Consequence Analysis of the MHTGR and PBMR

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1. Introduction

The probabilistic safety assessment of the VHTR design provides a systematic analysis to identify and quantify all risks that the plant imposes to the operators, general public, and the environment and thus demonstrates compliance to regulatory risk criteria. During the preliminary conceptual design of VHTR in Korea, both block- and pebble type-fuel are considered. Therefore, the consequence analysis of VHTR using both types of fuel were made in order to obtain the basic insights for the classification of events and the formation of the PSA framework of the VHTR.

2. Modeling and Assumptions

The reference plants considered in this study are MHTGR and PBMR. In the safety assessment of MHTGR, the occurrence probability and cumulative fractional releases of radioactive materials to the environment for various release scenarios are defined, which are summarized in Table 1[1]. Unlike the safety assessment of MHTGR, the release categories are defined and the amount of activity for each radionuclide available for release is determined and specified as the source term available for release. There are three sources of fission products in the PBMR core, that is, that contained in the helium circuit during normal operation, that plated-out in various surfaces in the primary circuit including dust, and that contained in defective particles that may be released during heat-up events. Events in which there is no forced cooling will have a delayed release from initially failed particles. The release categories for the PBMR are summarized in Table 2[2].

Table 1. MHTGR release scenarios

Release scenarios	Frequency/yr
Moisture inleakage without forced core cooling (DBE-7)	5.0×10^{-5}
Primary coolant leak with forced core cooling (DBE-10)	0.01
Primary coolant leak without forced core cooling (DBE-11	3.0×10^{-4}
Moisture inleakage with delayed steam generator isolation and leak without forced core cooling (EPBE-1)	3.0×10^{-7}
Moisture inleakage with delayed steam generator isolation and leak with forced core cooling (EPBE-2)	4.0×10^{-6}
Primary coolant leak in four modules without forced core cooling (EPBE-3)	7.0×10^{-7}

Table 2. PBMR release categories

Release Category	Description	Frequency /yr	Source Term
RC-1	Small leak, isolated, filtered vent	3.60×10^{-4}	Circulating
RCF-1	Small leak, not isolated, filtered vent	1.10×10^{-4}	Circulating and Fuel
RCF-2	Small leak, not isolated, without pump down, filtered vent	1.20×10^{-5}	Circulating and Fuel
RCP-1	Medium and large breaks, isolated, unfiltered vent	3.80×10^{-6}	Circulating and Plate-out
RCPF-1	Medium break, not isolated, unfiltered vent, vent reclosed	6.90×10^{-3}	Circulating, Plate-out and Fuel
RCPF-2	Large break, not isolated, unfiltered vent, vent open	4.60×10^{-6}	Circulating, Plate-out and Fuel

The health effects and resulting risks are calculated by using the MACCS2 code[3]. The KAERI is assumed to be the reference site for the VHTR. The site was selected as the center of a polar grid and the grid was divided into 16 equally spaced sectors with the outermost radius extending to 10 km. Each sector was divided further into 6 elements to reasonably account for the site specific population distribution. The hourly weather data of the site were used. Emergency response actions are not considered.

3. Results and Discussion

The mean individual risk of early fatalities for both MHTGR and PBMR due to all events is zero as the maximum doses are only a small fraction of the dose thresholds for early fatalities. The mean individual risk of cancer fatalities within 1 km from the site for both MHTGR and PBMR due to all events are summarized in Table 3. The overall cancer fatality risks considering the occurrence probabilities for MHTGR and PBMR are 1.59×10^{-11} and 1.53×10^{-10}, respectively. All these values are below the safety goal of USNRC.

The relative contribution of release scenarios to cancer fatalities for MHTGR is plotted in figure 1. And the relative contribution of release categories to cancer fatalities for PBMR is plotted in figure 2. The dominant release categories for MHTGR and PBMR are DBE-10 and RCPF-1, respectively. The most important factor for the dominant release category is the occurrence probability of the release category. The occurrence probabilities of release scenarios, DBE-10 and RCPF-1 for MHTGR and PBMR are much higher than the rest release scenarios.

Table 3. The individual cancer fatality risks

MHTGR		PBMR	
Release scenarios	Risk	Release scenarios	Risk
DBE-7	7.43E-08	RC-1	1.04E-10
DBE-10	6.05E-10	RCF-1	1.87E-08
DBE-11	1.62E-08	RCF-2	2.18E-08
EPBE-1	6.65E-08	RCP-1	3.24E-09
EPBE-2	3.18E-07	RCPF-1	2.18E-08
EPBE-3	9.41E-09	RCPF-2	2.18E-08

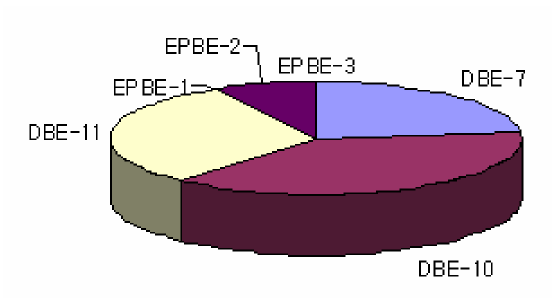

Figure 1. The relative contribution of release scenarios to cancer fatalities for MHTGR

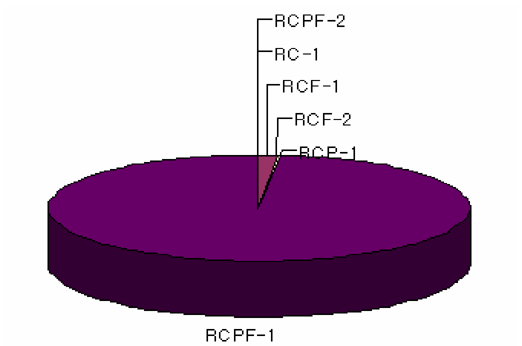

Figure 2. The relative contribution of release categories to cancer fatalities for PBMR

4. Conclusion

The consequence analysis of VHTR using block- and pebble type-fuel were made in order to obtain the basic insights for the classification of events and the formation of the PSA framework of the VHTR. Unlike the results of consequence analysis of PWR, the mean individual risk of early fatalities for both MHTGR and PBMR due to all events is zero due to the low amounts of radioactive materials released to the atmosphere. The overall cancer risks resulting from the various release categories for both MHTGR and PBMR are below the safety goal of USNRC.

The results of this study and more detailed analysis based on this study will be used as basic data for the classification of events and the formation of the PSA framework of the VHTR.

Acknowledgement

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REFERENCES

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