Detailed Assessment of Combustion Risk and PAR Efficiency in the Late Phase of a Severe Accident within the European AMHYCO Project

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ABSTRACT

The European AMHYCO project (Euratom 20192020, GA No 945057) aims at enhancing the understanding of H_2/CO combustion risk within the containment of a nuclear power plant in the late phase of a severe accident. The goal is to incorporate this knowledge into severe accident management guidelines and recommendations for long-term operation upgrades. Based on a critical review of existing methodologies and practices related to gas combustion risk, as well as the identification of accident sequences where the containment integrity may get challenged, experimental investigations were conducted to close knowledge gaps related to combustion characteristics and the operation of passive autocatalytic recombiner under late phase conditions.

To prepare the basis for the further assessment and refinement of existing SAMGs, systematic detailed analyses of the most challenging scenarios and possible mitigative measures were conducted for three generic European PWR containment designs, namely KWU, Westinghouse, and VVER. For each reactor type, one Loss of Coolant Accident and one Station Blackout scenario were selected for detailed analyses. Both scenarios cover a range of in-containment atmospheric conditions from potentially flammable at medium pressure to a steam-inertized atmosphere at high pressure, including the late phase with an active filtered containment venting system.

This paper outlines the employed methodology using a consecutive analysis chain consisting of three levels with increasing detail (system codes, 3D GOTHIC™ and CFD) to assess containment pressurization, efficiency and/or options of individual mitigation measures with respect to H_2/CO combustion risk and equipment and instrumentation survivability. As a common basis, the system code nodalization schemes and 3D models are developed from detailed CAD geometries. The paper summarizes the status of the work with a focus on the comparative assessment of the impact and effectiveness of mitigative measures (PARs, sprays, FCVS) on the combustion risk in the late phase. Concluding, challenges and lessons-learned are summarized.

KEYWORDS

AMHYCO, combustion risk, ex-vessel phase, Passive auto-catalytic recombiners, containment response, SAMG

1.0 INTRODUCTION

The severe reactor accident at the Fukushima Daiichi Nuclear Power Plant in 2011 has confirmed the need to develop a deeper understanding of the generation and distribution of combustible gases within the containment and connected compartments since their combustion can lead to dynamic loads on the containment structures and equipment and challenge containment integrity. While up to now, primarily the risk associated with H_2 combustion during the in-vessel phase was considered [1], the European AMHYCO project (Euratom 20192020, GA No 945057) [2] aims at enhancing the understanding of H_2+CO combustion risk within the containment of a nuclear power plant during the in-vessel (H_2) and during the ex-vessel (H_2+CO) phases of a severe accident (SA). A comprehensive analytical assessment of the containment behavior is conducted in AMHYCO Work Package (WP) 4 concerning:

- the H_2/CO combustion risk, e.g., flammability or potential of flame acceleration,
- the efficiency and options/timing of individual mitigative measures, including PARs, FCVS, or spray systems activation.

- and the equipment and instrumentation survivability and 'operators/control room view' on the containment status.

The analysis is conducted for generic European PWR concepts, W(French and Westinghouse designs), KWU (German PWR design), and VVER (Soviet/Russian design), to provide a database for a review and potential extension of the SAMGs and EOPs within WP5. For that purpose, WP4 utilizes scenarios selected in WP2 [3], existing empirical criteria and correlations supported by the WP1 literature review [4], and new correlations derived from experimental data on H_2/CO combustion [5] and PAR efficiency [6], [7] in the late phase, developed in WP3. In a nutshell, the integration of WP4 in AMHYCO is depicted in Figure 1.

