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Automated Oil Product Calculations Management System for Refineries: Enhancing Efficiency and Accuracy in Gasoline Preparation

Ali Abbas Abbod [1,*], Emad Hamde Matrood [1]
[1] *Ministry of Oil ,Bagdad,Iraq*
aliabbasabbod17@gmail.com

Abstract

The process of gasoline production in refineries often involves manual calculations to determine the correct mixing ratios of various oil products and to calculate the octane number of the final gasoline product. This manual process is not only labor-intensive but also prone to errors. To address these issues, we propose an Automated Oil Product Calculations Management System designed to enhance efficiency and accuracy in gasoline preparation. This system automates the calculation of oil product mixing ratios and octane numbers, ensuring precise and error-free results. The system, developed using Visual Basic 2019, features several key interfaces, including the main interface, data entry interface, results interface, previous data interface, settings interface, and information interface. Users input data into the system based on specific equations and specialized tables related to the storage tanks used in the gasoline preparation process. The system then accurately calculates the quantities and levels of oil products required, generates daily and monthly reports, and maintains reliable production records. This automated approach not only streamlines the gasoline production process but also improves the overall accuracy and reliability of the results.

Keywords: gasoline, octane number, material mixing, standard specification, oil refining, oil products, Catalytic Reforming units, naphtha, Visual Basic 2019, Visual Studio, system design, data entry, results, tanks, material balance reports.

النظام الآلي لإدارة حسابات منتجات النفط في المصافي: تعزيز الكفاءة والدقة في تحضير البنزين

علي عباس عبود[1]*, عماد حمدي صالح[1]
[1]وزارة النفط , بغداد , العراق

الملخص

غالبًا ما تتضمن عملية إنتاج البنزين في المصافي حسابات يدوية لتحديد نسب الخلط الصحيحة لمنتجات النفط المختلفة وحساب رقم الأوكتان لمنتج البنزين النهائي. هذه العملية اليدوية ليست كثيفة العمالة فحسب، بل إنها أيضًا عرضة للأخطاء. لمعالجة هذه المشكلات، نقترح نظام إدارة حسابات منتجات النفط الآلي المصمم لتعزيز الكفاءة والدقة في تحضير البنزين. يقوم هذا النظام بأتمتة حساب نسب خلط منتجات النفط وأرقام الأوكتان، مما يضمن نتائج دقيقة وخالية من الأخطاء. يتميز النظام، الذي تم تطويره باستخدام Visual Basic 2019، بالعديد من الواجهات الرئيسية، بما في ذلك الواجهة الرئيسية وواجهة إدخال البيانات وواجهة النتائج وواجهة البيانات السابقة وواجهة الإعدادات وواجهة المعلومات. يقوم المستخدمون بإدخال البيانات في النظام بناءً على معادلات محددة وجداول متخصصة تتعلق بخزانات التخزين المستخدمة في عملية تحضير البنزين. ثم يحسب النظام بدقة الكميات ومستويات منتجات النفط المطلوبة، ويولد تقارير يومية وشهرية، ويحافظ على سجلات إنتاج موثوقة. لا يعمل هذا النهج الآلي على تبسيط عملية إنتاج البنزين فحسب، بل يحسن أيضًا الدقة والموثوقية الشاملة للنتائج.

1. Introduction

Oil refining is one of the necessary processes that can process crude oil and extract a large number of consumer oil products such as kerosene, Gas oil, gasoline, liquefied petroleum gas (LPG), and other products[1]. Where Products from refineries, industrial refineries, closed refineries, petrochemical plants, terminals, and pipelines flow into tanks. Tanks are synthetic containers holding water, oil, oil products, compressed gases, and mediums for short- or long-term heat or cold storage.[2]. Gasoline suitable for consumption is produced by Catalytic Reforming units, and feed material is naphtha resulting from refining processes, but some refineries do not have Catalytic Reforming units, so it is prepared by mixing the naphtha product with high-octane gasoline in certain proportions to obtain suitable gasoline product for consumption inside Tanks and this preparation process requires several manual calculations for determining the correct mixing ratios of oil products, in addition to knowing the octane number of the prepared gasoline. These manual calculations may take a long time, in addition to the possibility of errors in the calculations.

