Increasing production of gasoline and diesel fuel in medium and small refineries to meet the needs of Iraqi market

Dr.Aed Jaber Imran*, Dr.Adnan Abdul jabbar**
*Ministry of oil, **Chemical Engineering, UOT, Baghdad

Abstract

Iraq is considered one of the countries exporters of oil in the world, but the output of motors fuels from the refined crude oil less than (45 wt %), which is associated with the lack of Iraqi refineries with secondary processes.

Iraq consist of five big capacity crude oil refineries which include (atmospheric crude distillation, hydrotreating, catalytic reforming and isomerization) and produce high quality motors fuel, in addition five medium and five small in capacity crude oil refineries include only atmospheric crude distillation which produce low quality raw products (light and heavy naphtha, light gasoil and reduced crude).

The total capacity of Iraqi oil in the last years changed from 28 to 35 million ton/year. Most of our refineries include old equipment, but in spite of the annual maintenance for these refineries the motor fuels products could not able to cover all the Iraqi requirements of motor fuels 27 million ton/year.

In these refineries produce reduced crude (fuel oil) in large quantity and because of this, Iraq imports gasoline fuel (30 wt%) of its requirements and LPG (17 wt%) of its requirements.

This situation impose on us to increase the output products quantity from the Iraqi crude oil by development the medium and small capacity refineries via installation thermal processes units instead of vacuum distillation units, by this actual research we will find that the deep of refinery will increase from 54 to 70 wt%, and production of motor fuel will change from 45 to 68 wt%.

Purpose of the work: development of the flowchart which is applied in Iraqi small capacity refineries (1.3 – 1.4 million Ton/year) by installation thermal cracking units to produce maximum allowable yield and quality of motors fuels.

This research depends on actual experiments which are done by me in Ufa state petroleum technological university on actual crude oil and reduced crude brought from Iraqi's refineries from the oil fields Basrah (Zubair) and Kirkuk.

Keywords: Delayed coking; coke; diesel fraction; gasoline fraction; thermal cracking; vacuum residue; hydrotreating; catalytic reforming and isomerization.

Thermal cracking units

Thermal cracking processes are the true work horses of the oil refining industry. The processes are relatively cheap when compared with the fluid cracker and the hydrocracker but go a long way to achieving the heavy oil cracking objective of converting low quality material into more valuable oil products. The process family
of thermal crackers has three members, which are:

- Thermal crackers.
- Visbreakers.
- Cokers or 'Delayed Coking'.

With the continuous depletion in world oil reserves and increasing demand of petroleum products, the refiners are forced to process more and heavier crude [1]. The cost advantage of heavy crudes over light crudes has incentivized many Indian Refineries to process heavier crude, therefore increasing the heavy residue produced at a time when fuel oil demand is declining [2]. In order to dovetail both the requirement for processing crude oil of deteriorating quality and enhancing distillates of improved quality, technological upgradation have been carried out at refineries which takes care of processing heavy crudes as well as maximizing value added products and stringent product quality requirements [3].

Cracking of heavy residue is most commonly used method for upgradation of residues. This involves of decomposition of heavy residues by exposure to extreme temperatures in thepresence or absence of catalysts.

Thermal cracking: Cracking at elevated temperatures in the absence of catalyst eg:Visbreaking, delayed coking, Fluid coking etc.

Thermal cracking process for upgradation of heavy residue has been used since long and still it isplaying an important role in the modern refinery through upgradation of heavy residue andimproving the economics of the refinery through the production of lighter distillate and othervaluable product like low value fuel gas and petroleum coke. Although petroleum coke was firstmade by North Western Pennsylvanian the 1860's using cracking, however, a real breakthroughin the thermal cracking process was with development of the first cracker by William Burton andfirst used in 1913.Heavy residues are a mixture molecules consisting of an oil phase and anasphaltene phase in physical equilibrium with each other in colloidal form.

Experiments [4]:

In this workstudied the properties ofthe twoIraqi oilfields"Kirkuk" and Basrah "Zubair". The main characteristicsobtainedaccording tothe assays of these two oil fields.

