TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

APPROVED BY

Director of Nuclear Science & Engineering School
_____________ / Oleg Yu. Dolmatov
"25" 06 2020

Course Name: Control and Safety of Nuclear Reactor

Field of Study: Nuclear Science and Technology

Programme name: Nuclear Science and Technology

Specialization: Nuclear Power Engineering

Level of Study: Master Degree Programme

Year of admission: 2020

Semester, year: semester 3, year 2

ECTS: 4

Total Hours: 144

Contact Hours: 64

- **Lectures:** 32
- **Practical experience:** 32

Self-study: 80

Assessment: Exam

Division: Nuclear Fuel Cycle

Director of Programme _____________ / Vera V. Verkhoturova

Instructor _____________ / Mikhail S. Kuznetsov

_____________ / Artem Naymushin

TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Course name: Control and Safety of Nuclear Reactor

Course Overview

Course Objectives	The objective of the course is to develop students' theoretical knowledge and practical skills, which are necessary to conduct professional activity involving the usage of techniques of operation, regulation and control of nuclear steam generating installation, calculation and design of engineering details of radiation safety at nuclear reactors.
Learning Outcomes	**Upon completion of the course, a graduate will obtain the knowledge of:** – the basics of structuring a report and preparing presentations in a foreign language, accepted in the international environment; – the concepts of reactivity, reactor period, methods and methods for calculating the basic neutron-physical characteristics of the reactor, methods and programs for calculating the distribution of neutron flux density and energy release along the radius of the cell of the reactor, methods and methods for calculating the main neutron-physical characteristics of the reactor, methods and programs for calculating density distributions neutron flux throughout the reactor volume; – the features and potential danger of unsteady processes in nuclear reactors, the role of delayed neutrons, the concept of reactivity, internal feedbacks in the reactor, their stabilizing and destabilizing role, coefficients and effects of reactivity. **Upon completion of the course, graduates are also expected to develop the following skills to:** – perceive authentic audio and video materials related to training; – apply the laws of kinetics and dynamics of nuclear reactors to predict the occurrence of unsteady processes in nuclear installations, calculate reactivity; parameters, regulatory efficiency, interference effects; – apply the laws of kinetics to predict non-stationary processes in nuclear reactors, to calculate internal feedbacks in the reactor (temperature, power, density effects and reactivity coefficients). **Upon completion of the course, graduates should acquire the practical experience in**: – application of knowledge of a foreign language at a sufficient level in his future professional activities; – conducting neutron-physical calculations of the reactivity and energy parameters of a nuclear reactor, calculating the unevenness of energy release, processing the results of these calculations and experiments, interpreting the results in the framework of the studied laws; – performing calculations and measurements in nuclear physics facilities, skills in processing the results of these measurements, and experience in interpreting the results obtained within the framework of the studied laws.
Course Outline	**Section 1. NR operation Tasks. Kinetics of a nuclear reactor. (lectures – 14 hours, seminars – 16 hours, self-study – 25 hours)**

	Features of controlling a nuclear reactor. Management tasks. Physical effects in the formation of managerial influences. Management technology. Control and protection system, calculation of the effectiveness of control rods. Neutron detectors. Kinetics of the reactor. Energy parameters of a nuclear reactor. Point model of the kinetics of the reactor. Features of kinetics associated with delayed neutrons. Kinetics equations for a stationary reactor. Models with one and six groups of delayed neutrons. Snapshot approach. Kinetics of a subcritical reactor. Sources of neutrons. Start subcritical reactor. Installed in a subcritical reactor neutron density. Transient processes with changes in the degree of subcriticality of the reactor. The time of practical establishment of subcritical neutron density. Kinetics of a subcritical reactor. Nuclear safety regulations. Step start procedure. **Section 2. Safety Dynamics of a Nuclear Reactor (lectures – 6 hours, seminars – 8 hours, self-study – 25 hours)** The dynamics of the reactor. Feedbacks in a nuclear reactor. Effects and reactivity factors. Dynamics models and features of non-stationary processes in reactors in the presence of feedbacks. Xenon poisoning and spatial instability of the energy release field. Xenon vibrations. Shutdown and damping of a nuclear reactor. Change in reactivity with burnout. The relationship between burnup and fuel enrichment. Reactor and fuel campaigns. Compensation for excess reactivity. **Section 3. Fuel overload. Major Accident Experience (lectures – 6 hours, seminars – 4 hours, self-study – 15 hours)** Fuel overload in nuclear reactors. The physical basis for increasing the depth of burnout. Fuel overload efficiency. Fuel overload in nuclear reactors. Full overload. Continuous overload. Periodic overloads. Experience of major accidents at nuclear reactors. On the concept of internal (natural) safety of nuclear reactors **Section 4. NPP safety systems (lectures – 6 hours, seminars – 4 hours, self-study – 15 hours)** General requirements for ensuring the safety of nuclear power plants. Classification of safety barriers in accordance with international requirements. Security systems of the reactor compartment. Ensuring radiation safety of nuclear power plants. Safety systems of the NPP-2006 project.
Prerequisites (if available)	1. Reactor Physics. 2. Nuclear and Radiation Safety 3. Nuclear Physics. 4. Special chapters of Advanced Mathematics. 5. Materials of Nuclear Installations.
Course Structure	The target course consists of four sections. 1. Management tasks. Kinetics of a nuclear reactor. 2. The dynamics of a nuclear reactor in safety matters 3. Fuel overload. Major Accident Experience 4. NPP safety
Facilities and Equipment	1. Lecture hall with multimedia equipment: 634050, Tomsk, 2б, Lenina ave., building 10, room 432a. 2. Research nuclear reactor IRT-T TPU: classroom for practical experience and labs: 634050, Tomsk, 4 building 2, Kuzovlevskiy Trakt ave.

