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IRIS PRESSURIZER DESIGN

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Abstract – *IRIS, the International Reactor Innovative and Secure, is an Integrated Primary System Reactor (IPSR) with innovative features that can meet most of the requirements considered in the Generation IV Roadmap Study. The IPSR concepts are characterized by the inclusion of the entire primary system within a single pressure vessel, including the steam generators and pressurizer. One of the challenges was the development of its internal pressurizer, which is located within the reactor vessel head, thus raising many interesting technical issues. This paper addresses technical challenges associated with the internal pressurizer, describes numerical tools and design calculations developed for these tasks, and presents the adopted solutions covering thermal-hydraulic design and fabrication issues.*

I. 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). These requirements are being addresses by the members of the Generation IV International Forum (GIF), for the Future of Nuclear Energy [1], including government organizations of the participant countries.. IRIS is a real international cooperation effort to design a reactor system capable of meeting most of these requirements. Westinghouse started the conceptual design of this new reactor to answer a DOE solicitation for what has later been called Generation IV nuclear energy systems. An important goal set forth from the beginning was to develop a commercially viable concept for developed and developing countries with large or small electrical grids.

One of the most important features in the IRIS concept is its "Safety by Design" approach, which takes maximum advantage of the integral reactor coolant system configuration to eliminate the possibility of some accidents, lessen the consequence of other accident scenarios and/or decreases their probability of occurring. To allow IRIS to achieve its safety by design goal while still meeting economic requirements,, specific components had to be submitted to special design analyses, which required the development of new design tools and models. One of these challenges was the development of the internal pressurizer, which is integrated into the reactor vessel head.

This paper discusses these technical challenges, describes numerical tools used for analyses, and presents design calculations. Many design solutions on thermal-hydraulic design and fabrication issues are discussed.

II. IRIS INTERNAL PRESSURIZER CHARACTERISTICS

IRIS is being designed to take full advantage of the integral reactor configuration in order to improve safety, reduce the site civil works, while improving plant availability. Fig. 1 shows the IRIS configuration: an integrated 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. The design of the reactor vessel and internals is discussed in detail in reference [2]. Reference [3] reports on the implementation of the safety by design approach in this innovative concept.

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Because the IRIS utilizes reactor coolant pumps that are located at a high elevation-in the reactor vessel for forced circulation through the core, and these pumps have a specific NPSH requirement for proper operation IRIS can not employ a simple self-pressurized system like the Otto Hahn [4] or CAREM [5] reactors. Initial studies have demonstrated that the best choice in such case is a pressurizer solution like those of a conventional PWR: a water-steam system, with the vapor formation accomplished by electric heaters. A gas-supported pressurizer has the great inconvenience of N2 absorption by hot water, with the associated problems of gas dissolution and accumulation in the colder regions of the system, and the reduction of the heat transfer effectiveness and even higher containment pressure due to gas evolution during postulated reactor depressurization events.

Since the coolant pumps in the IRIS design have a low developed head and they are pumping water that is at Thot conditions, it is difficult to implement an effective pressurizer spray for normal pressure reduction. However, the IRIS integral pressurizer makes possible, without any additional cost, the design of a much larger pressurizer system. As the surge flow - the pressure increase driver- is proportional to the power mismatch between reactor and steam generators, the maximum surge flow will be proportional to the nominal thermal power and the raw pressure smoothing capability of the pressurizer will be inversely proportional to the ratio reactor power and the pressurizer volume P0/Vp [6]. In the IRIS design, the relation of pressurizer volume to reactor power can be 3.4 times greater than a conventional 2-loop Westinghouse plant, 2.7 times greater than the AP600 advanced reactor, and more than 5 times greater than in the AP1000. This can provide enough margin to avoid the need of a pressurizer spray. The sketch of Fig. 2, which shows the IRIS internal pressurizer dimensions, shows why the IRIS pressurizer can be so large: *it can occupy almost the entire internal head space*.

As shown in Fig. 2, the pressurizer saturated water is separated from the reactor circulating, sub-cooled water, by an internal structure with an "inverted hat shape". The function of this structure includes: (a) preventing the head closure flange and its seals from being exposed to the temperature difference between the reactor and pressurizer water, thus reducing thermal stresses and maintaining sealing tightness; (b) it provides an effective thermal insulation to minimize heat transfer to maintain an adequate saturated water layer within the pressurizer; (c) it provides structural support for the CRDM drive lines, core instrumentation tubes, and heaters; and (d) it provides the communication flow paths between the reactor and pressurizer for the surge flows.

The closure head, as a part of the pressure retaining wall of the reactor pressure vessel, is designed as a Class 1 vessel according to the ASME Code Section III. The design data are presented hereinafter.