Table (1) physical-chemical properties of the Iraqi crude oils

Properties	Oil field	
	Kirkuk	Zubair
1. Density at 15°C, Kg/m^3	844.3	855.9
2. Sulfur contents, %	1.9	2.1
3. Carbon residue, %	4.80	4.76
4. light oil products, Vol.%		
- Wet gas	2.49	2.10
- Fraction C_5 – 170°C	25.24	21.71
- Fraction 170 – 350°C	33.28	37.28
- Residue > 350°C	38.99	38.91

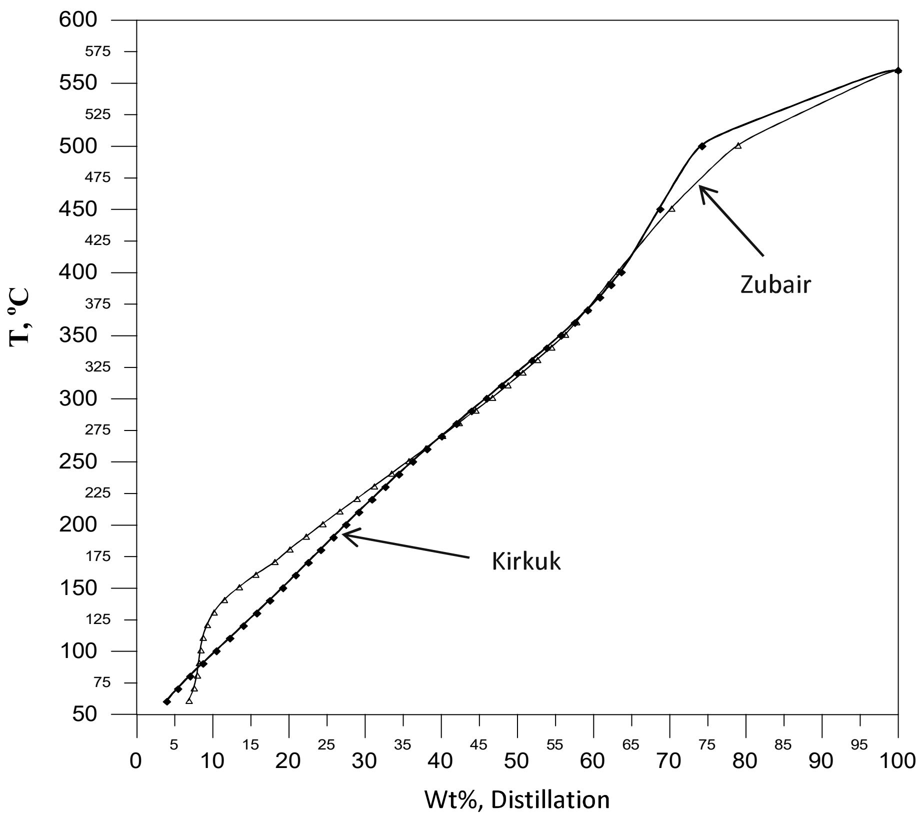


Table (2)material balance ofatmospheric crude distillation unit

Products	Oil field	
	Kirkuk	Zubair
Feed:crude oil, Wt%	100.00	100.00
Products:		
- C_1-C_2	1.18	1.38
- Gasoline fraction	23.08	18.71
- Diesel fraction	30.86	36.24
- Reduced crude	44.54	43.27
- Losses	0.40	0.40
Sum.	100.00	100.00

In table-3 are shown the quality specification of atmospheric crude distillation products.

Table (3) physical-chemical properties of atmospheric crude distillation products

Properties	Atmospheric crude distillation products			
	Kirkuk		Zubair	
	Gasoline fraction	Diesel fraction	Gasoline fraction	Diesel fraction
1. Density at 20°C, Kg/m^3	714.6	832.5	712.1	814.0
2. Contents, wt%.				
- sulfur	0.07	0.64	0.01	0.67
- N_2	0.0017	0.012	0.0017	0.012
3. Cut point, °C	35-175	175-350	35-176	176-350
4. Cetane index	–	50	–	56

To determine the material balance of thermal cracking and delayed coking units we carried out experiments on pilot plants in Ufa state petroleum technological university and the oil sample was real reduced crude (fuel oil) from Basrah (Zubair) and Kirkuk crude oil [5].

