(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 May 2013 (30.05.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/075752 A1

(51) **International Patent Classification**:
F23C 3/00 (2006.01)

(21) **International Application Number**:
PCT/EP2011/071016

(22) **International Filing Date**:
25 November 2011 (25.11.2011)

(25) **Filing Language**: English

(26) **Publication Language**: English

(71) **Applicant** *(for all designated States except US)*: **FLSmidth A/S** [DK/DK]; Vigerslev Allé 77, DK-2500 Valby (DK).

(72) **Inventors; and**

(75) **Inventors/Applicants** *(for US only)*: **NIELSEN, Mads** [DK/DK]; Hastrup Bygade 8, DK-4340 Gadstrup (DK). **RASMUSSEN, Mads Peter** [DK/DK]; Kåtrupvej 30, DK-8990 Fårup (DK). **STRÖMBERG, Karl Emil Andreas** [SE/SE]; Fredsgatan 4b, S-22 220 Lund (SE). **ULLITZ, Mads Kristian** [DK/DK]; Blegkilde Allé 34 st. tv., DK-9000 Aalborg (DK). **MANOHAR, Jagannath Pandian** [IN/IN]; 33/42 S.P. Koil third street, Periyar Nagar, Thiruvottiyur, Chennai, Tamilnadu 600019 (IN).

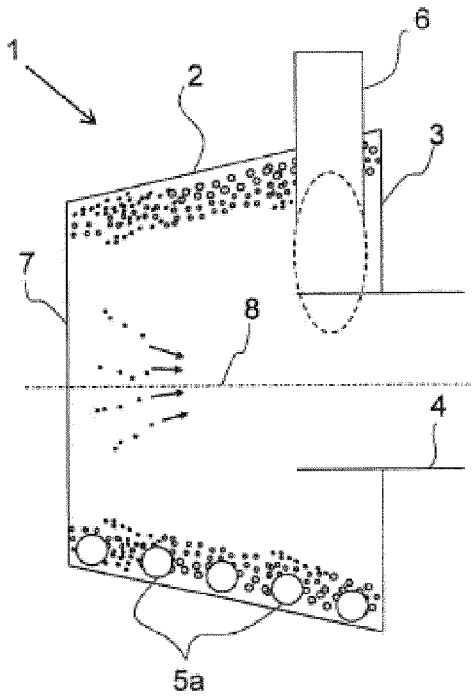
(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) **Title**: CYCLONE BURNER WITH CONICAL COMBUSTION CHAMBER

Fig. 1a



(57) **Abstract**: A cyclone burner for converting solid fuel comprising a substantially rotationally-symmetric whirling chamber (1), means (5a, 6) for introducing gas and fuel into the whirling chamber (1), means for bringing the gas and fuel into rotation in the whirling chamber (1) and an outlet (4) for the gas and the converted fuel where the outlet (4) is centrally positioned in the outlet end (3) of the whirling chamber (1). The the whirling chamber (1) comprises a conical shaped portion (2) having the smaller diameter furthest from the outlet end (3) and the means (5a) for introducing gas are connected to the whirling chamber (1) along the length of the conical shaped portion (2).

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

Title: CYCLONE BURNER WITH CONICAL COMBUSTION CHAMBER

The present invention relates to a cyclone burner for converting solid fuel comprising a substantially rotationally-symmetric whirling chamber, means for introducing gas and fuel into the whirling chamber, means for bringing the gas and fuel into rotation in the whirling chamber and an outlet for the gas and the converted fuel where the outlet is centrally positioned in the outlet end of the whirling chamber.

Cyclone burners of the above-mentioned type are well known in the industry, being used inter alia in power plants. From US7261047BB, for example, is known a horizontally positioned cyclone burner where the fuel is introduced at the back end of a cyclone chamber, whereafter it flows along with the gas stream towards a conical outlet end where particle separation takes place. In this type of cyclone burner, the fuel must be substantially converted before it reaches the outlet end, otherwise the result would be build-up of fuel at this location, eventually leading to complete interruption of the fuel flow and/or its discharge by entrainment out of the chamber. The associated disadvantage is that the particles must be so finely divided as to ensure almost complete conversion of the particles before they reach the outlet end of the burner. As a result, the total amount of retained fuel in the compartment will be at a comparatively modest level, therefore necessitating an unnecessary degree of comminution of the fuel in order to ensure an acceptable degree of conversion for a given chamber volume. Another consequence of the design is that the fuel will not be substantially distributed along the length of the compartment, but instead it will accumulate at one of the ends of the chamber, entailing poor control of the temperature distribution in the chamber and leading to undesirable formation of slags.

