Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

Preliminary Low Pressure Conduction Cooldown Analysis with Sensitivity on the Operating Conditions

Hong Sik LIM and Won Jae LEE
Korea Atomic Energy Research Institute, 150, Duckjin-Dong, Yusung-Gu, Deajeon, Korea, 305-353
hslim@kaeri.re.kr, wjlee@kaeri.re.kr

1. Introduction

To cope with the exhaustion of fossil fuel and the crisis on energy security in the upcoming future, Korea Atomic Energy Research Institute (KAERI) has started the nuclear hydrogen development and demonstration (NHDD) project. We are considering the two reactor types, a pebble bed modular reactor (PBR) and a prismatic modular reactor (PMR), as the candidate for massive hydrogen production. In this study, we are performing a preliminary safety analysis for the limiting event, a low pressure conduction cooldown accident, and investigating the impacts of various operating conditions on the NHDD design options

2. System Modeling and Assumptions

In order to assess the consequence of the low pressure conduction cooldown (LPCC) accident for two different types of GCRs, we selected the reference GCRs, 400MWth PBMR and 600MWth GT-MHR [1], respectively. The GAMMA multi-dimensional multi-component mixture analysis code [2] is used to model the selected reactor systems. Together with the properly selected chemical reaction models listed at Table 1, we assumed the volume of 50,000 m^3 (based on HTR-module data) for air source in a vault. For the PMR, a guillotine-type break of coaxial main pipe is assumed for PMR and, for the PBR having non-coaxial type piping, all the cold and hot main pipes are assumed to rupture.

Table 1 Chemical reaction models selected

Reaction	PBR	PMR
$CO\text{-}O_2$	Dryer & Glassmann	Dryer & Glassmann
$C\text{-}O_2$	KAIST oxidation data for IG-110 All graphite matrix: $r_{C-O_2} = 7500\exp\left(-218000/\bar{R}T\right)\left(P_{O_2}\right)^{0.75}$ Production ratio: $f_{CO/CO_2} = 7396\exp\left(-69604/\bar{R}T\right)$	German oxidation data A3 pebble: $R_C^{\ w} = 720\exp\left(-16140/T\right)P_{O_2}$ Reflector: $R_C^{\ w} = 8.5\times10^5\exp\left(-23440/T\right)P_{O_2}$ Production ratio: *Hinssen*
$C\text{-}CO_2$	Moormann	Moormann

The safety performance of each type of reactors is evaluated for the candidate operating conditions (reactor outlet temperature = 950 and 1000°C, reactor inlet temperature = 490, 540, and 590°C, system pressure = 40, 55, and 70bar) of Table 2.

Table 2 Operating conditions for sensitivity

Cases	T_{in} (°C)	T_{out} (°C)	P_{sys} (bar)
Original*	490/500	850/900	70/90
Case 0	490	950	70
Case 1	540	950	70
Case 2	590	950	70
Case 3	490	1000	70
Case 4	490	950	55
Case 5	490	950	40

* Original design value of GT-MHR600/PBMR400

3. Results and Discussions

(a) *Peak fuel and RPV temperature transients*

Fig. 1 and 2 show the calculated peak temperatures of Case 0 during the LPCC accident for both PBR and PMR. The results show no significant rise in both fuel and bottom reflector. However, the consequence of air ingress is very different in the two GCRs. The natural circulation starts at different times (about 50 hrs for PBR and about 350 hrs for PMR) as well as the natural circulation flow rates are different (3 times higher in PMR than in PBR). It seems due to smaller fluid volume inside the reactor pressure vessel (RPV) and the larger flow resistance in the PBR. Eventually, the oxygen ingressed is consumed faster in PMR than in PBR. Due to the combination of the earlier onset time of natural circulation (OTNC) and slower oxygen ingress in PBR, the PBR experiences more corrosion in the bottom reflector.

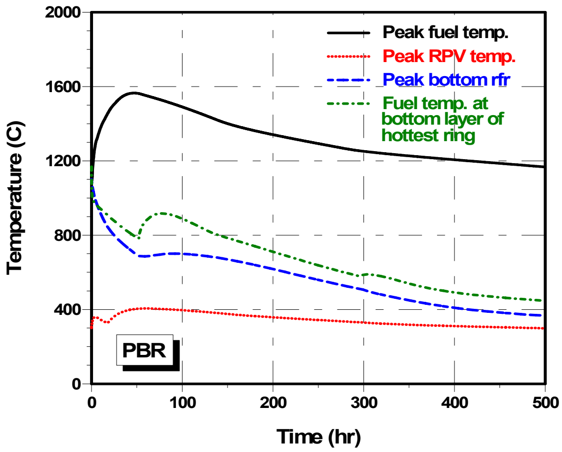

Fig.1 Peak fuel/RPV temperatures during the LPCC accident (PBR).

