PROGRAM OF ACTIVITIES FOR THE LINAC-DRIVER OF ITEP SUBCRITICAL FACILITY

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Abstract

On the base of existing linear proton accelerator and shut down heavy water ITEP reactor now is creating an electronuclear installation. Wide number of investigations is supposed to be carried out at the accelerator. One direction of the works covers functioning of the linac as driver, others concern the problems of the accelerator as a high intensity middle energy ion machine for applied purposes.

1 INTRODUCTION

Decision of a number of problems of nuclear power industry is sharply linked with high intensity linear accelerators. A number of these problems are necessary to be discussed study and solved before creation of a full-scale power installation. We know a number of scientific centers creating separate elements of intensive linac-drivers with the purpose to find physical and technical solutions for full-scale installations [1-3]. A number of problems is now in the process of solution at operating accelerators with ejection of the beams to experimental targets [4].

2 ITEP SUBCRITICAL FACILITY

An experimental electronuclear facility [5,6] propo-sed for investigation and foundation of efficiency and safety of subcritical assemblies controlled by an acelera-tor and also for utilization as a neutron generator (NG) in experimental works on optimization of target-blanket assembly and neutron-physical investigations is now under construction in ITEP on the base of the proton linac ISTRA-36 and shut down heavy water reactor. The main parameters of the installation are:

- average proton beam current 500 μA,
- particle energy 36 MeV,
- average beam power 18 kW,
- intensity of fast neutrons $1.4\cdot10^{14}$ n/s,
- thermal neutron flux in hevy-water reflertor $(1.5\text{-}3)\cdot10^{12}$ n/cm$^2\cdot$s,
- multiplication coefficient of the blanket 0.95 - 0.97.

The mode of operation is pulsed: amplitude of pulses of beam current is 150 mA, pulse duration - 150 μs and pulse repetition rate - 25 Hz. Structural diagram of the linac-driver is: RFQ(3MeV) – DTL-1(10 MeV) – DTL-2 (36 MeV). In addition to its own basical functions the accelerator ISTRA-36 will be a device for experimental tests of a number of physical and technical decisions to be used in full-scale installations. Applied utilization of the proton beam is also provided.

3 LINAC - DRIVER IN A SET OF THE NEUTRON GENERATOR

<u>The means of accelerator control</u> system must provide easy and safe operation of the target-blanket assembly under all modes of operation: individual adjustment of the linac, routine operation of the NG and emergency situations. Main logic links of safe control-ling of the accelerator are shown in Fig.1.

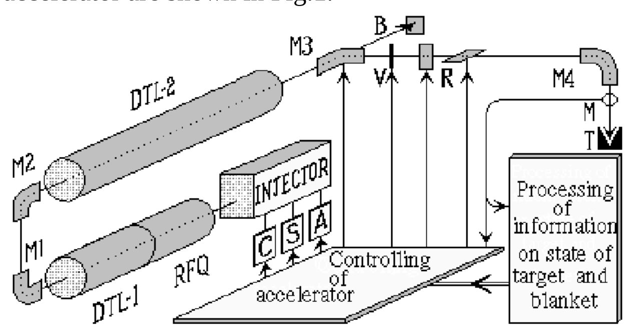

Fig.1. Logic links for controlling of the accelerator.

Autonomous adjustment will be carried out under power removed from the magnet *M3* and closed vacuum valve *V* that provides full disconnection of the accelerator and target-blanket assembly. The beam goes to the beam-stop *B*. Controlling of the bending magnet *M3* and the valve *V* is realized from the side of target-blanket part of the installation that excludes non-sanctionised transfer of the beam into the target *T*.

In the process of routine operation of the NG proton beam is sent to the target beginning from small amplitudes. Collimator *C* at the output of the injector is supposed to be used for varying the beam. Such solution allows to control beam current in the limits from 0 to 100% without variation of electric and thermal mode of operation of the source providing stability of operation. All systems of the acelerator should operate conserving the steady mode of operation and be full ready when short (not emergency) shut down of the beam occur. It may be done if to shift the moment of start *S* of accelerating voltage generator of the injector approximately by ~1 ms before. Capture of particles in RFQ and formation of the following pulse of beam current at the output of the accelerator becomes impossible. Automated correc-tion of beam position (the correctors *R*) in the HEBT on the base of results of continous measurement of proton flux density distribution at the target may turn out to be useful.

The amplitude of current directed to the target is fixed by the meter *M*.

Under emergency situations at the target-blanket assembly the beam is shut down by the commands of the system controlling the facility by switching off accelerating voltage *A* of the injector and simultaniously, for higher reliability, shifting of the starting pulse *S*. Duration of the process of the beam shut down does not exceed 200 μs. After completion of this operation the magnet *M3* is switched off and the valve *V* is closed. Non-sanctionised start up of the beam becomes impos-sivble. For higher reliability reverse logics may be used when not presence but absence of signals will be the command to shut down. All emergency situations at the accelerator lead to shut down of the beam and can not create radiation-nuclear threat.

