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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 October 2021 (28.10.2021)

(10) International Publication Number
WO 2021/215988 A1

(51) International Patent Classification:
F23G 5/16 (2006.01) ***F23G 5/027*** (2006.01) ***F23B 10/02*** (2011.01) ***F23L 9/00*** (2006.01) ***F23B 80/00*** (2006.01) ***F23M 5/02*** (2006.01) ***F23B 90/06*** (2011.01) *F23G 5/20* (2006.01)

(21) International Application Number: PCT/SE2021/050365

(22) International Filing Date: 21 April 2021 (21.04.2021)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2050453-6 21 April 2020 (21.04.2020) SE

(71) Applicant: GARTENA CONSULTING & INSTALLATION AB [SE/SE]; Ögärdesvägen 12 B, 433 30 PARTILLE (SE).

(72) Inventors: GÄRTNER, Klaus; Holkedalsvägen 3, 433 32 PARTILLE (SE). **GÄRTNER, Sven-Bertil**; Holkedalsvägen 3, 433 32 PARTILLE (SE).

(74) Agent: ZACCO SWEDEN AB; P.O. Box 5581, Valhallavägen 117N, 114 85 Stockholm (SE).

(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, IT, 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,

(54) Title: PLANT FOR BURNING WASTE

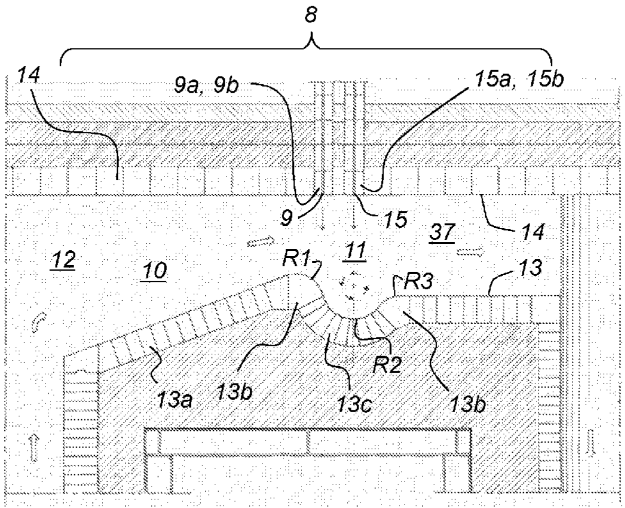

Fig. 2

(57) Abstract: A plant (1) for burning waste comprises a rotary furnace (2), an after-burning chamber (3) connected to the furnace (2), a primary incineration part (4) comprising the furnace (2) and a first part (5) of the after-burning chamber (3) for initial incineration of the waste in an oxygen deficient environment at a lower temperature interval in the furnace (2) and in the first part (5) of the after-burning chamber (3) for producing combustible fumes therein, a secondary incineration part (6) comprising a second part (7) of the after-burning chamber (3) and a contracted passage (8) between the first and second parts (5, 7) of the after-burning chamber (3) for subjecting the fumes to an increase in velocity between the first part (5) and the second part (7) of the after-burning chamber (3). The passage (8) comprises an inlet (9) for forced injection of combustion air into the contracted passage (8) for conclusive combustion of the combustible fumes at a higher temperature interval in the passage (8) and in the second part (7) of the after-burning chamber (3). The contracted

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NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, 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).

Published:

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

passage (8) comprises a narrowing part (10) followed downstream by a widening part (11) having a cross sectional area larger than the cross sectional area of the narrowing part (10) immediately upstream of the widening part (11).

PLANT FOR BURNING WASTE

TECHNICAL FIELD

The present invention relates to a plant for burning waste comprising a rotary furnace, an after-burning chamber connected to the furnace, a primary incineration part comprising the furnace and a first part of the after-burning chamber. The after-burning chamber is for initial incineration of the waste in an oxygen deficient environment at a lower temperature interval in the furnace and in the first part of the after-burning chamber for producing combustible fumes therein. Further, the plant comprises a secondary incineration part comprising a second part of the after-burning chamber and a contracted passage between the first and second parts of the after-burning chamber for subjecting the fumes to an increase in velocity between the first part and the second part of the after-burning chamber, the passage comprising an inlet for forced injection of combustion air into the contracted passage for conclusive combustion of the combustible fumes at a higher temperature interval in the passage and in the second part of the after-burning chamber.

BACKGROUND

WO2010123444 A1 discloses a method and an incineration plant where fuel can be burnt at high temperatures in order to avoid undesired imperfectly combusted residual products. The fuel is initially incinerated in an oxygen- deficient environment at a lower temperature interval in the furnace and in a first stage of the after-burning chamber to thereby produce combustible fumes therein. Means such as a suction blower are provided for drawing the fumes from the rotating furnace and through after-burning chamber. The combustible fumes are subjected to an increase in velocity by being passed through a contracted passage defined by a separating wall between the first stage and a second stage of the after-burning chamber.

Combustion air is blown into the contracted passage to thereby obtain a complete combustion of the combustible fumes at a higher temperature interval in the passage and in the second stage of the after-burning chamber.

In order to achieve a more complete combustion, a highest possible amount of combustion air should interact with a highest possible amount of combustible fumes per time unit. To blow the combustion air into a larger volume of combustible fumes, for example in the first or second stage of the combustion or after-burning chamber, will not result in such an efficient and complete combustion, since then the oxygen atoms of the combustion air and the carbon atoms of the fumes would have less opportunity to interact in the slower flow of the larger volume.

In the first stage of the after-burning chamber and in the rotating furnace, an oxygen-depleted gasification environment prevails, resulting in a state of partial pyrolysis at a sufficient high temperature to disintegrate the fuel into combustible flue-gas particles capable of being combusted at high velocity at the outlet of the contracted flue-gas passage in the second stage of the after-burning chamber. In other words, the after-burning chamber is divided into two stages: a first stage having a lower combustion temperature, for example 950 °C, and a second stage having a higher combustion temperature, for example 1200 °C. The flue-gas passage provides a high increase in velocity for the fumes or flue-gases that together with the extra supply of combustion air in the passage provide for a renewed combustion that substantially burns all non-combusted organic material in the fuel and the gases thereof.

