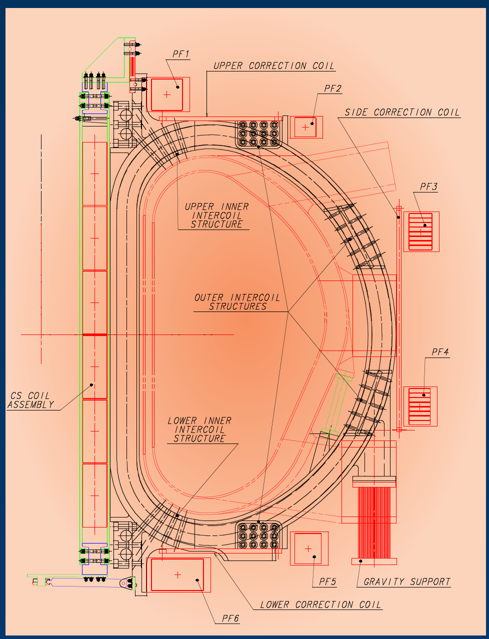
ITER Engineering Design Activities - R & D



Magnets and Structures

The superconducting magnet system has three main subsystems:

- *18 toroidal field (TF) coils which produce the confining/stabilizing toroidal field;*
- *6 poloidal field (PF) coils which contribute to the plasma positioning and shaping;*
- *a central solenoid (CS) coil which provides the main contribution to inducing current in the plasma.*

Correction coils (located above, outboard of and below the TF coils) are also required to correct error fields that arise due to imperfections in the actual PF and TF coil configuration, and to stabilize the plasma against resistive wall mode instabilities.

The magnet system weighs, in total, about 8,700 t.

The CS and TF coils use Nb_3Sn as superconductor, and the technology of "wind, react and transfer", whereas the PF and correction coils use NbTi. All coils are cooled by supercritical helium at ~ 4.5K.

The TF coil case is the main structural component of the magnet system and the machine core. The PF coils and vacuum vessel are linked to the TF coils such that all interaction forces are resisted internally in the system.
The TF coil inboard legs are wedged all along their side walls in operation and they are all linked at their two ends to two strong coaxial rings which provide toroidal compression and resist the local de-wedging of those legs under load.
At the outboard leg, the out-of-plane support is provided by intercoil structures integrated with the TF coil cases.

Central Solenoid Model Coil Project (L-1)

Objective

- *Verify conductor performance under ITER-relevant conditions.*
- *Demonstrate the major steps in manufacturing the conductor and ITER CS coil.*

The main coil consists of two modules nested inside each other. To test various types of conductor, "insert coils" can be fitted within its bore. Three insert coils relevant for ITER are foreseen.

Significant advances on present superconducting coil manufacturing technology were required:

- *substantial quantities of Nb_3Sn strand to a uniform quality;*
- *jacketing of a cable of this strand to provide structural support against magnetic forces;*
- *accurate conductor bending to the winding shape;*
- *heat treatment in a controlled atmosphere, insulation in an "unspringing" process before stacking to form the winding, and then impregnation with epoxy resin.*

Transfer of a layer onto a coil assembly to form the inner module at Lockheed Martin.

Outer module, manufactured by Toshiba, being placed outside the inner module, which has already been installed in the vacuum chamber.

Model coil and insert coil installed at the test facility in JAERI Naka. In the background is the vacuum chamber lid.

In April 2000, the maximum field of 13 T with a cable current of 46 kA and magnetic stored energy of 640 MJ were successfully achieved in the test facility. Pulsed operation has been experienced under conditions (ramp-up to 13 T at 0.6 T/s, ramp-down at 1.2 T/s) more severe than for ITER-FEAT operation. One insert coil has been tested at 13 T and charged/discharged 10,000 times. More tests are underway.

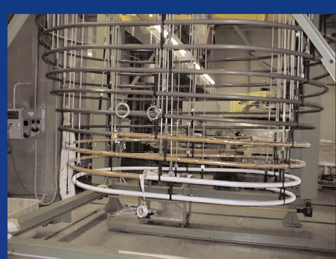
Toroidal Field Model Coil Project (L-2)

Objective

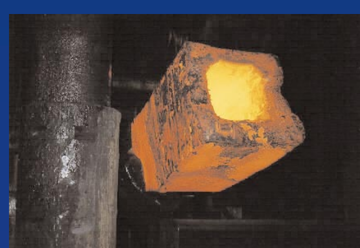
- *Validate design and analysis.*
- *Demonstrate industrial manufacturing methods.*
- *Test performance of each component integrated in the magnet.*
- *Test and demonstrate reliable operation.*

The model consists of a "race-track" shaped sub-size coil, about 4 m high and 3 m wide, and two full-size sections of the outer housing. The coil includes the key technical features and manufacturing approaches foreseen for the actual ITER TF coils.

Although the conductor will not be fully tested for superconducting properties (done in L-1) the manufacturing defines appropriate tolerance targets, procedures and quality control steps. The test of the sub-size coil will create realistic magnetic loads to demonstrate the structural concept.

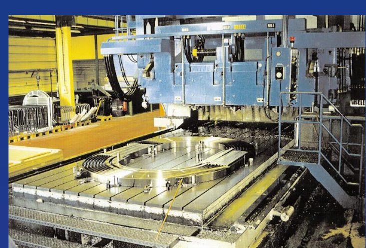


Conductor after heat treatment, opened out by 'unspringing' to give space to wrap with insulation without damaging the superconductor. The insulation has been applied to the lower turns (Ansaldo Energia).



Inner leg case section during forging as a hollow tube, before cutting into two U sections (Kind).

Machining of the radial plate which reinforces the conductor. The conductor is fitted into grooves in this plate (Mecachrome/Nöll).



The coil with the final surface finish (sand blasted and with interface surfaces machined) while it is leak tested and the inlet headers are preassembled on top of the coil (Alstom).

The top of the groove is closed by a cover plate which is laser welded into position (RTM).

The model coil is about to be moved to the TOSKA facility at Karlsruhe, Germany, which has been adapted to accommodate the coil and its test programme.