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

Department of Chemical Engineering and Oil Refining Industry

HIGH PRESSURE PROCESSES AND EQUIPMENT

Working program of the academic discipline (Syllabus)

Details of the academic discipline	
Level of higher education	***Second (master's)***
Branch of knowledge	*13 Mechanical engineering*
Specialty	*133 Industrial engineering*
Educational program	*Engineering and computer-aided design of innovative industry equipment*
Discipline status	*Selective*
Form of education	*full-time (day/distance/mixed)*
Year of training, semester	*1st year, spring semester, LM-41mp*
Scope of the discipline	*5 ECTS credits, 150 hours*
Semester control/ control measures	*Examination/current control*
Lessons schedule	*2 hours of lectures every week, 2 hours of practice (1 pair every two weeks)*
Language of teaching	*Ukrainian*
Information about lectors / teachers	Lector: *Ph.D. Husarova Olena Vitalyivna, +380663120701,.O.V.Husarova@nas.gov.ua* Practical / Seminar: *Ph.D. Husarova Olena Vitalyivna, +380663120701, O.V.Husarova@nas.gov.ua* Laboratory: not provided for in the curriculum
Placement of the course	https://classroom.google.com

Program of educational discipline

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

Thanks to synthesis processes using high pressure, one of the main problems of modern times has been solved - a raw material base has been created for the production of polymers, resins, fertilizers, paints, varnishes, explosives, biomaterials, etc.

Ensuring the reliable functioning of high-pressure equipment requires fundamental engineering knowledge and calculation methods.

Designing equipment for the implementation of such technological processes requires knowledge of process features, algorithms of complex time-consuming calculations using computer systems, which allows to significantly reduce the time for calculations and design work, operational and capital costs.

The basis of the educational component "High-pressure processes and equipment" is the study of physical principles and the determination of conditions for their rational implementation through the creation of appropriate equipment.

The purpose of the study *the educational component "High-pressure processes and equipment" consists in providing future masters with knowledge of the fundamental laws on which the main synthesis processes related to the chemical industry are based, their application to the theoretical analysis of specific processes, as well as the calculation and design of equipment for their implementation.*

A significant amount of the educational component is read with the use of materials that are a generalization of research and design works presented in monographs, textbooks and periodicals of various authors.

The purpose *the study of this discipline is the formation of students' complex of knowledge, namely:*

- *Carry out engineering calculations to solve complex problems and practical problems in equipment high pressure*
- *Relying on the methods of mathematical modeling and using computer technologists, CAD systems and other application programs to solve problems related to the synthesis of ammonia, methyl alcohol and urea (urea).*

In accordance with the goal, master's training in this specialty requires strengthening the competencies formed by students:

- *Ability to create, improve and apply quantitative mathematical, scientific and technical methods and computer software tools for solving engineering problems related to synthesis ammonia, methyl alcohol and urea (urea).*

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

The discipline "High pressure processes and equipment" is an optional discipline.

Requirements for starting studies include basic knowledge acquired during the first semester of master's training, in particular, knowledge of the disciplines: "Constructive design of equipment", "Engineering of innovative technologies and equipment".

The study of the discipline will be useful when learning the material of such disciplines as "Practice", "Performing a master's thesis", and will also contribute to better learning of the materials of elective disciplines, such as "Processes and equipment for the synthesis and processing of high molecular compounds", "Reliability, durability of equipment and the use of the latest cavitation technologies".

3. Content of the academic discipline

Topic 1. Synthesis equipment in ammonia production.

Topic 2. Synthesis equipment in the production of methyl alcohol.

Topic 3. Synthesis equipment in the production of urea (urea).

