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TRACE Model of Almaraz Nuclear Power Plant

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ABSTRACT

In the framework of several projects sponsored by the Spanish Nuclear Regulatory Commission (CSN) and the electric energy industry of Spain (UNESA), one of the most important objectives is the maintenance and translation of the Spanish NPP models between different codes, such as RELAP5/MOD3, TRAC-M and TRACE. In this context, the DSE-UPM group with the collaboration of Iberdrola Ingeniería and Almaraz-Trillo AIE, have carried out the translation from the RELAP5 model of Almaraz NPP, performed by Iberdrola Ingeniería, to TRAC-M and TRACE. This paper shows the results of different transient simulations. Though, we are in the first stage of validation, it is observed both a good behavior of the model and a good agreement with the plant data.

1 INTRODUCTION

In the framework of several national and international projects (ICAP, CAMP, CTC, SETH and CAMP2) sponsored in Spain by *Consejo de Seguridad Nuclear* (CSN) and the electric energy industry of Spain (UNESA), one of the most important objectives is the maintenance and development of the Spanish NPP models with the thermalhydraulic codes that are sponsored by NRC. As part of these activities, the Almaraz NPP model has been developed to several thermalhydraulic codes (Iberdrola Ingeniería: RELAP5/MOD3 [1] and TRAC-P [2]; DSE-UPM: TRAC-M [3] and TRACE [4]).

The conversion to the different codes, above mentioned, was performed in several steps. During the project *Consolidated Thermal-hydraulic Code* focused on the analysis of the capabilities of the TRAC-M code, the DSE-UPM group performed, among other activities, the conversion of a RELAP5/MOD3 Almaraz NPP model wich previously was made by Iberdrola Ingeniería, [5], to TRAC-M. [6], [7], [8] and [9]. In this model was taken into account that the input model also could be used with the TRAC-PF1 code. Finally, in the CAMP2 project (along the year 2005), the DSE-UPM group converted the TRAC-M model to the last code developed by the NRC, the TRACE code.

2 DESCRIPTION OF THE ALMARAZ NPP TRACE MODEL

The Almaraz NPP is a three loop Westinghouse design reactor. Calculations using the TRACE code were performed to simulate ten steady states at several power rates and the plant response to different transients. The TRACE model of Almaraz NPP, Figure 1, is composed of 252 termohydraulic components (1 VESSEL, 52 PIPE, 71 TEE, 41 VALVE, 3 PUMP, 20 FILL, 27 BREAK, 36 HEAT STRUCTURE and 1 POWER component), 685 signal variables, 1532 control blocks and 47 trips.

With regards to the primary circuit, the following components has been modelled,

- Reactor vessel, modelled by a VESSEL component, Figure 2,which includes the core region, guide tubes, support columns, core bypass, and the bypass to the vessel head via downcomer and via guide tubes.
- The three loops, with its pumps, steam generators and pressurizer in loop 2 (containing heaters, relief and safety valves and pressurizer spray system).
- Volumetric control system (CVCS).
- Safety injection system and accumulators.

With reference to the secondary circuit, the following components has been modelled,

- Normal feedwater and auxiliary feedwater systems of the steam generators
- The steam lines up to the turbine stop valves, with the relief, safety and isolating valves.
- The steam dump with the eight valves.

The control systems and protection and engineering safeguards systems-signals that were modelled are,

- Pressurizer level control: CVCS isolating discharge signal, CVCS charge flow and heaters.
- Pressurizer pressure control: including proportional and backup heaters, spray lines and PORVs.
- Steam generators level control system.
- Steam dump control
- Turbine control
- Protection and engineering safeguard system-signals:

  Emergency shutdown system (scram); safety injection; pressurizer safety valves logic; auxiliary feedwater system activation; relief, safety and isolating valves logic of steam lines; normal feedwater system isolation, turbine trip and pump trip.