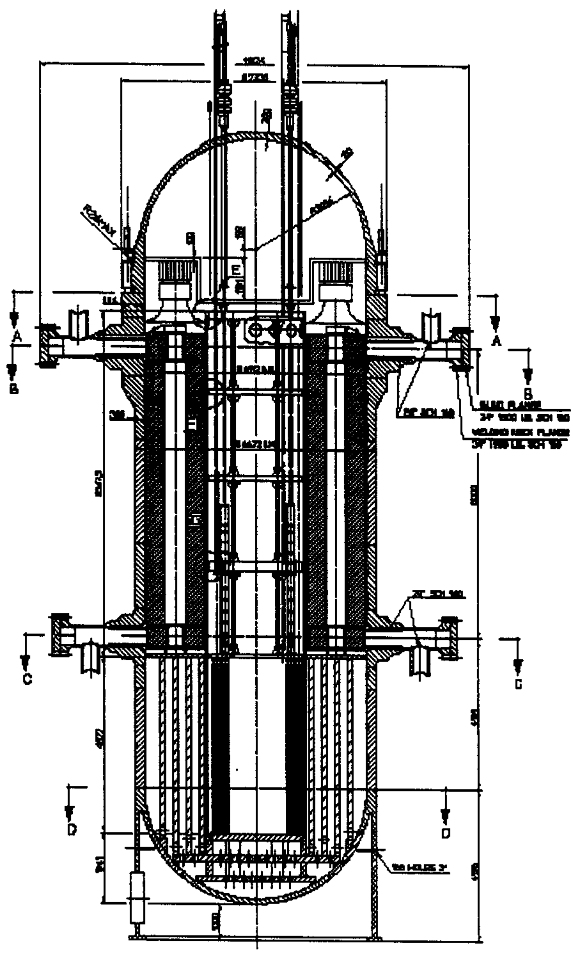

Figure 1 – IRIS: Integrated Primary Systems.

Design pressure:	17.24 MPa:
Design temperature:	353.4°C:
Inside diameter:	6,210 mm:
Inside height:	4,574 mm:
Cladding material:	Austenitic stainless steel:
Pressure retaining material:	SA 508 TP.3 CL.2;
Minimum cladding thickness:	6mm.

The low alloy forged steel SA 508 TP.3 CL.2 was chosen due to its acceptable strength at temperatures ranging from ambient to design values; high toughness properties, throughout the thickness of the required heavy sections; trouble free weldability for joint and clad welding; and high stability against neutron induced embrittlement. The plates of the divider/ thermal insulation, forged nozzles, and instrumentation and guide pipes are made of austenitic stainless steel. Forged SA 540 CL.3 steel was the choice for closure studs, nuts and washers.

The head is formed by three forged parts: the upper dome, the intermediate spherical ring, and the flange; and are joined by a full penetration narrow gap submerged arc welding. The internal surface is covered by a 6mm thick austenitic stainless steel cladding to assure the necessary protection against corrosion.

All penetrations of the closure head are located on the upper dome. There are 45 nozzles for control rod drive mechanisms (CRDMs), 90 nozzles for heating rods, and 48 instrumentation nozzles. To accommodate this requirement, the central region of the head forging, where the holes are located, has a thickness of 250mm whereas the external region is only 140mm thick, as shown in Fig. 2. All nozzles are made of austenitic stainless steel forgings and Inconel 690 is used to weld them to the internal side of the upper dome. The nozzles for the CRDMs and for the instrumentation tubes which extend through the head region have internal pipe extensions that go through the bottom plate.

The bottom of the pressurizer is manufactured from austenitic stainless steel plates and is joint welded to the upper part of the flange cylindrical shell extension. The thermal insulation is fixed on the upper surface of the bottom plate. The pipe extensions of the nozzles that go through the bottom plate are full penetration welded. This plate also has 8 surge orifices that are the only possible water passages from and to the cylindrical portion of the reactor.

The outer portion of the bottom plate (the brim of the inverted top hat) has a 560mm diameter manway, through which it is possible to access the interior of the pressurizer for inspection. It is interesting to note that the brim of the inverted top hat extends into the cap(the lower bottom cylindrical space) to provide support for the heaters assuring proper positioning and preventing vibration.

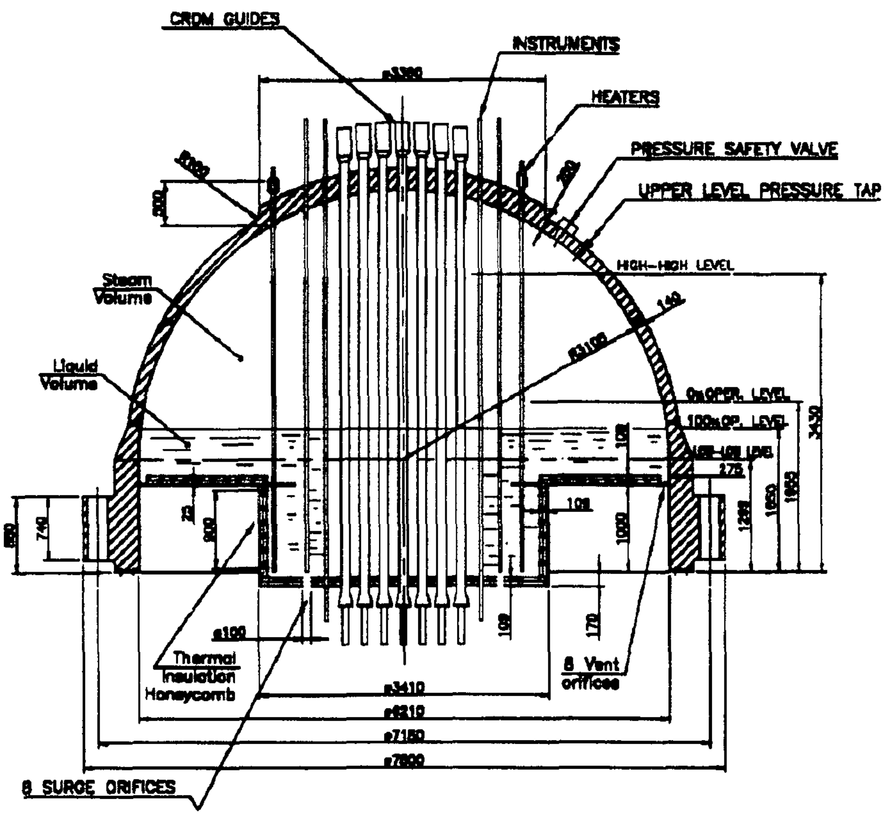

Figure 2 – IRIS Integral Pressurizer.