4. Educational materials and resources

Basic literature:

1. *Технологія зв'язаного азоту: Підручник / Товажнянський Л. Л., Лобойко О. Я. та ін. Харків: НТУ "ХПІ", 2007. – 536 с.*
2. *Кожухар В.Я. Технологія зв'язаного азоту : навчальний посібник / В.Я. Кожухар, Ю.М. Єпутатов, Л.В. Іванченко. Одеса: ОП, 2021. 280 с.*
3. *Технологія зв'язаного азоту: технологія та алгоритми розрахунків виробництва аміаку і метанолу. [Електронний ресурс] : навч. посіб. для студ. спеціальності 161 «Хімічні технології та інженерія», спеціалізації «Хімічні технології неорганічних речовин та водоочищення» / А.Л. Концевой ; КПІ ім. Ігоря Сікорського. – Електронні текстові данні (1 файл: 5,55 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2021. – 211 с. https://ela.kpi.ua/bitstream/123456789/42796/1/Amiak_metanol.pdf*
4. *Волошин М.Д. Технологія неорганічних речовин. Частина 3. Мінеральні добрива: навчальний посібник / М. Д. Волошин, Я. М. Черненко, А. В. Іванченко, М. А. Олійник. — Дніпродзержинськ : ДДТУ, 2016. — 354 с. ISBN 978-966-175-130-8*

Additional literature:

5. *Андреєв І. А., Зубрій О.Г. Апарати високого тиску. – К.: ІЗМН, 2000. – 178 с.*
6. *https://ua.waykun.com/articles/vlastivosti-amiaku-shhilnist-teploemnist.php*

7. Гринь С. О. Історичні аспекти створення промислового синтезу аміаку / С. О. Гринь, П. В. Кузнєцов // Вестник Нац. техн. ун-та "ХПИ" : сб. науч. тр. Темат. вып. : История науки и техники. – Харьков : НТУ "ХПИ". – 2009. – № 29. – С. 36-42.

8. Технологія аміаку: навч. посібник / М. А. Янковський, І. М. Демиденко, Б. І. Мельников, О. Я. Лобойко, Г. М. Корона ; УДХТУ. — Дніпропетровськ: УДХТУ; Горлівка: Концерн Стирол, 2004. — 293 с.

9. Chinchen, G. C., Mansfield, K., and Spencer, M. S. The methanol synthesis: how does it work // CHEMTECH. United States: N. p.: - № 20:11. - 1990. - p. 692-699.

10. Методи розрахунків у технології неорганічних виробництв (ч. І. Зв'язаний азот): Підручник / Лобойко О.Я., Товажнянський Л.Л., Слабун І.О. та ін. // За ред. О. Я. Лобойко і Л. Л. Товажнянського. – 3-тє вид., доп. і перероб. – Х. : НТУ "ХПІ", 2001. – 511 с.

11. Смолянкін О.О., Федік Л.Ю. Аналіз технологічного процесу отримання карбаміду як об'єкта керування // Перспективні технології та прилади. - № 21. – 2022. – С. 119-124. DOI: https://doi.org/10.36910/10.36910/6775-2313-5352-2022-21-18

12. Каталізатори в технології неорганічних речовин : монографія / Л. Л. Товажнянський О. Я. Лобойко, А. М. Бутенко, Г. І. Гринь, І. О. Слабун, М. В. Кошовець, А. С. Савенков, В. І. Тошинський ; ред.: Л. Л. Товажнянський, О. Я. Лобойко ; НТУ «ХПІ». — Харків : Підручник НТУ «ХПІ», 2013. — 220 с.

Educational content

5. Methods of mastering an educational discipline (educational component)

Lecture classes

Lectures are aimed at:

- *provision of modern, integral, interdependent knowledge in the discipline "Processes and high-pressure equipment", the level of which is determined by the target setting for each specific topic;*
- *ensuring creative work of students together with the teacher during the lecture;*
- *education of students' professional and business qualities and development of their independent creative thinking;*
- *forming the necessary interest in students and providing direction for independent work;*
- *definition at the current level of scientific development in the field of synthesis processes using high pressure;*
- *reflection of the methodical processing of the material (highlighting of the main provisions, conclusions, recommendations, their wording is clear and adequate);*
- *the use of visual materials for demonstration, combining them, if possible, with the demonstration of research results;*
- *teaching research materials in a clear and high-quality language with observance of structural and logical connections, clarification of all newly introduced terms and concepts;*
- *accessibility for perception by this audience.*