In order to obtain efficient combustion, a steady state condition should be maintained for the lower and higher temperature intervals in the furnace and the after-burning chamber. The furnace and the after-burning chamber should then have an efficient heat-insulating and heat-accumulating lining, i.e. the lining may need a certain minimum thickness. Such minimum thickness may vary depending on selected lining materials and plant size, but may for a typical waste incineration plant need to be about 1,3 m in the after-burning chamber and about 0,5 m in the rotating furnace. Even temperatures and an efficient combustion are thereby obtained in the process. There is thereby also little or no need for additional fuels such as combustible oil or gases to keep the process running.

The preservation of the steady state condition can further be controlled by selectively returning combusted fumes to the furnace from a combusted fumes outlet of the plant. The steady state condition may, however, also be controlled in other ways, for example by adaption of the fuel feed rate to the present type of fuel.

The lower temperature interval can extend between about 950 °C and 1100 °C and the higher temperature interval can extend between about 1100 °C and 1200 °C.

In an embodiment of the invention, non-combusted residual products can be received through an open bottom of the first stage of the after-burning chamber. Non-combusted residual products of the second stage of the after-burning chamber can be received by a particulate bed at a bottom of the second stage.

The lining of the furnace may further have a varying height or thickness to provide spaces between a temporary bottom face of the rotating furnace and the fuel, whereby cool solid fuel is not allowed to form an insulation against the temporary bottom face of the rotating furnace barrel. The hot gases in the furnace may then more easily access all faces of the fuel. If the height or thickness varies in the circumferential direction, the projecting portions of the lining may also more easily carry the fuel around and mix the fuel in the furnace so that all portions of the fuel positively comes into contact with the oxygen-depleted hot gases.

While the furnace is specifically adapted for the incineration of solid fuel, it can also incinerate fluid fuel.

SUMMARY

It is an object of the present invention to provide an improved plant. According to a first aspect of the present disclosure a plant for burning waste comprises a rotary furnace, an after-burning chamber connected to the furnace, a primary incineration part comprising the furnace and a first part of the after-burning chamber for initial incineration of the waste in an oxygen deficient environment in the furnace and in the first part of the after-burning chamber for producing combustible fumes therein, a secondary incineration part comprising a second part of the after-burning chamber and a contracted passage between the first and second parts of the after-burning chamber for subjecting the fumes to an increase in velocity between the first part and the second part of the after-burning chamber.

In the context of the present invention, the contracted passage may alternatively be referred to as a constricted passage, or passage. Relative directions such as downstream, upstream, lower, upper, and similar are used to refer to the corresponding directions when the plant is oriented for its intended use and the fumes flow in their intended direction, i.e. from the rotary furnace, towards the after-burning chamber, and onwards. Any reference to cross sectional areas are to be understood as referencing the cross sectional area taken perpendicular to an intended flow direction of said portion of the plant. Inner and outer respectively refer to directions facing towards or away from a center of the cross sectional area of the relevant portion of the plant.

According to one example embodiment, the initial incineration of the waste in the furnace and in the first part of the after-burning chamber is performed at a lower temperature than the conclusive combustion of the combustible fumes in the passage and in the second part of the after-burning chamber.

The passage comprises an inlet for forced injection of combustion air into the contracted passage for conclusive combustion of the combustible fumes in the passage and in the second part of the after-burning chamber. The contracted passage comprises a narrowing part followed downstream by a widening part having a cross sectional area larger than the cross sectional area of the narrowing part immediately upstream of the widening part.

The contracted passage is arranged to cause the speed of combustibles fumes flowing through the plant to increase as they pass through the contracted passage, such that the speed of the combustible fumes is at least 3 times higher at the end of the narrowing part than in the first and/or the second part of the after-burning chamber, preferably at least 4 times higher, most preferably at least 5 times higher.

In the context of the present invention, conclusive combustion is taken to mean that the combustion is more complete, i.e. that the combustion happens at a higher efficiency than what would happen had the inlet and the contracted passage not been present between the first and the second parts of the after-burning chamber.

Thus, by means of the narrowing part followed by a widening part, the turbulence is increased and as a result also the resulting combustion efficiency.

According to a further aspect of the present invention, the narrowing part is arranged on an inlet side of the contracted passage such that the opening of the contracted passage has a cross sectional area that is larger than the cross sectional area of the narrowing part downstream of the opening. The cross section area of the narrowing part is thus gradually decreasing from the opening of the contracted passage. The pressure drop is also minimized with a more funnel shaped part of the narrowing part.

In accordance with one aspect of the present invention, the widening part is followed downstream by a second narrowing part having a cross sectional area that is smaller than the cross sectional area of the widest part of the widening part. The second narrowing part following the widening part further increases the turbulence and therefor also the combustion efficiency.

According to a further aspect of the present invention, the cross sectional area of the second narrowing part is constant from the downstream end of the widening part and the second part of the after-burning chamber.

According to a further aspect of the present invention, a transition from the second narrowing part to the second part of the after-burning chamber is sharp. Preferably, an edge of the downstream end of the second narrowing part is sharp. For example, the edge may have a radius of less than 25 mm, preferably less than 15 mm, most preferably less than 5 mm. Additionally or alternatively, the edge may define a 90° corner between the lower wall of the contracted passage and the second part of the after-burning chamber.

Preferably, the contracted passage is arranged horizontally. It could of course also have a slight tilt, however, in order to have an easier control of the combustion process the contracted passage should be more or less horizontally arranged rather than vertically.

According to one example embodiment, the contracted passage is arranged at an angle of between 75 and 105° relative to the first part of the after-burning chamber and/or the second part of the after-burning chamber, preferably between 80 and 100°, most preferably between 85 and 95°.

According to yet another aspect of the present invention, the cross section of the contracted passage is rectangular. The construction of the contracted passage is facilitated having a rectangular shape as compared to for instance a circular cross section since the cross section area is changing throughout the contracted passage.

