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Passive Autocatalytic Recombiner perfomance assessment using COCOSYS code

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1. Introduction

Severe Accident (SA) in Pressurized Water Reactor (PWR) are Beyond Design Basis Accidents (BDBA) that causes failures in structures, systems and components, that could not allow the reactor core cooling system to work perfectly and therefore lead to its degradation [1].

One of the consequences of a reactor core cooling system failure is the oxidation of the fuel rods and core components, which culminates in the formation of the hydrogen gas. The accumulation of this gas can cause a deflagration with possible Deflagration to Detonation Transition (DDT), challenging the integrity of the protection barriers between the nuclear reactor and the environment [2].

Among the main hydrogen mitigation devices for PWR containment are the Passive Autocatalytic Recombiners (PAR) and the igniters, which are proving to be the most used option for current designs and reactors in operation [3].

Considering the point of view of nuclear reactors safety analysis, this paper aim to perform a computational assessment of PAR performance using COCOSYS V2.4 code [4] by means of the HR-14 experiment carried out in the Thermal-hydraulic, Hydrogen, Aerosols and Iodine (THAI) test facility.

2. Methodology

The Hydrogen Recombiner (HR) tests carried out at the THAI test facility had the objective of forming a wide spectrum of benchmarks to verify the operational performance of the PAR units from the manufacturers: NIS, AECL, and AREVA, which contemplate practically all the existing PAR models [5].

The hydrogen and nitrogen injections, the layout of the HR-14 experiment, and nodalisation model developed in COCOSYS are show in Figures 1, 2, and 3.

The NIS-PAR model used in the HR-14 experiment was the NIS ⅛, also commercially know as NIS-PAR 11, which contains 11 cartridges coated with austenitic steel and filled with the catalyst material (aluminum oxide as carrier, and Palladium as catalytic coating) [5].

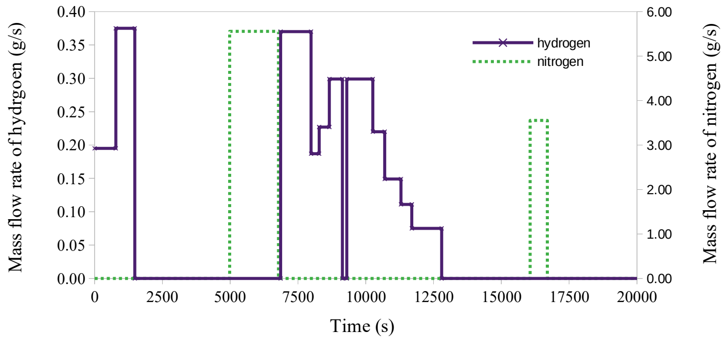

Figure 1: Hydrogen and nitrogen injection curve for experiment HR-14 [6]

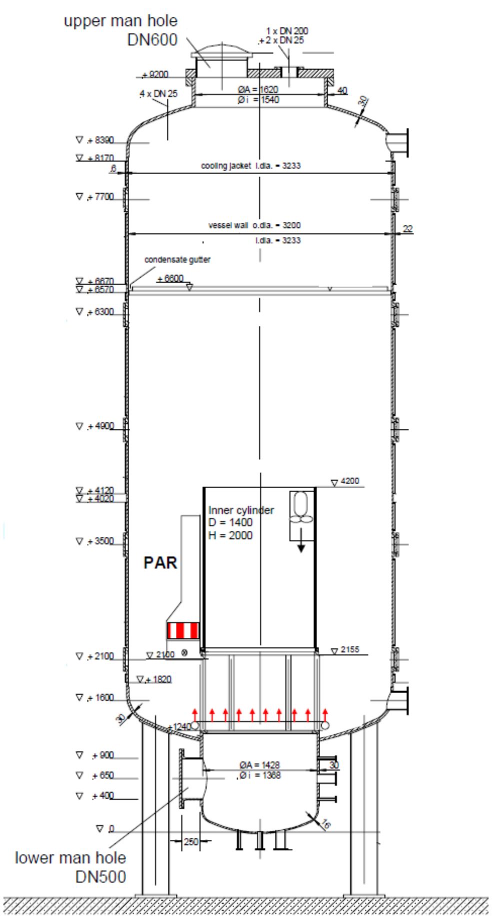

Figure 2: THAI installation overview for the HR-14 experiment [6]

