IHEP ACCELERATING-STORAGE COMPLEX

L. D. Soloviev

Institute for High Energy Physics
Protvino (Moscow Region)
Serpukhov, USSR

1. BASIC CHARACTERISTICS OF THE UNK

The IHEP accelerating-storage complex is a 3 TeV superconducting proton synchrotron in which a possibility to create colliding beams in the future has been forseen. The basic parameters of the complex are enlisted in Table 1.

Table 1 Basic parameters of the UNK

Parameter	Units	I stage	II stage
Circumference	m	20772	20772
Injection energy	GeV	70	400
Maximum energy	GeV	400	3000
Magnetic field strength at injection	T	0.117	0.669
Maximum magnetic field strength	T	0.669	5
Pulse intensity	ppc	$6 \cdot 10^{4}$	$6 \cdot 10^{4}$
Total number of normal periods		160	160
The length of the straight sections	m	800 and 490	800 and 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
Betatron oscillations		36.7	36.7
Critical energy	GeV	34	34

At present an underground fashion for the tunnel construction has been adopted. The depth from the earth surface will make up 30 - 50 m. The cross section of the tunnel and the arrangement of the magnets in the UNK is shown in Fig. 1.

Two rings available in the complex make possible a construction of proton-proton colliding beams with the energy of 0.4 and 3 TeV in the future and to reach the energy of 2.2 TeV in the c.m.s.. The UNK tunnel dimensions are such that a superconducting storage ring can be arranged in it in the future. This provides a possibility to stack a 3 TeV proton beam and its further collision with a beam of the same energy accelerated in the superconducting ring. The energy of pp-collisions in the c.m.s. may be thus increased up to 6 TeV. The luminosity of the order of 10^{32} $cm^{-2}s^{-1}$may be achieved at a proton intensity of $6 \cdot 10^{14}$ protons in each beam. An intersecting region for the proton synchrotron and the future storage ring has been forseen in the UNK magnetic structure for the 3 x 3 TeV proton beam collisions to be realized.

In each straight section the orbit is either shifted from the outer part of the tunnel to the inner one or vice-versa. The orbit intersection occurs in the centres of sections II, III, V and VI. These sections have been reserved for the experiments on the colliding beams. The basic UNK technological systems are installed in sections I and IV. The beam injection system for the first stage is installed in section I together with the accelerating stations for the first and second stages, beam losses localising system and emergency beam dump system. The ejection system is arranged in section II. To organize colliding beams an injection into the UNK in the opposite direction has been forseen in straight section VI.