It is an objective of the present invention to provide a cyclone burner whereby the aforementioned disadvantages are eliminated or significantly reduced.

This is achieved by a cyclone burner of the kind mentioned in the introduction and being characterized in that the whirling chamber comprises a conical shaped

portion having the smaller diameter furthest from the outlet end and in that the means for introducing gas are connected to the whirling chamber along the length of the conical shaped portion.

Hereby it is obtained that the gas and fuel are forcibly led along the wall of the conical shaped portion of the whirling chamber back towards the back end of the whirling chamber at which location they will subsequently be led towards the eddy flow centrally in the whirling chamber and then led to and discharged through the outlet. Hence a significant amount of fuel can be retained, thereby reducing the need for comminuting the fuel to a very small particle size. The angle of the conical shaped portion of the whirling chamber relative to the centre axis of the whirling chamber will influence the effect of the centrifugal counter force acting on the rotating fuel in the whirling chamber. At a given gas stream and gas velocity, a large angle will allow a greater amount of fuel to be retained than achievable if a smaller angle is applied for the same gas stream and gas velocity. However, if the angle is too big the whirling chamber may lose its self-discharging capability if excessively filled, potentially giving rise to an undesirable accumulation of the fuel. Therefore, the angle is also important in terms of preventing accumulation of fuel. It is preferred that the angle of the conical shaped portion is kept within the range of 5 to 20 degrees. The angle for optimization of operating characteristics varies in dependence of quality, size and type of fuel.

Converted fuel is taken to mean fuel which has been introduced to the whirling chamber, where the fuel has undergone combustion, pyrolysis, gasification and/or mechanical comminution due to forces of collision and friction.

It is preferred that the predominant portion or the entire whirling chamber is conically and that the means for introducing gas are arranged over the whole conical shaped portion in the longitudinal direction of the cyclone burner. The cyclone burner may be arranged inclined, however, it is preferred that the cyclone burner is arranged horizontally.

The means for bringing the gas and the fuel into rotation in the whirling chamber may in principle comprise any suitable means as long as they are capable of bringing the gases and fuel into rotation. For example, the means may comprise a number of fixed devices in the whirling chamber which are formed and positioned so that they will impart rotation to the gas and the fuel. However, it is preferred that the means for introducing gas (for example air, O_2, H_2O or CO_2, mixed or pure) are connected substantially tangentially to the conical shaped portion. The means for introducing fuel may also comprise a tangentially arranged fuel inlet. Generally a tangential inlet, which is a common feature of cyclone separators, will cause an introduced medium to be brought into rotation in the cyclone chamber when being fed hereto at sufficient velocity.

The means for introducing gas, which are connected to the whirling chamber along the length the conical shaped portion, may in principle comprise any suitable means as long as they are capable of introducing the gas along the conical shaped portion. The means are preferably arranged tangentially over at least the major part of the conical shaped portion in the longitudinal direction of the cyclone burner. For example the means may comprise a gas inlet with a single opening extending over the major part of the length of the conical shaped portion. However, it is preferred that the means for introducing gas comprise a number of gas inlets, at least two, arranged one after another along the length of the conical shaped portion, preferably along the major part of the conical shaped portion. Such tangentially inlets arranged at the conical shaped portion in the longitudinal direction of the cyclone burner combined with a fuel inlet connected to the half of the whirling chamber which is closest to the outlet end, will force the fuel and gas along the wall of the conical shaped portion of the whirling chamber back towards the back end of the whirling chamber. During this movement the fuel will be converted and subsequently led towards the eddy flow centrally in the whirling chamber for being transported to and discharged through the outlet.

It is further preferred that the end faces at each end of the whirling chamber are plane. One or several gas nozzles may advantageously be fitted to the back end face for co-firing with other fuels, such as oil, gas, coal or sawdust.

It is preferred that the outlet comprises an outlet duct which protrudes into the whirling chamber in order to stabilize the eddy flow in the whirling chamber.

In one embodiment the means for introducing fuel is connected to that half of the whirling chamber which is closest to the outlet end.

The cyclone burner may in principle be used for all types of industrial processes which require a source of heat like rotary kilns or power plant boilers. For example it may be used for manufacturing cement clinker where cement raw materials are introduced to a cement or mineral processing plant where raw materials are supplied with thermal energy and converted into cement clinker or other mineral products, e.g. burned lime. Here a cyclone burner may at least provide some of the thermal energy. If the cyclone burner is used for processing materials in a rotary kiln, its outlet may be fitted to a burner lance extending into the rotary kiln, thereby allowing the converted fuel to be fed and ignited at a distance further inside the rotary kiln. With this type of arrangement, it will be possible to use heated process gases, e.g. from a clinker cooler, for the gas inlets connected to the whirling chamber.

