National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

Department of machines and devices of chemical and oil refining industries

NAME OF THE COURSE

Calculation and design of equipment-2. Calculation and design of equipment elements of the industry

Working program of the academic discipline (Syllabus)

Details of the academic discipline

Level of higher education	First (bachelor's)
Field of knowledge	13 Mechanical engineering
Specialty	133 Industrial mechanical engineering
Educational program	Industrial Mechanical Engineering
Discipline status	Normative
Form of study	full-time
Year of training, semester	4th year, autumn semester
Scope of discipline	4 (120)
Semester control/ control measures	Exam
Lessons schedule	https://rozklad.kpi.ua/ https://ecampus.kpi.ua/ 3 hours per week (2 hours of lectures and 1 hours of practical classes)
Language of teaching	Ukrainian
Information about head of the course / teachers	Lecturer: Ph.D., Assoc. Andreiev I. A. Practical/Seminar: Ph.D., Assoc. Andreiev I. A. che@kpi.ua
Placement of the course	https://ecampus.kpi.ua/, http://ci.kpi.ua

Program of educational discipline

1 Description of the educational discipline, its purpose, subject of study and learning outcomes

Description of the educational discipline

The course covers the basics of designing heat exchangers and column devices, their application, theoretical information on the basics of engineering calculations, modern standard calculation formulas, normative methods of calculating strength, stiffness and stability.

Discipline "Calculation and design of typical equipment-2. Calculation and construction of equipment elements of the industry" considers the requirements for construction and calculation of equipment and individual elements, their application.

The subject of the academic discipline

The discipline "Calculation and design of typical equipment-2. Calculation and design of elements of industry equipment" is taught as the main component of training qualified specialists in the field of mechanical engineering, resource conservation, ecology and computer-integrated technologies.

Mastering the methods of construction and calculation involves not just mastering certain rules, but rather the development of a unique style of thinking, focused on the creation of modern technology in the field of chemical and oil refining engineering

The purpose of the educational discipline

The purpose of studying this discipline is the formation of students of a complex of knowledge, skills, and abilities necessary for qualified design and calculation of typical equipment of the chemical

industry. In accordance with the goal, the training of bachelors requires the formation of the following abilities:

• use and application in professional activity of normative methods of calculation of vessels and devices of chemical industries,

• using knowledge of design and construction of typical equipment,

• mastering the method of determining loads that occur during installation, testing and in working conditions,

• receiving information about the current state of equipment elements during operation,

• improvement of chemical production equipment,

• use of the method of calculating stresses and deformations that occur during the operation of typical equipment.

The main tasks of the credit module

According to the requirements of the educational and professional program, after mastering the academic discipline, students must demonstrate the following learning outcomes:

knowledge:

• basic designs of machines and devices, typical units and parts and requirements for them;

• materials used in chemical engineering and their properties;

• calculation parameters and rules for their determination;

• conditions of strength, stiffness, stability, vibration resistance, tightness;

• calculation models of shells, plates, rods;

• determination of stresses, analysis of the stress state, permissible and limit loads;

• regulatory methods of calculating vessels and devices;

• development of a structurally perfected product.

skill:

• based on the features of the technological process, determine the initial and limiting conditions and load scheme for the structure,

• on the basis of working conditions, determine the stress-strain state of the structure under static and dynamic thermoforce loads,

• based on the knowledge of theoretical training, using reference books and standards, choose structural materials and seal materials,

• using reference materials, perform calculations regarding the strength of typical equipment,

• perform parametric calculations of typical equipment using known analytical dependencies and reference information,

• take into account the need for assembly, disassembly, transportation and installation of the product,

• on the basis of the acquired knowledge, perform calculations on stiffness, stability, strength and develop design documentation,

• create constructions that are safe in operation.

experience:

• design development of a vessel or apparatus;

• ensuring strength, stability, rigidity, tightness, corrosion resistance, structural integrity and other requirements for elements of chemical equipment.

