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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 December 2018 (20.12.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/229720 A1

(51) International Patent Classification:
C21B 5/00 (2006.01) *C21B 5/02* (2006.01)

(21) International Application Number:
PCT/IB2018/054413

(22) International Filing Date:
15 June 2018 (15.06.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PCT/IB2017/000739
16 June 2017 (16.06.2017) IB

(71) Applicant: **ARCELORMITTAL** [LU/LU]; 24-26, Boulevard d'Avranches, L-1160 Luxembourg (LU).

(72) Inventors: **GEEROMS, Joris**; ArcelorMittal Gent, John-Kennedylaan, 51, 9042 Gent (BE). **SPELIER, Kurt**; ArcelorMittal Gent, John-Kennedylaan, 51, 9042 Gent (BE). **VAN DE CASTEELE, Stefaan**; ArcelorMittal Gent, John-Kennedylaan, 51, 9042 Gent (BE).

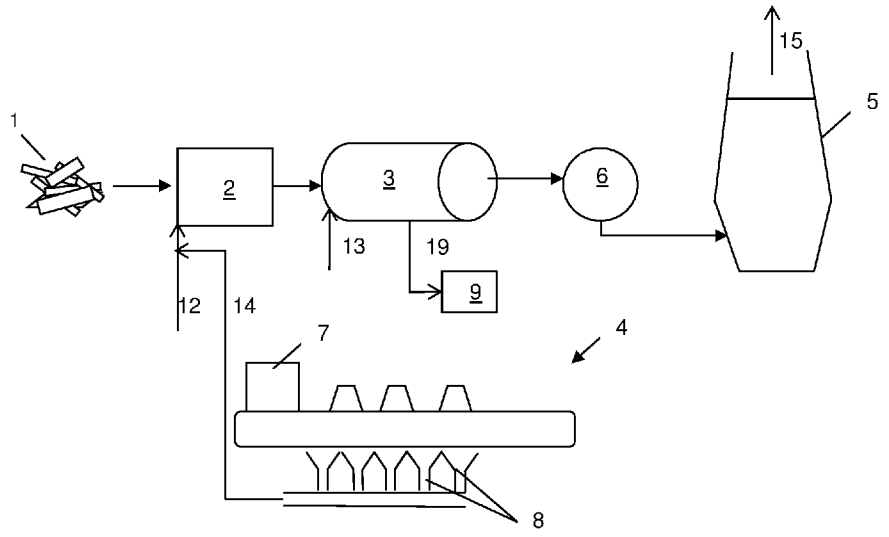
(74) Agent: **PLAISANT, Sophie**; ArcelorMittal France, Research & Development, Intellectual Property, 6 rue André Campra, 93200 Saint-Denis (FR).

(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, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, 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, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, 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, KM, ML, MR, NE, SN, TD, TG).

(54) Title: OPERATING METHOD OF AN IRON MAKING INSTALLATION AND ASSOCIATED OPERATING INSTALLATION

Figure 1



(57) Abstract: The invention is related to a method of operating an iron making installation, in which waste material is dried using a drying gas, the drying gas comprising an exhaust gas from a sinter plant, and the dried material is roasted a roasting gas, so as to produce coal and a roasting exhaust gas. The invention is also related to the associated installation.

[Continued on next page]

WO 2018/229720 A1

Published:

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

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

Operating method of an iron making installation and associated operating installation

[001] The invention is related to an operating method of an iron making installation and to the associated installation.

[002] The iron making process, which can be either performed in a blast furnace or a DRI furnace such as MIDREX® or COREX® always require the use of a carbon containing material as raw material. This carbon containing material can either be brought as pulverized coal, charcoal, coke or other forms.

[003] In recent years, in the course of CO_2 reduction there has been a lot of development aiming at recycling carbon-containing waste materials as substitute to these carbon containing materials. Those carbon-containing waste materials maybe for example wood from construction area, agricultural or food residues, home trash or industrial wastes. In the rest of the text, term waste material will be used and has to be understood as carbon-containing waste material.

