EAST superconducting tokamak device

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EAST is a Chinese National Project designed to develop scientific and technological basis on the steady state operation of advanced tokamak [1]. It is a full superconducting tokamak with Superconducting TF and PF magnets, has a long pulse operation capability and appropriate auxiliary heating and non-inductive current drive system, that offer a possibility for steady state advanced performance experiment. The design feature of the EAST and its kW/4K cryogenic system are described in this paper.

TOKMAK DEVICE

General Description

The EAST superconducting tokamak is a full superconducting device, which consists of superconducting toroidal filed (TF) and poloidal Field (PF) magnets, vacuum vessel and in vessel components, thermal shields and cryostat. The cooled components are TF magnets, PF magnets, support structure and thermal shields. Dimensions of the EAST device are 10 m (with the main support) in height and 7.6m in diameter. Its total weight is 360 tons. The main parameters of the EAST device are listed in Table 1

Table 1 Main Parameters

Toroidal Field, B_t	3.5 T
Plasma Current, I_P	1 MA
Major Radius, R_O	1.75 m
Minor Radius, a	0.4 m
Elongation, K_x	1.6 – 2
Triangularity, δ_x	0.6 - 0.8
Pulse length	10- 1000 s
Configuration	Double-null divertor
	Single null divertor

Conductor development

NbTi cable-in-conduit conductor (CICC) is used for both TF and PF magnets. [2] The configuration of the TF cable is (2SC+2Cu)×3×4×5. Two segregated pure copper wires are added in the first stage sub-cable to increase the copper ration in the cable and the last stage cable is formed by five bundles of the third stage sub-cables surround a 21 strands copper core. All of the wires in the cable are coated by Tin alloy. Stainless steel 316LN tube is used as conduit material, the tubes are welded together form a 600 meters long jacket, and the cable is pulled into the jacket.

The conductors for PF1-PF10 have same configuration with the TF cables, instead of Tin alloy, Ni coating on the surface of all strands is adopted to reduce AC losses. The conductor for other two pairs of outer PF coils has less SC strands and higher copper fraction. The sizes of conductors are 20.4mm×20.4mm for TF and PF1-PF10 coils and 18.6mm×18.6mm for PF11- PF 14 coils. The cabling configurations of two types of CICC are shown in Figure 1.

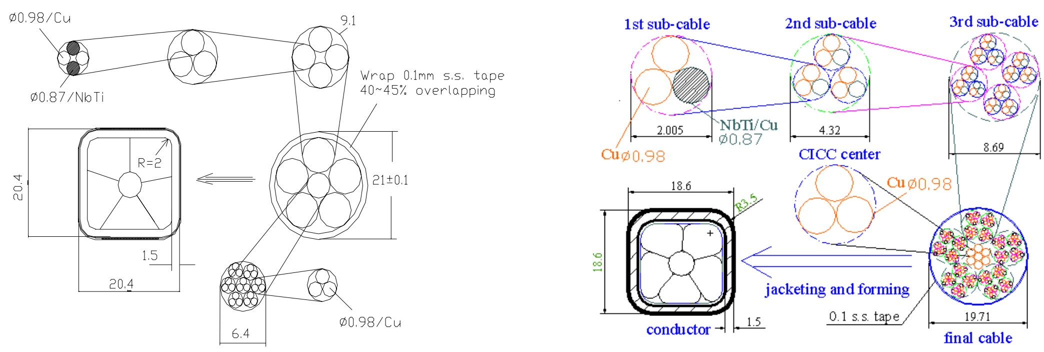


Figure 1 Two types of CICC configuration

<u>TF Magnet</u>

The TF magnet [3] is consists of 16 D-shaped coils, providing a field of 3.5T at the plasma radius of 1.75 m with a peak field of 5.8T at the TF coils. Table1 listed the parameters of the TF magnet.

Each TF coil contains 130 turns in the forms of 2 of 6 pancakes winding. The entire winding pack is vacuum pressure impregnated (VPI). There are 6 cooling channel in one TF coil and 96 cooling channel in total. All of the channel are connected in parallel and cooled by 3.8 K supercritical helium.

The TF coil cases, which enclose the TF coil winding pack, are welding structure. Stainless steel tubes are embedded and soldered all along the side surfaces of the cases. 4.5 K Supercritical helium will be used for the case cooling.

