Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 19-20, 2022

TRISO Fuel Performances of a Very High Temperature System under Normal Operation and Pressurized Conduction Cooling Conditions

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1. Introduction

The very high temperature system (VHTS) is a block-type high-temperature gas-cooled reactor (HTGR) that can supply the heat necessary for hydrogen production through 1500 EFPD of very high temperature operation at 950 °C [1]. The thermal output is 350 MW. There are axially nine fuel blocks in which a large number of compacts are loaded. A compact is a cylindrical mixture of matrix graphite and tri-structural isotropic coated fuel particle (TRISO). A TRISO consists of a spherical kernel at the center, a buffer surrounding the kernel and three concentric coating layers such as an inner high-density pyrocarbon (IPyC) layer, a silicon carbide (SiC) layer, and an outer high-density pyrocarbon (OPyC) layer. The kernel is UO_2.

A pressurized conduction cooling (PCC) is one of accidents that can be occurred in a VHTS. The PCC causes the change in the fuel performance of a VHTS. The study analyzes a TRISO fuel performance of a VHTS in which a PCC occurred at 350 EFPD.

2. Pressurized conduction cooling

A PCC causes a pressurized loss of forced convection (P-LOFC) in a core of a VHTS. The helium flow in the primary system is stopped, but the coolant pressure is maintained [2]. When a P-LOFC occurs, there is a potential for core heatup transients and delayed fission product releases.

Fig.1 shows the block numbering for the 1/6 core of a VHTS. To evaluate the average fuel performance of the core under PCC conditions, positions 2 (bottom), 10 (middle), and 17 (top) were chosen in the z-axis direction, and positions 3 (inner), 5 (middle), and 11 (outer) were selected in the radial direction to select a total of nine evaluation points. Fig. 2 shows the coolant temperature and half-block power at the nine core locations of the VHTS under PCC conditions which were calculated by the GAMMA code [3].

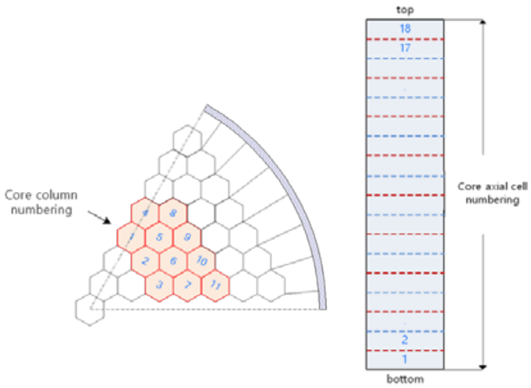

Fig. 1. Core numbering.

3. Fuel performances under normal operation and PCC conditions

It was assumed that a PCC had occurred at 350 EFPD. The fuel performances of fuel blocks at nine locations are analyzed using the COPA code [4].

Fig. 3 shows the maximum temperature of the buffer for each core location. The temperature is between 600 and 1300 °C during normal operation, and it is between 500 and 1200 °C under a PCC condition. Fig. 4 shows the total gas pressure in a TRISO at nine locations of the core. The highest gas pressure is about 20 MPa.

Fig. 5 shows the average failure fractions of 100 million TRISOs. The failure mechanisms considered are pressure vessel failure, fission product attack, and thermal decomposition. The following types of failure are occurred: IPyC failure-SiC intact-OPyC intact, IPyC intact-SiC intact-OPyC failure, IPyC failure-SiC intact-OPyC failure, IPyC intact-SiC failure-OPyC intact. IPyC intact-SiC failure-OPyC intact failure is the main form of SiC failure. One through-coatings failure occurred at 40 hours after a PCC.

Fig. 6 shows the average releases of the fission products Cs-137, Ag-110m, Sr-90, and Kr-85 into the coolant. The release of the fission gas Kr-85 is negligible. The average fractional releases of Cs-137, Ag-110m, and Sr-90 are 4.76×10^{-7}, 2.03×10^{-2}, and 9.80×10^{-7}, respectively.

4. Summary

The fuel performance of a VHTS where a PCC has occurred at 350 EFPD has been analyzed. The highest gas pressure in a TRISO is below 20 MPa. The common failure modes occurred under normal operation and PCC conditions are IPyC failure-SiC intact-OPyC intact, IPyC intact-SiC intact-OPyC failure, IPyC failure-SiC intact-OPyC failure, IPyC intact-SiC failure-OPyC intact. Only one through-coatings failure occurs under PCC conditions. The release of the fission gas Kr-85 is negligible. The average fractional releases of Cs-137, Ag-110m, and Sr-90 are 4.76×10^{-7}, 2.03×10^{-2}, and 9.80×10^{-7}, respectively. A PCC occurred at 350 EFPD does not deteriorate the fuel performance of a VHTS.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. 2020M2D4A2067322).

