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(54) Production of gasoline using new method, blending of petroleum material cuts

(57) A method of producing a reformate suitable for use in the production of gasoline, comprising the steps of: obtaining naphtha heart cut (C5-C10$^+$) from the distillation of gas condensate; removing undesired impurities from said naphtha heart cut (C5-C10$^+$) by a hydrotreating step to produce hydrotreated naphtha heart cut (C5-C10$^+$); and subjecting said hydrotreated naphtha heart cut (C5-C10$^+$) to a catalytic reforming step to produce said reformate, wherein the temperature of said catalytic reforming step is selected to be in the range 485-510 °C; and/or an amount of hydrotreated naphtha heart cut (C5-C10$^+$) is mixed with said reformate such that said reformate contains up to 45 %volume of hydrotreated naphtha heart cut (C5-C10$^+$), so as to reduce the %volume of aromatics in said reformate. In addition, the invention comprises a method of producing a gasoline using such a reformate and also a gasoline comprising such a reformate.

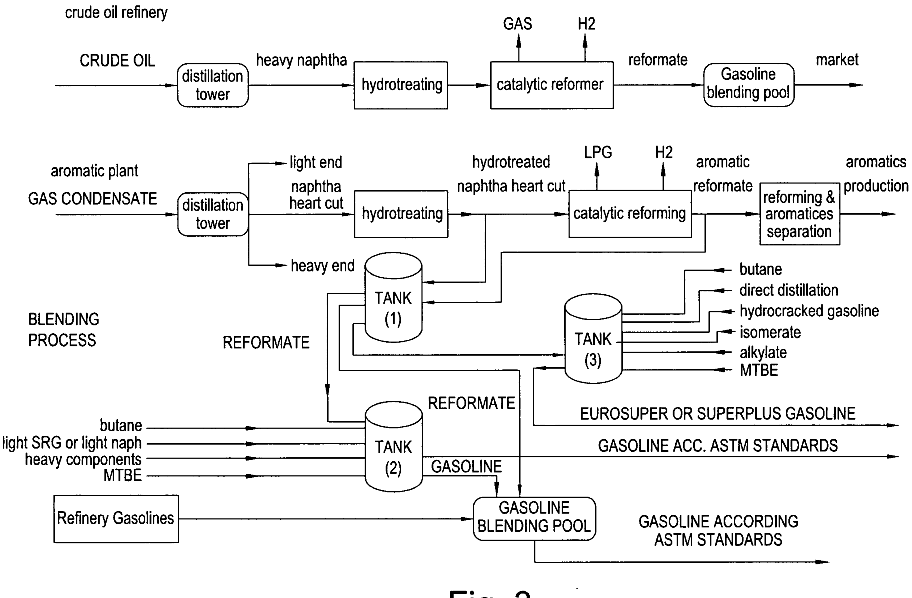

Fig. 3

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Description

[0001] This invention relates to the production of a gasoline, in particular from petroleum material cuts obtained from an aromatic petrochemical plant.

[0002] Typical gasoline comprises 30-80 %volume of a petroleum material known as reformate. Reformate is typically produced from a crude oil petroleum refinery process.

[0003] In a crude oil petroleum refinery process, crude oil as the feed material enters a distillation tower and different products are separated according to their boiling points. As seen in Figure 1, one of these products is heavy naphtha. Impurities in this heavy naphtha, such as sulphur, mercaptans, nitrogen, metals etc. are removed in a hydrotreater unit and the heavy naphtha then enters a reforming unit. In this unit, the naphtha linear compounds are transformed into branched and ring compounds and, as a result, the octane number of the material increases. The output of the reforming unit is known as reformate (hereinafter referred to as "refinery reformate") and is comprised of varying amounts of paraffins, olefins, napthenes and aromatics.

[0004] The American Society for Testing and Materials (ASTM) has set out the required international standards for the physical and chemical properties of a regular gasoline (RON = 91) and a premium gasoline (RON = 95) in order for it to be suitable for use in a vehicle. This set of standards ("the international ASTM standards") are set out below in Table 1:

Table 1: the international ASTM standards for regular and premium gasoline.

Test method	Analysis	Unit	Limit (Regular gasoline)	Limit (Premium gasoline)
ASTM D 1298	Density 15 °C	Kg/m^3	0.71 - 0.77	0.71- 0.79
Distillation				
ASTM D 86	10% Evaported (max) @	°C	65 max	70 max
ASTM D 86	50% Evaported (max) @	°C	115 max	115 max
ASTM D 86	90% Evaported (max) @	°C	180 max	180 max
ASTM D 86	Final Boiling Point (FPB) (max)	°C	205 max	205 max
ASTM D 86	Residue (max)	%vol	2 max	2 max
ASTM D 86	Loss (max)	%vol	1 max	1 max
ASTM D 323	Vapour Pressure	Psi	*	*
ASTM D 1266	Sulfur total (max)	%mass	0.1 max	0.1 max
ASTM D 525	Induction period @ 100 °C	minutes	480 min	480 min
ASTM 32341	Metallic lead	g/lit	0.013 max	0.013 max
ASTM D 2699	RON	-	91 min	95 min
ASTM D 3227	Mercaptan content	ppm	5 max	5 max
IP 17	Colour	-	Red	Green
D3606-4420/5580	Benzene	%vol	1.7 max	3 max
D1319 4420/5580	Aromatics	%vol	40 max	50 max
D1319-D5580	Olefins	%vol	10 max	10 max
*depends on the season, i.e. 12.7 Psi at 60 °F, 11.0 Psi at 70 °C, 9.4 Psi at 80 °F and 8.0 Psi at 90 °C				

[0005] Other specific sets of ASTM standards exist for gasolines such as European Eurosuper gasoline, European Special gasoline and European Superplus gasoline.

[0006] The physical and chemical properties of refinery reformate depend on the reactor conditions and also the physical and chemical properties of the feed material. Sometimes, refinery reformate has the required physical and chemical properties to be used on its own as a gasoline conforming to the international ASTM standards. When refinery reformate does not have the required physical and chemical properties in order to be used on its own as a gasoline according to the international ASTM standards and/or in order to increase the volume of the gasoline, refinery reformate is typically mixed with other materials from the gasoline blending pool (see Fig. 1) so as to obtain the chemical and physical properties which conform to the international ASTM standards.

[0007] Aromatic petrochemical plants carry out similar production processes to crude oil pertoleum refineries (see Fig. 2) and also produce reformate (hereinafter referred to as "aromatic reformate"). In these plants, gas condensate as feed material enters a distillation tower and the light end (C1-C4) and heavy end ($C10^+$) products are separated. The intermediate fraction, naphtha heart cut ($C5\text{-}C10^+$) (with boiling point range 80-205 °C), is then fed into a hydrotreating unit to remove impurities and the resulting product is known as "hydrotreated" naphtha heart cut ($C5\text{-}C10^+$). This product then enters a catalytic reforming unit, which is comprised of a number of reactors and catalysts, and the linear compounds are transformed into branched and ring compounds. The operating conditions of the catalytic reforming unit depend on the feed material, reactor pressure, space velocity and the type of catalyst, but under normal operating conditions, the temperature is typically in the region of 480-525 °C and the pressure is typically in the region of 3-5 bar. Higher temperatures lead to greater efficiency of the catalytic reforming unit whereas lower temperatures can lead to the undesired formation of large amounts of cokes. Accordingly, a temperature towards the higher end of the range 480-525 °C is preferably selected, preferably above 510 °C. The catalytic reforming unit is typically comprised of a number of reactors, each comprising a boiler and each boiler having a corresponding inlet temperature and outlet temperature. The control room of the aromatic petrochemical plant typically controls the temperature and pressure of the boilers via a computer. The product of the reforming unit is aromatic reformate and, like refinery reformate, it is also comprised of paraffins, olefins, napthenes and aromatics. The relative proportion of these different types of compounds varies depending on the operating conditions of the catalytic reforming unit as well as the input material.

