Development Status of Regulatory Infrastructure for Fusion Energy

Young-Joon CHOI

KINS Korea Institute of Nuclear Safety

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1. Introduction

1.1 Fusion Development

Fusion Energy Development Plan

- **Established by the Presidential Advisory Council on Science and Technology in 2005**
- **Ultimate goal of the plan**
  - **Secure the design and construction capability of fusion power plant by sometime in 2030s**
- **Development schedule**
  - **1st stage ('06~'10): Establish infrastructure for development of fusion energy**
    - **Construct and operate KSTAR (Korea Superconducting Tokamak Advanced Research)**
    - **Participate in the construction of ITER**

- **2nd stage ('11~'20): Progress in fusion technologies**
  - **Upgrade KSTAR and participate in the operation of ITER**
  - **Secure engineering design capability for DEMO plant**
- **3rd stage ('21~'35): Secure construction capability of fusion power plant**
  - **Construct DEMO plant and complete engineering design of fusion power plant**

Fusion Energy Promotion Act: Legislated in November 2006

Safety management of fusion energy

- **Entrusted to the current atomic energy act**
- **Revision of Atomic Energy Act (including Sub-acts) is under development in KINS* (Korea Institute of Nuclear Safety)**

*** KINS : A quasi-governmental institute supporting Ministry of Science and Technology (MOST) with its expertise in performing nuclear safety regulatory activities**

- **Approx. 25 years experience in nuclear safety regulation**
- **370 staff numbers**

KSTAR Construction: Launched in December 1995

- **Design goals**
  - **Achieving steady state D-D fusion reactions up to 300 seconds with a fully superconducting magnet system**

- **Licensing Status**
  - **Classified as a radiation generating device in accordance with the Atomic Energy Act**
    - **Subject to safety review for 'Permit for Use,' inspection prior to the commencement of operation, and annual safety inspection during operation**

- Submission of a radiation safety report, a provision for safety control, etc. for the 'Permit' → Under Licensing review in KINS
  - 5 rounds of questionnaire and response reviews related to docketing and main reviews, and field investigations to resolve questions

- **Review focus**
  - Radiation safety during the facility operation
  - Adequacy of the operating procedures

- **Permit is expected in August 2007**
  - Operation will start in September 2007 just after facility inspection

ITER Participation

- To secure and to improve its fusion related technologies

1.2 Fusion Regulation

Parallel Development of Regulatory Infrastructure with Technology Development

- **Consideration of domestic and international fusion development trends**
  - **KINS launched a project to establish regulatory infrastructure for fusion energy in May 2006**

- **Major activities**
  - **Establishment of the regulatory bases for fusion energy such as preparation of safety standards and revision of atomic energy act**
  - **Development of strategic technology roadmap for identification of key regulatory technologies and their development strategies**
  - **Cultivation of human resources**

Development schedule of regulatory infrastructure

- 1st stage ('06~'08): Establish regulatory infrastructure for fusion experimental device such as ITER
  - '06. 5~'07. 1 : Basic survey and setting-up of development strategies
  - '07. 2~'08. 1 : Development of technology roadmap, development of safety standards for fusion experimental device, and revision of atomic energy acts
  - '08. 2~'09. 1 : Finalization of safety standards for fusion experimental devices
- 2nd stage ('09~'20): Establish regulatory infrastructure for the DEMO plant
  - Extension of safety standards and reflection of up-to-date technologies

2. Current Status of Fusion Regulatory Activities

Consideration Factors

- **Fusion facility will use materials currently under development**
- **Will operate in harsh conditions such as extreme vacuum, extremely low and high temperature, and extremely dense magnetic field, etc.**

  → New areas to be considered in safety regulation

Strategic Technology Roadmap (STR)

- **Establish the contents, schedule, and strategies in developing regulatory technologies**

Development of STR

- **Thirteen (13) technical areas such as materials, system design, accident analysis, and radiation assessment, etc. were identified in the STR.**
  - **Composed of thirty nine (39) core regulatory technologies**

- **The followings were analyzed for each core regulatory technology:**
  - **Key technology and its Importance,**
  - **Maturity of the technology,**
  - **Trends and prospects in technology development,**
  - **Limiting factors of technology development and solutions,**
  - **Strategies for technology development, and**
  - **Plan of securing required technology.**
- **The developed STR will be modified in 2~3 years interval to improve its realization.**

2.2 Cultivation of Human Resources

Insufficient Experience in Fusion

- **Do not have sufficient experiences and human resources for fusion energy compared to those of fission reactor regulation**