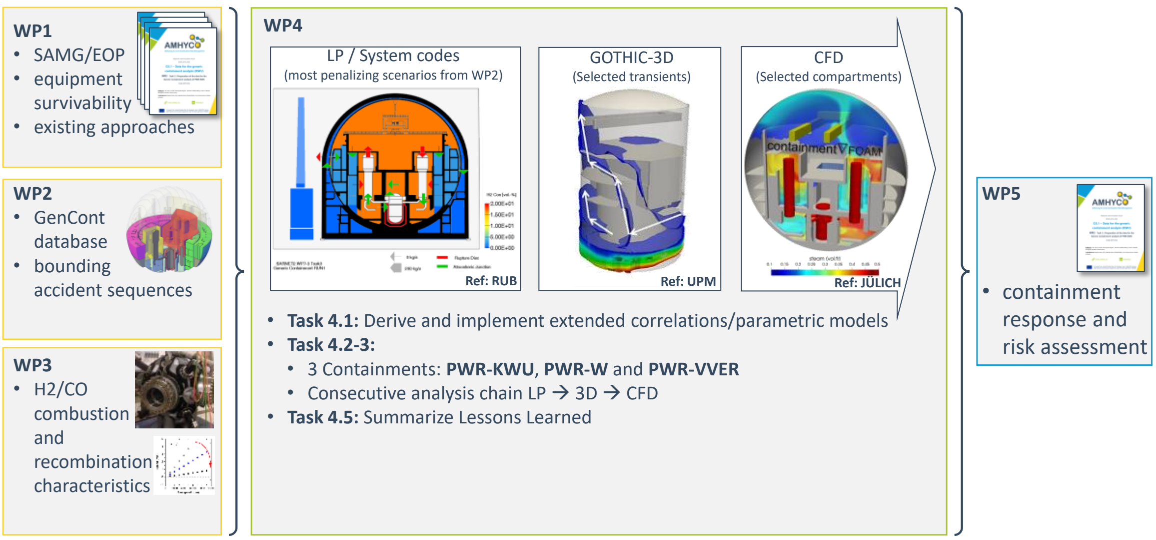

Figure 1. Integration of WP4 in the AMHYCO project

The preparative work in WP2 aimed at screening combustion risk in potential accident scenarios by using existing integral (in part non-public) plant models. As a follow-up, WP4's objective is to assess the containment response in more detail based on an open containment database. For that purpose, generalized nodalization schemes are employed to enable certain comparability of the simulation results as well as to pave the way for obtaining generic, i.e., non-plant-specific conclusions. Full containment analyses are conducted in a consecutive analysis chain, consisting of three levels of increasing detail:

- As a basis, the identified sequences are simulated completely with lumped parameter (LP) containment models e.g., built in AC^2/COCOSYS, SPECTRA, ASTEC or MELCOR.
- The most penalizing cases are additionally investigated with 3D models developed in GOTHIC™ to address potential asymmetric / 3D conditions that may lead to higher combustion risk.
- Finally, relevant compartments and/or time frames are simulated in detailed CFD-grade local containment studies to substantiate GOTHIC™ analysis and answer remaining open issues.

The increasing level of spatial resolution achieved with the different codes will also be utilized to assess the perspective on the accident from the control room (available instrumentation) against the full insights provided by the simulations to propose an upgrade of the SA instrumentation and the SA Management Guidelines (SAMG).

The basis for this comparative approach using different computational approaches relies on the generic containment nodalization schemes proposed in WP2, which were built from detailed 3D CAD models. Their consistent transfer to the employed LP codes together with the implementation of the mass and energy injection tables has been systematically verified using the unmitigated scenarios [8]. The converged containment models are used for the quantitative assessment of the impact and effectiveness of mitigative measures (PARs, sprays, FCVS) on the combustion risk in the ex-vessel phase. This paper summarizes the status of the work. Section 0 briefly introduces the characteristics of the SA scenarios selected from WP2. Within Section 0, the employed methodology is outlined. The combustion risk is assessed in Section 4.0 to provide a set of reference cases that will be used in the future to assess the impact and effectiveness of the mitigative measures on the combustion risk in the late phase. Concluding, Section 5.0 summarizes the current results and lessons learned from the analyses and outlines the future work.

2.0 SCENARIOS AND PARAMETRIC STUDIES

Within WP2, different sequences of the three European PWR designs, PWR-W, PWR-KWU, and PWR-VVER, were simulated with different system codes and different hypotheses, including the nodalization schemes used. These simulations cover several initiating events and involve diverse engineered safety features and SA management measures. The simulations were screened regarding the prevailing combustion risk to identify bounding scenarios for the detailed analysis of the containment response in WP4 [3]. For each containment type, two classes of scenarios were analyzed:

(1) A Loss of Coolant Accident (LOCA) characterized by a comparably early core damage and a large H_2 release, resulting in flammable conditions in the containment with a potential of flame acceleration when no mitigative measures or hardware is in place.
(2) A Station Blackout (SBO)/Total Loss of AC Power (TLAP) sequence, which results in delayed core damage and release of H_2.

For the LOCA scenarios, the size and break location were varied, and for the transient SBO accident, the boundary conditions, such as primary loop depressurization, were varied to determine the accident sequence bounding with regard to hydrogen risk. The in-vessel hydrogen release path into the containment is quite different in both types of sequences. In case of a LOCA hydrogen is released through the break location whereas for the SBO the release path is via the pressurizer relief tank to the containment. After RPV lower head failure, the molten corium-concrete interaction (MCCI) generates additional H_2 and CO. The main characteristics of the selected sequences for the specific PWR designs are briefly summarized in the following [3]:

PWR-KWU design:

- Medium-break (MB) LOCA (80 cm^2, behind the main coolant pump in the cold leg of the pressurizer loop) with a limited water injection by the extra borating system (MBLOCA+ECCS). For this sequence all active emergency injection systems, which would prevent the escalation into a nuclear accident, are postulated to fail. Only the hydro accumulators can inject their inventory. After the water level inside the pressurizer falls below a threshold, the extra borating system starts injecting water with a limited injection rate over a period of 2.5 h, which slightly delays the core uncovery but is insufficient to stop the accident. Core degradation begins after approx. 5.3 h. The delayed accident progression [9] poses a slightly higher combustion risk due to increased condensation in the containment. With a predicted RPV failure after ~6.5 h, the release of H_2 and CO by the MCCI starts. Within the transient, a total amount of ~1500 kg H_2 and ~7500 kg CO are released.
- TLAP with delayed Primary System Depressurization (PSD). The primary system is depressurized 30 mins after reaching the SAMG criterion “Core Outlet Temperature >650 °C” by opening all three pressurizer safety valves. This results in a large mass of H_2, which is initially stored within the primary loop and then released rapidly to the containment. RPV failure occurs after approx.

10 h. Within the considered problem time of 72 h a total amount of ~2300 kg H_2 and 25000 kg CO are released.