[004] For example, patent WO 2011/052796 describes a method of using biomass, such as wood waste from construction or agricultural waste as a substitute for pulverized coal in a blast furnace. In this method the biomass is dried in a rotary kiln to manufacture biomass coal, the biomass is then pulverized together with coal and blown through a tuyere into the blast furnace. The exhausts gas of the rotary kiln are collected and sent to a gas heater which further re-injects them into the rotary kiln as a heating source of the outer row.

[005] Patent EP 1 264 901 B1 from Kobe Steel describes a method for producing reduced iron in which organic matter-containing components such as wood, resin, trash or industrial waste are loaded into a carbonization furnace together with iron oxide which is used at heat medium. The product of this carbonization is then agglomerated and used as reducing agent into a reduction furnace. In the described method, the exhausts gas from the reduction furnace are used as combustion gas into the carbonization furnace, while the distilled gas resulting from the carbonization are used as fuel for the reduction furnace.

[006] Patent US 2014/0306386 describes a method of using wood as fuel into a blast furnace. In this method wood is sized and dried, coarse particles are then loaded into the

throat of the blast furnace while finer particles are sent to a combustion chamber. Hot gas exhausted from the combustion chamber are either sent to a power plant or used at heat source to preheat the hot blast further injected into the blast furnace. Top gas exhausted from the blast furnace is used as gas source for the combustion.

[007] Patent JP 2009-057438 describes aims to provide a manufacturing method of pulverized carbon material resulting from biomass carbonization whose resulting product may be easily turned into a fine powder suitable for blowing into the blast furnace while achieving high efficient recovery of energy in the biomass.

[008] In none of this patent is taken into account the variability of the waste materials. Indeed the characteristics of those materials may vary in terms of humidity and calorific power from one batch to another. Consequently the calorific power of the carbonization exhaust gas will also vary depending on the waste material which is roasted and in some cases the resulting exhausts gas will not release enough energy to roast the following batch of waste material. External energy supply may then be needed.

[009] Patent application DE 196 06 575 A1 discloses a method for managing residual and waste material of any kind. In this document, waste materials are pre-treated in a pyrolysis reactor which can be heated thanks to blast furnace top gas. Roasted material is then separated between ferrous and non-ferrous materials. Ferrous materials are then sent to a mill and injected in the blast furnace through the tuyere.

[0010] Moreover those waste materials may comprise a lot of volatile compounds which are detrimental to the environment. It is so necessary to have a specific treatment step of the exhausts gas so as to remove these components and avoid them to be released into the atmosphere.

[0011] The aim of the invention is to provide an operating method of an iron making installation which is independent of the characteristics of the waste materials used in the iron making process and which prevents pollutants from being released into the atmosphere without necessity of dedicated equipment.

[0012] An additional aim of the invention is to improve overall carbon balance by substituting fossil carbon used in an iron making process by organic carbon.

[0013] To this end, the invention relates to method of operating of an iron making installation, the method comprising the steps of:

a. Drying waste material using a drying gas, the drying gas comprising an exhaust gas from a sinter plant,

b. Roasting the dried waste material using a roasting gas, so as to produce coal and a roasting exhaust gas.

The operating method according to the invention may also comprise following characteristics, taken alone or in combination:

- the drying gas comprises at least 50% of an exhaust gas from a sinter plant,
- the method further includes a step of recycling at least a part of the roasting exhaust gas to the sinter plant,
- the drying gas has a temperature of at least 70°C,
- the sinter plant exhaust gas has a temperature comprised between 100 and 150°C when it is mixed with other components to form the drying gas,
- the roasting is performed at a temperature comprised between 200 and 320°C,
- at least a part of the roasting exhaust gas is used as part of the drying gas,
- the roasting exhausts gas is used in the roasting step as part of the roasting gas,
- after the roasting step the coal is used as raw material into an iron making process,
- after the roasting step the coal is subjected to a milling step and milled coal is injected into a blast furnace through a tuyere,
- the milled coal has a particle size inferior to 10 µm,
- at least 4% in weight of solid material injected through the tuyere is milled coal,
- after the drying step, the dried material has moisture content inferior to 10%,
- the roasting exhausts gas is injected into an iron making process,
- the roasting exhausts gas is sent to a power plant,
- the waste material is an organic waste material,

- the organic waste material is waste wood.

