

UDC 62-503.56

DOI <https://doi.org/10.52171/herald.313>

Automated Control System for Benzine Hydrotreating Block

E.A. Melikov, T.M. Maharramova

Azerbaijan State Oil and Industry University (Baku, Azerbaijan)

For correspondence:

Elchin Melikov / e-mail: elchin03@mail.ru

Abstract

In the article, minimizing energy losses is identified as a primary challenge for enhancing the productivity of the straight-run benzine hydrotreating process and improving the quality of the resulting target product. The ultimate goal, based on the comprehensive studies carried out, is to obtain high-quality hydrotreated benzine. The physical justification for the studied technological process and the development of a modern automated control system is presented. The development of such an effective automated control system is an actual and important task in the modern oil refining, petrochemical, and chemical industries. The main technological apparatus analyzed in the gasoline hydrotreating unit is the stabilization column. In this case, the minimum and maximum limits of the operating parameters have been established, as it is one of the key devices in the benzine hydrotreating system. After clarified the technological operating modes of the main apparatuses, important regulated and controlled parameters were determined. That is, the main goal of the conducted research is the correct choice for technological parameters of the studied process, their optimal regulation, monitoring, control and, ultimately, obtaining high-quality hydrotreated benzine. Technological and automated schemes for the studied system were developed using the modern graphic platform “Draw.io”.

Keywords: stabilization column, control system, benzine hydrotreating, straight-run benzine, technological apparatus, control process, modern system.

Submitted 27 October 2025

Published 6 November 2025

For citation:

E.A. Melikov, T.M. Maharramova

[Automated Control System for Benzine Hydrotreating Block]

Herald of the Azerbaijan Engineering Academy, 2025, vol. 17 (3), online

Benzin hidrotəmizləməsi blokunun avtomatlaşdırılmış idarəetmə sistemi

E.A. Məlikov, T.M. Məhərrəmov

Azərbaycan Dövlət Neft və Sənaye Universiteti (Bakı, Azərbaycan)

Xülasə

Məqalədə, birbaşa qovulmuş (distillə olunmuş?) benzinin hidrotəmizlənməsi prosesinin məhsuldarlığının və alınan məhsulun keyfiyyətinin artırılması üçün enerji itkisini minimuma endirmək əsas məqsədlərdən biri kimi qarşıya qoyulur. Aparılan çoxsaylı tədqiqatlara əsaslanaraq, hidrotəmizlənmiş benzinin alınması vacib hesab olunur. Bu texnoloji prosesin fiziki cəhətdən əsaslandırılması və müasir avtomatlaşdırılmış idarəetmə sistemlərinin işlənməsi zəruridir. Belə bir idarəetmə prosesinin işlənilib hazırlanması aktual və vacib elmi-praktik məsələlərdən biridir. Hidrotəmizlənmiş benzinin alınmasında əsas texnoloji avadanlıq stabilizasiya kolonu hesab olunur. Benzinin hidrotəmizlənməsi bölməsində əsas aparat olan stabilizasiya kolonunun iş rejiminin parametrləri üzrə minimal və maksimal hədləri təyin edilmişdir. Əsas aparatlar üzrə rejim parametrləri dəqiqləşdirilərək, onların nəzarəti və idarə olunması həyata keçirilmişdir. Tədqiqatın əsas məqsədi texnoloji prosesin texnoloji parametrlərinin düzgün seçilməsi, onların optimal idarə olunması və yüksək keyfiyyətli hidrotəmizlənmiş benzinin əldə edilməsidir. Tədqiqat olunan sistemə dair texnoloji və avtomatlaşdırma sxemləri müasir “Draw.io” grafik-dizayn proqram təminatı platformasında hazırlanmışdır.

Açar sözlər: stabilizasiya kolonu, idarəetmə sistemi, benzinin hidrotəmizlənməsi, birbaşa qovulmuş benzini, texnoloji aparat, idarəetmə prosesi, müasir sistem.

