TOMSK POLYTECHNIC UNIVERSITY | ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

APPROVED BY

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

Course Name: Steam Generators for Nuclear Power Plants

Field of Study: Nuclear Physics and Technologies

Programme name: Nuclear Science and Technology

Specialization: Nuclear Power Engineering

Level of Study: Master Degree Programme

Year of admission: 2019

Semester, year: semester 2, year 1

ECTS: 3

Total Hours: 108

Contact Hours: 48

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

Self-study: 60

Assessment: Credit-test

Division: Nuclear Fuel Cycle

Director of Programme _____ / Vera V. Verkhoturova

Instructors _____ / Konstantin V. Slyusarskiy

_____ / Evgeniya G. Orlova

TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Course name: Steam Generators for 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. Ability to apply modern communication technologies, including in a foreign language, for academic and professional interaction. 2. Ability to formulate research goals and objectives, select assessment criteria, identify priorities for solving problems. 3. Ability to develop and ensure the implementation of measures to improve, modernize, unify the manufactured devices and installations and their elements, develop draft standards and certificates, improve the reliability of equipment. 4. Ability to assess risks and determine safety measures for new installations and technologies, compile and analyze scenarios of potential accidents, develop methods to reduce the risk of their occurrence. 5. Ability to formulate technical specifications, use information technology, standard design automation tools and application packages for the design and calculation of physical installations, materials and devices, use the knowledge of methods for analyzing environmental and economic efficiency for the design and implementation of projects.
Learning Outcomes	**Upon completion of the course, a graduate will obtain the knowledge of:** – the features of professional etiquette of Western and domestic cultures; – the basics of structuring a report and preparing presentations in a foreign language, accepted in the international environment; – methods for analyzing the technical condition of equipment in a reactor compartment of a nuclear power plant; – the permissible deviations of the parameters of equipment, pipelines, technological schemes included in the service area of a nuclear power plant; – the basic technological schemes of the reactor compartment of a nuclear power plant; – the location, purpose and coverage areas of the main and auxiliary equipment, pipelines and technological systems of the reactor compartment of nuclear power plants; – the requirements for the coolant and methods of maintaining the water-chemical regime; – the technology for the production of electric and thermal energy at a nuclear power plant; – the design features and technical characteristics of equipment and technological systems of nuclear power plants; – materials used in structures and their operational properties; – the basics of nuclear reactor physics, heat engineering and water treatment.

	Upon completion of the course, graduates are also expected to develop the following skills: – 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; – to build a general plan of work on a given topic, suggest research methods and methods of processing the results; – to determine the degree of influence of identified defects on the technical condition of the equipment of a nuclear power plant; – to record and analyze data on changes in parameters and the results of inspections, approbations, tests of serviced equipment of a nuclear power plant; – to analyze and control the technical condition of serviced equipment; – to analyze and control the permissible values of various parameters and safety measures that guarantee the safe operation of equipment and the conduct technological processes; – to assess the risks associated with the safe operation of technical equipment, equipment, devices and mechanisms of the reactor compartment; – to analyze technical and economic performance indicators of operating units of a nuclear power plant; – to develop technical documentation for the design and repair of nuclear power plant equipment. **Upon completion of the course, graduates should acquire the practical experience in:** – applying monologue utterance in a foreign language according to the profile of specialty, reasonably expounding 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 direction of future professional activity; – conducting preventive testing of equipment of the reactor compartment of a nuclear power plant; – performing engineering calculations and certification assessments of the state of equipment of a nuclear power plant; – analyzing the results of post-repair inspection of nuclear facilities; – calculating reactor power using the heat balance method; – identifying the dominant factors of degradation and damage to equipment; – developing technical documentation for the operation of nuclear power units in the field of responsibility.
Course Outline	The target course is taught using a variety of teaching forms such as: – 8 lectures; – 8 labs; – 8 practical experiences; – 6 individual homework assignments; – 1 review; – 6 lab reports.

	The course consists of 8 sections, which are given below. Section 1. Introduction Section 2. The place of the steam generator in the thermal scheme of NPP Section 3. Heat carriers and working fluids of steam generators of NPP Section 4. Design and heat engineering schemes of steam generators Section 5. Hydrodynamic processes in steam generators of NPP Section 6. Temperature conditions of heat transfer surfaces of NPP steam generators Section 7. Steam separation Section 8. Water regime of NPP steam generators Each section includes several lectures and practical experiences. The course ends with a credit test. *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 7 individual homework assignments and one review performed in small groups. *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 a class. This suggests students answering from 3 to 5 questions related to the topic of the assignment. *Review* is performed in groups of 2-3 students. Each group receive their individual topic, which must be thoroughly researched. The results of the research work must be presented in a review, which is accompanied by a multimedia presentation. Review must include the literature overview on the given topic and have the following parts: a title page, outline, introduction, main body sections, conclusion and reference list.
Course Structure	The content of the course covers 11 topics. Each topic is studied through lectures, practical experiences and labs. **Section 1. Introduction** Course subject and objectives. Problems of the development of world nuclear energy. The current state and prospects for the development of nuclear power plants in Russia. **Lecture topics:** 1. Introduction. Course structure. Recommended Reading. Problems of the development of world nuclear energy. **Section 2. The place of the steam generator in the thermal scheme of nuclear power plants** Schemes of steam production at nuclear power plants. General concepts of a steam generator. Steam generator requirements. General characteristics of the steam generators. Classification of steam generators. **Lecture topics:** 2. The place of the steam generator in the thermal scheme of nuclear power plants. Classification of NPP steam generators. **Practice topics:** 1. Heat balance and tQ - diagram of a direct-flow steam generator of nuclear power plants. 2. Heat balance and tQ - diagram of a steam generator of a nuclear power plant