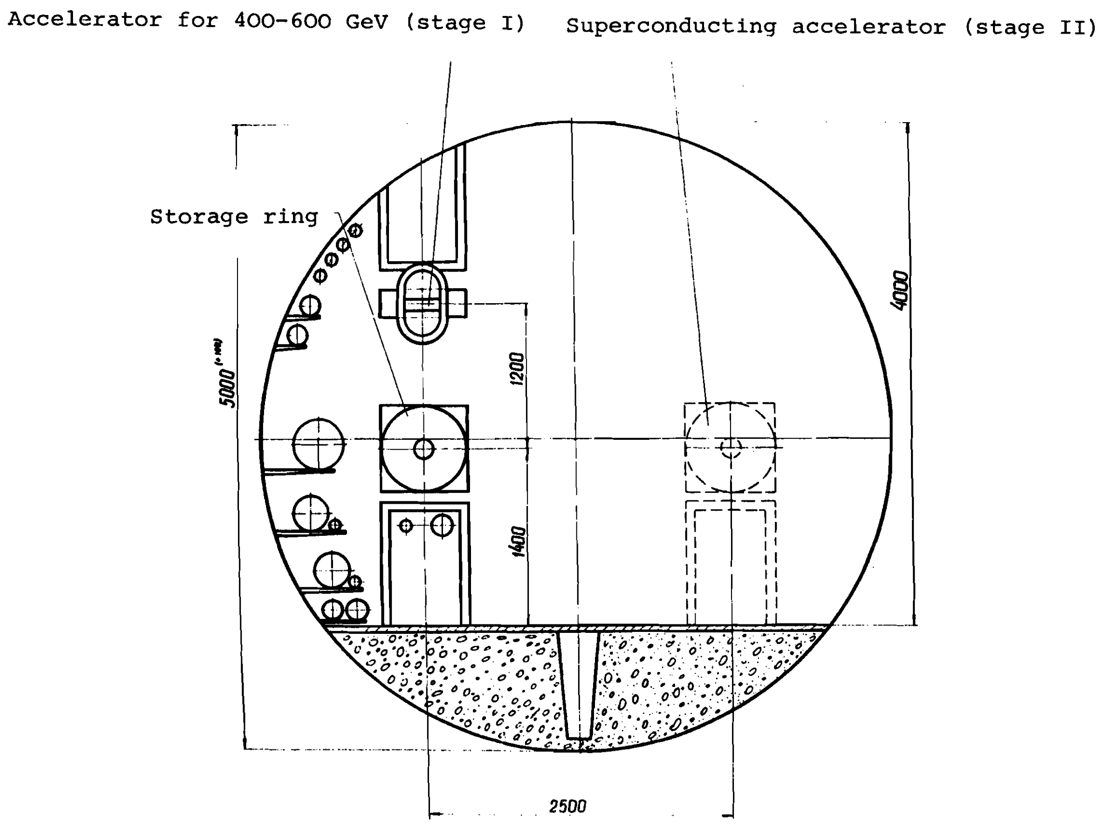

Fig. 1

We have also considered opportunities to realize 3 x 3 TeV colliding proton antiproton beams in the UNK superconducting ring. With electron cooling the luminosity that can be reached will be $5 \cdot 10^{30}$ cm^{-2} s^{-1}. There will also be supplementary systems for stacking and preacceleration of antiprotons.

2. THE MAGNET OF THE UNK FIRST STAGE

The electromagnet in the first UNK stage is assigned for the operation as a booster and collider. The magnetic field in the dipole varies from 0.117 up to 0.669 T. According to the aperture size the dipoles are divided into two groups with respect to the envelope. The working area for the dipoles of the first type is 70 x 60 mm^2, and for the second type of dipoles it is 43 x 91 mm^2. All the dipoles and quadrupoles are connected in series and fed by twelve 2 kV power supply sources inserted into the gaps between the windings. The operational current is 2.5 kA and maximum power consumption is 60 MW.

By the end of the year the manufacturing equipment for widescale production of warm magnets will be worked out.

At present the dipole prototype is being produced. Its cross section is shown in Fig. 2. The admissible value for magnetic field nonlinearity at the edge of the aperture is $2 \cdot 10^{-4}$, the admissible value for the RMS spread of the dipole fields makes up $5 \cdot 10^{-4}$.

