# LINEAR INDUCTION ACCELERATORS FOR INDUSTRIAL APPLICATIONS

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A technology of Linear Induction Accelerators (LIA) is developed in Research Institute of Electrophysical Apparatus (NIIEFA) during more than 25 years. The first LIA - LIA-3000 started to work in 1967 in Joint Institute for Nuclear Research (JINR), Dubna.

This accelerator was constructed for researches of collective acceleration of heavy ions by electron rings. It produced an electron beam with energy up to 3 MeV, current up to 200 A and pulse duration about 500 ns. The second accelerator LIA-5000 was performed for the same purposes in Theoretical and Experimental Physics Institute (Moscow). At this accelerator the following parameters of the electron beam were achieved: 5 MeV, 2 KA, 50 ns. Than the first section of LIA-30/250 was adjusted in JINR (250 A, 3 MeV, 500 ns).

The experience received during the designing and adjusting of these accelerators was used further in the works for creation of industrial LIA. Two types of accelerators were designed: powerfull long pulse LIA for power-consuming processes and compact short pulse LIA - the source of brake radiation (X-ray source). In the first case it is supposed to realise unique potential posibilities of LIA to produce powerfull electron beams for high energy technological processes. In the second case it is supposed to create X-ray apparatus on the base of two sections of LIA induction system with total voltage on the tube up to 1 MeV.

The industrial LIA of NIIEFA as earlier constructed LIA for scientific researches have a small section induction system and pulse generators with hydrogen thyratrones workings without heighten transformers. The cores of the long pulse accelerators LIA-1.25-200 are performed from 50 NiFe permalloy tape 10 mkm width, and short pulse accelerator LIA-1-5 is performed from nickel-zinc ferrites. The injector of the accelerator LIA-1.25-200 looks like a diod with 120 mm diameter oxide thermocathode and 100 mm curvature radius, works with perveance about $2 \times 10^{-6} AV^{-3/2}$. Electron-optical system of injector and its general view are shown in fig. 1 and 2. Maximum cathode voltage reaches 400 KV and output beam current about 600 A.

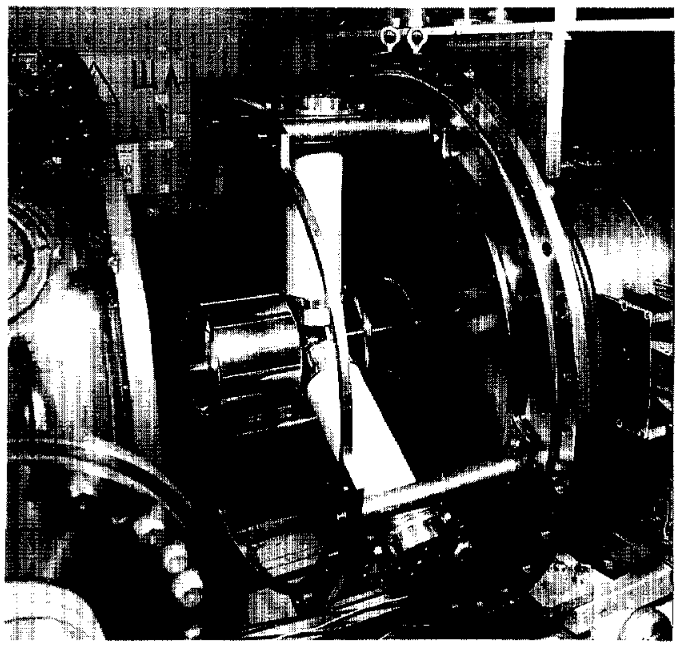

Fig. 1. General view of the injector

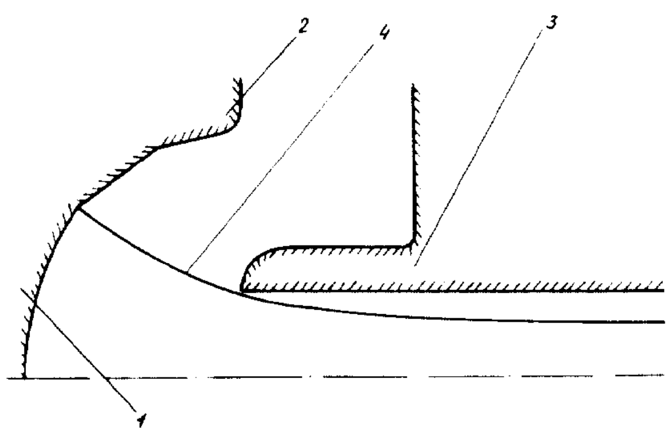


Fig. 2. Electronic-optical system of the electron gun: 1 - cathode; 2 - focusing electrode; 3 - anode; 4 - beam envelope

