CONSTRUCTION OF SMALL-SCALE MULTIPURPOSE ADS AT ITEP

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Abstract

A small-scale 100 kW experimental ADS with 36 MeV 0.5 mA proton linac, Be-target and heavy water subcritical blanket assembly is under construction at ITEP. The hybrid system intends for study a number of nuclear energy and neutron physical problems, for study interaction between linac-driver and subcritical assembly, for production of radionuclides.

1 INTRODUCTION

The idea of controlling of a nuclear reactor by external neutron fluxes from target irradiated by accelerated charged particles has been in development for about 40 years. Many leading scientific nuclear-physical centers of the world are engaged in this research [1]. Work on the ATW (USA), OMEGA (Japan), GEDEON (France), ESS and CONCERT (Europe), HYPER (Korea) programs have been actively conducted recently. The APT and SNS (USA), JAERI/KEK (Japan), TRISPAL and IPHI (France), TRASCO (Italy), EA (CERN), KOMAC (Korea) projects are developed and gradually implemented. "The program of researches electronuclear systems" is prepared in Russia [2]. All of them are focused on constructing full-scale ADS for solving different transmutation problems, proposing ways to obtain absolutely safe nuclear power, manufacturing tritium (APT and TRISPAL), and also using in physical researches and practical applications.

Today there is no doubt that a real opportunity exists for the construction of full-scale ADS with accelerator-driver beam power of up to 50-100 MW. However technical and engineering-technological complexities should not be underestimated. Now on the foreground of development of ADS-technologies, besides development of separate full-scale units, creation and experimental operation of small-scale ADS, which will serve as a prototype of full-scale facilities, are completely justified [3]. Such facilities will allow understanding features of interrelation and a problem of such unusual hybrids better: the accelerator of the charged particles and the nuclear reactor, based on completely different technology. Usually planned applied use of accelerated beam and neutron fluxes will help to facilitate the financing problem.

Today some experimental subcritical facilities are upgraded and will be controlled by fluxes from D-T generators (MASURCA, France [4]; YALINA, Byelorussia [5]). However, operational ADS, driven by accelerators do not yet exist. There is a number of offers for a construction of test ADS facilities in Japan [6], Russia [7, 8], Korea [9], China [10].

2 ITEP'S SMALL MULTIPURPOSE ADS

Electro-Nuclear Neutron Generator (ENNG, [11], Fig.1, Table 1), representing experimental ADS is in the process of construction on the basis of the linear

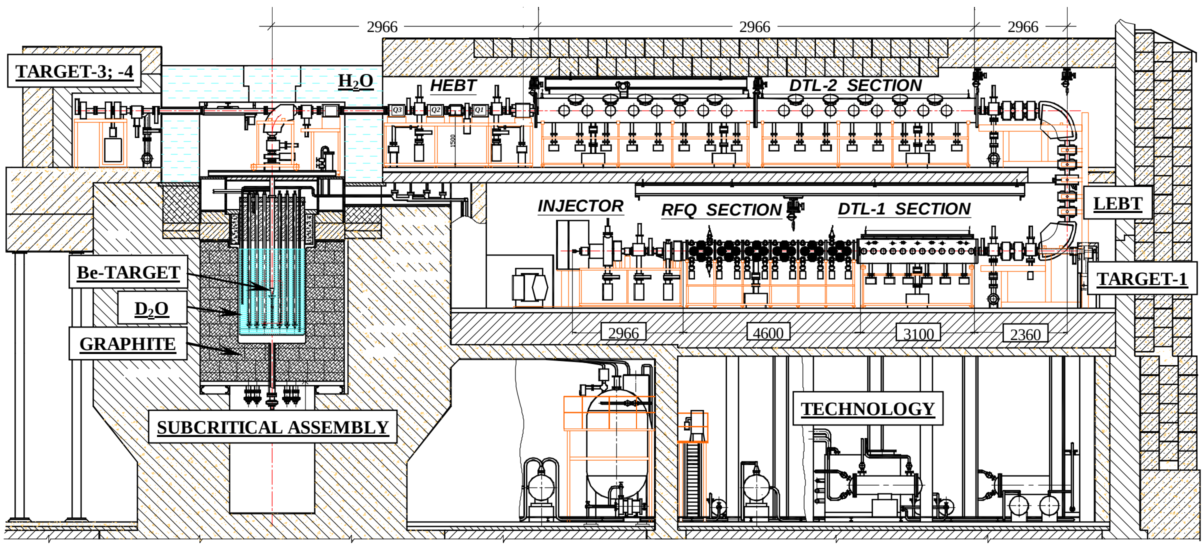

Fig.1. Electro-Nuclear Neutron Generator of ITEP.

accelerator of protons ISTRA-36 and the equipment of a stopped heavy water reactor in ITEP (Moscow). The accelerator-driver is placed on two floors of a special hall near to subcritical assembly. In section RFQ the beam is accelerated to energy of 3 MeV, in resonator DTL-1 – up to 10 MeV then rises on the second floor and in resonator DTL-2 increases energy up to 36 MeV. The accelerated beam with the help of a bending magnet can be directed on a subcritical target, or without bending – on targets for applied uses.

