GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Passive cooling systems in nuclear power systems, PG_00065901					
Field of study	Nuclear Engineering					
Date of commencement of studies	February 2025		Academic year of realisation of subject		2025/2026	
Education level	second-cycle studies		Subject group		Specialty subject group Subject group related to scientific research in the field of study	
Mode of study	Full-time studies		Mode of delivery		at the university	
Year of study	1		Language of instruction		Polish	
Semester of study	2		ECTS credits		3.0	
Learning profile	general academic profile		Assessment form		assessment	
Conducting unit	Zakład Systemów i Urządzeń Energetyki Cieplnej -> Institute of Energy -> Faculty of Mechanical Engineering and Ship Technology					
Name and surname of lecturer (lecturers)	Subject supervisor		dr inż. Paweł Szymański			
	Teachers					
Lesson types and methods of instruction	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	15.0	0.0	0.0	15.0	0.0	30
	E-learning hours included: 0.0						
Learning activity and number of study hours	Learning activity	Participation in didactic classes included in study plan		Participation in consultation hours	Self-study		SUM
	Number of study hours	30		8.0	37.0		75
Subject objectives	The aim of the course is to familiarise students with the principles of operation, design and operation of passive cooling systems in nuclear power plants. Students learn about the mechanisms of passive heat and mass transport under normal and emergency conditions, learn to identify, select and design appropriate passive technologies (heat pipes, thermosyphons, phase change materials, etc.), and analyse their efficiency and operational safety. In doing so, they acquire the competences necessary to work on nuclear reactor safety projects and the development of modern cooling solutions.					

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[K7_U15] evaluates the feasibility of advanced methods and tools for solving complex engineering tasks of a practical nature, characteristic of the field of study, and selects and applies appropriate methods and tools for this purpose	Knowledge Be able to identify under which conditions and for which types of issues (different heat pipe configurations, thermosyphons or systems with phase-change materials) particular computational tools are of greatest cognitive and practical value. Skills The student is able to properly select advanced design and simulation tools (e.g. engineering software) to solve specific problems related to passive cooling systems in nuclear power plants, taking into account the complexity of phenomena (heat and mass transport, phase change, natural convection). Is able to interpret and critically evaluate the results obtained from the methods used (e.g. numerical, experimental), comparing them with available literature data or industry standards. Is able to prepare appropriate assumptions and simplifications of the model (preserving the relevant physical aspects of the phenomena) and justify their influence on the final evaluation of the effectiveness of the passive cooling system. Social competence The student demonstrates maturity in selecting research tools and methods, taking into account not only technical criteria and computational efficiency, but also cost, time-consumption and availability of resources and infrastructure. He/she realises the need for continuous improvement in modern technologies and tools for nuclear systems analysis and their application in engineering practice. Through these learning outcomes, the student acquires the ability to critically evaluate the suitability of various methods and tools (both computational software and experimental methods) in solving complex engineering tasks related to the design and evaluation of passive cooling systems in nuclear power, and is then able to select and apply the most suitable one for a given project.	[SU1] Assessment of task fulfilment [SU2] Assessment of ability to analyse information [SU3] Assessment of ability to use knowledge gained from the subject [SU4] Assessment of ability to use methods and tools

Course outcome	Subject outcome	Method of verification
[K7_W03] demonstrates structured and theory supported knowledge encompassing key issues in the field of Nuclear Power Technologies, enabling design of energy processes and systems	Knowledge: The student knows and understands the basic principles of passive cooling systems in nuclear power plants, including their role in reactor safety and their impact on the overall efficiency of energy processes. Can characterise the main passive technologies (heat pipes, thermosyphons, phase change materials, etc.) and explain their application in the context of different reactor types. Knows the key material requirements and design criteria necessary for the selection and implementation of passive cooling systems. Skills The student is able to design an initial passive cooling system scheme for a selected reactor, taking into account normal operating conditions and emergency scenarios. He/she is able to carry out a thermodynamic analysis and evaluate the efficiency of the applied solutions by selecting appropriate computational tools (e.g. numerical models). Be able to identify the risks and constraints arising from the performance characteristics of passive equipment under changing process and environmental conditions. Competences The student understands the importance of nuclear safety and is able to work effectively with the design team on solutions to increase the reliability of cooling systems. He/she demonstrates an attitude of continually expanding his/her knowledge of new passive technologies and prospects for their development in the nuclear power industry, which fosters informed design decisions.	[SW2] Assessment of knowledge contained in presentation [SW1] Assessment of factual knowledge

	Course outcome	Subject outcome	Method of verification
	[K7_U04] creatively designs or modifies, either entirely or at least in part, nulear power systems, considering both technical and non-technical aspects, estimating costs and utilizing design techniques appropriate for tasks within the scope of Nuclear Power Technologies	Knowledge The student knows and understands the principles of integrating passive cooling systems into existing and newly designed nuclear power systems. He/she can indicate in which areas of the reactor (core, auxiliary systems, steam circuits) the use of passive systems is most effective and which aspects (technical, environmental, economic) should be taken into account. Skills The student is able to creatively design or modify a selected component of a passive cooling system (e.g. a set of heat pipes, thermosyphons), taking into account the given technical specifications and limitations resulting from safety regulations. Is able to carry out a preliminary cost analysis for the implementation of a passive cooling system in a nuclear power plant, taking into account, among other things, the choice of materials, complexity of the installation or operating costs. Uses appropriate design and simulation techniques (e.g. numerical calculations) to optimise cooling solutions in the context of various criteria (e.g. efficiency, reliability, safety). Is able to present a proposed concept for the implementation or modification of a passive cooling system, taking into account technical and non-technical (environmental, economic, social) arguments. Soft skills The student understands the necessity of cooperation in an interdisciplinary team (designers, technologists, health and safety specialists, economists) and is able to take into account different perspectives (technical, legal, environmental, social) during design. He/she demonstrates responsibility for engineering decisions, particularly with regard to nuclear safety and economic-environmental consequences.	[SU1] Assessment of task fulfilment [SU2] Assessment of ability to analyse information [SU4] Assessment of ability to use methods and tools

