IHEP ACCELERATING AND STORAGE COMPLEX (UNK)

K.P.Myznikov, L.D.Soloviev, V.A.Yarba

Institute for High Energy Physics,
Serpukhov, Moscow region, USSR

1. CHARACTERISTICS

The project of IHEP accelerating and storage complex envisages a feasibility of operation in the following modes /1/:

1) acceleration of protons to 3 TeV for fixed-target experiments;

2) proton-proton colliding beams of energies 400x3000 GeV which will give a c.m.s. energy of 2.2 TeV;

3) further increase of energy in pp-collisions up to 6 TeV in the c.m.s.

Figure 1 shows the cross-sectional view of the UNK ring tunnel. It will comprise a 600 GeV booster (stage 1) with conventional magnets and a superconducting ring to accelerate protons up to an energy of 3 TeV (stage II). There is a reserve space left in the tunnel with a view to accomodate there in the future another superconducting storage ring (stage III). This will make it possible to arrange collisions at the maximum energy.

The UNK magnetic structure /2/ will allow to operate in all these modes. The structure is presented in fig.2. Stages II and III will lie in the same horizontal plane. They will alternate going from one inner wall of the tunnel to the outer one and vice versa. The orbits of stages II and III will intersect in four matched straight sections (SS 2, 3, 5, 6). Each will be 490 m long and will have no equipment. All these straight sections are intended for colliding beam experiments only. The beams of stages I and II will also collide there.

The injection and extraction straight sections, SS1 and SS4, are 800 m long each and will house all the technological systems of the accelerator. Three extraction modes are foreseen: single-turn, slow resonance during about 30 sec and fast resonance of 10 pulses at 3-sec intervals with $6\cdot10^{13}$ protons in the pulse, each having the duration of about 1 msec. In the case of resonance extraction, $3Q_x = 110$ nonlinear resonance will be used. With the chosen ratio of the maximum values for the amplitude functions in the extraction section and the accelerator structure, which is about 6, the extraction efficiency will be 99%. Section SS4 will have enough room left for the equipment protecting the superconducting magnets from irradiation during beam extraction.

The basic parameters of stages I and II of UNK are enlisted in Table 1.

The present 70 GeV accelerator (U-70) whose intensity is planned to be upgraded to $5\cdot10^{13}$ ppp will be used as an injector. The UNK circumference is 14 times that of the U-70 which will allow to stack in it a proton beam of an intensity of $6\cdot10^{14}$ ppp. With such an intensity, the luminosity to be attained in colliding mode will be 10^{32} cm^{-2} sec^{-1}.

Figure 3 shows the operational scheme of UNK. An accelerated proton beam will be prebunched in U-70 by an RF field at 200 MHz frequency equal to the UNK accelerating RF. Proton intensity will be stacked by 12 successive pulses injected from U-70 into stage I of UNK within 71.5 sec. On stacking, the beam will be accelerated in stage I and transferred into stage II by single-turn injection. The cycle of stage II consists of 20 sec acceleration, 38 sec flattop, and 20 sec field fall. For consideration of economy, in the initial period of UNK construction the field rise and fall time in the superconducting stage will be increased to 40 sec. In this case the mean intensity will be $5 \cdot 10^{12}$ p/sec.

2. STATUS

Presently, the major systems of UNK are under development and technological and energy supply buildings are being designed and constructed.

Superconducting Magnets

Above 20 shortened 1-m dipoles and some quadrupoles have been manufactured. They are used to study the problems of training, dynamic losses, field quality (edge field included), cooling conditions for various distributions of helium flow in the coil, etc./3/. On the basis of experience gained on short sample a few 6-m full-scale magnets have been manufactured (fig. 4). The training curves of such a magnet are presented in fig.5.Their coils have been manufactured from a keystoned cable transposed from 23 strands, 0.85 mm in diameter. Each strand has 2970 Ni-Ti filaments, 10 μm in diameter, in a copper matrix. The nominal field, 5T, was attained after a few quenches. There is a reserve in critical current necessary under the conditions of irradiation-induced heat releases in the coils. The results of magnetic measurements corroborate a good mechanical rigidity of the construction. Figs. 6 and 7 present the results of measuring even and odd nonlinearities at a distance of 35 mm from the aperture centre versus the current. The field harmonics remain constant within the whole operating range of the field and their values are close to those calculated.

The dynamic losses measured in trapezoidal cycles of change in current at 100 A/sec ramp rate and 6 kA amplitude (the real cycle of UNK) were 750 J, 550 J being hysteresis losses.

This design of the magnet has been chosen as the basis for further development. A full-scale dipole model has been manufactured and assembled with a force-circulating cryostat and magnet shield (fig. 8). It has been tested at a circulating test facility. The bore field, 5 T,was attained without training

Cryogenic System

The basic parameters of the cryogenic system for UNK/4/ are given in Table 2.

At present the experimental modules of refrigerators and liquefiers are being developed and tested, the entire cryogenic complex for UNK is being designed.

Magnet of Stage I

The dipoles of stage I are broken into two groups, 1084 in each, with a useful area of 70x60 mm^2 (type A) and 91x42 mm^2 (type B). The efficient length of each dipole is 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 another.

Now a few full-scale dipole models of type A (fig. 9) are manufactured. The magnetic measurements showed that they had fairly satisfactory charactestics: the value of field inhomogeneity in the aperture did not exceed $2 \cdot 10^{-4}$.

Accelerating System

Work on full-scale simulation of the UNK acceleration system/5/ was continued. Its basic characteristics are given in Table 3.

An experimental module of the accelerating system consisting of two cavities and a wave-guide hybrid divider (see fig. 10) has been manufactured. Its tests showed a good agreement between the measured and calculated characteristics. The measured Q-quality of cavities was $53 \cdot 10^3$ and the shunt impedance was 10 MOhm. A system designed to damp parasitic higher-order oscillations has been tested. It proved to be efficient and yielded good results.

Technological Buildings

Figure 11 shows the layout of the major buildings for UNK. By now work on the choice of the optimal tunnel layout has been terminated with regard for the results of geological study. The accelerator will be located in stable limestones at a depth 15-60 m below the surface. To inject a beam in both directions, two 3.5 m in diameter tunnels are envisaged. The power supply and control systems for technological equipment will be housed in surface buildings. They are connected with the underground tunnel by vertical shafts. The cryogenic refrigerators will be put in the underground buildings adjacent to each vertical shaft. Twelve surface buildings will be distributed uniformly over the ring. Buildings 1/14 and 1/15 will be used for power supplies of injection and extraction systems, building 1/13 will house the RF accelerating system.

