

UDC: 663.55-022.344

CYCLIC RECTIFICATION TECHNOLOGY IN ALCOHOL PRODUCTION

DOI: <https://doi.org/10.15673/fst.v13i4.1563>

Article history

Received 27.10.2018
Reviewed 12.12.2018
Revised 24.06.2019
Approved 03.09.2019

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Cite as Vancouver style citation

Buliy Y., [Shiyan P.](#), Kuts A., Melnik I. Cyclic rectification technology in alcohol production. Food science and technology. 2019;13(4):104-111. DOI: <https://doi.org/10.15673/fst.v13i4.1563>

Цитування згідно ДСТУ 8302:2015

Cyclic rectification technology in alcohol production / Buliy Y. et al. // Food science and technology. 2019. Vol. 13, Issue 4. P. 104-111 DOI: <https://doi.org/10.15673/fst.v13i4.1563>

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Introduction. Formulation of the problem

Industrialised nations are energy-dependent on suppliers of natural gas and oil, and, thus, have to search for alternative energy sources. One of these is ethyl alcohol (bioethanol). To make bioethanol competitive with hydrocarbon energy resources, it is necessary to develop and introduce innovative resource-and-energy-saving technologies, and to improve the operational and

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Abstract. Alternation of the stages of vapour supply and liquid overflow allows intensifying the mass transfer between the liquid and the vapour and reducing the specific consumption of heating steam when separating multicomponent mixtures. Known methods and models have not become widely used. This is explained by no mass transfer in the vapour supply stage, fluctuations in the steam pressure in the collector, the complexity of construction principles supposed to ensure the cyclic mode, etc. The authors have suggested a rectification technology that involves cyclic motion of the liquid without interrupting the supply of heating steam, and designed a rectification column for this technology. The purpose of the work was to study how effective the technology is when distilling alcohol-containing fractions and to establish the specific steam flow rate in the rectification column. To ensure the cyclic mode, the column was equipped with movable weirs connected to actuating mechanisms that acted according to the controller programme, and with perforated (scale-shaped) trays, or plates. The primary task was to determine the hydrodynamic mode of operation of the contact devices – the lower and the upper critical vapour velocities, at which the liquid remains on the plates and drop entrainment takes place. It has been established that the vapour velocity in the free section of the column can be 1.2 m/s or more, and in the perforations, it must exceed the first critical velocity 6.5–7.5 m/s. The downflow of the liquid occurs when the vapour velocity in the perforations is 1.5–1 m/s. The research was carried out in the industrial environment of the Chudniv branch of the *State Enterprise Zhytomyr liquor and vodka distillery factory*. It has been experimentally proved that in the course of rectification of alcohol-containing fractions, the main impurities are removed completely, the extraction of higher fusel-oil alcohols and of methanol increases by 38% and by 15.6%, respectively, the concentration multiplicity of the main impurities increases by 25%, that of higher alcohols by 40%, of methanol by 34%, of acrolein by 36%. The heating steam consumption is reduced by 30%, compared to that in typical installations, and does not exceed 13 kg/dal of absolute alcohol introduced with the feed. When the bottom liquid of the fractionating column is cleared from the key impurities, it can be used for hydroselction in the purifying column.

Key words: cyclic rectification, volatile impurities, heating steam, bottom liquid, rectification column.

technological characteristics of rectification plants. A promising direction to solve this problem is using the non-stationary (cyclic) mode of operation of the plants, which is based on alternation of the stages of vapour supply and liquid overflow.