According to a further aspect of the present invention, the contracted passage comprises an upper wall and a lower wall, wherein the inlet is provided on the upper wall and wherein the narrowing part and the widening part are provided by the lower wall.

Further, according to another aspect of the present invention the lower wall of the rectangular shape of the contracted passage varies in distance to the upper wall such that the narrowing and widening parts are presented or achieved. Having the change in cross section area made by adjusting only the lower wall facilitates the construction.

According to a further aspect of the present invention, the upper wall extends straight between the first and second parts of the after-burning chamber, i.e. between an inlet side and an outlet side of the contracted passage. Consequently, the lower wall provides the narrowing part and the widening part. Additionally or alternatively, the lower wall also provides the second narrowing part.

According to a further aspect of the present invention, the lower wall, at the narrowing part of the contracted passage, is angled relative the upper wall such that the cross-sectional area of the contracted passage decreases in a downstream direction.

According to a further aspect of the present invention, the lower wall, at the widening part of the contracted passage, is concave such that the cross sectional area of the contracted passage increases in a downstream direction until a widening part bottom is reached, after which the cross sectional area decreases to the second narrowing part.

According to a further aspect of the present invention, the contracted passage is defined by a plurality of shaped stones lining the upper wall, the lower wall and the walls connecting the upper wall and the lower wall of the contracted passage. On the upper wall, the stones are provided with a flat inner surface. On the narrowing part of the lower wall of the contracted passage, the stones are provided with a flat inner surface and arranged at an angle relative to the stones defining the upper wall, such that a funnel is formed thereby.

The widening part of the contracted passage is formed by a combination of stones having convex inner surfaces and concave inner surfaces. The widening part comprises a first convex radius formed by at least one stone having a convex inner surface, wherein the first convex radius is between 300 and 450 mm, preferably between 325 and 425 mm, most preferably between 350 and 400 mm. The widening part further comprises a first concave radius formed by a plurality of stones each having a concave inner surface, wherein the first concave radius is between 500 and 900 mm, preferably between 550 and 850 mm, most preferably between 600 and 800 mm. The widening part further comprises a second convex radius formed by at least one stone having a convex inner surface, wherein the second convex radius is between 300 and 450 mm, preferably between 325 and 425 mm, most preferably between 350 and 400 mm.

According to a further aspect of the present invention, the shaped stones are made from a silicon carbide material. According to a further aspect of the present invention, the inner surface of the shaped stones is polished. According to a further aspect of the present invention, the shaped stones are joined by a seam having a thickness of no more than 3 mm, preferably no more than 2 mm, most preferably no more than 1 mm. According to one embodiment, the seam is made from a silicon carbide material.

According to a preferred aspect of the present invention the inlet for forced injection of combustion air into the contracted passage is arranged to inject air in the widening part of the contracted passage. This placement increases the turbulence created.

In a further aspect of the present invention the inlet for forced injection of combustion air into the contracted passage is an elongated slot. An alternative could be several nozzles arranged in a line.

According to a further aspect of the present invention, the inlet comprises inlet stones. According to one aspect of the present invention, said inlet stones are made from the same material as the shaped stones defining the contracted passage. According to one aspect of the present invention, the inlet stones define an air channel in the shape of an elongated slot for passage of air from a source of inlet air into the contracted passage. The inlet stones are arranged in a row such that a channel is formed therethrough. The channel extends at least 90% of the width of the contracted passage. The source of inlet air may for example be connected to the inlet through a blower, which forces air into the widening part of the contracted passage such that a turbulent flow is achieved.

According to a further aspect of the present invention, the inlet stones comprises at least one H-shaped stone, and two C-shaped end stones provided on opposite ends of said H-shaped stone.

According to one aspect of the present invention, the H-shaped stones have a width of between 120 and 170 mm, preferably between 130 and 160 mm, most preferably between 140 and 150 mm. According to one aspect of the present invention, the H-shaped stones have a length of between 300 and 360 mm, preferably between 310 and 350 mm, most preferably between 320 and 340 mm.

According to one aspect of the present invention, each one of the H-shaped stones define an air channel for passage of air, said channel extending in a width direction of the H-shaped stone, and said channel having a width of between 5 and 25 mm, preferably between 10 and 20 mm. Said channel is interrupted by a central support connecting the two sides of the H-shaped stone, wherein the central support has a width of between 15 and 45 mm, preferably between 20 and 40 mm, most preferably between 25 and 35 mm.

According to a further aspect of the present invention, the C-shaped stones have the same width as the H-shaped stones, and also define an air channel for passage of air, said air channel having the same width as that defined by the H-shaped stones.

According to a further aspect of the present invention, the width of the contracted passage is between 2400 and 3600 mm, preferably between 2600 and 3400 mm, most preferably between 2800 and 3200 mm.

Preferably, the elongated slot is arranged transversely to the direction of the flow in the contracted passage.

According to another aspect of the present invention, the plant further comprises a second inlet for forced injection of combustion air into the contracted passage.

The second inlet is arranged downstream of the first inlet in the contracted passage according to a further aspect of the present invention.

Also, the second inlet for forced injection of combustion air in the contracted passage is an elongated slot according to yet a further aspect of the present invention.

According to a further aspect of the present invention, the second inlet comprises inlet stones defining an air channel for passage of air from a source of inlet air into the contracted passage. According to one embodiment, the inlet stones of the second inlet are identical to the inlet stones of the first inlet.

According to a preferred aspect of the present invention the elongated slot of the second inlet is arranged transversely to the direction of the flow in the contracted passage.

According to yet a further aspect of the present invention the first and second inlets are elongated slots arranged in parallel and transversely to the direction of the flow in the contracted passage.

Also, according to one aspect of the present invention the slots of the first and second inlets are both arranged to inject air into the widening part of the contracted passage.

Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. The skilled person realize that different features of the present invention may be combined to create embodiments other than those described in the following, without departing from the scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The above, as well as additional objects, features and advantages of the present invention, will be better understood through the following illustrative and non-limiting detailed description of exemplary embodiments of the present invention, wherein:

Figure 1 is a diagrammatic sectional view of a portion of a plant according to the invention,

Figure 2 is a side view of a contracted passage according to the present invention, and

Figure 3 is a schematic view of the upper wall of the contracted passage, including the first and second inlet and the stones forming the two inlets.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. The invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness. Like reference character refer to like elements throughout the description.

With reference to figure 1, a plant 1 for burning waste comprises a rotary furnace 2, an after-burning chamber 3 connected to the furnace 2, a primary incineration part 4 comprising the furnace 2 and a first part 5 of the after-burning chamber 3 for initial incineration of the waste in an oxygen deficient environment at a lower temperature interval in the furnace 2 and in the first part 5 of the after-burning chamber 3 for producing combustible fumes therein. Further, a secondary incineration part 6 comprises a second part 7 of the after-burning chamber 3 and a contracted passage 8 between the first and second parts 5, 7 of the after-burning chamber 3 for subjecting the fumes to an increase in velocity between the first part 5 and the second part 7 of the after-burning chamber 3, the passage 8 comprising a first inlet 9 for forced injection of combustion air into the contracted passage 8 for conclusive combustion of the combustible fumes at a higher temperature interval in the passage 8 and in the second part 7 of the after-burning chamber 3.

Turning to figure 2, the contracted passage 8 comprises a narrowing part 10 followed downstream by a widening part 11 having a cross sectional area larger than the cross sectional area of the narrowing part 10 immediately upstream of the widening part 11.

As further can be seen in figure 2, the narrowing part is arranged on an inlet side 12 of the contracted passage 8 such that the opening of the contracted passage 8 has a cross sectional area that is larger than the cross sectional area of the narrowing part 10 downstream of the opening.

Also, the widening part 11 is followed downstream by a second narrowing part 37 having a cross sectional area that is smaller than the cross sectional area of the widest part of the widening part 11.

The contracted passage 8 is defined by a plurality of shaped stones 13a, 13b, 13c, 14a lining its upper wall 14, its lower wall 13 and the walls connecting the upper wall 14 and the lower wall 13. The widening part 11 of the contracted passage 8 is formed by a combination of stones 13b, 13c having convex inner surfaces and concave inner surfaces, such that a curved shape is formed. The curved shape defines a space in which the combustion gas may turbulently mix with the air injected from the two inlets 9, 15, such that the combustion efficiency is increased.

The lower wall 13 of the widening part 11 has an upstream first convex radius R1 formed by a stone 13b having a convex inner surface, such that a smooth transition from the narrowing part 10 to the widening part 11 is achieved. The upstream first convex radius R1 is approximately 375 mm.

The widening part 11 also has a first concave radius R2 formed directly downstream of the first convex radius R1. The first concave radius R2 is formed by a number of stones 13c each having a concave inner surface. Thus, a concave widening part 11 is provided such that a space for turbulent mixture of combustion gas and inlet air is formed. The first concave radius R2 is approximately 700 mm.

Finally, the widening part 11 has a second downstream convex radius R3 formed by a stone 13b having a convex inner surface, such that a smooth transition between the widening part 11 and the second narrowing part 37 is formed. The second downstream convex radius R3 is approximately 375 mm.

This means that the lower wall 13, at the widening part 11 of the contracted passage 8, is concave such that the cross sectional area of the contracted passage 8 increases in a downstream direction until a widening part bottom is reached, after which the cross sectional area of the contracted passage 8 decreases to the second narrowing part 37.

The shaped stones 13a, 13b, 13c, 14a used to form the contracted passage 8 are made from a polished silicon carbide material, that has a smooth inner surface such that very little material from the combustion gas is deposited thereon when the plant 1 is used.

Figure 3 is a schematic view of the upper wall 14 of the contracted passage 8, including the first and second inlet 9, 15 and the stones 9a, 9b, 15a, 15b forming the two inlets 9, 15.

As shown in figure 3, the shaped stones 13a, 13b, 13c, 14a are joined by a very thin seam 43. This seam has a thickness of no more than 1 mm, thus further increasing the overall smoothness of the walls formed by the shaped stones 13a, 13b, 13c, 14a.

The seam 43 is made from the same material as the shaped stones 13a, 13b, 13c, 14a, i.e. a silicon carbide material

The upper wall 14 has, in an area immediately above the widening part 11, two inlets 9, 15. The inlets 9, 15 are made from inlet stones 9a, 9b, 15a, 15b defining a respective air channel therethrough in the shape of an elongated slot for passage of air from a source of inlet air into the contracted passage 8. The inlet stones 9a, 9b, 15a, 15b are arranged in a row such that the channel formed thereby extends at least 90% of the width of the contracted passage 8.

The inlets 9, 15 are made from two types of inlet stones 9a, 9b, 15a, 15b. Each inlet 9, 15 has a number of H-shaped stone 9a, 15a arranged so that the short ends thereof abut, and two C-shaped end stones 9b, 15b provided on opposite ends of the H-shaped stones 9a, 15a. Each one of the H-shaped stones 9a, 15a define an air channel for passage of air. The channel extends in a width direction of the H-shaped stone 9a, 15a, and has a width of approximately 15 mm. In the center of each H-shaped stone 9a, 15a, there is a central support 9c, 15c interrupting the channel formed thereby, thus connecting the two sides of the H-shaped stone 9a, 15a. The central support 9c, 15c has a width of approximately 30 mm.

According to the plant 1 shown in figures 1-3 the contracted passage 8 is arranged horizontally. Further, the cross section of the contracted passage 8 is rectangular and wherein a lower wall 13 of the rectangular shape of the contracted passage 8 varies in distance to an upper wall 14 of the contracted passage 8 such that the narrowing and widening parts are presented. The lower wall 13 does this by having different portions thereof being angled, curved or parallel relative to the upper wall 14, as will be described in the following.

