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Double-Ended LBLOCA Containment Analysis in Trillo NPP with GOTHIC 8.1

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The radioactive material confinement in a nuclear power plant (NPP), , is a fundamental safety function to be ensured during a design basis accident (DBA). For plant licensing analysis, the containment is usually modeled with a lumped parameter approach. The assumption that within each region the fluid is well mixed is inherent to this approach. However, the containment is a large building with a complex configuration. It is distributed in several compartments that avoid the well mixing of the fluid and that provoke three-dimensional effects that affect the thermal–hydraulic behavior. Reactors like Trillo NPP are highly compartmentalized in order to reduce the dose to the personnel, in contrast with PWR-W reactors that present a more diaphanous layout. Accordingly, this kind of reactors are more liable to have three dimensional effects and/or local differences than a PWR-W. The collaborative project between the UPM and CNAT has enabled the development of highly detailed three-dimensional models of the Trillo NPP containment building. The objective of this study is the detailed 3D thermal-hydraulic analysis during a mass and energy release where local effects can be observed. Most of DBA analysis are performed using lumped-parameters models which only allow to know the average containment state, and that has several assumptions related with 0D models. For this reason a generic double-ended LBLOCA is simulated in a GOTHIC 3D model in order to study the local phenomenology occurring during this kind of transient.
Analyzing the results, an homogeneous pressurization over the whole containment can be observed, with the exception of the rooms near the break. This is predictable given that pressure is transmitted at the speed of sound. However, temperature evolution is different between compartments. Temperature behavior obeys to convective-diffusive processes, and it presents strong differences between compartments that cannot be seen with lumped parameters models. The steam residence time becomes one of the critical parameters in the containment thermal behavior, and this is strongly dependent on the building geometry.

1. INTRODUCTION

Loss of Coolant Accident (LOCA) and Main Steam Line Break (MSLB) containment accident are usually simulated in GOTHIC using Lumped Parameters Models (LPM), because these kind of models are considered adequate for licensing analysis [1, 2, 3, 4, 5]. However, in order to perform a detailed thermal-hydraulic analysis in each and every containment room, it could be necessary a three-dimensional model with a more realistic geometry representation [6].

The objective of the UPM-CNAT collaboration is the development of three-dimensional containment models with the GOTHIC code [7] for PWR KWU type Trillo NPP (CNT).

To better study the containment response to transients, several models were created for CNT. The main differences between those models is the nodalization scheme and the geometrical precision. On the one and, an integral model (DIM) has been created, and the whole containment is represented just in one subdivided control volume with a heterogeneous mesh. The DIM includes geometric modifications to adapt it to the mesh. This method has been denominated Geometric

Simplified Grid Adapted (GSGA), and allows a considerably reduction of the cells needed. On the other hand, a Multi-Zone Model has been done. In this model, 7 rooms are separately considered as control volumes and the two volumes of the integral model are present.

The goal of the analysis presented in this paper is to analyze the thermal-hydraulic containment behavior in a LBLOCA accident in the Detailed Integral Model (DIM).

2. LBLOCA SIMULATION

The postulated accident consist in a Doubled Ended Large Break Loss of Coolant Accident (DE LBLOCA) located in the cold leg 1. The input data has been extracted from published data [10, 6]. The location of the break will be in the lower part of the Steam Generator II cage, **¡Error! No se encuentra el origen de la referencia.**. The break is divided in two jets, one for each side of the break. One of the break is oriented to the vessel concrete shield, and the other part to the contrary.

The break has been modeled following existing methodologies for containment accident analysis [3, 4, 11].Two flow paths which connect two flow boundary conditions to the containment were used. As the break occurs in the cold leg, the flow path area is set to area is 0.38 m^2.

