Національний технічний університет
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Інженерно-хімічний факультет

# Збірник тез доповідей XXXI всеукраїнської науково-практичної конференції студентів, аспірантів і молодих вчених

# ”ОБЛАДНАННЯ ХІМІЧНИХ ВИРОБНИЦТВ І ПІДПРИЄМСТВ БУДІВЕЛЬНИХ МАТЕРІАЛІВ”

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# СЕКЦІЯ 1
# «ПРОЦЕСИ ТА АПАРАТИ ХІМІЧНИХ І НАФТОПЕРЕРОБНИХ ВИРОБНИЦТВ»

**УДК 661.72**

# MODERNIZATION OF PHENOL AND ACETONE PRODUCTION UNIT WITH DEVELOPMENT OF RECTIFICATION COLUMN

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**ANNOTATION:** *The production of phenol and acetone, its composition and production by rectification through isopropylbenzene hydroperoxide are considered. The technological scheme and its description are also given.*

**KEY WORDS:** *PHENOL, ACETONE, ISOPROPYLBENZENE, DISTILLATION COLUMN.*

# МОДЕРНІЗАЦІЯ УСТАНОВКИ ВИРОБНИЦТВА ФЕНОЛУ ТА АЦЕТОНУ З РОЗРОБКОЮ РЕКТИФІКАЦІЙНОЇ КОЛОНИ

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**АНОТАЦІЯ:** *Розглянуто виробництво фенолу та ацетону, його склад та отримання шляхом ректифікації через гідроперекис ізопропілбензолу. Також наведено технологічну схему та її опис.*

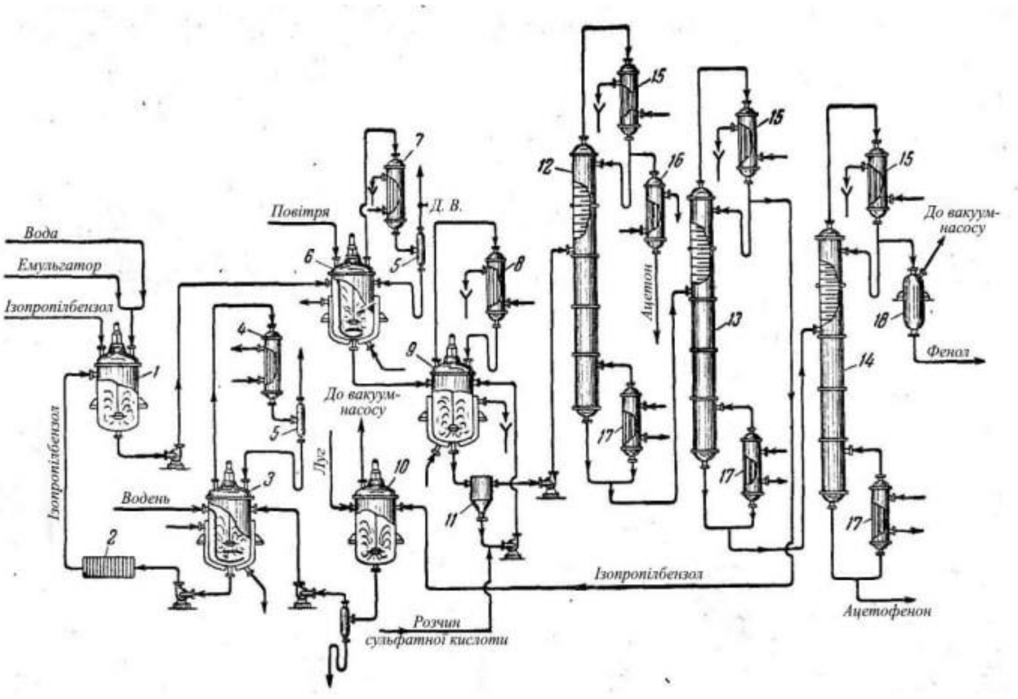
**КЛЮЧОВІ СЛОВА:** *ФЕНОЛ, АЦЕТОН, ІЗОПРОПІЛБЕНЗОЛ, РЕКТИФІКАЦІЙНА КОЛОНА.*

Phenol is produced in large quantities and used in many industries - chemical, oil, pharmaceutical, perfumery, etc.  In the petroleum industry phenol is used for selective purification of oils and as an azeotropic agent in the separation of toluene from gasoline by rectification.  Very large amounts of it are used in the production of phenol-formaldehyde resins, which are processed into plastic masses.  Phenol serves as a semi-product in the synthesis of cyclohexanol.  Many dyes are synthesized from phenol; it was also used for production of one of the oldest high explosives - picric acid (trinitrophenol).  Epoxy polymers, herbicides, salicylic acid, aspirin, tallow and other medicinal substances are obtained from phenol.  It is also used in the production of synthetic fragrances, synthetic tannins, etc.

Acetone - the simplest aliphatic ketone - is one of the most widely used solvents.  In very large quantities it is used in the paint and varnish industry, in the production of chemical fibers, film, in the production of gunpowder, in various extraction processes, for cleaning lubricants.  Acetone is used when filling cylinders with acetylene.  Due to its high octane number it can also be used as an additive to motor fuel.  The chemical properties of acetone are determined by the presence in its molecule of a carbonyl group and two methyl groups located in the position to it.  As a result, acetone has a high reactivity and can serve as a semi-product for numerous organic syntheses.

Acetone in relatively small quantities is obtained by dry distillation of wood together with acetic acid.  For a long time it was obtained by fermentation of carbohydrates in the presence of special bacteria.  Fermentation products contain 30.5% acetone, 62% n-butyl alcohol, 7.5% ethyl alcohol and other substances.  At present, this method is rapidly being replaced by synthetic methods of acetone production, where products of oil, petroleum gases and coal processing are used as raw materials.

The scheme of phenol and acetone production via isopropylbenzene hydroperoxide is shown in Figure 1.



1 - Emulsion production unit; 2 - filter; 3 - a-methylstyrene hydrogenation unit; 4, 7, 8, 16 - refrigerators; 5 - separators; 6 - isopropylbenzene oxidation unit; 9 - hydroperoxide decomposition unit; 10 - phenol saponification unit; 11 - separator; 12, 13, 14 - distillation columns; 15 - diffuser; 17 - boiler; 18 - phenol recipient.

Figure 1 - Technological scheme of phenol and acetone production

An emulsion of isopropyl benzene in water is prepared in apparatus 1 under intensive stirring.  To do this, fresh isopropylbenzene from the benzene alkylation shop, reverse isopropylbenzene purified by hydrogenation from a-methylstyrene, emulsifier and water, in which carbonate is pre-dissolved, are fed to apparatus 1.  The ratio of fresh and reverse isopropylbenzene is approximately 1:4. The isopropylbenzene emulsion is pumped to the apparatus 6 for oxidation.  Here at 130 °C air is passed through the liquid under pressure.  After about 25% of propylbenzene is converted to hydroperoxide, the reaction liquid is sent for decomposition with sulfuric acid in apparatus 9. Decomposition of isopropylbenzene hydroperoxide into phenol and acetone proceeds with the release of large amounts of heat.  The reaction rate depends on the concentration of the acid and hydroperoxide used.  When gaseous sulfur dioxide is passed through concentrated hydroperoxide, its decomposition is accompanied by an explosion. In the presence of 1% sulfuric acid, decomposition lasts 5 hours, while using 10% acid it lasts 1 hour. The use of vitriol oil in an amount even less than 0.1% of the amount of hydroperoxide causes its rapid decomposition. Therefore, the process of decomposition of hydroperoxide into phenol and acetone in production conditions is carried out under appropriate precautions. Excess heat is removed in a reflux condenser 8 . From apparatus 9 the liquid flows into separator 11; the separated sulfuric acid can be used again for decomposition of hydroperoxide. The reaction products containing after separation of sulfuric acid 8 % acetone, 14 % phenol, 76 % unreacted isopropylbenzene and up to 2 % impurities are sent for rectification. Acetone is distilled off in the distillation column 12; isopropylbenzene with impurities of a-methylstyrene and phenol is distilled off in the distillation column 13. These impurities interfere with the normal course of the oxidation reaction, so isopropyl benzene is purified. In apparatus 10, it is treated with an aqueous alkali solution, as a result of which the phenol is converted into phenolate and passes into a solution, which is separated from the hydrocarbon layer in a separating vessel. In apparatus 3, hydrogen is passed through isopropylbenzene in the presence of suspended metal nickel (catalyst). At the same time, a-methylstyrene is hydrogenated into isopropylbenzene. Then isopropylbenzene is sent through filter 2 to mix with fresh isopropylbenzene in apparatus 1. The cubic liquid from the column 13 flows into the rectification column 14, where phenol is separated from acetophenone by dilution. Phenol vapors are removed from the top of the column and crystallized in the receiver 18. The cubic liquid from column 14 contains mainly acetophenone.

The distillation column is an important apparatus that is depicted in the process flow diagram, so to modernize the production we decided to improve the column as in my opinion it is in it that the main process takes place.

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**УДК 66.047**

# MODERNIZATION OF THE ROTARY DRYER OF THE SALT PRODUCTION UNIT

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**ANNOTATION:** *The technological scheme of production of table salt is considered. The advantages and disadvantages of the drum dryer are formulated.*

**KEY WORDS:** TECHNOLOGICAL SCHEME, TABLE SALT, ROTARY DRYER.

# МОДЕРНІЗАЦІЯ БАРАБАННОЇ СУШАРКИ УСТАНОВКИ ВИРОБНИЦТВА СОЛІ

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**АНОТАЦІЯ:** *Розглянуто технологічну схему виробництва кухонної солі. Сформульовано переваги і недоліки барабанної сушарки.*

**КЛЮЧОВІ СЛОВА:** ТЕХНОЛОГІЧНА СХЕМА, КУХОННА СІЛЬ, БАРАБАННА СУШАРКА.

Salt industry is a branch of industry producing table salt. Obtaining salt from natural salt sources, brines extracted from wells and wells, as well as from sea water has long been one of the main human activities [1].

Underground dissolution of rock salt is carried out through boreholes with the supply of brine to the earth's surface. A network of wells with a distance of 250-300 m between them is laid depending on the depth and thickness of the formation. Borehole salt extraction with dissolution has advantages over other extraction methods: unmanned extraction, low brine cost, the ability to develop deposits with deep deposits, salt enrichment due to the sedimentation of water-insoluble impurities to the bottom of the underground dissolution chamber.

The halite solution, which is extracted through wells, is used to produce evaporated salt, as well as soda ash, chlorine and caustic. The production of precipitated salt is 50% of the total solid salt production and is carried out by open-pit mining.

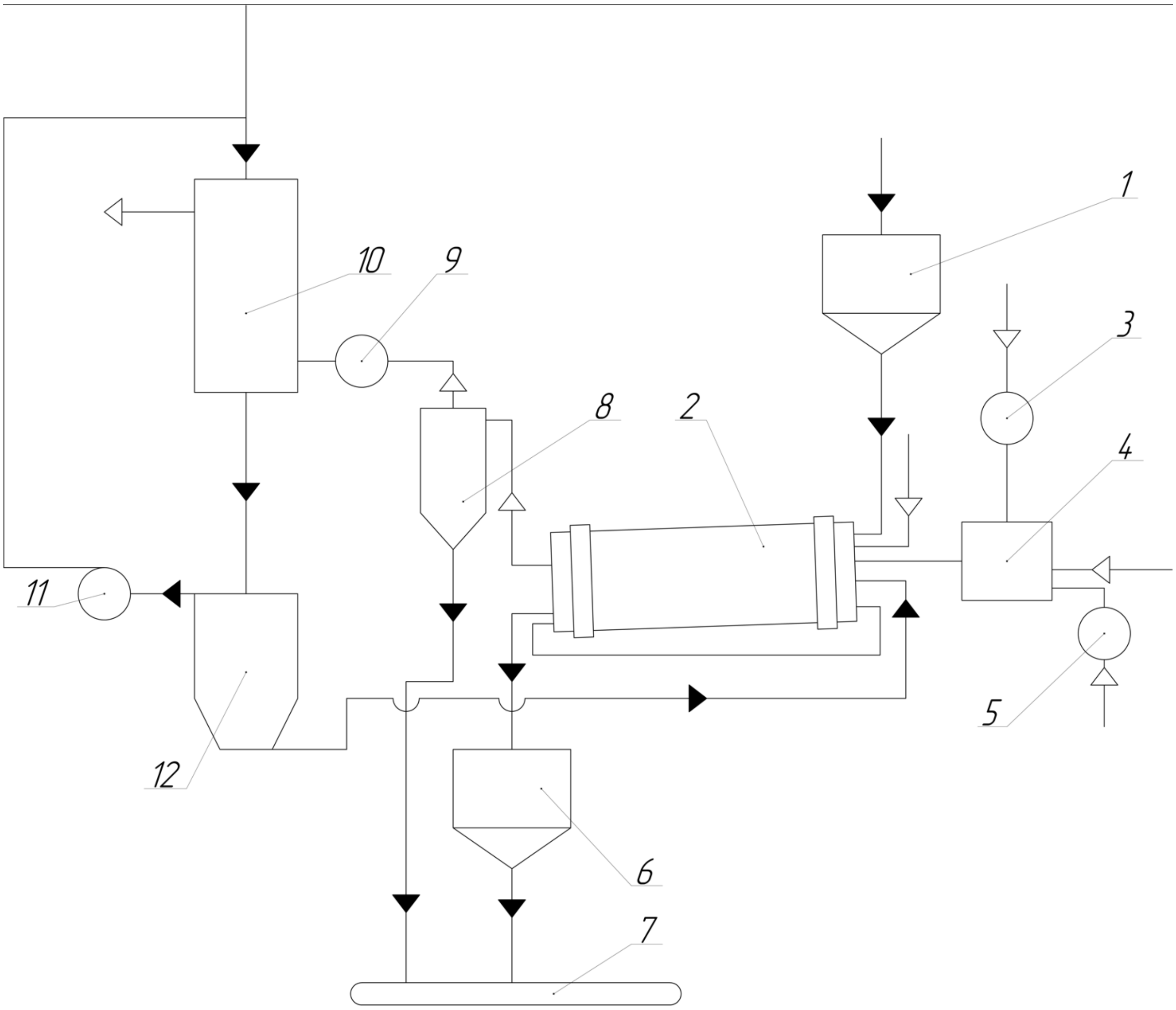
Primary crushing is carried out in gyratory crushers, secondary crushing or coarse grinding - in centrifugal crushers. Grinding of salt into flour takes place in roller mills. Drying of salt is carried out in rotary dryers and fluidized bed dryers.

Technological scheme of salt production in Figure 1 [2].

The initial product enters the hopper 1. Then it is fed to the rotary dryer 2, where the material is dried by flue gases. After that, the dried material is fed through the hopper 6 to the belt conveyor 7.

Flue gases are formed in the furnace 4. For fuel combustion, air is supplied to the furnace by means of a fan 5. After fuel combustion, the flue gases enter the mixing chamber, where they are diluted to the desired temperature by air coming from the fan 3.

The drying agent leaves the mixing chamber and is fed to the rotary dryer 2. The spent agent, together with dust, leaves the drum dryer 2 and enters the cyclone 8. Solid particles settle and fall on the belt conveyor 7. After the cyclone, the gas is fed by a fan 9 to a wet dust collector 10 for further cleaning of the exhaust gases, for which water is supplied to the top of the dust collector. The purified gas is discharged into the atmosphere.



1,6 - hopper; 2 - rotary dryer; 3,5 - fan; 4 - furnace; 7 - belt conveyor; 8 - cyclone; 9,11 - pump; 10 - wet dust collector; 12 - sump.

Figure 1 - Technological scheme of salt production [2]

The sludge consisting of dust and water formed in the wet dust collector 10 is fed to the settling tank 12. Here the slurry is settled, after which the sludge from the lower part is fed to the drying drum 2 by means of a screw. The liquid from the upper part of the settling tank is fed by means of a pump 11 to the wet dust collector 10.

The rotary dryer is the main apparatus of the technological scheme of salt production, since the process of drying salt takes place in it, so there is a need for more rational use of heat and energy resources. The main way to save fuel is to create technological processes and devices with maximum efficiency of using these resources.

The advantages of rotary dryers include: high productivity, high efficiency in heat and electricity consumption, reliability in operation, simplicity of design and ease of operation. The disadvantages of dryers are due to their bulkiness, high capital costs, grinding of the material during drying, prolonged contact of the material with the heat agent (up to 40 minutes), contamination of products with ash from the furnace (0.2-0.7%), sticking of wet material to the inner surface and nozzles of the drum, as well as fire hazard and emissions into the atmosphere. Rotary dryers are usually used at concentrating plants of large capacity.

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**UDC 661.715.3**

# THE MODERNIZATION OF THE PLANT FOR THE BUTADIENE PRODUCTION FROM ETHANOL

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***Abstract***: *The production of butadiene1,3, its importance and its production by separation from ethanol are considered, a technological scheme is given.*

***Key words***: *butadiene, ethanol, separation*

# МОДЕРНІЗАЦІЯ УСТАНОВКИ ВИРОБНИЦТВА БУТАДІЄНУ З ЕТАНОЛУ

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***Анотація***: *Розглянуто виробництво бутадієну1,3, його важливість та отримання шляхом виділення з етанолу, наведено технологічну схему.*

***Ключові слова***: *бутадієн, єтанол, виділення*

All modern civilization exists and is supported, first of all, thanks to the production of millions of different products, without which the infrastructure that supports our life cannot work and, if these capabilities are lost, humanity will not be able to live on. Many of these production processes are interconnected and impossible without each other. One of these production processes is the process of producing 1,3-butadiene from ethanol.

The production of 1,3-butadiene is important and relevant because this substance is necessary for production of butadiene rubbers and ABS(Acrylonitrile butadiene styrene) by polymerization.

Butadiene rubbers are general purpose rubbers. The main field of application is the production of tread and covering (frame, sidewall) tire rubbers. These rubbers are also used in the production of shoe soles, cable insulation, impact-resistant polystyrene, etc. ABS is used for the production of hulls of household appliances and industrial batteries, parts of cars, medical equipment, etc.

Of all the possible processes for the production of butadiene, this scheme was chosen because, while taking into account the fact that the production of butadiene from butane (the most frequently used method in the modern world) at the moment is more economical at large capacities, ethanol is a biofuel the production of which is currently significantly increasing [1], as well as this process requires lower capital costs and becomes profitable at a low price of ethanol[2, 4] therefore this direction is promising.

Diagram of butadiene production from ethanol is presented in fig. 1.

Ethanol coming from storage in a mix with ethanol returned after regeneration from the other stages of the process enters tubular evaporators, from which ethanol vapors are sent to heaters installed in the retort furnace. There superheated vapors undergo contact decomposition. The contact gases leaving the furnace are cooled first in water coolers, and then in brine coolers. When the contact gases are cooled to -7°C, part of the vapor-like products condenses, and the non-condensed vapor-gas mixture is sent to the absorbers. Condensate mostly consists of water (30-40%), ethyl alcohol (50-60%), diethyl ether (2-4%), small amounts of high-boiling hydrocarbons (1-2%).

After washing, the condensate is settled for separation from hydrocarbons and then goes to rectification. Result of the process consists of several fractions.

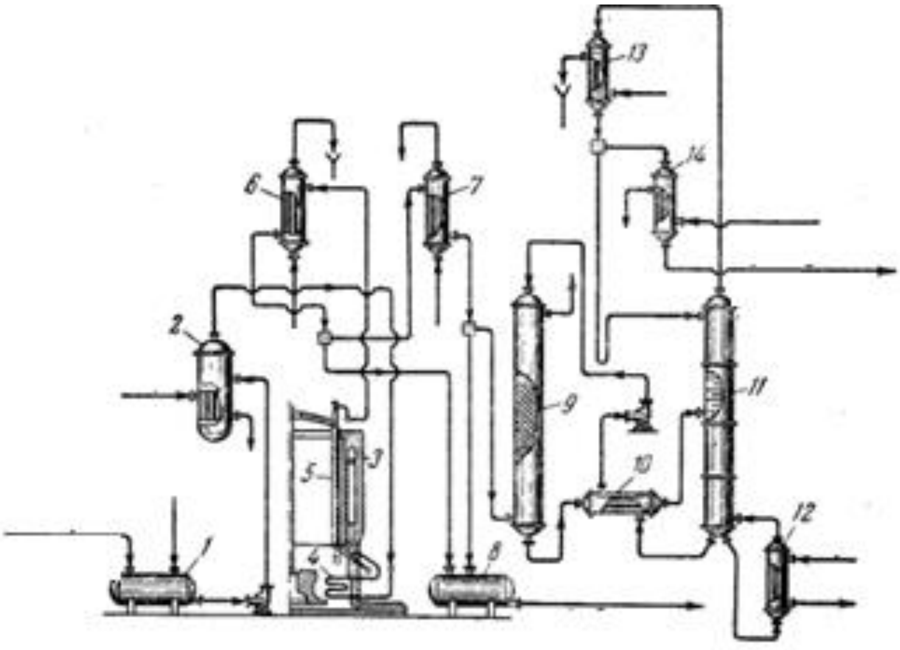

Figure 1. – The technological scheme

The steam-gas mixture that is not condensed in refrigerators mainly consists of hydrogen (44.6%), butadiene-butylene (33.3%) and ethylene (8.6%), as well as propylene, ethane, carbon dioxide and other gases.

To extract butadiene, the mixture in the absorbers is washed with ethanol cooled to -7$^{o}$C. Under such conditions, alcohol absorbs up to 99% of butadiene in the gas mixture, and besides butadiene ethanol additionally absorbs carbonyl compounds, ether and hydrocarbons that boil at higher temperatures than butadiene. Gas containing 75-78% hydrogen, about 14% ethylene, 2% C4 hydrocarbons (butadiene + butylene) and some other components is removed from the upper part of the absorbers. The calorific value of waste gas is about 3500 kcal/nm3. Due to the high content of hydrogen and a significant amount of olefins in the gas, it is used as a material for chemical processing.

The alcoholic butadiene solution is sent to the desorber (distillation column). After distillation, the regenerated ethyl alcohol is cooled and directed to the absorbers. After distillation, crude butadiene is formed, containing about 60% butadiene and 40% aldehydes, ethers, hydrocarbons, etc. Crude butadiene is not suitable for polymerization, so it is subjected to purification. First of all, dissolved impurities, are extracted from the crude using water in a column extractor. An alternative to the extractor can be centrifugal pumps, centrifugal mixers, devices with stirrers, injectors, etc. So, for example, if water and raw butadiene are fed into the suction nozzle of a centrifugal pump at the same time, then when the blades of the impeller rotate, both liquids are mixed. "oil in water", which is fed to a settling tank, where the emulsion layers are separated. Washed crude butadiene is taken from the top of the sump, aldehyde water from below. Using several pumps and clarifiers in success for washing and directing both liquids against each other it is possible to achieve a good washing of butadiene from water-soluble impurities. The raffinate is washed butadiene

Washed butadiene also goes to rectification. First, it is separated from volatile impurities (light hydrocarbons, carbon monoxide and dioxide), then from higher hydrocarbons. The composition of these hydrocarbons is approximately the same as the composition of the hydrocarbon fraction released from the condensate. The end result is a butadiene rectifier containing about 90% pure butadiene, the rest is pseudo butylene [3].

The most promising and important in this scheme seems to be the modernization of the ethanol evaporator, since this structure performs an important role, evaporating ethyl alcohol for use in contact decomposition and removal of impurities, therefore, increasing the productivity and efficiency of using the evaporator makes it possible to increase the productivity of the entire structure and remove or prevent possible bottlenecks in the process.

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# КОНСТРУКЦІЇ МОБІЛЬНИХ ТЕПЛОВИХ АКУМУЛЯТОРІВ

к.т.н., с.н.с., пр. н. с. Коник А.В., пр. інженер Хоменко М. В.

**Інститут технічної теплофізики НАН України**

Використання мобільних теплових акумуляторів (далі M-TES, Mobile Thermal Energy Storage) є перспективним альтернативним рішенням теплопостачання розрізненим споживачам з використання у якості джерела - теплоти промислових відходів та актуальною темою шляхів їх впровадження. Мобільне транспортування теплоти дає можливість вирішити такі проблеми як:

- зменшити кількість викидів $CO_2$ з виробництв з метою збереження екології до 60%, 78% та 95% залежно від системи використання в порівняні з звичайними опалювальними системами, що використовують викопне паливо;

- зменшення кількості первинної необхідної теплоти споживачів;

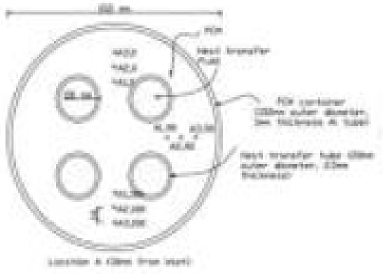
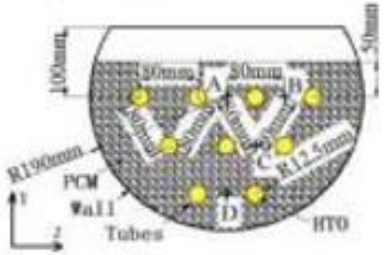
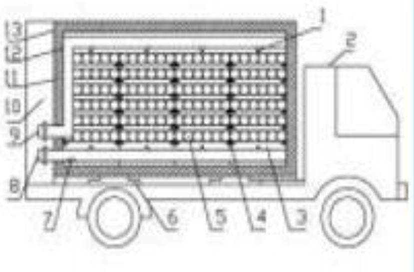
- забезпечити опаленням та гарячим водопостачанням споруди, віддалені від централізованих систем;

- тимчасова альтернатива при виникненні аварійних ситуаціях.

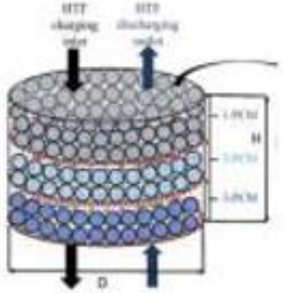
На сьогоднішній день активним пошуком та розробкою займаються у Великобританії, Японії, Німеччині та Китаї. Наразі не існує універсального способу зарядки та розрядки акумуляторів, як і оптимальної конструкції теплового акумулятора для транспортування теплоти. Наявні конструкції доцільно використовувати тільки в залежності від умов експлуатації.

У таблиці 1 наведено перші реалізовані зразки мобільних теплових акумуляторів, їх конструкції, способи розташування матеріалу з фазовим переходом (далі PCM, Phase Change Materials) та його види, що були розроблені за останні роки.

