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[Continued on next page]

(54) Title: SYSTEM AND METHOD FOR GENERATING A CARBON DIOXIDE STREAM

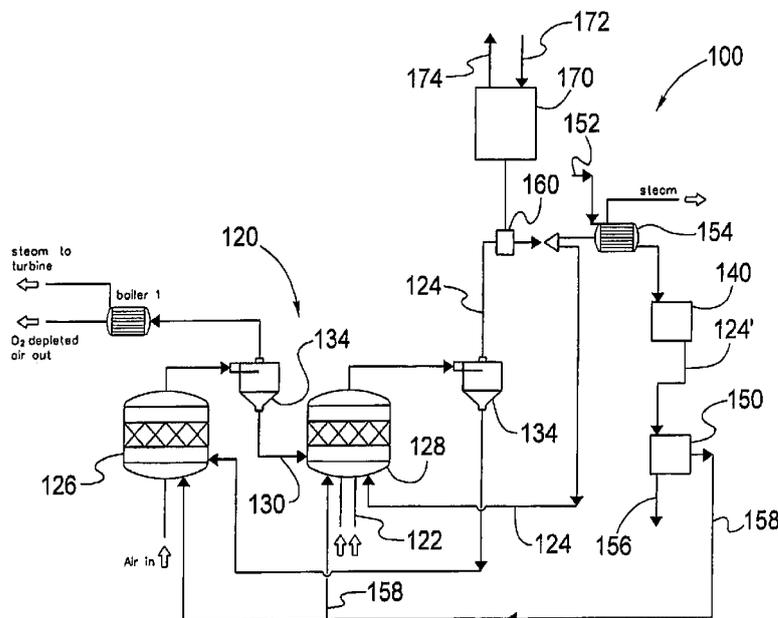


FIG. 1

(57) Abstract: A flue gas stream processing system includes a fuel reactor for combusting a fuel to generate a flue gas stream including water vapor, carbon monoxide and carbon dioxide. The system includes an oxidation catalyst downstream of the fuel reactor, the oxidation catalyst configured to receive the flue gas stream and oxidize the carbon monoxide to form a carbon dioxide rich flue gas stream, and a processing unit to liquefy carbon dioxide in the carbon dioxide rich flue gas stream and generate an exhaust gas.

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SYSTEM AND METHOD FOR GENERATING A CARBON DIOXIDE STREAM

BACKGROUND

1. Field

[0001] The present disclosure generally relates to a system and method for generating a carbon dioxide stream. More particularly, the present disclosure relates to generating a carbon dioxide stream in a flue gas stream processing system employing a chemical looping combustion system.

2. Related Art

[0002] Chemical looping combustion (CLC) is a combustion technology that affords inherent separation of carbon dioxide (CO₂). Typically, CLC employs two reactors: an air reactor and a fuel reactor. A solid oxygen carrier, which may be a metal, transfers the oxygen from the air to the fuel. The fuel is fed to the fuel reactor where it is oxidized by the oxygen carrier and the oxygen carrier is reduced and returned to the air reactor, where it is oxidized and the loop of oxidizing the fuel and reducing the carrier continues. The exit stream from the fuel reactor, commonly referred to as the flue gas, typically contains CO₂ and water vapor. However, depending on the fuel, the flue gas may also contain trace contaminants. The water vapor in the flue gas is separated from the CO₂ by cooling and condensation, while the CO₂ is liquefied or compressed for further transport.

[0003] Due to its limited residence time in the fuel reactor and the lack of free oxygen, the CO₂ stream may be contaminated with products of incomplete combustion, such as carbon monoxide (CO), hydrogen (H₂), and methane (CH₄). Additionally, the flue gas stream may be diluted with air, which may in-leak to the boiler.

[0004] Contaminants such as CO, H₂, and CH₄ are more difficult to liquefy than CO₂ during liquification of the CO₂. The contaminants take the form of a non-condensable phase commonly referred to as an exhaust gas. The level of contaminants within the exhaust gas is often too high to be released to the atmosphere without further treatment. Recycling of the exhaust gas to the fuel reactor would result in gradual accumulation of N₂ and other inert gases in the flue gas and may also dilute the CO₂ stream, thereby reducing the efficiency of the CLC system.

