



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
17.02.2010 Bulletin 2010/07

(51) Int Cl.:
C10G 69/04 (2006.01) C10G 65/12 (2006.01)
C10G 69/14 (2006.01)

(21) Application number: **08161022.2**

(22) Date of filing: **23.07.2008**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

- **Rashidzadeh, Mehdi**
16947-39114, Tehran (IR)
- **Rashtchi, Maryam**
Tehran (IR)
- **Zarkesh, Jamshid**
Teheran (IR)
- **Farshi, Amir**
14786-35893, Tehran (IR)
- **Masoudian Targhi, Seyed Kamal**
Teheran (IR)

(71) Applicant: **Research Institute of Petroleum Industry (RIPI)**
18799 Tehran (IR)

- (72) Inventors:
- **Sadighi, Sepehr**
Tehran (IR)
 - **Seif Mohaddecy, Seyed Reza**
Tehran (IR)
 - **Bahmani, Majid**
Tehran (IR)

(74) Representative: **2K Patentanwälte Blasberg Kewitz & Reichel Partnerschaft**
Corneliusstraße 18
60325 Frankfurt am Main (DE)

(54) **An integrated process for the conversion of heavy hydrocarbons to a light distillate and/or mid-distillate**

(57) The invention relates to an integrated process for the conversion of heavy hydrocarbons to a light distillate and/or mid-distillate such as diesel or kerosene, including a catalytic cracking, hydrocracking and hydroconversion stage.

In the process the heavy hydroconversion products (3; 16) of the hydroconversion unit (25) are recycled to the hydrocracking unit (4) or both to the hydrocracking unit (4) and to the catalytic cracking unit (17). Furthermore, at least a portion (13) of a first residue (12) of heavy

hydrocarbons from the hydrocracking unit is recycled to the hydroconversion unit (25).

By changing the ratio of the recycling streams (3; 16) of heavy hydroconversion products of the hydroconversion unit to the catalytic cracking unit (17) and to the hydrocracking unit (4), one can adjust the amount of the gasoline or diesel production.

A portion (2) of a first residue of heavy hydrocarbons of the hydrocracking unit can be fed to the hydrocracking unit (4) and the rest (14; 13) can be fed to the catalytic cracking unit (17) and/or to the hydroconversion (25).

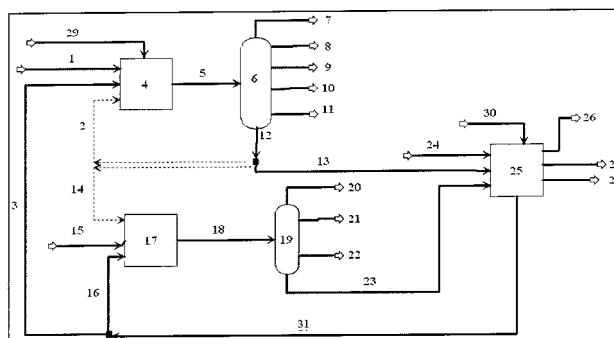


Fig. 1

Description

Field of the invention

[0001] The invention generally relates to the upgrading of residues of heavy hydrocarbon residues and relates in particular to an integrated process including catalytic cracking, hydrocracking and hydroconversion in order to convert a wide range of heavy hydrocarbons such as crude oil, the residues of atmospheric and vacuum distillation, asphaltene, coking heavy oil, visbreaking, natural bitumen, and sand oils to more valuable products like diesel and/or kerosene.

Background

[0002] Advances in the automotive industry and the extensive use of gasoline or diesel combustion engines, have increased the demand for processes for conversion of heavy hydrocarbon feedstocks to mid-distillate products, especially to gasoline and diesel of low sulfur content.

[0003] Due to the high cost of low-sulfur gasoline and diesel and the reduced consumption of heavy refinery products, processes for the conversion of heavy hydrocarbon feedstocks are both essential and economical, and hence, many efforts have been made to change a heavy oil feedstock to lighter products through the integration of upgrading processes.

[0004] US patent No. 3,891,538 discloses an integrated hydrocarbon conversion process, in which a crude oil feedstock is first desulfurized before entering a distillation tower. The fraction with the boiling point in the range between 344°C and 538°C enters a catalytic cracking process and the bottom flow of the catalytic cracking unit is sent to a coking unit. Application of the coking process, in this process, yields gasoline of high sulfur content. Furthermore, a fraction of the product is converted to coke, reducing the efficiency of the process.

[0005] US patent No. 3,072,560 discloses a process for the integration of coking, hydrocracking, catalytic cracking and reforming units to convert the heavy residues of atmospheric distillation to gasoline, in which, as a result of the presence of the coking unit, the yield is low and the product has a high sulfur content.

[0006] The process disclosed in US patent No. 3,983,029 includes the integration of the hydrocracking, reforming and catalytic cracking units according to which the outlet of the hydrocracking process is sent to the catalytic cracking unit. A fraction of the same stream is returned to the hydrocracking unit and the naphtha of the hydrocracking unit is sent to the reforming unit. The outlet of this process still contains heavy residues.