3 STEADY STATE SIMULATION

Before simulating the different transients, ten steady states from 100% to 1% of thermal power were obtained in order to check the ability of the model in that power levels. Results of some important magnitudes at different power levels such as primary average temperature, secondary pressure and secondary mass flow are included in Figures 3 and 4 and Table 1. The simulation results show good agreement with the plant data.

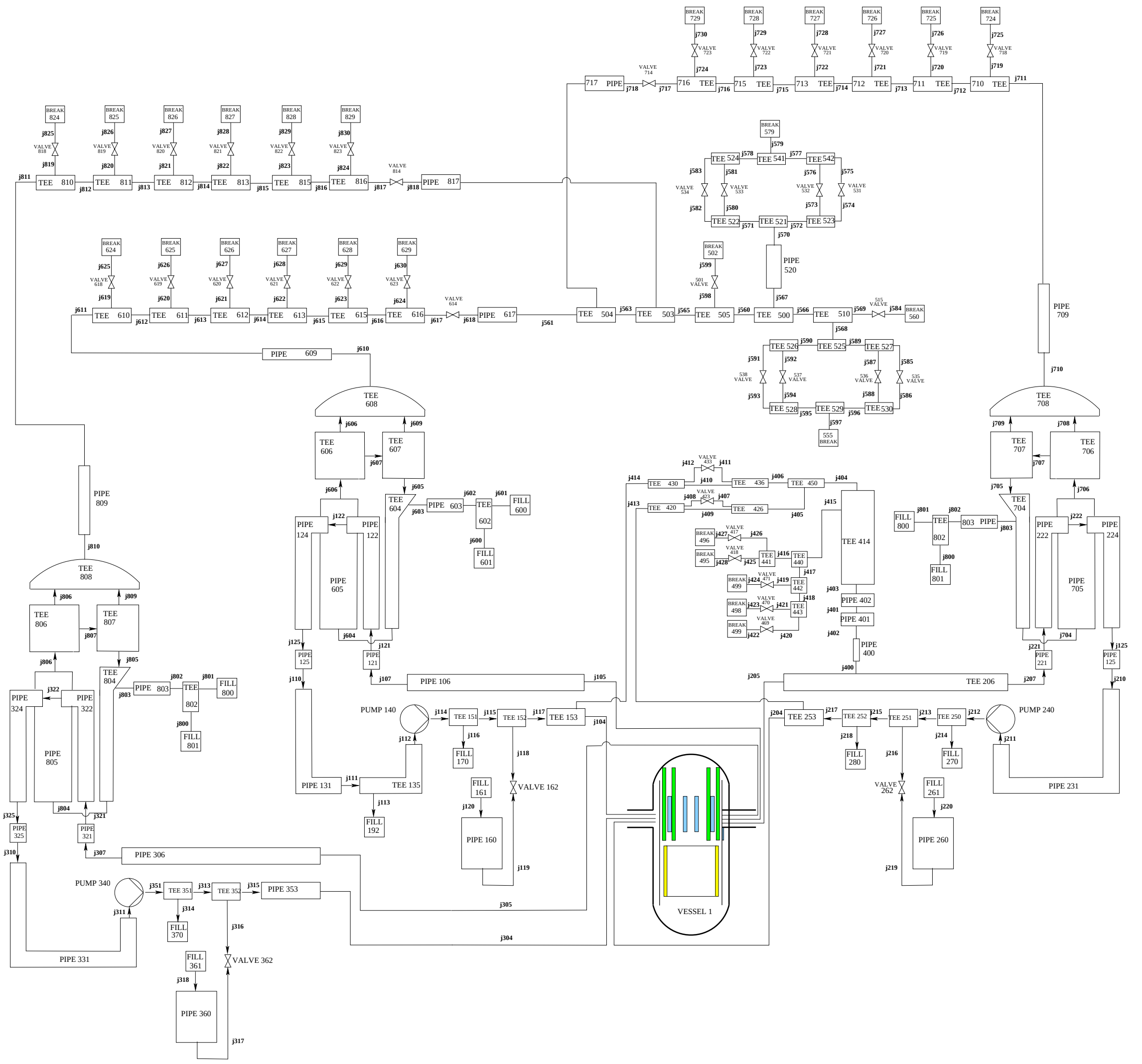

Figure 1: Nodalization of the TRACE model of Almaraz Nuclear Power Plant

4 TRANSIENT SIMULATIONS

Transient calculations were run for different cases. A first group of transients deals with turbine trips. Other transients developed are the opening of a pressurizer relief valve (SBLOCA) and the Main Steam Line Break (MSLB). The transients performed are,