Таблиця 1 – Відомі конструкції використання РСМ в транспортуванні теплової енергії M-TES

| Рік / країна створення | Автори | Параметр конструкції, РСМ | Час повного зарядження | Опис конструкції | Схема конструкції M-TES |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 2010 р.<br>Велико-британія | Agyenim та інші | 20 кг еритриту | 285 хв | Кожухотрубний:<br>4 циліндричні трубки на вході |  |
| 2014 р.<br>Китай | Wang та інші | 60 кг еритриту | 600 хв<br>(потужністю<br>680 Вт) | Кожухотрубний:<br>9 циліндричних трубок на вході |  |
| 2016 р.<br>Китай | Zhang та інші | Об’єм для Інкапсульованих сфер РСМ, м:<br>3,6×1,8×1,1 | в 3 рази > чистого еритриту | Інкапсульвоний:<br>864 інкапсульованих сфер РСМ |  |

Продовження таблиці 1

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| 2017 р.<br>Китай | Yang та інші | Більше 7 кг RT35 | На 65% швидше при додаванні кільцевих ребер | Кожухотрубний:<br>1 впускна трубка з кільцевими ребрами |  |
| 2020 р.<br>Велико-британія | Al-Mudhafar та інші | RT82 | 105 хв.<br>(на 45% швидше від звичного контейнера без перетинчастої трубки) | Перетинчаста трубка та оболонка: 4 вхідні трубки з ребрами |  |
| 2020 р.<br>Китай | Wang та інші | 215 кг тригідрату ацетату натрію | 20 хв<br>Тепловий ККД 79,4% | Кожухотрубний: 80 вхідних трубок з нержавіючої сталі |  |
| 2020 р<br>Китай | Mao та Zhang | В 1 контейнер:<br>1. $Na_2CO_3$-$Li_2CO_3$<br>2. $MgCl_2$-NaCl<br>3. KOH | Кількість енергії: від $5{,}2\times10^{12}$ до $1{,}3\times10^{13}$ Вт·год при пористісті 0,6-0,1 | Сферична тара з оболонкою |  |

Пошук та розробка оптимальної конструкції залишається актуальним питанням і на сьогоднішній день. При проектуванні нових конструкції враховують:

- доцільність використання - швидкість заряджання/розрядки для економії часу та витрат на електроенергії;
- діапазон температур, в якому працює PCM і теплоносій;
- стабільність технологічних показників;
- кількість працездатних циклів роботи;

Технологічні показники демонструють, що мобільні теплові акумулятори при прямому контакті мають ефективність до 60% за коротший період зарядки/розрядки в порівнянні з аналогічними системами при непрямому контакті. Для скорочення періоду зарядки/розрядки також використовують різні методи покращення теплопередачі. Наприклад, графітова добавка при прямому контакті пришвидшує процес до 29%, а при непрямому зарядку на 74%, розрядку на 67% [1].

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**УДК 66.047**

# HEAT EXCHANGER FOR HEATING OF THE GAS MIXTURE COOLING IN TECHNOLOGICAL SCHEME OF ACETIC ACID PRODUCTION

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**ANNOTATION:** *The process of ethanol production by hydration of ethylene is considered. The technologocsl scheme has also been presented and reviewed.*

**KEY WORDS:** METHANOL, ACETIC, ACID, CARBONIZATION, SHELL AND TUBE, HEAT EXCHANGER.

# ТЕПЛООБМІННИК ДЛЯ НАГРІВУ ГАЗОВОЇ СУМІШІ ТЕХНОЛОГІЧНОЇ СХЕМИ ПРОЦЕСУ ВИГОТОВЛЕННЯ ЕТАНОВОЇ КИСЛОТИ

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**АНОТАЦІЯ:** *Розглянуто процес виробництва етанової кислоти шляхом карбонілюванням метанолу. Технологічна схема також розглянута та додана.*

**КЛЮЧОВІ СЛОВА:** МЕТАНОЛ, ЕТАНОВА, КИСЛОТА, КАРБОНІЛЮВАННЯ, КОЖУХО-ТРУБНИЙ, ТЕПЛООБМІННИК.

World production of acetic acid has been growing recently, as it is used for the production of artificial silk, plastics, dyes. It is also actively used in the food industry, where it is an officially registered food additive under the number E260 and is used as an acidity regulator [1].

Acetic acid is a transparent and colorless liquid with a characteristic and pungent odor and sour taste. It has hygroscopic properties, miscible with water in any proportions. It is effectively mixed with many other solvents, and has good dissolving properties [1].

In concentrated form it is a caustic chemical that can adversely affect human tissues. It leaves burns on the organs of the digestive system when consumed. It belongs to toxic reagents, 20 ml of concentrated acetic acid is considered a lethal dose for humans. When inhaled, acid vapors irritate the mucous membrane of the respiratory system. Acetic acid is also flammable. Aqueous solutions with a concentration of no more than 30% are considered safe [1].

A large amount of acetic acid is used in the food industry. It is used for the production of canned products, sauces and confectionery.

Acetic acid is also used in pharmacology, where it is an ingredient of many drugs, such as aspirin, phenacetin.

Acetic acid is also used in the chemical industry. It is used to produce acetone, acetyl cellulose, as well as many paints and varnishes and other substances. In production, the soluble properties of this compound are used, which are necessary for cleaning, fumigating procedures.

It can be used in the perfumery industry in the production of perfumes, colognes and deodorants. Also in the textile industry acetic acid salts are used for the treatment of fabrics before dyeing.

Part of the technological scheme of methanol carbonylation in Figure 1 [2].

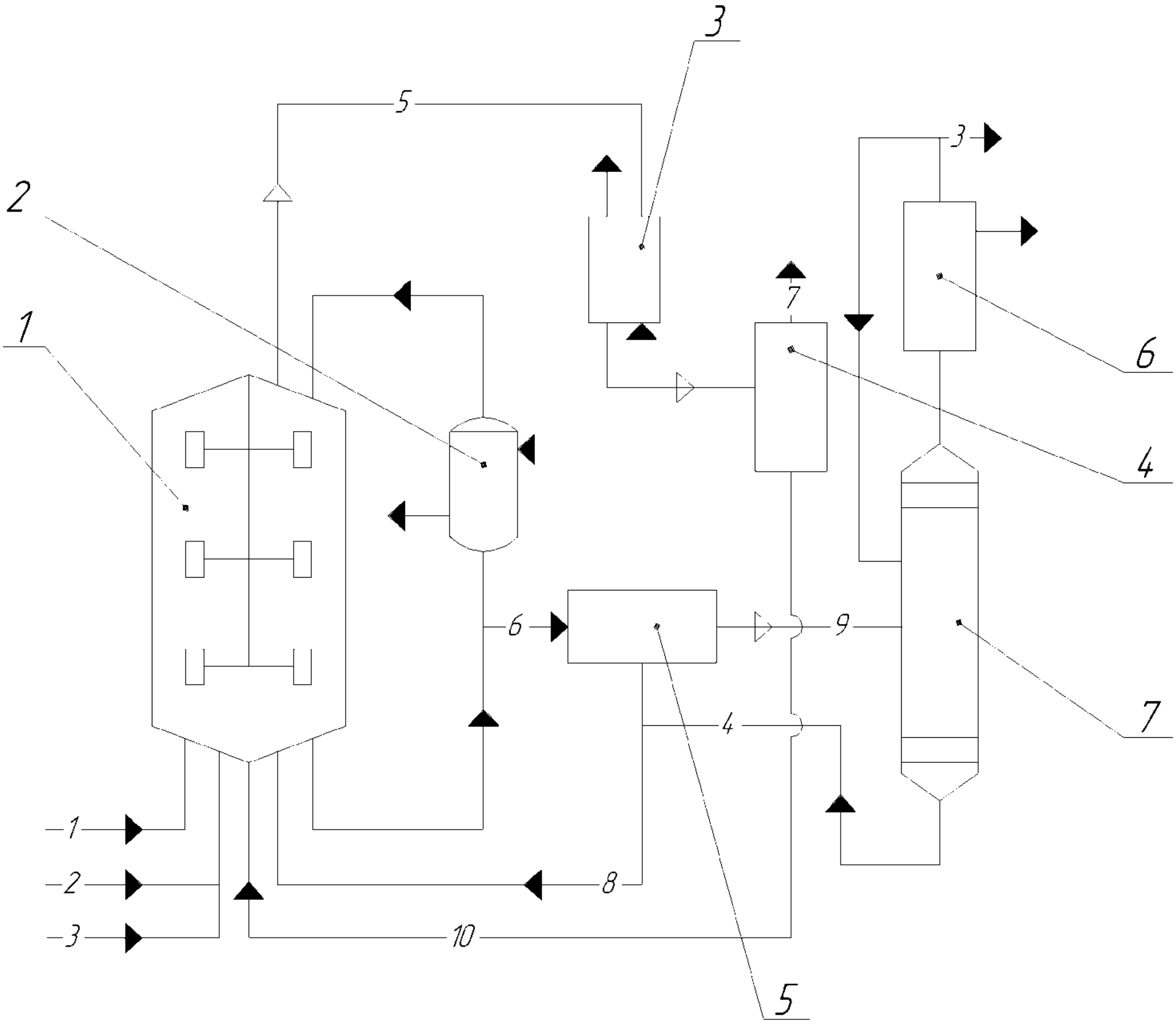
The bubbling type 1 synthesis reactor, equipped with a stirring device, is fed by a pump from the assembly with methanol, which is preheated with water vapor from 40 to 140-180 ° C. Carbon monoxide enters the reactor through the bubbling ring, resulting in the formation of a dispersed phase that promotes rapid dissolution of gas in the reaction mixture. The residence time of the substances in the reaction zone (0.25-0.30 h) is regulated by the liquid level in the reactor (75-80% of its capacity), and the completeness of the synthesis process at a pressure of 2.8 MPa and a temperature of 185 ° C is thoroughly mixed by stirring all the streams entering the reactor with a stirrer.

The reaction liquid (acetic acid and catalyst solution with a promoter) from reactor 1 enters the separator 5, where due to a decrease in pressure to 62 kPa, partial evaporation of the liquid occurs and the temperature drops to 116 ° C. Here, steam is separated from the liquid. The liquid containing the catalyst is returned from the lower part of the separator 5 to the reactor 1, and the vapors coming from the upper part of the separator enter the light fraction distillation column 7. These vapors contain acetic acid, methyl iodide, hydrogen iodide, water and small amounts of methanol, methyl acetate,

Methyl iodide with water and acetic acid vapors is taken from the upper part of column 7, condensed in the condenser refrigerator 3 and separated in the separator 6 into two phases: heavy and light. The heavy phase, containing mainly methyl iodide, is returned to reactor 1; part of the light phase is used as phlegm for irrigation of column 7, and part is returned to the synthesis reactor.

The heavy phase consisting of methyl iodide and acetic acid is removed from the cube of column 1; this stream flows by gravity to separator 5 and thus hydrogen iodide and rhodium are returned to the cycle.

Crude acetic acid is taken from the middle part of the column 7 and sent to the purification stage.



1 – reactor; 2 – tube heat exchanger; 3 – refrigerator; 3 – hydrator;

4, 5, 6 – separator; 7 – rectification column;

Flues: 1 – carbon monoxide; 2 – methanol; 3 – water; 4 – cubic residues;

5, 7, 9 – flue gases; 6, 8, 10 – liquid phase;

Figure 1 – Technological scheme of methanol carbonylation

Exhaust gases containing vapors of methyl iodide, acetic acid and water are removed from the upper part of the synthesis reactor 1. After cooling in the condenser refrigerator 3, the gas phase is separated from the liquid phase in the separator 4, after which the liquid is returned to the synthesis reactor, and the gas is sent for purification.

The heat exchanger is not the main apparatus of the technological scheme shown in Figure 1, but it is an integral part of the technological scheme of acetic acid production. It is where the liquid is heated and cooled, which is necessary for the further process. Therefore, it is necessary to choose the device, which in these conditions will show the greatest productivity.

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УДК 661.72

# ЗАЛЕЖНІСТЬ КОНВЕРСІЇ ЦЕЛЮЛОЗИ В РЕЗУЛЬТАТІ ФЕРМЕНТАТИВНОГО ГІДРОЛІЗУ ВІД ПАРАМЕТРІВ ПОПЕРЕДНЬОЇ ПІДГОТОВКИ РОСЛИННОЇ БІОМАСИ В РОТОРНО-ПУЛЬСАЦІЙНОМУ АПАРАТІ

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**Анотація:** Розглянуто вплив концентрації лугу (NaOH) в процесі попередньої підготовки соломи пшеничної до гідролізу в роторно-пульсаційному апараті за температури обробки 90°С, та швидкості обертання ротора 47,75 об/с. Результати обробки порівняно з аналогічною обробкою шляхом автоклавування за температури 121ºС.

**Ключові слова:** біоетанол, солома пшенична, попередня підготовка, конверсія целюлози, роторно-пульсаційний апарат.

**Abstract:** The effect of alkali concentration (NaOH) in the process of pretreatment of wheat straw for hydrolysis in a rotor-pulsation apparatus at a treatment temperature of 90°C and a rotor rotation speed of 47.75 rps was considered. Treatment results compared to similar treatment by autoclaving at a temperature of 121ºC.

**Keywords:** bioethanol, wheat straw, pretreatment, conversion of cellulose, rotor-pulsation apparatus.

Виробництво етанолу з лігноцелюлозної сировини ускладнюється наявністю в ній геміцелюлоз та лігніну.

Головною метою попередньої підготовки лігноцелюлозної сировини до гідролізу є руйнування гетерогенної матриці, збільшення площі поверхні та пористості целюлозного матеріалу, а також звільнити вуглеводи від зв’язку лігніну, тим самим покращуючи ферментативну засвоюваність [1].

Перетворення полісахаридів являє собою ефективність гідролізу лігноцелюлозної біомаси на основі її попередньої обробки та доступності для ферментів. За ідеальних умов усі полісахариди в лігноцелюлозній біомасі гідролізуються в моносахариди. Зазвичай не всі полісахариди можуть бути кількісно гідролізовані в моносахариди. Залишаються деякі полісахаридні ланцюги, особливо найменш доступні.

Зв’язок між попередньою підготовкою лігноцілюлозної сировини та ступенем конвертації целюлози в результаті ферментативного гідролізу вивчалась багатьма авторами, зокрема [2].

**Метою роботи** було визначення впливу обробки лужної дисперсії соломи пшеничної в роторно-пульсаційному апараті на швидкість конверсії целюлози в результаті ферментативного гідролізу.

**Матеріали і методи**. Сировиною була солома пшениці наступного складу (% мас./мас.): целюлоза 45,6 %, лігнін 17,1 %, екстрактивні речовини 5,4 %, геміцелюлози 25,8 %, зола 4,2 %., подрібнена до середнього розміру частинок 0,1...0,4 мм. Обробка лужної суспензії соломи пшеничної відбувалась в дослідній установці з реактором-змішувачем, що є роторно-пульсаційним апаратом. Відділені після попередньої обробки, нейтралізовані, відфільтровані, промиті та висушені зразки було піддано ферментативному гідролізу із використанням 35 FPU/г целюлази з *Trichoderma reesei* (Celluclast 1,5 L) і 61,5 FPU/г целлюлази з *Aspergillus niger* (Novozym 188) в цитратно-натрійовому буфері (pH 4,8, 50 мМ). Потім гідролізат центрифугували для збору супернатанту для визначення виходу мономерного цукру за допомогою ВГРХ.

## Результати

Порівняння результатів попередньої підготовки соломи пшеничної ( гідромодуль 1:10) до гідролізу методом дискретно-імпульсного введення енергії за температури обробки 90°C, за швидкості обертання ротора 47,75 об/с та автоклавуванням за температури 121°C протягом однієї години за різних концентрацій лугу представлено на рисунку 1.

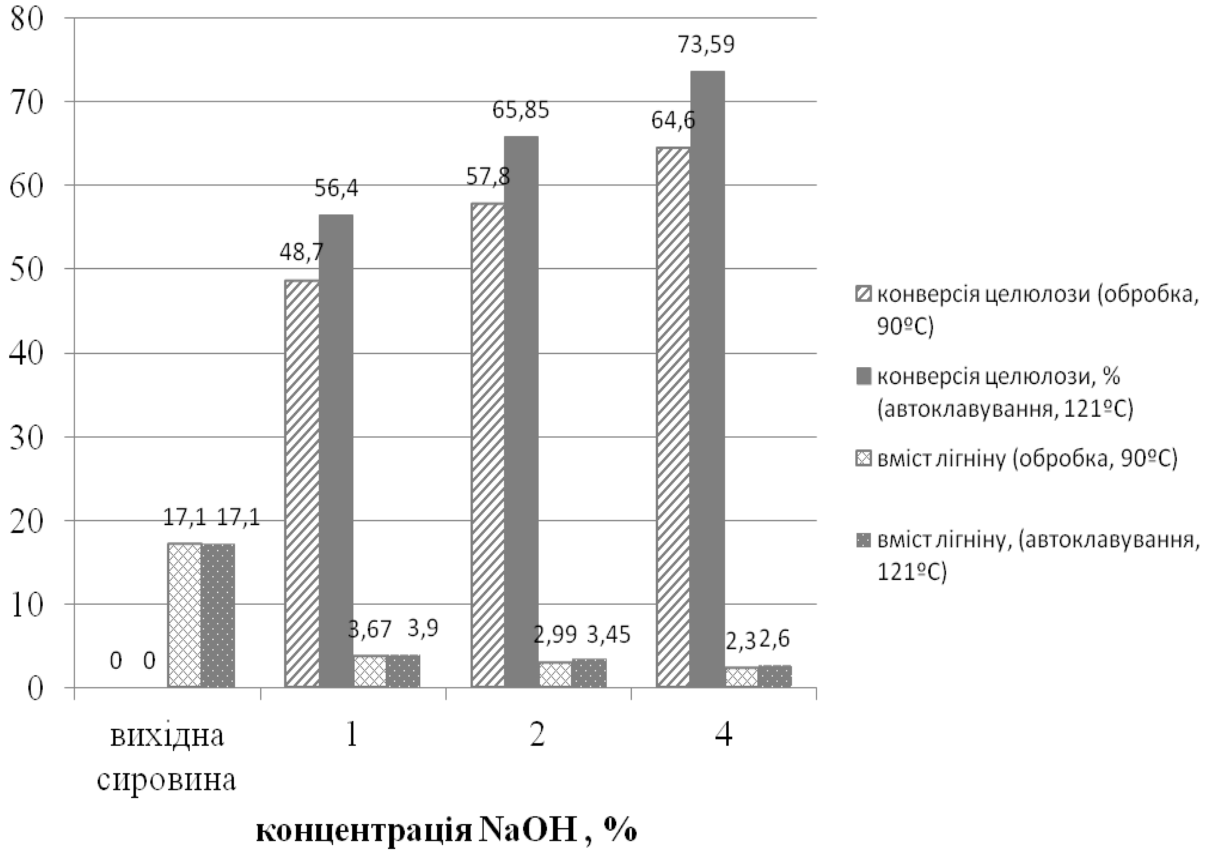

Рис. 1. Залежність конверсії целюлози в результаті ферментативного гідролізу після попередньої обробки в автоклаві (121ºС) та дискретно-імпульсним підведенням енергії (90ºС; швидкість обертання ротора 47,75 об/с) при концентраціях лугу 1, 2 і 4 (% мас)

З рисунку можна зробити висновок, що обробка методом дискретно-імпульсного введення енергії призводить до підвищення швидкості конверсії целюлози для всього діапазону концентрацій лугу. Так, при концентрації лугу 1% підвищення швидкості конверсії целюлози склала 48,7% при автоклавуванні та 53,4% при обробці. Для концентрації лугу 2% швидкість конверсії целюлози склала 57,8 та 65,85 % відповідно. Для концентрації лугу 4% швидкість конверсії целюлози склала 64,6 та 73,59 % відповідно. Вміст лігніну після попередньої обробки 1% концентрацією лугу становив 3,9% в автоклаві та 3,67% в обробці. Для концентрації лугу 2% вміст лігніну становив 3,45 і 2,99% відповідно. Для концентрації лугу 4% вміст лігніну становив 2,6 і 2,3% відповідно.

**Висновок:**

В результаті досліджень було встановлено, що підвищення концентрації лугу протягом лужної попередньої підготовки соломи пшеничної шляхом обробки методом дискретно-імпульсного введення енергії призводить до підвищення швидкість конверсії целюлози при наступному ферментативному гідролізі. Визначено, що обробка сприяє підвищенню швидкість конверсії целюлози в порівнянні з автоклавуванням.

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**UDC 665.7**

# MODERNIZATION OF THE RECTIFICATION COLUMN OF THE METHANOL-ETHANOL MIXTURE SEPARATION UNIT

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***ABSTRACT.*** *Methanol-ethanol rectification. Purpose and characteristics of the process. Physico-chemical properties of raw materials and products. Description of the technological scheme of the process.Design and justification of the choice of the device.*

***KEYWORDS.*** RECTIFICATION, METHANOL, ETHANOL

# МОДЕРНІЗАЦІЯ РЕКТИФІКАЦІЙНОЇ КОЛОНИ БЛОКУ РОЗДІЛЕННЯ СУМІШІ МЕТАНОЛ-ЕТАНОЛ

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***АНОТАЦІЯ.*** Ректифікація метанол-етанол. Призначення і характеристика процесу. Фізико-хімічні властивості сировини і продуктів. Опис технологічної схеми процесу. Конструкція і обгрунтування вибору апарату.

***КЛЮЧОВІ СЛОВА.*** РЕКТИФІКАЦІЯ, МЕТАНОЛ, ЕТАНОЛ,

Ethanol, ethyl alcohol - chemical formula $C_2H_5OH$ - colorless lively liquid with a burning taste and a characteristic smell. The molecular mass of ethanol is 46 g/mol. Temperatureethanol boiling point 78.4°C, melting point = - 114.15°C, density at 20°C = 0.794 t/m3, nD20 = 1.3611.Ethanol is miscible in all respects with water, alcohols, glycerin, diethyl ether and other organic solvents. With some of them (water, benzoscrap, ethyl acetate, chloroform) it will form azeotropic mixtures of various compositions. An azeotropic mixture of ethanol and water containing 95.6% by volume of ethanol boils at a constant temperature of 78.1°C. To obtain anhydrous ("absolute") ethanol in industry, usethere are special methods of its dehydration, for example, absolutization with benzene, oxides or salts of calcium and magnesium. Autoignition temperature of ethanol is 422.8°C. With air, its vapors will form explosive mixtures with a flash point of 13.0°C in the followingundermining limits: lower 3.28 vol.% and upper 18.95 vol.%. Ethanol has a narcotic effect, the MPC of ethanol is 1000 mg/m3, the fourth danger class. Ethanol is one of the most important and large-scale products of basic organic synthesis [1,2].

By chemicalproperties, methyl alcohol is a typical monoatomic aliphatic alcohol: it combines the properties of a very weak base and an even weaker acid. Reacts with alkali metals with the release of hydrogen, forming methylates,for example, CH3ONa; will be formed in the reaction with acidscomplex esters in the presence of strong mineral acids, the reaction is accelerated, for example, with $HNO_2$ gives methyl nitrite $CH_3ONO$, with H2SO4 at a temperature below 100°C: - methyl sulfate $CH_3OSO_2OH$, with carboxylic acids - $RCOOCH_3$. When interacting with ammonia in the presencehundred dehydrating catalysts, methanol gives methylamine. It decomposes with water vapor on a catalyst: $CH_3OH + H_2O = 3H_2 + CO_2$[1,2].

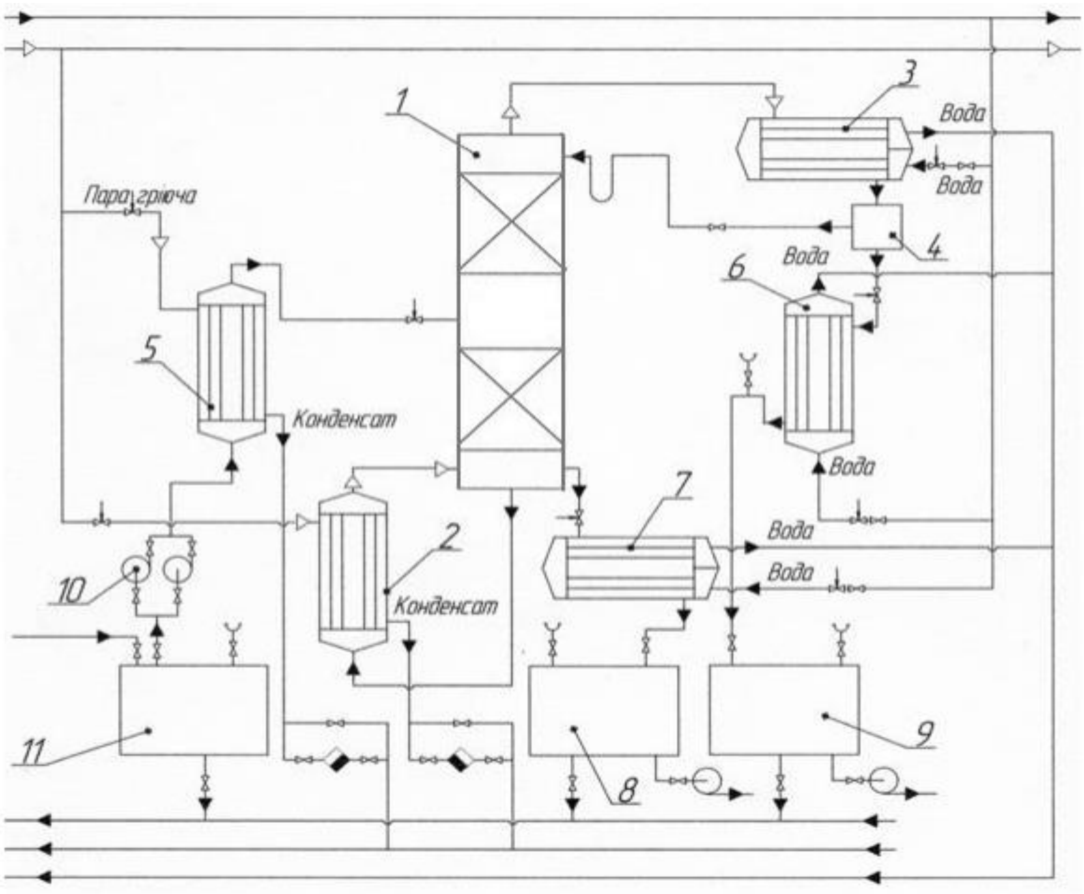
The technological scheme is shown in Figure 1 [3].

The schematic diagram of the rectification unit of continuous action is shown in Figure 1. The initial mixture, which contains low-boiling and high-boiling components, is fed from the intermediate tank 11 by the pump 10enters the heat exchanger - heater 5, in which it is heated to the boiling temperature, and 12 then enters the rectification column 1 on the so-called feed plate, which divides the column into the upper (strengthening) and lower (exhaustive) parts. There is liquid on the power platemixes with the phlegm, which is in the strengthening part of the column and, flowing down the plates or the nozzle, interacts with the steam that rises to meet it. At the same time, the low-boiling (volatile) component is removed from the liquid. Thus, in the comprehensive part ofthey undergo a rectification process. A liquid, consisting almost entirely of a high-boiling component, flows into the cube of column 2. Its part, the so-called cubic residue, is continuously removed and cooled in the heat exchanger - refrigerator 7 and is fedin a capacity of 8. The rest of the liquid evaporates thanks to the dead steam supplied to the cube of the column. The cube can be remote or embedded in the column. The vapor phase rises throughout the column from the bottom to the top, interacts with the phlegm in the strengthening part of the column, and becomes saturatedis a low-boiling component and enters the dephlegmator 3.

