STATUS OF THE NSC KIPT NEUTRON SOURCE

O. Bezditko, I. Karnaukhov, A. Mytsykov, A. Zelinsky, D. Tarasov
NSC KIPT, Kharkiv, Ukraine

Abstract

In NSC KIPT, Kharkov, Ukraine the state of art nuclear facility Neutron Source on the base of subcritical assembly driven with 100 MeV/100 kW electron linear accelerator has been build. The electron beam generates neutrons during bombarding the tungsten or uranium target. The subcritical assembly of low enrichment uranium is used to multiply the initial neutrons due to fission of the uranium nuclei. The facility is the first world facility of such kind. It is supposed that maximal value of multiplying neutron factor in the source will be equal to 0.95. So, the neutron flux will be increased as much as 50 times. Because of sub-criticality the facility eliminates the possibility to produce the self-sustained chain reaction. Now the Neutron source is under commissioning. In the report the facility and its control system current status is presented.

Introduction

Since February 2012 ADS Subcritical Assembly Neutron Source is under construction and assembling in NSC KIPT, Kharkov, Ukraine [1]. 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. All buildings, technological constructions were completed in the end of 2014 year. 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. The electron beam commissioning for the whole accelerator was started in March 2017. As a result of the first experiments the electron beam was delivered to the middle of the transportation channel [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% *235U*). 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.

Neutron Source is nuclear facility all technological systems of the facility are under regulation of State Inspection of Nuclear Regulation of Ukraine that is working in accordance with international nuclear regulation legislation. This regulation demands certain requirement to the design and realization of the facility control system in order to provide the conditions of the facility safe operation [4].

Table 1: Main NSC KIPT Neutron Source parameters

Parameter	Value
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 0,95
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, $n/cm^2 \cdot s$	$2 \cdot 10^{13}$
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:

1. Neutron Source building and technological constructions.
2. Biological shielding.
3. Linear accelerator and electron beam transportation channel.
4. Neutron generating target.
5. Facility core with fuel elements and moderator.
6. Cooling systems of the facility core and neutron generating target.
7. Fuel machine.
8. Control system.
9. Radiation monitoring system.
10. Neutron flux and criticality measurement system.
11. Waist fuel and target storage pools.
12. Neutron channels.
13. Special sewage system.
14. Special ventilation system.
15. Physical protection system

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 systems, mentioned above.

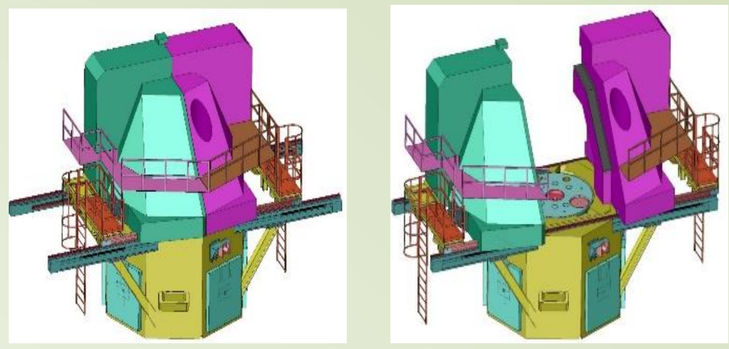

Figure 1: Layout of the NSC KIPT Neutron Source biological shielding

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. For the facility maintenance there is possibility to open the biological shielding . 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. Biological shielding is shown in Figure 1.

Linear accelerator

100 MeV/100 kW electron linear accelerator is a driver of the ADS neutron source that is under commissioning in NSC KIPT, Kharkov, Ukraine. The main accelerator parameters are shown in Table 2.

The assembling of the accelerator in NSC KIPT was started in May 2013. Now, all accelerator system are assembled and installed.

Table 2: Main KIPT accelerator parameters

Parameter	Value
RF frequency	2856 MHz
Beam energy	100 MeV
Beam current (max.)	0.6 A
Average beam power	100 kW
Energy spread (1σ)	1 %
Emittance (1σ)	5×10^{-7} m-rad
Beam pulse length	2.7 μs
RF pulse duration	3 μs
Pulse repetition rate (max)	625 Hz
Klystron power	30MW/50kW
Number of klystron	6
Number of ACC. structure	10
Length of ACC. structure	1.336 m
Gun voltage	~120 kV
Gun beam current (max)	2 A

Neutron generating target

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

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 (Fig. 2).

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. Simultaneously, such scheme requires very high accuracy of the manipulator part manufacturing and adjustment. Now the fuel machine is under adjustment and upgrade in NSC KIPT.

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

Neutron channels

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

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. The system was designed, manufactured, assembled and tested by Khartron, Kharkov, Ukraine company. Now system is passing through individual State testes. There is neutron source in the subcritical assembly. The range of neutron source is 10^5 $n/cm^2 \cdot s$. All neutron sensors are working and calculating neutron flux.

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

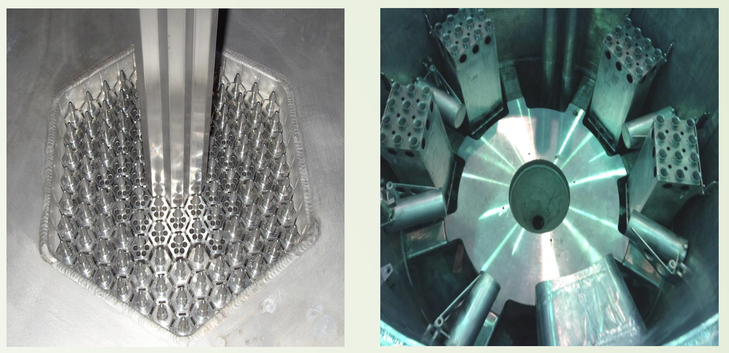

Figure 2: NSC KIPT neutron source core with target

Control and radiation monitoring system

For providing of radiation safety of staff and population, monitoring of the Ukrainian radiation safety norms and rules during the nuclear facility operation of the SCA the Automatic Radiation Monitoring System was designed, manufactured and put in operation. 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. 6 industrial air conditioning in klystron gallery were installed, for supporting 25C° temperature in this room.

Figure 3: Neutron Source secondary cooling loop building

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.

References

[1] O. Bezditko et al. NSC KIPT Neutron Source on the base of Subcritical Assembly Driven with Electron Linear Accelerator// Proc. Of IPAC’2013, 12-17 May, 2013, Shanghai, China, THPFI080, pp. 3481-3483, http://www.JACoW.org
[2] Yunlong *Chi* et al. 100 MeV/100 kW Electron Linear accelerator driver of the NSC KIPT Neutron Source// Proc. Of IPAC’2013, 12-17 May, 2013, Shanghai, China, THOAB203, pp. 3121-3123, http://www.JACoW.org.
[3] A. Zelinsky et al. Test and Commissioning Results of NSC KIPT 100 MeV/ 100 kW Electron Linear Accelerator, Subcritical Neutron Source Driver// IPAC’2017, 14-19 May, 2017, TUPIK033, http://www.JACoW.org.
[4] D. Tarasov et al. Control system of the linear accelerator as a part of Nuclear facility NSC KIPT Neutron Source// ICALEPCS’2017, 07-13 October, Barcelona, Spain, TUPHA060, http://www.jacow.org

ICALEPCS 2017