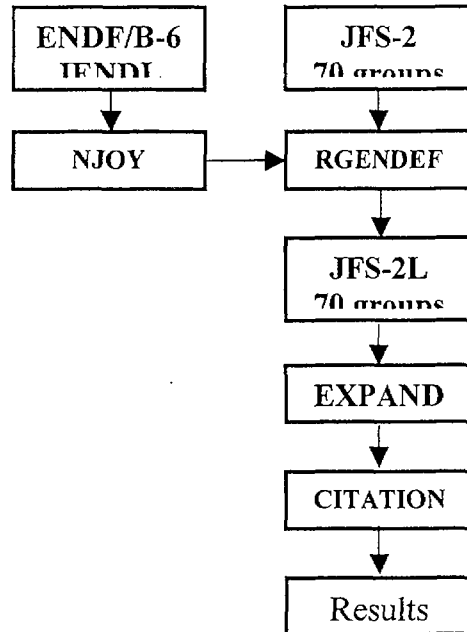
Research and Development in Nuclear Science and Technology is conducted by Research Institutes of the Brazilian Nuclear Energy Commission, such as IPEN in São Paulo (Radioisotopes and Radiation, Reactor Physics and Engineering, Material Science, Accelerators, Environmental, etc), IEN in Rio de Janeiro (Fast Reactors), and CDTN, in Belo Horizonte. Besides these Institutes, also Universities are doing some Basic Research, and at São José dos Campos an Institute of the Airforce (CTA), was engaged in Fast Reactor R&D, and Brazilian Navy has an R&D program for Nuclear Propulsion Development.

In Fast Reactor, R&D activities started in the sixties at IEN in cooperation with TECHNICATOME, and in 1972 a small Na loop (100 kW) was constructed. At same time, during the seventies at IPEN, research in cooperation with GA for Gas Cooled Fast Breeder Reactor were developed. The motivation of such research was Thorium Fuel Cycle. As results of this research a Helium Loop was constructed and a Split Table Critical Assembly (ZPR) was designed. During the eighties, at IEN, an agreement with ANSALDO-NIRA results in an acquisition of a Sodium Loop for Termohydraulics studies, however it never had been assembled. At same time at CTA, a concept of a Binary Breeder Reactor using two cycles Th and U was developed. During the nineties, a National Program (IPEN, IEN, CTA) to conduct R&D (pyroprocess; U-Zr Metallic Fuel; HT-9; Electromagnetic Pump; and a conceptual design of a Experimental Reactor (60/20 MWth/MWe) was proposed, however it was closed in the end of the decade. Now days, only academic Research are being conducted at IPEN/CTA, and they will be summarized in this report. Basically, they are: 1. An Integral Lead Fast Reactor Concept

for Developing Countries (Santos&Nascimento), 2. Alternative Concept for a Fast Energy Amplifier Accelerator Driven System (Maiorino et alli).

2. AN INTEGRAL LEAD FAST REACTOR CONCEPT (ILR)/2/

Santos, A. & Nascimento, J., are proposing a concept of an Integral Lead Reactor (300, 900, 1500 Mew), to be used in developing countries, which is an



association of the best characteristics of the American Integral Fast Reactor and of the Russian Lead Cooled Reactor. The reactor core is a hexagonal pin types illustrated bellow:

Power (MWe)	300	900	1500
Fuel pin numbers	34146	104064	170730
# Assemblies			
Inner core	66	204	342
Outer core	60	180	288
Control	13	25	43
Blanket	48	78	96
Neutron shield	114	174	210
Gamma shield	66	96	114

The reactor is start with U-Zr and shifts cycle-by-cycle to the U-TRU-Zr fuel. Homogeneous reactor cores based on the American and Russian experiences on fast reactor technology have been designed with the aim of conception evaluation. Besides electricity generation it is being idealized an association of the ILR and a Chemical Heat Pump for high-temperature industrial process use.

The calculation model is as illustrated bellow, and had been benchmarked against several Critical Assemblies (VERA, ZEBRA ETC).

