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INNOVATIVE TECHNOLOGICAL SCHEME OF IRAQ OILS REFINING

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Abstract. The article deals with the development of technological scheme for refining oils extracted in Iraq. Basiccharacteristics and physico-chemical properties of Iraq oils have been considered. The main stages of oil refining and processing have been described. Material balances of each processing stage have been calculated.

Keywords: crude oil, oil refining, technological scheme, distillation, gasoline, diesel fuel, jet fuel, material balance.

1. Introduction

It is known that oil is a fossil fuel with unique physical and chemical properties. Oil product share increases every year in chemical, food and building industry. The fuel-energy complex requirements constitute the main direction of oil operation. For example, in accordance with OPEC assessments, oil takes more than one third of the world energy balance (Table 1).

Traditionally, depending on the obtained oil product properties, the rational, economically efficient oil refining ways are selected [4-11]. Choice of oil refining direction and obtained oil products range is determined by physical and chemical oil properties, oil refining engineering development level and needs for marketable oil products within the specific economic region [5-13]. There are three main ways of oil refining: 1) fuel; 2) fuel-oil; 3) petrochemical (complex). To define the most acceptable way for refining, oil classification is used. Nowadays, the most widespread classification is the technological one [5-13]. Its fundamentals include features important for oil refining technology or obtaining some product range.

In spite of prospective reduction of the oil share in the total scope of energy carriers, the absolute oil consumption (like other energy sources) will increase. Oil requires effective management as it is non-renewable natural resource. Oil refining processes efficiency improvement is one of the ways of this unique fossil fuel rational use.

Table 1

World energy balance (OPEC prognosis, World Oil Outlook 2010 data) [1]

Energy resource name	Volume, BOE million per day				Part, %			
	2008	2010	2020	2030	2008	2010	2020	2030
Oil	80.9	80.4	89.9	97.6	35.7	35.0	32.7	30.2
Coal	64.8	66.2	80.1	92.1	28.6	28.8	29.2	28.5
Gas	51.4	52.1	64.5	79.1	22.7	22.7	23.5	24.5
Nuclear energy	14.4	14.7	16.9	20.7	6.3	6.4	6.2	6.4
Hydroenergy	5.5	5.8	7.3	9.0	2.4	2.5	2.7	2.8
Biofuel	8.6	9.2	12.9	17.5	3.8	4.0	4.7	5.4
Another renewable energy resources	1.3	1.5	3.2	6.8	0.6	0.7	1.2	2.1
Totally:	226.8	229.9	274.8	322.9	100.0	100.0	100.0	100.0

Note: heating ability of 1 kg coal = 29.3 MJ is considered to be the conditional fuel unit (C.F.). International Energy agency (IEA) accepted oil equivalent as one, usually abbreviated as TOE (Tons of Oil Equivalent). One ton of oil equivalent is equal to 41.868 GJ or 11.63MW·h. Barrel oil equivalent (BOE) is applied as well. 1 TOE = 7.11, 7.33 or 7.4 BOE.

Social and economic situation in Iraq, directly connected with oil, is the unique "indicator" of the state economic development. 9 % of extracted oil is used in the country, while the other part is exported abroad as crude oil or oil products. In 2012 Iraq exported \$94 billion worth 886.8 million barrels of crude oil. Thus, Iraq spent 30 billion dollars for oil products purchased during last ten years, but did not build any oil refining enterprise [2, 3]. Development of oil refining enterprises network and their modernization may be logically considered as a rational direction of economic development. This article is the logical continuation of our work evolution.

2. Experimental

Physical and chemical properties of oils such as density, content of sulphur, water and mechanical impurities concentration of chloride salts, fractional composition were determined using standard procedures. Standard methods for determining the physical and chemical quality of indicators, the method of comparison, monographic method, and feasibility analysis method were used as well.

