
INDUSTRIAL ELECTRON ACCELERATOR
ILU-6

ILU 8

# THE INDUSTRIAL ELECTRON ACCELERATOR ILU-6

## 2.5 MeV, 20 kW

(Technical manual)


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A large scientific centre widely known both in the USSR and abroad, the Institute of Nuclear Physics of the USSR Academy of Sciences (INP) conducts fundamental research on high energy physics, plasma physics and controlled thermo-nuclear fusion coupled with applied research on creation and usage of synchrotron radiation sources and industrial electron accelerators.

The present specification describes one of such accelerators for industrial irradiation processing, namely, the ILU-6 accelerator.

## 1. INTRODUCTION

The electron accelerator ILU-6 is a basic model in the family of ILU type accelerators. It is designed at the Novosibirsk Institute of Nuclear Physics both for the development of new technologies and for the use in industrial technological processes. Main accelerator parameters are the following: electron energy $1 \div 2.5$ MeV, beam power is no less than 20 kW within the whole energy range (in the middle part of the range up to 40 kW). The ILU-6 accelerator is simple in its design, has a high reliability and maintainability; it is easily serviced and simply controlled. Computer control is also envisaged.

## 2. DESIGN AND OPERATIONAL MODE

The ILU-6 accelerator is a single-resonator linear accelerator operating in the pulsed regime. The copper toroidal cavity *2* (see Fig. 1), which is made of two separate halves—the upper half partly entering the lower one—is mounted inside the stainless steel vacuum tank *1*. On the cylinder-shaped parts of resonator (protruding into the resonator cavity) the electrodes are installed for shaping the accelerating gap (about 10 cm). The electron injector *5* consists of a grid, made in the upper electrode, and a cathode node installed at an insulator on this electrode. The lower electrode in combination with the injector forms a triode accelerating system. The accelerated beam current is controlled by changing the value of tne positive bias voltage on the cathode with respect to the grid.

The lower half of the resonator is installed on the insulators and supplied with a bias voltage of $-6 \div -8$ kV through tne coil *3* to suppress the high frequency discharge.

The r.f. current of the resonator is shorted out by a coaxial line, which is formed by the side surfaces of the resonator halves and loaded on the volume between the lower half of the resonator and the bottom of the vacuum tank.

Under the lower electrode there is a focusing lens forming the accelerated beam in the accelerator channel and in the extraction device *6*.

The high-frequency generator is placed directly on the vacuum tank of the resonator and it is connected to the resonator by means of the inductive loop. This self-excited generator using a grounded grid circuit operates at a coupling frequency close to the eigen-frequency of the resonator ($115 \div 120$ MHz). The feedback regime is adjusted by means of a moving plate of the capacitor *11*, which connects the anode and the cathode, and of the cathode stub *12* having a moving shorting-out contact (being moved by means of a service-driver). The anode circuit of the generator is preliminarily adjusted by varying the capacitance of the capacitor *10* and by varying the position of the base *9* of the coupling loop.

To stabilize the high-frequency pulse leading edge while powering the tube anode, the generator is preexcited by supplying the anode with the $0.9 \div 1.5$ kV constant voltage.

The vacuum in the tank is maintained by four magnetodischarge pumps *4*, each of 250 l/s capacity, placed in pairs on the upper and lower flanges of the tank.

The inductive loop *7* is mounted on the upper flange of the tank. Its signal, proportional to the resonator voltage, is used to measure the energy of accelerated electrons.

The extraction device is connected, through a sliding valve, to the lower flange of the tank.

The following types of beam extraction devices are designed for the most widely used industrial irradiation processes:

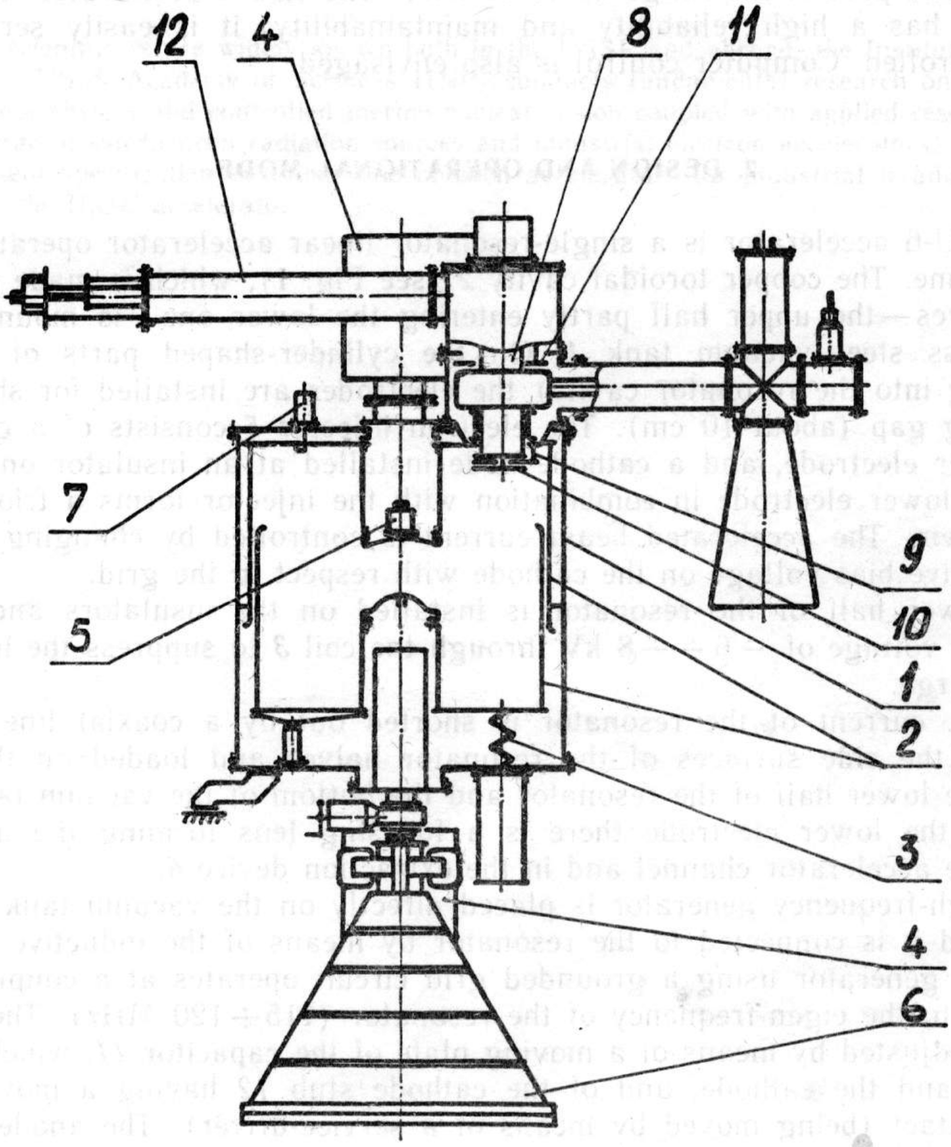


*Fig. 1.* The general view of the accelerator:

*1*—vacuum tank; *2*—resonator; *3*—inductive coil of the bias at the lower half of the resonator; *4*—magneto-discharge pumps; *5*—electron injector; *6*—extraction device; *7*—measuring loop; *8*—generator tube; *9*—base of the coupling loop; *10*—vacuum capacitor of the coupling loop; *11*—movable plate of the feedback capacitor; *12*—cathode stub; *13*—focusing lens.

1. A device with linear scanning of the beam along the extraction window for single-sided irradiation of flat or band-like products («linear scanning» shown in Fig. 1). The beam is scanned along the entire useful length of the extraction window during each pulse.

2. A device for three-sided irradiation of round products at an angle of 120° («quasiring scanning», Fig. 2).

3. A device for double-sided irradiation of long products at two levels («fir-like scanning», Fig. 3).

Some other types of extraction devices can be designed by special request of a customer.

## 3. PULSE VOLTAGE SOURCE

The pulse voltage source supplying the tube anode of the r.f .generator operates directly on the 380/220 V three-phase mains (Fig. 4).

The thyristor rectifier G1 is connected to the inductive storage L1. During the time of shorting of tne inductive storage by the switches N1 and N2 the storage current increases. After the switches N3 and N4 are on the switches N1 and N2 become off, the current ceases to accumulate and the full energy stored in the inductive storage L1 is transferred to the capacitors of the forming line (C13 $\div$ C28, L2 and L3) charging them up to a voltage, determined by the stored energy. After the charge stops the switches N5 and N6 open and tney connect the pulse transformer T2 to the forming line. On the load of the transformer secondary winding (on the tube anode of the r.f. generator) the pulse is formed whose parameters are: voltage up to 30 kV, duration 0.4 $\div$ 0.7 ms at a load current of up to 150 A.

The trailing edge of the pulse is formed by means of the switch N7 which shorts the primary winding of the pulse transformer.

The pulse repetition frequency can be changed step-by-step from 2 to 50 Hz (to 100 Hz when the pulse amplitudes are low).

The constant voltage, necessary for the r.f. generator preexcitation, is applied to the tube anode from the source G3 through the secondary winding of the pulse transformer. It is also used to demagnetize the transformer core after a high-voltage pulse.

The power supply system of the accelerator includes the source of pulse voltage, the source of preexcitation power supply and the source of bias voltage to the lower half of the resonator. This system is assembled in three cabinets placed closely to each other in the power supply room.

## 4. CONTROL

The accelerator is controlled by number of controls and electronic units placed on the panels of the control console or built-in into it.

The arrangement of the buttons on the control console corresponds to the required sequence of switching the accelerator systems on. Above the buttons there are the lamps illuminating when the appropriate system is on.

The interlock system is designed to avoid an emergency when the order of switching on fails.The state of the interlock system shows the signal lights on the panel of the blocking and signal control unit.

