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Changes in the tandem accelerator in the second version of the VITA-II accelerator neutron source.

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***Abstract* — In the second version of the VITA-II accelerator neutron source, outer corrugated ceramic surface is using in the vacuum part of the feedthrough insulator to increase the reliability of the tandem and increase the electrical strength, and the height of individual insulators is increased. When the high-voltage power source is turned 180 degrees, the lower part of the feedthrough insulator is located inside the rectifier sections. This allowed the accelerating potential to be supplied through the lower gas part of the feedthrough insulator to the high-voltage electrodes of the vacuum part of the accelerator directly from its sections. Which made it possible to create a uniform voltage distribution in the accelerating gaps of the tandem and eliminate the voltage drop in the gaps when dark currents appear. The changes made allowed to reduce the height of the facility, which is essential for placing the facility in a medical clinic. The report describes the changes made and the results of the experiments.**

Keywords—accelerator neutron source, tandem-accelerator, feedthrough insulator, electrical strength

I. Introduction

Accelerator based neutron source VITA (Vacuum Insulated Tandem Accelerator) has proposed developed and is operating at the Budker Institute of Nuclear Physics [1]. It includes an electrostatic tandem accelerator of charged particles of an original design (a tandem accelerator with vacuum insulation), a lithium neutron-generating target and a number of neutron beam shaping assemblies. The facility ensures the production of a stationary proton beam with an energy of up to 2.3 MeV, with a current of up to 10 mA, the generation of a powerful neutron flux and the formation of a neutron beam of various energy ranges: from cold to fast. The facility are used actively for the development of boron neutron capture therapy of malignant tumors (BNCT), radiation testing of promising materials, measuring the cross-section of nuclear reactions and a number of other applications. The second version of the accelerator based neutron source VITA-II has created and delivered to the BNCT clinic in Xiamen (China) for the treatment of patients using the BNCT method. For clinical trials of the BNCT method in the Russian Federation, the second VITA-II accelerator neutron source has manufactured and is installing at the Blokhin National Medical Research Center of Oncology in Moscow.

I. Accelerator design

Fig. 1 shows the tandem accelerator with vacuum insulation.

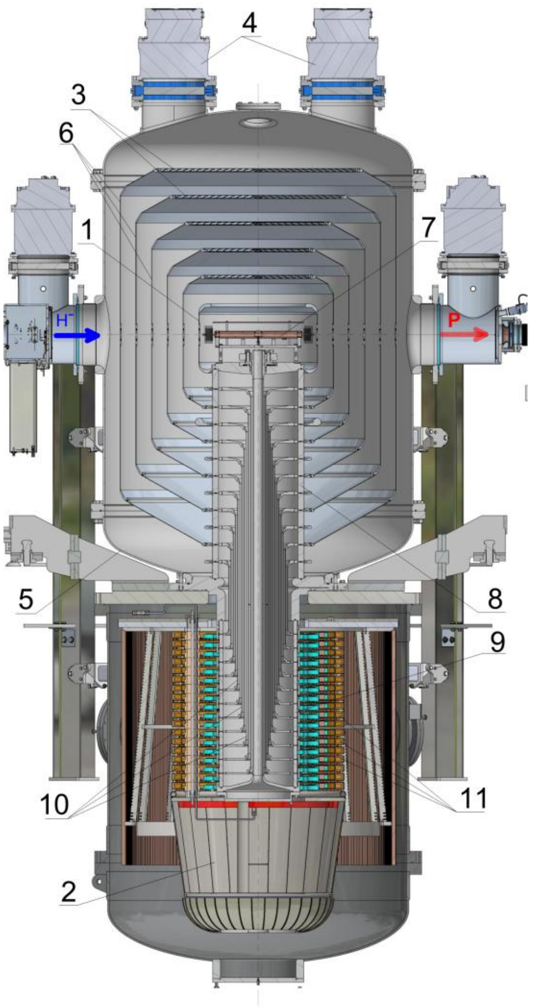

Fig. 1. General cross-section view of the electrostatic 6-gap tandem-accelerator with vacuum insulation: 1 - high-voltage electrode of the tandem- accelerator; 2 - high-voltage electrode of direct voltage source; 3 - jalousies of electrodes; 4 - turbo molecular pump; 5 - vacuum tank; 6 - intermediate electrodes of the tandem-accelerator; 7 - gas stripping target; 8 - vacuum part of feedthrough insulator; 9 - gas part of feedthrough insulator; 10 - internal coaxial cylinders, 11 – sections of high-voltage rectifier.