2 Pre-requisites and post-requisites of the discipline (place in the structural and logical scheme of training according to the relevant educational program)

Mastering the discipline "Calculation and design of typical equipment-2. Calculation and construction of equipment elements of the industry" is based on the principles of integration of the complex of knowledge obtained by students during the bachelor's education when studying natural and engineering disciplines in the field of "Mechanical Engineering". To successfully master this discipline, it is necessary to have basic knowledge in the field of higher mathematics, physics, resistance of materials, hydraulics, processes and equipment of chemical industries, to be able to use a computer to provide the necessary calculations, to have skills in the field of applied programming, mathematical modeling of processes and systems.

As a result of mastering the discipline, the student will be ready to use fundamental and natural scientific knowledge and methods to solve complex scientific and technical problems in the field of professional and research and innovation activities.

3 Content of the academic discipline

Chapter 1 Design and calculation of heat exchangers.

Topic 1. Heat exchange devices. Application. Basic constructions.

Topic 2. Axial loads and stresses caused by pressure and temperature difference in the casing and pipes of the TN type heat exchanger. Conditions of strength and stability of casing and pipes.

Topic 3. Constructions of compensators. Axial loads caused by the temperature difference in TC type heat exchangers. Calculation of the strength and stability of the casing and pipes, the strength of the compensator.

Topic 4. Placement of pipes in shell-and-tube heat exchangers. Structures of pipe grids. Design calculation of pipe grids. Checking the strength of the pipes in the grid.

Topic 5. Designs of devices with shells. Forces acting on the body and shell Calculation of temperature forces. Heat exchangers of other designs.

Chapter 2. Calculation and design of column apparatus.

Topic 6. Column devices. Basic constructions and applications. Design requirements.

Topic 7. Internal devices of column apparatuses. Calculation of grates. Bubble column devices. Calculation of plates for strength and stiffness.

Topic 8. Load on the body of the column apparatus. Determination of wind load. Bending moment in the cross-sections of the column apparatus.

Topic 9. Calculation of the strength of the body and support frame of the column apparatus.

Topic 10. Calculation of the body and the supporting frame of the column apparatus for stability.

4 Educational materials and resources

Basic literature

1. Андреєв І.А. Конструювання і розрахунок типового устаткування хімічних виробництв. Основні положення. Елементи тонкостінних посудин, навантажених внутрішнім тиском. Навч. посібник. – К.: «Видавництво «Політехніка», 2011. – 272 с.
2. Андреєв І.А., Мікульонок І.О. Розрахунок, конструювання та надійність обладнання хімічних виробництв: Термінологічний словник. – К.: ІВЦ “Видавництво «Політехніка» , 2002. – 216 с.
3. Андреєв І.А., Зубрій О.Г., Мікуленок І.О. Застосування матеріалів у хімічному машинобудуванні. Сталі і чавуни,- К.: ІЗМН, 1999. – 148 с.
4. Правила будови та безпечної експлуатації посудин, що працюють під тиском, –К.: Держнаглядохорона праці, 1998. – 273с.
5. ГОСТ 34233.1–12–2017 (міждержавні стандарти).
6. І. А. Андреєв. Конструювання та розрахунок опор колонних апаратів. Навч. посібник.- К.: ВПН, 1997.-80 с.
7. І. А. Андреєв, І.О. Мікульонок. Розрахунок лінзових і сильфонних компенсаторів. Навч. посібник. – К.: «Видавництво «Політехніка», 2008.-88 с.
8. І. А. Андреєв. Конструювання і розрахунок елементів тонкостінних посудин та апаратів, які знаходяться під зовнішніми навантаженнями [Електронний ресурс] : навч. посіб. для студ. спеціальності 133 «Галузеве машинобудування», спеціалізацій «Інжиніринг, обладнання та технології хімічних та нафтопереробних виробництв» і «Інжиніринг, обладнання та технології целюлозно-паперового виробництва»: КПІ ім. Ігоря Сікорського. – Електронні текстові данні (1 файл: 6,86 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2018. – 121 с. Доступ: http://ela.kpi.ua/handle/123456789/23885.