[0014] The invention also relates to an installation comprising:

a. drying mean able to dry waste materials using a drying gas and comprising injection means to inject the drying gas into the drying means,

b. roasting mean able to roast the dried waste material at a temperature comprised between 200 and 320°C using a roasting gas, so as to produce coal and a roasting exhaust gas,

c. a sinter plant producing sintered material and sinter exhaust gas,

d. first collection means to collect sinter exhaust gas,

e. connexion means defined to connect the first collection means to the injection means so as to inject a part of the sinter exhausts gas into the drying means.

The installation according to the invention may also comprise a belt dryer as drying mean.

The installation according to the invention may also comprise a pyrolysis reactor as roasting mean.

[0015] The invention will be better understood upon reading the description which follows, given with reference to the following appended figures:

- FIG. 1 illustrates an example of installation to implement a method according to a first embodiment the invention

- FIG. 2 illustrates an example of installation to implement a method according to another embodiment of the invention.

[0016] The installation comprises a drying equipment 2, a roasting equipment 3, a sinter plant 4 and an iron making installation 5. In another embodiment the installation may further comprises a mill 6. In the following description the iron making installation 5 is a blast furnace 5 but it could also be a Direct Reduction furnace or any DRI installation.

[0017] Waste material 1 which can be for example chosen among waste trash, industrial waste or organic waste, is loaded into drying equipment 2. The waste material 1 is

preferably organic waste, and more preferably wood waste, by example coming from dismantled buildings. The drying equipment is for example a belt dryer or a rotary kiln dryer.

[0018] During the drying step, a drying gas 12 is injected inside the drying equipment 2 in order to bring the necessary heat to dry the waste material 1. The gas 12 has preferably a temperature of at least 70°C.

[0019] Once the drying step is over, preferably when the waste material has moisture content inferior to 10%, and most preferably inferior to 5%, the dried waste material is sent to roasting equipment 3. The roasting equipment 3 is preferably designed so as to avoid contact between roasting gas and dried material. It is, for example, a pyrolysis reactor or a rotary kiln.

[0020] During the roasting step, a roasting gas 13 is injected inside the roasting equipment 3 so as to heat the dried waste material. The heat can be brought directly by the roasting gas or through burners, fuel of which being the roasting gas 13. The roasting step is preferentially performed at a temperature comprised between 200°C and 320°C. It produces a roasted waste material but generates also roasting exhaust gas 19. This roasting exhaust gas 19 contains volatile compounds such as Cl, SO_x or NO_x resulting from the roasting of the waste material. This roasting exhaust gas has to be treated in a specific treatment installation 9 to capture the volatile compounds and avoid releasing them into the atmosphere.

[0021] The roasted waste material, also called coal or biocoal is then injected into the blast furnace 5. It may so replace traditional coke or fossil coal as carbon source and consequently improve the overall carbon balance by avoiding use of fossil carbon.

[0022] Optionally the coal or biocoal is first sent to a mill 6 where it is milled to particles having a size inferior to 200 µm, and preferentially a size inferior to 150µm. The fine coal or biocoal is then injected into the blast furnace through a tuyere (not represented) as a substitute to coal in the known method of Pulverized Coal Injection (PCI).

[0023] According to the invention the installation further comprises a sinter plant 4. In a sinter plant, iron ore fines are agglomerated with fluxes, such as limestone or olivine, and with solid fuel, such as coke breeze or anthracite, at high temperature, to create a product that can be used in a blast furnace 5. Basically, and as way of illustration, in a sinter plant, material is fed by hoppers in multi layers to a circular belt where it is ignited by an ignition

hood 7. Air and fumes are sucked by wind boxes 8 from the bottom of the bed of material throughout the sintering machine to help the ignition process. Fire penetrates the material gradually along the belt, until it reaches the hearth layer. The fine particles are then melted together and agglomerated in a sinter cake once cooled. This sinter cake is then cracked and further cooled in a sinter cooler (not illustrated) before being loaded into the blast furnace 5. The sinter cooler also emits exhaust gas, mainly hot air.