[0007] The process disclosed in US patent No. 4,354,922 includes the integration of the processes of catalytic cracking of heavy hydrocarbons without hydrogen, hydroconversion and solvent separations. In this process, the outlet of the hydroconversion together with

the heavy hydrocarbon feedstock is purified and then sent to the hydroconversion, distillation and the catalytic cracking unit. This process requires several steps and operating apparatus for the preparation of the catalytic cracking feedstock and the purification of heavy stream. The heavy hydroconversion stream is recycled indirectly to the catalytic cracking process, according to this integrated process. The process has, however, a high sulfur diesel yield and there is no control on production of gasoline and diesel.

[0008] US patent No. 4,426,276 discloses an integrated combination of fluid catalytic cracking with hydrocracking to produce gasoline and to optimize hydrogen consumption. In this process the species, heavier than mid-distillates, are separated from the hydrocracking products and are returned to the catalytic cracking unit. The naphtha fractions of the distillation tower, the catalytic cracking and hydrocracking are converted to gasoline through reforming and alkylation. The products of the process comprise refinery gases, gasoline, and mid-distillates. However a portion of the feed, remains as a slurry and fuel oil.

[0009] US patent No. 5,026,472 discloses the integration of hydrocracking and hydrogenation units. Heavy (high boiling) hydrocarbons are converted to mid-distillates like kerosene and jet fuel in the hydrogenation reactor. However, during the process, some of the feedstock is converted to fuel oil and other high-boiling point residues, reducing the overall yield of the process.

[0010] The process disclosed in US patent No. 6,123,830, is on the integration of catalytic cracking and hydro-processing processes. Although this process aims at maximizing the olefin yield, the octane number of the cracking products and also the quality of mid-distillates, some heavy (high boiling) products are also yielded.

Summary of the invention

[0011] It is an object of the present invention to provide a process which enables a highly efficient and economical conversion of heavy hydrocarbons to light distillates and/or mid-distillates.

[0012] The above and further objects are accomplished by a in integrated process according to claim 1. Further advantageous embodiments are the subject-matter of the dependent claims.

[0013] According to the present invention the processes of hydroconversion, hydrocracking and catalytic cracking are integrated. According to the subject matters of the present invention all of the heavy products (where heavy means heavier than the diesel fraction) are returned to the catalytic cracking, hydrocracking and hydroconversion units to produce lighter products. Thus, according to the present invention the yield of heavy hydrocarbons can be minimized to approach or even reach zero. In addition, the subject matter of the present invention leads to an increase in the production of mid-distillate products as well. According to the present invention, the

yields of gasoline and/or diesel products can be adjusted to increase or decrease as desired, simply by varying the ratio the ratio of the recycling stream of heavy hydroconversion products of the hydroconversion unit to the catalytic cracking unit to the recycling stream of heavy hydroconversion products of the hydroconversion unit to the hydrocracking unit.

[0014] According to the present invention there is provided an integrated process for the conversion of heavy hydrocarbons to a light distillate and/or mid-distillate, comprising the steps of: a) Hydrocracking of a feedstock of heavy hydrocarbons in a hydrocracking unit; b) Distillation of the products of the hydrocracking unit from step a) to produce a first residue of heavy hydrocarbons; c) Catalytic cracking of a feedstock of heavy hydrocarbons in a catalytic cracking unit; d) Distillation of the products of the catalytic cracking unit from step c) to produce a second residue of heavy hydrocarbons; e) Hydroconversion of the second residue of heavy hydrocarbons from step d) with or without the addition of heavy hydrocarbons in a hydroconversion unit; f) Recycling the heavy hydroconversion products of the hydroconversion unit from step e) to the hydrocracking unit in step a) or both to the hydrocracking unit in step a) and to the catalytic cracking unit in step c); and g) Feeding (recycling) at least a portion of the first residue of heavy hydrocarbons from step b) to the hydroconversion unit in step e).

[0015] The feedstock of heavy hydrocarbons to the hydrocracking process or unit is one or a mixture of fractions of light and vacuum gas oil, coking gas oil and visbreaking, the boiling point of which is in the range between 260°C and 590°C and preferably in the range between 285°C and 520°C.

[0016] The hydrocracking in the present invention can be one of the conventional processes known to the person skilled in the art.

[0017] In the hydrocracking unit or process, heavy fractions are converted to more valuable products like naphtha, kerosene, diesel and LPG (liquefied petroleum gases). By choosing the proper reactor (hydrocracking) conditions and using proper catalysts one can increase the selectivity of the process towards mid-distillates or naphtha. Cracking of the heavy fractions to lighter compounds occurs under high pressure and in the presence of hydrogen and a suitable catalyst.

[0018] In a process according to this invention, the hydrocracking of heavy oil fractions can be performed at temperatures in the range between 340°C and 400°C, at a space velocity in the range between 0.6 h⁻¹ and 1.3 h⁻¹ and at a pressure in the range between 30 bar and 200 bar. The present invention can be used in the case of any common hydrocracking catalysts.