	with natural circulation. **Lab topic:** 1. The influence of the parameters of the coolant on the characteristics of the once-through steam generator and the station as a whole. Thermal balance tQ - diagram of a steam generator of a nuclear power plant. 2. The influence of the parameters of the coolant on the characteristics of the steam generator with natural circulation and the station as a whole. Thermal balance TQ - diagram of a steam generator of a nuclear power plant. **Section 3. Heat carriers and working fluids of steam generators of nuclear power plants** Comparative characteristics, advantages and disadvantages of the main types of coolants and working fluids (water, liquid metals, gases). Promising types of coolants (lead). **Lecture topics:** 3. Heat carriers and working fluids of steam generators of nuclear power plants. **Practice topics:** 3. Determination of the parameters of the coolant and the working fluid in the characteristic elements of the steam generator. **Section 4. Design and heat engineering schemes of steam generators** Steam generators heated by water under pressure: steam generator parameters, basic principles for choosing a design scheme. Steam generators heated by liquid metal coolants (LMF): steam generator parameters, design features. Steam generators heated by gas coolants: parameters, design schemes. Comparative advantages and disadvantages of steam generators heated by various coolants. **Lecture topics:** 4. Thermotechnical schemes and structural schemes of steam generators of nuclear power plants. Control test. **Lab topics:** 3. The study of the design of the steam generator of power unit WWER-1000. 4. The study of the design of once-through steam generator of power units BN-600, BN-800. **Section 5. Hydrodynamic processes in steam generators of nuclear power plants** The main laws of hydrodynamics and methods for calculating hydraulic resistance during the movement of a single-phase flow. Hydrodynamics of two-phase flows: flow regimes, flow rates and true characteristics of a two-phase medium. Methods for calculating the hydraulic resistance during the movement of a two-phase medium. **Lecture topics:** 5. Hydrodynamic processes in steam generators of nuclear power plants. Methods for calculating the hydraulic resistance during the movement of a two-phase medium. **Practice topics:** 4. Calculation of pressure losses in a single-phase flow. 5. Calculation of friction pressure loss in a two-phase flow. **Lab topic:** 5. The study of the hydraulic resistance of the surface heat exchanger.

	6. The study of the static stability of the steam-generating channel. **Section 6. Temperature regime of heat transfer surfaces of nuclear power plant steam generators** Heat transfer during the movement of single-phase non-metallic (water, gas) coolants: during fluid flow in pipes, during flow around pipe bundles. Features of heat transfer in heating surfaces of steam generators with liquid metal coolants (sodium, potassium, lead). Heat transfer during boiling water movement. Heat transfer crisis at boiling. Types of crises (1st and 2nd kind) and methods for assessing the conditions of their occurrence. **Lecture topics:** 6. Heat transfer during the movement of single and two-phase coolants. **Practice topics:** 6. Calculation of heat transfer during boiling. Mechanical calculations of steam generator elements. **Section 7. Steam separation** Requirements for the quality of steam in nuclear power plants. Causes of steam pollution: the transition of impurities from water to steam, mechanical entrainment of impurities and entrainment due to the solubility of substances in the vapor. Methods for producing pure steam. Factors affecting steam humidity. Steam separation: in free volume, in internal case separation devices. Design features. **Lecture topics:** 7. Requirements for the quality of steam in nuclear power plants. Methods for producing pure steam. Factors affecting steam humidity. Steam separation: in free volume, in intra-drum separation devices. **Practice topics:** 7. Calculation of separation in steam generators with saturated steam. **Lab topics:** 7. Investigation of the influence of steam space parameters on the efficiency of the separation process. **Section 8. Water regime of steam generators of nuclear power plants** Corrosion and water regime of steam generators of nuclear power plants. Requirements for steam generator and feed water. Composition of steam generating water: deposits of water impurities, volatile and non-volatile compounds. Water regime of steam generators with natural and multiple forced circulation. Features of the water regime of once-through steam generators. **Lecture topic:** 8. Corrosion and requirements for steam and feed water. Water regime of steam generators with various and multiple forced circulation. Features of the water regime of once-through steam generators. Control test. **Practice topic:** 8. Calculation of purge in steam saturated steam. **Lab topic:** 8. Organization of coolant circulation in steam generators of nuclear power plants.
Facilities and Equipment	1. Lecture Hall with multimedia equipment: Tomsk, Lenin ave. 30a, build. 4, room 302. 2. Computer classroom: Tomsk, Lenin ave. 30a, build. 4, rooms 31, 101a. 3. Physical modelling laboratory which includes 1 steam turbine, 1 air turbine, 6

	heat exchangers, 5 heat exchange loops, 4 electric boilers, 5 air blowers, 1 steam generator, 1 deaerator, 2 pumps, 1 compressor, etc.: Tomsk, Lenin ave. 30a, build. 4, rooms 101b, 101c.
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 (performance tests, perform tasks, problem solving). Max score for current assessment is 80 points, min – 44 points. – Course final assessment (colloquim) 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. Annaratone D. Steam Generators. Description and Design / D. Annaratone – Berlin : Springer-Verlag, 2008. – 434 p. – Текст : электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-3-540-77715-1 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ. **Additional reading:** 1. Souza G. Thermal Power Plant Performance Analysis / G. Souza. – London : Springer-Verlag Ltd., 2012. – 287 p. – Текст: электронный // SpringerLink. – URL: https://link.springer.com/book/10.1007/978-1-4471-2309-5 (дата обращения: 20.09.2020). – Режим доступа: из корпоративной сети ТПУ.
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