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INDIVIDUAL ACCEPTANCE TESTING AND COMPREHENSIVE TESTING OF NSC KIPT SCA NEUTRON SOURCE TECHNOLOGICAL SYSTEMS AND EQUIPMENT*

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Abstract

During 2016-2017 the installation, assembling and commissioning of the NSC KIPT SCA Neutron Source technological systems were completed. The facility was designed and developed by NSC KIPT of Ukraine in collaboration with ANL of USA. The construction of the neutron source facility was started in 2012. The neutrons of the subcritical assembly are generated by 100 MeV/ 100 kW electron beam uniformly distributed at the surface of the tungsten target. It is supposed that the facility will be used to perform basic and applied nuclear research, produce medical isotopes, and train nuclear specialists. The individual acceptance testing and comprehensive testing were conducted for the technological and engineering systems of the neutron source. The tests were performed in compliance with programs and methodologies agreed by the State Nuclear Regulatory Inspectorate of Ukraine. The testing results confirmed compliance of the equipment with technical specifications, standards, regulations and rules on nuclear and radiation safety and preparedness of these systems for trial operation with the KIPT neutron source. The trial operation of the NSC KIPT SCA Neutron Source has been started.

INTRODUCTION

During 2010-2017 ADS Subcritical Assembly Neutron Source [1-6] was under design and construction in NSC KIPT, Kharkov, Ukraine. In 2016 the construction, assembling and installation of the main technological systems of the Neutron source were completed. During 2016-2017 commissioning of the facility technological systems were started.

The main facility specifications are shown in Table 1.

The electron linear accelerator, driver of the SA, was designed and manufactured in Institute of High Energy Physics (IHEP), Beijing, China [1]. Now the accelerator assembled in NSC KIPT and is under beam commissioning and tests [6, 8]. Taking into account the current stage of the SCA Neutron Source development, the modification of the accelerator control system should be done to satisfy the requirements of the Ukraine Nuclear Regulator [7]. The last accelerator tests show that some modifications should be done in triode electron gun pulser and modulator electronic circuits [8].

Simultaneously, all licensing and technical documentation that, in accordance with Ukraine and international nuclear regulation, is necessary for the NSC KIPT SCA Neutron Source start up were under preparation and accepting. Till the end of May 2018 the complete set licensing documentation will be prepared and agreed with Ukraine Nuclear Regulator.

Now NSC KIPT SCA Neutron Source facility is on the stage of State individual Tests.

Table 1: Main NSC KIPT Neutron Source Parameters

Parameter	Value
Electron energy, MeV	100
Electron beam average power, kW	100
Neutron generating target	U, W
Target photo neutron output, n/s	$3{,}01\cdot10^{14}$ (U-target) $1{,}88\cdot10^{14}$ (W-target)
Neutron multiplication constant k_{eff}	Not more then 0,98
Fissionable material of the core	Low enriched uranium with 19,7% of ^{235}U isotope
Neutron reflector	Two zone: intrinsic zone is beryllium, outside zone is graphite
Moderator, coolant	Demineralised water (H_2O)
Energy release, kW	192 (U-target) 131 (W-target)

NSC KIPT NEUTRON SOURCE START UP PREPARATION

According to the official procedure, all technological systems of the NSC KIPT ADS Subcritical Assembly Neutron Source facility should pass through the following State test stages:

- individual system testing that should confirm the compliance of the system parameters and performance to the technical design documentation and regulatory documentation;
- comprehensive testing of the Nuclear SCA facility including assembling of the neutron generating target in the facility core and operating of all technological systems in all operation modes without fuel loading;
- SCA facility start up that includes nuclear fuel loading, providing design value of the k_{eff}, experimental

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investigation of the neutron characteristics of the facility in order to confirm facility nuclear safety.