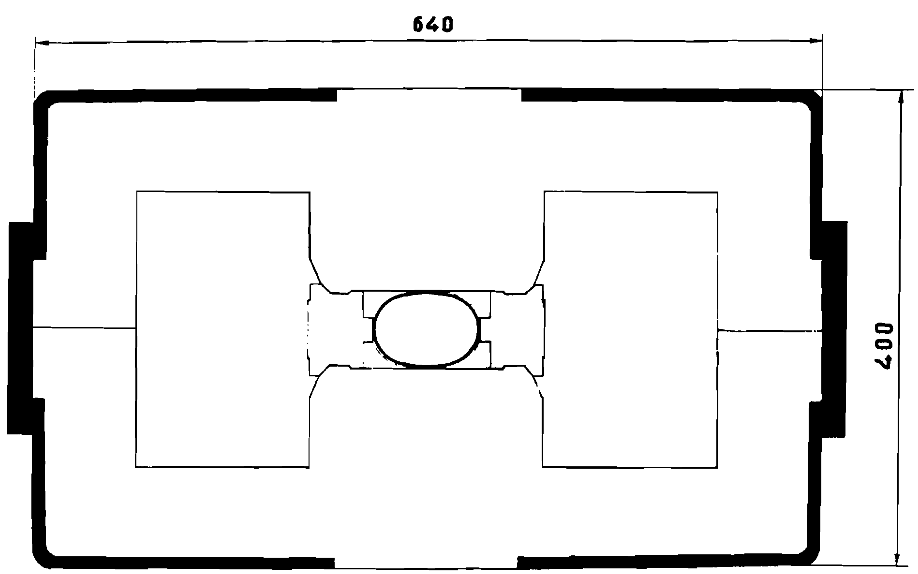

Fig. 2
Cross section of the dipole prototype

Magnetic field correction at the first stage will be carried out with the help of special magnets, installed near all the quadrupole lenses in the 3 m sections. The following correction systems are being designed: the one for the closed orbit, for chromaticity and betatron oscillations in both planes, field cubic nonlinearities as well as linear difference of the coupling resonance.

3. ACCELERATING SYSTEM

The accelerating system for both UNK stages has several identical stations. Each consists of an accelerating device and 0.8 MV RF generator. The accelerating frequency is 200 MHz. The basic parameters of the accelerating system are presented in Table 2.

Table 2 The Basic Parameters of the UNK Accelerating System

Parameters	Units	I stage	II stage
Acceleration time	sec	11	40
RF voltage amplitude	MV	7	10
Equilibrium phase	0	74	56
Maximum power transferred to the beam	MV	3.1	9
Number of accelerating stations (including reserve)		4	8
Total maximum RF power	MW	4.9	9.4
Average power from the mains	MW	3.1	6.1
Total length of RF stations in the tunnel (spacings included)	m	28	45.5

As a result of our studies the accelerating system of resonance type has been chosen. For the UNK conditions ($\frac{\Delta f}{f} < 1 \cdot 10^{-4}$) it is more advantageous as compared with the wave-guide version, being of smaller length and less expensive, the requirements for stabilization of the amplitudes and phases in transition processes are not so strict and the efficiency in damping the highest modes in the cavities is quite high. The accelerating device itself consists of a pair of cylindrical cavities operating the E_{oio} wave and fed by the RF generator through the gap bridge. The bridge - type power supply system provides a good agreement between the RF power supply feeder under ever changing loading of the cavity by the beam which allows to install the generators in the service rooms. This scheme allows one to use the cavities without their readjustment during the acceleration cycle and makes their design simpler, the range of frequency variations being quite narrow.

At present the investigations connected with the measurement of the cavity parameters and adjustment of the power supply and cooling system have been carried out and the design of dampers for high-order oscillations has been worked out.

4. SUPERCONDUCTING MAGNET FOR THE UNK

The main problem is to construct a prototype of the superconducting dipole magnets for the UNK. At present investigations are being carried out with 1 m models. The Institute for High Energy Physics, NIIEPhA and CEN (Saclay) are participating in these investigations. The program forsees a search for the solution of three basic problems: the design of the cables whose current carrying capacity would provide a 5 T field with double shell windings and with the dynamic losses as low as possible; high precision in winding production and high field quality in the working area of 60 x 70 mm^2 in the magnet provision for intense heat exchange in the superconducting winding cooled by helium, so that considerable heat release caused by beam losses will greatly be reduced.

By now 12 short models have been manufactured at Saclay, IHEP and NIIEPhA. Dipoles produced at IHEP are similar to those at FNAL. The dipole cross section is shown in fig. 3.

