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(54) Title: PROCESS FOR REDUCING THE BENZENE CONTENT OF GASOLINE BY ALKYLATING BENZENE USING A LOWER OLEFIN IN THE PRESENCE OF A PARAFFINIC DILUENT

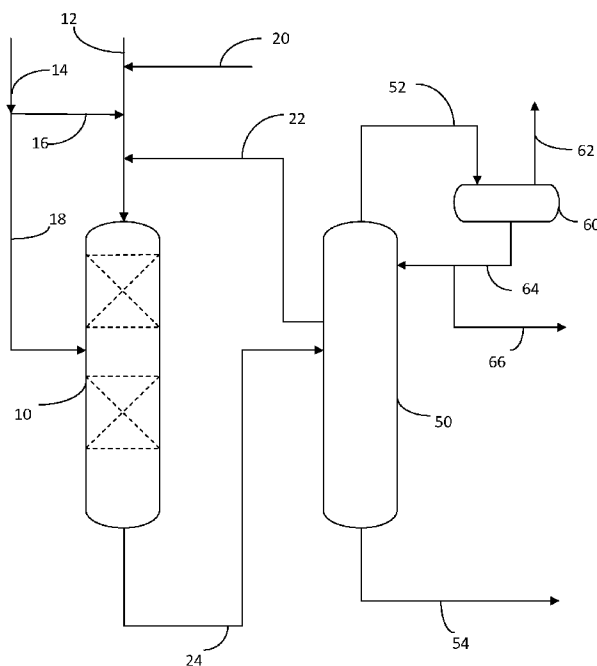


FIGURE 1

(57) Abstract: A process for reducing the benzene content of gasoline stream, such as a reformate or light naphtha, comprises alkylating the gasoline stream in a reaction zone with an olefin alkylating agent. A paraffinic stream comprising C5 to C10 paraffins is fed to the inlet of the alkylation reaction zone.



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**PROCESS FOR REDUCING THE BENZENE CONTENT OF GASOLINE BY ALKYLATING BENZENE
USING A LOWER OLEFIN IN THE PRESENCE OF A PARAFFINIC DILUENT**

FIELD

[0001] This invention relates to a process for reducing the benzene content of gasoline.

BACKGROUND

[0002] Benzene is considered to be environmentally hazardous. As a result, the State of California and the United States Environmental Protection Agency have instituted regulations to limit the amount of benzene which may be present in gasoline. As of January 2011, the US MSAT-2 (Mobile Source Air Toxics) regulation requires reduction of this annual average benzene content in gasoline to no greater than 0.62 volume %.

[0003] One known route for reducing the benzene content of gasoline is to selectively alkylate the benzene using a lower olefin. For example, Holtermann et al U.S. Patent No. 5,149,894 describes a process for converting benzene to alkylated benzenes in a gasoline blend stock. The process involves contacting a benzene-containing gasoline blend stock with a C2 to C4 olefin stream in the presence of a catalyst containing the zeolite, SSZ-25, to produce an alkylated light hydrocarbon stream with reduced benzene content.

[0004] Cheng et al. U.S. Patent No. 5,545,788 describes a process for the production of a more environmentally suitable gasoline by removing a substantial portion of benzene in gasoline by alkylation of reformate. The process involves alkylation using a light olefin feed at low temperature over the zeolite catalyst, MCM-49.

[0005] Umansky et al. U.S. Patent No. 7,476,774 describes a process where light olefins including ethylene and propylene are extracted from refinery off-gases, such as from a catalytic cracking unit, into a light aromatic stream, such as a reformate containing benzene and other single ring aromatic compounds, which is then reacted with the light olefins to form a gasoline boiling range product containing alkylaromatics. The alkylation reaction is carried out in the liquid phase with a catalyst which preferably comprises a member of the MWW family of zeolites, such as MCM-22, using a fixed catalyst bed.

