

Series No. 97-07

**THE KOREAN NATIONAL FUSION
PROGRAM BASED ON THE KSTAR
TOKAMAK PROJECT**

DUK-IN CHOI
President
Korean Basic Science Institute

This article is one in a series of occasional papers published by the Center for Science, Trade, and Technology Policy of George Mason University and the Science and Technology Policy Institute of Korea as part of their U.S.-Korea Science and Technology Cooperation Program. This article is drawn from Dr. Choi's presentation at the U.S.-Korea Forum on Fusion Science and Technology held on February 18-19, 1997 in Washington, D.C.
STEPI-GMU/CSTP Occasional Paper 97-07

Background

Korea has been involved in plasma and fusion research in a modest way since the mid-1970s. Most activities were small in scale and housed within various universities. These activities evolved in the 1980s and 90s into small-scale tokamak projects at the Seoul National University (SNUT-79), the Korea Advanced Engineering Research Institute (KT-1), and at the Korea Advanced Institute for Science and Technology (KAIST Tokamak, formerly PreTEXT from the University of Texas at Austin). In 1995, the Korea Basic Science Institute installed a medium-sized device called HANBIT, based on the TARA tandem mirror machine from MIT which is now fully operational. HANBIT is devoted to basic plasma research such as basic plasma diagnostics and radio frequency/microwave heating method development. It is operating as a national-user facility and drawing more than 20 research work groups from universities and research institutes throughout the nation.

Within the Korean Physical Society, the plasma physics division was formed in 1982 and has grown steadily, with over 300 members today and numerous activities from low-temperature plasmas to high-temperature fusion plasmas. Other related societies are the Korea Accelerator and Plasma Research Association (KAPRA), the plasma division of the Korean Vacuum Society, IEEE of Korea, and the Atomic Energy Society of Korea. Along with an active accelerator program centered at Pohang Accelerator Laboratory (PAL), which is supported by Pohang Steel Company (POSCO) and the Korean Government, these societies are covering a vast range of plasma applications activities from plasma-assisted semiconductor fabrication to plasma waste disposal. Industrial and academic sites are closely involved with this community by exchanging materials and research personnel. Membership in the community and overall funding support from industrial sites is growing rapidly every year.

With the active support of these organizations, the national government, and industry, a national program for fusion energy development was discussed and formulated. In 1995, the Korean

National Fusion Program (KNFP) was adopted with the construction and operation of the KSTAR tokamak as its centerpiece.

KSTAR

Mission

KSTAR stands for Korea Superconducting Tokamak Advanced Research. The mission of the project is to develop a steady-state-capable advanced superconducting tokamak to establish the scientific and technological basis for an attractive fusion reactor as a future energy source.

When the national program was formulated, several key objectives were agreed upon. They are: first, when the device becomes operational, it should be “relevant” to the world-wide fusion community. That is to say, the results of the experiments performed on the device, as well as its operation, should attract the interest of the scientific community world-wide and contribute to development of existing and future devices. Second, the construction and operation of the device should contribute to the advancement of knowledge in both Korean industry and academia. Third, the cost of the project must be within the financial capability of the Republic of Korea.

KSTAR will be the world’s first fully superconducting magnet tokamak. Present day tokamaks such as Tore-Supra of France, Triam-1M of Japan, and Russian devices such as T-15, as well as the planned devices in India and China, are all only partially superconducting. Thus, except for the International Thermonuclear Experimental Reactor (ITER), which will not be operational until ten years after the KSTAR device is completed, there are no other tokamaks with the fully superconducting features.

With the development of two fully superconducting magnet stellarators—the LHD (Large Helical Device) in Japan, to be commissioned in 1998; and Wendelstein 7-X in Germany, approved in 1996 with construction to be completed in 2005—there will be three major contributing devices

operational during the first decade of the next century, even before ITER becomes available for use in 2010.

Research Objectives

There are three research objectives imbedded in the KSTAR project. They are: to extend tokamak performance boundaries through active control of profiles and transport; to achieve steady state operation using non-inductive methods which will overcome a major limitation of the present-day tokamak operation; and to contribute to the optimization of an attractive fusion reactor in the next decades.

Design Features

Figure 1 shows the design features of KSTAR. The first two are for long-pulse operation adopting the fully superconducting magnets (central solenoid coil, toroidal magnet coil, and poloidal magnet coil). The remaining features (flexible control of plasma profile, shape, and position) apply to "advanced tokamak scenarios." They are the elaborated results of the experimental and theoretical advances from the most intensive recent activities of the world-wide fusion community, but they have not yet been applied to the long-pulse devices.

Figure 1
KSTAR Tokamak Design Features

Fully superconducting magnets
Long pulse operation capability
Flexible pressure and current profile control
Flexible plasma shape and position control
Advanced profile and control diagnostics

Parameters

The parameters of the KSTAR project are displayed in Figure 2. Its major radius, which defines the baseline machine size, is 1.8 meters, and the plasma volume is basically determined by the minor radius which is 0.5 meters. Toroidal magnetic field and plasma current which define the machine's performance is 3.5 Tesla at the center of the plasma and 2 mega-amperes respectively. Nb₃Sn has been chosen for the superconducting central solenoid and toroidal magnet coil material. Both NbTi and Nb₃Sn have been selected for the superconducting poloidal magnet coil material. Plasma shape, which is crucial in advanced tokamak scenarios, has also been determined by elongation of 2.0 and triangularity of 0.8 for the case of double-null plasma. Pulse length will be 20 seconds during the initial operation phase and will be extended to 300 seconds for full-powered operation phase. Major heating and current drive for KSTAR will be carried by neutral beam injection (NBI) systems using positive and negative ion beam sources, and additional ICRH (Ion Cyclotron Resonance heating) and Fast/Lower Hybrid (LH) wave heating and current drive system will be adopted.

