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THEORETICAL ANALYSIS OF DISTILLATORS USED IN THE DISTILLATION OF VEGETABLE OIL MISCELLA

RASULOVA MAHLIYO

PhD student, Namangan Institute of Engineering Technology, Namangan, Uzbekistan
Phone.: (0893) 946-7218, E-mail.: mahliyoasadbek201@gmail.com
Corresponding author

XAMDAMOV ANVAR

Docent, Namangan Institute of Engineering Technology, Namangan, Uzbekistan
Phone.: (0893) 946-0956, E-mail.: anvarkhamdamov@rambler.ru

Abstract: This article thoroughly examines the advantages and disadvantages of existing distillation equipment used in the process of distilling vegetable oil miscella. Each stage of the distillation process, including technological regimes and their optimization, has been analyzed from both theoretical and practical perspectives. The theoretical analysis of the distillation process of vegetable oil miscella in currently used distillation equipment has been studied. During the research, the operating mechanisms of various distillation devices were compared, and details regarding their efficiency and application were highlighted. The advantages of the equipment used in the distillation process include aspects such as energy efficiency, high productivity and operational stability. Additionally, some disadvantages of certain distillation devices, such as high pressure and temperature requirements, the complexity of the equipment and difficulties in maintenance, have also been studied. Work has been carried out to improve distillation equipment and optimize their operating regimes in order to make the process of distilling vegetable oil miscella more efficient.

Keywords: vegetable oil miscella, ND-1250 extraction membrane distillator, De-Smet distillation unit, MEZ extraction line DS-70, DS-130 distillers, centrifugal force, distillation stage, steam, flash temperature, sight glass, heat exchanger, economizer, pump.

Introduction. The further development of the oil and fat industry requires the introduction of modern and competitive technologies in every enterprise, as well as the creation of high-productivity equipment that improves product quality, including for distillation. The composition of the miscella obtained during the extraction of oil from oilseeds consists of a light volatile solvent, oil, and fine particles of the extracted material. The light volatile component - the solvent - is converted into a vapor state and separated from the practically non-volatile oil. This process is called distillation in the oil and fat industry.

The existing distillation equipment in current oil and fat industry enterprises is designed to perform specific tasks in product processing. The primary function of a distillator is to evaporate vegetable oil miscella, and its effectiveness depends on the proper selection of the distillator.

In vegetable oil production enterprises, extraction lines that have been used until today are equipped with the ND-1250 extraction distillator, the De-Smet distillation unit, and the MEZ extraction line DS-70 and DS-130 distillers, which are widely used in production. These distillers, in turn, consist of several auxiliary devices that significantly impact production efficiency.

ND-1250 Extractor Distillator**.** The ND-1250 extractor distillator consists of a heat exchanger, a preliminary film distillator, a tubular miscella heater, and a final distillator operating under vacuum. Membrane distillers (Figure 1) are made of steel and consist of two parts. The lower part has a diameter of 900 mm, while the upper part has a diameter of 1450 mm. Inside the lower part, 215 steel tubes with a diameter of 30/35 mm and a length of 5000 mm are installed. The total heating surface area is 100 m². This distillator is cylindrical in shape and is positioned vertically. The first section of the distillator primarily performs the function of initial distillation and operates at atmospheric pressure. The second section serves as the final distillator and operates under vacuum. Inside the distillator, tubes (1) are arranged, through which the miscella flows. At the top of the apparatus, a separator (2) is installed, and above it, a droplet collector is placed. Here, there are gasoline and steam vapors, as well as droplets of partial oil.

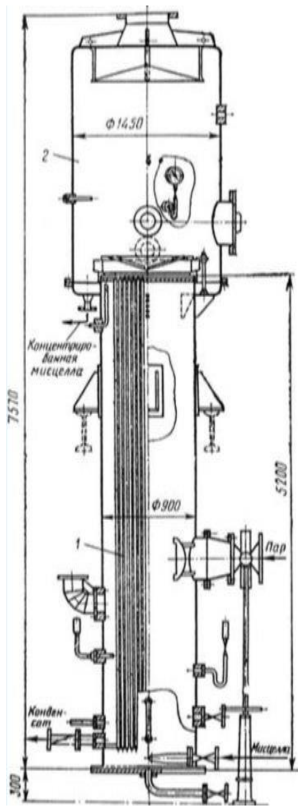


Figure 1. Schematic diagram of the ND-1250 extractor membrane distillatory
1 - Tubes, 2 - Separator.

