Syllabus
Course Program

Equipment and Basics of Designing Environmentally Safe Technologies Using CAD

Specialty
E2 – Ecology

Specialization
Engineering ecology

Educational program
Engineering ecology

Level of education
Master’s level

Semester
2

Institute
Institute of mechanical engineering and transport

Department
Department of Car and Tractor Industry (152)

Course type
Optional

Form of study
Full-time, part-time, distance learning

Language of instruction
English, Ukrainian

Lecturers and course developers

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Ph.D., Associate Professor, Associate Professor of the Department of Chemical Engineering and Industrial Ecology. Work experience – 20 years. Author of over 50 scientific and educational works. Leading lecturer in the following disciplines: “Introduction to the Profession,” “Information Technologies in Engineering,” “Fundamentals of Industrial Facility Design Using CAD,” “Theory of Technical Systems.”

More about the lecturer on the department's website

General information

Summary

The discipline develops students' knowledge of constructions and principles of operation of environmentally safe production equipment, as well as the use of modern technologies of automated production design that meet modern requirements for minimizing the impact on the environment. In the course of training, students will learn about technologies and equipment for increasing energy efficiency, the degree of use of raw materials and reducing waste and gas emissions.

Course objectives and goals

Acquaintance of students with the equipment used in environmentally safe technologies, methods and systems of design of such technologies and capabilities of CAD in design; formation of skills in the use of equipment calculation methods and execution of drawings with the help of Auto CAD, Microsoft Visio, etc. programs.

Format of classes

Lectures, laboratory classes, consultations, self-study. Final control in the form of an differentiated grading.

Competencies

The ability to apply modern methods of calculating conditions for conducting processes, geometric dimensions of devices, as well as optimization calculations of processes and devices for the development of new environmental protection technologies, as well as the ability to use modern computer software complexes for the design of environmental protection objects and devices.

Learning outcomes

The ability to use knowledge of the physico-chemical essence of the main technological processes, as well as calculation methods and automated design of modern equipment and environmentally safe technologies to optimize environmental protection processes and equipment.

Student workload

Total course duration 120 hours (4 ECTS credits): lectures – 32 hours, practical work – 16 hours, independent work – 72 hours.

Course prerequisites

Possession of competences and learning outcomes, which are provided for by the standard of higher education in the specialty 101 "Ecology" of the first bachelor's level, as well as general knowledge of natural sciences

Features of the course, teaching and learning methods, and technologies

Lectures are conducted interactively using multimedia technologies. In practical and laboratory classes, reproductive and problem-solving learning methods are used and attention is focused on solving real problems of environmentalization of industrial production, as well as skills are formed in the use of equipment calculation methods and execution of drawings with the help of CAD programs, MS Visio, etc. programs.

Program of the course

Academic classes

Lectures

Topics of the lectures	Hours
Topic 1. Introduction. The purpose of the course and the main areas of development of environmentally safe technologies and equipment	2
Topic 2. Technology of separation of gas mixtures in the gas-liquid system Basic provisions of the theory of absorption and its use in the calculation of mass transfer in the gas-liquid system	6

Topic 3. Absorption equipment Classification, construction types and principles of absorption equipment	4
Topic 4. Separation of disperse systems. Concept of dispersed systems, terminology. Technology and equipment for separation of suspensions. Technology and equipment for separation of gas and dust systems.	4
Topic 5. Technologies and equipment for conducting chemical reactions Catalytic and non-catalytic chemical reactions. Designs and principles of operation of chemical reactors	4
Topic 6. Equipment for heating and cooling. Theoretical foundations of heat transfer. Heat exchange equipment. Secondary energy resources. Equipment for recovery and utilization of secondary heat.	4
Topic 7. Design of environmentally safe production What is a project? The structure of the project organization. The content of the project and the sequence of its development.	4
Topic 8. CAD and its implementation in the design process CAD structure. Opportunities that CAD provides to the design process.	4
Total hours	**32**

