Status of high-current tandem accelerator for the neutron therapy facility

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The development of a neutrons source for boron neutron capture therapy based on the compact and inexpensive accelerator is possible [1].

Results and discussion

Fig. 1 shows the construction of vacuum insulation tandem accelerator developed at BINP, as a base of neutrons source, using the sectionalized rectifier 5 from industrial ELV-type electron accelerator, as a powerful source of high voltage. Negative hydrogen ion beam, produced in ion source 1, after passing low energy beam tract 2 is injected into electrostatic tandem accelerator with vacuum insulation. After charge-exchange of negative hydrogen ion in proton inside stripper tube in the center of high-voltage electrode, a proton beam, which is accelerated to double voltage of high-voltage electrode, is formed at the outlet of the tandem.

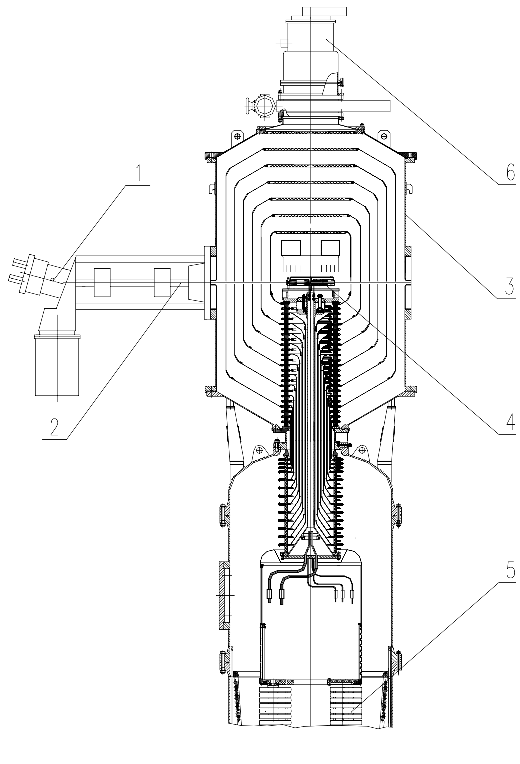

Fig. 1. Vacuum insulation tandem accelerator.

The high voltage electrode is surrounded by system of different potential shields providing the homogeneous distribution of the potential and preventing the full voltage effect.

The most important component of the accelerator is the high-voltage feedthrough insulator 4, which transfers the high-voltage powerful source 5 potential into the vacuum tank from the ELV tank filled with SF_6 gas. Insulator can be arbitrarily remote from the accelerated beam passage region. The high-voltage electrode is placed on the vacuum part end of the feedthrough insulator on the metal flange which is vacuum tightened by the tightening pipe passing along its axis connected to the another metal flange placed on the gas part end of insulator. This metal flange contacts with high-voltage source. The gas part of the feedthrough insulator (placed in SF_6) manufactured of ceramic rings separated by metal rings for the potential distribution. The vacuum part of the insulator manufactured of glass rings, also separated by metal rings. Inside the insulator (under SF_6 gas pressure lower, than outside gas part insulator pressure) around the tightening pipe thin wall pipes of various lengths are concentrically located to connect the respective metal rings of different potential on the gas part of the insulator and its vacuum part. The voltage is applied to these rings from the resistive divider providing the homogeneous distribution of the potential along the insulator length. Vacuum pumping is carried out through mouth in the top oa vacuum tank 3 by pump 6.

Coaxial round holes for the beam passage are in the walls of vacuum tank, high-voltage electrode and in the shields. Since the thin-wall shields placed along the equipotential surfaces of the electrostatic field hardly contribute into focusing.

In general, there are two kinds of consequences of vacuum breakdowns in dependence on vacuum gap storage energy: with increasing and decreasing of electrical strength of high-voltage vacuum gap. For tandem accelerator with vacuum insulation the separate vacuum gap storage energy is depended on number of accelerating (vacuum) gaps. Maximum separate vacuum gap storage energy is 44 J for 4-gaps system, 30 J for 6-gaps system and 15 J for 12 gaps system (Fig. 2).