Activities

- **Basic education for fusion energy and related technologies: in 2006**
- **Fusion Information Conference**
  - **Held in May 2007 to catch up with the current technical progress in the areas identified in the STR**
  - **For KINS experts and outside researchers and experts interested in the fusion safety**
  - **Will be held periodically to pursue up-to-date technical development**

- **Fusion Safety Experts Group**
  - **Experts from universities and research institutes**
  - **Organized to periodically discuss the fusion related safety and technologies**

Recruit

- **Plans to recruit the fusion experts or students who majored in fusion energy.**

2.3 Revision of Atomic Energy Act

Fusion Energy Promotion Act: Legislated in 26 December, 2006

- **Prescribed research, development, production and utilization of fusion energy**
- **Entrusted the safety management for fusion energy to the Atomic Energy Act.**

Development Activities

- **Drafts for Atomic Energy Act**

  Enforcement Decree of the Atomic Energy Act

  Enforcement Regulation of the Atomic Energy Act

Introduction

- **To develop safety and regulatory requirements and guides for the fusion experimental device**
- **Establishment of a hierarchy of the safety standards and a format**
  - **Contents of each hierarchical tier are being developed**
- **Ultimate goal**
  - **Preparation of licensing review for the fusion power plant.**
- **For an effective step by step development**
  - **Being developed for the fusion experimental device such as the ITER**

- **Further extension after completion of 1st phase**
  - **For licensing review of the DEMO which will generate the electricity**
  - **Reflection of technical progress**

Work Scope

- **Establishment of hierarchy and format**
- **Analysis and evaluation of domestic/foreign safety and regulatory documents for identifying requirements**
- **Establishment of basic requirements (Safety Objectives, Safety Principles, and General Safety Criteria, Specific Safety Requirements)**
- **Development of Safety Review Guidelines**

Basic Approach

- **To utilize and modify existing safety standards for fission reactors**
  - **Format, contents commonly applicable to the fission and fusion energy**
  - **Incorporation of the safety concepts specifically related to the fusion energy**
- **Reflection of experiences obtained from KSTAR safety review**

In-depth Study

- **Safety and regulatory requirements and guides for fusion energy established by foreign countries**
- **Design requirements and features considered in ITER**
- **Safety issues raised by domestic or foreign organizations**

Framework of Safety Standards

- A comprehensive framework of 5 tiers
  - Safety Objectives (SO),
  - Safety Principles (SP),
  - General Safety Criteria (GSC),
  - Specific Safety Requirements (SSR), and
  - Safety Review Guidelines (SRG)
- Upper four tiers (SO, SP, GSC, and SSR) cover compulsory requirements, while SRG, forming the understructure of the hierarchy, is not considered as mandatory requirements but as a guide.

Safety Objectives	• Ultimate aim which has to be achieved in fusion safety
Safety Principles	• Essential ingredients which have to be observed in achieving what is stated in safety objectives
General Safety Criteria	• Criteria for complying with safety principles in general aspects
Specific Safety Requirements	• Requirements for complying with safety principles in specific aspects
Safety Review Guidelines	• Internal guideline on review scope, review method, interface identification, etc.
Industrial Codes and Standards	

※ Industrial Codes and Standards are not a part of the safety standards but they are shown as a reference.

Safety Objectives

- **Top tier requirement**
- **Safety Objectives**
  - **General Safety Objective**
  - **Radiation Protection Objective**
  - **Technical Safety Objective**

• General Safety Objective	
• Radiation Protection Objective	• Technical Safety Objective

Safety Principles

- **Second tier in the hierarchy**
- **Consist of four areas**
  - **General considerations, siting, design, and operation**

KINS

General Considerations		
• Safety management • Establishment and Implementation of a Quality Assurance Program • Consideration of Human Factors • Assessment of Safety • Preparedness for Emergency • Protection from Radiation		
Siting	**Design**	**Operation**
• Evaluation of Site- related actors	• Defense-in-depth	• Establishment of Limits and Conditions for Operation • Establishment of Operating Procedures • Maintenance, Testing and Inspection • Technical Support Organization

Structure and Elements of Safety Principles

General Safety Criteria

- **Substantially the top tier requirement in the actual regulation of the fusion energy**
- **Consists of 4 areas**
  - **Site/environment, design, operation, and quality assurance**
- **To date, drafts of the GSC in siting and design is being developed**
  - **Components and their key contents of the GSC in operation will be developed later.**

The structure and components of the GSC

I. Site/Environment

1. Geological Features and Earthquakes
2. Limitations on Location
3. Meteorological Conditions
4. Hydrologic and Oceangraphic Conditions
5. Impact of Man-Made Accident
6. Feasibility of Emergency Plan
7. Assessment of Radiological Impacts