[0019] The feedstock of the catalytic cracking process is a fraction or mixture of fractions of light or heavy vacuum gas oil, and vacuum heavy slops, atmospheric residues, coking and visbreaking gas oil or desulfurized or demetalized fractions. The boiling point of the feedstock mixture is in the range between 240°C and 620°C and

higher, and preferably in the range between 265°C and 595°C.

[0020] The invention can use different common catalytic hydroconversion processes.

5 **[0021]** In the catalytic cracking unit, heavy oil fractions are cracked in contact with small catalyst particles and are converted to lighter compounds.

10 **[0022]** All hydroconversion processes in which the boiling point of the heaviest products is at most 620°C, and preferably hydroconversion processes which do not undergo coking which satisfy the above mentioned boiling point requirement can be used in the process according to the present invention. In case the process undergoes coking, the heavy product is de-coked before entering the hydrocracking unit or before entering both the catalytic-cracking and hydrocracking unit. In addition to the heavy products of the distillation tower after the catalytic cracking, one or a combination of heavy hydrocarbon streams such as crude oil, atmospheric and vacuum residues, asphaltene, heavy coking and visbreaking gas oil, natural bitumen and sand oils can be used as the hydroconversion feed.

20 **[0023]** All common hydroconversion processes can be used according to the present invention such as the disclosed processes in patents US 6,004,454, US 7,214,309, EP 1 754 770 A1 and US 7,238,273 the whole contents of which are hereby incorporated.

30 **[0024]** According to the present invention, the heavy hydrocarbon products of the hydroconversion unit from step e), which are heavier than diesel (of the single distillation unit or from the plural distillation units downstream of the hydroconversion reactor), are recycled to the hydrocracking unit or both to the catalytic cracking unit and to the hydrocracking unit. By changing the ratio of the recycling stream of heavy hydroconversion products of the hydroconversion unit from step e) to the catalytic cracking unit to the recycling stream of heavy hydroconversion products of the hydroconversion unit from step e) to the hydrocracking unit, one can adjust the amount of the gasoline or diesel production. This ratio can be in the range between 0 and 0.99, more preferably in the range between 0.1 and 0.3 and most preferably in the range between 0.13 and 0.16. An increase of the recycling stream to the hydrocracking unit(s) leads to an increase in the diesel yield while an increase of the recycling stream to the catalytic cracking unit(s) boosts the gasoline production yield.

45 **[0025]** According to another embodiment, a portion of the first residue of heavy hydrocarbons of the hydrocracking unit (from step b)) can be fed to the hydrocracking unit and the rest can be fed to the catalytic cracking unit and/or to the hydroconversion. According to the present invention, all of the heavy products (the entire first residue of heavy hydrocarbons) of the hydrocracking unit enter the hydrocracking unit and/or hydroconversion unit.

55 **[0026]** The term hydroconversion as used in this application generally refers to a form of hydrocracking in which hydrogenation and cracking occur simultaneously.

[0027] More specifically, a hydroconversion process in the sense of this application may be a catalytic hydrocracking process for deep upgrading of heavy residues/ heavy crude oil with the purpose of maximizing distillates. The main objective of this process is the breakup of high molecular hydrocarbons in order to obtain light and medium molecular hydrocarbon. This process is one of the most effective methods of getting light products through deep upgrading of heavy residues.

[0028] In an exemplary hydroconversion process two types of reactions, namely, cracking and mild hydrogenation may occur simultaneously.

[0029] In a typical hydroconversion process the hydrogen, feed and the catalytic complex are heated separately. Then feed and the catalytic complex are mixed and heated again. Finally, the mixture of feed, catalytic complex and hydrogen are heated and entered into a reactor where heavy residue feed is cracked and hydrogenated. Outlet gas products from the top of the reactor are condensed and separated. In the first stage of separation, unreacted hydrogen and light hydrocarbon can be separated, treated e.g. in an amine contactor and recycled to the system by a compressor. In the second stage, off gas can be separated, treated e.g. in amine contactor and conducted to the flare system. After separation, liquid products are fractionated by distillation.

Brief Description of Drawings

[0030] In the following, the invention will be described in an exemplary manner and with reference to the accompanying drawings, from which further features, advantages and problems to be solved may be derived by a person skilled in the art, and wherein:

Figure 1 illustrates the overall diagram of the process according to the present invention.

Detailed description of an embodiment according to the invention

[0031] As shown in Fig. 1, according to the present invention, the hydrocracking (HCR) feedstock 1 comprising one or a mixture of light or heavy vacuum gas oil, coking or visbreaking gas oil together with the recycling stream 3 of the hydroconversion unit 25 are sent to the HCR unit 4. The outlet 5 of the HCR (hydrocracking) reactor 4 is sent to the distillation tower 6 and is distilled to light gaseous products and LPG (liquefied petroleum gases) as indicated by reference numeral 7, light naphtha with a boiling point of at most 90°C as indicated by reference numeral 8, heavy naphtha with a boiling point range between 90°C and 160°C as indicated by reference numeral 9, kerosene with a boiling point in the range between 160 and 290°C as indicated by reference numeral 10, hydrocracking diesel with a boiling point in the range between 290°C and 390°C as indicated by reference numeral 11, and the HCR offset (residue) as indi-

cated by reference numeral 12 with a boiling point above 390°C.