The miscella is fed from the collection tank into the tubes of the apparatus via a pump. Under the influence of the steam temperature, the miscella boils. Gasoline vapors rise in the form of bubbles to the top of the tubes and enter the separator. The separator operates on the principle of centrifugal force, causing the miscella to separate into two components: gasoline vapors and oil. The gasoline vapors exit through a separate hole at the top and are collected in one place, while the oil exits from the lower part of the apparatus. The separator is made of spirally bent tubes, and a droplet collector is installed at its top. In the upper part of the apparatus, there are passages for steam, condensate, and air. The apparatus operates at a pressure of 3 atm with steam at 180–220°C. The membrane distillator processes the miscella on a thin surface, meaning it is concentrated.

This is why the distillator is called a membrane (or film) distillator. In this type of distillator, the phase boundary between the liquid miscella and gasoline vapors is very large. As a result, during this process, the miscella evaporates, separating into oil and gasoline vapors. Due to its high productivity, it can evaporate 12 m³ of miscella per hour and achieve a concentration of up to 85%.

During the process, the separated oil is discharged from the lower part of the apparatus and cooled. To prevent the oil from oxidizing, it is cooled immediately after exiting the distillator. The miscella is then transferred from the preliminary distillator to the next distillator using a pump. After this process, the miscella is heated, and the gasoline is evaporated and removed under vacuum. In the first section of the distillator, it is washed with high-pressure steam. The oil, purified from gasoline, is sent to the oil collection tank using a pump.

It is impossible to completely separate the solvent (gasoline) without converting it into a vapor state. Therefore, as the miscella is purified from gasoline, the concentration of oil in it also increases. Its boiling temperature also rises, which can lead to the oil darkening and a deterioration in its quality. Based on this, when the miscella concentration increases from X to X_2, the amount of gasoline removed can be calculated using the following formula;

$$\frac{G_1 * X_1}{100} \quad (1)$$

here, G_1 is the amount of miscella entering the apparatus.

The amount of oil exiting the apparatus can be determined as follows:

$$\frac{(G - B_1) * X_2}{100} \quad (2)$$

here, B_1 is the amount of gasoline evaporating and exiting, and X_2 is the amount of miscella initially exiting the apparatus.

Disadvantages of this distillator:

- It is very tall, requiring a large amount of metal.
- The length of the tubes makes repairs difficult.

The initial distillation process is not uniform.