Analysis of recent research and publications

As early as in the 1960–1970s, researchers started studying the physico-chemical conditions of

fractionating multicomponent systems in the mode of controlled rectification cycles, developing, based on the laws of thermodynamics, rational methods of designing multicycle rectification columns, computer modelling of liquid holdup and overflow cycles. The problems of intensification of mass transfer between the liquid and the vapour, and reduction of specific steam flow rate by periodically changing the mode parameters were considered in the works by McWhirter and Cannon (1961), Sommerfield, Chien, Robinson, and Engel (1966), Schrod (1976), Gelperin (1976), Baron (1980–1981), Furzer, Thompson, Szonyi, Anton Kiss, Matsubara (1985), and others. The authors managed to achieve a 48% increase in the vapour load, with the constant pressure difference, making no structural changes in the column. Besides, they doubled the capacity of the installation with bubble-cap plates, compared to the typical one, at the same degree of separation, developed a hydrodynamic rectification model with alternate phase motion, presented the theory of stepwise periodic distillation (a new periodic operating mode where the liquid flow was manipulated through pulsations of the vapour flow rate), and suggested a new tray design consisting of a traditional sieve plate with a special inclined surface to slow down the liquid overflow [1].

In recent years, a rise in energy prices has resulted in more interest to studying cyclic distillation in Ukraine, too. At the National University of Food Technology, special valve contact devices have been proposed to provide controlled cycles of liquid holdup and overflow [2,3]. Pilot testing of the devices showed a 30% reduction of the specific heating steam consumption in cyclic rectification column compared to the conventional ones. However, they have some disadvantages. The operation of their overflow devices depends on the vapour pressure, a rectification column is limited in height, there is a need to install intermediate plates, a delay impulse can appear when opening and closing the movable weirs, etc.

Despite the positive results of the experimental studies, and though the benefits of cyclic rectification have been validated by mathematical modelling, the above methods and models are not widely used. The absence of mass transfer at the vapour supply stage, and steam pressure fluctuations in the collector, bottom section, and reflux condenser (dephlegmator) of the rectification column affect the quality of the final product and the operation of other columns. And the complexity of the suggested design solutions to ensure the cyclic operation reduces the reliability of the rectification equipment.

To eliminate the above disadvantages and thus improve the mass transfer efficiency, a method of controlled rectification was suggested. It provides periodic (cyclic) motion of the liquid after its holdup at the contact stages, with continuous supply of heating steam to the bottom section of the column. For the cyclic motion of the liquid on the plates of the column,

the steam flow is cut at each plate by means of valves (weirs) located on the bypass conduits [4]. According to the authors, at the stages when the respective valves are opened and the steam is directed along the respective bypass conduits, this technical solution can ensure the periodic motion (dumping) of the liquid on the plates and prevent its mixing with the portions of the liquid on the nearest plates below

However, the method was not put in practice because, at the moment of opening the valves, the vapour flowed not only along the bypass conduits but also through the slits in the upper plates, which complicated the liquid downflow onto the lower plates.

The purpose of the work was to improve the cyclic rectification technology, to design a distillation column that ensures the cyclic motion of the liquid with continuous vapour supply, to study the effectiveness of the innovative technology in rectification of alcohol-containing fractions, to determine the rectification column's optimum operational modes, specific steam consumption, degree of extraction, and concentration multiplicity of volatile impurities of alcohol.

To achieve this purpose and run production tests, **the primary task** was to determine the hydrodynamic operation mode of the scale-shaped and sieve dumping trays to ensure their cyclic action:

1. To establish the working range of vapour velocity in the free section of the rectification column and in the slits (holes) of the plates – the lower limit where the liquid stops flowing down from the upper plate to the lower one, and the upper limit where liquid is entrained to the upper plates.

2. To determine the vapour velocity in the slits (holes) of the plates, at which there is an intense dumping of the liquid from the upper plates to the lower ones.

Research materials and methods

The objects of study were the experimental rectification column, the feed distillate cuts, the bottom water-alcohol liquid, the experimental samples of the liquid from the 2nd, 6th, 11th, 17th, and 26th plates, the reflux liquid, and the ester-fusel concentrate. The water temperature in the collector and after the reflux condenser was determined with TRP1-3-Pt100 sensors. The liquid flows were controlled with liquid flowmeters RM.