- Turbine trip (TT)
- Turbine trip without steam dump (TT1)
- Turbine trip without steam dump or relief valves (TT2)
- Turbine trip without relief valves (TT3)
- Turbine trip without Auxiliary Feedwater (TT4)
- Opening of a Pressurizer PORV (SBLOCA)
- Main Steam Line Break (MSLB)

Other transients like *loss of feedwater* (LOFW), *inadvertent injection of ECCS* (ECCS), *load rejection* (LR) and *shutdown of the three RCP* (3RCP), are being performed by our group in order to validate the whole model of Almaraz NPP.

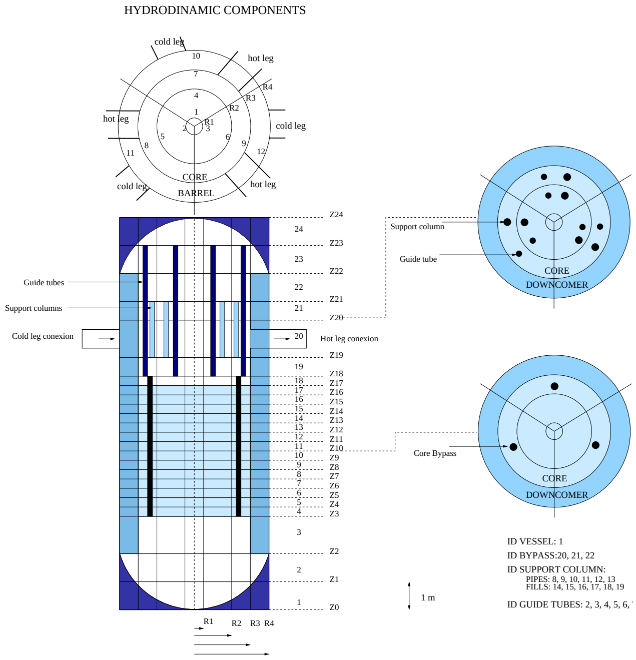

Figure 2: Nodalization of the component VESSEL of Almaraz Nuclear Power Plant

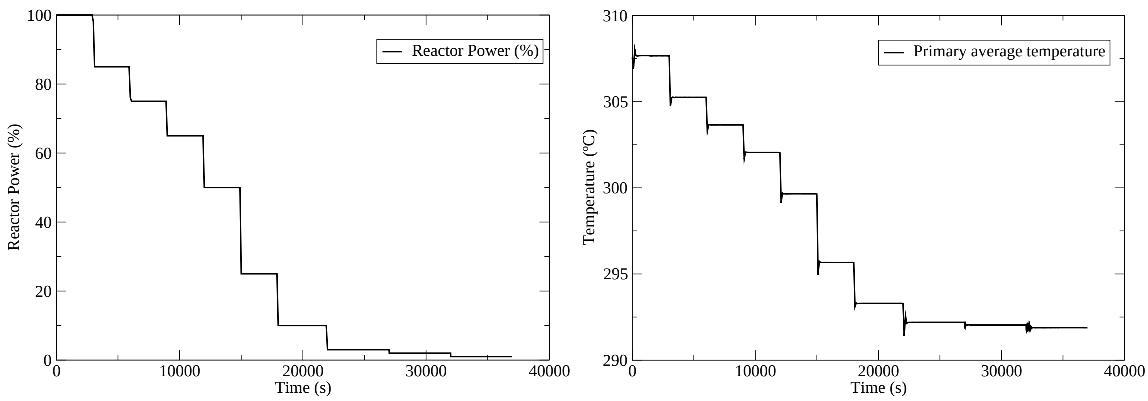

Figure 3: Different reactor power rates and primary average temperatures at these power levels