[0032] The light and heavy naphtha produced (streams 8 and 9) can be sent to the isomerization and catalytic reforming units respectively (not shown), for quality improvement. Stream 12, i.e. the residue of the hydrocracking unit 4 with a boiling point range above 390°C, can be divided into two substreams 2 and 13 or optionally can be divided into three sub-streams 2, 13 and 14, in each case with adjustable ratios of the sub-streams. In Fig. 1, the substreams 2 and 14 are each indicated by a dashed line.

[0033] Preferably, the stream 12 is only divided into two sub-streams 2 and 13. In each of the afore-mentioned configurations, stream 2 is used as the hydrocracking feedstock, i.e. the feedstock to the hydrocracking unit 4, and stream 13 is fed to the hydroconversion unit 25. Furthermore, stream 14 (in case it is desired under the specific operating conditions) can be fed to the catalytic cracking unit 17. The branching ratio of the stream 12 into substreams 2 and 14 can be adjusted freely and can be set to zero even. In such a case, the stream 12 would be sent as a stream 13, i.e. a stream of the residue of the hydrocracking unit 4 with a boiling point range above 390°C, only to the hydroconversion unit 25, whereas streams 2 and 14 would not exist at all, as indicated by the dashed lines in Fig. 1.

[0034] The hydrocracking unit 4 can be operated with or without a recycling stream as feedstock. According to the present invention, all heavy products of the hydrocracking unit 4, i.e. the residue 12 of the hydrocracking unit 4, can be sent either to the hydroconversion unit 25 or to the hydroconversion unit 25 and to one or more catalytic-cracking unit 17.

[0035] The catalytic cracking (FCC) feedstock 15, i.e. the feedstock 15 to the catalytic cracking unit 17, comprises one or a mixture of the following products: atmospheric and vacuum residues, heavy or light atmospheric and vacuum gas oil, heavy vacuum slops and coking and visbreaking gas oil. Furthermore, the hydrocracking residue 14 and/or the recycling stream 16 of the hydroconversion unit 25 can be fed to the catalytic cracking unit 17. According to the present invention, the ratio of the recycling stream 16 from the hydroconversion unit 25, which is fed to the catalytic cracking unit 17, to the recycling stream 3 from the hydroconversion unit 25, which is fed to the hydrocracking unit 4, can be adjusted freely to be in the range between 0 and 0.99, more preferably in the range between 0.1 and 0.3 and most preferably in the range between 0.13 and 0.16.

[0036] The products 18 of the catalytic cracking unit 17 are sent to the distillation tower 19. The output of this distillation tower 19 consists of light products, liquefied petroleum gases (LPG) as indicated by reference numeral 20, catalytic cracking gasoline with boiling points of less than 180°C as indicated by reference numeral 21, mid-distillates or light cycle oil (LCO) with a boiling point in the range between 180°C and 370°C as indicated by

reference numeral 22 and a heavy product as indicated by reference numeral 23 which consists mainly of clarified cycle oil (CSO) with a boiling point above 370°C. Kerosene and diesel are produced from LCO 22 after its desulphurization and distillation.

[0037] Stream 23, i.e. the heavy products with a boiling point above 370°C, can be sent to the hydroconversion unit 25 together with a stream of one or a mixture of crude oil, heavy residues of refineries like the heavy residue of the coking unit or visbreaking, residues of atmospheric or vacuum towers, residues of the asphaltene or other thermo-cracking units, natural bitumen and sand oils (which stream is indicated by reference numeral 24 in Fig. 1), together with un-cracked substances 13 of the hydrocracking unit 4. The outlet of the distillation units of the hydroconversion unit 25 includes light products and LPG as indicated by reference numeral 26, hydroconversion gasoline with a boiling point of less than 180°C as indicated by reference numeral 27, hydroconversion diesel with a boiling range between 180°C and 370°C as indicated by reference numeral 28 and heavy hydroconversion product with a boiling point above 370°C as indicated by reference numeral 31. The heavy hydroconversion product 31 of the hydroconversion unit 25 is recycled as a feedstock 16 to the catalytic cracking unit 17 and/or as a feedstock 3 to the hydrocracking unit 4.

[0038] Streams 29 and 30 supply the hydrogen required by the hydrocracking unit 4 and hydroconversion unit 25, respectively. According to the process shown in Fig. 1, the stream 3, which is recycled to the hydrocracking unit 4, leads to increases in the diesel production yield and the yield of products heavier than diesel approaches zero. By changing the ratio of the recycling stream 3, which is fed to the hydrocracking unit 4, to the recycling stream 16, which is fed to the catalytic cracking unit 17, the yields of the products can be changed in favor of diesel or gasoline as desired.