The electron energy is controlled by means of a potentiometer varying the time of current accumulation in the inductive storage of the high-voltage pulse source (modulator) and placed on the panel of the modulator control unit. On this panel there is also a pulse frequency switch. A built-in digital meter is used to measure

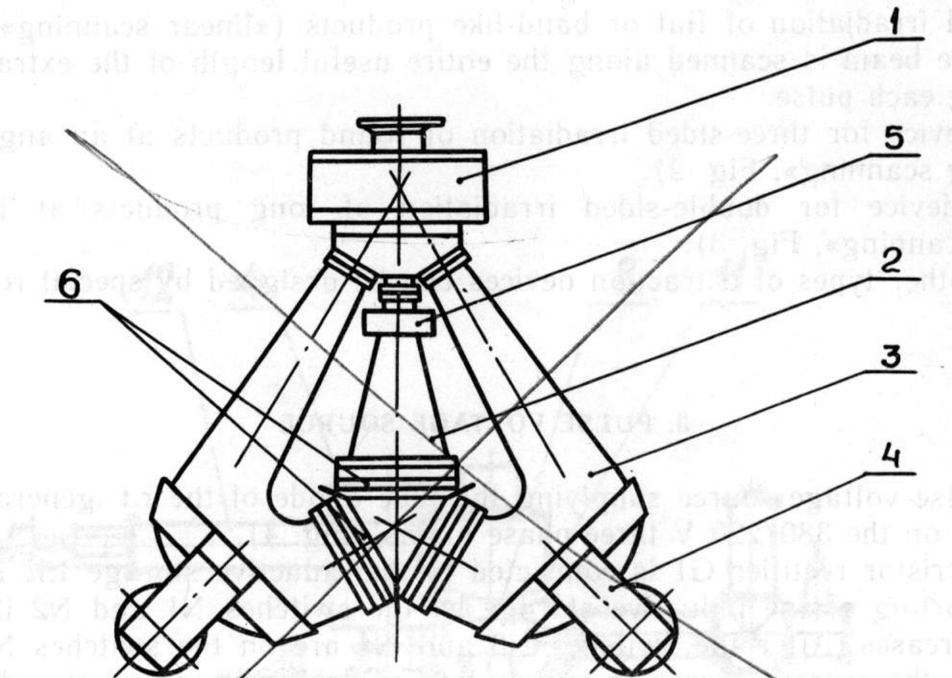


*Fig. 2.* «Quasiring scanning» type extraction device:
*1* — distributing magnet; *2* — middle channel; *3* — side channels; *4* — bending magnets; *5* — scanning magnet; *6* — extraction windows.

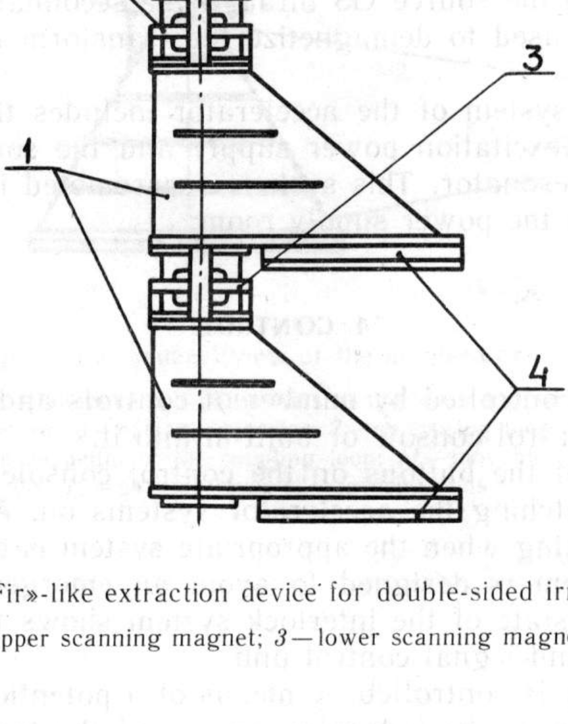


*Fig. 3.* «Fir»-like extraction device for double-sided irradiation:
*1* — vacuum chamber; *2* — upper scanning magnet; *3* — lower scanning magnet; *4* — extraction windows.