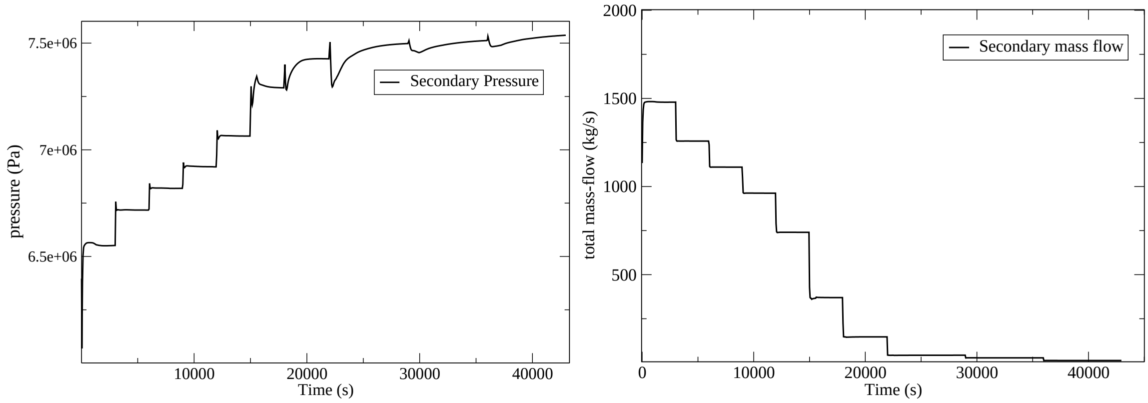

Figure 4: Secondary pressure and mass flow at different power rates

The whole set of transients will allow to check all the system models and signals included in the TRACE model of Almaraz, Table 2. The results of the simulations shows the behavior

Table 1: Steady states at different power levels

Power (%)	**100%**	**75%**	**50%**	**25%**	**10%**	**3%**	**2%**	**1%**
Steam flow (kg/s)								
TRACE	1488.24	1072.6	683.1	322.2	126.3	37.6	24.6	12.6
PLANT	1489.5	1072.8	683.1	323.4	126	37.8		
Primary flow per loop (kg/s)								
TRACE	4643	4648	4652	4654	4654	4654	4654	4652
PLANT	4650.4	4650.4	4650.4	4650.4	4650.4	4650.4	4650.4	4650.4
Average primary temp. (^oC)								
TRACE	307.6	303.6	299.65	295.6	293.3	292.15	292.03	291.8
PLANT	307.63	303.64	299.6	295.6	293.3	292.8	292.05	291.9
Recirc. Ratio of SG								
TRACE	3.6	4.73	6.72	11.37	22.5	45.8	58.02	85.9
PLANT	3.64	5.12	7.91	15.352	33.564			
SG Dome Pressure (bar)								
TRACE	68.22	69.85	71.52	73.3	74.45	75.13	75.31	75.48
PLANT	68.3	69.5	70.5	72	73.5			

Table 2: Systems which are actuated for the different transients

System/control		TT	TT1	TT2	TT3	TT4	MSLB	SBLOCA	3RCP	ECCS	LOFW	LR
Pres. Control	RV	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES
	Spray	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES
	Heat. Prop	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
	Heat. Backup	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	YES
SV-PZR		NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO
Lev. control	CVCS	YES	YES	YES	YES	YES	NO	NO	YES	NO	YES	YES
	Isolat.Disch	NO	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO
	Activ. Heat	NO	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO
	Disact Heat	NO	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO
Control rods		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
ECCS	HPIS	NO	NO	NO	NO	NO	YES	YES	NO	■	NO	NO
	LPIS	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	ACCS	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
RCPs		NO	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO
Turb. control		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES
Steam dump	T mode	YES	■	■	YES	YES	NO	YES	YES	YES	YES	YES
AFW		YES	YES	YES	YES	■	YES	YES	YES	YES	YES	YES
RV Secondary		YES	YES	■	■	YES	YES	NO	NO	NO	NO	NO
SV Secondary		NO	NO	YES	NO	NO	NO	NO	NO	NO	NO	NO
IV Secondary		NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO
Turbine trip		■	■	■	■	■	YES	YES	YES	YES	YES	YES