Автоматизированная система управления блоком гидроочистки бензина

Э.А. Меликов, Т.М. Магерамова

Азербайджанский Государственный Университет Нефти и Промышленности
(Баку, Азербайджан)

Аннотация

В статье минимизация потерь энергии рассматривается как одна из основных задач повышения производительности процесса гидроочистки прямогонного бензина и улучшения качества получаемого целевого продукта. Важно, на основании проведенных исследований, в конечном итоге получить гидроочищенный бензин. Представлено физическое обоснование исследуемого технологического процесса и разработка современной автоматизированной системы управления. Разработка такой автоматизированной системы управления является актуальной и важной проблемой. Основным исследуемым технологическим аппаратом в рассматриваемом блоке гидроочистки бензина является стабилизационная колонна. При этом установлены минимальные и максимальные пределы рабочих параметров колонны стабилизации. Уточнив технологические режимы работы основных аппаратов, определены важные регулируемые и управляемые параметры, т.е. основной целью проведенных исследований является правильный выбор технологических параметров исследуемого процесса, их оптимальное регулирование, управление и, в конечном итоге, получение высококачественного гидроочищенного бензина. Технологические и автоматизированные схемы исследуемой системы были разработаны с использованием современной графической платформы «Draw.io».

Ключевые слова: стабилизационная колонна, система управления, гидроочистка бензина, прямогонный бензин, технологический аппарат, процесс управления, современная система.

Introduction

Currently, the economic development of Azerbaijan, especially its achievements in the country's energy sector, largely depends on the activities of enterprises that efficiently process crude oil. The control and measurement systems used in the oil refining industry several decades ago did not meet modern technological requirements. Thus, the existing systems mainly worked on electrical and pneumatic principles and faced the following problems during operation:

- the air quality used in pneumatic control systems was extremely low;
- the accuracy of control and measuring devices was low;
- control systems were not working properly and with large delays.

The above-mentioned shortcomings indicate that in modern conditions it is more appropriate to implement effective automated control and regulation systems based on electronic means instead of the above-mentioned systems [1-6]. Improvements in this area play an important role in optimizing information processing and production control in general [7-13].

Measuring sensors and other control and measuring devices used in modern automation systems operate with high accuracy, transmitting signals in digital (with codes 0 and 1) or analog (4÷20 mA) form.

This ensures the control processes' centralization and implementation ease of monitoring over them through a common system. This reduces the need for additional technological installations, which creates advantages from both a technical and economic point of view. One of the main priorities for the fuel and energy complex of Azerbaijan is the further this industry

development both in social and economic terms. The produced oil products meet the needs of both the domestic market and are exported to foreign countries. Since straight-run benzene has a high sulfur content, its content is reduced by the hydrotreating process.

Purpose and importance of the hydrotreating process straight-run benzene

In the modern oil refining industry, the hydrotreating process for straight-run benzene fractions is of great strategic importance both in terms of improving product quality and increasing its processing stage efficiency. The primary objective of the technological process under consideration is to produce a high-quality final commodity product by removing undesirable components from the raw materials, including nitrogen, sulfur, oxygen-containing compounds, unsaturated and organometallic compounds, as well as resinous substances. In particular, since the mentioned stage is carried out before the implementation of the catalytic reforming technological process, it directly affects the subsequent stages' efficiency. Correct organization for the technological hydrotreating stage leads to a service life extension of the catalysts used, an increase in the octane number of the target product, and an increase in the aromatization hydrocarbon degree. Although the technological schemes of hydrotreating installations generally have similar elements in their structure, there are differences in the technical characteristics, productivity, and dimensions of the stabilization and separation blocks. These differences are formed mainly depending on the raw materials composition, processing

capacity, and the required resulting product quality.

From a technological point of view, flexible and optimal control of hydrotreating installations is important both from the point of technical safety view and economic efficiency. When hydrotreated benzene fractions are sent to subsequent processing stages, products for various purposes are obtained, depending on their boiling ranges. For example, fractions with a boiling point of

$80\div 180^{\circ}\text{C}$ or $100\div 180^{\circ}\text{C}$ are processed into high-octane benzene using the platforming (catalytic reforming) method. On the other hand, narrower fractions, such as toluene in the $85\text{--}105^{\circ}\text{C}$ range, benzene in the $60\div 85^{\circ}\text{C}$ range, and xylene in the $130\div 165^{\circ}\text{C}$ range are used in the various concentrates production.