The invention will now be explained in further details with reference to the drawing, being diagrammatical, and where

Fig. 1a and Fig. 1b show a cross-sectional view and a view from the outlet end, respectively, of a cyclone burner according to the invention, and

Fig. 2 shows a cross-sectional view of another embodiment of a cyclone burner according to the invention.

In Fig. 1a and Fig. 1b are shown a cyclone burner for converting solid fuel. The cyclone burner is arranged horizontally and comprises a conical shaped portion 2, which makes up the whirling chamber 1, having the smaller diameter furthest from the outlet end 3 and terminated with a plane back end face 7. An outlet 4 for the gas and the converted fuel is centrally positioned in the outlet end 3 of the

whirling chamber 1. A fuel inlet 6 is connected tangentially to the whirling chamber 1 close to the outlet end 3. Furthermore a number of tangentially arranged gas inlets 5a for introducing gas and for bringing the gas and the fuel into rotation in the whirling chamber 1 are arranged one after another along the whole length of the conical wall. In this way the gas and the fine fuel particles are forcibly led along the conical wall towards the back end face 7 of the whirling chamber 1 where they will be led towards the eddy flow centrally in the whirling chamber 1 and then led to and discharged through the outlet 4, whereas the larger particles will be led towards the larger diameter end, hence a significant amount of fuel can be retained, thereby reducing the need for comminuting the fuel to a very small particle size. The angle of the conical wall in the whirling chamber 1 relative to the centre axis of the chamber will influence the effect of the centrifugal counter force acting on the rotating fuel in the whirling chamber 1. It is preferred that the angle of the conical shaped portion relative to the centre axis 8 of the whirling chamber is between of 5 and 20 degrees. The angle for optimization of operating characteristics varies in dependence of quality, size and type of fuel. The whirling chamber 1 is heated by use of oil, gas or other medium to at least 550°C so as to ensure self-ignition and conversion of the solid fuel which is introduced through the fuel inlet 6. When switching from oil/gas to solid fuel, the gas/fuel ratio is kept at an over-stoichiometric or near-stoichiometric level to ensure effective ignition and additional heating. Once the target operating temperature has been reached, the fuel rate is increased so that the whirling chamber 1 will have the exact capability to convert all the input fuel to gas. This is achieved at a temperature of around 900-1100 °C and at a gas/fuel ratio of around 20–40 % (air deficit) of the stoichiometric level necessary for complete combustion. The aim is to operate at the lowest possible temperature and at a minimum air/fuel ratio, which is achieved by increasing the volume of fuel particles so that it will be slightly higher than the volume which can be converted in the whirling chamber 1. Hence the rotating amount of particles is gradually increased and more and more particles will be forcibly led towards the smaller end of the conical whirling chamber 1, while, at the same time, the particles at this location will be moving closer to the centre of the whirling chamber 1. The particles rotate at increased angular velocity when moving with the gas towards

the gradually diminished radius of the cone. Because of the increased centrifugal force thereby generated and the out flowing gas stream the particles separate in such a way that the large particles will remain near the large conical end of the whirling chamber 1 while the small particles are simultaneously entrained in the gas stream moving towards the small conical end of the whirling chamber 1. At some point in time, the accumulation of the small particles will reach an extent where their rotation are reduced and some of the particles will "drop" out into the central gas stream which is discharged through the outlet 4. The particles which are most easily entrained in the outgoing gas stream will be those having a relatively large surface relative to mass, i.e. the smallest and lightest fuel particles, whereas any large/heavy particles will to a certain extent have a tendency to drop out of the gas stream and back into the rotating particle mass. The now continuously separated stream of fine particles will restore the balance in the whirling chamber 1, whereby the volume of retained particles will find an equilibrium position. The separated particles are burnt out together with the gas in the subsequent flame. The overall aim is to ensure that the gas/fuel ratio is adjusted exactly so that the particles will have time to burn out sufficiently in the subsequent flame. In order to maintain full circulation of the entire particle mass, the gas (air or other gases) is introduced through the gas inlets 5a with a high tangential velocity in the whirling chamber 1. Regulation of gas volume and velocity is achieved by adapting the area in the gas inlets 5a and the air pressure ahead of the gas inlets 5a. The adapting may also be achieved by having a number of gas inlets 5a fully opened while keeping the remaining gas inlets 5a closed. The gas inlets 5a may be arranged in one or more rows in the longitudinal direction of the conical wall of the whirling chamber 1. Furthermore a number of gas inlets 5b (one gas inlet 5b is shown with dotted lines in Fig. 1b) may be connected to the whirling chamber 1 in locations along the length of the conical shaped portion 2 and being offset from each other both in the circumferential direction and in the longitudinal direction.