The ethyl alcohol concentration was determined by the pycnometric method according to (State Standard of Ukraine) 7457:2013 with a liquid pycnometer PZh2 after distilling the water-alcohol solutions. The mass concentrations were measured: that of aldehydes by means of the reaction with fuchsin sulphurous reagent I; of fusel oil by the method based on the reaction of higher alcohols with salicylic aldehyde solution in the presence of sulphuric acid; of free acids by the amount of sodium hydroxide solution

spent on titration; of complex esters titrimetrically after saponifying them with sodium hydroxide solution. The volume fraction of methyl alcohol was determined by the method based on methanol oxidation with potassium permanganate and sulphuric acid to form formaldehyde, which, in turn, is colour-forming with fuchsin sulphurous agent II according to DSTU 4222:2003.

To determine the chemical composition of the test samples, a gas chromatograph with a HP FFAP column

(50 m × 0.32 m) was used. The analysis was performed according to DSTU 4222:2003.

The research was carried out in the industrial environment of the Chudniv branch of the *State Enterprise Zhytomyr liquor and vodka distillery factory*. The equipment and process flow diagram of rectification of alcohol-containing fractions is presented in Fig. 1.

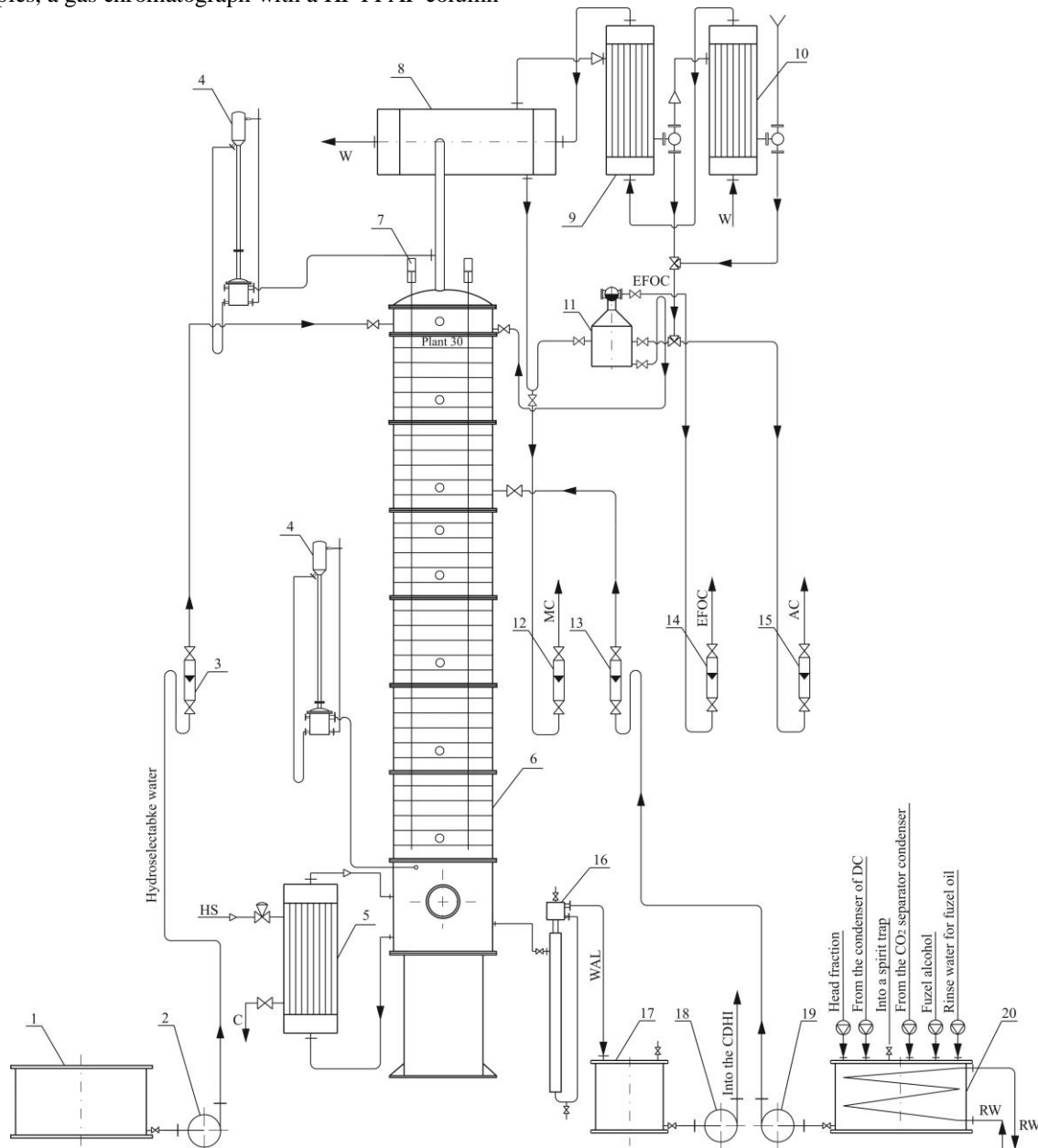


Fig. 1. The equipment and process flow diagram of ethyl alcohol extraction from alcohol-containing fractions:

1 – water container; 2, 18, 19 – centrifugal pumps; 3, 12, 13, 14, 15 – flowmeters; 4 – vacuum breakers; 5 – evaporator; 6 – rectification column; 7 – pneumatic cylinders; 8 – dephlegmator; 9 – condenser; 10 – alcohol-collecting vessel (spirit trap); 11 – decanter; 16 – hydraulic valve for the bottom WAL; 17 – WAL tank; 20 – alcohol-containing fraction tank

Notation conventions: CW – cooling water; HS – heating steam; DC – distillation column; CDHI – column for deletion of head impurities (purifying column); C – condensate; WAL – water-alcohol liquid (still bottoms); EFOC – ester and fusel oil concentrate; AC – aldehyde concentrate; MC – methanol concentrate; RW – residue water