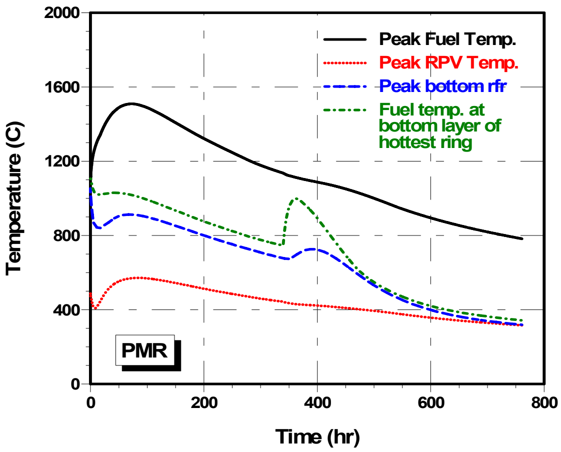

Fig.2 Peak fuel/RPV temperatures during the LPCC accident (PMR).

(b) *Sensitivity on the operating conditions*

Fig. 3 and 4 show the peak fuel and peak reactor vessel temperatures for the LPCC sensitivity analyses with the inlet/outlet temperatures and the operating pressure varying. First, the pressure effects are negligible. Second, when the coolant inlet or outlet temperature increases, the peak fuel and RPV temperatures increase due to the increased initial stored energy. Since the outlet temperature is the target value, the only controllable variable to affect the consequence of LPCC is the inlet temperature. The lower inlet temperature is preferable in the view of the peak fuel and RPV temperatures.

The peak fuel temperature of PBR is higher than that of PMR due to the much higher power peaking as well as the higher core bypass in the PBR. The peak RPV temperature of PBR is much lower than that of PMR due to the different selection of RPV material and RCCS cooling option. The PMR adapts 9Cr-1Mo vessel having the high safety limit (593°C) and the air-cooled RCCS, meanwhile the PBR adapts SA508 conventional vessel having the low safety limit (476°C) and the water-cooled RCCS.

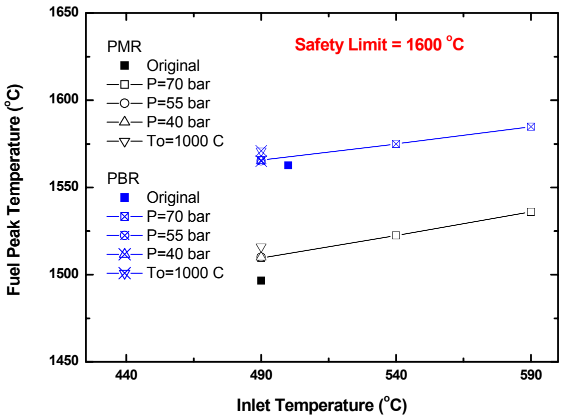

Fig.3 LPCC sensitivity results for peak fuel temperature

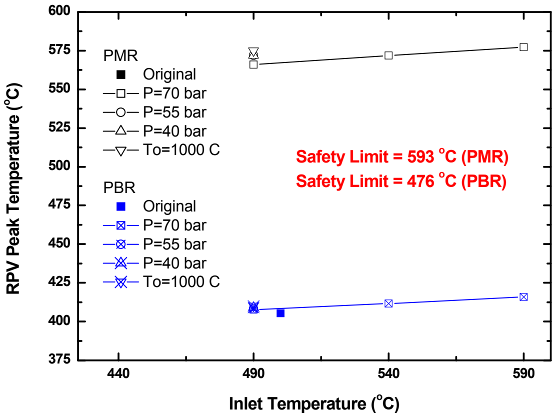

Fig.4 LPCC sensitivity results for peak RPV temperature

4. Conclusions

Although the lower inlet temperature is preferable for the LPCC accident, the choice of inlet temperature should be compromised with the system performance. It has beneficial effect on the circulator power, meanwhile it has adverse effect on the intermediate heat exchanger sizing and the operating fuel temperature margin.

The selection of RPV material is also important. The conventional RPV is preferable in the view of the cost and the operational experience. Due to its low temperature limit, however, it will restrict the RCCS coolant option as well as the decay heat removal. Therefore, to overcome the two adverse effects from the selection of the lower inlet temperature and the conventional RPV, some improvements of the core fuel performance and the RCCS heat removal capacity are required.

REFERENCES

[1] IAEA, Evaluation of High Temperature Gas Cooled Reactor Performance, IAEA-TECDOC-TBD, 2004.

[2] H. S. Lim, Transient Multi-component Mixture Analysis for Air Ingress Phenomena in a High-Temperature Gas-Cooled Reactor (HTGR), Doctorial Thesis in KAIST, 2005.