TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

APPROVED BY

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

Course Name: Design, Maintenance and Engineering of Nuclear Power Plants

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: 3

Total Hours: 108

Contact Hours: 48

- **Lectures:** 24
- **Labs:** 16
- **Practical experience:** 8

Self-study: 60

Assessment: Exam

Division: Nuclear-Fuel Cycle

Director of Programme _____ / Vera V. Verkhoturova

Instructor _____ / Konstantin V. Slyusarskiy

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Course name: Design, Maintenance and Engineering of Nuclear Power Plants

Course Overview

Course Objectives	The objective of mastering the discipline is the formation of certain set of student's competence to prepare them for professional activities. Current course is aimed to form a following competences: 1. Able to run the project on different stages of its life cycle. 2. Able to apply modern communication technology for academic and professional interactions including those on foreign language. 3. Able to formulate goal and objectives of research, chose evaluation criteria, prioritize solution of tasks. 4. Able to manage the personnel considering behavior motives and methods of personnel professional behavior development, apply methods for evaluation of quality and results of personnel work, develop and implement means of prophylaxis and prevention of industrial injuries, prevention of ecological failures. 5. Able to analyze technical and calculation-theoretical solutions, consider their accordance to requirements of law in field of industry, ecology, safety and other normative acts.
Learning Outcomes	Upon completion of the course, a graduate **will obtain the knowledge of:** – the stages of the project life cycle; – the stages of project development and implementation; – the features of professional etiquette of western and domestic cultures; – the basics of structuring a report and preparing presentations using foreign language, accepted in the international environmentж – the goals and objectives of scientific research in the field of professional activity, basic principles and methods of their organization; – the technical conditions, standards for installation, repair, adjustment, testing of equipment assigned to NPP units; – the rules for assessing the compatibility of equipment, components, materials and semi-finished products supplied to nuclear facilities; – the main directions of creating fundamentally new nuclear reactors and power plants that meet modern safety and environmental requirements. Upon completion of the course, graduates are also expected to develop the following **skills:** – to develop a project taking into account the analysis of alternative options for its implementation, determine the target stages, the main directions of work; – to explain goals and formulate tasks related to the preparation and implementation of the project, determine the main stages and directions of work; – to compile and present technical and scientific information used in professional activities in the form of a presentation; – to perceive authentic audio and video materials related to training direction; – to compose a general plan of work on a given topic, suggest research methods

	and methods of result processing; – to apply optimization methods for planning working hours, consumption of materials, energy and fuel; – to determine the degree of influence of identified defects on the technical condition of the equipment of the owner unit; – to apply methods of simulation, calculation and experimental research in the field of the development of new nuclear reactors and power plants; – to analyze the design decisions of the existing and developing power plants; – to calculate the basic physical characteristics of nuclear reactors; – to compose technical documentation (work schedules, instructions, plans, estimates, requests for materials, equipment, operating instructions); – to perform an approximate or evaluation engineering calculation of equipment, station indicators; – to apply methods of engineering calculations of processes in nuclear reactors and power plants. Upon completion of the course, graduates should acquire **the practical experience in**: – applying methods of development and project management; – applying methods for assessing resource requirements and project effectiveness; – applying skills of monologue speech in a foreign language according to the profile of specialty, reasonably expressing his position and using auxiliary means (tables, graphs, charts, etc.); – applying acquired knowledge of a foreign language at a sufficient level in his future professional activities; – applying systematic knowledge in the field of future professional activity; – applying in-depth knowledge on the chosen direction of training, basic skills for conducting research on the proposed topic; – performing engineering calculations for the main types of professional tasks; – safety analysis of existing nuclear power plants; – conducting thermohydraulic calculation of reactors and other technological equipment using modern methods; – drawing schemes, graphs, drawings, diagrams, nomograms and other professionally significant images; – using his knowledge to solve specific problems, for comparative assessments in situational circumstances and when making alternative decisions; – calculating the effectiveness and layout of the control system and reactor protection..
Course Outline	The target course is taught using a variety of teaching forms such as: – 12 lectures; – 8 labs; – 4 practical experiences; – 4 individual homework assignments; – 8 lab reports. The course consists of 12 sections, which are indicated below. Section 1. Introduction Section 2. Indicators of thermal and overall efficiency of nuclear power plants Section 3. The parameters of the coolant and working fluid in nuclear power

