KnE Engineering

AtomFuture-2017
XIII International Youth Scientific and Practical Conference
"FUTURE OF ATOMIC ENERGY - AtomFuture 2017"
Volume 2017

Conference Paper

Unmovable Detection Unit of the Thermal Neutron Flux in the Source Range of the Reactor

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Abstract

This paper presents the results of theoretical and experimental research of the new unmovable detection unit of the thermal neutron flux in the source range of the reactor. The design features and the main parameters of this unit are also shown.

Keywords: PWR, nuclear power plants, the detection unit, counter SNM-11, sensitivity.

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Received: 23 December 2017
Accepted: 15 January 2018
Published: 21 February 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the AtomFuture Conference Committee.

1. Introduction

At start-up of the reactor and the refueling during the planned stops there are used a highly sensitive detecting device (DD), on the basis of gas-discharge counters. To control the flux density of thermal neutrons at the plant, before the start of the PWR reactor, it is used detection units (DU) with corona counters of SNM-11, the application of which is caused to the relatively high sensitivity, but they have performance limitations, i. e. in case of power increase the unit required to be moved within the channel of ionization chamber (IK channel) in the region of the weakening of the neutron flux [1], [2].

In this regard, it is necessary to improve technical and operational parameters of equipment of neutron flux monitoring, specifically to modernize in the design of the moveable detecting unit with a soft cable-KAGE, which is susceptible to degradation in the neutron flux and frays because of frequent movements.

JSC "SNIIP-SYSTEMATOM" has developed a new unmovable detecting unit of neutron flux density with high performance and extended life

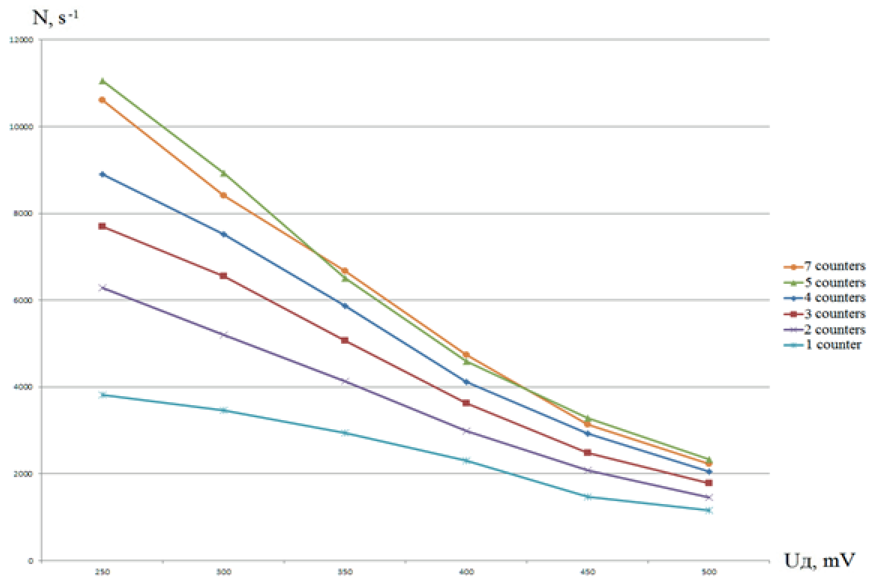

Figure 1: The dependence of the sensitivity of the DU of the number of counters.

2. Determination of main parameters of unmovable detection unit

Before performing of development works was carried out theoretical and experimental research to identify the main technical parameters unmovable DU [3], [4], [5], based on the requirements of the technical specifications [6] for the radiation and temperature requirements in the course of which was determined as the optimal design solution, namely:

- choice of housing material and composite parts DU;
- cable, for signal transmission from the DU to the inverter;
- the number of detectors of the density of thermal neutron flux in the design of DU.

For the experimental work was designed experienced DU in a portable version, allowing the experiment to change the amount of counters, their position in the database, use aluminum shell or stainless steel. Such an embodiment of DU provided the opportunity to conduct a comprehensive analysis of the influence of noise parameters, the effects of mutual shielding of counters, determining the dependence of the sensitivity of the DU of the number of counters.

The dependence of the sensitivity of the detection unit of the number of counters is shown in Figure 1.

