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THE PROGRESS IN PHYSICAL START-UP OF THE NSC KIPT SUBCRITICAL NEUTRON SOURCE FACILITY DRIVEN BY AN ELECTRON LINEAR ACCELERATOR *

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Abstract

National Science Center "Kharkov Institute of Physics &Technology" (NSC KIPT), Kharkov, Ukraine and Argonne National Laboratory (ANL), Chicago, USA are jointly constructing and commissioning the Ukraine Neutron Source facility. The facility consists of a subcritical assembly driven by a 100MeV/100kW electron linear accelerator. The electron beam will be used for generating the neutrons for operating the subcritical assembly using tungsten or natural uranium target. The facility is planned to support the Ukraine nuclear industry, and provide a capability for performing reactor physics, material research, and basic science experiments, to produce medical isotopes, train young nuclear professionals.

The integrating facility tests were completed at the end of 2018, and physical start-up operation began in 2019.

The facility commissioning and current start-up results are presented and discussed in the paper.

INTRODUCTION

During 2010-2017 ADS Subcritical Assembly Neutron Source [1-2] 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. In 2016-2017 commissioning of the facility technological systems were started. During 2018, a modification of the accelerator control system, an electron gun, and a diagnostic system was performed [3].

In 2018, individual tests of all systems were completed.

Integrating tests of the Nuclear SCA facility including assembling of the neutron producing target in the facility core and operating of all technological systems in all operation modes without fuel loading were completed in the end of 2018.

Now NSC KIPT SCA Neutron Source facility is at the stage of preparation for a physical start-up that includes nuclear fuel loading, measurement of the multiplication factor k_{eff}, value, experimental investigation of the neutron characteristics of the facility in order to confirm the facility's nuclear safety.

The main facility specifications are shown in Table 1.

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 photoneutron output, n/s	$3.01\cdot10^{14}$ (U-target) $1.88\cdot10^{14}$ (W-target)
Neutron multiplication factor k_{eff}	0.98 max
Fissionable material of the core	Low enriched uranium with 19.7% of ^{235}U isotope
Neutron reflector	Two zones: beryllium inner zone, graphite external zone
Moderator&coolant	Demineralised water (H_2O)
Thermal power, kW	200 (U-target) 136 (W-target)

NSC KIPT NEUTRON SOURCE START-UP PROCEDURE

The procedure of the NSC KIPT Source start-up, loading 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 performed on the base of, at least, two independent neutron flux measuring:

The loading procedure approved by the State is the following:

- The first set of the fuel element loading is 10 % out of the calculated SCA facility critical mode ($k_{eff}=1$) fuel element number;
- The second 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 remained part of the fuel loading with k_{eff} monitoring with the area measuring method after each loading step.

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

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QUALIFICATION OF SYSTEMS FOR A PHYSICAL START-UP

The State individual nuclear regulation tests of all facility technological and engineering systems were carried during 2017-2018 and the facility was ready for the State integrating tests in October 2018. The NSC KIPT SCA Neutron Source facility integrating tests were done successfully in the beginning of December 2018. Official permission for the physical start up preparation was obtained.

To prepare NSC KIPT SCA Neutron Source to the physical start up the addition efforts were required to test, tune and adjust 100 MeV/100 KW electron linear accelerator [4], neutron flux measurement system, SCA fuel loading machine.

NSC KIPT NEUTRON SOURCE NEUTRON FLUX MEASUREMENT SYSTEM

In accordance with the program of physical start up that was approved by State Nuclear Regulator the basic k_{eff} measurement method that is an area measuring method. In the method, the neutron response of the SCA on the electron beam pulse is measuring. The measurements are performed by the set of the neutron flux detectors, and the measurement data are handled with specified software.

The SCA Neutron Source neutron flux measurement system has been designed, manufactured, assembled and tested. The general layout of the system was described in [3].

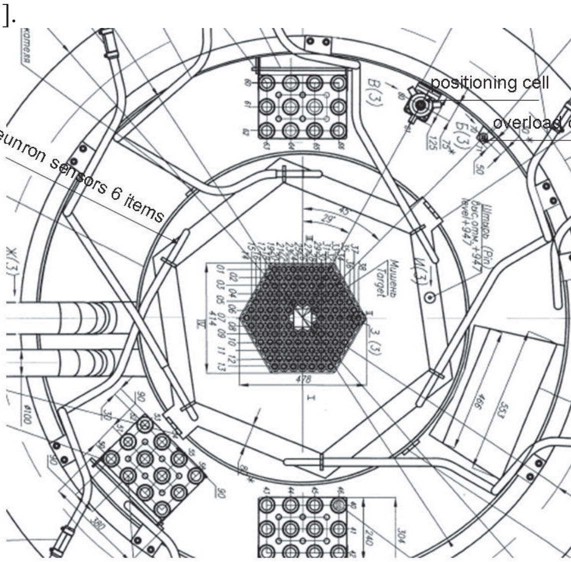

Figure 1: Layout of the SCA Neutron Source neutron flux measurement system.

