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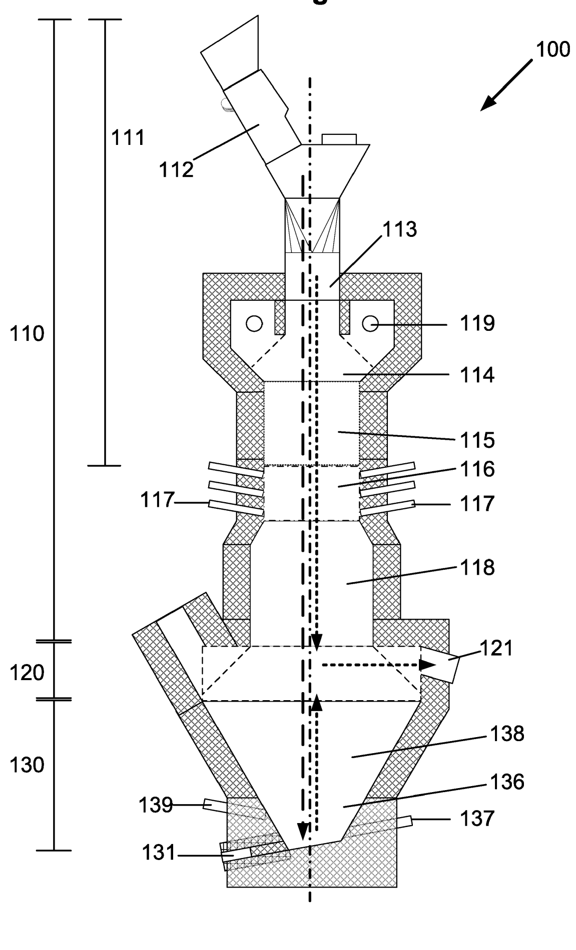
(54) **REACTOR AND PROCESS FOR GASIFYING AND/OR MELTING OF FEED MATERIALS**

(57) The present invention relates to a reactor (100) for the gasifying and/or melting of feed materials. The reactor comprises:
a co-current section (110), comprising a plenum zone (111), comprising a feed zone with a sluice (112), wherein feed materials are introduced into the reactor (100) from above via the feed zone, a buffer zone (113), a pyrolysis zone (114), which adjoins a bottom of the buffer zone (113) to create a cross-sectional enlargement, and an intermediate zone (115) adjoining the pyrolysis zone, an upper oxidation zone (116) adjoining a bottom of the intermediate zone and comprising tuyeres (117) in at least one plane, and an upper reduction zone (118) adjoining a bottom of the upper oxidation zone (116), a gas outlet section (120) comprising at least one gas outlet (121), and a countercurrent section (130) comprising a conical lower reduction zone (138) adjoining the gas outlet section (120) and a conical lower oxidation zone (136) adjoining the lower reduction zone (138) comprising at least one tuyere (137) and at least one tapping (131).

Fig. 1



EP 3 660 132 A1

Description

[0001] This invention relates to a reactor and a method for gasifying and/or melting substances. In particular, the invention relates to the material and/or energy recovery of any waste, for example, but not exclusively household waste, used tires, hazardous waste, asbestos, hospital waste, coal or coal dust. The reactor and the method are also suitable for the gasifying and melting of feed materials of any composition or for the generation of energy through the use of waste and/or coal.

[0002] For some time now, solutions have been sought for the thermal disposal of various types of waste and other materials. In addition to combustion processes, various gasification processes are known, the main aim of which is to achieve results with a low pollutant load on the environment and to reduce the cost of treating the feed materials, but also the gases produced in the process. However, the known processes are characterized by a complex technology that is difficult to master and the associated high disposal costs for the feed material or waste to be treated.

[0003] EP 1 261 827 B1 discloses a reactor for the gasifying and/or melting of feed materials. This reactor does not follow the approach of the previously frequently used circulating gas process. In contrast, the disclosed reactor operates according to the co-current principle. The complete elimination of conventional recirculation gas management avoids many of the problems associated with the condensation of pyrolysis products and the formation of unwanted deposits. Furthermore, EP 1 261 827 B1 discloses that already in the upper part of the reactor a partial conglomeration of the feed materials takes place due to the shock-like heating of the bulk material (bulk column), whereby adherences to the inner wall of the reactor are largely excluded. In EP 1 261 827 B1 it is disclosed that a reduction section is formed between two injection means through which all gases flow before extraction, thereby reducing them to a large extent.

[0004] One problem to be solved by the present invention is therefore to provide an improved reactor and an improved method for gasifying and melting feed materials.

[0005] This and other problems are solved by the reactor specified in claim 1.

[0006] The reactor according to claim 1 comprises an upper co-current section, a central gas outlet section and a lower countercurrent section. In the co-current section, the gas flows downwards to the gas outlet section. In the countercurrent section, the gas flows from below to the gas outlet section. The gas escapes via at least one gas outlet in the gas outlet section.

[0007] The co-current section comprises a plenum zone, an upper oxidation zone and an upper reduction zone.

[0008] The plenum zone comprises a feed zone with at least one sluice (which may be a load-lock and/or an air-lock), a buffer zone, a pyrolysis zone and an intermediate zone.

[0009] Via the feed zone with a sluice, feed materials such as waste, toxic or biological waste, water, used tires, biomass, wood, coal, automotive shredder residues, aggregates or the like can be fed into the reactor from above. The sluice ensures that the uncontrolled entry of ambient air and the discharge of gases from the reactor are avoided as far as possible. It is intended that the sluices may have hydraulic, pneumatic or electrically operated hatches. These hatches can preferably be designed in such a way that the hatches are additionally closed in the event of unintentional overpressure in the reactor and no gas can escape unintentionally. In addition, pressure equalization lines may be provided to the atmosphere or other areas of the reactor. Due to this embodiment, the hatches can also be opened at the desired overpressure in the reactor, since the hatches drive does not have to work against a pressure difference.

[0010] The plenum zone also includes a buffer zone for buffering and pre-drying the feed material volume. The temperature of the buffer zone is preferably adjustable. For example, a set temperature of approx. 100°C to 200°C can be provided for the pre-drying of waste.