[0005] Accordingly, a method or system for processing the exhaust gas in an efficient way without impacting the CLC system is desired.

SUMMARY

[0006] According to aspects illustrated herein, there is provided a method of generating a liquefied carbon dioxide stream, the method comprising: generating a flue gas stream including carbon monoxide and water vapor; subjecting the flue gas stream to an oxidation catalyst for oxidizing the carbon monoxide, thereby generating a carbon dioxide rich flue gas stream; and processing the carbon dioxide rich flue gas stream to form a liquefied carbon dioxide stream.

[0007] According to other aspects illustrated herein, there is provided a flue gas stream processing system comprising: a fuel reactor for combusting a fuel to generate a flue gas stream including water vapor, carbon monoxide and carbon dioxide; an oxidation catalyst downstream of the fuel reactor, the oxidation catalyst configured to receive the flue gas stream and oxidize the carbon monoxide to form a carbon dioxide rich flue gas stream; and a processing unit to liquefy carbon dioxide in the carbon dioxide rich flue gas stream and generate an exhaust gas.

[0008] According to other aspects illustrated herein, there is provided a method for reducing an amount of contaminants released by a flue gas stream processing system, the method comprising: generating a flue gas stream by combustion of a fuel in a fuel reactor of a chemical looping combustion system, the flue gas stream includes water vapor and carbon monoxide; forming a liquefied carbon dioxide stream by removing water vapor and carbon monoxide from the flue gas stream; generating an exhaust gas during formation of the liquefied carbon dioxide stream; and providing at least a portion of the exhaust gas to an air reactor in the chemical looping combustion system, thereby reducing an amount of contaminants released by a flue gas stream processing system.

[0009] The above described and other features are exemplified by the following figures and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Referring now to the figures, which are exemplary embodiments, and wherein the like elements are number alike:

[0011] FIGURE 1 is a schematic block diagram of one embodiment of the system disclosed herein; and

[0012] FIGURE 2 is a schematic block diagram of one embodiment of the system disclosed herein.

DETAILED DESCRIPTION

[0013] FIG. 1 illustrates a flue gas stream processing system 100 having a combustion system 120. The combustion system 120 may be any system capable of combusting a fuel 122 to form a flue gas 124. The combustion system 120 illustrated in FIG. 1 is a chemical looping combustion system that includes an air reactor 126 and a fuel reactor 128. The flue gas stream processing system 100 is not limited in this regard since the combustion system 120 may be other combustion systems, including, but not limited to boilers, furnaces, and the like.

[0014] In operation, the chemical looping combustion system 120 includes an oxygen carrier 130, which transfers oxygen from the air present in the air reactor 126 to the fuel 122 provided to the fuel reactor 128. The fuel 122 is oxidized by the oxygen carrier 130 in the fuel reactor 128 and the oxygen carrier is reduced and returned to the air reactor 126 as a reduced oxygen carrier 132. The reduced oxygen carrier 132 is oxidized in the air reactor 126 and the loop of oxidizing the fuel 122 and reducing the oxygen carrier 130 continues. The oxygen carrier 130 may be a metal, such as, but not limited to nickel, copper, iron, manganese, cadmium, and cobalt.

[0015] As shown in FIG. 1, the chemical loop combustion system 120 may include one or more cyclones 134, which facilitate the separation of the oxygen carrier 130 from depleted air and separation of the flue gas stream 124 from the reduced oxygen carrier 132.

[0016] Oxidation of the fuel 122 in the fuel reactor 128 produces the flue gas stream 124, a portion of which may be recycled to the fuel reactor 128. The flue gas stream 124 typically contains carbon monoxide (CO) carbon dioxide (CO₂) and water vapor. However, depending on the fuel, the flue gas stream 124 may also contain varying concentrations of trace contaminants, such as, but not limited to sulfur oxides (SO_x), nitrogen oxides (NO_x), mercury, hydrogen (H₂), and methane (CH₄). The flue gas stream 124 may also include contaminants such as fly ash as well as unburnt fuel (referred to as "unburnts").