Here, part of the steam condenses and, passing through the divider 4, returns to the column, where it flows in the form of phlegm from top to bottom. The second part of the steam enters the refrigerator - condenser 6,where its condensation and cooling of the obtained distillate takes place. The cooled distillate is collected in container 9. The continuous distillation unit can operate with full or partial condensation of steam in the dephlegmator.

The best indicators formesh plates and S-shaped plates with valves have hydraulic resistance, and in terms of efficiency - valve ballast and S-shaped plates with a valve.

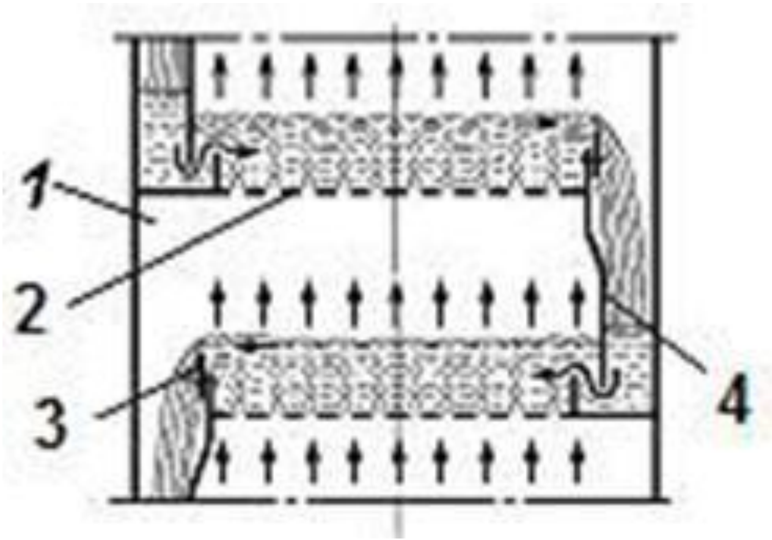
It should be noted that there are no universal designs of plates that work effectively "always and everywhere". When choosing a specific type of plates from a multitude of options, preference should be given to the design whose main performance indicators satisfy the requirements to the greatest extent.It is preferable to use contact devices that have as little hydraulic resistance as possible.



1– rectification column, 2 – boiler; 3 –dephlegmator; 4 – phlegm divider; 5 – heater of the initial mixture; 6 – distillate refrigerator (condenser-refrigerator); 7 – refrigerator of cubic residue; 8 – capacity collector of cubic residue; 9 – distillate collector container; 10 – pump; 11 – capacity of the original mixture

Figure 1 – Technological scheme of the rectification plant

Columns with grid plates are much simpler in terms of device and cheaper than, for example, columns with cap plates. Columns with mesh platesconsist of a vertical cylindrical body with horizontal plates in which evenlya significant number of small holes are drilled over the entire surface. There are overflow tubes on the plate to drain the liquid and adjust its level. The lower ends of the tubes are immersed in the glasses located on the lower plates and will form hydraulic valves (Figure 2).



1 - column; 2 - plate; 3 - overflow bar; 4 - overflow wall

Figure 3 –The principle of operation of a plate with drain devices

Gas or steam passes through the holes of the plate and is distributed in the liquid in the form of small streams; only at some distance from the bottomplate, a layer of foam and splashes will form - the main area of mass transfer and heat transfer on the plate.

In a certain range of loads, mesh plates have a fairly high efficiency. In order for the efficiency of the plate not to decrease sharply, the pressure and speed of the gas or steam passing through the holes of the plate must besufficient to overcome the pressure of the liquid layer on the plate and thereby prevent the liquid from flowing through the holes.

In addition, the flow of liquid through the holes increases with an increase in the diameter of the plate and when it deviates from a strictly horizontal position. Therefore, the diameter and number of holes should be selected in such a way that the liquid is kept on the plates and is not mechanically absorbed by the steam. Usually, the diameter of the holes of the mesh plates is 0.8-3 mm.

Cleaning, rinsing andmesh plates are repaired relatively conveniently and easily.

But there are also disadvantages. Mesh columns work efficiently only at certain speeds of rectification, and adjustment of their mode of operation. With significant loads, the pressure loss is quite large. In addition,as previously indicated, the plates must be placed strictly horizontally, otherwise the gas or steam will pass through part of the holes without coming into contact with the liquid. And in the event of a sudden cessation of gas or steam supply, or a significant decrease in its pressure, the plates of the mesh column are completely emptied of liquid, and the column must be restarted to achieve the specified process mode.

Sensitivity to load fluctuations, as well as dirt and sediment, which quickly clog the holes of the plate, limit the area of usecheap mesh columns. But for the rectification of alcohol and liquid air, they are mainly used.

To increase the efficiency of mesh plates, the duration of contact between the liquid and gas or steam is increased, for example, by forced circular movement of the liquid on the plate with the same direction of its movement on all plates of the column.

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**УДК 661.72**

# MODERNIZATION OF THE PLANT FOR THE PRODUCTION OF COMPLEX ADDITIVES FROM THE SALT MELT WITH THE EXPANSION OF THE EVAPORATION APPARATUS

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***Abstract***: *The production of fertilizers with granulation of salt melts is considered. The technological scheme and its description are given.*

***Key words***: *salt melt, granulation, evaporation apparatus.*

# МОДЕРНІЗАЦІЯ УСТАНОВКИ ВИРОБНИЦТВА КОМПЛЕКСНИХ ДОБРИВ З СОЛЬОВОГО ПЛАВУ З РОЗРОБКОЮ ВИПАРНОГО АПАРАТА.

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***Анотація***: *Розглянуто виробництво добрив із гранульуванням сольових плавів. Наведено технологічну схему та її опис.*

***Ключові слова***: *сольовий плав, гранулювання, випарний апарат.*

The purpose of granulation is to obtain a substance in the form of a loose, non-adhering product consisting of uniform, strong granules with a diameter of 1.5-3 mm.

The granulation process is carried out in special apparatuses-granulation towers. The towers mainly granulate mineral fertilizersthat can be obtained in molten form: ammonium nitrate, urea, complex fertilizers containing nitrogen, phosphorus, and potassium. The float is sprayed in the upper partof the tower with the help of centrifugal, static or vibrating granulators, which are devices for obtaining the most equal- sized drops of melt and for their distribution in the tower along various trajectories.

The main requirements for granulators used ingranulation towers are as follows: obtaining uniform drops of a given diameter without intensive dust formation; Uniform distributionof drops (granules) over the entire volume of the tower; long run of the granulator without clogging; reliable operation of the granulator mechanisms; the ability to work in a wide range of loads with a stable granulometric composition of the product; simplicity of operation high corrosion and erosion resistance; ability to adjust the size of pellets while maintaining their uniformity: eliminating the possibility of collision of pellets in flight.

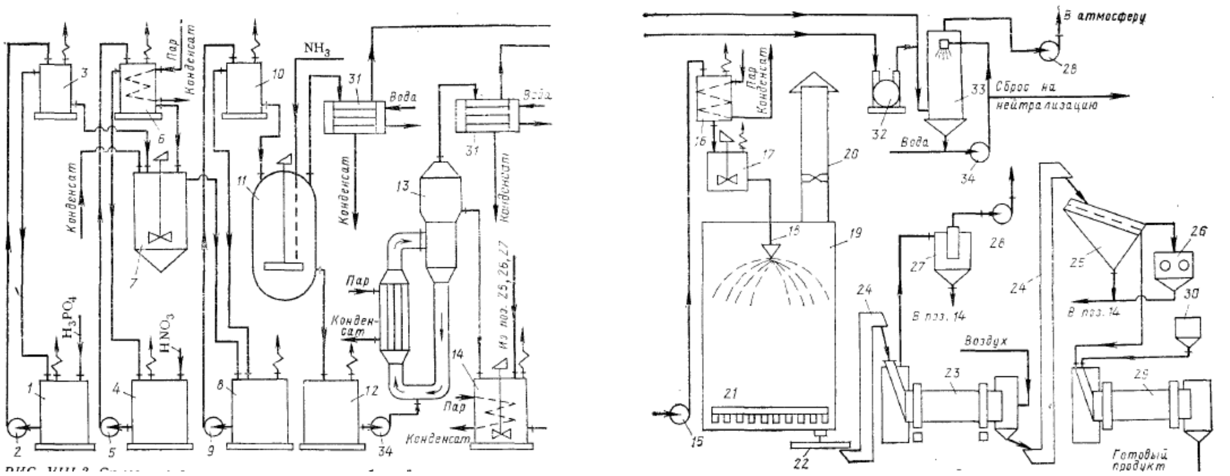
Currently, melts of ammonium nitrate, urea, and complex fertilizers are pelletized in the industry. The physical properties of industrial melts subject to granulation are different. The viscosity of melts at the spray temperature is very different.

During melt granulation, physical properties such as viscosity and surface tension undergo rapid changes after they flow outof the granulator holes. For these reasons, the value of the surface tension coefficient of the melt undergoes even greater changes.

Solid impurities contained in the melt have a great influence on the process of effluent flow and granule formation. The amount of solid impurities in the melt depends on many factors: the type of additive used, the technology of its preparation, the quality of softened water, and the specifics of the technological schemeof production. In some cases, a scale-like film of salts is deposited on the surfaces of pipelines, granulator tanks, and flow holes in contact with the melt. If you do not apply special hydrodynamic modes of operation of the granulator, then the holes are often clogged after several hours of operation.

Complex fertilizer float is a mixture of NP fertilizer float and powdered potassium chloride. The properties of this dispersed system are even more variable with temperature changes.

For granulation of complex fertilizer floats and floats with a large amount of sludge, granulators are necessary that allow the use of relatively large flow holes, but allow you to get fairly uniform pellets of a given size without sticking andclumps of water in the tower. Centrifugal granulators are most acceptable here.



1 - collection $H_3PO_4$: 2, 5, 9, 15, 34 - pumps; 3 - pressure tank for $H_3PO_4$; 4 - $HNO_3$ collector; 6 - pressure tank for $HNO_3$; 7 - mixer: 8 - collection of replacement acids; 10-pressure tank; 11 - neutralizer; 12 - collector: 13 - evaporator with remote heating chamber; 14 - collection for swimming; 16 - pressure tank for melt; 17 - mixer: 18 - granulator; 19 - granulation tower, 20 - fan; 21 - scraper, 22 - belt conveyor: 23 - cooling drum, 24 - elevator: 25 - screen, 26 - crusher, 27 - cyclone; 28 - fans; 29 - drum-conditioner; 30 - bunker for powdering additive; 31 - capacitor; 32 - vacuum pump: 33 – scrubber

Fugure 1 – Technological scheme

Phosphoric acid with a concentration of 52-54% $P_2O_5$ from the collector 1 pump 2 through the pressure tank 3 is fed into the mixer of acids 7. Here from the collector 4 pump 5 is supplied with nitric acid concentration of 47-56% $HNO_3$. The mixture of acids from the mixer 7 enters the collector 8, from where it is sent by pump 9 through the shut-off tank 10 to ammonization saturator 11. Ammonization of the acid mixture is carried out at atmospheric pressure with gaseous ammonia to a pH of about 4,5. Due to the heat of the neutral reaction neutralization of acids in the saturator develops a temperature of 115-120 °C. Part of the water on the reaction mixture evaporates. The gas-vapor mixture from the saturator passes through condenser 31, where water vapor is condensed, and then enters absorber 33, where it is purified from ammonia.

The nitrate-phosphate solution from the saturator with a moisture content of 22-26% enters the collector 12, from where it is sent by a pump 34 to a vacuum evaporator 13 with an external heating chamber and natural circulation. Evaporation of the solution is carried out at a residual pressure of 28-30 kPa and a temperature of 170 °C. Heating steam is supplied to the heating chamber of the vacuum evaporator at a pressure of 1.3-1.5 MPa. The vapor-gas mixture released during evaporation enters the condenser 31, where water vapor is condensed. Uncondensed vapors and gases are fed by a vacuum pump 32 for purification into an absorber 33 irrigated with water, and then by a fan 28 they are thrown into the atmosphere.

The melt of nitroammophos with a moisture content of up to 1% from a vacuum evaporator it enters the heated collection 1. From here, the melting pump is 15 years old. They are fed into the pressure tank 16 and then into the granulation tower 19.

In most modern workshops producing complex fertilizers in floating, evaporators are installed directly on granulation towers, which increases the overall height of the latter, HO removes the difficulties associated with the supply of easily crystallizing melts with volume (1.45-1.55 g/cm³) to a greater height. K Same high density

When obtaining NPK fertilizers, the melt of nitroammophos in mixer 17 is mixed with potassium chloride, due to the reactions occurring during the interaction of the NP-melt with potassium chloride, the viscosity of the salt system increases with time. In this regard, the residence time of KS1 in the mixer should be minimal (as a rule, no more than 30 s).

Sprinkling of the melt in the granulation tower is carried out by a centrifugal type granulator with a conical perforated shell. Melt droplets formed during splashing crystallize in the process of falling due to their cooling by air drawn through the tower by fan 20.

The pellets that have fallen to the bottom of the tower are removed with a scraper and fed to DILNIK 23, where they are air-cooled from 85-95 to 40-45°C. Some drying of the granules also occurs during the cooling process. Next, the granulated product is classified and conditioned. Re-tour. which is a granule of non-standard size, is returned for dissolution to the melt collector 1. The amount of reture usually does not exceed 5-8% of the amount of the finished product.

The the evaporator is the main apparatus in considered technological scheme. Therefore the miodernization of thechnological sheme souhld indlude the modernisation of this apparatus.

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**УДК 661.9**

# MODERNIZATION OF THE PHOSPHATE MATERIAL DECOMPOSITION PLANT WITH DESIGN OF EVAPORATOR

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***Abstract:*** *The scheme of the process of nitric-sulfuric acid decomposition of phosphate raw materials with pre-precipitation of calcium ions by ammonium sulfate is described*

***Key words:*** *sulfate recycle, phosphate raw materials, pulp, phosphogypsum*

# МОДЕРНІЗАЦІЯ УСТАНОВКИ РОЗКЛАДАННЯ ФОСФАТНОЇ СИРОВИНИ З РОЗРОБКОЮ ВИПАРНОГО АПАРАТА.

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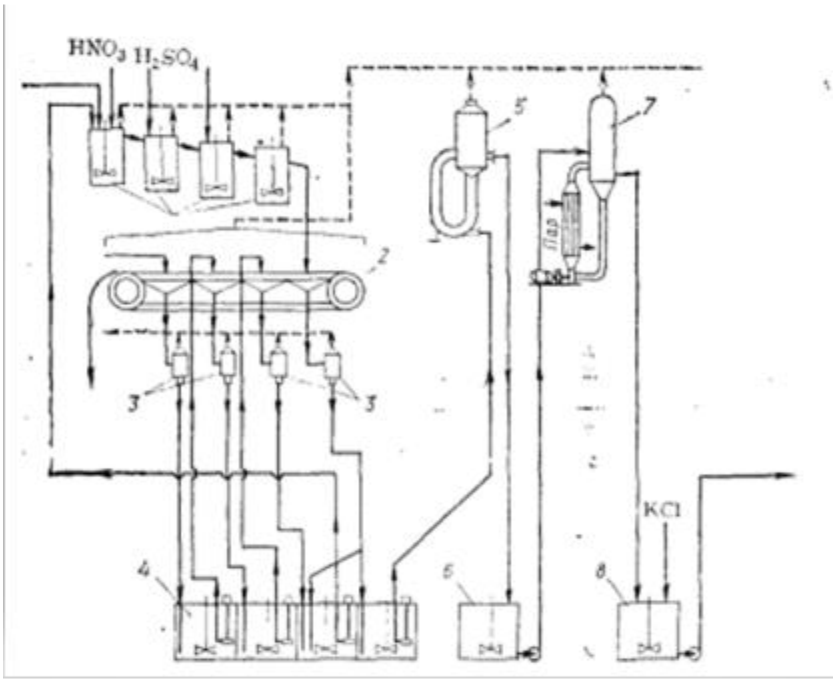
***Анотація:*** *Описується схема процесу азотно-сірчанокислотного розкладання фосфатної сировини з доосадженням іонів кальцію сульфатом амонію*

***Ключові слова:*** *сульфатний рецикл, фосфатна сировина, пульпа, фосфогіпс*

The phosphate fertilizers are the kind of the mineral fertilizers which include the phosphor, required for growing of plants. The phosphate from soil, primarily calcium phosphate is the main source of phosphor which is metabolized in a form of orthophosphate acid. Moreover, the plats are able to metabolize phosphor from several organic compounds such as phytinum, glicero-phosphate, glicero-phosphate acid, glucose phosphate etc. But for the most soils the consistence of calcium phosphate is insufficient. Moreover, due to the insolubility in water it is practically unavailable for plants. Moreover, the soil microorganisms are continuously mineralizating the organic compounds with available phosphor for the plants in unavailable inorganic form. Therefore, the introduction in soil soluble phosphates has significant importance for increasing of the harvest of crops. Phosphor promote the development of the root system of plants, increase the sugars content, because of what the winter resistance, yielding capacity is increased, the ripening is accelerated, organoleptic properties are improved. The plants react to the top dressing by phosphate fertilizers in following way. In sugar beets the sugar content is increased, in potato the content of starch is increased, in corn the oil content is increased.

The production of the phosphate fertilizers requires large amounts of chemicals. To achieve the economy of the sulphate and nitrate, except increasing of the water-soluble part of $P_2O_5$ in fertilizers, allows reusing of ammonium sulphate for extra precipitation of calcium ions in nitrate acid extract. The ratio among acids and ammonium sulphate, which are used in process, are chosen depending on the raw material composition and obtained fertilizer type. For the obtaining of product with ratio 1:1:1 from the apatite concentrate it is necessary 60% of phosphate acid to decompose by nitrate acid, 40% sulphate acid, and 60% of calcium ions to extra-precipitation by ammonium sulphate. During the phosphorite treatment with high ratio $CaO:P_2O_5$ the components ratio is changed in direction of increasing of sulfonate acid requirement for the impurities decomposition and corresponding decreasing of nitrate acid and ammonium sulphate requirements. When in fertilizer the $P_2O_5$ content higher than nitrogen content, the sulfate acid requirement for the obtaining fertilizers with ratio $N: P_2O_5 : K_2O$ 1:1:1 also should be increased. If it is necessary to obtain fertilizer in which the ratio $N:P_2O_5$ is varied in the range (1.5-2):1, there is no sulfuric acid should not be introduced into the process and all calcium should be precipitated by the sulphate ammonium. The scheme of this process is represented in figure 1.



1-reactor, 2-belt vacuum filter, 3 – separator, 4- collector filter, 5, 6, 8 - collectors; 7-vacuum evaporation apparatus

Figure. 1. – Scheme of the process of nitric-sulfuric acid decomposition of phosphate raw materials with pre-precipitation of calcium ions by ammonium sulfate

Ammonium sulfate is fed into the third section for additional calcium deposition, and the phosphogypsum sediment matures in the fourth. The total residence time of the pulp in the reactor is 4.5 hours. temperature 55°C. From the fourth section, the pulp enters the vacuum filter 2 to separate calcium sulfate dihydrate sediment. Filtration of $CaSO_4$, $2H_2O$ is carried out according to the four-filter scheme with three times countercurrent washing of the sediment. The second filtrate and part of the first filtrate are returned as a reversible solution to reactor 1 to create an optimal ratio of solid and liquid phases (W:T=3). The rest of the first filtrate enters for ammonization in a high-speed ammonizer - evaporation 5. The ammonization process is carried out to pH 4.5 at a temperature of 110-120ºC. Next, the ammoniated pulp enters the evaporator 7, where it evaporates to a $H_20$-15% content. The evaporated pulp at 135 ° is mixed in the mixing tank 8 with potassium chloride and sent for granulation and drying in the BGS apparatus. Next, the granulated product is classified and cooled. Phosphogypsum from the vacuum filter is converted into calcium carbonate and ammonium sulfate. Calcium carbonate is removed, and ammonium sulfate is returned to the calcium precipitation reactor. Thus, the process of obtaining nitrophoska takes place with sulfate recycling. Using this process, it is possible to obtain fertilizers of various brands with good physical and mechanical properties even when working with low-quality raw materials: phosphorites containing 24-26% P2O5 and 3.0-3.8% MgO; calcined phosphorites containing up to 6% Fe203. Phosphorite processing produces a product that contains 92% of the total amount of $P_2O_5$ in a water-soluble form. The scheme, based on the use of nitric and sulfuric acids with the recycling of ammonium sulfate, allows to obtain the maximum saving of sulfuric acid.

Analyzing modern designs, materials and methods of decomposition of phosphate raw materials and sulfate recycling, this evaporator has plays role in technological scheme, so it is reasonable to modernize this apparatus.

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**UDC 66.21**

# DIRECTIONS OF MODERNIZATION OF THE CAROUSEL FURNACE

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**Annotation.** *Describe the design of the carousel electric furnace. The advantages and disadvantages of the carousel electric furnace are indicated.*

**KEYWORDS:** CAROUSEL FURNACE, POD, GEARS, TRACKING, HEATING.

# НАПРЯМИ МОДЕРНІЗІЦІЇ КАРУСЕЛЬНОЇ ПЕЧІ

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**Анотоція.** *Описано конструкцію карусельної електропечі. Вказано переваги і недоліки карусельної електропечі.*

**КЛЮЧОВІ СЛОВА:** КАРУСЕЛЬНА ПІЧ, ПОД, ШЕСТЕРНІ, ХІД, НАГРІВ.

In carousel furnaces, the product is transported along a ring. The working temperature is up to 1300°C, with a significant load on the line [1].

The furnace contains a cylindrical working chamber, in the lower part of which there is a plate-shaped pod, which has a drive gear connected to the drive of the drive gear. There are several additional gears in mesh with the drive gear (depending on the nomenclature of heated parts), and cams are fixed on their input shaft, which rotate at different speeds when the pod rotates. Limit switches are installed in the plane of rotation of the cams at a distance from the axis of their rotation, sufficient to ensure the contact of the cams with the rollers.

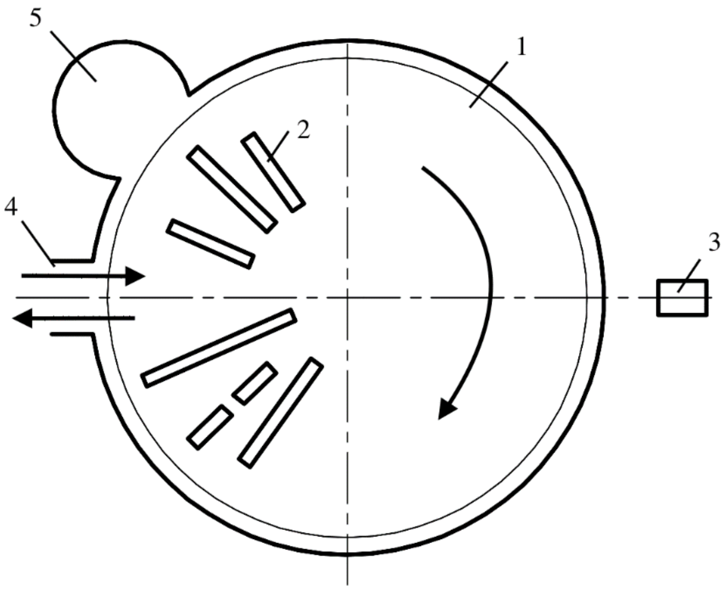
Carousel furnaces with a ring and plate tray (Figure 1), rotating from a hydraulic and electric drive, are equipped with various devices that send commands to start, stop and rotate the tray, as well as to activate the mechanisms for loading and unloading parts.

Only one limit switch is connected with the switch. When the limit switch is activated, a command is given to load and unload the furnace. The loading-unloading mechanism in one full stroke when moving into the furnace feeds the heated workpiece into the hole in the center of the furnace (at the beginning of the furnace operation - idle speed) and when moving out of the furnace, installs the cold workpiece on the working plane of the furnace. There are switch settings in the position of heating workpieces of minimum size and in the position of heating workpieces of maximum size. In this way, a fuller loading of the furnace is achieved in a wide range of workpiece sizes.

A carousel oven with a floor rotates with an electric drive. The drive receives an impulse to turn the pod from the device that regulates the cycle and stop times. There are furnaces that use pneumatic ratchet mechanisms to turn and stop the furnace [2].

**Advantages of the furnace:**

- convenient form;
- does not have heat-resistant parts inside;
- massive parts are heated.



1. rotating disk pod, 2. heated product, 3. mechanism for rotating the cutting, 4. loading and dispensing window, 5. flue for removal of combustion products.

Figure 1 – Diagram of a rotary kiln

**Disadvantages of the furnace:**

– the disadvantages of known carousel furnaces are low reliability;

– low accuracy of control of pod rotation, loading and unloading mechanisms;

– the impossibility of changing the interval of placing parts on the floor during the operation of the furnace;

– the complexity of the design of operation;

– the loading and unloading holes are close by, which may cause difficulties

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**УДК 66.047**

# HEAT EXCHANGER FOR HEATING of the GAS MIXTURE COOLING in TECHNOLOGICAL SCHEME OF ETHANOL PRODUCTION

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***ANNOTATION:*** *The process of ethanol production by hydration of ethylene is considered. The advantages and disadvantages of the heat exchanger are described.*

**KEY WORDS:** *ETHANOL, ETHYLEN, HYDRATATION, SHELL AND TUBE, HEAT EXCHANGER.*

# ТЕПЛООБМІННИК ДЛЯ НАГРІВУ ГАЗОВОЇ СУМІШІ ТЕХНОЛОГІЧНОЇ СХЕМИ ПРОЦЕСУ ВИГОТОВЛЕННЯ ЕТАНОЛУ

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***АНОТАЦІЯ:*** *Розглянуто процес виробництва етанолу шляхом гідратації етилену. Описано переваги та недоліки теплообмінника .*

***КЛЮЧОВІ СЛОВА:*** *ЕТАНОЛ, ЕТИЛЕН, ГІДРАТАЦІЯ, КОЖУХО-ТРУБНИЙ, ТЕПЛООБМІННИК.*

The world ethanol production has recently seen an incremental growth mainly due to economic and environmental security concerns, worldwide. Ethanol has good burning characteristics and may be considered as attractive transportation fuel alternates.

Ethanol is a liquid substance, a colorless liquid with a slight odor. This substance burns with a blue flame, no smoke is emitted during combustion. Ethanol is widely present in nature and has many industrial and pharmaceutical applications as a solvent for substances intended for human consumption, including odors, flavorings, dyes and medicines. There are vehicles running on 100% ethanol.