Table 1 Specifications of the TF system

Magnetic field at the plasma center	3.5T
Maximum field at the coil	5.8T
Number of TF coils	16
Total turns of the TF system	2080 (16×130)
Operating current	14.31kA
Total stored energy	298.39MJ
Conductor length of each coil	1187m
Length of cooling channel	200 m
Operating temperature	3.8 K

<u>PF Magnet</u>

The EAST PF system [4] consists of a central solenoid (CS) and four pairs of PF coils located symmetrically about the vertical axis of the equatorial plane of the device.
All PF coils are circular. The six inner PF coils form the CS assembly, each coil is

vacuum pressure impregnated with epoxy resin. The inlets and outlets for liquid helium are put in the inner side for CS and divertor coils and in the outer side for two pairs of the outer coils.

All PF coils are attached to the TF coil cases to support the electro-magnetic and gravity loads. The main parameters of the PF coils are listed in Table 1.

Table 1 Specifications of the PF system

	PF1- 6	PF 7- 8	PF 9-10	PF 11-12	PF13-14
Out/inner diameter/ Height mm	1418/1085/476	2401/1889/103	2670/188/289	6054/5779/221	6650/6468/179
Turn/cooling channel	140 / 5	44 / 2	204 / 12	60 / 10	32 / 8
Conductor mm	20.8×20.8			18.6×18.6	
B_{max} T	4.3			1.5	
dB/dt_{max} T/s	6.8			0.7	
I_{max} kA	14.5				
Temperature K	3.8				
Total flux swing VS	10				

<u>Thermal Shields</u>

The thermal shields comprise of the vacuum vessel thermal shield (VVTS), the cryostat thermal shield (CTS) and the ports thermal shield (PTS) [5]. The VVTS is consisting of 16 sectors and the CTS is divided into three parts: upper cap, middle cylinder and bottom platform, each part consists of 8 sectors. The PTS connecting VVTS and CTS are bolted on them during assembling. The Total surface area of thermal shield is 310 m2. All of the thermal shields are double-wall structures. 19×19mm2 cooling tube is sandwiched between two 3mm thick stainless steel panels. There are 32 parallel cooling circuits for VVTS and PTS and 24 parallel cooling circuits for CTS. The VVTS and PTS are cooled by 58K helium gas at first and then, the return gas will be cooled down to 80 K in a liquid nitrogen sub-cooler and used for CTS cooling.

CRYOPLANT AND CRYOGENIC DISTRIBUTION SYSTEM

The cryogenic system includes the cryoplant and the distribution system [6]. The cryoplant provides supercritical helium to cool TF and PF coils, their superconducting bus-lines, magnet support structures and current leads. It also provides cold helium flow to thermal shields.

According to the estimation of the heat loads, the helium refrigerator is designed at the capacity of 1050W/3.5K+200W/4.5K+13g/s LHe + 13KW/80K. An oil ring pump is used to reduce the pressure and obtain the temperature of 3.5K Figure 2 shows a schematic flow sheet of the refrigerator.

The compressor station consists of five screw compressors arranged in two stages; four stages oil removal system and 9000Nm^{3}helium recovery system. A 10000 L Dewar is used as the storage of liquid helium and regulates cooling capacity of the plant when the heat load increases or decreases.