[0017] The oxygen required for the oxidation of the carbon monoxide can be introduced by an air stream 152 that leaks into a boiler 154, through which the flue gas stream 124 passes. Oxidation of carbon monoxide forms carbon dioxide, which can be

condensed and liquefied in the processing unit 150. The leakage of air stream 152 into the boiler 154 is typically about 2% of the volume flue of the flue gas stream 124.

[0018] Removal of the contaminants present in the flue gas stream 124 may be conducted by providing the flue gas stream to a contaminant removal system 140 prior to introduction to a processing unit 150. Examples of contaminant removal systems 140 include, but are not limited to, particle removable devices, desulfurization systems such as wet flue gas desulfurization (WFGD) or dry flue gas desulfurization (DFGD), nitrogen oxide (NO_x) removal systems, mercury removal systems (*e.g.*, activated carbon), and the like, and combinations thereof. Removal of at least a portion of the contaminants from the flue gas stream 124 produces a carbon dioxide rich flue gas stream 124', which is introduced to the processing unit 150.

[0019] The processing unit 150 condenses and liquefies the carbon dioxide present in the carbon dioxide rich flue gas stream 124', while removing any remaining contaminants to produce a carbon dioxide stream 156 and an exhaust gas 158. The carbon dioxide stream 156 is transported in liquefied form to another location for compression, use and/or storage.

[0020] The exhaust gas 158 typically contains material that was not removed from the flue gas stream 124, such as nitrogen, hydrogen, oxygen and carbon monoxide.

[0021] In one embodiment, as shown in FIG. 1, if the carbon monoxide present in the flue gas stream 124 is less than about one percent by volume (1% by vol.) of the carbon dioxide concentration in the flue gas stream, at least a portion of the exhaust gas 158 may be returned to the air reactor 126.

[0022] Measurement of the carbon monoxide concentration in the flue gas stream 124 may be obtained by a measuring device 160. The measuring device 160 may be any device capable of obtaining measurements of a carbon monoxide concentration. Examples of the measuring device 160 include, but are not limited to a sensor or a combustion gas analyzer, *e.g.*, a Fyrite® analyzer. The measuring device 160 may be coupled to a controller 170, *e.g.*, a data processor, capable of accepting operating instructions 172 from a user and provide the user with data 174 concerning the measured concentration.

[0023] In another embodiment, as illustrated in FIG. 2, if the concentration of the carbon monoxide present in the flue gas stream 124 is about one percent by volume (1% by vol.) or greater than the carbon dioxide concentration in the flue gas stream 124, the exhaust gas 158 is not returned to the air reactor 126 and is instead provided to the atmosphere. Additionally, the carbon dioxide rich flue gas stream 124' is subjected to further processing prior to introduction to the processing unit 150. Specifically, an oxidation catalyst 180 is

placed downstream from the fuel reactor 128 at a location between the contaminant removal system 140 and the processing unit 150. The oxidation catalyst 180 facilitates the oxidation of carbon monoxide present in the carbon dioxide rich flue gas stream 124' to form carbon dioxide.

[0024] The oxidation catalyst 180 works in conjunction with the air stream 152 to oxidize the carbon monoxide present in the flue gas stream. If the carbon monoxide concentration in the flue gas stream 124 is less than about 3% by volume of the carbon dioxide concentration in the flue gas stream, the air stream 152 that is 2 % of the volume of the flue gas stream should be sufficient for oxidation. However, if the volume of air stream 152 is less than 2 % of the flue gas stream 124, or the carbon monoxide concentration is 3 % by volume or greater, additional oxygen may be added for oxidation purposes. To increase efficiency of oxidation of the carbon monoxide, or to ensure the volume of air stream 152 is at the desired level, the amount of air stream that leaks through the boiler 154 can be increased. Alternatively, an oxygen producing unit, such as an air separator, may provide an oxygen stream 182 to increase the oxidation of the carbon monoxide.