Transients which result in large and rapid pressurizer in-surge were simulated and reported previously 7, 8] for the purpose of analyzing the viability of the current pressurizer design with no spray capability. Simplified adiabatic models and also more realistic RELAP 5 mod 3.3 models were used and the results were more than satisfactory to go ahead with present design solution. The ability to cope with very large in-surge transients was tested using some very demanding cases, e. g. full load rejection, with a 1s delayed shut down (after the occurrence of the high pressure signal) and a 4s delayed actuation of the Passive Emergency Heat Removal System (PEHRS) for decay heat removal. The pressure response in all cases was kept within adequate limits and, even with no credit for any power operated relief valves actuation, the safety valve pressure set point was not reached.

Analyses indicate that in IRIS, in-surge transients promote a non-equilibrium stratification in the pressurizer, water in the entire liquid region is subcooled and steam within the upper region is superheated. When the transient driving forces have vanished and surge flow has substantially returned to its steady state value, the thermodynamic conditions in the IRIS pressurizer are further apart from the steady state ones than if there were a spray system. The reason this occurs is that the very effective homogenizing action of the spray – cooling the steam region and also promoting a mass flow of saturated water droplets into the liquid region – that reduces the temperature difference between the two regions does not occur. For this reason, the return to pure steady state conditions is more sluggish than if a spray system was present. How much slower to recovering the optimum conditions of the saturate layer is a question that is going to be answered later, when studying possible passive spray systems and with the use of higher fidelity models for the pressurizer. However this small unavoidable draw back of the current IRIS design does not affect the capability of the pressurizer to adequately cope, even when an out-surge operational transient happens after an in-surge transient.

Thus, it is clear so far that conventional pressurizer spray capability is not necessary in the IRIS, however special passive spray design concepts will be considered in future efforts. A research project will be conducted to investigate if such systems are in fact feasible for our design and if they are capable of providing a cost effective means of providing even better response to operational transients.

The pressurizer heaters are designed to create and maintain the saturated water layer and to produce enough steam to prevent a pressure decrease during increases in plant power. There are 90 electrical heaters providing a total heating power of 2430 kW in the IRIS pressurizer. They are grouped into three heater banks: a proportional bank with 459kW; a backup bank with 810 kW; and a second backup bank with 1161kW. For the initial analyses the heater bank control setpoints were not optimized, but a single set of reasonable control parameters was chosen.. The analysis results show that the proposed heater configuration, with even the simple controller setpoints, provide excellent response to adjust the pressure for any expected power level changes, with any reasonable power level vs. temperature programs for the reactor coolant.

CFD calculations [9] were performed to get some bound values for the effective thermal resistance of the simplified "honeycomb" insulation, that we are considering. A 1-D model was developed to analyze the heat losses from the pressurizer. Fig. 4 shows a picture of the interface of the 1-D Model and Fig. 5 shows the results for the product of the heat transfer area by the global heat transfer coefficient (UA). Thermal loss results and expressions from this model are fed into the dynamic models of the pressurizer for the transient simulations. An experimental setup was designed to provide measured values of the heat loss for different kind of thermal insulation devices under consideration.

III. Operational Transients and Numerical Tools

This paper will only discuss the normal operational transients specified for IRIS:

a) step load changes of plus or minus 10% of full power;
b) ramp load increases and decreases of 20% at 5%/minute.

Although the thermal-hydraulic code choose for the IRIS accident and transient analyses is the RELAP 5 MOD 3.3, the model prepared for accident analyses does not have the normal control setpoints needed for operational transients analyses. A simplified and specific tool was developed for this purpose. It was developed and implemented using a set of inter-related MS Excel and VBS macro programmed worksheets. Files generically named as IRIS-n.xls were organized to keep control of different pressurizer data and transient analyses. The most recent file created for this paper was labeled as IRIS-11.

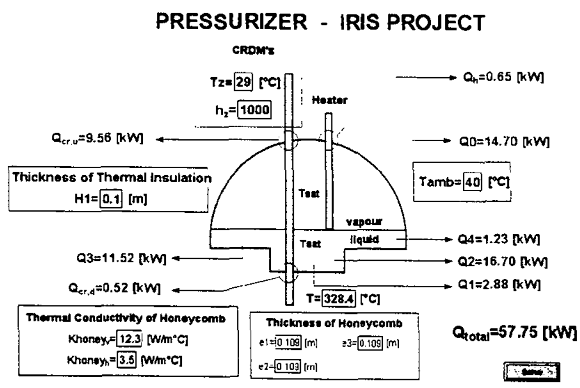

Figure 4 – HETRANS_PZ.exe Interface.

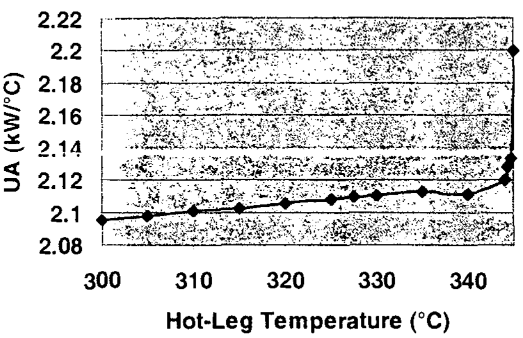

Figure 5 – Product UA: Heat Loss from the Pressurizer to the Reactor Water.