PWR-W (Framatome and Westinghouse designs):

- Large-break (LB) LOCA in the hot leg (PWR-W-1000) without availability of auxiliary feed water and safety injections, except for accumulators. Due to the fast core uncovery and depressurization of the reactor cooling system, the core degradation begins already 20 mins after the initiating event. The RPV failure occurs ~2.7 h and at about 6 h the corium in the cavity gets completely oxidized. Activating the containment spray systems (fan coolers are not used in the reference case) significantly reduces the pressure before the generation of non-condensable gases by MCCI leads to a continuous depressurization. At around 2 h, the spray operation is switched to recirculation mode, which reduces their efficiency. The high release rate of hydrogen in the in-vessel phase and the significant drop of steam molar fraction due to the actuation of the spray systems lead to flammable conditions at the end of the in-vessel phase. The further release of combustible gases during the ex-vessel phase leads to a concentration maximum at about 6 h, while the subsequent CO_2 generation results in a certain dilution of the mixture. Within the considered problem time of 48 h, a total amount of 1000 kg H_2 and 13000 kg CO are released.
- SBO with loss of all offsite power (scaled from PWR-W-1300 to the generic PWR-W-1000). All active safety systems (e.g. sprays, emergency core cooling, cavity flooding) are unavailable. Steam and hydrogen release to the containment after rupture of the pressurizer relief tank burst discs after around 2.5 h. The pressurizer relief valves lock open after approx. 4.5 h. The loss of coolant is partly compensated by accumulator injection at 4.75 h. The ex-vessel phase begins with RPV failure and melt relocation to the cavity at 11.5 h. Within the considered problem time of 48 h, a total amount of 4900 kg H_2 and 1900 kg CO are released.

PWR-VVER:

- LB LOCA at the cold line weld at the reactor pressure vessel with complete loss of power supply and failure to start all emergency diesel generators (SBO). Due to the loss of power supply, water injection from the spray system does not take place. Two of the four hydro accumulators inject water into the upper plenum of the RPV, while the other two inject into the leak zone. Due to the loss of power supply, water injection from the low pressure ECCS does not take place. The core materials and water in the PRV begin to heat up rapidly and boils. Cladding oxidation and H_2 release into the containment begins after 20 min. The continuous degradation of the core leads to RPV failure and melt relocation to the cavity and MCCI. More than 2900 kg H_2 8000 kg CO are released during the considered problem time to the containment.
- SBO: A complete loss of power supply and failure to start all emergency diesel generators is considered. Consequently, water injection from the high-pressure ECCS does not take place. At the initial stage of the accident, heat is removed from the RPV due to the boiling of water from steam generators in 1 hour. The core materials and water in the PRV begin to heat up, and the relief steam is transferred to the bubbler tank and then to the containment. The bubbler tank membrane breaks in 1.7 h and releases steam to the containment with moderate pressure and temperature increase in the containment. Cladding oxidation and H_2 release into the containment starts 3.5 hours after the beginning of the accident. Continuous degradation of the core leads to RPV failure and MCCI in the cavity. More than 3000 kg H_2 and 7800 kg CO are released during the simulated duration.

Based on the selection of bounding scenarios in WP2, systematic parametric studies of these scenarios are conducted in WP4 to assess various effects on mitigative effects / efficiency, combustion risk (see Figure 2). In general, the following main aspects are considered:

- The efficiency of PAR operation in the late phase.

- A reduction of the installed PAR system capacity from 100% to 75% and 50%.
- The impact of cooling systems (re-)activation, e.g.
    - ECCS system reactivation after PRV failure (PWR-KWU MBLOCA and TLAP)
    - Spray system recovery during an SBO (PWR-W-SBO)
    - Spray system droplet diameter, injection temperature and fan cooler operation (PWR-W-LBLOCA)
- The effect of containment venting on the combustion risk (PWR-KWU TLAP)