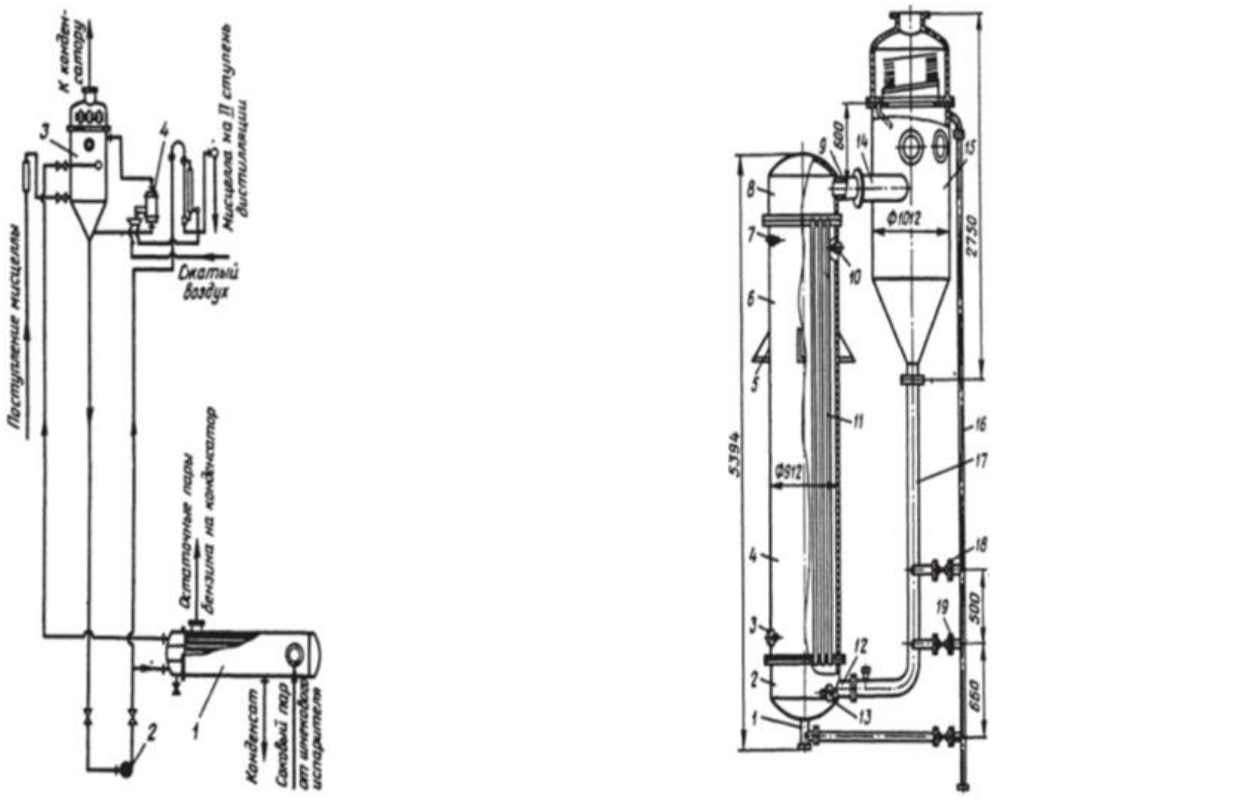
Advantages:

It has a high heat transfer coefficient and superior productivity.

Table 1. Technical characteristics of the ND-1250 extractor distillator.

Productivity, m³/hour	14,5
Heating surface area, m²	100
Overall dimensions:	
Diameter of the preliminary distillator, mm	1450-960
Height, mm	7570
Diameter of the final distillator, mm	1200
Height, mm	6670
Diameter of the heat exchanger, mm	27/30
Length of the tubes, mm	2160

From table 1, we can observe the technical specifications of the ND-1250 extractor distillator and the heat exchanger. In turn, the productivity depends on the thickness of the film, the physical properties of the miscella, the characteristics of the surface where the film is formed, the orientation of this surface, and the conditions of the distillation process. When the surface temperature increases, small, slowly growing bubbles initially form. Later, larger bubbles that expand more rapidly appear. This eventually leads to the disruption of the film layer. The method under consideration differs from the evaporation window method.



a) b)

Figure 1.3. Schematic diagram of the De-Smet distillation unit apparatus.

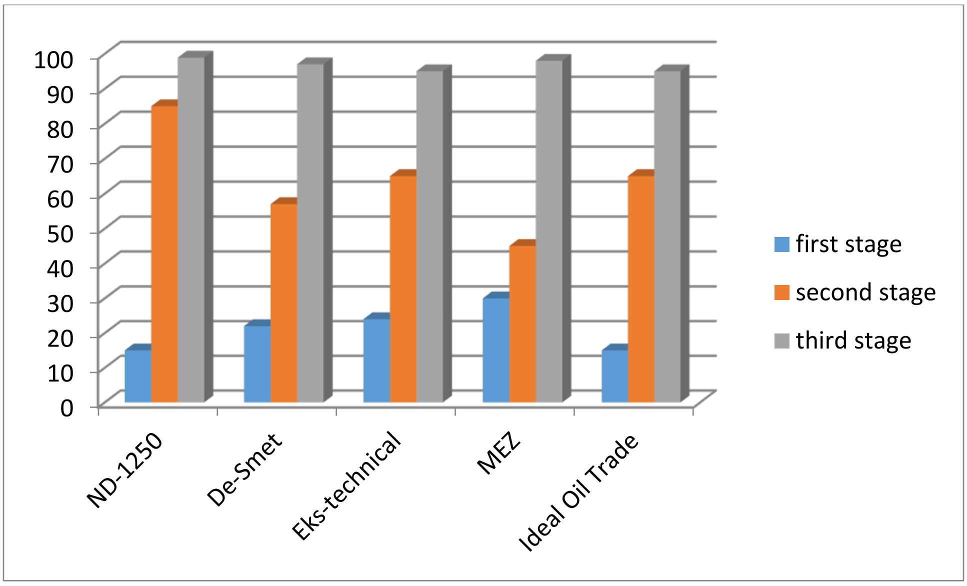
a) First-stage distillator:

1 - Miscella, 2 - Miscella pump, separator, automatic low-level regulator.

b) Second-stage distillator.