IRIS-11 contains several MS Excel Worksheets and Visual Basic Macros linked to allow a quick review of the pressurizer data and automatically run simplified analyses of its behavior under different temperature/power programs, reactor and control characteristics, pressurizer level programs and volumetric control system capacity.

The first Worksheet (Main Analyses) contains several conveniently labeled input and output cells. Most are used only to store nominal values. This worksheet is the main entrance for a transient analysis. The outputs are generated from formulas stored in this and several other auxiliary worksheets.

There are worksheets reserved to present time evolution graphical outputs such as: a) Reactor and SG power; b) Reactor temperatures; c) Thermal expansion; d) Pressure; e) Water level; and, f) Heaters' power; formulas used to calculate the transient response; the Temperature Program; Level Program; reactor data; a sketch of the pressurizer defining its main variables presented in the eighth Worksheet -PRZ Data- in which the pressurizer volume is calculated; two more worksheets reserved for the data used for water properties calculations; and, the steam generators data.

Fig. 6 represents the volumes considered in the reactor simplified thermal modeling that was coupled with a two-volume saturation-line model for the pressurizer.

The mass, energy and volume equations were written and programmed to analyze ramp transients. The 10% Step Load transients were simulated as fast ramps from 90% to full power and from full power to 90% just by inputting rates such as 3000%/minute. The ramp load increases and decreases at 5%/minute were simulated from 80% to full power and vice versa.

The ramps are applied to the thermal power at the secondary side of the steam generators and the control acts on the reactor power (reactor kinetics was not modeled in this initial phase). A simplified saturation-line model was used to account for the mass exchange between the liquid and steam regions of the pressurizer. The pressure, level and reactor power control strategies used will be described later.

Two power level operation programs were considered: a) constant Thot temperature (Fig. 7); and, b) sliding average temperature (Fig. 8). Both programs share identical full power thermal conditions.

Two pressurizer level programs were considered: a) a constant level set point at 1.65m, managed by a simple controller; and b) a constant mass program, but any kind of program can be inputted.

Different values of the manipulated variable were tested. The following were the two extreme situations considered in the analysis: a) no net flow from or to the volumetric control system (VCS), represented by maximum VCS flow set to zero; and b) a maximum net VCS flow of 2.0 kg/s. Of course the 0 net flow case cannot work properly with the constant level program of the pressurizer.

The proportional heater banks are operated by a PI controller and the two backup heater banks are actuated by an on-off with hysteresis controller type. On-off banks are not necessary in normal operating transients. The PI controller programmed is illustrated in the diagram of Fig. 9. It became apparent that for this IRIS pressurizer arrangement, the heat losses vary . depending on the hot leg and pressurizer liquid region temperatures, and the pressurizer pressure response can be substantially modified by the heater control parameters.

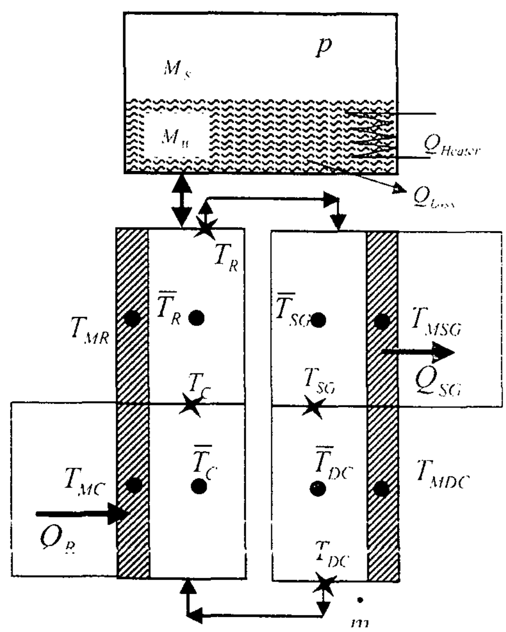

Figure 6 – Reactor Model.

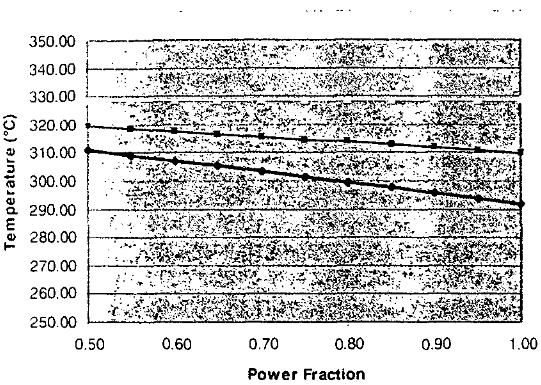

Figure 7 – Constant Thot Temperature Program.

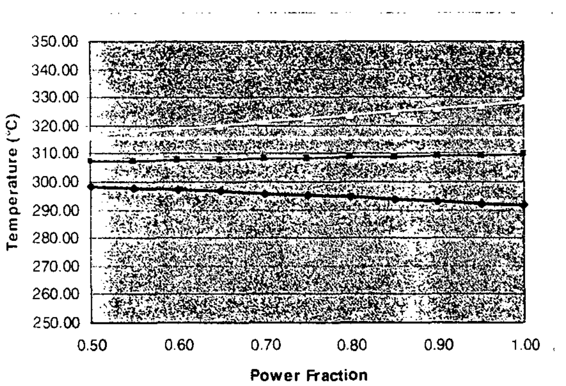

Figure 8 – Sliding Average Temperature Program.