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The injector induction system is supplied from a set of pulse generators with pulse hydrogen thyratrones. The stable work in the regimes close to the industrial exploatation was demonstrated on the injector and first acceleration section for two combinations of the parameters:

| | | |
|---|---|---|
| voltage on the injector, KV | - 400; | 200 |
| beam current, A | - 600; | 250 |
| pulse length, ns | - 250; | 500 |
| pulse repetition rate, 1/s | - 400; | 1000 |

Taking into account that LIA is built usually from the succession of the same type modules, on the base of received parameters two variants of the accelerator performing can be suggested:

| | | |
|---|---|---|
| acceleration rate, KV/m | - 100; | 200 |
| rate of beam power collection, KW/MeV | - 100; | 50 |

As the accelerator turnes out rather bulky, actual task becomes to reduce energy expenses on beam transportation, that is reached first of all by improving its quality. The scientific researches of beam parameters at the output of the first acceleration section were carried out. The emittance measurement apparature was performed on the base of widely spreaded scheme: chink aperture, fluorescent screens, mirrors system and registration system. In our case the registration system has at the output the electron-optical transformer with electron "shutter", that makes possible to measure beam emittance in the separate time layer of the current pulse. Transverse phase beam volume versus the part of the current included in it for the beam current about 600 A in various parts of the pulse and integraly for all pulse (without strobing) are shown in fig. 3. The received experimental and calculated data allow the conclusion that for transportation the beam in the 100 mm diameter channel the transverse magnetic field with induction about 0.7 T is enough.

The further works at this accelerator are concentrated on the creation of the accelerator for a smoke clean-up from sulphur and nitrogen oxydes with average power about 500 KW and the total efficiency net-beam not less than 40%.

Compact LIA is performed on the base of hydrogen thyratron with the magnetic compressor (the scheme in fig. 4). In the magnetic compressor the pulse duration is