[0008] The products and by-products of the aromatic petrochemical plant, such as aromatic reformate and hydrotreated naphtha heart cut ($C5\text{-}C10^+$), are much cheaper to produce than refinery reformate but these products have not been previously mixed in order to be used in the production of gasoline. In addition, aromatic reformate has a higher RON (research octane number) than refinery reformate. However, unlike refinery reformate, aromatic reformate is not suitable for the production of gasoline according to the international ASTM standards. This is due to the large proportion of aromatic compounds contained in aromatic reformate, which is often in the region of 75-85 %volume. Whilst the presence of high levels of aromatic compounds increases the RON of a reformate (up to RON = 113 in the case of aromatic reformate), or of a gasoline containing such a reformate, it can lead to other unfavourable physical and chemical properties such as an undesired initial boiling point, final boiling point, vapour pressure or other composition and distillation properties. In addition, various health concerns are associated with aromatic compounds due to, for example, their carcinogenic nature. Therefore, in order for an aromatic reformate to be suitable for use in the production of gasoline according to the international ASTM standards, the %volume of aromatics contained therein must be reduced, preferably to below 70 %volume.

[0009] Accordingly, it is an object of the present invention to provide a method of producing a reformate from an aromatic petrochemical plant, which is suitable for use in the production of a gasoline according to the international ASTM standards. It is another object of the present invention to provide a method of producing gasoline according to the international ASTM standards, which contains a reformate obtained from an aromatic petrochemical plant. It is a further object to provide a gasoline according to the international ASTM standards when produced by these methods.

[0010] In the catalytic reforming step, the linear compounds of the hydrotreated naphtha heart cut ($C5\text{-}C10^+$) are transformed into branched and ring compounds. This results in an increase in the octane number. As mentioned above, the typical operating conditions of a catalytic reforming unit of an aromatic petrochemical plant involve a temperature in the region of 480-525 °C, preferably above 510 °C, and a pressure in the region of 3-5 bar. Surprisingly, it has been found by the present inventors that by selecting the temperature of the catalytic reforming unit to be below 510 °C, the physical and chemical properties of the resultant reformate can be altered, in particular the %volume of aromatic compounds contained in the resultant reformate can be reduced whilst ensuring at least 80% efficiency of the catalytic reforming unit. Surprisingly, it has also been found by the present inventors that by adding an amount of hydrotreated naphtha heart cut ($C5\text{-}C10^+$) to the reformate petroleum material, the %volume of aromatic compounds contained in the resultant reformate is reduced.

[0011] In a first aspect of the present invention, there is provided a method of producing a reformate suitable for use in the production of gasoline, comprising the steps of: obtaining naphtha heart cut ($C5\text{-}C10^+$) from the distillation of gas condensate; removing undesired impurities from said naphtha heart cut ($C5\text{-}C10^+$) by a hydrotreating step to produce hydrotreated naphtha heart cut ($C5\text{-}C10^+$); and subjecting said hydrotreated naphtha heart cut ($C5\text{-}C10^+$) to a catalytic reforming step to produce said reformate, wherein the temperature of said catalytic reforming step is selected to be in the range 485-510 °C, and/or wherein an amount of hydrotreated naphtha heart cut ($C5\text{-}C10^+$) is mixed with said reformate such that said reformate contains up to 45 %volume of said hydrotreated naphtha heart cut ($C5\text{-}C10^+$), so as to reduce the %volume of aromatics in said reformate.

[0012] Preferably, the reformate is suitable for the production of gasoline which meets the requirements of the international ASTM standards. More preferably, the gasoline meets the requirements of a set of ASTM standards corresponding to a gasoline selected from US Regular gasoline, US Premium gasoline, European Eurosuper gasoline, European Special gasoline and European Superplus gasoline.

[0013] The naphtha heart cut is typically obtained from an aromatic petrochemical plant and the distillation of gas condensate is typically carried out in the distillation tower of an aromatic petrochemical plant. Impurities removed from the naphtha heart cut ($C5-C10^+$) by hydrotreating include sulphur, mercaptans, nitrogen and metals.

[0014] In the case that the temperature of the catalytic reforming step is selected to be in the range 485-510 °C, preferably the temperature should be selected to be in the range 490-505 °C, more preferably, in the range 495-505 °C. Reducing the temperature in this way can reduce the %volume of aromatics in the reformate to as low as 50 %volume. The temperature of the catalytic reforming step preferably refers to the temperature of the boiler(s) within the catalytic reactor(s), more preferably the inlet temperature. The temperature of the catalytic reforming step is typically controlled by the control room of the aromatic petrochemical plant, typically by the use of a computer. Preferably, the temperature of the catalytic reforming step is selected such that the catalytic reforming unit operates at an efficiency of 80 % or higher.

[0015] In the case that hydrotreated naphtha heart cut ($C5-C10^+$) is mixed with the reformate, preferably the amount of hydrotreated naphtha heart cut ($C5-C10^+$) added is such that the reformate contains between 5-45 %volume hydrotreated naphtha heart cut ($C5-C10^+$), more preferably between 5-25 %volume hydrotreated naphtha heart cut ($C5-C10^+$). The hydrotreated naphtha heart cut ($C5-C10^+$) contains lower amounts of aromatic compounds than the reformate. Therefore, the addition of the hydrotreated naphtha heart cut ($C5-C10^+$) reduces the %volume of aromatics in the reformate without the need to reduce the temperature of the catalytic reforming step. This alters the physical and chemical properties of the reformate such that it can now be used in the production of a gasoline according to the international ASTM standards. As the temperature does not need to be reduced, this has the advantage that the operation of the aromatic petrochemical plant is not affected. As mentioned above, reducing the temperature of the catalytic reforming step reduces the efficiency of the catalytic reforming unit and also leads to increased formation of undesired cokes. Hydrotreated naphtha heart cut ($C5-C10^+$) has not been mixed with aromatic reformate in order to be used in the production of gasoline before. An advantage of this feature is that hydrotreated naphtha heart cut ($C5-C10^+$) is cheaper to produce than other petroleum material cuts which comprise the gasoline blending pool. Therefore, the present invention provides a method of producing a reformate suitable for use in the production of a gasoline according to the international ASTM standards, which is cheaper to produce than refinery reformate.

[0016] Hydrotreated naphtha heart cut ($C5-C10^+$) has a lower RON than aromatic reformate. Therefore, the addition of hydrotreated naphtha heart cut ($C5-C10^+$) to aromatic reformate will reduce the RON of aromatic reformate. However, due to the high RON of aromatic reformate, the addition of hydrotreated naphtha heart cut ($C5-C10^+$) does not reduce the RON below a level such that the aromatic reformate cannot be used in the production of gasoline according to the international ASTM standards.

[0017] Within the specified range of up to 45 %volume, the amount of said hydrotreated naphtha heart cut ($C5-C10^+$) added to said reformate depends on the desired physical and chemical properties of the reformate. The hydrotreated naphtha heart cut ($C5-C10^+$) added to said reformate is typically obtained from an aromatic petrochemical plant or an oil refinery. As an alternative to hydrotreated naphtha heart cut ($C5-C10^+$), naptha and heavy S.R.G (C5-C10), with boiling points in the range 75-210 °C, obtained from a crude oil refinery process can be used. This is because these cuts have similar chemical and physical properties to hydrotreated naphtha heart cut ($C5-C10^+$).

[0018] In a second aspect of the present invention, there is provided a method of producing gasoline comprising the steps of: producing a reformate according to the method of the first aspect of the present invention; and blending said reformate with at least one other petroleum material cut to produce gasoline. The addition of other petroleum material cuts alters the physical and chemical properties of the resultant gasoline.

[0019] Preferably, the at least one other petroleum material cut is other petroleum materials in a gasoline blending pool.

[0020] Preferably, the gasoline meets the requirements of the international ASTM standards. More preferably, the gasoline meets the requirements of a set of ASTM standards corresponding to a gasoline selected from US Regular gasoline, US Premium gasoline, European Eurosuper gasoline, European Special gasoline and European Superplus gasoline.

