CNEN IN THE IRIS PROJECT

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Abstract – IRIS, the International Reactor Innovative and Secure is an international development program of an innovative, water cooled reactor designed to meet the requirements of proliferation resistance, enhanced safety, cost effectiveness, modular deployment, innovative waste management and high efficiency fuel. By the end of 2001 CNEN signed a collective agreement with Westinghouse Electric Company to officially participate in the development of this integral primary system reactor (IPSR). CNEN team is responsible for the internal pressurizer design and for the independent review of RELAP 5 input file. The design tasks for the pressurizer have included steam-water volume sizing, pressurizer to vessel physical separation, thermal insulation and surge connections dimensioning. Future work will address the need of passive spray devices, honeycomb insulation and surge baffles. This paper present some of the most relevant characteristics of the IRIS design and the preliminary results of pressurizer design, operating modes analysis and transients analysis with RELAP 5.

Index Terms – Advanced Nuclear Reactors, Generation IV, Integrated Pressurized Water Reactors.

1.0 - Introduction

The future of nuclear energy depends on the development of new reactors concepts that can fulfill requirements such as those defined by the US Department of Energy (DOE), in cooperation with other participants of the Generation IV International Forum (GIF) for the Future of Nuclear Energy [1]. IRIS is a real international cooperation effort to design a system to meet these requirements. Westinghouse started the conceptual design of this new reactor to answer a DOE solicitation for what have later been called Generation IV nuclear energy systems. An important goal set forth since the beginning was to develop a commercially viable concept for developed and developing countries with large or small electrical grids.

Such approach immediately found a positive response around the world and the IRIS team grew from the initial four members and two countries to the present international consortium led by Westinghouse/BNFL and comprising 17 organizations from eight countries (Table 1). The Comissão Nacional de Energia Nuclear (CNEN) started to work in the IRIS development team in July 2001 and signed the collective IRIS agreement by the end of that year.

Before signing this agreement, CNEN discussed with almost all Brazilian Institutions linked to nuclear energy possible areas of cooperation, to fit the best interest of all parts. A meeting, the first *CNEN-IRIS Workshop*, took place at NUCLEP facilities, in the beginning of the second half of 2001. At first, the attendants mentioned many areas of interest: neutronics, thermal-hydraulics, control systems, monitoring and diagnostics, structural analysis, ergonomics and so on. Later on, after better evaluating the needs of expertise from the international IRIS team and the interests of the Brazilian institutions, we had to reduce a bit the scope of our participation, therefore only the three institutes of CNEN and NUCLEP had joined the IRIS team.

Under the coordination of the Research and Development Directorate of CNEN (DPD), the initial work done by the Brazilian team made it possible to assume the responsibility for the development of the internal pressurizer and for the independent review of RELAP 5 IRIS input file. The pressurizer design task includes the steam-water volume sizing, the development of a thermal insulation between the saturated water layer and the reactor water, the definition of surge connections, pressurizer internals, safety valves, controls, analysis of a design basis transients set and so on. The IRIS input file verification includes input data verification, conceptual evaluation of estimated key parameters and execution and evaluation of safety analysis calculations. This paper intends to present some of the most relevant characteristics of IRIS design and the preliminary results of the pressurizer design, some aspects of IRIS operating modes, and comments on transient analysis with RELAP 5.

Table I
IRIS Consortium Membership

Industry		Universities	
Westinghouse	(USA)	Polytechnic of Milano	(Italy)
BNFL	(UK)	U. California Berkeley	(USA)
MHI	(Japan)	MIT	(USA)
Bechtel	(USA)	Tokyo Institute of Technology	(Japan)
Ansaldo	(Italy)	University of Pisa	(Italy)
NUCLEP	(Brazil)	University of Zagreb	(Croatia)
ENSA	(Spain)		

Utilities		R & D	
JAPC	(Japan)	National Institute Nuclear Studies	(Mexico)
		CNEN, Nuclear Energy Commission	(Brazil)
		Oak Ridge National Laboratory	(USA)

+ Associates	
University of Tennessee	(USA)
Ohio State University	(USA)
Iowa State University	(USA)
University of Michigan	(USA)
Ames Laboratory	(USA)

2.0 – IRIS main characteristics

IRIS plant thermal power is 1000 MW(t) with a net electrical output of about 335 MW(e). The primary system operates at the pressure of 15.513 MPa.

The three most innovative features, which characterize IRIS project, are:

- Safety by design;
- Optimized maintenance; and,
- Long core life.