Figure 2
Korean National Fusion Project
Advanced Superconducting Tokamak Experiment

	Parameters	Remarks
Major Radius (R ₀)	1.8 meter	Nb ₃ Sn, NbTi
Minor Radius (a)	0.5 meter	
Toroidal Field (B _{T0})	3.5 Tesla	
Plasma Current (I _p)	2.0 MA	
Elongation (κ)	2.0	
Triangularity (δ)	0.8	
Pulse Length	20 sec < t _{pulse} < 300 sec	Current Drive
Heating & Current Drive	NBI ICRH / FWCD, LHCD	PI, NI
Plasma Species	H / D	Neutron Budget

Cost and schedule

Figure 3 provides an overview of the cost and funding sources for the project. When converted to U.S. dollars, the production of the tokamak costs approximately \$200 million and the facility \$100 million, for a total of \$300 million excluding personnel costs. Concept definition activities were completed at the end of 1996. Conceptual engineering design activities started in the first quarter of 1997 and will be completed by the end of 1998. Major subsystem fabrication will begin in mid-1998. Along with the tokamak R&D activities, the main experimental building and subsystem construction will proceed in parallel. Civil and experimental building construction work will be completed with first priority given to providing on-site system integration. System integration in the new facility will begin in 2000, and KSTAR will be commissioned on August 15, 2002. The Korean government is funding three-fifths of the total cost with the additional two-fifths being picked up by the Korean Electric Power Company and industry.

Figure 3
KSTAR R&D and Consturction Project Cost

Advanced Superconducting Tokamamk R&D (HAN-Project)					
	1995	1996	1997	1998-2001	Sub-Total
Government	3.0	6.1	8.0	72.9	90.0
KEPCO	2.0	3.0	4.0	21.0	30.0
Industries	1.5	2.0	4.0	22.5	30.0
Total	6.5	11.1	16.0	116.4	150.0
Building and Conventinal Facility Construction					
	1997	1998	1999	2000	Total
Government	6.8	18.0	23.3	21.4	69.5

Organization and Structure

The policy of KNFP is discussed, updated, and determined by the National Fusion Council with help from the Fusion R&D advisory committee. KBSI, which oversees the National Fusion

Research and Development Center, is the lead institution in the KSTAR project, but receives help from the national laboratories, universities, industry, and international collaborators. Figure 4 shows the structure of the project.

Figure 4
Project Structure

	Project Names	Responsible Institutions
Tokamak Design & System Integration	Tokamak Conceptual and Engineering Design	Korea Basic Science Institute (Lead Institute)
	Tokamak System Integration	
	Tokamak Physics & Modeling	Korea Advanced Institute of Science and Technology
Tokamak Device Development	Tokamak Structure and Vacuum System	Korea Basic Science Institute
	Superconducting Magnet System	Samsung Advanced Institute of Technology
	Power & Control System	Pohang University of Science and Technology
	Plasma Diagnostics System	Korean Advanced Institute of Science and Technology
	Plasma Heating System - NBI - RF - Microwave	Korea Atomic Energy Research Institute

There are five major institutions participating with KBSI on the project. These are the Korea Advanced Institute of Science and Technology (KAIST) working on the tokamak physics and modeling, and plasma diagnostics system; Samsung Advanced Institute of Technology (SAIT) developing the superconducting magnet and cryostat system; Pohang University of Science and Technology (POSTECH), PAL, and POSCO working on power supply and control system

development. KBSI, together with Korea Heavy Industry and Samsung Heavy Industry, is responsible for the tokamak conceptual and engineering design, tokamak system integration, and the fabrication of the tokamak structure and vacuum system and the plasma heating system.

International Collaboration

International participation is essential to the success of this program. KBSI has formal arrangements with some institutions in other countries, such as with the Princeton Plasma Physics Laboratory (PPPL), the lead institution for the KSTAR design efforts in the United States; and the National Institute of Fusion Science (NIFS), the lead institution for the development of LHD in Japan. KBSI also is discussing cooperation with other institutions such as Max Plank Institute of Plasma Physics in Germany, which is the lead institution for the development of Wendelstein7-X.

The Korean National Fusion Program is very much indebted to PPPL, the Plasma Fusion Center at the Massachusetts Institute of Technology, General Atomics, Lawrence Livermore National Laboratory, and Oak Ridge National Laboratory for their contributions to the design development of the KSTAR project, especially in advanced superconducting tokamak system design, superconducting magnet system design, and vacuum vessel and plasma facing components design activities. KNFP anticipates in-depth collaborations with major fusion research institutions for the forthcoming tokamak engineering and operation phases.

Conclusion

KSTAR will make critical contributions to the world fusion research and development program by extending advanced tokamak research to high-performance and steady-state operation regimes, by contributing techniques for successful steady-state physics operation of ITER, and by comparing advanced tokamak physics results with those from superconducting stellarators and spherical tokamaks.

We believe that the successful construction and operation of KSTAR will advance Korea's scientific and technological capability in significant ways. Some of the benefits we envision are in superconducting magnet design, fabrication, and operation; in the development of high power neutral beam sources, and microwave and radio frequency technology development; in advanced plasma state-of-the-art computational methods for massive long-pulse data acquisition and archiving; in the development of large-scale ultra high vacuum technology; and in high temperature material development and fabrication.