The construction of the southern part of the ring tunnel has begun. In the region of buildings 1/1, 1/12 and 2/2 vertical shafts 30 m deep have been built and tunneling has begun (figs. 12 and 13). Access roads to the northern part of the ring have been built, the working areas are under construction.

The construction of the 3 TeV accelerator is planned to be finished in 1992-1993.

References

1. Balbekov V.I., Gridasov V.I., Gurov G.G. et al. The IHEP Accelerating and Storage Complex (UNK). Report at XII International Conference on High Energy Accelerators, FNAL, 1983.
2. Balbekov V.I., Fedotov Yu.S., Myznikov K.P. Proceedings of VIII All-Union Conference on High Energy Accelerators, Dubna, JINR, 1983, v. 1, p. 187.
3. Andreyev N.I., Balbekov V.I., Bulatov E.A. et al. Development and Study of UNK Superconducting Dipole Models. Report at XII International Conference on High Accelerators, FNAL, 1983.
4. Butkevich I.K., Dukhanin Yu.I., Grigorenko I.M. et al. Proceedings of VII All-Union Conference on High Energy Accelerators, Dubna, JINR, 1981, v. 1, p. 115.
5. Katalev V.V., Kovalev S.S., Korzov B.V. et al. Proceedings of VII All-Unoin Conference on High Energy Accelerators, Dubna, JINR, 1983, v. 1, p. 138.

Parameter	Unit	Stage I	Stage II
Circumference	m	20771.8	20771.8
Maximum energy	GeV	600	3000
Injection energy	GeV	70	400÷600
Transition 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 sections for colliding beams	m	490	490
Total number of dipoles		2176	2176
Dipole length	m	5.8	5.8
Total number of quadrupoles		454	438
Quadrupole length	m	3.7	3.7
Gradient/field ratio	m^{-1}	16	16

Table 1. The Basic Parameters of Stage I and Stage II of UNK.

Parameter	Unit	Power	Amount
Heat load on the level of 4 K	kw	50	
Heat load on the level of 80 K	kw	110	
Helium liquifier	l/h	1000	6
Satellite refrigerator	kw	2.1	24
Compressors	kg/h	500	40
Power consumed	Mw	40	

Table 2. The Basic Parameters of Cryogenic System for UNK

Parameter	Unit	Stage I	Stage II
Acceleration time	sec	11	40
Acceleration voltage frequency	MHz	200	200
Total amplitude of RF voltage	MV	8	11
Maximum energy gain per turn	MeV	2.1	6
Maximum power transferred to a 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
Mean power consumed	Mw	4.4	6.1

Table 3. Characteristics of the UNK Accelerating System.

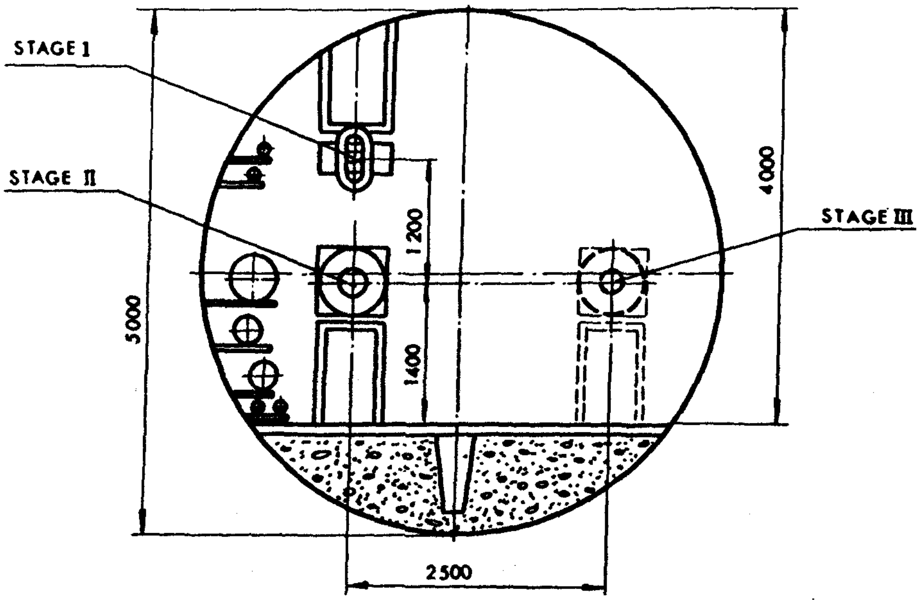

Fig. 1. The location of the equipment in the UNK tunnel.

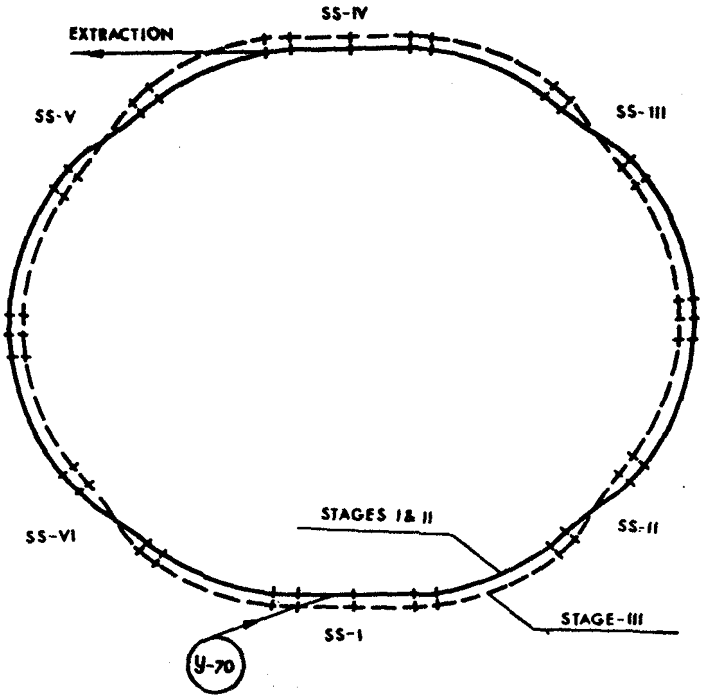

Fig. 2. The magnetic structure of the UNK.