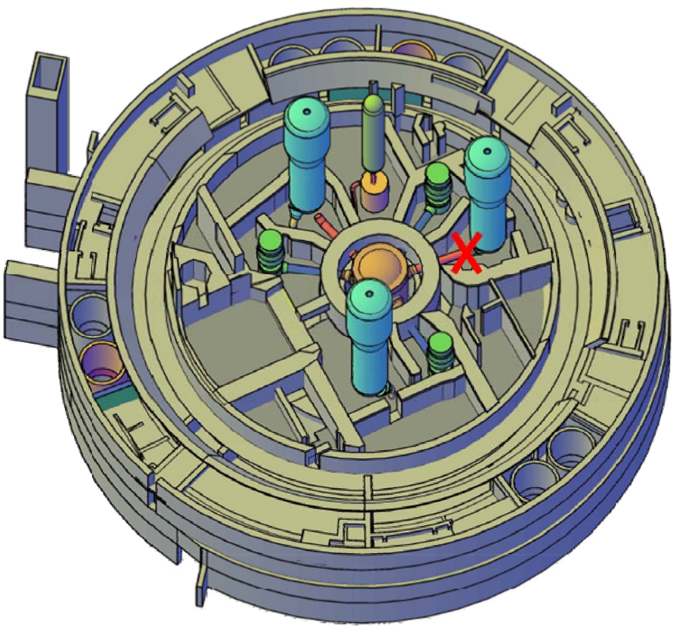

Figure 1. CNT break location

3. POST-PROCESING AND RESULTS

The output files generated by the GOTHIC models become an enormous quantity of data to analyze. Therefore, a specific tool, named ProTON, has been developed at the UPM to process the GOTHIC data. With this code, temperature and heat flux throughout the walls and compartment average pressure and temperature can be obtained. For a qualitative post-processing, the open source ParaView software is used.

In terms of pressure there is no difference between compartments except for the early peak produced in the SG2 cage (where the pipe break is assumed).

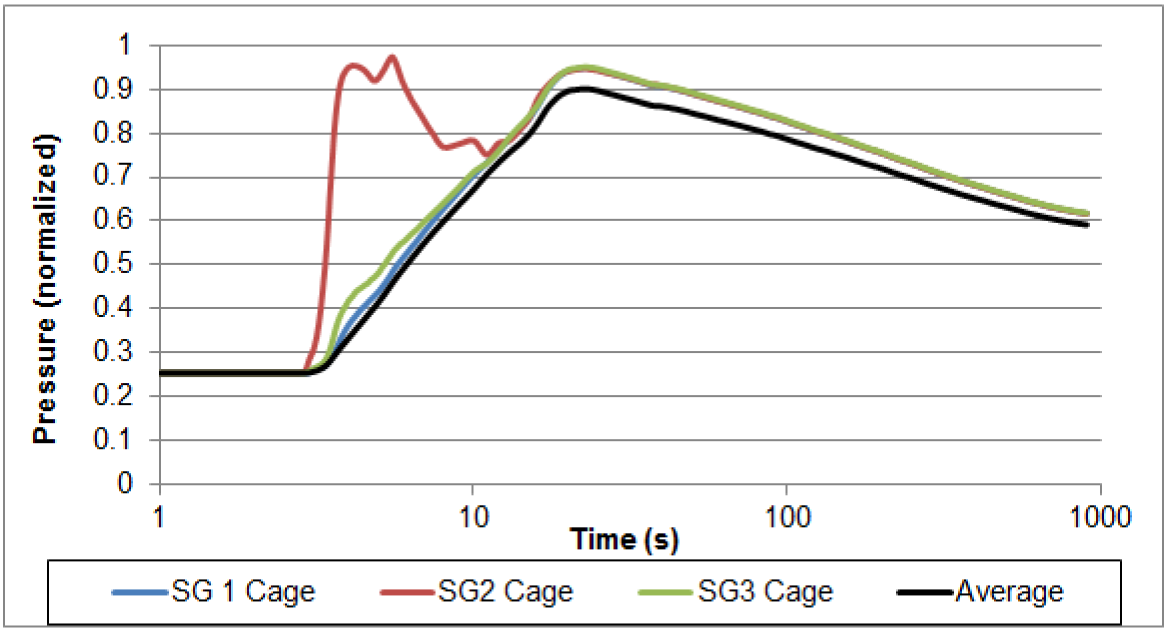

Figure 2: Pressure

The pressurization is almost homogeneous in the whole containment building. The peak value of these rooms occurs at 22.5 seconds, 20 seconds after the break started. There is an early peak produced in the SG where the break occurs, immediately after the start of the break.

