IHEP ACCELERATING-STORAGE COMPLEX

(STATUS AND DEVELOPMENT)

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1. Basic Characteristics of UNK

The construction of the IHEP Accelerating and Storage Complex is going on in accordance with the project reported previously [1]. The UNK structure and parameters have been chosen with consideration for operation in both acceleration and colliding beam modes [2]. The project envisages the following operational modes:

- acceleration of protons up to 3 TeV for fixed-target experiments;
- 0.4x3 TeV p-p colliding beams enabling to attain the 2.2 TeV energy in the c.m.s.;
- further increase of colliding beam energy up to 6 TeV in the c.m.s.

A possibility to have p-$\bar{p}$ [8] collisions has also been considered. Preliminary studies have shown that with the existing U-70 used as the injector, the luminosity reached in p-p collisions may be as large as 10^{32} cm^{-2}sec^{-1} and the one reached in p-$\bar{p}$ collisions about 10^{30} cm^{-2}sec^{-1}.

Figure 1 shows the lattice of UNK. Four matched straight sections, MSS 2,3,5,6, each 490 m long will be used for colliding beam physics. Matched straight sections 1 and 4 are each 800 m long. The phase advances within the insertion are 4π in both directions. MSS 1 will house the equipment for injection, acceleration, beam loss absorption and abort systems. Extraction will be carried out from MSS 4 containing the relevant equipment and elements to protect the superconducting magnets against irradiation.

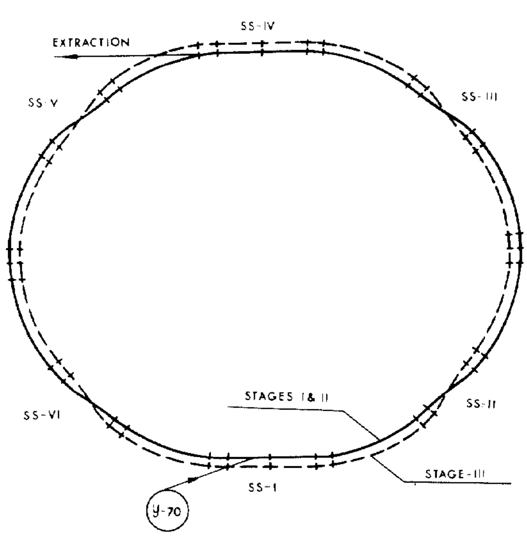

Fig. 1. Lattice of UNK.

The presently existing 70 GeV accelerator (U-70), whose intensity is planned to be up-graded to $5\cdot10^{13}$ppp, will be used as the injector into UNK. From U-70 the the beam will be injected into the first stage of UNK, UNK-1, which is the accelerator with conventional magnets. The maximum energy of particles in UNK is 600 GeV in the acceleration mode and 400 GeV in the colliding one. The UNK-1 circumference is 14 times of U-70, therefore the beam will be stacked by manifold injection. For this to be done, the beam accelerated in U-70 will be prebunched at the UNK accelerating field frequency of 200 MHz and stacked in UNK-1 up to the intensity of $6\cdot10^{14}$ ppp. For this purpose 12 pulses will be required. A part of the UNK circumference is left unfilled with the beam allowing to create time intervals necessary to facilitate the operation of injection and extraction systems. On stacking, the beam will be accelerated in UNK-1 and transferred into the second stage, UNK-2, by single-turn injection whereupon it will be accelerated up to 3 TeV. The UNK-2 cycle is as follows: 40-sec field rise, 40-sec flattop, and 40 sec field drop.

UNK-1 is placed in the tunnel above the superconducting ring of UNK-2 (see fig. 2). In the horizontal plane, the theoretical orbits of these accelerators are equal. The tunnel dimensions are chosen in such a way that another accelerator, superconducting storage ring UNK-3, could be placed there in the future. This will make it possible to obtain p-p colliding beams having the energy of 6 TeV in the c.m.s. The orbits of the two accelerators, UNK-2 and UNK-3, lie in the same horizontal plane. For them to collide beams in the four straight sections, the beam lines are transferred from one wall of the tunnel to another (see fig. 1).