[0024] The air and fumes sucked by the wind boxes 8 as well as hot air emitted by the sinter cooler are called sinter exhaust gas 14. According to the invention, this sinter exhaust gas 14 is sent to the drying equipment so as to be used as part of the drying gas 12. This drying gas 12 comprises at least 50% of sinter exhaust gas 14, and more preferably more than 80%. The drying gas 12 may additionally be composed of natural gas. The sinter exhaust gas 14 may be composed exclusively of the air and fumes sucked by the wind boxes 8, or exclusively of hot air emitted by the sinter cooler, or of both of them. Optionally, the sinter exhaust gas 14 is first subjected to a cleaning step before being mixed with other components to form the drying gas 12. This cleaning step maybe for example performed by a filter bag installation.

[0025] The sinter exhaust gas 14 has preferentially a temperature comprised between 100 and 150°C when it is mixed with other components to form the drying gas 12. The drying gas 12 may be exclusively constituted of the sinter exhaust gas 14.

[0026] As the sinter exhaust gas 14 comes from the ignited material on the circular belt, it has a high calorific power and so when used as part or total of the drying gas 12 in the drying step it always bring enough heat to dry the waste material 1, whatever its characteristics, and notably its moisture content. There is no more need to use external energy sources.

[0027] In a further embodiment, as illustrated in figure 2, the roasting exhaust gas 19a is not sent to a gas treatment installation 9 but is rather sent to the sinter plant 4 where it may replace a portion of the solid fuel which is mixed with the iron fines. This prevents the use of additional costly equipment and avoids the release of pollutants into the atmosphere.

[0028] In another embodiment, also illustrated on figure 2 in dotted lines, the roasting exhaust gas 19b is recycled into the roasting equipment 3, where it serves as part of the

roasting gas 13 to heat the dried waste material. It can also be used as part 19c of the drying gas 12 for the drying step.

[0029] In another embodiment, not illustrated, the roasting exhaust gas may be used in stoves to heat air which is then blown into the blast furnace.

[0030] In another embodiment, not illustrated, the roasting exhaust gas may be sent to a power plant to produce electricity.

[0031] In further embodiment, not illustrated, the exhaust gas of the blast furnace, also called top gas or any steelmaking exhaust gas such as coke oven gas or converter gas maybe used as part of the drying or roasting gases.

[0032] All the embodiments of the invention thus described may be used in combination with one another.

CLAIMS

1) Method of operating of an iron making installation, the method comprising the steps of:

    a. Drying waste material using a drying gas, the drying gas comprising an exhaust gas from a sinter plant,

    b. Roasting the dried waste material using a roasting gas, so as to produce coal and a roasting exhaust gas.

2) Operating method according to claim 1, wherein the drying gas comprises at least 50% of an exhaust gas from a sinter plant.

3) Operating method according to claim 1 or 2, wherein the method further includes a step of recycling at least a part of the roasting exhaust gas to the sinter plant.

4) Operating method according to anyone of the previous claims, wherein the drying gas has a temperature of at least 70°C

5) Operating method according to anyone of the previous claims, in which the sinter plant exhaust gas has a temperature comprised between 100 and 150°C when it is mixed with other components to form the drying gas.

6) Operating method according to anyone of the previous claims, the roasting being performed at a temperature comprised between 200 and 320°C.

7) Operating method according to anyone of the previous claims, wherein at least a part of the roasting exhaust gas is used as part of the drying gas.

8) Operating method according to anyone of the previous claims, wherein the roasting exhausts gas is used in the roasting step as part of the roasting gas.

9) Operating method according to anyone of the previous claims, wherein after the roasting step the coal is used as raw material into an iron making process.

10) Operating method according to claim 9 into which after the roasting step the coal is subjected to a milling step and milled coal is injected into a blast furnace through a tuyere.

11) Operating method according to claim 11 into which the milled coal has a particle size inferior to 10 µm.

12) Operating method according to claim 10 or 11 wherein at least 4% in weight of solid material injected through the tuyere is milled coal.

13) Operating method according to anyone of the previous claims wherein, after the drying step, the dried material has moisture content inferior to 10%.

14) Operating method according to anyone of the previous claims wherein the roasting exhausts gas is injected into an iron making process.

15) Operating method according to anyone of the previous claims wherein the roasting exhausts gas is sent to a power plant.

16) Operating method according to anyone of the previous claims wherein the waste material is an organic waste material.