Gasoline product is considered one of the important products in daily life and is used as a fuel in internal combustion engines [3]. Gasoline is a product extracted from crude oil through refinery processes and consists mainly of hydrocarbons. Octane number is one of the most important characteristics of gasoline, and it is a measure of the ability of gasoline to resist the phenomenon of early combustion, a phenomenon that results in a knocking sound inside the engine, which indicates the octane ratio of heptane in the gasoline mixture [4]. Octane number is one of the most important factors based on which gasoline is sold commercially. In addition, there has been a great amount of past and current research on engines in which octane numbers have been used to help understand fuel properties and build a comprehensive understanding of motor fuels [5]. Gasoline octane number is usually measured in two ways: Research Octane Number (RON) and Motor Octane Number (MON). Both values are tested in an engine but in different conditions regarding engine rotational speed, intake air temperature, and the temperature of the fuel mixture with air and coolant temperature [6].

The continuous development in industries in general and the oil industry in particular. The continuous development of industries prompts us to use modern methods in production processes to ensure obtaining accurate and approved specifications for petroleum products. Material balancing equations are an important aspect of production processes to know the efficiency of the separation of oil products in refining towers. Previously, the process of material balance is done manually by special equations, and these procedures require time and effort to complete, whereas paper accounts have become forgotten, because they consume more effort and time and require special places to store them and because modern technology has dealt with these matters, where it can store billions of information in parts of a second in very small areas, where modern technologies can receive important data and transform it into the information of high value and store it in different storage media, and usually Able to exchange these results and information with other compatible devices, all these developments prompted us to follow modern ways to accomplish tasks.

The proposed system was established to manage the quantities of oil products to prepare and calculate the octane number of the gasoline product, which is prepared by mixing some oil products such as (high-octane gasoline, light naphtha, and heavy naphtha). also, the proposed system is characterized by calculating the levels and quantities of oil products inside the tanks that are used in the gasoline preparation process. The proposed system will be designed by a programming Visual Basic 2019 language in a Windows environment. The

Visual Basic language (abbreviated: V.B.) can be defined as a programming language created and developed by Microsoft, which is the visual form of BASIC, and it was developed by Professor John Smiley and Thomas Kurtz, and this language is characterized by Its simplicity and ease of understanding, as many programmers consider it the starting point in learning programming, and gives users a set of tools that can be used to create applications with a graphical user interface (GUI), Visual Basic can be considered more than just a programming language; It includes a variety of libraries useful in creating object-oriented programs. Microsoft Visual Basic Microsoft has released many different versions of Visual Basic, to suit users and their fields of work, and the following are some of the editions such us Educational Edition, Professional Edition, and Enterprise Edition [7]. most important features that motivate users to use Visual Basic are the following: Simplicity of language; Many actions can be easily performed by it, which is difficult to do with other languages. This involves offering a wide range of educational resources, including books, websites, and other materials, to cater to the diversity of languages. It also encompasses providing a diverse array of downloadable tools from the internet, which users can integrate into their programs. [8]. Databases are employed by organizations for the storage, retrieval, and management of information[9]. The evolution of databases in the mid-20th century introduced a novel approach to enhance database management, employing dedicated software known as database management systems. Notable database programs include ADABAS, IBM DB2, Microsoft Access, Microsoft SQL Server, MySQL, Oracle RDBMS, Quick Base, SAP Sybase ASE, and Teradata. Given that networking is not currently a project requirement, the Access program will be utilized.

2. Related works

This section provides a concise survey of significant research, drawing insights from the context of "Automated Oil Product Calculations Management System for Refineries: Enhancing Efficiency and Accuracy in Gasoline Preparation." These studies employ various methodologies to investigate aspects related to the system's optimization and performance in the domain of gasoline preparation. The methodologies encompass the prediction of key parameters, assessment of efficiency enhancements, and evaluation of accuracy improvements, all aimed at advancing the effectiveness of the automated oil product calculation management system.

Pasadakis et al[3]. In a Greek refinery, created Artificial Neural Network (ANN) models to forecast Research Octane Numbers (RON) for gasoline mixtures. These models made use of input data such as the RON numbers and volumetric composition of common fractions. Because of the limitations on octane boosters and engine improvements, the study underscored how important precise octane estimates are. The ANN models shown efficacy in RON prediction, supporting the optimization of gasoline blends to achieve targeted quality while taking cost and availability considerations into account.