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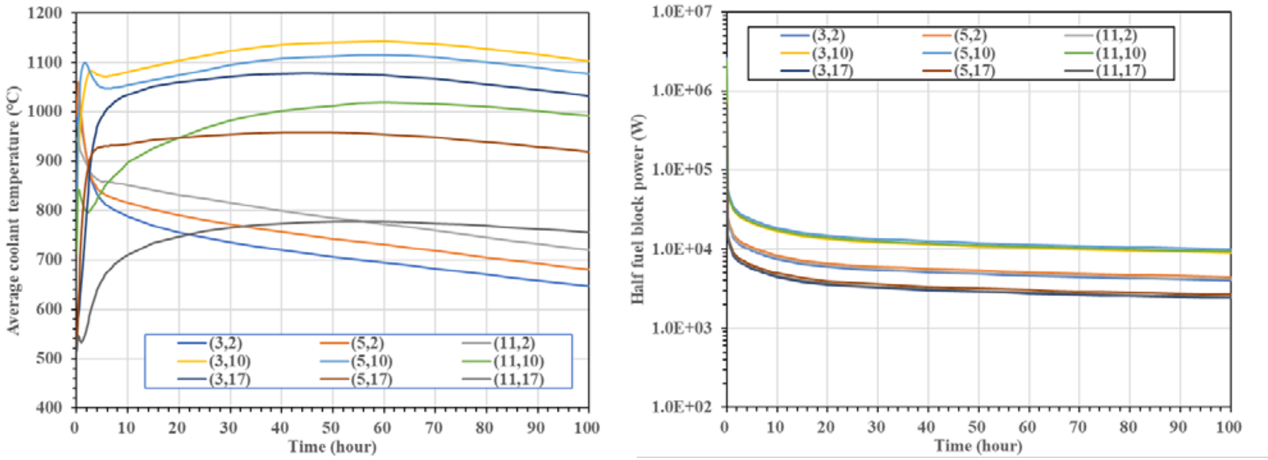

Fig. 2. Coolant temperature and half-block power under PCC conditions.

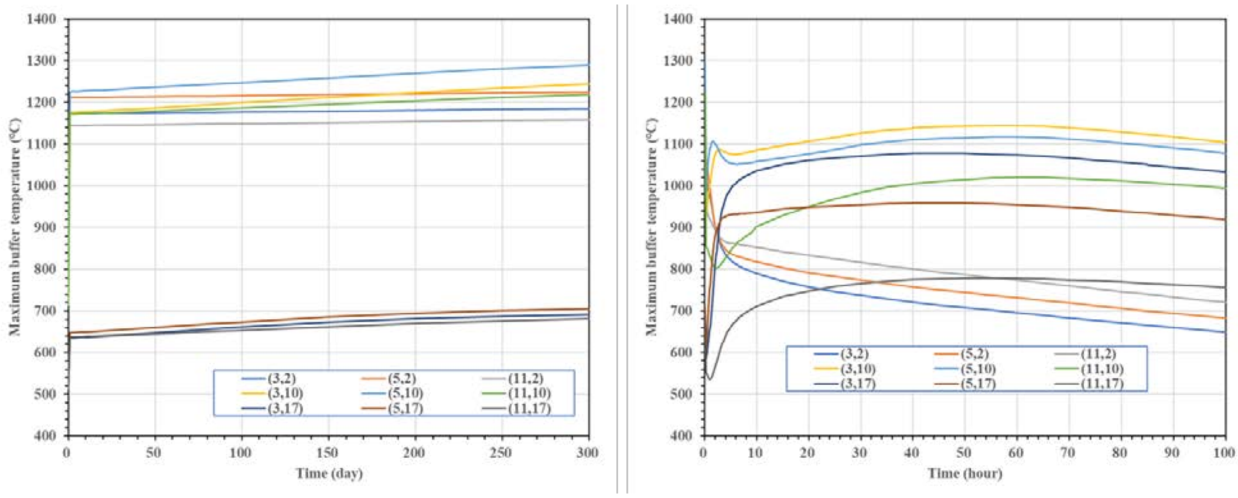

Fig. 3. Maximum buffer temperatures under normal operation and PCC conditions.