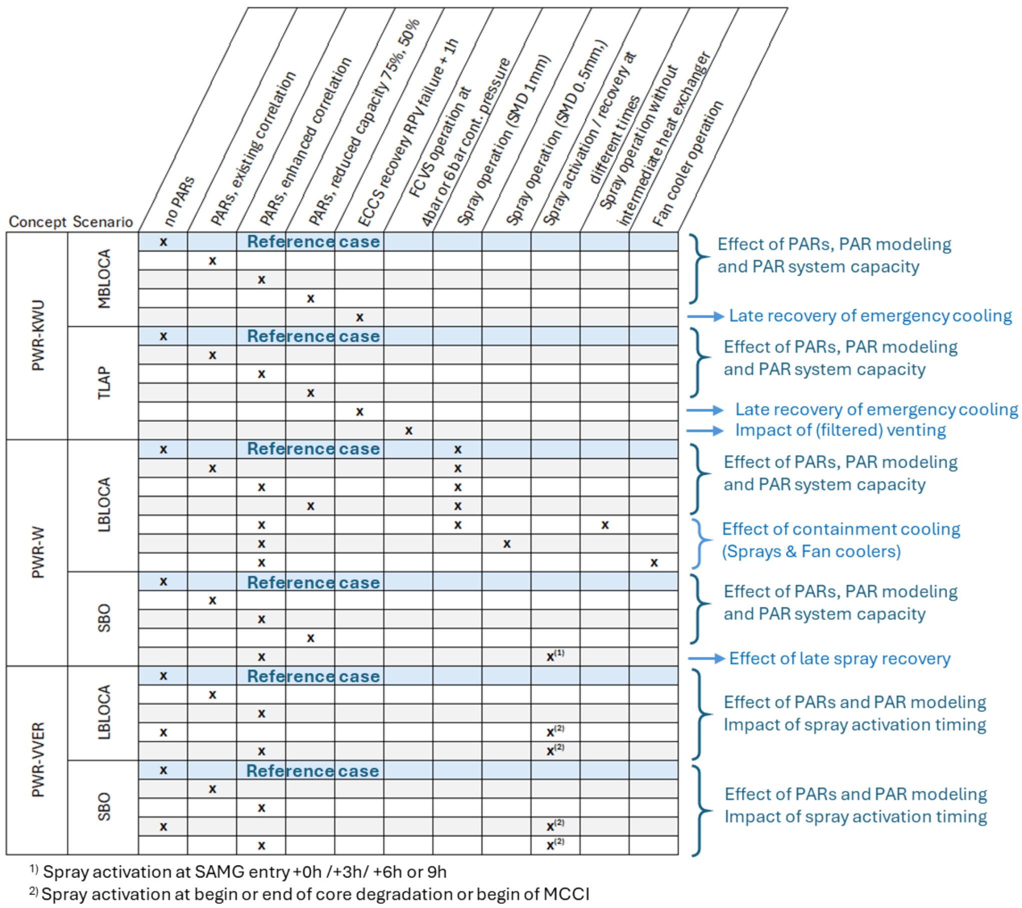

Figure 2. Simulation matrix of parametric analyses

3.0 METHODOLOGY AND COMPUTATIONAL APPROACH

The computational approach employed in WP4 is based on the experiences gained during the European SARNET-II Generic Containment benchmark series [10] and its continuation in the frame of SAMYCO-net. Though a code-to-code benchmarking is explicitly not objective of the work, a certain consistency of the codes results is required to obtain a quantitative database for further assessment and extension of SAMG in WP5. Moreover, several codes ranging from system to CFD codes (see Table 1) are employed and consistent transfer of the information obtained from WP2 is the fundamental step.

Table 1. Codes used in WP4

	PWR-KWU	PWR-W	PWR-VVER
System codes	COCOSYS 3.1 (RUB) MELCOR 2.1 (Framatome) SPECTRA 23-12-0000 (NRG) COCOSYS 2.4 (FZJ)	ASTEC (JSI) ASTEC v2.2 (IRSN) MELCOR 2.2_r2023.0 (CIEMAT)	MELCOR 1.8.6_RL_2011 (Energorisk)
3D codes	GOTHIC8.3 Q.A (UPM)		
CFD codes	ANSYS FLUENT (IRSN)	ANSYS FLUENT (NRG) containmentFOAM (FZJ)	

The Generic Containment nodalization schemes were derived from 3D CAD models [11], [12], generating a consistent and freely usable data basis for all code users to develop their LP, 3D, and CFD containment models. Material properties were defined using a best-estimate concrete density of 2500 kg/m^3 - upper end of typical values due to the high rebar content of nuclear concrete, the upper limit of the concrete thermal conductivity as defined by EUROCODE 2 Chapter 3.3.3(2) [13] - to be bounding with regard to steam condensation, and a specific heat as given by EUROCODE 2 Chapter 3.3.2(1) without considering evaporation of crystal water, which is prevented by the pressurization of the containment. The generic PAR system design is based on IAEA recommendations [14] and publicly available data on Framatome type PAR units [15]. It includes 40 large recombiners, distributed in all CVs except for the reactor cavity and an increased number close to the potential release points and in spaces where flammable gas may accumulate.

Different verification steps were taken to assess the created code input decks and ensure consistent use of the database. e.g. a comparison of the compartment volumes and the associated steel mass/surface and concrete mass/surface. The second step was a comparative evaluation of a scenario with the lowest modeling complexity, i.e. the ‘unmitigated reference’ cases. In these cases, neither PARs nor other mitigative measures (except sprays for the LB-LOCAs) were considered. Figure 3 compares the pressure evolution obtained for the unmitigated PWR-KWU MB LOCA and TLAP sequences with different codes.

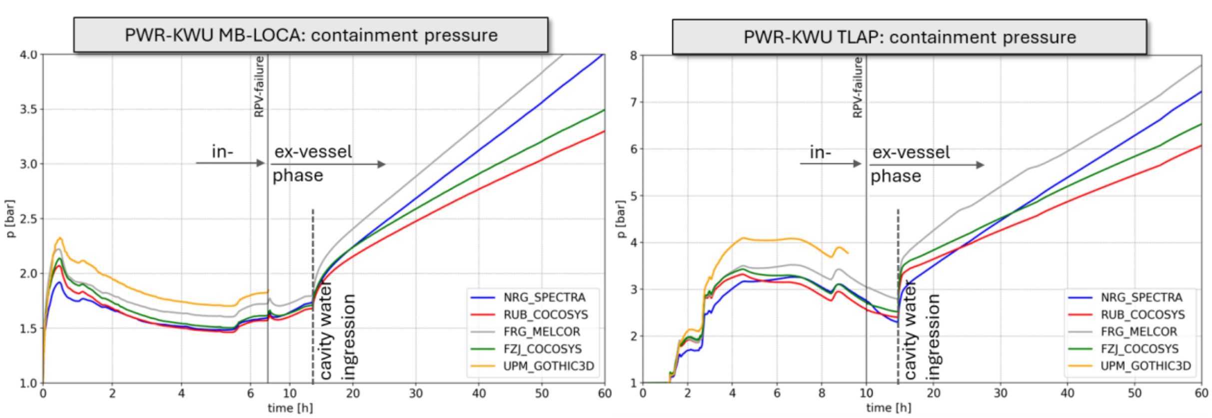

Figure 3. Pressure evolution for the unmitigated PWR-KWU sequences.