[0011] In addition, a pyrolysis zone is provided in the plenum zone, which is connected to the bottom of the buffer zone by creating a cross-sectional enlargement being preferably abrupt. Preferably, the cross-section increases at least twice. The cross-sectional enlargement ensures that the sinking speed of the feed materials is reduced and that a cone-shaped discharge area (discharge cone) made of bulk material forms within the gas space of the reactor. The discharge cone is supplied centrally with the pre-dried feed materials (from the buffer zone). Gas supply means (e.g. burners, nozzles, wall openings or other devices enabling hot gases to be supplied to the bed) are also provided above the discharge cone, in a so-called annular space, via which hot gases (e.g. combustion gases, temporarily stored or recirculated excess gases or inert combustion gases provided by combustion) can be supplied to the discharge cone. The bed is shock-heated by the hot gases at the surface, whereby sticking of the feed materials with the refractory lining (e.g. brick lining or castable lining) is prevented as far as possible. Shock heating can be achieved, for example, by means of burners directed radially at the bed. Alternatively or additionally, shock heating can also be achieved by means of a ringshaped channel in which a flame rotates. This rotation can be achieved constructively by blowing the hot gas tangentially to the discharge cone and burning it.

[0012] The plenum zone also includes an intermediate zone located below and adjacent to the pyrolysis zone. In the intermediate zone, the heat from the pyrolysis zone and the waste heat from the upper oxidation zone below are used for final drying and complete pyrolysis of the feed materials. It may be advantageously provided that the intermediate zone comprises a lined (e.g. brick lined or castable lined) steel shell, wherein the refractory can be of a thickness similar to that of other zones. This embodiment simplifies the commissioning (starting up) of the reactor, as high temperatures can also occur in the intermediate zone during this time. It may be advantageous to provide for a tapered cross-section in the lower area of the intermediate zone, which changes the rate at which the feed material sinks.

[0013] Below the intermediate zone in the co-current section there is an upper oxidation zone in which tuyeres are arranged.

[0014] Here it can be provided that the tuyeres (of the upper and conical lower oxidation zone) are made of copper or steel. Furthermore, it may be provided that the tuyeres have a ceramic inner tube. This embodiment of the tuyeres (with a ceramic inner tube) enables the tuyere to be protected against melting of the metal by adding oxygen and/or air, whereby oxygen and/or air can also be preheated (e.g. to temperatures > 500°C). It can also be advantageous that a compressible and temperature-resistant layer is arranged between the ceramic inner tube of the tuyere and the metal tuyere itself, whereby thermally induced mechanical stresses can be compensated. This compressible and temperature-resistant layer consists, for example, of high-temperature felt, high-temperature cardboard or high-temperature foam.

[0015] Alternatively, the tuyeres (of the upper and conical lower oxidation zones) may be made of ceramic. Through this embodiment it can be achieved, for example, that the oxidation zone can be operated with a supply of hot air and/or oxygen having temperature more than 1000°C and thus a bed temperature of more than 2000°C, since ceramics can withstand higher temperatures than metals.

[0016] The inevitably necessary cooling of metallic tuyeres is not necessary for tuyeres made entirely of ceramics, whereby the heat loss can be reduced by more than 5 %. The chemical load caused by melting without cooling and the high thermal stress can be achieved for these tuyeres by a combination of ceramics with good thermal conductivity (e.g. silicon carbide with e.g. 85 W/(m·K)) and slag freezing, followed by insulating ceramics (e.g. spinel corundum with less than 4 W/(m·K)).

[0017] The tuyeres made of metal or ceramic are arranged on at least one level (height or vertical distance from the reactor bottom). By adding oxygen and/or air, whereby oxygen and/or air can also be preheated, the temperature in the oxidation zone is increased to such an extent that all substances are converted into inorganic gas, such as carbon monoxide (CO), hydrogen (H_2), water (H_20), carbon dioxide (CO_2), hydrogen sulphide (H_2S), ammonia (NH_3), nitrogen dioxide (NO_2) or sulphur dioxide (SO_2), liquid metal or liquid slag, coke or carbon (C). The temperature at the edge, for example, can be about 1500°C to 1800°C, with temperatures above 2000°C to 3000°C in the center of the bed.

[0018] Below the upper oxidation zone, an upper reduction zone is arranged in the co-current section, into which essentially no organic components enter. It can be advantageously provided that the upper reduction zone has a cross-sectional enlargement compared to the upper oxidation zone, which changes the sinking rate of the feed materials and increases the residence time (compared to a reactor of the same height). In the upper reduction zone, the gas flows through the coked fixed bed in co-current and thermal energy is converted into chemical energy, producing carbon monoxide (CO) and hydrogen (H_2). In particular, carbon dioxide (CO_2) is converted into carbon monoxide (CO) and water (H_2O) into hydrogen (H_2), whereby the carbon still contained in the bed is further gasified. As they pass through the upper reduction zone, the gases are simultaneously cooled (by the endothermic reaction), for example to temperatures between approx. 800 °C and approx. 1500 °C. As all material flows necessarily-through the upper oxidation zone and cannot be returned, there is no longer any contact with the unreacted materials above the oxidation zone after they have passed through the upper reduction zone. In this way, all cleanly cracked and/or melted, exclusively inorganic substances reach the gas outlet section without anew contamination.

[0019] It is provided that the gas outlet section comprises at least one gas outlet. It is also conceivable that several (e.g. four) gas outlets are arranged all-round, preferably radially distributed.

[0020] Below the gas outlet section there is an essentially conical countercurrent section. This comprises a conical lower reduction zone to convert the thermal energy of the gas from the conical lower oxidation zone into chemical energy (mainly CO) and to generate the countercurrent. This conical lower reduction zone is connected to the gas outlet section, wherein the cut-off tip of the cone of the conical lower reduction zone points downwards.

[0021] In the conical lower reduction zone and in the gas outlet section, during reactor operation, the bed of residual coked material (which has not yet been converted into gas), slag and metals can also be arranged in the form of a double truncated cone. Here the upper truncated cone, the outer surface of which corresponds substantially to the gas outlet section surface, projects into the gas outlet section and the lower truncated cone is arranged in the conical lower reduction zone.

[0022] Below the conical lower reduction zone a conical lower oxidation zone is arranged with the cut tip of the cone pointing downwards. In the conical lower oxidation zone the residual coked material is converted into gas. In the conical lower oxidation zone at least one tuyere, consisting of metal or ceramic, as previously described for the upper oxidation zone, is arranged in at least one plane, via which air and/or oxygen can be introduced and via which the temperature can be adjusted in such a way that the slag and the metals can emerge in liquid form via at least one tapping for collection and discharge. Here it can be provided that the introduced air and/or oxygen is preheated, e.g. to temperatures > 500°C. The resulting gas then flows via the conical lower reduction zone to the gas outlet section.