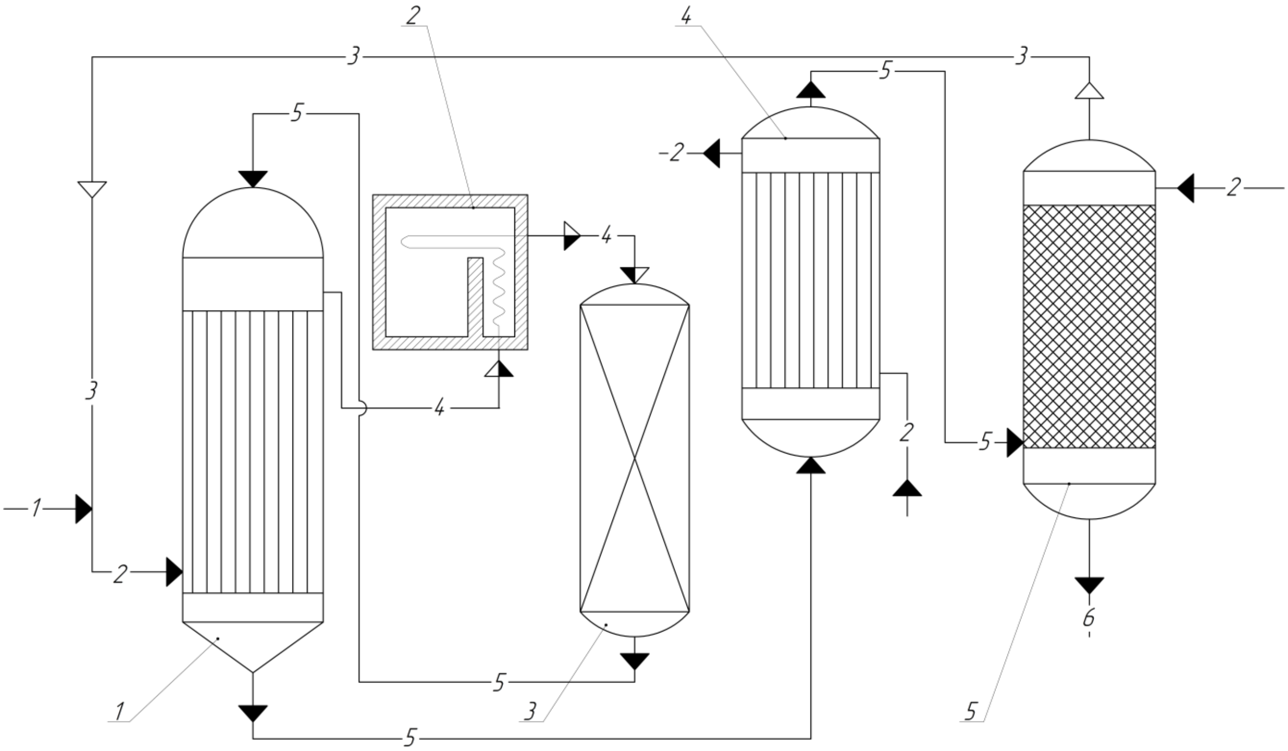
The most ethanol used as motor fuel or an additive to gasoline to increase its octane number. As liquid fuel, ethanol has long-term advantages. Ethanol has good properties for spark ignition with motor octane number (MON) and research octane number (RON) 90 and 109, respectively, which is much more than that of regular gasoline[2].

Increase in world ethanol production is mainly related to economic and environmental security.

There are several ways to produce ethanol, for example ethanol fermentation, the process of indirect hydration (esterification-hydrolysis) and direct hydration of ethylene. Ethanol is produced petrochemically in direct and indirect ways hydration, as well as through biological processes by fermenting sugars with yeast. Majority industrial processes were carried out by fermentation, but this method was not reliable.

For the first time, direct hydration of ethylene was presented in 1947. Ethanol is produced by the chemical reaction of ethylene with water vapor. The ethylene and aqueous reagent used in the process had to be purified. Reaction is a reversible and exothermic process. Reaction of direct hydration of ethylene consists of three processes, namely; reactions, recovery and purification, and production anhydrous ethanol.

Part of the technological scheme for ethylene hydratation in Figure 1.



1, 4 – tube heat exchanger; 2 – tube furnance ;3 – hydrator; 5 – separator;

Figure 1 - Technological scheme of ethylene hydratation [1]

The process takes place at a high pressure (60-80)105Pa and a temperature of 280-300°C. As a catalyst use phosphate acid N3PO4 on an aluminosilicate carrier. In order to increase the output of the product in the technological scheme there is a multiple circulation of the gas mixture.

The mixture of ethylene, circulating gas and water, compressed to (60—80)105 Pa, is fed into the heat exchanger 1 (fig. 1). In it, the gas mixture is heated by the heat of reaction products. Then the mixture is heated in the tubular oven 2. Heated up to 280—300 °C the reaction mixture is delivered to the hydrogenerator 3, where the ethylene is being hydrothated.

Reaction products cool in the heat exchanger 1, and then in the refrigerator 4. In separator 5 there is separation of liquid ethanol from the gas mixture, which is not modified; it is mixed with a new quantity of ethylene and is included in the technological process. The alcohol obtained under this technological scheme is further cleaned by rectification (overrunning).

Ethyl alcohol is a prescribed product. It is used in many industries: Machine building to food industry.

It would be advisable to increase production productivity, namely to reduce the time of thamen’s tear. In the technological scheme many components and all of them somehow influence the process performance.

It would be advisable to upgrade the shell-pipe heat-exchange. This will make it possible to heat the gas mixture that comes to it faster and more efficiently.

The task for the diploma design is to choose the heat exchange equipment among modern designs, check its patent purity, modernize the equipment, which should improve the quality of the intermediate product and increase the productivity of the equipment.

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**УДК 661.7**

# THE MODERNIZATION OF THE BENZENE ALKYLATION PLANT

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***Absrtact:*** *The technological scheme of benzene alkylation was considered. The main apparatuses are determined and the direction of the further developents are defined.*

***Key words:*** *rectification column, benzene alkylation, benzene*

# МОДЕРНІЗАЦІЯ УСТАНОВКИ АЛКІЛУВАННЯ БЕНЗЕНУ

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***Анотація:*** *Розглянуто схему алкілування бензену пропіленом. Визначено головні апарати схеми та напрямок подальшої модернізації.*

***Ключові слова:*** *Ретифікаційна колона, алкілування бензену, бензен.*

The processes of the benzene alkylation by ethylene and propylene are widely developed. By this way, the ethylbenzene and cumene. Ethylbenzene is the raw material for the styrene production, which is used for the synthetic rubber and plastic masses production. The cumene is used in large amounts as initial component for joint obtaining of phenol and acetone, and also for α-methyl-styrene production [1-3].

The technological scheme of the benzene alkylation by the propylene in liquid phase which using the aluminum chloride as catalysator is shown in figure 1. Initial benzene and recycled benzene from the tank 8 through the heat exchanger 6 and heater 4 is pumped to the rectification column 3/ The vapors leaving the top part of column (91.17% of benzene and 8.83%of water) are condensed in dephlegmator 1, separating in the 2vessel 2, benzene is flown to the tank 8. From the bottom part of the rectification column the dehydrated benzene (the water consistence is 0.001-0.003 wt.%) flows continuously, which directed to the alkylation in the apparatus 10. In this apparatus the catalysator in form of complex compound of the aluminum chloride with cumene. The powdered dehydrated aluminum chloride is treated by mixing in apparatus 9, the cumene is added with small amount of water, around 2% from aluminum chloride amount. The obtained complex is the red-brown oily low-viscous liquid, which is easily transported by pump [1].

The liquid products are continuously taken away from top part of the alkylator 10 at the high of 8 meters from the base and pumped to the sedimentation tank 11, where the particles of catalysator taken by the liquid are sedimented. From the sedimentation tank, the catalysator particles are returned to the bottom part of the alkylator, and from the reaction liquid propane is taken away in column 18. Propane from the column 18 is purificator from the liquid in separator 17 and arrive to the rinsing and then in the pyrolysis plant. The bottom liquid from column 18 (alkylate) is taken away through the throttle in the cooler and the arrive to the purification from impurities, which can cause the corrosion on the next rectification stage. Durin the alkylate purification, alkylate is rinsed by water for the decomposition of complex compounds of the aluminum chloride, the stopped, mixed with alkali and then sedimented and rinsed again. The pacificated in this way alkylate if followed to the rectification [1].

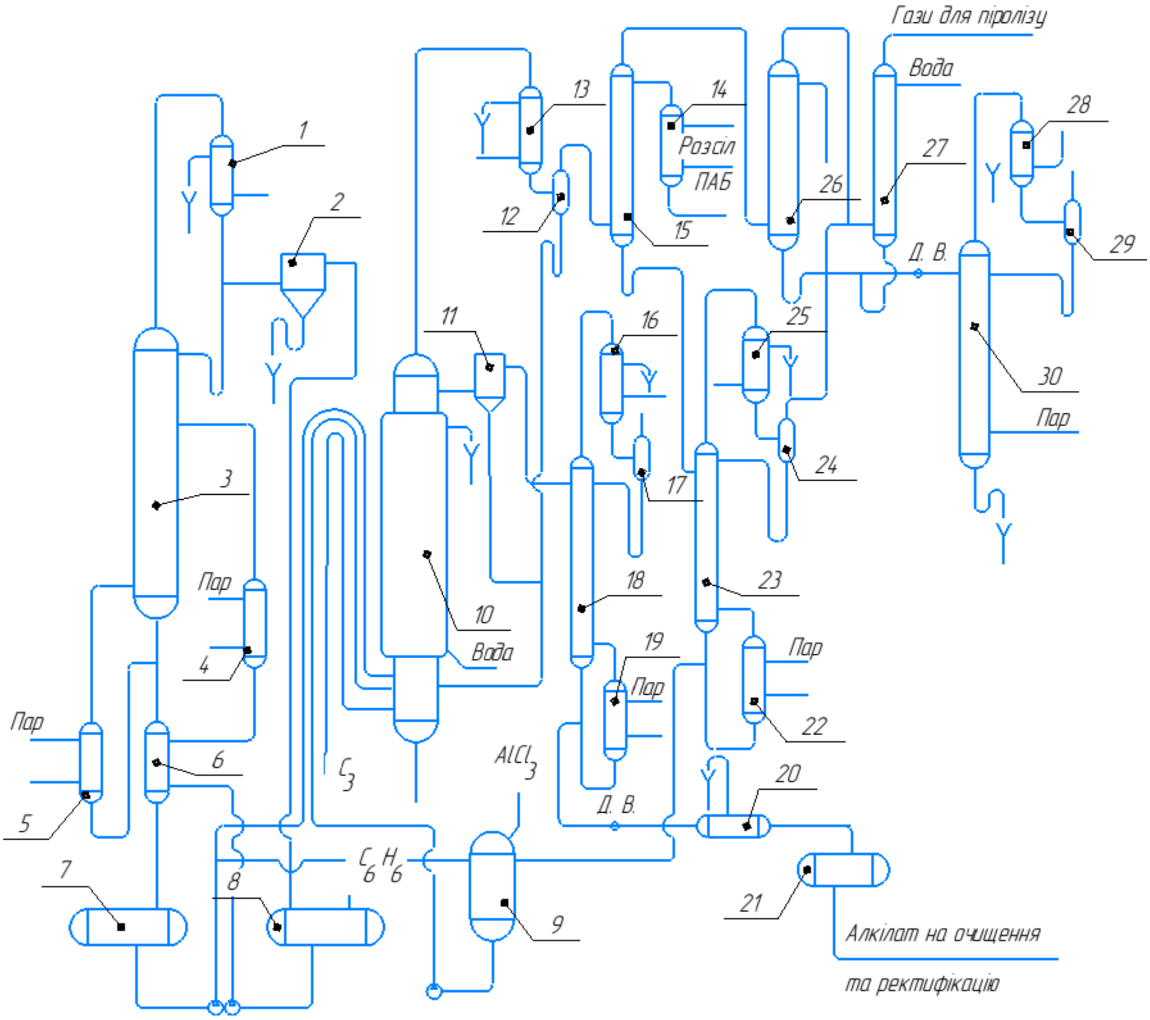

Figure 1 – The scheme of liquid phase alkylation of benzene by propylene

The gases which leave the top part of the alkylator 10 with benzene vapors are cooled to 20°C in condenser 13, with that the part of benzene vapors is condensed. Condensate is separated from the gases in separator 12 and turn back into the absorption column 15 for the capture of the uncondensed benzene vapors. The mixture of the cumene cooled to the 10°C pumped from rectification column is used as absorbent. The absorbent saturated with benzene and propane from bottom part of absorber is flows to the depolarization in column 23 by gravity. The condensed benzene is recycled to the column 23 [1].

Propane is rinsed by water in column 27. The bottom liquid from column 23 is pumped into apparatus 9 for the dissolving the catalysator. Gases, that leaves the absorption column 15, arrive firstly in neutralization column 26, showered by water alkali solution, then into rinsing column 27. The cleaned gases are the almost pure propane which can be used for example for pyrolysis [1].

For prevent the contamination of natural water bodies, the hydrocarbons must be fully removed from wastewaters, which discarded to the sewer. For this the exhausted alkali from column 26 and water from column 27 pumped through the throttle in the evaporation column 30, which is heated by steam. After decantation of the hydrocarbons bottom liquid can be discarded to the sewer [1].

In this scheme it is reasonable to modernize the packed bed rectification column 3, since it play significant role, separating benzene from water for further alkylation

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UDC 663.5

# MODERNIZATION OF THE RECTIFICATION COLUMN FOR SEPARATION OF THE MIXTURE: METHANOL-BENZENE

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**ANNOTATION**: This provides an overview of the work and the differences between different distillation columns. Examples of constructions are given, and advantages and disadvantages are described.

**KEY WORDS**: RECTIFICATION, RECTIFICATION COLUMN, TYPES, COMPARISON.

# МОДЕРНІЗАЦІЯ РЕКТИФІКАЦІЙНОЇ КОЛОНИ ДЛЯ РОЗДІЛЕННЯ СУМІШІ: МЕТАНОЛ-БЕНЗОЛ

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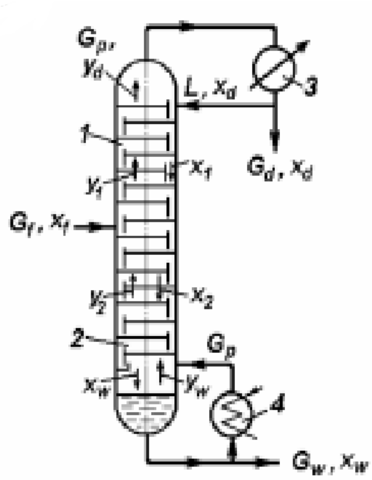
**АНОТАЦІЯ**: В даній роботі наведено огляд роботи та основні відмінності різних типів ректифікаційних колон. Наведено приклади конструкцій, описано переваги та недоліки.

**КЛЮЧОВІ СЛОВА**: РЕКТИФІКАЦІЯ, РЕКТИФІКАЦІЙНА КОЛОНА, ВИДИ, ПОРІВНЯННЯ.

Rectification is a physical process of separating liquid mixtures into pure components or fractions that differ in boiling point, separating binary or multicomponent mixtures due to countercurrent mass and heat exchange between steam and liquid (Figure 1).

The starting mixture heated to the feed temperature in the vapor, vapor-liquid, or liquid phase enters the column as feed. The zone to which power is supplied is called the evaporative zone because evaporation occurs - a one-time separation of steam from the liquid. The vapors rise to the top of the column, are cooled and condensed in the condenser cooler, and fed back to the top plate of the column as irrigation.



1 - the upper ( concentration ) part of the column; 2 - the lower ( retract ) part of the column; 3 - condenser-dephlegmator; 4- boiler-evaporator

Figure 1 - The schematic of the work of a rectification column for separation binary mixture

Thus, in the upper part of the column, vapor moves countercurrent and liquid flows. Flowing down the plates, the liquid is enriched with high-boiling substances components, and the vapors that rise to the top of the column are enriched with low-boiling components.

Thus, the product removed from the top of the column is enriched with a low-boiling component. The product removed from the top of the column is called the distillate. Part of the distillate condensed in the refrigerator and returned to the column is called irrigation or phlegm. The ratio of the amount returned to the phlegm column and the amount of distillate removed is called the phlegm number.

To create an upward flow of vapors in the cubic part of the rectification column, part of the cubic liquid is sent to the heat exchanger, and the vapors formed are fed back under the lower plate of the column.

Thus, two flows are created in the cube of the column: the first flow is liquid flowing from the top, and the second flow is vapor rising from the bottom of the column.

The cubic liquid, flowing down the plates, is enriched with a high-boiling component, and the vapors are enriched with a low-boiling component.

The advantage is that the plate-type rectification column separates the fractions more finely than, for example, the packing column, which has high resistance and difficulty in the correct distribution of vapors and phlegm. Disadvantages include high cost and large dimensions.

Modern rectification devices must have a high distribution capacity and productivity, be characterized by sufficient reliability and flexibility in operation, ensure low operating costs, have a small mass, and, finally, be structurally simple and technological in production.

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**UDC 662.73**

# HEAT EXCHANGER FOR BIOGAS COOLING in TECHNOLOGICAL SCHEME OF BIOGAS CLEANING PROCESS

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**ANNOTATION:** *The production of amophos, its composition and production by evaporation of a neutralized suspension in a multi-body vacuum-evaporation unit are considered. Technological production of ammofos and its description are also given.*

**KEY WORDS:** *AMPHOS, PHOSPHORUS, FERTILIZER, EVAPORATION INSTALLATION.*

# ТЕПЛООБМІННИК ДЛЯ ОХОЛОДЖЕННЯ БІОГАЗУ ТЕХНОЛОГІЧНОЇ СХЕМИ ПРОЦЕСУ ОЧИЩЕННЯ БІОГАЗУ

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**АНОТАЦІЯ:** *Розглянуто виробництво амофосу, його склад та отримання шляхом упарки нейтралізованої суспензії в багатокорпусній вакуум-випарної установки. Також наведено технологічну виготовлення амофосу та її опис.*

**КЛЮЧОВІ СЛОВА:** *АМОФОС, ФОСФОР, ДОБРИВО, ВИПАРНА УСТАНОВКА.*

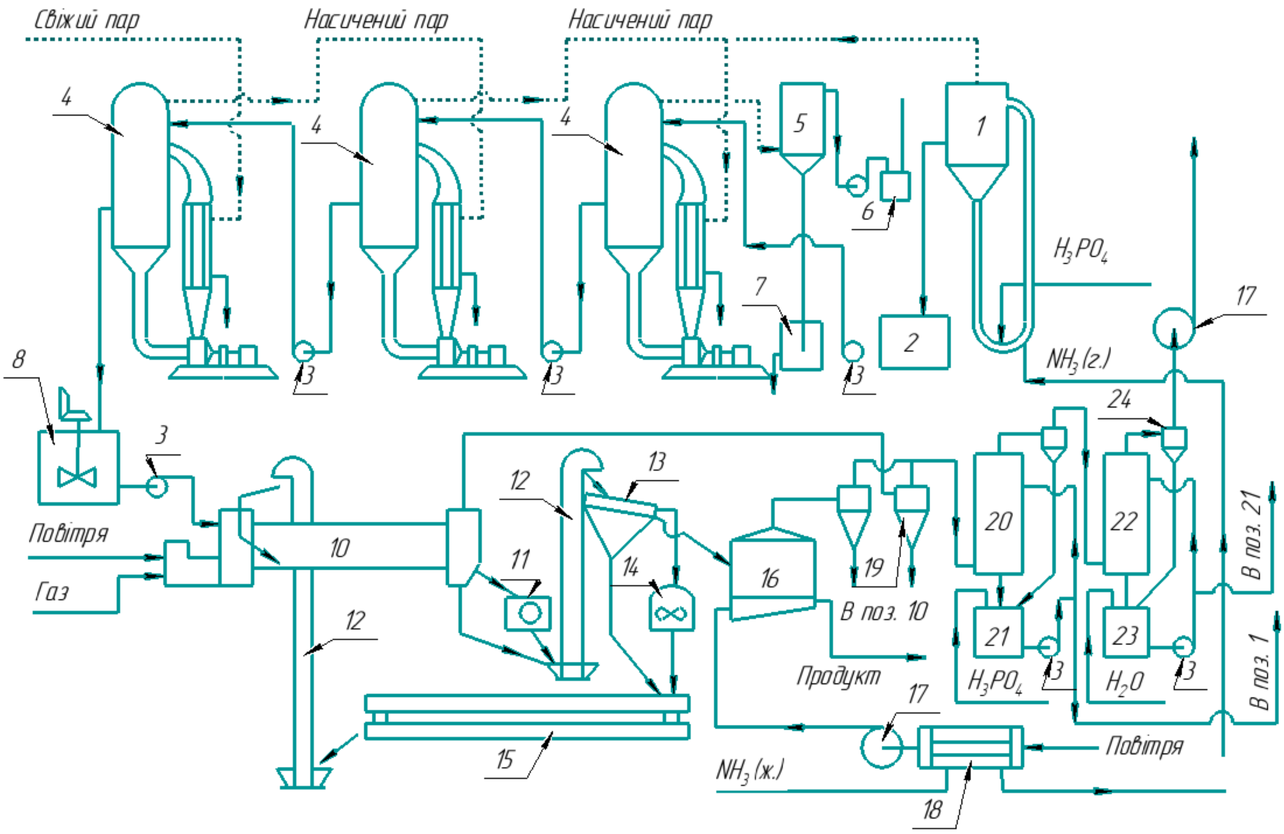
During the lifecycle in agricultural conditions, in ground the sources which the plants can used for growing are expired. In this regard the necessity of adding of the fertilizers in ground appears. For the satisfying grow of plants and good harvest the ammophos is suitable. This material can be obtained by the technique of ammophos production with evaporation of ammophos pulp and the granulation in the BGS apparatus [1, 2].

Ammophos is the nitrogen and phosphoric fertilizer, which consists mainly of monoammoniumphospahte with impurities of biammoniumphospate (10-20%), ammonium sulfate, iron phosphate, aluminum phosphate etc. By the content of the active compounds the amophose is one of the most concentrated. Ammophos can be added as main fertilizer in the rows during the sowing of the all cultures and for the top dressing for technical cultures and vegetables [3].

The phosphor plays key role in lifecycle of the fruit and berry crops. It is a part of the complex proteins which take part in the process of the cell nucleus division and forming of the new organs of the plant, ripening of the fruits and berries, promotes the accumulation of the starch, sugars and lipides. Phosphor significantly increases the drought and cold resistance of plants. It plays significant role in ripening of fruits [2].

In the ammophos, which is produced by to types “A” and “B”, there are 9-11% of N and 42-50% of $P_2O_5$, therefore the ratio N to $P_2O_5$ in the fertilizer is excessively wide and equal to 1:4 (the content of nitrogen if four time lower than content of phosphor). This is concentrated fertilizer, which consists the nitrogen and phosphor in form which is well absorbed by plants. The 100 kg of ammophos can replace 250 kg of superphosphate and 35 kg of the ammonium saltire nitrate [2].

On the scheme (figure 1) it can be seen the process of the ammopos production with intermediate evaporation of the neutralized suspension in multiple-effect vacuum evaporation plant [1].



1 – CAI apparatus; 2 – tank; 3 – centrifugal pump; 4 – evaporators; 5 – barometric condenser; 6 – vacuum pump; 7 – barometric tant; 8 – tank of the evaporated sludge; 9 – furnace; 10 – BGS apparatus; 11 – hammer mill crusher; 12 – elevetor; 13 – mechanical screening machine; 14 – roll crusher; 15 – vibratory conveyor; 16 – chiller КС; 17 – fan; 18 – evaporato of the liquid ammonia (air chiller); 19 – cyclone separators; 20 – acidic gas washer; 21, 23 – circulating tanks; 22 – gas washer; 23 – drop separator

Figure 1 – The technological scheme of the ammopos production

The phosphoric acid (20-29% of $P_2O_5$) is neutralized by the gas ammonium to the pH = 5–5.5 in the CAI apparatuses (the residence time is 2-3 minutes). The water vapor, which stand out in this process, is taken away in heat exchanger, where it condensed heating the feed acid. The ammophos suspension ($NH_3$:$H_3PO_4$ = 1:1) is concentrated in the three-stage evaporation plant to the final humidity of the 18-25%. The first stage is operated under vacuum, the second stage is operated under atmospheric pressure, and third stare is operated at elevated pressure. The feed steam (0.3-0.6 MPa) is pumped into third stage, first and second stages are heated by the secondary steam. Then the suspension with temperature 112-115°C is dried and simultaneously granulated in the BGS apparatuses [1].

After product cooling and sieving on the mechanical screening machine the small fraction with dimensions of particles less than 1 mm is returned in BGS apparatus as external retut. The general amount of retut (small fraction and some part of the standard product) is less that 1-2. The big fraction is followed to the crushing and standard is cooled to the 40-45°C and send to the warehouse [1].

In the ammophos production scheme the evaporator has a significant role. Therefore, it is reasonable to modernizate this apparatus

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UDC 665.642.26

# MODERNIZATION OF THE STEAM GENERATOR FOR THE MIXTURE SEPARATION COLUMN

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**ABSTRACT:** This work provides an overview of the operation of the rectification column of the steam generator. The advantages and disadvantages of using a steam generator for column separation are described.

**KEY WORDS** : STEAM GENERATOR, BOILER, COMPARISON

# МОДЕРНІЗАЦІЯ ПАРОГЕНЕРАТОРА ДЛЯ КОЛОНИ РОЗДІЛЕННЯ СУМІШІ

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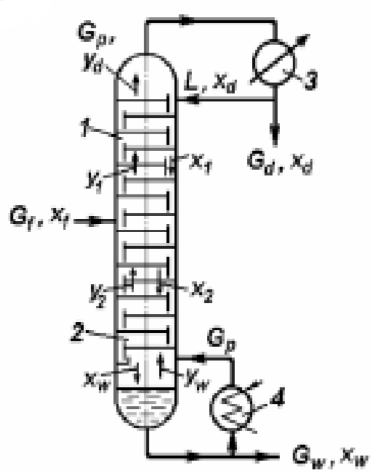
**АНОТАЦІЯ:** В даній роботі наведено огляд роботи ректифікаційної колони ра парогенератора. Описано переваги та недоліки використання парогенератора для колони розділення.

**КЛЮЧОВІ СЛОВА**: ПАРОГЕНЕРАТОР, КИП’ЯТИЛЬНИК, ПОРІВНЯННЯ

Rectification is used when the temperature of the boiling components is different but at the same tick. And the different volatilities of the vapor mixture at the same temperature. It is also the central use area when the components are mutually soluble (Figure 1).

The initial mixture enters the column, usually heated to the boiling temperature, and is fed to the feed plate in the middle between the lower and upper columns.

The steam formed during boiling rises the column and comes into contact with the liquid flowing down from the top. During the movement of steam from the middle part of the column to the upper part, a process of gradual enrichment of the vapor phase with a low-boiling component occurs. The highly concentrated vapor phase is removed from the column into the condenser-dephlegmator 3. The condensate obtained as a result of condensation is partially removed as a finished product - distillate, and partially fed to the upper plate of the column in the form of phlegm.