A beam of negative hydrogen ions is injecting into the accelerator and accelerating to 1.15 MeV. The negative hydrogen ions are converting into protons in the gas (argon) stripping target 7, which is install inside the high-voltage electrode 1. Then, protons with the same potential of 1.15 MV are accelerating to an energy of 2.3 MeV. Gas is pumped by a turbo molecular pump 10 installed at the output of the accelerator and a cryogenic pump 4 through the jalousies 3 in the electrodes.

One of the main elements of the vacuum-insulated tandem accelerator is a sectional detachable feedthrough insulator (Fig. 2).

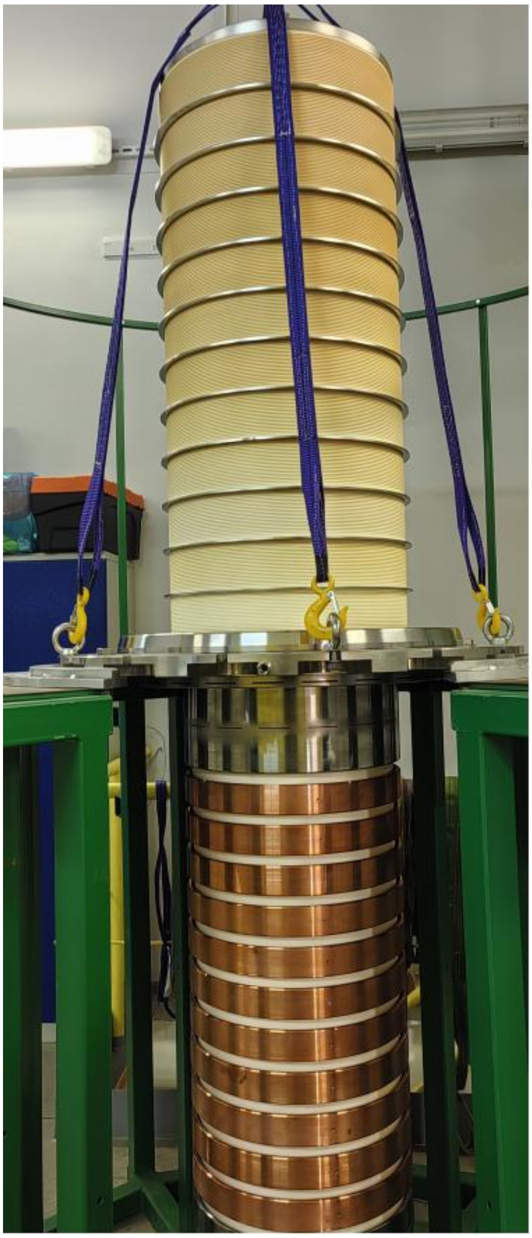

Fig. 2. The feedthrough insulator assembly.

Electrodes of the same potential of the lower (gas) 9 and upper (vacuum) 8 parts of the feedthrough insulator are connecting by a system of internal coaxial cylinders 10 of different lengths and diameters. The lower part of the feedthrough insulator is located inside the sections of the high-voltage rectifier. The electrodes are connecting to the sections directly. The potential distribution over the intermediate electrodes 6 is set from the sections of the high-voltage rectifier. It possible to remove of the low-power resistive divider used in the previous version and eliminate the influence of the dark current on the uniformity of the voltage distribution in the vacuum gaps.

Studies of insulators with different geometries of the outer surface showed that a corrugated surface with peaks and valleys radii from 0.5 to 1 mm provides an increase in electrical strength up to 1.5 times compared to a smooth surface. With the same height of the insulators, the length of the surface of the corrugated insulator is $\pi/2$ times greater than that of the smooth insulator. The developed technology for processing inorganic insulators allows for the implementation of ribbed surface geometry and manufacturing in China.

In the new version of VITA-II, the shape of the surfaces remained unchanged. The outer surface of the upper vacuum part of the feedthrough insulator is corrugated (Fig. 3). The radius of the ribs and depressions was selecting 1 mm, based on the previously obtained results [2].

Fig.3. Corrugated surface upper vacuum part of the individual insulator.

The internal gas surface is smooth. The external and internal surfaces of the lower gas part of the feedthrough insulator are smooth (Fig. 4).

Fig.4. Smooth surface of the lower gas part of the individual insulator with shielding rings.

The changes were making to increase the electrical strength of the tandem accelerator.