Workshops

Topics for workshops	Hours	Weighting coefficients *a*
Topic 1. Methodology for calculating heat and material balances of the absorption process. Review of the fundamentals of absorption processes (gas–liquid systems). Step-by-step procedure for preparing a material balance equation. Heat balance calculations in absorption columns. Practical task: Solving example problems and comparing results with CAD-based calculations.	2	0,125
Topic 2. Determination of the mass transfer process and the main dimensions of the absorber. Determination of the driving force of mass transfer in gas–liquid systems. Calculation of the height and diameter of absorbers. Application of empirical correlations and graphical methods. Practical task: Case study with dimensioning of a packed or plate absorber.	2	0,125
Topic 3. Calculation of hydrodynamic characteristics of equipment. Review of flow regimes in pipes and process equipment. Calculation of pressure drop in columns, filters, and pipelines. Determination of flooding velocity and operating limits in mass transfer equipment. Practical task: Hydrodynamic modeling.	2	0,125
Topic 4. Selection of equipment for separation of dispersed systems. Classification of dispersed systems (suspensions, emulsions, aerosols). Principles of separation: sedimentation, filtration, centrifugation. Comparison of alternative equipment types for specific processes. Practical task: Choosing equipment for industrial wastewater treatment.	2	0,125
Topic 5. Selection of the type of chemical reactor. Types of chemical reactors: batch, continuous, catalytic, tubular, fluidized bed. Criteria for reactor selection (kinetics, heat transfer, scale of production). Safety and ecological aspects in reactor design. Practical task: Comparative analysis of reactor types for a given chemical process.	2	0,125

Topic 6. Calculation of the heat balance of the heat exchange process. Fundamentals of heat transfer: conduction, convection, radiation. Calculation of heat loads in heat exchangers. Determination of required heat exchange surface area. Practical task: Heat balance calculation for a gas cooling process.	2	0,125
Topic 7. Selection of equipment for separating gas from dust Types of dust collection devices: cyclones, bag filters, electrostatic precipitators. Criteria for selecting dust separation equipment. Efficiency calculations and ecological performance indicators. Practical task: Equipment selection for reducing emissions in a thermal power plant.	2	0,125
Topic 8.Selection of equipment for solid and liquid fraction separation. Mechanical separation methods: sedimentation, filtration, centrifugation, flotation. Equipment overview: clarifiers, thickeners, centrifuges, filters. Application fields in ecological and industrial technologies. Practical task: Selecting a separation unit for sludge treatment in wastewater facilities.	2	0,125
Total hours	**16**	$\sum_{i=1}^{n} b_i = 1$

Self-study

The course involves the completion of an individual task in the form of a term paper, which concerns the calculation of an absorber for cleaning gases from harmful impurities. Independent work also includes:

1. Elaboration of lecture material.
2. Preparation for practical classes
3. Improving the skills of performing calculations and drawings using a computer.
4. Acquaintance with additional literature.

Work on theoretical materials

Topics for self-study	Hours
Topic 1. Modern Trends in Eco-Design of Industrial Equipment. Explore innovations in designing equipment with minimal energy consumption, reduced emissions, and higher recyclability. Focus on circular economy principles.	4
Topic 2. Digital Twins in Environmental Equipment Design Study the concept of creating virtual models (digital twins) of equipment to predict performance, optimize parameters, and reduce experimental costs.	4
Topic 3. Life Cycle Assessment (LCA) of Industrial Equipment Learn methods for assessing the environmental footprint of equipment during design, production, use, and disposal stages.	4
Topic 4. Additive Manufacturing (3D Printing) in Eco-Technology Development Research how 3D printing is applied for creating prototypes and components of environmental protection equipment, improving efficiency and material use.	4
Topic 5.Smart Sensors and IoT for Monitoring Emissions Examine the role of Internet of Things technologies in controlling emissions, tracking process parameters, and ensuring regulatory compliance.	4
Topic 6. Energy Recovery Technologies in Process Equipment Study methods and devices for recovering heat, pressure, or chemical energy from waste streams to improve overall plant efficiency.	4