[0021] In one embodiment of the second aspect, the at least one other petroleum material cut is selected from butane (C4), light naphtha (C4-C5), pentane (C5), light straight run gasoline (S.R.G) (C5-C6), heavy components ($C7-C10^-$) and hydrotreated naphtha heart cut ($C5-C10^+$). Butane (C4) is added in order to increase the pressure of the resultant gasoline. Light naphtha (C4-C5), pentane (C5) and light S.R.G (C5-C6) are added to increase the pressure, to decrease the initial boiling point and to reduce the %volume of aromatics in the resultant gasoline. Throughout the specification, the term "pentane" is deemed to include all geometric isomers of pentane, including normal pentane and isopentane as well as combinations thereof. Heavy components ($C7-C10^-$), which includes heavy naphtha (C7-C8), have high boiling points, and are added to increase the initial and final boiling points of the resultant gasoline. Hydrotreated naphtha heart cut ($C5-C10^+$), which has a low %volume of aromatics, is added to reduce the %volume of aromatics in the resultant gasoline. These other petroleum material cuts have a lower RON than the reformate, meaning that their addition reduces the RON of the resultant gasoline. However, due to the high RON of the reformate, it is still possible to make the RON of the resultant gasoline acceptable under the international ASTM standards.

[0022] Preferably, the gasoline contains up to 60 %volume of light S.R.G (C5-C6) and/or up to 25 %volume pentane

(C5) and/or up to 5 %volume butane (C4) and/or up to 15 %volume light naphtha (C4-C5) and/or up to 5.0 %volume heavy components ($C7-C10^-$) and/or up to 45 %volume hydrotreated naphtha heart cut ($C5-C10^+$) and/or between 30-98 %volume of the reformate. More preferably, the gasoline contains 5-60 %volume of light S.R.G (C5-C6) and/or 2-5 %volume butane and/or 5-25 %volume hydrotreated naphtha heart cut ($C5-C10^+$) and/or 2-3 %volume heavy naphtha and/or 50-90 %volume of the reformate. Even more preferably, the gasoline contains 2-4 %volume butane and/or 10-40 %volume light S.R.G. Preferably, the amount of the other petrochemical material cut added is selected depending on the desired physical and chemical properties of the resultant gasoline.

[0023] Further additives can be added to the gasoline. Examples of such additives include, but are not restricted to, octane enhancers, metal deactivators, anti-oxidants, anti-knock agents, gum and rust inhibitors, detergents, etc. These are added during and/or after blending to achieve the desired chemical and physical properties of the resultant gasoline. Preferably, the additive is an octane enhancer and more preferably is methyl tertiary butyl ether (MTBE). Even more preferably, the gasoline contains up to 9 %volume of MTBE. It is not essential to add MTBE to the gasoline. This is because, although the RON of a gasoline produced according to the present invention will depend on the composition of the feed material, typical gasolines produced according to the present invention have an RON of approximately 87-99.5. However, if MTBE is added, the RON of a gasoline produced according to the present invention can be increased.

[0024] The gasoline can be mixed with other refinery gasolines in a gasoline blending pool. This has the effect of altering the physical and chemical properties of the gasoline and also increasing the volume of the gasoline. The gasoline can be mixed with the other refinery gasolines in order to increase their octane number.

[0025] In another embodiment of the second aspect, the at least one other petroleum material cut is selected from butane (C4), direct distillation gasoline, FCC hydrocracked gasoline, isomerate gasoline, alkylate gasoline and MTBE.

[0026] Typically, such other petroleum materials are obtained from an oil refinery.

[0027] Preferably, the gasoline comprises 30-80 %volume of said reformate, 10-40 %volume of FCC hydrocracked gasoline, up to 5 %volume of butane (C4), up to 10 %volume of direct distillation gasoline, up to 8 %volume isomerate gasoline, up to 20 %volume alkylate gasoline and up to 9 %volume MTBE. Even more preferably, the gasoline comprises up to 4 % volume butane and, still even more preferably, the gasoline comprises 2-4 %volume butane.

[0028] Preferably, the gasoline is European Eurosuper gasoline or European Superplus gasoline.

[0029] In a third aspect of the present invention, there is provided a gasoline produced according to the methods of the first and second aspects.

[0030] Preferred embodiments of the method of the first aspect (1) are as follows:

(2) A method according to (1), wherein said reformate contains 5-45 %volume of hydrotreated naphtha heart cut ($C5-C10^+$).

(3) A method according to (2), wherein said reformate contains 5-25 %volume of hydrotreated naphtha heart cut ($C5-C10^+$).

(4) A method according to (1)-(3), wherein said naphtha heart cut ($C5-C10^+$) is obtained from an aromatic petrochemical plant.

(5) A method according to (1)-(4), wherein said an amount of hydrotreated naphtha heart cut ($C5-C10^+$) which is mixed with said reformate is obtained from an aromatic petrochemical plant or an oil refinery.

[0031] Preferred embodiments of the method of the second aspect are as follows:

(6) A method of producing gasoline comprising the steps of:

producing a reformate according to (2)-(5); and
blending said reformate with at least one other petroleum material cut to produce gasoline.

(7) A method according to (6), wherein said at least one other petroleum material cut is selected from butane (C4), light naphtha (C4-C5), pentane (C5), light straight run gasoline (S.R.G) (C5-C6), heavy components ($C7-C10^-$) and hydrotreated naphtha heart cut ($C5-C10^+$).

(8) A method according to (7), wherein said gasoline contains up to 60 %volume light S.R.G (C5-C6).

(9) A method according to (7) or (8), wherein said gasoline contains up to 5 %volume butane (C4).

(10) A method according to (7)-(9), wherein said gasoline contains up to 5.0 %volume heavy components ($C7-C10^-$).

(11) A method according to (7)-(10), wherein said gasoline contains up to 45 %volume hydrotreated naphtha heart cut ($C5-C10^+$).

(12) A method according to (7)-(11), wherein said gasoline contains up to 25 %volume pentane (C5).

(13) A method according to (7)-(12), wherein said gasoline contains up to 15 %volume light naphtha (C4-C5).

(14) A method according to (6)-(13), wherein said gasoline contains between 30-98 %volume of said reformate.

(15) A method according to (6)-(14), wherein the method further comprises a step of adding MTBE to the gasoline.

(16) A method according to (15), wherein said gasoline contains up to 9 %volume MTBE.

(17) A method according to (6), wherein said at least one other petroleum material cut is selected from butane (C4), direct distillation gasoline, FCC hydrocracked gasoline, isomerate gasoline, alkylate gasoline and MTBE.

(18) A method according to (17), wherein said gasoline comprises 30-80 %volume of said reformate, 10-40 %volume FCC hydrocracked gasoline, up to 5 %volume butane (C4), up to 10 %volume of direct distillation gasoline, up to 8 %volume isomerate gasoline, up to 20 %volume alkylate gasoline and up to 9 %volume MTBE.

(19) A method according to (17) or (18), wherein said gasoline is Eurosuper gasoline or Superplus gasoline.

(20) A method according to (1)-(19), wherein said gasoline meets the requirements of the international ASTM standards.

(21) A method according to (1)-(19), wherein said gasoline meets the requirements of a set of ASTM standards corresponding to a gasoline selected from US Regular gasoline, US Premium gasoline, European Eurosuper gasoline, European Special gasoline and European Superplus gasoline.

[0032] A preferred embodiment of the gasoline according to the third aspect is:

(22) A gasoline produced according to the method of (6)-(21).

[0033] The invention will next be described by reference to the following figures, in which:

Fig. 1 is a schematic of a typical oil refinery.

Fig. 2 is schematic of a typical aromatic petrochemical plant.

Fig. 3 is a schematic of both a typical oil refinery and a typical aromatic petrochemical plant, indicating the processes the present invention.

Fig. 4 is a graph showing a typical distillation curve for motor gasoline, northern winter grade.

Fig. 5 is a graph showing typical distillation curves for heavy and light components.

