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Recent VVER-440 severe accident analyses with MELCOR 1.8.6

Petr Vokáč, vok@ujv.cz
Nuclear Research Institute Řež plc

Two VVER-440/213 accident scenarios were analysed with MELCOR 1.8.6 YT. The first scenario is a reactor overdraining at shutdown and the second is a test of the IVR strategy for the station blackout. Input models for these two scenarios were developed from a base case input model developed and tested earlier.

The base case VVER-440/213 input model for MELCOR 1.8.6 was presented at MCAP 2009 [1]. It was derived from the previous input for 1.8.5. The input model for the COR package was redesigned completely in order to benefit from the new 1.8.6 capabilities. The new model was parametrised using Python scripts to allow easier changes in nodalization for specific simulations. Simulations run with the Intel FORTRAN 10.0 compiled MELCOR 1.8.6. YT executable (-O1 optimised) on Linux. Few post-processing tools were developed for analysis of the results on Linux [2]. These tools were recently tested also on Mac OS X. Examples of graphical outputs are shown in the presentation.

Overdraining

The accident scenario "Overdraining during the preparation to remove the reactor lid" was selected from the existing PSA-1. It has large relative frequency. The reactor lid is still in place in this scenario but control rod drives are being dismantled. Untightness of control rod drives provides release path for fission products to the reactor hall. It is expected that fission products will be released to the reactor hall with some retention. Therefore, the preliminary estimation of the source term was large but not as large as for the scenario with the reactor lid completely removed.

Adaptation of the base case input model concerned mainly the primary and secondary circuits. The primary circuit input model consists of three loops with weights 1, 2 and 3. Single loop with the pressuriser is connected to a coolant sink representing the draining pump. Triple loop is stand-by, isolated from secondary and closed by the main isolation valves at cold legs. The secondary circuit input model is limited to two SGs connected to the double primary loop on natural circulation. Secondary coolant in these two SGs is cooled by a heat exchanger. It is assumed that this heat exchanger keeps the constant temperature of secondary coolant no matter how much power is removed.

The simulated accident scenario is initiated by the start of the draining pump. Coolant is removed from the single primary loop at maximum flow rate allowed by operator instructions. It is assumed that the water level measurements accidentally fail and the draining is stopped only when the water level in the RPV is below the hot leg nozzles. Then draining pipes are closed, therefore coolant can be further released from primary through the open pressuriser and the dismantled control rod drivers.

According to the MELCOR prediction, this scenario does not lead to a severe accident, even core damage conditions are not reached. Due to the primary coolant thermal expansion, natural circulation in the primary double loop is partially recovered after the draining closure. This limited natural circulation is enough for long term core cooling with boiling in RPV or even with temperatures few degrees below saturation.

Sensitivity study on draining duration showed that complete loss of natural circulation occurs only if the draining pump is left operating for some time during boiling in the RPV. This seems to be a very unlikely situation.

Uncertainties in the presented MELCOR calculations are considered very large. Conclusions should be confirmed by a detailed TH code simulation.

IVR

The first simulations of the IVR strategy on VVER-440/213 were prepared with the assumption that the plant modification is possible. The coolant flow around the RPV bottom head was assumed unrestricted and without any obstacles. Outflow from the cavity to the SG boxes was assumed unrestricted.

The station blackout with primary depressurisation was selected as a reference scenario. With the COR and CVH input models for RPV from the base case input model, the external cooling was not successful. The base case input model uses single CVH volume, `cv020`, for the whole lower plenum (space below the fuel followers). Presence of liquid coolant in `cv020` limits heat transfer between the debris and the RPV wall. The RPV failure occurs shortly after the liquid coolant in `cv020` diminishes. It occurs in both the reference scenario with non-flooded cavity and the scenario with the cavity flooded. Difference in the RPV failure timing is just about 2 h.

For the second test, the COR nodalization in the lower plenum was refined. The refined input model better describes axial temperature profile in the debris bed or molten pool in the lower plenum. The whole lower plenum was still in the single CVH volume `cv020`. In this case the RPV failure did not occured up to 28 h of the simulated IVR scenario. Nevertheless, the analysis of results again indicates dependency of heat transfer from debris to the RPV wall on presence of liquid coolant in `cv020`. This is considered not very realistic.

In the third test, `cv020` was split into six CVH volumes. Five CVH volumes were designed to contain two bottom COR nodes in each COR ring. These five CVH volumes roughly represent volume between the perforated core barrel bottom and the RPV wall. Volume inside the perforated core barrel bottom is represented by the sixth CVH volume. Unfortunately, the simulation with the refined CVH model was not successful. The simulation was very slow and failed at $\sim$10 h due to a rapid vapour temperature increase in small CVH volumes adjacent to the RPV wall.

References

[1] Petr Vokáč: MELCOR 1.8.6 core input model for VVER-440,
MCAP, Bethesda (MD), 17$^{\text{th}}$ September 2009

[2] Petr Vokáč: Postprocessing of MELCOR results in Linux,
MCAP, Bethesda (MD), 18$^{\text{th}}$ September 2009