



КГЭУ

МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ
РОССИЙСКОЙ ФЕДЕРАЦИИ

Федеральное государственное бюджетное образовательное учреждение
высшего образования
«КАЗАНСКИЙ ГОСУДАРСТВЕННЫЙ ЭНЕРГЕТИЧЕСКИЙ
УНИВЕРСИТЕТ»

(ФГБОУ ВО «КГЭУ»)

УТВЕРЖДАЮ
Директор ИДПО

 В. К. Ильин

« __ » _____ 2022 г.



**ОБРАЗОВАТЕЛЬНАЯ ПРОГРАММА
ПОВЫШЕНИЯ КВАЛИФИКАЦИИ
«HYDROGEN TECHNOLOGIES FOR ENERGY INDUSTRY»**

1. The purpose of the program

Formation of professional competencies (in-depth knowledge, practical skills) in the field of hydrogen technologies. The internship program "Hydrogen technologies for energy industry" is aimed at training personnel in the field of hydrogen energy, including the field of creation and operation of installations for the production, storage, transportation of hydrogen and the use of hydrogen energy carriers.

2. Requirements for learning outcomes

Planned learning outcomes:

Key professional and professionally significant competencies:

- the ability to plan and conduct research on projects in the field of hydrogen energy and hydrogen technologies;

- the ability to solve problems of increasing the reliability and efficiency of hydrogen power supply systems and hydrogen production; reduction of negative impacts on the environment.

Projected learning outcomes:

Formation of the ability to design hydrogen production systems; ability to manage projects and effectively coordinate fundamental, applied research in the field of hydrogen technologies.

3. Program content

Academic plan professional development program

"Hydrogen technologies for energy industry"

Category of students – persons, who speak English and have secondary (according to training programs for mid-level specialists) or higher professional education, or who receive secondary (according to training programs for mid-level specialists) or higher professional education from among undergraduates, graduate students of specialized universities, as well as teachers, managers and responsible for the processes of energy saving and energy efficiency improvement of energy complex enterprises, design and service companies, developers and manufacturers of energy efficient energy equipment and materials.

The training period is 72 hours.

Form of study - with a break from work (full-time) or without a break from work (correspondence, on-line)

№	Section names	Total, hour	Including hour		
			Lectures	Practical and laboratory work	Independent work
1	Strategy for the development of hydrogen energy	14	2	4	8
2	Hydrogen production technologies	22	6	8	8
3	Problems of storage and transportation of hydrogen	18	6	4	8
4	Hydrogen is the fuel of the future	18	4	6	8
	Final examination		Abstract		

№	Section names	Total, hour	Including hour		
			Lectures	Practical and laboratory work	Independent work
	Total	72	18	22	32

Educational and thematic plan professional development program
«Hydrogen technologies for energy industry»

№	Section names	Total, hour	Including hour.		
			Lectures	Practical and laboratory work	Independent work
1	Section 1. Strategy for the development of hydrogen energy	14	2	4	8
1.1	Formation of hydrogen energy in the world	4	2	-	2
1.2	Production of fuel cells and power plants based on them	4	-	2	2
1.3	The use of hydrogen fuel cells in various fields of activity	6	-	2	4
2	Section 2. Hydrogen production technologies	22	6	8	8
2.1	Hydrogen production from non-renewable and renewable energy sources	12	4	4	4
2.2	Design of hydrogen production systems	10	2	4	4
	Section 3. Problems of storage and transportation of hydrogen	18	6	4	8
3.1	Efficient ways to store and transport hydrogen. Hydrogen energy storage	6	2	2	2
3.2	Intermetallic compounds and their application in hydrogen energy	4	2	-	2
3.3	Hydrogen safety and environmental issues	8	2	2	4
	Section 4. Hydrogen is the fuel of the future	18	4	6	8
4.1	Technologies of hydrogen fuel consumption	6	-	2	4
4.2	Hydrogen auto industry: development prospects	6	2	2	2
4.3	Hydrogen filling station: device,	6	2	2	2

№	Section names	Total, hour	Including hour.		
			Lectures	Practical and laboratory work	Independent work
	technologies, problems, prospects				
	Final examination		Abstract		
Total:		72	32	22	18

Training plan professional development program
«Hydrogen technologies for energy industry»

Section 1. Strategy for the development of hydrogen energy (14 hours)

Topic 1.1 Formation of hydrogen energy in the world (4 hours)

Key milestones in the history of hydrogen energy. World hydrogen market. The current state of research and development in the field of hydrogen energy technologies. The main directions of scientific research in the field of hydrogen energy. Components of hydrogen energy.

Topic 1.2 Production of fuel cells and power plants based on them (4 hours)

Hydrogen energy technologies. Fuel Cell Technologies. Fuel cell modules. Hydrogen-oxygen steam generators of megawatt power class. Internal combustion engine on hydrogen. Nickel-hydrogen battery.

Topic 1.3 Application of hydrogen fuel cells in various fields of activity (6 hours)

Hydrogen power plants. Advantages of fuel cells in comparison with other methods of energy generation. Industrial electrochemical plants for processing liquid waste from thermal power plants with hydrogen generation. Autonomous power supply of city facilities on hydrogen fuel cells.