[0034] Fig. 3 contains schematics of the production methods of both refinery reformate and aromatic reformate. In addition, a schematic of the methods of the present invention are shown. It can be seen that the reformate produced according to the present invention (in tank (1)) can be used to produce gasoline according to the international ASTM standards by blending it with other petroleum material cuts such as butane (C4), light naphtha (C4-C5), light S.R.G (C5-C6) and heavy components ($C7-C10^-$) and additives such as MTBE (tank (2)). Alternatively, the reformate can be blended with other petroleum material cuts such as butane (C4), direct distillation gasoline, FCC hydrocracked gasoline, isomerate gasoline and alkylate gasoline and additives such as MTBE to produce gasolines such as Eurosuper gasoline or Superplus gasoline (tank (3)).

EXAMPLES

Example 1:

[0035] Tables 2 and 3 list laboratory test results for samples of a typical refinery reformate and a typical aromatic reformate, respectively:

Table 2: laboratory test results for a typical refinery reformate.

Distillation test	Result	Composition test	Result
Sp. Gr @60°C	0.7730	iC_4 / %vol	0.4
I.B.P/°C	43	nC_4 / %vol	2.1
5 % / °C	60	iC_5 / %vol	4.5
10 % / °C	69	nC_5 / %vol	3.2
30 % / °C	95	iC_6 / %vol	7.8
50 % / °C	115	nC_6 / %vol	3.7
70 % / °C	135	C_7^+ / %vol	78.3

(continued)

Distillation test	Result	Composition test	Result
90 % / °C	157		
95 % / °C	171		
F.B.P / °C	187		
Color	25		
R.V.P / psi	6.7		
R.O.N	92.4		
Aromatics / %vol	51.4		
Dr Test	NEG		
R-SH / ppm	<2		

Table 3: laboratory test results for a typical aromatic reformate.

Distillation test	Result	Composition test						
I.B.P / °C	73	**Composition / %vol**	**P**	**O**	**N**	**A**	**Other**	**Total**
5 % / °C	86	C1	-	-	-	-	-	-
10 % / °C	91	C2	-	-	-	-	-	-
20 % / °C	98	C3	-	-	-	-	-	0.00
30 % / °C	105	C4	-	-	-	-	-	0.00
40 % / °C	113	C5	2.04	-	0.86	-	-	2.90
50 % / °C	120	C6	10.68	0.01	0.41	8.76	-	19.86
60 % / °C	127	C7	8.56	0.02	0.42	22.03	-	31.03
70 % / °C	134	C8	2.05	0.08	0.10	26.66	-	28.89
80 % / °C	140	C9	0.18	-	0.00	14.77	-	14.95
90 % / °C	147	C10$^+$	-	-	-	-	2.37	2.37
95 % / °C	152	Total	23.51	0.11	1.79	72.22	2.37	100.00
F.B.P / °C	176							
Total Recovery / %	98.5							
Residue / %	1.2							
Loss / %	0.3							
R.V.P / psi	3.2							
Density / g/ml	0.7266							

[0036] In Table 3, P = parafins, O = olefins, N = naphthas and A = aromatics. It can be seen that the physical and chemical properties of both samples do not allow them to be used as a gasoline on their own according to the international ASTM standards. For example, among others, the Reid vapour pressure (RVP) is too low, the final boiling point (FBP) is too low and the %volume of aromatics is too high. Therefore, in order to produce such a gasoline, this refinery reformate must be mixed with other materials from the gasoline blending pool according to the desired physical and chemical properties of the resultant gasoline. However, due to the high levels of aromatic compounds in aromatic reformate (72.22 %volume in this sample), it is not possible to substitute refinery reformate with aromatic reformate in the conventional production of gasoline according to the international ASTM standards.

Example 2:

[0037] Table 4 lists laboratory test results for a sample of reformate produced according to the first aspect of the present invention wherein an amount of hydrotreated naphtha heart cut (C5-C10$^+$) is mixed with the reformate:

Table 4: laboratory test results for a reformate produced according to the first aspect of the present invention

Test	Result	Test	Result
Sp. Gr @ 60°C	0.7995	T.S / %wt	Trace
I.B.P / °C	58	RON	94.6
Temp 10 % / °C	85	Dr Test	NEG
Temp 30 % / °C	100	Mercaptane / ppm	<2
Temp 50 % / °C	115	i-C_5 / %mol	2.3
Temp 70 % / °C	133	n-C_5 / %mol	1.7
Temp 90 % / °C	154	i-C_6 / %mol	6.9
Temp 95 % / °C	163	n-C_6 / %mol	3.2
F.B.P / °C	189	Aromatics / %vol	65
Color	30	C7$^+$ non aromatic / %mol	20.9
RVP / KPa	26.2		

In this sample, the reformate contains 90 %volume of aromatic reformate (the sample of table 3) and 10 %volume hydrotreated naphtha heart cut (C5-C10$^+$). It can be seen that the addition of hydrotreated naphtha heart cut (C5-C10$^+$) results in the physical and chemical properties of the reformate being closer to those of the refinery reformate. In particular, the aromatic content is reduced. Accordingly, the reformate is suitable for use in the production of gasoline according to the international ASTM standards.

Example 3:

[0038] Table 5 lists values corresponding to the production of reformate according to one embodiment of the first aspect of the present invention when the inlet temperature of the catalytic reforming unit is selected to be in the range 485-510 °C and the reactor is operating at 80 % efficiency:

Table 5: laboratory test results corresponding to the production of reformate according to the first aspect of the present invention wherein the inlet temperature of the catalytic reforming unit is selected to be in the range 485-510 °C

Test	Reactor 1	Reactor 2	Reactor 3
Inlet temperature / °C	503	503	503
Outlet temperature / °C	433	470	495
Decrease temperature / °C	70	33	8
Octane number	68	83	92.5
Increase octane number	23	15	9.5
Coke	2 %	3 %	8 %
Efficiency of liquid	95 %	88 %	80 %
Aromatics / %vol			52 %

It can be seen that, when selecting the inlet temperature of each reactor in the catalytic reforming unit to be in the range 485-510 °C (in this case 503 °C), the %volume of aromatics in the resultant reformate is significantly lower than in typical aromatic reformate.

Example 4:

[0039] Table 6 lists the compositions for an example of a reformate produced according to the first aspect of the present invention and a gasoline containing this reformate produced according to embodiments of the second aspect of the present invention and their corresponding RONs:

Table 6: compositions of an example of a reformate and an example of a gasoline produced according to the methods of the present invention.

Reformate			
Component	**%vol**	**RON**	**Pressure / psi**
Aromatic reformate	94.3	98.2	-
Hydrotreated naphtha heart cut	5.7	50	-
Final results	100	96	4.8

Gasoline (RON = 95.1)	
Component	**%vol**
Reformate	76.8
Light S.R.G	11
Butane	3.2
Heavy naphtha	0
MTBE	9
Total volume	100
Total Pressure @ 100 °F / psi	8

Table 7 lists test results for the gasoline shown in Table 6:

Table 7: laboratory test results for a sample of gasoline produced according to the present invention.

Test	Result	Test	Result
Sp. Gr. @60°F	0.779	Copper / ppm	Nil
IBP / °C	38	Phosphorus / ppm	Nil
10% / °C	64	Lead / ppm	Nil
50% / °C	115	i-C_4 / %vol	0.5
90% / °C	156	n-C_4 / %vol	2.7
95% / °C	168	i-C_5 / %vol	5.2
FBP / °C	191	n-C_5 / %vol	3.8
Induction period / mins	Min 480	i-C_6 / %vol	6.5
RVP / psi	8	n-C_6 / %vol	2.8
RON	95.1	$C7^+$ / %vol	78.5
Dr Test	NEG	Olefines / %vol	TRACE
R-SH / ppm	<2	Aromatics / %vol	44
T.S / ppm	TRACE	Color	Green

The test results show that the gasoline meets the requirements of the international ASTM standards for a premium gasoline.