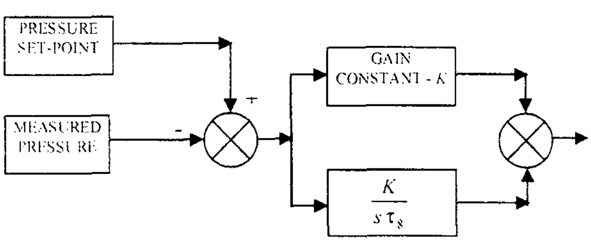

Figure 9 – PI controller for the Proportional Heater.

For the simplified model implemented as IRIS-11.xls and represented in Fig. 6, the reactor power in the energy equation is assumed to be directly applied to the whole mass of the core material and the heat transfer to the secondary system is a boundary condition in the steam generator energy equation. The equations in IRIS-11 are:

$$M_F\, C_F \frac{d\, T_{MC}}{d\, t} = Q_R - (UA)_{MC}\,(T_{MC} - \overline{T}_C) \qquad (1)$$

$$M_C\, Cp_C \frac{d\, \overline{T}_C}{d\, t} = (UA)_{MC}\,(T_{MC} - \overline{T}_C) + \dot{m}\, Cp_C\,(T_{DC} - T_C) \qquad (2)$$

$$M_{MR}\, C_M \frac{d\, T_{MR}}{d\, t} = -(UA)_R\,(T_{MR} - \overline{T}_R) \qquad (3)$$

$$M_R\, Cp_R \frac{d\, \overline{T}_R}{d\, t} = (UA)_R\,(T_{MR} - \overline{T}_R) + \dot{m}\, Cp_R\,(T_C - T_R) \qquad (4)$$

$$M_{MSG}\, C_M \frac{d\, T_{MSG}}{d\, t} = -Q_{SG} - (UA)_{SG}\,(T_{MSG} - \overline{T}_{SG}) \qquad (5)$$

$$M_{SG}\, Cp_{SG} \frac{d\, \overline{T}_{SG}}{d\, t} = (UA)_{SG}\,(T_{MSG} - \overline{T}_{SG}) + \dot{m}\, Cp_{SG}\,(T_R - T_{SG}) \qquad (6)$$

$$M_{MDC}\, C_M \frac{d\, T_{MDC}}{d\, t} = -(UA)_{DC}\,(T_{MDC} - \overline{T}_{DC}) \qquad (7)$$

$$M_{DC}\, Cp_{DC} \frac{d\, \overline{T}_{DC}}{d\, t} = (UA)_{DC}\,(T_{MDC} - \overline{T}_{DC}) + \dot{m}\, Cp_{DC}(T_{SG} - T_{DC}) \qquad (8)$$

The boundary condition is the steam generator power, programmed as a single ramp. The reactor power is controlled by a two-channel controller: Power + Mean Temperature channels. The mass flow rate is assumed to be constant and the pressure is uniform in each reactor volume.

The solution of the above equations is used to calculate the fluid expansion or contraction that feeds a simplified two-volume saturation-line model of the pressurizer to obtain the system pressure. This model considers the solution of energy, mass and volume conservation equations and also considers the heat loss from the pressurizer (assumed constant for now).

IV. TRANSIENT ANALYSES RESULTS

The 10% negative step load transient was analyzed with one set of control parameters and following the constant Thot temperature program of Fig. 7 and considering a constant water level program. Fig. 10 shows the steam generator (Q_{SG}) and the core thermal power (Q_R) evolution observed in the minus 10% step load. With the control parameters used, besides a fast and stable power response at the beginning of the transient, minor power instabilities can be observed at the end of simulation due temperature dead band effects. Fig. 11 shows the temperature results and Fig. 12 the pressure response, which show a fast, stable convergence to the programmed temperature and pressure without any overshoot. The results for the 10% positive step load are presented in Figures 13 to 15.

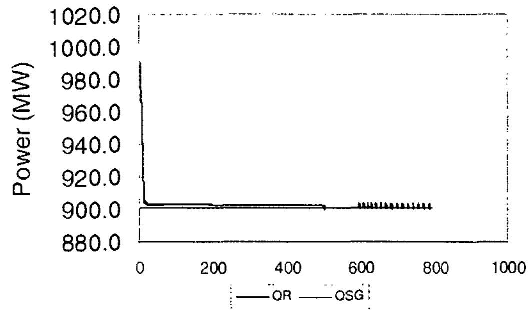

Figure 10 – Step Load of –10%: Power response.

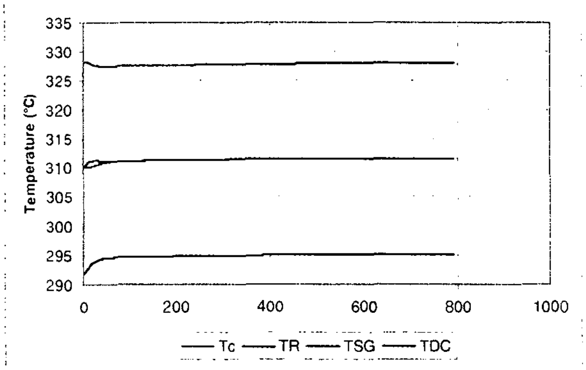

Figure 11 – Step Load of –10%: Temperature.

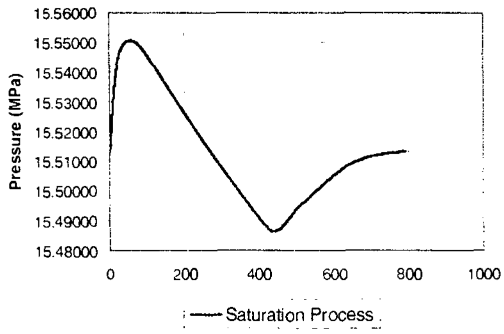

Figure 12 – Step Load of –10%: Pressure.