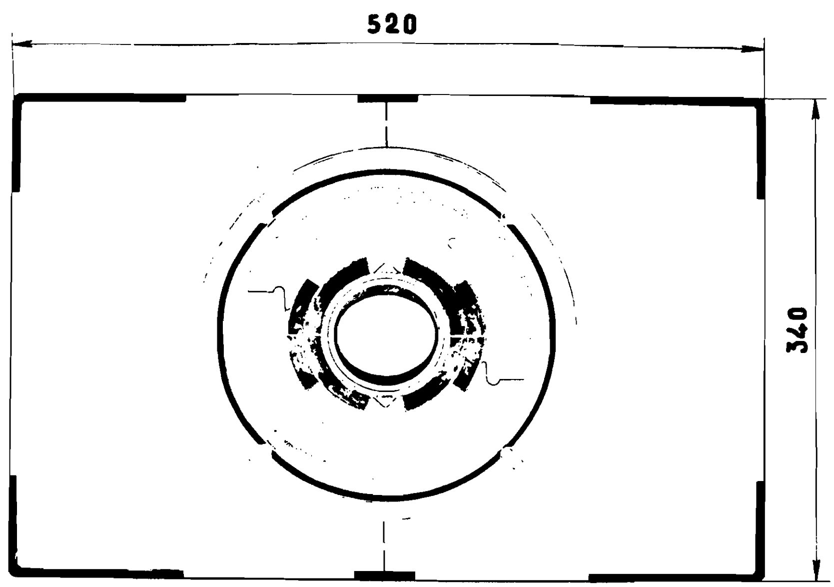

Fig. 3
Cross section of the superconducting model magnet

The magnetic field is created by the double-shell winding. Spacers of fibreglass are inserted between the shells as well as between the collar and the winding itself, thus there are channels available for helium circulation. In the median plane of the magnet windings there are spacers. The collar half-rings create prestress in the windings.

The calculated value for the field in the dipole centre is 5 T at the current in the winding of 5.9 KA. The quoted characteristics are considerably greater than those for the FNAL dipoles.

With account for this fact the construction of the cables has also been changed. In particular, to increase the current density in the cable, it was transposed from 23 strands with the diameter 0.85 mm. Since the thickness of the electrical insulation was reduced the winding elasticity module became higher and the azimuthal displacement of the turns at excitation of the magnetic field became less. The measurement of the azimuthal dimensions of the model made it clear that within one model the accuracy in manufacturing of separate quadrants of the winding made up 90 - 100 which per turn yields the accuracy better than 3 m.

The windings are compressed with the collars azimuthally. The stresses on the winding are controlled with a capacitance-type pick-up. Their layout is shown in fig. 4. The pick-up P, is installed in the straight part at the edge turn of the winding; P_2, P_3 are installed on the end parts of the dipoles where two

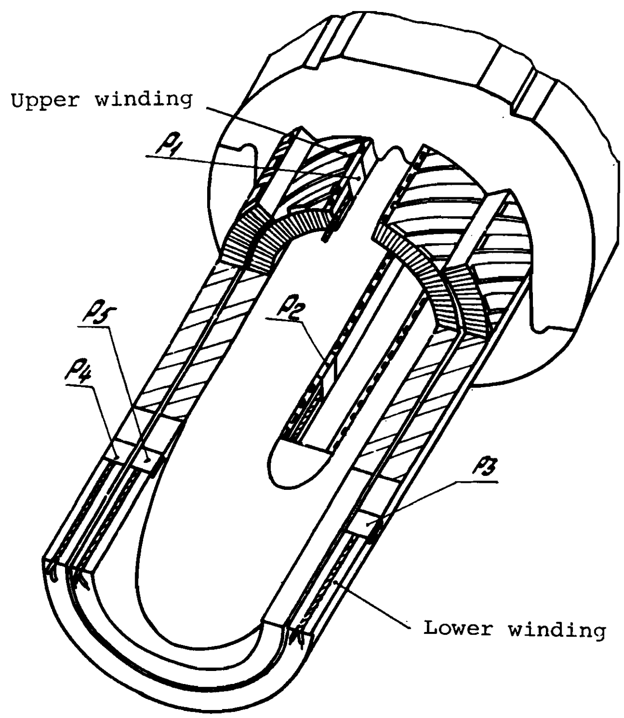

Fig. 4 Layout of the double-shell windings

halves of the winding are brought together. From the readings of P_1 in cyclic operation of the dipole when the maximum current is achieved it follows that at the current close to the maximum one the stress from the collar on to the edge turn of the first shell becomes smaller, and after removal of the current it comes back to its initial value without any hysteresis. In other words owing to considerable stresses when assembling which conserve even after cooling down, the winding still works as an elastic system with irreversible displacement of the turns.