Figure 1 shows the flowchart of the straight-run benzene hydrotreating section,

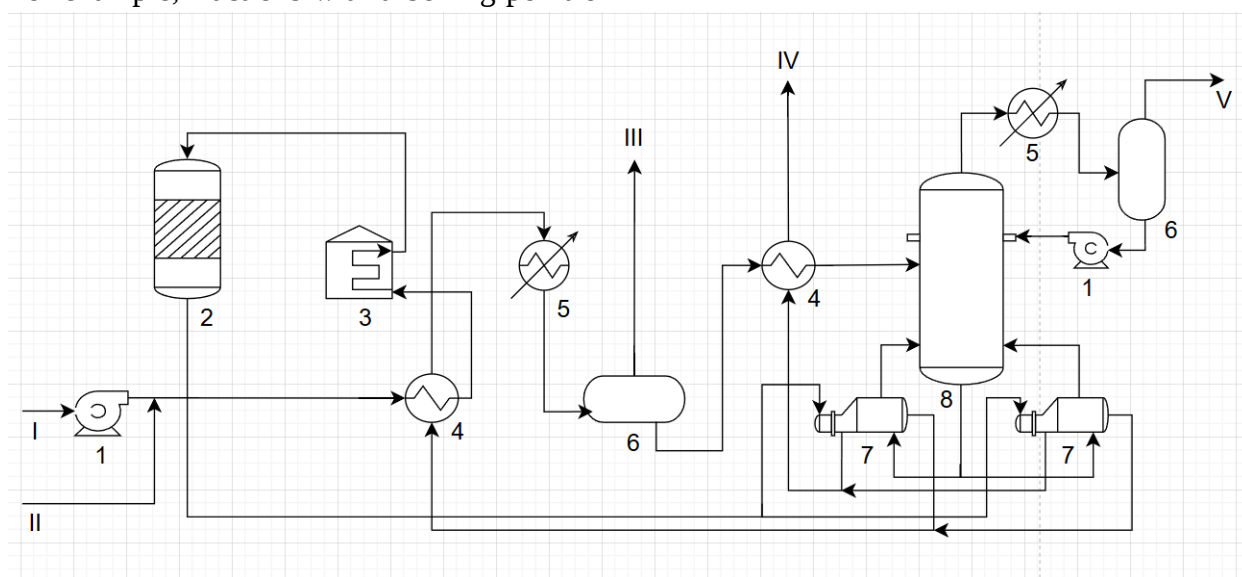


Figure 1 – Flowchart of the straight-run benzene hydrotreatment section

I – feedstock (straight-run benzene); II – hydrogen-containing gas; III – hydrogen-containing gas (enters the evaporation coil); IV – hydrotreated benzene; V – hydrogen-containing gas (part of which is utilized).

The main apparatuses in the technological scheme: 1 – pump; 2 – reactor; 3 – furnace; 4 – heat exchanger; 5 – refrigerator; 6 – separator; 7 – reboiler; 8 – stabilization column.

The process of hydrotreating benzene fractions is carried out in two main directions. The first direction involves hydrotreating straight-run fractions (naphtha). These fractions are mainly intended as feedstock for the catalytic reforming process.

The second direction involves the benzene hydrogenation obtained as a result of

coking, catalytic cracking, and other thermal or thermocatalytic processes. The above hydrotreating methods, applied in both directions, allow for the minimization of the sulfur content and other harmful components in the commodity product, which ensures that the final product meets the required environmental and technological requirements.

Let us consider the course of the technological process in the section under study. The feedstock, straight-run benzene, is first filtered and mixed with hydrogen-

containing gas using a pump. The resulting mixture passes through a heat exchanger and is heated to 380°C in the convection and radiation furnace chambers.

At this stage, the gas mixture is heated by fuel gas, and in the case of a reserve, by liquid fuel. The heated mixture then enters the hydrotreating reactor. The main technological process in this reactor is the reaction of sulfur compounds contained in the raw material with hydrogen, ultimately forming hydrogen sulfide. The product leaving the reactor passes through a reboiler and a heat exchanger, lowering its temperature, and then enters a separator, cooled to 40°C using an appropriate cooler. The separator separates gas and liquid into the following phases:

- the upper phase is a hydrogen-containing gas (part of which is recycled, the rest is removed);
- the lower phase is the unstable hydrogenate (then transferred to the next stage).