The status of the NSC KIPT SCA Neutron source facility technological systems, as for the State comprehensive testing, is the following:

- Neutron Source building and technological constructions passed through the individual testing and are ready for the comprehensive testing;
- Biological shielding passed through the individual testing and are ready for the comprehensive testing;
- Linear accelerator and electron beam transportation channel is under preparation to the State individual testing;
- Neutron generating target is under preparation to the State individual testing;
- Facility core with fuel elements and moderator passed through the individual testing and are ready for the comprehensive testing;
- Cooling systems of the facility core and neutron generating target passed through the individual testing and are ready for the comprehensive testing;
- Fuel machine is under preparation to the State individual testing;
- Control system passed through the individual testing and are ready for the comprehensive testing;
- Radiation monitoring system passed through the individual testing and are ready for the comprehensive testing;
- Neutron flux and criticality measurement system passed through the individual testing and are ready for the comprehensive testing;
- Waist fuel and target storage pools passed through the individual testing and are ready for the comprehensive testing;
- Special sewage system is under preparation to the State individual testing;
- Special ventilation system is under preparation to the State individual testing;
- Physical protection system is under preparation to the State individual testing;
- Fire protection system is under preparation to the State individual testing.

NSC KIPT NEUTRON SOURCE START UP PROCEDURE

The procedure of the NSC KIPT Source start up, loading of the fresh fuel to the SCA core is determined by the Ukraine Nuclear Safety Regulatory documents. According to the documents, the fuel loading should be proceeded on the base of, at least, two independent neutron flux measuring channels on the base of *1/N* curves.

The State approved loading procedure is the following:

- The first set of the fuel elements number is 10 % out of calculated number of SCA facility critical mode ($k_{eff}=1$) fuel element number;
- The second set of the set of the fuel elements is loaded to the core after k_{eff} measurements, that should match with 10 % core loading;
- The next steps of the loading should not exceed 25 % of the residual part of the fuel loading with monitoring by the *1/N* curve method.

According to the Ukraine State Expertise of the NSC KIPT SCA Neutron Source facility design project and Preliminary Safety Analysis Report (PSAR) conclusion, it was agreed that the first set of the fresh fuel elements should include 35 elements with further increasing of the fuel elements number up to 38 with correspondent background and Ukraine nuclear regulation agreement.

NSC KIPT NEUTRON SOURCE NEUTRON FLUX MEASUREMENT SYSTEM

The basic k_{eff} measurement method, that was accepted by the Ukraine nuclear regulator is area measuring method. The method is based on the integration of the neutron flux curve and measurements of the velocity of the neutron flux registration. The measurements are performed with the set of the neutron flux detectors and the measurement data are calculated with the certain software.

The SCA Neutron Source neutron flux measurement system was manufactured, assembled and tested. The general layout of the system is shown in Fig. 1

The system passed through the individual State Accepting tests and is ready to the comprehensive State testing.

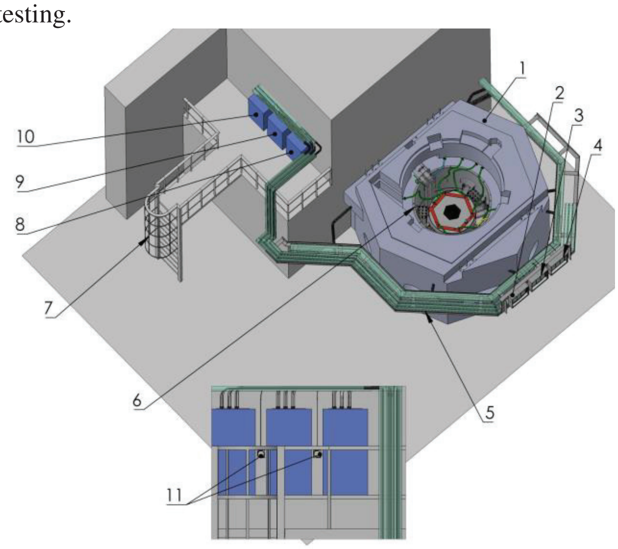

Figure 1: 3D model of the NSC KIPT Neutron Source neutron flux measurement system equipment layout: 1 is bio shielding with neutron sensors, 2-4 are control cabinets, 5 are cable lines, 6 is SCA tank with neutron detectors, 7 is ladder, 8-10 are measuring cabinets, 11 is commutation boxes.

