Preliminary Evaluation of Applicability of Current General Design Requirements to Hydrogen Generation Nuclear Plant

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1. Introduction

The development of very high temperature gas cooled reactor (VHTR) for hydrogen production was launched with target dates of 2022 for the completion of construction and 2026 for prototypical demonstrations according to the "Action Plan for Developing Future Nuclear Systems" approved by the Atomic Energy Commission in 2008. KINS also requires regulatory research in preparation for the licensing of VHTR for hydrogen production. The designs of VHTR are very different from those of light water reactors (LWRs), so the existing regulatory environment may not be suited for the VHTR for hydrogen production and, therefore, proper safety requirements should be developed incorporating the unique characteristics of VHTR. In relation to this, the preliminary research is currently underway to evaluate the applicability of the current general design requirements to VHTR for hydrogen production.

2. KINS Regulatory Research for VHTR

To prepare the license of the demonstration reactor of VHTR, KINS starts the R&D project for the development of VHTR licensing technologies with three phases: phase 1('10-'11) - establishment of licensing framework, phase 2('12-'17) - development of safety evaluation technologies, phase 3('18-'26) - safety review of demonstration reactor. The detailed research plan in the 1st phase is;

1) Development of regulatory requirements and guides: due to the design differences and approach to safety employed in VHTR reactor, many LWR requirements may not be applied to the VHTR design. Based on the applicability evaluation of the current LWR requirements to the VHTR, the existing requirements will be modified, and new requirements will be developed
2) Identification and resolution of licensing issues: regulatory research activities can be performed in parallel with the design process, so the identification of licensing issues and their resolution will be helpful for designer to reduce the licensing risk.
3) Establishment of licensing procedures for demonstration reactor: the construction of demonstration reactors is planned to verify the design performance and economics before the commercialization of the VHTR. For the optimization of the licensing of demonstration reactors, it is needed to establish a licensing procedure for the demonstration reactors.

3. Applicability Evaluation of Current Requirements to VHTR

3.1 VHTR System Design for Hydrogen Production

The VHTR design is characterized by 1) the use of refractory triple isotropic layers coated fuel particles (TRISO CFP) which retain the fission products and then provides a unique robustness of the first barrier for the fission products, 2) the use of inert, single phase helium gas as coolant and of graphite with high temperature stability and long response times as moderator, and 3) passive core cooling and decay heat removal by natural process, etc.

From the preliminary NHDD (Nuclear Hydrogen Development & Demonstration) system design of KAERI[1], the system consists of a reactor, intermediate loop and coupled hydrogen systems as shown in Fig. 1.

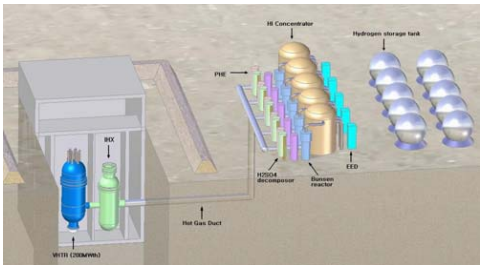

Fig. 1 Layout of NHDD System

These systems are completely separated to reduce a potential risk during normal operations and accident conditions. The primary coolant system is cooled by helium and consists of a reactor pressure vessel, a concentric hot gas duct, a circulator and a compact intermediated heat exchanger (IHX). The high temperature heat from the reactor is fully dedicated to the hydrogen production with no electricity generation. As in the figure, an underground reactor installation concept is employed, which allows for heat transfer to the ground even in the loss of passive cooling and can protect reactor system from a possible explosion in a hydrogen storage area.

This preliminary NHDD design is used as a reference in evaluating the applicability of the existing general design requirements to VHTR of hydrogen production.

3.2 Evaluation of Applicability of Current General Design Requirements to VHTR

The general design requirements, which correspond to the Technical Standards of the MEST[3] in Korea Nuclear Legislative Framework, are intended to provide guidance in establishing the principal design criteria. The current requirements were developed for pressurized water reactors (PWRs) and a stable regulatory environment for PWRs has been established for many years.

Because the designs of VHTR are very different from those of PWRs, the development of VHTR specific safety requirements and regulatory guides should be established in order to prepare the licensing of a demonstration reactor for VHTR.

For the development of new general design requirements meant for VHTR, the applicability of the current general design requirements was preliminary evaluated by assessing Technical Standards for Structure, Installations, and Performance of Reactor Facilities (Article 11 to 49). This evaluation is based on the preliminary NHDD system design of KAERI which refers to the MHTGR plant design[2].

After this evaluation, the general design requirements are classified in the following categories:

1) Directly applicable to VHTR without any changes,
2) Applicable to VHTR but changes are needed ,
3) Not applicable to VHTR, and
4) Recommended additional requirement for VHTR.

The evaluation results were summarized in Table I.

4. Conclusions

For the development of the regulations directly suited to the VHTR, new regulatory requirements should have to be crafted out of the existing general design requirements for the preparation of VHTR licensing. At this preliminary evaluation, it has been recognized that some of the current PWR-specific requirements are applicable to VHTR design, some are not applicable, and some are partially applicable. There are also some features of the VHTR design such as confinement building, reactor cavity cooling system (RCCS), which cannot be addressed by any current requirements, thus new requirements shall be developed. Due to the lack of the VHTR design information, final determination of the applicability of the general design requirements will necessarily be made when more specific design is available.

REFERENCES

[1] Jonghwa Chang, et al, A Study of A Nuclear Hydrogen Production Demonstration Plant, Nuclear Engineering and Technology, Col.39 No.2, pp. 111-122, 2007

[2] P.M. Williams, T.L. King, and J.N. Wilson, Draft Pre-application Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor, U.S.NRC, NUREG-1338, 1989

[3] Ministry of Education, Science, and Technology, Ordinance No.1, "Regulation on Technical Standards for Nuclear Reactor Facilities, Etc."

Table. I General Design Requirements (Technical Standards) applicable to VHTR

Categories	Articles of Technical Standard	Remark
Directly Applicable	12,13,14,16,17,18,19,26,31,32,33,34,35,36, 37, 38, 40, 41, 44, 45,46, 47,48, 49	
Applicable but needing changes	2 (Definitions) 15 (Environmental Effects Design Bases, etc.) 20 (Instrumentation and Control System) 21 (Reactor Coolant Pressure Boundary) 22 (Reactor Coolant System, etc.) 23 (Reactor Containment, etc.) 24 (Electric Power System) 25 (Control Room, etc.) 27 (Diverse Protection System) 28 (Reactivity Control System) 29 (Residual Heat Removal System) 30 (Emergency Core Cooling System) 42 (Design Basis Accidents) 43 (Protection during Startup, Shutdown, and Low Power Operations)	▪ Delete PWR specific terminologies, such as boiling(15), DNB(2), water quality(22), oxidation and hydrogen generation in cladding (30) ▪ No Leak-tight Containment Vessel should be modified to containment building (2,20,23,43) ▪ No steam generator and turbine (20, 27) ▪ No liquid reactivity control (28) ▪ No electricity generation (24) ▪ Use of passive RCCS with no ECCS (25, 29, 30)
Not applicable	39 (Prevention of Collapse of Steep Slope, etc.)	
Recommended additional TS	▪ Helium Supply and purification system ▪ Graphite and high temperature material ▪ Air/Steam-graphite interaction ▪ Reactor Cavity Cooling System ▪ Reactor Vessel Cooling System ▪ Hydrogen Production Facilities	