[0006] When benzene, such as that contained in a gasoline feed, is alkylated with an olefin in the liquid phase over a fixed bed catalyst, the reaction is highly exothermic, with an adiabatic temperature rise across the reactor. The maximum temperature rise across the reactor is set by practical limitations determined by the difference between the minimum reactor inlet temperature required for reaction, and the maximum outlet temperature which is deemed practical for the mechanical design of the reactor system.

[0007] To control the temperature rise, the quantity of olefin to each reactor stage is limited. In applications where the concentration of benzene in the refinery stream is relatively high, for example 20 volume % and above, the temperature limitation in an adiabatic process, according to current technology, requires that at least four stages in series are used, in order to be able to limit and distribute the olefin. The use of such a large number of reactors increases the cost of the plant substantially.

[0008] According to the present invention, it has now been found that the problem of the adiabatic temperature rise during the alkylation of a benzene-containing gasoline stream, such as a reformat or light naphtha, with an olefin alkylating agent can be reduced by diluting the feed to the alkylation reactor with a C5 to C10 paraffin stream. This problem of adiabatic temperature rise is more pronounced in a single phase system. i.e. vapor phase or liquid phase, as opposed to a mixed phase system including both a vapor phase and a liquid phase.

SUMMARY

[0009] In an alkylation process, benzene contained in a refinery gasoline stream is alkylated. The alkylation process comprises contacting said refinery gasoline stream with an alkylating agent comprising one or more C2 to C5 olefins in an alkylation reaction zone under alkylation conditions to produce an alkylated effluent. The alkylation reaction zone comprises at least one alkylation reaction stage. A paraffinic stream comprising C5 to C10 hydrocarbons is fed to the inlet of at least one of the alkylation reaction stages.

[0010] The paraffinic stream may comprise less than 2.0 wt % aromatics and/or olefins.

[0011] The refinery gasoline stream may be, for example, a reformate or a light naphtha. The alkylating agent may be, for example, propylene or a mixture of propylene and propane.

[0012] The refinery gasoline stream may comprise at least 10 volume % benzene. The refinery gasoline stream may be substantially in the liquid phase during contact of the refinery gasoline stream with the alkylating agent in the alkylation reaction zone.

[0013] The contact of the refinery gasoline stream with the alkylating agent in the alkylation reaction zone may take place under substantially adiabatic conditions.

[0014] The refinery gasoline stream may be a reformate or a light naphtha. The paraffinic stream may be a distillation product obtained by distilling the alkylated effluent from the reaction zone.

[0015] The alkylated effluent may comprise less than 2.0 volume % benzene, for example, less than 0.62 volume % benzene.

[0016] The alkylated effluent may comprise no more than 2 volume % of compounds having a boiling point greater than 236 °C at atmospheric pressure.

[0017] The alkylation reaction may take place over a catalyst comprising an MWW zeolite.

BRIEF DESCRIPTION OF THE DRAWING

[0018] Figure 1 is a schematic diagram of one embodiment of a process for alkylating a benzene containing feedstock.

DETAILED DESCRIPTION

[0019] Refinery streams which may be alkylated to decrease benzene content include streams comprising benzene and alkylbenzenes. Examples of such streams include reformates and naphtha streams, especially light naphtha streams. Blends of refinery streams may also be alkylated. The refinery streams employed in the present process typically comprise at least 10 wt %, such as about 15 wt% to about 20 wt%, benzene.

[0020] Reformates have high octane number attributable to their high aromatics content. However, high concentrations of benzene in reformate, e.g., 4 to 6 wt %, can limit reformate utility as a blending component where environmental considerations

require low benzene levels in gasoline product. Various efforts to reduce benzene content in reformat, e.g., selective hydrogenation, high temperature fluid-bed MBR, and reformat alkylation with methanol all suffer from octane losses or total liquid product losses associated with undesired cracking of C5+ non-aromatics.

[0021] The present invention relates to a process whereby benzene-containing reformates and other refinery streams are treated to reduce benzene content by alkylation. Undesirable alkylation of higher boiling aromatics, such as xylenes, may be minimized.

