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DESIGN PARAMETERS OF TOKAMAK-7 SYSTEM

D.P. Ivanov, V.E. Keilin, E.Yu. Klimenko, and V.S. Strelkov

Kurchatov Atomic Energy Institute

Translated by S. J. Amoretty
Technical Information Division
Brookhaven National Laboratory
Upton, L.I., New York 11973

At present one of the key objectives of the Tokamak research program is the enlargement of the cross section of the plasma column. This design parameter largely distinguishes the existing devices from the hypothetical reactor. The cross-sectional dimension of the plasma column essentially determines the behavior of plasma - the energy balance, plasma contamination, screening of current, etc.

Since the production of strong magnetic fields by conventional methods becomes more difficult as the size of the machine increases, the potential advantages of superconducting magnets became more attractive. However, superconducting magnets have not been used so far, largely because of insufficient expertise in design and construction and misgivings of the majority of experimental physicists.

To obtain experience in building superconducting magnets for Tokamaks and in working with them under experimental conditions, Tokamak-7, the first Tokamak with superconducting windings for the main magnetic field, is being built at the Kurchatov Atomic Energy Institute.

The parameters of this facility are based on the following considerations. Commercially available superconducting materials can be used in fields up to 80 kOe. At maximum field intensity, however, the amount of superconducting material needed, and hence the cost of the facility, is prohibitively large. The field at the coil's surface, therefore, should be greater than $\approx$ 50 kOe.

The superconducting magnets for the T-7 device must be sufficiently large to accomodate the next generation of Tokamaks. Machines with a 1-m winding diameter are well within the present capabilities of the superconducting technology.

The experience gained from construction of large-scale superconducting magnets shows that when the amount of energy is $\geq$10 MJ, the rated current density must be $\leq$4000 A/cm^2. The coil thickness for the required field should be at least 15 cm and may be as much as 30 cm if the frame, the nitrogen screen, and the cryostat are taken into account.

If the Tokamak's field is to be used effectively, the torus's pitch angle must be maximum in order to satisfy the stability condition. This means that the inside radius of the solenoid must be at least as large as the thickness of its windings. Therefore the minor radius of the discharge chamber should be a = 35 cm, and the major radius of the torus should be R = 122 cm.

The field at the solenoid's axis is 30 kOe and the stored energy is $\approx$ 20 MJ. At q = 2.5 the plasma current can be as high as 500 kA.

A hollow, electrolytic conductor made of HT-50 alloy (Fig. 1) is the current-carrying element in the longitudinal field windings of the T-7 device. The conductor's cross section is 28 x 4.2 mm^2, the space factor is 4%, and the rated current in the 50-kOe field is $\approx$ 6000 A.

The winding consists of 48 pancake coils of 60 turns each. The length of the bus bar, which has no connections inside the disk coil, is 200 m.

The system is cooled by forced circulation of helium in the 2-mm-diam channels. To provide minimum hydraulic resistance, the channels of all the pancake coils are connected in parallel. The total amount of helium required to maintain the facility's operating temperature at 4.5 K is $\approx$80 liter/h, of which about 20 liter/h is used for radiation heat leak, about 5 liter/h, for the heat flux in the magnet supports; about 25 liter/h, for cooling the current leads; and about 30 liter/h, for removing the eddy current heat from the variable magnetic fields in the winding caused by the excitation of the plasma current. The last value limits the repetition frequency of the pulses, which we estimate as 20-30/h.

A pressure of 3-5 atm is needed to circulate the specified quantity of helium in the cold system and 15-20 atm during cool-down. A special liquefier-refrigerator is under construction for this purpose.

The superconducting magnets and the working chamber of the T-7 device are shown in Fig. 2. The superconducting coils are held in position by an aluminum stabilizing shell that absorbs all the electrodynamic forces acting on the coil. The shell is cooled by helium from the channels in the coils. The shell and the coils, weighing $\approx$13 tons, are mounted on eight Textolite supports inside the nitrogen screen, which also serves as a jacket providing plasma equilibrium. The entire device is enclosed in an air-tight casing for vacuum heat insulation.

The working chamber is normally an all-welded, 0.8-mm-thick stainless-steel vessel, which can be heated to 400°C for degassing.

Such heating is possible only after the magnets have been preheated and the water is circulating in the nitrogen screen so that the heat liberated by the hot chamber can be removed. When the magnets are cooled, the continuous heating temperature can be limited to 200-250°C. The magnet windings will be made and tested at the Kurchatov Atomic Energy Institute. The cryostat, the working chamber, and the magnet frame will be manufactured by a commercial vendor, who will also assemble the entire facility. The superconducting magnets will be built at the end of 1975.

After being tested in an alternating electromagnetic field, the solenoid will replace the chamber and coil in the T-4 machine. Using this machine's iron yoke, the power supply for the vortex field and correction coils, the control systems, diagnostic systems, etc., we shall begin studying the plasma.

