NSC KIPT NEUTRON SOURCE ON THE BASE OF SUBCRITICAL ASSEMBLY WITH ELECTRON LINEAR ACCELERATOR DRIVER*

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Abstract

National Science Center Kharkov Institute of Physics & Technology (NSC KIPT) together with ANL, Chicago, USA developed up to date scientific facility that is Neutron Source on the base of subcritical assembly driven with 100 MeV/100 kW electron accelerator. During bombarding of the Tungsten or Uranium targets the electron beam generates the original neutrons that are multiplied in the facility core of low enriched uranium trough the fission process. The maximal value of the neutron multiplication factor is 0.98. So the total neutron flux output is increased as much as 50 times and is $2 \cdot 10^{13}$ n·cm^{-2}·c^{-1}. The subcriticality of the system eliminates the possibility of self-sustained chain reaction existence that increases the nuclear safety of the facility drastically. The neutron source mentioned above is the first facility of such type in the world. The results that will be obtained at studies of neutron characteristics of the neutron source with low enriched uranium core and during optimization of the operation modes of the facility systems will became the scientific background for the further development of the safe, ecological nuclear energetics of the future.

INTRODUCTION

Since February 2012 ADS Subcritical Assembly Neutron Source [1] is under construction in NSC KIPT, Kharkov, Ukraine. In 2016 the construction, assembling and installation of the main technological systems of the Neutron source were completed and commissioning of the 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 [2]. Now the accelerator assembled in NSC KIPT and is under beam commissioning and tests [3].

The SA core is a set of fuel elements of WWR-M2 type by the TVEL corporation production (Russia) of low enriched uranium (19,7% ^{235}U). The fuel is finely dispersed uranium dioxide UO_2 that is uniformly distributed in aluminium matrix. The main fissions of actinides are produced with thermal neutrons.

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	$3{,}01 \cdot 10^{14}$ (U-target) $1{,}88 \cdot 10^{14}$ (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)
Neutron flux at the core, n/cm^2·s	625 Hz
Energy release, kW	192 (U-target) 131 (W-target)

NSC KIPT NEUTRON SOURCE SUBSYSTEMS

NSC KIPT ADS Subcritical Assembly Neutron Source consists of the following main technological systems:

- Neutron Source building and technological constructions.
- Biological shielding.
- Linear accelerator and electron beam transportation channel.
- Neutron generating target.
- Facility core with fuel elements and moderator.
- Cooling systems of the facility core and neutron generating target.
- Fuel machine.
- Control system.
- Radiation monitoring system.
- Neutron flux and criticality measurement system.
- Waist fuel and target storage pools.
- Neutron channels.
- Special sewage system.
- Special ventilation system.
- Physical protection system

* Work supported by US Department of Energy
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To provide the start up of the Nuclear facility that is NSC KIPT ADS Subcritical Neutron Source should provide and carry out the commissioning, State Accept and Licensing Procedure for technological system systems, mentioned above.

Construction

All buildings, technological constructions were completed in the end of 2014 year.

Biological Shielding

Biological shielding consists of radial core biological shielding with shutters for the neutron channels and two moveable parts of the top biological shielding. During Neutron Source operation both parts of biological shielding are closed. For the facility maintenance there is possibility to open the biological shielding (Fig. 1). The shielding was designed to provide natural radiation conditions on the surface of the shielding during the facility operation.

At 2016 the assembling and adjustment of the biological shielding was completed and now it is in operation. The verification of the control system software is in progress.

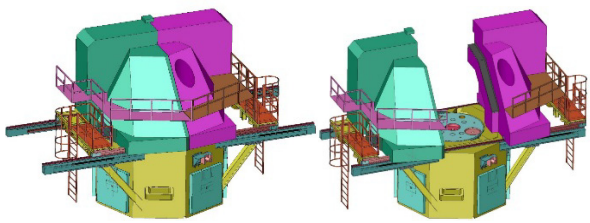

Figure 1: Layout of the NSC KIPT Neutron Source biological shielding.