The predicted pressurization is generally quite consistent among the codes for the early accident phase. An increasing spread is visible over time for the late ex-vessel phase when sump water ingression leads to the cavity flooding. This observation is to be expected, e.g. since the codes use different models for heat transfer from the gas to structures, and for heat conduction within these structures. The resulting differences accumulate over time so that the spreading increases with problem time. Consequently, in the context of the ongoing quantitative assessment, the individual results are considered with equal probability and representativeness, which leads to a band of possible results. In the following, those bands are compared instead of the individual results within the following parametric assessment of the accident sequences and mitigative measures or actions.

Within AMHYCO WP4, combustion events are not analyzed, i.e. the combustion risk is evaluated in terms of the evolution of a flammable cloud and its potential to undergo flame acceleration in case of a combustion process. The flammability limits of H_2 derived by Martín-Valdepeñas et al. [16], using the data of Stamps and Bearman [17], are employed based on WP1 review [4].

1. $x_{H2}^{LFL} \geq 0.037 + 0.011 x_{H2O} - 4.16 \cdot 10^{-5}(T - 373)$ (1)
2. $x_{H2}^{UFL} \leq 0.772 - 1.087 x_{H2O} - 2.71 \cdot 10^{-4}(T - 373)$ (2)
3. $x_{Inert} \leq 0.63 + 3 \cdot 10^{-4}(T - 373)$ (3)

Here, x denotes molar fractions, and T is the gas temperature in Kelvin. The lower flammability limit (LFL) considers upward flame propagation conditions for the sake of conservativeness.

While the combustion of hydrogen in an air-steam mixture is well understood, the additional release of carbon monoxide due to the molten corium-concrete interaction introduces additional challenges to assess the flammability of the containment atmosphere. The usually employed conservative approach is to replace the carbon monoxide by a comparable amount of hydrogen, mostly on a molar base, and continue to employ the flammability limits of hydrogen. This approach is also used in the remaining part of this paper. However, to avoid this simplification, within AMHYCO WP3 (e.g. [5], [18]), refined criteria are currently developed, which consider the flammability and potential of flame acceleration for a H_2+CO mixture and explicitly for late phase conditions i.e. low O_2 and high dilutant concentrations.

To provide a quantitative insight to the transient behavior of the flammable cloud, the flammable H_2 mass is integrated over all control volumes, and its transient evolution is compared in Figure 4 .

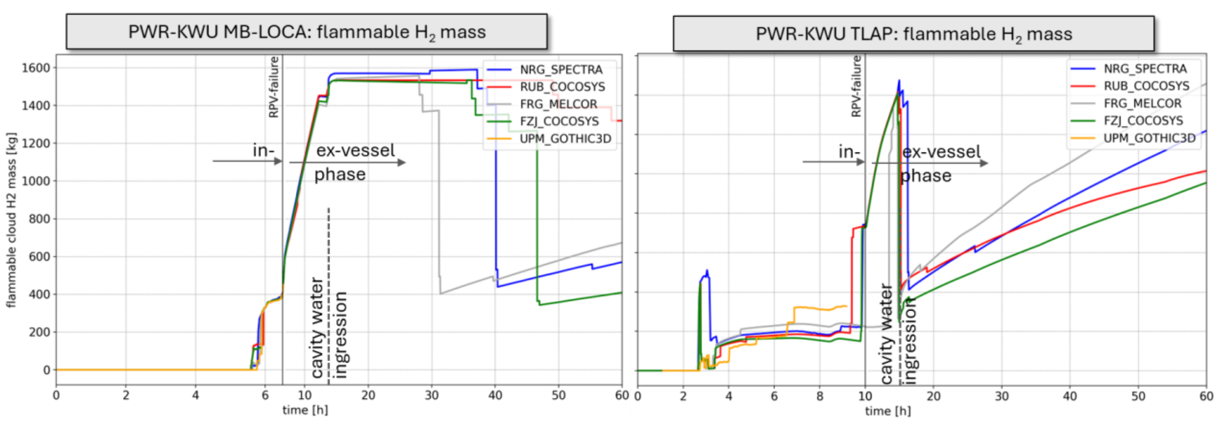

Figure 4. Flammable cloud volume and H_2 mass for the unmitigated PWR-KWU sequences.

While the different codes generally predict the formation of a flammable cloud in the early phase of the SA quite consistently, the results spread after sump water ingress to the cavity when a large part of the containment (primarily the dome region) becomes steam inerted again, while smaller compartments close to the release remain inerted. These heterogeneities motivate a closer look with 3D and CFD models in the future.