Pulsed mode of operation of the NG brings some advantages. Under such mode of operation it is possible to provide continuous monitoring of blanket sub-criticality reliably providing approach to critical state. Analysing the manner of thefall in neutron flux in the pauses between the pulses of proton beam it is definitely possible to find out what are the reasons of reactivity variation - state of the blanket or variation of beam current-and to take corresponding measures.

Operation technique with the beam of increased intensity puts new tasks which in some extent will be investigated at the ITEP electronuclear facility. It will be necessary to investigate the following problems: development of exact dosing of the beam, development of the output window and experimental investigation of its characteristics, searches of a reliable method of variation of proton flux density at the target and automated formation of optimal distribution of this density.

4 LINAC - PROTOTYPE OF A HIGH CURRENT ACELERATOR

Controlling of the RF power level. Contradicting requirements to the RF systems of high current accelerators are to be met. From one point they should provide huge powers and from the other point they must quickly react to variation of the beam not allowing damgerous overvoltages in acelerating gaps. We estimate the bandwidth of the sustem of automated control of the amplitude of the field as 500 kHz and the ratio of the hoghest level of RF power for excitation of room-temperature resonators to minimal level may reach 4-6. Such technical problems were never investigated in full scale.

The accelerator ISTRA-36 is close to high current linear accelerators by the power necessary for excitation of the resonators (3.5) and the accepted radio frequencies (300 and 150 MHz). And during 150 μs pulse under beam current 150 mA it is obviously high-intensity accelerator. That is the reason why the solutions developed at its RF system on autocompensation of beam loading effects may be useful for other accelerators.

Operation of permanent magnet lenses. The focusing channel in the DTL resonators is constructed on the base of quadrupoles with permanent magnets ($SmCo_5$, see Fig.2) [7], that makes it suitable, reliable and economical. The main factor capable to cause degradation of the lenses in the conditions of the accelerator ISTRA-36 is irradiation of the permanent magnets by neutrons born

Fig.2. Quadrupole with permanent magnet in a drift tube (the end cover of the tube is removed).

under bombarding of copper walls of the aperture channel by lost protons. Neutron yield at proton energy of 36 MeV is approximately $\varepsilon \approx 0.015$ n/p. Experimen-tal results [8] show that rare earth alloy Sm-Co which is used for fabrication of the lenses lose to 1-5% of magnetization in presence of external field 0.55 T that is close to our conditions after neutron irradiation by $D \approx 1.7 \cdot 10^{15}$ n/cm^2 fluence. The pointed above fluence may be accumulated in the magnets of the lenses at the output of the accelerator under average beam current i and relative losses of the particles δ uniformely distributed along the focusing channel of the DTL for continuous operation $t \approx D \cdot K \cdot e/(\varepsilon \cdot \delta \cdot i)$. Here K - geometry factor of the channel, e - the proton charge. Approximate link between t and δ presented in the Fig.3 points to necessity to decrease the losses and possible lowering of neutron irradiation of the lenses in our specific case, in particular, due to utilization of graphite.

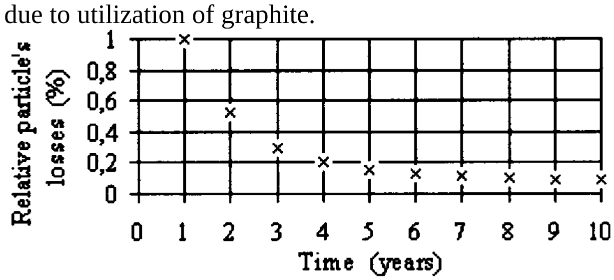

Fig.3. Estimation of the time of operation of PMQ fabricated of $CmCo_5$ at the output of the accelerator under different values of δ.

Tests of graphite absorbers of the lost particles. The ITEP proposal on sharp decrease of the level of radiation at the accelerators [9] due to placement of graphite at the periphery of the aperture channel is supposed to be used. The graphite is characterised by low output of secondary radiation and formation of mainly short-lived radionuclides. At proton energy 10 MeV neutron yield in graphite is appr. 100 times less than in copper and at energy 36 MeV - by 10 times.

After 1 hour of "cooling" hand maintenance of the output part of the accelerator ISTRA-36 is possible if beam losses (without graphite) are not higher than 0.01 μA/m. Placement of graphite insertions of the thickness 0.5-1 mm in the aperture channel or ionguide rises available level to 1 μA/m without significant decrease of aperture diameter. The rings will be installed in the places near quadrupole lenses (Fig.4) where the dimension of the beam in one of coordinates are the highest. In order to exclude gas inleakage a thin layer of a metal, for example, aluminium should be deposit on the surface of graphite or it will be necessary to select harder types of graphite.