1 - The upper (concentration) part of the column; 2 - the lower (retract) part of the column; 3 - condenser-dephlegmator; 4- boiler-evaporator

Figure 1 is a schematic of the work of a rectification column for separation binary mixture

The supply of phlegm to the upper plate of the column ensures the constancy of the composition of the phases interacting with the contact elements of the upper column in the column. When phlegm flows from plate to plate from top to bottom, the liquid is depleted of the low-boiling component and enriched with the high-boiling component.

On the feeding plate, the concentrations of the substance in the phases equal to the concentrations of the initial mixture are reached.

A steam generator is specialized equipment designed to convert liquid into steam.

To obtain water vapor specified parameters we use a kettle, Figure 2.

Flue gases, entering through the fitting, pass into the pipe simple p and transfer heat chemically cleaned water, which is in the intertube spacious. As a result summary heat water evaporates and exits through the upper fitting. The tube is made in the form of a bundle of tubes with a floating head for compensation for temperature deformations. The case is completed with cylindrical forms with steam space.

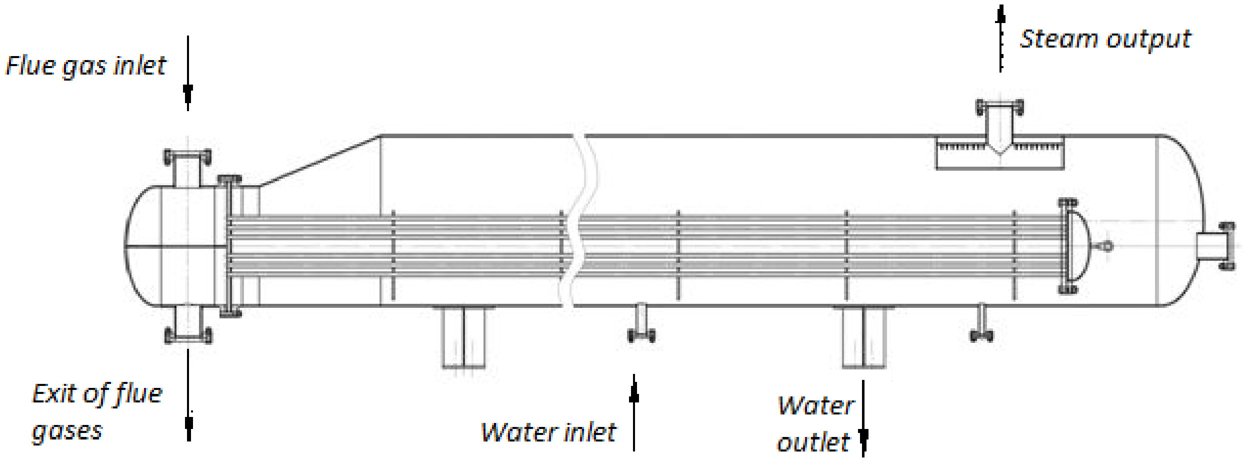


Figure 2 – Structural diagram of the steam generator

The advantages of using a boiler in a mixture separation column are compactness and low energy consumption. The disadvantage of such a boiler is a rather complex design.

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**UDC 66.047**

# HEAT EXCHANGER FOR BENZENE COOLING IN THE TECHNOLOGICAL SCHEME OF THE BENZENE COOLING PROCESS

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**NOTES:** *The production of liquefied benzene, its production by cooling using a refrigerator is considered. The technological scheme is also presented.*

**KEY WORDS:** *BENZENE, COOLING, SHELL-TUBE, HEAT EXCHANGER.*

# МОДЕРНІЗАЦІЯ ТЕПЛООБМІННИКА ДЛЯ ОХОЛОДЖЕННЯ БЕНЗЕНУ ТЕХНОЛОГІЧНОЇ СХЕМИ ПРОЦЕСУ ОЧИЩЕННЯ БІОГАЗУ

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**АНОТАЦІЯ:** *Розглянуто виробництво скрапленого бензолу, отримання шляхом його охолодження за допомогою кожухотрубного холодильника-. Також наведено технологічну схему охолодження бензолу та її опис.*

**КЛЮЧОВІ СЛОВА:** *БЕНЗОЛ, ОХОЛОДЖЕННЯ, КОЖУХОТРУБНИЙ, ТЕПЛООБМІННИК.*

The equipment presented in my work will produce liquefied benzene, which is very relevant for the oil refining industry as it is the main component of benzene. Benzene is an important element in the chemical industry, as it acts as a starting reagent for the creation of all kinds of compounds: ethylbenzene, cyclohexane, cumene, chlorobenzene. For maximum safety, benzene is transported in special canisters or tanks [1, 2].

Benzene is also important for chemical industry, since there israw materialfor the synthesis of many different compounds: ethylbenzene, cumene, cyclohexane, nitrobenzene, chlorobenzene, etc. In addition, it is used as a solvent in some reactions. It is considered a kind of "organic water" because it is able to dissolve almost all organic compounds. A significant number of semi-products obtained with the help of benzene are further used in the production of plastics, synthetic fibers and rubber, surfactants, insecticides and medicines.

The technological scheme of benzene production is shown in Figure 1 [3].

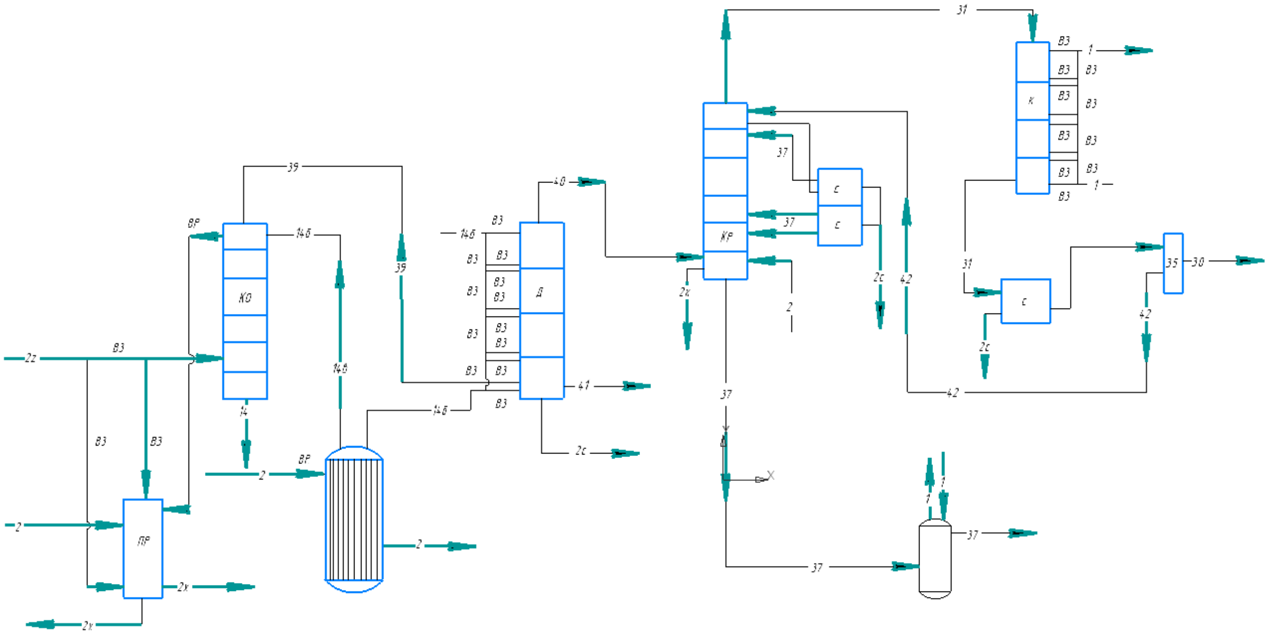
According to this scheme, the benzene-saturated lubricant, which is absorbed, is fed to the dephlegmator (D), which is assembled from four horizontal tubes located one above the other. Saturated lubricant enters the tube space of the upper tube, and then successively passes through all the lower tubes.

Vapors of benzene hydrocarbons mixed with water vapor from the benzene column 1 (KD) enter the dephlegmator (D) and pass countercurrently from the bottom to the mountain through the intertube space up the four tubes.

Grease heated in a dephlegmator to a temperature of 70-75°C, enters for further heating to 135-140°C in steam heaters (P).

During the heating process, part of the benzene hydrocarbons dissolved in the lubricant (in the amount of approximately 25% of the total amount of lubricant) and water (lubricant moisture) evaporate in the heater.

Lubricant with a temperature of 90°C enters the lower fitting of the heater and, passing through the pipes, enters the upper chamber, where the vapor-liquid phase is separated from the liquid phase. Steam under a pressure of 0.6-0.8 MPa enters the intertube space, giving off heat to the heating oil.



D-deflegmator, KD-distillation column, K-condenser, P-heater, PR-steam condenser, C-separator, X-refrigerator, ZB-collector, VZ1-28-stop valve, BP1-2-regulating valve

Figure 1 - Technological diagram

From the heaters (P), the saturated lubricant enters the distillation column (KD), into the lower part of which hot steam is supplied under a pressure of 0.3-0.4 MPa in order to distill benzene hydrocarbons from the lubricant.

From the lower part of the column, the debenzene lubricant enters the intermediate collector, from which it is supplied by a pump for cooling to 25-30°With irrigation heat exchangers.

Lubricant regeneration is carried out in a steam regenerator (SP). To do this, from one of the upper plates of the benzene column (KD), the lubricant, in the amount of approximately 1-1.5%, is diverted to the regenerator (PR), where a large amount of water vapor is blown; the lubricant evaporates almost completely and together with water vapor enters the lower part of the column. Formed under the action of high temperature (approximately 180°C) from the mixtures contained in the lubricant, polymers, as well as hard-boiling parts of the lubricant (anthracene, etc.) are released through the lower fitting of the regenerator into the polymer collector. Lubricant output during regeneration ranges from 80-90% (depending on its quality).

The mixture of vapors of benzene hydrocarbons and water, which comes out from the upper part of the distillation column, enters the lower tube of the dephlegmator (D) - into the pipe space, where, cooling, the lubricant saturated with benzene, which flows countercurrently in the pipe space, is heated.

Phlegm, formed during cooling of vapors, is a condensate of solvent oil, absorbing oil and water, flows from the lower tube of the dephlegmator (D) and is directed to the separator (C), designed to separate water from phlegm. After separation from water, the phlegm is sent to the absorbing lubricant cycle, and the water is diverted to special sedimentation tanks, where it is finally separated from the lubricant.

The mixture of benzene and water vapors from the dephlegmator (D) enters the rectification column (KR), which is designed to separate the mixture of benzene hydrocarbon vapors into two fractions: light and heavy benzene.

The rectification column consists of two parts: the lower - exhaustive and the upper - rectification.

Three steam heaters for heating heavy benzene are installed in the lower part of the column. The upper part is a typical structure of a distillation column, which consists of plates of the cap type.

Condensate condensed on the upper plates of the steaming column is diverted to the separator (C), from which the heavy benzene, after separation from water, returns to the steaming part of the column, where the light benzene is driven off by steam.

Heavy benzene from the lower part of the column (KR) enters the refrigerator (X), from where it is transferred to the warehouse by a pump. Vapors of light benzene and water vapor from the upper part of the column (KR) flow to the condenser (K), which consists of four horizontal tubes, similar in design to a dephlegmator. Condensation and cooling of raw benzene and water takes place in the dephlegmator. Steam enters the inter-tube space, passing through all the tubes sequentially from top to bottom, and the water that cools passes through the tubes of each tube in a counter current - from the lower tube of the refrigerator to the upper one, leaving it with a temperature of 45-50°C. Light benzene and water from the condensate (K) go to the separator (C), from where, after separation from the water, the light benzene is sent to collector 10 (ZB), and then through the meter to the warehouse. Part of the light benzene as a reflux from the collector (ZB) is pumped to the upper plates of the rectification column (KR). The separator (C) is designed to separate the reflux from the water that condenses on the upper plates of the column during cooling of the water vapor.

The purpose of the work ismodernization of the heat exchanger for cooling benzene of the technological scheme of the biogas purification process.The device is designed for cooling heavy benzene at its exit from the rectification column. The refrigerator for heavy benzene is a vertical shell-and-tube heat exchanger. Cooling water passes through the pipes, and hot heavy benzene moves in the middle of the case. Heavy benzene cools to 40-45 in the refrigerator°Cafter which it enters the warehouse.

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**УДК 661.56, 66.045**

# MODERNIZATION OF THE REFRIGERATOR FOR COOLING NITRIC ACID

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***Abstract.*** Description of nitric acid. Description of the technological scheme for the production of nitric acid. Selection of equipment for cooling nitric acid.

***Key words.*** Nitric acid, cooling, heat exchanger

# МОДЕРНІЗАЦІЯ ХОЛОДИЛЬНИКА ДЛЯ ОХОЛОДЖЕННЯ АЗОТНОЇ КИСЛОТИ

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***Анотація.*** Характеристика азотної кислоти. Опис технологічної схеми виробництва азотної кислоти. Вибір обладнання для охолодження азотної кислоти.

***Ключові слова.*** Азотна кислота, охолодження, теплообмінник

Nitric acid is a common substance in the chemical industry with a wide range of applications. First of all, it is caused by its characteristics.

Nitric acid, HHO3 (Figure 1) is a strong monobasic acid. Colorless fuming liquid with a sharp smell. The density of anhydrous nitric acid is 1522 kg/m3, tpl. = 41.15 °C, tboil. = 86 °C; easily decomposes, acquiring a yellow color. Dissolves in water in all proportions; forms an azeotropic mixture containing 68.4% HNO3. Concentrated nitric acid is a strong oxidizer; oxidizes

sulfur to sulfuric acid, phosphorus to phosphoric acid, destroys organic substances. The products of the interaction of nitric acid with metals are salts — nitrates. Aluminum, iron, chromium react with diluted nitric acid and do not interact with concentrated acid due to the formation of an oxide film on their surface. Nitric acid interacts with many organic compounds, forming nitro compounds.

Nitric acid is obtained by catalytic oxidation of ammonia with air oxygen. Nitric acid is used in the production of fertilizers, explosives, dyes, varnishes, in the metallurgy of non-ferrous metals, in chemical laboratories, etc.

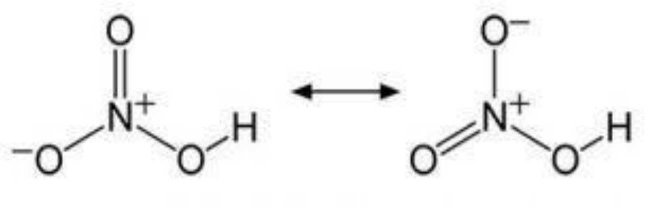
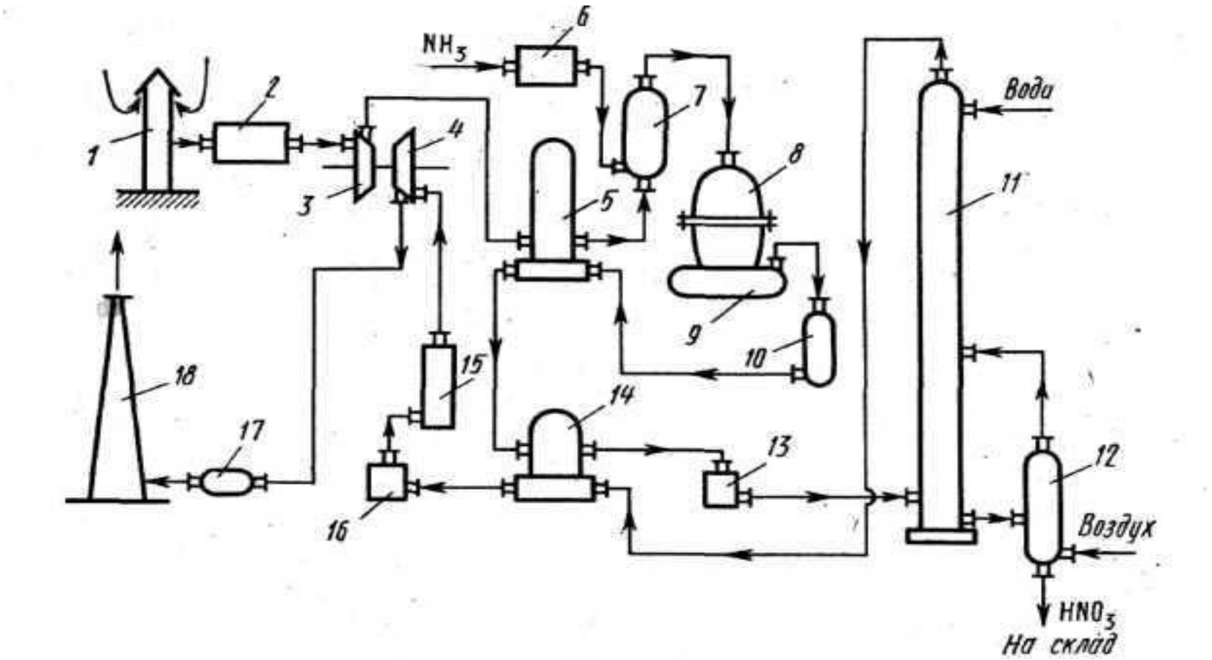


**Figure 1 – Structure of nitric acid**

Nitric acid is reduced to highly toxic chemicals. When heated or under the influence of light, the concentrated acid decomposes with the formation of a highly toxic red-brown gas - nitrogen dioxide (NO2). The maximum allowable concentration for nitric acid in the air of the working area for NO2 is 2 mg/m3.

The basic technological scheme for obtaining diluted nitric acid under high pressure is shown in the figure 2



1 - air intake pipe; 2 - air cleaner; 3 - gas compressor; 4 - gas turbine; 5 - air heater; 6 - ammonia evaporator; 7 - mixer with filter; 8 - contact device; 9, 17- boiler-utilizer; 10- oxidizer with a filter; 11 - absorption column; 12 - blowing column; 13 - refrigerator-condenser; 14 - tail gas heater; 15 - catalytic purification reactor; 16 - combustion chamber; 18 - exhaust pipe

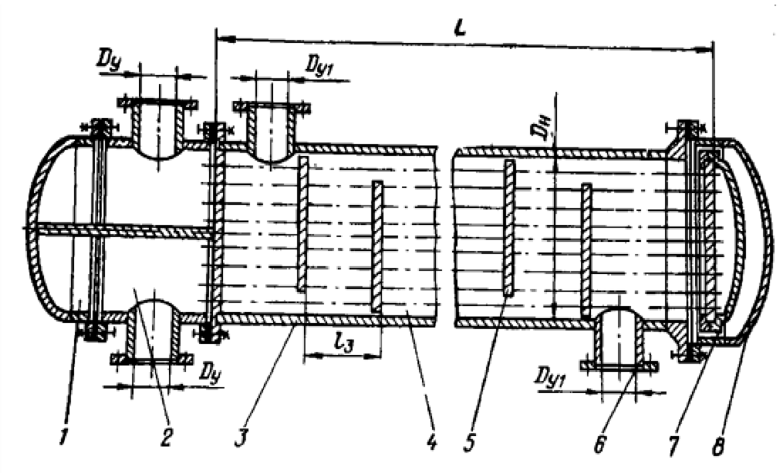
**Figure 2 – Basic technological scheme for obtaining diluted nitric acid under high pressure (0.73 MPa)**

The heat exchanger designed for cooling nitric acid operates under a high temperature load, as there is a significant temperature difference between the heat carriers. This determines the choice of design of heat exchange equipment.

The literature review established that in this case it is appropriate to use the following types of heat exchangers: a heat exchanger with U-shaped tubes, a heat exchanger with a lens compensator on the body, heat exchanger with a floating head, a combination of both types of compensators.

The use of shell-and-tube heat exchangers with a temperature compensator on the casing (lens compensator) is limited by the maximum allowable pressure in the casing equal to 1.6 MPa. With higher pressure in the casing (1.6-8.0 MPa), heat exchangers with a floating head or U-shaped pipes should be used.

Figure 3 shows a shell-and-tube heat exchanger with a floating head, designed for cooling (heating) liquid or gaseous media without changing their aggregate state. The second pipe grid, which is not attached to the casing, together with the inner cover, which separates the pipe space from the inter-pipe space, forms a so-called floating head. These heat exchangers, standardized in accordance with OST 26-01-1507-76 and OST 26-01-1512-76, can be two- or four-pass, horizontal 3, 6 and 9 m long or vertical 3 m high.



1 – cover of the distribution chamber; 2 – distribution chamber; 3 – casing; 4 – heat exchange pipes; 5 – a partition with a segmental cutout; 6 – fitting; 7 – cover of the floating head; 8 – casing cover.

**Figure 3 – Shell and tube heat exchanger with a floating head**

Shell-and-tube condensers with a floating head (TU 3612-023-00220302-01) differ from similar heat exchangers by the large diameter of the fitting for introducing steam into the intertube space.

The permissible pressure of the cooling medium in the pipes is up to 1.0 MPa, in the inter-pipe space - from 0.1 to 2.5 MPa. These devices can be two-, four-, and six-way through the pipe space. The diameter of the casing is from 600 to 1400 mm, the height of the pipes is 6.0 m.

So, it was established that for cooling nitric acid under the given conditions according to the given technological process, it is expedient, first of all, to use a heat exchanger with a floating head.

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**УДК 66.081.63**

# MODERNIZATION OF THE SEAWATER DESALINATION PLANT WITH DEVELOPMENT IF THE REVERSE OSMOSIS APPARATUS

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**Abstract:** The system of sea water desalination based on reverse osmosis is considered. The solution of modernization of the plant is proposed. The technological scheme and its description are also given.

**Key words:** reverse osmosis, membrane distillation, water desalination.

# МОДЕРНІЗАЦІЯ УСТАНОВКИ ОПРІСНЕННЯ МОРСЬКОЇ ВОДИ З РОЗРОБКОЮ АПАРАТА ЗВОРОТНОГО ОСМОСУ

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**Анотація:** *Розглянуто систему опріснення морської води на основі зворотного осмосу. Запропоноване рішення модернізації устоновки. Також наведено технологічну схему та її опис.*

**Ключові слова:** зворотний осмос, мембранна дистиляція, опріснення води.

The current lifestyles require large quantities of fresh water to use in industrial activities, agricultural and domestic purposes. Now, the scarcity of fresh water resources has emerged as a global crisis and for overcoming it, desalination of seawater is a good solution and suitable choice. The main reasons of water scarcity are the global climate changes, earth warming, reducing rainfall and increasing consumption of freshwater [1].

Among the membrane methods for the separation of liquid mixtures, reverse osmosis and ultrafiltration occupy an important place [2-4]. In the process of reverse osmosis, water and substances dissolved in it are separated at the molecular level, with almost perfectly pure water accumulating on one side of the membrane, and all contaminants remain on the other side. Thus, reverse osmosis provides a much higher degree of purification than most traditional filtration methods based on the filtration of mechanical particles and adsorption of a number of substances using activated carbon. In addition, the reverse osmosis method is much simpler and cheaper to operate compared to ion exchange systems [3-4].

The general schematic diagram of the system is shown in figure 1.

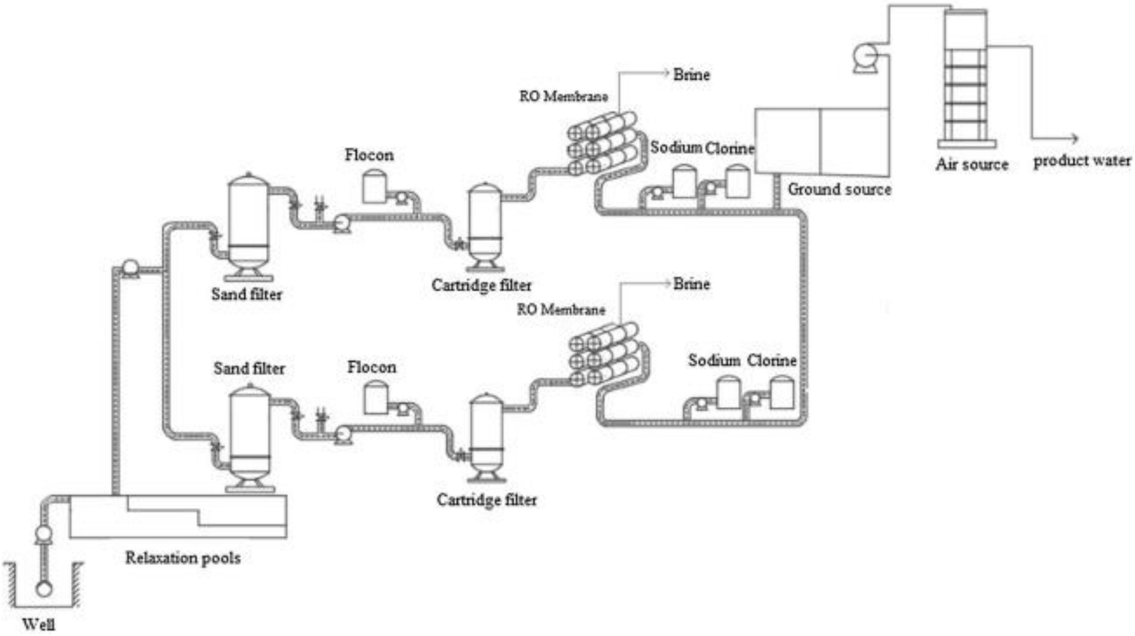

Figure 1 – Schematic of the reverse osmosis desalination plant

At first, the saline water is pumped from two wells by the low-pressure pump (LPP). Then, the feed water is directed to the relaxation pools, sand tanks and then cartridge filter as pretreatment process to get rid of any suspended particles. Next, in a mixer and during the initially treated saline water passing, certain chemicals are added to it that are required to prevent any damage to the RO elements. Like any conventional RO plant, the feed water pressure is raised to the RO operating pressure upper than osmotic pressure and then injected to two trains of RO membrane. The permeate water leaves the modules to achieve the required TDS of the final product water. Here, in this RO system a DOW filmtec SW30HRLE 400 spiral wound membrane modules are used for SWRO desalination propose. Membrane specifications such as active area (37 $m^2$), maximum operating pressure (83 bar), permeate flow rate (28 $m^3$/day), minimum salt rejection (99.65 %). The 120 membranes of this type of membrane in two trains of five pressure vessels, work for the water desalination [1].

In this technological scheme, shown in Fig.1, the most important apparatus is the membrane apparatus. The membrane separation process depends on the pressure, hydrodynamic conditions and design of the apparatus, the nature and concentration of seawater, the content of impurities in it, as well as the temperature. An increase in solution concentration leads to an increase in the osmotic pressure of the solvent, an increase in the viscosity of the solution, an increase in concentration polarization and a decrease in permeability and selectivity. It is worth noting that the performance of the entire plant depends on the operation of the apparatus. Therefore, to improve the performance of the plant, it is necessary to modernize the membrane apparatus, which is the purpose of our work.