Part of the obtained hydrogen-containing gas is sent to the stabilization column, and the other part enters the evaporator, where it is purified and returned to the reactor (with a hydrogen concentration of 70% and a circulation requirement of 500 kg/m³).

The unstable hydrogenate is heated in a heat exchanger using the heat of the stabilized hydrogenate and fed into a stabilization column. Steam heating is carried out using a reboiler located at the column bottom. The top product passes through a condenser-cooler, then through a cooler, and enters the separator.

The products obtained at the outlet of this separator are separated into water and hydrogen sulfide. The water is returned to the

stabilization tank, and the hydrogen sulfide is used to produce sulfur or sulfuric acid.

The stable hydrogenates (hydrotreated benzine) leaving the column bottom is the final product and after filtration is sent to the reforming stage.

The monoethanolamine solution saturated with hydrogen sulfide is purified, regenerated through a heat exchanger and evaporator, and then returned to the technological process.

The following main technological functions are distinguished:

- hydrogen purification from sulfur compounds;
- purification and stabilization of hydrocarbon gas;
- regeneration and monoethanolamine solution reuse.

Below, Table 1 shows the minimum and maximum operating limits of the main process apparatus, the stabilization column.

Analysis of the control system for the hydrotreating straight-run benzine process

The technological process of hydrotreating straight-run benzine is aimed at preliminary purification of the fraction obtained from the distillation crude oil fractions in the temperature 85–180 °C range and the removal of sulfur, nitrogen, and other undesirable components by its interaction with catalytic hydrogen. This process not only improves the resulting product quality but also extends the service life of the technological installations that will be involved in subsequent production cycle stages. Figure 2 shows a principal scheme for the automation of the hydrotreating straight-run benzine process.

Table 1 – Minimum and maximum limits of operating parameters for the stabilization column

The apparatus	Parameters	Restrictive condition		Unit of measure
		Min	Max	
Stabilization column	Consumption of supplied raw materials	250	360	m ³ /h
	top temperature	90	120	°C
	level	5	6.5	M
	pressure	2	3.6	kgf/cm ²
	hydrotreated benzine consumption	93	118	m ³ /h