■ indicates failed system.

expected for the transients TT figure 5 and 6; TT1, TT2, TT3 and TT4 figure 7; SBLOCA figures 8 and 9; MSLB figures 10, 11 and 12, and it has been verified the appropriate actuation of the simulated systems of Almaraz NPP.

5 CONCLUSIONS

A TRACE model of Almaraz Nuclear Power Plant has been obtained, and it has been checked that the response of the plant to steady states and different transients has been satisfactory. Besides, a midloop model of Almaraz for analyzing transients in such conditions has been created. During the next months, more transients will be simulated and later on, simulation results of different scenarios will be compared with plant data.

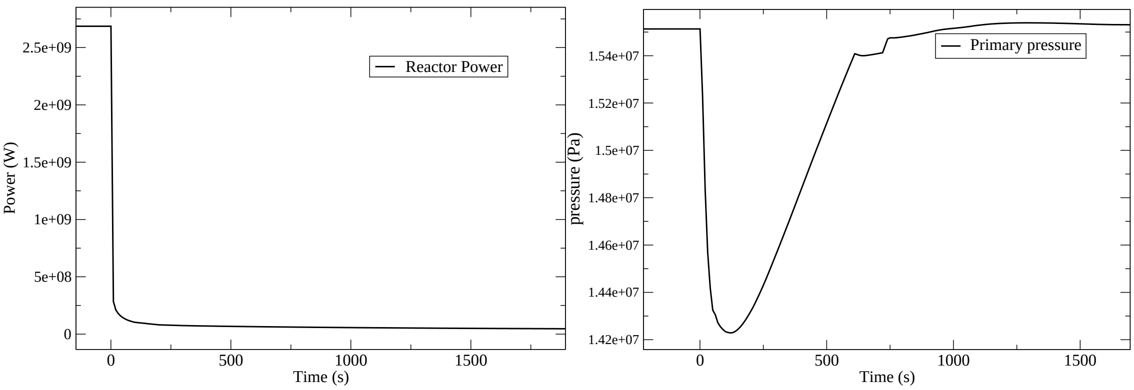

Figure 5: Reactor power and primary pressure in TRACE model of Almaraz NPP after a turbine trip (TT)

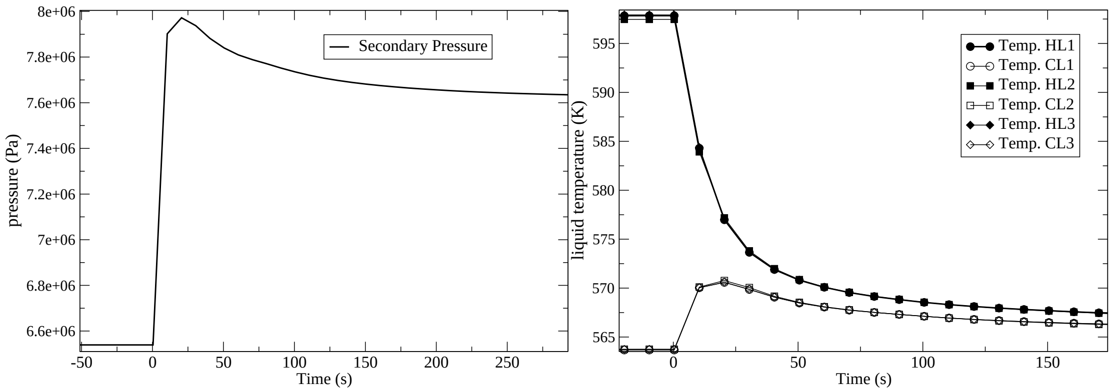

Figure 6: Secondary pressure and primary temperatures in TRACE model of Almaraz NPP after a turbine trip (TT)