Since the T-7 Tokamak is nearly the same size as the T-10 machine and can be operated at 1 pulse every 2 minutes, it will be able to handle a large part of the program to investigate the containment and heating of plasma of large cross section in magnetic fields of up to 30 kOe. Thus, apart from incorporating cryogenic technology, the T-7 machine will increase the volume of information obtained from the T-10 facility.

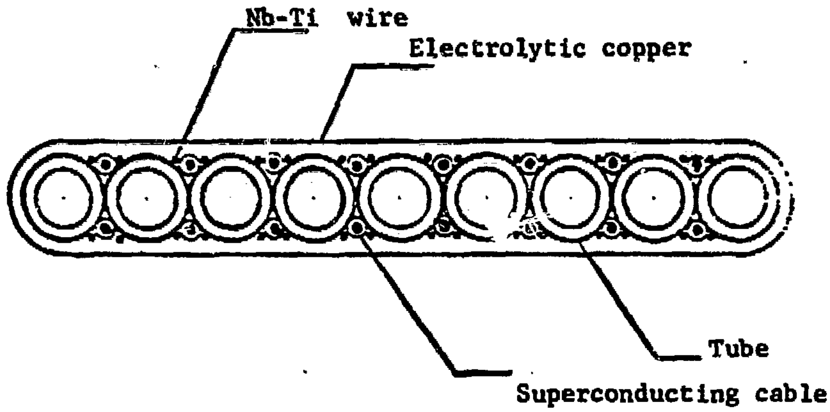
Nb-Ti wire
Electrolytic copper
Tube
Superconducting cable

Fig. 1.

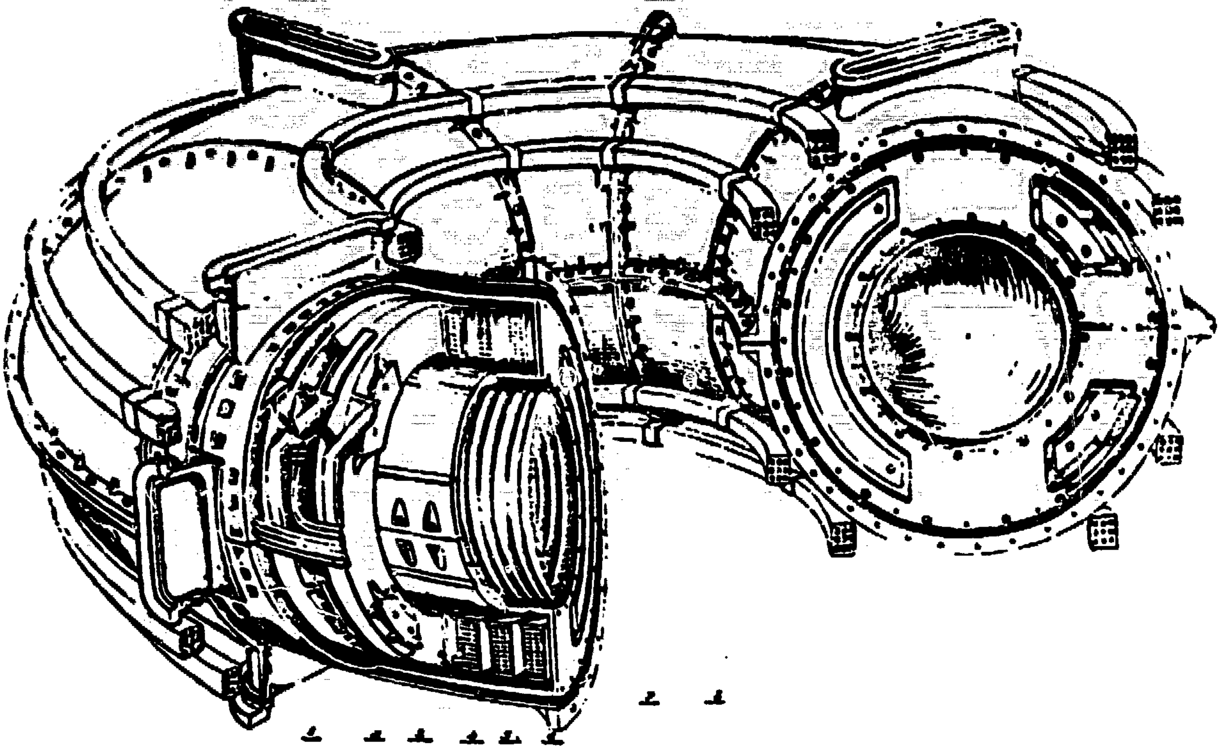

Figure 2. General view of the Tokamak-7 device. 1, Winding and control coils; 2, vacuum envelope of the cryostat; 3, diagnostic ports; 4, external nitrogen screen; 5, coil form; 6, helium collectors; 7, internal nitrogen screen; 8, discharge chamber.