Taking into account that light oil fractions (up to 633 K) are always used as fuels, oil refining ways are chosen depending on an oil group and subgroup. Principal technological flowchart of AVD is chosen after refining way selection. When the flowchart is chosen, content and characteristics of refined oil, range of obtained products and their quality requirements are taken into account. Detailed characteristics of investigated oils are represented in the following Tables (physical and chemical properties, potential fractions content in oil, characteristics of raw material for catalytic cracking (633–733 K), characteristics of 473 K boiling fractions, characteristics of kerosene fraction (453–513 K), diesel fraction characteristics (513–633 K), basic and residual oils potential content) [5–13].

Oil refining way is chosen taking into account oil marking. Based on previously conducted experimental results [14, 15] we composed the complex Table of oils properties for their cipher determination (Table 2).

On the base of the above ciphers (see Table 2) one can affirm that Iraq oils are sulfureous, with the medium light distillates content (~53.0 %). Therefore, they may be refined according to the fuel option.

3. Results and Discussion

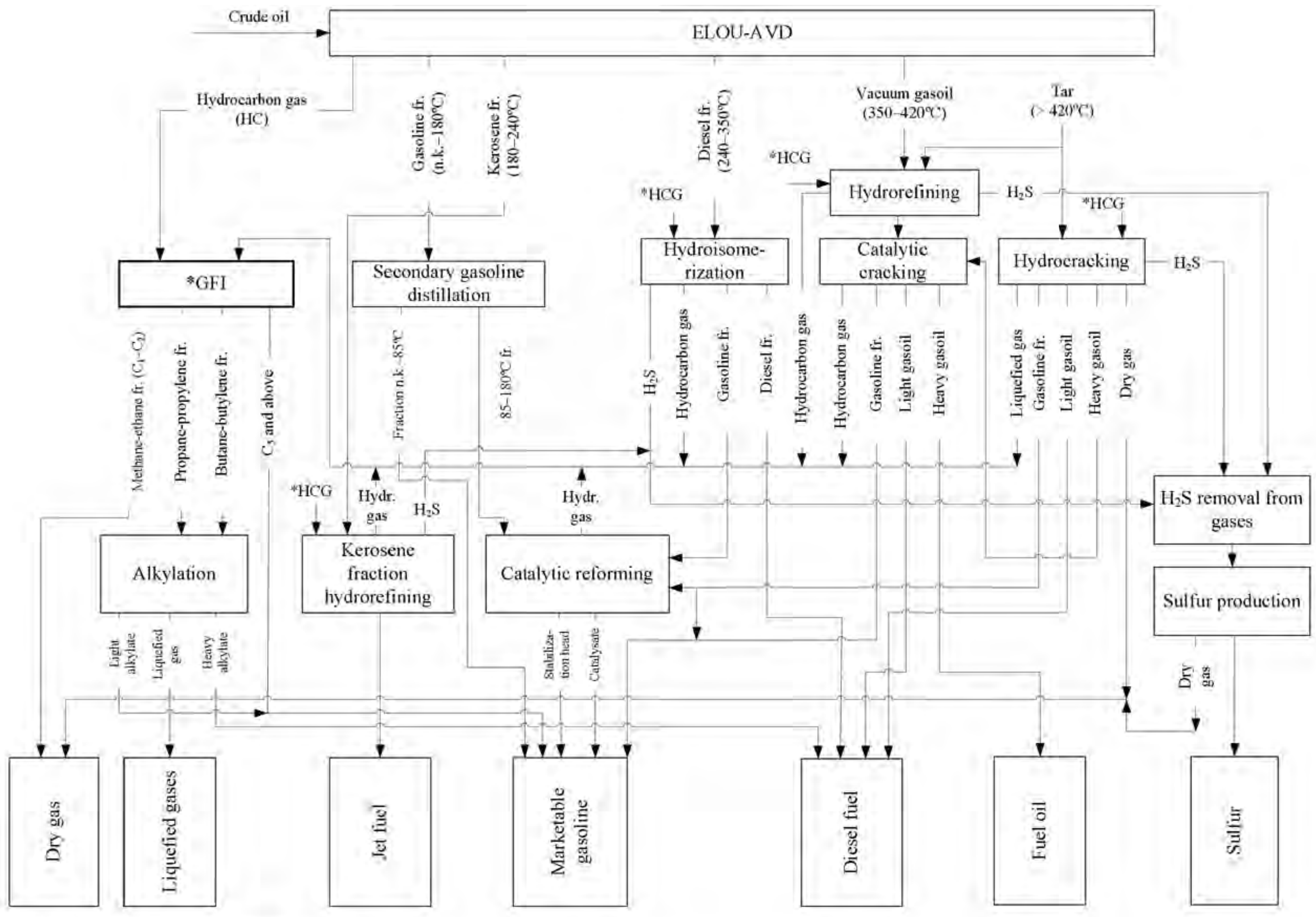
Presented results were baseline data to substantiate a flowsheet oil refining enterprise (ORE). Basing on these results, we justified a fuel variant ORE deep processing of oil.