According to the diagram, the head fraction of ethyl alcohol, distillate cuts from the condensers of the distillation column and CO₂ separator condenser, fusel alcohol, and the water fraction of fusel oil were to be introduced on the feed plate of the rectification column. The installation included the RC 6 equipped with plates connected to the double-acting pneumatic cylinders 7 (the upper plates and the lower plates being connected to the vacuum breakers 4), the evaporator 5, the condenser 9, the alcohol-collecting vessel 10, the softened water container 1 for hydroselection, the intermediate collectors of bottom water-alcoholic liquid (WAL) 17 and alcohol-containing fractions 20, the flowmeters 3, 12, 13, 14, and 15, the centrifugal pumps 2, 18, 19, and the decanter 11.

The experimental RC with a diameter of 630 mm was equipped with 30 plates with holes with a diameter of 2.4 mm. The clear opening of the plate in the sparging period was 2.5%, and in the liquid overflow period, 51.7%. The distance between the plates was 300 mm. All structural elements of the column were made of stainless steel 12X18H10T. The feed flow, the flows of water for hydroselection, of the ester and fusel oil concentrate (EFOC), and of the WAL were measured by appropriate rotameters. Alcohol-containing fractions in the amount 135 dm³/h were fed onto the feed plate of the RC and calculated in terms of absolute alcohol (a. a.). Of these, the head fraction of ethyl alcohol was 8.5%, the distillate cuts from the distillation column condenser 9.4% and from the CO₂ separator condenser 3.0%, fusel alcohol 1.5%, water fraction of fusel oil 1.5% of the a. a. of the brew. The liquid holdup on the plates lasted 20 s, the overflow time was 2 s. The pressure in the bottom part of the RC was 17.5 kPa, in the upper part, 2–5 kPa. The temperature in the bottom of the column was 102–103°C, in the upper part, 90–91°C, the temperature of the cooling water at the condenser inlet was 15°C, at the outlet after the reflux condenser, 65°C.