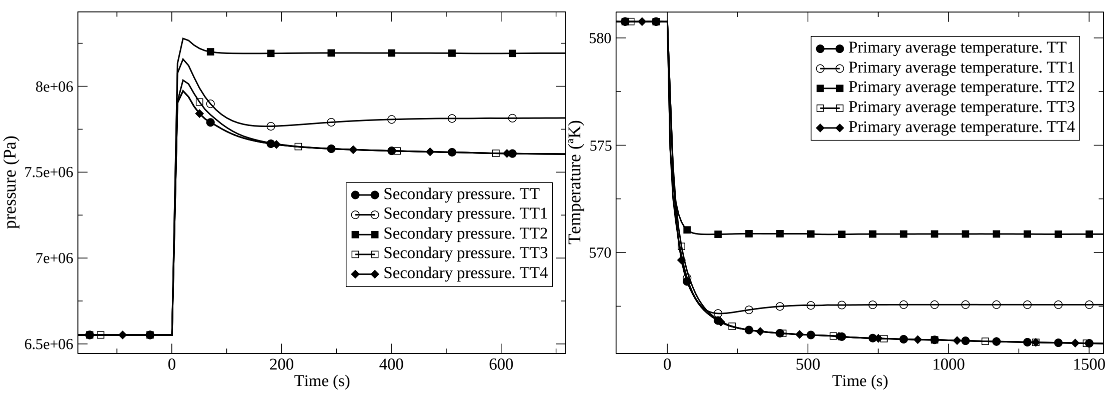

Figure 7: Secondary pressure and primary temperatures in TRACE model of Almaraz NPP after the different turbine trips performed