Table(4)physical-chemical properties of the Iraqi reduced crude

Properties	Oil field	
	Kirkuk	Zubair
1. Density at 15°C, Kg/m^3	957.9	967.1
2. Contents, wt%.		
- sulfur	3.91	4.02
- vanadium	0.0058	0.0068
- nickel	0.0025	0.0012
3. Carbon residue, %	10.8	9.7
4. Viscosity at 50°C, cSt	478	423

Thermal cracking process experiments are carried out in pilot plant, oil sample in case of Thermal Cracking was heated to 430 ^{o}C and for 8 minutes under 0.8 MPa, and in case of Delayed Coking oil sample was heated to 460-470 ^{o}C for 2.5 hr, during these experiments we have got the following results:

Table (5) material balance of thermal cracking unit

Feed: Reduced crude, Wt%.	100.00
Products:	
- wet gas	4.1
- gasoline fraction	12.3
- diesel fraction	24.8
- cracking residue	58.4
- losses	0.4
Sum.	100.00

Table (6) material balance of delayed coking unit

Feed: Reduced crude, Wt%.	100.00
Products:	
- wet gas	11.1
- gasoline fraction	8.9
- diesel fraction	33.4
- gasoil fraction	28.8
- coke	16.3
- losses	1.5
Sum.	100.00

In table-7 are shown the quality specification of thermal cracking and delayed coking products.

Table(7) physical-chemical properties ofthermal cracking and delayed coking products

Properties	Thermal cracking products		Delayed coking products	
	Gasoline fraction	Diesel fraction	Gasoline fraction	Diesel fraction
1. Density at 20°C, Kg/m^3	774.7	876	772.1	867.8
2. Contents, wt%.				
- sulfur	1.13	2.69	1.02	2.49
- N_2	0.046	0.059	0.040	0.062
3. Iodine number, g I_2/100g	58.7	25.5	77.5	35.6
4. Cut point, °C	37-187	184-345	31-183	180-351
5. Cetane index	–	45	–	44