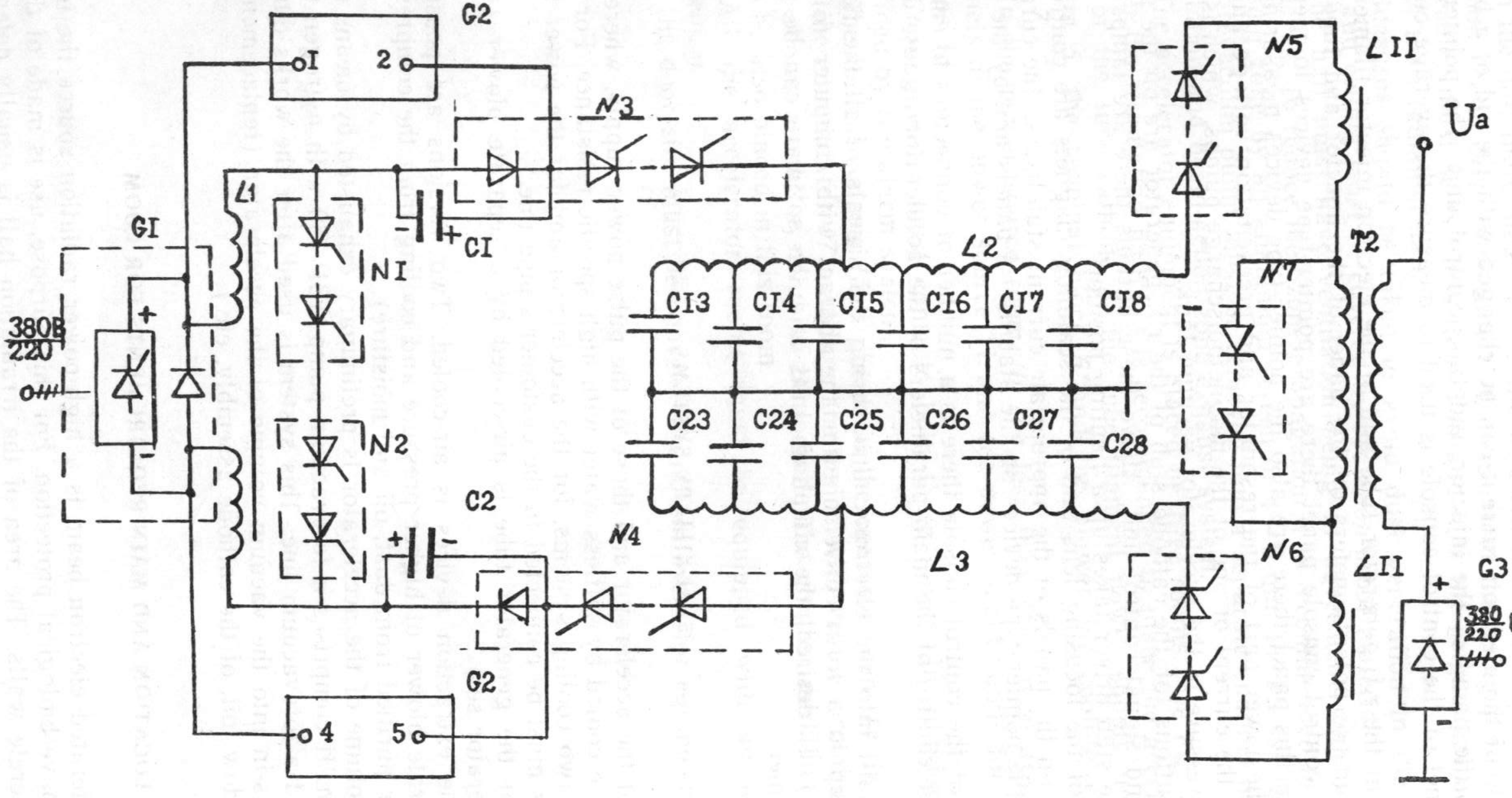


*Fig. 4.* Simplified block-diagram of the pulse voltage source:

G1 — rectifier; L1 — inductive storage; G2 — recharge circuit; C1 and C2 — recharge capacitors; N1 ÷ N7 — thyristor switches; C13 ÷ C28, L2, L3 — forming line; T2 — pulse transformer; G3 — preexcitation voltage source.

the electron energy and some other parameters of accelerator systems. A choice of the parameter being measured is made by a button switch placed on the panel of the digital meter.

The magnitude of the electron current can be changed with the aid of a button switch placed on the panel of the injector and tube control unit. The pointer-type device on the panel of the control console is used to measure the average current of beam.

The currents of the r.f. generator tube and of tne electron injector filaments is controlled by means of potentiometers on tne panel of the injector and tube control unit. On the control console panel there are pointer-type devices to measure these currents. On this panel there are also the pointer-type devices measuring the bias voltage at the lower part of tne resonator and preexcitation voltage and the device measuring the current of one of the magnetodischarge pumps, which is proportional to the pressure in the accelerator vacuum tank.

The control buttons for the cathode stub of the r.f. generator are on the panel of the blocking and signal control unit. Above these buttons there are lamps illuminating when the stub driver takes up a limiting position.

The currents of the focusing lens and of the scanning magnets are controlled by potentiometers on the panels of the appropriate current stabilisers. The currents are measured by the pointer-type devices on the stabiliser's panels and by the digital meter.

On the panel of the control console there is a number of connectors to employ an oscillograph for control of the main parameters of the accelerator in case of its adjustment.

The circuits built into the electronic units bring the signals of all the necessary parameters up to a form convenient for the contact with computer (of the CAMAC standard). If desired, the coupling units and the software can be delivered to the customer.

## 5. AUXILIARY SYSTEMS

All the units of the accelerator and those of the pulse power supply, where the heat is released, are cooled by saltless water with high specific resistance. For this purpose there are two cooling systems, for the accelerator and for the power supply. These systems must be connected to the customer's pipe line.

The cathode of the generator tube is air-cooled by a separate blower (delivered in tne accelerator set).

The foil of the extraction devices is air-cooled. Two versions are possible: cooling by a separate blower of higher pressure and cooling from the compressed air line (by the air purified from dust, oil and moisture).