No.	***The name of the topic of the lecture and the list of main questions (list of didactic tools, references to the literature and tasks on the independent processing)***	*Hour*
1	*Lecture 1. High-pressure devices in various industries. Physical and chemical properties of ammonia. Ammonia synthesis. Methods of binding atmospheric nitrogen. Technological schemes. Material balances.* *Literature [1-3].* *Tasks for SRS: Historical reference. Alternative methods of nitrogen fixation [7].*	*2*
2	*Lecture 2. Raw material for ammonia synthesis. Obtaining a nitrogen-hydrogen mixture. Physico-chemical basis of ammonia synthesis. Equilibrium concentration. Optimal conditions for conducting the process.* *Literature [1-3].*	*2*

	Task for SRS: Effect of catalysts on ammonia synthesis reaction [2, 3, 12].	
3	*Lecture 3. Ammonia synthesis reactors. Classification. Reactors are tubular, shelf. Temperature mode. Material balance as a whole and components. Determination of ammonia concentrations at the outlet of the reactor.* *Literature [1-3].* *Task for SRS: Design of nozzle [2, 3].*	*2*
4	*Lecture 4. Ammonia synthesis catalysts, mechanism and kinetics of ammonia synthesis. Catalyst deactivation. Technology of production of industrial ammonia synthesis catalyst. Brands and characteristics of industrial catalysts.* *Literature [1-3].* *Tasks for SRS: Modern catalysts for ammonia synthesis [2].*	*2*
5	*Lecture 5. Determination of the volume of the catalyst and the main dimensions of the reactor. The main regularities for determining the geometric dimensions of the catalyst box. Calculation of the volume of the catalyst on the shelves of the reactor. Material balance of shelves.* *Literature [1-3]* *Task for SRS: Use of gas laws.*	*2*
6	*Lecture 6. Built-in and external heat exchangers. Calculation of the heat exchange process. Heat recovery boilers. Calculation of heat exchange equipment. Heat exchange devices for heating fresh gas and heating the reactor.* *Literature [1-3]* *Tasks for SRS: Starting heaters [8].*	*2*
7	*Lecture 7. Separation of a gas mixture. Methods of isolating ammonia from a gas mixture. Calculation of the refrigerator - condenser.* *Literature [1-3]* *Tasks for SRS: Designs of capacitors [2, 3, 8].*	*2*
8	*Lecture 8. Separation of a gas-liquid mixture. Discharge and circulation compressors. Purpose, designs and main parameters.* *Literature [1-3].* *Tasks for SRS: Designs of separators [2, 3, 8].*	*2*
9	*Lecture 9. Testing for assimilation of lecture material on topic 1.* *Literature [1, 3].* *Task for SRS: repeat the material for topic 1 [1-3, 8]*	*2*
	Topic 2. High-pressure devices in the production of methyl alcohol	
10	*Lecture 10. High-pressure devices in the production of methyl alcohol. Methyl alcohol. Properties, use. Product characteristics. Historical reference. Physico-chemical bases of the synthesis of methyl alcohol.* *Literature [3, 9].* *Tasks for SRS: Characteristics of the finished product [3, 9].*	*2*
11	*Lecture 11. Technological schemes of methyl alcohol synthesis. Modern technological trends of methanol synthesis. Catalysts for the synthesis of methanol at high pressure. Review of modern methanol synthesis catalysts ("Johnson Matthey Catalysts", "Sud-Chemie" AG, "Haldor Topsoe").* *Literature [1, 3, 12].* *Tasks for SRS: Ecology during methanol production [3, 9].*	*2*
12	*Lecture 12. Methyl alcohol synthesis reactors. Requirements for structural materials. Protection of equipment from corrosion. Reactors are tubular, shelf. Temperature mode. Calculation of the methanol synthesis reactor.* *Literature [1, 3, 9].* *Task for SRS: Nozzle design.*	*2*
13	*Lecture 13. Testing for assimilation of lecture material on topic 2.* *Literature [1, 3, 9].*	*2*