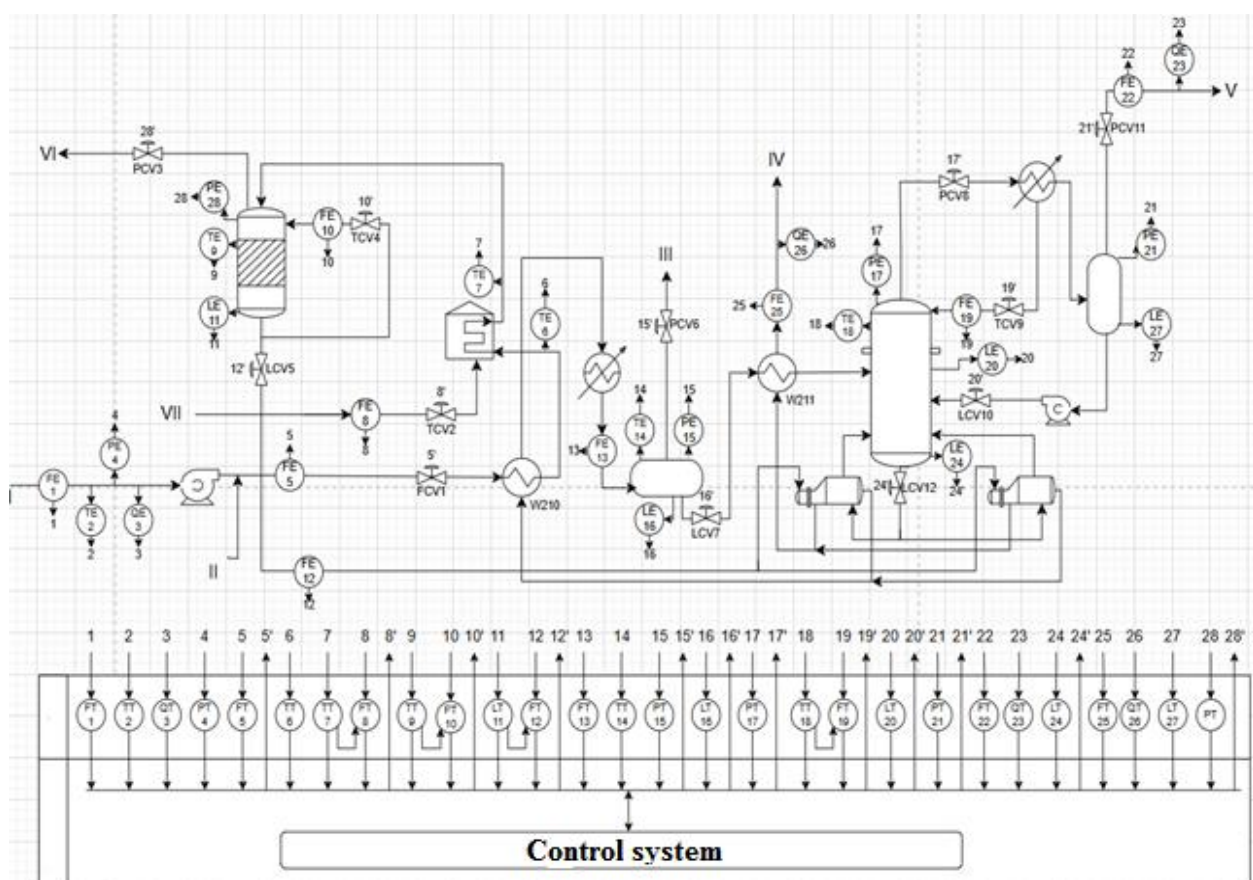


Figure 2 – Principal scheme for the automation of the hydrotreating straight-run benzene process

The feedstock is fed into the process line using a pump and is monitored using a FE-1 flow meter, a TE-2 temperature sensor, a QE-3 quality analyzer and a PE-4 pressure sensor. The flow value from the pump is dynamically regulated by an FCV1-type control valve. The basic automation principle of technological

processes here is that when the actual measured values deviate from the setpoint values, the process is intervened in and the parameters are returned to the optimal mode. Such parameters are usually called “regulated parameters”.

The gas-air mixture, passing through the heat exchangers, enters the tube furnace after heating to approximately 304°C. The furnace outlet temperature (TE-7) is of particular importance due to the combustion process sensitivity inside the furnace to external influences, especially to changes in ambient temperature. For this reason, the fuel consumption is controlled by the TCV2 control valve, located on the fuel line entering the furnace, as a result of which the furnace outlet temperature is maintained constant. As a result, the gas-feed mixture enters the upper reactor part at a temperature of about 374°C. The hydrotreating process carried out in the reactor occurs at high temperatures and pressures. Based on the data from the PE-28 pressure sensor located in the upper reactor part, the pressure in the reactor is stabilized by the PCV3 valve located on the gas product outlet line. The flow value is regulated by the TCV4 valve on the irrigation line, which is located at the reactor outlet and recirculates the product part, maintaining a constant temperature inside the reactor. This control cycle type is based on data from the TE-9 temperature sensor. This connection controls the LCV5 valve, which ultimately maintains the required optimum level inside the reactor.

The gas product mixture obtained at the reactor outlet is preheated by entering the tubular part of the reboiler section for the stabilization column and then sent to the stabilization column itself. The flow coming out of here passes successively through the W210 heat exchanger, the raw material cooler, and enters the separator. The separator is monitored by the FE-13 flow sensor at the inlet and the TE-14 temperature sensor inside. The pressure in the gas main located at the separator top is regulated by the PCV6 drive.