The neutron flux and criticality measurement system is based on CFUF34, CFUF54 detector set (6 over graphite reflector inside ADS tank, see Fig. 1) and CFUF28 (3 outside), Photonic Ltd, France neutron sensors provide the neutron flux measurements in a range of 10^2–10^{11} cm^{-2}s^{-1} (Fig. 2). During the last tests, the system was checked for flux measurements from a tungsten neutron target with fuel dummies in the tank.

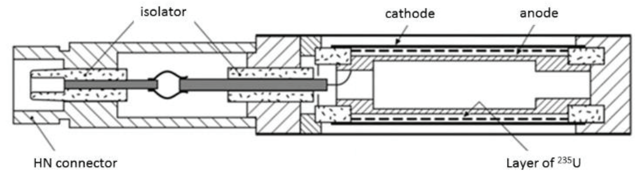

Figure 2: NSC KIPT SCA Neutron Source neutron detector scheme.

During the measurements, there was found a significant effect of the gamma-quanta flux on the signals of the detectors. During the accelerator pulse (2.7 µs), the signals caused by the gamma rays ionization were recorded at the detector output (Fig. 3).

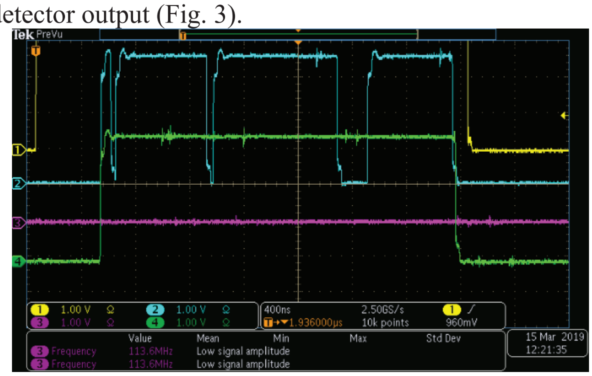

Figure 3: CFUF34 detectors signals. The yellow curve is synchropulse, green & blue are for unshielded detectors, and magenta is a lead shielded detector.

With accelerator pulse currents up to 120 mA, the gamma background could be suppressed with lead protection of 4 cm thickness. To compare the measurement results with simulations on MCNPX we eliminated the signals from the detectors during the 2.7 µs of accelerator pulse. Fig. 4 shows the measurement results of the pulse response using three CFUF34 detectors.

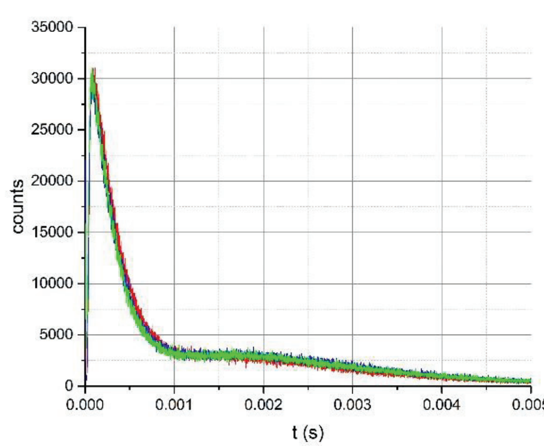

Figure 4: The pulse response of CFUF34 detectors.

FUEL LOADING MACHINE

The rigid connection of accelerator vacuum chamber with 2.96 meter length neutron producing target causes

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difficulties in operation of core elements (elements contact and friction, Fig. 5). To avoid such situation and add some flexibility to the procedure of the vacuum chamber adjustment the accelerator vacuum chamber was equipped with bellows of the same cross section (Fig. 5). The modified vacuum chamber was installed in design position and incorporated in the accelerator vacuum system. After vacuum evacuation the residual gas pressure in the transportation channel shows design value of something on 10^{-8} torr. The modified construction provides freedom for loading manipulations in the SCA core and transportation of the electron beam to the target.