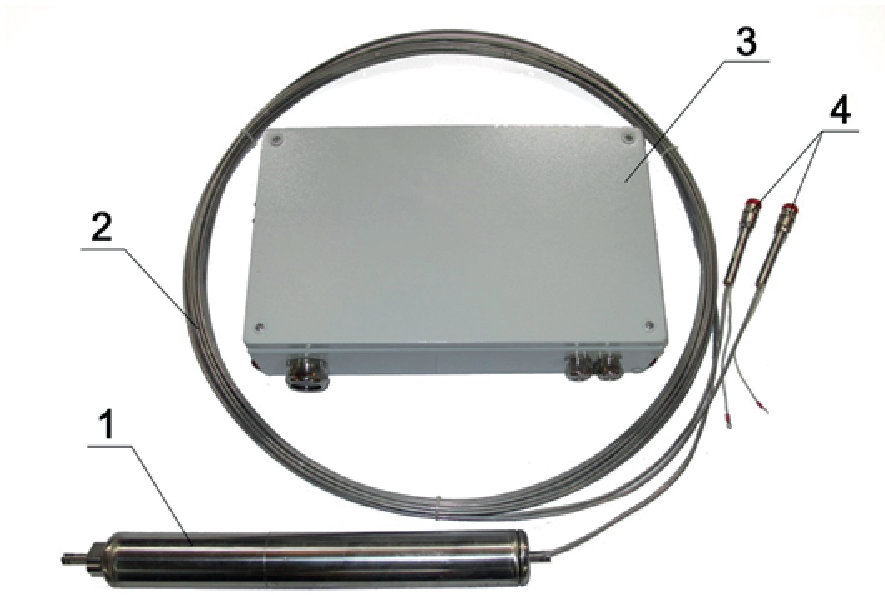

Figure 2: General view of the DD.

The results of the research showed that the increase in the number of counters in the design of DU with five to seven leads to a minor increase in sensitivity, and the levels of discrimination from 350 mV to 450 mV to a slight decrease.

The experimental results show that the best sensitivity DU is reached with five counters in the sensor design, which corresponds to the theoretical calculations.

After analyzing the data, was developed by the second detection unit in the monolith version with the optimal number of counters that provide maximum sensitivity of DU at the set temperature and radiation parameters.

Unmovable DU was developed on the basis of radiation-resistant modification of corona counters of neutrons similar to the neutron counters of the type SNM-11 ОДо.339.070 ТУ [7]. DU intended for registration of thermal neutrons. The sensitivity of DU to thermal neutrons in the energy range from 0.025 to 0.5 eV is of 4.0±1.0 cm^2 (the number of pulses within 1 s under the influence of the neutron flux density 1.0 $cm^{-2}\bullet s^{-1}$).

Structurally, the DU consists of a housing 1, made in the form of thin-walled stainless steel cylinder, inside which is located the neutron counters 5. The housing is separated from the counters with insulators, which eliminates the influence of external factors on the signal. One of the end surfaces connected to the heat-resistant type cables KNMMS 2 [8]. The DU connects to the conversion unit 3 through an RF connector SR 4.

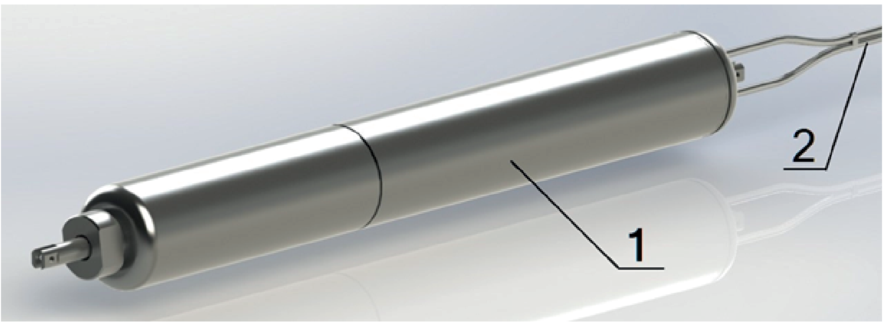

Figure 3: General view of the DU.

