(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 825 633 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
26.05.2021 Bulletin 2021/21

(21) Application number: **20209549.3**

(22) Date of filing: **24.11.2020**

(51) Int Cl.:
F28D 1/047 *(2006.01)*
C21B 3/08 *(2006.01)*
F22B 15/00 *(2006.01)*
F28D 21/00 *(2006.01)*
F28F 27/02 *(2006.01)*
F27D 17/00 (2006.01)
F28F 1/42 (2006.01)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
KH MA MD TN

(30) Priority: **25.11.2019 FI 20196012**

(71) Applicant: **SFTec Oy**
90570 Oulu (FI)

(72) Inventors:
- **Isokääntä, Jani**
  90570 Oulu (FI)
- **Roininen, Juha**
  90570 Oulu (FI)

(74) Representative: **Kolster Oy Ab**
Salmisaarenaukio 1
P.O. Box 204
00181 Helsinki (FI)

(54) APPARATUS AND METHOD FOR HEAT RECOVERY

(57) There is provided a heat exchange apparatus (100), comprising: a heat transfer area (102) for receiving material having a first temperature; and a heat transfer arrangement (104) attached to the underside of the heat transfer area. The heat transfer arrangement (104) comprises vertical layers (106, 108, 110) of tube arrangements where each layer comprises a number of tubes side by side. The heat transfer arrangement is configured to receive via an input tube section (116) gas for receiving heat radiated or conducted from the material, the gas having a second temperature, where the first temperature is higher than the second temperature. The heat transfer arrangement further comprises a deflector structure (112, 114) for directing the gas from tubes of one layer to tubes of another layer, a heat collecting structure inside the tubes and an output tube section (118) for delivering the heated gas out from the heat exchange apparatus. The heat exchange apparatus further comprises a controller (124) configured to control the amount and velocity of gas in the tubes.

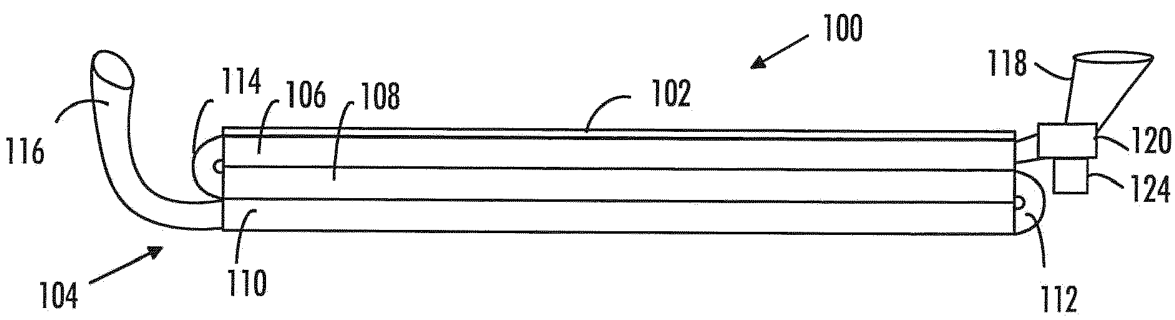

FIG. 1

Printed by Jouve, 75001 PARIS (FR)

Description

FIELD OF THE INVENTION

[0001] The invention relates generally to recovery of heat from hot material.

BACKGROUND

[0002] The operation of processing and refining ore and metals, for example in steelworks, produces as a by-product large quantities of slag which typically is very hot. In metallurgical industry today across the world there is keen interest in reducing energy costs and emissions while ensuring maximum reuse of otherwise wasted energy. For example, iron and steel slags and off gas which add up to huge energy loss, have become a major object of investigation. It may be estimated that a hot ferrous slag may contain large amount of energy, about 1-2 GJ/ton slag. Finding a method for heat recovery would not only lower production costs, but also reduce the carbon footprint in the steel production chain.

[0003] Currently the energy of metallurgical slags or other respective material is wasted when the hot slag or material is cooled on contact with the atmosphere or by water during the solidification process. Currently there is no commercially available heat recovery process available.

BRIEF DESCRIPTION OF THE INVENTION

[0004] According to an aspect of the invention, there is provided an apparatus as specified in claim 1.

[0005] According to an aspect of the invention, there is provided a method as specified in claim 11.

[0006] According to an aspect of the invention, there is provided an apparatus comprising means for performing any of the embodiments as described in the appended claims.