	Course outcome	**Subject outcome**	**Method of verification**
	[K7_U03] identifies and formulates task specifications in the scope of energy processes and systems including non-standard problems and taking into consideration their non-technical aspects.	Knowledge The student has a structured knowledge of the technical and regulatory requirements to be considered when formulating specifications for energy systems based on passive cooling systems. Skills The student is able to identify and define the design tasks necessary for the specification or modification of a passive cooling system in a nuclear power plant, taking into account both technical aspects (e.g. thermodynamic parameters, material selection) and nuclear safety constraints. He/she is able to formulate detailed design requirements for new and unusual applications (e.g. small modular reactors, hybrid cooling systems) using knowledge of the specifics of passive systems and their role in the heat removal process under different operating conditions.	[SU1] Assessment of task fulfilment [SU4] Assessment of ability to use methods and tools [SU3] Assessment of ability to use knowledge gained from the subject

Subject contents	1 Introduction to cooling systems in nuclear power plants.- The role of cooling systems in the safety of nuclear reactors.- Basic cooling requirements for different reactor types.2 Types of cooling systems.- Active and passive systems.- Examples of implemented solutions worldwide.Passive cooling systems - principle of operation.- Gravity cooling systems.- Heat sinks and fins- Modern cooling devices with (heat pipes, thermosyphons, LHP loop heat pipes, CPL capillary flow tubes, phase change materials)4 Cooling systems under failure conditions- Failure scenarios and their impact on the performance of cooling systems.5. analysis and design of passive cooling systems using heat pipes as an example- Design methods.- Material selection criteria.- Performance requirements.6 Future of passive cooling systems- Technological challenges.- New technologies and developments.
Prerequisites and co-requisites	Knowledge of basic mathematics, physics, thermodynamics, materials science, fluid mechanics.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
	56.0%	50.0%
Egzamin ustny	56.0%	50.0%

Recommended reading

Basic literature	Bahman Zohuri "Heat Pipe Applications in Fission Driven Nuclear Power Plants"
Supplementary literature	Hussam Jouhara, David Reay, Ryan McGlen, Peter Kew, Jonathan McDonough "Heat Pipes: Theory, Design and Applications"
eResources addresses	Adresy na platformie eNauczanie:

Example issues/ example questions/ tasks being completed	1 Classification and theoretical background 1. Explain the difference between active and passive systems in the context of nuclear safety. 2. What is the role of gravity in passive heat dissipation in a nuclear power plant? 3. Compare the cooling requirements in PWR and BWR reactors. What aspects should be taken into account when designing passive cooling systems for them? 2 Passive system technologies and principle of operation 1. Describe the principle of operation of a heat pipe (Heat Pipe). What processes take place inside the tube during heat transport? 2. How do loop heat pipes (LHP) differ from classical heat pipes? 3. Define the term phase change material (PCM). How can the use of PCM improve the reliability of a cooling system? 4. Provide a diagram of how a thermosyphon works and discuss what physical phenomena enable it to work efficiently. 3. design and analysis of passive systems 1. What factors are considered when selecting a working material for a heat pipe (e.g. water, ammonia, liquid metals)? 2. List and discuss the most important design criteria (e.g. maximum temperature, corrosion resistance, thermal properties) of a passive cooling system. 3. What calculation methods are used to analyse the performance of passive cooling systems? In which situations is a particular method most justified? 4 Emergency conditions and nuclear safety 1. Present a Loss of Coolant Accident (LOCA) type of emergency scenario. What role do passive cooling systems play in it? 2. Discuss how passive cooling systems can reduce the risk of core meltdown in an emergency without access to external electrical power. 3. What cooling system parameters need to be monitored under emergency conditions to confirm the correct operation of passive solutions? 5 Examples of implementation and new technologies 1. Provide examples of reactors with advanced passive solutions (e.g. AP1000, ESBWR). Indicate the key features of these systems. 2. Discuss development trends in passive cooling systems for small modular reactors (SMRs). 3. What role can nanofluids (nanofluids) play in further improving passive cooling systems? 6 Problem / practical tasks 1. Propose a passive cooling system concept for a selected part of a nuclear power plant (e.g. heat exchanger, reactor shield), taking into account: 2. Operating conditions (pressure, temperature). 3. Selection of working material and casing. 4. Main safety constraints. 5. Conduct a simplified heat balance of a heat pipe system with 100 MW of thermal energy to be dissipated. 6. Evaluate the validity of using phase change materials in passive cooling for potential reactor load fluctuations: What properties of PCMs are crucial for dynamic temperature variations? How do you select the melting point of the material?
Work placement	Not applicable