

## ITEP PROTON SYNCHROTRON INJECTOR

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(Presented by K. K. Onosovsky)

Electrostatic generator of the type EG-5 (1) is used as injector of ITEP proton synchrotron from October 1961. From October 1964, the synchrotron works according to the two-week schedule. The graph corresponding to this schedule of injector operation is given in Fig. 1.

The improvements discussed below have been introduced in order to raise the intensity of the beam, to shorten maintenance and the time of high-voltage training. In 1963 we have designed, installed and put into operation a new ion source with emission current 0,3 A in a pulse (instead of 0,025 mA previously) and a new focusing system. Intensity increase caused a more pronounced dependence of injector stability on the vacuum quality. The pumping system was therefore changed.

### PULSED ION SOURCE WITH CATHODE NEEDLE

To stabilize the discharge region and to raise the beam intensity we use now a cold cathode source with a cathode needle.

One of the well known construction of cold cathode sources (1) was taken as a basis.

The cathodes are made of stainless steel IXL8H9T - that is the material resistant to ion bombardment in the presence of oil cracking products. In Fig. 2 the construction of the ion source and of the experimental set-up is given.

When testing the source the following potentials were applied to the accelerating tube: source corp + 35 kV, the first (8) and the third (13) electrodes 0, the second electrode (11) + 29 kV. The emission current was measured by a Faraday cup (the second electron emission was depressed by 600 V potential) and by induction gauge (2). The measurements were performed behind the first electrode as well as at the exit of the tube. There were no considerable beam losses in the tube. Fig. 3 shows the dependence of the ion current  $J_i$  on the discharge cur-

rent  $J_d$  in the source at various fields  $H_c$  of magnetic coil and at constant potentials on the electrodes of the accelerating tube for the source with the cathode needle and without it (their construction is shown on Fig. 4b and 4a correspondingly).

Fig. 5 shows the voltamper characteristics of the pulse discharge  $J_d(U_a)$  for the same types of the sources. Coil field variation from 400 to 700 Oersted does not affect the voltamper characteristics.

As seen from the comparison of the plots, the discharge in the source with a cathode needle considerably different from Penning discharge. The discharge seems to have a strong non-homogeneity with high concentration of charge carriers on the axis. This follows from the fact that the emission current is nearly constant (it changes) from  $J_{max} = 300$  mA to  $J_{max} = 320$  mA) when emission aperture is varied from 2 mm to 3 mm.

Thus, the cathode needle made it possible to stabilize the position of the intensive part of discharge relative to the emission aperture, to increase considerably (Fig. 3) and to stabilize the emission current. It made the emission current independent of emission properties of the cathode material and made it possible to use for cathodes are the stainless steel IXI8H9T.

Voltamper characteristics at the new source are shown in Fig. 6. They were measured by simultaneous oscillographing the discharge current and tension. The initial point of the tension oscillogram corresponds to the 300 V level, since in the interval between pulses the source works with small constant discharge current. The time of discharge development which is 1:4 mcsec long is well seen. The discharge extinguishes at a voltage, considerably less than 300 V and returns gradually to the voltage corresponding to the constant current regime.

The main working parameters of the source are the following:

Maximal discharge current	12 A	Proton component	85%
Magnet coil field	250 : 750 Oersted.	Cathodes working resource <sup>1</sup>	more than 3000 h
Maximal ion current with the pulse length 50 msec and with the extraction voltage 35 kV	300 mA	<sup>1</sup> Proton beam component and cathodes working resource have been determined on the electrostatic generator with the emission current from the source up to 100 mA in the pulse with the pulsing rate 0,2 cycles/sec.	
Power consumption	35 watts		