[0007] One or more examples of implementations are set forth in more detail in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims. The embodiments and or examples and features, if any, described in this specification that do not fall under the scope of the independent claims are to be interpreted as examples useful for understanding various embodiments of the invention.

LIST OF THE DRAWINGS

[0008] In the following, the invention will be described in greater detail with reference to the embodiments and the accompanying drawings, in which

Figure 1 presents a schematic side view of a heat exchange apparatus according to an embodiment;
Figure 2 shows a view of the heat exchange apparatus;
Figure 3A shows an exploded view of the heat exchange apparatus;
Figure 3B shows an exploded view of the heat transfer arrangement according to an embodiment;
Figure 4 shows a transverse cross section of a heat transfer arrangement according to an embodiment;
Figure 5 illustrates an example of the flow of gas through the heat transfer arrangement; and
Figure 6 is a flowchart illustrating an embodiment.

DESCRIPTION OF EMBODIMENTS

[0009] The following embodiments are exemplary. Although the specification may refer to "an", "one", or "some" embodiment(s) in several locations of the text, this does not necessarily mean that each reference is made to the same embodiment(s), or that a particular feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments.

[0010] Globally, the annual production of slags is approximately 400 million tons of Blast Furnace (BF) slag and approximately 350 million tons of steel slags (Basic Oxygen Furnace (BOF) slag, Electric Arc Furnace (EAF) slag and Ladle Furnace (LF) slag from secondary metallurgy). The slags features are usually affected by multiple aspects of the inner- and outer-furnace processing, which determines the conversion of the slag into suitable by-products. The slag processing displays thermal energy losses of approximately 1-2 GJ per ton of slag however, there are not any previous methods or instrumentations capable of utilizing these energy losses. In practical terms, considering an amount of 10 tonnes of liquid slag by a heat of 100 ton of liquid steel, the possible thermal recovery is of more than 3.5 MW_{th} (thermal megawatts) or more than 1 MW_{el} (electrical megawatt).

[0011] Solidifying molten steelmaking slag is usually performed by slow cooling in slag pits, usually with amounts of cooling water. This may occur directly under the furnace ("clean pit"), or by transporting the slag in pots to a pit outside the steelwork's facilities, or by dipping the whole slag pot into water basins. In several cases the hot slag is just poured on the ground to cool down or collected in pots before being poured on the ground of a separate facility to cool down. A traditional approach to control the cooling rate of the hot slag is water quenching, which consumes huge amount of water and fails to recover the heat of the slag.

[0012] In all these cases the heat recovery is not possible due to the direct contact between the slag and the water. After traditional solidification and processing, ferrous slags from different metallurgical processes can be broadly used in several fields of applications, for example in civil construction and building industry.

[0013] Recycling by-products from the iron and steel production as such is not new. Early reports from the metallurgical industry indicates the use of slags as a source for earthworks. The growth of the iron and steel production also increased the amount of slags, consequently raising the importance of the driving forces to utilize such materials. In the recent past, the costs of the raw materials have increased due to the reduction in availability of natural resources, which has raised the necessity of developing new routes for optimum recycling of industrial by-products, generating high quality products from them. The usage of these side by-products in high quality applications is an important goal of the steel industry. The slag production processes, and the characteristics of its by-products need to remain stable to guarantee their sustainable use. The treatment and alternative solidification of liquid slag can bring interesting new aspects, such as heat recovery and new properties of the newly formed products, which ensure their use in the future. Nevertheless, alternative cooling or treatment of liquid steelmaking slag should not impair the slag quality.

[0014] The proposed solution is an apparatus and method to enable recovery of heat of the molten slag and to increase energy efficiency of metallurgical industry. The heat exchanger to recover heat from hot slag (or other hot medium) is low-priced and simple. Heat recovery from the hot slag or medium by the heat exchanger structure enables its utilization as a free energy for example for material drying without a need to covert the heat again to other energy form. Further, the cooling process may be controlled and thus the properties of the cooled down slag may be controlled.

[0015] Let us study an example of a heat exchange apparatus referring to examples illustrated in Figures 1, 2, 3A, 3B and 4. Figure 1 presents a schematic side view of a heat exchange apparatus according to an embodiment. Figure 2 shows a view of the heat exchange apparatus and Figure 3A shows an exploded view of the heat exchange apparatus. Figure 3B shows an exploded view of the heat transfer arrangement from another angle. Figure 4 shows a transverse cross section of a heat transfer arrangement according to an embodiment.

