THE IHEP ACCELERATING AND STORAGE COMPLEX (UNK) STATUS

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The present paper reports the changes introduced into the UNK project due to changes in the ring site when putting the tunnel underground. It also presents the results obtained when simulating the basic systems for the UNK: superconducting and warm magnets, accelerating system and vacuum system. The current status and plans for the nearer future are described.

THE CHARACTERISTICS AND STRUCTURE

Work on the choice for the UNK tunnel site was completed in 1982. As shown by the results of geological studies, the accelerator can be disposed in stable limestones providing a firm basis for tunnel 20-60 m deep underground. In view of changes in the ring site when putting the tunnel underground, the earlier reported UNK project/1/ has undergone modifications. The UNK magnetic structure has been altered essentially. In the new structure favourable conditions to attain the maximum luminosity in the colling beam mode, to extract protons efficiently and protect the superconducting equipment from irradiation have been created.

Fig.1 shows the cross-sectional wiev of the UNK tunnel. In it there will be positioned a 600GeV booster (stage I) consisting of warm magnets and a superconducting accelerator for further acceleration of protons to 3000 GeV (stage II). An energy to be attained in stage I in stacking mode will be 400 GeV. An option is forseen to arrange 400 GeV and 3000 GeV pp colliding beams which will enable attaining a c. m. energy of 2.2 TeV.

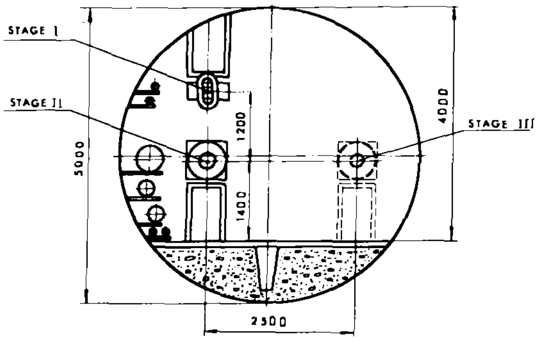

Fig. 1. The location of the equipment in the UNK tunnel.

The tunnel dimensions are chosen so that in the future it will be able to accomodate an additional superconducting ring. This will make colliding beam mode at the maximum energy possible.

Fig. 2 presents a general scheme of the UNK magnetic structure. It also shows future stage III. Stages II and III will lie in the same horizontal plane. They will alternate going from the inner tunnel wall to the outer one and vice versa.

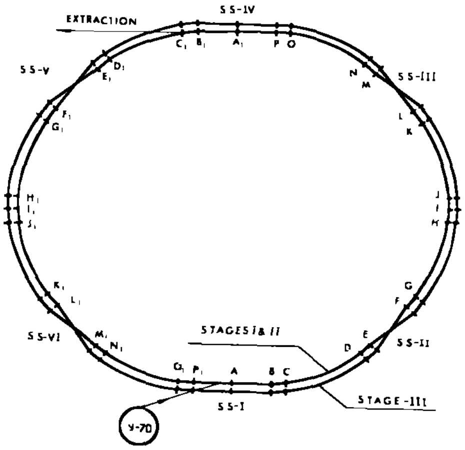

Fig. 2. The magnetic structure of the UNK.

The orbits of stages II and III will intersect in four matched straight sections (SS 2, 3, 5, 6). In the adjacent areas there will be positioned dipoles to transfer a beam from one wall of the tunnel to the other. These straight sections are 490 m long each and will be used for colliding beam physics. Also collisions of beams of stage I and II are anticipated in them.

The injection and extraction straigt sections SS1 and SS4 are 800 m long each and will house all the technological systems of the accelerator. There will be enough space left to room equipment protecting superconducting magnets from irradiation.

Either side of each straight section will have 164-m sections for suppression and subsequent restoration of orbit dispersion/2/. Owing to this, dispersion will be absent in all the straight sections, which is necessary to attain the maximum luminosity of colliding beams.