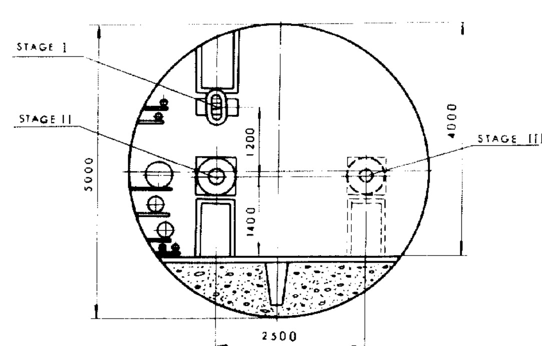

Fig. 2. Cross section of the UNK tunnel.

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Table. Parameters of UNK for Acceleration Mode

Parameter	UNK-1	UNK-2
Maximum beam energy, GeV	600	3000
Injection energy, GeV	70	400-600
Circumference, m	20771.8	20771.8
Maximum field, T	1	5
Injection field, T	0.116	0.67-1
Acceleration time, sec	11	40
RF voltage, MV	8	11

A possibility is also envisaged to collide 0.4 TeVx x3 TeV beams in these sections. In this case they will collide in the vertical plane.

Table 1 presents the parameters of UNK for acceleration mode.

The useful aperture of UNK, ± 3 cm, satisfies the acceleration, stacking and extraction conditions [3]. The vacuum chamber of the accelerators will be smooth over the whole length, with all the corrugations available covered with liners in order to reduce its effects on the intense beam.

A great attention is paid to decrease of irradiation of the UNK-2 superconducting magnets due to beam loss during acceleration. The beam is stacked in UNK-1 whose equipment is less sensitive to radiation. In the two stages of UNK, there are envisaged systems of beam loss localization and scrapers. In the case of deterioration of normal acceleration process, there will be an emergency beam extraction onto the absober [5].

Three extraction modes are foreseen from UNK-2: 40-sec slow extraction, fast resonance extraction of 1-2 msec 10 pulses each having $6\cdot10^{13}$ protons with 3-sec intervals and single-turn fast extraction. Slow extraction will be carried out with the help of a 3d-order nonlinear resonance.

Multi-turn fast resonance extraction may take place simultaneously with slow one. The design extraction efficiency is 99%. With this extraction efficiency there arise problems due to radiation-induced heating of superconducting magnets positioned close to the extraction section, caused by unavoidable proton loss at the extraction equipment. Special measures to protect the superconducting magnets positioned in radiation areas [6] have been elaborated. They allow to bring the level of radiation heating of magnet coils to the tolerable value. With account of an uncertainty in the extraction efficiency, the temperature reserve in the critical current accepted for coils is at least 0.5 K [7]. For the chosen parameters of the magnetic cycle, the mean power consumed by UNK is 120 MW, the peak power being 200 MW. The power of the cryogenic system operating at 4.2 K is 50 KW.

2. Development of Superconducting Magnets

Work on the design of superconducting dipoles for UNK [9,10] is going on at IHEP. To study full-scale models in the force-circulating cooling mode a special test facility (fig. 3) has been manufactured. It is designed to test both single magnets and strings of magnets connected in series. The cryogenic system of the test facility allows to carry out cooldown and warmup in the automatic control mode and cooling by both single- and two-phase helium. The results on tests can be found in [11].

The magnets were studied in the force-circulating mode under the conditions close to the operating ones for UNK. Each dipole has been cooled by single-phase helium flow with a consumption rate of 100 g/sec and inlet temperature of 4.2 K. All the magnets are trained

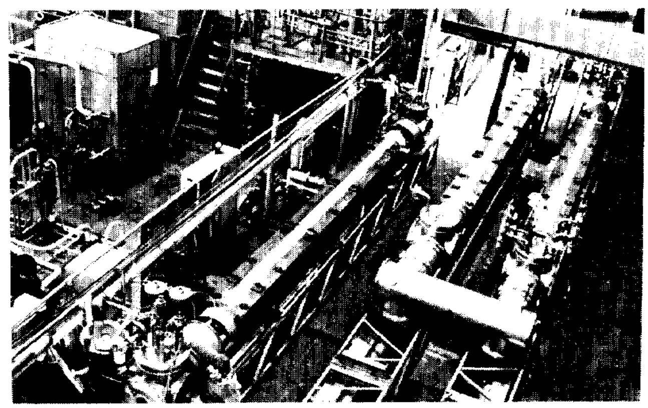

Fig. 3. Test facility for full-scale superconducting magnets.

