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Phenomena Identification and Ranking Table for K-DEMO

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1. Introduction

The purpose of this paper is to describe the current status of the Phenomena Identification Ranking Table (PIRT) for the conceptual design of K-DEMO, Korean Fusion DEMO Plant. K-DEMO is to be planned as the first fusion power plant constructed in South Korea. However, several key technologies such as plasma, materials, and cooling still have large uncertainties. There are also no relevant references to facilitate the design process of K-DEMO due to its different size, commercializing purpose, and regulatory framework [1]. For this reason, the discussion of safety issues that should be considered in deciding significant design parameters was required even though K-DEMO is staying in pre-conceptual design phase. PIRT is suitable tool to recognize and investigate safety issues from previous engineering experience. It was proposed to define the phenomena of systems, components, and processes in an accident condition.

2. PIRT for K-DEMO

The PIRT is a practical and flexible technique allowing a systematic and graded approach to technical issues of varying complexity and importance. The technique can also incorporate uncertainties in the assessment and characterize them explicitly. One of the distinct advantages of the technique is to identify the knowledge level in the phenomena, which helps identify the gaps in knowledge areas requiring additional research and data collection. It should identify, recognize, and qualify the relative importance of all relevant phenomena with the associated rationales through a nine-step process. Steps 1-5 are typically defined by the facilitator of the PIRT. The expert panel provides the information developed in Steps 6-8 in concert with a facilitator [2].

● Step 1 Issue Definition

This step defines the issue that drives the needs for development of technical bases and analytical tools to perform safety analyses and regulatory reviews and other research and development needs to support K-DEMO licensing [3].

● Step 2 PIRT Objectives

The objectives of K-DEMO PIRT were to identify safety-relevant phenomena for accident scenarios and ranking the importance of these phenomena.

● Step 3 Background information

Background information relates to relevant information developed before that PIRT that can be used as the basis for determining the PIRT results. We used ITER data that is considered as a base data of PIRT for K-DEMO.

● Step 4 Potential Scenarios

The accident scenario is the double-ended rupture of multiple first wall coolant pipes during plasma burn. All first wall and blanket modules around the inboard and outboard are damaged in this scenario. Coolant will be discharged at a high flow rate directly into the vacuum vessel. The rapid coolant ingress will terminate the plasma by a disruption.

● Step 5 Evaluation Criterion

The evaluation criteria are used to judge the relative importance of each phenomena or issue. These criteria should be directly related to implications associated with the scenario in the previous step [4]. The evaluation criteria in this paper are equipment of system damage that can cause release of radioactive material.

● Step 6 Identify Phenomena

The phenomena or technical issues are identified by the experts and are informed by their experience and by background information.

● Step 7, 8 Importance Ranking & Knowledge Level

The importance ranking and level of knowledge is performed by each expert with respect to the evaluation criteria. The rationale for the importance ranking and knowledge level is also provided.

Table.1 Importance ranking

Voting value	Meaning
High (H)	First order of importance.
Medium (M)	Secondary importance.
Low (L)	Negligible importance.

Table.2 Knowledge ranking

Voting value	Meaning
High (H)	At least one mature physics-based or correlation-based model is available.
Medium (M)	At least on candidate model form or correlation form has emerged.
Low (L)	Model form is unknown or speculative.

Table.3 PIRT result for K-DEMO

System	Subsystem	Phenomena	Importance	Knowledge level	Additional comment
Vacuum Vessel	Structure	EM force	H	H	Distortion of structure or local damage
		Release of dust	H	L	Dust explosion
		Pressure increase	H	H	Local damage
		Decay heat	L	H	
	Divertor	EM force	H	H	Distortion of structure or local damage
		Production of hydrogen	M	M	
	Blanket	EM force	H	L	Distortion of structure or local damage
		Li + Water reaction	M	M	
		Be + Water reaction	M	M	
Magnet	Structure	EM force	M	H	Distortion of structure or local damage
Fueling system	Pellet system	Pressure increase	H	H	Release of source
	Gas puffing system	Pressure increase	H	H	Release of source
Heating & Current Drive System	Neutron bean injector	Pressure increase	H	H	Release of source
		Electrical damage	M	M	
Cryostat	Structure	Pressure increase	M	H	

Table 3 shows the PIRT result for the K-DEMO. Highly important phenomenon is Electro Magnetic (EM) force which is generated in vacuum vessel due to disruption of plasma. It is not yet known at what position EM force has high intensity. EM force has impact on other systems, structures or components, but the extent and nature of impact should be studied. This is instigating factor to research impact of EM force and safety issues related to this as in ITER project. Similarly, EM force should be considered as major safety issue and parameter for K-DEMO design.

3. Conclusions

In this paper, PIRT for K-DEMO was described and analysis based on this tool was performed. We have carried out researches related to safety for fusion power plant in collaboration with the academies funded by NFRI during the past 3 years. As part of this research, Integrated Safety Assessment Methodology (ISAM), which was used to develop GEN-IV nuclear systems, was used to determine the technical safety issues and regulatory requirements for K-DEMO. PIRT is one of ISAM tools. It can recognize vulnerabilities of systems and identify the gaps in technical areas requiring additional research. The results through this tool are expected to contribute on detailed design for K-DEMO as guidance for regulatory requirements and safety systems in the future.

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