[0016] In an embodiment, the heat exchange apparatus 100 is placed on a given handling area (such as a slag pit). In an embodiment, the heat exchange apparatus 100 comprises a heat transfer area 102 for receiving material having a first temperature. The material may be hot slag or other hot material or medium. In an embodiment, heat transfer area 102, where the hot slag or material is placed, is a steel or metal plate or plates.

[0017] The heat exchange apparatus 100 further comprises a heat transfer arrangement 104 attached to the underside of the heat transfer area 102. Thus, the heat transfer area plate covers the heat transfer arrangement 104. The heat transfer area plate or plates may be formed from a one or a several pieces of plates depending on the size of the heat transfer area. The plate joints may be protected by a sealant material to avoid the hot slag or material contact with the heat transfer arrangement 104.

[0018] In an embodiment, there may be protection walls around the heat exchange apparatus. The protection walls may be made from solidified slag, earth material or refractory material, for example, or other suitable material. The walls surround the heat exchange apparatus and protect the heat exchange apparatus for the heat losses during heat recovery operation. The protection walls restrict the hot material leakage from the heat transfer area of the heat exchange apparatus surface and form a heat transfer bed or channel for the hot material. The walls are not shown in the figures due to clarity.

[0019] In an embodiment, the heat transfer arrangement 104 comprises more than one vertical layer of tube arrangements, where each layer comprises a number of tubes side by side. In the example of Figure 1, there are three layers 106, 108, 110 of tube arrangements. However, the number of layers may vary depending on the application. In fact, the heat transfer arrangement has a modular structure where the plurality of vertical layers of tube arrangements, which may be considered as modules, are stacked on to each other and the number of vertical layers is easily adjustable. Thus, layers may be removed or added by removing the heat transfer area plate to access the layers. In addition, the number of tubes side by side in a layer is a design parameter and may vary depending on the application.

[0020] Figure 4 illustrates a cross section of an example heat transfer arrangement. The example heat transfer arrangement comprises three layers 106, 108, 110 of tubes side by side. The tubes may be metal tubes and the cross section of each tube may be rectangular as in Figure 4 or circle or ellipsoid. In the figures the tubes in a layer are straight tubes from one end to another. However, in an embodiment the tubes are not necessarily straight tubes but may have bends or curves.

[0021] The heat transfer arrangement 104 is configured to receive gas which flows in the tubes. The gas receives heat radiated or conducted from the slag or material, the gas having a second temperature, where the first temperature of the slag or material on the heat transfer area is higher than the second temperature. The gas may be air or some other gas. The temperature difference of the first and second temperature enables heat transfer from the hot slag or material to the gas.

[0022] The heat transfer arrangement 104 is a multilayer structure of metal tubes. The gas is circulated from layer to layer to recover the heat from the hot slag or medium on the heat transfer area.

[0023] In an embodiment, the heat transfer arrangement 104 comprises a deflector structure 112, 114 for directing the gas from tubes of one layer to tubes of another layer. The deflector structure may direct the gas from a tube of a first layer to a tube of a second layer or the structure may simply direct gas from first layer to second layer and the gas may flow freely from a tube on the first layer to any tube on the second layer. In an embodiment, the gas flows from lower layers to the upper layers. In an embodiment, the gas flows from a lower layer to the adjacent upper layer.

[0024] In an embodiment, the heat exchange apparatus 100 comprises one or more input tube sections 116 for receiving gas to be circulated in the tube layers. In an embodiment, the input tube section is connected to the lowest tube layer 110. The input tube section may also be connected also to other layer than the lowest. In an embodiment, one or more input tube sections are connected to more than one layer. To obtain preheated gas, the input tube section may be directed such that it takes gas above the hot slag or material on the heat transfer area. This is especially useful if the gas used is air.

[0025] In an embodiment, the heat exchange apparatus 100 comprises one or more output tube sections 118 for outputting heated gas. In an embodiment, the output tube section is connected to the upmost tube layer 106. The output tube section may also be connected also to other layer than the upmost layer. In an embodiment, one or more output tube sections are connected to more than one layer.

[0026] The heat exchange apparatus 100 may further comprise a device 120 for moving the gas. The device 120 may be a pump, for example, that sucks gas to the apparatus. The device may also be a blower or a fan or any other device suitable for causing movement of gas. In Figure 1 the device is placed in connection with the output tube. The device might as well be placed in connection with the input tube section. The device may as be blowing the gas into the tubes.