As seen in figure 1, the contracted passage 8 is arranged at an angle of approximately 90° relative to both the first part 5 of the after-burning chamber 3 and the second part 7 of the after-burning chamber 3.

The first inlet 9 for forced injection of combustion air into the contracted passage 8 is arranged to inject air in the widening part 11 of the contracted passage 8. The first inlet 9 for forced injection of combustion air into the contracted passage 8 is an elongated slot arranged transversely to the direction of the flow in the contracted passage 8.

There is further a second inlet 15 for forced injection of combustion air into the contracted passage 8, wherein the second inlet 15 is arranged downstream of the first inlet 9 in the contracted passage 8. The second inlet 15 for forced injection of combustion air in the contracted passage 8 is an elongated slot arranged transversely to the direction of the flow in the contracted passage 8. The first and second inlets 9, 15 are thus arranged in parallel and transversely to the direction of the flow in the contracted passage 8. They are further both arranged in and arranged to inject air into the widening part 11 of the contracted passage 8.

The diagrammatic view of figure 1 shows an incineration plant 1 having a rotational furnace or kiln 2 which is fed from a conduit 16 with fuel 17 in the form of, for example municipal solid waste, by means of a screw feeder 18. As indicated, when starting the plant 1, and when otherwise needed during use, the furnace can also be fed with gaseous and liquid fuels through fuel lines 19, 20 connected to the furnace 2. Also combusted fumes that have passed the plant 1 can be returned to the furnace 2 through a line 21.

On a typical incineration process, the furnace 2 is rotated about 1 rpm by a known drive (not shown), and it will then take about 1 hour for newly fed-in fuel to be gasified to primary fumes / combustive gas and other particles to be introduced in a first part 5 of two parts 5, 6 in the after-burning chamber 3. Non-gasified solid materials drop down into a water container 22, for example, in the bottom of the first part 5 and are transported away for further handling by means of a conveyor 23 such as a screw conveyor. According to the invention, the after-burning chamber 3 as well as the furnace 2 has a large mass (typically totaling to 1500 tons), i.e. a thick lining 24, for example of refractory ceramic material, such as brick material or cast compounds, serving as a heat insulation and a heat accumulator, and thereby is able to maintain the high temperatures in a steady state condition with small fluctuations during the operation of the plant 1. The lining 24 in the after-burning chamber 3 may typically have a thickness of about 1,3 m. The heat losses through the lining of the afterburning chamber 3 may typically be about 200 kcal/m^2/h, while those in the furnace 2 may be about 1700 kcal/m^2/h; the furnace 2 has a relatively smaller mass of refractory and insulating material as otherwise the weight of the furnace 2 would be too high.

In order to facilitate the maintenance of the lining 24 in the after-burning chamber 3, the interior surface layer of chamber 3 can be composed of relatively thin refractory blocks 25 having a thickness of about 40 mm, whereby the thick blocks 26 located behind the thin blocks 25 do not need to be replaced when renovating the after-burning chamber 3.

In the after-burning chamber 3 there is further provided a separating wall 27 that divides chamber 3 into its both parts 5 and 7.

In the example shown, the vertical separating wall 27 extends also a distance horizontally between the both parts 5 and 7 of the after-burning chamber 3 to define an elongate passage in the shape of a flue-gas channel or a flame port 8 in the top portion of the after-burning chamber 3. In the flue-gas channel or passage 8 there is an inlet 9 for combustion air fed by a blower 28 that typically delivers an airflow having a flow rate of about 30 m/s.

In the flue-gas channel or passage 8 there is further a second inlet 15 for air fed by a blower 29. It typically delivers a pulsed airflow for increasing the turbulence in the widening part 11 and thus the overall efficiency of the plant 1. Both inlets 9, 15 supply air with a high content of oxygen. The higher the carbon content of the passing gas, the higher the temperature will be.

By the arrangement described above the plant 1 can be regarded as divided into a primary incineration part 4 with an oxygen-depleted, gasifying incineration environment and a secondary incineration part 6 with an oxygen-rich, highly combustive combustion environment.

In the example shown, a boiler in the shape of a gas-liquid heat exchanger 30 is connected to an outlet 31 for the smoke gases or fumes from the second part 6 of the after-burning chamber 3. Steam capable of powering a turbine 32 is generated in the heat exchanger 30. Turbine 32 is in turn capable of driving a generator 33 for producing electrical power.

A suction blower or fan 34 is present at an outlet of the fumes from the boiler 30 for providing a sufficient negative pressure or vacuum in the furnace 2, afterburning chamber 3 and boiler / heat exchanger 30 to draw the fumes or smoke gases through the plant 1.

In connection to the plant 1, a plurality of different components (not shown) may further be present, such as a flue-gas purifier, and other components capable of handling solid, liquid and gaseous residual products needed to be taken care of during plant operation. During plant operation a steady state condition is maintained in the rotating kiln/furnace 2 and in the after-burning chamber 3. In order to obtain such steady state condition and a complete combustion process the following measures are taken:

1) In the primary incineration part 4 an initial incineration condition prevails in the form of partial pyrolysis in a gasifying, oxygen-depleted environment that produces combustive gas in a substantially constant, lower temperature interval of about 950-1100 °C. Thereby, the fuel 17 can be almost totally gasified so as to leave a minimum amount of residual ash of only about 4-5 % of the original fuel content, which residual ash falls down into the vertical shaft formed by the first part 5. As a comparison, conventional furnaces of the prior art are expected to leave about 20-30% residual ash, The residual ash may also comprise solid components of a high melting point in the fuel, such as glass and metals, which are prevented from being melted in the lower temperature and may detrimentally adhere to the lining 24.

