TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

APPROVED BY

Director of ~~Nuclear Science~~ & Engineering School

_____________ / Oleg Yu. Dolmatov

"25" 06 ____________ 2020

Course Name: Reactor Kinetics and Control

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

Department: Nuclear Fuel Cycle

Director of Programme	_____________	/ Vera V. Verkhoturova
Instructors	_____________	/ Dmitry G. Vidyaev
	_____________	/ Andrey D. Poberezhnikov

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Course name: Reactor Kinetics and Control

Course Overview

Course Objectives	The objective of the course is to develop knowledge and skills to perform professional activity in a variety of forms including research and technological activities in the fields related to nuclear power engineering.
Learning Outcomes	**Upon completion of the course, a graduate is expected to acquire the knowledge of:** – physics of transients in nuclear reactors; – basic laws of natural science disciplines; – basic structural solutions of units and elements of the core, reactor and reactor plant as a whole; – safety systems and analysis of the reliability of safety systems; – behavior of various nuclear reactor materials and nuclear power plants materials under the influence of ionizing radiation and complex temperature fields; – main characteristics of subcritical, critical and supercritical multiplying systems; – methods for determining the effectiveness of reactor control and safety systems; – methods for determining the operating state of the reactor according to the reactor instrumentation data obtained; – methods for determining the effectiveness of shim rods and control and protection systems; – methods of calibration of shim rods. **Graduates are also expected to develop the following skills:** – to calculate the basic physical characteristics of nuclear reactors; – to determine the critical characteristics (position, concentration, etc.) of the regulating bodies at any time during the operation of the reactor; – to calculate poisoning, slagging of the reactor, burning out and accumulation of fuel isotopes; – to apply methods of calculations accompanying the process of designing reactors; – to apply the acquired knowledge to determine the optimal combinations of core materials depending on the purpose and type of nuclear power plant, and also to argue the decisions taken; – to use the basic laws of natural science in professional work – classify nuclear reactor safety systems; – to analyze design decisions of the developed and created power installations; – to determine the state of the reactor (multiplying system) according to the testimony of the instrumentation; – to determine and use the differential and integral characteristics of reactor regulators;

	– to draw up a schedule for the physical start-up of the reactor and for the reactor to be output to the required power level; – to analyze the fast and slow neutron-physical processes in the reactor; – to participate in the discussion of topics related to the specialty; – to prepare oral presentations on professional topics using multimedia technologies. **Upon completion of the course, a graduate will have experience in:** – drawing up regulations for the physical start-up of the reactor and for the reactor power raising; – calculating reactor reactivity as a result of poisoning, slagging, burnout, reproduction, temperature effects of nuclear fuel; – designing under conditions when there are is standard operating time; – making analysis of the safety of existing nuclear power plants; – solving direct and inverse problems of reactor control; – calculating efficiency and layout of the reactor control and protection system; – starting-up and controlling the parameters of a research nuclear reactor; – controlling the parameters of the neutron field when moving the moving regulating bodies; – calculating the efficiency and layout of the reactor control and protection system; – writing messages, articles, theses and reports, abstracts on professional; – using professional terminology to communicate ideas and information related to the professional context.
Course Outline	Within the framework of the course, students study the following sections: **Section 1. Physical bases of reactor control** Problem solving is devoted to obtaining practical skills on the following topic: Subcritical state of VVER-1000 reactor **Section 2. Transient and steady-state processes in nuclear reactor** Problem solving is devoted to obtaining practical skills on the following topics: – Determination of effects and coefficient of reactivity. – Measuring the reactivity of the VVER-1000 reactor by the asymptotic period method. **Section 3. Reactor control and regulation** Problem solving is devoted to obtaining practical skills on the following topic: Measurement of characteristics of the VVER-1000 reactor control system.
Prerequisites (if available)	1. Dosimetry and Protection from Ionizing Radiation. 2. Nuclear Physics. 3. Special chapters of Advanced Mathematics. 4. Materials of Nuclear Installations.
Course Structure	The target course consists of three sections. **Section 1. Physical basics of reactor control (8 hours - lectures, 8 hours - seminars, 20 hours - self-study)** Neutron field and its characteristics. Neutron multiplication factors. Critical and subcritical reactor. The concept of neutron generation. Reactivity and units of reactivity measurement (2 hours - lectures, 2 hours - seminars, 5 hours - self-study).