There are temperature differences between rooms in the model (**¡Error! No se encuentra el origen de la referencia.**). The SG cages, which are linked between each other, have the same pressure behavior. Even though they present different temperature evolution schemes. The highest temperature peak has been registered in the SG2 cage. However, another earlier peak is registered, also in the SG2 cage, few seconds after the break. The reason is that the hot steam is introduced in this compartment at a high temperature, and during the first instants, the vapor tends to fill the room before escaping it. This can be seen in the streamlines and the velocities of the figures above (Figure 4 and Figure 5).

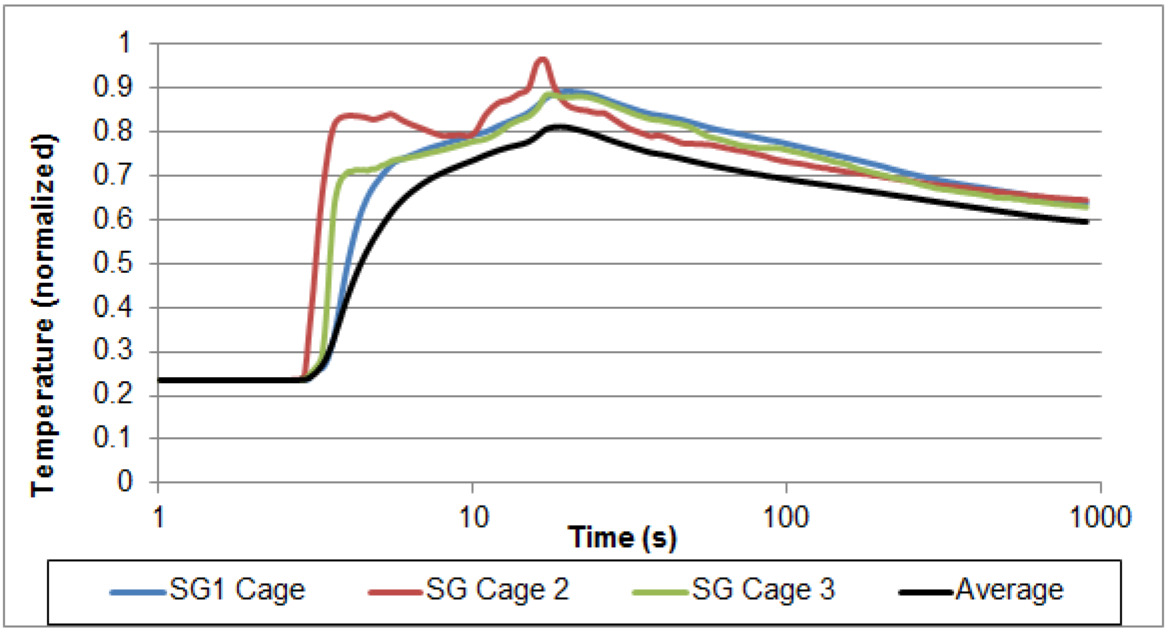

Figure 3. Temperature

The streamlines and the velocities indicate that the vapor has lower velocities (this is, higher residence time) in the broken SG than in the unbroken.