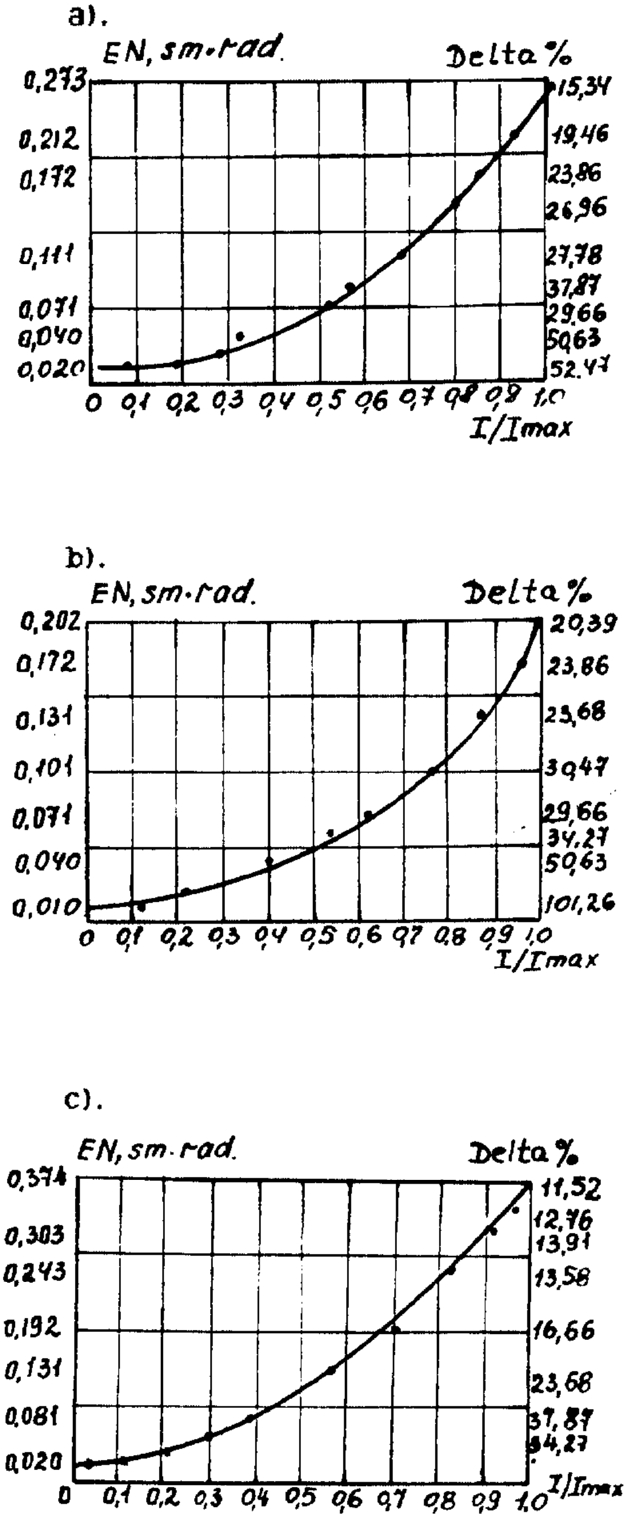


Fig. 3. Dependence of transverse phase beam volume upon the part of the current included in it:
a) $t=0.25\ T_p$
b) $t=0.5\ T_p$
c) $t=0.75\ T_p$

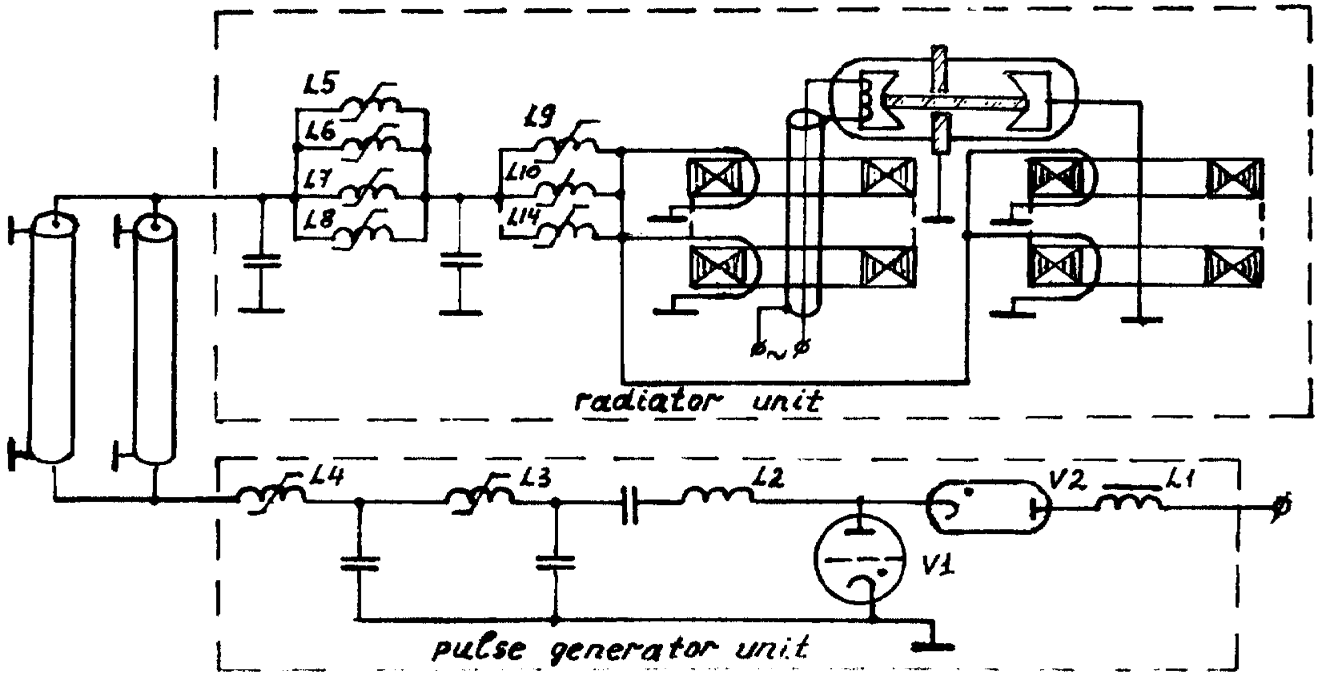

Fig. 4. Scheme of compact LIA with a magnetic compressor

reduced more than 100 times up to about 20 ns. During designing the main problem was to transmit such a short pulse into load. The load of two ferrit cell sections was pulse metal-glass X-ray tube with the thermocathode. The section, X-ray tube and two last compression units are mounted in the radiator block with dimensions 800x460x260 mm. The rest of equipment is mounted in the block with dimensions 1000x600x1200 mm connected with the radiator by 10 m length cables. The accelerator control is performed from carried out control panel. In recent time the voltage about 600 kV with average power about 3 kW and pulse frequency 5 kHz is obtained on the X-ray tube and the works on construction modernization are carried out for the purpose of receiving the voltages up to 1 MV and increasing the stability of the output pulse parameters with the repetition rate more than 3 kHz.