Example 5:

[0040] Table 8 lists test results for a typical sample of hydrotreated naphtha heart cut after it has left the hydrotreating unit of an aromatic petrochemical plant:

Table 8: laboratory test results for a typical sample of hydrotreated naphtha heart cut (1) and a typical sample of gas condensate feed for comparison (2).

<table>
<tr><th colspan="2">Distillation test</th><th colspan="3">Result (1)</th><th colspan="2">Result (2)</th></tr>
<tr><td colspan="2">I.B.P / °C</td><td colspan="3">81</td><td colspan="2">75</td></tr>
<tr><td colspan="2">5 % / °C</td><td colspan="3">90</td><td colspan="2">86</td></tr>
<tr><td colspan="2">10 % / °C</td><td colspan="3">92</td><td colspan="2">96</td></tr>
<tr><td colspan="2">20 % / °C</td><td colspan="3">95</td><td colspan="2">105</td></tr>
<tr><td colspan="2">30 % / °C</td><td colspan="3">99</td><td colspan="2">118</td></tr>
<tr><td colspan="2">40 % / °C</td><td colspan="3">103</td><td colspan="2">131</td></tr>
<tr><td colspan="2">50 % / °C</td><td colspan="3">108</td><td colspan="2">151</td></tr>
<tr><td colspan="2">60 % / °C</td><td colspan="3">114</td><td colspan="2">171</td></tr>
<tr><td colspan="2">70 % / °C</td><td colspan="3">121</td><td colspan="2">199</td></tr>
<tr><td colspan="2">80 % / °C</td><td colspan="3">130</td><td colspan="2">236</td></tr>
<tr><td colspan="2">90 % / °C</td><td colspan="3">141</td><td colspan="2">279</td></tr>
<tr><td colspan="2">95 % / °C</td><td colspan="3">149</td><td colspan="2">315</td></tr>
<tr><td colspan="2">F.B.P / °C</td><td colspan="3">163</td><td colspan="2">346</td></tr>
<tr><td colspan="2">Total Recovery / %vol</td><td colspan="3">97.9</td><td colspan="2">98.1</td></tr>
<tr><td colspan="2">Residue / %vol</td><td colspan="3">1.1</td><td colspan="2">0.8</td></tr>
<tr><td colspan="2">Loss / %vol</td><td colspan="3">1</td><td colspan="2">1.1</td></tr>
<tr><th colspan="7">Composition test (1)</th></tr>
<tr><th>Comp$^{\underline{n}}$ / %vol</th><th>P</th><th>O</th><th>N</th><th>A</th><th>Other</th><th>Total</th></tr>
<tr><td>C1</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>C2</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>C3</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>C4</td><td>-</td><td></td><td>--</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>C5</td><td>1.185</td><td>-</td><td>0.388</td><td>-</td><td>-</td><td>1.573</td></tr>
<tr><td>C6</td><td>15.974</td><td>0.002</td><td>4.547</td><td>2.585</td><td>-</td><td>23.108</td></tr>
<tr><td>C7</td><td>16.815</td><td>-</td><td>9.604</td><td>5.302</td><td>-</td><td>31.721</td></tr>
<tr><td>C8</td><td>16.754</td><td>-</td><td>7.099</td><td>6.732</td><td>-</td><td>30.586</td></tr>
<tr><td>C9</td><td>9.976</td><td>-</td><td>2.533</td><td>0.230</td><td>-</td><td>12.739</td></tr>
<tr><td>C10$^+$</td><td>-</td><td>-</td><td>-</td><td>-</td><td>0.274</td><td>0.274</td></tr>
<tr><td>Total</td><td>60.704</td><td>0.002</td><td>24.171</td><td>14.849</td><td>0.274</td><td>100.00</td></tr>
</table>

As with Table 3, P = parafines, O = olefins, N = naphthas and A = aromatics. It can be seen that the %volume of aromatics contained in hydrotreated naphtha heart cut is significantly lower than in typical aromatic reformate.

Claims

1. A method of producing a reformate suitable for use in the production of gasoline, comprising the steps of:

obtaining naphtha heart cut ($C5-C10^+$) from the distillation of gas condensate;
removing undesired impurities from said naphtha heart cut ($C5-C10^+$) by a hydrotreating step to produce hydrotreated naphtha heart cut ($C5-C10^+$); and
subjecting said hydrotreated naphtha heart cut ($C5-C10^+$) to a catalytic reforming step to produce said reformate,

wherein

the temperature of said catalytic reforming step is selected to be in the range 485-510 °C; and/or
an amount of hydrotreated naphtha heart cut ($C5-C10^+$) is mixed with said reformate such that said reformate contains up to 45 %volume of hydrotreated naphtha heart cut ($C5-C10^+$),

so as to reduce the %volume of aromatics in said reformate.

2. A method of producing gasoline comprising the steps of:

producing a reformate according to claim 1; and
blending said reformate with at least one other petroleum material cut to produce gasoline.

3. A method according to claim 2, wherein said at least one other petroleum material cut is selected from butane (C4), light naphtha (C4-C5), pentane (C5), light straight run gasoline (S.R.G) (C5-C6), heavy components ($C7-C10^-$) and hydrotreated naphtha heart cut ($C5-C10^+$).

4. A method according to claim 3, wherein said gasoline contains up to 60 %volume light S.R.G (C5-C6).

5. A method according to claims 3 or 4, wherein said gasoline contains up to 5 %volume butane (C4).

6. A method according to claims 3-5, wherein said gasoline contains up to 5.0 %volume heavy components ($C7-C10^-$).

7. A method according to claims 3-6, wherein said gasoline contains up to 45 %volume hydrotreated naphtha heart cut ($C5-C10^+$).

8. A method according to claims 3-7, wherein said gasoline contains up to 25 %volume pentane (C5).

9. A method according to claims 3-8, wherein said gasoline contains up to 15 %volume light naphtha (C4-C5).

10. A method according to claims 2-9, wherein said gasoline contains between 30-98 %volume of said reformate.

11. A method according to claims 2-10, wherein the method further comprises a step of adding MTBE to the gasoline.

12. A method according to claim 2, wherein said at least one other petroleum material cut is selected from butane (C4), direct distillation gasoline, FCC hydrocracked gasoline, isomerate gasoline, alkylate gasoline and MTBE.

13. A method according to claim 12, wherein said gasoline comprises 30-80 %volume of said reformate, 10-40 %volume FCC hydrocracked gasoline, up to 5 %volume butane (C4), up to 10 %volume of direct distillation gasoline, up to 8 %volume isomerate gasoline, up to 20 %volume alkylate gasoline and up to 9 %volume MTBE.