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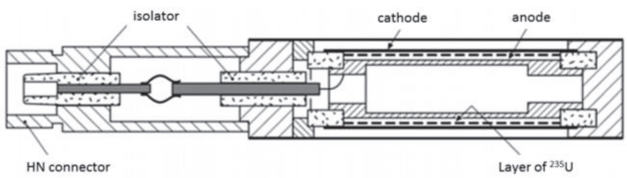

Figure 2: NSC KIPT SCA Neutron Source neutron detectors.

The neutron measurement system uses gas-filled fission cameras as neutron detectors with ^{235}U sputtered cathode. The detectors camera filled with argon-nitrogen gas mixture (Fig. 2). At neutron bombarding of the uranium layer one can observe the fission reaction:

$1n + {}^{235}U \dashrightarrow {}^{236}U \dashrightarrow P1 + P2 + Nn$

The fission fragments P1, P2 have big ionizing capacities and ionize the gas inside camera volume. The distance between anode and cathode is small and generated charge (of about $2*10^{-13}$ C/n) is quickly consumed by electrodes. The velocity of the ion consumption determines the detector dead time τ, that means that during that time the next pulse can not be registered (about 20 ns).

The number of registered pulses per one neutron determines the efficiency of the detector. In NSC KIPT SCA Neutron Source two types of detectors are used with efficiency of 10^{-5} (15 µg ^{235}U) and 10^{-3} (1.5 mg ^{235}U) respectively. Detectors with 10^{-3} sensitivity are used for the 10^3 – 10^9 / cm*s) neutron registration. To measure neutron fluxes of 10^5 – 10^{11} / (cm^2*s) the low sensitivity detectors are used.

During the last accelerator testing sessions the first measurements of the neutron flux were done. The example of the typical screen short of the neutron flux measurement panel is shown in Fig. 3. A one can see the value of the neutron flux during experiments was about 10^6-10^7 n/(s*cm^2).

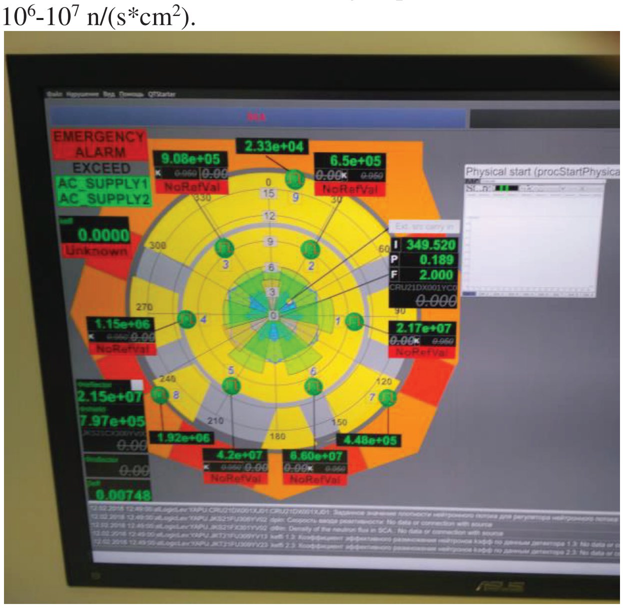

Figure 3: The typical view of the NSC KIPT SCA Neutron Source neutron flux measurement system panel.

CONCLUSION

NSC KIPT Neutron Source on the base of subcritical assembly driven with 100 MeV/100 kW electron accelerator construction has been completed. All technological systems of the facility were assembled and tested. During 2017-2018 individual acceptance testing of several technological systems were successfully done.

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