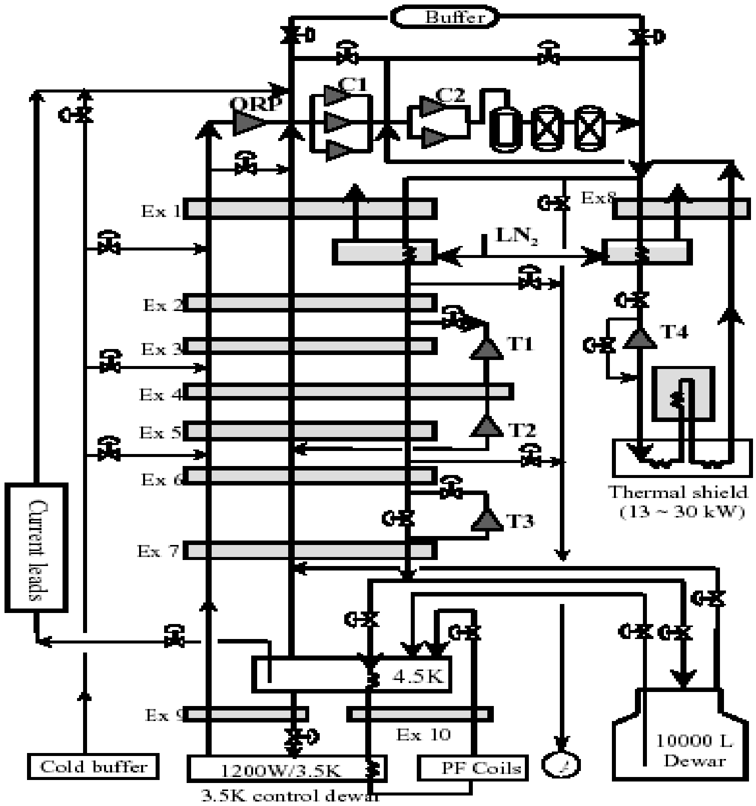
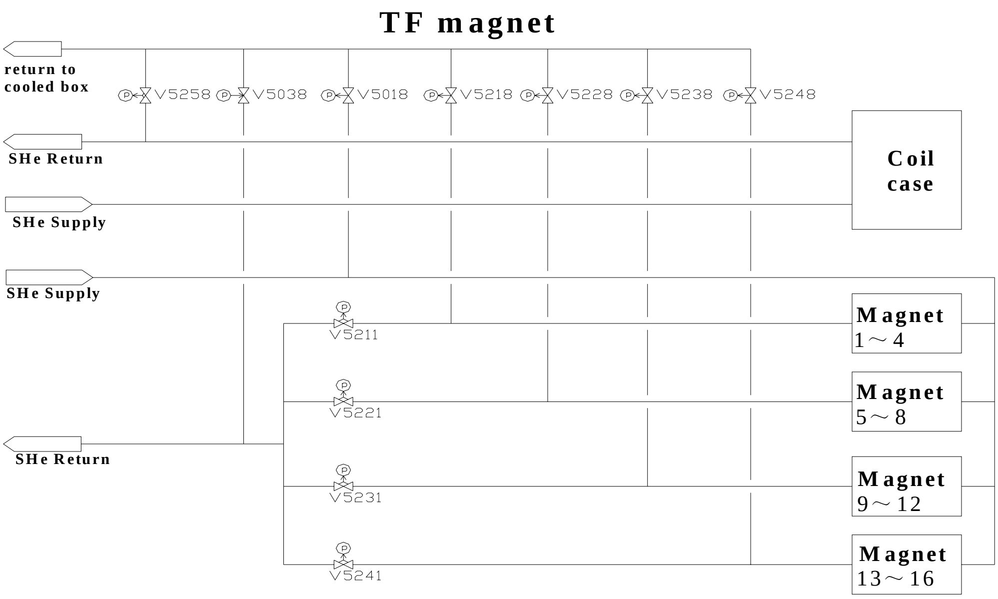


Figure 2 Simplified flow sheet of the helium refrigerator

The cryogenic distribution system comprises the auxiliary control Dewars with a sub-cooler, two circulating pumps and the cryogenic transfer lines which distribute SHe at 4K and 80K helium to the different components of the tokamak.

110g/s-3.8K supercritical Helium flow from refrigerator will be used for the PF coils cooling; 260 g/s-3.8K/ 320 g/s-4.5K supercritical Helium flow circulated by pumps will be used for TF windings and TF coil cases cooling separately; 110g/s-60K Helium flow will be used for cooling of thermal shield.



The flow diagram of the cooling cryogenic components is shown in Figure 3,4,5.