[0027] Thus, preheated gas may be sucked up or blown in from above of the heat transfer area and the gas conducted to the lowest layer 110. From the lowest layer the gas is circulated to the second lowest layer 108 with the deflector structure 112 and so on from layer to layer to the upmost layer 106. Figure 5 illustrates the flow of the gas 500 through the layers 110, 108, 106.

[0028] The size and form of the deflector structure is based on the height of tube layers and wideness of the overall structure. The deflectors may be attached to the heat transfer arrangement 104 to keep those in place while installed. The gas is circulated through the all the layers of the heat transfer arrangement and is collected from the upmost layer to the output tube section 118, where the hot/heated gas is further conducted to the collector piping 122 and further use.

[0029] When the gas is flowing in the tubes, it is advantageous to maximise the contact time of gas with the heat transfer arrangement structure to recover the heat from hot slag or material. To increase the heat transfer surface area of the tubes a heat collecting structure may be installed inside the tubes. The heat collecting structure may be a metal net, mat, profile, folding panel, structural cell (honeycombs) or composites, for example. Figure 4 illustrates an example of the heat collecting structure. In the example of Figure 4, there is a metal net installed in the tubes and it is illustrated schematically by the circles in the tubes. In an embodiment, the heat collecting structure may touch the inside surface of the tube.

[0030] From the hot slag or material heat is transferred to the heat exchange apparatus 100. As the cooling of hot slag or material proceeds the heat recovery and heat transfer from the hot slag or material slows down. The temperature of the recovered hot gas changes during cooling of the hot slag or material.

[0031] In an embodiment, the temperature of the recovered air may controlled by operational parameters of the heat exchange apparatus, such as the air volume, residence time, air temperature, air velocity sucked or blown through the heat exchanger apparatus. In an embodiment, the heat exchange apparatus further comprises a controller 124 configured to control the amount and velocity of gas in the tubes. The controller may be located beside the device 120, for example, as illustrated in Figure 1.

[0032] During cooling the heat transfer from the hot slag or material slows down so the operational parameters may need to be adjusted to maintain the maximum heat recovery. In an embodiment, the controller 124 may be a valve controlled manually. The controller 124 may also be a computer controlling the operational parameters according to some measurements.

[0033] In the heat transfer apparatus 104, the layers of tubes may be connected by the overall support structure that keeps the whole structure steady. The heat exchange apparatus as a whole has a modular structure, which enables adjustment of the heat transfer area based on need, the size of transportation vessel, and amount of the hot slag or material. In an embodiment, the layer modules of heat transfer apparatus 104 may be are attached with flange connections 200, 202, 204, 206 of the supportive structure. The layer modules may be assembled on the supportive I beams 210 and set on the ground.

[0034] The tubes of the heat transfer apparatus layers may be metal tubes that are lumped together. In an embodiment, the tubes of a layer may be welded together with dashed weld, and the supportive I beam attached to the layer modules. Different fastening solutions may be applied, such as bolts, for example.

[0035] Figure 6 is a flowchart illustrating an embodiment of recovering of heat of the molten slag or other hot material.

[0036] In step 600, a heat transfer area receives material having a first temperature.

[0037] In step 602, gas is obtained for receiving heat radiated or conducted from the material, the gas being directed to a heat transfer arrangement attached to the underside of the heat transfer area and comprising more than one vertical layer of tube arrangements where each layer comprises a number of tubes side by side, the tubes comprising a heat collecting structure inside the tubes, the gas having a second temperature, where the first temperature is higher than the second temperature,

[0038] In step 604, a deflector structure directs the gas from tubes of one layer to tubes of another layer.

[0039] In step 606, a gas outlet delivers the heated gas out from the heat exchange apparatus; and

[0040] In step 606, the amount and velocity of gas in the tubes is controlled.

[0041] Even though the invention has been described above with reference to an example according to the accompanying drawings, it is clear that the invention is not restricted thereto but can be modified in several ways within the scope of the appended claims. Therefore, all words and expressions should be interpreted broadly, and they are intended to illustrate, not to restrict, the embodiment. It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. Further, it is clear to a person skilled in the art that the described embodiments may, but are not required to, be combined with other embodiments in various ways.