Water for hydroselection in the amount of 2400 dm³/h was supplied from the water container 1 through the flowmeter 3 to the top plate of the column by the pump 2. The ethyl alcohol concentration on the plates in the concentration part was 7% vol., and in the bottom part, 5–6% vol. The alcohol-containing fractions were heated with the residue water heat in the tank 20, from where were supplied to the feed plate by the pump 18. The bottom WAL cleared of the head volatile impurities and of some intermediate ones was pumped into the upper zone of the concentration part of the purifying column by means of the centrifugal pump 18. The vapour containing volatile impurities passed from the upper part of the column 6 first into the dephlegmator 8 and then into the condenser 9. In the dephlegmator, mainly water and higher alcohols, and partially esters and ethanol condensed. In the condenser, low-boiling aldehydes and methanol condensed, as their vapour had not condensed in the dephlegmator. The reflux liquid from the dephlegmator

8 and most of the condensate of the head and tail impurities from the condenser 9 was sent to the decanter 11. In the decanter, the heterogeneous mixture was fractionated, forming the upper layer – EFOC that contained esters, higher alcohols, and some aldehydes, – and the lower layer – the water cleared of the head impurities, some intermediate ones, and the tail ones. The EFOC was removed from the installation through the flowmeter 13. The water-alcohol liquid, which flowed on the top plate of the DC as reflux liquid, was removed from the lower part of the decanter. To reduce the concentration of methanol in the WAL, some of the reflux liquid was removed from the installation in the form of methanol concentrate (MC) through the flowmeter 12. From the condenser 8, aldehyde concentrate (AC) was taken through the flowmeter 15.

The taking of EFOC was 0.23–0.27% of the ethanol content in the brew. Of these, the AC/EFOC ratio was 1:2–1:2.5. MC was taken in cases when the methanol concentration in WAL exceeded 0.001% vol.

To calculate the degree of extraction (α) and the concentration multiplicity (β) of volatile alcohol impurities, experimental samples of feed, WAL, reflux liquid, EFOC, and samples of the liquid from the 2nd, 6th, 11th, 17th, and 26th plates of the RC were selected and chromatographically analysed. Each series of tests was performed in triplicate. Average values were selected as the determining ones. The value of (α) was determined by the ratio of the impurity concentration in the feed to its concentration in the bottom liquid, (β) by the ratio of the impurity concentration in the EFOC to its concentration in the feed by the formulae:

$$\alpha = \frac{x_g}{x_b}; \beta = \frac{x_d}{x_g}$$

where x_g , x_d , x_b – concentrations of alcohol impurities, respectively, on the feed plate, in the distillate (EFOC), and in the WAL, mg/dm³.

Results of the research and their discussion

To solve the task set, the staff of the Department of Biotechnology of Fermentation and Winemaking Products (National University of Food Technologies) and Ltd. *TISER LCC* proposed an innovative technology of controlled rectification, which involves the cyclic motion of liquid, without interruption of the heating steam supply, and a design of a rectification column for the technology [5,6]. The effectiveness of the technical solutions was determined in the course of extracting ethanol from alcohol-containing fractions enriched with organic impurities. For the research, the experimental rectification column was equipped with movable overflow devices (weirs) connected to the actuators that acted according to the controller programme, and with perforated (scale-shaped) trays, or plates.