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# MODERN DIRECTIONS OF IMPROVEMENT OF CONTACT PLATES OF COLUMN APPARATUS

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***Annotation:*** *The main modern directions of improvement of tray mass-exchange column apparatuses are given, which allow to increase the efficiency of the process, the coefficient of efficiency and reliability of contact plates, to provide with improve the conditions of mass transfer between phases.*

***Key words:*** *mass-transfer apparatus, contact plate, bubbling.*

# СУЧАСНІ НАПРЯМКИ УДОСКОНАЛЕННЯ ТАРІЛЧАСТИХ КОЛОННИХ АПАРАТІВ

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***Анотація.*** *Наведені основні сучасні напрямки удосконалення тарілчастих масообмінних колонних апаратів, які дозволяють збільшити ефективність процесу, коефіцієнт корисної дії і надійність контактних тарілок, забезпечити поліпшення умов масообміну між фазами.*

***Ключові слова:*** *масообмінний апарат, контактна тарілка, барботаж.*

Most distillation and absorption columns, according to the method of organizing phase contact, belong to tray column apparatus. In this case, various designs of poppet contact devices are used, both with drain (overflow) devices and without them, which are adapted to specific media and loads.

Despite the large number of existing designs of plates of mass transfer devices, their improvement continues all the time. A significant contribution on this path was also made by specialists of KPI named after Igor Sikorskyi, the results of which research are given below.

### Improvement of bubble cap

Bubble cap are currently widely widespread and provide high performance in a wide range of loads in heavy and light phases. To simplify the adjustment of the distance of each bubble cap from the plate web, the thrust element can be made in the form of a cylindrical compression spring, and then for the necessary location of the cap, it is enough just to screw the nut onto the rod or turn it off (pat. of Ukraine № 147974, B01D 3/20).

To exclude the use of lubricant for the rotation of the bubble caps, each cap and the corresponding rod are equipped with permanent magnets, which are made in the form of bodies of revolution and form a magnetic bearing. This design simplifies the operation of the mass transfer apparatus due to the absence of lubricant entering the processed phases (pat. of Ukraine № 146614, B01D 3/20, H01F 7/00).

To increase the strength and rigidity of the horizontal web of the plate, each of the gas nozzles is proposed to be made in the form of a truncated cone, the diameter of the larger base of which is equal to the diameter of the corresponding cylindrical ring protrusion (pat. of Ukraine № 146174, B01D 3/20).

## Improvement of shaped and perforated tray

Ensuring the uniformity of the distribution of the heavy phase over the round horizontal sheet of the plate, and therefore, improving the conditions for mass transfer between the phases can be done by directing the flakes in the direction of movement of the heavy phase within the contact area (pat. of Ukraine № 140913, B01D 3/18).

Regulated turbulence of the heavy phase is produced by placing an elastic web with holes on the upper surface of a rigid horizontal web. Sections of rigid horizontal and elastic webs around the holes are hermetically interconnected to form common channels, and the space between said webs is connected to the pneumatic line. The results of increasing the efficiency of mass transfer between phases and simplifying the removal of the heavy phase from the plate after stopping the mass transfer apparatus (pat. of Ukraine № 136150, B01D 3/22, B01D 53/18, C07C 7/04).

An increase in the phase contact surface on the tray web, and consequently an increase in the efficiency of mass transfer between the phases, is achieved by flanging each hole of the cavity formed by it, tapering upwards, while on the specified flanging at least one petal is formed, bent outward (pat. of Ukraine № 136149, B10 3/22 , B01D 53/18).

An increase in the efficiency of mass transfer between the phases on the plate is achieved by the impossible slippage of bubbles or streams of the light phase through the layer of the heavy phase. To do this, on vertical rods located on a horizontal perforated canvas, photog to fix horizontal disks with holes and anvane wheel are fixed at different levels (pat. of Ukraine № 136111, B01D 3/22, B01D 53/18).

Another way to increase the efficiency of mass transfer can be the intensive dispersion of the heavy phase in the flow of the light phase not only above the plate cloth, but also below it (pat. of Ukraine № 135088, B01D 3/22, B01D 53/18, C07C 7/04)

The practical use of improved contact plates of mass transfer devices makes it possible to increase the efficiency of such technological processes as rectification, absorption, desorption, extraction, as well as to increase the reliability of technological equipment.

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**UDC 66.21**

# MODERNIZATION OF ROTARY FURNACE

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**ANNOTATION:***The design of the rotary furnace is described, and the possible nozzle options are considered. Ways to modernize the furnace are given.*

**KEYWORDS:**DESIGN, ROTARY FURNACE, NOZZLE, MODERNIZATION

# МОДДЕРНІЗАЦІЯ ОБЕРТОВОЇ ПЕЧІ

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**АНОТАЦІЯ:** *Описано конструкцію обертової печі, розглянуто можливі варіанти насадки. Наведено шляхи модернізації печі.*

**КЛЮЧОВІ СЛОВА:** КОНСТРУКЦІЯ, ОБЕРТОВА ПІЧ, НАСАДКА, МОДЕРНІЗАЦІЯ

The rotary kiln is widely used in factories all over the world. Such a furnace serves as a reliable unit, where various materials and metal products are subjected to heat treatment to the required temperatures before further use in various fields of construction, constructions of machine tools of various classes, machine building and aircraft construction. The materials for which rotary kilns are used are cement, lime refractory material, meta-kaolin, titanium dioxide, aluminum, vermiculite, iron ore pellets [1, 2, 3].

This figure 1 shows the diagram of a rotary kiln.

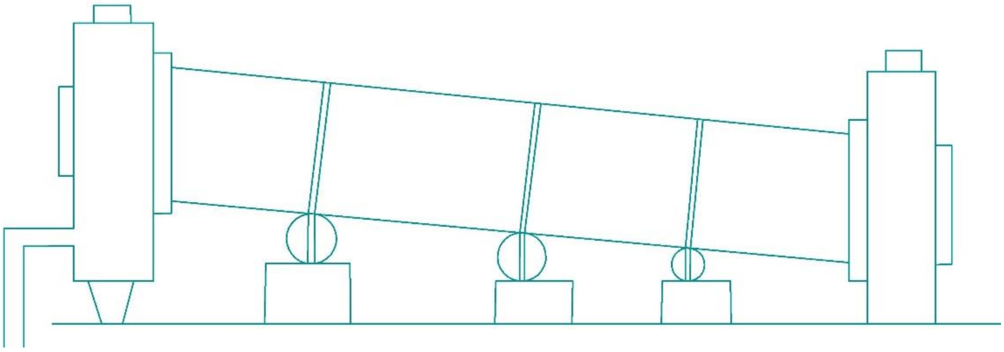

Figure 1 – Diagram of a rotary kiln

The principle of operation of the rotary kiln consists in heating and drying various materials for the purpose of their physical and chemical processing. The advantage of this furnace is that it works continuously and allows you to process the material at high temperatures.Also, this stove can be located outdoors, because it does not depend on the environment. The rotary kiln is a fully automated design, which is a great advantage for large multi-purpose productions and is easy to manufacture. The disadvantages include the fact that the manufacture, repair and reconstruction of such equipment is also very expensive. Another disadvantage of a rotary furnace is that such a furnace does not allow the use of solid fuel according to its characteristics fuelgas, fuel oil, or powdered coal can be used for such a furnace.

The furnace has a cylindrical shape and rotates around the longitudinal axis, the furnace is located at an angle to the horizon and has the ability to work continuously to heat the material for a long time. The oven rotates quite slowly. The principle of operation of the furnace consists in loading the material into the upper end of the cylinder, where the loading device is located. In the process of operation, the material inside the furnace rotates and goes to the lower end of the furnace, while it is mixed, which makes it possible for this furnace to work well. Hot gases can pass both in the opposite direction to the material - counterflow, and in the opposite direction - direct flow.

The main components of a rotary kiln are: a lining, a refractory lining, supporting bands, rollers, a traction device and various nozzles.

The furnace body is made of low-carbon steel with a thickness of 15-30 mm, welded in the form of a cylinder, which can reach a length of up to 6 m and a diameter of up to 2300 mm. Restrictions regarding the diameter of the common thread are caused by the fact that it has a tendency to deformation that occurs during rotation during operation. The limitation regarding the length of the pipe is not mandatory, but here it is necessary to take into account that if the furnace is very long, there are difficulties in heating and cooling the material.

Refractory lining consists of refractory concrete or refractory brick and may be absent in parts of the furnace where the temperature inside does not exceed a temperature of 250°C. The lining material is selected depending on the temperatures in the furnace and the chemical properties of the material being processed. The main purpose of the refractory lining is: storage of the steel lining inside the furnace from high temperatures and protection against corrosion of the casing under the influence of the material being processed. The thickness of the lining can reach 80-300 mm. The lining can withstand a temperature of 1000°C. The temperature of the core should not exceed 350°C in order to prevent the destruction of the case.

Internal heat exchangers are used in parts of the pipe where there is insufficient heating or in processes where the temperature is low.

Bandages and rollers. The bandage is a ring-shaped part that is cast and processed to the required surface cleanliness, is attached to the body with the help of various fasteners, and is on rollers. Also, it is necessary that the bandage adheres to the collar, but it should not interfere with free movement in work. Rollers provide rotation with minimal friction.

Occasion. Thanks to the drive, the oven can rotate. The drive consists of a toothed crown gear, which is connected to the electric motor through a reducer, which provides the speed at which the furnace will rotate.

Rotary furnace nozzles (Figure 2).

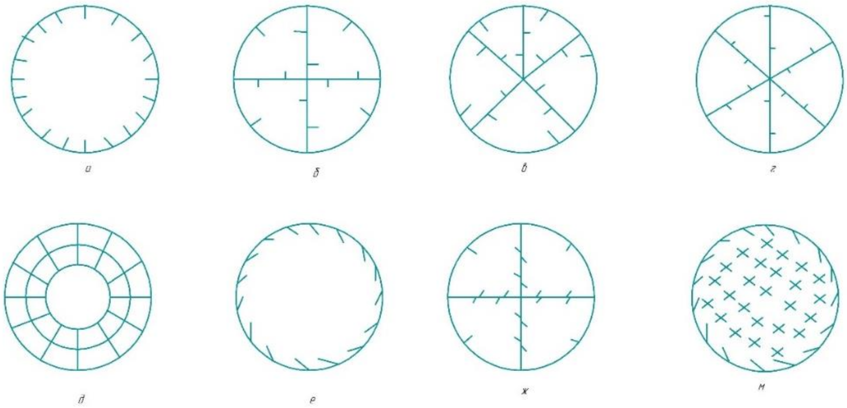

Figure 2 – Nozzles of a rotary kiln

There are different types of nozzles. They differ in the consistency of the material to be dried. They exist for loose materials, materials that stick to walls, and materials that create a lot of dust. For bulk materials, a distribution system of nozzles is used, for materials that tend to stick to the walls and to be in the form of large particles, nozzles with blades are used, for materials that tend to create a lot of dust, we use a transshipment with closed cells. Nozzles "a" and "e" are used for materials that are in the form of large particles and tend to stick to the walls, nozzle "m" is used for the distribution system, that is, for bulk materials, and nozzle "n" is used to form a chain system. The most common type of nozzles "b", "c", "g", "g",

Considering the design of the sand drying oven, it is proposed to modernize the nozzle of the rotary oven (Figure 3). The sand is loose, it can be wet and can thus stick to the walls of the rotary kiln, so it is suggested toconnect nozzles of options "a" and "m".

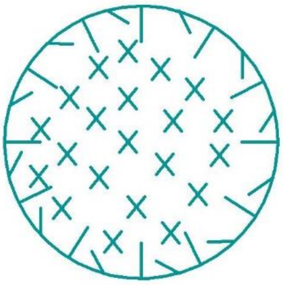

Figure 3 – Modernization of the nozzle of the rotary kiln

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2. https://www.wiki.uk-ua.nina.az/%D0%9E%D0%B1%D0%B5%D1%80%D1%82%D0%BE%D0%B2%D0%B0_%D0 %BF%D1%96%D1%87.html

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**УДК 66.047**

# MODERNIZATION OF THE AIR COOLER OF THE GAS FRACTIONATION UNIT

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**ANNOTATION:** THE TECHNOLOGICAL SCHEME OF THE GAS FRACTIONATION INSTALLATION IS CONSIDERED.

**KEY WORDS:** TECHNOLOGICAL SCHEME, GAS FRACTIONATION, AIR COOLER.

# МОДЕРНІЗАЦІЯ ПОВІТРЯНОГО ХОЛОДИЛЬНИКА УСТАНОВКИ ГАЗОФРАКЦІЮВАННЯ

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**АНОТАЦІЯ:** Розглянуто технологічну схему установки газофракціювання.

**КЛЮЧОВІ СЛОВА:** ТЕХНОЛОГІЧНА СХЕМА, ГАЗОФРАКЦІЮВАННЯ, ПОВІТРЯНИЙ ХОЛОДИЛЬНИК.

For the separation of hydrocarbon gases into individual or narrow technical fractions, such physical processes as condensation, compression, rectification, and absorption have become the most widespread at oil and gas refineries. The specific choice of the scheme (sequence) of separation, temperature, and pressure is determined by the composition of the initial gas mixture, purity requirements, and the given assortment of the commodity product [2].

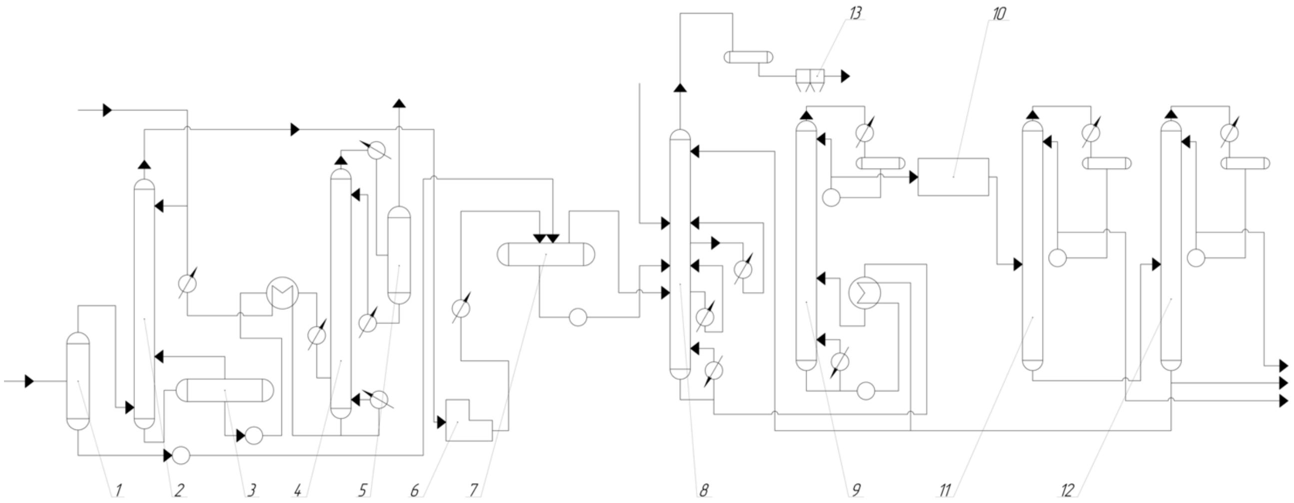
For the clear separation of gaseous hydrocarbons, rectification or a combination of rectification with absorption is used, if there is a need to separate gas in which there is a lot of "dry" part, mainly methane. In this case, it is advisable to first separate the "dry" part using absorption, followed by separating the remaining gas by rectification.

Gas fractionation is the process of separating hydrocarbon raw materials (unstable gas gasoline) to obtain individual light hydrocarbons or hydrocarbon fractions of high purity, which differ in boiling point. Gas fractionation processes have been used to obtain from oil refinery gases and gases from low-temperature processing plants individual low-molecular hydrocarbons C1-C6 (both limiting and non-limiting, normal or isostructure) or their fractions of high purity. A combination of condensation, compression, rectification, and absorption processes has found use at gas fractionation plants (HFU).

The products of gas fractionation plants, depending on the scale of production, the composition of the initial raw materials, the requirements for commercial gas, and the depth of processing, are the following narrow hydrocarbon fractions or components: methane-ethane (sometimes ethane), propane, butane, isobutane, pentane, isopentane, propane-propylene, butane-butylene, ethane-ethylene, pentane-amylene. It is also promising to obtain the hexane fraction or iso- and normal hexane. When using narrow fractions as raw materials for petrochemical syntheses, the content of the main components in them should be at least 96...98%. Fractions of hydrocarbon gases, which leave the installation as a final product, must meet the technical conditions according to the current standards.

The technological scheme of the gas fractionation installation is shown in Figure 1. [1]

The gas from the catalytic cracking unit is supplied to separator 1. The liquid fraction is collected in the collector of separator 7, the gaseous fraction is supplied to absorber 2. A mixture of mono ethanol amine (MEA) and alkali is supplied as irrigation of the absorber. The purified gases are compressed in compressor 6, cooled, and then fed to the collector of separator 7. The mixture of MEA with alkali and sulfur compounds is fed to separator 3, the gaseous fraction is used as steam feed for column 2, and the liquid fraction is heated in the furnace and fed to rectification column 4. Purified MEA after cooling is supplied as the phlegm of absorber 2, and hydrogen sulfide is diverted to storage. The liquid fraction from the separator 7 and the gaseous fraction is fed to the fractionating absorber 8. From the upper part, dry gases are taken through the condenser and fed to the air cooler 13. Unstable gasoline is taken from the middle part of the column, and gases mixed with gasoline are removed from the lower part. Stable gasoline is supplied to the upper part as irrigation. A mixture of gasoline and gases is fed to the stabilizer 9. From the lower part of the stabilizer 9, stable gasoline is taken, which is partly fed to the warehouse, and partly to the irrigation of column 8. From the upper part of column 9, the mixture of gases is fed to propane column 11, from the top of which the propane-propylene is taken faction. The cubic residues of column 11 are fed to butane column 12, where the butane-butylene fraction is selected from the top and stable gasoline from the bottom.



1,3,5,7 – separators; 2 – absorber; 4 – a column for cleaning mea from hydrogen sulfide; 6 – compressor; 8 – fractionating absorber; 9 – stabilizer; 10 – cleaning unit; 11 – propane column; 12 – butane column; 13 – air cooler;

Figure 1 – Technological scheme of the gas fractionation installation

The air cooler is not the main device of the technological scheme shown in Figure 1, but it is an integral part of the gas fractionation installation. It is in it that the process of condensation and cooling of unstable gasoline takes place. Therefore, it is necessary to choose the most productive device.

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**УДК 662.61, 662.66, 532.528.**

# ВПЛИВ ГІДРОДИНАМІЧНОЇ КАВІТАЦІЇ НА ДИСПЕРСНУ ФАЗУ ВОДОВУГІЛЬНОЇ СУСПЕНЗІЇ

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***АНОТАЦІЯ.*** *Наведені результати дослідження інтенсифікації процесу отримання водовугільної суспензії (ВВС) з використанням гідродинамічної кавітації. З метою дослідження розроблено та виготовлено гідродинамічний змішувач, основою якого є сопло, оснащене турбулізатором потоку. Проведені дослідження довели ефективність диспергування твердої фази водовугільної суспензії.*

***Ключові слова***: *гідродинамічна кавітація, водовугільне паливо, дисперсність.*

# INFLUENCE OF HYDRODYNAMIC CAVITATION ON THE DISPERSION PHASE OF A WATER-COAL SUSPENSION

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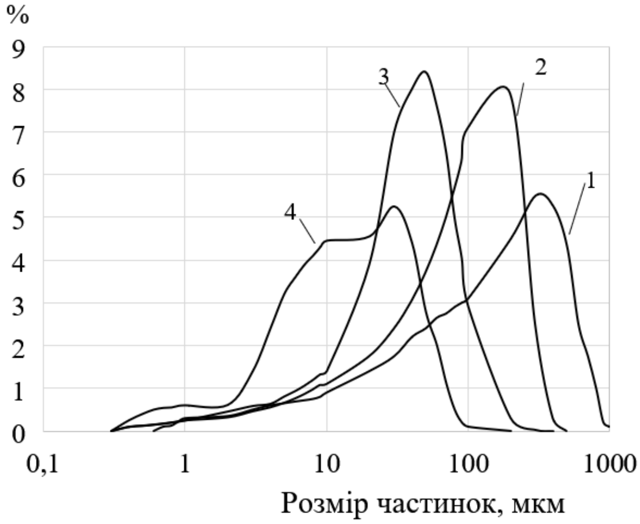
***ABSTRACT:*** *The article presents the results of a study of the intensification of the process of producing coal-water suspension using hydrodynamic cavitation. For the purpose of the research, a hydrodynamic mixer was developed and manufactured, the basis of which is a nozzle equipped with a flow turbulator. The conducted studies proved the effectiveness of dispersing the solid phase of the hydrocoal suspension.*

***Key words:*** *hydrodynamic cavitation, hydrocarbon fuel, dispersity***.**

На сьогоднішній день перед Україною та багатьма країнами світу гостро стоїть питання енергетичної безпеки та пошуку альтернативних видів палив, що здатні повноцінно замінити традиційні. Розвиток технологій виробництва водовугільних суспензій (ВВС) є дуже актуальним для вирішення глобальних проблем ресурсоощадності та екології. Метою даної роботи є створення технології виробництва водовугільного палива на основі процесу гідродинамічної кавітації. Однією з характеристик, що визначає якість водовугільного палива є його дисперсний склад, тому в дослідженні даному показнику приділено увагу. Було створено експериментальний стенд, робочим органом якого стало кавітаційне сопло з турбулізатором потоку у вигляді крильчатки. Відбір проб суспензії зі змішувача здійснювали через 10 хв., 20 хв., 30 хв., після виходу на стабільний режим течії суспензії. За контрольний параметр було взято тривалість подрібнення.

Дисперсійний аналіз водовугільної суспензії проводили методами мікроскопічного аналізу на світловому мікроскопі Carl Zeiss Axio Imager Z1m. Обробку даних виконували за стандартною методикою. Криві розподілу за розмірами вугільних частинок в зразках ВВС зображено на рисунку 1.

Експериментальні дослідження показують, що дисперсний склад суміші змінюється з часом обробки. Так, обробка в кавітаційному диспергаторі протягом 30 хв дозволяє отримувати фракційний склад палива, що відповідає вимогам використання як для ТЕС так і для котельних. Обробка протягом 20 хв вже дозволяє досягти необхідних показників для ТЕС. Тобто, в залежності від вимог до дисперсного складу суспензії можна використовувати різну тривалість обробки.



ВВС в залежності від часу обробки: 1 – вихідний зразок; 2 – після 10 хв обробки; 3 – після 20 хв обробки; 4 – після 30 хв обробки.

Рисунок 1 – Диференційні криві розподілу за розмірами вугільних частинок

**УДК 662.61, 662.66, 532.528.**

# ВПЛИВ ГІДРОДИНАМІЧНОЇ КАВІТАЦІЇ НА СТІЙКІСТЬ ВОДОВУГІЛЬНОЇ СУСПЕНЗІЇ

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***АНОТАЦІЯ.*** *Наведені результати дослідження інтенсифікації процесу отримання водовугільної суспензії (ВВС) з використанням гідродинамічної кавітації. З метою дослідження розроблено та виготовлено гідродинамічний змішувач, основою якого є сопло, оснащене турбулізатором потоку. Було визначено вплив гідродинамічної кавітації на седиментаційну стійкість суспензії в залежності від її масової концентрації.*

***Ключові слова***: *гідродинамічна кавітація, водовугільне паливо, седиментаційна стійкість.*

# INFLUENCE OF HYDRODYNAMIC CAVITATION ON THE RHEOLOGICAL PROPERTIES OF HYDROCARBON SUSPENSION

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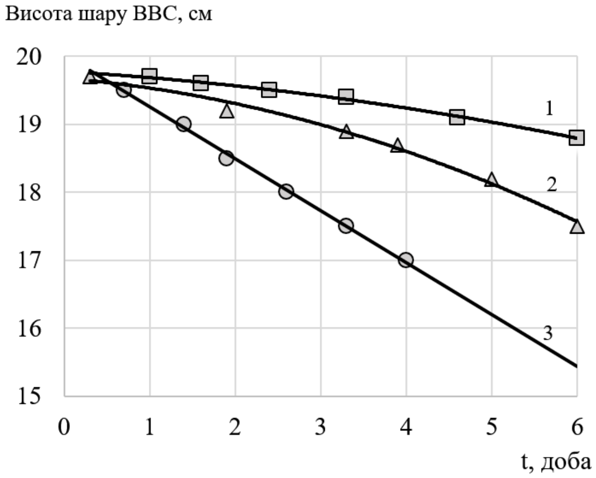
***ABSTRACT:*** *The article presents the results of a study of the intensification of the process of producing coal-water suspension using hydrodynamic cavitation. For the purpose of the research, a hydrodynamic mixer was developed and manufactured, the basis of which is a nozzle equipped with a flow turbulator. The influence of hydrodynamic cavitation on the sedimentation* *resistance of the water-coal suspension was determined, depending on its mass concentration.*

***Key words:*** *hydrodynamic cavitation, hydrocarbon fuel, sedimentation resistance.*

На сьогоднішній день перед Україною та багатьма країнами світу гостро стоїть питання енергетичної безпеки та пошуку альтернативних видів палив, що здатні повноцінно замінити традиційні. Розвиток технологій виробництва водовугільних суспензій є дуже актуальним для вирішення глобальних проблем ресурсоощадності та екології. У зв'язку з цим було створено експериментальний стенд, робочим органом якого стало кавітаційне сопло з турбулізатором потоку у вигляді крильчатки. Метою даної роботи є дослідження седиментаційної стійкості водовугільного палива в умовах гідродинамічних режимів, що реалізуються на даному стенді.

Седиментаційну стійкість водовугільної суспензії визначали по висоті шару осадження дисперсної твердої фази і зміні технологічних характеристик з плином часу. Отримані залежності, наведені в графічному вигляді, на рисунку 1, показують стабільність суспензії протягом 5-6 діб.



1 – масова концентрація вугілля 56%; 2 – масова концентрація вугілля 60%; 3 – масова концентрація вугілля 65%.

Рисунок 1 – Залежність висоти шару дисперсної фази з плином часу.

Зниження висоти шару дисперсної фази свідчить про дестабілізацію дисперсної системи, що приводить до поступового осадження і згущення вугільних частинок.

Отже, при високих масових концентраціях суспензії для довготривалого зберігання є необхідність використання хімічних стабілізаторів, що підвищують седиментаційну стійкість емульсії.