Ahmad et al[10] . examined how blockchain technology may be used in the oil and gas sector. The research examines how supply chain management, manufacturing, and exploration might benefit from blockchain's traceability, transparency, and security. The writers show how blockchain might improve operational efficiency and accountability in the sector by examining blockchain-based plans, research initiatives, and case studies. The report also discusses issues with energy use, privacy, and legal systems. It is suggested that future research follow certain paths to fully utilize blockchain in the oil and gas industry.

Macias-Hernandez and Angelov[11] examined how emerging intelligence systems (EISs) may be used in the oil and gas (O&G) sector. Unique features of the O&G industry include low margins, high throughput, intricate procedures, a multitude of variables, and ongoing product monitoring. The authors emphasized how important EISs are for automating decision-making processes with the help of intelligent sensors, especially for process control and monitoring. Online quality monitoring is required during the refining process since it entails complex material selection and intermediate component balance. The industry benefits at different stages from the quality monitoring, diagnostic, and prediction solutions provided by the EIS implementation. In order to handle industry complexity, the authors stressed the usefulness of fuzzy rule-based systems, model creation, and soft analyzers. Key areas for EIS application were also highlighted, including control engineering, predictive maintenance, and intelligent sensors, which promise increased productivity and efficiency throughout the O&G industry.

Akopov [12] presented a fresh method for creating integrated simulation models for big businesses, with an emphasis on the oil and gas (O&G) sector. The technique took into account both direct and feedback relationships while building models for vertically integrated company segments using system-dynamics methodologies. A potent simulation application called Powersim Studio was used to create these models. Additionally, a corporate data warehouse and a genetic optimization algorithm were connected to the built simulation system. With the ability to optimize decision-making processes for maximizing shareholder value while taking into account a variety of restrictions and eventualities, this novel technique holds great promise for improving investment activity management for vertically integrated oil corporations.

Marchenko and colleagues [13] give a thorough examination of how digital methods are being incorporated into oil refineries' commercial operations. Their research focuses on the dynamic demands that quickly shifting market conditions place on the production sector, particularly in high-tech industries like oil refining. The authors support the integration of corporate information systems (I.S.) like ERP, MES, and ACSPP in order to promote automation of business and technical operations. They suggest that re-engineering core business processes is required to achieve effective integration. By switching to automated systems and enabling real-time modifications of equipment operating modes based on anticipated demands and technological limitations, this strategy seeks to improve raw material processing. There is additional consideration for the particular complexity involved in oil refining procedures. The writers examine the significance of analytical calculation models in predicting the effects of operational modifications on semi-product attributes. They recommend applying machine learning methods to these kinds of investigations. In order to maximize the operating modes of processing equipment, the conclusion highlights the necessity of having a clearly defined interaction mechanism between planning, sales, and automation systems.

Westbrook, Sjöberg, and Cernansky [14] presented a brand-new chemical kinetic technique [14] that can be used to calculate the Motor Octane Number (MON) and Research Octane Number (RON) of gasoline mixes that contain both single and multiple components. Using chemical kinetic reaction modeling, the method is shown to work by comparing data from ASTM test protocols with data from experiments done in a Cooperative Fuels Research (CFR) engine. By forecasting RON and MON for a variety of neat fuels, main reference fuel (PRF) blends with toluene, and gasoline surrogate mixtures with ethanol, the method's capabilities are demonstrated. When compared to traditional engine test techniques, the authors describe the benefits of the kinetic modeling approach in terms of cost, time, and experimental complexity.

3. Methods

This section delves into the sophisticated manual calculation method and further explores the integration of technology-driven practical steps that enhance efficiency and accuracy.

3.1. Manual calculation method

The gasoline product is prepared in the South Refineries Company by adding different quantities of the following products (light naphtha (L.N) - local gasoline (REF) - imported gasoline (R.G.) - Heavy Naphtha (H.N)) and the steps for finding the results in Manual calculation method are summarized in the following example

1. Determining the total quantity of gasoline to be prepared and assumed (6250 m^3) depends on the available products and required specifications.
2. Determining the amount of light naphtha (L.N) to be added to the preparation tank and assume (1000 m^3) with the octane number (RON) which was determined from the laboratory and we assume it is 65.
3. Determining the amount of local gasoline (REF) to be added to the preparation tank, we assume (1500 m^3) with the octane number (RON) determined from the laboratory and we assume it is 86.
4. Determining the amount of imported gasoline (R.G.) and assuming (3000 m^3), specifying the octane number (RON) from the laboratory and imposing it as 95.
5. Determining the quantity of heavy naphtha (H.N) and assuming (750 m^3) with determining the octane number (RON) from the laboratory and assuming it is 45.
6. Test the value of the resulting octane number after preparation according to the following equation:

   Ron of the prepared gasoline =
   *(L.N quantity /total quantity * octane number of L.N) +*
   *(REF quantity / total quantity * octane number of REF) +* *(1)*
   *(R.G. quantity / total quantity * number octane of R.G.) +*
   *(H.N quantity /total quantity * number octane of H.N)*

   After entering the values into the equation, we get
   (Ron) = (1000/6250 * 65) + (1500/6250 * 86) + (3000/6250 * 95) + (750/6250 * 45) =<u>82.04</u>
7. Then we determine the factor of the preparation tank and assume the tank used here is F16(A) and its factor = 0.684 from Table 1.
8. We determine the level of prepared gasoline according to the quantity (6250 m^3) in the preparation tank after adding each substance according to the following equation:

Preparation tank height = added quantity/tank parameter *(2)*

Then, depending on the proposed quantity of materials to be added to prepare the quantity of gasoline, we find the level of each substance in the preparation tank

a) Adding (L.N) quantity to make the tank height 1000/684 = 1.461m
b) Add (REF) quantity to make the tank height 1500 /684 + 1.461 = 3.654 m
c) Adding (R.G.) quantity to make the tank height 3000 /684 + 3.654 = 8,040 m
d) Add (H.N) quantity to make the tank height 750 /684 + 8.040 = 9.137 m

Note \ The level of additives after the first article is cumulative, that is, it combines the level with the level of materials that precede it, and as shown in the equations above, the final result is: - The height of the prepared gasoline inside the preparation tank = 9.137 m

To check the amount of gasoline prepared

$$\text{quantity of prepared gasoline} = \text{height of gasoline inside the tank} * \text{tank coefficient} \quad (3)$$

quantity of prepared gasoline = 9.137 * 684 = 6250 m^3

3.2. Computer-Aided Calculation Method

The system's architecture unfolds with a focus on the cutting-edge "Computer-Aided Calculation Method." This method illustrates how harnessing the computational power of computers can expedite complex calculations, demonstrating a new era of enhanced efficiency and accuracy. Where, the design of the system encompasses a series of pivotal steps, redefining the landscape of gasoline preparation. The following primary phases are elucidated:

1. Install the Visual Studio environment on the computer.
2. Design the system interfaces.
3. Entering the information necessary for the system which includes equations and data as shown in Table -1.

Table 1- Example of Tanks Data

No.	Tank Name	level Max	Base area
1	4F (C)	13	0.660
2	4F (B)	16	0.445
3	17F (C)	12.5	0.407
4	4F (D)	13	0.660
5	16 F (A)	16.2	0.684
6	16 F (B)	16.2	0.684
7	7 F(A)	11	0.531

The above table contains some details of the products tanks use for gasoline preparation, where the second column shows the tank’s names, the third column represents the maximum level of the product inside the tank, and the fourth column represents the tank base area.

3.3. System Architecture

The system's interfaces are ingeniously engineered via VB.net 2019, ensuring adaptability for all users. These interfaces are meticulously crafted to prioritize user ease in both design and learning. The system is composed of the following primary interfaces

3.3.1. Main Interface

Through the main interface, all system resources can be accessed, as shown in the figure-1.

Figure -1 Main interface

3.3.2. Data-Entry Interface

Through this interface, all the necessary information is entered to obtain the octane number of the prepared gasoline, as shown in the figure-2.