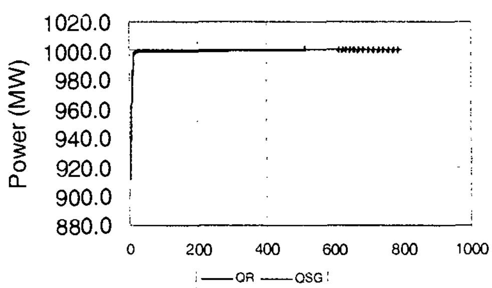

Figure 13 – Step Load of +10%: Power response.

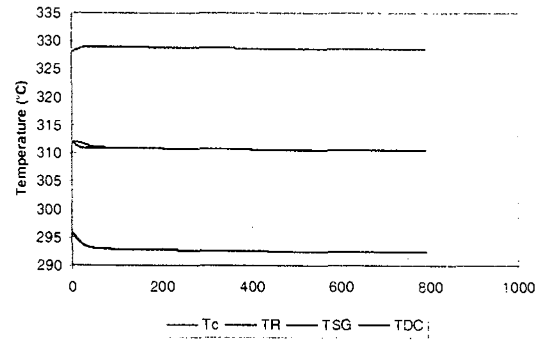

Figure 14 – Step Load of +10%: Temperature.

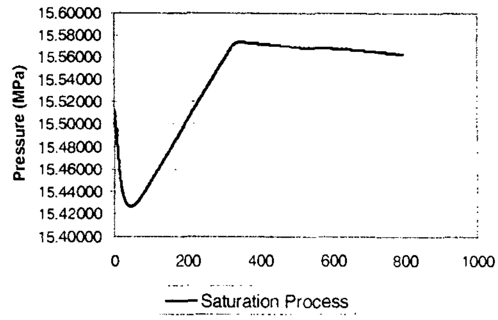

Figure 15 – Step Load of +10%: Pressure.

The pressure results for both transients show the excellent pressure smoothing capability of the pressurizer. In the case of the positive step load, Fig. 15 illustrates the slower return to nominal pressure (15.513 MPa) that is a consequence of the absence of a spraying system. This is an incentive to study methods to incorporate passive spraying. It is important to note that, even for the step load transients, the saturation model for the pressurizer can give good results because of the high IRIS inertia, which propitiates a slow temperature response; and because of the large pressurizer size, for which the -10% step load generates a water mass variation below 5% of the pressurizer water mass and less than 2% variation in the steam volume.

Similar results for the ramp load increases and decreases of 20% at 5%/minute are shown Figures 16 to 21.

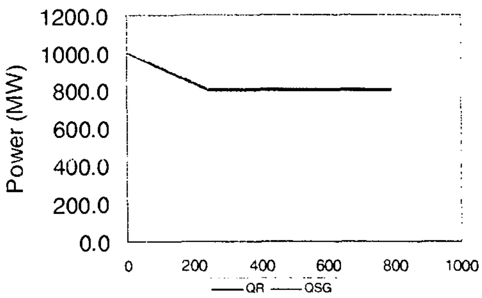

Figure 16 – Negative ramp load : Power response.

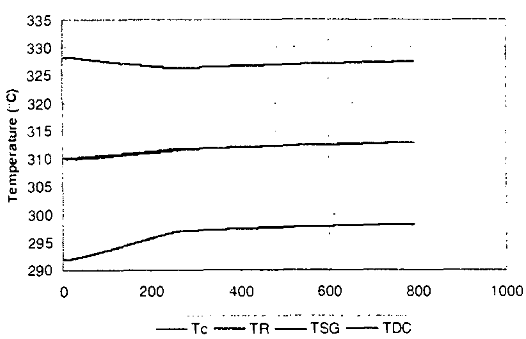

Figure 17 – Negative ramp load: Temperature.

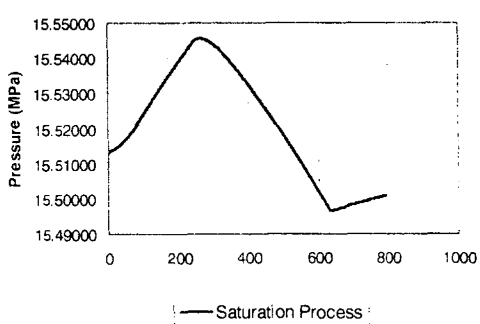

Figure 18 – Negative ramp load: Pressure.

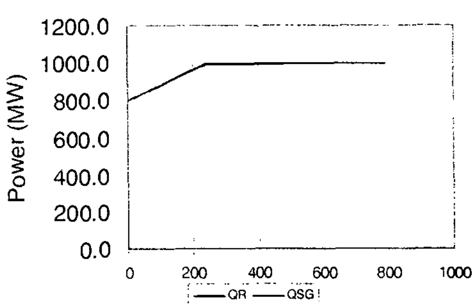

Figure 19 – Positive ramp load: Power response.

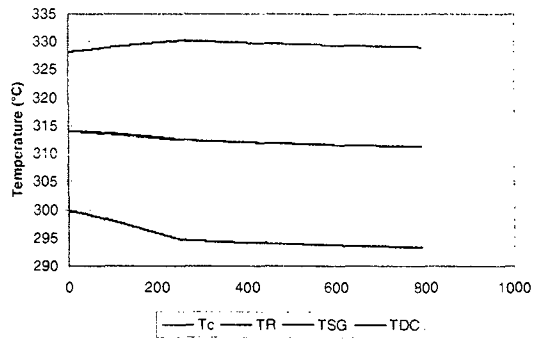

Figure 20 – Positive ramp load: Temperature.