	Task for SRS: study topic 2.	
	Topic 3. High-pressure devices in the production of urea (urea)	
14	*Lecture 14. High-pressure devices in the production of urea (urea). Purpose of urea. Properties, use. Characteristics of raw materials and finished products. Historical reference. Physico-chemical basis of urea synthesis.* *Literature [1, 4, 11].* *Tasks for SRS: Historical reference.*	*2*
15	*Lecture 15. Methods of urea production. Description of the technological scheme with liquid recycling. Combined production of urea and ammonia. Joint process of Mitsui Toatsu and Snam Progertti. Economic advantages of combined processes.* *Literature [1, 4, 11].* *Task for the SRS: Description of the technological scheme of the granulated urea production unit [4].*	*2*
16	*Lecture 16. Basic devices in the production of urea. Urea synthesis reactors. Calculation of the urea synthesis reactor. Technological process management and production control.* *Literature [1, 4, 11].* *Tasks for SRS: The main devices in the production of urea, their advantages and disadvantages [4].*	*2*
17	*Lecture 17. Testing for assimilation of lecture material on topic 3.* *Literature [1, 4, 11].* *Task for SRS: study the material for topic 3.*	*2*
18	*Lecture 18. Analysis of equipment and comparison of technologies for the synthesis of ammonia, methyl alcohol and urea (urea). Ways of improving technologies.* *Literature [1-12].* *Task for SRS: repeat the material of topics 1-3.*	*2*
	Together	*36*

Practical training

In the system of professional training of students in this discipline, practical classes occupy 30% of the classroom load. As a supplement to the lecture course, they lay and form the foundations of the master's qualification. The content of these classes and the method of conducting them should ensure the development of the creative activity of the individual. They develop technical thinking and the ability to use special terminology, allow you to test knowledge, so this type of work is an important means of operational feedback. Practical classes should perform not only cognitive and educational functions, but also contribute to the growth of students as creative workers.

The main tasks of the cycle of practical classes:

- *help students systematize, consolidate and deepen knowledge of a theoretical nature in the field of modern synthesis methods;*
- *to teach students in the methods of solving practical tasks, to promote the mastery of skills and abilities to perform calculations, graphic and other tasks;*
- *to teach their work with scientific and reference literature;*
- *to form skills to learn independently, that is, to master the methods, methods and techniques of self-learning, self-development and self-control.*

No.	***Name of the subject of the practical session and list of main questions (a list of didactic support, references to the literature and tasks on the independent processing)***	***Hour***
1	*Practical lesson 1.*	*2*

	Determination of equilibrium constant, equilibrium concentration, working concentration of ammonia at the reactor outlet. *Literature [1-3, 6]*	
2	*Practical lesson 2.* *Material balance of the ammonia synthesis reactor.* *Literature [1-3, 6]*	*2*
3	*Practical lesson 3.* *Calculation of volume flow in reactor channels and their geometric dimensions.* *Literature [1-3, 6]*	*2*
4	*Practical lesson 4.* *Determination of thermophysical properties of gas and air, calculation of heat transfer coefficients.* *Literature [1-3, 6]*	*2*
5	*Practical lesson 5.* *Determination of heat flows in the ammonia synthesis reactor.* *Literature [1-3, 6]*	*2*
6	*Practical lesson 6.* *Refinement of the temperature regime in the ammonia synthesis reactor.* *Literature [1-3, 6]*	*2*
7	*Practical lesson 7.* *Calculation of the catalyst volume in the ammonia synthesis reactor.* *Literature [1-3, 6]*	*2*
8	*Practical lesson 8.* *Calculation of material and heat balances of condensation, temperature regime.* *Literature [1-3, 6]*	*2*
9	*Practical lesson 9.* *Algorithm for calculating the methyl alcohol synthesis reactor.* *Elements of the calculation of the urea (urea) synthesis reactor.* *Literature [1, 3, 4, 9, 11]*	 *1* *1*
	Together	*18*

Independent work of student

Independent work takes up 64% of the time of studying the discipline, including preparation for the exam. The main task of students' independent work is to acquire knowledge from the course that was not included in the list of lecture questions by personally searching for information, forming an active interest in a creative approach to educational work. In the process of independent work within the framework of the educational component, the student must learn to model modern synthesis and separation processes used in chemical engineering.