Claims

1. A heat exchange apparatus (100), comprising:

a heat transfer area (102) for receiving material having a first temperature; and a heat transfer arrangement attached to the underside of the heat transfer area;
the heat transfer arrangement (104) comprising more than one vertical layer (106, 108, 110) of tube arrangements where each layer comprises a number of tubes side by side, the heat transfer arrangement configured to receive via an input tube section (116) gas for receiving heat radiated or conducted from the material, the gas having a second temperature, where the first temperature is higher than the second temperature, the heat transfer arrangement further comprising:

heat collecting structure inside the tubes and
an output tube section (118) for delivering the heated gas out from the heat exchange apparatus;

the heat exchange apparatus further comprising a controller configured to control the amount and velocity of gas in the tubes, **characterised by** deflector structure (112, 114) for directing the gas from tubes of one layer to tubes of another layer.

2. The apparatus of claim 1, wherein the heat transfer arrangement comprises gas input connected to the lowest layer of tubes and wherein the gas outlet is connected to the uppermost layer of tubes.

3. The apparatus of claim 1 or 2, wherein the heat collecting structure is attached to or is a part of the inner surface of the tubes and is one of the following: metal net, folding panel, structural cell, profile.

4. The apparatus of any of claims 1 to 3, wherein apparatus comprises a sensor measuring the temperature of the heated gas coming out of the gas outlet and the controller controls the amount and velocity of gas in the tubes at least partly based on the temperature.

5. The apparatus of any of claims 1 to 4, wherein the deflector structure is configured to direct the gas from a tube of a lower layer to a tube of a higher layer.

6. The apparatus of any of claims 1 to 5, wherein the gas input is configured to receive gas from above the material on the heat transfer area.

7. The apparatus of any of claims 1 to 6, wherein the heat transfer arrangement has a modular structure, where the plurality of vertical layers of tube arrangements are stacked on to each other and the number of vertical layers is adjustable.

8. The apparatus of any of claims 1 to 7, wherein cross section of the tubes is rectangular.

9. The apparatus of any of claims 1 to 7, wherein cross section of the tubes is circle.

10. The apparatus of claim 1, wherein the heat transfer arrangement comprises gas input connected to more than one layer.

11. A heat exchange method, comprising:

receiving (600), by a heat transfer area, material having a first temperature;
receiving (602) gas for receiving heat radiated or conducted from the material, the gas being directed to a heat transfer arrangement attached to the underside of the heat transfer area and comprising more than one vertical layer of tube arrangements where each layer comprises a number of tubes side by side, the tubes comprising a heat collecting structure inside the tubes, the gas having a second temperature, where the first temperature is higher than the second temperature,
delivering (604), by a gas outlet, the heated gas out from the heat exchange apparatus; and
controlling (606) the amount and velocity of gas in the tubes, **characterised by** directing (602), by a deflector structure, the gas from tubes of one layer to tubes of another layer.

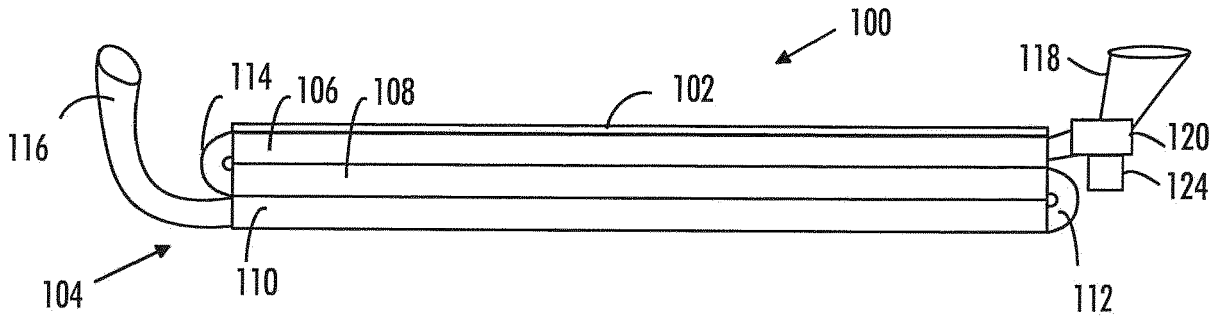
100
118
102
114
106
108
116
120
124
110
104
112