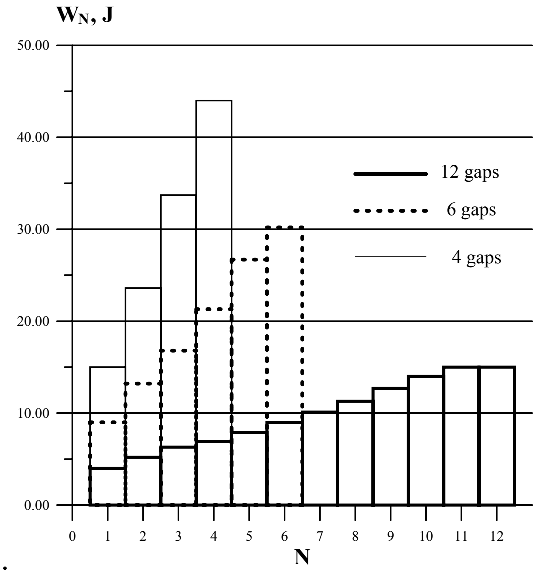

Fig. 2. Gap storage energy at high voltage electrode potential equal 1.25 MV.

There are 2 types of breakdowns in accelerator - tandem: breakdowns at full voltage and breakdowns of any separate vacuum gap. Fig. 3 shows vacuum gaps overvoltages E_N/E_0 under breakdowns at full voltage. E_N and E_0 are vacuum gap electric field intensities after and before breakdown, accordingly. The vacuum gap number increases from high-voltage electrode to “ground” one.

Maximum near by vacuum gaps overvoltages E_N/E_0 under breakdowns of any vacuum gap are 0.08, 0.14, 0.17 for 12, 6 and 4 gaps accordingly.

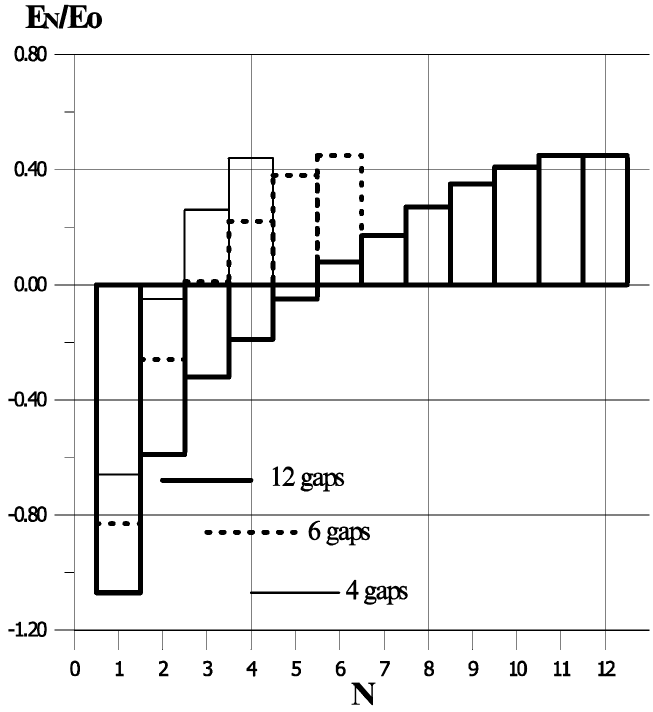

Fig. 3. Vacuum gaps overvoltages under breakdown at full voltage.

A set of experiments on study of high voltage strength of vacuum gap with large square electrodes is carried out at prototype tandem-accelerator with electrodes area ≈ 0.7 m^2 and 45 mm high voltage vacuum gap. Fig.4 shows the breakdown electric field intensity E opposite number of regular breakdown N in high voltage experiments. First breakdowns of vacuum gap took place at intensity of electrostatic field higher, than vacuum gaps accelerator tandem one: ≈ 33 kV/cm (●●●●●) and storage energy up to 31 J released at breakdowns did not result in detraining of vacuum gap.