14. A method according to claims 1-13, wherein said gasoline meets the requirements of the international ASTM standards.

15. A gasoline produced according to the method of claims 2-14.

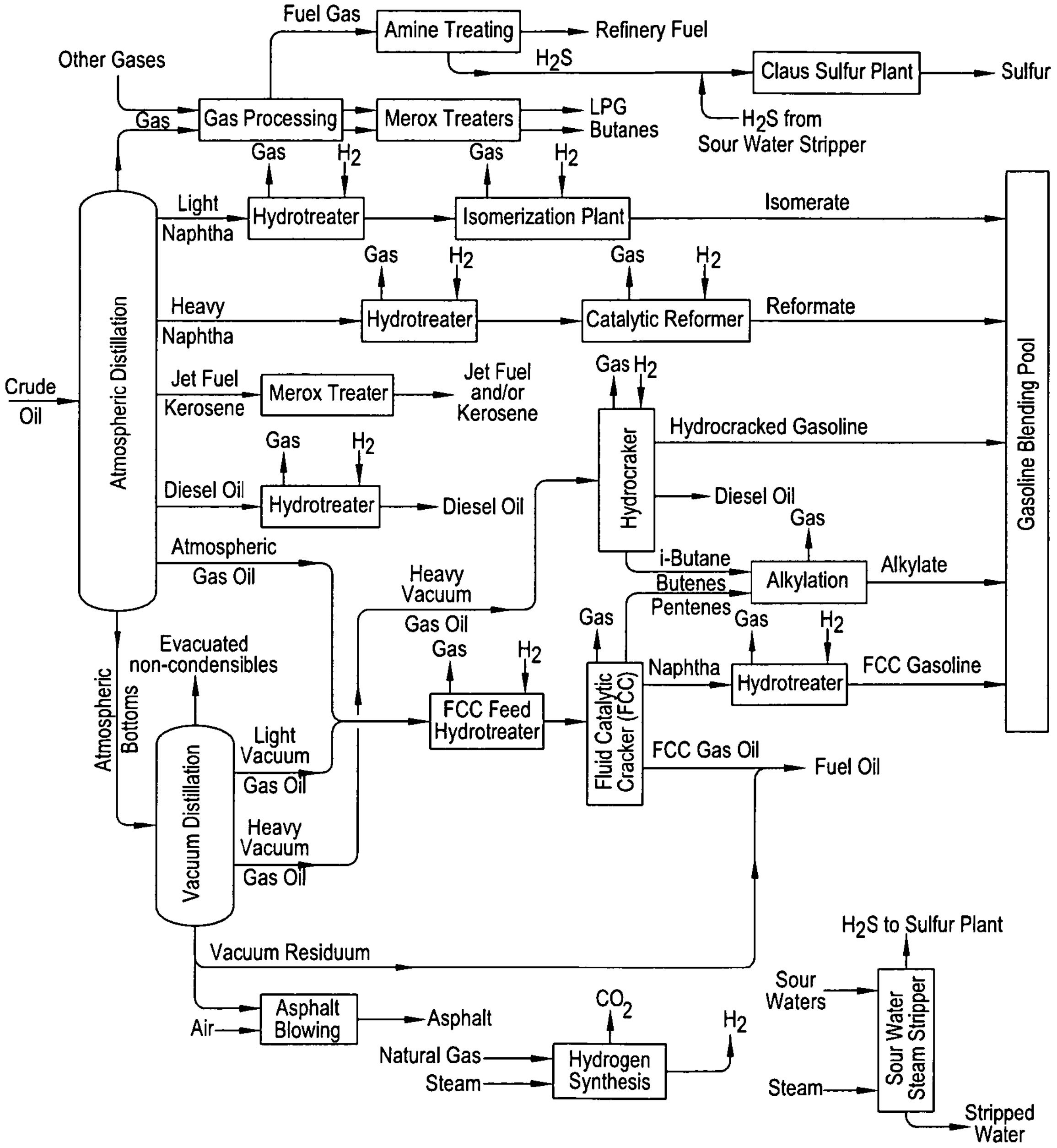

Fuel Gas
Amine Treating
Refinery Fuel
H_2S
Claus Sulfur Plant
Sulfur
Other Gases
Gas
Gas Processing
Merox Treaters
LPG
Butanes
H_2S from
Sour Water Stripper
Gas
H_2
Gas
H_2
Light
Naphtha
Hydrotreater
Isomerization Plant
Isomerate
Gas
H_2
Gas
H_2
Heavy
Naphtha
Hydrotreater
Catalytic Reformer
Reformate
Crude
Oil
Atmospheric Distillation
Jet Fuel
Kerosene
Merox Treater
Jet Fuel
and/or
Kerosene
Gas H_2
Hydrocraker
Hydrocracked Gasoline
Gasoline Blending Pool
Gas
H_2
Diesel Oil
Hydrotreater
Diesel Oil
Diesel Oil
Gas
Atmospheric
Gas Oil
i-Butane
Butenes
Pentenes
Alkylation
Alkylate
Heavy
Vacuum
Gas Oil
Gas
Gas
H_2
Evacuated
non-condensibles
Gas
H_2
Naphtha
Hydrotreater
FCC Gasoline
Atmospheric
Bottoms
FCC Feed
Hydrotreater
Fluid Catalytic
Cracker (FCC)
Light
Vacuum
Gas Oil
FCC Gas Oil
Fuel Oil
Vacuum Distillation
Heavy
Vacuum
Gas Oil
H_2S to Sulfur Plant
Vacuum Residuum
Sour
Waters
Asphalt
Blowing
Asphalt
Air
CO_2
H_2
Natural Gas
Steam
Hydrogen
Synthesis
Steam
Sour Water
Steam Stripper
Stripped
Water