[0022] Examples of suitable alkylating agents for use in the present process are olefins having 2 to 5 carbon atoms, such as ethylene, propylene, butenes, and pentenes. Mixtures of light olefins are especially useful as alkylating agents in the alkylation process of this invention. Accordingly, mixtures of ethylene, propylene, butenes, and/or pentenes which are major constituents of a variety of refinery streams, e.g., fuel gas, gas plant off-gas containing ethylene, propylene, etc., naphtha cracker off-gas containing light olefins, refinery FCC propane/propylene streams, and FCC off-gas, etc., are useful alkylating agents herein. Compositions of examples of olefin containing streams suitable for use as alkylating agents are described, for example, in U.S. Patent No. 7,476,774.

[0023] In addition to the olefinic alkylating agent and the benzene-containing refinery stream, in the present process a paraffinic stream comprising C5 to C10 hydrocarbons is fed to the alkylation reactor, typically in amount such that the weight ratio of paraffinic stream to benzene-containing refinery stream is between about 0.25 and about 4. Generally, the paraffinic stream contains less than 2.0 wt % aromatics and/or olefins. In one embodiment, the refinery gasoline stream is a light reformat, and wherein said paraffinic stream is a distillation product obtained by distilling the alkylated effluent from the alkylation reaction.

[0024] The alkylation process may be conducted such that the organic reactants, i.e., the alkylatable aromatic compound, the alkylating agent and the paraffinic stream, are brought into contact with a zeolite catalyst composition in a suitable reaction zone, such as, for example, in a flow reactor containing a fixed bed of the catalyst composition, under effective alkylation conditions. Such conditions may include a temperature of from about 0 °C to about 500 °C, for example, between about 50 °C and about 300 °C, and a pressure of from about 0.2 to about 250 atmospheres, for example, from about 1 to

about 50 atmospheres. The feed weight hourly space velocity (WHSV) will generally be between 0.1 hr^{-1} and 500 hr^{-1} , for example, from 0.5 hr^{-1} to 100 hr^{-1} . The latter WHSV is based upon the total weight of active catalyst (and binder if present). The reaction may be conducted under substantially adiabatic conditions.

[0025] The reactants may be in the vapor phase or the liquid phase or in a mixture of liquid and vapor phases. The reactants may be neat, i.e., free from intentional admixture or dilution with other material, or they can be brought into contact with the zeolite catalyst composition with the aid of carrier gases or diluents such as, for example, hydrogen or nitrogen.

[0026] The alkylation reaction zone may comprise one or more alkylation reaction stages. When more than one alkylation stage is used, fresh refinery gasoline feed or fresh alkylating agent feed may, optionally, be introduced between one or more stages.

Catalyst System

[0027] The catalyst system used in the alkylation of the present process is preferably one based on a zeolite of the MWW family because these catalysts exhibit excellent activity for the desired aromatic alkylation reaction using light olefins, especially propylene. It is, however, possible to use other molecular sieve catalysts for this alkylation, including catalysts based on ZSM-12 as described in U.S. Patent Nos. 3,755,483 and 4,393,262 for the manufacture of petrochemical cumene from refinery benzene and propylene or catalysts based on zeolite beta as described in U.S. Patent No. 4,891,458, all of which are reported to have activity for the alkylation of light aromatics by propylene.

MWW Zeolite

[0028] The MWW family of zeolite materials has achieved recognition as having a characteristic framework structure which presents unique and interesting catalytic properties. The MWW topology consists of two independent pore systems: a sinusoidal ten-member ring [10 MR] two dimensional channel separated from each other by a second, two dimensional pore system comprised of 12 MR super cages connected to each other through 10 MR windows. The crystal system of the MWW framework is

hexagonal and the molecules diffuse along the [100] directions in the zeolite, i.e., there is no communication along the c direction between the pores. In the hexagonal plate-like crystals of the MWW type zeolites, the crystals are formed of relatively small number of units along the c direction as a result of which, much of the catalytic activity is due to active sites located on the external surface of the crystals in the form of the cup-shaped cavities. In the interior structure of certain members of the family such as MCM-22, the cup-shaped cavities combine together to form a supercage. The MCM-22 family of zeolites has attracted significant scientific attention since its initial announcement by Leonovicz et al. in *Science* 264, 1910-1913 [1994] and the later recognition that the family includes a number of zeolitic materials such as PSH 3, MCM-22, MCM-49, MCM-56, SSZ- 25, ERB-1, ITQ-1, and others. Lobo et al. *AIChE Annual Meeting* 1999, Paper 292J.