The main core parameters are evaluated in the first cycle as a function of the fuel pin diameter, p/d ratio and reactor power in the 300 to 1500 MWe range. To mitigate the TOP accident a requisite is to have a burn up reactivity swing (Δk_{Bu}) $< \beta_{eff}$. The use of enriched uranium results in a poor core conversion ratio due to the small η of the fuel. The recycling of enriched uranium and its utilization as feed increase the ^{236}U content and degrade the core performance. Therefore, in the first few cycles, the goal Δk_{Bu} is not satisfied in the core power range analyzed and the enriched uranium must be substituted as quickly as possible by the generated plutonium. The Doppler effect is small; as expected in a fast reactor loaded with metallic fuel. The reactor power envelope for negative lead void reactivity is 1000 – 400 MWe for a pin diameter in the range 6.35 – 10.4 mm and p/d ratio > 1.308 . The average burn up aim of 100 GWd/tHM is possible only with a reactor power of less than 620 MWe due the fast fluence limit of 4.0×10^{23} n/cm². An enrichment higher than 20 % and a $\Delta k_{Bu} > \beta_{eff}$ must be tolerated in the initial cycles. Only after the equilibrium cycle (EC) behaviour is attained the core power can be defined. In the EC the enrichment will be restricted by the American technologic experience of 30 w/o.

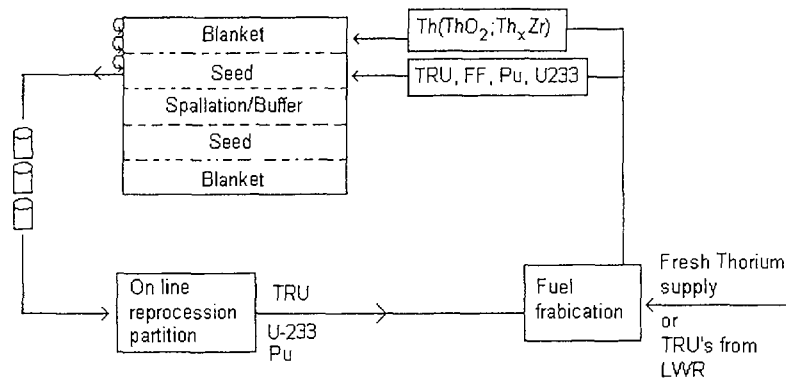
3.ALTERNATIVE CONCEPT FOR A FAST ENERGY AMPLIFIER ACCELERATOR DRIVEN SYSTEM/3/

As an alternative of the Rubbia's Energy Amplifier ADS, recently a research at IPEN (J.R. Maiorino, A. Santos, A.T. Silva, and S.A. Pereira) are investigating a conceptual design of a ADS cooled by gas (He) imbedded in a solid lead subcritical array of fuel and using more than one point of spallation trying to reduce the requirement on the energy and current of the accelerator. The first step of this research was to introduce the calculation methodology(LAHET/MCNP-4A), and benchmarking it against FLUKA using the EA-ADS proposed by Rubbia. The results found are illustrated bellow:

	FLUKA	LAHET/MCNP
Thermal Power	1500 MW	1576
K _{eff}	0.98	0.967
Specific Power	52.8 W/g	53 W/g
Power Density	523 W/cm ³	527 W/cm ³
N ₂₃₃ /N ₂₃₂	0.11	0.107
Cladding Temperature	Maximum 707 C(Pb)	706 C(Pb) 883 C(He)

The benchmark studies are still in developing (MUSA). Also using a core hexagonal type with inner core with MOX and a Breeder region of ThO₂, a study was conducted for 1, 2, 4, and 5 spallation region varying the accelerator current for an energy of the proton of 500 MeV at BOL was conducted showing some advantages in using more than one point of spallation (more flat neutron distribution, and a gain in power for the system). The studies on this concept are under way.

Another proposal is to study a ADS consisting of a solid lead calandria, similar to the CANDU Reactor with the fuel elements in channels cooled by helium, allowing on line refueling or shuffling, and a fuel cycle (Th) as illustrated bellow. This study is just starting and there are some hopes that by using a direct thermodynamic cycle similar to the proposed by the modular HTGR, a greater advantage could be achieved.



REFERENCES

1. Menezes, A. A. Review of Fast Reactor Activities in Brazil, **28th Meeting of the International Working Group on Fast Reactor** , Vienna, Austria, May 9-11, 1995, p.221-224, IAEA-TECDOC-1015 (1996).
2. Santos, A. & Nascimento, J. , Integral Lead Reactor Concept for Developing Country: First Cycle Analysis, submitted for publication in **J. Nuclear Technology** (2001)
3. J.R. Maiorino, S.A. Pereira, A. Santos, A. T. Silva, New Proposal for the Fast Energy Amplifier, **8th International Symposium on Radiation Physics**, Prague (Czech Republic), June 5-9, 2000