KSTAR PROJECT

Korea Superconducting Tokamak Advanced Research

KSTAR ASSEMBLY

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## Overview

### KSTAR Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Radius, $R_0$</td>
<td>1.8 m</td>
</tr>
<tr>
<td>Minor Radius, $a$</td>
<td>0.5 m</td>
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<tr>
<td>Plasma Current, $I_p$</td>
<td>2.0 MA</td>
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<tr>
<td>Elongation, $\kappa$</td>
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</tr>
<tr>
<td>Triangularity, $\delta$</td>
<td>0.8</td>
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<tr>
<td>Toroidal Field, $B_0$</td>
<td>3.5 Tesla</td>
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<tr>
<td>Pulse Length</td>
<td>300 sec</td>
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</table>

| Dimension                | 8.6 m (H)      |
|                          | 8.8 m (D)      |

| Superconductor           | Nb$_3$Sn, NbTi|
|                         |                |
| Magnet Weight            | 270 Ton        |
| Cryogenic System         | 9 kW           |
Scope of the KSTAR Assembly

◆ Assembles all of the major systems

◆ Regulates the schedule, interface, space allocation, safety, and QS for In-cryostat components and ancillary systems including

  ● Current feeder system
  ● He piping system
  ● Diagnostics for 1st plasma
  ● Heating systems for 1st plasma
  ● In-Vessel components for 1st plasma
  ● Local I&C sensors and cables
  ● Fueling & glow discharge systems
  ● Port blanking

◆ Establishes and maintains the survey and alignment (S&A) network system

◆ Design, fabrication, and construction of the assembly jigs & tools system
Major Systems of the KSTAR

Warm Structures
- PFC & IVCC
- VV & PORT
- CRYOSTAT
- ASSEMBLY TOOLS

Cold Structures
- SC COILS
- MAGNET STRUCTURE
- THERMAL SHIELD
Key Features

1. Coordinate System

- Two coordinate sets during the assembly
- The 1\textsuperscript{st} coordinate is established from the geometry of cryostat support beam
- After assembly completion of the TF, the 2\textsuperscript{nd} data is set-up to provide a reference for SC magnet installation
- Reference in the 2\textsuperscript{nd} data set has offsets from 1\textsuperscript{st} set to coincide each other in cryogenic temp.

- ✓ Mid-plane Level of VV & Cryostat : 4,200 mm
- ✓ Mid-plane level of the SC magnets: 4,205 mm
- ✓ The TF is assembled 7 mm outward in radial direction @ room temp.

Illustration - thermal contraction of the TF
2. Assembly of the VV and TF Magnets

- TF magnet is inserted through the 22.5° gap of the VV, and positioned one by one
- Narrow clearance between VV (VVTS) and TF magnet
- Assembly tolerance requirement of the TF: within ±1mm
- VV sector 3 is divided into 24 small pieces
- It needs a special jig system
Main Assembly Jig System
Key Features

3. Assembly of the Central Solenoid

- Segmented CS coils operating in difference current values
- Compressive force during reference scenario
- Separation force between CS1 & CS2: about 10MN (MRF condition)
- Preload on CS coils to prevent coil separation and lateral movement
- Designed preload: ~1,000 tons
- Strategy:
  - Heating the shells
  - Measuring strain
Progress – Before TF Magnet Assembly

- Cryostat Base
- Gravity Support
- Assembly Jig for the TF Magnet
- Install. of the VVTS
- VV 337.5° Sector
- Site Weld of the VV
- Positioning of the VV & VVTS
- Pre-Install. Of the Lower PF Coils
- Assembly Jig Test with TF00
Progress—Assembly of the TF Magnet

1. Site Delivery of a TF Magnet
2. Insulation Plates Bonding
3. Start Site Assembly of the TF Magnet
4. Loading on the Assembly Tool
5. Insertion through 22.5° Gap of the V.V.
6. Installation on the Gravity Support
7. Measurement & Alignment
8. Shear Key Insertion
9. TF Magnet System after Assembly Finish
Components between Two TF Magnet

Cylindrical Shear Key

Rectangular Shear Key

Conical Bolt

Bolt & Nut
Alignment Result of the TF Magnet
After the TF Magnet Assembly
Assembly of the PF Coils

PF6U Coil
PF7U/L Coil
PF6L Coil
PF5L Coil
Assembly of the Central Solenoid (CS)

- Setup jig installation
- Bottom block assembly
- Lower buffer assembly
- CS4L subassembly
- CS4L turning over
- CS4L standing
- CS4L assembly
- CS4L alignment
- CS3L assembly
- CS2L assembly
- CS1L assembly
- CS1U assembly
- CS2U assembly
- CS3U assembly
- CS4U assembly
- Wedges & block & shells
- Shell heater assembly
- Support lug assembly
- Preloading

Main Assembly
Pre-Loading of the CS

Heating the CS Structure for Preloading

Results

- Max. Temperature: 140°C at outer shell
- Expansion of the shell: 6 mm
- Preloading @ room temperature: 800 tons
Installation of the CS on the TF
Summary of the KSTAR Assembly Progress

- Cryostat Support
- Base Frame of Main Jig
- Cryostat Base
- Supports of Rail System
- Gravity Support
- Partly Removal of Main Jig
- Accept. Test of Main Jig
- Assembled Main Jig
- Top Frame of Main Jig
- Main Column of Main Jig
- Install. VV and VVTS
- Re-assemble of Main Jig
- Assembly of 1st TF
- Assembly of the Last TF
- VV Sector 3 after Site Weld

It took more than 1 year
Summary of the KSTAR Assembly Progress

- Mechanical Assembly Completion
- Port Blanking
- Basic Diagnostic Install.
- 1st Heating Device Install.
- Ready for Integrated Machine Commissioning
Status - Current Feeder System

see Y. M. Park, et. al, FT/P7-1
Status – Inside of the Vacuum Vessel
Integrated Commissioning - Objectives

• Objective:
  - to test the engineering performance and operational reliability of the KSTAR device
    ✓ assembly status of the tokamak structures
    ✓ superconducting magnet system & interfaces
    ✓ vacuum system & gas fueling system
    ✓ cryogenic facility for cool-down
    ✓ power supply & quench protection system
    ✓ control system & local I&C
    ✓ plasma heating and diagnostics
    ✓ Safety & interlock

• Key parameters to achieve
    ✓ Vacuum in VV : 5.0 e-7 torr
    ✓ Vacuum in cryostat : 1.0 e-4 torr at room temp.
    ✓ Thermal shield temperature : 80 K
    ✓ Coil temperature : 5 K
    ✓ Toroidal magnet flux density : 1.5 T
    ✓ Plasma heating device test : ECH system (0.5 MW)
    ✓ 1st Plasma : about 100 kA
Overall Commissioning Procedure

- System Assembly
  - Individual System Test
    - Evacuation & Leak check
      - Cool-down
        - Coil Excitation
          - 1st Plasma Scenario
## Overall Commissioning Schedule

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</table>
2. 2006. Mar: Completion of TF Magnet Assembly
3. 2006. Oct: Completion of CS Magnet Assembly
4. 2007. Mar: 154 kV Power Connection (50MVA)
5. 2007. Aug: Tokamak Assembly Finish
Thank You for Attention