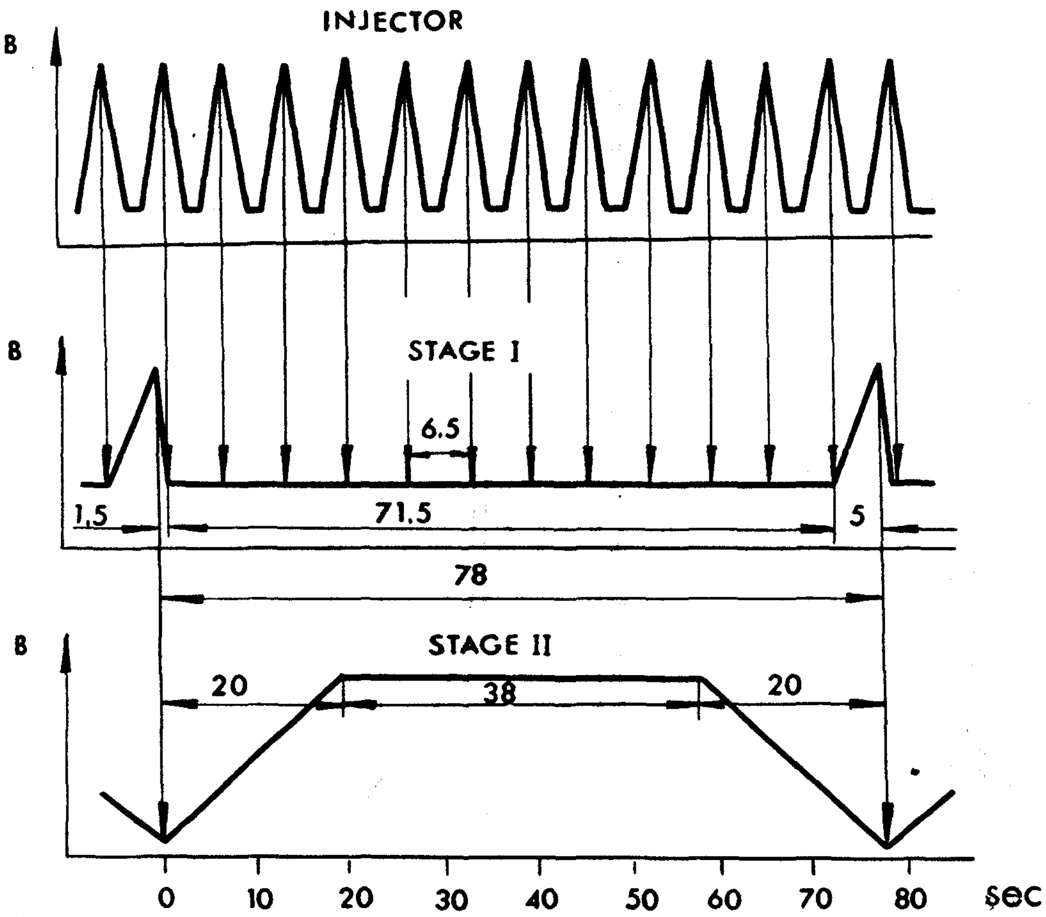

Fig. 3. The cycles of the U-70, of stage I and II of UNK.

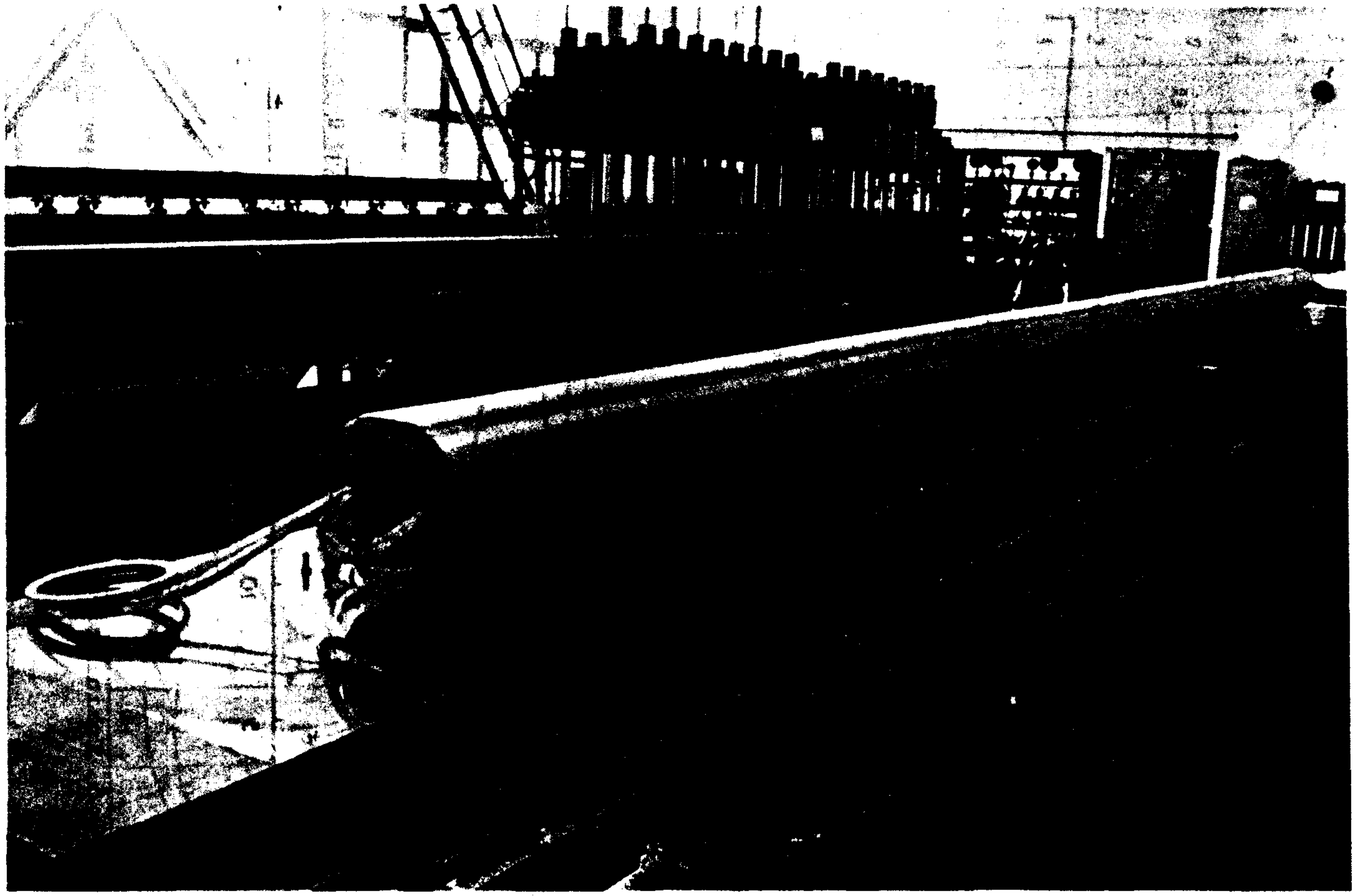

Fig. 4. Full-scale dipole model.