**УДК 065.143**

# INSTALLATION OF AIR PURIFICATION FROM AMMONIA

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***ABSTRACT:*** *A description of the technological scheme of the air purification plant from ammonia was considered and made.*

***KEY WORDS:*** *AMMONIA, PURIFICATION, MASS TRANSFER, ABSORBER, DESORBER.*

# УСТАНОВКА ОЧИЩЕННЯ ПОВІТРЯ ВІД АМІАКУ

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***АНОТАЦІЯ:*** *Розглянуто та зроблено опис технологічної схеми установки очищення повітря від аміаку.*

***КЛЮЧОВІ СЛОВА:*** *АМІАК, ОЧИЩЕННЯ, МАСООБМІН, АБСОРБЕР, ДЕСОРБЕР.*

In connection with the development of industry based on the creation of high-performance installations, the importance of heat and mass transfer processes is increasing from the point of view of the rational use of thermal power and raw materials. One of the most important tasks of industry is the intensification of technological processes and the saving of valuable raw materials. The main way to achieve this is the creation of technologies and technological processes in which the entire flow of raw materials and all energy resources are fully or maximally used in the production of products [1, 2].

Absorption has become widespread in the chemical industry. Absorption processes are used mainly to extract valuable components from gas mixtures or to purify these mixtures from harmful impurities. Absorption processes are the main technological stage of a number of the most important industries. In addition, absorption processes are the main processes in the sanitary purification of gases from harmful impurities that are released into the atmosphere.

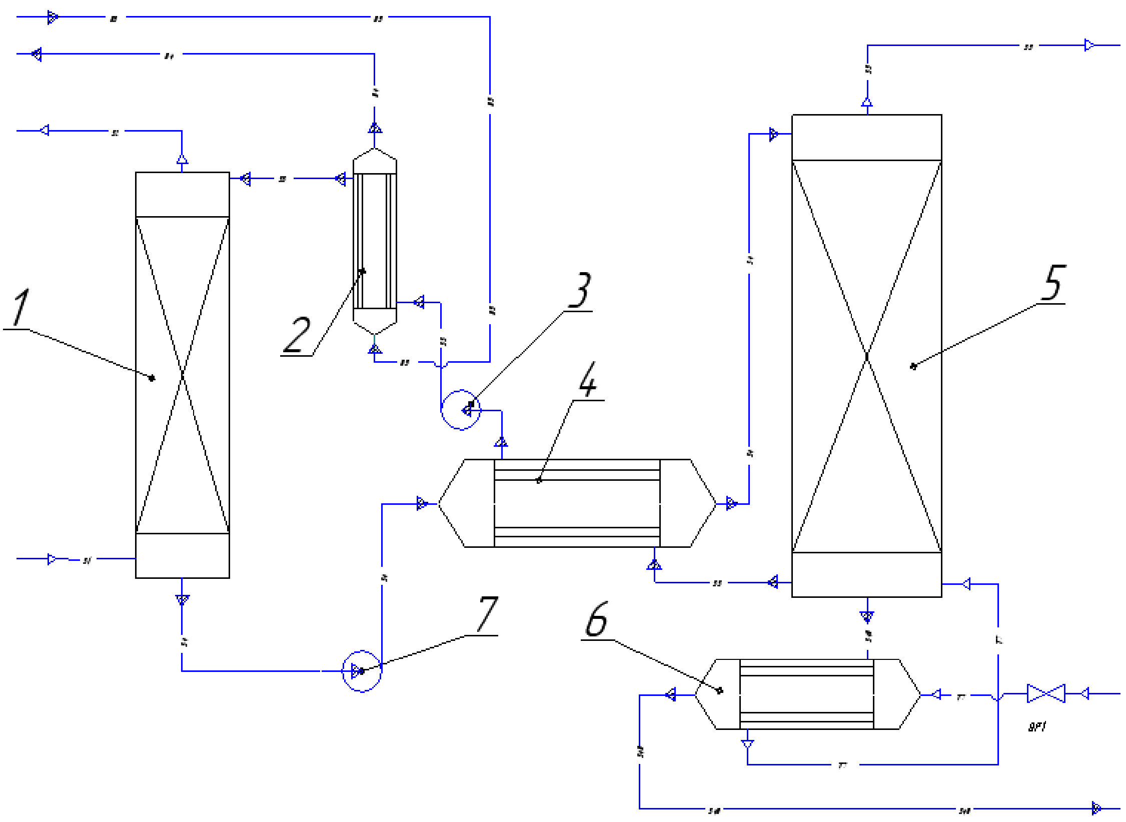
With the current state of technology and equipment, it is not yet possible to exclude the ingress of toxic substances into the atmosphere completely. Therefore, at the moment, gas treatment facilities serve as an affordable way to protect it. The main task of gas purification is to bring the concentration of harmful impurities in industrial emissions to the limit permissible by sanitary standards.

All methods of gas purification are mainly determined by the physical and chemical properties of impurities, their composition, aggregate state, dispersion, etc. The variety of harmful impurities in industrial emissions causes a great variety of cleaning methods and reagents or liquid absorbers to achieve the set results. Purification of gases from gaseous and vaporous impurities is particularly characteristic of the chemical industry and is widely used at chemical enterprises.

Among the technological schemes in the chemical industry, circular schemes are among the most widespread. Figure 1 shows the technological scheme of the air purification plant from ammonia.

The gas mixture enters the lower part of the absorber 1, where it is evenly distributed along the cross-section of the column and falls on the contact elements (nozzle or plates). The absorbent (water) is supplied into the upper part of the column and is evenly distributed along the cross-section of the absorber at the expense of the sprinkler. In the column, countercurrent interaction of the gas with the liquid absorber is carried out.

The purified gas leaves the column after absorption. The liquid absorber (water), saturated with ammonia, is sent by pump 7 for regeneration to desorber 5 after preheating in heater 4.



1 – absorber; 2 – refrigerator; 3, 7 – pump; 4 – heater;
5 – desorber; 6 - boiler.

Figure 1 – Technological scheme of the air purification plant from ammonia

Depletion of the absorber occurs in the lower part of desorber 5. Before being supplied to the upper part of absorber 1, the absorbent, passing through heater 4 is sent to refrigerator 2 by pump 3, where it is further cooled. The driven ammonia leaving the desorber 5 contains water vapor in the amount corresponding to its partial pressure at the desorption temperature. In this installation absorption and desorption are carried out at the same pressure (atmospheric). In this case it is not necessary to free the component from the vapors of the absorber, since the driven component is returned to the production cycle where it is cleaned from the vapors.

Since in this technological scheme air purification from ammonia takes place directly in the absorber, it is customary to choose an absorber for the diploma project that would meet the modern designs of this type of apparatus of the chemical industry, as well as the basic requirements for energy-efficient mass transfer equipment.

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**УДК 065.143**

# TAIL GAS TREATMENT PLANT

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***ANNOTATION:*** *The technological scheme of sulfur production with a tail gas purification plant is considered and described.*

***KEY WORDS:*** *SULFUR, AB*SORBER, CLEANING, TAIL GASES.

# УСТАНОВКА ОЧИЩЕННЯ ХВОСТОВИХ ГАЗІВ

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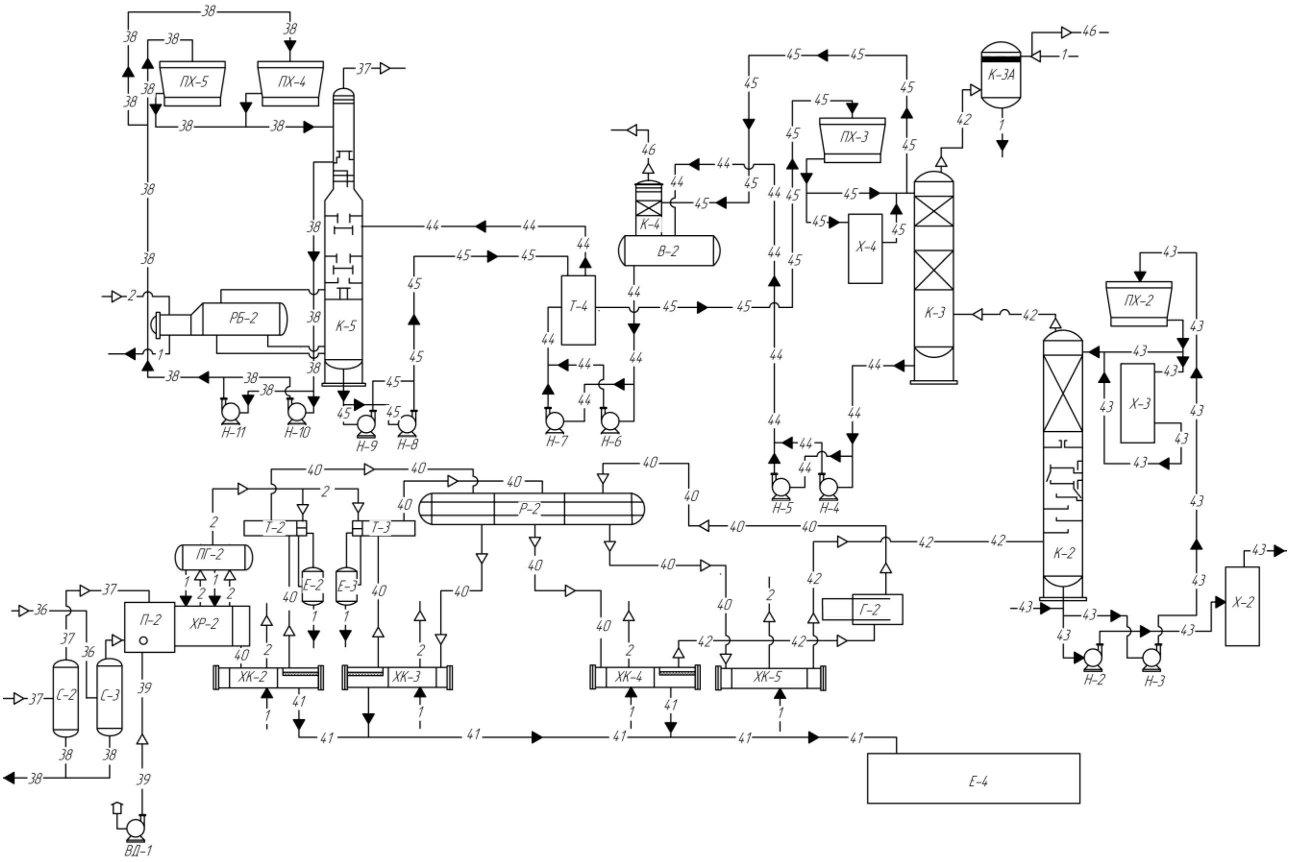
***АНОТАЦІЯ:*** *Розглянуто та описано технологічну схему виробництва сірки з установкою очищення хвостових газів.*

***КЛЮЧОВІ СЛОВА:*** *СІРКА, АБСОРБЕР, ОЧИЩЕННЯ, ХВОСТОВІ ГАЗИ.*

The technological scheme of the sulfur production unit is shown in Figure 1.

Ammonia-containing gas from the acid waste stripping section and sulphur dioxide-containing gas from the amine regeneration section are supplied to separators C-2 and C-3 of the sulphur production unit.

In separators C-2 and C-3 the removed moisture is separated from gases. Condensate (sour water with hydrogen sulfide content up to 4 % by weight) from separators 1 is automatically discharged by level into a drainage tank, from which sour water is fed for processing to the section of acid waste stripping. Gases from separators C-2 and C-3 are fed to the reaction furnace П-2. To organize the combustion process, air is supplied to the burners, which is injected by gas blower ВД-2.



*С* – separator; *ВД* – gas blower; *П* – stove; *ХР* – reaction cooler; *ПГ* – steam heater; *ХК* – condenser; *Е* – receptacle; *Т* – heat exchanger; *Р* –reactor; *К* – column; *Н* – pump; *РБ* – reboiler; *ПХ* – air cooler; *Г* – enewable gas generator; *Х* – cooler; *В* – evaporator

Figurte 1 – The technological scheme of the sulfur production

A mixture of ammonia-containing and sulfur dioxide-containing gases is supplied to the main burner of the furnace. In this case, the flow rate of sulfur dioxide gas is regulated depending on the amount of ammonia-containing gas. Air consumption is regulated by the total amount of sulfur dioxide and ammonia-containing gases.

Correction of air consumption is carried out depending on the results of analytical control of tail gases. At the same time, small changes in the composition of feed acid gases and errors in flow rate measurements are automatically compensated.

Another amount of sulfur dioxide-containing gas is supplied to the middle section of the reaction furnace П-2. Such distribution of flows is carried out to obtain the temperature conditions necessary for complete decomposition of ammonia.

The gas from the reaction furnace П-2 enters the reaction cooler ХР-2, where it is cooled to a temperature of 622 K due to the boiler feed water supplied to the steam heater ПГ-2. At the same time, high pressure water steam P=4.2 MPa is removed from the steam heater.

Process gas coming out of the cooler ХР-2 enters the condenser ХК-2, where it is cooled by purified water. At the same time, low pressure water vapor P=0.35 MPa, t=423 K is generated.

Condensed sulfur flows into the sulfur storage facility Е-4.

The process gas leaving the condenser is heated by high pressure steam in the Т-2 heater and then enters the first stage converter of the Р-2 reactor. In the converter, in the presence of a catalyst (aluminum oxide), the reaction continues with the formation of sulfur.

The steam and gas flow from the first stage converter Р-2 and unreacted gases are cooled by purified water in the condenser ХК-3. At the same time, low-pressure water vapor is generated, and condensed sulfur flows into the sulfur storage Е-2.

Process gas leaving the condenser ХК-3 is again heated by high pressure steam in the heater Т-3 and enters the converter Р-2.

Sulphur is also formed in the converter. The flow leaving the converter is cooled in the condenser ХК-4, and the condensed sulfur flows into the sulfur storage E-2.

The recovered sulphur is collected in a sulphur storage facility. This sulphur contains a small number of dissolved gases. As it cools, some of the gases will be released into the vapor space of the storage. To ensure that the hydrogen sulfide contained in these gases does not form an explosive mixture with the air, an ejector is used to remove the gases released from the sulfur from the vapor space. The air that comes out of the ejector and contains the released gases is sent to the thermal oxidizer, where it is burned, after which the combustion products are released into the atmosphere.

Liquid sulphur from the storage is pumped to the granulation section.

All liquid sulphur lines are heated to prevent sulphur solidification and pipeline blockage.

Tail gases from the last condenser ХК-4 are supplied to the reducing gas generator Г-2. The reducing gas generator has a dual purpose: heating the tail gases to the temperature required for the hydrogenation process, and the hydrolysis reaction, which results in the formation of reducing gas (H2 + CO). To organize the hydrogenation process, the generator is supplied with fuel gas and air, which is blown by a blower.

Hot combustion products from the Г-2 generator are fed to the P-2 hydrogenation reactor. The hydrogenation and hydrolysis reactions for the four main sulfur compounds present in the tail gases are exothermic. Therefore, the gases leaving the reactor are cooled in the condenser ХК-5. At the same time, due to the removed heat, low-pressure water vapor P=0.35 MPa, t=423 K is generated.

Further, the tail gases are directed to the lower part of the mixing condenser K-2, where they are cooled and saturated with water vapor in direct contact with the circulating water flow. A 20% alkali solution is added to the circulating water.

In the upper nozzle part of the mixing condenser K-2 most of the water vapor condenses.

Tail gases from the mixing condenser K-2 enter the amine absorber K-3. To minimize pressure losses the absorption process takes place in a packed column.

Gases coming out of the upper part of the absorber are directed to the stripper K-3A, where the removed amine and water solution is captured. To minimize losses of amine solution, flushing water is added to the gas stream. Fresh condensate is added to the flush water circulation system, and a purge stream is discharged from this system to maintain a relatively low amine concentration in the flush water.

Amine solution saturated with hydrogen sulfide is removed from the amine absorber K-3, which is sent by pumps H-4 and H-5 to the evaporator B-2 of the amine regeneration section. Gas from the amine absorber enters the thermal oxidizer.

The saturated amine solution evaporator B-2 is also an intermediate tank for temporary storage of methyl diethanolamine (MDEA). In the evaporator, dissolved hydrogen and light hydrocarbons are released from the saturated amine solution. The vapors coming out of the saturated amine solution evaporator also contain a small amount of hydrogen sulfide.

In the section of the nozzle K-4, located in the upper part of the evaporator, the main part of the released hydrogen sulfide is absorbed by the cold recirculating flow of the regenerated amine solution supplied from the column K-5 by pumps H-8 and H-9. The gas washed with regenerated amine solution is further supplied to the thermal oxidizer for afterburning.

Liquid hydrocarbons released in the evaporator of the saturated amine solution accumulate over time and are discharged into the drainage tank.

From the evaporator, the saturated amine solution is pumped by pumps H-6 and H-7 through the plate heat exchanger T-4, being heated by the heat of the cube product (regenerated amine solution) of the amine regenerator K-5, and is fed to the column K-5 for regeneration.

Heat for evaporation of hydrogen sulfide from the amine solution comes from the thermosiphon reboiler РБ-2. A part of the amine solution from the column cube is pumped into the reboiler, where it is heated to boiling and amine vapors enter the column as heat for hydrogen sulfide evaporation, and the remaining solution is returned to the column cube. Low pressure water steam P=0.35 MPa, T=423 K is used as a heat carrier in the reboiler.

The use of low pressure steam allows to avoid the decomposition of methyl diethanolamine (MDEA) due to overheating of the solution.

To maintain the heat balance in the process of regeneration of saturated solution of methyl diethanolamine (MDEA) in the column, a stream of acidic water circulates, which is taken from the blind plate by pumps H-10 and H-11 and fed as cold irrigation to the upper plate of the column, pre-cooled in the air cooler ПХ-4 and ПХ-5.

Acid gases coming from the top of column K-5 enter the sulphur production section. In case of violation of the technological regime in the sulphur production section, acid gases are released into the flare collector.

In order to prevent an increase in the concentration of methyl diethanolamine (MDEA) solution due to the fact that part of the water is withdrawn along with the acid gas flow, chilled condensate is fed into the K-5 irrigation flow for recharge.

In case of receipt of light hydrocarbons with a saturated amine solution, it is possible to remove them from the first plate of the K-5 column into the drainage tank.

From the column cube, the regenerated methyl diethanolamine (MDEA) solution is fed by pumps H-8 and H-9 for cooling to the heat exchanger T-4, where it gives its heat to the stream of saturated methyl diethanolamine (MDEA) solution, and then sequentially to the air cooler ПХ-3 and the water cooler X-4. After cooling, a part of the regenerated methyl diethanolamine (MDEA) solution is used as irrigation of the nozzle sections of the column K-4 and the upper part of the evaporator B-2, and the balance amount is sent to the units of delayed coking and hydrotreatment of distillates.

Fresh methyl diethanolamine (MDEA) solution is used as feed for the K-5 regenerator, which is fed into the column cube.

To prevent clogging of the K-4 column packing, part of the total flow of regenerated amine (30%) is pumped through a series of filters.

The first filter removes mechanical impurities from the methyl diethanolamine (MDEA) solution.

The second filter is used to purify the solution from the decomposition products of methyl diethanolamine (MDEA).

The next, carbon filter, captures all soluble hydrocarbons captured by the flow of the regenerated amine solution.

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**УДК 66.047**

# MODERNIZATION OF ABSORBER OF AMIN ENGINE CLEANING PLANT FROM CARBON ACID

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**ANNOTATION:** *The technological scheme of amine gas purification from carbon dioxide is considered and the outline of the technological scheme of the process and the method of modernization is given.*

**KEY WORDS:** AMINES, CARBON GAS, ABSORBER, AMINE PURIFICATION.

# МОДЕРНІЗАЦІЯ АБСОРБЕРА УСТАНОВКИ АМІНОВОЇ ОЧИСТКИ ГАЗУ ВІД ВУГЛЕКИСЛОТИ

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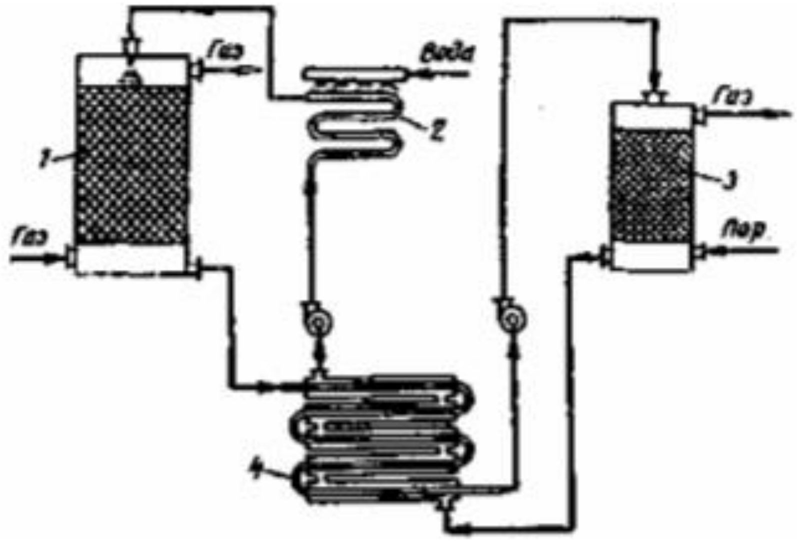
**АНОТАЦІЯ:** *Розглянуто технологічну схему амінового очищення газу від вуглекислоти, наведено опсис технологічної схеми процесу та спосіб модернізації.*

**КЛЮЧОВІ СЛОВА:** АМІНИ, ВУГЛЕКИСЛИЙ ГАЗ, АБСОРБЕР, АМІНОВА ОЧИСТКА.

On the modern stage for most industrial enterprises of cleaning of vent extrass from harmful substances is one of basic measures on defence of air pool.Rendering of extrass harmless assumes or moving away of harmful admixtures from inert газуносія, or converting of them into harmless substances.Both principles can be realized through different physical and chemical processes it is needed for realization of that certain terms. The calculations of processes and vehicles of gas purification at their planning must be sent to conditioning, that provide the maximally complete rendering of extrass harmless.

The different methods of catching and rendering of steam- and gaseous substances harmless are presently used from air. In practice next methods of the gas : cleaning absorption, adsorption, catalytic,thermal and etc. The absorption method is to absorb the individual components of the gas mixture with an absorbent (absorber), which is the liquid. The absorbent is chosen from the condition of solubility in it gas, the subtraction removal from the gas, the mixture. For example, for the purification of gases from ammonia, chloride and fluoride hydrogen as an absorbent, water is used to capture water vapor – sulfuric acid, to capture aromatic hydrocarbons – oil. In absorption, there is a convective diffusion of steam and gaseous components of the purified gas in liquid absorbers. Highly efficient removal of the pollutant requires good mixing of the cleaned gas with an absorbent. This is realized when cleaning the ventilation air, which is filled with herbal and galvanic baths, in columns with nozzles, in nozzles and barbounding apparatus.

Schematic installation scheme for absorbation -nodezorbcial capture of a certain component from a gas mixtureis shown on Figure 1.



1 – absorber; 2 – refrigerator; 3 – desorber; 4 – heat exchanger

Figure 1 – Schematic installation scheme for absorbation -nodezorbcial capture of a certain component from a gas mixture

The gas mixture containing the component extracted from it enters the absorber, where there is contact with the absorbent that absorbs the given component. The gas purified from the component is removed (purified air can be thrown into the atmosphere), and a solution of an absorber containing an absorbed component enters the heat exchanger where it is heated. Heated solution The pump is fed into the desorber, where it is released (desorbed) absorbed by the component by evaporation as a result of heating the absorber with steam. The absorber, freed from the component, enters the heat exchanger, where it gives the heat of the absorbent when it is a counter -flow in Desorber, and then goes to the refrigerator, having passed which, again enters the absorber. The circle was closed. This cycle works for the absorption-dessorption of catching a certain vapor and gases from the gas mixture (from the air).

The invention refers to the oil and gas and chemical industry, namely ways to clean up from $H_2S$ and $CO_2$ of natural, confession, oil factories and others industrial hydrocarbon gases under pressure using as absorbent activated by additives that accelerate the rate of absorption of $CO_2$ of an aqueous solution of methyldetanlamine. The closest technical solution to the stated invention is Method of purification of gas from $H_2S$ and $CO_2$, including the supply of gas-purified gas absorbent, absorption of acidic components from the cleaned gas components, an aqueous solution of planned methyldetanlamine, weathering of saturated with acidic gas. And the weathering of the solution by the second stage at low pressure, the division of the rugging of the coarse-generated solution into two parts with the subsequent part of it in the middle of the absorber, and the smaller part - in the desorber, and the regeneration, and the submission of the regeneration, and the smaller part, and the smaller part.

The main disadvantages of the known way are:

- high general circulation of a solution of activated methyldetanlamine;
- increased cost of activator and methyldetanolamine to fill the solution systems;
- high losses of the activator.

Substrate disadvantages are high energy consumption for pumping solution activated methyldetanlamine, high cost of acquiring activator the need for reconstruction of the absorber and the solution circulation system, Figure 2.

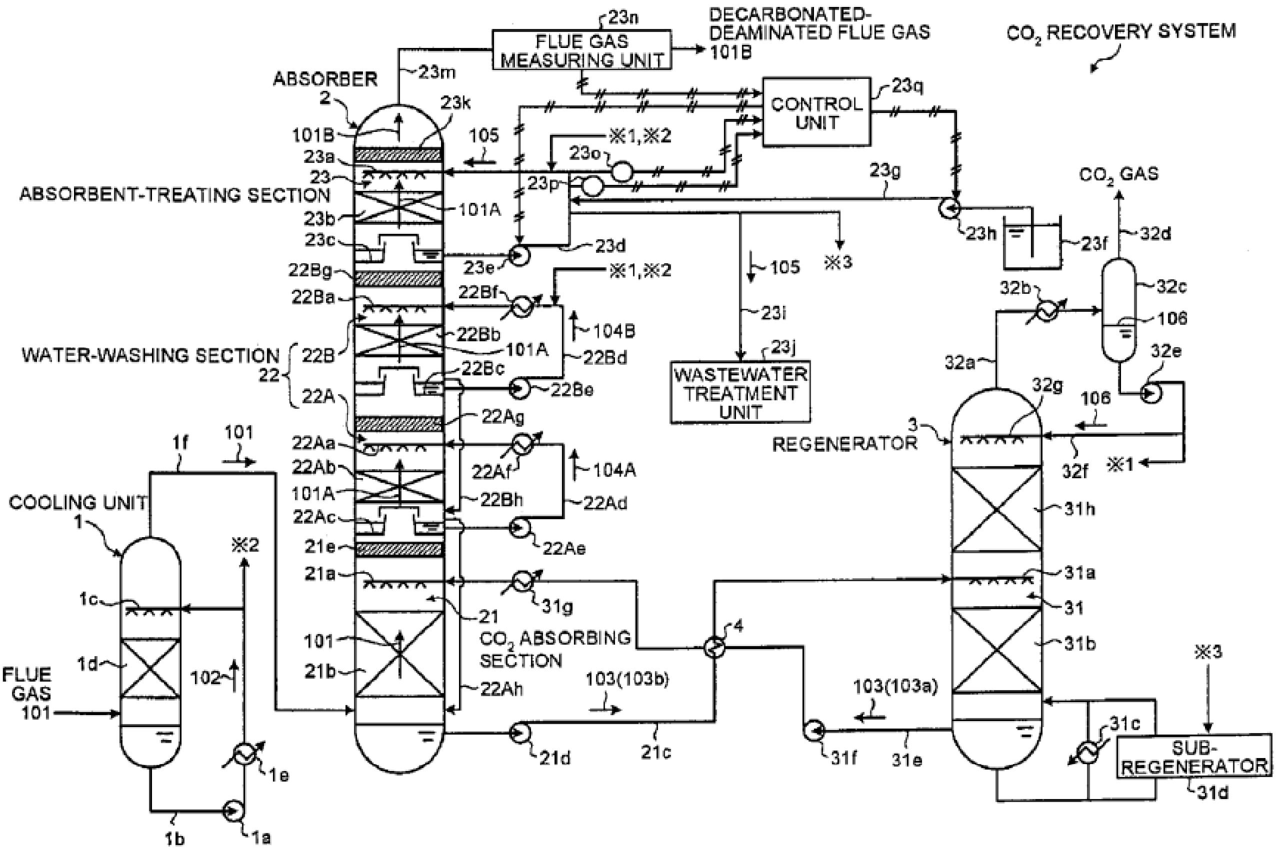


Figure 2 – Operating principle of the device

To further reduce the concentrations of basic amine compounds remaining in decarbonated flue gas. A $CO_2$ recovery system includes an absorber 2 and a regenerator 3. The absorber 2 includes a $CO_2$ absorbing section 21 and at least one water-washing section 22. The $CO_2$ absorbing section 21 allows flue gas 101 to come into contact with a basic amine compound absorbent 103 so that the basic amine compound absorbent 103 absorbs $CO_2$ in the flue gas 101. The at least one water-washing section 22 allows the decarbonated flue gas 101A in which the amount of $CO_2$ has been reduced in the $CO_2$ absorbing section 21 to come into contact with wash water 104A and 104B to reduce the amounts of the basic amine compounds entrained in the decarbonated flue gas 101A. The regenerator 3 releases the $CO_2$ from the basic amine compound absorbent 103 containing $CO_2$ absorbed therein. This $CO_2$ recovery system further includes an absorbent-treating section 23 disposed downstream of the at least one water-washing section 22 through which the decarbonated flue gas 101A flows. The absorbent-treating section 23 allows the decarbonated flue gas 101A to come into contact with circulating acidic water 105 to further reduce the amounts of the basic amine compounds entrained in the decarbonated flue gas 101A.