4.0 RESULTS OF THE MITIGATED TRANSIENTS

4.1 PAR performance in the late phase

In the frame of AMHYCO WP3, experiments and model development have been conducted to enhance the validity of established approaches with respect to late phase accident conditions. In particular, under the prevailing oxygen lean conditions, the SAMHYCO-NET PAR modeling exercise revealed a visible overestimation of the H_2 recombination rate [19]. Furthermore, new experimental data from the REKO-3 and THAI facilities allowed to understand the impact of carbon monoxide on the PAR performance and to derive criteria for catalyst poisoning [7]. An enhanced generic correlation for plate-type recombiners, based on the empirical Framatome engineering correlation, implemented in many codes (e.g. [20]) was derived and implemented in the employed codes (see Table 1). Figure 5 exemplarily compares the evolution of the mean H_2 concentration and flammable H_2 mass in the containment for both approaches based on the PWR-KWU MBLOCA sequence.

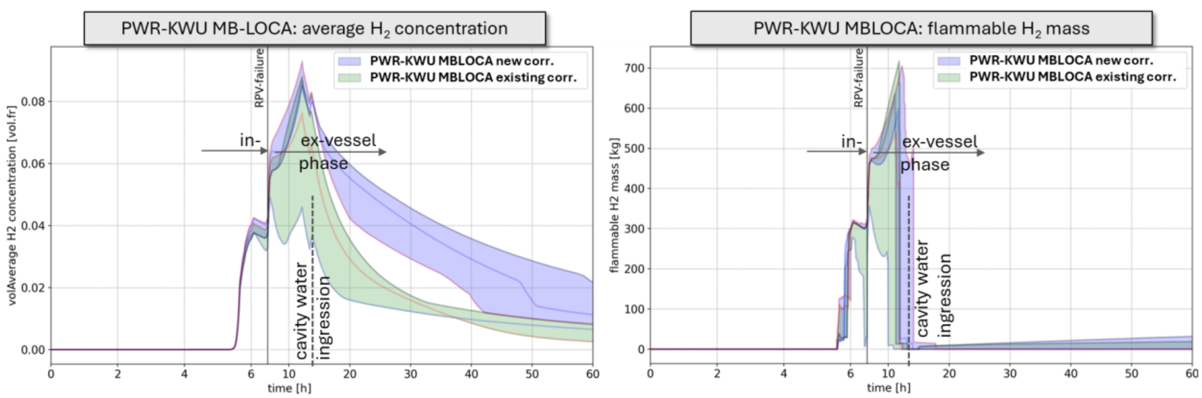

Figure 5. Average H_2 concentration in the containment and integral flammable H_2 mass for the PWR-KWU MBLOCA sequences with PAR for the existing and new correlation

In order not to further elaborate the remaining differences among the different code predictions, bands representing the different parametric runs are compared. They are defined by the minimum and maximum values of the results obtained from the individual LP code simulations, indicated by the curves (here only three code results per case). While in both cases the H_2 risk in terms of the flammable H_2 mass is significantly reduced compared to the unmitigated case (refer to Figure 4 left), for this case, it is apparent that the new model yields slightly more conservative results in the ex-vessel phase.

During a plant outage, a representative sample of the catalytic sheets from various PAR are tested in a mobile test facility. In case the tested catalytic sheets show a start-up delay longer than specified, the affected PAR undergo "regeneration". These periodic inspections shall ensure the long-term availability of the system. Even though unlikely, for nowadays unknown reasons, the PAR system may be impaired to perform as specified. Therefore, a parametric study was conducted to investigate a hypothetical PAR system performance degradation to 75% or 50% of the installed capacity for all scenarios. A characteristic result is depicted in Figure 6. As expected, a reduced PAR system capacity leads to higher peak H_2 concentrations in the containment. The dependency of peak gas concentrations on the assumed PAR performance impairment seems to be continuous, not exhibiting a cliff-edge effect. While the resulting difference in terms of average H_2 concentration and flammable mass are comparably small in the in-vessel phase, when the release rate is in the order of or exceeds the recombiner capacity in the ex-vessel phase, the deviations become more apparent. Here, the recombination rate is primarily limited by the previous consumption of oxygen in the in-vessel phase.

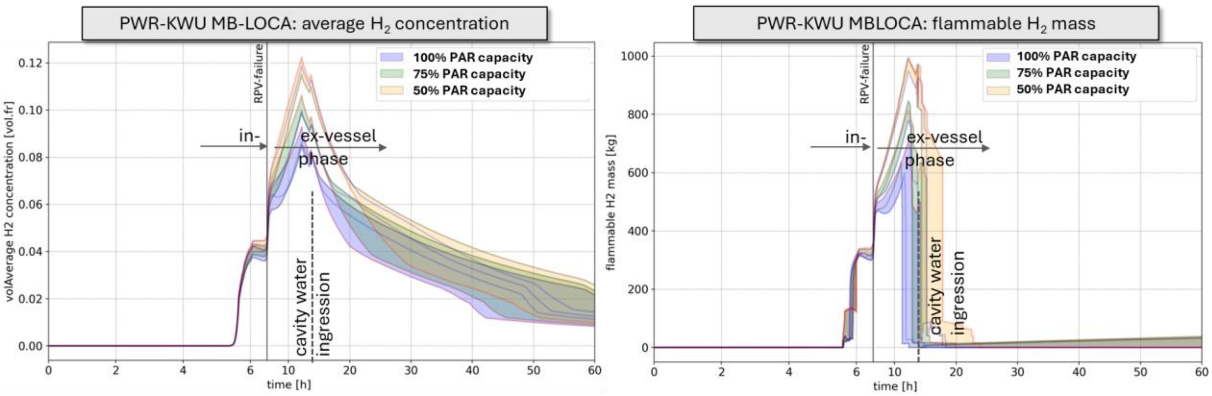

Figure 6. Average H_2 concentration in the containment and integral flammable H_2 mass for the PWR-KWU MBLOCA sequences for different PAR system capacities.

