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Preassembly of the tokamak T-15MD magnet system

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HIGHLIGHTS

- T-15MD project is the initial technical base for creating fusion neutron sources.
- Magnet system of T-15MD will confine the hot plasma in the divertor configuration.
- Toroidal magnetic field at the plasma axis is 2 T.
- Preassembly of magnet system was completed.
- T-15MD should begin operations in 2018.

GRAPHICAL ABSTRACT

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ABSTRACT

Presently, the Tokamak T-15MD is being built in NRC "Kurchatov Institute", Russia. All elements of the magnet system have been manufactured by the end of 2015. The preassembly of the tokamak T-15MD magnet system is carried out at plant in Bryansk. The purpose of the preassembly of the magnet system is to bring together all of the elements, which will provide the necessary experience for the later assembly of the tokamak at the NRC "Kurchatov Institute" in Moscow. The results of the preassembly of the tokamak T-15MD magnet system are presented.

1. Introduction

The accelerated development of atomic power engineering around the world has aggravated the problems related to fuel supply and disposal of long-lived high-activity wastes. The development and creation of a stationary fusion neutrons source (FNS) based on tokamak is the best way to solve these problems. At the present time, in the NRC "Kurchatov Institute" within the Federal Target Programme "Nuclear energy-technologies of new generation for period 2010 – 2015 and to the prospect until 2020" the tokamak T-15MD is being built. Tokamak T-15MD is the first step

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Table 1
T-15MD main parameters.

Parameter	Value
Major radius of torus R, m	1.48
Aspect ratio	2.2
Plasma current I_P, MA	2.0
Elongation, k	1.9
Triangularity, δ	0.3–0.4
Plasma configuration	SN,DN
Discharge pulse duration, s	10
Toroidal magnetic field at plasma axis, T	2
Magnetic flux swing in central solenoid, Wb	6
Neutral beam injection power, MW	6
ECR heating power, MW	7
ICR heating power, MW	6
LH heating power, MW	4

on the way to the creation of an FNS. The main goals of the tokamak T-15MD are presented in [1,3].

All elements of the magnet system were manufactured by the end of 2015. The preassembly of the tokamak T-15MD magnet system is being carried out at a plant in Bryansk. The purpose of the magnet system preassembly is to bring together all of the elements, which will provide the necessary experience for later assembly of the tokamak at the Kurchatov Institute in Moscow. The T-15MD main parameters are presented in Table 1.

2. T-15MD magnet system design

2.1. Toroidal magnet system

The toroidal magnet system consists of 16 D-shaped coils (Fig. 1) that form an arched structure [2,3]. The level of ripples at the outboard plasma boundary is approximately 0.8%. Each coil has 50 turns that are wound by a hollow conductor made of silver-copper alloy.

The toroidal winding is cooled with distilled water. Each coil has four parallel water branches. The total water mass flow rate through the winding is 43 m^3/h, with a pressure drop of 0.8 MPa.

The toroidal magnet is charged by eight thyristor convertors (22 kA, 1 kV each). The rated value of the toroidal magnetic field at the plasma axis is $B_0 = 2$T. The current plateau duration is ten seconds.

Fig. 1. D-shape coil at plant in Bryansk.

Fig. 2. Central solenoid.

2.2. Poloidal magnet system

2.2.1. Central solenoid

The central solenoid (Fig. 2) consists of three separated coils. Each coil is wound with two parallel hollow conductors that have a trapezoidal form and are made of silver-copper alloy. The coils are charged by independent power supply systems. The magnetic flux swing in the central solenoid Ψcs is approximately 6 Wb ($I_{cs} = \pm 40$ kA).

2.2.2. Poloidal field coils

The poloidal field (PF1-6) coils (Fig. 3) must compensate for stray magnetic fields on the breakdown stage, maintain the equilibrium of the plasma column during current ramp-up, maintain the ramp-down of the plasma current and create the limiter and different divertor configurations.

PF coils are placed outside the toroidal winding and are fastened to the TF coil cases. All coils are cooled by distilled water. Each PF coil is fed by an independent current source.

For fast plasma position control, the four framed active control coils (HFC) are placed around the torus in the space between the vacuum chamber shell and the toroidal winding (Fig. 3). The power source for the HF coils is intended to perform on the basis of the single-phase voltage inverter. The power source provides current up to 10 kA, power up to 15 MW and a frequency of 1 kHz.

3. Assembly of the magnet system

3.1. Preparation of the assembly site

For assembly of magnet system elements at plant in Bryansk (GKMP Group) a foundation pit (Fig. 4) with a depth 1.6 m and a diameter of 10 m has been excavated under the base slab (Fig. 5). It has been reinforced with wire mesh.

Sixteen bolts M30 for the fastening fixing the central farm and 16 bolts M30 for fastening sectors, support structure were installed in the foundation pit. The surface of the foundation pit has been reconciled in the horizontal plane to install the central farm sectors and support structure by using a laser level with high precision ($3 \cdot 10^{-4}$ mm/m). This made is possible to use the minimal number of seals (total 3).