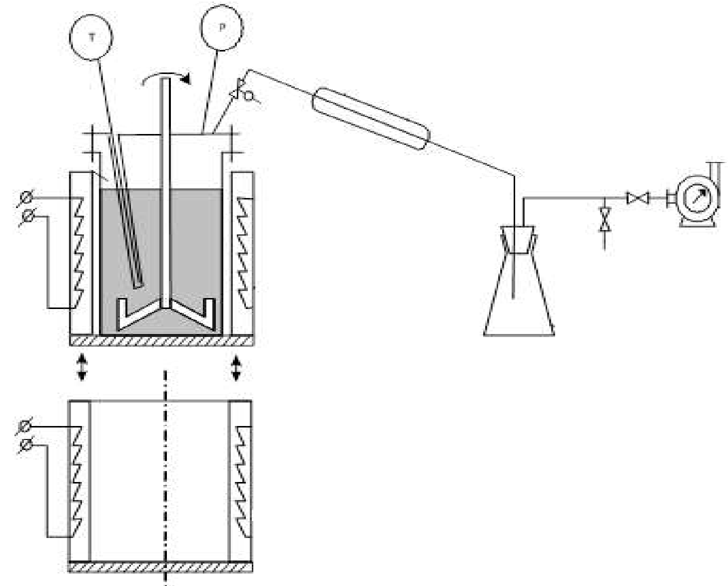


Fig.(1) Thermal cracking pilot plants

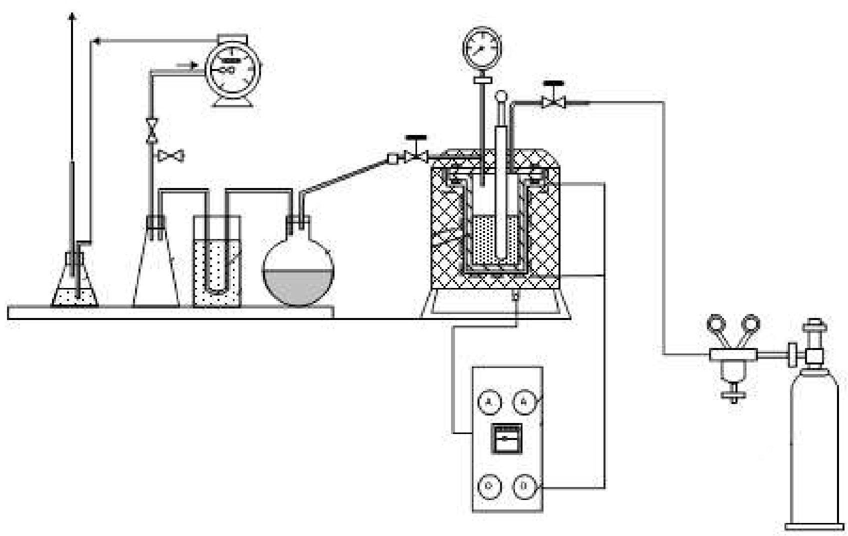


Fig.(2)Delayed coking pilot plants

Gasoline fraction produced from atmospheric distillation consist of mainly saturated hydrocarbons, aromatics (10-11%) and (24%) naphthenes in Kirkuk crude oil and (19%) in Zubair crude oil.

Gasoline fraction produced from thermal processes consist of olefins (31-32%), paraffines (41-42%), naphthenes (13-14%) and (13%) aromatics.

Diesel fraction produced from thermal processes consist of (14-15%) olefins, (20%) aromatics and (65-66%) paraffin-naphthen hydrocarbons.

Heavy gasoil fractionproducedfrom delayed coking reduced crude possess the following physical properties: density at 20°C – 958.6 Kg/m^3, sulfur 2.7%, viscosity at 80°C – 10.5 cSt, flash point – 182°C.

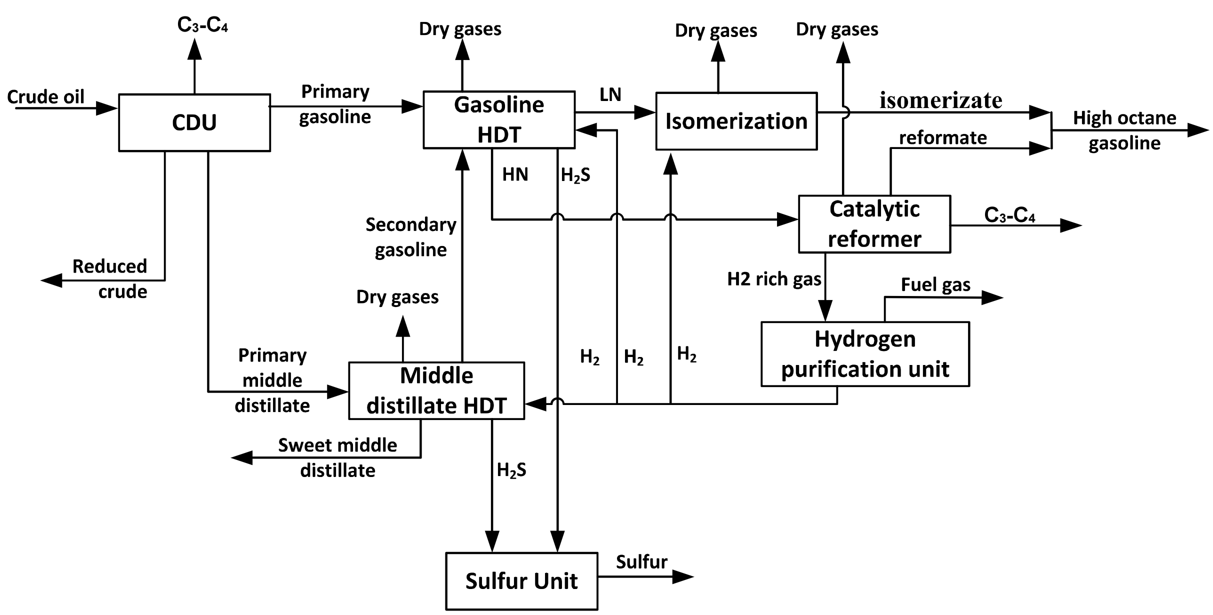
Cracking Residueproducedfrom thermal cracking reduced crude possess the following physical properties: density at 20°C – 989 Kg/m^3, sulfur 4.5%, viscosity at 80°C – 57 cSt, flash point – 225°C.