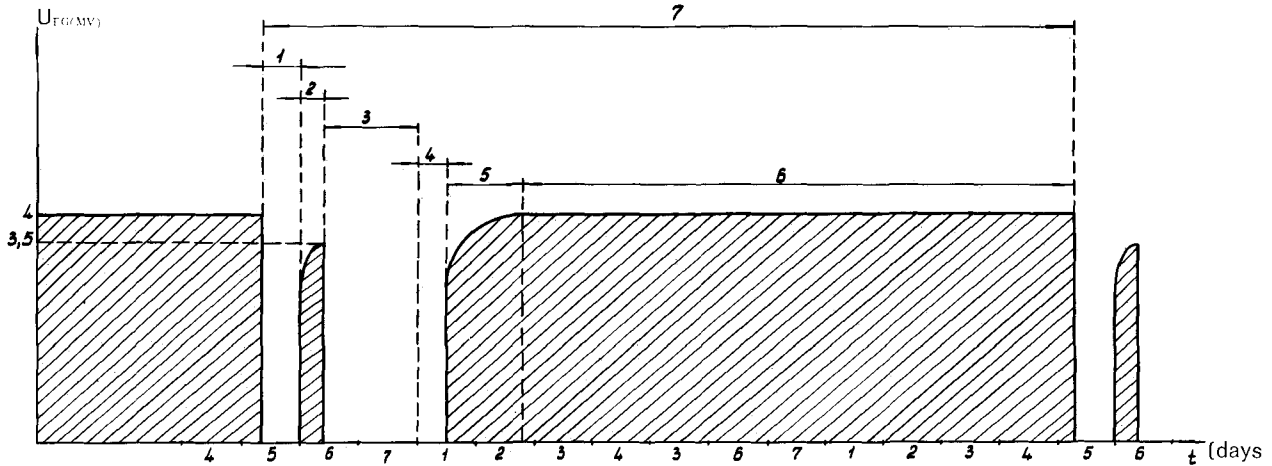


Fig. 1 - Schedule of injector operation. 1 - Opening for maintenance of the generator's tank; 2. High-voltage test of generator; 3. Revision of all the injector's systems; 4. Vacuum pumping of the accelerating tube; 5. High-voltage training of injector; 6. Operation in the injector regime (228 hours); 7. Two week schedule. Time of belt operation is 276 hours.