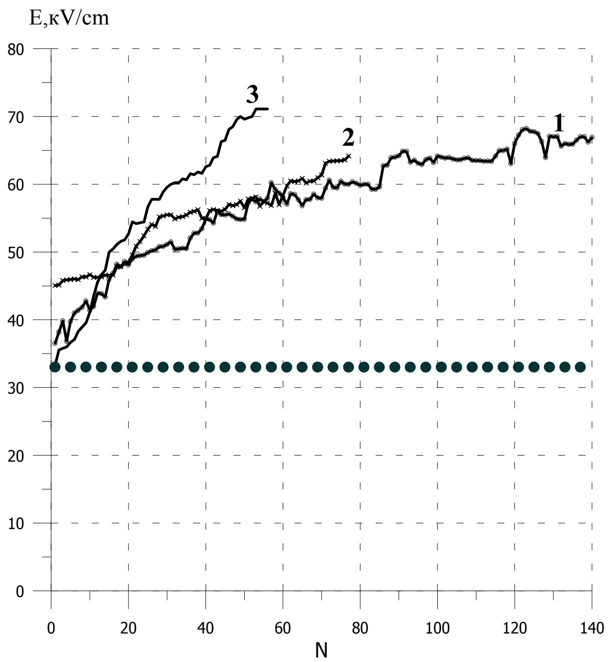

Fig. 4. Example of 3 training curves of 45 mm vacuum gap. 1,2 – 9 J; 3-31 J.

Full electrons emission current from high voltage electrode surface under 33 kV/cm electrostatic field intensity was determined practically to be equal to zero.

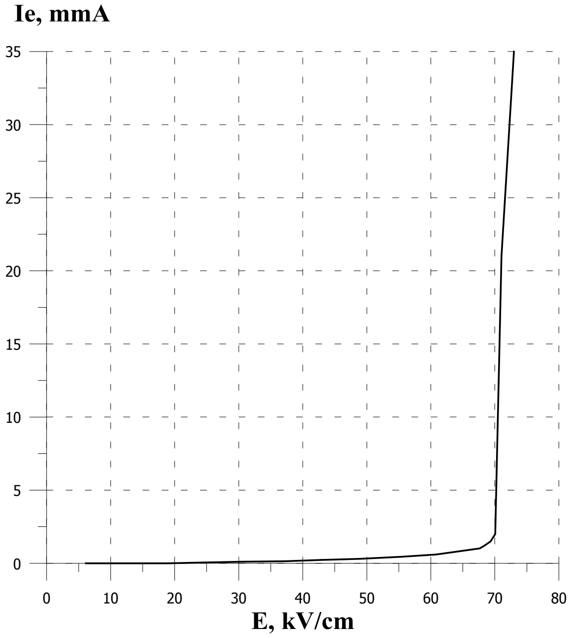

Fig. 5. Full electrons emission current opposite electrostatic field intensity.

Up to this time tandem is under realization.

Fig. 6-9 shows units of tandem, which have been manufactured up to this time.

Fig. 6. The vacuum part of feedthrough insulator.

Fig. 7. The gas part of feedthrough insulator

Fig. 8. Tandem vacuum tank.

Fig. 9. View of a tool for assembly of the tandem feedthrough insulator and "clean" room.

Conclusions

1. The breakdown strength of vacuum gap with electrodes of large area was confirmed by experiment for the expected value of residual pressure in the tandem vacuum tank.
2. For the expected value of residual pressure it was determined the value of dark current for the large area electrodes vacuum gap under different electric fields and for various gases of stripper. It was obtained more specific timing performances information about high voltage gap training.
3. The electrical strength of dielectric tubes for the stripper system was investigated in necessary range of electric fields.
4. There was made the warming-up of the vacuum tank in the heat - vacuum chamber.
5. The ELV gas vessel was modernized and high voltage rectifier is ready for use.

Reference

[1] B. Bayanov *et al.*, Nucl. Instr. and Meth. in Phys. Res. A 413 (1998) 397.