Figure 3 TF cooling

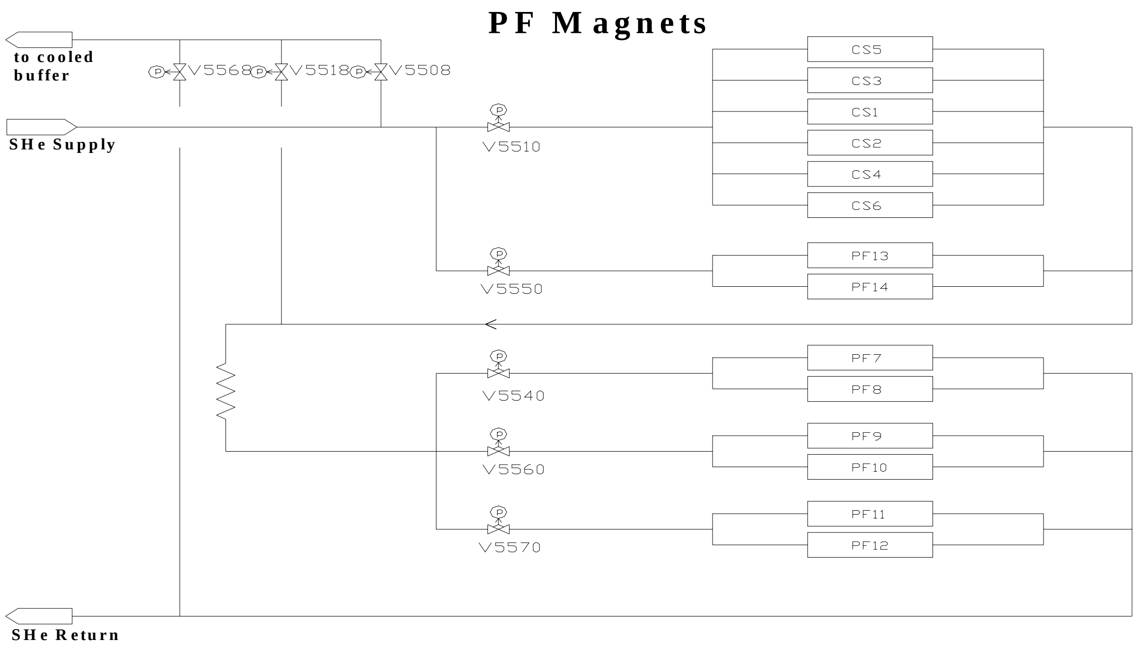


Figure 4 PF cooling

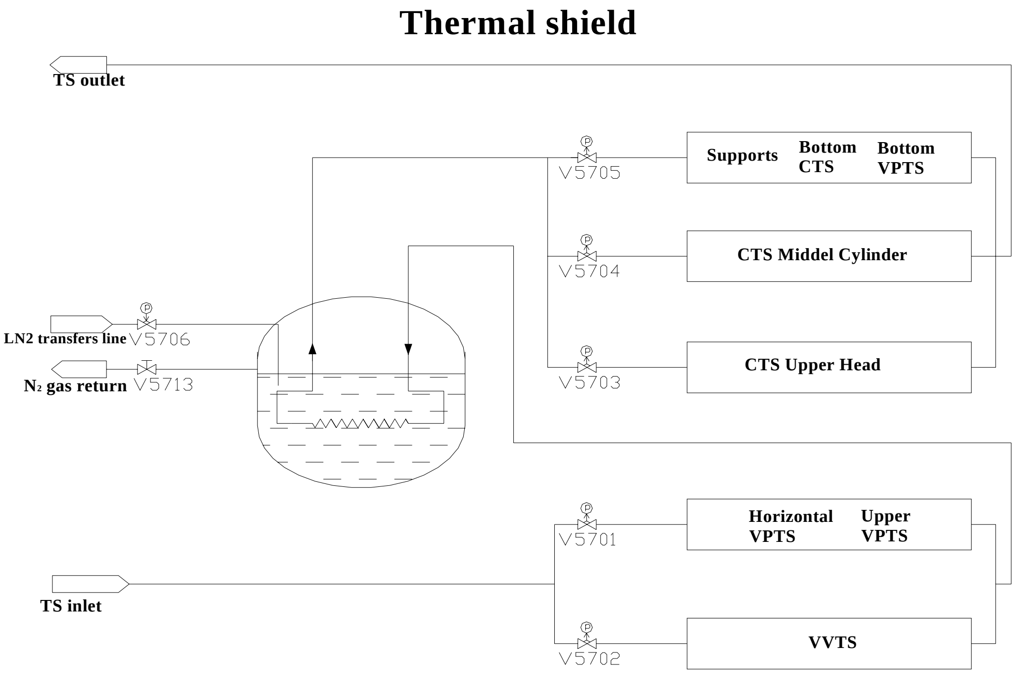


Figure 5 TS cooling

SUMMARY

The EAST project provides a very good opportunity to develop large-scale supperconducting magnet and cryogenic technology in China. Up to now the device fabrication is going on smoothly, all part of SC Magnet, Cryostat, Vacuum Vessel and Thermal Shield will be completed this year. One CS coil and 10 of TF coil has been tested, the results show that all of the magnets can meet the design requirement. The fabrication and installation of cryogenic system is in progress, the test run of cryogenic system will be made this year. It is hopeful to finish machine assembly and begin startup test of the device in 2005.

ACKNOWLEDGEMENTS

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