The ring part of the accelerator will have 160 normal cells, each 91,8 m long. Since the optics of the straigt sections is different and can be retuned as may be required with time by colliding beam physics experiments, measures are taken so that the dynamic accelerator characteristics remain unchanged. Betatron oscillation phase advance is multiple of 2 ,so that the coordinates and transverse momenta of any particle in the input and output of each insertion coincide. So, influence of special insertions on particle motion in the regular part of the ring is eliminated. Structural resonances may be induced due to field deviation of the magnets in special insertions from the nominal value or due to the difference between the particle momentum and that of equilibrium. These perturbations can be appreciable when arranging insertions for collisions. They will be suppressed locally with the help of correction systems placed inside each special insertion and designed with due account of its optics.

The basic parameters of stage I and II of the UNK are enlisted in Table.

Table 1

The Basic Characteristics of the UNK

Parameter	1st stage	2nd stage
Circumference, m	20771.8	20771.8
Maximum energy, GeV	600	3000
Injection energy, GeV	70	400-600
Critical energy, GeV	42	42
Maximum field, T	1	5
Injection field, T	0.116	0.67÷1
Number of technological sections	2	2
Technological section length, m	800	800
Number of sections for colliding beams	4	4
Length of a section for colliding beams, m	490	490
Total number of dipoles	2176	2176
Total number of quadrupoles	454	438
Dipole length, m	5.8	5.8
Quadrupole length, m	3.7	3.7

The present IHEP 70 GeV accelerator (U-70) whose intensity is planned to be increased up to $5 \cdot 10^{13}$ ppp will be used as an injector. The UNK circumference is 14 times that of the U-70 which will enable stacking a proton beam of an intensity of $6 \cdot 10^{14}$ ppp. With such an intensity there could be attained a luminosity of 10^{32} cm^{-2} sec^{-1} in the colliding beam mode.

Fig. 3 shows the scheme of the UNK operation. An accelerated $5 \cdot 10^{13}$ ppp beam will be prebunched in the U-70 by an RF field at 200 MHz frequency equal to the UNK accelerating RF. Proton intensity will be stacked by 12 sucessive pulses injected from the U-70 into stage I of the UNK. A part of the UNK circumference is left unfilled by the beam which will make it possible to arrange time intervals between pulses necessary to ease the opeartion of the injection and extraction systems as well as to reduce particle losses. On stacking, the beam will be accelerated in stage I and transferred into stage II by one-turn injection. A cycle of stage II consists of 20 sec acceleration, 38 sec flat-top and 20 sec field fall. In the initial period of the UNK construction, from economic reasons, the field rise and fall time in the superconducting stage will be increased up to 40 sec.

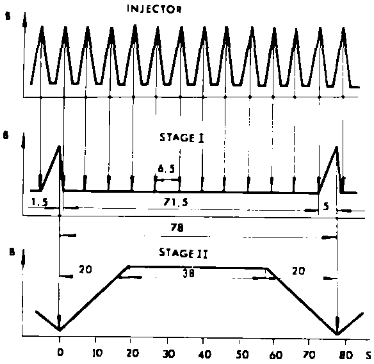

Fig. 3. The magnetic cycle of the U-70 injector, of stage I and II of the UNK.

The layout of the basic constructions for the UNK is shown in fig. 4. To install the equipment for beam injection in both directions, 3.5 m in diameter tunnels are envisaged. Power supply and control systems for the technological equipment are installed in surface buildings connected with the underground tunnel by vertical shafts. In 12 buildings distributed uniformly over the UNK circumference (buildings 1/1-1/12) there will be positioned power supplies, computers for control and diagnostic systems, cooling systems, heat exchangers and ventillation systems. The cryogenic equipment will be put in the underground areas adjacent to each vertical shaft (fig. 4).

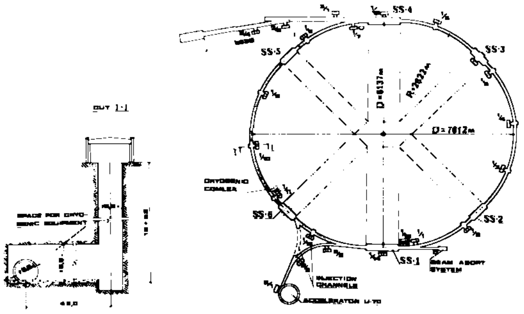

Fig. 4. The layout of the basic constructions of the UNK.