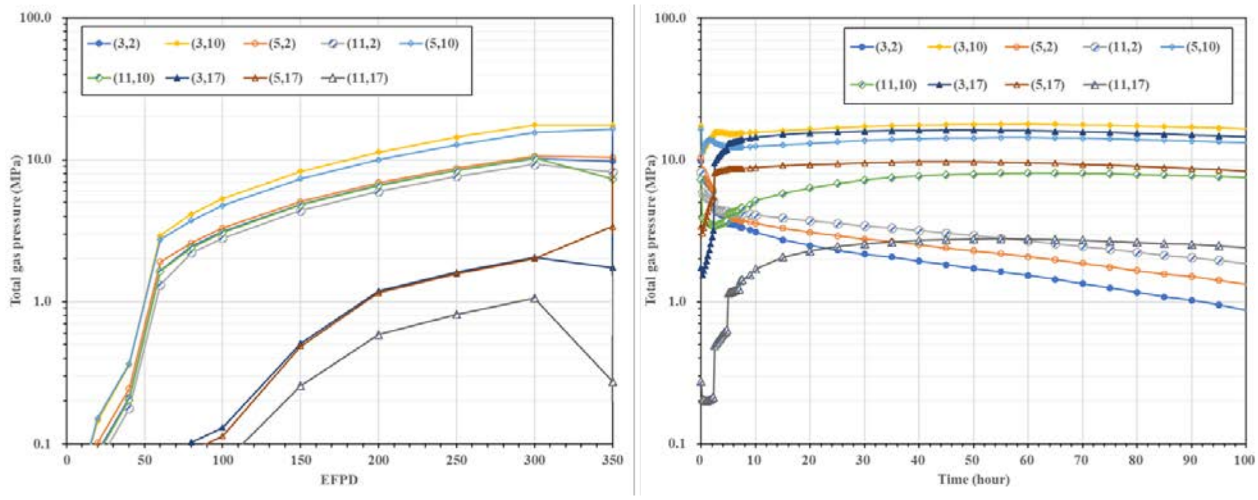

Fig. 4. Total gas pressures in a TRISO under normal operation and PCC conditions.

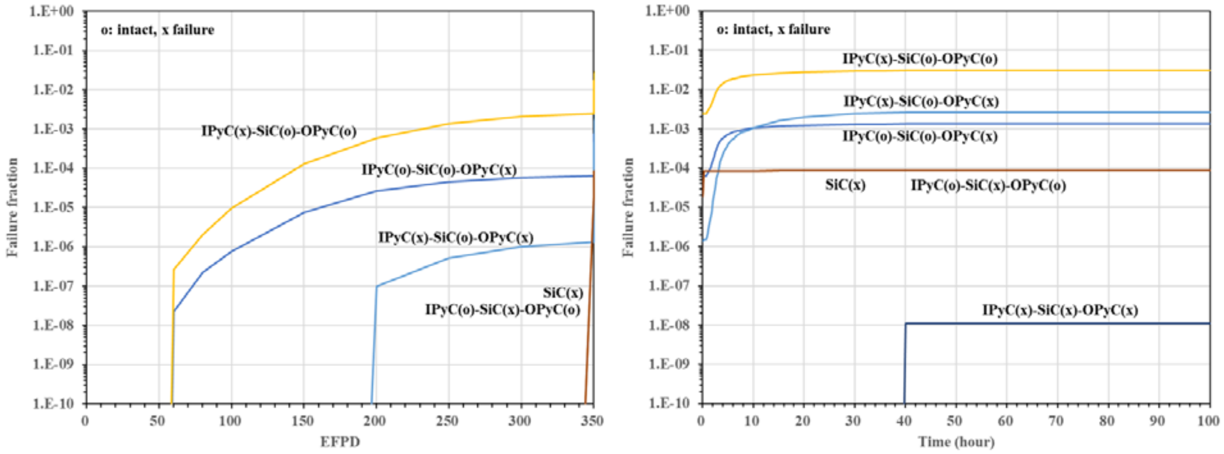

Fig. 5. TRISO failure fractions under normal operation and PCC conditions.

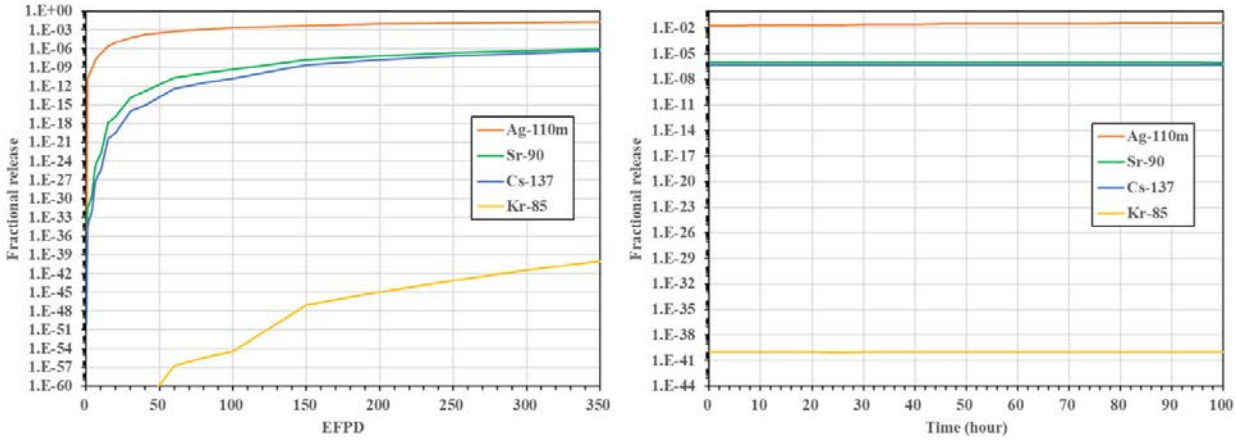

Fig. 6. Fission product releases under normal operation and PCC conditions.