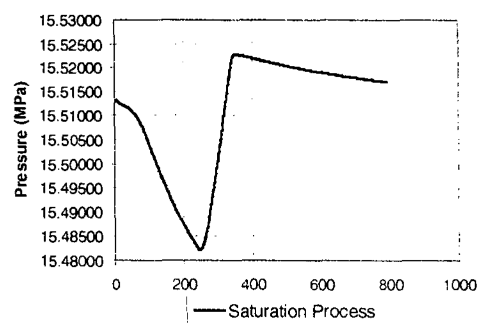

Figure 21 – Positive ramp load: Pressure.

V. CONCLUSIONS

IPSR concepts are characterized by the inclusion of the entire primary system within a single pressure vessel, including the steam generators and pressurizer. The development of an internal pressurizer raises many interesting technical issues, like the maintenance of the saturated water layer and the pressure control under different operational transients.

This paper identified most of the technical challenges of this development and presented results that demonstrate that the IRIS pressurizer system, although extremely simple, is able to deal with the main normal operating transients, even considering that the control parameters were not optimized.

Although extremely simplified, the numerical tools described provided a quick way to make design analysis, which are not simple to be performed with complex codes like RELAP 5. This kind of numerical tool can be considered a very good method to evaluate and establish workable design solutions during the initial phase of design.

NOMENCLATURE

C_F : specific heat capacity of the core materials,
Cp_C : mean specific heat capacity of the core water,
C_M : specific heat capacity of the stainless steel,
Cp_R : mean specific heat capacity of the riser water,
Cp_{SG} : mean specific heat capacity of the steam generators water,
Cp_{DC} : mean specific heat capacity of the downcomer water,

$\dot{m}$: coolant mass flow rate,
M_F : core materials mass,
M_C : core water mass,
M_{MR} : riser materials mass,
M_R : riser water mass,
M_{MSG} : steam generators materials mass,
M_{SG} : steam generators water mass,
M_{MDC} : downcomer materials mass,
M_{DC} : downcomer water mass,

Q_R : total power generated in the reactor core,
Q_{SG} : the heat transfer to the secondary water,

T_{MC} : core materials mean temperature,
$\overline{T}_C$: core water mean temperature,
T_{DC} : downcomer outlet water temperature,
T_C : core outlet water temperature:

$$T_C = \tfrac{1}{2}\left(\overline{T}_C + \overline{T}_R\right)$$

T_{MR} : riser materials mean temperature,
$\overline{T}_R$: the riser water mean temperature,
T_R : riser outlet water temperature:

$$T_R = \tfrac{1}{2}\left(\overline{T}_R + \overline{T}_{SG}\right)$$

T_{MSG} : steam generators materials mean temperature,
$\overline{T}_{SG}$: the steam generators water mean temperature,
T_{SG} : SG's outlet water temperature:

$$T_{SG} = \tfrac{1}{2}\left(\overline{T}_{SG} + \overline{T}_{DC}\right)$$

T_{MDG} : downcomer materials mean temperature,
$\overline{T}_{DC}$: downcomer water mean temperature,
T_{DC} : downcomer outlet water temperature:

$$T_{DC} = \tfrac{1}{2}\left(\overline{T}_{DC} + \overline{T}_C\right)$$

$(UA)_{MC}$: the product of the global core heat transfer coefficient with the heat transfer area,
$(UA)_R$: product of the global riser heat transfer coefficient with the heat transfer area,
$(UA)_{SG}$: the product of the global steam generators heat transfer coefficient with the heat transfer area,
$(UA)_{DC}$: product of the global downcomer heat transfer

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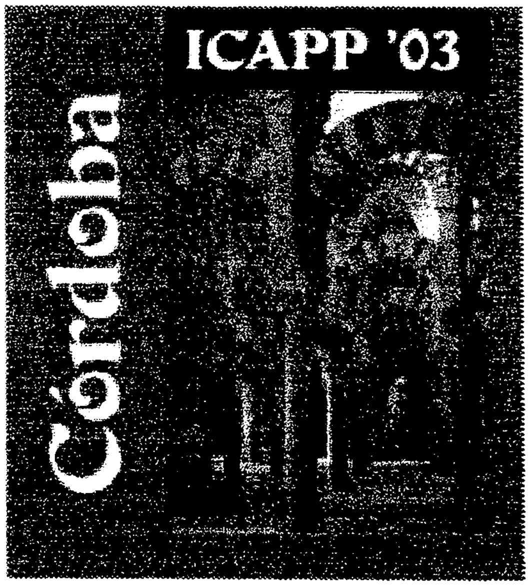

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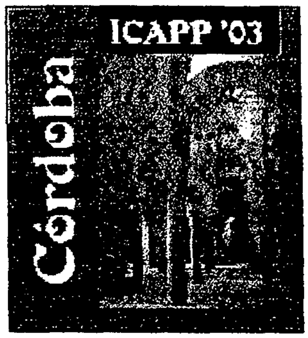

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ICAPP Topical Areas

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Abs.r = Abstract received awaiting review.
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Draft = Draft received - sent for review.
Revd. = Draft reviewed.
Final = Final paper received.
Cdrom = All materials received (electronic paper and copyright information...) at ICAPP office and final paper sent to CD Publication.