Building 1/13 is intended for installation of RF generators of the accelerating system. Building 1/14 will house power supplies for the injection and beam abort systems. Building 1/15 is designed for power supplies for the extraction systems in SS4.

2. SIMULATION OF THE UNK EQUIPMENT

Development of Superconducting Dipoles for the UNK

Work on development and study of a UNK full-scale superconducting dipole prototype is going on. A new series of 1-m dipoles has been developed, whose coils are manufactuted from a wire with an improved current density. This allows to have a reserve in the critical current for the UNK working field under conditions of higher heat releases in the coil due to irradiation. This series of magnets, from the viewpoint of their construction, does not differ from those reported earlier/4/. The coils are manufactured from a keystoned cable containing 24 strands, o.85 mm in diameter. Each strand has 2970 Ni-Ti filaments, 10 m in diameter, embedded into a cooper matrix. The strands are coated with an alloy of Sn-5 wt % Ag.

In detail the results on tests of these magnets will be reported separately/5/ at this conference. Fig. 5 illustrates the behaviour of magnets at high fields. It shows the training curves for one of the magnets in a pooling cryostat at various temperatures of the helium bath. The critical current reached the maximum value at each level after some quenches. The character of training does not change up to the fields close to 7 T. All the magnets of the new series are trained only in the fields going beyond the UNK working field which is 5 T. This testifies to a good mechanical rigidity of the magnets of the given construction and to their operational capability at 5 T.

This conclusion is also supported by the results of mechanical and magnetic measurements. Figs. 6 and 7 present the results of measuring harmonics of even and odd nonlinearities of inhomogeneous part of the magnetic field which is given in the form

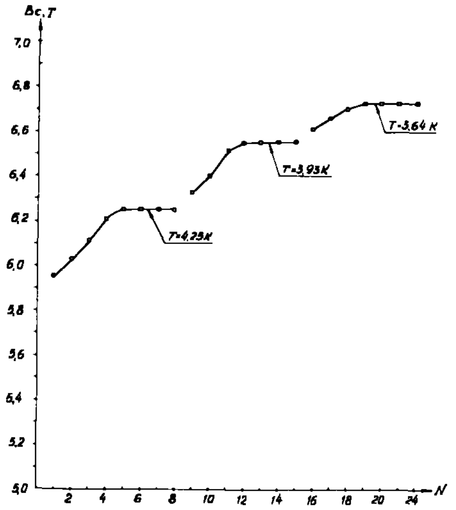

Fig. 5. The training curves for magnets of DB series at various temperatures.

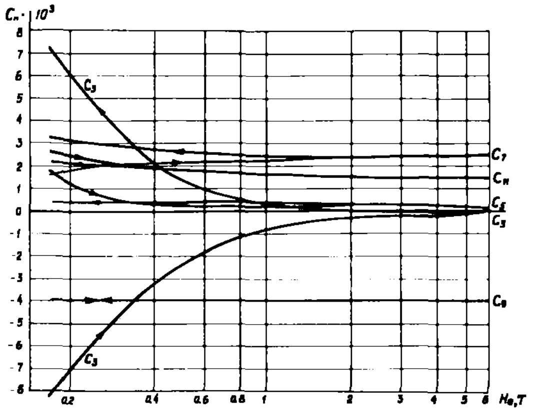

Fig. 6. Normal even nonlinearities of a dipole versus field level.

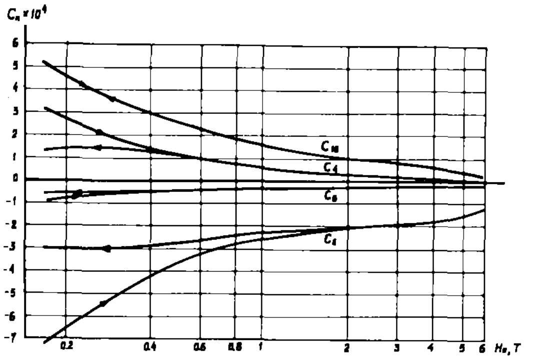

Fig. 7. Normal odd nonlinearities of a dipole versus field level.

$$\Delta By(x)/By0 = \sum_{n=2}^{\infty} C_n \left(\frac{x}{r}\right)^{n-1},$$

$$\Delta Bx(x)/By0 = \sum_{n=2}^{\infty} C_n \left(\frac{x}{r}\right)^{n-1},$$

where r = 35 mm. Over the whole working range, up to 6 T, nonlinearities remain practically unchanged.This points to a high rigidity of the construction and absence of noticeable deformations due to ponderomotive forces. Remanent field nonlinearity at the injection field does not go beyond the tolerable level. The measured values of harmonics of "skew" nonlinearities are within tolerable limits suggesting thereby a good quality of magnet assembling.