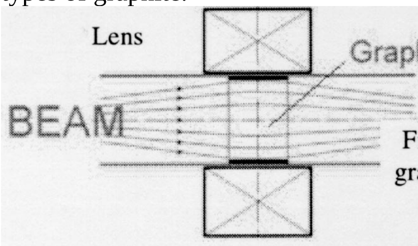

Fig.4. Placement of graphite absorbers of the lost protons.

Checking of technological and design solutions. The proposed in ITEP and realized at the accelerator ISTRA-36 junction of internal cavities of the drift tubes and the vacuum volume of the DTL resonators simpli-fying fabrication and rising reliability of the tubes [7] will be checked in real conditions of long operation. Absence of gasemission materials in design of PMQ in internal cavities of the tubes allowed not to provide hermetization of these volumes and to pump out through the holes which may be seen at the external cylindrical surface of the tubes (Fig.2).

If there is a necessity to align, to repare or to replace one or several drift tubes complications linked with possible activation may arise. This problem will be significantly simplified by fixation of the drift tubes to a removable rigid girder that is provided in one of the resonators of the accelerator ISTRA-36 (Fig.5). A set of the drift tubes requiring reparation or adjustment may be removed as a whole without direct contact of the people and activated elements. Reserve set adjusted at a special stand may be quickly installed into the resonator.

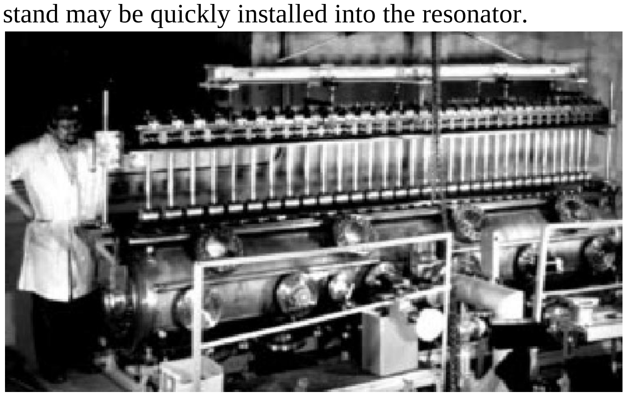

Fig.5. Removable girder with drift tubes of the resonator DTL-1.

5 APPLIED UTILIZATION OF THE BEAM

Three challels of beam ejection are provided for applied utilization of beam.

The first channel will be used for ejection of the beam with energy 3 and 10 MeV for element analysis and production of radionuclides for positron tomography (^{11}C, ^{13}N, ^{15}O, ^{18}F, ^{45}Ti, ^{52}Cu and so on).

The second channel will eject beam with energy 36 MeV with current 100 - 400 μA for production of a wide spectrum of radionuclides for medical, biological and industrial utilization (^{55}Co, ^{87}Ga, ^{82}Sr, ^{87}Y, ^{123}I, ^{201}Tl and so on) and also for investigation of radiation stability of materials.

The third channel (36 MeV, low density of particle flux) will be used for radiation tests of components and fabricated elements supposed to be used in cosmic space. The provided at the accelerator energies of particles are suitable for these tasks as most of positively charges particles in interplanetary space are the protons with energies not higher than 10 - 20 MeV and in near Earth space with some higher energy.

Production of pulses of proton beam with pulse slope < 10 ns. A method of production of intensive pulses of proton beam of nanosecond region duration proposed in ITEP is tested at operating part of the accelerator [10]. Under accelerating voltage at the injector lower the threshold value injection of particles in the RFQ section was provided only during action of additional field of additionally accelerating inductors installed at the input into RFQ (Fig.6). Improvement of this method will give practical results for technics of remote definition of fissile materials, definition of element composition of the surfaces of the planets and investigation of fast reactions by the method of pulsed radiolysis.

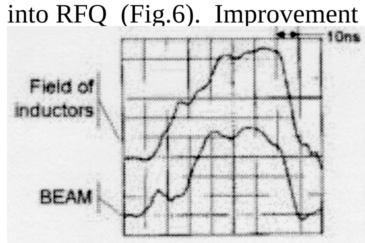

Fig.6. Short pulse of proton beam.

6 CONCLUSION

The experimental neutron generator in ITEP will be one of the first in the world specially created electro-nuclear installations controlled by proton beam. It will allow to find and test solutions of already put questions and to find the problems which are not yet known. Estimations show that under acceleration of average currents higher than 70 - 80 mA room temperature reso-nators are more economical than the superconducting. Information obtained at the accelerator-driver with room temperature resonators ISTRA-36 will be useful for designing of high current accelerators.

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