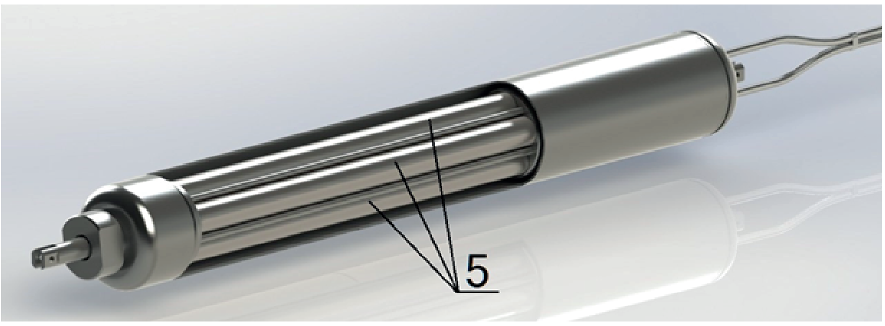

Figure 4: The section of DU.

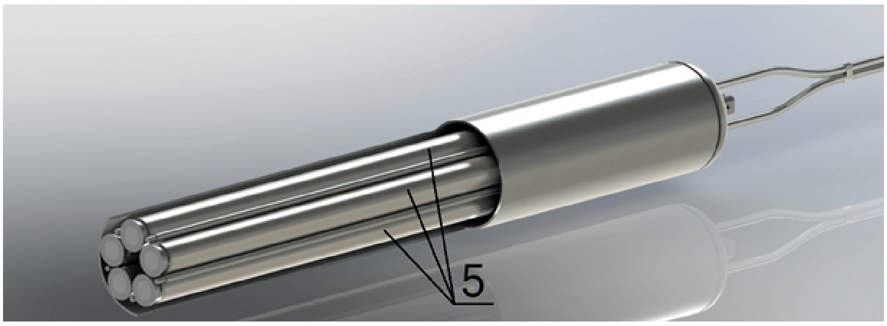

Figure 5: Location of counters in the DU.

The design of DU non-separable and watertight, thermo - and radiation-resistant. And, therefore, there is no need to move DU in the channel IK in the process of operation (up to the operating position prior to refueling and back down into position with a minimum of neutron flux density after the completion of refueling).

3. Factors influence on the sensitivity of the DU

Consider the factors that can affect the sensitivity of unmovable DU

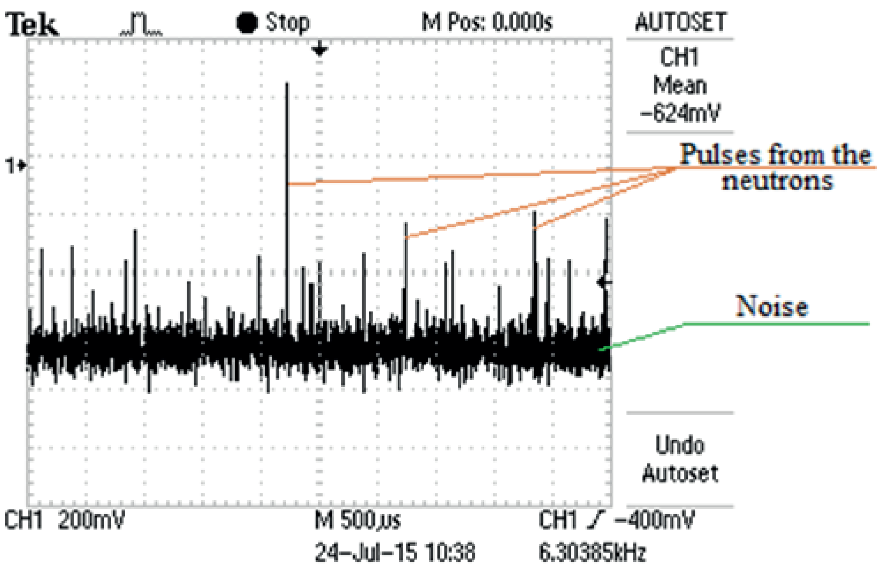

Figure 6: Waveform of output signal on linear output of the pulse amplifier of neutrons and noise of corona discharge counters of SNM-11.

3.1. Mutual shielding of counters in the design of DU

Was estimated the change in the sensitivity of DU on the basis of the number of interactions of neutrons with atoms of boron-10 per unit surface area [9]. The calculations are made without taking into account the influence of factors affecting the sensitivity (noise, quality of boron-10 in the counter and the absorption of thermal neutron flux). The calculation was performed based on the spatial location of the counters inside the volume of DU.