Cokeproducedfrom delayed coking reduced crude possess the following physical properties: light hydrocarbons – 7.7%, sulfur 4.48%, vanadium – 0.039%, Nickel – 0.007%, Ash – 0.44%.

In order to develop the flowchart which is applied in Iraqi small or medium capacity refineries (1.3 – 1.4 million Ton/year) we suggest installation the following thermal cracking process units to produce maximum allowable yield and quality of motors fuels and make comparison between these two processes and the existing flowchart.

1. Without thermal cracking process (*Base flowchart*).
2. With liquid phase thermal cracking unit.
3. With delayed coking unit.

The three suggested flowcharts are presented below in figures (2 – 4).



Fig(3) Refinery flowchart without thermal cracking process (Base flowchart)

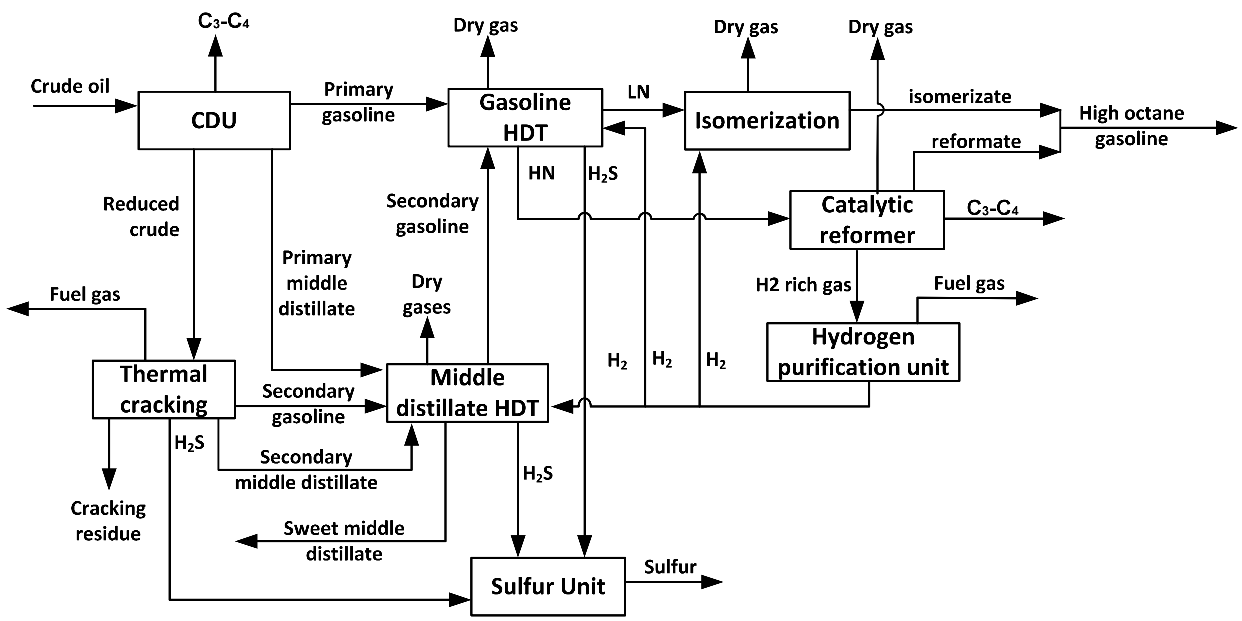


Fig. (4) Refinery flowchart with thermal cracking process

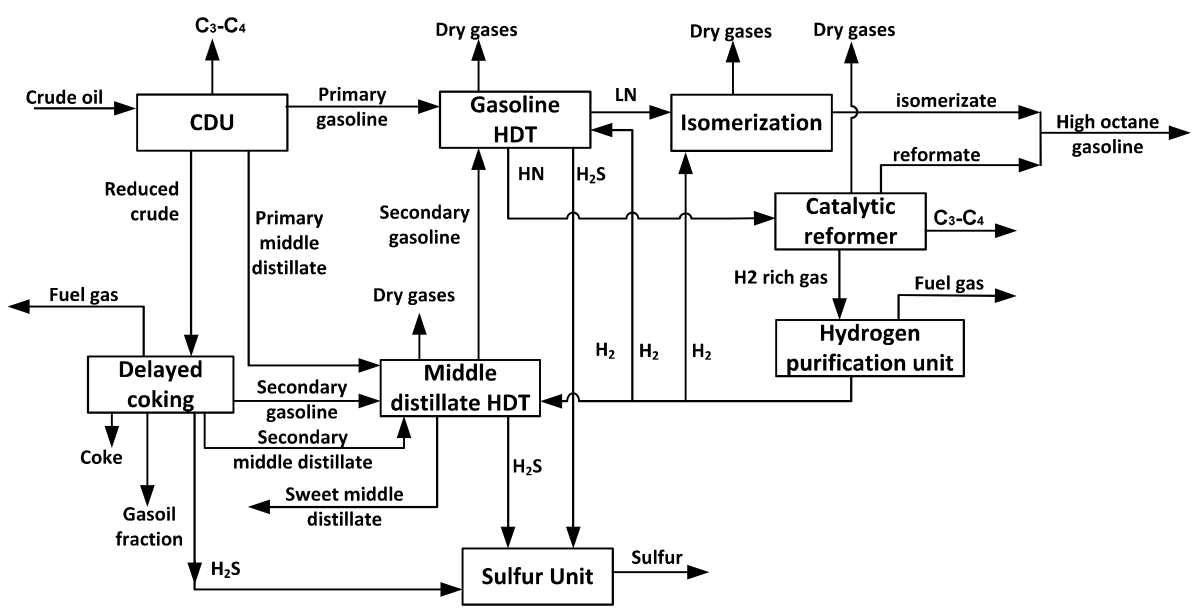


Fig.(5) Refinery flowchart with delayed coking process

Weevaluatedresources ofhydrogen producedbythe catalyticreforming(via block hydrogen purification unit) and the hydrogen requiredforthe isomerizationandhydrotreatingunits (HPU).

The evaluation resultsshowed that the produced hydrogen will be enough for the serefineries with percent of excess.

Table (8) Quantity of hydrogen (100%) released from catalyticreforming unit (via block hydrogen purification unit), Thousand ton/year

Variable	Kirkuk crude oil			Zubair crude oil		