[0023] Since according to the invention the reactor has both a reduction zone in the countercurrent section and an upper reduction zone in the co-current section, the total reduction zone volume (sum of the volumes of the upper and conical lower reduction zones) can be considerably larger than the one reduction zone of known reactors. As an example, reference is made to EP 1 261 827 B1, in which only one reduction zone is arranged in the area of the gas outlet section.

[0024] In the upper reduction zone, the gas flows through the coked fixed network in co-current and converts thermal energy into chemical energy. At the same time, CO and H_2 are produced and the gas is cooled.

[0025] By the free choice of height and diameter of the upper reduction zone different residence times can be realized. The longer the residence time at sufficient heat, the more H_2 and CO can be formed. Furthermore, the upper reduction zone can be designed in such a way that cooling can take place in such a way that standard refractory lining materials such as aluminium-/spinel- or chrome-corundum can also be used in high-temperature applications.

[0026] Since according to the invention the reactor has two reduction zones, namely an upper reduction zone in the co-current section and a conical lower reduction zone in the countercurrent section, considerably more thermal energy can be converted into chemical energy, in the form of more H_2 or CO. A further advantage may be that the arrangement of the upper reduction zone in the co-current section means that considerably lower temperatures can be achieved in the gas outlet. Alternative it may be achieved by this embodiment that the upper oxidation zone can be operated at higher temperatures, e.g. with a temperature at the edge of the oxidation zone of more than 1800°C, but the gas outlet temperature is comparable to the gas outlet temperatures of known reactors, e.g. about 800°C to 1000°C. Furthermore, it may be conceivable that the upper oxidation zone can be operated at higher temperatures, e.g. at a temperature at the boundary between bulk material and refractory of the oxidation zone of more than 1800°C, whereby the gas outlet temperature can be up to 1500°C or even more than 1500°C. The upper oxidation zone may also be operated at higher temperatures.

[0027] Thus according to the invention the reactor achieves a simple, inexpensive and environmentally friendly material and/or energetic utilization of feed materials. In addition, a capacity increase is made possible by employing the reactor described herein.

[0028] For one embodiment of the reactor it is intended that the upper reduction zone is arranged above the gas outlet section, wherein the gas outlet section adjoins the lower part of the upper reduction zone by creating a cross-sectional enlargement. Here it could be conceived, that the cross-sectional enlargement is abrupt/discrete.

[0029] Preferably, the cross-sectional area of the gas outlet section increases by at least twice that of the cross-sectional area of the upper reduction zone.

[0030] This embodiment ensures that the bed widens conically thereby increasing the surface area or discharge area of the bed. The surface or discharge area of the bed essentially corresponds to the outer surface for a truncated cone-shaped design.

[0031] An embodiment provides that the cross-sectional enlargement is such that the discharge area of the bed is at least three times larger than the cross-sectional area of the upper reduction zone. Furthermore, the cross-sectional enlargement can be so large that the discharge area of the bed is at least seven times or even at least nine times larger than the cross-sectional area of the upper reduction zone.

[0032] For this or a further embodiment, it may also be provided that the cross-sectional enlargement of the gas outlet section is such that the discharge area of the bed is increased by at least five times the cross-sectional area of the upper oxidation zone. Furthermore, the cross-sectional enlargement can be so large that the discharge area of the bed is at least nine times larger than the cross-sectional area of the upper oxidation zone.

[0033] The advantage of the above-mentioned embodiments is that the gas flow velocity (through the gas outlet) is reduced proportionally to the increased discharge area of the bed (compared to known reactors) so that the dust entrainment from the bed can be reduced to minimized.

[0034] A reduced dust entrainment is particularly advantageous in order to be able to carry out a subsequent gas cleaning or dust separation economically. Furthermore, this embodiment enables the dust (due to the small quantities) to be returned to the gasifier inlet without significantly reducing the capacity of the reactor for fresh feed material.

[0035] Alternatively, it may be provided for the reactor that at least a portion of the upper reduction zone arranged in the co-current section is arranged or inserted in the gas outlet section.

[0036] This embodiment may also provide for the gas outlet section to have a larger cross-section than the upper reduction zone.

With this embodiment, the co-current section with a part of the upper reduction zone is introduced or partially inserted into the gas outlet section. For example, the refractory lining (e.g. brick lining or castable lining) of the upper reduction zone may protrude into the gas outlet section. Since the gas outlet section has a larger cross-sectional area than the upper reduction zone and the at least one gas outlet is located in the edge portion of the gas outlet section, the gas produced in the co-current section must bypass the refractory lining (e.g. brick lining or castable lining) extending out into the gas outlet section in order to reach the gas outlet, whereby less dust enters the dust separation. This embodiment allows the overall height of the reactor to be reduced. Furthermore, the dust separation can be improved by this embodiment, since the gas and the entrained dust must additionally flow upwards in order to achieve at least one gas outlet.

[0037] It may also be provided that the refractory lining (e.g. brick lining or castable lining) of the upper reduction zone extending out into the gas outlet section is formed as a hollow cylindrical shape. The hollow cylindrical shape may be made of steel, which has an ability to withstand high thermal and consequently mechanical stresses. For example, the hollow cylindrical shape can be protected by water cooling and/or lined on both sides.

[0038] For a further embodiment of the invention, it is provided that the volume ratio of the upper oxidation zone volume to the plenum zone volume is a ratio of 1 : N volume units, wherein N is a number greater than or equal to (≥) 4 and less than or equal to (≤) 20.

[0039] Thus the upper oxidation zone volume is many times larger compared to previously known reactors, whereby a considerably higher capacity can be achieved. Here it is further conceivable that $5 \leq N \leq 15$ or even $6 \leq N \leq 11$.

[0040] In a reactor embodiment, it is provided that the volume ratio of the upper oxidation zone volume to the total volume of the upper reduction zone volume and the plenum zone volume is a ratio of 1 : N volume units, wherein N is a number greater than or equal to (≥) 7 and less than or equal to (≤) 25.

[0041] A further embodiment provides that the volume ratio of the upper oxidation zone volume to the total volume of the upper reduction zone volume and the plenum zone volume is a ratio of 1 : N volume units, wherein $8 \leq N \leq 15$ or even $9 \leq N \leq 14$.

[0042] This embodiment of the reactor is advantageous in that a larger capacity is achieved with a fictitious same height of the reactor. This is possible because the plenum zone volume compared to the oxidation volume has a smaller ratio than in known reactors.