17) Operating method according to claim 16 wherein the organic waste material is waste wood.

18) Installation comprising:

a. drying mean 2 able to dry waste materials 1 using a drying gas 12 and comprising injection means to inject the drying gas into the drying mean 2,

b. roasting mean 3 able to roast the dried waste material using a roasting gas 13, so as to produce coal and a roasting exhaust gas 19,

c. a sinter plant 4 producing sintered material and sinter exhaust gas 14,

d. first collection means to collect sinter exhaust gas,

e. connexion means defined to connect the first collection means to the injection means so as to inject a part of the sinter exhausts gas 14 into the drying mean 2.

19) Installation according to claim 16 in which the drying mean 2 is a belt dryer.

20) Installation according to one of the claims 16 or 17 in which the roasting mean 3 is a pyrolysis reactor.

Figure 1

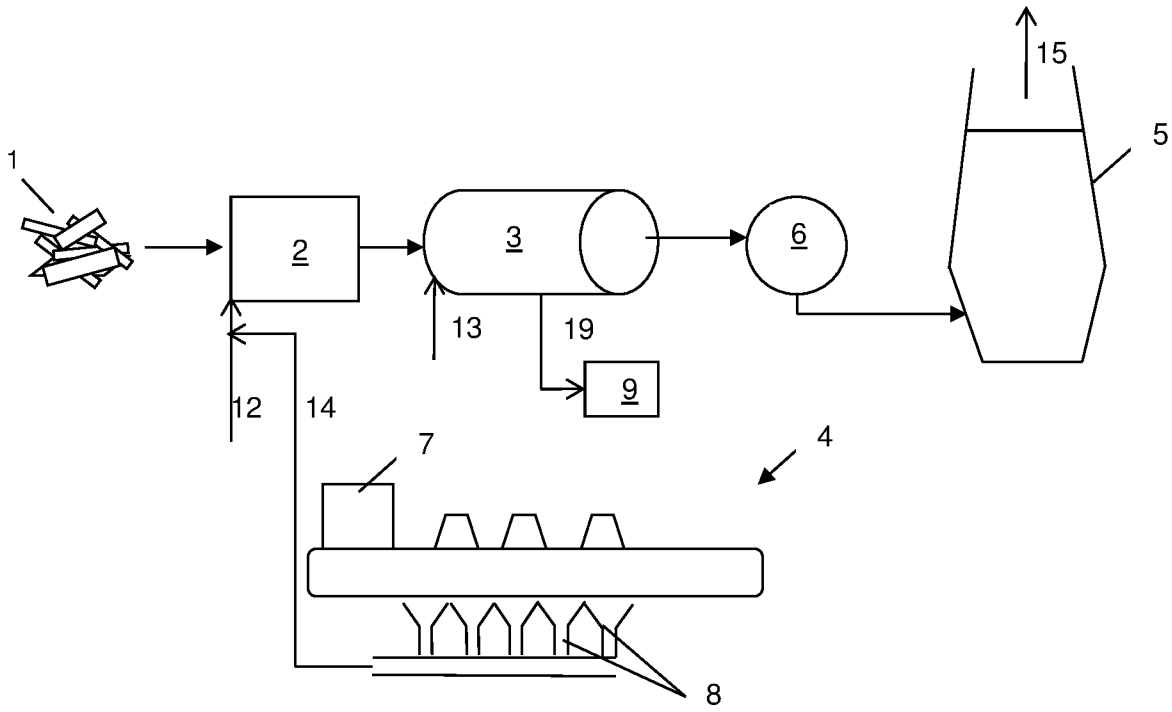
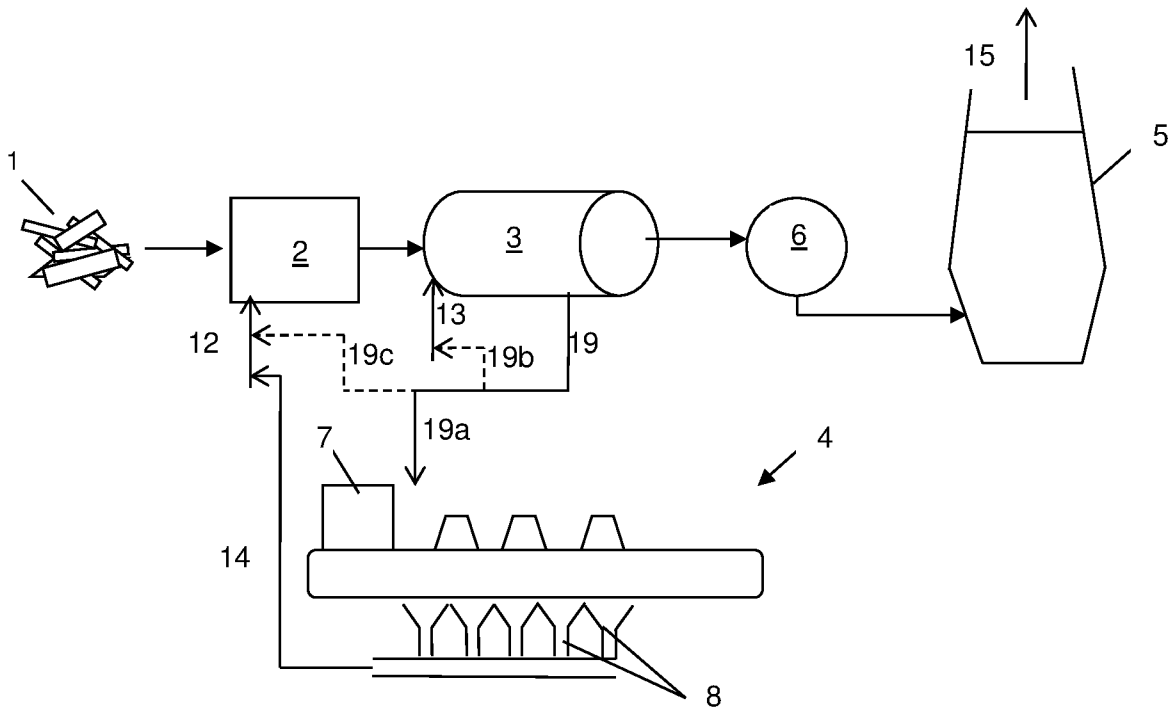