The vacuum volume of the accelerator is preliminary exhausted by means of a forevacuum system. It comprises a forevacuum pump ABP-150 with nytrogen trap for oil vapours and a forevacuum line. This system is used after the works during which the air leaks-in into the vacuum volume of the accelerator (replacement of the extraction window foil, of the cathode assembly, etc.).

## 6. LOCATION AND MAIN REQUIREMENTS FOR ROOM

Since the accelerated electron beam is a high-power radiation source the irradiation hall must have biological protection. For this purpose, use is made of thick (about 1.5 m) concrete walls. The area of the irradiation hall is usually determined by technological requirements. To locate the accelerator itself a relatively small area is required (about 3×4 m).

We find it most convenient to place the accelerator on a steel entresole with metallic floor, at height of 2.5—3 m above the hall floor.

In the hall there must be a crane of 2 ton load capacity with a slow motion of the hook (hand drive is possible). The rise from the fixing plane of the accelerator (entresole) must be not less than 3 m and it is the height that determines the height of the irradiation hall.

Measures should be taken to avoid dust generation in the hall. The walls, floor and ceiling must be covered by radiation-proof material.

The hall must have ventilation being in agreement with tne local sanitary standards. To reduce the ozone propagation it is recommended to confine the beam damping zone by an aluminium screen of 4—5 mm thickness. The exhaust gas of the forevacuum pump must be removed into a separate channel not connected with ventilation and beam-action zone exhaust system.

The accelerator equipment is placed in three rooms (see Fig. 5).

In the irradiation hall *1* it is recommended to place the accelerator *2*, the blower of the tube cathode *3*, the tube filament power supply unit *4*, forevacuum system *5*, the terminal block *6* and the blower for cooling extraction window foils *7*.

In the power source room *10* (no less than 3×5 m in area) there are three cabinets of the power source 11 and the power supply units for magnetodischarge pumps *13*.

Cooling water must come to both these rooms. In addition these should be provided by fire-alarm system.

The control console *15* is placed in the operator room *14*. In this room there is also the commutator *17* switching the mains with visible circuit disconnection. This unit allows all the systems to be locked. The control desk for technological line may be also placed in this room.

All the accelerator rooms must be equipped with an intercommunication system.

The door size must be convenient and sufficient for equipment transportation.

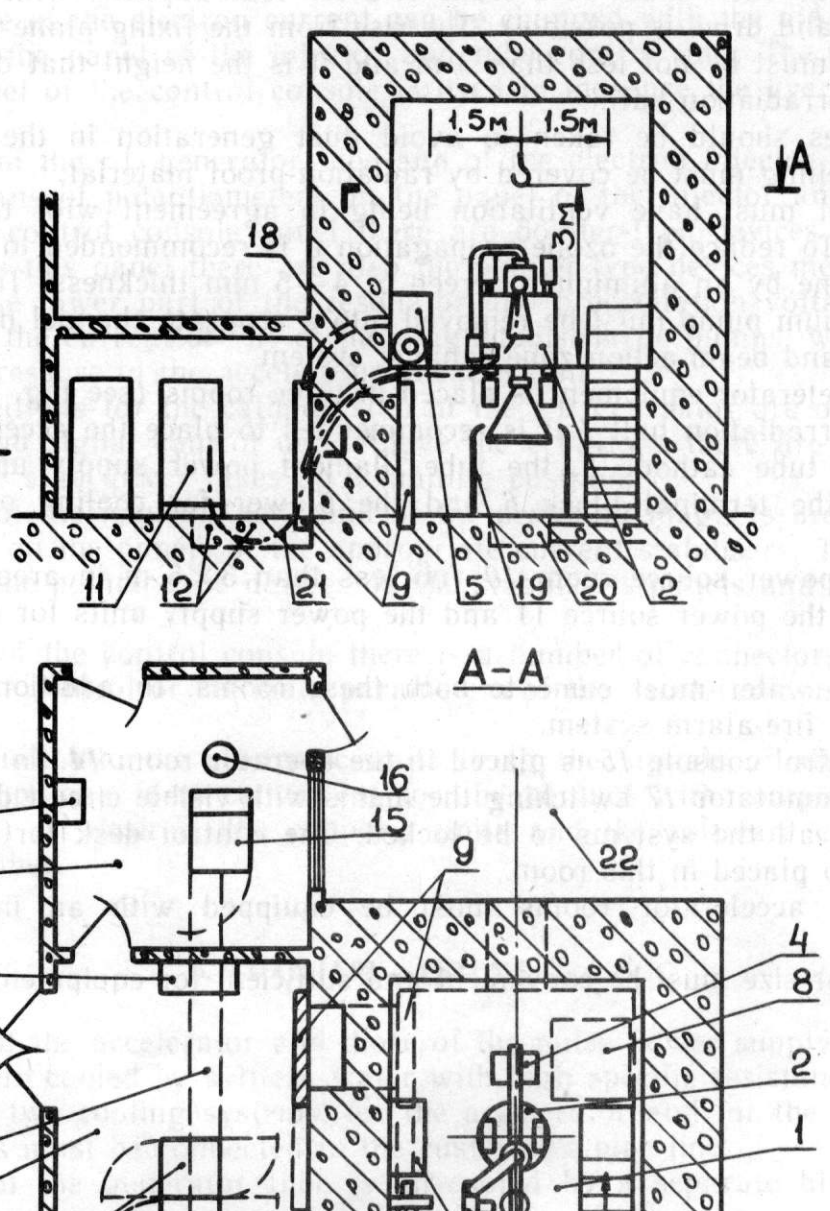


*Fig. 5.* The accelerator equipment location (version):