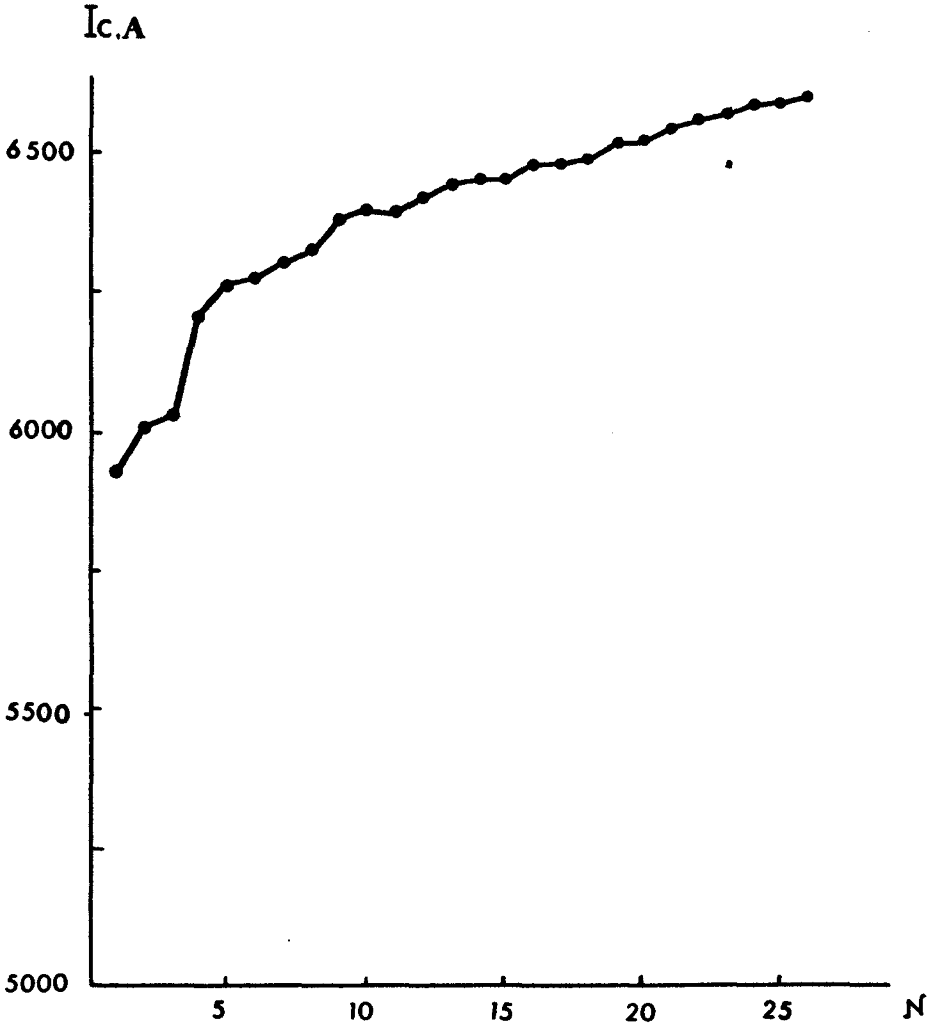

Fig. 5. Training curves for a full-scale model

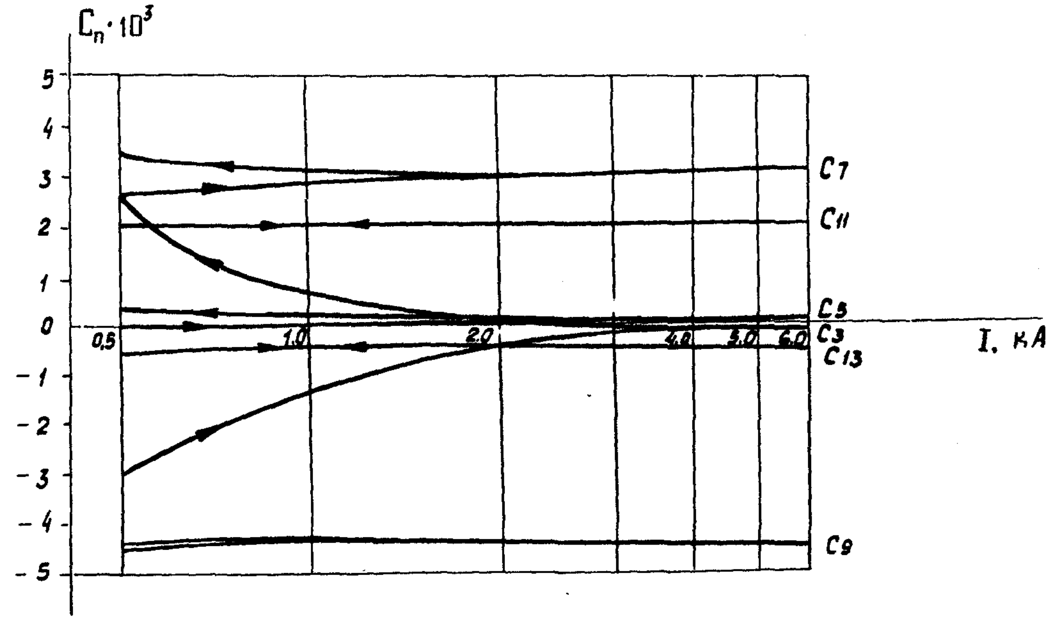

Fig. 6. Normal even nonlinearities versus magnet current.

