

UPDATING OF THE “ELECTRON-3M2” ACCELERATOR IN THE LINE FOR RADIATION CURING OF POLYMER COATINGS

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Abstract

More than thirty years ago the «Electron-3M» accelerator was delivered to FSUE “Admiralty Shipyards” to be operated in the line for radiation curing of polymer coatings. In 2008-2009, works on updating the machine were performed to increase its reliability and make much easier its maintenance in the process of operation. After obtaining nominal parameters on the updated accelerator «Electron-3M2», the intensity of bremsstrahlung on the surface of the accelerator shielding was measured; the obtained data confirmed its compliance with corresponding normative documents. Measurements of parameters of the accelerator electron radiation field have demonstrated that the uniformity coefficient of the beam current linear density is 5%, and the symmetry coefficient amounts to 1%. The beam current and accelerating voltage instability during one hour of operation does not exceed 1%. After the updating, the lifetime of the accelerator will be not less than 10 years.

High voltage «Electron-3» accelerators and their modifications manufactured in NII-EFA in 1975-1985 [1, 2, 3] have been widely used in various research and industrial radiation-processing facilities. More than fifteen similar machines have been manufactured including 12 accelerators to be used in the shipbuilding industry. Inspection of these machines performed after the end of the planned 10-year operation period have demonstrated that major components, in particular, high voltage generator, electron source and accelerating structure remained in good working condition. However, a series of units and systems needed replacement because of depreciation and obsolescence.

The «Electron-3M1» accelerator was put into operation in 1977 in the JSC “Admiralty Shipyards”. In 2001-2002, works on its updating were performed. In the process of the updating the following devices and systems were designed, manufactured, adjusted and put into operation:

- scanning device with a bellows branch pipe, which allowed the non-uniformity of the beam current distribution in the irradiation zone to be reduced;
- independent closed water cooling system;
- systems to control the filament current of the electron source and to stabilize the accelerator beam current by using fiber-optics lightguides;
- system for automatic control of the accelerator based on an industrial computer.

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High-vacuum pumps were also replaced with pumps of higher pumping capacity.

To meet the requirements of the new Principal Sanitary Radiation Safety Rules (OSPORB-99), means of radiation monitoring have been replaced and thickness of the radiation shielding has been increased.

In the updated accelerator, there was used an extraction window with a supporting grid made with wedge ribs with a variable inclination angle α (see Fig. 1), which transparency coefficient for the electron beam K is higher than its optical transparency (see Table 1).

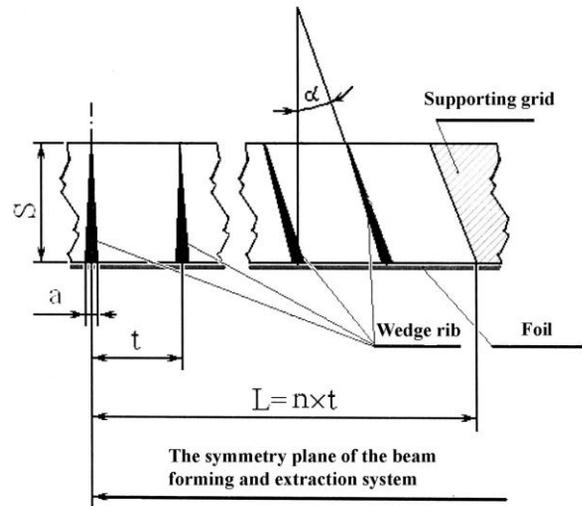


Figure 1: Fragment of the extraction window with the supporting grid (the cross-section along the window long side): “L” is the maximum beam deviation from the plane of symmetry; “S” is the thickness of the supporting grid; “t” is the distance between ribs; “a” is the rib thickness.

Table 1: Measurement of the beam current passed through the extraction window.

Distance from the beam absorber to the diaphragm, mm	Supporting grid	Current recorded by the beam absorber, mA	K
50	Without grid	0.80	0.95
	With grid	0.76	
105	Without grid	0.76	0.93
	With grid	0.71	

K is the transparency coefficient of the supporting grid for electrons; it is found as a ratio of current magnitudes at the beam absorber with and without supporting grid. Measurements were carried out with an accelerating tube beam current of 1 mA and accelerating voltage of 700 kV. The extraction window was covered with a titanium foil of 50 μm thickness. Optical transparency of the supporting grid was 0.86. Beam dimensions at the extraction window diaphragm were 15×940 mm.