FIG. 1

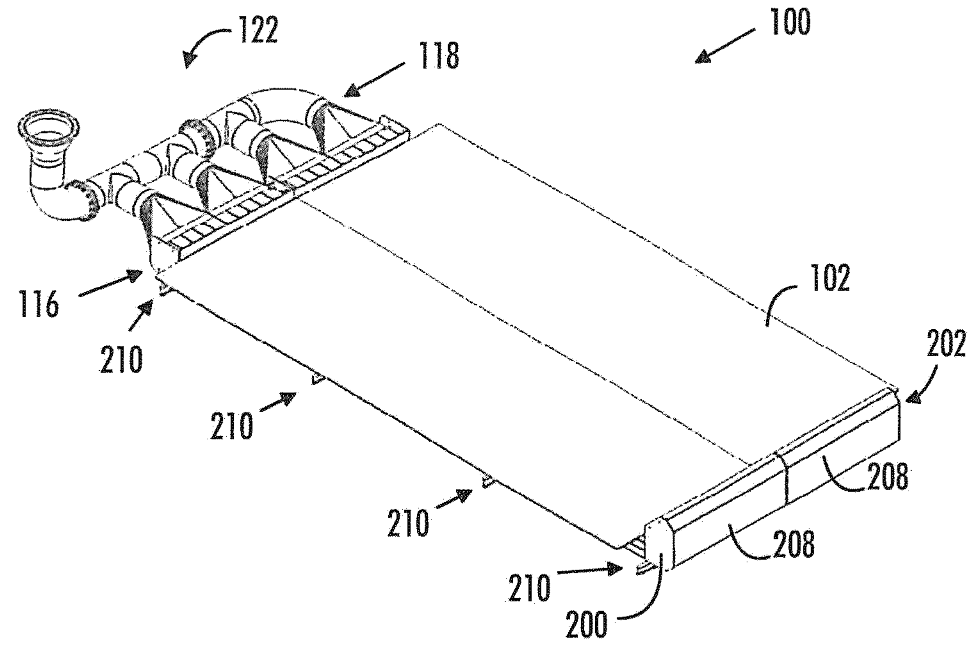
122
118
100
116
210
102
202
210
208
210
208
210
200

FIG. 2

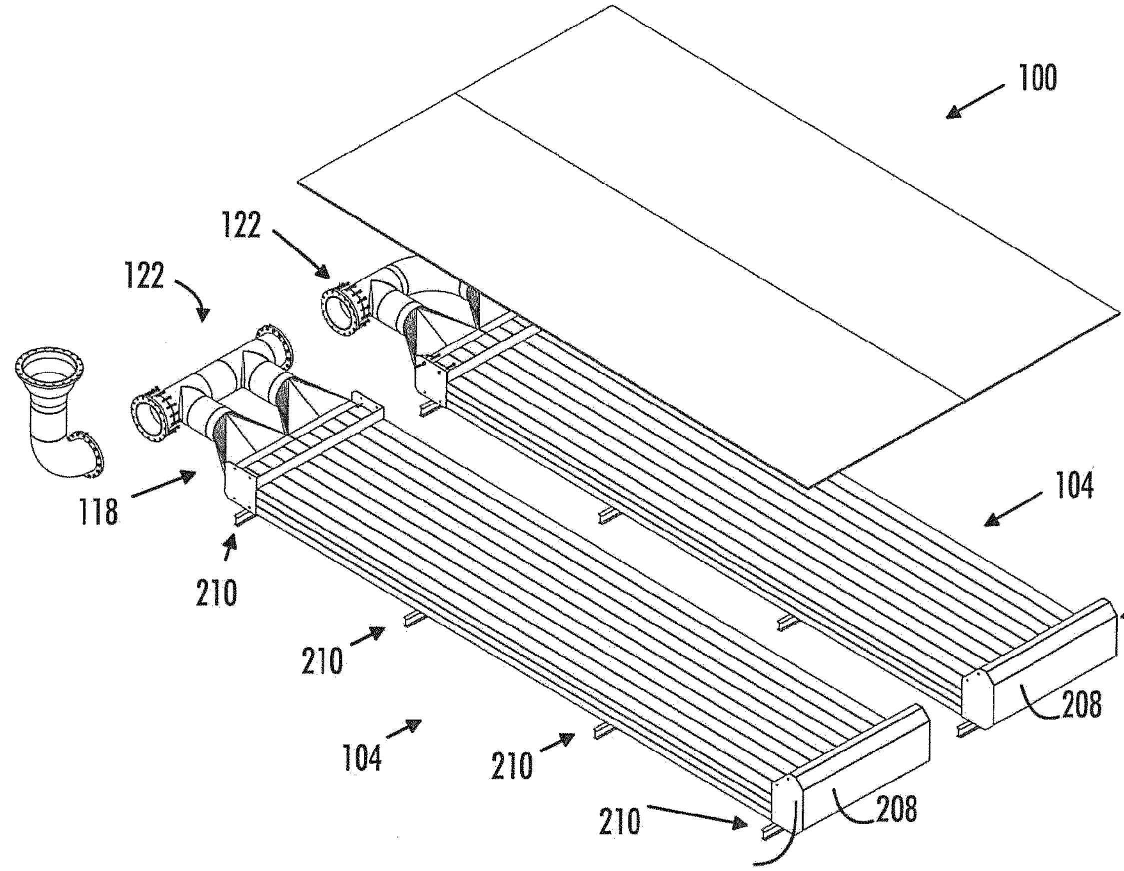
100
122
122
118
210
210
104
210
210
104
202
208
208