2) In the secondary incineration part 6 a final incineration condition prevails with a substantially constant increased temperature interval of about 1100-1200 °C. The increased temperature is obtained in that the combustive gas produced in the incineration part 4 is accelerated to a high velocity (typically about 30 m/s) according to the principle of Bernoulli in the contracted passage 8, and in that combustion air is blown across the combustive gas by the blower. As indicated above, very large amounts of O_2 may then effectively interact in the reduced passage with very large amounts of combustible CO in the combustive gas for being transformed into CO_2 in the resulting heated and combusted fumes that leaves the after-burning chamber 3. At entry into the larger volume in the second part 7 of the after-burning chamber 3,

the velocity of the fumes is decreased. Possible remaining solid residual products, such as magma, fall down onto the bottom of the secondary part 6 in the vicinity of the boiler and are cooled into solid phase. To facilitate removal of such residual products that may form a glassy skin on the bottom, that bottom may have a particle bed layer 35 of clay granules, such as chamotte clay granules.

As diagrammatically indicated in figure 1, a number of temperature sensors 36 may be located at suitable places in the plant 1 to sense the steady state condition in the plant 1. The temperatures sensed by the sensors 36 are signaled via signal connections such as signal lines 38 to a computer 39 such as a control computer for the plant 1. Computer 39 can then, by means of the temperature information, compare the actual state with a desired steady state in a software application. On deviations between the actual and desired states, the computer can, for example, increase or decrease the return flow of cool fumes through line 21, by controlling a valve 40 in the line 21 via a signal connection 41. If, for example, a larger amount of synthetic resin material having a large energy content (typically about 9-10 Mcal/kg compared to normally about 2,5 Mcal/kg) is temporary present in the fuel, the return flow of cool fumes need to be increased to decrease the mean temperature in the part 4 down to at least 1100 °C. It may also be possible to feed water into the plant 1 for cooling purposes. If, on the other hand, the temperature sensors 36 signals that the plant 1 runs the risk of being cooled down to a temperature below the steady state condition, the return flow of cool fumes will be throttled down and possibly also the furnace 2 and the after-burning chamber 3 may temporarily be fed by additional fuel via lines 19 and/or 20. These processes are also controlled in a manner known as such by the computer 39 via signal connections 38, 41, as schematically indicated in figure 1.

When starting a cool plant 1 up to steady state condition, the gaseous or liquid fuels that are supplied through lines 19, 20 can be burned in the furnace 2. To this end, one or more gas or oil burners 42 (only one oil burner is shown in figure 1) may additionally be provided in the walls of the after-burning chamber 3.

It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims. For example, the first inlet 9 could be the inlet with pulsed flow and the second inlet 15 could have a steady flow in the contracted passage 8. A further possibility could be a combination, wherein the inlets could both supply gas with pulsed flows or both with constant flows.

CLAIMS

1. A plant (1) for burning waste comprises a rotary furnace (2), an after-burning chamber (3) connected to the furnace (2), a primary incineration part (4) comprising the furnace (2) and a first part (5) of the after-burning chamber (3) for initial incineration of the waste in an oxygen deficient environment in the furnace (2) and in the first part (5) of the after-burning chamber (3) for producing combustible fumes therein, a secondary incineration part (6) comprising a second part (7) of the after-burning chamber (3) and a contracted passage (8) between the first and second parts (5, 7) of the after-burning chamber (3) for subjecting the fumes to an increase in velocity between the first part (5) and the second part (7) of the after-burning chamber (3), the contracted passage (8) comprising at least one inlet (9, 15) for forced injection of combustion air into the contracted passage (8) for conclusive combustion of the combustible fumes in the contracted passage (8) and in the second part (7) of the after-burning chamber (3),
c h a r a c t e r i z e d i n
that the contracted passage (8) is defined by a plurality of shaped stones (13a, 13b, 13c, 14a) lining an upper wall (14), a lower wall (13) and walls connecting the upper wall (14) and the lower wall (13) of the contracted passage (8), and wherein the contracted passage (8) comprises a narrowing part (10) followed downstream by a widening part (11) having a cross sectional area larger than the cross sectional area of the narrowing part (10) immediately upstream of the widening part (11), and wherein the widening part (11) is followed downstream by a second narrowing part (37) having a cross sectional area that is smaller than the cross sectional area of the widest part of the widening part (11), and wherein the widening part (11) of the contracted passage (8) is formed by a combination of stones (13b, 13c) having convex inner surfaces and concave inner surfaces.

2. The plant (1) according to claim 1, wherein the lower wall (13) of the widening part (11) comprises an upstream first convex radius (R1) formed by at least one stone (13b) having a convex inner surface, wherein the upstream first convex radius (R1) is between 300 and 450 mm, preferably between 325 and 425 mm, most preferably between 350 and 400 mm.

3. The plant (1) according to any one of the preceding claims, wherein the widening part (11) further comprises a first concave radius (R2) formed by a plurality of stones (13c) each having a concave inner surface, wherein the first concave radius (R2) is between 500 and 900 mm, preferably between 550 and 850 mm, most preferably between 600 and 800 mm.

4. The plant (1) according to any one of the preceding claims, wherein the widening part (11) further comprises a second downstream convex radius (R3) formed by at least one stone (13b) having a convex inner surface, wherein the second downstream convex radius (R3) is between 300 and 450 mm, preferably between 325 and 425 mm, most preferably between 350 and 400 mm.

5. The plant (1) according to any one of the preceding claims, wherein the lower wall (13), at the widening part (11) of the contracted passage (8), is concave such that the cross sectional area of the contracted passage (8) increases in a downstream direction until a widening part bottom is reached, after which the cross sectional area decreases to the second narrowing part (37).

6. The plant (1) according to any one of the preceding claims, wherein the shaped stones (13a, 13b, 13c, 14a) are made from a polished silicon carbide material.

7. The plant (1) according to claim 6, wherein the shaped stones (13a, 13b, 13c, 14a) are joined by a seam (43) having a thickness of no more than 3 mm, preferably no more than 2 mm, most preferably no more than 1 mm, wherein the seam (43) is made from a silicon carbide material.

8. The plant (1) according to any one of the preceding claims, wherein the narrowing part (10) is arranged on an inlet side (12) of the contracted passage (8) such that the opening of the contracted passage (8) has a cross sectional area that is larger than the cross sectional area of the narrowing part (10) downstream of the opening.