*1* — irradiation hall; *2* — accelerator; *3* — blower for cooling the r.f. generator tube cathode; *4* — tube filament power supply unit; *5* — forevacuum pump; *6* — terminal block; *7* — blower for cooling the extraction window foils; *8* — window in the entresole; *9* — irradiation hall door; *10* — power source room; *11* — pulse voltage source; *12* — cable channels; *13* — power supply units for the magnetodischarge pumps; *14* — operator room; *15* — control console; *16* — operator's chair; *17* — commutator for locking all the accelerator systems; *18* — input cable channel for irradiation hall; *19* — screen confining the beam damping zone; *20* — hollow for beam-action zone exhaust system; *21* — high-voltage cable channel; *22* — technological equipment location.

## 7. MAIN PECULIARITIES OF ACCELERATOR MAINTENANCE

In comparison with the widely used high-voltage accelerators the accelerator ILU-6 has a number of peculiarities in its construction and operation.

The major peculiarity is that none of the accelerator units have a potential relative to the housing, which is comparable with the accelerating voltage, i. e. these units do not require high-voltage insulation. The highest voltage is the pulse voltage of up to 30 kV which supplies the tube anode.

Owing to this,there is no necessity to apply complex units, which fail at breakdowns (accelerating tube, rectifying sections and so on). The insulating gas in the vessels under pressure is not required either. Consequently, it is very difficult to destroy the basic assemblies. Even if considerable vacuum deterioration occurs (by personnel's error) the accelerator will be ready to operate after a proper cleaning and training.

The units of limited lifetime are, as a rule, commercial products or those having simple design and cheap in manufacturing. This enables one to repair the accelerator units under the conditions of any industrial plant.

Using the principle of r.f. acceleration, we have the relatively simple design of the accelerator, small overall dimensions and weight. Therefore, the irradiation hall may be smaller in dimensions as compared to the hall necessary for a high-voltage accelerator.

The possibilities and the production rate of an industrial irradiation technological line are determined by the electron energy, beam power and the efficiency of beam utilization.

The average power of the beam generated by a linear accelerator is determined by the power produced by a r.f. generator. The average r.f. power supplied by the ILU-6 generator tube ГИ-50А at matched load is 50 kW (with the pulse power of 2 MW). At 2 MV on the resonator gap and duty factor 40 the losses in the ILU-6 resonator are 12 kW. Hence, the beam power can reach 38 kW at an electron energy of 2 MeV. If the accelerator operates in a wide range of energies and beam currents, the tube load varies considerably. Consequently, the r.f. power released by the tube to the load is lower than a maximum one within the operating range and achieves its maximum value only in a comparatively narrow, middle part of the range. Therefore, in the $1 \div 2.5$ MeV range, at the end points the beam power is 20 kW, while in the middle part ($1.7 \div 1.9$ MeV) it can reach 40 kW.

For technological processes calling for a narrow range of energies tne beam power can achieve $35 \div 40$ kW,depending on the average energy of this range, through a proper adjustment of the accelerator.

The required electron energy is determined by the thickness and shape of the product to be irradiated. Irradiation of the products of complex or round shape can be successful at lower energy if the shape of the irradiation zone corresponds to the shape of the product to be irradiated. In case of three-sided irradiation of round products the required energy is more than twice lower than that required for single-sided irradiation of the same product. For the case of plane multilayer products, similar results can be obtained using double-sided irradiation.

The pulse nature of the ILU-6 beam enables one to direct it into different channels of the extraction device without losses in the average beam power. Therefore, the extraction devices are capable of forming the irradiation zone in accordance with the shape of the products being irradiated. The efficiency of beam utilization increases also due to a shortening of the electron path in the air.

These peculiarities of ILU-6 allow in some cases the same production rates to be achieved when performing the technological processes calling for as high electron energy as $5 \div 6$ MeV at a beam power from 50 to 60 kW in case of the conventional single-sided irradiation.