Safety by design

IRIS design takes the advantage of the integral configuration to improve safety. Its configuration physically eliminates the possibility of many accidents to occur, decreases the probability of occurrence, and minimizes the consequences of the remaining ones. Fig. 1 shows the actual IRIS configuration: an integral primary system in a 6.78m outside diameter by 21.4m-height vessel with eight helical coil steam generators, eight primary coolant pumps, an internal pressurizer and internal shielding. An impressive feature in IRIS is the primary coolant pumps that are completely contained inside the vessel, thus eliminating large vessel penetrations. Reference [2] reports the implementation of the safety by design in IRIS.

The helical steam generators operate with superheated steam at the pressure of 7 MPa. The steam generators tubes operate in compression, since the primary water flows outside the tubes, thus steam generator tube rupture are less probable. Even in this case, the SGs are designed to withstand the primary system design pressure, IRIS can operate with some SGs isolated in the case of tube failures.

The relatively high primary water mass, the low primary pressure drop and the high steam generators elevation enables enough natural circulation reducing the consequences of loss of flow accidents.

The use of eight spool pumps inside the reactor vessel makes possible to have a single locked rotor or pump seizure accidents without any core damage, moreover no scram is needed and the reactor could continue to operate at full power.

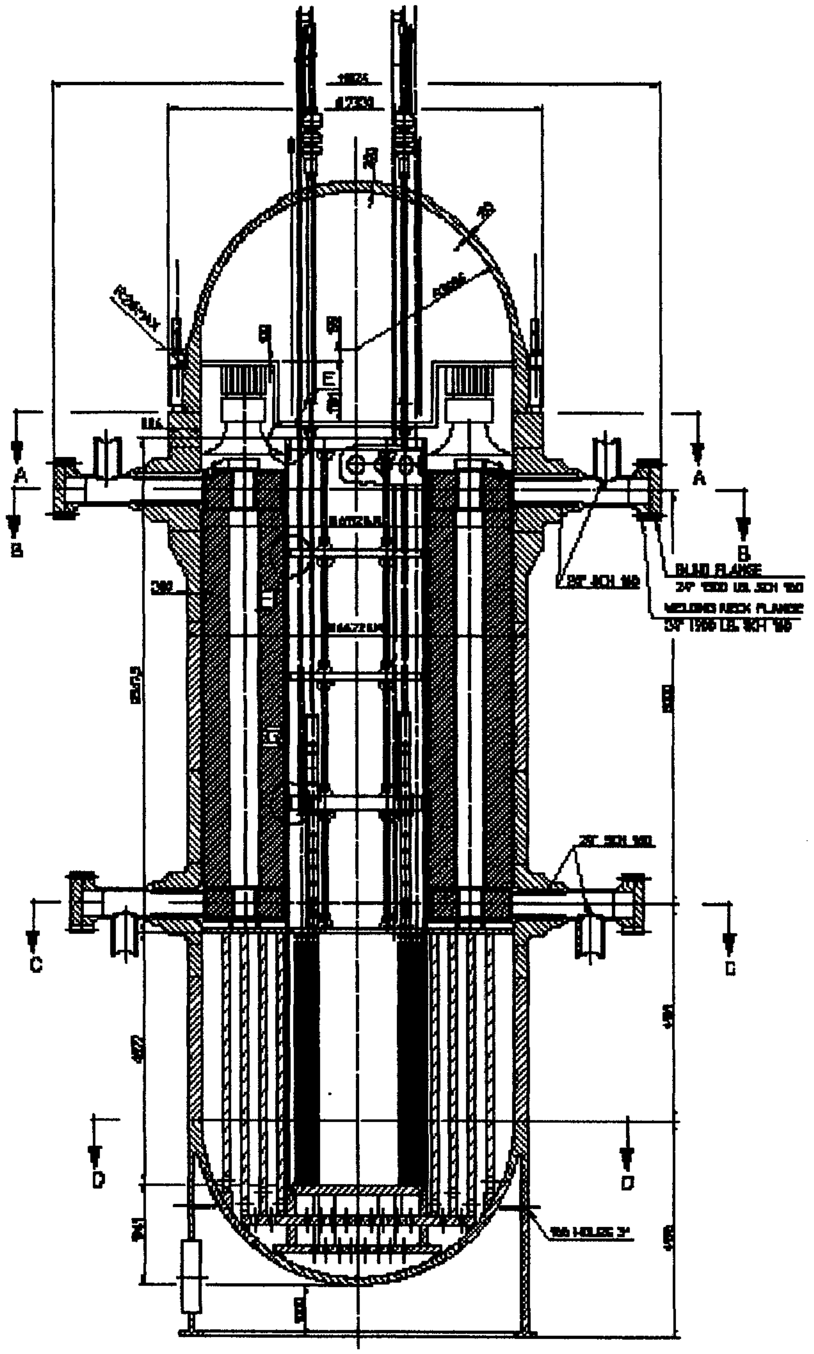

Figure 1 – IRIS: Integrated Primary Systems.