in the fields exceeding considerably the UNK operating field, 5T. A typical training curve is shown in fig. 4. After 5-7 quenches the field in the aperture reaches the maximum value of 6.2 T. The measurements of the field harmonics at various field levels show that their relative values begin to deviate from the tolerable ones by $1\cdot10^{-4}$ at fields exceeding 6 T. This means that the reserve in the critical current and mechanical stability of the dipoles operating at 5 T are quite satisfactory.

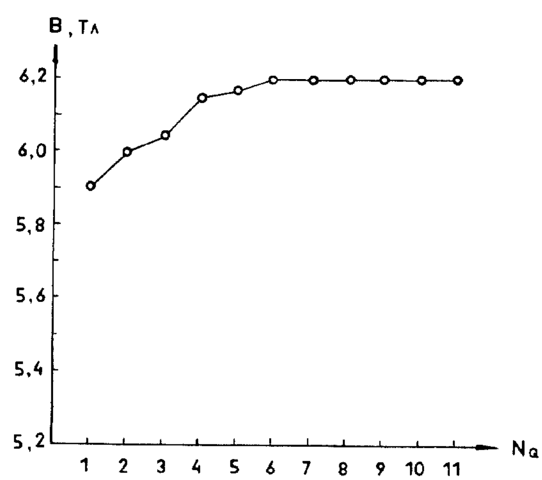

Fig. 4. The training curve for a full-scale superconducting dipole model.

The maximum value of the field in the aperture versus current ramp rate is within the requirements for the operating cycle and emergency energy removal. The quench load ($\int idt$) when the dipoles were made to go normal with the help of heaters did not exceed $8\cdot10^6$ A^2 sec and the relevant maximum temperature of the coil did not exceed 160 K which is less than the tolerable value.

The dynamic heat loss of the dipole in the operating cycles of UNK was 1.2 W/m. The measured value of heat leaks in the mode of cooling by single-phase helium was 2.5+0.8 W/m.

Presently, a string of connected in series warm iron dipoles is being tested.The test is aimed at studying heat exchange processes and hydraulics of the magnets, energy and helium removal processes during quenches, simulations of possible cooldown and warmup systems.

The warm iron dipole has certain disadvantages, the basic ones being a large value of static heat leaks and a complicated cryostat. These disadvantages can be eliminated by using a cold iron. In order to make a substantiated choice of the dipole for mass production the development of this design has been carried out in parallel with the warm iron one. Figure 5 shows the cross sectional view of a cold iron dipole. The two-shell coil is accepted to be its basic element as earlier. To cut the amount of the superconductor used, the coil and shield diameters have been decreased. With the planned increase of the current density of superconducting wires up to $2.3\cdot10^5$ A/cm^2, this will make it possible to cut this amount by 30%.

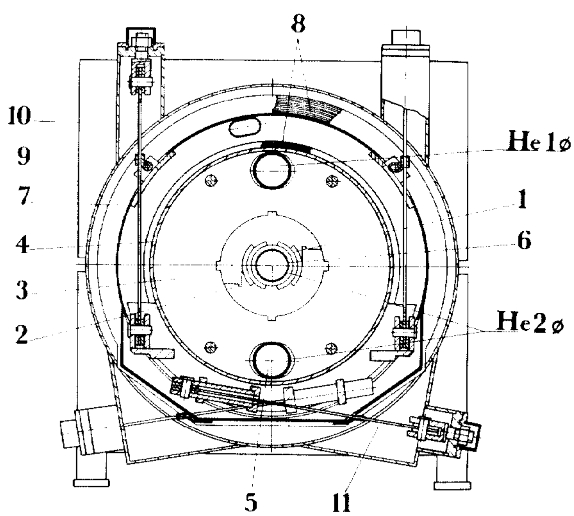

Fig. 5. Cross sectional view of a cold iron dipole.