[0043] A further embodiment of the reactor provides that the volume ratio of the countercurrent section volume to the total volume of the reactor is a ratio of 1 : N volume units, where N is a number between 1 and 10 ($1 \leq N \leq 10$). Here it is further conceivable that $2 \leq N \leq 7$ or even $3 \leq N \leq 5$.

[0044] Due to the cross-sectional enlargement of the gas outlet zone and the countercurrent section, the discharge cone area of the bed in the conical lower reduction zone is also enlarged, whereby smaller gas flow velocities flow out of the bed and less dust is entrained.

[0045] Another advantageous embodiment of the reactor is that the cone angle of the conical lower reduction zone and the cone angle of the conical lower oxidation zone are between 50° and 70°. Due to this embodiment, the slag, which is kept liquid at sufficiently high temperatures in the conical lower oxidation zone and the conical lower reduction zone, drains off better, since the walls run at an angle of approx. 50°-70°, preferably approx. 60°C, from the horizontal or at an angle of 20° to 40° from the vertical.

[0046] A further embodiment of the reactor provides that gas supply means are arranged in the area of the cross-sectional enlargement in the pyrolysis zone. This embodiment ensures that hot gases (e.g. preheated air or combustion gases) are supplied to the discharge cone.

[0047] In one embodiment of the invention, it is also provided that the tuyeres of the upper oxidation zone are arranged on several levels (heights). This is particularly advantageous because a better distribution of the gas is achieved with uniform heating of the bed. In addition, this embodiment ensures that local overheating of the refractory lining (e.g. brick lining or castable lining) is avoided as far as possible.

[0048] Another advantageous embodiment of the reactor is that at least one further tuyere is arranged on a level (height) of the conical lower reduction zone.

[0049] The further tuyere additionally supplies air and/or oxygen in a defined way, so that no CO_2 is produced, but almost exclusively CO. Furthermore, it can be achieved through this embodiment that the throughput can be increased. Furthermore, it can be achieved that the gas outlet temperature at the gas outlet can be increased to temperatures of up to 1500°C without impairing the quality of the gas.

[0050] For applications that prefer thermal energy over chemical energy it may be further advantageous that at least one additional tuyere is arranged in the upper reduction zone. Through this embodiment it can be advantageously achieved that chemical energy (CO, H_2) is turned back to thermal energy by oxidizing the CO to CO_2 and H_2 to H_2O.

[0051] A further embodiment provides that at least one other tuyere is arranged on a further level (height) of the conical lower oxidation zone. The tuyere at the next level is located preferably above the tapping.

[0052] By arranging the blast pipe above the tapping, the melting can be facilitated in the area of the tapping, as the heat is generated in the area where the melt is to run off liquid. At the same time, the arrangement of the tuyere above the tapping ensures that the solidified melt desired on the opposite side of the tapping (so-called slag freezing, which protects the refractory lining as, e.g. brick lining) is not liquefied and therefore does not flow off.

[0053] In order to achieve a further increase in capacity, the invention provides that the internal cross-sectional area of the upper oxidation zone is designed in such a way that the maximum distance from any point within the bed to the outlet of at least one tuyere is less than a predetermined minimum distance, wherein the minimum distance is

- less than 2.3 m at gas temperatures below 100°C and at gas velocities below 100 m/s
- less than 3.8 m at gas temperatures below 100°C and at gas velocities between 100 m/s and 343 m/s (sound velocity), and
- less than 6.3 m at gas temperatures above 100°C and/or at gas velocities > 343 m/s.

[0054] Through this embodiment and through suitable tuyeres, which can be designed as high-speed or even supersonic nozzles, an increase in diameter of the reactor and thus an increase in capacity can be achieved, since also the center of the bed can be easily reached by the oxygen and/or air introduced via the tuyeres. As described above, the supplied oxygen and/or the supplied air may be preheated, for example to a temperature greater than or equal to 100°C or even between 500°C and 1000°C.

[0055] Areas of the pyrolysis zone, the intermediate zone, the upper oxidation zone and the upper reduction zone may have a substantially uniform cross-sectional area, for example a circular cross-sectional area.

[0056] It is also conceivable that the inner cross-sectional area of the oxidation zone is formed as a circular ring or an elliptical ring.

[0057] A further increase in capacity may be achieved by designing the internal cross-sectional area of the upper oxidation zone as a non-circular internal cross-sectional area. Likewise, regions of the pyrolysis zone, the intermediate zone and the upper reduction zone may have a, preferably uniform, substantially non-circular cross-sectional area.

[0058] The non-circular internal cross-sectional area can, for example, be designed as a polygon with five or more corners, for example a truncated square, a regular polygon, parallelogram, extended hexagon or the like. The inner cross-sectional surface can also be designed as a round shape. Particularly suitable are internal cross-sectional areas which are designed as rounded rectangles, stadiums, oval, ellipses, epicycloids, multi-circles or super-circles n = 4.

[0059] For reactors having a non-circular cross-sectional area of the upper oxidation zone, it may also be provided that the maximum distance from any point within the bed to the outlet of at least one tuyere is less than a predetermined minimum distance, wherein the minimum distance is

- less than 2.3 m at gas temperatures below 100°C and at gas velocities below 100 m/s,
- less than 3.8 m at gas temperatures below 100°C and at gas velocities between 100 m/s and 343 m/s (sound velocity) and
- less than 6.3 m at gas temperatures above 100°C and/or at gas velocities > 343 m/s.

[0060] For example, a stadium-shaped embodiment (e.g. consisting of two semicircular surfaces with a respective diameter = M and a centrally arranged square surface with a side length = M) of the internal cross-sectional area of the reactor may achieve a capacity increase of approximately 2.1 times. Furthermore, it is conceivable that with a further extension of the stadium (e.g. consisting of two semicircular surfaces with a respective diameter = M and Y centrally arranged square surfaces with a side length = M, where Y ≥ is 1.1), the capacity of the reactor may be increased almost arbitrarily to the extent that the building site permits this. Furthermore, it is conceivable that the internal cross-sectional area is also curved and cross-shaped in the event that the reactor has to be adapted to a building site.

[0061] For all the aforementioned embodiments of the internal cross-sectional area of the upper oxidation zone and/or the pyrolysis zone, the intermediate zone and the upper reduction zone, it may also be provided that thermal stresses occurring in the refractory lining can be compensated for temperatures up to 1500°C by high-temperature expansion joints and for temperatures above 1500°C by tongue-and-groove arrangements with or without circumferential water-cooled consoles.