The works carried out increased appreciably the reliability of the accelerator and made much more easy maintenance of the machine. However, the irradiator with the film-oil insulation was still used, which long ago had worked out its lifetime and was not subject to repair in the case of its failure.

Therefore, in 2008-2009 works to replace the irradiator of the «Electron-3M1» accelerator installed in the JSC «Admiralty Shipyards» with a gas-insulated irradiator shown in Fig. 2 were performed. Its design is similar to that of the «Electron-10» accelerator [4], differing in larger number of turns in sections of its secondary winding. This allows the available ATO-20 electric generator to be used to supply power to the irradiator.

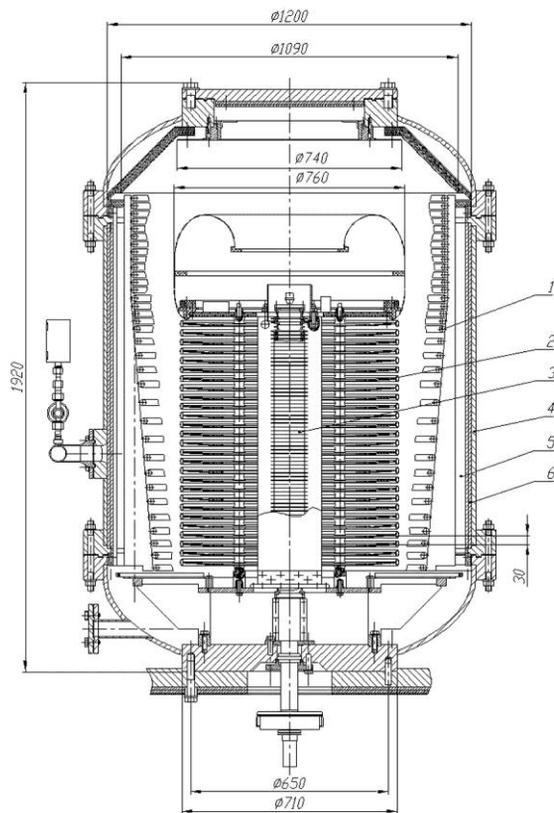


Figure 2: Irradiator with the gas insulation of the «Electron-3M2»: 1 - primary winding, 2 - section of the secondary winding, 3 - accelerating tube, 4 - high-pressure vessel, 5 - core-type magnetic circuit, 6 - lead shielding.

The single-layer primary winding of the irradiator, disk sections of the secondary winding (located coaxially with the primary winding) with connected to it rectified voltage doubling circuits and accelerating tube are placed

inside a metal vessel filled with a pressurized gas. On the inner surface of the vessel, core-type magnetic circuits, which close the magnetic flux created in the primary winding of the irradiator, and the lead shielding against bremsstrahlung are installed.

The irradiator and a site for its maintenance/repair are installed on the chamber of the accelerator radiation shielding (see Fig. 3).

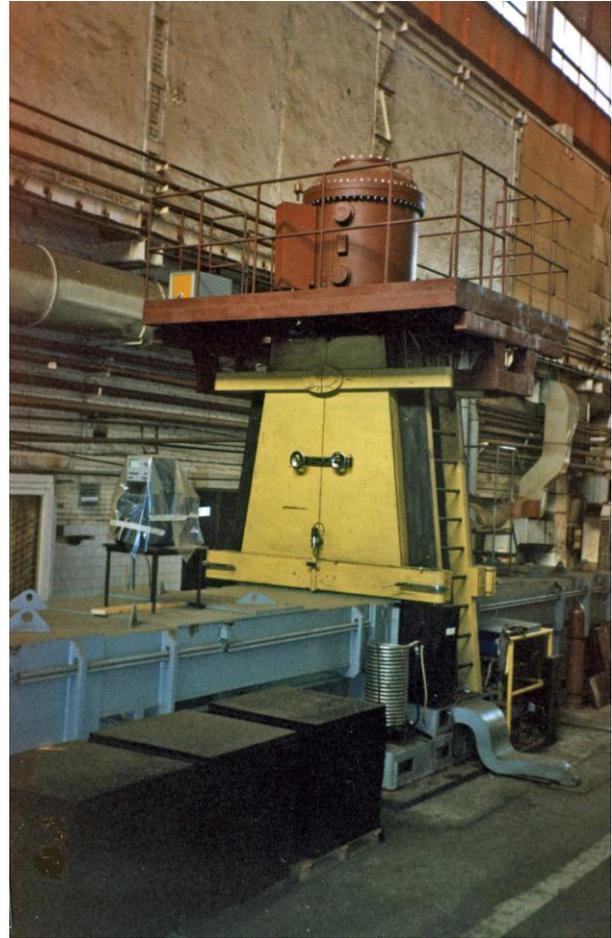


Figure 3: The «Electron-3M2» accelerator in the line for radiation curing of polymer coatings.