The efficiency of the cycled operation of the perforated trays depends on the hydrodynamic modes that determine the column's stable operation boundaries. There are no general methods to calculate the boundaries of hydrodynamic modes for bubble trays. That is why, when designing the devices with trays, it was necessary to calculate the vapour velocity corresponding to the lower and upper limits of a tray's operation, and then to determine the working velocities of vapour in the free section of the column and in the slits of the trays. The lower limit corresponded to the vapour velocity at which the dumping of the liquid from the plate stopped. The upper limit corresponded to the vapour velocity at which the liquid was entrained onto the upper plate. In this case, the phase contact area decreased sharply. Such plates are called versatile, or varying cross-section plates. Many studies have been devoted to determining the conditions under which sparging takes place on the plates (the liquid is retained on the plate), and the ones under which the liquid overflows through the overflow openings and dumps through the slits of the contact devices [7-14]. To make it impossible that the liquid be entrained to the top plate, the vapour velocity in the free section of the column equipped with sieve plates should not exceed 0.7 m/s. In the holes, the vapour velocity at

which the liquid is retained on the plate is 4–5.5 m/s. When using perforated plates with the optimum flow section 10%, the vapour velocity in the free cross-section of the column can be 1.2 m/s or more, and in the perforations of the scales, it must exceed the first critical velocity 6.5–7.5 m/s. The liquid dumping occurs when the vapour velocity in the perforations is 1.5–1 m/s [15,16].

The differentiated selection of alcohol impurities from the places of their maximum accumulation and regulating their ratio autonomously depending on the feed's qualitative composition allowed increasing the efficiency of rectification [17]. The reflux liquid from the dephlegmator and the condensate from the condenser were directed to the decanter to separate the heterogeneous mixture, and the water-alcohol mixture was additionally selected from the lower part of the decanter. This helped reduce in the bottom liquid the content of the tail impurities, some of the head and intermediate ones, and the atypical impurities (methanol, acetaldehyde, *n*-propyl and isopropyl alcohols, crotonaldehyde, acrolein), as well as esters (methyl acetate, ethyl acetate, ethyl formate, and ethyl butyrate). As a result, the quality of rectified alcohol improved. The results of the chromatographic analysis of the test samples are given in Table 1.

Table 1 – The distribution of volatile organic impurities of alcohol along the height of the RC

Name of the impurity	Concentration, mg/dm ³ (in terms of a. a.)								
	Distillate cuts	Bottom WAL	The plate number					Reflux liquid	EFOC
			2	6	11	17	26		
acetaldehyde	605.1	traces	traces	2.6	3.3	5.3	16.7	12304.2	13591.2
methyl acetate	32.3	traces	traces	traces	traces	traces	traces	756.1	770.8
ethyl acetate	509.4	traces	traces	4.7	8.3	18.6	traces	14448.9	15344.4
isobutyl acetate	14.6	traces	traces	traces	traces	9.1	47.5	122.9	137.2
isoamyl acetate	81.4	traces	traces	traces	traces	traces	traces	1573.2	1652.9
isopropyl alcohol	2.0	traces	traces	traces	1.0	4.4	12.5	47.7	42.2
<i>n</i> -propanol	10063.8	1080.3	1419.3	2331.1	4894.4	8035.3	6254.5	49045.5	53570.4
isobutanol	6851.2	6.5	7.6	47.9	347.5	1749.3	6718.3	218161.5	204757.3
<i>n</i> -butanol	36.1	traces	5.4	8.6	23.4	24.1	28.7	422.4	379.9
isoamylol	10354.8	7.1	8.0	156.7	731.9	1672.4	8531.7	211033.0	203311.7
<i>n</i> -pentanol	traces	traces	traces	traces	traces	traces	traces	12.3	17.4
acrolein	25.9	traces	traces	traces	traces	traces	traces	446.9	447.6
crotonaldehyde	traces	traces	traces	traces	traces	traces	traces	121.8	136.7
Aldehydes	605.1	traces	traces	2.6	3.3	5.3	16.7	12304.2	13591.2
Esters	637.7	traces	traces	4.7	8.3	27.7	47.5	16901.1	17905.2
Fusel oil	27307.9	1093.9	1440.2	2544.4	5998.2	11485.4	21545.6	478712.5	462078.9
Methanol, % vol.	0.026	0.001	0.001	0.002	0.004	0.003	0.005	2.9	2.1
Ethanol, % vol.	82.0	5.4	10.0	13.0	13.0	12.4	7.0	65.0	68.0
Atypical	25.9	traces	traces	traces	traces	traces	traces	446.9	447.6