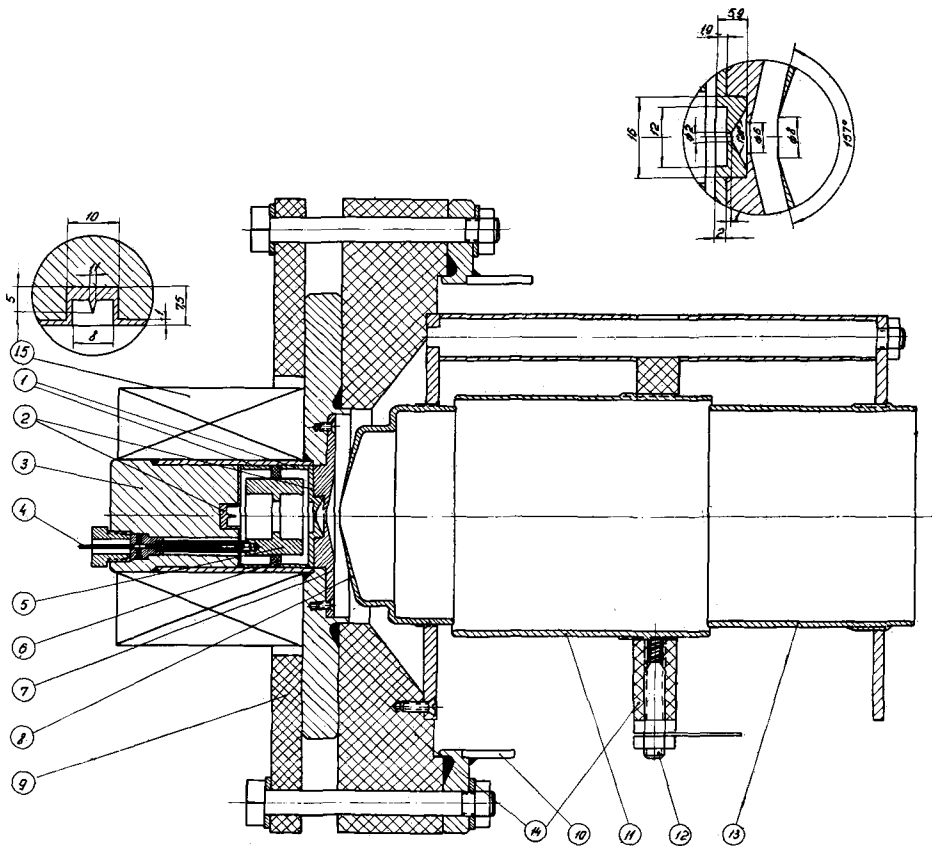


Fig. 2 - Construction of the ion source and of the experimental set-up.

1. Adjustment rings (stainless steel IX18H9T);
2. Cathodes (IX18H9T);
3. Source frame (steel 3, stainless steel IX18H9T);
4. Anode voltage input;
5. Anode (IX18H9T);
6. Insulator (porcelain);
7. Magnetic poles (steel 3);
8. First electrode (IX18H9T);
9. Clamping washer (plexiglass);
10. Frame;
11. Second electrode (IX18H9T);
12. High-voltage input;
13. Third electrode (IX18H9T);
14. Insulators (plexiglas);
15. Magnetic coil.

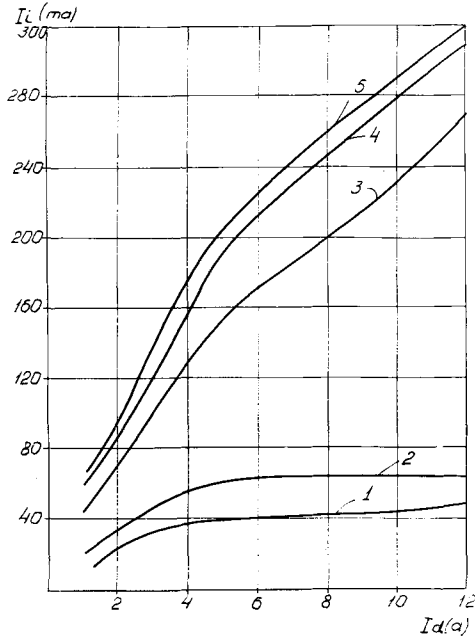


Fig. 3 - Dependence of ion current  $I_i$  on discharge current  $I_d$ . Extraction voltage is 35 kV.

- 1 - Source with the cold cathode ( $H_c = 250$  Oersted)
- 2 - Source with the cold cathode ( $H_c = 400$  Oersted)
- 3 - Source with the cathode needle ( $H_c = 400$  Oersted)
- 4 - Source with the cathode needle ( $H_c = 600$  Oersted)
- 5 - Source with the cathode needle ( $H_c = 720$  Oersted)

The ion source is used at the electrostatic generator (the injector of ITEP proton synchrotron during 2 years). For the sake of maintenance the source was opened 2-3 times a year after 3000 hours for revision and cleaning of the cathodes. There were no essential changes on the cathode surface.

**FOCUSING SYSTEM**

After a new source was installed we had got first no significant raise the current in the ion guide because of beam losses at the acceleration in the tube and at the entrance into the magnetic analyzer's chamber.

The ion optics of the accelerating tube cannot be reliably calculated due to the fact that the dimensions of the region of ion extraction and the voltage distribution in the region are never known. The ion optics was improved on the basis of qualitative considerations on the form of the focused beam. The operating focusing system possibly is not yet optimal, since the experiments in this direction were strictly limited by the generator's operation as an injector.

The system now in operation (Fig. 7) differs from the previous one by increased potentials and by increased aperture of electrodes. On the lower electrode (4) the tungsten-wire 9 grid was installed, the wires being 0,05 mm diameter.