When the «Electron-3M2» accelerator with the updated irradiator was put into operation, the following nominal parameters of the electron beam were attained: energy of electrons of 700 keV and beam current of 10 mA. In this case the voltage of the ATO-20 generator was 220 V and the load current amounted to 65A. An increase in the accelerator beam current up to 15 mA will result in the ATO-20 generator voltage and current of 225 V and 80 A, which are also acceptable.

Radiation inspection of the accelerator has been performed and a sanitary-epidemiological certificate has been issued by Interregional Administration №122 of the Federal Medical and Biological Agency of the Russian Federation certifying the compliance of the accelerator with normative documents.

Specialists of the Department of Ionizing Radiation Measurement Department of FSUE «All-Russian D.I.

Mendeleev research Institute for Metrology” measured parameters of the accelerator electron radiation field. Figure 4 shows a graph demonstrating a current distribution at the electron beam probe (Faraday cup) along the accelerator radiation field with a total beam current of 5 mA. At the 70 mm distance between the accelerator foil and the probe and an irradiation field width of 1000 mm, the uniformity coefficient was 5%, and the symmetry coefficient amounted to 1%.

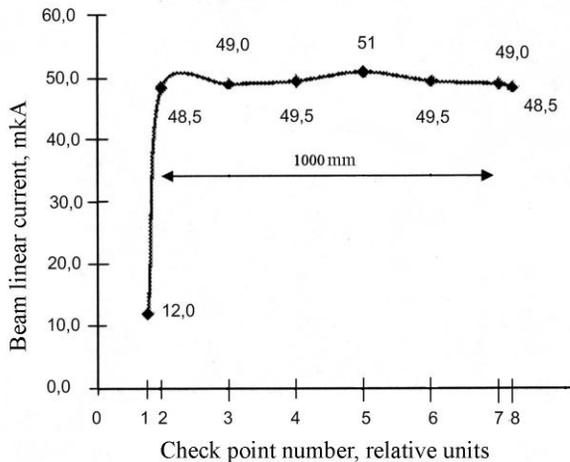


Figure 4: The «Electron-3M2» accelerator. Current distribution of the beam current probe in the irradiation zone.

Measurements carried out in the process of testing the accelerator with the updated irradiator, have also shown that the beam current and accelerating voltage instabilities during one hour did not exceed 1%.

Nowadays, the «Electron-3M2» accelerator is still operated in the line for radiation curing of polymer

coatings in the JSC “Admiralty Shipyards” and ensures the fulfillment of a production program.

The results obtained allow similar updating to be recommended at other enterprises where accelerators of the «Electron-3» series are used. After the updating, the lifetime of these accelerators will be not less than ten years.

REFERENCES

- [1] A.E. Kurbatov, O.B. Ovchinnikov, M.T. Fedotov et al., “Operation experience and possibilities for updating radiation chemical facilities with «Electron» accelerators for production of radiation cured articles of polyethelene”, Proceed of the 3rd All-Union Conference on Applied Charged Particle Accelerators, St. Petersburg, v. 1, p. 74 (1979).
- [2] V.V. Akulov, A.S. Ivanov, V.P. Ovchinnikov et al., “The «Electron-3M1» accelerator and its updating”, Proceed. of the 3rd All-Union Conference on Applied Charged Particle Accelerators, v. 1, p. 81 (1979).
- [3] B.I. Albertinsky, M.P. Svinin, S.G. Tsepakin, “The use of the operation experience of high voltage accelerators to increase their reliability indices”, Proceed of the 4th All-Union Conference on Applied Charged Particle Accelerators. St. Petersburg, v.1, p. 186 (1982).
- [4] M.P. Svinin, “Status of high voltage accelerators development in the D.V. Efremov Institute (NIEFA)”, Proceed of the 10th International Conference on Applied Charged Particle Accelerators in Medicine and Industry (ICAA’01), St. Petersburg, p. 15 (2001).