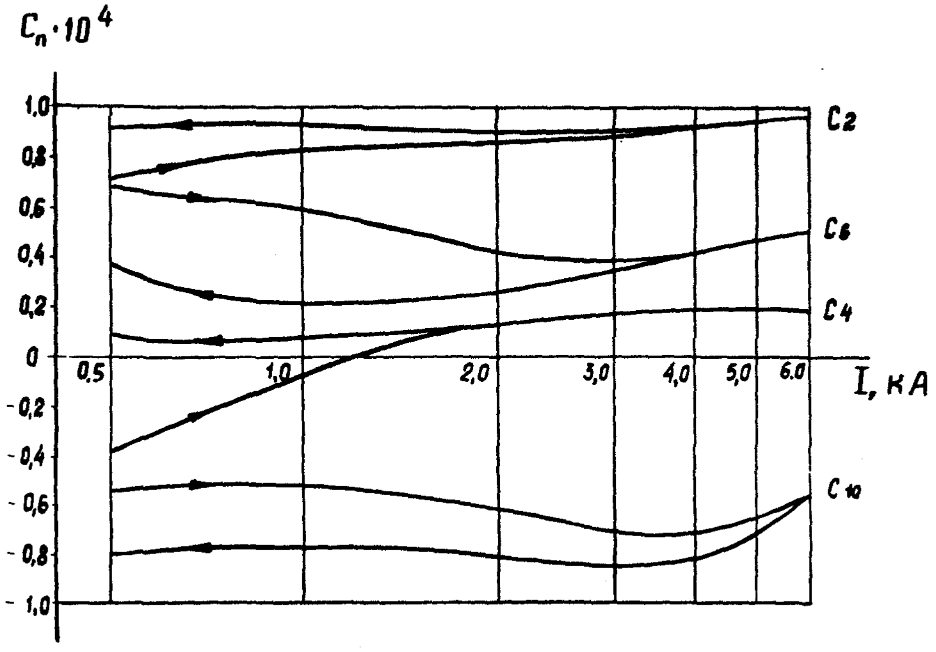

Fig. 7. Normal odd nonlinearities versus magnet current.