[0039] The following examples illustrate representative teachings of features of the present invention. It is noted, however, that such examples should not be construed as being exclusive embodiments. All examples refer to a process plant as shown in Fig. 1.

Example 1

[0040] Vacuum gas oil (VGO) entered the hydrocracking unit containing a nickel-molybdenum catalyst with a rate of 240,900 bbl/day as the feedstock and it was cracked in the presence of H₂ gas at the temperature and pressure of about 380°C and 194 bar, respectively. The hydrocracking unit had two four bed reactors, the total catalyst weight on which was 67 Tons. About 131,500 bbl/day of the cracking offset (residue) was remixed with the new feedstock (fresh VGO) and returned to the hydrocracking reactor.

[0041] The specifications of the hydrocracking product are shown in table 1.

Table 1- The products of the hydrocracking in example 1

Product Rate		
L.Naphta	bbl/day	1,733
H.Naphta	bbl/day	3,079
Kerosene	bbl/day	10,110
Diesel	bbl/day	11,370
OffTest	bbl/day	674.3

[0042] In Table 1, L.Naphta stands for light naphta, whereas H.Naphta stands for heavy. Light vacuum gas oil (LVGO), heavy vacuum slops (HVS), the atmospheric residue and heavy atmospheric gas oil (HGO), each having rates of 10,430 bbl/day, 9,568 bbl/day, 60,860 bbl/day and 5,344 bbl/day respectively, were mixed to yield the catalytic cracking feedstock with a rate of 86,200 bbl/day. The feedstock had a specific density of 0.94, a sulfur content of 1 wt%, a (Ni + V) content of about 14.723 ppm (wt) and a boiling point in the range between 264.5°C and 592.6°C. The catalytic cracking reactions occurred in the presence of a USY catalyst (zeolite catalyst of ultra-stable Y-type) in an amount of 300 tons, at a temperature of about 525 °C and at a pressure of about 11bar. The feedstock was converted to lighter products according to table 2.

Table 2- The products of the catalytic cracking of example 1

Product Rates		
FRCG (Gasoline)	bbl/day	42,810
LCO	bbl/day	27,480
CSO	bbl/day	8,951

[0043] All CSO (clarified cycle oil) and offset material (heavy products of the catalytic cracking unit and heavy products of the hydrocracking unit) were sent to the hydroconversion unit in accordance with the teaching of European patent application EP 1 754 770 A1 of the applicant, the whole content of which is hereby incorporated by reference. The catalyst used in this unit was an aqueous molybdenum -ammonium catalyst. The products of this step are summarized in table 3.

Table 3- The hydroconversion products of example 1

Product Rates		
Gasoline	bbl/day	2,326
Diesel	bbl/day	4,535

(continued)

Product Rates		
Heavier than diesel	bbl/day	2,914

[0044] The total gasoline produced according to the afore-mentioned process, which is a mixture of light and heavy naphtha, and fluid catalytic cracking and hydro-conversion gasoline, is 49,948 bbl/day and the total (hydrocracking and hydroconversion) diesel equals 15,905 bbl/day. In this case, in the hydroconversion unit, approximately 2,914 bbl/day uncracked hydrocarbon (heavier than diesel) is produced.

Example 2

[0045] Under identical operating conditions as example 1 for the hydrocracking unit, catalytic cracking unit and hydroconversion unit, the heavy outlet stream of the hydroconversion unit was returned to the catalytic cracking unit, in order to stabilize the flow rate of the feedstock of the catalytic cracking unit, a fraction of the atmospheric residue of the catalytic cracking unit, namely about 5,051 bbl/day, was sent to the hydroconversion unit.

[0046] The products of the hydrocracking, catalytic cracking and hydroconversion units, under these conditions are summarized in tables 4 to 6 respectively.

Table 4- The hydrocracking products of example 2

Product Rate		
L.Naphtha	bbl/day	1,733
H.Naphtha	bbl/day	3,079
Kerosene	bbl/day	10,110
Diesel	bbl/day	11,370
OffTest	bbl/day	674.3

Table 5- The FCC products of example 2

Product Yields		
FRCG (Gasoline)	bbl/day	42,310
LCO	bbl/day	28,550
CSO	bbl/day	8,959

Table 6- The hydroconversion products of example 2

Product Rates		
Gasoline	bbl/day	3,547
Diesel	bbl/day	6,523

(continued)

Product Rates		
Heavier than diesel	bbl/day	5,040

[0047] The total gasoline and diesel in this example equals 50,669 bbl/day and 17,893 bbl/day which have totally increased by 4.15 % as compared to example 1, given that the feedstock and operating conditions are identical.

[0048] The heavy product (heavier than the mid-distillates) equals zero.

Example 3

[0049] In accordance with Fig. 1 and the teaching of the present invention, the process was performed under the same hydrocracking, catalytic cracking and hydro-conversion operating conditions as for example 1 and the heavy outlet of the hydroconversion unit was recycled as a recycling stream to the hydrocracking unit. In order to stabilize the flow rate of the feedstock of hydrocracking unit, an amount of about 5,709 bbl/day of the output of the hydrocracking unit was sent to the hydroconversion unit. The products of the hydrocracking unit, catalytic cracking unit and hydroconversion unit are summarized in tables 7 to 9 below.