IRIS pressure vessel is connected with a small spherical containment designed to a relatively high pressure. In the case of small or medium LOCA, the core remains covered for several days, or even weeks, depending on the natural heat removal over the containment external surface, without any emergency water injection.

IRIS containment design makes use of suppression pools that are used also as a source of water gravity feed. For all analyzed accidents, the core remained covered. Further analyses are being made to show that IRIS can meet the requirement of "no need for off-site emergency response."

90% of the heat loss occurs in this part. These results showed the importance of investigate some device to reduce the convective heat-transfer through the pressurizer bottom.

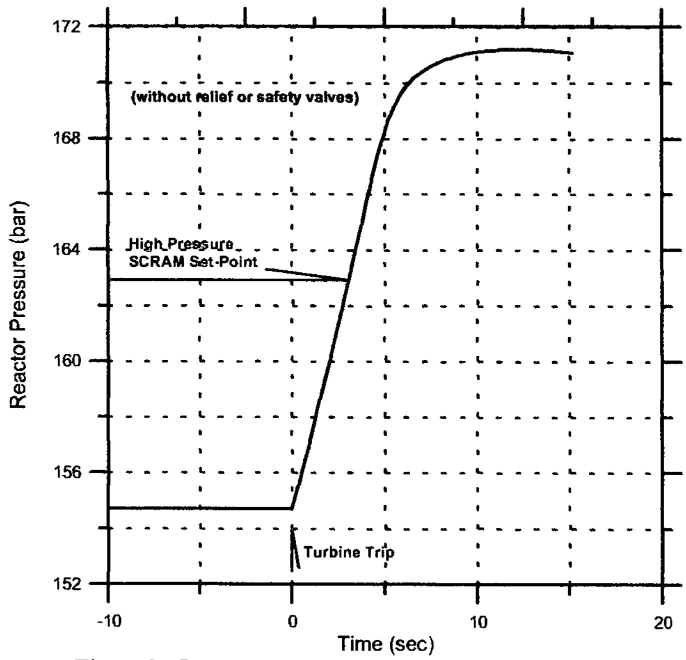

Figure 2 - Reactor Pressure – simplified model result.