	plants Section 4. NPP Schemes Section 5. Feeding Installations Section 6. NPP condensation units Section 7. Parameters and schemes of external steam separation and intermediate overheating at nuclear power plants Section 8. Deaeration plants. Section 9. Parameters and equipment of the system of regenerative feedwater heating Section 10. Main reactor circuit and its auxiliary systems Section 11. Pipelines and NPP fittings Section 12. NPP General Plan. The layout of the main building. Each section includes several lectures and practical experiences. The course ends with an ecamination. *Learners' self-study* is arranged in a form of individual homework assignments and individual research of the topics. During the course of study, learners are expected to complete 4 individual homework assignments. *Individual homework assignment* is a set of tasks each containing unique set parameters. It is obligatory for each student to present the results of individual homework assignment completion in a form of a report. The report must have a title page, initial data, task solution, conclusions, and final statement. The report must be defended in class. This suggests students answering from 3 to 5 questions related to the topic of the assignment. *Lab* is performed in groups of 2-3 students. Each group receive their individual set of data. The results of lab performance must be presented in a report. The report must have a title page, initial data, description of solution methods, solution, conclusions, and final statement. The report must be defended in a class by the group. This suggests each student within a group answering up to 3 questions related to the topic of the assignment.
Course Structure	The content of the course covers 12 topics. Each topic is studied through lectures, practical experiences and labs. **Section 1. Introduction** Content and course construction. Recommended literature. Nuclear energy, its role and development prospects in the energy sector of the world. Types and classification of nuclear power plants. Simplified diagrams of the main types of nuclear power plants (NPP): with pressurized water reactors (PWR and WWER), fast reactors (BN), with channel water-graphite reactors (RBMK); nuclear combined heat and power plant (CHPP) and heating nuclear plant (HNP). The main requirements for nuclear power plants: cost-effectiveness, safety, reliability, environmental friendliness. **Lecture topic:** 1. Introduction, content and structure of the course. Types and characteristic features of modern NPPs. Basic requirements for modern NPPs. **Section 2. Indicators of thermal and overall efficiency of nuclear power plants** Indicators of thermal efficiency of turbine installation and NPP power unit. The energy balance of nuclear power plants. Features of determining the indicators of thermal efficiency of a nuclear power plant during combined supply of electricity and heat. Indicators of the overall efficiency of nuclear power plants.

	Lecture topic: 2. NPP efficiency indicators. Energy balance of NPPs. Features of determining the indicators of efficiency of NPP with and without heat release. **Lab topic:** 1. Study of the composition of the main equipment of the turbine site of nuclear power plants. **Practice topic:** 1. Determination of NPP efficiency indicators in the condensation and cogeneration mode. **Section 3. The parameters of the coolant and working fluid in nuclear power plants** The influence of the initial parameters of steam on the thermal efficiency of nuclear power plants and on technical and economic indicators. Selection and justification of the initial parameters of the working fluid and the coolant at nuclear power plants of various types. Selection and justification of the final parameters of steam in nuclear power plants. **Lecture topic:** 3. The influence of initial and final parameters on the efficiency of NPP. Justification of the choice of values of the corresponding parameters for various types of NPP. **Section 4. NPP Schemes** Technological and thermal schemes. The principal thermal scheme (PTS) of nuclear power plants. Content of PTS. Examples of PTS of standard nuclear power plants. Methods and objectives of calculating the PTS. Features of turbine units of saturated steam at nuclear power plants. Examples of full thermal schemes of NPP power units. **Lecture topic:** 4. Technological schemes of modern NPP: classification, content, features. Principles of building a thermal scheme of NPP. **Lab topic:** 2. Study of the principal thermal scheme of NPP. **Section 5. Feeding Installations** Feedwater pump installations. Types of pump groups (one and two lift schemes). Booster pumps. Types of drive of feed pumps. Circuits for driving turbines. NPP pumps. Classification, device and principle of operation. Pump-less movement: the concept and patterns of the bubbling process. Steam distribution perforated sheets: design, characteristics, working conditions. The concept of the contour of the natural circulation (CNC). Driving head along the contour of the natural circulation and its determining factors. The sequence of calculation of the CNC. **Lecture topic:** 5. Feeding pumping units: purpose, device, principle of operation. Features of injection equipment of NPP. Head-less movement: concept, implementation principle, application at NPP. The circuit of natural circulation. **Lab topic:** 3. Study of the design of feeding and condensation pumps. 4. Study of the design of the main circulation pump. **Section 6. NPP condensation units** Condensation units of NPP: purpose, principle of operation, design and features. Factors determining the vacuum in the condenser (cooling water temperature,