Internal level control is provided by the LE-16 level sensor and the LCV7 outlet valve. The monitored parameters are flow and temperature, and the controlled parameters are pressure and level. The liquid product removed from the separator passes through the W211 heat exchanger and enters the stabilization column. The main function of the column is to separate hydrogen, sulfur components (mainly H₂S), and other light gases from the gas-liquid mixture. The pressure is controlled by the PCV8 valve, connected to the PE-17 pressure sensor at the column top. To maintain a stable temperature inside this column, the FE-19 flow meter and the TCV9 thermoregulating valve are used on the reflux line. The temperature is monitored by the TE-18 sensor. The pressure in the separator outlet line is regulated by the PCV11 valve, located on the V line. Both the quality and the flow rate of the hydrogen-containing gas leaving this line are monitored. The liquid product removed from the tank bottom is returned to the tank through the LCV10 valve and the LE-20 level sensor, ensuring internal level stability. After the hydrogenate discharged from the stabilization column bottom passes through the reboiler and heat exchanger W211, hydrotreated benzine is obtained. Here, the outlet level is monitored by the level sensor LE-24 and the valve LCV12. The result is hydrotreated benzine, i.e. purified from sulfur and other harmful components. At the final stage, technological control over the quality indicators and consumption of the obtained products continues.

Thus, within the complex automation framework for the technological process under study, monitored, and control of the modes parameters for the main technological apparatuses, such as the reactor, furnace,

stabilization column, separator, and pumps, is carried out using modern automatic control systems. These systems guarantee process efficiency, product quality, and production safety, and also allow for effective, high-

precision, and stable control with minimal human intervention. Table 2 shows the monitored and regulated parameters of the main technological devices involved in the process under consideration.

Table 2 – Monitoring and regulation of parameters for the main technological apparatuses involved in the process under study

№	Apparatuses		Parameters	Monitoring	Regulating
1	Pump	at the entrance	Consumption	+	-
			Pressure	+	-
			Temperature	+	-
			Quality	+	-
		at the exit	Consumption	-	+
2	Furnace	at the entrance	Temperature	+	-
		at the exit	Temperature	-	+
3	Reactor	at the top	Pressure	-	+
		inside	Temperature	-	+
		at the bottom	Level	-	+
4	Separator	at the entrance	Consumption	+	-
		at the top	Pressure	-	+
		inside	Temperature	+	-
			Level	-	+
5	Stabilization column	at the top	Pressure	-	+
		inside	Level	-	+
			Temperature	-	+
		at the bottom	Level	-	+

Conclusions

Thus, the technological process occurring in the straight-run benzene hydrotreatment section has been physically substantiated and analyzed in detail. The monitored and regulated parameters of the main equipment participating in the technological process have been set. The main technological apparatuses in the process under consideration have been identified and studied. After detailed research and study of technological processes occurring in the main technological apparatuses, the stabilization column was determined as a significant

control object, in which the target and high-quality final product are obtained. Based on the monitored and regulated parameters (temperature, pressure, flow, level, and quality), specifying the operating modes of the technological processes in the apparatus under study, an effective automated control system scheme for them was developed.

Conflict of Interests

The authors declare there is no conflict of interests related to the publication of this article.