[0062] Since no corners with an angle of ≤ 90° are provided for all the above-mentioned embodiments of the internal cross-sectional area of the upper oxidation zone and/or the pyrolysis zone, the intermediate zone and the upper reduction zone, a gas short-circuit (bypass) in such corners can be prevented.

[0063] Another feature of the invention is that only a single gas outlet is arranged in the gas outlet section of the reactor.

[0064] This embodiment may allow a simpler arrangement of the gas cleaning stages and/or lower equipment costs, as for example only one steam generator instead of several is connected to the single gas outlet.

[0065] A further embodiment of the reactor according to the invention provides that the central vertical longitudinal axis of the co-current section is horizontally offset from the central vertical longitudinal axis of the gas outlet section and the gas countercurrent section. The central vertical longitudinal axes are essentially arranged in the center of each section. Due to the above embodiment, the co-current section is not concentrically arranged with respect to the gas outlet section and the gas countercurrent section. However, the gas outlet section and the gas countercurrent section are arranged concentrically to each other.

[0066] This embodiment ensures that the surface or discharge area of the bed (cone-shaped bed that protrudes from the conical lower reduction zone into the gas outlet section) is increased, since the designed configuration of the bed corresponds to an oblique truncated cone at the same height due to this arrangement.

[0067] Due to the increased surface area or discharge area of the bed, it may be advantageously achieved that the gas outlet velocity (through the at least one gas outlet) is reduced proportionally to the increased discharge area of the bed, whereby the dust entrainment from the bed is reduced.

[0068] A further embodiment provides advantageously that only a single gas outlet is arranged in the gas outlet section of the reactor, that the central vertical longitudinal axis of the co-current section is horizontally offset with respect to the central vertical longitudinal axis of the gas outlet section and the gas countercurrent section, and that the single gas outlet is arranged closer to the central vertical longitudinal axis of the gas outlet section and the gas countercurrent section than to the central vertical longitudinal axis of the co-current section.

[0069] This embodiment also may provide that the surface area or discharge area of the bed (cone-shaped bed protruding from the conical lower reduction zone into the gas outlet section) is increased, since the configuration of the bed corresponds to an oblique truncated cone at the same height. Since it is further provided that the only gas outlet is arranged closer to the central vertical longitudinal axis of the gas outlet section and the gas countercurrent section than to the central vertical longitudinal axis of the co-current section, it further results that the oblique truncated cone of the bed is inclined away from the single gas outlet, thus the enlarged surface or discharge area of the bed is arranged from opposite the gas outlet to below the gas outlet. Thus the gas can escape directly or without detours with an increased volume flow from the increased bed surface or the inside of the bed to the gas outlet.

[0070] The advantage of this reactor embodiment is that the surface area or discharge area of the bed is increased, which reduces the discharge velocity and the costs may be reduced by using fewer downstream devices. In addition, a local entrainment of large quantities of dust can be avoided, since the discharge area opposite the gas outlet is very small, which means that the gas flows out with a smaller volume flow due to the greater distance to the gas outlet and the resulting greater flow resistance. The speed profile is thus uniform across the entire discharge area.

[0071] A further embodiment of the reactor according to the invention provides that gas suction means (e.g. at least one explosion-protected high-temperature blower) are arranged in the area of the gas outlet section. This is particularly advantageous if the reactor is operated under negative pressure. The extraction by means of gas extraction medium is advantageously carried out in such a way that on the one hand hardly any or no gas escapes upwards from the reactor and on the other hand only minimal quantities of additional ambient air are sucked in by the reactor.

[0072] Furthermore, it can be advantageously provided that the reactor can also be run or operated at overpressure. For this purpose, it is intended that high-temperature gate valves are arranged in the area of the tuyeres. The high-temperature gate valves are advantageous, since gas can escape from the reactor when the tuyeres are exchanged during overpressure operation. It is therefore advantageous that the tuyeres are first pulled behind a high-temperature pusher, whereby at this moment the tuyeres are still in an outer tube and are sealed in this tube. In the event that the tuyere is to be pulled or replaced, the high temperature gate valve is closed. The installation of the new or repaired tuyeres can then be carried out by insertion, whereby the gate valve is opened and the tuyere is pushed in and fixed/secured. Advantageously, the high-temperature gate valves are either ceramic, heat-resistant, cooled or a combination of the above features.

[0073] In order that hot gases with temperatures above 1500°C, for example between 1600°C and 1750°C, can be generated at the at least one gas outlet, it can be provided for all the above-mentioned embodiments that the reactor is designed in such a way that temperatures above 1800°C can be reached in the oxidation zones in the peripheral area (boundary between bulk material and refractory) and between 2000°C and 4000°C in the interior (center) of the bed. These high temperatures may cause the refractory lining (e.g. brick lining) to expand axially, tangentially and radially up to 20 mm per lining meter, creating stresses in the refractory lining which in turn affect the outer steel shell of the reactor in a radial direction. In order that the stability of the reactor is not impaired by these high temperatures and the resulting stresses in the lining, it may be provided, in accordance with the invention, that the refractory lining of the reactor consists of at least two lining sections arranged one above the other. Each lining section is arranged between means of thermal expansion compensation (e.g. expansion joints or a tongue-groove combination). Here it can be conceived that the refractory lining of the reactor has a further lining section every 2 to 4 height meters. For reactors which have a gas outlet temperature of 1500°C to 1600°C, it may be provided that the reactor lining has a further lining section every 3 to 4 height meters. For reactors which have a gas outlet temperature of 1600°C and 1750°C, it may be provided that the reactor lining has an additional lining section every 2 to 3 height meters. Since particularly high temperatures (temperatures between 1800°C and 4000°C) are generated for high gas outlet temperatures, in particular in the upper oxidation zone and the conical lower oxidation zone, it may be provided that the lining sections arranged one above the other are arranged in such a way that exactly one lining section is arranged in each of the upper oxidation zone and the conical lower oxidation zone. Furthermore, it may be provided that a further lining section is arranged below and above the oxidation zones. This can ensure that the hot oxidation zones each are composed of only one lining section, each can expand in the direction of the respective further lining section. In order that no hot gases or high temperatures continue to escape outside via the region between the at least two lining sections, it may also be provided that a tongue-and-groove connection is formed between the lining sections arranged one above the other, wherein one of the lining sections has the groove on the side facing the reactor interior and the other lining section has the tongue on the side facing the reactor interior. The tongue-and-groove connection can be designed in such a way that even when the reactor is at a standstill, the tongue in the groove is arranged in a positive-locking manner, whereby the vertical outer wall of the tongue is connected to the vertical wall of the groove, but a vertical gap opening remains between the groove and the tongue. This is an advantage in ensuring that despite the gap opening no heat can reach the outer insulating layer(s) and the steel shell during start-up or high heating of the reactor, and that less or no gas can escape to the outside. Furthermore, it may be provided that the gap opening between the groove and the tongue is a temperature-dependent gap opening. The temperature-dependent gap opening between the groove and the tongue can be for example 50 mm. As described above, the refractory lining can expand at high temperatures, where the tongue can expand into the groove due to the tongue-and-groove connection. Furthermore, it may be provided that between the at least two lining sections arranged one above the other there is arranged a circumferential water-cooled console for holding the refractory lining and stabilizing the lining during heating up and cooling down of the reactor. This circumferential water-cooled console can be produced by bending hollow section tubes with square, circular or rectangular cross-sectional areas without welding seams. It can be advantageously provided here that the water-cooled console has a high heat flow, which is achieved by flow velocities of the cooling water from 1.2 m/s to 25 m/s. The high flow velocities of the cooling water are advantageous for maintaining the thermal and mechanical stability of the circumferential water-cooled console when arranged in areas with high temperatures (> 1500°C). The arrangement described above of at least two superimposed tongue-and-groove brick lining sections and a circumferential water-cooled console may be arranged in the co-current section and/or the gas outlet section and/or the countercurrent section. Each section can also have several arrangements of two lining sections arranged one above the other with tongue-and-groove connection and circumferential water-cooled console. It may also be provided that the upper lining section has the groove and the lower lining section has the tongue. This can cause the refractory lining to expand upwards when exposed to hot temperatures. Furthermore, it is conceivable that each of the at least two lining sections comprises at least one inner lining and an outer lining encasing the inner lining. Here it can be provided that the interior lining is a brick lining made of fired bricks or a monolithic (e.g. castable) refractory lining.