## 8. MAIN PARAMETERS

### 8.1. Working Parameters

| | | |
|---|---|---|
| 8.1.1. | Electron energy | $1.0 \div 2.5$ MeV. |
| 8.1.2. | Smooth control of energy in the whole range. | |
| 8.1.3. | Beam power: | |
| | in the whole energy range | no less than 20 kW, |
| | in the middle part of the range | up to 40 kW, |
| 8.1.4. | Smooth variation of power from 0 to a maximum value (through varying the beam current and pulse repetition frequency). | |
| 8.1.5. | Energy instability | $\pm 5\%$. |
| 8.1.6. | Instability of the beam current | $\pm 5\%$. |
| 8.1.7. | Pulse duration | $0.4 \div 0.7$ ms. |
| 8.1.8. | Pulse repetition frequency: | |
| | in the whole energy range | $2 \div 50$ Hz, |
| | at energies up to 1.1 MeV | $2 \div 100$ Hz. |
| 8.1.9. | The time necessary for injector to attain the rated operating conditions (cathode heating) | no more than 90 s. |
| 8.1.10. | The time necessary to attain the rated operating regime after switching the modulator | no more than 1 s. |

*NOTE*. At some breakdowns in tne cavity the next pulse is omitted and the accelerator attains the rated operating regime without switching off.

### 8.2. Dimensions

| | | |
|---|---|---|
| 8.2.1. | Accelerator: | |
| | A. maximum height from the base plane | 1880 mm, |
| | B. maximum length (including the protruding parts of the r.f. generator) | 2950 mm, |
| | C. maximum width (the flanges of the vacuum tank) | 1210 mm, |
| | D. distance from the fixing plane to the extraction window of the «Linear scanning» type extraction device | 1280 mm, |
| | E. distance from the fixing plane to the centre of the «Quasiring scanning» type extraction device action zone | 1110 mm. |
| 8.2.2. | Pulse power supply: three cabinets, each of $950 \times 1000 \times 2060$ (height) mm, placed closely to each other | $1000 \times 3850 \times 2060$ mm. |
| 8.2.3. | Control console (including the demountable operator's desk at face side) | 1310 (950) $\times 1000 \times 2060$ mm. |
| 8.2.4. | Power supply unit for magnetodischarge pump | $530 \times 520 \times 318$ mm. |

*NOTE*. The accelerator set includes 4 power supply units for pumps.

### 8.3. Weights

| | | |
|---|---|---|
| 8.3.1. | Accelerator (including vacuum tank with resonator, r.f. generator and four magnetodischarge pumps) | 2200 kg, |
| 8.3.2. | «Linear scanning» type extraction device | 150 kg, |
| 8.3.3. | «Quasiring scanning» type extraction device | 250 kg, |
| 8.3.4. | Pulse power supply: | |
| | cabinet 2 | 1000 kg, |
| | cabinet 3 | 2460 kg, |
| | cabinet 4 | 1140 kg. |
| 8.3.5. | Control console (cabinet 1) | 480 kg. |
| 8.3.6. | Power supply unit for tne tube filament | 200 kg. |

8.3.7. Accessories:

A. power supply unit for magnetodischarge pump 72 kg,

B. ABP-150 type forevacuum pump 300 kg,

C. system for blowing the cathode of the generator tube 60 kg.

## 9. FACILITY REQUIREMENTS

### 9.1. Mains

9.1.1. Voltage — 380/220 V ± 10%.

*NOTE.* If desired, the accelerator may be powered at the other voltage. At a mains voltage below 380 V it is necessary to use a separate transformer whose power is not less than 180 kVA with 380 V secondary voltage. In the other cases it is recommended to use a separate transformer with these parameters.

9.1.2. Number of phases — 3 with zero.

9.1.3. Frequency — 50 Hz.

*NOTE.* If desired, 60 Hz frequency may be envisaged.

9.1.4. Consumed power — up to 120 kW.

### 9.2. Cooling Water

9.2.1. Acidity value — PH=6÷8.

9.2.2. Carbonate hardness — no more than 2.5÷3 mg·equiv/l.

9.2.3. Specific resistance — no more than 100 Ohm·m.

9.2.4. Input pressure — 392 kPa (4 atm) ÷ 588 kPa (6 atm).

9.2.5. Output pressure — no more than 98 kPa (1 atm).

9.2.6. Input temperature — no more than +30°C.

*NOTE.* Water temperature must be no less than dew point in the accelerator room.

9.2.7. Consumption by the accelerator — no less than 60 l/min.

9.2.8. Consumption by the power supply — no less than 17 l/min.

*NOTE.* The cooling line must be made of stainless steel; bronze valves may be applied.

### 9.3. Air Cooling for Foils
### (In case of cooling from compressed air line).

9.3.1. No dust, oil and water.

9.3.2. Input pressure — 294 kPa (3 atm) ÷ 588 kPa (6 atm).

9.3.3. Input temperature — no more than 30°C.

9.3.4. Consumption — no less than 3.5 $m^3$/min.

### 9.4. Environment

9.4.1. Temperature — +10÷+35°C.

9.4.2. Humidity — no more than 90% at a temperature of +25°C.

### 9.5. Ventilation

9.5.1. General ventilation with a capacity according to the customer's sanitary standards.

9.5.2. It is recommended (to reduce ozone propagation) to confine the beam damping zone by an aluminium screen of 4÷5 mm thickness. The air must be exhaust from this zone by pump with a capacity no less, than 17 $m^3$/min.

*NOTES.* A. The air lines of the ventilation system must be made of aluminium.

B. The exhaust gas of the forevacuum pump must be removed to a separate channel not connected to the ventilation and ozone exhaust system.

