# TRAINING OF NEW GENERATION SPECIALISTS

# IN THE FIELD OF FAST NEUTRON REACTORS

# AND NUCLEAR FUEL CYCLE CLOSURE

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**Abstract**

The role of fast nuclear reactors in the future power industry is discussed. The experience of implementing personnel training for the Proryv project area within the Department of Closed Nuclear Fuel Cycle Technologies of NRNU MEPhI is presented. The trends in the development of world nuclear education and the role of international cooperation in it are considered. Examples of innovative educational technologies used in the educational process of NRNU MEPhI and its branches are given.

## INTRODUCTION

Over the past decades, almost all experts have recognized the need to reduce greenhouse gas emissions generated by the energy activities of mankind. In 2015, the UN developed the Paris Climate Agreement, under which countries commit to limit annual greenhouse gas emissions to early 21st century levels, which requires the development of carbon-free power production. In 2020, the International Energy Agency published a report that presents a schedule for reducing carbon dioxide emissions to zero by 2050 [1]. This report predicts a significant increase in the power supply due to nuclear power, almost doubling between 2020 and 2050. What types of reactors will generate this power? What contribution will fast reactors make to nuclear power generation in 2050? Today, the spread of experts' assessments on such issues is very large, but they all agree that specialists are needed to implement any concept, and therefore personnel training for the nuclear industry should be carried out taking into account not only its current state, but also the prospects for its development.

The existing technologies for the production of electricity in thermal neutron nuclear reactors are not provided with fuel reserves that would allow the development of large-scale power generation. According to IAEA experts, the raw material reserves for thermal neutron nuclear power engineering operating in an open nuclear fuel cycle will last for 100-150 years with the existing growth rates of power generation [2]. Therefore, in order to switch to large-scale nuclear energy, provided with resources for thousands of years, humanity needs to switch to a closed nuclear fuel cycle and nuclear reactors with a fast neutron spectrum.

## THE NUCLEAR INDUSTRY OF RUSSIA AND PLANS FOR ITS DEVELOPMENT

The Russian nuclear industry includes the State Corporation “Rosatom”, the National Research Center Kurchatov Institute, specialized institutes of the Russian Academy of Sciences and leading technical universities that provide training in nuclear specialties.

The nuclear power industry of Russia ranks fourth in the world in terms of the number of operating power units of 38 units at 11 NPPs. At the same time, only in Russia at the moment two fast neutron power nuclear reactors (BN-600 and BN-800) are in operation. at 11 nuclear power plants

In 2018, Russia developed the Strategy for the Development of Nuclear Energy in Russia until 2050 and prospects for the period up to 2100, which was approved by the decision of the Presidium of the Scientific and Technical Council of the State Corporation “Rosatom” on December 26, 2018 [3]. Within the framework of this Strategy, principles are formulated for the formation of a two-component nuclear power industry, which will include both VVER thermal reactors and fast reactors operating in the closed nuclear fuel cycle mode. Since 2021, this strategy for the development of two-component nuclear energy technologies, including the Proryv project [4], has already been implemented in Russia as part of the Comprehensive Program "Development of equipment, technologies and scientific research in the field of the use of atomic power in the Russian Federation for the period up to 2024", in essence and in its form being a strategic project. As part of the Proryv project, construction has already begun at the site of the Siberian Chemical Combine (SChC) in the city of Seversk (Tomsk Region) of the Experimental Demonstration Energy Complex (ODEC). ODEC will include on the same site Fabrication/Refabrication Modules (start-up in 2024) and Nuclear Fuel Processing Modules (start-up in 2030), as well as an innovative lead-cooled fast reactor BREST-OD-300 (start-up in 2026). The first concrete at the base of the foundation slab of the BREST-OD-300 reactor was poured in June 2021, which marked the beginning of the main construction period and is reflected in the statistics of the IAEA power units under construction. Work on the construction of the ODEC is the first step in building a new generation of nuclear power, the principles of which are set out in the White Books of Nuclear Power [5, 6].

## TRAINING OF PERSONNEL FOR NUCLEAR POWER IN RUSSIA

The Association of Higher Educational Institutions “Consortium of Flagship Universities of the State Atomic Energy Corporation “Rosatom” (hereinafter referred to as the Consortium) is a voluntary association of Russian universities established in 2011 to coordinate their activities in the field of higher and postgraduate professional education, as well as in the field of scientific activities, in order to promote innovative development and technological modernization of the State Corporation “Rosatom”. In 2022, the consortium includes 18 leading technical universities in Russia, a list of which can be seen on the website of the Consortium [7]. The universities of the Consortium train more than 75% of graduates who are annually employed at the enterprises of the State Corporation “Rosatom”, the National Research Center Kurchatov Institute and specialized institutes of the Russian Academy of Sciences.

In order to carry out the current management of the activities of the Association in the period between the convocations of the General Meeting, a permanent collegial governing body was formed - the Council of the Association. The current management of the activities of the Association is carried out by the sole executive body - the Chairman of the Association, which is the rector of NRNU MEPhI ex officio.

General meetings and interaction between the participants led to successful cooperation in the following areas:

- Creation of joint olympiads, tournaments, career days, summer/winter schools, such as “Ya Professional”, “TEMP”, etc., in order to attract the most talented students to study at the universities of the Association and work in the nuclear industry;

- Creation of joint network educational programs that allow to combine unique competencies in various fields;

- Organization of internships for foreign students of the Association in the resource centers of NRNU MEPhI and providing access to the infrastructure of State Corporation “Rosatom”;

- Organization of internships for undergraduate and graduate students, as well as young scientists;

- Improving the qualifications of university staff;

- Preparation of a list of professional standards for employees of the nuclear industry;

- Participation in joint scientific projects to solve global challenges in the nuclear industry.