[0029] The relationship between the various members of the MCM-22 family have been described in a number of publications. Significant members of the family are MCM-22, MCM-36, MCM-49, and MCM-56. When initially synthesized from a mixture including sources of silica, alumina, sodium, and hexamethylene imine as an organic template, the initial product will be MCM-22 precursor or MCM-56, depending upon the silica: alumina ratio of the initial synthesis mixture. At silica:alumina ratios greater than 20, MCM-22 precursor comprising H-bonded vertically aligned layers is produced whereas randomly oriented, non-bonded layers of MCM-56 are produced at lower silica:alumina ratios. Both these materials may be converted to a swollen material by the use of a pillaring agent and on calcination, this leads to the laminar, pillared structure of MCM-36. The as-synthesized MCM-22 precursor can be converted directly by calcination to MCM-22 which is identical to calcined MCM-49, an intermediate product obtained by the crystallization of the randomly oriented, as-synthesized MCM-56. In MCM-49, the layers are covalently bonded with an interlaminar spacing slightly greater than that found in the calcined MCM-22/MCM-49 materials. The as-synthesized MCM-56 may be calcined itself to form calcined MCM-56 which is distinct from calcined MCM-22/MCM-49 in having a randomly oriented rather than a laminar structure. In the patent literature MCM-22 is described in U.S. Patent No. 4,954,325 as well as in U.S. Patent Nos. 5,250,777; 5,284,643 and 5,382,742. MCM-49 is described in U.S. Patent

No. 5,236,575; MCM-36 in U.S. Patent No. 5,229,341 and MCM-56 in U.S. Patent No. 5,362,697.

[0030] A preferred zeolitic material for use as the MWW component of the catalyst system is MCM-22.

Catalyst Matrix

[0031] In addition to the zeolitic component, the catalyst will usually contain a matrix material or binder in order to give adequate strength to the catalyst as well as to provide the desired porosity characteristics in the catalyst. High activity catalysts may, however, be formulated in the binder-free form by the use of suitable extrusion techniques, for example, as described in U.S. Patent No. 4,908,120. When used, matrix materials suitably include alumina, silica, silica alumina, titania, zirconia, and other inorganic oxide materials commonly used in the formulation of molecular sieve catalysts. For use in the present process, the level of zeolite, such as MCM-22 or ZSM-5 type (intermediate pore size) zeolite, in the finished matrixed catalyst will be typically from 20 to 70% by weight, and in most cases from 25 to 65% by weight. In manufacture of a matrixed catalyst, the active ingredient will typically be milled with the matrix material using an aqueous suspension of the catalyst and matrix, after which the active component and the matrix are extruded into the desired shape, for example, cylinders, hollow cylinders, trilobe, quadlobe, etc. A binder material such as clay may be added during the milling in order to facilitate extrusion, increase the strength of the final catalytic material and to confer other desirable solid state properties. The amount of clay will not normally exceed 10% by weight of the total finished catalyst. Unbound (or, alternatively, self-bound) catalysts are suitably produced by the extrusion method described in U.S. Patent No. 4,582,815, to which reference is made for a description of the method and of the extruded products obtained by its use. The method described there enables extrudates having high constraining strength to be produced on conventional extrusion equipment and accordingly, the method is suitable for producing the catalysts which are silica-rich. The catalysts are produced by milling the zeolite with water to a solids level of 25 to 75 wt % in the presence of 0.25 to 10 wt % of basic material such as sodium hydroxide. Further details are to be found in U.S. Patent No. 4,582,815.