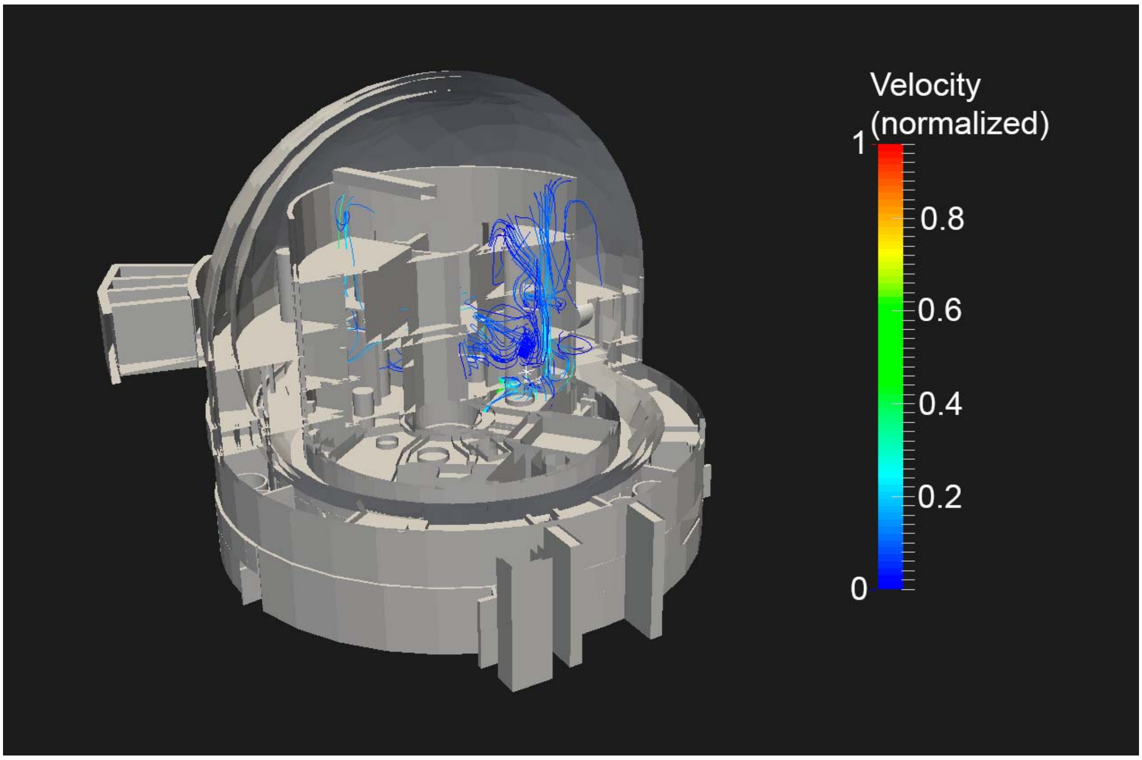

Figure 4. Streamlines of the vapor in SG II

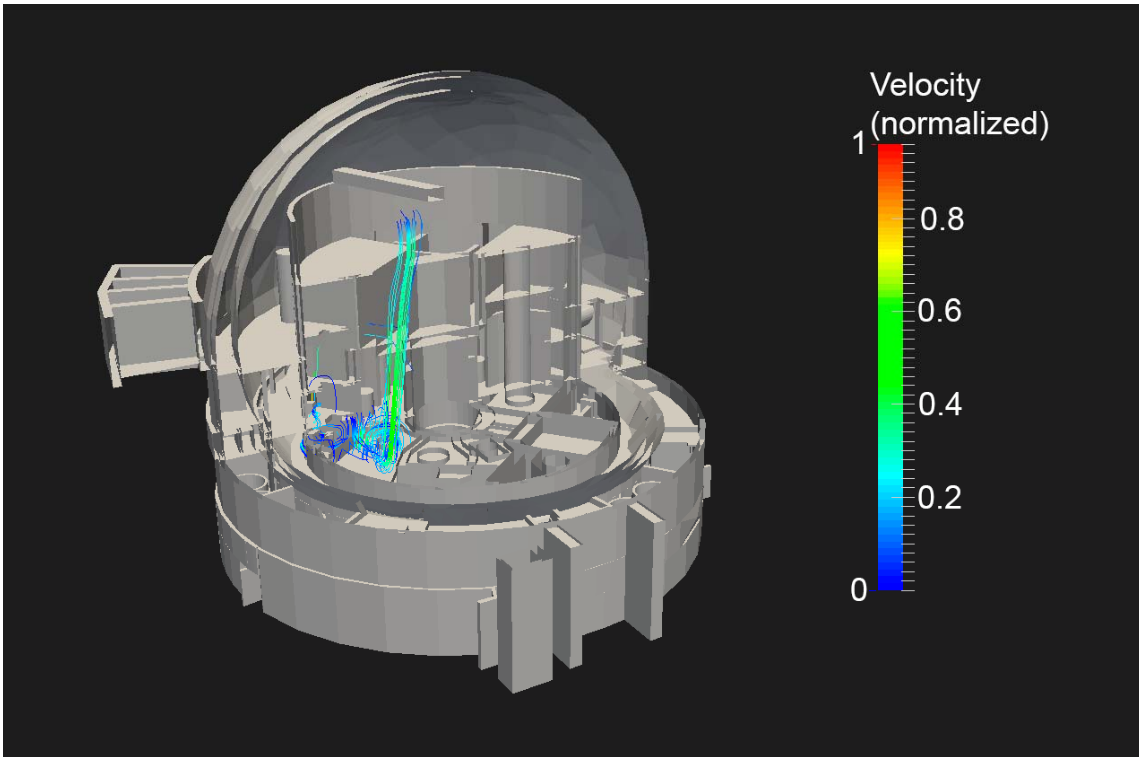

Figure 5. Streamlines in the SG III

4. FINAL REMARKS

The methodology used in [6] has been applied in order to develop GOTHIC 3D containment models for Trillo NPP.

A LBLOCA was simulated in order to compare the thermal-hydraulic behaviour. Can be conclude that there are several parameters in competence which highly affect the results in a containment accident analysis:

- The Integral model, because of the GSGA model it was based, has a lot of free cells with a thermal conductor attached to it. This means that the integral model has several conductors with a big hydraulic diameter, and a big hydraulic diameter make worse the heat transfer. This leads to higher pressures and temperatures in the integral model.
- Big cells have a bigger volume, therefore the thermal conductor can interchange heat with a bigger air–steam mixture mass and as a result this leads to a heat flux increase.
- The temperature behavior is also influenced by the building geometry. Different buildings with different geometric distribution will produce different flow currents and different steam residence time in compartments [6].

REFERENCES

[1] R. P. Ofstun and J. H. Scobel, "Westinghouse Containment Analysis Methodology," 2006.