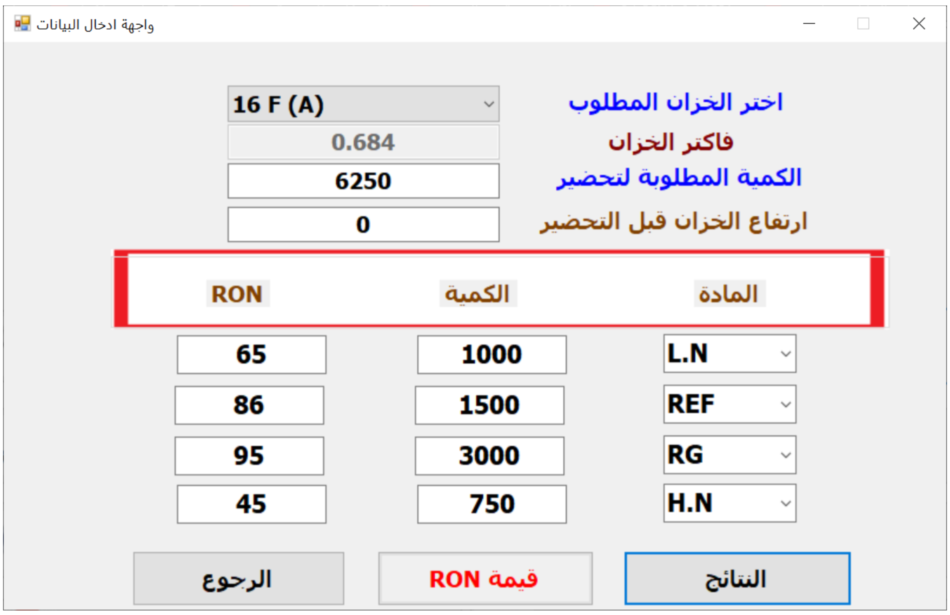

Figure -2 Data Entry interface

3.3.3. Result Interface

Through this interface, it is possible to see all the results and the entered values, where The results can be stored in a database by pressing the "Save Data" button. In addition to the possibility of printing the final report by pressing the "Print the final report "button as shown in the figure-3.

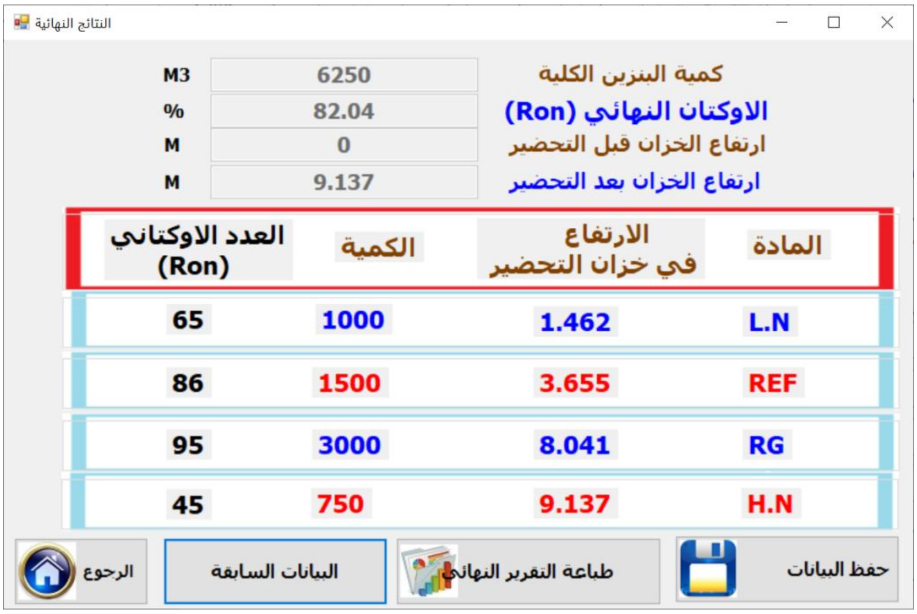

Figure -3 Result interface

3.3.4. Previous Data Interface

Through this interface, all previous data can be accessed within a table in the database as shown in the figure-4

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Figure -4 Previous Data Interface

3.3.5. System Settings Interface

Through this interface, it is possible to enter all the values necessary for the work of the system, including the values of the preparation tanks, the information of the company used for the system, etc. as shown in the figure-5.