Fig. 1

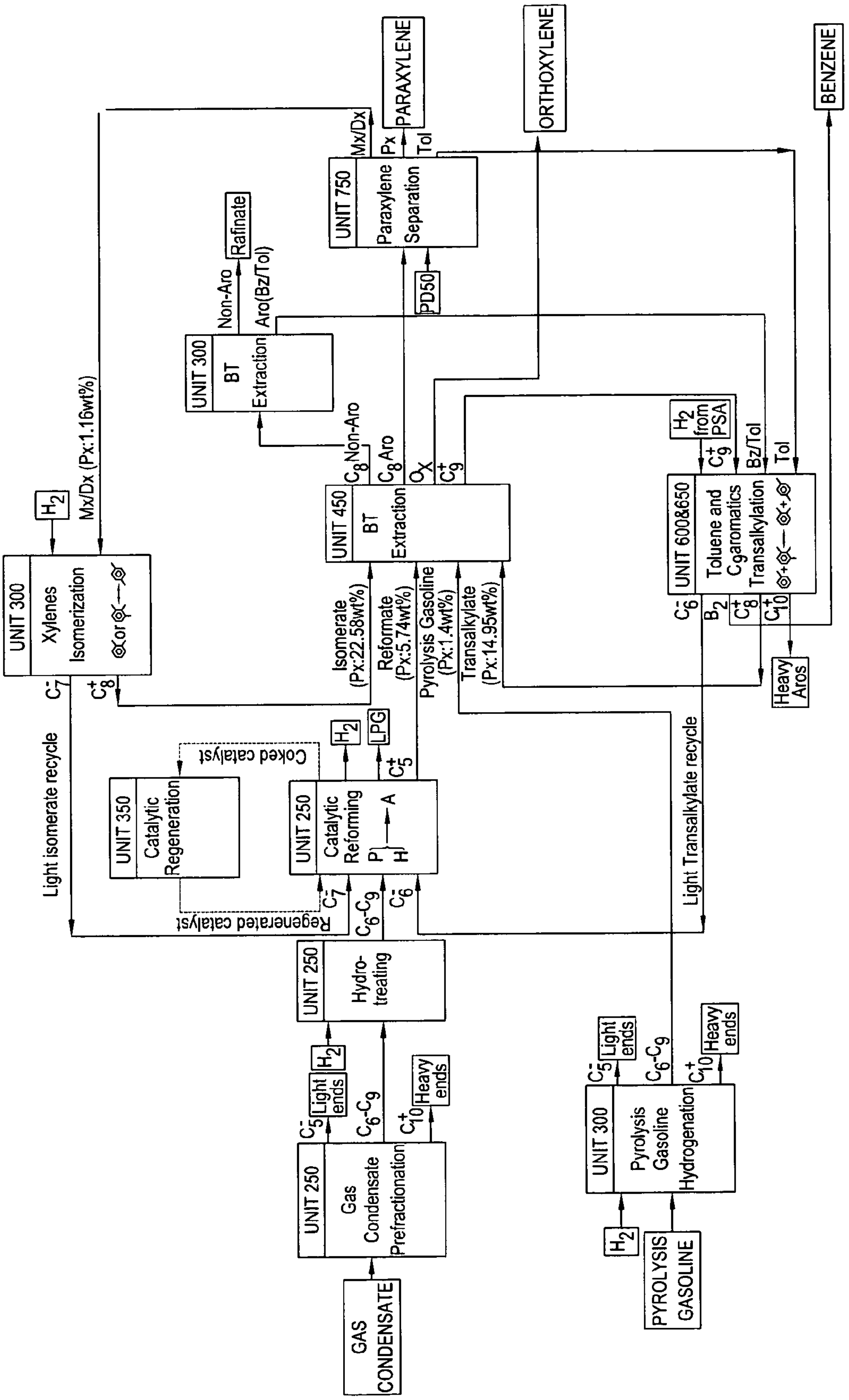

GAS CONDENSATE
UNIT 250 Gas Condensate Prefractionation
C_5^- Light ends
H_2
C_6-C_9
C_{10}^+ Heavy ends
UNIT 250 Hydro-treating
C_6-C_9
C_7^-
C_6^-
Regenerated catalyst
UNIT 350 Catalytic Regeneration
Coked catalyst
UNIT 250 Catalytic Reforming
P, H → A
H_2
LPG
C_5^+
Light isomerate recycle
C_7^-
C_8^+
UNIT 300 Xylenes Isomerization
H_2
Mx/Dx (Px:1.16wt%)
Isomerate (Px:22.58wt%)
Reformate (Px:5.74wt%)
Pyrolysis Gasoline (Px:1.4wt%)
Transalkylate (Px:14.95wt%)
UNIT 450 BT Extraction
C_8 Non-Aro
C_8 Aro
OX
C_9^+
UNIT 300 BT Extraction
Non-Aro
Aro(Bz/Tol)
Rafinate
PD50
UNIT 750 Paraxylene Separation
Mx/Dx
Px
Tol
PARAXYLENE
ORTHOXYLENE
H_2 from PSA
C_9^+
Bz/Tol
Tol
UNIT 600&650 Toluene and C_9aromatics Transalkylation
C_6^-
B_2
C_8^+
C_{10}^+
Heavy Aros
BENZENE
Light Transalkylate recycle
UNIT 300 Pyrolysis Gasoline Hydrogenation
C_5^- Light ends
C_6-C_9
C_{10}^+ Heavy ends
H_2
PYROLYSIS GASOLINE

Fig. 2

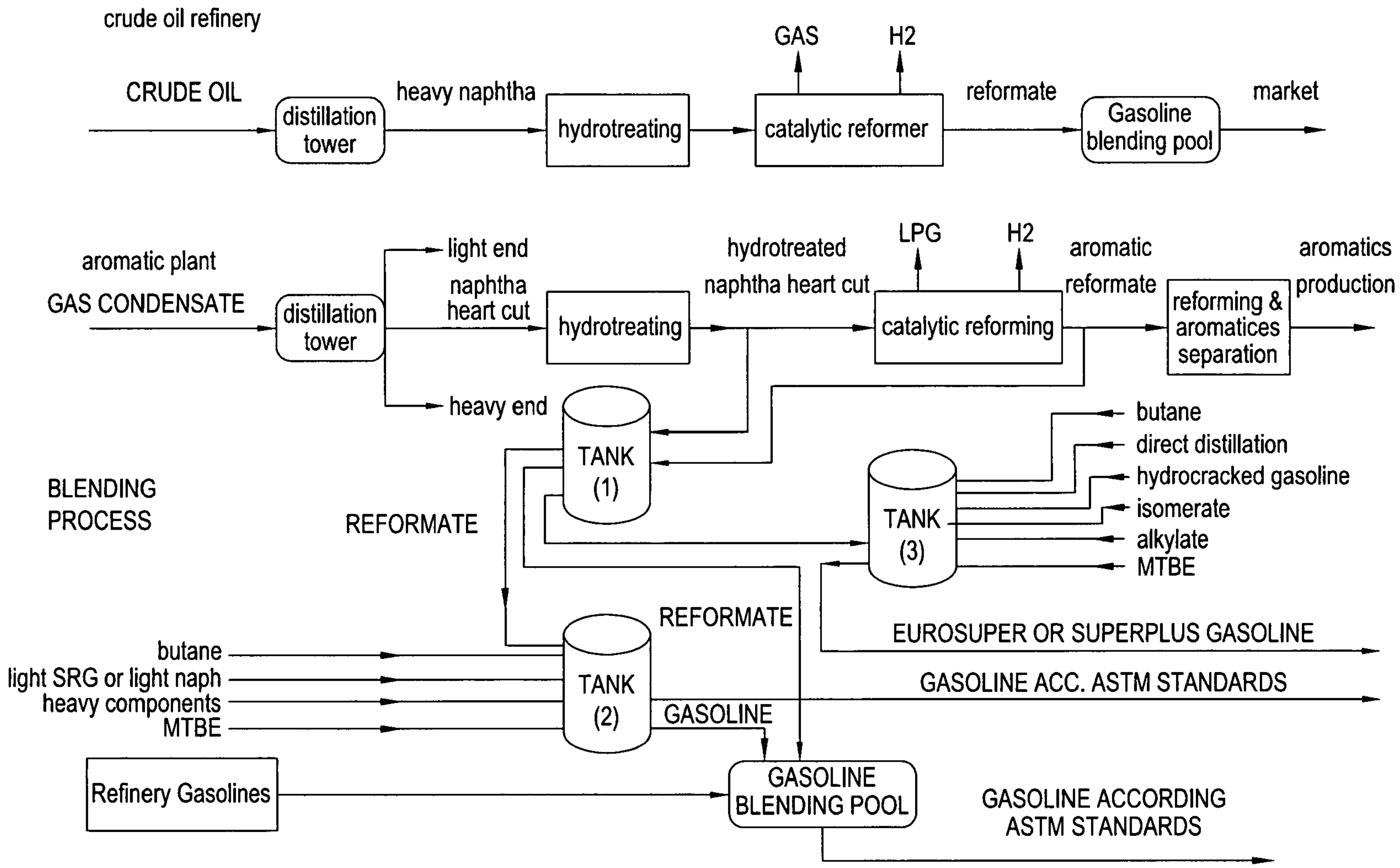

crude oil refinery
CRUDE OIL
distillation tower
heavy naphtha
hydrotreating
GAS
H2
catalytic reformer
reformate
Gasoline blending pool
market
aromatic plant
GAS CONDENSATE
distillation tower
light end
naphtha heart cut
heavy end
hydrotreating
hydrotreated naphtha heart cut
LPG
H2
catalytic reforming
aromatic reformate
reforming & aromatices separation
aromatics production
BLENDING PROCESS
REFORMATE
TANK (1)
TANK (3)
butane
direct distillation
hydrocracked gasoline
isomerate
alkylate
MTBE
REFORMATE
EUROSUPER OR SUPERPLUS GASOLINE
butane
light SRG or light naph
heavy components
MTBE
TANK (2)
GASOLINE
GASOLINE ACC. ASTM STANDARDS
Refinery Gasolines
GASOLINE BLENDING POOL
GASOLINE ACCORDING ASTM STANDARDS