The view of the half winding assembled is shown in fig. 5. Fig. 6 shows the machine used for winding of superconducting layers, a completely assembled dipole is presented in fig. 7.

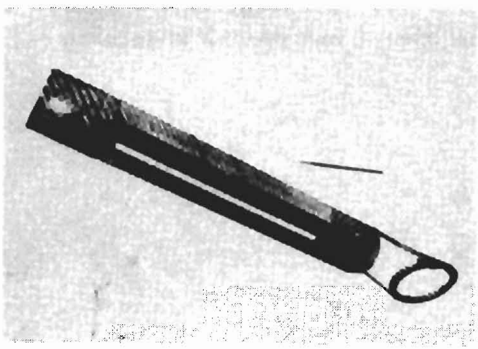

Fig. 5

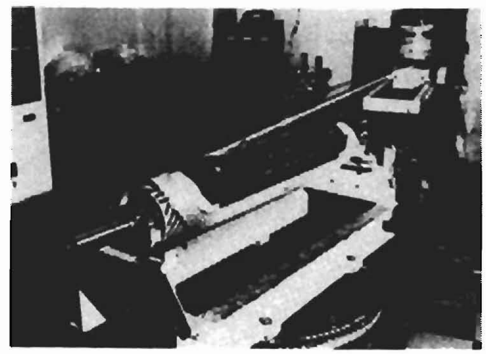

Fig. 6

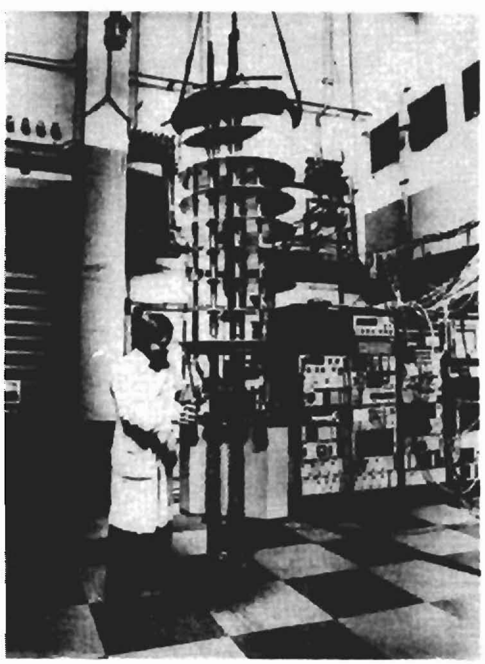

Fig. 7

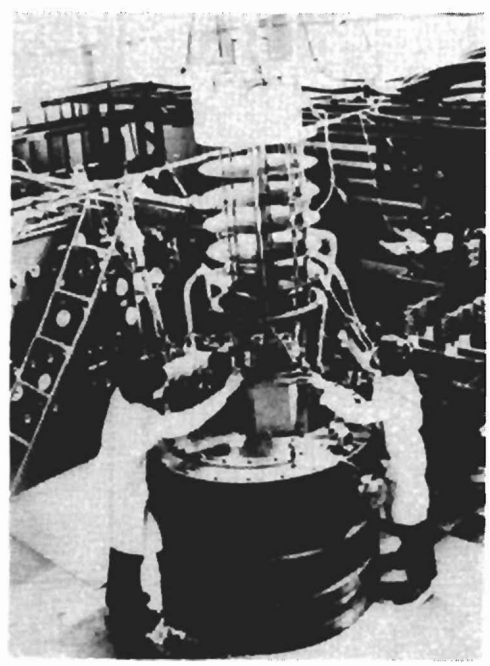

Fig. 8

A test stand has been created at IHEP for testing magnets in the bath cooling mode (fig. 8) which is equipped with the apparatus for harmonic analysis of the magnetic field and for measurements of dynamic losses. A circulating system is used for investigation of the heat exchange processes. The system has a necessary number of pick-ups for temperature, pressure and cooling flow consumption measurements. Heat deposition and heat removal in the magnets are being computed using the measurement results.