On the basis of the experience gained when developing 1 m long models a first 6-m UNK full-scale magnet model has been manufactured. To provide long models, IHEP has developed an assembling workshop equipped with necessary instrumentation and hardware. The general view of this workshop is shown in fig. 8. Fig. 9 shows the first full-scale magnet manufactured. To test this magnet in a pool-cooling mode,there was created a test facility on the basis of the 400 w cryogenic plant (fig. 10). Fig. 11 presents the training curves for the magnet. As is seen, the maximum critical current was attained already after the 3d quench, at the first quench the value of current being 97% from that of the maximum. During long-term tests and after repeated warming-up and cooling-down of the magnet, a good repetition of the quench current was observed, the spread being ± 10 A. The magnetic measurement results corroborate a good mechanical stability of the construction, i.e. the field harmonics remain constant over the whole range of the working field. The values of harmonics are close to those calculated.

Fig. 8. The area for assembling full-scale magnets.

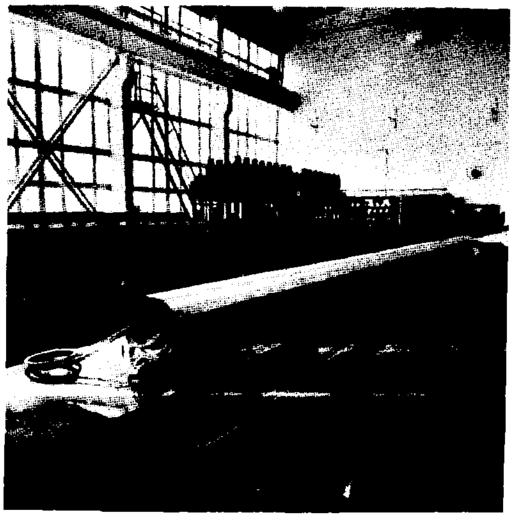

Fig. 9. Full-scale dipole model.

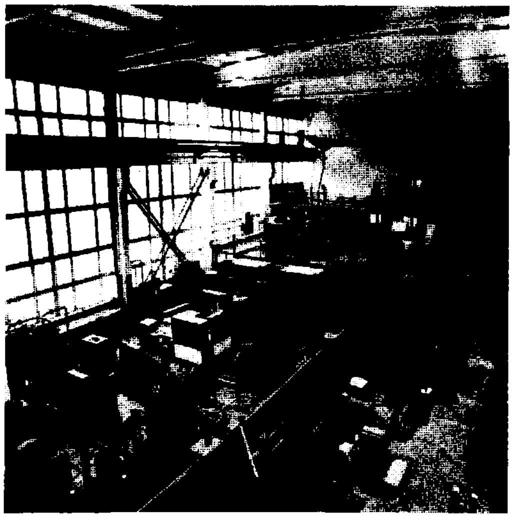

Fig. 10. The facility for testing full-scale magnets.

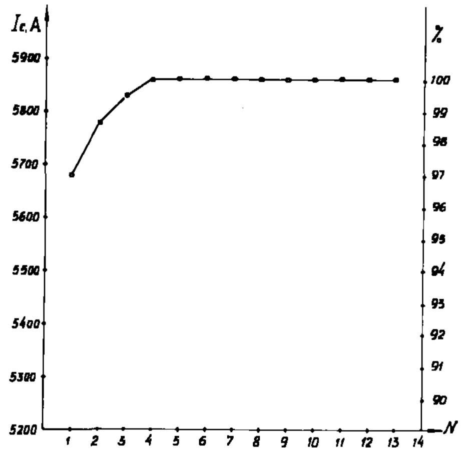

Fig. 11. The training curves for a full-scale magnet.