Table 7- The hydrocracking products in example 3

Product Rate		
L.Naphtha	bbl/day	835.6
H.Naphtha	bbl/day	1,694
Kerosene	bbl/day	8,943
Diesel	bbl/day	12,710
OffTest	bbl/day	2,981

Table 8- The catalytic cracking products in example 3

Product Yields		
FRCG (Gasoline)	bbl/day	42,810
LCO	bbl/day	27,480
CSO	bbl/day	8,951

Table 9- The products of the hydroconversion unit in example 3

Product Rates		
Gasoline	bbl/day	4,087
Diesel	bbl/day	7,568

(continued)

Product Rates		
Heavier than diesel	bbl/day	6,257

[0050] The total gasoline and diesel produced according to this example and the teaching of the present invention are 49,426.6 bbl/day and 20,278 bbl/day, respectively, which represents an increase in total of about 5.84 % as compared to example 1. It is to be noted that this increase could be obtained under the same feedstock and operating conditions. The yield of the heavy product (heavier than the mid-distillates) equals zero.

Example 4

[0051] In accordance with Fig. 1 and the teaching of the present invention, the process was performed under the same hydrocracking, catalytic cracking and hydroconversion operating conditions as set forth for example 1 above, but with the following deviations:

- 85% of the heavy outlet of the hydroconversion unit was recycled and fed as a recycling stream to the hydrocracking unit; and
- 15% of the heavy outlet of the hydroconversion unit was recycled and fed as a fluid recycling stream to the catalytic cracking unit.

[0052] In order to stabilize the flow rate of the feedstocks, an amount of about 5,781 bbl/day of the fresh feed of the hydrocracking unit (VGO) and 1,826 bbl/day of the fresh feed of fluid catalytic unit (atmospheric residue) were sent to the hydroconversion unit. The products of the hydrocracking unit, catalytic cracking unit and hydroconversion unit are summarized in tables 10 to 12 below.

Table 10- The hydrocracking products in example 4

Product Rates		
L.Naphtha	bbl/day	881.2
H.Naphtha	bbl/day	1,831
Kerosene	bbl/day	8,976
Diesel	bbl/day	12,540
OffTest	bbl/day	2,536

Table 11- The catalytic cracking products in example 4

Product Rates		
FRCG (Gasoline)	bbl/day	41,990
LCO	bbl/day	27,430

(continued)

Product Rates		
CSO	bbl/day	2,013

Table 12- The products of the hydroconversion unit in example 4

Product Rates		
Gasoline	bbl/day	4,436
Diesel	bbl/day	8,142
Heavier than Diesel	bbl/day	6,943

[0053] The total gasoline and diesel produced according to this example and in accordance with the teaching of the present invention are 49,138.2 bbl/day and 20,682 bbl/day, respectively, which is an increase of the total output of about 6.02 % as compared to example 1. It is to be noted that this increase was achieved under the same feedstock and operating conditions. The yield of the heavy product (heavier than the mid-distillates) equals zero.

[0054] To summarize, the integrated process according to the present invention enables the complete conversion of heavy hydrocarbons to light products of at most diesel range. The yield of the integrated process according to the present invention is 100% for light gases, gasoline and mid-distillates. The integration of the catalytic cracking, hydrocracking and hydroconversion together with the application of recycled flows as set forth above leads to an increase in the yield of mid-distillate products as compared to the prior art. By changing the ratio of the recycling streams, the product yield of the integrated process can be switched to a higher gasoline or diesel output.

[0055] Another significant advantage of the integrated process according to the present invention is that gasoline and diesel with a low sulfur content can be produced in an efficient and economical manner.

[0056] Although the accompanying Fig. 1 shows only a single hydrocracking unit, hydroconversion unit and catalytic cracking unit, it will become apparent for a person skilled in the art that these individual units may also be replaced by a plurality of such units in a suitable interconnection. As will become apparent to a person skilled in the art when studying the above description, this application is also directed to a corresponding apparatus for the conversion of heavy hydrocarbons to a light distillate and/or mid-distillate, said apparatus being configured for carrying out the integrated process as set forth above.

Claims

1. An integrated process for the conversion of heavy hydrocarbons to a light distillate and/or mid-distillate, comprising the steps of:

a) Hydrocracking of a feedstock (1) of heavy hydrocarbons in a hydrocracking unit (4);
 b) Distillation of the products of the hydrocracking unit (4) from step a) to produce a first residue (12) of heavy hydrocarbons;
 c) Catalytic cracking of a feedstock (15) of heavy hydrocarbons in a catalytic cracking unit (17);
 d) Distillation of the products of the catalytic cracking unit (17) from step c) to produce a second residue (23) of heavy hydrocarbons;
 e) Hydroconversion of the second residue (23) of heavy hydrocarbons from step d) with or without the addition of heavy hydrocarbons in a hydroconversion unit (25);
 f) Recycling the heavy hydroconversion products (31; 3; 16) of the hydroconversion unit (25) from step e) to the hydrocracking unit (4) in step a) or both to the hydrocracking unit (4) in step a) and to the catalytic cracking unit (17) in step c); and
 g) Feeding at least a portion (13) of the first residue (12) of heavy hydrocarbons from step b) to the hydroconversion unit (25) in step e).