Consequently, a larger flammable H_2 mass is to be expected for a reduced PAR capacity i.e. slower depletion of the available oxygen. Besides, the overall flammability of the gas mixture depends on steam inertization and thus on containment heat losses / cooling measures.

4.2 De-inertization of the containment atmosphere by cooling means

In case of the PWR-KWU concept, the steam release subsequent to the (designed) sump water ingress to the cavity and MCCI leads to a rapid steam inertization of the containment atmosphere. A reactivation of the emergency cooling systems by the operators one hour after the RPV failure was also investigated. While this action may help to stabilize the MCCI, the injected cold water forms a subcooled pool on top of the MCCI and prevents a further release of steam. Subsequently, due to heat losses into the containment concrete structure, the steam-inertization of the containment weakens with time. In case of a full PAR system capacity, however, the early depletion of O_2 by the PAR prevents a significant effect of the reduced quantity of steam on the flammability.

The PWR-W concepts rely on containment spray systems to homogenize the containment atmosphere and reduce pressure by means of steam condensation. In the fast LBLOCA sequence, the spray is activated nearly immediately after the break and switched to recirculation mode later. In this case, different possible configurations were studied, including a reduction of the spray droplets Sauter Mean Diameter (SMD) from 1000 µm to 520 µm, which leads to increased condensation. On the contrary, parallel operation of fan coolers and a failure of the intermediate heat exchanger (between the sump and the spray nozzles) was considered, which results in lower spray flow rates (the cooling water flow rate is shared by sprays and coolers) or higher spray temperature during recirculation mode, respectively and thus less condensation. The results are depicted in terms of the evolution of the average steam concentration in the containment as well as the integral flammable H_2 mass in Figure 7.

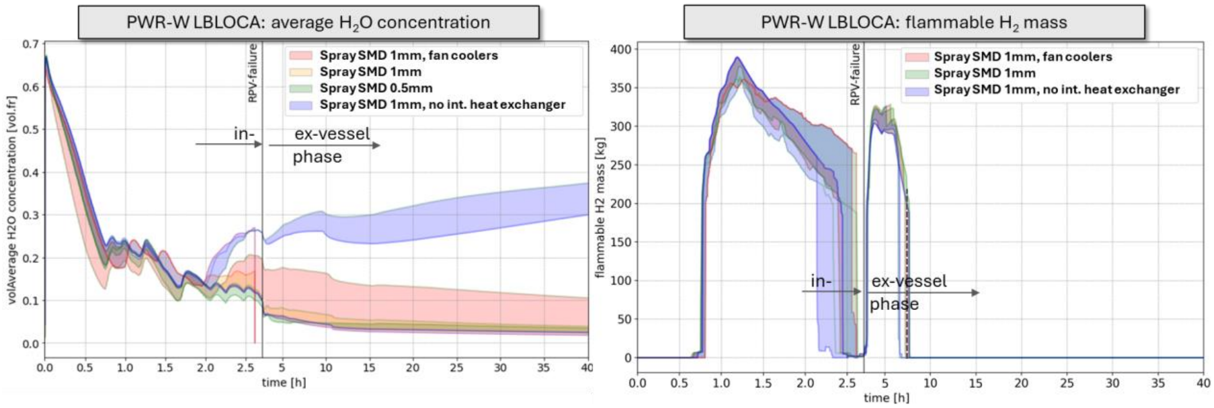

Figure 7. Average steam concentration in the containment and integral flammable H2 mass for the PWR-W LBLOCA sequences for different Spray configurations.

The major combustion risk occurs in the early phase of the accident when PAR operation did not consume a significant part of the oxygen in the containment. Considering the steam concentration in the containment, it is clear that for all options, the steam concentration is far below the steam inertization limit, and thus, the effects on the flammability are small. However, as the difference in the steam concentration is visible for the case without available decay heat removal, future analysis will investigate the potential of flame acceleration under these conditions.

Considering the PWR-W-SBO sequence, sprays were assumed to be not available due to the lack of power supply.

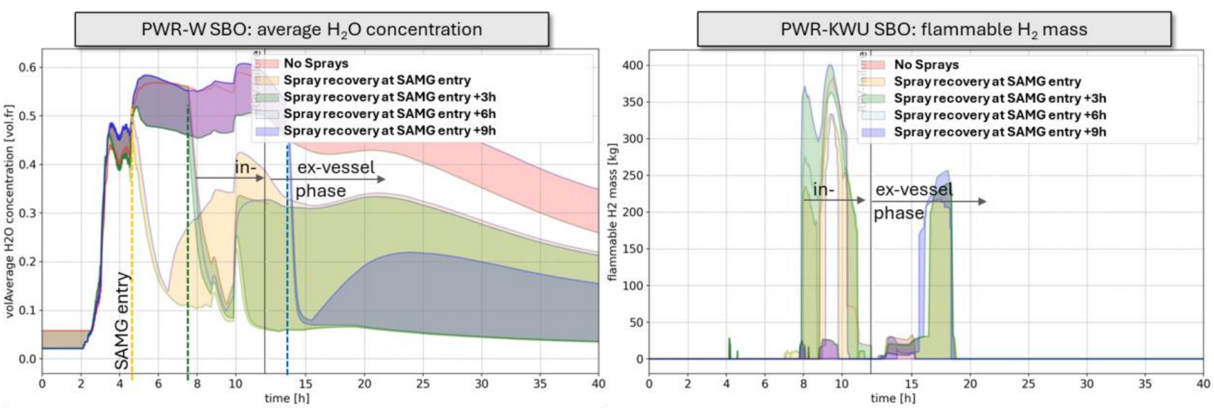

Figure 8. Evolution of the average steam concentration in the containment and integral flammable H_2 mass for the PWR-W SBO for different spray recovery times.