Gasoline Product

[0032] Even with a refinery gasoline feed comprising at least 10 volume % benzene, the present process allows the production of a gasoline product which contains less than 2 volume %, typically less than 0.62 volume %, benzene and generally no more than 2 volume % of compounds having a boiling point greater than 236 °C at atmospheric pressure.

[0033] The invention will now be more particularly described with reference to the following non-limiting Examples.

Example

[0034] As shown in Figure 1, a benzene containing feed, such as a light reformate, is introduced into an alkylation reactor **10** via line **12**. In Figure 1, alkylation reactor **10** is illustrated as a two stage reactor. However, it will be understood that alkylation reactor **10** may also have a single alkylation stage or more than two alkylation stages.

[0035] In Figure 1, an olefin feed, such as a propylene feed, from line **14** is split into line **16** and **18**. Line **16** combines olefin feed with the benzene containing feed of line **12** upstream of the alkylation reactor **10**. Line **18** introduces olefin feed at a midpoint of the alkylation reactor **10**, e.g., at a point between a first reaction stage and a second reaction stage. Although Figure 1 illustrates splitting of the olefin feed and introduction of the olefin feed into the alkylation reactor **10** at two points, it will be understood that other reactor configurations are possible. For example, all of the olefin feed may be introduced to the beginning of the first alkylation stage along with the benzene containing feed through the same or different lines.

[0036] In one embodiment, a paraffinic stream comprising C5 to C10 hydrocarbons is combined with the benzene containing feed in line **12** via line **20**. The paraffinic stream in line **20** may be an externally provided refinery stream, such as a light naphtha stream. In another embodiment, an internally provided paraffinic stream comprising C5 to C10 hydrocarbons is introduced into line **12** via line **22**. This internally provided stream is taken as a side draw from stabilizer column **50** as described below. Although not shown in Figure 1, it will be understood that other configurations for introducing a paraffinic

stream into alkylation reactor are possible. For example, lines **20** and **22** may pass directly into the beginning of the first alkylation stage of the alkylation reactor, instead of into line **12**.

[0037] Effluent from alkylation reactor **10** is passed via line **24** to stabilizer column **50**. As mentioned above, a paraffinic stream comprising C5 to C10 hydrocarbons may be taken as a side draw from stabilizer column **50** via line **22** to be introduced into alkylation reactor **10**. Optionally, however, line **22** may be omitted and all of the paraffinic cofeed introduced into the alkylation reactor **10** may come from an external source via line **20**.

[0038] The overhead stream from the stabilizer column **50** includes light paraffins, such as paraffins having less than five carbon atoms. This overhead may also comprise unreacted olefins, if any, in the effluent stream from the alkylation reactor **10**. This overhead stream passes from stabilizer column **50** to condenser **60** via line **52**.

[0039] Vent gas may be removed via line **62**. The condensate from condenser **60** may be recycled to the stabilizer column **50** via line **64**. A portion of this condensate may also be taken from line **64** and recovered via line **66**, for example, as a liquefied petroleum gas (LPG).

[0040] The alkylated product with reduced benzene content is recovered from the stabilizer column via line **54**.

[0041] While the present invention has been described and illustrated by reference to particular embodiments, those of ordinary skill in the art will appreciate that the invention lends itself to variations not necessarily illustrated herein. For this reason, then, reference should be made solely to the appended claims for purposes of determining the true scope of the present invention.

WHAT IS CLAIMED IS:

1. A process for alkylating benzene contained in a refinery gasoline stream, said process comprising contacting said refinery gasoline stream with an alkylating agent comprising one or more C2 to C5 olefins in an alkylation reaction zone under alkylation conditions to produce an alkylated effluent, wherein said alkylation reaction zone comprises at least one alkylation reaction stage, wherein a paraffinic stream comprising C5 to C10 hydrocarbons is fed to the inlet of said at least one of the alkylation reaction stage, and wherein said paraffinic stream is a distillation product obtained by distilling the alkylated effluent from the reaction zone.
2. A process according to claim 1, wherein said paraffinic stream contains less than 2.0 wt % aromatics and/or olefins.
3. A process according to any of the above claims 1 and 2, wherein said refinery gasoline stream comprises at least 10 volume % benzene.
4. A process according to any of the above claims 1-3, wherein said refinery gasoline stream is substantially in the liquid phase during said contacting.
5. A process according to any of the above claims 1-4, wherein said contacting takes place under substantially adiabatic conditions.
6. A process according to any of the above claims 1-5, wherein said refinery gasoline stream is a reformat comprising C5 to C10 hydrocarbons.
7. A process according to any of the above claims 1-6, wherein said alkylating agent is propylene.

8. A process according to any of the above claims 1-7, wherein said alkylated effluent comprises less than 2.0 volume % benzene, preferably, less than 0.62 volume % benzene.
9. A process according to any of the above claims 1-8, wherein said alkylated effluent comprises no more than 2 volume % of compounds having a boiling point greater than 236 °C at atmospheric pressure.
10. A process according to any of the above claims 1-9, wherein the alkylation reaction takes place over a catalyst comprising an MWW zeolite.