Figure 2



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2018/054413

A. CLASSIFICATION OF SUBJECT MATTER
INV. C21B5/00 C21B5/02
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)
C21B C10L C10B C22B F27D F27B

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	JP 2009 057438 A (UNIV TOHOKU) 19 March 2009 (2009-03-19) figure 1 Enclosed automatic translation; paragraph [0001] Enclosed automatic translation; paragraph [0004] Enclosed automatic translation; paragraph [0008] Enclosed automatic translation; paragraph [0017] Enclosed automatic translation; paragraph [0023] - paragraph [0023] Enclosed automatic translation; claim 1 ----- -/--	1-20

[X] Further documents are listed in the continuation of Box C.

[X] 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 application or patent 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
4 October 2018	10/10/2018

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	Desvignes, Rémi

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2018/054413

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 196 06 575 A1 (NOELL ENERGIE & ENTSORGUNG [DE]) 28 August 1997 (1997-08-28) figure 1 column 1, line 15 - column 1, line 31 column 4, line 22 - column 4, line 64	1-20
A	JP 2010 078202 A (JFE STEEL CORP) 8 April 2010 (2010-04-08) Enclosed automatic translation; paragraph [0001] Enclosed automatic translation; paragraph [0020]	1
A	WO 2016/043651 A1 (ÅBYHAMMAR MED ENSKILD SCANDRY TOMAS F [SE]) 24 March 2016 (2016-03-24) figure 1 page 21, line 32 - page 22, line 10 page 23, line 37 - page 23, line 30	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2018/054413

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2009057438 A	19-03-2009	NONE	
DE 19606575 A1	28-08-1997	DE 19606575 A1	28-08-1997
		JP H09235559 A	09-09-1997
JP 2010078202 A	08-04-2010	JP 5604781 B2	15-10-2014
		JP 2010078202 A	08-04-2010
WO 2016043651 A1	24-03-2016	EP 3194536 A1	26-07-2017
		SE 1451097 A1	19-03-2016
		WO 2016043651 A1	24-03-2016