	Base flowchart	Withthermalcracking	With delayed coking	Base flowchart	Withthermalcracking	With delayed coking
H_2 from cat. Reforming via (HPU).	4.61	5.17	5.41	3.69	4.43	4.64
Theoretical H_2 required for HDT middle distillate.	1.33	3.02	3.07	1.31	2.94	3.03
HDT mid. distills.	0.86	2.46	2.52	0.99	2.54	2.63
HDT of gasoline.	0.26	0.31	0.31	0.20	0.24	0.25
Isomerization	0.21	0.25	0.24	0.12	0.16	0.15
Excess of H_2	3.28	2.15	2.34	2.38	1.49	1.62

As a result of technological calculations of these three choices we get the following material balance for Kirkuk and Zubair crude oil which are tabulated below.

Table (9) Quantity of products in case of Kirkuk crude oil

Products	Base flowchart (Fig. 3)		With thermal cracking (Fig. 4)		With delayed coking (Fig. 5)	
	Thousand ton/year	Wt%	Thousand ton/year	Wt%	Thousand ton/year	Wt%
1. Crude oil (input)	1350.00	100.00	1350.00	100.00	1350.00	100.00
2. products (output)						
- Gasoline	277.35	20.40	321.21	23.79	323.11	23.93
- Diesel fuel	405.87	30.08	572.05	42.37	600.57	44.49
- LPG	25.61	1.96	27.99	2.07	28.21	2.09
- Fuel oil	601.29	44.54	351.15	26.01	171.37	12.69
- Coke	–	–	–	–	99.84	7.39
- Sulfur	4.73	0.35	11.20	0.83	16.54	1.23
- C_1 - C_2	9.37	0.69	10.86	0.81	11.01	0.82
- Fuel gas	17.57	1.30	41.71	3.09	78.34	5.80
- Sum.	1313.82	97.33	1283.60	95.07	1239.16	91.82
3. Losses	9.24	0.68	13.83	1.03	21.04	1.56
4. Losses + Fuel gas	36.18	2.67	66.40	4.91	110.39	8.18
5. Deep of refining	–	52.78	–	**69.07**	–	**79.12**
6. yield of motor fuel	–	50.47	–	**66.17**	–	**68.42**