The sizes of the individual insulators of the upper and lower parts were changed. The height of the individual insulators of the upper vacuum part of the bushing insulator was from 85 mm to 100 mm. The height of the individual insulators of the lower gas part was 70 mm. It was making to reduce the electrostatic field strength on the surfaces of the ceramic insulators.

Experience with accelerators showed that for it to work without breakdowns, it is necessary that the electric field strength on the surface of ceramic accelerator tubes be ~ 10 kV/cm. In our case, the calculation showed that at a voltage of 1.15 MV, the electric field strength on the vacuum corrugated surface of the feedthrough insulator would decrease by approximately 2 times compared to the previous version.

II. Experimental Results

The new feedthrough insulator with an outer corrugated vacuum surface of ceramic rings has installed. After opening to the atmosphere standard training has performed. The voltage of 1.15 MV was obtaining over a time that was 3 times less and with a smaller number of breakdowns than at the feedthrough insulator with a smooth ceramic surface (Fig. 5).

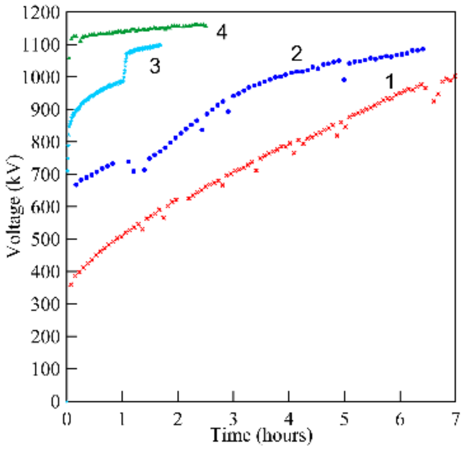

Fig. 5. Graphs of the first increase in voltage at the accelerator after modernization: 1 - smooth ceramic (VITA), 2 - corrugated ceramic (VITA), 3 – corrugated ceramic (VITA-II), 4 - corrugated ceramic (VITA-II) after training.

The testing with proton beam current is showing in Fig. 6. The mode without breakdowns was reaching.

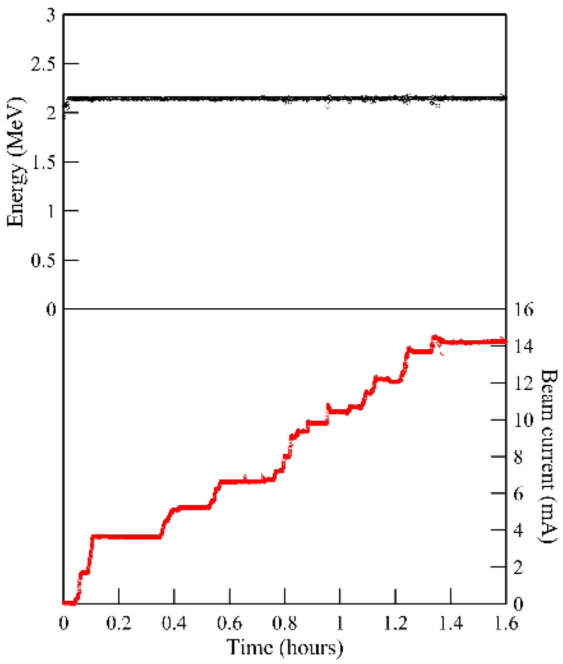

Fig. 6. Graph of the energy and beam current dependence of the accelerator versus time.

In this case, the average electric field strength on the vacuum surface of the feedthrough insulator was ~ 7.2 kV/cm, taking into account increase in its length by $\pi/2$.

As the result of the tests conducted at an energy of 2.3 MeV, a proton beam current of 14 mA was obtaining. When disassembling the tandem accelerator, no traces of breakdowns were finding on the ceramic surface of the feedthrough insulator.

III. Conclusion

The VITA-II epithermal neutron source based on a vacuum tandem accelerator and a lithium target was manufacturing and testing at the INP SB RAS. To increase electrical strength, changes were proposed and implemented in the feedthrough insulator and accelerating electrodes. The height and dimensions of individual ceramic insulators with a corrugated surface were increasing; the gaps in the accelerating gaps of the intermediate electrodes were increased. It was establishing that the changes introduced into the VITA II vacuum-insulated tandem accelerator provide greater reliability compared to previous versions. The required voltage of 1.15 MV was obtaining. The operation mode without high-voltage breakdowns is maintaining, which is important for using the neutron source in therapy and other applications. At present, the VITA II accelerator neutron source has being installed at the Blokhin National Medical Research Center of Oncology in Moscow and is being prepared for testing.

Acknowledgment

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References

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