REFERENCES

1. **Guseinov I.A.**, et al. Nonstationary Multistage Process Control in the Petrochemical Industry. Journal of Computer and Systems Sciences International, Pleiades Publishing, Ltd., 2014, Vol. 53, No. 4, pp. 556-564. { [HYPERLINK "https://doi.org/10.1134/S1064230714030095"](https://doi.org/10.1134/S1064230714030095) }
2. **Melikov E.A., Maharramova T.M., Safarova A.A.** Control problem for a vacuum technological complex, Eurasian Physical Technical Journal, Publisher: Karaganda University named after Academician E.A. Buketov, ISSN: 1811-1165, e-ISSN: 2413-2179, Vol. 21, No. 4 (50), 2024, pp. 71-78. { [HYPERLINK "https://doi.org/10.31489/2024No4/71-78"](https://doi.org/10.31489/2024No4/71-78) }
3. **Safarova A.A., Melikov E.A., Magerramova T.M.** Construction of a multi-connected control system for safe coke production. Reliability: Theory and Applications, Electronic Journal of International Group on Reliability Journal is Registered in the Library of the U.S. Congress, USA. The 5-th Eurasian Conference and Satellite Symposium, RISK-2023, Special Issue 5 (75), Vol.18, 2023, pp. 510-517. { [HYPERLINK "https://doi.org/10.24412/1932-2321-2023-575-510-517"](https://doi.org/10.24412/1932-2321-2023-575-510-517) }
4. **Melikov E.A., Magerramova T.M., Safarova A.A.** Automated control system for the supply of liquid fuel to a tube furnace. Reliability: Theory and Applications, Electronic Journal of International Group on Reliability Journal is Registered in the Library of the U.S. Congress, USA, RISK-2024, Special Issue 6 (81), Part-1, Vol. 19, 2024, pp. 442-448. { [HYPERLINK "https://doi.org/10.24412/1932-2321-2024-681-442-448"](https://doi.org/10.24412/1932-2321-2024-681-442-448) }
5. **Guseinov I.A., Khanbutaeva N.A., Melikov E.A., Efendiev I.R.** Models and Algorithms for a Multilevel Control Systems of Primary Oil Refinery Installations. Journal of Computer and Systems Sciences International, Pleiades Publishing, Ltd., 2012, Vol. 51, No. 1, pp. 138-146. { [HYPERLINK "https://doi.org/10.1134/S1064230711060098"](https://doi.org/10.1134/S1064230711060098) }
6. **Melikov E.A., Maharramova T.M., Safarova A.A.** Automation and control of the vacuum block. EPJ Web of Conferences (France), EDP Sciences – Web of Conferences, III International Conference on Advances in Applied Physics and Mathematics for Energy, Environment and Earth Science (AAPM-III 2025), Vol. 318, 2025, 05009. { [HYPERLINK "https://doi.org/10.1051/epjconf/202531805009"](https://doi.org/10.1051/epjconf/202531805009) }
7. **Safarova A.A., Melikov E.A., Magerramova T.M.** Optimal control of the alkylation process reactors. Operational Research in Engineering Sciences: Theory and Applications, Serbia, vol. 6, Issue 1, 2023, pp. 312-321. { [HYPERLINK "https://doi.org/10.31181/oresta/0601130"](https://doi.org/10.31181/oresta/0601130) }
8. **Safarova A.A., Melikov E.A., Magerramova T.M.** Principles of modeling and optimal control of a fraction purification reactor from micro impurities, III International scientific and practical conference "Technologies, materials science and engineering" (EEA-III-2024), AIP Conference Proceedings, AIP Publishing, Vol. 3243, Issue 1, 020014. { [HYPERLINK "https://doi.org/10.1063/5.0247869"](https://doi.org/10.1063/5.0247869) }
9. **Melikov E.A., Magerramova T.M.** Strategy for Optimizing the Functioning of the Vacuum Block at the Technological Equipments. HERALD of the Azerbaijan Engineering Academy The international science-technical journal, Vol. 15, No. 2, 2023, pp. 110-115. { [HYPERLINK "https://doi.org/10.52171/2076-0515_2023_15_02_110_115"](https://doi.org/10.52171/2076-0515_2023_15_02_110_115) }

10. **Melikov E.A., Maharramova T.M.** Control of the gasoline hydrotreating process. Proceedings of Azerbaijan High Technical Educational Institutions (AATMX). Refereed & Reviewed Journal. ISSN: 1609-1620 (Print), Vol. 26, No. 5 (151), pp. 36-43, 2024
{ HYPERLINK "<https://doi.org/10.36962/PAHTEI149052024-36>" }
11. **Safarova A.A., Melikov E.A., Magerramova T.M.** Features of modelling in automation for the primary oil refining technological process, Proc. SPIE 13217, Third International Conference on Digital Technologies, Optics, and Materials Science (DTIEE 2024), 132170M. { HYPERLINK "<https://doi.org/10.1117/12.3035889>" }
12. **Melikov E.A., Maharramova T.M.** Development of an automated control system for fuel oil vacuum distillation. Materials of VIII International scientific and practical conference “Readings of A.I. Bulatov”, Russian Federation, March 31, 2024, vol. 2, pp. 163-167.
13. **Melikov E.A.** Approach to optimal process control in atmospheric-vacuum sections. Oil refining and petrochemistry. Scientific and technical achievements and the best practices, TsNIITeneftexhim, Moscow, Russia, 2022, No. 6, pp. 35-39.