Fig. 3

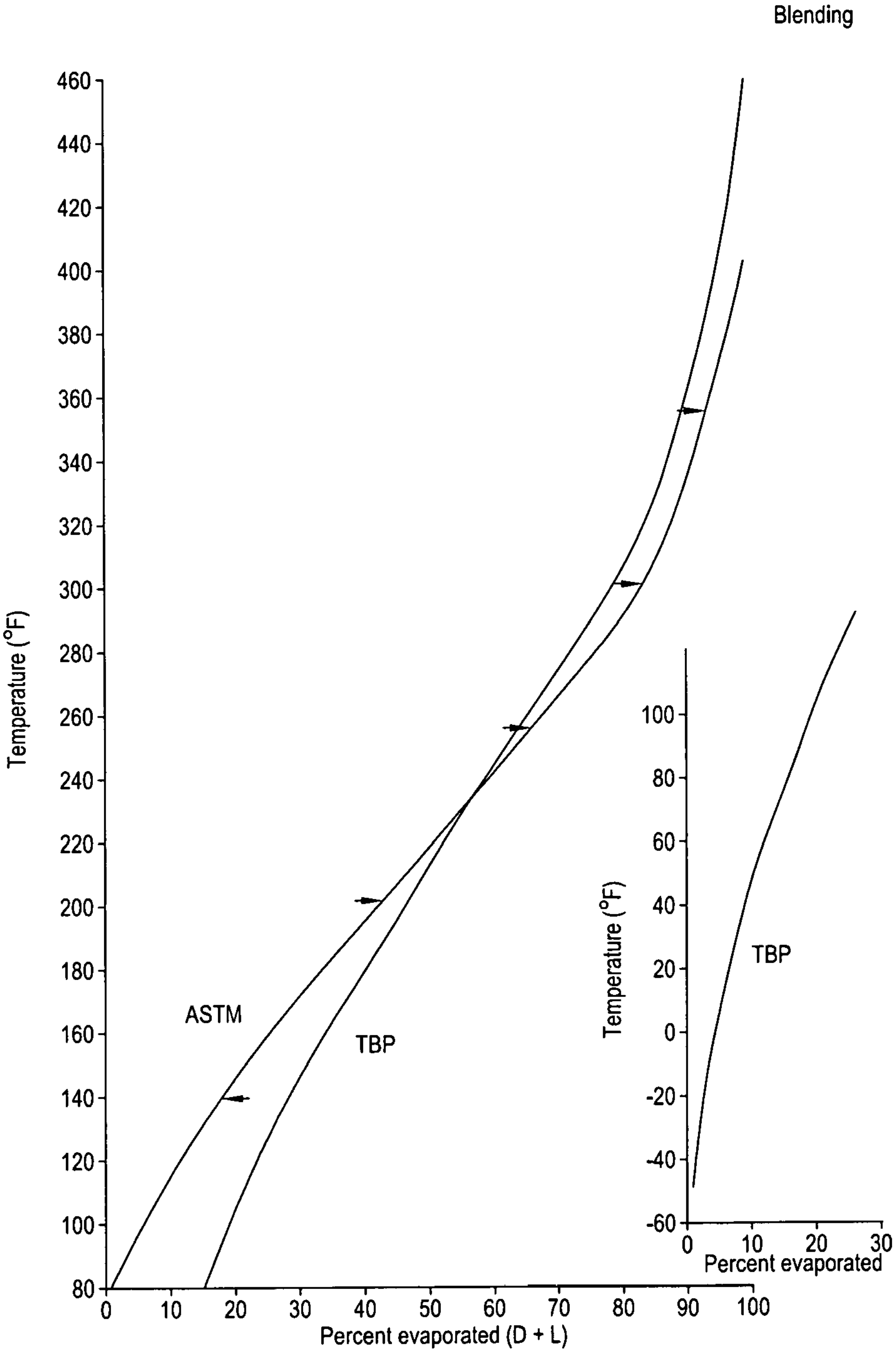
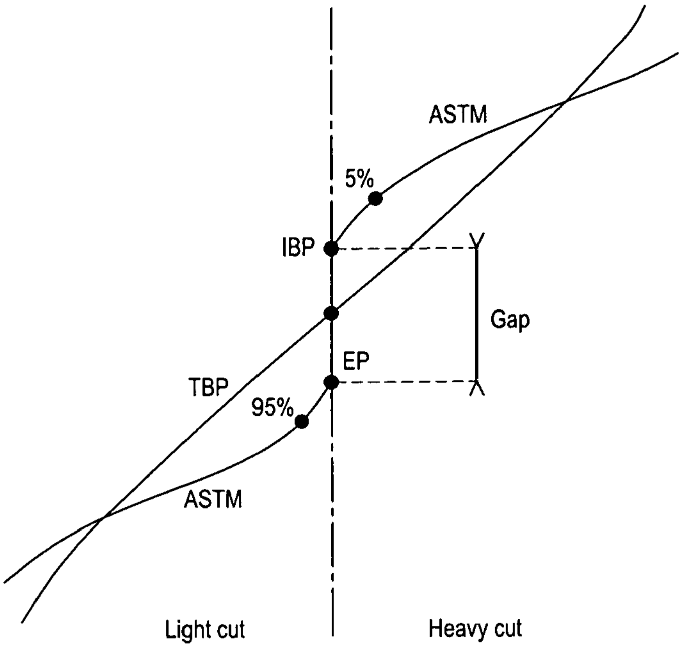
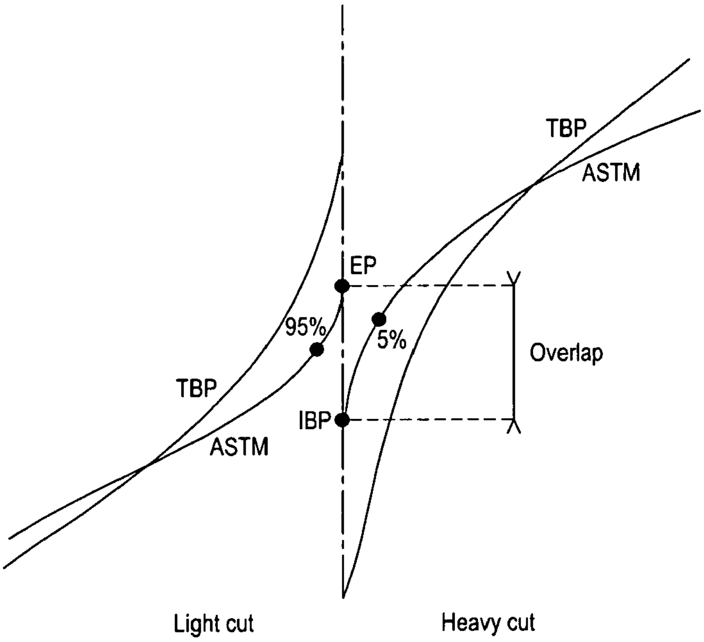

Blending
Temperature (°F)
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
ASTM
TBP
0
10
20
30
40
50
60
70
80
90
100
Percent evaporated (D + L)
Temperature (°F)
100
80
60
40
20
0
-20
-40
-60
TBP
0
10
20
30
Percent evaporated

Fig. 4



Perfect TBP fractionation



Low selectivity fractionation

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 09 25 1755

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X	GB 2 386 904 A (CHEVRON USA INC [US]) 1 October 2003 (2003-10-01) * page 6, line 14 - line 18 * * page 11, line 3 - page 12, line 8 * * figure 2 * -----	1-15	
X	ALIEV V S ET AL: "High-octane reformed gasolines and the selective adsorption of normal paraffinic hydrocarbons" CHEM TECHNOLOGY FUELS OILS; CHEMISTRY AND TECHNOLOGY OF FUELS AND OILS FEB 1965 NEW YORK, NY, UNITED STATES, no. 2, February 1965 (1965-02), pages 97-100, XP002557760 * page 97 - page 99; tables 1,2 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC) C10G C10L
X	PROKOPYUK S G ET AL: "Experience in processing naphtha from Karachaganak condensate in catalytic reformer" CHEMISTRY AND TECHNOLOGY OF FUELS AND OILS 1989 JAN, vol. 24, no. 5-6, January 1989 (1989-01), pages 237-239, XP002557761 * the whole document * -----	1-15	
A	US 2004/218547 A1 (RHODEY WILLIAM GEORGE [CA]) 4 November 2004 (2004-11-04) * the whole document * ----- -/--	1-15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	30 November 2009	Gzil, Piotr

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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L : document cited for other reasons
& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

Application Number
EP 09 25 1755

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	EMEL'YANOV V E ET AL: "Use of natural gasoline as a motor fuel" CHEMISTRY AND TECHNOLOGY OF FUELS AND OILS 1979 NOV-DEC, vol. 15, no. 11-12, November 1979 (1979-11), pages 886-888, XP002557763 * the whole document * -----	1-15	
A	PROKOPYUK S G ET AL: "Experience in hydrotreating naphtha from Karachaganak gas condensate" CHEMISTRY AND TECHNOLOGY OF FUELS AND OILS 1989 JAN, vol. 24, no. 5-6, January 1989 (1989-01), pages 239-242, XP002557764 * the whole document * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	30 November 2009	Gzil, Piotr

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3

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 25 1755

30-11-2009

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82