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Fig. 3. Poloidal field (PF1-6) coils and HF coils.

Fig. 4. Foundation pit.

Fig. 5. Base slab.

3.2. Assembly of the support structure

During the first stage, the central farm has been installed on the base slab. Installation on a horizontal plane with the required tolerances allowed the installation of beacons between the farm and the base slab, which was followed by mortar that filled in the resulting gap. The sectors support structure was set in the horizontal plane with the required tolerances by the installation of insulating gaskets between the base slab and the sector support structure. In the center of the farm a technological column with an outer diameter 830 mm was installed (Fig. 6). Deviation from the vertical to an accuracy of 1 mm ensured that the technological gaskets were installed between the flange of the column and sectors support structure. The technological column was fastened to sectors produced through the flange that fastened to the sectors through the flange by welding.

To install the toroidal field (TF) coils on the sectors support structure, the montage of supports under the TF coils and the technological thumbs were used for temporary installation TF coils with

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Fig. 6. Technological column and support structure.

Fig. 7. Toroidal field magnet assembly.

wedge jacks. TF coils were installed with the required tolerance in the vertical plane (<2 mm/5 m height).

3.3. Assembly of toroidal magnet system together with horizontal field coils and poloidal coils

The first TF coil with insulating wedged surface was installed attached to the technological column using a clamp. The second TF coil was attached to the first, by using isolated pins. The remaining TF coils were mounted like the second TF coil. The TF coils were fully installed in the vertical plane with the required accuracy by using wedge jacks. The TF coils were fixed in the radial plane, and technological threaded couplers were established between the coils. The toroidal field magnet assembly is shown in Fig. 7.

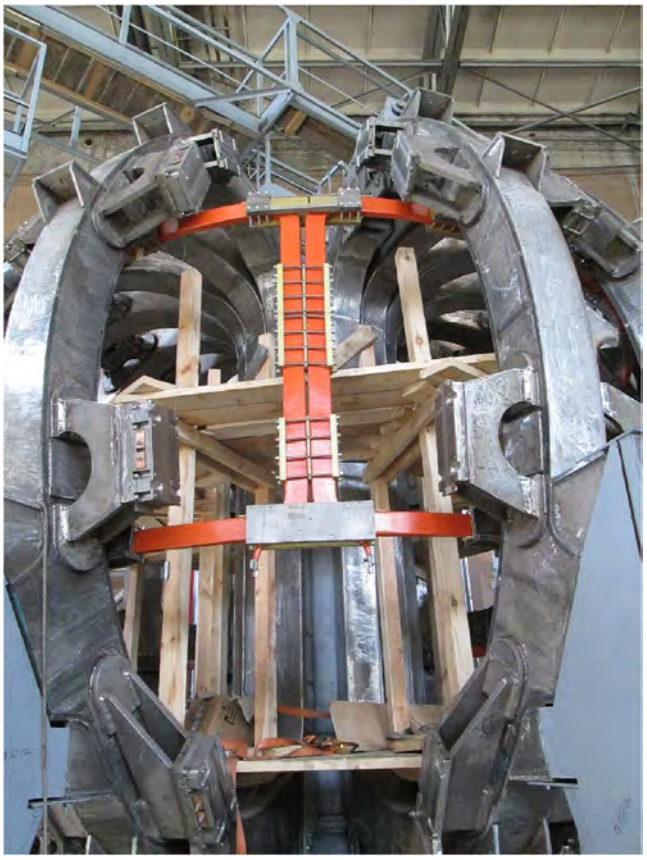

Fig. 8. Placements of HF coils inside toroidal winding.

Fig. 9. Toroidal winding together with poloidal field coils.

The inter-coil mechanical structure was attached to coil cases by welding. Initially, all four of the inter-coil mechanical structures (lower, lower intermediate, upper intermediate, upper) were

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Fig. 10. Vacuum vessel shell.

welded with point contacts. Final welding was performed after verification the installation of the inter-coil structures.

To install the four framed active control coils around the torus in the space between the vacuum chamber shell and the toroidal winding, one toroidal field coil was removed. The position of the horizontal field coils relative to the TF coils was controlled by a laser level. Mount of HFC was carried out with the help of brackets that are welded to the to TF coil cases. The HF coils were clamped between them. Placements of HF coils inside toroidal winding are shown in Fig. 8.

Finally, the three control coils PF1, PF3, PF4 were installed outside the toroidal winding (Fig. 9).

3.4. Assembly of the magnet system together with vacuum vessel

The next step of preassembly of the magnet system will be the integration of part of the vacuum vessel into toroidal winding. The vacuum vessel shell (Fig. 10) will be cut to four parts (four quarter sections). Half of the toroidal coils and two horizontal field coils will disassembled. Using the special rails two sectors of the vacuum vessel will be integrated inside the half of the toroidal winding.

After finishing the preassembly of magnet system together with vacuum vessel parts, all elements will be disassembled and delivered to the Kurchatov Institute for assembly of the tokamak T-15MD in 2017 year. The Tokamak T-15MD should begin operations in 2019.

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