9. The plant (1) according to any one of the preceding claims, wherein the contracted passage (8) is arranged at an angle of between 75 and 105° relative to the first part (5) of the after-burning chamber (3) and/or the second part (7) of the after-burning chamber (3), preferably between 80 and 100°, most preferably between 85 and 95°.

10. The plant (1) according to claim 9, wherein the contracted passage (8) is arranged horizontally.

11. The plant (1) according to any of the preceding claims, wherein the at least one inlet (9, 15) for forced injection of combustion air into the contracted passage (8) is arranged to inject air in the widening part (11) of the contracted passage (8).

12. The plant (1) according to any one of the preceding claims, wherein the at least one inlet (9, 15) comprises inlet stones (9a, 9b, 15a, 15b) defining an air channel in the shape of an elongated slot for passage of air from a source of inlet air into the contracted passage (8), wherein the air channel extends at least 90% of the width of the contracted passage (8).

13. The plant (1) according to claim 12, wherein the inlet stones (9a, 9b, 15a, 15b) comprise at least one H-shaped stone (9a, 15a), and two C-shaped end stones (9b, 15b) provided on opposite ends of said H-shaped stone (9a, 15a), wherein each one of the H-shaped stones (9a, 15a) define an air channel for passage of air, said channel extending in a width direction of the H-shaped stone (9a, 15a), and said channel having a width of between 5 and 25 mm, preferably between 10 and 20 mm, and wherein said channel is interrupted by a central support (9c, 15c) connecting the two sides of the H-shaped stone (9a, 15a), wherein the central support (9c, 15c) has a width of between 15 and 45 mm, preferably between 20 and 40 mm, most preferably between 25 and 35 mm.

14. The plant (1) according to any one of the preceding claims, wherein the at least one inlet (9, 15) is at least a first inlet (9) and a second inlet (15) arranged downstream of the first inlet (9).

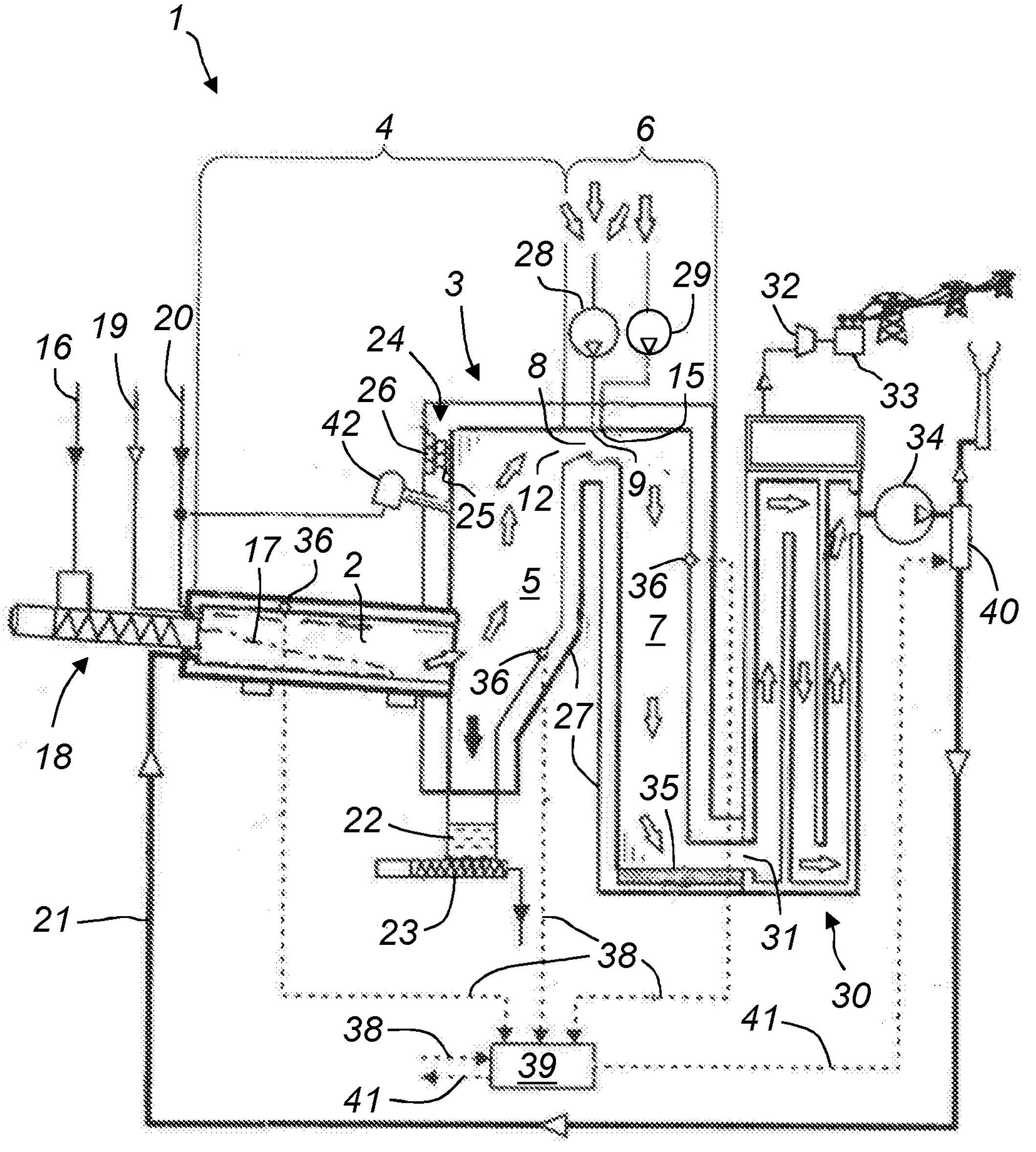
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Fig. 1