The experimental program forsees the investigation of the magnet training processes. Fig. 9 shows the dependence of the quench current on the number of the current leads for the DB-1-1 and DB-1-2 models. As is seen starting from the second input, the quench value for the current in the two dipoles is maximum and remains practically constant. This result is one of the best in the world experience in constructing the superconducting magnets for operation in 5 T field. The maximum fields obtained in the aperture in the DB-1-1 and DB-1-2 models is 5.2 T, and on the winding -5.7 T.

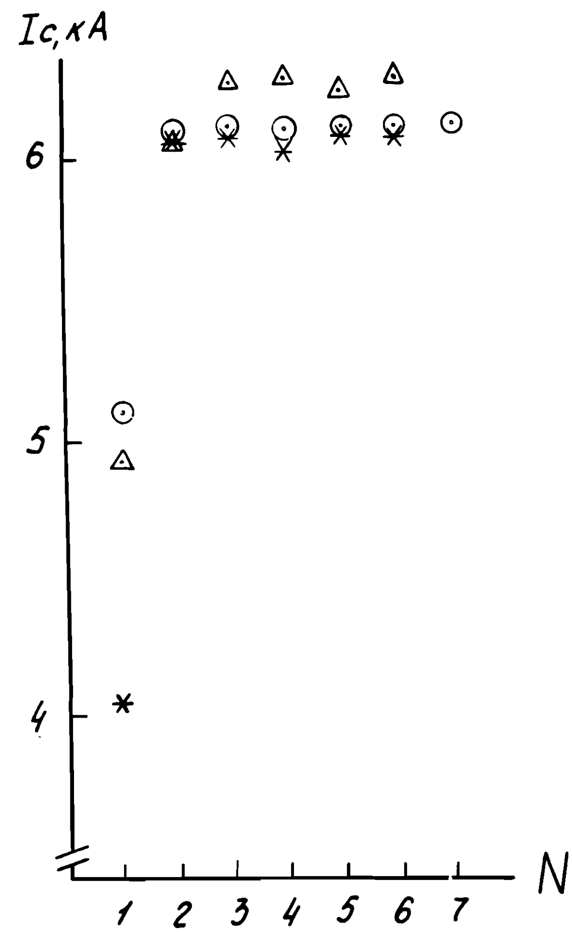

Fig. 9

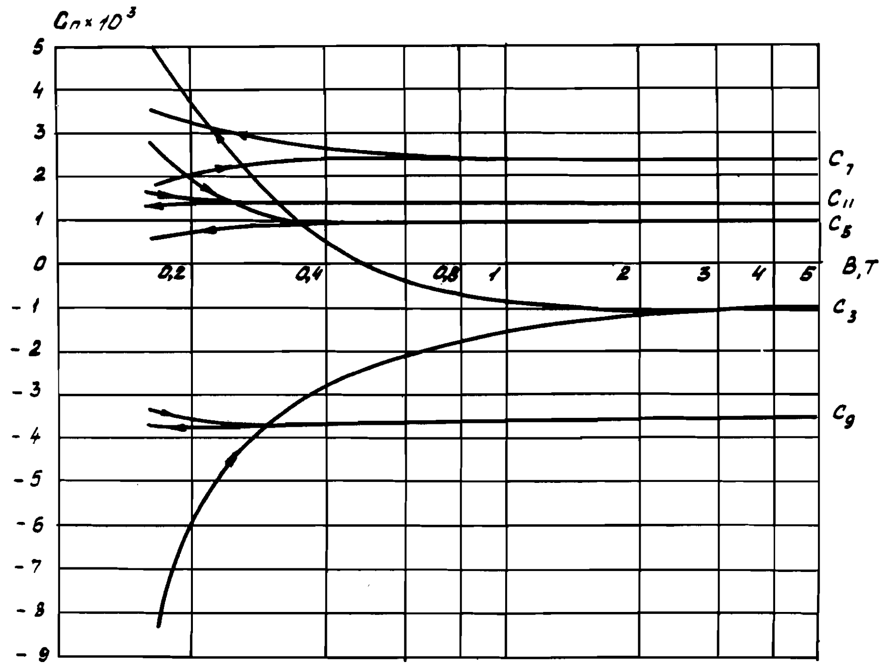

Fig. 10

The dependence of some measured nonlinearities of the field on the inductance level for the DB-1-2 dipoles is given in fig. 10. Similar curves have been obtained for other models. The arrows show the direction of magnetic field changes. At inductance hysteresis is observed, which is caused by eddy-currents in superconducting filaments and it agrees with calculations. At B 1 nonlinearities remain constant, which once more points to the absence of considerable winding displacements under the influence of electromagnetic forces and magnetic saturation of iron.