Table(10) Quantity of products in case of Zubair crude oil

Products	Base flowchart (Fig. 3)		With thermal cracking (Fig. 4)		With delayed coking (Fig. 5)	
	Thousand ton/year	Wt%	Thousand ton/year		Thousand ton/year	Wt%
1. Crude oil (input)	1350.00	100.00	1350.00	100.00	1350.00	100.00
2. products (output)						
- Gasoline	223.47	16.55	279.41	20.70	281.39	20.84
- Diesel fuel	475.42	35.22	623.74	46.21	650.75	48.20
- LPG	27.75	2.06	29.87	2.21	30.46	2.23
- Fuel oil	584.15	43.27	341.14	25.27	165.90	12.29
- Coke	–	–	–	–	97.54	7.23
- Sulfur	5.37	0.40	11.52	0.85	16.96	1.25
- C_1 - C_2	8.85	0.66	10.39	0.77	10.76	0.80
- Fuel gas	15.65	1.16	40.11	2.97	75.79	5.61
- Sum.	1316.16	97.50	1285.68	95.24	1242.68	92.05
3. Losses	9.34	0.68	13.82	1.02	20.77	1.54
4. Losses + Fuel gas	33.84	2.50	64.32	4.76	107.32	7.95
5. Deep of refining	–	54.22	–	**69.97**	–	**79.76**
6. yield of motor fuel	–	51.77	–	**66.90**	–	**69.05**

Table (11) Expected quality of motor fuels produced by the suggested flowcharts

Expected quality	Kirkuk crude oil	Zubair crude oil
Gasoline		
Research Octane No.	93.8	94.1
Benzene content	2.36%	2.52%
Aromatics content	49.6%	52.5%
Diesel fuel		
Cetane index	53	55
Sulfur content, Wt%	0.0040%	0.0045%
Polycyclic aromatic hydrocarbon	3.1%	3.3%
Pour point	- 10°C	- 11°C

Conclusions

1. The lowestannual incomeis achieved byimplementing flowchart presented in fig-3 gives the lowest depth of crude oil processing (52.8-54.2%) when theoil refinerynot consists ofsecondary processes (liquid-phasethermal cracking or delayed coking).
2. The highestannual incomeis achieved byimplementing flowchart presented in fig-4 gives the depth of crude oil processing (69 – 70%) when theoil refineryincludesin the flowchart secondary processes (liquid-phasethermal cracking).
3. Choice flowchart presented in fig-5 gives the depth of crude oil processing (70-80%) which consist delayed coking unit instead of liquid-phase thermal cracking unit and gives

the maximum yield, but because of the high quantity of the produced fuel gas and low price of coke due to high quantity of sulfur make this choice unpreferable in spite of the high deep refining reach (80%).

4. Technical andeconomic performance ofrefineries in case of using (liquid-phase thermal cracking) are preferable in comparison with refineries consist of delayed coking, in both profitability and payback periodof capitalinvestment(2–2.5years).
5. Hydrogen producedbythe catalyticreforming(via block hydrogen purification unit) covers the hydrogen demandsfor isomerizationandhydrotreatingunitswith a sufficientexcess.
6. Installation secondary processes in Iraqi medium refineries will ensure production of gasoline fuel grade Euro-2 with octane number (93 – 94) and benzene content (2.3 – 2.5%). Diesel fuel grade Euro-4 with a cetane index (52 – 55), sulfur content (40 – 45 ppm) and polycyclicaromatichydrocarbons inthe rangeof (3.1 – 3.3%).

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