Linear Accelerator

The assembling of the 100 MeV/100 kW linear accelerator was completed in the middle 2016 and vacuum evacuation, injector tests, RF conditioning and beam commissioning were started. The status of the accelerator commissioning is described in [3].

Neutron Generating Target and Facility Core

The design of the target was chosen on the base of numerical simulations in order to provide the maximal neutron output [1].

In Fig. 2 a 3D model of the tungsten target are presented. The target consists of the square plate set of 64×64 mm transverse sizes and total thickness of 80 mm with 2 mm gaps between target plates to provide target cooling.

To eliminate the cooling water contamination by radioactive corrosion products the target plates are covered with protection layer of aluminum of 0.2 mm thickness.

The housing of the target is made of aluminum alloy. The target construction is connected to the electron beam guide with flange connections.

The neutron generating target and the facility tank with core were manufactured, tested on water and vacuum leakages, installed in biological shielding and adjusted. Figure 3 shows the assembled facility core and assembling of the core.

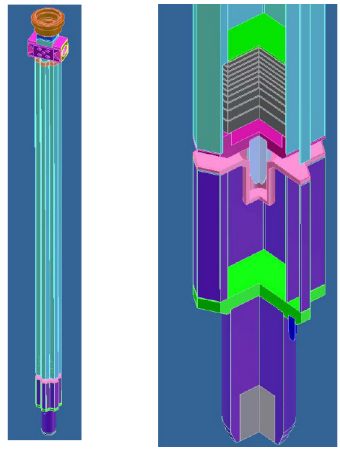

Figure 2: Layout of the NSC KIPT neutron generating target.

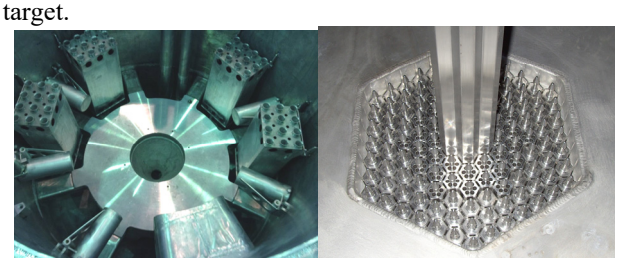

Figure 3: Assembled and installed NSC KIPT neutron source core with target.

Fuel Machine

NSC KIPT ADS Subcritical Assembly Neutron Source fuel machine was designed and manufactured by "Diakont" company. The fuel machine design is based on pantograph scheme that can provide high accuracy of the manipulator movement and targeting to the fuel elements (Fig. 4). Simultaneously, such scheme requires very high accuracy of the manipulator part manufacturing and adjustment. Now the fuel machine is under adjustment in NSC KIPT.

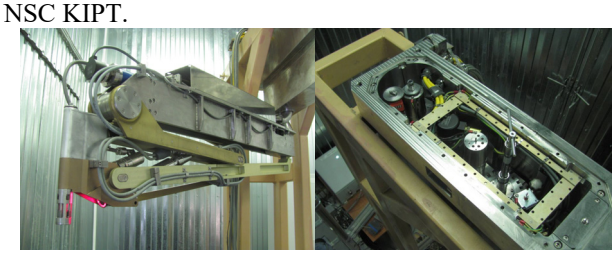

Figure 4: NSC KIPT Neutron Source fuel machine.

Cooling System

NSC KIPT neutron source cooling system consists of four cooling loops that are: secondary cooling loop of the neutron source core, secondary cooling loop of the linear accelerator, primary cooling loop of the neutron source core, primary cooling loop of the neutron generating target. All equipment of the cooling were installed, assembled and tested (Fig. 5). In 2016 the test operation of the secondary cooling loop of the linear accelerator was started to provide linear accelerator beam commissioning.

ISBN 978-3-95450-182-3

Now the cooling system is under preparation to the individual and complex State Accepting tests.