FIG. 3A

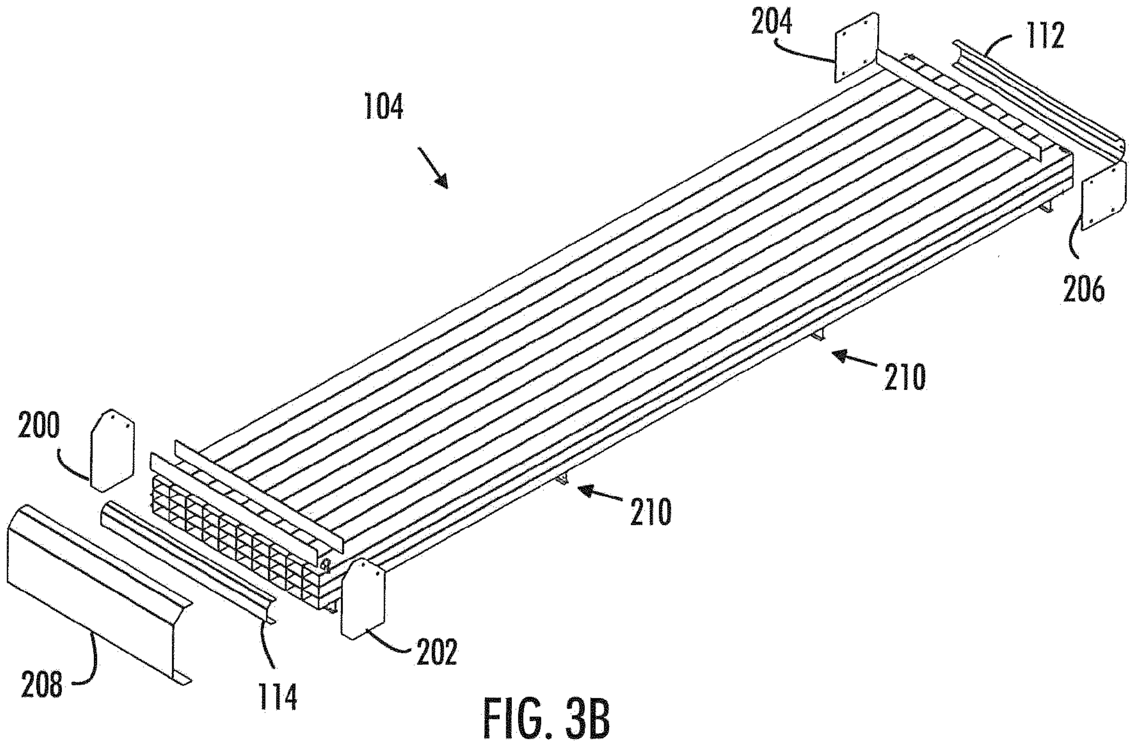
204
112
104
206
210
200
210
208
114
202

FIG. 3B

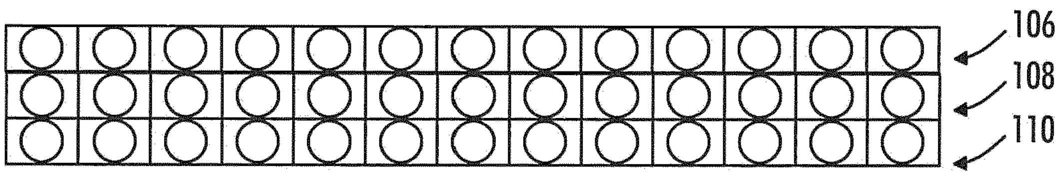

FIG. 4

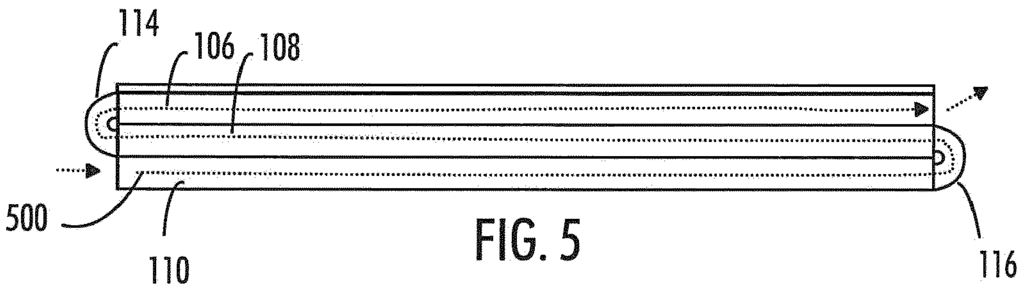

FIG. 5

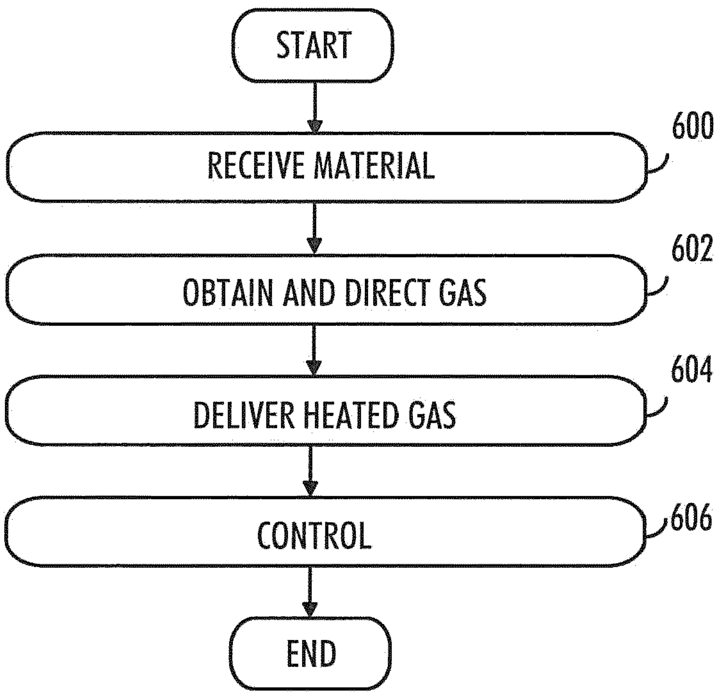

FIG. 6

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 20 20 9549

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CN 106 403 660 B (XI'AN JIAOTONG UNIV) 11 December 2018 (2018-12-11) * figures 1-6 *	1-6,8-11	INV. F28D1/047 C21B3/08 F22B15/00 F28D21/00 F28F27/02 ADD. F27D17/00 F28F1/42
A	WO 2013/186664 A1 (G A P S P A [IT]) 19 December 2013 (2013-12-19) * figures 3,5 *	1-11	
A	CN 108 592 658 A (CENTRAL RES INST BUILDING & CONSTR CO LTD MCC GROUP ET AL.) 28 September 2018 (2018-09-28) * figures 1-4 *	1-11	
A	KR 2013 0034526 A (HYUNDAI STEEL CO [KR]) 5 April 2013 (2013-04-05) * figure 1 *	1-11	
A	WO 00/47779 A1 (KUEMMEL JOACHIM [DE]) 17 August 2000 (2000-08-17) * figure 1 *	1-11	

TECHNICAL FIELDS SEARCHED (IPC)

F28D
F22G
F27D
C21C
C21B
F22B
F28F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	6 April 2021	Vassoille, Bruno

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 20 20 9549

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-04-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 106403660 B	11-12-2018	NONE	
WO 2013186664 A1	19-12-2013	BR 112014031339 A2	27-06-2017
		CN 104603294 A	06-05-2015
		EA 201492085 A1	30-04-2015
		EP 2861771 A1	22-04-2015
		ES 2621346 T3	03-07-2017
		JP 6246801 B2	13-12-2017
		JP 2015528094 A	24-09-2015
		KR 20150037817 A	08-04-2015
		MA 20150359 A1	30-10-2015
		MX 365535 B	06-06-2019
		PL 2861771 T3	31-07-2017
		US 2015159232 A1	11-06-2015
		WO 2013186664 A1	19-12-2013
CN 108592658 A	28-09-2018	NONE	
KR 20130034526 A	05-04-2013	NONE	
WO 0047779 A1	17-08-2000	EP 1070146 A1	24-01-2001
		WO 0047779 A1	17-08-2000

EPO FORM P0459

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