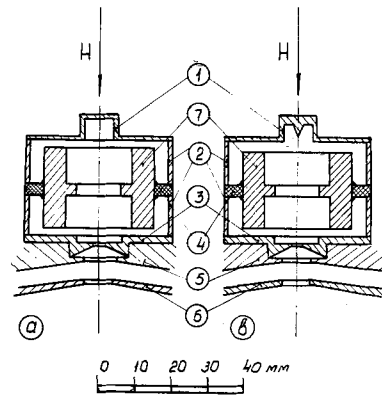


Fig. 4-a - Ion source chamber with cold cathode. The cathodes are made of aluminium.

Fig. 4-b - Chamber of the ion source with cathode needle. The cathodes are made of stainless steel (IX18H9T).

- 1 - Upper cathode; 2. Adjustment rings; 3. Ower cathode;
- 4. Insulator; 5. Magnet poles; 6. First electrode; 7. Anode.

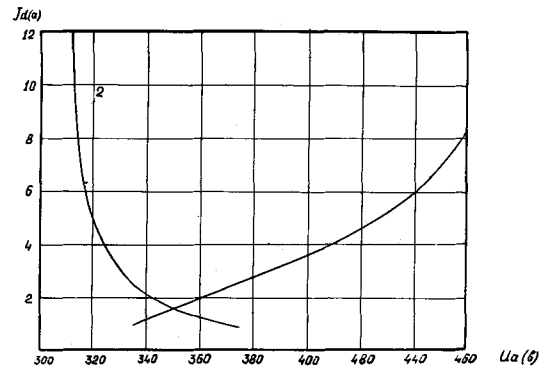


Fig. 5 - Dependence of the discharge current  $I_d$  on the anode tension  $U_a$  - 1. Source with cold cathode 2. Source with the cathode needle.

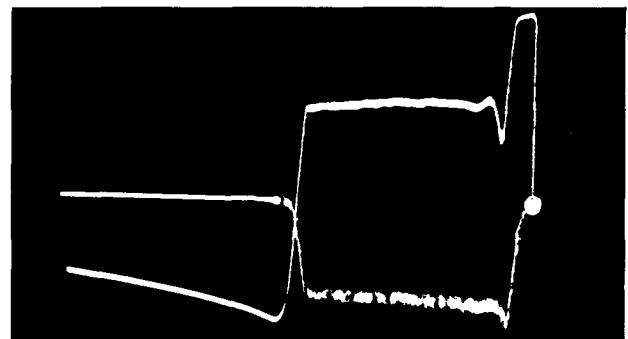


Fig. 6 - Current (above) and discharge tension (below) oscillograms. Discharge current — 4,5 a; Discharge firing voltage — 420 V; Firing voltage (limited by oscillograph amplifier) — 1250 V; Firing time — 4 mcsec; Pulse time — 50 mcsec.

Defocusing forces act in this lens only normally to the tungsten wires what provides a « strip » focusing. As a result, at the entrance into the analysing magnet chamber we obtained a 45 mA

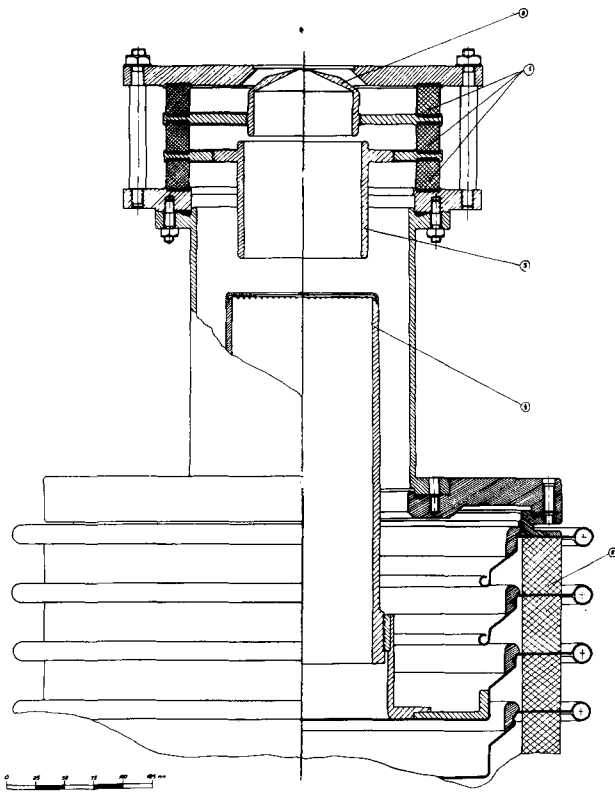


Fig. 7 - Preliminary beam focussing system - 1. Porcelain rings; 2. First electrode (40 kV); 3. Second electrode (25 kV); 4. Third electrode with the grid (65 kV); 5. Accelerating tube. The potentials are shown relative to the source corp.