9. І. А. Андреєв. Методичні вказівки до практичних занять для студентів спеціальності “Галузеве машинобудування” з дисципліни “Розрахунок і конструювання типового обладнання-2. Розрахунок і конструювання товстостінних посудин, теплообмінних та колонних апаратів”: [Електронний ресурс] / КПІ ім. Ігоря Сікорського ; уклад. І. А. Андреєв. – Електронні текстові данні (1 файл: 9,989 Кбайт). – Київ : КПІ ім. Ігоря Сікорського, 2017. – 99 с. – Назва з екрана. – Доступ: http://ela.kpi.ua/handle/123456789/19342.
10. І. А. Андреєв. Розрахунок колонних апаратів на міцність і стійкість [Електронний ресурс]: навч. посіб. для студ. спеціальності 133 «Галузеве машинобудування», освітньо-професійної програми «Обладнання хімічних, нафтопереробних та целюлозно-паперових виробництв» / КПІ ім. Ігоря Сікорського. – Електронні текстові данні (1 файл: 4,53 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2021. – 112 с. https://ela.kpi.ua/handle/123456789/38716.
11. Ігор Андреєв. Конструювання і розрахунок кожухотрубних теплообмінників [Електронний ресурс]: навч. посіб. для студ. спеціальності 133 «Галузеве машинобудування» Київ: КПІ ім. Ігоря Сікорського, 2022. – 140 с. URL: https://ela.kpi.ua/handle/123456789/50426.

5 Methods of mastering an educational discipline (educational component)

Lecture classes

Lectures are aimed at providing modern, integral knowledge in the discipline "Calculation and design of typical equipment-2. Calculation and construction of equipment elements of the industry", definition at the current level of scientific development in the area of calculation and construction of machines and devices; ensuring fruitful work of students during the lecture; application of effective methods of teaching, presentation of material and its assimilation; education of students' professional qualities and development of creative thinking; formation of their scientific and practical interest in mastering the course material, the desire for independent work.

№№	The name of the topic of the lecture, a list of main questions, references to the literature and tasks for students' independent work	Hours
1	**Heat exchange devices.** Heat exchange devices. Application. Basic constructions. Literature: [2, 4, 11]	6
2	**Loads arising in the heat exchanger.** Axial loads and stresses caused by pressure and temperature difference in the shell and tubes of the TN type heat exchanger. Conditions of strength and stability of casing and pipes. Literature: [2, 4, 7, 11]	2
3	**Temperature compensators.** Constructions of compensators. Axial loads caused by the temperature difference in TC type heat exchangers. Calculation of the strength and stability of the casing and pipes, the strength of the compensator. Literature: [2, 4, 7, 11]	4
4	**Pipes and pipe grids of heat exchangers.** Placement of pipes in shell and tube heat exchangers. Structures of pipe grids. Design calculation of pipe grids. Checking the strength of the pipes in the grid. Literature: [2, 4, 7, 11]	4
5	**Heat exchangers with shells.** Designs of devices with shells. Forces acting on the body and shell Calculation of temperature forces. Heat exchangers of other designs. Literature: [2]	2
6	**Column devices.** Column devices. Basic constructions and applications. Design requirements. Literature: [2, 10]	4
7	**Internal devices of column apparatuses.** Internal devices of column apparatuses. Calculation of grates. Bubble column devices. Calculation of plates for strength and stiffness. Literature: [2]	6

8	**Loads acting on the body of the column apparatus.** Load on the body of the column apparatus. Determination of wind load. Bending moment in the cross-sections of the column apparatus. Literature: [2, 10]	***4***
9	**Strength and stability of the column apparatus.** Calculation of the body and the supporting frame of the column apparatus for strength and stability. Literature: [2, 10]	***4***
	Hours in general	***36***

Practical training

When studying a credit module, 1/3 of the classroom load is allocated to practical classes. A practical lesson on a separate topic of this discipline is aimed at consolidating the material presented in the lecture by considering specific examples, exercises and problems on this topic. This enables students to systematize and deepen their theoretical knowledge. The practical session is conducted in a dialogue mode with educational discussions. At the beginning of the class, a control survey of the students is conducted based on the materials of the previous lectures, their familiarization with literary sources on the subject of the discipline.