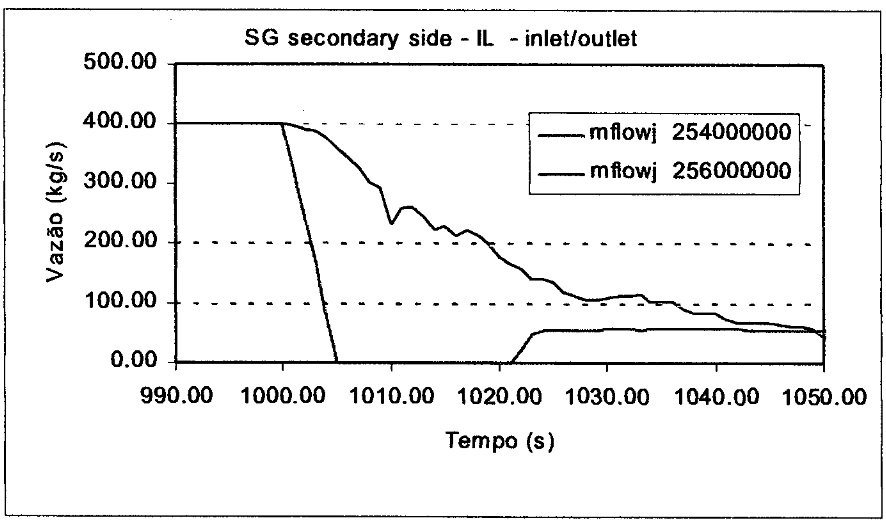

Figure 3 - Reactor Pressure – RELAP 5 model result

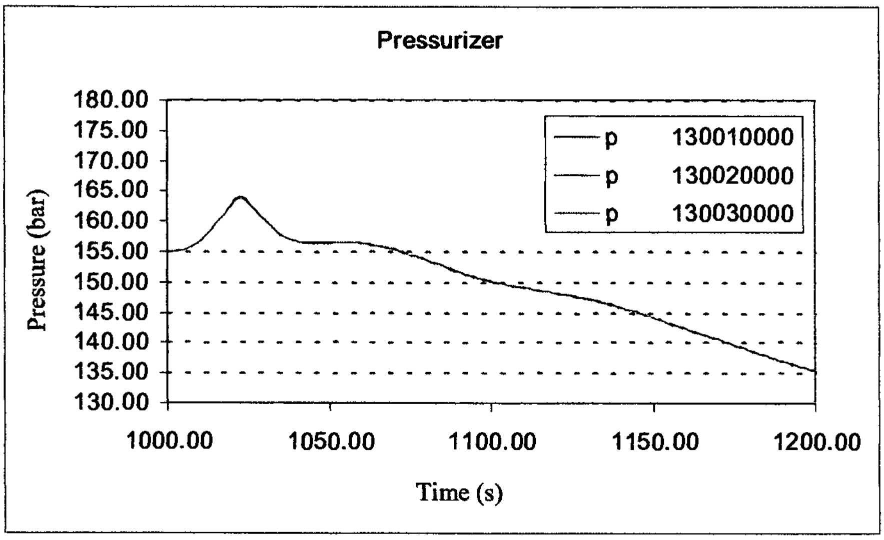

Figure 4 - Reactor Pressure – RELAP 5 model result

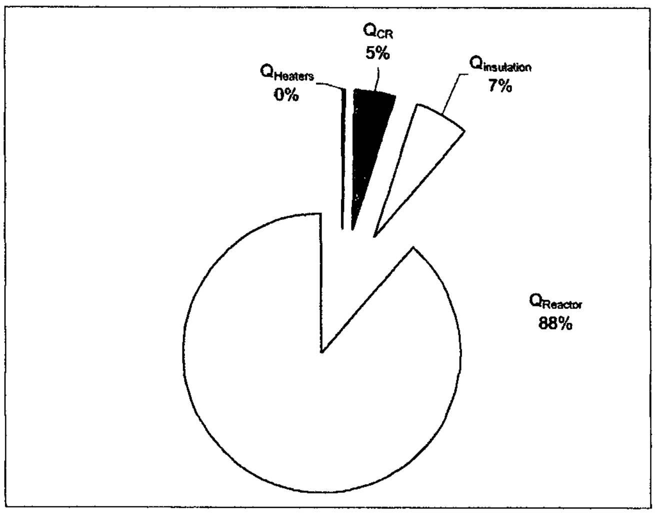

Figure 5 – Fraction of Pressurizer Heat Losses.

4.0 – A discussion on IRIS Power operating modes

For PWRs that use U-tube steam generators, most of the heat transfer from the primary happens at a constant temperature of the secondary water, that is the saturation temperature. Therefore, to increase from a given level to a higher level of power operation, one must either increase the primary side mean temperature or maintain it constant allowing for the consequent reduction of the secondary pressure and saturation temperature. These are the two extreme archetypes of power level operation modes and because of their inherent inconveniences; commercial PWRs generally employ a trade off between the two. The first option implies large variations of control rods position and/or soluble boron concentration, while the second causes large variations in the secondary pressure.

IRIS steam generators are of once through type, with a secondary constant pressure program. In a secondary system with a constant pressure control philosophy, the feed-water flow and steam flow varies almost simultaneously. The steam generators do not have enough water mass to deal with flow mismatches. In this control scheme, instead of a three-element controller with the level as the third variable, we have the feed water as the main control variable and the pressure as the goal.

One important task being conducted in the IRIS development is the analysis of the power operating modes. CNEN has started a work to develop a power level operational program that can fulfill the plant control demand with the additional objective of accommodating, if possible, all the volume variations of the primary system without any action of the "chemical and volume control system." This proposal considers the operation with a constant core outlet temperature for the medium-to-high power range, and at the same time maintaining constant the secondary pressure.

5.0 – RELAP 5 Transients and Accidents Analysis

CNEN team had received an initial IRIS modeling in the form of a RELAP5 input. IRIS development team decided to make all analyses based on RELAP5/3.2.2gamma.

The original nodalization was prepared for accident analysis, thus it is inadequate for operational transients. Minor problems were solved for initial tests but it was necessary to propose a new model, to be developed at a later stage. The remaining problems concern heat transfer from pressurizer bottom to reactor water and the internal nodalization of the pressurizer.

Besides the preliminary analyses, CNEN team developed an isolated model for Steam Generator analysis and another one for pressurizer analysis. Next action is to improve the pressurizer model, and integrate it with the reactor, pumps and steam generators models being developed by the Italian and American teams.

6.0 – Conclusions

Even in the nuclear energy field, the word that represents a global tendency is *cooperation*. IRIS is a real international cooperation effort to offer a nuclear system that can fulfill the world needs in power supply.

Such approach may be one of the best solutions to develop a commercially viable concept for developed and developing countries with large or small electrical grids. At the same time that the individual interests are considered, the synergistic effect contributes to increase the overall knowledge. The expected final result is to bring a real useful concept to all partners.

Since the time that CNEN had started to work in the IRIS development team, in July' 2001, the involvement of the three institutes of CNEN and NUCLEP, an effort coordinated by DPD, has grown in an harmonious way, creating several opportunities of research and increasing the Brazilian nuclear engineers knowledge.

This paper reported few of the most relevant characteristics of the IRIS design and a few activities being developed by the Brazilian team, as the pressurizer design, IRIS operating modes, and transient analysis with RELAP 5.

7.0 – REFERENCES

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