List of laboratory works

Topic number	Name of laboratory work
1.2	Fuel cell research. Determination of current-voltage characteristics of a fuel cell with a proton-exchange membrane. Establishment of conditions under which the fuel cell has a maximum voltage (2 hours)

List of practical exercises

Topic number	Name of practical exercise
1.3	Using fuel cells to supply energy to social consumers (2 hours)

Section 2. Technologies for hydrogen production (22 hours)

Topic 2.1 Hydrogen production from non-renewable and renewable energy sources (12 hours)

Technologies for centralized production of hydrogen. Steam reforming of hydrocarbons. Gasification of solid fuels. Pyrolysis. Evaluation of technical and economic indicators of centralized hydrogen production. Obtaining hydrogen using alternative energy sources.

Topic 2.2 Design of hydrogen production systems (10 hours)

New directions in hydrogen production. Electrolysis technologies for hydrogen production. Improvement of water electrolysis methods. Types of electrolyzers (alkaline electrolyzer, ion-exchange membrane electrolyzer, solid oxide electrolyzer). Design of electrochemical equipment for hydrogen production. Technologies for environmentally efficient hydrogen production.

List of laboratory works

Topic number	Name of laboratory work
2.1	Study of the electrolyzer. Studying the dependence of the current on the voltage of the electrolyzer connected to the voltage source (2 hours)
2.2	Study of water electrolysis. Obtaining hydrogen and oxygen by decomposition of water in an electrolytic cell. Carrying out chemical analysis of gases and their use in a fuel cell (2 hours)

List of practical exercises

Topic number	Name of practical exercise
2.1	Production of hydrogen by electrolysis using solar energy (2 hours)
2.2	Determination of the efficiency of the system electrolyzer - fuel cell (2 hours)

Section 3. Problems of storage and transportation of hydrogen (18 hours)

Topic 3.1 Efficient ways to store and transport hydrogen (6 hours)

Classification of hydrogen storage methods (physical, physicochemical, chemical). Storage of gaseous and liquid hydrogen. Hydrogen compression and liquefaction technologies. Storage and transportation of hydrogen in a chemically bound state. Physicochemistry of hydrogen storage materials.

Topic 3.2 Intermetallic compounds and their application in hydrogen energy (4 hours)

Hydride forming materials. Adsorption and absorption hydrogen characteristics of materials used for hydrogen storage. Hybrid hydrogen storage system. Cryoadsorption storage of hydrogen. Feasibility study of various options for hydrogen storage. Energy storage systems.

Topic 3.3 Hydrogen security and environmental issues (8 hours)

Carbon neutrality. Specific emissions of carbon dioxide in electric power systems. Types of hydrogen. Strategy for the development of "green" hydrogen. Consumption of "dirty" hydrogen (SOFC, gas turbines, heat generators, technological processes). Consumption of pure hydrogen (low-temperature fuel cells, technological processes). Hydrogen purification methods (membrane, cryogenic, sorption). Features of technical regulation of the use of hydrogen fuel. Devices for measuring the concentration of hydrogen in the air. Hydrogen safety

List of laboratory works

Topic number	Name of laboratory work
3.3	The use of gas analyzers to determine the pre-explosive concentration of hydrogen in the air (2 hours)

List of practical exercises

Topic number	Name of practical exercise
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3.1	Hydrogen energy storage (2 hours)
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Section 4. Hydrogen - the fuel of the future (18 hours)

Topic 4.1 Technologies of hydrogen fuel consumption (6 hours)

Characterization of hydrogen as a technical gas and fuel (properties of hydrogen fuel). Hydrogen power supply system. Comparison of classical energy supply systems and a low-power hydrogen autonomous energy supply system up to 5 kW. The cost of hydrogen fuel in terms of its centralized production. The concept of an integrated fuel supply system.

Topic 4.2 Hydrogen auto industry: development prospects (6 hours)

Hydrogen transport: hybrid cars, buses, rail, water transport, submarines, unmanned aircraft for high altitudes and long flight duration. Existing programs for the development of hydrogen transport.

Topic 4.3 Hydrogen filling station: device, technologies, problems, prospects (6 hours)

Hydrogen filling stations, mode of operation. Mobile, stationary, home hydrogen filling stations. Hydrogen gas filling stations. Different models of a hydrogen filling station.

List of laboratory works

Topic number	Name of laboratory work
4.1	Hydrogen as a source of energy (fuel). Possibility of hydrogen storage (2 hours)
4.2	Energy supply of the car platform due to hydrogen energy (2 hours)

List of practical exercises

Topic number	Name of practical exercise
4.3	Investigation of the dependence of the operating time of an automobile platform on the supply of hydrogen (2 hours)

4. Material and technical conditions for the implementation of the program

Name of classrooms, lecture rooms, laboratories	Type of exercises	Name of equipment, software
1	2	3
classroom B-503, B-513 lecture computer, multimedia projector, screen, whiteboard	lecture	computer, multimedia projector, screen, whiteboard
classroom B-525 "Hydrogen and electrochemical energy"	laboratory work	practical and laboratory classes samples for the study, storage, transportation and use of samples, electrochemical equipment: fuel cells, electrolyzers