strong pulsed beam with cross section, geometrically similar to the rectangular cross section of the chamber. The aperture of the chamber in the analysing magnet and in the ion-guide was also widened.

#### PUMPING SYSTEM

The accelerating tube is pumped by two oil-vapour (the oil BM-1) pumps BA-5-4 (one of the pumps being spare) with liquid nitrogen traps (Fig 8). In the by-path line the magnet-discharge trap is located (3).

The time needed for high-voltage training of the accelerating tube, the frequency of the appearance of weak discharges in the tube and, consequently, the maximal voltage at a normal operation regime is determined by the quality of the vacuum. The quality of the vacuum means the amount of hydrocarbons in high-vacuum system. The presence of hydrocarbons in the accelerating tube leads to considerable increase of the Röntgen radiation, the electron load and the constant component of the ion current. As a result the training time considerably increases, as does the number of breakdowns.

In order to improve the quality of the vacuum, to increase the reliability and the convenience of the operation, we have constructed the 100 liters liquid-nitrogen trap providing continuous work during 3 days. The trap has a special screen to prevent oil migration along the walls. The same screen eliminates the penetration into accelerating tube of the desorption products leaving the walls of the volume when their temperature changes due to decrease of liquid nitrogen level. The temperature of the trap baffle does not depend on liquid nitrogen level in the volume.

The traps exclude the penetration of the oil vapours into the accelerating tube at normal operation regimes (vacuum better than  $10^{-5}$  Torr). However, even after the installation of new traps the oil vapours continued to penetrate into the system, and the number of breakdowns remained considerable. It was due to rapid emission of large amount of gas in the accelerating tube at the moments of discharges. When the vacuum is spoiled, the possibility of penetration of oil vapours through the baffles increases, the vapour stream in the pump may break down and large amount of oil may get into the volume.

It has been noted that high-voltage training time of the tube and the number of breakdowns are considerably reduced if oil is swepted out even from the upper surfaces of baffles only. To explain this effect the following mechanism has been proposed. The cracking products produced in the accelerating tube in the process of high-voltage training and spoiling the high-voltage qualities of the tube, are normally frozen at the surfaces of baffles and therefore are removed from the vacuum volume of the tube. After a number of oil vapour penetrations, the baffles are covered with oil film, their radiation coefficient increases and therefore their temperature also increases. As a result the baffles stop to freeze out the cracking products.

To freeze out the cracking products we use now the trap of the spare (switched off) high-vacuum pump. As a result, the high-voltage training time of the accelerating tube is reduced up to several hours, the number of breakdowns and the Röntgen radiation level are sharply decreased.

Presently the injector has the following working parameters:

- |   |         |
|---|---------|
| 1. Generator voltage  | 4 MeV   |
| 2. Steady ion current   | 1-3 mkA |
| 3. Pulse current of unseparated beam with the pulse length 40 mcsec | mA      |
| 4. Proton pulse current at the entrance                             |         |