The analysis of the experimental data of Table 1 has shown that controlled cycled rectification of alcohol-containing intermediates and brew rectification products allows effectively removing not only the head impurities of alcohol, but also the intermediate and tail ones. Under these preset conditions, aldehydes (acetaldehyde), esters (methyl acetate, ethyl acetate, isobutyl acetate, isoamyl acetate), atypical impurities (acrolein, crotonaldehyde), *n*-pentanol, and isopropyl

alcohol are completely removed. It is known from practice that isopropanol is one of the volatile impurities that is most difficult to separate from ethanol. So, its content in the final product characterises the efficiency of the rectification plant. The isopropanol concentration in commercial alcohol should not exceed 1.5 mg/dm³.

Among the esters, ethyl acetate had the highest concentration multiplicity, and isobutyl acetate had the

lowest. Of the higher fusel alcohols, isobutanol was most effectively concentrated, and n-propanol had the lowest recovery rate and concentration multiplicity. During the rectification, the ethanol concentration on the plates of the column did not exceed 13% vol. The predicted values of (α) and (β) for aldehydes, esters, higher fusel alcohols, methanol, and atypical alcohol impurities (acrolein) during typical and cyclic rectification are given in Table 2.

The analysis of the data from Table 2 shows the advantages of cyclic rectification. It has been experimentally proved that in the course of rectification of alcohol-containing fractions, aldehydes, esters (head impurities), and acrolein are completely removed. But the extraction rate (α) of higher fusel alcohols (upper intermediate impurities) increased by 38%, and that of methanol, by 15.6%. The concentration multiplicity (β) of the head impurities increased by 25%, of higher alcohols, by 40%, of methanol, by 34%, of acrolein, by 36%.

Table 2 – The degree of extraction (α) and the concentration multiplicity (β) of impurities of alcohol during typical and cyclic rectification

Name of the impurity	Conventional distillation		Cyclic distillation	
	α	β	α	β
Aldehydes	86.4	16.9	max	22.5
Esters	79.7	21.1	max	28.1
Fusel oil	21.1	10.0	25.0	16.9
Methanol	16.2	67.4	26.0	102.3
Acrolein	64.7	11.2	max	17.4

After including the RC in the scheme of the brew-rectification plant, the output of rectified ethanol increased by 3.5–3.7%. Its characteristics met the requirements for the alcohol variety Lux according to DSTU 4221:2003, and those of the EFOC met the requirements of TU U (Technical Specifications of Ukraine) 24.6-30219014-004:2005.

The heating steam consumption in the process of rectification was determined basing on the heat balance, by the water spent on cooling and by its temperature on entering the condenser and on leaving the dephlegmator of the RC. It was found that, in the conditions of cyclic distillation, the heating steam consumption decreased by 30% compared to conventional plants, and did not exceed 13 kg/dal of a.a. supplied with the feed.

It has been proved that for effective separation of the mixture in the mode of controlled cycles of liquid holdup and overflow in the DC, it is sufficient to install the 30 contact devices mentioned above.

From the experience of operating the DC, it is known that WAL is usually returned to be re-rectified,

namely, onto the top plate of the rectification column [18]. This is due to the fact that conventional rectification does not always completely clear the residue of the key organic impurities that are later concentrated during rectification and impair the rectified ethanol quality. That is why, rectification plants equipped with typical RCs require increased heating steam consumption to produce a high quality final product.

The suggested cyclic rectification technology allows obtaining bottom WAL as free from alcohol impurities as possible. Under these rectification conditions, the total amount of impurities in the bottom liquid decreases by 94–96% of their concentration in the feed. It is practical to use such WAL for hydroselection of impurities in the purifying column. The technical solution reduces the hot softened water spent on hydroselection and the heating steam spent to distill the brew. It also prevents the concentration of organic impurities in the brew-rectification plant.