The construction of the first full-scale model has been chosen as the basis for further developments. Presently a full-scale dipole model is manufactured and assembled with a force- circulating cryostat and magnetic shield (fig. 12). It will be tested in the nearer future.

Fig. 12. Full-scale dipole with a force-circulating cryostat and magnetic shield.

Magnet of Stage I of the UNK

Stage I of the UNK will operate with conventional magnets. The dipole field varies from 0.116 T to 1 T. The dipoles are broken into two groups, 1084 dipoles in each, with a useful area of 70x60 mm^2 (type A) and 91x43 mm^2 (type B). Each dipole has an efficient length of 5800 mm. Besides, 8 dipoles of type B shortened to 1854 mm will be used to transfer a beam from one wall of the tunnel to the other.

Currently a full-scale dipole protopype of type A has been manufactured. Its general view is given in fig. 13. Fig. 14 shows the measured relative inhomogeneity of the vertical field component in the central cross-section for three field levels. Table 2 presents relative values of the multipole coefficients for the inhomogeneous part of the field at a distance of 35 mm from the centre. Skew multipoles have also been measured, their values are much less than $1\cdot10^{-4}$.

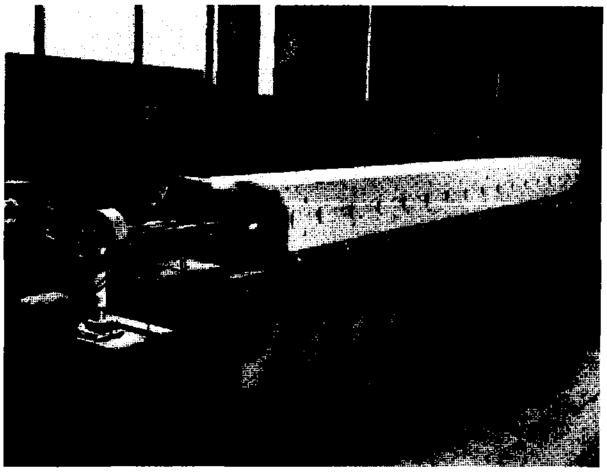

Fig. 13. The magnet of stage I of the UNK.

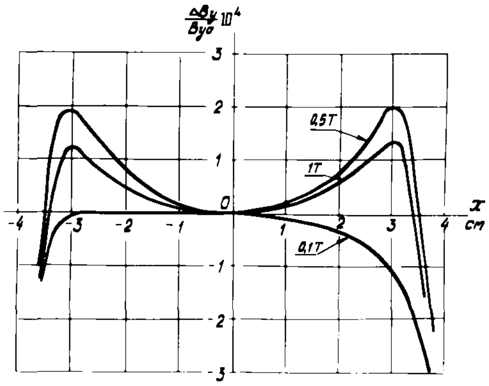

Fig. 14. The relative value of dipole field inhomogeneity.

The tolerable value of the field inhomogeneity is $2\cdot10^{-4}$. Therefore the prototype manufactured meets the required characteristics satisfactorily.

Accelerating System

Work on full-scale simulation of the UNK accelerating system/6/ (see Table 3) is going on.

A test module of the accelerating system consisting of two cavities and wave-guide hybrid divider (see fig. 15) has been manufactured. The cavities have a

Table 2

Multipole Components of the Field in the Central Dipole Cross-Section ($C_n \times 10^4$)

n \ B_{y_0}	0,1 T	0,5 T	1 T
2	-0,5	0,0	0,1
3	0,2	2,4	1,4
4	0,3	-0,3	0,2
5	1,1	0,5	0,6
6	0,1	-0,1	0,1
7	1,4	1,4	1,4
8	0,3	0,1	0,1
9	-1,8	-2,3	-2,3
10	0,2	0,3	0,2
11	2,1	1,9	1,9
12	0,4	0,3	0,3
13	-2,2	-2,8	-2,8