Grading Policy	In accordance with TPU assessment system we use: - Current assessment, which is performed on a regular basis during the semester by scoring the quality of mastering of theoretical material and the results of practical activities (lab completing, problem solving). Max score for current assessment is 80 scores, min – 56 scores. - Course final assessment (credit test) is performed at the end of the semester. Max score for course final assessment is 20 scores, min – 12 scores. The final score is determined by summing the scores of the current assessment during the semester and credit test scores at the end of the semester. Maximum overall score corresponds to 100 scores, min pass score is 68.
Course Policy	Testing. Undergraduate in accordance with the option gives answers in writing to tasks with a choice of answer. The event takes 30 minutes. Testing includes 10 questions with a choice of answer. Full performance of the test is estimated at 10 points. Evaluation of the results of the test is as follows: 1 point - the answer is correct; 0 points, the answer is incorrect. Colloquium. Master student in accordance with the option gives written answers to the questions posed. 60 minutes are allotted for the event. The colloquium includes 2 questions. The full answer to the question of the colloquium is estimated at 10 points. The maximum score for a colloquium is 20 points. Evaluation of the results of the colloquium issue is carried out according to the following scheme: 10 points - the answer to the question is given completely with all theoretical and mathematical justifications; 8 points - the answer is generally correct, but there are flaws; 6 points - the course of the answer is correct, but one or two errors were made that led to the wrong answer; 4 points - the answer is not presented in the work and incorrect theoretical calculations are given, but the formulas used and the course of the given part of the answer are correct; 2 points - an incorrect answer was received in the work related to a gross error reflecting a student's misunderstanding of the material read; 0 points - no answer. Problems solving. The undergraduate in accordance with the option gives written answers to the questions posed. The event takes 30 minutes. Examination includes 2 tasks. The complete solution of the control problem is estimated at 5 points. The maximum number of points for completing the test is 10 points. Evaluation of the results of the control work is carried out according to the following scheme: 5 points are set if the solution to the problem is correct and a rational solution is chosen; 4 points are set if the problem is solved basically correctly, but a slight mistake or a mistake is made; 3 points are given if the course of solving the problem is correct, but one or two errors were made that led to the wrong answer; 2 points are given if the answer is not received in the work and an incomplete solution of the problem is given, but the formulas used and the course of the given part of the solution are correct;

	1 point is given if the work received an incorrect answer related to a gross error reflecting a student's misunderstanding of the material read; 0 points are set if there is no solution to the problem. Exam. The undergraduate in accordance with the chosen option gives verbal answers to the questions posed in the ticket. The event takes 1.5 hours. Examination ticket includes 2 questions. Preparation time is 40 minutes. After preparation, the student verbally answers the teacher to the questions of the exam ticket. The teacher during the oral examination has the right to ask additional questions on the exam program, propose tasks for solving. The answer to each question is estimated at 10 points. The maximum number of points that a student can get in the exam is 20 points. Evaluation of each question of the exam ticket is carried out according to the following system: 10 points - demonstrates a complete understanding of the problem and gives a detailed answer; 8 points - demonstrates a significant understanding of the problem and gives an answer with shortcomings, requiring clarifying questions. 6 points - demonstrates a partial understanding of the problem. 4 points - demonstrates a superficial understanding of the problem. 2 points - demonstrates a misunderstanding of the problem. 0 points - no answer. Upon successful completion of intermediate certification, students receive a rating of "excellent", "good", "satisfactory" depending on the total points scored for the current and intermediate certification in accordance with the TPU assessment system.
Teaching Aids and Resources	**Compulsory reading**: 1. Marguet, S. The Physics of Nuclear Reactors / S. Marguet. — Cham : Springer International Publishing AG, 2017. — 1445 p. – Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-3-319-59560-3 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ. 2. Yoshiaki, O. Nuclear Reactor Design / O. Yoshiaki. - New York : Springer, 2014. - 337 p. - Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-4-431-54898-0 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ. 3. Oka Y. Nuclear Reactor Design / Y. Oka. – Tokyo : Springer, 2014. – 327 p. – Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-4-431-54898-0 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ. **Additional reading**: Shimjith, S. R. Modeling and control of a large nuclear reactor / S. R. Shimjith, A. P. Tiwari, B. Bandyopadhyay. – New York : Springer, 2010. – 327 p. - Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-3-642-30589-4 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ.
Instructors	1. Mikhail S. Kuznetsov, associate professor, Nuclear Fuel Cycle Division, School of Nuclear Science and Engineering, Tomsk Polytechnic University, tel.: +7 (3822) 701-777 ext.2330, e-mail: kms@tpu.ru, personal site: https://portal.tpu.ru/SHARED/k/KMS/eng

	2. Artem Naymushin, associate professor, Nuclear Fuel Cycle Division, School of Nuclear Science and Engineering, Tomsk Polytechnic University, tel.: +7 (3822) 701-777 ext.2258, e-mail: agn@tpu.ru, personal site: https://portal.tpu.ru/SHARED/a/AGN/eng