№№	**Name of the subject of the practical session, list of main questions, references to the literature**	**Hours**
1	**Design and calculation of heat exchangers** Design calculation of a shell-and-tube heat exchanger. Literature [1 – 3, 5, 8, 9, 11].	***2***
2	**Inspection of pipes and casing for strength.** TN type heat exchanger. Determination of forces in pipes and casing. Inspection of pipes and casing for strength and stability. Literature [1 – 3, 5, 8, 9, 11].	***2***
3	**Calculation of the temperature compensator** TC type heat exchanger. Calculation of the temperature compensator. Inspection of pipes and casing for strength and stability. Literature [1 – 3, 5, 7 – 9, 11].	***2***
4	**Calculation of the column apparatus** Determination of the wind load on the column apparatus. Determination of static and dynamic components of the load on the column apparatus. Calculation of the bending moment in the sections of the column apparatus. Literature [1 – 3, 5, 8, 9].	***8***
5	**Checking the conditions of strength and stability of the column apparatus** Checking the body of the column apparatus for strength and stability. Literature [1 – 3, 5, 8, 9].	***4***
	Hours in general	***18***

6 Independent work of the student

When teaching the educational discipline "Calculation and design of typical equipment-2. Calculation and construction of equipment elements of the industry" independent work of the student occupies 55% of the time of studying the credit module, taking into account the preparation for the exam. Independent work of students includes preparation for classroom classes, performance of modular control work, and study of sections of the program and topics that are not included in the list of lecture questions or require more detailed study. The acquisition of knowledge on these topics is carried out through detailed familiarization with the relevant sections of the recommended basic and additional literature and independent scientific and informational research on one's own initiative. The student's preparation for the next classroom classes involves mastering the material of the previous lectures in the process of independent work.

№№	Type of work and titles of topics submitted for independent study	Hours
1	***Preparation for classroom classes***	***10***
2	***Performance of individual practical tasks on the topic of the module***	***27***
	Working out sections of the program and topics that are not taught in lectures	
3	***Chapter 1. Design and calculation of heat exchangers*** Basic designs of heat exchangers. Analysis of axial loads and stresses in a shell-and-tube heat exchanger. Designs of temperature deformation compensators. Checking the strength of the pipes in the grid. Basic designs of devices with shells. Classification of heat exchangers. Classification of shell and tube devices. To analyze the influence of various factors on the forces that arise in pipes and casing. Analyze the designs of temperature compensators. Design the structures of pipe grids. Give designs of devices with shells. Analyze the operation of heat exchangers. Literature [1-6, 8-11].	***7***
4	***Chapter 2. Calculation and design of column apparatus*** Internal devices of column apparatuses. Designs of internal devices of bubble column apparatuses. Intensity of wind load. Analysis of the magnitude of the moment in the sections of the device. Calculation of the strength of the body and support of the column apparatus. The stability of the custom of the column apparatus. Consider the influence of internal devices on column stability. Analyze the impact of seismic loads on the column apparatus. Analyze the impact of loads on the column during installation and in working conditions. Analyze the change of the bending moment along the height of the column. Checking the body of the column apparatus for strength. Ways to increase column stability. Literature [1 – 7, 9, 10].	***7***
6	***Preparation for the exam***	***15***
	Hours in general	***66***

Policy and control

1 Policy of academic discipline (educational component)

Rules for attending lectures and practical classes

Attending lectures and practical classes is a mandatory component of studying the material. At the lecture, the teacher uses his own presentation material. Students are obliged to take an active part in the educational process, not to be late for classes and not to miss them without a good reason, not to be distracted by actions unrelated to the educational process.

Policy of deadlines, rescheduling and incentive rules

Missed classes must be made up. The student independently prepares a synopsis of the missed lecture or practical session, answers control questions to the teacher on the materials of the topic of the missed session. Individual practical tasks should be performed carefully and in a precisely defined time. Fulfillment of these requirements ensures an increase in the rating assessment of the results of mastering the educational discipline.