Table 1: Basic parameters of ENNG facilities.

Output proton beam energy, MeV	36
Pulse proton beam current, mA	100
Average beam current, mA	0.5
Beam power (pulse), MW	3.6
Beam power (average), kW	18
Target	Be (Al)
Intensity of fast neutrons, n/s	3×10^{14}
Number of heat-exiting elements	16 - 17
The basic multiplying material	^{235}U
Fuel enrichment of ^{235}U, %	90
Loading of ^{235}U, kg	1.3
Moderator and heat-carrier	D_20
Reflector	D_20; graphite
k_{eff}	0.95 – 0.97
Thermal neutron flux in experimental channels, n/sm^2·s	2×10^{12}
Thermal power at $k_{eff} = 0.95$, kW	100

3 ACCELERATOR-DRIVER

The accelerator [12] consists of an injector with cold cathode ion source, section RFQ and two resonators DTL in which drift tubes with rare-earth ($SmCo_5$) quadrupoles are used. Linac will work in pulse mode.

The accelerator scheme, beam transport channels (LEBT and HEBT) and all targets are shown in Fig.2. The output of a beam with energy 10 MeV is possible to direct on Target-1. The possibility is provided to direct full energy proton beam (36 MeV) to current beam stop – Target-2 (for works during commissioning of the linac), to the target placed inside subcritical assembly, or to Targets 3 and 4.

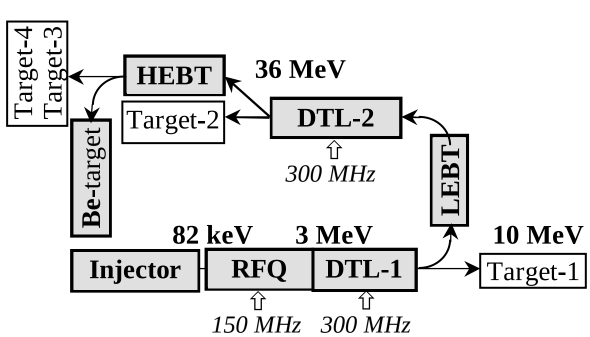

Fig. 2. Scheme of the linac and beam transportation.

4 SUBCRITICAL ASSEMBLY

The horizontal section of the target-blanket part of the ENNG [13] is shown in Fig.3. Beryllium target has a thickness of 6 mm. The proton beam with energy 36 MeV is completely absorbed in the first 2 mm.

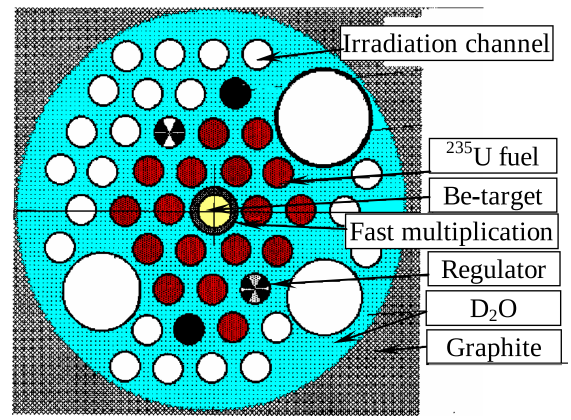

Fig.3.Horizontal section of the subcritical assembly.

Additional thickness multiplies fast neutrons according to the reaction Be(n,2n). Due to that the flux of fast neutrons from a target is increased by 25 %. The thermal blanket has a triangular lattice with step of 110 mm. In its corners heat-generating channels with highly enrichment (90 %) fuel of ^{235}U are placed, the height of an active part of assembly is 110 cm. Vertical experimental channels are located in the blanket's reflector.