[0074] The above-mentioned tasks of the invention are also solved by the method specified in claim 19 for gasifying, cracking and/or melting of feed materials, which is advantageously suited, among other things, for the material and/or energetic recycling of wastes and other feed materials.

[0075] The method steps in accordance with the invention initially include providing of feed materials into the co-current section, whereby the feed materials are introduced via the feed zone with a sluice. In the subsequent buffer zone, the feed materials are preheated and pre-dried and then reach the pyrolysis zone, wherein the cross-section of the pyrolysis zone is enlarged with respect to the buffer zone, where the feed materials form a discharge bed having a discharge cone. The bed is heated in the pyrolysis zone to at least 800° by supplying oxygen and/or air and/or combustion gases or by supplying preheated oxygen and/or air or combustion gas, which are supplied via burners and/or nozzles, in order to trigger at least partial pyrolysis on the surface of the feed materials or in the feed materials. In the subsequent intermediate zone, the feed materials are fully pyrolysed and fully dried. By supplying oxygen and/or air, a hot upper oxidation zone is created, which is located below the intermediate zone. The pyrolysis products and parts of the feed materials burn, crack and/or melt in this hot upper oxidation zone, whereupon further coking of the not yet converted feed materials takes place. In the subsequent upper reduction zone, thermal energy is then converted into chemical energy. The gas flows in the co-current section from the feed zone to the gas outlet in co-current.

[0076] A hot zone is also created in the conical lower oxidation zone by supplying oxygen and/or air. Metal and/or slag melts are also collected in this lower-arranged hot lower oxidation zone. These slag melts and/or metal melts are tapped off via at least one tapping (e.g. in molds) or run out continuously (e.g. to a slag granulation) as required. In the conical lower oxidation zone and in the conical lower reduction zone, gases are also generated which flow upwards (in countercurrent) in the direction of the gas outlet. The gases from the co-current section (from top to bottom) and the gases from the countercurrent section (from bottom to top) are discharged from the gas outlet section through at least one gas outlet.

[0077] The method steps essential for the invention can be advantageously further developed by exhausting the gases produced in the co-current section and the gases produced in the countercurrent section by suction. For this purpose, gas suction means are used. The suction creates a negative pressure in the reactor. The use of negative pressure in the reactor allows maintenance of the reactor during operation, as air can be sucked in when the gasifier is opened, but no gas can escape.

[0078] Alternatively, an overpressure may be generated in the co-current section, whereby the gases produced in the co-current section are discharged by overpressure.

[0079] At overpressure, as low as 200 mbar overpressure, the reactor forces the hot gas into the subsequent process steps. This embodiment eliminates the need for an explosion-protected high-temperature suction blower. Furthermore, higher pressures up to 10 bar overpressure, which are possible in the reactor according to the invention, allow the volume of the escaping gas to be reduced, whereby smaller apparatuses can be used for gas purification. The positive pressure mode or the operation with positive pressure is advantageous in that the gas is forced out of the reactor. For this purpose, the pressure in the reactor is created by the resulting gas, the thermal expansion of the gas and the supply of the gaseous media with excess pressure.

[0080] The at least one sluice for the feeding of the feed materials can be opened or closed without any problems. This can be solved constructively for example, with hydraulically operated hatches (doors). The hatches are arranged in such a way that in the event of desired or accidental overpressure in the reactor or gasifier, the hatches are additionally pressed closed and no gas can escape unintentionally. It may also be advantageous that the sluices have additional pressure equalization lines to the atmosphere and/or to a safe area inside the reactor. Accordingly, the hatches can also be opened at the any desired overpressure in the reactor because the hatches drive does not have to work against a pressure difference.

[0081] It may also be provided that nitrogen is injected to start up the reactor.

[0082] A further aspect of the invention comprises a tuyere for a reactor, wherein the tuyere is made of ceramic. The reactor may be the above described reactor, a metallurgical reactor or any other reactor, in which high temperatures may be present in the vicinity of the tuyere.

[0083] A tuyere made entirely of ceramic is beneficial since ceramics can withstand higher temperatures than commonly used tuyeres made of metals. Hence, cooling of the tuyere made entirely of ceramic is not necessary. Further, by using tuyeres made of ceramic the heat loss of a reactor can be reduced, if compared to commonly used tuyeres made of metals.

[0084] By using the tuyere made entirely of ceramic it may be further achieved that a oxidation zone of a reactor can be operated with a supply of hot air and/or oxygen having temperature more than 1000°C, and therefore possibly a bed temperature of more than 2000°C, since ceramics can withstand higher temperatures than commonly used metals without being destroyed.

