Establishment and Progress of K-DEMO Design Activities: A Coordinated National Approach for Future Fusion Demonstration Reactor

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1. Introduction

The Korean fusion energy development program has made significant progress with the establishment of K-DEMO design activities. In February 2023, the Korean National Fusion Energy Committee approved K-DEMO's basic concept, setting clear technical objectives and organizational framework. [1]

Design activities are structured through a task force of academia, national laboratories, and industry partners, with provision for international collaboration. This approach incorporates diverse expertise while maintaining domestic leadership in fusion technology development. The task force follows a defined timeline, with design phases spanning from pre-conceptual design assessment (pre-2026) through conceptual design (2026-2030) to engineering design activities (2031-2035).

K-DEMO's approved basic concept includes four essential goals: electric power generation exceeding 500 MW, demonstration of tritium breeding ratio ≥1, verification of intrinsic fusion safety, and acquisition of economic evaluation data. These goals come with specific design criteria, including tokamak major radius ≤7.0 m, availability ≥60%, design lifetime ≥40 years, and seismic safety standard of 7.0. The design process is supported by an organizational structure where twelve specialized working groups address core technologies under the System Integration Design Team, with oversight from both Executive Committee and National Fusion Energy Committee.

2. Design Framework Task Force

The K-DEMO design task force uses a multi-layered organizational structure for efficient collaboration and decision-making. The National Fusion Energy Committee provides strategic oversight, while the Executive Committee manages overall direction and approvals. The System Integration Design Team serves as the central coordination body, ensuring coherent integration of technical aspects and managing project timelines.

The working group structure reflects the comprehensive scope of fusion demonstration reactor design, with twelve specialized groups addressing distinct technical domains. The core plasma working group focuses on plasma physics and operational scenarios, while superconducting magnet and tokamak main device structure groups handle fundamental machine architecture. Additional groups cover heating & current drive, assembly & maintenance, control & diagnostics, and fuel cycle. The breeding blanket and divertor groups address fusion power extraction and plasma-facing components. Balance of Plant, building, and safety & licensing groups ensure integration of the fusion core into a complete power plant system.

Cross-divisional communication occurs through regular technical meetings and System Integration Design Team oversight. This structure ensures design decisions consider system-wide implications. The workflow enables concurrent engineering across working groups, maintains consistent interfaces between subsystems, provides clear paths for technical issue resolution, and ensures proper documentation of design decisions.

Performance targets for each working group derive from top-level project requirements, emphasizing system integration and interface management. The staged approach allows systematic refinement of these targets through pre-conceptual, conceptual, and engineering design phases.

3. Technical Approach and Analysis Strategy

The K-DEMO design activity explores parallel design pathways to address fusion energy development challenges. [2-5] Rather than committing to a single design, the task force evaluates both conventional large-scale demonstration reactor approaches and more compact concepts that could accelerate the timeline to fusion energy commercialization.

The conventional approach envisions a comprehensive demonstration reactor addressing all aspects of fusion power plant operation simultaneously. This pathway uses established physics understanding and engineering approaches but requires significant resources and longer timelines. In parallel, compact device concepts are being explored as pathways to faster fusion energy demonstration, focusing on specific high-priority technological challenges while accepting trade-offs in other performance areas.

This dual-track approach recognizes the evolving global fusion landscape, where various compact fusion concepts are pursued through public-private partnerships. By maintaining design options for both pathways, the K-DEMO task force ensures Korea's fusion program remains adaptable to emerging technologies and changing priorities in the global fusion development ecosystem.

To evaluate these design pathways, the task force uses complementary analysis frameworks. The Korean Tokamak System Code provides integrated physics and engineering assessments adapted for Korean fusion development priorities, incorporating lessons from the KSTAR program. The FUSE framework [6] from General Atomics enhances the design process through comprehensive multi-dimensional analysis capabilities, enabling detailed component design from system-level concepts to engineering implementation.

Through this methodical approach to design assessment, the K-DEMO task force aims to establish technically sound and economically viable pathways to fusion energy demonstration, positioning Korea's fusion program for leadership in this critical energy technology.

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