As it is known [5-13, 16-19], in accordance with the fuel option, oil is mainly processed into motor and fuel oils. Fuel option of oil refining is differed by the least number of technological installations and low capital

Table 2

Properties determining Iraq oils ciphers

Index name	Value				
	Rumayla	Nakhran-Omar	Buzyrgan	Kircuck	Madzhnun
Sulfur content, mas %					
- in oil	1.30	0.73	1.54	1.69	1.30
- fraction (b.b.–453 K)	0.144	0.029	0.29	0.136	0.17
- fraction (453–643 K)	1.12	0.64	1.42	1.67	1.67
Oil class:	3	2	3	3	3
Up-to 633 K boiling fractions content, mas %	50.02	59.87	43.77	46.59	44.27
Oil type:	2	1	3	2	3
Water content, mas %	Absent	Absent	Absent	0.02	Absent
Mechanic impurities content, mas %	Absent	Absent	Absent	Absent	Absent
Chlorine salts concentration, mg·dm^{-3}	14.06	23.01	17.52	21.16	19.22
Oil group:	1	1	1	1	1
Paraffins content in oil, mas %	3.4	3.0	2.7	2.8	1.4
Temperature, K					
- Kerosene fraction crystallization temperature	219	214	211	225	200
- Diesel fraction chilling point	262	261	259	262	261
Oil sort:	2	2	2	2	1
Oil cipher:	**3.2.1.2**	**2.1.1.2**	**3.3.1.2**	**3.2.1.2**	**3.3.1.1**



* HCG – hydrogen-containing gas

Fig. 1. Principal flowchart of proposed ORE according to the fuel option

investments in case of the same oil processing capacity of the factory. There is deep and mild oil refining according to the fuel option. Deep oil refining makes it possible to obtain the maximal outcome of high-quality aviation and automobile gasolines, winter and summer diesel fuels and jet fuels. For this case majority of specific secondary refining processes is foreseen, as a result of which high-quality light motor fuels are obtained from heavy oil fractions and residuals (tar). These processes include catalytic ones – catalytic cracking, catalytic reforming, hydrocracking and hydrofining, and also thermal processes, such as coking [5-13, 16-19]. Artificial gases reprocessing in this case is directed to increasing high-quality gasolines and liquefied gas outcome.

Fuel option of investigated oils refining is economically efficient, as these oils contain insufficient amount of oil fractions [7, 9-11, 13]. Proceeding from the assumption of oils cipher (Table 2), we chose three-stage flowchart of atmospheric vacuum oil distillation (AVD) to obtain required end products. As the base of developed flowchart we took one of industrial AVD scheme with the triple evaporation (Fig. 1). According to the scheme, oil passes three stages of previous dewatering. Dewatered and desalted oil is directed to the primary oil processing (POP) in AVD. Hydrocarbon gas produced in AVD, is directed to the gas fractionation installation (GFI), where it is fractionated into dry (methane-ethane) and liquefied gases (propane, butane and isopentane fractions). Dry gas may be used as a household and industrial fuel. Liquefied gas is directed to the liquefied hydrocarbon gases section.