Approbation of results. The innovative cyclic rectification technology has been introduced at the Chudnovsky and Lopatinsky alcohol plants in Ukraine. The results of the research can be used to produce bioethanol, and to obtain fuel and oils in the course of oil refining.

Conclusion

The results of the production research have proved the advantages of cyclic rectification over the typical one. The authors have improved the cyclic rectification technology that involves periodic motion of the liquid on the plates with continuous vapour supply, suggested a design of a cyclic-action rectification column, and established the optimum technological parameters of its operation in the process of extracting alcohol from alcohol-containing fractions. It has been found that in cyclic rectification, the heating steam consumption is reduced by 30% compared to typical installations, and does not exceed 13 kg/dal of a. a. supplied with feed. It has been proved that during distillation, the head impurities are removed completely, the degree of extraction (α) of higher fusel alcohol increases by 38%, that of methanol by 15.6%, the concentration multiplicity (β) of the head impurities increases by 25%, of higher alcohols by 40%, of methanol by 34%, of acrolein by 36%. The bottom aqueous-alcoholic liquid cleared of the key volatile impurities can be used for hydroselection of the impurities in the purifying column.

A promising area of further research is studying how efficient the proposed technology will be in brew distillation and in purification of ethanol.

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ТЕХНОЛОГІЯ ЦИКЛІЧНОЇ РЕКТИФІКАЦІЇ У СПИРТОВОМУ ВИРОБНИЦТВІ

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Анотація. Почергова зміна періодів пропускання пари і переливу рідини дозволяє інтенсифікувати масообмін між рідиною і парою та зменшити питомі витрати у гріючої пари в процесі розділення багатокомпонентних сумішей. Відомі способи і моделі не знайшли широкого практичного використання через відсутність масообміну в паровий період, коливання тиску пари в колекторі, складність конструктивних рішень для забезпечення циклічного режиму та ін. Авторами запропоновано технологію ректифікації, що передбачає циклічний рух рідини без переривання подачі гріючої пари та конструкцію ректифікаційної колони для її здійснення. Метою роботи було дослідження ефективності запропонованої технології в процесі розгонки спиртовмісних фракцій і встановлення питомої витрати пари в розгінній колоні. Для забезпечення циклічного режиму колони була оснащена рухомими переливними пристроями, з'єднаними з приводними механізмами, дія яких відбувалася відповідно до програми контролера, та провальними (лускоподібними) тарілками. Першочерговою задачею було визначення гідродинамічного режиму роботи контактних пристроїв – нижньої і верхньої критичної швидкості пари, при яких рідина утримується на тарілках та відбувається її бризковиніс. Встановлено, що швидкість пари у вільному перерізі колони може сягати 1,2 м/с і більше, а в отворах лусок повинна перевищувати першу критичну швидкість 6,5–7,5 м/с. Провал рідини відбувається за швидкості пари в отворах 1,0–1,5 м/с. Дослідження проводились у виробничих умовах Чуднівської філії ДП «Житомирський лікеро-горілчаний завод». Експериментально доведено, що в процесі розгонки спиртовмісних фракцій головні домішки видаляються в повній мірі, ступінь вилучення вищих спиртів сивушного масла зростає на 38%, метанолу – на 15,6%, кратність концентрування головних домішок збільшується на 25%, вищих спиртів – на 40%, метанолу – на 34%, акролеїну – на 36%. При цьому витрати гріючої пари скорочуються на 30% порівняно з типовими установками і не перевищують 13 кг/дал абсолютного алкоголю, що вводиться з живленням. Звільнену від ключових домішок кубову рідину розгінної колони доцільно використовувати для проведення гідроселекції в епюраційній колоні.

Ключові слова: циклічна ректифікація, леткі домішки, гріюча пара, кубова рідина, ректифікаційна колони

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