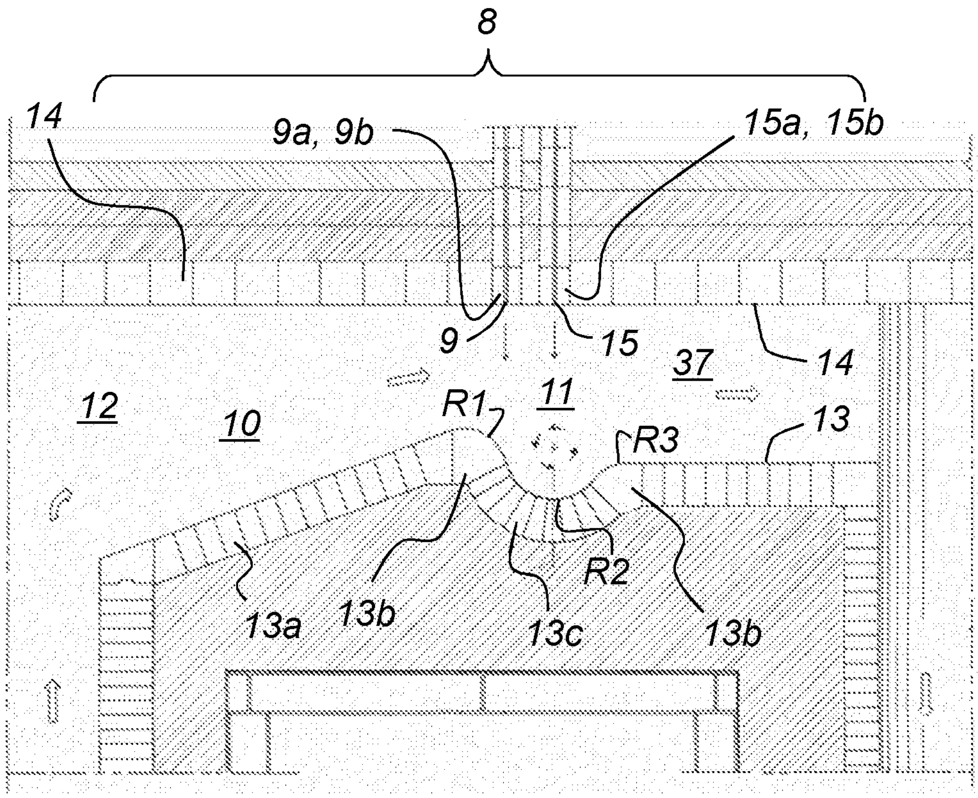

Fig. 2

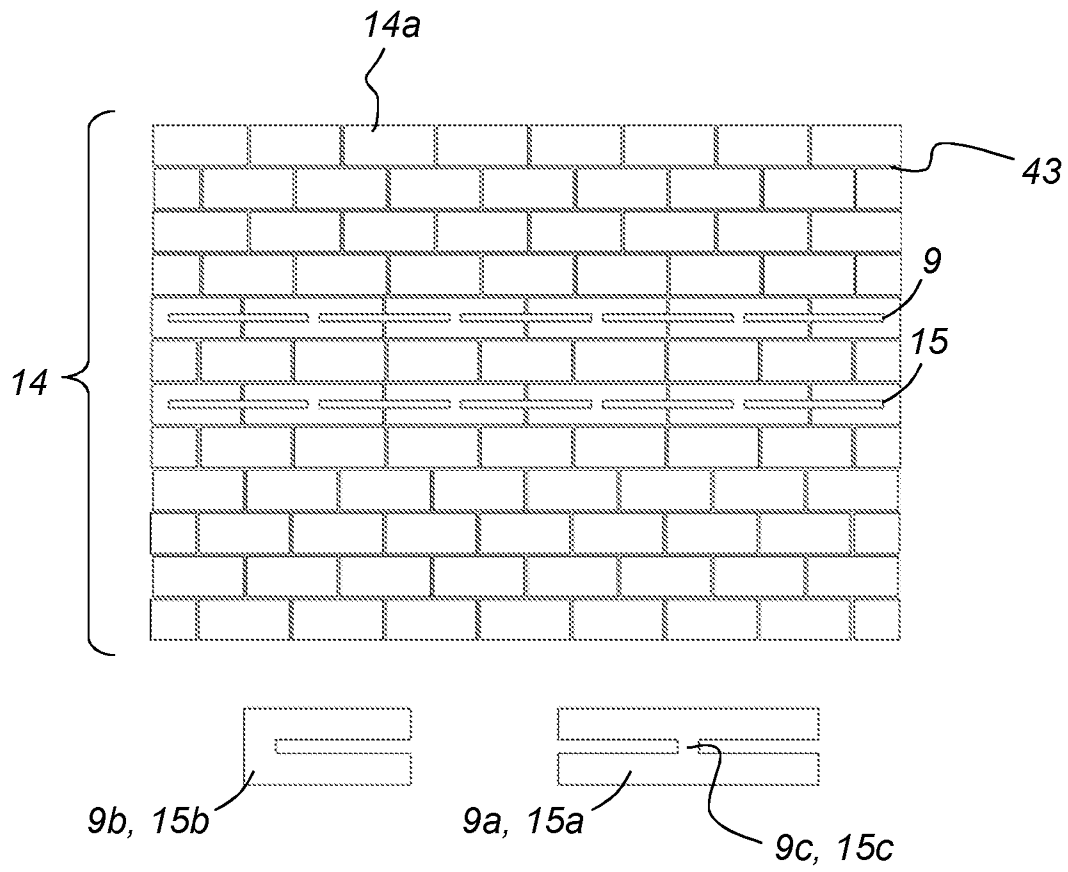

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2021/050365

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: F23B, F23G, F23L, F23M

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, 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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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

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"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

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Date of the actual completion of the international search	Date of mailing of the international search report
26-05-2021	28-05-2021
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INTERNATIONAL SEARCH REPORT

International application No.
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International Patent Classification (IPC)

F23G 5/16 (2006.01)
F23B 10/02 (2011.01)
F23B 80/00 (2006.01)
F23B 90/06 (2011.01)
F23G 5/027 (2006.01)
F23L 9/00 (2006.01)
F23M 5/02 (2006.01)
F23G 5/20 (2006.01)

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