	vacuum in the condenser etc.). Ways of non-condensable gases into the condenser and methods of removing the vapor-air mixture. Ejector installations: purpose, composition and schemes including start-up and main ejectors. The design of the ejectors. **Lecture topic:** 6. Condensation units. Design and principle of operation. Features of the calculation of condensers. Conditions for safe and efficient operation of condensers. **Practice topic:** 2. Determination of the optimal pressure in the condenser of an NPP. **Section 7. Parameters and schemes of external steam separation and intermediate overheating at nuclear power plants** The purpose of intermediate steam superheating. Types of intermediate steam overheating at nuclear power plants. The inclusion of separation and intermediate heating in the scheme of nuclear power plants. Optimum values of pressure and temperature of an intermediate overheating. Types and arrangement of separators and superheaters. Features of nuclear power plant separators. **Lecture topic:** 7. Intermediate steam overheating at NPPs: purpose, principle of operation, features. Devices for separation and intermediate overheating at NPPs with reactors of different kinds. **Section 8. Deaeration plants.** Necessity of deaeration. Routes of gases in the tubes of nuclear power plants. Methods of gas removal from feed water. The physical basis of thermal deaeration, the factors determining its effectiveness. Classification of thermal deaerators. The composition of the deaerated feedwater unit (DFU). The inclusion of thermal deaerators feed water in the thermal scheme of nuclear power plants. Constructive execution of the DFU. Placement of feedwater deaerators in the building of nuclear power plants. **Lecture topics:** 8. Deaeration: definition, necessity, implementation methods. Design and features of NPP deaerators, their classification and principle of operation. Control test. **Practice topic:** 3. Determination of the optimal selection pressure for powering the NPP deaerator. **Section 9. Parameters and equipment of the system of regenerative feedwater heating** Influence of feedwater temperature on the efficiency of the power unit. Schemes for the inclusion of surface and mixing regenerative heaters. The use of drainage coolers. Block diagrams of high and low pressure channels Surface and mixing regenerative heater designs. **Lecture topics:** 9. Regeneration: definition, necessity, implementation methods. Design and features of regenerative heaters of NPP, their classification and principle of operation. The basics of choosing the amount and calculation of regenerative heaters. **Practice topic:** 4. Calculation of the parameters of the regenerative heating system of NPP. **Section 10. Main reactor circuit and its auxiliary systems** Process flow diagram of the primary circuit using the WWER-1000 as an

	example. Pressure compensation system. Technological systems associated with the primary WWER circuit. The system of purging, feeding and boron regulation of the primary circuit of nuclear power plants with WWER reactors, subsystems. The system of organized leaks. System of industrial circuit. System of high-temperature cleaning coolant. System SGC-2. Reactor systems for nuclear power plants with RBMK and BN. **Lecture topic:** 10. Schematic diagram of the primary circuit on the example of WWER-1000. Pressure compensation system. Technological systems associated with the first circuit of WWER. A system of organized leaks. Industrial circuit system. The system of high-temperature cleaning of the coolant. **Lab topic:** 5. Studying the special gas cleaning system. 6. Study of systems and layout solutions of the WWER reactor compartment. 7. Study of the systems and layout solutions of the BN reactor compartment. **Section 11. Pipelines and NPP fittings** Classification of plant pipelines. Materials of pipelines at NPP. Fastened pipelines. Thermal insulation of pipelines. Fitting classification by purpose and parameters. Construction of shut-off, control and safety valves. Purpose and schemes for the inclusion of reduction and reduction-cooling installations. **Lecture topic:** 11. Classification of station pipelines. Thermal insulation of pipelines. Classification of valves according to their purpose and parameters. The device of locking, regulating and safety valves. Appointment and schemes of inclusion of reduction and reduction and cooling units (RU, FRU, RCU, FRCU). **Lab topics:** 8. The study of the effect of bleed on the efficiency of the turbine drive. **Section 12. NPP General Plan. The layout of the main building.** Selection of NPP site. Requirements for sites. NPP master plan. Indicators of layouts and general layout of nuclear power plants. Requirements for the layout of the main building. Types of NPP layouts. General principles of the layout of the main building. The layout of the equipment of the reactor and turbine departments, deaerator department. **Lecture topic:** 12. General plan and layout of NPP: reactor and turbine sections, auxiliary workshops of the station. The basic principles of the layout of the equipment of NPP. Control test.
Facilities and Equipment	1. Lecture hall with multimedia equipment: Tomsk, Lenin ave. 30a, building 4, room 301. 2. Computer classroom: Tomsk, Lenin ave. 30a, building 4, room 31.
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 (control tests, defense of individual task and lab reports). Max score for current assessment is 80 points, min – 44 points. – Course final assessment (exam) is performed at the end of the semester. Max score for course final assessment is 20 points, min – 11 points. The final rating is determined by summing the points of the current assessment during the semester and credit test scores at the end of the semester. Maximum

	overall rating corresponds to 100 points, min pass score is 55.
Course Policy	Attendance is strictly controlled. All classes are obligatory for attendance.
Teaching Aids and Resources	**Compulsory reading:** 1. Breeze, P. Combined Heat and Power [Электронный ресурс] / P. Breeze. — Электрон. дан. — Elsevier Ltd.: Academic press, 2018. — 95 p. — Режим доступа: https://ezproxy.ha.tpu.ru:2056/book/9780128129081/combined-heat-and-power. — Загл. с экрана. **Additional reading:** 1. Structural Materials for Generation IV Nuclear Reactors [Электронный ресурс] / edited by Pascal Yvon. - Электрон. дан. — Elsevier Ltd.: Woodhead Publishing, 2017. -664 p. - Режим доступа: https://www.sciencedirect.com/book/9780081001493/handbook-of-generation-iv-nuclear-reactors. - Загл. с экрана.
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