Gasoline fraction (b.b. – 453 K) is directed to the secondary refining. It is divided into two parts. The first one is gasoline fraction (b.b. – 358 K), usually directed to isomerization. We make a decision not to direct this fraction to isomerization to prevent additional expenses, but immediately to marketable gasolines compounding section (Fig. 1). The second part of 358–453 K gasoline fraction is directed to the catalytic reforming, where the high-octane number gasoline is obtained. Reforming gasoline is directed to the "Marketable Gasolines" section, where it is mixed with the gasoline fraction (b.b.–358 K). Hydrocarbon gas is directed together with other gases to GFI.

Table 3

Total material balance of proposed ORE

Product name	Thousand tons per year	Mass % per raw material unit of the process	1 ton production cost, $	Annual production cost, thousand $
Received:				
Dewatered, desalted oil	5000	100		
Obtained:				
1. C_1–C_2 dry gas	103.67	2.07	200.00	20734.00
- C_1–C_2 dry gas from the GFI process	57.42			
- C_1–C_2 dry gas from hydrocracking process	23.25			
- C_1–C_2 dry gas from H_2S removal process	23.00			
2. Liquefied C_3–C_4 gas	97.01	1.94	700.00	67907.00
- liquefied C_3-C_4 gas from secondary gasoline distillation process	32.41			
- liquefied C_3 gas from alkylation process	38.94			
- liquefied C_4 gas from alkylation process	25.66			
3. Gasoline	2414.84	48.30	1150.00	2777066.00
- stabilization head of the catalytic reforming installation	68.57			
- light alkylate	187.44			
- b.b.–358 K	151.12			
- reformate	1401.99			
- catalytic cracking gasoline	241.83			
- hydrocracking gasoline	342.79			
- C_5 and higher fractions from GFI	21.10			
4. Diesel fuel	1951.08	39.02	1010.00	1970590.80
- hydrorefined diesel fuel	1029.49			
- vacuum gasoil hydrofining distillation	46.09			
- light gasoil from catalytic cracking	310.68			
- heavy alkylate	36.33			
- hydrocracking diesel fraction	528.49			
5. Jet fuel	199.94	4.00	1050.00	209937.00
6. Residuum is the heavy catalytic cracking gasoil	124.79	2.49	620.00	77369.8
7. Sulfur	35.05	0.70	105.00	3680.25
Totally:	4926.38	98.54		5127284.85
Losses	73.62	1.46		

Table 4

Building cost of proposed ORE of prospective technological chart

Installation	Planned productivity, thousand tons per year	Installation cost, thousand $
AVD-1	3 000	250 000
AVD-2	2 000	230 000
Secondary gasoline distillation 1	1 000	120 000
Secondary gasoline distillation 2	800	110 000
Catalytic reforming 1	1 000	260 000
Catalytic reforming 2	800	240 000
Diesel fuel hydroisomerization	1100	260 000
Jet fuel hydrofining	250	190 000
Vacuum gasoil hydrofining	800	310 000
Hydrocracking	1500	680 000
Catalytic cracking	1 000	380 000
Gas fractionation installation 1	200	70 000
Gas fractionation installation 2	200	70 000
Alkylation	300	160 000
Sulfur production	70	70 000
H_2S removal from gases	50	40 000
All installations cost:		3 130 000
Infrastructure building (25 % cost of installations)		782500
Totally through refinery:		3 912 500
Reagents, plant-starting catalysts purchase (10% cost of the plant)		391250
Totally:		4 303 750

Note: cost is mentioned according to the oil refining installations investment indexes and numerous publications analysis in leading journals of developed countries “Oil & Gas Journal”, “Petroleum Review” and “Hydrocarbon Processing”

Table 5

Payback period and profitability of proposed ORE

Installations building equipment, catalysts, and reagents cost	4 303 750 thousand $
Oil purchase costs	5 000 000 · 642 = 3 210 000 000 $
Oil refining costs (*20 % raw material cost*)	3 210 000 000 · 0.2 = 642 000 000 $
Annual production cost (table 15)	5 127 284 850 $
Annual production profit (*annual production cost*) – (*oil purchase costs*) – (*oil refining costs*)	5 127 284 850 $ – 3 210 000 000 $ – – 642 000 000 $ = = 1 275 284 850 $
ORE payback period *(complete ORE building cost)/(annual production profit)* ORE profitability *(annual production profit/complete ORE building cost)* · 100 %	4 303 750 000 / 1 275 284 850 = 3,37 years (1 275 284 850 / 4 303 750 000) · 100 % = 29.6 %

Kerosene fraction (453–513 K) is directed to the aviation kerosene production. Hydrofining installation is foreseen for this process (Fig. 1).