In Fig. 2 is shown an embodiment of a cyclone burner similar to the one in Fig. 1 except for the arrangement for introducing the gas into the whirling chamber 1. The gas inlet 5c has a single opening extending over the major part of the conical

wall in the whirling chamber 1 whereby only one gas inlet 5c is needed for introduction of gas as it will affect the whole length of which it extents. The gas inlet 5c may comprise means for adjusting the opening area through which the gas flows.

Claims

1. A cyclone burner for converting solid fuel comprising a substantially rotationally-symmetric whirling chamber (1), means (5, 6) for introducing gas and fuel into the whirling chamber (1), means for bringing the gas and fuel into rotation in the whirling chamber (1) and an outlet (4) for the gas and the converted fuel where the outlet (4) is centrally positioned in the outlet end (3) of the whirling chamber (1) **characterized in** that the whirling chamber (1) comprises a conical shaped portion (2) having the smaller diameter furthest from the outlet end (3) and in that the means (5) for introducing gas are connected to the whirling chamber (1) along the length of the conical shaped portion (2).

2. A cyclone burner according to claim 1 **characterized in** that the means (5) for introducing gas are connected tangentially to the conical shaped portion (2).

3. A cyclone burner according to claim 1 or 2 **characterized in** that the means for introducing gas comprise a number of gas inlets (5a) arranged one after another along the length of the conical shaped portion (2).

4. A cyclone burner according to claim 1 or 2 **characterized in** that the means for introducing gas comprise a gas inlet (5c) with a single opening extending over the major part of the length of the conical shaped portion (2).

5. A cyclone burner according to any preceding claim **characterized in** that the means for introducing fuel comprise a tangentially arranged fuel inlet (6).

6. A cyclone burner according to any preceding claim **characterized in** that the angle of the conical shaped portion (2) relative to the centre axis (8) of the whirling chamber (1) is between of 5 and 20 degrees.

7. A cyclone burner according to any preceding claim **characterized in** that the predominant portion or the entire whirling chamber (1) is conically.

8. A cyclone burner according to any preceding claim **characterized in** that the cyclone burner is arranged horizontally.

9. A cyclone burner according to any preceding claim **characterized in** that the outlet (4) comprises an outlet duct which protrudes into the whirling chamber (1).

10. A cyclone burner according to any preceding claim **characterized in** that the means (6) for introducing fuel is connected to that half of the whirling chamber (1) which is closest to the outlet end (3).