1 - lower section pipeline, 2-8 - lower and upper parts of the evaporator, 3 - condensate outlet, 4-6 - cylinder body, 5 - support, 7 - air outlet, 9-14 - pipeline for discharging the mixture of solvent and steam, 10 - steam outlet, 11 - tubular section, 12 -miscella circulation path, 13 - miscella inlet, 14 - cylinder body, 15 - miscella outlet.

The miscella, concentrated to 50–57%, exiting the first stage of the De-Smet distillator, enters the tubular heat exchanger grid of the second stage. In the second stage, the same processes are repeated. The only difference is the specific gravity difference between the emulsion inside the heat exchanger and the miscella in the tubes. In the second stage of this distillator, the miscella is concentrated to 95–97% and is fed to the third stage using a pump. At the end of this stage, the temperature of the exiting oil reaches 100–103°C.



The change in the concentration of miscella in distillers of various designs depending on temperature

From the graph below, we can observe how the concentration of vegetable oil miscella changes in the stages of the distillers studied above.

Advantages of the De-Smet distillator:

- Low steam consumption.
- The heat from the screw evaporator can be utilized.
- High-quality oil is obtained through vacuum operation.
- The heat transfer coefficient in the apparatus is high

Disadvantages:

- It is very tall, occupies a lot of space, expensive, and consumes a significant amount of electrical energy.

DS-70 and DS-130 type distillers are also three-stage, similar to the distillers mentioned above, but they differ in terms of productivity, consumption, the size of the apparatus, the degree of product concentration, and temperature. Table 2 provides information on the operating volume of the distillers and the dimensions of the apparatus.

Table 2. Technical characteristics of the DS-70 distillator

Productivity, m³/hour	5
Heating surface area, m²	78,6
Overall dimensions:	
Diameter of the preliminary distillator, mm	1352-912
Height, mm	5404
Number of tubes, units	363
Diameter of the final distillator, mm	1020
Height, mm	6516

The first stage of the distillator consists of four elements: an economizer made of tubes, a separator, a pump to circulate the miscella, and a device to control the level of the miscella. The heating surface of the DS-70 economizer is 40.5 m², while that of the DS-130 is 78.9 m².

The advantages of the DS-70 equipment include relatively low consumption of heating steam, the ability to carry out the process under vacuum to reduce distillation temperature and improve oil quality, and the automation of equipment control.

Table 3. Differences in temperature and concentration of miscella processed in distillers of various designs.

№	Distillator name	Concentration %			Temperature °C		
		I	II	III	I	II	III
1	ND-1250	10-15	85	98,9	40-60	60-85	115
2	De-Smet	22-25	50-57	95-97	40	70	100-103
3	Extraction-technical distillator	24	65	95	55	70	105
4	MEZ extraction distillator	30-35	45	95-98	40-50	60-65	95-100
5	Ideal oil trade MCHJ	15	65	95	80-85	100	105-115

The concentration of the miscella varies depending on the temperature provided, according to the process carried out in each distillator. Table 3 shows that the temperature of the miscella differs in various distillers. As can be seen from the table, due to the temperature provided to the miscella in distillers of different designs, the concentration varies at each stage.

Conclusion. Existing distillator devices operate on a three-stage principle, which results in varying miscella concentrations at each stage. This leads to inconsistent performance. Multi-stage production requires more time and energy consumption. To improve the distillation process, factors influencing this process are being studied, and the equipment is being optimized. By using compact and energy-efficient devices in the oil and fat industry, it is possible to achieve high-quality products. Through these studies, efforts are being made to streamline the distillation process and address existing shortcomings in the equipment by developing a relatively larger, yet energy-efficient, two-stage distillation unit. This will further enhance the vegetable oil industry.

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