[0025] Oxidation of carbon monoxide present in the flue gas stream 124 allows the exhaust gas 158 to either be reused within the flue gas processing system 100 or contain concentrations of contaminants that are acceptable in release to the atmosphere.

[0026] While the invention has been described with reference to various exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A method of generating a liquefied carbon dioxide stream, the method comprising:
generating a flue gas stream including carbon dioxide, carbon monoxide and water vapor;
subjecting the flue gas stream to an oxidation catalyst for oxidizing the carbon monoxide, thereby generating a carbon dioxide rich flue gas stream; and
processing the carbon dioxide rich flue gas stream to form a liquefied carbon dioxide stream.
2. A method according to claim 1, wherein the flue gas stream is generated by combusting a fuel in a fuel reactor of a chemical looping combustion system.
3. A method according to claim 1, wherein processing the carbon dioxide rich flue gas stream generates an exhaust gas.
4. A method according to claim 3, further comprising:
venting the exhaust gas to an atmosphere.
5. A method according to claim 1, further comprising:
storing the liquified carbon dioxide stream.
6. A method according to claim 1, wherein the flue gas stream further comprises contaminants selected from the group consisting of sulfur oxides, nitrogen oxides, mercury, and combinations thereof.
7. A method according to claim 1, wherein the carbon monoxide is present in the flue gas stream in a concentration of at least 1% by vol. of the carbon dioxide concentration.
8. A method according to claim 1, wherein prior to subjecting the flue gas stream to the oxidation catalyst, the method further comprises:
subjecting the flue gas stream to a contaminant removal system selected from a group consisting of a desulfurization system, a particle removal device, a nitrogen oxide removal system, a mercury removal system and combinations thereof.

9. A method according to claim 1, further comprising:
adding oxygen to the flue gas stream.
10. A flue gas stream processing system comprising:
a fuel reactor for combusting a fuel to generate a flue gas stream including water vapor, carbon monoxide and carbon dioxide;
an oxidation catalyst downstream of the fuel reactor, the oxidation catalyst configured to receive the flue gas stream and oxidize the carbon monoxide to form a carbon dioxide rich flue gas stream; and
a processing unit to liquefy carbon dioxide in the carbon dioxide rich flue gas stream and generate an exhaust gas.
11. A system according to claim 10, wherein the flue gas stream further comprises contaminants selected from the group consisting of sulfur oxides, nitrogen oxides, mercury, and a combination thereof.
12. A system according to claim 11, further comprising:
a contaminant removal system downstream of the fuel reactor and upstream of the oxidation catalyst, the contaminant removal system selected from a group consisting of a sulfur oxide removal system, a nitrogen oxide removal system, a mercury removal system and combinations thereof.
13. A system according to claim 10, further comprising an oxygen producing unit downstream of the fuel reactor, the oxygen producing unit introduces oxygen to the flue gas stream.

14. A method for reducing an amount of contaminants released by a flue gas stream processing system, the method comprising:
- generating a flue gas stream by combustion of a fuel in a fuel reactor of a chemical looping combustion system, the flue gas stream includes water vapor and carbon monoxide;
 - forming liquefied carbon dioxide by removing water vapor and carbon monoxide from the flue gas stream;
 - generating an exhaust gas during formation of the liquefied carbon dioxide;
- and
- providing at least a portion of the exhaust gas to an air reactor in the chemical looping combustion system, thereby reducing an amount of contaminants released by a flue gas stream processing system.
15. The method according to claim 14, wherein the flue gas stream further comprises contaminants selected from the group consisting of sulfur oxides, nitrogen oxides, mercury, carbon dioxide and a combination thereof.
16. The method according to claim 15, wherein the exhaust gas comprises carbon monoxide.
17. The method according to claim 14 wherein the carbon monoxide concentration in the flue gas stream is less than 1% by volume of the carbon dioxide concentration in the flue gas stream.