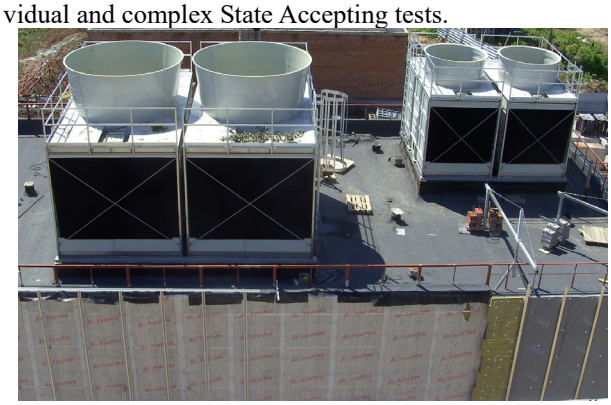

Figure 5: NSC KIPT Neutron Source secondary cooling loop building.

Neutron Channels

The shutters of the NSC KIPT neutron source neutron channels were designed, manufactured, tested and adjusted (Fig. 6). Now all shutters are ready for the individual and complex State tests.

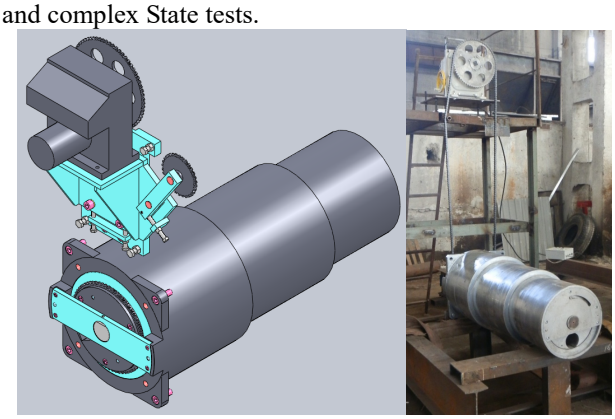

Figure 6: 3D model of the NSC KIPT Neutron Source neutron channels shutters.

Neutron Flux and Criticality Measurement System

The neutron flux and criticality measurement system is based on CFUF28, CFUF34 (10 inside), CFUF54/HA1 (3 outside), Photonic, France neutron sensors and RNL-04.06 detector blocks provides the neutron flux measurements in range of $10^2 – 10^{11}$ cm^2/s and signals on k_{eff} value (Fig. 7). The system was designed, manufactured, assembled and tested by Khartron, Kharkov, Ukraine company. System passed through individual State testes and now is ready for the State complex tests.

Waist Fuel and Target Storage Pools

The system was manufactured, assembled and tested. In 2016 the system passed through the individual State Accepting tests and is ready to the complex State tests.

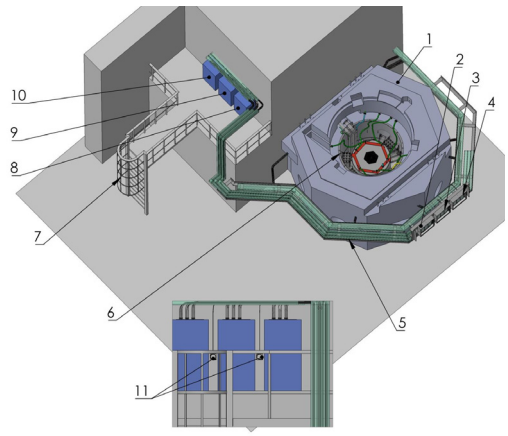

Figure 7: 3D model of the NSC KIPT Neutron Source neutron flux measurement system equipment layout: 1 is bio shielding with neutron sensors, 2-4 are control cabinets, 5 are cable lines, 6 is SCA tank with neutron sensors, 7 is ladder, 8-10 are measuring cabinets, 11 is commutation boxes.

Control and Radiation Monitoring System

The system was manufactured, assembled and tested by Hartron company. In 2016 the system passed through the individual State Accepting tests and is ready to the complex State tests.

Ventilation and Sewage Systems

The systems were manufactured, assembled and tested. Now the systems are ready to the individual State Accepting tests.

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. Since the end of 2016 all technological systems are under commissioning and State accepting procedure.

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