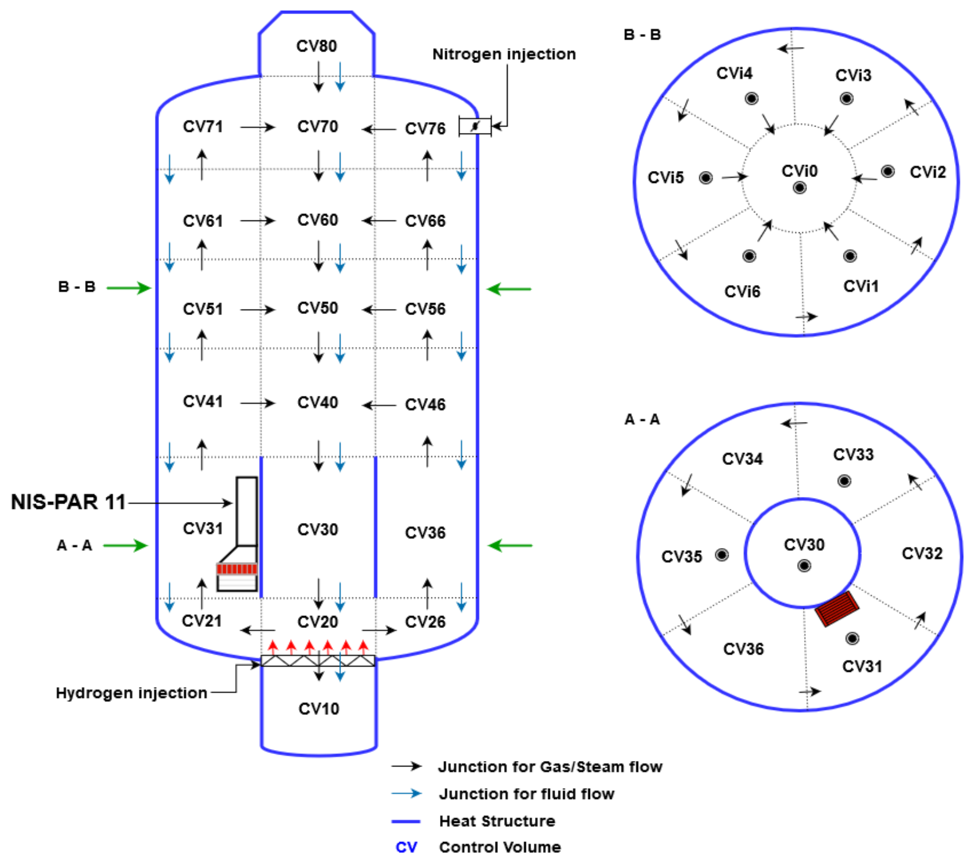

Figure 3: Nodalisation of THAI containment in COCOSYS V2.4

The THAI Containment was modeled in the COCOSYS V2.4 code with 44 Control Volumes (CV) distributed radially and axially as shown in Figure 3. The COCOSYS V2.4 deals separately with the transposition of fluids and gas/vapour, so the junctions are also presented between the control volumes for these types of flows. The heat structures (blue line) that represent the containment and the internal structures were modeled according to the information from the experiment.

3. Results and Discussion

Initially, the first test carried out with the computational model was the verification of the initial condition parameters of experiment HR-14, in order to reach the steady state conditions (Table 1). In addition, the model was tested for an interval of 500 seconds of computer simulation, and the stability of steady-state values was verified.

Table 1: Initial condition of HR-14 [6] and COCOSYS V2.4 calculation

HR-14 test	P (bar)	T (°C)	C_{steam}(vol.%)
Specified	1.500	74.0	25.0
Measured	1.442	73.5	24.2
COCOSYS V2.4	1.442	73.5	25.1

The HR-14 experiment at THAI was monitored by a large number of sensors that acquired data at different positions of its containment [5], however, as the main object of this work is to assess the performance of the NIS-PAR 11, the results that are presented (Figures 4, 5, 6 and 7) are related only to the Control Volume of PAR position (CV 31).

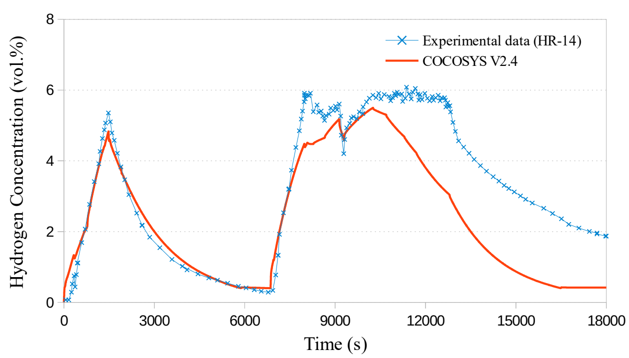

Figure 4: Hydrogen concentration inside containment (CV 31)