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**УДК 66.047**

# MODERNIZATION OF SHELL AND TUBE HEAT EXCHANGER IN TECHNOLOGICAL SCHEME OF BIOGAS CLEANING PROCESS

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**Annotation:** The purpose of the shell-and-tube heat exchanger for heating and cooling of gas of the technological scheme of biogas purification is described and the methods of eliminating the shortcomings of the heat exchanger design are proposed.

**KEY WORDS:** *BIOGAS, BIOMETHANE, CLEANING, SHELL AND TUBE HEAT EXCHANGER.*

# МОДЕРНІЗАЦІЯ КОЖУХОТРУБНОГО ТЕПЛООБМІННИКА ТЕХНОЛОГІЧНОЇ СХЕМИ ПРОЦЕСУ ОЧИЩЕННЯ БІОГАЗУ

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**АНОТАЦІЯ:** *Описано призначення кожухотрубчастого теплобмінника для нагрівання та охолодження газу технологічної схеми очистки біогазу та запропоновано методи усунення недоліків конструкції теплообмінника*.

**КЛЮЧОВІ СЛОВА:** БІОГАЗ, БІОМЕТАН, ОЧИЩЕННЯ, КОЖУХОТРУБНИЙ ТЕПЛООБМІННИК.

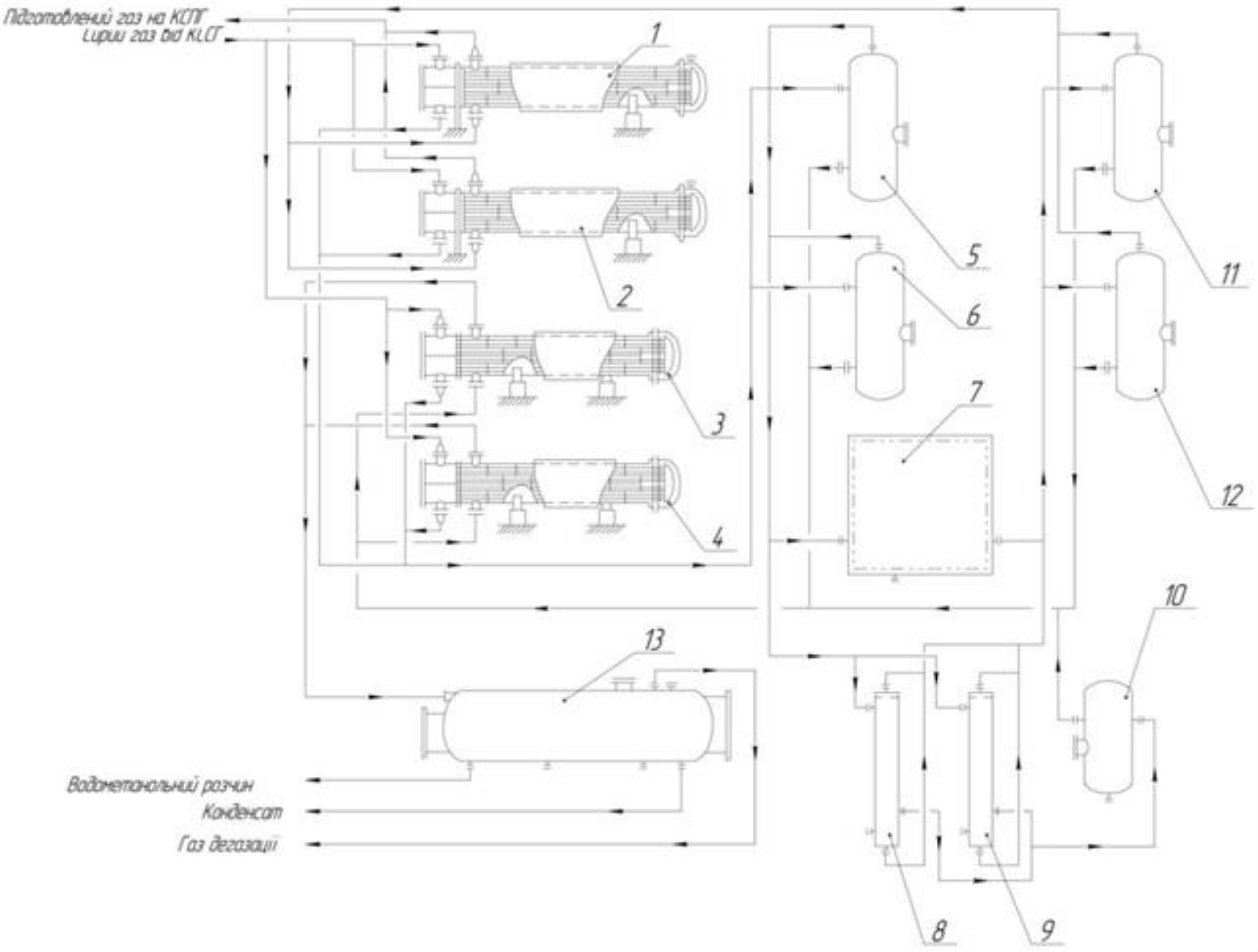
Energy development determines the technical level and well-being of any country. The cost of electricity to produce a unit of output is the main indicator of the profitability of the enterprise. For the future engineer it is very important to know the most energy-intensive thermal processes of various industries.

The main group of heat exchangers used in industry are surface heat exchangers, in which the heat from the hot carrier is transferred to the cold coolant through separating their wall. Another group consists of mixing heat exchangers, in which heat is transferred by the direct interaction of cold and hot coolants. In chemical technology, heat exchangers are used for heating and cooling substances in various physical states, evaporation of liquids and vapor condensation, distillation and sublimation, absorption and adsorption. According to the method of heat transfer, there are surface heat exchangers and mixers. In the first case, heat transfer occurs through the separating solid walls, in the second - by direct contact (mixing) of heated and cold media (liquids, gases, solids).

When designing heat exchangers it is necessary to take into account: compliance with the conditions of the process, higher heat transfer coefficient, resistance of the heat exchange surface to corrosion, ease of cleaning the device, economical use of the material. Shell and tube heat exchangers can be vertical, horizontal and inclined in accordance with the requirements of the technological process or ease of installation. Depending on temperature extensions of tubes and the case shell-and-tube heat exchangers of a firm, semi-rigid and not rigid design are applied. The industry uses heat exchangers made of carbon and alloy steels, copper, brass, titanium, as well as non-metallic materials such as graphite, Teflon.

Due to the simplicity of construction and reliability, shell and tube heat exchangers are today the most common devices among recuperative heat exchangers used in industry. In industry, heat exchangers are used to heat the "hot" coolant "cold" and cooling or heating various substances to specified parameters. A hot coolant is a working fluid that gives off heat, and a cold coolant is a substance that absorbs this heat. Saturated low-pressure steam was chosen as the hot heat carrier (according to the condition of the task), and an aqueous solution of salt, acid or technical water was chosen as the cold one.

The technological scheme of biogas purification is shown in Figure 1.



1, 2 – shell-and-tube heat exchanger (gas-gas); 3, 4 – shell and tube heat exchanger (condensate gas); 5, 6, 11, 12 – separator; 7 – throttling unit; 8, 9 – three-flow vortex tube; 10 – condensate separator; 13 – liquid separator (settling tank).

Figure 1 – Technological scheme of biogas purification

Gas from the metering unit enters heat exchangers 3 and 4, where unstable condensate is heated. The cooled gas from heat exchangers 3 and 4 enters intermediate separators 5 and 6. Gas from the metering unit also enters heat exchangers 1 and 2, where it is cooled. The cooled gas from heat exchangers 1 and 2 then enters the intermediate separators, where it is separated.

A more detailed description of the technological scheme of the process of "Biogas treatment" is given by the authors [1].

The heat-exchanging shell-and-tube apparatus with fixed tubular gratings, Figures 2 and 3, consists of two semi-cylindrical shell casings 1, to which parts of the tubular gratings 2, welded in the form of a crescent, are welded on both ends. In the pipe gratings 2 tightly fixed bundle of pipes 3. Semi-cylindrical shells-shells 1 through the sealing gasket 9 by means of fasteners 6 are connected to each other, forming a tubular apparatus. To the tubule, by means of flanges, from both ends are connected by fastening elements 7 through sealing gaskets 8 of the chamber 5. For input and output of heat carriers to the casings 1 and chambers 5 welded pipes 4. The device can be both vertical and horizontal in this way. One stream of coolant (I) is directed through the pipe 4 into the chamber 5, passes inside the pipes 3 and exits through the pipe of the opposite chamber.

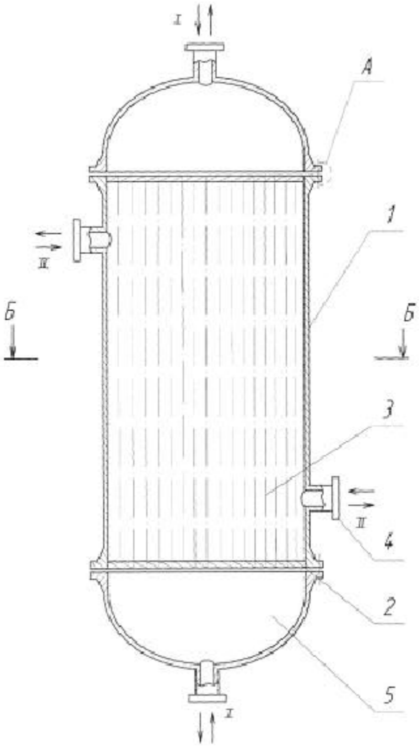


Figure 2 – Structural diagram of the shell-and-tube heat exchanger

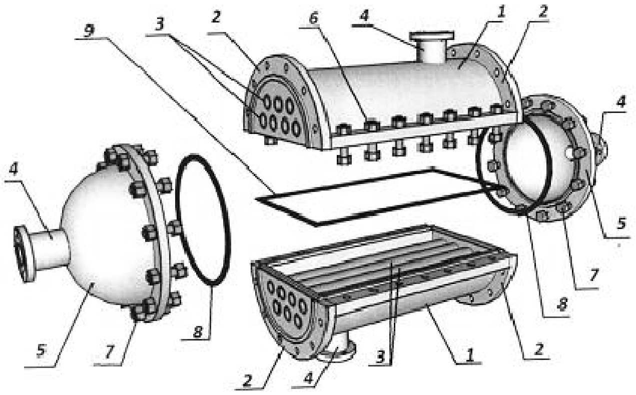


Figure 3 – Structural diagram of the shell-and-tube heat exchanger in cross section

The second flow of coolant (II) is introduced through the pipe 4 on the casing 1 into the intertube space of the heat exchanger, in contact with the outer surface of the pipes 3 and is discharged through the second pipe on the casing. To clean the pipes 3 of the device from contamination, it is disassembled into components, thus providing free access to the pipe and intertube spaces.

The disadvantage of this heat exchanger is the lack of control over the flow of one of the coolants at a constant flow rate of another coolant (for example, when utilizing a constant heat flux and the need for periodic heat consumption), which significantly narrows the technological capacity of the heat exchanger.

The utility model is based on the task of improving the shell-and-tube heat exchanger, in which its new design provides the ability to regulate a wide range of consumption of one of the coolants with constant consumption of another coolant, which expands the technological capabilities of the heat exchanger.

The problem is solved by the fact that in the shell-and-tube heat exchanger, containing the housing at least one pipe lattice, heat exchange pipes, fittings for supply and removal of coolant pipe and intertube spaces, as well as located in the housing transverse partitions to form multi-way utility model, the fittings for supply and removal of coolant in the intertube space is connected to the corresponding collector, with a shut-off valve installed between each of these fittings and the corresponding collector.

Execution of the heat exchanger with the specified signs provides an opportunity of regulation of the heat carrier of intertube space in each of moves of intertube space (each course is limited by two cross partitions or a pipe lattice and a cross partition).

This is ensured by opening or closing the shut-off valves on one or more corresponding passages of the intertube space. Thus the expense of the heat carrier processed in intertube space in a wide range of sizes is regulated.

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# СЕКЦІЯ 2
# «ЕКОЛОГІЯ ТА ТЕХНОЛОГІЯ РОСЛИННИХ ПОЛІМЕРІВ»

**УДК 676.**

# ІННОВАЦІЇ В ТЕХНОЛОГІЇ ВИРОБНИЦТВА КАРТОНУ

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**АНОТОЦІЯ**. Показано використання волокон деревини павловнії у композиції картону. Обґрунтовано вплив пресової частини на зневоднення полотна картону.

**КЛЮЧОВІ СЛОВА**: КАРТОН, ВОЛОКНА ПАВЛОВНІЇ, ПРЕС Tri-Vent

Дослідники, вчені та працівники фондів останнім часом відзначають погіршення стану документів на папері, переважно друкованих, які виготовлялися вже з другої половини XIX ст, що пояснюється різким зростанням попиту на друковану продукцію, яке призвело до зміни та здешевлення сировинної бази. У більшості це масові видання, які виготовлено із деревної целюлози, замість бавовняної або лляної сировини, застосування друкарських машин, зниження вимог до оформлення.

Щороку до Національного Архівного Фонду надходить на зберігання більше 400 тис. одиниць документів, що відображають сучасну історію України. Внаслідок впливу агресивного навколишнього середовища, антропогенних та природних факторів архівні документи руйнуються, а частина з них – під загрозою невиправного пошкодження. Для збереження матеріалів на паперовій основі їх зберігають у картонних коробках, які виготовляють з лужним резервом [1].

Для надання картону відповідних показників якості, пропонується використання целюлозних волокон у комплексі з хімічними речовинами, що мають нейтральну або слабколужну реакцію, які не містять компонентів, здатних до утворення кислоти в структурі картону. Використання волокна лише з хвойної целюлози робить кінцевий продукт занадто дорогим у виготовленні та у реалізації. Пропонується створити композицію хвойної та листяної целюлози з метою здешевлення виробництва картону із збереженням показників якості.

Отримана нами в лабораторії целюлоза з деревини павловнії з показниками міцності на злом більше 7 тисяч, розривною довжиною більше 7 км частково може замінити хвойну у композиції картону без зниження його якості. Це дозволить досягнути значної економії коштів із-за її нижчої вартості; листяна целюлоза сприятиме кращому формуванню листа за рахунок переплетення її коротких волокон з довгими хвойними, що також підвищить показники міцності.

У технологічному потоці підготовка целюлози листяної та хвойної ведеться з використанням окремого обладнання. Це обґрунтовано тим, що хвойна целюлоза має менший приріст ступеня млива маси у порівнянні з листяною.

Для покращення зневоднення, підвищення сухості картонного полотна пропонується модернізація пресової частини картоноробної машини. Відомо, що зниження вологи у полотні після пресової частини на 1 % дає змогу економити витрати пари в сушильній частині машини на 4 %. Отже, для оптимізації зневоднення картону пропонується встановлення преса Tri-Vent [2].

Запропонована пресова частина дозволить підвищити сухість картонного полотна перед сушильною частиною машини до 50 %.

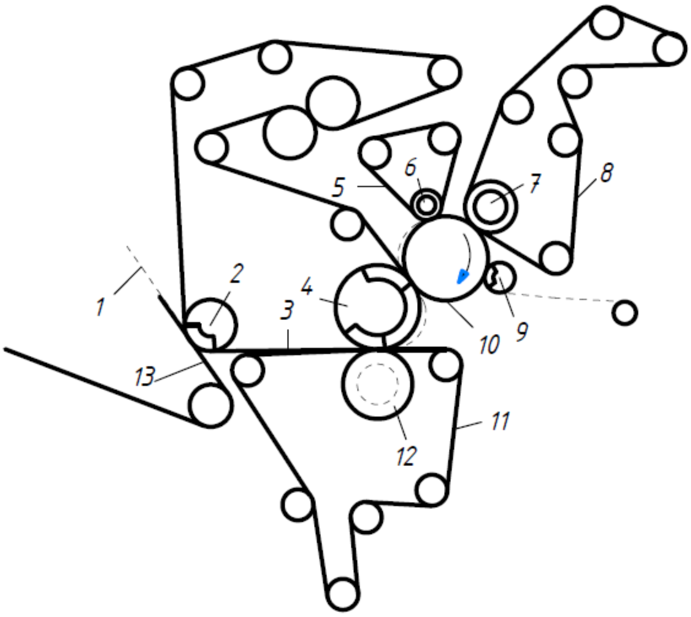

**Рисунок 2 – Tri-Vent прес:**

1 – картонне полотно; 2 – пересмоктувальний вал; 3 – сукно «пікап»;
4 – відсмоктувальний вал; 5, 8 – верхні сукна; 6, 7, 12 – жолобчаті вали;
9 – картоноведучий вал; 10 – гранітний вал; 11 – нижнє сукно; 13 – сітка

Після формуючої частини у картонному полотні утримується значна частина вологи. Окрім води, що утримується капілярними силами, в картонному полотні також є вільна вода, яка не могла бути видалена у формуючій частині через недостатнє розрідження та через невеликий час дії вакууму. Під час пресування полотно позбавляється вільної води, що призводить до зростання  числа контактів між волокнами, ущільнюється під дією зовнішніх сил, та, як наслідок, набуває міцності. У процесі пресування зростають сухість, щільність та міцність картону. Від ефективності роботи пресової частини залежать витрати пари на обігрів сушильних циліндрів та продуктивність машини. З метою скорочення витрат пари у сушильній частині папероробної або картоноробної машини під час виготовлення продукції намагаються досягти максимальної сухості полотна перед сушильною частиною [2].

У преса Tri-Vent відсмоктувальний вал використовується тільки для першого захвату у парі з жолобчатим валом. Далі полотно разом із сукном першого преса поступає на другий захват, утворений гранітним та жолобчатим валами. Третій захват з другим пресовим сукном утворюється тим же гранітним валом та ще одним жолобчатим валом. Така конфігурація дозволяє працювати з більш високими лінійними тисками у захватах, а також використовувати парову камеру на поверхні відсмоктувального вала для коригування профілю вологи [2].

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# ПІДХОДИ ДО АПРОКСИМАЦІЇ ДИСПЕРСНОГО СКЛАДУ МІНЕРАЛЬНО-ГУМІНОВИХ ДОБРИВ

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***Анотація.*** *Наведено апроксимацію дисперсного складу гуміново-мінеральних композитів та підходи до її розрахунку*

***Ключові слова:*** *виснаження ґрунтів, апроксимація, гамма функція.*

До основних викликів XXI століття відноситься протидія глобальній продовольчій кризі, що здійснюється за рахунок збільшення навантаження на країни-виробники сільськогосподарської продукції.

Серед цих країн провідне місце належить Україні, на території якої зосереджено до 29% світових площ родючих ґрунтів із задовільними умовами вирощування сільськогосподарських культур високої якості.

Традиційні методи збереження родючості ґрунтів за рахунок внесення мінеральних та органічних добрив в теперішній час себе вичерпали. Окрім того, обсяги внесення мінеральних добрив в Україні за останні 20 років зменшились з 190 кг д.р. (N:P:K) /га до 20 кгд.г./га і це тільки азотні добрива. Кризові явища в економіці звели практично до нуля внесення органічних добрив тваринного походження.

Проте, внаслідок соціальних і політичних причин родючість наших земель деградує у бік інтенсивних втрат гумусу, так, динаміка втрат гумусу збільшилась за останні 60 років в 2,5 рази і досягла 600 кг/га і більше.

Відбувається збільшення кислотності ґрунтів, пов’язане з декальцинацією земель в обробітку.

Деградаційні процеси посилюються у зв’язку із відсутністю державної програми хімічної меліорації земель з кислою (понад 10 млн. га в обробітку) або з лужною (понад 4 млн. га) реакцією ґрунтового розчину.

Тому світова практика ефективної протидії цим негативним явищам полягає у створенні нових видів добрив: агрофос, гранфос, мікрофос, верміфос, аммофосфат, мінеральні добрива на основі продуктів метаболізму мікроорганізмів, гумусовані мінеральні добрива тощо. [1]

Перші п'ять видів добрив з фосфорними компонентами в теперішній час є недоступними для України через високу вартість сировини.

Разом з тим, в Україні на виробництвах капаролактаму утворюється до 540 тис. м$^3$ в рік водяних розчинів сульфату амонію, який за традиційною багатоступінчатою схемою переробляється в дрібнокристалічний продукт, що має високу злежуваність.

На кафедрі МАХНВ розроблено спосіб одержання гранульованого сульфату амонію зі змінним вмістом гумінових, мінеральних, поживних і розкислюючих речовин, які при проведенні агродосліджень показали більшу ефективність у порівнянні з аміачною селітрою.

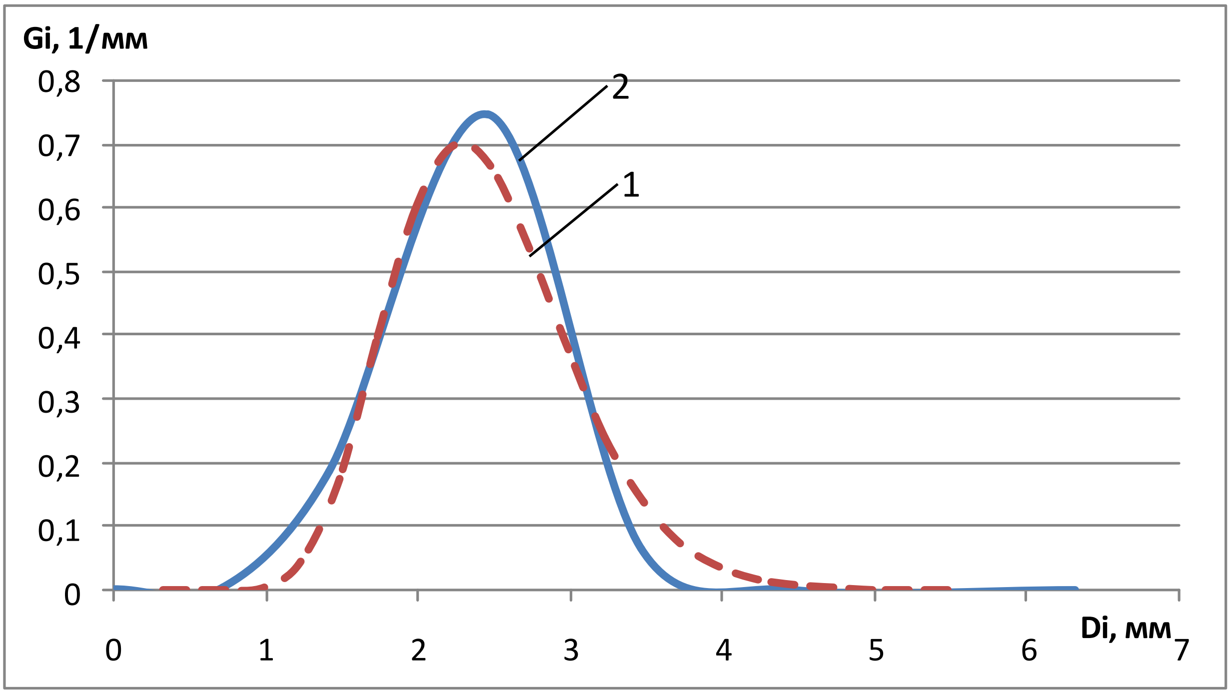
Для реалізації цього способу найбільш ефективним є застосування техніки псевдозрідження для зневоднення композитних розчинів.

Разом з тим, при проведенні промислових випробувань дослідно-промислового апарату на ПАТ «Азот» виникали складності зі стабілізацією гранулометричного складу частинок в псевдозрідженому шарі в стаціонарному режимі. Це негативно впливало на енергоефективність самого процесу і якість гранульованого продукту.

Встановлення закономірностей динамічної рівноваги дисперсного складу частинок в апараті при реалізації безперервного процесу одержання мінерально-гумінових твердих композитів забезпечить підвищення ефективності процесу, тому тема дисертаційної роботи є актуальною.Тому розроблення ефективного процесу для одержання багатошарових мінерально-гумінових твердих композитів та обладнання для його проведення є актуальним.

На рисунку 1 наведено порівняння заданого дисперсного складу готового продукту, крива 2, та реального масового розподілення, крива 1.

Апроксимація була проведена емпіричною функцією гамма-розподілення з визначенням її параметрів методом найменших квадратів. Середня похибка складає 1,4%.



1 – експериментальне, 2 – розрахункове (заданий De=)2,3 мм

Рисунок 1 – Порівняння масового розподілення гранул за розмірами в апараті гуміново-азотних композитів в усталеному процесі

Виходячи з наведених розрахунково-експериментальних даних можна дійти висновку, що для розрахунку апроксимуючих коефіцієнтів емпіричної функції можна використовувати в подальшому для стабілізації дисперсного складу мінерально-гумінових добрив.

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