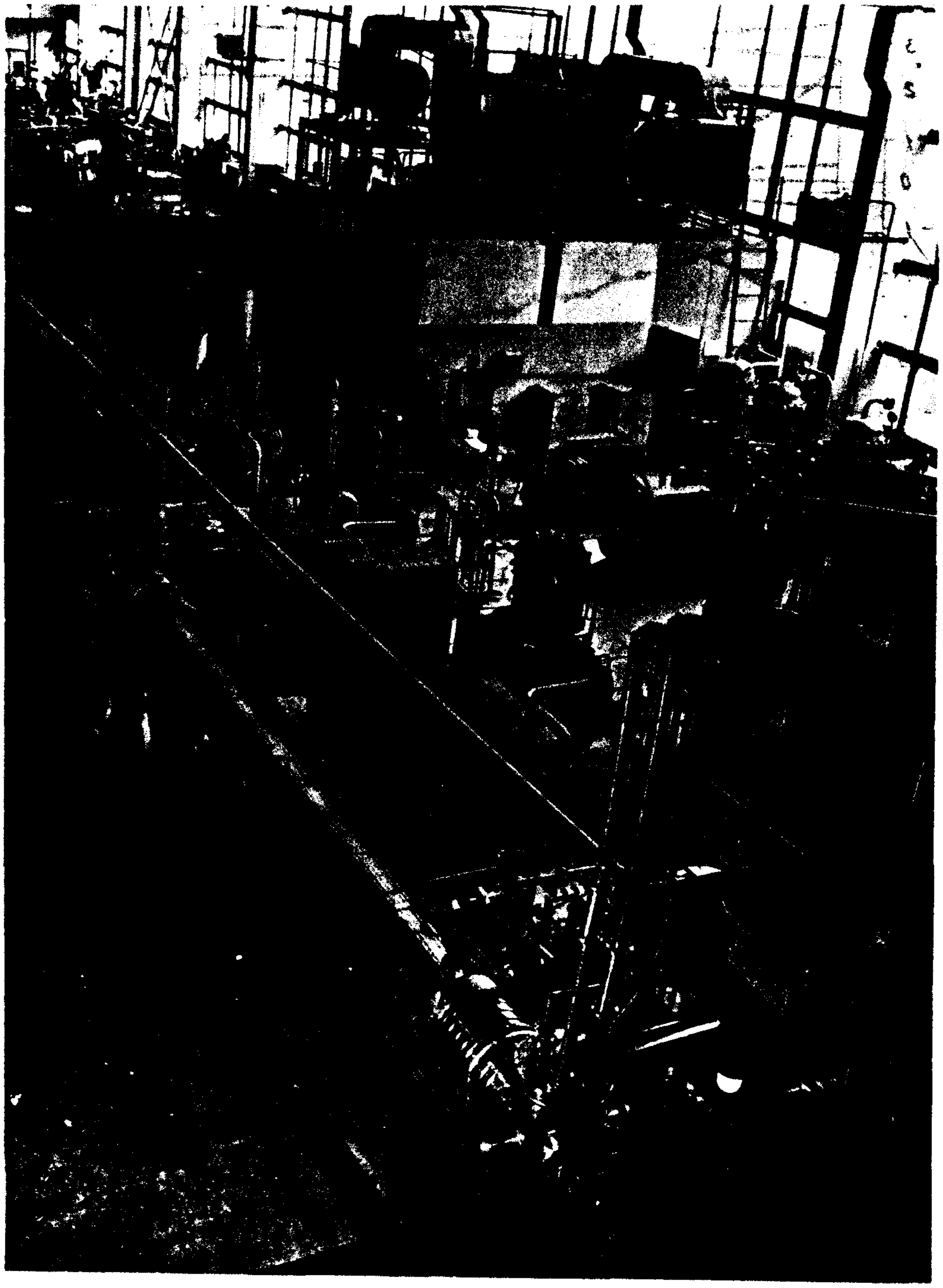

Fig.8. Full-scale dipole in a force-circulating cryostat at the test facility

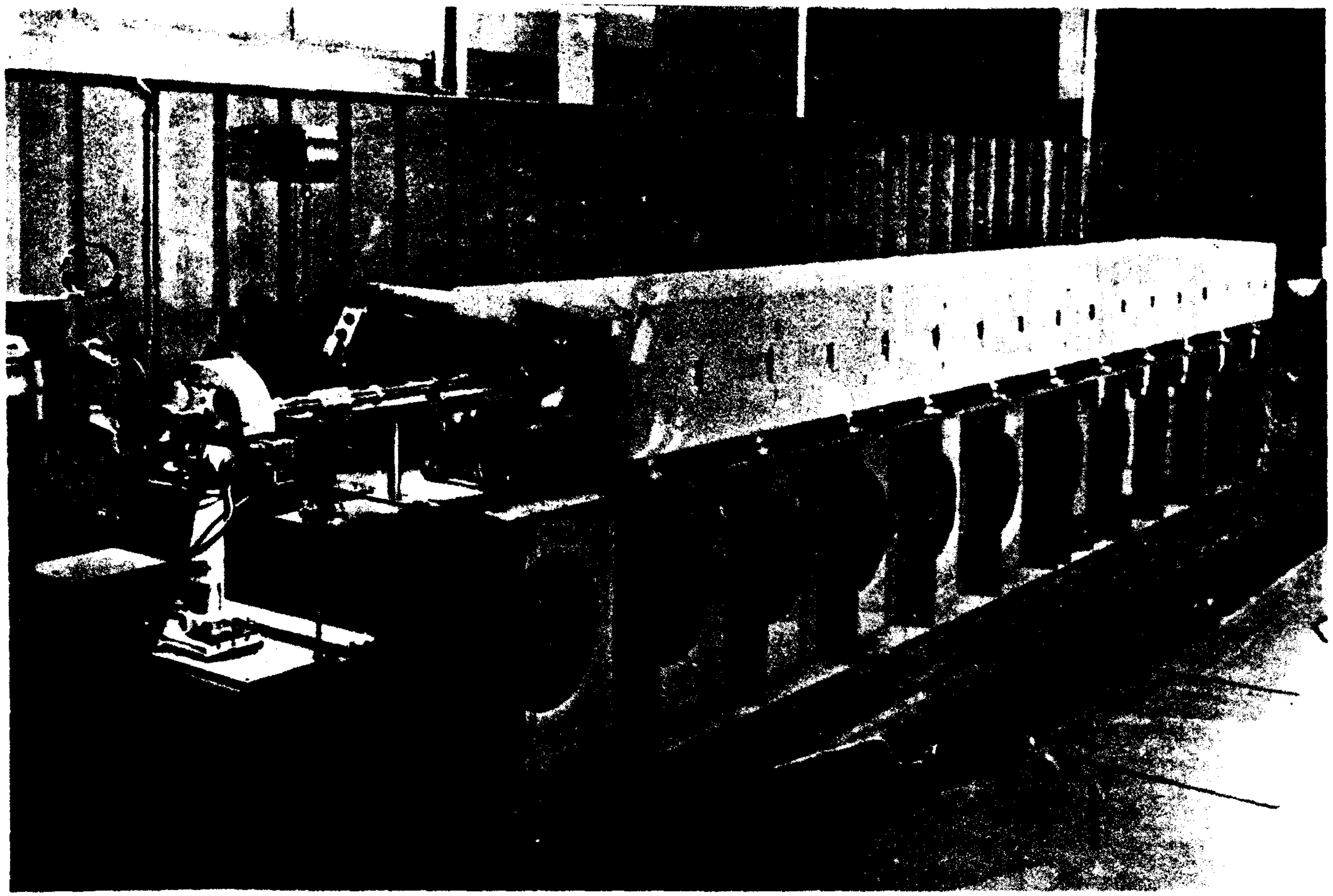

Fig. 9. Magnet of stage I of UNK.