Up

0.00: Unassigned Abstracts/Papers

3366 Abs.r

Up

1.00: Water Cooled Reactor Programs and Issues

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1.01 Overall Status of All New Water-Cooled Reactor Programs
Monday, May 5, 2003 • 13:15 - 14:45

J. P. Py, *Framatome ANP*; , ; , France; Ph: 33 1 47960425 or 33 1 44837233 FAX: E-mail: jeanpierre.py@framatome-anp.com

3318	Cdrom	Design Rule Using North American Set of Codes and Standards for the EUR Document Safety Classification	1	3
3249	Cdrom	European Utility Requirements: Actions in Progress and Next Steps	1	3
3231	Cdrom	EPRI's Technical Path Towards New US Nuclear Plants	1	
3210	Cdrom	IAEA Activities in Technology Development for Advanced Water-Cooled Nuclear Power Plants	1	
3113	Pres.	Evaluating the Viability of Future Nuclear Developments in the United States	1	

1.02 Advanced PWRs: Developmental Stage
Tuesday, May 6, 2003 • 11:45 - 13:15

Dong Wook Jerng, *Korea Hydro & Nuclear Power Company (KHNP)*; Center for Advanced Reactors Development , NETEC, KHNP Munji-Dong 103-16 (KEPRI); Yusung-Gu, Deajon 305-380 Korea; Ph: 82-42-865-5710 FAX: 82-42-865-5704 E-mail: dwjerng@khnp.co.kr

3059	Cdrom	Design of the Reactor Pressure Vessel and Internals of the IRIS Integrated Nuclear System	3	
3047	Cdrom	The Feasibility of Using a 15 MW General Atomics TRIGA Core as an Autonomous Marine Power Supply (AMPS)		
3228	Cdrom	SCOR Simple Compact Reactor - An Innovative Medium-Sized PWR	1	3
3227	Cdrom	IRIS Pressurizer Design	1	
3201	Cdrom	Integral Layout of the IRIS Reactor	1	
3129	Cdrom	Status of Integrated Modular Water Reactor (IMR) Development	1	

1.03 Advanced PWRs: Conceptual Design/Basic Design Stage
Monday, May 5, 2003 • 15:00 - 16:00

Pierre Berbey, *Electricité de France / SEPTEN*; 12 avenue Dutrièvoz, ; Villeurbanne, 69628 &France; Ph: 33 47282 7135 FAX: 33 47282 7701 E-mail: pierre.berbey@edf.fr

3235 Cdrom Westinghouse AP1000 Advanced Passive Plant 1

3028 Cdrom The EPR – A Safe and Competitive Solution for Future Energy Needs

1.04 Advanced BWRs: Developmental Stage

Wednesday, May 7, 2003 • 16:15 - 18:00

Robert E. Gamble, *GE Nuclear Energy*; M/C 365, 175 Curtner Ave. ; San Jose , CA 95125 USA; Ph: 408-925-3352 FAX: 408-925-3991 E-mail: robert.gamble@gene.ge.com

3294 Cdrom Research and Development Program of Innovative Simplified and Severe-Accident-Free BWR by High-Performance Steam Injector System 1 6

3281 Cdrom Development of Medium Sized ABWR 1 5

3008 Cdrom A Small Modular Advanced Reactor Technology (SMART) 1

3275 Cdrom Development of Small Simplified Modular Reactor 1

3317 Cdrom ALWR Spanish Industry Participation in Their Construction Phase 1 3

1.05 Advanced BWRs: Conceptual Design/Basic Design Stage

Wednesday, May 7, 2003 • 10:00 - 11:30

Werner Brettschuh, *Framatome ANP GmbH*; NGPF, P.O. Box 101063 ; Offenbach, 63010 Germany; Ph: 0049 69 807 93527 FAX: 0049 69 807 94327 E-mail: Werner.Brettschuh@framatome-anp.com

3312 Cdrom Development of Next Generation BWR with Internal CRD 6 1

3222 Pres. SWR 1000: Framatome ANP's Boiling Water Reactor 1

3119 Cdrom ABWR-II Core Development: Economically Competitive 1700MWe BWR with Large Bundle Concept 1 7

3003 Pres. ESBWR – Towards the New Era of Nuclear Reactors 1

3353 Pres. Conceptual Core Catcher Design for Boiling Water Reactors 1.04b

1.07 Economics, Regulation, Licensing and Construction

Wednesday, May 7, 2003 • 11:45 - 13:15

Bob Twilley, *Framatome*; , ; , USA; Ph: FAX: E-mail: bob.twilley@framatome-anp.com

Layla Sandell, *EPRI*; 3412 Hillview Avenue , ; Palo Alto , CA 94304 USA; Ph: 650-855-2756 FAX: 650-855-2002 E-mail: LSANDELL@epri.com

3188 Cdrom The Business Case for Building a New Nuclear Plant in the United States 3 9

3009 Cdrom Co-generation Nuclear Power Plant with Innovative Simplified Passive Boiling Water Reactor VK-300 1

3043 Cdrom Regulatory Approach on Pool Temperature Limit of In-containment Refueling Water Storage Tank under Accident Condition 1

3241 Cdrom Advances in CANDU NPP Technology and Construction Techniques 1

3199 Cdrom A Report of the Latest Results of the Modularization: Technology in Nuclear Power Plant Construction

3062 Cdrom Nuclear Power Plant Construction for Advanced Concepts 1 2

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IRIS Pressurizer Design

(International Congress on Advances in Nuclear Power Plants – ICAAP'03)

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