## 9.6. Hoist Crane

There must be a Hoist crane in tne irradiation hall with the slow rise of the hook (hand drive is possible), which allows one to serve a strip 1.5 m wide each side from the axis lying above the centre of the accelerator. The strip length should be no less than 4 m.

9.6.1. Weight-carrying capacity 2 t.

9.6.2. Height of the hook from the fixing plane of the accelerator — no less than 3 m.

## 10. TECHNICAL DOCUMENTATION

Just upon signing the contract the buyer is supplied with the set of documentation nessesary for preparing the site for accelerator. The set comprises the main electric circuits and assembly drawings for the accelerator units, technical conditions on the accelerator, its technical description and instruction on the accelerator assembly and its maintenance.

In addition, the delivery of the accelerator envisages attachement of the extra set of documentation comprising the second set of circits, descriptions and instructions providing technical details for the assembly and adjustment both for the accelerator on the whole and its individual units.

If desired the buyer can order additional documentation on manufacturing the details and units of the accelerator.

## 11. ACCESSORIES, TOOLS, SPARE PARTS

### 11.1. Accessories

11.1.1. Transport support for the cavity.
11.1.2. Transport and mounting support for the generator.
11.1.3. Set of cables to connect some of the accelerator components.
11.1.4. Terminal block for the commutation of the cables of the systems being in the protected room.
11.1.5. Cooling fan of the generator tube cathode.
11.1.6. Forevacuum pump ABP-150 as a unit of the pipe line of the forevacuum pumping system with the nitrogen trap.
11.1.7. Press to manufacture indium seals.
11.1.8. Device to expand the pipes of the cooling system.
11.1.9. Unit to suspend the lower part of the resonator.
11.1.10. Energy calibrator.

Additional accessories (if required).

11.1.11. Cooling fan for the extraction window foil with a capacity of no less than 3.5 $m^3$/min and with an output pressure of no less than 2.94 kPa (0.03 atm).
11.1.12. Runaway unit. This unit is designed to ensure a smooth change in the pulse repetition frequency from zero to the established value as a function of the external signal (the velocity of shifting the material being irradiated or another technological parameter).

### 11.2. Servise Tools

A set of service tools is delivered according to the contract.

### 11.3. Spare parts

| | | |
|---|---|---|
| 11.3.1. | An electron gun as a unit | 1 |
| 11.3.2. | Cathode node | 5 |
| 11.3.3. | Generator tube ГИ50-А | 5 |
| 11.3.4. | Ti foil (50 μm, 120 mm width) | 1 kg |
| 11.3.5. | Seal | 2 (for each of the extraction windows) |
| 11.3.6. | Indium | 0.5 kg |

The range of additional spare parts and their number could be varied by mutual agreement.

## 12. SITE PREPARATION AND PERSONNEL TRAINING

The customer will provide the building including electro- and hydrocommunications, air lines for foil cooling, ventilation and ozone pumping down systems and dosimetric control, as well as the accelerator staff.

The INP carries out training of the customer's staff at the producer's stands.

## 13. INSTALLATION

To ensure high quality of essembly the INP provides technical supervision for these works at the customer's site.

The INP specialists carry out the start-up and adjustment works on the customer's site with attraction of the future accelerator staff to make it acquainted with the assembly and adjustment procedures.

## 14. TEST, TRAINING, ACCEPTANCE

Before the dispatching to the customer the accelerator is tested on the producer's stand for 8 hours at quoted beam power. The INP welcomes the customer to participate in these tests.

The starting and adjustment program includes the accelerator training after its assembly at the customer's site by the producer specialists to attain the rated operating conditions.

Upon completion of the assembiy, adjustment and training of the accelerator at the customer's site the acceptance test will be performed. The test consists of a 8-hour period at the regimes by the customer's desire but being not higher than the rated regimes.

## 15. CHANGES AND WARRANTY

The equipment and components supplied by the INP are warranted for one (1) year. During the warranty period, wheh parts are damaged under normal operation, their replacement will be supplied by the INP free of charge. The warranty period starts on the day of acceptance by the purchaser or no more than 6 months after delivery from the INP.

The producer leaves the right to himself to incorporate without notice any changes and improvements it may consider necessary.

## 16. SERVICE

The producer will provide the «engineering» and «know-how» services:

16.1. Data required for the design of room, radiation protection, hardware systems (electric energy, water, ventilation air).

16.2. Engineering specifications for the repair of the nodes and components the purchaser is able to manufacture with its own efforts.

16.3. Training of the customer's personnel (hotel accomodation and per diem expenses are covered by the customer).

16.4. The start-up works at the customer's site by the INP specialists.

16.5. Preparation of the software for a computer-controlled acclerator.

16.6. Spare parts in excess of the accelerator set stipulated in the Contract (to be charged extra).

16.7. The producer offers the possibility to use the INP experimental base for technological research.

16.8. The producer is ready to help in the designing of industrial technological lines for product irradiation.

16.9. The training and improvement in training the buyer's personnel for the operational run and maintenance of accelerators.

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