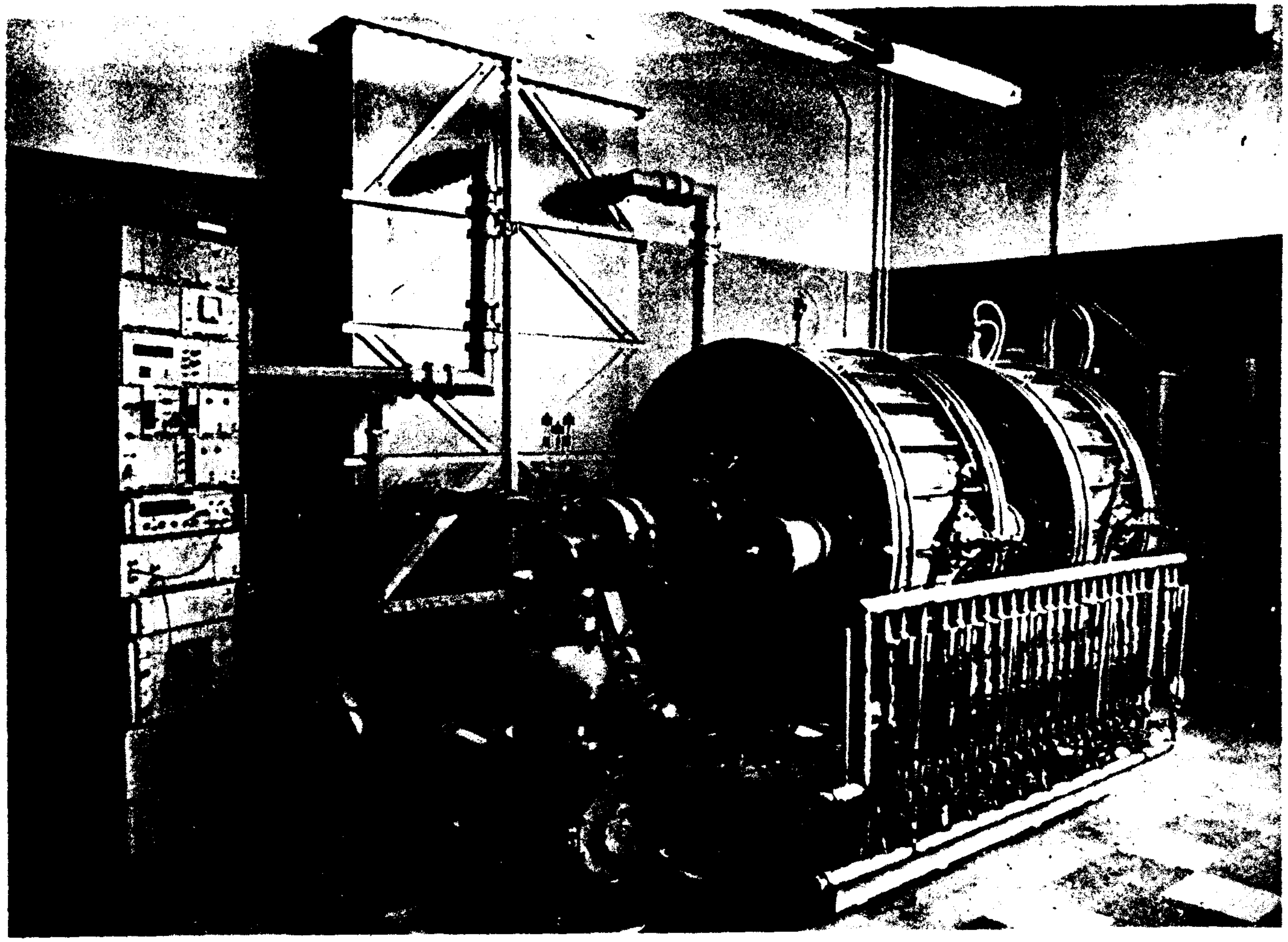

Fig. 10. Test module of the accelerating system.

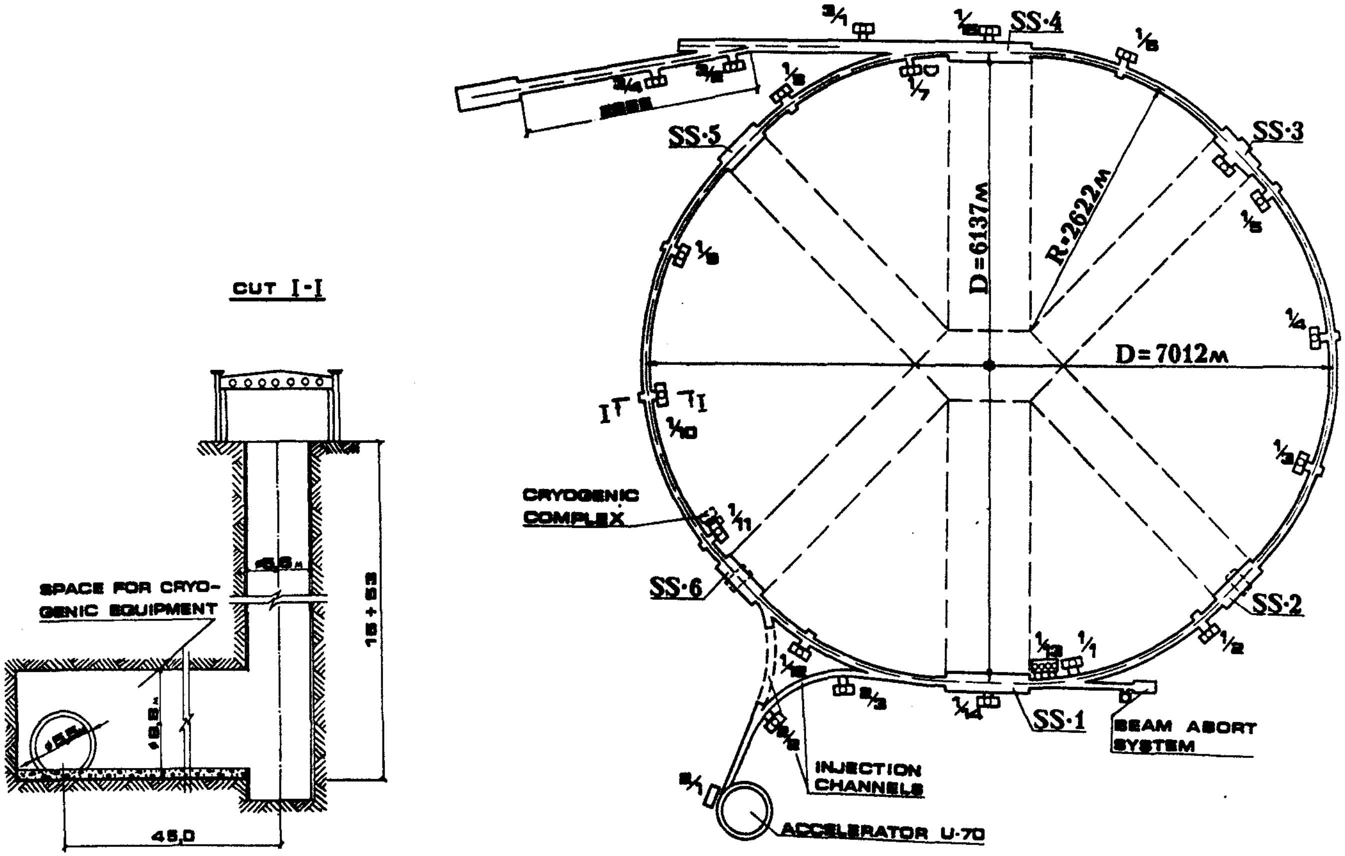

Fig. 11. The layout of the major constructions of UNK.