II. Design

1. Consideration of fusion related features	12. Control Room, etc	23. Prevention of Collapse of Steep Slope, etc.
2. Safety Classes and Standards	13. Protection System	24. Use of Qualified Equipment
3. External Events Design Bases	14. Plasma Control System	25. Testability, Monitorability, Inspectability, and Maintainability
4. Provision against Fire Protection, etc.	15. Heat Removal System	26. Design Basis Accidents
5. Environmental Effects Design Bases, etc.	16. Fusion Power Shutdown System	27. Reliability
6. Sharing of Structures, Systems, and Components	17. Ultimate Heat Sink	28. Human Factors
7. Fusion Reactor Design	18. Processing and Storage Systems of Radioactive Wastes	29. Optimization of Radiation Protection
8. Inherent Protection of Fusion Power	19. Fuel Handling and Storage Facilities	30. Emergency Response Facilities and Equipment
9. Instrumentation and Control System	20. Radiation Protection Provisions	31. Establishment, Adjustment, etc. of Limiting Conditions for Operation
10. Confinement (or Containment)	21. Vacuum Vessel Pressure Suppression System	32. Initial Tests
11. Electric Power System	22. Alarm Devices, etc.	

III. Operation

(To be developed later)

IV. Quality Assurance

(Current existing standards will be reviewed and modified if necessary)

1. Organization for Quality Assurance	10. Document Control
2. Quality Assurance Program	11. Test Control
3. Design Control	12. Control of Measuring and Testing Equipment
4. Procurement Document Control	13. Handling, Storage and Shipping
5. Instructions, Procedures and Drawings	14. Inspection, Test and Operating Status
6. Control of Purchased Items and Services	15. Control of Nonconforming Items
7. Identification and Control of Items	16. Corrective Action
8. Control of Special Process	17. Quality Assurance Records
9. Inspection	18. Audits

Specific Safety Requirements (SSR)

- **Provide detailed rules and Form the lowest tier of the mandatory requirements**
- **Categorized into four areas**
  - **Site/environment, design, operation, and quality assurance**
- **Current structure of the SSR is composed of 16 chapters for site/environment and design**

Safety Review Guidelines

- **Provide the KINS' internal guidance on review scope, review method, interface identification, etc.**
  - **Will be developed after development of higher tiers**

Structure of the Specific Safety Requirements

Areas	Chapters	Components
I. Site/ Environment	1. Site	1.1 Meteorology 1.2 Hydrology .... (5 elements)
	2. Radiological Environment	2.1 Environmental Description 2.2 Environmental Effects of Radiation .... (5 elements)

II. Design	3. Design Common Requirements	3.1 Classification of Systems 3.2 Codes and Standards .... (14 elements)
	4. Structural Design	4.1 Geology and Foundation 4.2 Seismic Design .... (10 elements)
	5. In-Vessel System	5.1 Plasma Performance 5.2 Blanket 5.3 Diverter 5.4 Vacuum Vessel
	6. Ex-Vessel System	6.1 Magnetic System 6.2 Cryostat
	7. Fueling & Tritium System	7.1 Fueling 7.2 Tritium System
	8.Engineering Safety System & Confinement (or Containment) System	8.1 Control of Energy Sources 8.2 Engineering Safety System 8.3 Confinement System

	9. Instrument and Control System	9.1 Common Requirements 9.2 Safety Related I&C System
	10. Electric Power System	10.1 Offsite Electric Power System 10.2 Onsite Electric Power System 10.3 Coil Power Supply & Distribution System 10.4 Additional Heating Power Supplies
	11. Auxiliary System	11.1 Additional Heating & Current Drive 11.2 Cryoplant 11.3 Vacuum System 11.4 Thermal Shield 11.5 Tokamak Cooling System 11.6 Remote Handling System ..... (13 elements)
	12. Power Conversion System	(To be developed later)
	13. Radioactive Waste System	(5 elements)
	14. Radiation Protection System	(4 elements)
	15. Human Factors Engineering	(2 elements)
	16. Accident Analysis	(6 elements)

III. Operation		(To be developed later)
V. QA	Quality Assurance (18 elements)	(To be Reviewed & Modified if necessary)

3. Concluding Remarks

- **The current status of fusion regulatory activities in KINS was introduced based on the interim results.**

- **The technology development in company with the regulatory preparation result in better outputs.**
  - **Therefore, in the development process of fusion related regulatory technology, interim results will be periodically open to domestic fusion societies to draw a broad consensus or comments.**

- **In parallel with the domestic fusion regulatory activities, KINS is willing to cooperate with international regulatory societies in developing global safety standards.**
  - **For example, a technical meeting on regulators will be the possible way to discuss the technical issues for fusion energy in the regulatory point of view.**

Thank you for attention!