A manufacturing system for full size prototypes for the UNK magnets and their testing has been constructed at IHEP. Workshops of 500 m^2 have been built. Equipment and nonstandard apparatus necessary for production of the magnets have been designed and manufactured. A cabling machine has already been adjusted (fig. 11). Being rather small in size, the machine braids, welds and insulates the cable. The operating mode of the machine is controlled by a specially designed automatic unit. The device for winding of 6 m windings is being adjusted at present (fig. 12). Both flat and saddle-type windings can be produced with this machine. Laminated collars have been manufacturd (fig. 13 and 14) assigned for 6 m magnets, the manufacturing procedure being very close to that at Fermi laboratory. A 4000 T hydraulic press and manufacturing equipment necessary for winding and assembling of 6 m magnets are being tested at present.

A system for bath cooling tests of 6 m magnets has been constructed on the basis of 400 V cryogenic setup (fig. 15).

By the end of 1981 we plan to produce full-size winding with collars and to test them in the bath cooling mode.

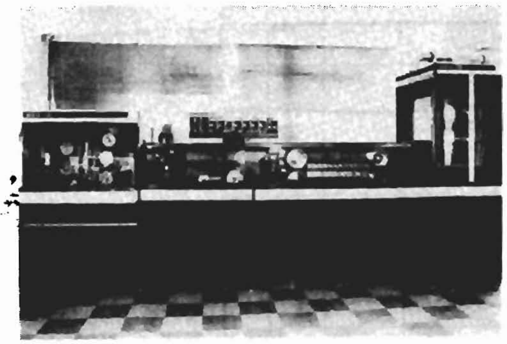

Fig. 11

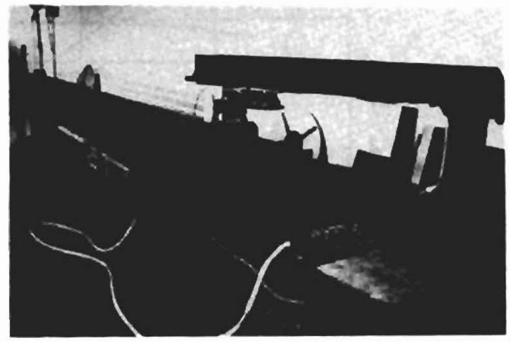

Fig. 12

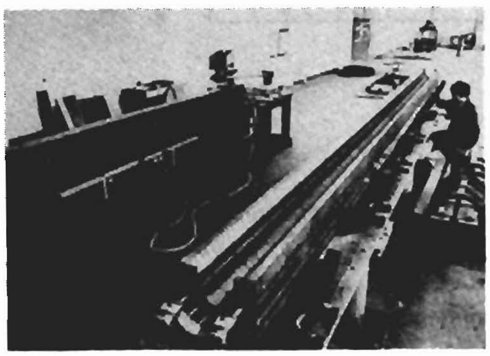

Fig. 13

Fig. 14

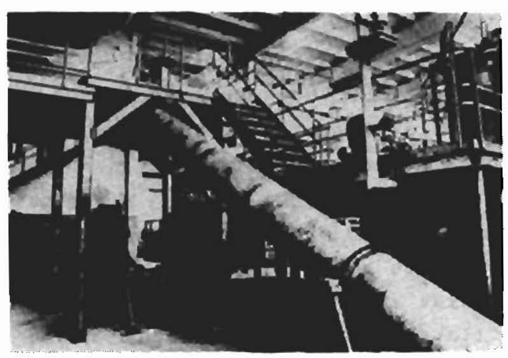

Fig. 15