No. z/p	*The name of the topic submitted for independent processing*	*Number of hours of SRS*
1	*Operating conditions of industrial catalysts.* *Poisons for catalysts.* *Control and automation of the ammonia synthesis process.* *Ammonia storage and transportation.* *Control and automation of the methyl alcohol synthesis process.* *Storage and transportation of methyl alcohol.* *Control and automation of the urea (urea) synthesis process.* *Storage and transportation of urea (urea).* *Literature [1-14]*	*66*
2	*Preparation for the exam*	*30*

	Hours in general	*96*

Policy and control

6. Policy of academic discipline (educational component)

Rules of attending classes and behavior in classes

Attending classes is a mandatory component of the assessment. 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 interfere with the teacher conducting classes, not to be distracted by actions unrelated to the educational process. When solving problems in practical classes, students can use any sources of information and means of calculations. All tasks are performed individually.

Rules for assigning incentive and penalty points

• incentive points can be awarded by the teacher exclusively for the performance of creative works in the discipline or additional completion of online specialized courses with the receipt of the appropriate certificate, but their sum cannot exceed 25% of the rating scale.

• Penalty points are not provided within the academic discipline.

Policy of deadlines and rescheduling

In the event of arrears from the academic discipline or any force majeure circumstances, students should contact the teacher through the available (provided by the teacher) communication channels to resolve problematic issues and agree on the algorithm of actions for practice.

Policy of academic integrity

Plagiarism and other forms of dishonest work are unacceptable. Plagiarism includes the absence of references for the use of printed and electronic materials, quotes, opinions of other authors. Inadmissible tips and write-offs during writing tests, conducting classes; passing the exam for another student; copying materials protected by the copyright system without the permission of the author of the work.

The policy and principles of academic integrity are defined in Chapter 3 of the Code of Honor of the National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute". More details: https://kpi.ua/code

Policy of academic behavior and ethics

Students should be tolerant, respect the opinions of others, formulate objections in the correct form, constructively support feedback during classes.

Standards of ethical behavior of students and employees are defined in Chapter 2 of the Code of Honor of the National Technical University of Ukraine "Ihor Sikorskyi Kyiv Polytechnic Institute". More details: https://kpi.ua/code

7. 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:

Semester	Training time		Distribution of study hours				Control measures
	Credits	Acad. hours	audio hour	Lectures	Practical	SRS	Semester control
2	5	150	54	36	18	96	exam

System of rating (weighted) points and evaluation criteria

The system of rating points and evaluation criteria:

Performing tasks in practical classes.

The weighted point is 4. The maximum number of points for practical classes is 4·9=36.

Testing of assimilation of lecture material.

The weighted score is 8. The maximum number of points for testing the learning of the lecture material is 3·8=24.

Answers on the exam: 40 points.

The condition of the first attestation is the completion of 50% of practical work (at the time of attestation). The condition of the second attestation is the completion of 75% of practical work (at the time of attestation).

The condition for admission to the exam is the completion of all tasks in practical classes and tests.

The sum of the points received by the student is transferred to the examination grade according to the table:

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

8. Additional information on the discipline (educational component)

An approximate list of questions that are submitted for semester control

1. *Fields of application of high pressure devices.*
2. *Methods of binding atmospheric nitrogen.*
3. *Ammonia synthesis (historical reference).*
4. *Use of ammonia.*
5. *Physico-chemical basis of ammonia synthesis.*
6. *Equilibrium reaction of ammonia synthesis. The equilibrium constant of the ammonia synthesis reaction.*
7. *Equilibrium concentration of ammonia synthesis reaction.*
8. *Thermal effect of ammonia synthesis reaction.*
9. *Influence of pressure and temperature on the equilibrium reaction of ammonia synthesis.*
10. *Raw material for the production of synthetic ammonia.*
11. *Obtaining a nitrogen-hydrogen mixture.*
12. *Schemes of medium pressure ammonia synthesis.*
13. *Low-pressure ammonia synthesis schemes.*
14. *High-pressure ammonia synthesis schemes.*
15. *Tubular ammonia synthesis reactor.*
16. *A shelf ammonia synthesis reactor.*
17. *Material balance of the ammonia synthesis reactor.*
18. *Determination of concentrations and material flows of components at the outlet of the ammonia synthesis reactor.*
19. *Calculation of the main dimensions of the ammonia synthesis reactor.*
20. *The use of gas laws when calculating the geometric dimensions of the reactor.*

21. *Designs of heat exchangers of the ammonia synthesis reactor.*
22. *Calculation of the heat exchanger of the ammonia synthesis reactor.*
23. *Kinetics of ammonia synthesis.*
24. *Brands and characteristics of industrial catalysts.*
25. *Catalyst deactivation.*
26. *Technology of production of industrial ammonia synthesis catalyst.*
27. *Determination of the volume of the catalyst.*
28. *Calculation of the volume of the catalyst and the height of the shelf of the shelf reactor.*
29. *Calculation of heat losses to the environment.*
30. *Calculation of heat flows in the ammonia synthesis reactor.*
31. *Heat exchange equipment of the ammonia synthesis unit.*
32. *Designs of heaters.*
33. *Calculation of electric heaters.*
34. *Methods of isolating ammonia from a gas mixture.*
35. *Equilibrium of the liquid-vapor system.*
36. *Designs of water coolers-condensers.*
37. *Designs of ammonia refrigerators-condensers.*
38. *Condensation column design.*
39. *Material balance of the refrigerator-condenser.*
40. *Features of the process of ammonia condensation from a gas mixture.*
41. *Calculation of the heat transfer coefficient during ammonia condensation.*
42. *Separation (separation) of a gas-liquid mixture.*
43. *Designs of separators.*
44. *Separator calculation. The rate of sedimentation of a particle in the field of gravity.*
45. *Circulating compressors.*
46. *Methyl alcohol. Use of methyl alcohol.*
47. *Synthesis of methyl alcohol (historical reference).*
48. *Raw material for the production of methyl alcohol.*
49. *Physico-chemical bases of the synthesis of methyl alcohol.*
50. *Equilibrium reaction of methyl alcohol synthesis.*
51. *Materials for devices for the synthesis of methyl alcohol.*
52. *Protection of methyl alcohol synthesis equipment from corrosion.*
53. *Methyl alcohol production scheme.*
54. *Modern technological trends of methanol synthesis.*
55. *Synthesis catalysts methyl alcoholat high pressure.*
56. *Modern synthesis catalysts methyl alcohol("Johnson Matthey Catalysts", "Sud-Chemie" AG, "Haldor Topsoe").*
57. *Methyl alcohol synthesis reactors.*
58. *Control and automation of the methyl alcohol synthesis process.*
59. *Storage and transportation of methyl alcohol.*
60. *Urea (urea). Use in the national economy.*
61. *Urea synthesis (historical reference).*
62. *Physico-chemical basis of urea synthesis.*
63. *Reaction parameters and their effect on urea yield.*
64. *Urea synthesis schemes.*
65. *Combined production of urea and ammonia.*
66. *Joint process of Mitsui Toatsu and Snam Progertti.*
67. *Urea synthesis reactor.*
68. *Protection of urea synthesis equipment from corrosion.*
69. *Control and automation of the urea (urea) synthesis process.*
70. *Storage and transportation of urea (urea).*

Working program of the academic discipline (syllabus):

Compiled by Ph.D, Olena Husarova

Approved by the Department of Chemical Engineering and Oil Refining Industry (protocol No. 20 dated June 20, 2024)

Agreed by the Methodical commission of the faculty[1] (protocol No. 11 dated June 28, 2024)

[1] Methodical council of the university – for general university disciplines.