The National Research Nuclear University MEPhI (NRNU MEPhI) [8] is the leading university in Russia and the world in the field of nuclear technology. Since its founding in 1942, the university has been training specialists for the Russian nuclear industry in all innovative projects. In addition to the Moscow site, it has a large branch network, the institutes of which, as a rule, are located in the locations of the key enterprises of the Russian nuclear industry. One of the branches of NRNU MEPhI - the Seversk Technological Institute (STI) is located directly next to the ODEC construction site.

## PERSONNEL TRAINING FOR THE Proryv PROJECT

To train personnel for the Proryv project, in 2013, the Department of "Closed Nuclear Fuel Cycle Technologies" was established at the MEPhI, headed by one of the heads of the State Corporation “Rosatom”, V.A.Pershukov. In 2019, the Rosatom Technology Development Center was established on the basis of this department. The center implements master's programs in several profiles: Nuclear power technologies of the new generation, Engineering computer modeling and Codes of the new generation. The principles and educational approaches implemented at the Center and the specifics of personnel training for the Proryv project were presented at the FR-17 conference [9]. The main of these principles are: the active participation of industry specialists in the educational process, the network form of the implementation of educational programs, the research work of students and final qualification works are carried out on specific tasks of the project direction "Proryv", the use of modern educational technologies and the participation of students in specialized seminars and conferences. Since 2018, the master's program "Nuclear Power Technologies of the new generation" has also been implemented with STI with the participation of teachers of the Moscow site.

Training of engineers of a new generation should be based on new principles. Today it is not enough to be a specialist in a narrow field of neutronics, radiochemistry or materials science. CNFC technologies are an example of intersectoral synergy of various physical phenomena that require special training of engineers and researchers. The master's program "Nuclear Energy Technologies of the New Generation" applies the principles of interdisciplinary training and a practice-oriented approach to training specialists.

As an example of educational technologies used at the Center, one can cite the participation of students in independent testing of the codes of the Proryv project. The concept of independent testing was developed by the employees of the National Research Nuclear University MEPhI together with the specialists of JSC "Proryv" [10]. As part of research work and final qualification works, students participate in the development of computational test problems and calculations using new codes. The results of independent testing are used by code developers to improve them and correct inaccuracies in the code and its description.

Since 2019, students have the opportunity to choose courses in the learning process and participate in scientific seminars, which are included in all educational programs of the Center. Topics may be related to the student's scientific work, which he performs as part of the curriculum, or chosen by him at his own discretion. For example, students are invited to independently watch the webinars of the Generation IV international forum and discuss at the seminars the features of innovative reactor projects that are of interest to them. Depending on the topic of discussion, experts from various institutes of the nuclear industry are invited to the seminar.

## THE ROLE OF INTERNATIONAL COOPERATION FOR TRAINING SPECIALISTS FOR THE NUCLEAR POWER INDUSTRY OF THE FUTURE

For more than twenty years, NRNU MEPhI has been actively developing international cooperation and training foreign students in programs in the field of nuclear energy and nuclear technology. In general, foreign students study at NRNU MEPhI from countries where ROSATOM develops its business. These students study design and operation programs for Russian Design Pressurized Water Reactors (VVER) and nuclear research reactors.

To study the international experience of nuclear education in countries with developed nuclear power engineering, NRNU MEPhI participates in various international projects. NRNU MEPhI employees actively participate in IAEA projects related to the International Nuclear Information System (INIS), the Nuclear Knowledge Management Section (NKM), and the INPRO Section. NRNU MEPhI became the second university after the University of Manchester, where the master's program was certified by IAEA experts within the framework of the Academy of International Nuclear Management (INMA). NRNU MEPhI is a member of the European Nuclear Education Network (ENEN). Within the framework of the ENEN-RU project, an analysis of the educational programs of NRNU MEPhI and a number of European universities was carried out and a conclusion was made about the possibility of re-crediting credits, if necessary.

In 2016, NRNU MEPhI actively cooperates with the Nuclear Energy Agency NEA/OECD. As part of this cooperation, NRNU MEPhI masters and postgraduates undergo internships at the Agency, and university staff participate in working groups. It is no coincidence that NRNU MEPhI took an active part in organizing the Global Forum on Nuclear Education Science Technology and Policy. NEA CEO William D. Magwood IV has repeatedly noted the importance of engaging with the academic community: “In recent years, we have realized we need to be much broader in our deliberations. While we are a governmental framework, we also need to pull in the views of the private sector, social and civil society, and the biggest missing component: the academic community” [11].

Since 2020, foreign students who are interested in innovative nuclear energy projects have been recruited for the programs of the Rosatom Technology Development Center. These students are planned to be actively involved in international projects. Also, participation in international projects is especially important for students planning an academic career in the field of nuclear technology.

## CONCLUSIONS

The training of specialists for innovative projects in the nuclear industry is an important task, given the growing role of fast reactors in the future energy industry. Russia has accumulated experience in training specialists for the Proryv project. In order to train university teachers for programs in the field of innovative nuclear reactors, it is necessary to support international cooperation and interuniversity projects.

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