2. The process of claim 1, wherein the heavy hydroconversion products (31; 3; 16) of the hydroconversion unit (25) from step e) are heavier than diesel and have a boiling point which is equal to or below 620°C.

3. The process of claim 1 or 2, wherein in the case of coke formation in step e), the heavy hydroconversion products (31; 3; 16) of the hydroconversion unit (25) which are heavier than diesel are decoked before being recycled to the hydrocracking unit (4) in step a) or both to the hydrocracking unit (4) in step a) and to the catalytic cracking unit (17).

4. The process of claim 1 or 2, wherein the hydroconversion unit (25) does not produce coke in step e) and the heavy hydroconversion products (31; 3; 16) of the hydroconversion unit (25) from step e) have a boiling point which is equal to or below 620°C.

5. The process of any of the preceding claims, wherein a portion (14) of the first residue (12) of heavy hydrocarbons of the hydrocracking unit (4) from step b) is sent to the catalytic cracking unit (17).

6. The process of any of the preceding claims, wherein a portion (2) of the first residue (12) of heavy hydrocarbons of the hydrocracking unit (4) from step b) is

recycled to the hydrocracking unit (4).

7. The process of any of the preceding claims, wherein the ratio of the recycling stream (16) of heavy hydroconversion products of the hydroconversion unit (25) from step e) to the catalytic cracking unit (17) to the recycling stream (3) of heavy hydroconversion products of the hydroconversion unit (25) from step e) to the hydrocracking unit (4) is in the range between 0 and 0.99.

8. The process of claim 7, wherein the ratio of the recycling stream of heavy hydroconversion products of the hydroconversion unit (25) from step e) to the catalytic cracking unit (17) to the recycling stream of heavy hydroconversion products of the hydroconversion unit (25) from step e) to the hydrocracking unit (4) is preferably in the range between 0.1 and 0.3 and more preferably in the range between 0.13 and 0.16.

9. The process of claim 7 or 8, wherein the ratio of the recycling stream (16) of heavy hydroconversion products of the hydroconversion unit (25) from step e) to the catalytic cracking unit (17) to the recycling stream (3) of heavy hydroconversion products of the hydroconversion unit (25) from step e) to the hydrocracking unit (4) is changed to vary the yield of the process in favor of diesel or gasoline as desired.

10. The process of any of the preceding claims, wherein the yield for products that are heavier than diesel is zero, and the feedstock (1) of heavy hydrocarbons to the hydrocracking unit (4) is completely converted to light gases, gasoline and mid-distillates like kerosene and diesel.

11. The process of any of the preceding claims, wherein the first residue (12) of heavy hydrocarbons from step b) has a boiling point above 390°C.

12. The process of any of the preceding claims, wherein the second residue (23) of heavy hydrocarbons from step d) consists mainly of clarified cycle oil (CSO) with a boiling point above 370°C.

13. The process of any of the preceding claims, wherein the heavy hydroconversion products (31; 3; 16) of the hydroconversion unit (25) have a boiling point above 370°C.

14. The process of any of the preceding claims, wherein products (18) of the catalytic cracking unit (17) are distilled in a distillation tower (19) and wherein kerosene and diesel are produced from mid-distillates or light cycle oil (LCO) of the distillation tower (19) with a boiling point in the range between 180°C and 370°C

15. The process of any of the preceding claims, wherein products (5) of the hydrocracking unit (4) are distilled in a distillation tower (6) so as to produce kerosene (10) with a boiling point in the range between 160 and 290°C and hydrocracking diesel with a boiling point in the range between 290°C and 390°C.