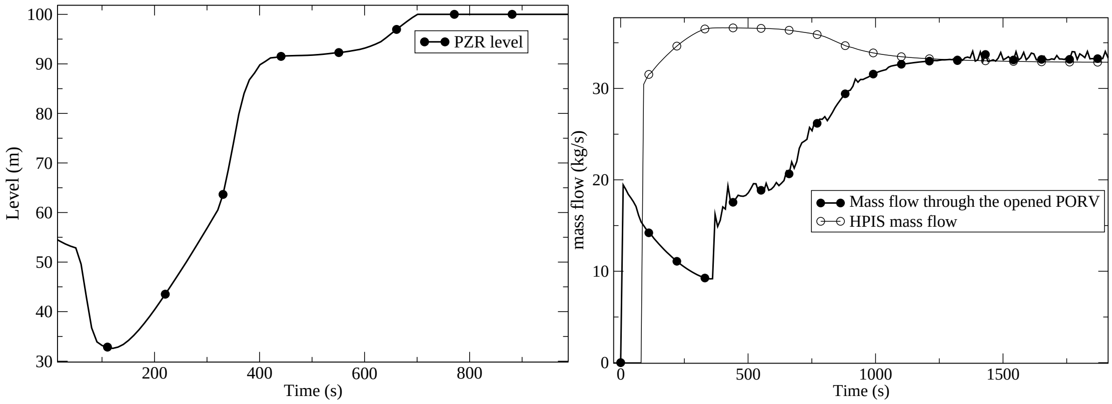

Figure 8: PZR level and mass flow through PORV and HPIS mass flow after SBLOCA

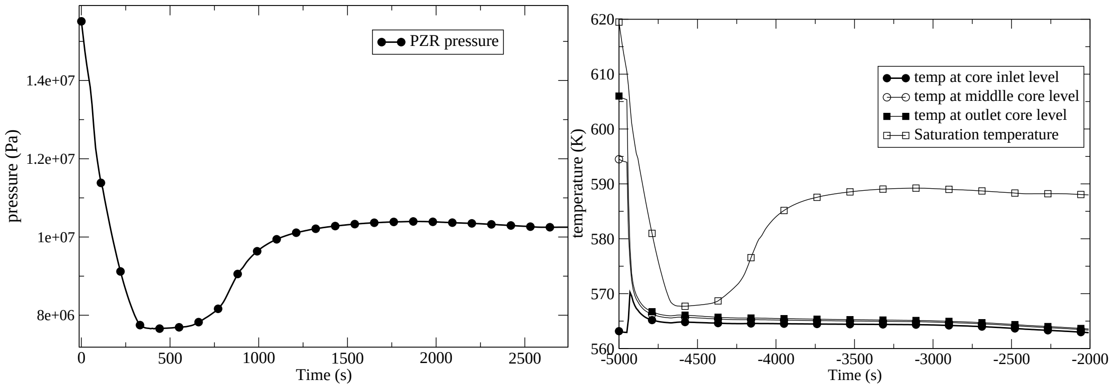

Figure 9: Primary pressure and liquid temperature at vessel region after SBLOCA

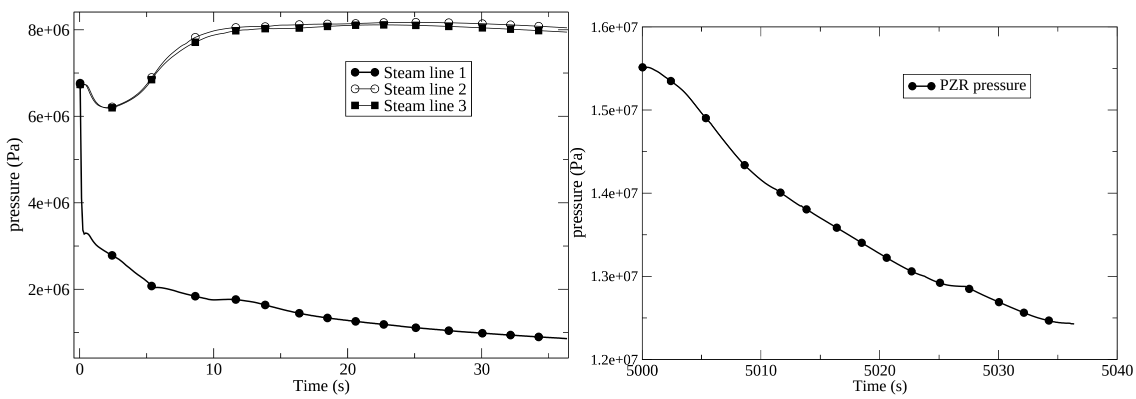

Figure 10: Primary and secondary pressure after MSLB

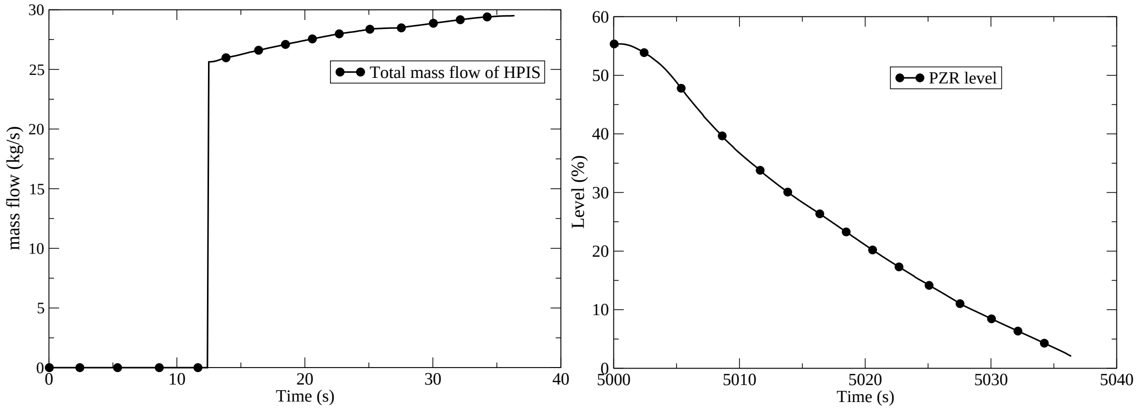

Figure 11: Total mass flow and pressurizer level after MSLB

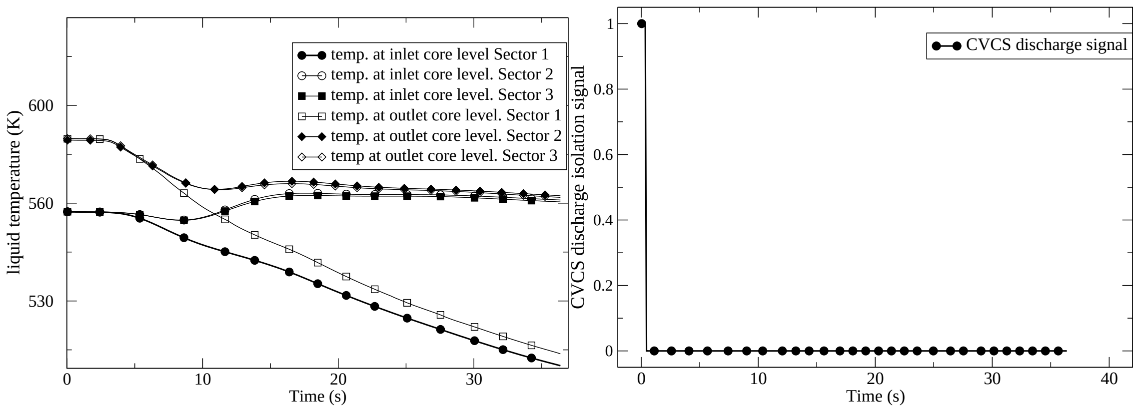

Figure 12: Liquid temperatures at vessel and isolation of the CVCS discharge mass flow after MSLB

References

[1] RELAP5 Code Development Team. RELAP5/MOD3 Code Manual VolumeII: User's Guide and Inputs Requirements. NUREG/CR-5535-V2. Technical report, U.S. Nuclear Regulatory Commission. Office of Nuclear Regulatory Research, 1995.

[2] TRAC-P User's Guide. Vol. II. Technical report, Los Alamos National Laboratory, 1996.

[3] TRAC-M User's Guide. Technical report, U.S. Nuclear Regulatory Commission. Office of Nuclear Regulatory Research, 2001.

[4] TRACE V4.0 User's Manual. Technical report, U.S. Nuclear Regulatory Commission. Office of Nuclear Regulatory Research, 2000.

