PRESENT STATUS OF AND PROSPECTS FOR THE DEVELOPMENT OF THE NG-12I NEUTRON GENERATOR FOR NEUTRON THERAPY AND APPLIED RESEARCH

G. G. Voronin,1 A. V. Morozov,1
M. P. Svin’in,1 D. A. Solnyshkov,1
S. V. Kiryushkin,2 É. P. Magda,2
G. V. Mokichev,2 A. I. Saukov,2
and A. L. Semkov2

The NG-12I neutron generator, which accelerates deuterium ions with a 200 kV accelerating voltage and 10 mA current of the atomic-ion beam on target, was developed and built in 1995 at the D. V. Efremov Scientific-Research Institute of Electrophysical Apparatus. Since 1995, it has been used at the Russian Federal Nuclear Center – All-Russian Scientific-Research Institute of Technical Physics as a source of ~14 MeV (D–T) and ~2.5 MeV (D–D) neutrons for investigating the nuclear-physical properties of structural materials and for neutron-activation measurements.

The initial variant of the accelerator was supposed to use a single beam-transport channel, which was separated by an electromagnet positioned at angle of 45° after the accelerator tube and was focused on a 230 mm in diameter rotating titanium-tritium target using a pair of electromagnetic quadrupole lenses [1]. In 1996, scientific-research work in neutron therapy and a program of research on nonuniform radiation protection of thermonuclear reactors were started using the generator. This required substantial modifications in the number and configuration of the transport channels for the accelerated beam and installation of additional target devices. The mass separator with a turn angle of 45° was replaced with an electromagnetic separator, positioned at an angle of 90°, with double focusing, after which three beam-transport channels were formed: the first one (0°) for performing neutron therapy on malignant tumors, the second one (45°) for setting up time-of-flight measurements of neutron spectra, and the third one (90°) for research on protection of thermonuclear reactors and other research. An overall view of the beam-transport channels with the target setups is shown in Fig. 1.

In the third transport channel, a pair of electromagnetic quadrupole lenses focuses the atomic-ion beam, after the mass separator, onto a rotating 90 mm in diameter target. A target setup (Fig. 2) where a vacuum-tight connection of a rotating unit and a stationary case is accomplished with a liquid which a strong magnetic field confines in the gap between the shaft and the stationary cylinder was developed for the generator. The target rotates at a rate of 1000 rpm and is cooled with water flowing in the gap between the substrate and the screen. For a 10 mA beam current the neutron yield is (0.9–1.1)·10^{12} sec^{-1} depending on the target quality.

The main components of the system for the pulsed regime are the deflecting system, the generator of deflecting pulses, the current collector with a diaphragm, and the target. The ion guide is built in such way that a straight beam of ions strikes the current collector, which is cooled with water. Voltage pulses with amplitude 5 kV, duration 20 nsec, and frequency

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1 Federal Unitary State Enterprise, D. V. Efremov Scientific-Research Institute of Electrophysical Apparatus.
2 Russian Federal Nuclear Center – E. I. Zababakhin All-Russia Scientific-Research Institute of Technical Physics.
Fig. 1. Structural layout of the ion guide of the NG-12I neutron generator: 1) analyzing magnet; 2) deflection system; 3) vacuum chamber with a “threading” diaphragm; 4) vacuum lock valve; 5) triplet of quadrupole lenses; 6) beam interrupter; 7–9) target setup.

Fig. 2. Target setup: 1) diaphragm; 2) flange; 3) magnet; 4) magnetic circuit; 5) rotation unit; 6) target; 7) cooling unit.