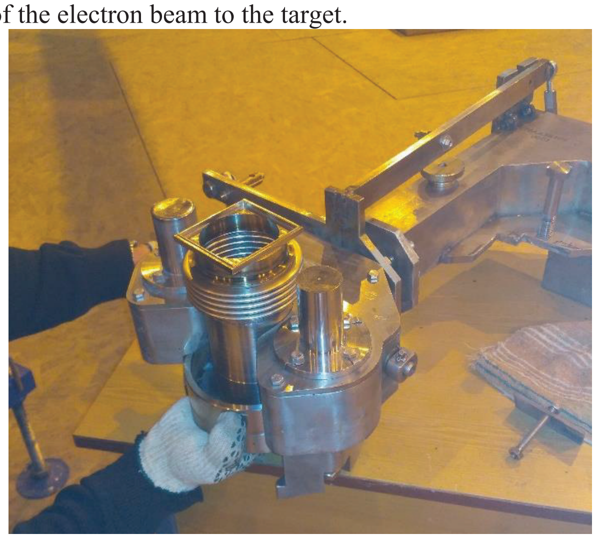

Figure 5: End of accelerator vacuum flange with added bellows.

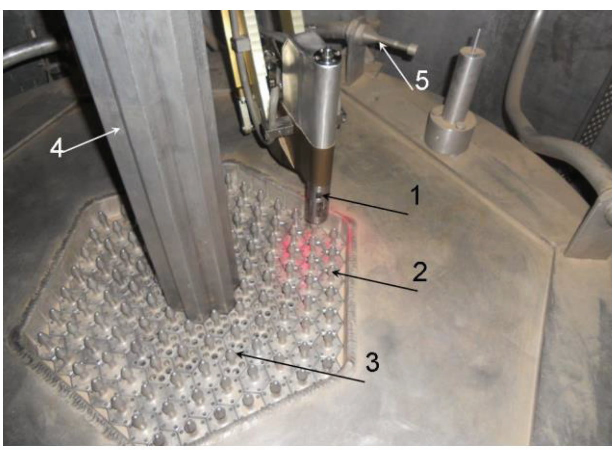

Figure 6: Service of an active zone. 1 – a manipulator grip; 2 – a beryllium core element; 3 – a core fuel cell; 4 – a target; 5 – a neutron sensor

The fuel loading machine is designed to service the neutron source core (see Fig. 6). Fig. 1 shows the core layout. Each cell has a label consisting of two numbers. For example, the reloading cell in Fig. 1is marked (70.71), and one of the 120 cells of the active zone is marked (01-13, 14-38).

The fuel loading machine is currently in pilot operation. Fig. 7 shows the window of a fuel loading machine operator panel. Unfortunately, the operator is unable to control the accurate guidance on the tip of the element visually. This leads to problems with starting targeting after manipulator maintenance. Special tools were developed at the NSC to redefine the coordinates of the overloaded elements. An additional camera is mounted in the gripper. It is pre-calibrated to the centre of the model element. After that, targeting at each cells (159 items at all) is performed, and coordinates of all cells are defined (redefined). The test reload of fuel element dummies at the core cells is currently in progress.

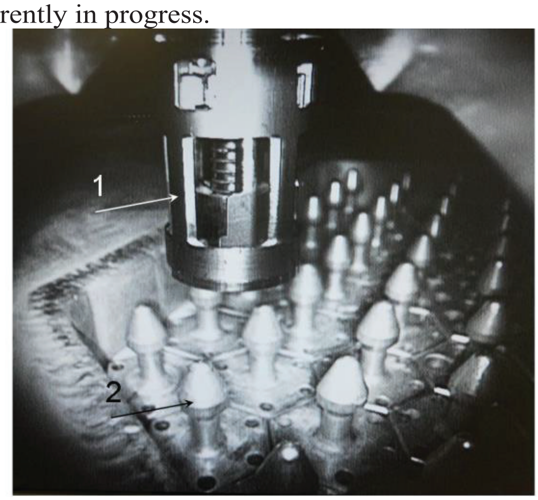

Figure 7: Screen of a fuel reloading machine operator. 1 – a manipulator grip; 2 – a beryllium core element

CONCLUSION

NSC KIPT Neutron Source on the base of subcritical assembly driven by 100 MeV/100 kW electron accelerator construction has been completed. All technological systems of the facility have been assembled and tested. During 2017-2018, individual and acceptance testing of technological systems and integrating facility tests were successfully performed. The preparation to the facility physical start up is in progress.

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