Topic 7. Artificial Intelligence in CAD for Environmental Equipment Explore AI-assisted design tools for optimizing process equipment layouts, predicting failures, and reducing environmental risks.	4
Topic 8. Nanomaterials in Filtration and Absorption Equipment Review applications of advanced nanomaterials (membranes, adsorbents) that enhance the efficiency of gas purification, water treatment, and waste minimization.	4
Topic 9. International Standards and Regulations for Eco-Equipment Design Analyze ISO standards, EU directives, and US EPA regulations governing environmentally safe technologies and equipment.	4
Topic 10. Case Studies of Eco-Industrial Parks Investigate practical examples of industrial complexes that integrate environmentally safe equipment and CAD-based eco-design solutions.	4
Total hours	**40**

Topics for individual assignments

The requirements for the performance of individual task and the terms of execution are detailed at the methodical instructions.

Topics for individual assignments

Topic 1. Calculation and CAD Modeling of an Absorber Column Students apply knowledge of mass transfer and hydrodynamics to design a gas-liquid absorber.. Select a gas mixture and absorbing liquid. Calculate material and heat balances. Determine key column dimensions and packing type. Create a 2D/3D model of the absorber in CAD software.	
Topic 2. Design of a Dust Separation Unit (Cyclone or Bag Filter) Develop skills in analyzing dispersed systems and air purification equipment. Choose a type of dust source (industrial process). Estimate dust particle size distribution and concentration. Calculate efficiency of separation for different devices. Propose an optimal design and draw a schematic in CAD/Visio.	
Topic 3. Heat Exchanger Selection and Energy Balance Analysis Train students in thermal calculations and energy efficiency assessment. Define input process conditions (fluids, flow rates, temperatures). Calculate heat transfer surface area and thermal efficiency. Compare two types of heat exchangers (shell-and-tube, plate). Prepare a technical note with CAD visualization of chosen equipment.	
Topic 4. Environmental Impact Assessment of a Designed Device Integrate eco-design principles into technical solutions. Choose one previously designed unit (absorber, filter, or reactor). Perform simplified Life Cycle Assessment (LCA): material, energy, waste. Identify possible environmental risks and propose improvements. Write a short analytical report with diagrams.	
Topic 5. Development of a CAD-Based Layout for a Small Eco-Plant Apply system thinking to project organization and equipment placement. Define purpose (e.g., wastewater treatment, air purification, recycling). Select key equipment (absorber, separator, heat exchanger). Create a block diagram and a 2D layout in CAD software. Justify the design in terms of efficiency, safety, and eco-standards.	
Total hours	**32**

Non-formal education

The elements of non-formal education recommended in the syllabus may be enrolled in a simplified procedure without additional validation of results (creation of a subject commission).

Recommended training courses, internships

1. Online course «New paradigms in wastewater management»
https://www.coursera.org/learn/new-paradigms-in-wastewater-management
2. Online course "Utilities, Safety & Environmental Care in Oil & Gas Industry"
https://www.coursera.org/learn/utilities-safety--environmental-care-in-oil--gas-industry
3. Online course "Intro to Siemens NX: Engineering Essentials and Part Design"
https://www.coursera.org/learn/engineering-essentials-with-nx

Literature, training materials, and information resources

Main literature

1. . Chemical Process Equipment. Selection and Design Book, Revised Second Edition, 2010.
https://doi.org/10.1016/C2009-0-25918-6
https://www.sciencedirect.com/book/9780123725066/chemical-process-equipment
https://archive.org/details/0450-pdf-chemical-process-equipment-selection-and-design/mode/2up
https://dn790007.ca.archive.org/0/items/0450-pdf-chemical-process-equipment-selection-and-design/0450%20pdf%20Chemical_Process_Equipment_Selection_and_Design.pdf
2. Solid-Liquid Separation. Lecturer in Chemical Engineering, University of Bradford. Editor Ladislav Svarovsky, Dipl. Ing., Ph.D., C.Eng., M.I.Chem.E. http://himatekkim.ulm.ac.id/id/wp-content/uploads/2021/06/Svarovsky-L-%E2%80%93-Solid-Liquid-Separation-4th-Edition.pdf
3. PLANT DESIGN AND ECONOMICS FOR CHEMICAL ENGINEERS. Max S. Peters, Klaus D. Timmerhaus
https://www.davuniversity.org/images/files/study-material/PLANT%20DESIGN%20AND%20ECONOMICS%20FOR%20CHEMICAL%20ENGINEERS.pdf
4. Chemical Process Equipment, Selection and Design, Third Edition, James R. Couper, W. Roy Penney, James R. Fair Stanley M. Wal https://www.slideshare.net/MarianitaPrez/chemical-process-equipment-selection-and-designpdf