Starting with the three counters in the design of the DU when they are located closely, the effect of mutual shielding is appears, which affects the sensitivity of the DU. Therefore, the optimal number of counters that will provide the maximum number of interactions of flux of thermal neutrons with atoms of boron-10, and, consequently, optimum sensitivity, was chosen to be five at the posted position.

The calculations confirmed the correctness of the choice of the number of counters in the design unmovable DU.

3.2. Influence of noise parameters

In Figure 6 for example given the output signal of linear output of the pulse amplifier of neutrons and noise of corona discharge counters of SNM-11.

The waveforms show that the output signal consists of pulses of noise meter (noise corona discharge) and pulses from the interaction of the neutrons with atoms of boron-10. And in order for information to be reliable it is necessary to exclude the noise component. This is achieved by setting the discrimination threshold above the noise level.

In research of the sensitivity of the new detection unit was measured not only the counting parameters, the number of pulses per unit time, but also the noise parameters [10].

The results showed that the optimum combination of the parameters of the account-the noise has the DU with 5 counters. Because the values of the sensitivities of DU with 5-th and 7-th counters vary slightly, and for some values of the discrimination threshold is better, and the values of noise components in 7 counters make a significant contribution to the output signal. Thus, when the selected number of counters is 5, the working voltage at which the noise component does not influence the sensitivity of DU is 400 mV.

3.3. Sensitivity to gamma radiation

According to the requirements of TY and T3 at the NFME [6] for the detection unit should be resistant to background gamma radiation at the dose of $1.0 \cdot 10^2$ G $\cdot$ h^{-1}.

To comply with this requirement were conducted the tests.

The tests were carried out on the installation of the GUT 200M, RRC "Kurchatov Institute" under normal conditions in accordance with GOST 15150-69.

The position of the accommodation DU inside the irradiation chamber of the GUT selected according to the certificate of attestation in place with the power absorbed in the air dose rate of gamma radiation $> 10^2$ Gy $\cdot$ h^{-1}.

The test results are positive, DU is resistant to background gamma radiation at the dose of $1.0 \cdot 10^2$ G $\cdot$ h^{-1}, and meets the requirements of TY and T3, the background frequency of the pulses does not exceed 0.1 s^{-1}.

3.4. The influence of neutron fluence on the sensitivity of the

To assess the influence of neutron fluence on the sensitivity of the DU was developed, agreed and approved the program for the installation of a prototype DU in the channel IR № 12 unit № 4 of Novovoronezh NPP and test its performance [11].

The execution of work under this program is performed in two stages. Each of the stages is executed when reaching the corresponding conditions in the condition of the equipment and technological parameters DU.

The implementation of the first phase of the program was conducted after the refueling of the reactor, the output from the system control refueling (UPC) and prior to heating of the primary circuit.

The first phase of work included the installation of a DU channel IR № 12 at the center of the active zone, as well as on levels 1, 2, 3, 4, 5, 6 m from the center of the active zone, instead of the standard DU equipment NFI. On each level were measured the discriminatory features of the DU.

The measurements were carried out by varying the level of discrimination Uд from the values at which the contribution of pulses from the noise maximum, to values in which the noise characteristic does not affect to the DU.

The second phase of the program was conducted at the end of the neutron-physical measurements and start-up of the reactor.

The second stage included the same measurements at the same elevations, but the working reactor.

DU will be in the channel IR № 12 throughout the campaign, and disposed of in a separate program during the decommissioning unit 4 in 2017÷2018.

The second stage included periodic measurement of the sensitivity of the DU during operation of the reactor. At the moment, in the second stage, was performed 3 sub-stages.

Measurement of the first sub-stage was carried out at Nnom = 95%.

Second, third, fourth at Nnom = 100%.

Fifth at Nnom = 0%.

Dimension, each sub-stage was conducted by the same method as the measurement of the first stage.

The results of the measurements are presented in Figure 7.

Measurements of the second stage showed that the DU, after finding in the channel IR working reactor for 12 months, maintains their efficiency. I e the sensor is in good condition, since the slope of the discriminative curves on a running reactor, Nnom = 95% and Nnom = 100%, comparable with the slope of the discriminatory curves taken before the start of the reactor and in the laboratory.