[2] R. P. Ofstun and T. S. Andreychek, "WGOTHIC Application to AP600 and AP1000," 2004.

[3] Westinghouse, "Development and Qualification of a GOTHIC Containment Evaluation Model for the Prairie Island Nuclear Generating Plants," 2004.

[4] Framatome ANP, "Analysis of Containment Response to Postulated Pipe Ruptures Using GOTHIC," 2004.

[5] A. B. Wang, "Fort Calhoun Station, Unit 1, Issuance of Amendment 222, Authorizing Revisions to the Updated Safety Analysis Report to Incorporate the NRC Approval of the GOTHIC 7.0 Computer Program for Performing Containment Analysis," 2005.

[6] R. Bocanegra, G. Jimenez and M. K. Fernández-Cosials, "Development of a PWR-W GOTHIC 3D model for containment accident analysis," *Annals of Nuclear Energy,* no. 87, pp. 547-560, 2015.

[7] F. Rahn, "GOTHIC 8.0 (QA) Thermal Hydraulic Analysis Package User Manual," 2012.

[8] Empresarios Agrupados, «Estudio Final de Seguridad C.N.Almaraz, Recisión AC.30».

[9] Siemens, "Estudio Final de Seguridad C.N. Trillo".

[10] ENUSA, "LBLOCA Analysis in a Westinghouse PWR 3-Loop Design Using RELAP5/MOD3", NUREG-IA-0195, 2001.

[11] Westinghouse, "Development and Qualification of a GOTHIC Containment Evaliation Model for the Kewaunee Nuclear Power Plant," 2001.

[12] F. Rahn, "GOTHIC 8.0 Tech Manual," 2012.