Computer Class B-600A	practical training, testing	computers
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5. Educational and methodological support of the program

Section 1

Apollonsky, S. M. Energy-saving technologies in the energy sector. Volume 1. Energy saving in the energy sector: a textbook for universities / S. M. Apollonsky. - St. Petersburg: Lan, 2022. -436 p. URL: <https://e.lanbook.com/book/221123>

Sibikin Yu.D. Non-traditional and renewable energy sources: Textbook / M. : Knorus, 2019. <https://www.book.ru/book/931415>

Baranov, N. N. Non-traditional sources and methods of energy conversion: a textbook for universities / Baranov N. N. - Moscow: MPEI Publishing House, 2017. - ISBN 978-5-383-01185-0. - Text: electronic // EBS "Student Consultant". <https://www.studentlibrary.ru/book/ISBN9785383011850.html>

5. GOST R IEC 62282-2-2014 "Fuel cell technologies. Part 2 Fuel Cell Modules.

6. Chemical current sources: textbook / V. Ya. Solovieva, I. V. Stepanova, M. Abu-Khasan, A. S. Sakharova. - St. Petersburg: PGUPS, 2020. – 53p.

Section 2

1. Galdin, V. D. Combustible gases: production, transportation, receipt: textbook / V. D. Galdin. –2nd ed., derivative. – Omsk: SibADI, 2021. –234 p.

2. GOST R ISO 22734-1-2013 "Hydrogen generators based on the water electrolysis process. Part 1 Industrial and commercial applications.

3. Tkachek Z. A. Electrolysis of water / Z. A. Tkachek - M. : Book on Demand, 2012. - 263 p.

4. Equipment for electrochemical production. Tutorial. Istomina N.V., Sosnovskaya N.G., Kovalyuk E.N. Angarsk State Technical Academy. – 2nd ed., revised. - Angarsk: AGTA, 2010 - 100 p.

Section 3

1. Shishulkin, S. Yu. Types of energy resources and energy sources: textbook / S. Yu. Shishulkin. – Ulan-Ude: BSU, 2017. – 152 p.

2. GOST R 54114-2010 "Mobile devices and systems for hydrogen storage based on metal hydrides".

3. Radchenko, R. V. P15 Hydrogen in the energy sector: textbook. allowance / R.V. Radchenko, A.S. Mokrushin, V.V. Tulip. - Yekaterinburg: Ural Publishing House. un-ty, 2014. - 229, [3] p.

4. Hydrogen energy technologies: Proceedings of the seminar of the laboratory VET JIHT RAS: Sat. scientific tr. / editorial board: D.O. Dunikov (responsible ed.) [and others]. - M.: OIVT RAN, 2017. - Issue. 1. - 190 p.

Section 4

1. Bezzubtseva, M. M. The future of human energy: study guide / M. M. Bezzubtseva, V. S. Volkov. – St. Petersburg: SPbGAU, 2014. – 133 p.

2. GOST R 55226-2012 Gaseous hydrogen. Filling stations.

3. GOST 54110-2010 "Hydrogen generators based on fuel processing technologies. Part 1 Safety.

4. General energy: hydrogen in the energy sector: a textbook for universities / R. V. Radchenko, A. S. Mokrushin, V. V. Tyulpa; under the scientific editorship of S. E.

6. Evaluation of the quality of mastering the program

The assessment of the quality of mastering the program is carried out by the attestation commission in the form of the abstract assessment (passed - failed). The listener is considered certified if he has a positive response to the abstract (passed).

Recommended essay topics

1. The place of hydrogen energy in the modern world.
2. The problems of hydrogen energy in the modern world.
3. The developed countries position regarding hydrogen for the period up to 2030.
4. Factors determining the development of hydrogen energy.
5. Directions and formations of the development of hydrogen energy.
6. The concept of large-scale application of hydrogen.
7. Modern fuel power plants on hydrogen.
8. Technologies for environmentally efficient production of hydrogen.
9. Hydrogen energy and fuel cells.
10. Modern achievements in the field of hydrogen energy.
11. Ecological pressure on the environment in the transition to a hydrogen economy.
12. Transportation of hydrogen using carriers.
13. Areas of application of hydrogen and energy sources for its production.
14. Technical and economic indicators of hydrogen production by water electrolysis.
15. Plasma-chemical methods for producing hydrogen.
16. Prospects for the use of hydrogen in road transport.
17. Hydrogen and its properties.
18. Obtaining hydrogen using alternative energy sources.
19. Fuel cell vehicles.
20. Hydrogen filling stations - device, mode of operation.

Составители программы:

*Гайнутдинова Д.Ф., канд. хим. наук,
доцент (раздел 1, темы 1.1- 1.13;
раздел 2, темы 2.1-2.2)*



подпись

*Филимонова А.А., канд мед. наук,
доцент (раздел 3. темы 3.1-3.3;
раздел 4, темы 4.1-4.4)*



подпись

Согласовано:

Зав. кафедрой ХВ



А. А. Чичиров

Зам. директора ИДПО



Э. Х. Давлетшина