Academic Integrity Policy

The policy of the academic discipline is built taking into account the norms of Ukrainian legislation on academic integrity, the Code of Honor of the National Technical University of Kyiv "Ihor Sikorsky Kyiv Polytechnic Institute" and is determined by the system of requirements that the teacher presents to the student when studying the discipline (rules of behavior in classes, absences, retakes, etc.).

2 Types of control and rating system for evaluating learning outcomes (RSO)

Distribution of study time by types of classes and tasks in the discipline according to the working study plan:

Training time		Distribution of study hours				Control measures		
Credits	Hours	Lectures	Practical	Laboratory	Independent work of students	Modular control work	Calculation and graphic work	Semester control
4	120	36	18	–	66	1	–	Exam

Контроль знань студентів проводиться за допомогою співбесіди під час практичних занять, результатів виконання індивідуальних практичних завдань , а на екзамені – за допомогою білетів.

Під час оцінювання враховується таке:

1. Відвідування лекцій та практичних занять, плідність роботи під час аудиторних занять .
2. Вчасне і акуратне виконання контрольних практичних завдань для самостійної роботи.
3. Вивчення базової та допоміжної літератури.

Control of students' knowledge is carried out with the help of an interview during practical classes, the results of individual practical tasks, and at the exam - with the help of tickets.

During the evaluation, the following is taken into account:

1 Attending lectures and practical classes, productive work during classroom classes.

2 Timely and accurate performance of control practical tasks for independent work.

3 Study of basic and auxiliary literature.

1 The rating of the student from the credit module consists of the points he receives for work in practical classes, for the performance of control module and calculation-graphic works on the topic of the module, and according to the results of the semester control – exam.

2 Scoring criteria:

2.1 Work in practical classes:

– fruitful work – 5 points;

– untimely completed task – 3 points;

– passive work or absence from class – 0 points.

The maximum number of points for work during practical classes is 45.

2.2. Evaluation criteria for modular control work

– "excellent" – 14–15 points;

– "good" – 10–13 points;

– "satisfactory" – 3–9 points;

– "unsatisfactory" – 0 points.

For 18 weeks of study, based on the results of the educational work and the performance of the control module work, the maximum number of points that a student can score is 60 points.

2.3. Compilation of examination exams.

At the exam, students receive an exam ticket. Each ticket contains four questions (two of which are more difficult).

Each difficult question is valued at 12 points, and easier – 8 points.

The system of evaluating difficult questions:

– "excellent", complete answer (at least 90% of the required information) – 11–12 points;

– "good", sufficiently complete answer (at least 75% of the required information, or minor inaccuracies) – 9–10 points;

– "satisfactory", incomplete answer (at least 60% of the required information and some errors) – 7– 8 points;

– "unsatisfactory", an unsatisfactory answer – 0 points.

Evaluation system for simpler questions:

– "excellent", complete answer (at least 90% of the required information) – 7–8 points;

– "good", sufficiently complete answer (at least 75% of the required information, or minor inaccuracies) – 5–6 points;

– "satisfactory", incomplete answer (at least 60% of the required information and some errors) – 3–4 points;

– "unsatisfactory", an unsatisfactory answer – 0 points.

The maximum number of points that a student can receive as a result of successfully passing the exam is 40 points.

According to the rating scale (R), the maximum number of points is 100.

A prerequisite for admission to the exam is a rating of at least 30% of the rating scale (R), i. e. 30 points.

Distribution of rating points that students receive after studying a credit module and passing exams.

Content module	Total points
Practical training	45
Control module work	15
Semester control	
Exam	40
Together:	**100**

The procedure for enrolling missed lectures and practical classes: the student independently prepares a synopsis of the missed lecture and/or practical class, answers the teacher's control questions.