[5] Iberdrola Ingeniería y Consultoría. Master Document for Almaraz 1 and 2 NPP RELAP5/MOD2.5 Simulation. Technical report, 2001.

[6] C. Queral, J. Mulas, I. Collazo, A. Concejal, and N. Burbano. Conversion of the Thermal Hydraulics Components of Almaraz NPP Model from RELAP5 into TRAC-M. In *Nuclear Energy for New Europe*, pages 0902.1–0902.8, 2002.

[7] C. Queral. Conversion of Almaraz NPP Model from RELAP5 into TRAC-M. In *2003 ANS/ENS International Winter Meeting*, 2003.

[8] C. Queral, J. Mulas, N. Burbano, I. Collazo, and A. Concejal. Conversion of the Almaraz NPP model from RELAP5/MOD3 to TRAC-M. DSE-02/02. PCI-CSN/UNESA *In spanish*. Technical report, Energy Systems Department, Nuclear engineering area. Polytechnic University of Madrid, 2002.

[9] C. Queral, J. Mulas, N. Burbano, I. Collazo, and A. Concejal. Problems Found in the Conversion of Almaraz NPP Model from RELAP5 into TRAC-M. DSE-01/02. PCI-CSN/UNESA. Technical report, Energy Systems Department, Nuclear engineering area. Polytechnic University of Madrid, 2002.