[0085] The ceramic used for the manufacture of the tuyere may be a ceramic with good thermal conductivity (e.g. a ceramic with a thermal conductivity > 50 W/(m·K), as for example silicon carbide, which has a thermal conductivity of e.g. 60 - 85 W/(m·K)), a ceramic with insulating properties (e.g. a ceramic with a thermal conductivity < 30 W/(m·K), as for example spinel corundum, which has a thermal conductivity < 4 W/(m·K)), a combination of the aforementioned ceramics or a construction made of the aforementioned ceramics (e.g. first inner a layer of ceramics with good thermal conductivity followed by an outer layer of ceramics with insulating properties). The latter construction may be particularly suitable when a chemical load, caused by melting without cooling, and high thermal stress are present. It may be further advantageous, if slag freezing is applied to the construction.

[0086] Further advantages, details and developments result from the following description of the invention, with reference to the attached drawings.

Fig. 1 shows a simplified cross-sectional view of an embodiment of an invented reactor.

Fig. 2 shows a simplified cross-sectional view of a further embodiment of an invented reactor with the upper reduction zone partially inserted into the gas outlet section.

Fig. 3 shows a simplified cross-sectional view of another embodiment of an invented reactor, where the central vertical longitudinal axis of the co-current section is horizontally offset from the central vertical longitudinal axis of the gas outlet section.

Fig. 4 shows the internal cross-sectional area of the upper oxidation zone of a reactor, wherein the internal cross-sectional area is substantially formed as a circular area.

Fig. 5 shows the internal cross-sectional area of the upper oxidation zone of a reactor, wherein the internal cross-sectional area is substantially designed as a stadium.

[0087] Like-numbered elements in these figures are either identical or fulfill the same function. Elements previously discussed are not necessarily discussed in later figures if the function is equivalent.

[0088] In the following, Figure 1 describes an embodiment of a substantially cylindrical reactor 100. In connection with the explanation of the details of the reactor, the method steps that take place during the treatment of wastes with organic components as feed materials in this reactor are also specified.

[0089] By using other feed materials, modifications of the reactor and/or method may be useful. In general, different feed materials can also be combined, for example by adding feed materials with a higher energy value (e.g. organic waste, contaminated waste wood, car tires or the like) during the gasifying/cracking/melting of non-organic feed materials.

[0090] The reactor 100 shown in Figure 1 has three sections. A co-current section 110, a gas outlet section 120 and a countercurrent section 130. The co-current section 110, the gas outlet section 120 and the countercurrent section 130 are arranged substantially concentrically to each other (represented by the vertical dash-dot line passing substantially through the center of the reactor). In the co-current section a plenum zone 111, an upper oxidation zone 116 and an upper reduction zone 118 are arranged. The plenum zone 111 comprises a feed zone with a sluice 112, whereby feed materials such as waste, water, car tires, additives or other feed materials are fed into the reactor from above via the feed zone. The material flow of the solids is shown as a dashed arrow from top to bottom. A downstream buffer zone is arranged below the pyrolysis zone 114 for buffering and pre-drying the feed material volume, which adjoins the bottom of the buffer zone thereby creating a cross-sectional enlargement. In the pyrolysis zone 114, a discharge cone can form from feed materials (represented by the oblique dashed lines; between 114 and 119). Pyrolysis can therefore take place on the surface of the bed. The pyrolysis zone can also be made inert with combustion gas or any other low oxygen gas (e.g. N_2 or CO_2), therefore flammable gases moving to the sluice 112 burn safely. Below the pyrolysis zone 114 there is an intermediate zone 115 which is equipped for final drying and complete pyrolysis. An upper oxidation zone 116 adjoins the intermediate zone 115, wherein in the upper oxidation zone 116 tuyeres are arranged circumferentially in a plurality of planes as shown. Oxygen and/or air is added via the tuyeres 117, which increases the temperature to such an extent that all substances are converted into inorganic gas, liquid metal, coke, carbon and/or mineral slag. In the upper reduction zone 118, which adjoins the upper oxidation zone 116 and which is arranged substantially above a subsequent gas outlet section 120, the endothermic conversion of thermal energy into chemical energy takes place. At the same time, the gas flowing co-current with the solids (represented by a dotted arrow running from top to bottom), which is generated from the plenum zone to the upper reduction zone 118 from top to bottom, is generated here and introduced into the gas outlet section 120.

[0091] As shown, the gas outlet section 120 is connected to the upper reduction zone 118, thereby creating a cross-sectional enlargement. The gas produced is - approximately in cross-flow to the bed - discharged in the gas outlet section 120 through at least one gas outlet 121 (shown by a dotted arrow running from left to right). It may be provided, for example, that four or more gas outlets 121 are radially distributed around the circumference (not shown), so that the gas produced in the co-current section and in the countercurrent section can be diverted radially in the cross-flow.

[0092] Below the gas outlet section is the conical lower reduction zone 138. In the conical lower reduction zone 138 the conversion of thermal energy into chemical energy also takes place.

[0093] Below the conical lower reduction zone there is, as shown, a conical lower oxidation zone 136 in which at least one tuyere 137 and at least one tapping 131 are arranged. The tuyere 137 introduces air and/or oxygen to oxidize the remaining coked material and prevents the melt from solidifying. The collection and discharge of metal melts and slag melts takes place in at least one tapping 131.

[0094] The gas generated in the conical lower oxidation zone and in the conical lower reduction zone also flows in countercurrent with the solid's flow through the bed (represented by a dotted arrow running from bottom to top) to the gas outlet section 120, where it is discharged via at least one gas outlet 121.

[0095] The reactor according to the invention can have the following internal volumes, for example (see Table 1):

Table 1

Reactor	Example 1 [m^3]	Example 2 [m^3]
Co-current section:	**19,80**	**118,70**
Feed zone with sluice	2,70	3,20
Buffer zone	4,00	6,00
Pyrolysis zone	4,70	41,60
Intermediate zone	4,00	20,40
Upper oxidation zone	1,50	9,90
Upper reduction zone	2,80	37,70
Gas outlet section:	**3,20**	**32,20**
Countercurrent section:	**6,80**	**59,50**

[0096] It may be advantageous that the gases produced in the co-current section 110 and in the countercurrent section 130 are discharged by suction. Furthermore, it can be advantageously provided that an overpressure is generated in the co-current section 110, whereby the gases produced in the co-current section 110 are discharged by overpressure.