The sum of the rating points received by the student after mastering the discipline and passing the exam is transferred to the final grade according to the table:

Scores	Rating
95...100	perfectly
85...94	very good
75...84	good
65...74	satisfactorily
60...64	enough
< 60	unsatisfactorily
Admission conditions not met	not allowed

7 Additional information on the discipline (educational component)

Preliminary list of questions submitted for semester control

1 Classify column devices. Design of columnar apparatuses.

2 List nozzles of column devices, classification, main characteristics and requirements for nozzles.

3 Analyze the types and justify the use of irregular and regular nozzles.

4 Design and justify the use of distribution and redistribution devices. Give an estimate of the critical height of the packing layer.

5 Give an assessment of plate column apparatuses.

6 To analyze the nodes of attachment of plates to the body and the nodes of input of raw materials into the column.

7 Classify plate contact devices.

8 Analyze the cap plates. Guide the constructions of fastening the caps to the nozzles.

9 Analyze the plates of column apparatuses with tunnel caps. State the design and use of plates.

10 Analyze the plates of column apparatus with S-shaped elements. State the design and use of plates.

11 To analyze valve plates of column apparatuses. State the design and use of plates.

12 Analyze the ballast valve plates of the column apparatus. State the design and use of plates.

13 Analyze the mesh plates of the column apparatus. State the design and use of plates.

14 Analyze the grid plates of column apparatuses with 2 phase contact zones. State the design and use of plates.

15 To analyze the lamellar plates of the column apparatus. State the design and use of plates.

16 Analyze jet plates of column apparatus. State the design and use of plates.

17 Analyze the failure plates of the column apparatus. State the design and use of plates.

18 To provide an algorithm for calculating the strength of a flat solid round plate (perforated supporting disc for the nozzle).

19 Provide an algorithm for calculating the strength of a plate consisting of separate rectangular sections (a support disk for the nozzle).

20 Provide an algorithm for calculating the stiffness of column apparatus plates.

21 Provide an algorithm for calculating support beams under plates for strength.

22 Provide an algorithm for the constructive calculation of capsule caps.

23 Analyze wind and seismic loads on the column body.

24 Provide an algorithm for calculating the wind load on the column apparatus.

25 Provide an algorithm for calculating the bending moment from the wind load on the column apparatus.

26 Provide an algorithm for calculating the strength of a column.

27 Provide an algorithm for calculating the stability of a column.

28 Classify heat exchangers.

29 Classify shell and tube heat exchangers.

30 Analyze shell-and-tube heat exchangers with fixed tube grids. List the options for attaching the pipe grids to the device body.

31 Give options for placing pipes in pipe grids and connecting pipes to pipe grids.

32 To justify the use and design of multi-pass heat exchangers.

33 Analyze the calculation of stresses in the casing and pipes of a heat exchanger with fixed pipe grids, which are caused by pressure.

34 Analyze the calculation of stresses in the shell and pipes of the heat exchanger with fixed pipe grids, which are caused by temperature deformations.

35 Justify the use of devices with temperature compensators on the casing. Give designs of temperature compensators.

36 Design heat exchangers with a floating head.

37 Design heat exchangers with a floating head and a compensator on it.

38 To justify the use and provide designs of transverse partitions in shell-and-tube heat exchangers. The use of baffles at the entrance of the medium into the intertube space.

39 To provide an algorithm for calculating tube grids of shell-and-tube heat exchangers.

40 State the design and use of heat exchangers with U-shaped pipes.

41 State the design and use of heat exchangers with an expander on the casing.

42 Give ways of intensifying heat exchange in shell and tube heat exchangers.

43 Analyze the design, conditions of use and calculation of valves with a double-cone ring.

Working program of the academic discipline (syllabus) was compiled by an associate professor of the Department of the Academy of Sciences of the Russian Academy of Sciences, Ph.D. Andreev Ihor Anatoliyovych

Approved by the Department of Machines and Apparatus of Chemical and Oil Refining Industries (Protocol No. 20 dated 20.06.2024)

Agreed by the Methodical Commission of the Faculty of Engineering and Chemistry (protocol No. 11 dated 28.06.2024)