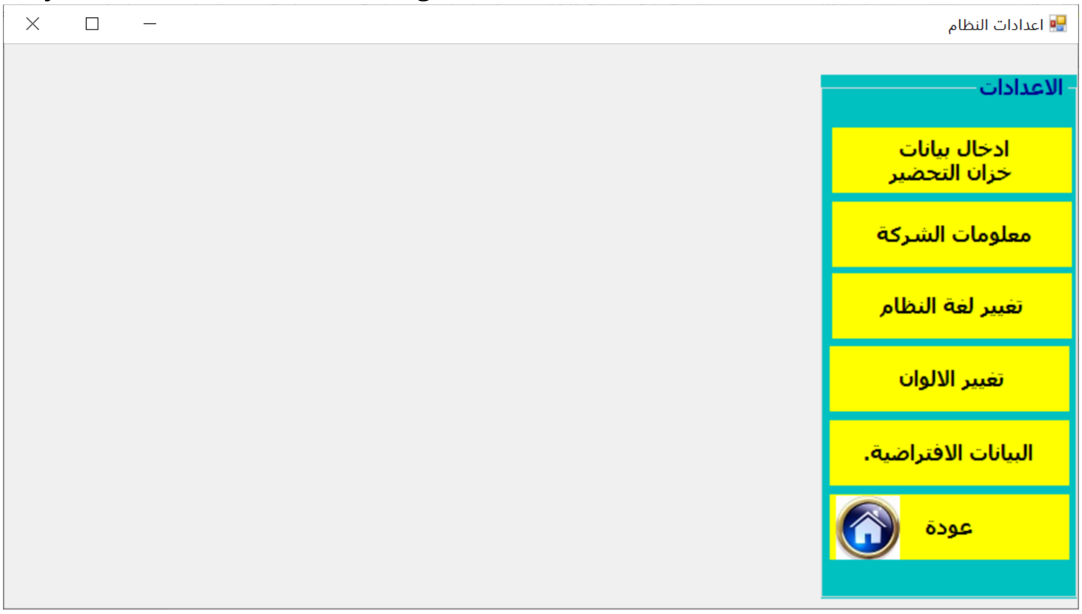

Figure -5 System Settings interface

By embracing the prowess of VB.net 2019, the system interfaces are adeptly molded to be intuitive and accessible for all users. This intelligent fusion of technology and usability paves the way for a future where calculations are not just expedited but elevated to unprecedented levels of accuracy and efficiency.

4. Result and Discussion

The implementation of the proposed computer-aided calculation method revolutionizes the efficiency and accuracy of gasoline preparation in refineries. By automating complex manual calculations, the system streamlines the process while significantly reducing the potential for errors. The accuracy of the calculated octane numbers is improved, leading to more reliable production records and optimized gasoline blends. The comparison between the traditional manual calculation method and the computer-aided calculation method showcases the advantages of the latter. The manual method, although functional, is time-consuming and susceptible to human errors. On the other hand, the computer-aided method offers instant results with higher precision. The ability to store and retrieve previous data enhances the efficiency of the system, allowing for quick reference and historical analysis. Furthermore, the system's interfaces, designed using VB.net 2019, provide user-friendly interaction and intuitive data entry. This facilitates the adoption of the system across various users with varying levels of technical expertise.

When compared to the state-of-the-art methodologies discussed in related works, our system offers several advantages:

Similar to Pasadakis et al.'s ANN models, our system improves the precision of octane number calculations but with greater efficiency through full automation , Like the blockchain applications explored by Ahmad et al., our system enhances operational efficiency and traceability within the refinery, although focused specifically on gasoline preparation, While Akopov's integrated simulation models focus on optimizing decision-making, our system simplifies day-to-day operations, offering instant and precise results with historical data for analysis, In line with Marchenko et al.'s advocacy for digital methods, our system integrates seamlessly with existing refinery operations, enhancing real-time modifications and efficiency and Although Westbrook et al. used kinetic modeling for octane prediction, our approach provides similar benefits in cost, time, and complexity reduction through automated calculations.

5. Concluding and Future Recommendations

In conclusion, the "Automated Oil Product Calculations Management System for Refineries" demonstrates a leap in efficiency and accuracy in gasoline preparation. The integration of technology, particularly the computer-aided calculation method, redefines the process by automating complex equations, reducing errors, and enhancing the precision of calculated octane numbers. As a future recommendation, the system could be expanded to include predictive capabilities. Machine learning algorithms could be incorporated to predict the impact of different oil product combinations on the octane number, taking into account historical data and trends. This predictive feature could assist refinery operators in making informed decisions about the optimal blend ratios for different market conditions. Furthermore, the system's database could be integrated with real-time monitoring sensors in the refinery. This would enable continuous data collection and refinement of the prediction models, ensuring the system's accuracy evolves. In the long term, collaboration with refineries and research institutions could lead to the development of a standardized industry tool that enhances the efficiency and accuracy of gasoline preparation processes globally.

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