To assess the change in the sensitivity DU on the working reactor is not possible, because of the uneven distribution of neutron flux at the reactor. The rating change can

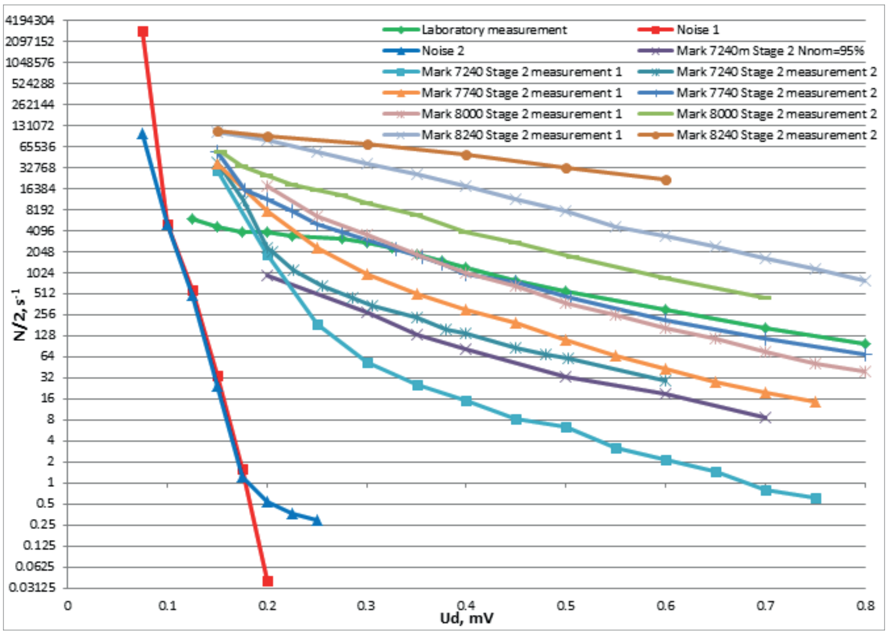

Figure 7: Comparison of sensitivity DU, step 1, 2.

be given after reactor shutdown. To make measurements, to remove discriminatory features, and to compare the values obtained at the beginning of the campaign.

Verification of the received data is carried out by comparing the experimental values with the values obtained by the sensor of control system overload in-core after reactor shutdown.

Also before starting the reactor and the beginning of a cycle endurance test, comparison of the testimony of unmovable database with the readings of in-core sensor of the control system overload. The sensors detectors are different, unmovable BU more sensitive, upgraded counters of SNM-11 and the sensors of the SKP coarser, designed for higher neutron fluxes. Indication DU SKP and unmovable BU was comparable.

4. The main parameters of the BU

A DU maintains its performance after exposure to IR under the influence of the neutron flux with a density of $4.0 \bullet 10^9$ $cm^{-2} \bullet s^{-1}$ and gamma-radiation with an intensity of $1.0 \bullet 10^3$ $G \bullet h^{-1}$ for 10 years.

The DU is operable under the influence of the ambient temperature from minus 50 to + 155 °C.

DU is stable for 24 h in the accident conditions at ambient temperature up to 250 °C.

DU is stable for 24 h in conditions of excessive pressure of 0.46 MPa at the location of the DU.

The DU provides control of the density of thermal neutron flux in the channels of ionization chambers in the range between 2.0 • 10^{-2} and 2.0 • 10^{3} cm^{-2} • s^{-1} at a power absorbed in the air dose-background gamma radiation at the location of the detection unit is not more than 1 G • h^{-1} (1,0 • 10^{2} R • h^{-1}).

Permissible basic relative error DU in the range of thermal neutron flux from 5 • 10^{-2} to 2.0 • 10^{3} cm^{-2} • s^{-1} not more than 25% at a confidence level 0,95 [12], [13], [14].

5. Conclusion

Shown in this work the calculations and measurements lead to the following conclusions:

- Confirmed the theoretical evaluation of the change in the sensitivity of DU under the action of neutron fluence.
- Endurance tests confirm the correctness of the choice of structural materials and construction in general;
- The results of endurance tests as well as mechanical and climatic test confirmed the thermal and radiation resistance unmovable DU;
- New unmovable detection unit matches to all necessary technical and operational requirements set in the technical task.

The author is grateful to I. V. Sokolov for the idea of writing this article.

The author thanks Konyshev N. V., Zaikin A. A., Lokantsev A. A., Bakharev S. A., Prokhorov Yu. B., Lobanov S. G., Grachev L. E. for providing materials and valuable advice, as well as other employees of JSC "SNIIP-SYSTEMATOM" for work in the preparation of the experiments.

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