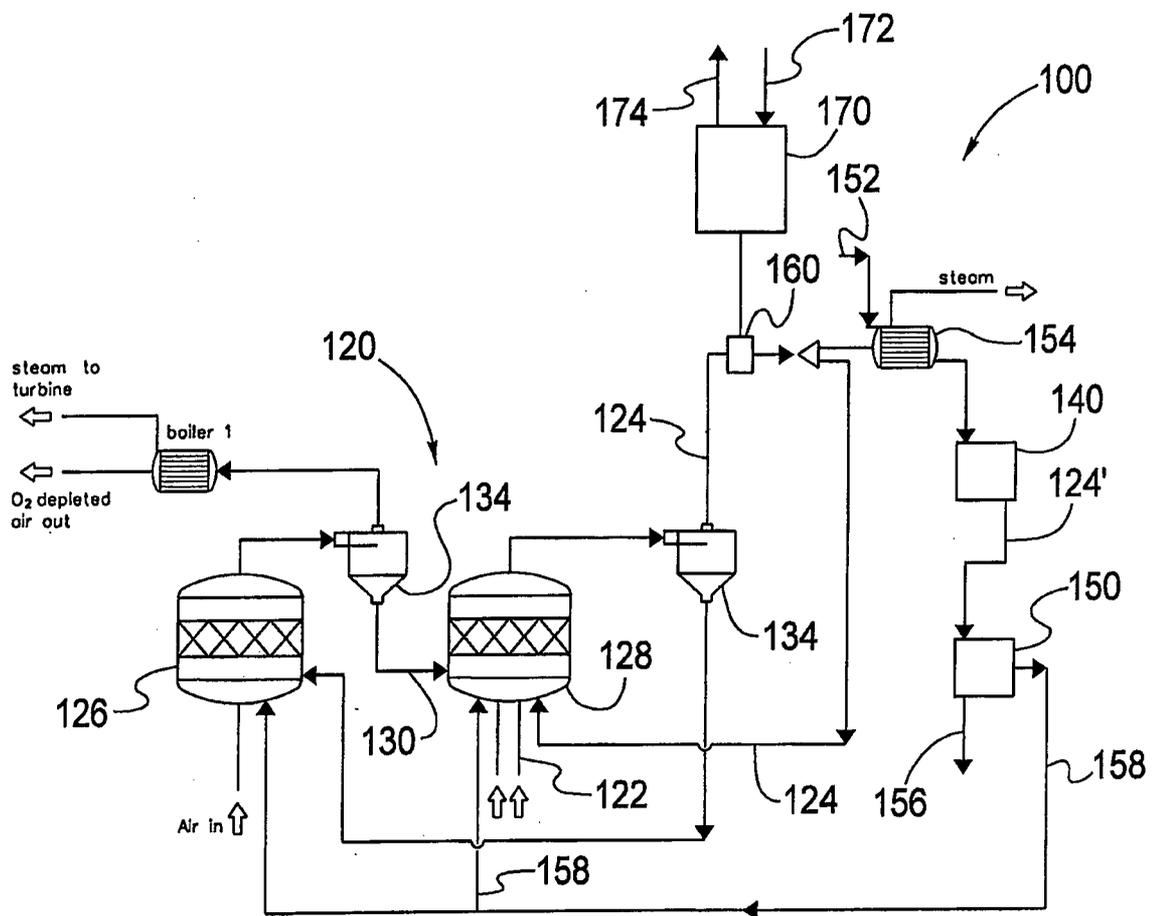


FIG. 1

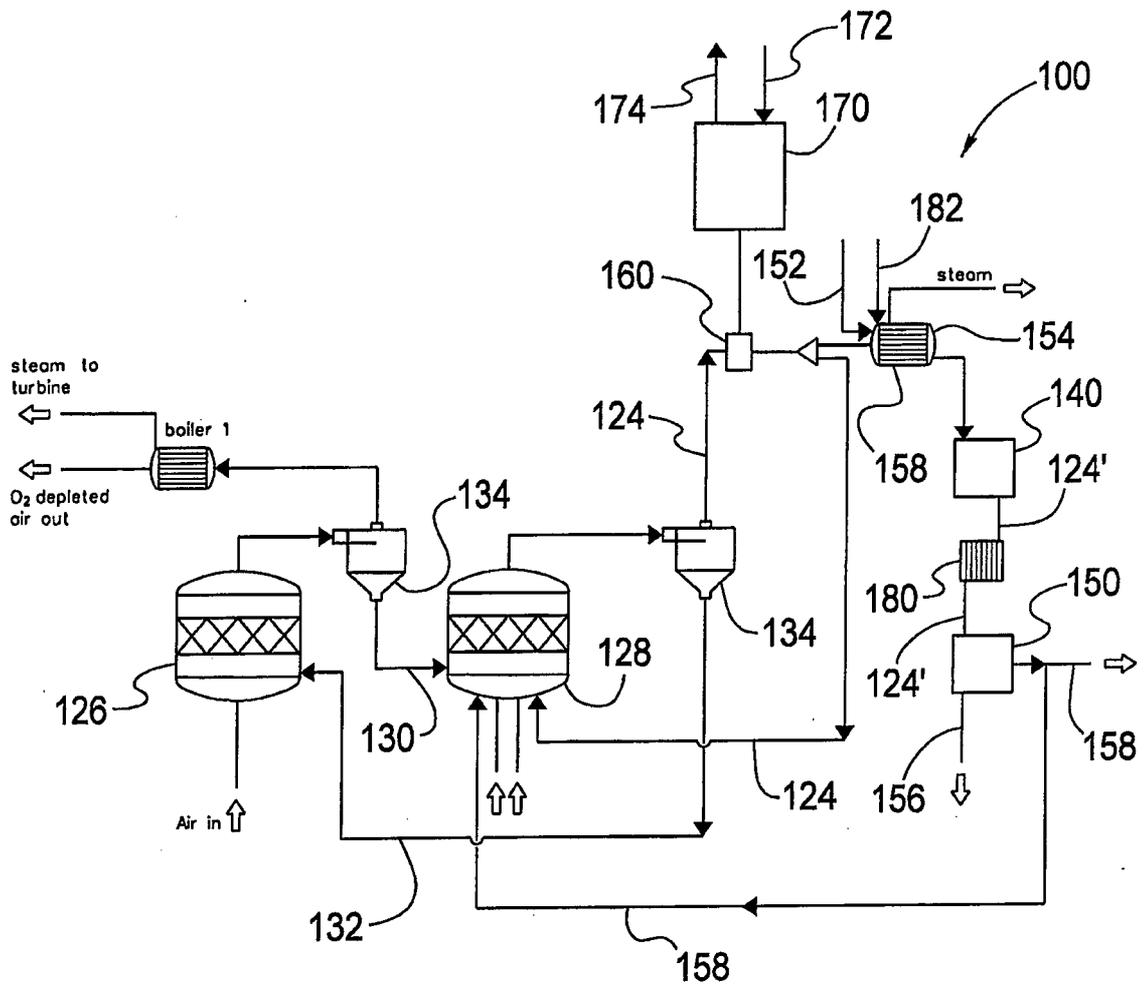


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No PCT/IB2011/000423

A. CLASSIFICATION OF SUBJECT MATTER INV. C01B31/20 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) C01B		
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, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	page 3, lines 9-21; claims 1,7 -----	2,14-17
A	WO 03/070635 A1 (PRAXAIR TECHNOLOGY INC [US]; JOHNSON MICHAEL CLINTON [US]; HEIM CARL J) 28 August 2003 (2003-08-28) claims 1-5 -----	14-17
A	US 4 364 915 A (PROCTOR RUSSELL C) 21 December 1982 (1982-12-21) claims 1-9 -----	1-17
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> 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 "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "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	Date of mailing of the international search report	
28 June 2011	06/07/2011	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Gerwann, Jochen	

INTERNATIONAL SEARCH REPORT

Information on patent family members

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