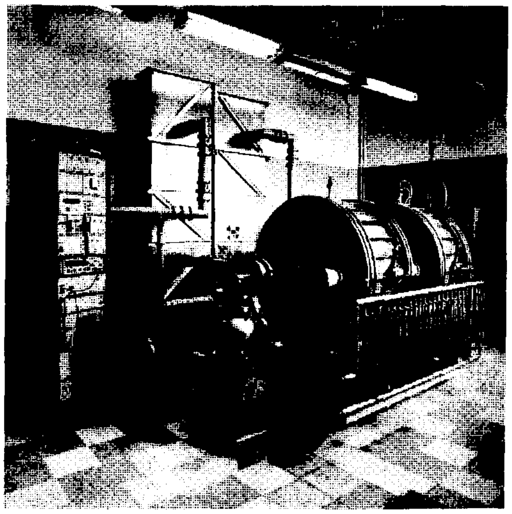

Fig. 15. An experimental module of the accelerating station.

built-in system to damp higher-order oscillations.The study performed shows that this damping system reduces the impedance of one module coupling with the beam to a tolerable level of 0.4 Ohm in a frequency range from 300 to 1500 MHz, with power losses not exceeding 3%. The cavities are also furnished with probe-type input power blocks, control coupling loops, and with tuning devices which allow to vary the cavity frequency by ± 100 MHz. The measured Q-factor of the cavities was $53 \cdot 10^3$ and the shunt impedance was 10 MOhm. The coupling between the cavities was 90 dB at the operating frequency and 30 dB between the adjacent arms of the hybrid. The cooling system for the cavity walls maintains their temperature constant to an accuracy of ±1°C in a quasistationary operating mode.

Table 3

Characteristics of the UNK Accelerating System

Parameter	1st atage	2nd stage
Acceleration time, sec	11	40
Total amplitude of RF voltage, MW	8	11
Maximum energy gain per turn, MeV	2.1	6
Maximum power transferred to beam, MW	3.4	9.6
Number of modules in the accelerating system	8	14
Maximum RF power supplied to a module, MW	0.8	0.8

During tests the cavities were RF-powered and the multipactor discharge was suppressed at the vacuum of $1 \cdot 10^{-6}$ Torr. A 250 kW output amplifier has been designed. Its tests are under way.

Vacuum System

In the colliding mode, the vacuum chambers of both stages of the UNK should have a vacuum not less than $2 \cdot 10^{-9}$ Torr. As reported earlier/1/, the vacuum chamber of the superconducting accelerator will be cooled by liquid nitrogen down to 77 K which will make it possible to remove heat releases in the chamber walls due to the induced current of a high-intensity beam. A study made on the cold chamber model showed that at this temperature no layers of gases form on the chamber surface, ion desorption is absent and the amount of gas released is very small/7/.

To visualize a possibility of obtaining the required vacuum in the chamber of the UNK stage I its full-scale section serviced by one pump has been tested. Influence of thermal treatment of the chamber prior to its assembling was studied. Electrochemical polishing of the chamber, baking in the furnace at 600°C as well as surface treatment at the initial stage of pumping down by an argon discharge with the total dose of $3 \cdot 10^{18}$ ions/cm^2 allow to reduce sufficiently the evacuation time. With a 100 l/sec ion pump and a sublimation pump with periodic evaporation of titanium a vacuum of $2 \cdot 10^{-9}$ Torr was attained in 900 hours at the first pumping down. During subsequent pumpings after filling with dry nitrogen a vacuum of $1{,}4 \cdot 10^{-9}$ Torr was attained within less than 100 hours.

The obtained results testify to a feasible opportunity to attain the required vacuum in stage I of the UNK without baking the vacuum chamber after its assembling.

3. PRESENT STATUS

Currently, the design of the UNK equipment, technological and power supply buildings and constructions are terminating. Simulation of the basic elements for the UNK is in progress. A station for beam recapture at a frequency of 200 MHz is under construction. Cryogenic equipment is being simulated and tested. For production of the UNK superconducting elements, IHEP is constructing a specialized workshop including automized test facilities for their calibration.

Geological studies and work on choosing the optimal tunnel location with consideration for the actual geological slit are terminating. Construction of the southern part of the tunnel is being preparated, i.e. sites and access roads are being built. In the region of buildings 1/1 and 1/2 (fig. 4) first vertical shafts about 25 m deep have been built. Horizontal tunneling will be started in the nearer future.

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