Fig. 1a

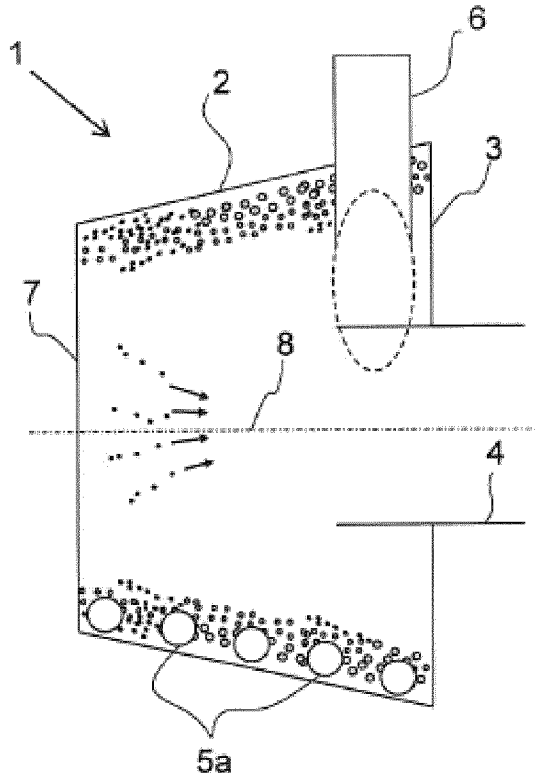


Fig. 1b

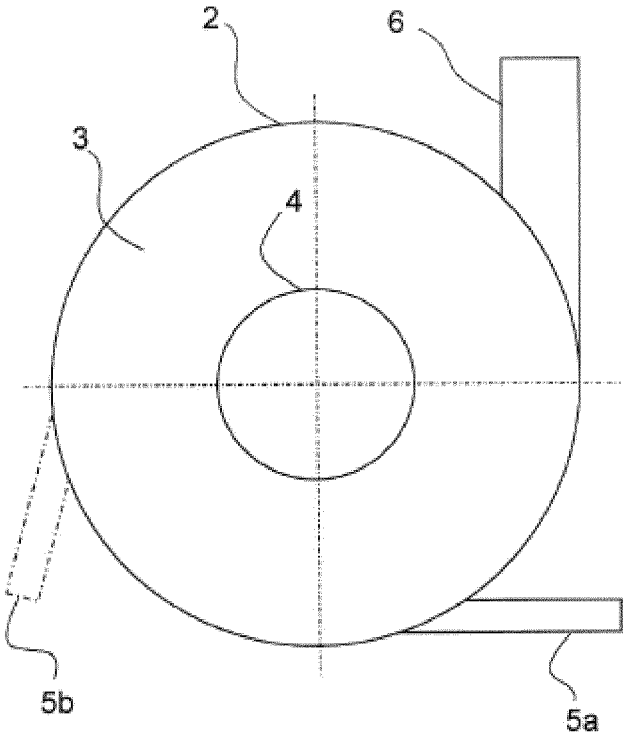
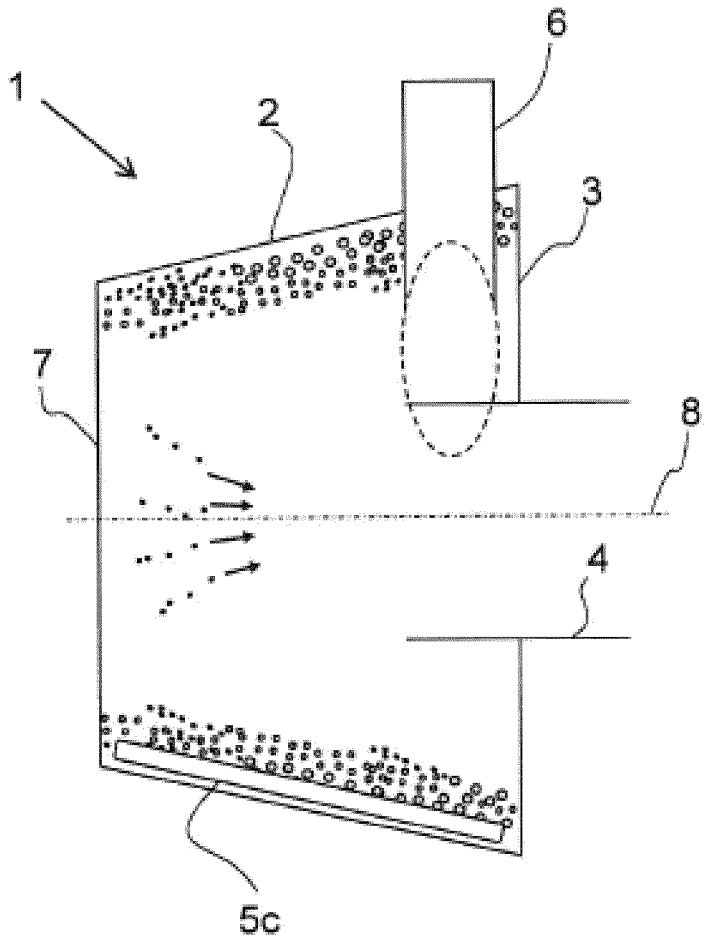


Fig. 2



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/071016

A. CLASSIFICATION OF SUBJECT MATTER
INV. F23C3/00
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)
F23C

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 practicable, 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.
X	DE 464 455 C (BURG EUGEN) 17 August 1928 (1928-08-17) the whole document	1-3,6-8
X	FR 1 135 171 A (BABCOCK & WILCOX FRANCE) 25 April 1957 (1957-04-25) the whole document	1-3,5, 7-10
X	BE 513 392 A (BABCOCK & WILCOX LIMITED ENGLAND) 30 August 1952 (1952-08-30) claims 1,5; figure 1 page 1, line 28 - page 2, line 28 page 4, lines 1-6	1-3,6,7, 9
X	WO 2011/073948 A2 (SMIDTH AS F L [DK]; NIELSEN MADS [DK]) 23 June 2011 (2011-06-23) paragraphs [0001], [0007], [0015]; figures 1a,1b	1,2,6,7, 10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 July 2012	30/07/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Vogl, Paul

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2011/071016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 464455 C	17-08-1928	NONE	
FR 1135171 A	25-04-1957	NONE	
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WO 2011073948 A2	23-06-2011	NONE	