	Kinetics of a nuclear reactor. Elementary equation of kinetics. Reactor period. Delayed neutrons. Photoneutrons. The average lifetime of a neutron in a reactor. (4 hours - lectures, 4 hours- seminars, 10 hours - self-study). Sources of neutrons in a subcritical reactor. The neutron density in subcritical reactor. Equations of kinetics with delayed neutrons. Solution of the equations of kinetics. (2 hours - lectures, 2 hours - seminars, 5 hours - self-study). **Section 2. Transient and steady-state processes in nuclear reactor (16 hours - lectures, 16 hours- seminars, 40 hours - self-study)** Transient processes with changes in the subcriticality of the reactor. Analysis of transient processes with positive and negative jumps of reactivity. Criticality on delayed neutrons. (4 hours - lectures, 4 hours - seminars, 10 hours - self-study). A reduction of reactivity margin from poisoning of nuclear reactor. Quantitative measures of reactor poisoning. Change in reactivity of poisoning. (2 hours - lectures, 2 hours - seminars, 5 hours - self-study). Reproduction of nuclear fuel. System of differential equations for the reproduction of plutonium-239. Increase in the reactivity reserve for fuel reproduction. Reproduction ratio. Accumulation of actinides in the reactor. (2 hours - lectures, 2 hours - seminars, 5 hours - self-study). Poisoning of the reactor by xenon-135. Scheme of formation and loss of xenon-135. Stationary and non-stationary poisoning. The effect of poisoning on reactivity. Re-poisoning of the reactor by xenon after shutdown. Calculation of reactivity change due to reactor poisoning with xenon-135. Spatial effects associated with poisoning. (4 hours - lectures, 4 hours - seminars, 10 hours - self-study). Poisoning of the reactor by samirium-149. Scheme of formation and decrease in poisoning of the reactor by samarium-149. Stationary and non-stationary poisoning. Loss of reactivity in poisoning with samarium-149. Non-stationary poisoning by samarium after a shutdown. (2 hours - lectures, 2 hours - seminars, 5 hours - self-study). Temperature effect of reactivity. The components of the temperature effect of reactivity. The concept of stability of the reactor at power. Power reactivity effect. (2 hours - lectures, 2 hours - seminars, 5 hours - self-study). **Section 3. Reactor control and regulation (8 hours - lectures, 8 hours - seminars, 20 hours - self-study)** Neutrons absorbers in nuclear reactors. Absorption rods. Behavior of neutron absorbing material when rods are introduced into the core. The effective radius of the absorber rod. (2 hours - lectures, 2 hours - seminars, 5 hours - self-study). Total and operational reactivity margin. The curve of energy production. Use of burnable absorbers. (2 hours - lectures, 2 hours - seminars, 5 hours - self-study). Characteristics of burnable absorbers. Dependence of changes in reactivity margin on different burnable absorbers and methods of their placement. (2 hours - lectures, 2 hours - seminars, 5 hours - self-study). Self-regulation of nuclear reactors. The physical conditions of the reactor stability. Spatial stability. Safety of nuclear reactors. (2 hours - lectures, 2 hours - seminars, 5 hours - self-study).
Facilities and Equipment	1. Lecture hall with multimedia equipment: Tomsk, Lenin ave. 2, build. 10, room 313. 2. Lecture hall with multimedia equipment: Tomsk, Lenin ave. 2, build. 10, room 340. 3. Lecture hall with multimedia equipment: Tomsk, Lenin ave. 2, build. 10, room 431.

Grading Policy	In accordance with TPU rating 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 (problem-solving activities, tests, presentation reports). Max score for current assessment is 80, min – 56. – Course final assessment (exam) is performed at the end of the semester. Max score for the course final assessment is 20, min – 12. 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, min pass score is 68.
Course Policy	Current assessment involves defense of reports based on problem-solving activity, slide deck and tests. The course provides for the solution of four tests. Tests are solved in practical classes: it is necessary to solve 5 tasks and each solved task is estimated at 3 scores. The maximum score is 15. Mastering the course provides for the solution of one problem-solving activity. Each student receives a detailed assignment and control questions. Report on problem-solving activity should be presented in paper and protected at the conference week. The maximum score is 10. Criteria for evaluation are: completeness and integrity of the given material (4 scores); the worked out structure of the report and its compliance with TPU guidelines (2 scores); responses to the questions (4 scores). The performance of slide deck takes place at a conference week in front of the group. The report takes 10 minutes and then a student answers the questions of the audience. The maximum score is 10. Criteria for evaluation are: material integrity, compliance of the developed presentation with the chosen topic and TPU guidelines (4 scores); logically structured and tested report structure, completeness of the topic disclosure (4 scores); responses to the questions (2 scores). Final assessment is carried out orally using an exam paper. Each exam paper includes two questions or tasks and one problem. Time for answer preparation is 45 minutes. Each answer to a theoretical question is estimated at 5 scores, the solved problem gives 10 scores. Maximum score is 20.
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%2F978-3-319-59560-3 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ. 2. Basdevant J.-L. Fundamentals in Nuclear Physics / J.-L. Basdevant, M. Spiro, J. Rich. – New York: Springer Science, 2005. – 515 p. – Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/b106774 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ. **Additional reading:** 1. Воробьева, И. А. Nuclear reactor types (learn to read by reading) : учебное пособие / И. А. Воробьева, С. Н. Смирнова. – Москва : НИЯУ МИФИ, 2010. – 268 с. – ISBN 978-2-7262-1282-1. – Текст : электронный // Лань : электронно-библиотечная система. – URL: https://e.lanbook.com/book/76014 (дата обращения: 15.04.2020). – Режим

	доступа: для авториз. пользователей. 2. Годовых А. В. Актуальные проблемы ядерной безопасности = Current ussues of nuclear security. Student's book : книга для студента : учебное пособие / А. В. Годовых, Ю. В. Фалькович, Н. А. Шепотенко. – Томск : Изд-во ТПУ, 2014. – URL: http://www.lib.tpu.ru/fulltext2/m/2015/m235.pdf (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ. – Текст : электронный.
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