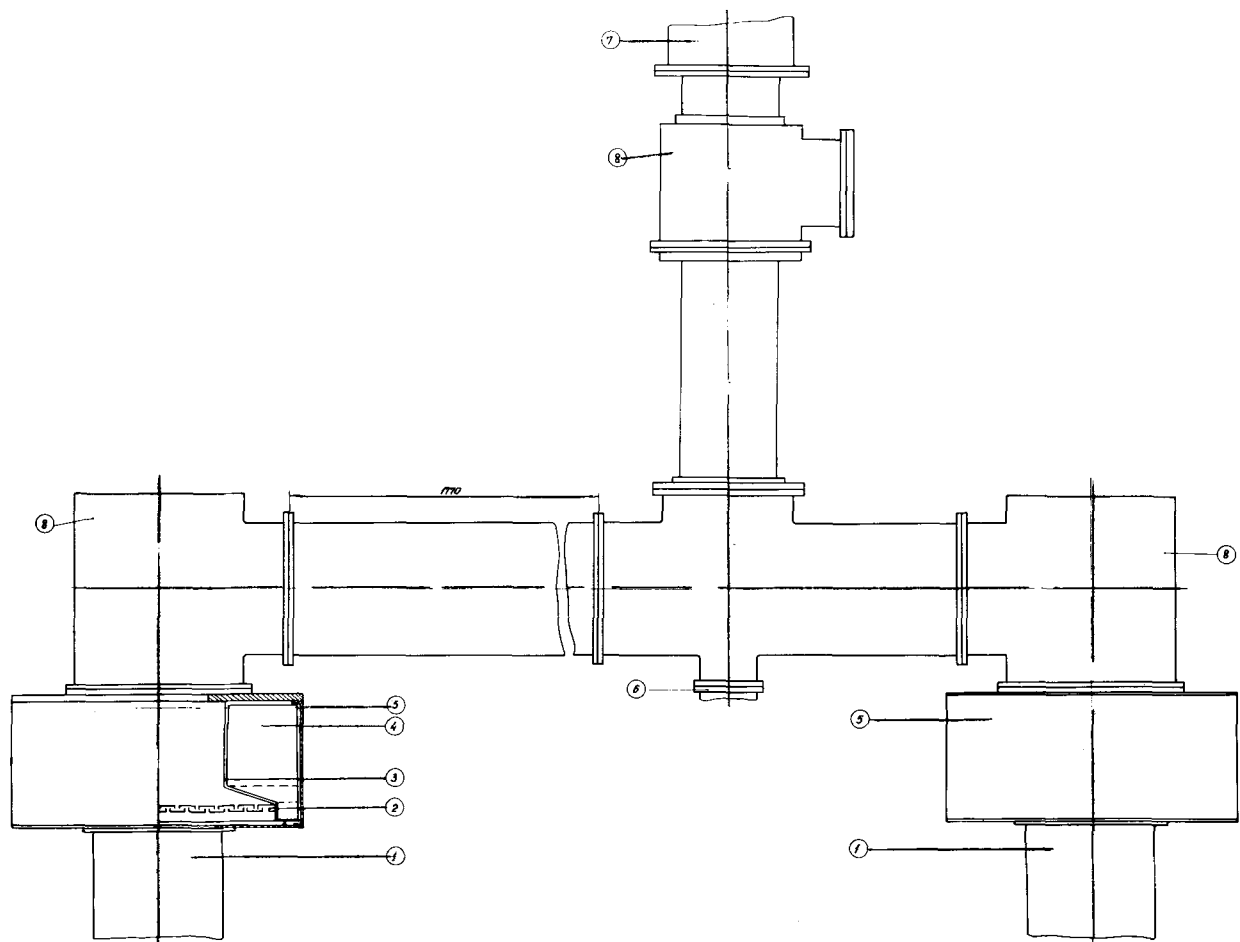


Fig. 8 - System of accelerating tube pumping - 1. Oil - vapour pumps BA-5-4; 2. Trap's baffles; 3. Screen preventing migration of oil along the walls; 4. Liquid nitrogen volume; 5. Frame of liquid nitrogen trap; 6. Flange of magnetic analyzer chamber; 7. Crossing of accelerating tube (1500 mm length; 8. Vacuum valves.

ce into synchrotron (pulse length  
40 msec) 10 mA

5. Energy stability 0,1%

From the 1 January 1965 up to May 1965 the electrostatic generator injected the beam during 1924 hours out of the planned 2070 hours.

#### Acknowledgement

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