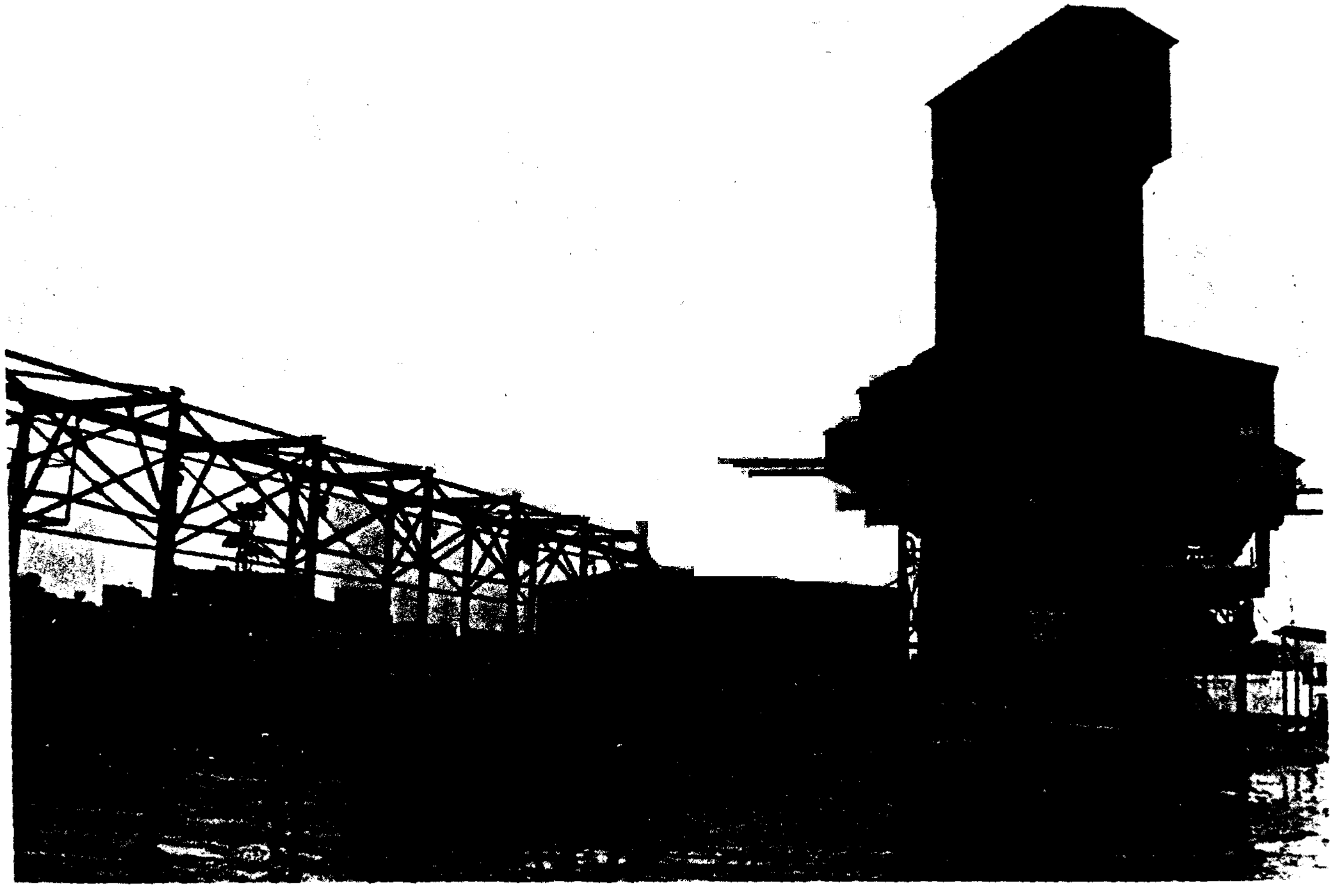

Fig. 12. View of a working area.

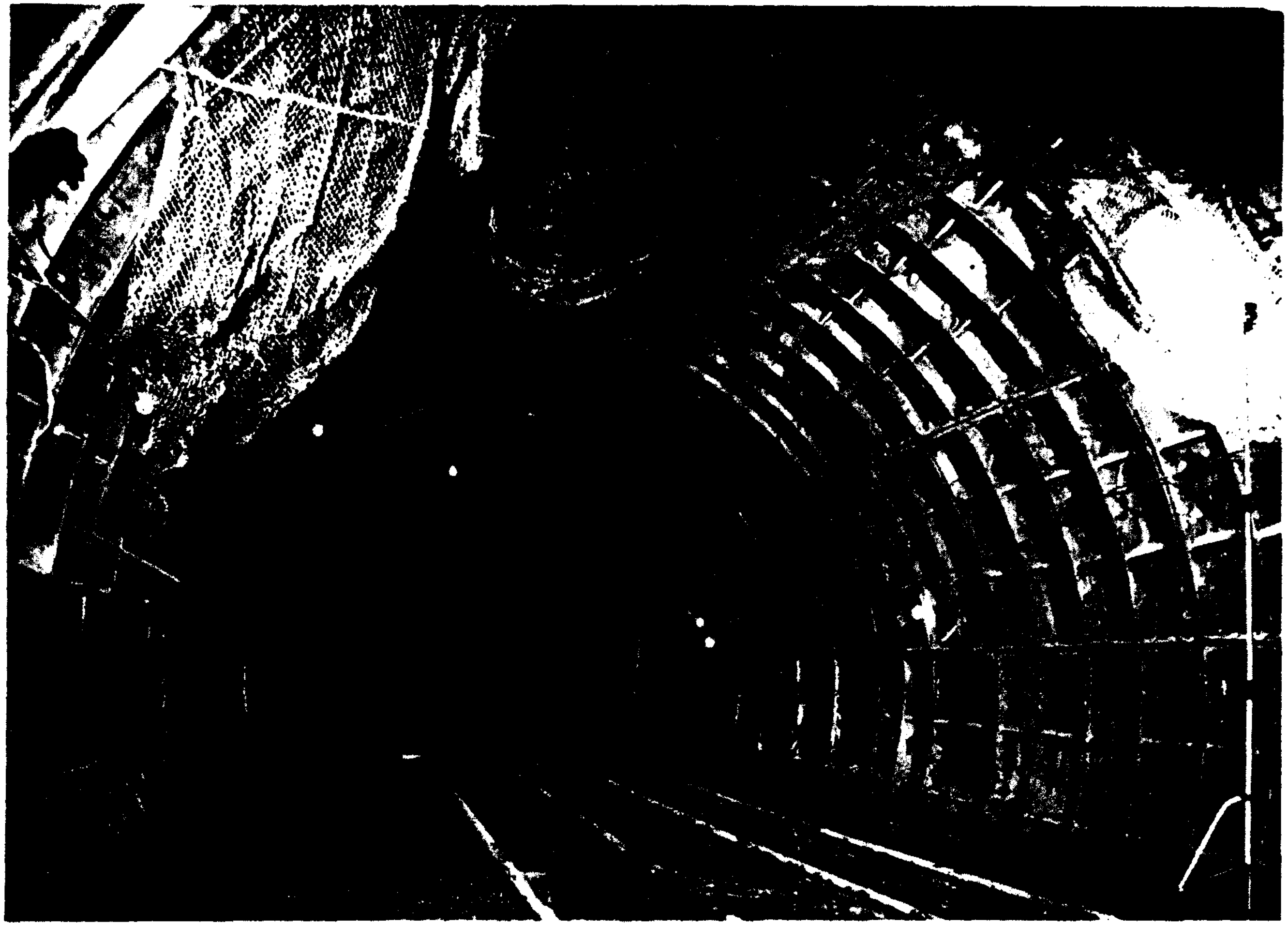

Fig. 13. Section of the tunnel under construction.