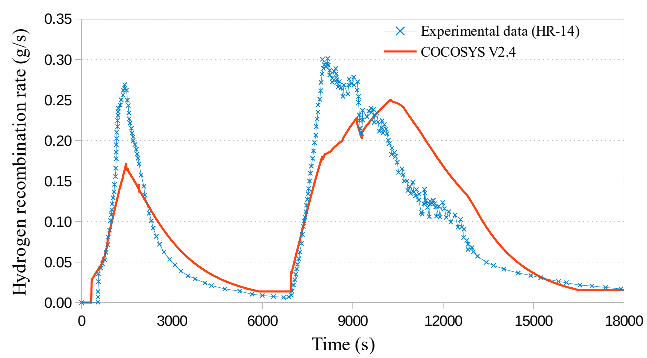

Figure 5: NIS-PAR 11 recombination rate

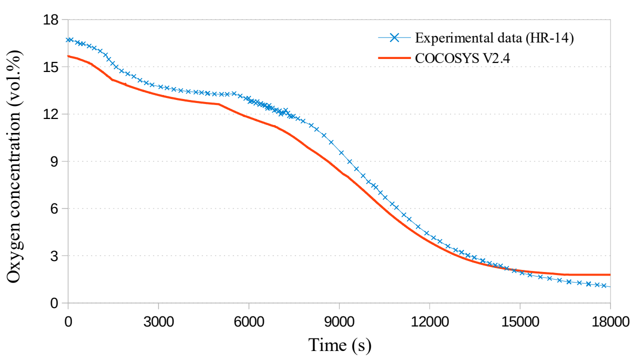

Figure 6: Oxygen concentration inside containment (CV 31)

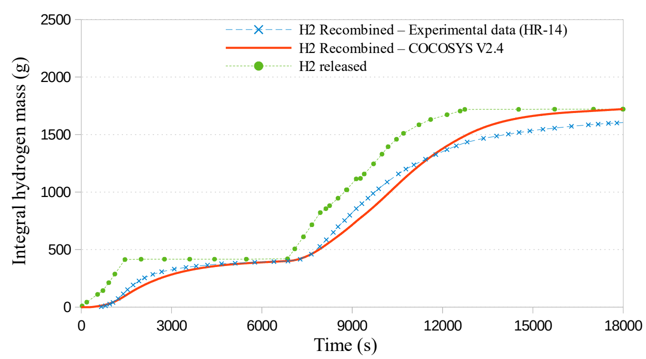

Figure 7: Integral H_2 masses injected and recombined

The NIS-PAR actuation in COCOSYS model was consistent with the experimental value (Figure 4), being a good parameter for analysis because a delay operation of the PAR can culminate in an increase of hydrogen concentration. As also seen in Figure 5, the first peak of the reaction rate was underestimated, due to escape of bright particles from the PAR housing at instants in the highest H_2 concentration as observed in the experiment, which justifies the assumption of an additional mass recombination that occurs outside the range of the catalytic plates [7]. After the first interruption of hydrogen injection, the hydrogen keeps consuming some of the available oxygen (Figure 6). At the beginning of the second feeding phase, the model is in agreement with the measurements, but when the hydrogen concentration becomes higher, the simulation deviates from the experimental values due to the absence of the model's capacity to interpret this additional gain effect of recombined mass.

4. Conclusions

The results for accuracy quantification obtained applying the Fast Fourier Transform Based Method (FFTBM) [8] show that the simulation reproduced with a good agreement the experimental data, as can be verified in Table 2, with all acceptability factors lower than 0.4, even considering the deviations observed during the assessment of the simulation results.

Table 2: FFTBM results

f_{cut} - Cut frequency (Hz)	0.011	0.022	0.033	0.044	0.056
AA_{tot} - Total accuracy	**0.324**	**0.336**	**0.343**	**0.348**	**0.351**
acceptability factor is $AA_{tot} < 0.4$					

References

[1] Comissão Nacional de Energia Nuclear (CNEN), Relatórios de Operação de Usinas Nucleoelétricas, Norma CNEN NN 1.14, Resolução CNEN 16/0, Publicação: DOU 10.01.2002 (2002).

[2] Institut de Radioprotection et de Sûreté Nucléaire (IRSN), Didier Jacquemain Coordinator, Nuclear Power Reactor Core Melt Accidents, Current State of Knowledge (2015).

[3] International Atomic Energy Agency (IAEA), TECDOC-1661-Mitigation of Hydrogen Hazards in Severe Accidents (2011).

[4] Gesellshaft für Anlagen- und Reaktorsicherheit (GRS) mbH, COCOSYS V2.4, User’s Manual. Revision (2016).

[5] Kanzleiter, T., Hydrogen Recombiner Tests HR-14 to HR-16 (Tests using a nis par), Areva, AECL and NIS PAR Comparison. Tech. Rep. 150 1326-HR-QLR-4, Becker Technologies GmbH (2009).

[6] Jaehwan Park, Gilbeom Kang, Yu Jung Choi, Development and Validation of the Passive Autocatalytic Recombiner Performance Analysis, 26TF International Conference Nuclear Energy for new Europe (2017).

[7] Gesellshaft für Anlagen- und Reaktorsicherheit (GRS) mbH. Weiterentwicklung der Rechenprogramme COCOSYS und ASTEC (2014).

[8] A. Proek, F. D’Auria, B. Mavko, Review of quantitative accuracy assessments with fast Fourier transform based method (FFTBM), Nuclear Engineering and Design 217 (2002) 179–206.