10

15

20

25

30

35

40

45

50

55

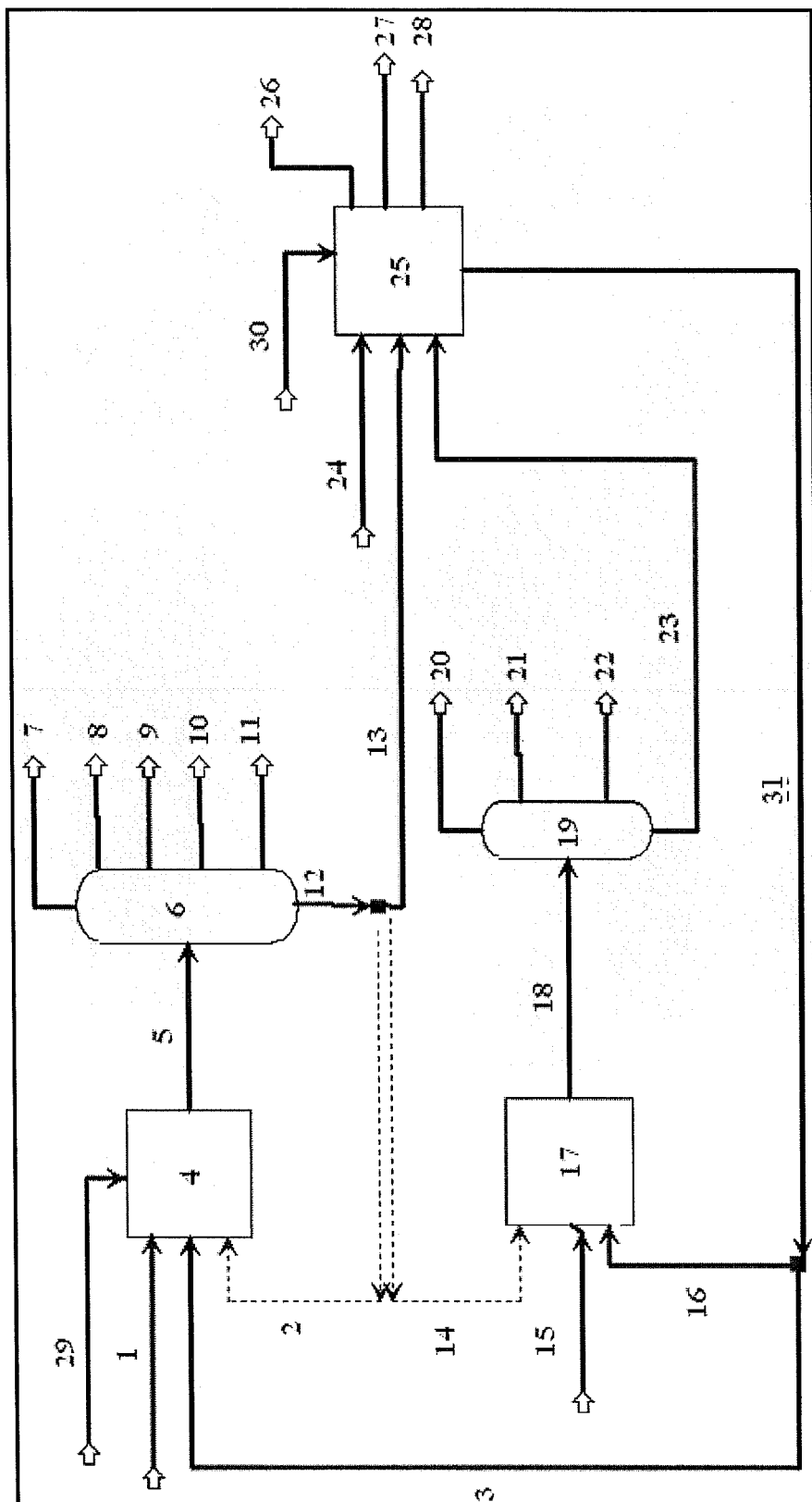


Fig. 1



EUROPEAN SEARCH REPORT

Application Number
EP 08 16 1022

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	GB 1 270 607 A (TEXACO DEVELOPMENT CORP [US]) 12 April 1972 (1972-04-12) * claim 1; figure 1; example 1 *	1-15	INV. C10G69/04 C10G65/12 C10G69/14
Y,D	US 3 072 560 A (PATERSON NORMAN J ET AL) 8 January 1963 (1963-01-08) * column 10, line 10 - column 11, line 39; claim 1; figure 1 *	1-15	
Y	US 4 983 273 A (KENNEDY CLINTON R [US] ET AL) 8 January 1991 (1991-01-08) * claim 1; figure 1 * * column 2, lines 36-49 * * column 6, lines 3-39 *	1-15	
A	US 4 192 734 A (PAVLICA ROBERT T [US] ET AL) 11 March 1980 (1980-03-11) * claim 1; figure 1 *	1-15	
A	US 5 009 768 A (GALIASO ROBERTO [VE] ET AL) 23 April 1991 (1991-04-23) * claim 1; figure 2 *	1-15	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			C10G
Place of search		Date of completion of the search	Examiner
Munich		16 March 2009	Harf, Julien
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

1
EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 08 16 1022

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

16-03-2009

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
GB 1270607	A	12-04-1972	NONE	
US 3072560	A	08-01-1963	GB 923246 A NL 121187 C NL 262015 A	10-04-1963
US 4983273	A	08-01-1991	AU 639027 B2 AU 6378390 A	15-07-1993 11-04-1991
US 4192734	A	11-03-1980	NONE	
US 5009768	A	23-04-1991	NONE	

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 3891538 A [0004]
- US 3072560 A [0005]
- US 3983029 A [0006]
- US 4354922 A [0007]
- US 4426276 A [0008]
- US 5026472 A [0009]
- US 6123830 A [0010]
- US 6004454 A [0023]
- US 7214309 B [0023]
- EP 1754770 A1 [0023] [0043]
- US 7238273 B [0023]