5 MULTIPURPOSE ENNG's USE

Target-blanket unit. After commissioning ENNG facility it will be possible to carry out the following:

- to investigate concepts of safe control of subcritical assembly and interactions between accelerator-driver and target-blanket systems;
- to study certain questions of full power subcritical assemblies creation for production of energy, transmutation NPP waste, production of tritium, etc.;
- to select the structure of the blanket;
- to check the program's correctness in calculating blanket systems;
- to receive a source of cold and ultra cold neutrons for fundamental researches, etc.

The linac-driver. The ENNG will serve as training grounds for investigation and improvement of decisions for the design of full-scale high current accelerator project. On the linac-driver, it is planned to investigate features and to develop safe technologies of the accelerator operation with a beam of increased intensity and to test certain questions to find the physical and technical design decision for constructing the linac with increased beam current for their use in full-scale linac-driver project.

Production of radionuclides. Short- and ultra-short living radionuclides will be prepared on a proton beam with energy 10 MeV (Target-1) – emitters for positron-emission tomography, which will then be carried out on a tomograph developed and made in our Institute. The beam with energy 36 MeV will be used to manufacture a wide spectrum of radionuclides diagnostic, therapeutic and industrial purposes (Target-3).

Irradiation of products. Radiation tests of different materials, products and hardware are planned to carry out on the 36 MeV proton beam in a vacuum chamber or after being released to the atmosphere through thin foil with energy ~33 MeV (area Target-4).

Activation analysis. The activation analysis with the use of a proton beam with energy 10 MeV and 3 MeV, will allow finding out the tiniest presence of one metals in others, traces of sulfur in mineral oil etc.

Applied use of neutron fluxes. Neutron fluxes are supposed to be used for implantation technologies (an irradiation of silicon for manufacture of semi-conductor elements), reactor-type isotopes and the development of neutron-capture therapies.

6 CURRENT SITUATION

ITEP possesses the main parts of the accelerator. Its head part, including sections RFQ and DTL-1, is mounted in a temporary room and has already been tested at energy 10 MeV and 100 mA, but at low intensity. The hull of the stopped heavy-water reactor is prepared for the installation of target-blanket assembly. The orders for all parts of subcritical assembly, the accelerator-driver and their technological systems have already been placed in the native industry, and partly received by ITEP. The efforts of several institutes and industrial organizations are joined in the design and implementation of this project. The program of experimental works on hybrid facilities and applied use of a proton beam and neutron fluxes is developed.

7 DEVELOPMENT

Physical commissioning of ENNG will be started by accelerating short (1-30 μs) pulses of a beam with low (1-3 Hz) repetition rate and direct them at the Al target inside the subcritical assembly. At the second stage the average current of a beam should be increased up to 0.5 mA due to the rise of frequency of pulses repetition rate up to 25 Hz and their duration up to 220 μs. Efficiency of a target will be raised by transition from Al on Be. The further development of the accelerator provides increase of the current and energy of the beam with the purpose of expansion of research opportunities of facility.

The factors limiting the upgrade of the facility are as follows. With increase of power of RF power supply and injector systems it will be possible to raise an average current of the beam up to 3-5 mA. Changing of RT DTL-2 cavity on superconducting sections will allow to increase the acceleration rate to about 8 MeV/m and to increase energy of the beam up to ~100 MeV. Thus the maximal average power of the beam on the target may reach 500 kW, and neutrons yield from a target will increase up to 30 times.

For a significant reduction of the activation of the accelerator structures by particles losses, it is planned to install graphite absorbers of lost protons along the accelerating-focusing channel [14]. The graphite has low exit of secondary radiation and produces, basically, short-living radionuclides. It also creates neutrons yield approximately 100 times smaller than copper at protons energy of 10 MeV, and at energy 36 MeV – 10 times smaller. The experience of decreasing the radiation level on the accelerator is extremely important for a full-scale linac-driver as well.

After the optimization of transportation of the beam with the electromagnetic focusing elements, which provide a wide range of adjustments, focusing lenses and some bending magnets will be replaced by rare-earth ones (from alloys Nd-Fe-B or Sm_2Co_{17}) [15], as they are more compact, reliable and convenient in operation. Utilization of pulse commutation a beam will allow to implement common efforts of several users.

8 CONCLUSTIONS

1. Experimental data that can be obtained on small-scale ADS, is very important for substantiated design of full-scale facilities.
2. In ITEP (Moscow), on the basis of proton linac ISTRA-36 and the equipment of the stopped heavy-water reactor, the ENNG representing small-scale test ADS facility is being constructed.
3. The ENNG will allow to carry out a wide spectrum of experimental researches in field of target-blanket and accelerating problems and also to use neutron fluxes and primary proton beam for fundamental research and practical applications.

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