Simultaneously, the dynamic loss and static heat leaks are planned to be reduced considerably in which case the load on the cryogenic system will be decreased and the energy removal during quenches made easier. A disadvantage of the cold iron is an unavoidable increase of the cooldown and warmup times. A detailed study has shown that with the chosen cryogenic system for UNK the warmup time of a string of magnets is about 40 hours and the cooldown time is 50 hours. As to the repair cycle, these times seem acceptable.

Figure 6 presents the training curve. The value of the dynamic loss in the coil was 0.6 W/m. The study of this dipole is going on. The decision on the dipole design for mass production for UNK is planned to be made in 1987.

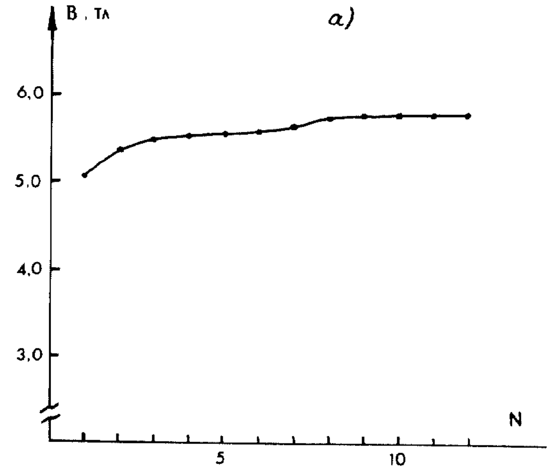

Fig. 6. Training curve of a short cold iron dipole.

3. Complex under Construction

Civil engineering work is being carried out on the whole territory of the complex: 12 sites for underground work have been built, the construction of 7 vertical shafts out of 26 is over, 3 more will be ready very soon, the construction of the underground tunnels has begun. Presently, horizontal tunneling is being done from 5 vertical shafts in 9 directions.

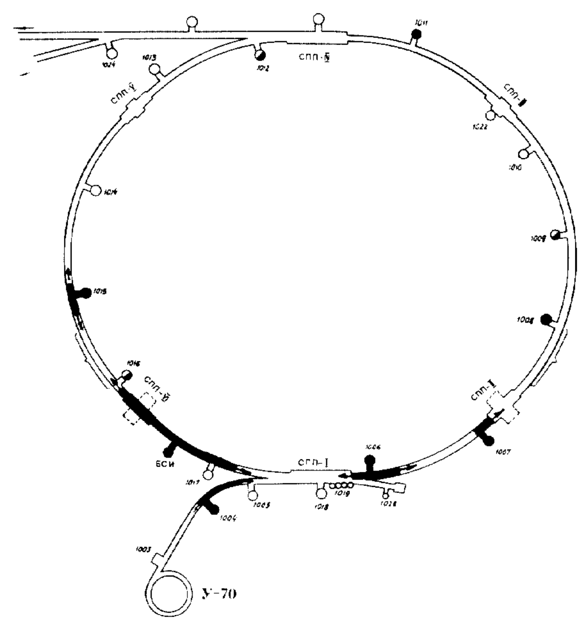

Fig. 7. Underground systems for UNK and their status. The dark areas indicate the completed sections of the UNK tunnel.

About 700 m of the injection channel out of the total length of 2.6 km and 3.3 km of the main ring tunnel have been bored. Figure 7 shows the layout of the underground systems for UNK and status of the construction work.

To carry out large-scale tests of the most important equipment of the complex under operating conditions, work out the installation technique and the modes of extracting the beam from U-70 into UNK, a decision has been made to construct and mount four typical sections of the accelerator before the construction work is completed: the injection channel, the technological section of the main ring intended for the accelerating system, injection and emergency beam abort systems, a section of the normal cell of the 1st stage with a string of 100 warm magnets (1/24 part of the ring) and a section containing superconducting magnets.

At present, seven surface auxiliary equipment buildings for servicing the above mentioned sections are being designed and their construction is to start this year.

The modeling of the equipment for the 1st stage is being completed, its manufacturers have been specified and the preparation of the production technology has begun. Orders to manufacture the vacuum system, the main ring magnet, injection channel magnets and their power supplies have been put into industry.

The first items of the equipment are planned to be tested in 1987 and their mass production is to start in 1988.

The construction and installation work for UNK is to be completed in 1992.

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