Diesel fraction (513–633 K) also requires hydrofining and pour point lowering, that is why we direct this fraction to hydromerization installation. Produced hydrocarbon gas is directed to GFI, and distillation gasoline is directed to the catalytic cracking installation for octane number (ON) boost. Hydrorefined vacuum gasoil (633–693 K) and vacuum hydrockracking gasoil are directed to catalytic cracking resulting in hydrocarbon gas, gasoline, light and heavy gasoils. Light gasoil is used as a diesel fuel component, the heavy one – as the fuel oil. Residuum (> 693 K) is directed to the hydrocracking process, where hydrocarbon gas, gasoline, light and heavy gasoil may be obtained (Fig. 1).

Saturated and unsaturated hydrocarbons C_3–C_4 are directed to the alkylation installation. Produced hydrogen sulfide, resulting from gas cleaning, is directed to sulfur production installation.

Total material balance of ORE by the example of 5 million tons/year power Nakhran-Omar deposit is represented in Table 3. Building cost of proposed ORE of prospective technological chart is represented in Table 4. Results of payback period and profitability of proposed ORE calculations are illustrated in Table 5.On the base of these data, we calculate the refining depth (G), using formula G = (NP – TM – P), where NP and TM are the amounts of produced in ORE marketable oil products and residual oil respectively; P – refers to irretrievable losses, %.

Thus, $G = 2.07 + 1.94 + 48.30 + 4.00 + 39.02 + + 2.49 – 2.49 – 1.46 = 93.87$ %

4. Conclusions

Thus, the results of our work show that investigated Iraq oils contain the medium amount of light fractions (~53.0 %) and they are sulfureous and paraffin-containing. It was the reason of the fuel option refining choice, with the maximal light fractions outcome. Deep oil refining gives possibilities to obtain the maximal outcome of high-quality aviation and automobile gasolines, winter and summer diesel fuels and jet fuels. Fuel oil outcome according to this option is minimized. Consequently, we provided such a set of secondary refining processes, according to which high-quality motor oils (gasoline, diesel fuel, air-jet fuel) are produced from heavy oil fractions and tar residual. This set includes catalytic processes – catalytic cracking, catalytic reforming, hydrocracking and hydrofining. Artificial gases reprocessing in his case is aimed at high-quality gasolines and liquefied gases outcome increase.

The key result of this work is the substantiation of the maximally efficient Iraq oil refining option with the choice of optimal refining installations number. Refining depth according to the proposed technological flowchart of ORE is about 94 %.

Results of this work based on the previous research of oils and their fractions physical and chemical properties formulate a significant reason for the statement about economic efficiency of the fuel option of Iraq oils refining. It was confirmed by pay-back period and profitability of 3.5-year and 30 %, respectively.

In addition, this work formulates required and sufficient conditions for further technological ORE flowcharts improvement.

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УДОСКОНАЛЕННЯ ТЕХНОЛОГІЧНОЇ СХЕМИ ПЕРЕРОБКИ ІРАКСЬКИХ НАФТ

Анотація. *Розроблено технологічну схему переробки нафти, видобутої в Іраку, з врахуванням основних характеристик та фізико-хімічних особливостей цих нафт. Описано основні етапи процесів переробки нафти, а також розраховано матеріальні баланси кожної стадії процесу.*

Ключові слова*: нафта, нафтопереробка, технологічна схема, дистиляція, бензин, дизельне паливо, паливо для реактивних двигунів, матеріальний баланс.*