A recovery of AC power, which would enable the operators to activate the sprays to reduce the containment pressure, was postulated at the time of SAMG entry (depressurization of the primary system) and +3 h, +6 h and +9 h later (see Figure 8). Combustion risk is increased in all spray activation cases, while the strongest effect on the flammability is observed for the spray recovery 3-6 h after SAMG entry, when the largest H_2 concentrations are present. In the case of a later spray recovery, the flammable mass is reduced due to the previous consumption of H_2/CO and oxygen by the PARs.

4.3 Effect of containment venting

Based on the PWR-KWU TLAP sequence, the effect of FCVS operation on the combustion risk was investigated. Two set points for FCVS activation, i.e. when reaching containment design pressure (6 bar) and an early venting (4 bar), were investigated and compared against the case without venting (Figure 9).

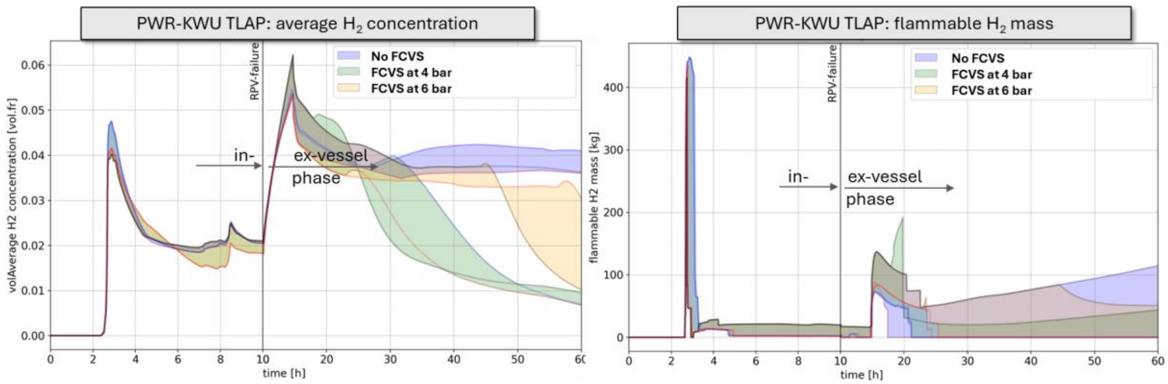

Figure 9. Evolution of the average hydrogen concentration in the containment and integral flammable H_2 mass for the PWR-KWU TLAP sequences for different FCVS activation times.

Since the activation criteria limit venting to the ex-vessel phase, where additional pressurization results from the release of steam and non-condensables from the decomposition of concrete, the effect on combustion risk is low. The FCVS effectively removes both oxygen and H_2/CO, as well as steam from the containment and thus reduces the flammable cloud. Nevertheless, at that time PAR operation already consumed most of the available oxygen. Since the vented gas mixture can be flammable, mitigative measures against combustion in the venting line need to be considered, compare [21].

5.0 CONCLUSIONS AND FUTURE WORK

The simulations consistently show, that without any hydrogen mitigation measures, the containment atmosphere always develops pockets where an ignition and flame propagation could occur. Further, the mass of combustible hydrogen increases with time due to the ongoing MCCI. This emphasizes the need for combustible gas control hardware to protect the containment integrity.

The experimental work as well as the extended generic PAR correlation used for the parametric simulations confirm that PAR operation in the late phase is impaired by oxygen starvation and parallel recombination of CO. Besides limiting the H_2 mass in the containment the main effect of PARs is the consumption of O_2 and thus the inertization of the containment atmosphere in the late phase. The capacity and efficiency of the PAR system primarily affect the time until this inertization is reached, but PAR systems can deplete the combustible mixtures even with reduced capacities. Furthermore, thanks to the O_2 removal, cooling actions to decrease the containment pressure in the late phase of the accident can be taken without increasing the risk of combustion. In the specific case of containment venting, the combustion risk was further reduced by the removal of combustible gases.

Ongoing work in AMHYCO WP4 aims at a further assessment of the combustion risk by utilizing its experimental database to derive tailored correlations for the assessment of flammability and potential of flame acceleration of arbitrary mixtures of H_2-CO-O_2 mixtures, including inert gases. Furthermore, the integral insights are refined and substantiated by means of 3D and CFD codes to assess the effect of local heterogeneities and phenomena.

The comparative evaluation of LP, 3D, and CFD models is expected to provide an insight into the control room view of the containment conditions based on the SA instrumentation and the full phenomenology and thus allow to review and extend the existing SAMGs and EOPs. A major advance in the State-of-the-Art is expected to result from the use of an extended PAR correlation that captures the effects of oxygen starvation and CO poisoning in the late phase, as well as the application of new criteria for the H_2/CO combustion risk.

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