Additional materials

1. Chemical Process Equipment Selection and Design. URI:
http://ndl.ethernet.edu.et/bitstream/123456789/54474/1/40.pdf
2. CHEMICAL AND PROCESS DESIGN HANDBOOK. URI:
https://ia803401.us.archive.org/23/items/0446-pdf-chemical-process-design-handbook/0446%20pdf%20Chemical_Process__Design_Handbook.pdf

Information resources

1. MIT ChemE
https://cheme.mit.edu/academics/mooc
2. Free Online Chemical Engineering Courses from Top Universities
learningpath.org/articles/Free_Online_Chemical_Engineering_Courses_from_Top_Universities.html
3. Learncheme
https://learncheme.com

Grading system

The final grade for the educational component is determined by the lecturerand is based on topics, types of activities, etc., in accordance with the syllabus. It is an integrated assessment of the results of all types of student learning activities. The final grade should reflect all the grades for the different parts of the educational process, taking into account their weighting coefficients k:

Continuous assessment (during workshops, seminars, laboratory classes) k_1	Control works (if any), k_2	Individual assignment (if any), k_3	Final assessment (for courses with exams), k_4
0,4	0,4	0,2	

The sum of the coefficients must be equal to one: $k_1 + k_2 + k_3 + k_4 = 1$. The weighting coefficients for the final assessment are decided by the course developer..
The final gradeis calculated using the following formula:

$$G = C \cdot k_1 + K \cdot k_2 + \mathrm{I} \cdot k_3 + E \cdot k_4$$

where: C – weighted average score for the continuous assessment
I–individual assignment grade
K–weighted average score for the continuous assessment
E – final assessment (exam) grade

$$C = \frac{C_1 \cdot a_1 + C_2 \cdot a_2 + \ldots + C_n \cdot a_n}{\sum_{i=1}^{n} \quad a_i}$$

де: a_i - weighting coefficient for each workshop (seminar) or laboratory class.

$$K = \frac{K_1 \cdot b_1 + K_2 \cdot b_2 + \ldots + K_m \cdot b_m}{\sum_{i=1}^{m} \quad b_i}$$

де: b_i - weighting coefficient for each control work.

The assessments for each component (C, K, I, etc.) are based on a 100-point scale in line with the provisions of the “Criteria and System for Assessing Knowledge and Skills, and Rating of Higher Education Students” of the National Technical University “Kharkiv Polytechnic Institute.”

The final grade is finalized as the calculated value of G, rounded up to the nearest integer.

Grading scale

Total points	National	ECTS
90–100	Excellent	A
82–89	Good	B
75–81	Good	C
64–74	Satisfactory	D
60–63	Satisfactory	E
35–59	Unsatisfactory (requires additional learning)	FX
1–34	Unsatisfactory (requires repetition of the course)	F

Norms of academic integrity and course policy

Students must adhere to the Code of Ethics of Academic Relations and Integrity of NTU "KhPI": to demonstrate discipline, good manners, kindness, honesty, and responsibility. Conflict situations should be openly discussed in academic groups with a lecturer, and if it is impossible to resolve the conflict, they should be brought to the attention of the Institute's management.
Regulatory and legal documents related to the implementation of the principles of academic integrity at NTU "KhPI" are available on the website: http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

Approval

Approved by

30.08.2025

Head of the department
Oleksii SHESTOPALOV

30.08.2025

Guarantor of the educational program
Eugenia MANOILO