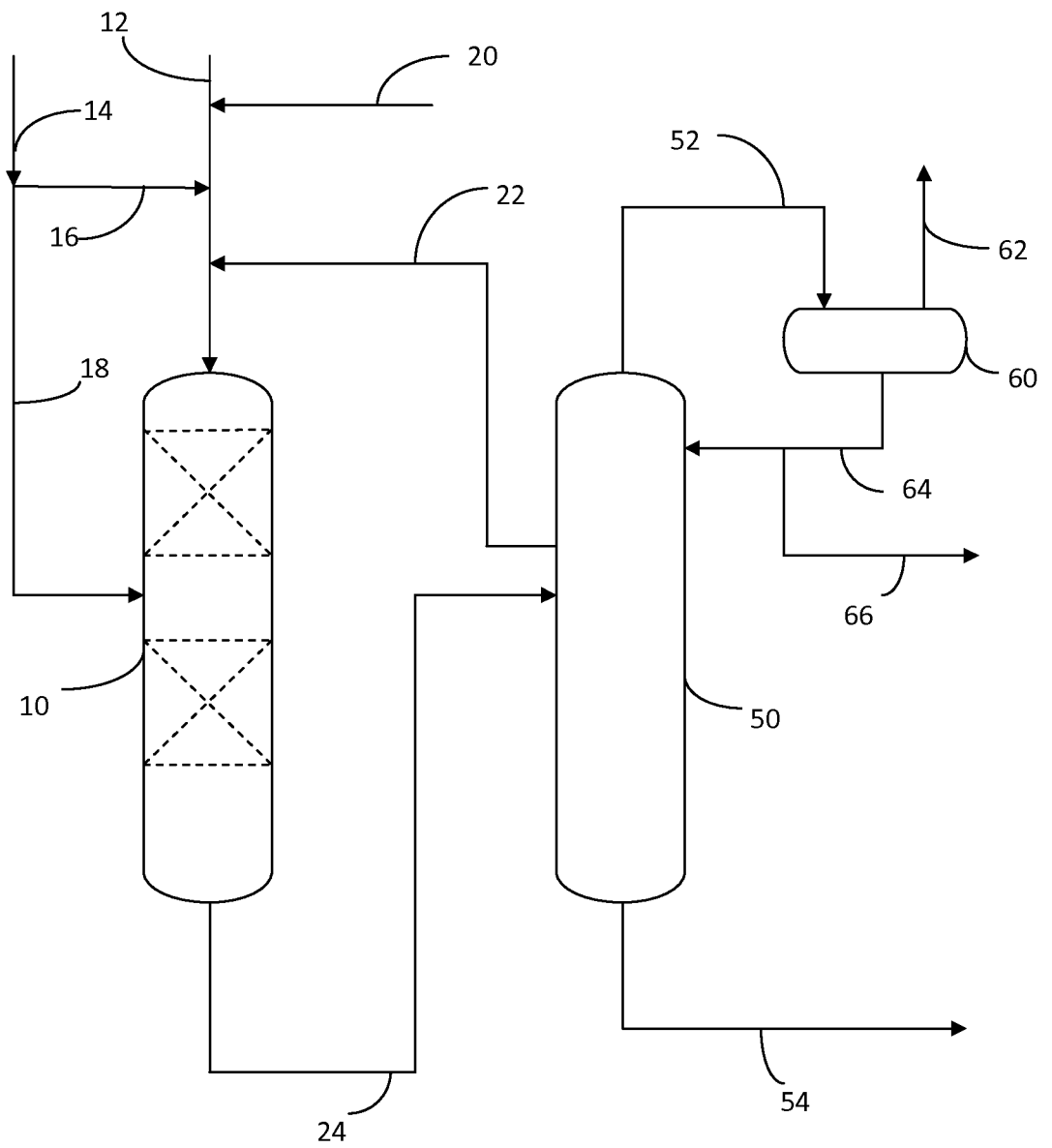


FIGURE 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/023904

A. CLASSIFICATION OF SUBJECT MATTER
INV. C07C2/66 C10G29/20
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C07C C10G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 950 823 A (HARANDI MOHSEN N [US] ET AL) 21 August 1990 (1990-08-21) figure 1 column 1, lines 6-15, 31-46 column 2, lines 14-29, 35-62 column 3, lines 14-19, 32-36, 59-63 column 4, lines 5-15 column 5, lines 3-12, 20-39, 58-68 column 6, lines 1-2 column 7, lines 8-34 column 8, lines 8-17, 20-39, 48-68 column 9, lines 14-15, 21-66 column 11, line 36 - column 12, line 33 ----- -/-	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search

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20/05/2011

Name and mailing address of the ISA/

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Authorized officer

Marchand, Karin

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/023904

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/300930 A1 (CLARK MICHAEL C [US] ET AL) 2 December 2010 (2010-12-02) abstract paragraphs [0003], [0008], [0012], [0015] - [0018], [0031] - [0033], [0037] - [0038], [0042] - [0043], [0054] - [0055], [0065] - [0066], [0069] tables 1-5 -----	1-10
A	US 2010/249472 A1 (CLARK MICHAEL C [US] ET AL) 30 September 2010 (2010-09-30) abstract paragraphs [0017], [0054], [0059], [0068], [0077] claim 1 -----	1-10
A	UMANSKY B ET AL: "Banish the benzene, boost the octane", HYDROCARBON ENGINEERING, PALLADIAN PUBLICATIONS, FARNHAM, GB, vol. 12, 1 January 2007 (2007-01-01), pages 61-62, XP009146927, ISSN: 1468-9340 the whole document -----	1-10
A	El-Mekki EL-MALKI, Michael CLARK: "BenzOUT Reducing Benzene Enhancing Gasoline Product Value", NPRA Conference, Phoenix, AZ, March 21-23, 2010 21 March 2010 (2010-03-21), XP002632311, Retrieved from the Internet: URL: http://www.exxonmobil.com/Apps/RefiningTechnologies/Files/Conference_2010_benzout_march.pdf [retrieved on 2011-04-04] the whole document -----	3,5,6
A	US 2006/194999 A1 (BROWN STEPHEN H [BE] ET AL) 31 August 2006 (2006-08-31) figure 1 tables 1-2 paragraphs [0007], [0009], [0015], [0021] - [0022], [0028] -----	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2011/023904

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4950823	A	21-08-1990	NONE
US 2010300930	A1	02-12-2010	WO 2010104581 A2 16-09-2010
US 2010249472	A1	30-09-2010	CN 101466815 A 24-06-2009
		EP 2029696 A1	04-03-2009
		KR 20090078305 A	17-07-2009
		US 2009137855 A1	28-05-2009
		US 2007265481 A1	15-11-2007
		WO 2007133353 A1	22-11-2007
US 2006194999	A1	31-08-2006	NONE