[0097] Although the embodiment form specifically described above is particularly suitable for the treatment (gasifying, cracking and/or melting) of wastes with organic components, it will be obvious to the skilled person in the art that modifications of the reactor are necessary or expedient when other feed materials are used. In general, however, the reactor described above can also be used to treat hazardous wastes or feed materials with higher metal contents, whereby the gasification/cracking principle and the melting principle will predominate in some cases. Different feed materials can also be combined. For example, it is possible to add specific feed materials with a higher energy value (e.g. organic waste, contaminated waste wood, but also coal or the like) for melting non-organic feed materials.

[0098] The reactor 100 shown in Fig. 2 corresponds substantially to the reactor 100 shown in Fig. 1, but in this embodiment the co-current section 110 with a portion of the upper reduction zone 118 is inserted into the gas outlet section 120. As shown, the refractory lining (e.g. brick lining) of the upper reduction zone 118 protrudes into the gas outlet section 120. Since the gas outlet section 120 has a larger cross-sectional area than the upper reduction zone 118 and the at least one gas outlet 121 is located in the edge region of the gas outlet section 120, the gas produced in the co-current section 110 must bypass the refractory lining (e.g. brick lining) protruding into the gas outlet section 120 in order to reach the gas outlet 121, whereby less dust enters the following apparatus.

[0099] Fig. 3 shows another version of the reactor 100. The reactor according to Fig. 3 corresponds substantially to the reactor 100 according to Fig. 1, but in the gas outlet section 120 of the reactor only a single gas outlet 121 is arranged, the central vertical longitudinal axis of the co-current section 110 is arranged horizontally offset with respect to the central vertical longitudinal axis of the gas outlet section 120 and the gas countercurrent section 130, and the single gas outlet 121 is arranged closer to the central vertical longitudinal axis of the gas outlet section 120 and the gas countercurrent section 130 than to the central vertical longitudinal axis of the co-current section 110.

[0100] The central vertical longitudinal axes are shown as dash-dot lines in Fig. 3. As shown, the central vertical longitudinal axes are essentially arranged at the center of each section. As shown, the co-current section 110 is not arranged concentrically with respect to the gas outlet section 120. However, the gas outlet section 120 is arranged concentrically to the countercurrent section 130.

[0101] The advantage of this embodiment of the Reactor 100 is that the surface area or the discharge area of the bed is increased, which increases the discharge rate and reduces costs by reducing the number of downstream devices.

[0102] Fig. 4 shows a configuration of the internal cross-sectional area of the upper oxidation zone 116 of a reactor 100, wherein the internal cross-sectional area is essentially formed as a circular area. The reactor 100 according to Fig. 1, according to Fig. 2 or according to Fig. 3 can be a reactor with a circular internal cross-sectional area, as shown here. As shown, several tuyeres are arranged (here at one level) through which oxygen and/or air are blown onto or injected into the bed. The tuyeres 117 are distributed radially around the circumference of the circular area, so that preferably every point of the bed can be supplied with the blown in or injected in oxygen and/or air.

[0103] Figure 5 shows a configuration of the internal cross-sectional area of the upper oxidation zone 116 of a reactor, wherein the internal cross-sectional area is essentially designed as a stadium. The reactor 100 according to Fig. 1, Fig. 2 or Fig. 3 can be a reactor with a stadium-shaped internal cross-sectional area. As shown, several tuyeres are arranged (here at one level) through which oxygen and/or air are blown in or injected in the bed. The tuyeres 117 are distributed radially around the periphery of the stadium area, so that preferably every point of the bed can be supplied with the injected in oxygen and/or air. This embodiment of the internal cross-section of zones of the co-current section of the reactor and thus of the upper oxidation zone 116 results in an increase in the diameter of the reactor and thus in an increase in capacity. Due to the non-circular cross-section, the bed, in particular also the center of the bed, is easily accessible for the oxygen and/or air introduced via the tuyeres 116. A 2.1-fold increase in capacity is achieved through a stadium-shaped embodiment of the internal cross-sectional area of the reactor.

List of reference numerals

[0104]

100	Reactor
110	Co-current section
111	Plenum zone
112	Sluice
113	Buffer zone
114	Pyrolysis zone
115	Intermediate zone
116	Upper oxidation zone
117	Tuyeres
118	Upper reduction zone
119	Gas supply materials
120	Gas outlet section
121	Gas outlet
130	Countercurrent section
131	Tapping
136	Conical lower oxidation zone
137	Tuyere
138	Conical lower reduction zone

Claims

1. Reactor (100) for gasifying and/or melting of feed materials, the reactor comprising

- a co-current section (110) comprising

    - a plenum zone (111) comprising

        ◦ a feed zone with a sluice (112), wherein feed materials are introduced into the reactor (100) from above via the feed zone,
        ◦ a buffer zone (113),
        ◦ a pyrolysis zone (114) that adjoins the bottom of the buffer zone (113) while providing a cross-sectional enlargement; and
        ◦ an intermediate zone (115) that adjoins the bottom of the pyrolysis zone (114),

    - an upper oxidation zone (116) that adjoins the bottom of the intermediate zone and comprises tuyeres (117) in at least one plane, and
    - an upper reduction zone (118) that adjoins the bottom of the upper oxidation zone (116),

- a gas outlet section (120) comprising at least one gas outlet (121), and
- a countercurrent section (130) comprising

    - a conical lower reduction zone (138) adjoining said gas outlet section (120), and
    - a conical lower oxidation zone (136) adjoining the conical lower reduction zone (138) and comprising at least one tuyere (137) and at least one tapping (131).

2. Reactor (100) for gasifying and/or melting feed materials of claim 1, wherein the upper reduction zone (118) is arranged above the gas outlet section (120), the gas outlet section (120) adjoining the bottom of the upper reduction zone (118) while providing a cross-sectional enlargement.

3. Reactor (100) for gasifying and/or melting feed materials of claim 1, wherein at least a portion of the upper reduction zone (118) is arranged in the gas outlet section (120), the gas outlet section (120) having a cross-sectional enlargement with respect to the upper reduction zone (118).

4. Reactor (100) for gasifying and/or melting of feed materials of any one of claims 1 through 3, wherein the volume ratio of the upper oxidation zone volume to the plenum zone volume is a ratio of 1 : N volume units, wherein $4 \leq N \leq 20$.

5. Reactor (100) for gasifying and/or melting feed materials of any one of claims 1 through 4, wherein the volume ratio of the upper oxidation zone volume to the total volume of the upper reduction zone volume and the plenum zone volume is a ratio of 1 : N volume units, wherein $7 \leq N \leq 25$.

6. Reactor (100) for gasifying and/or melting feed materials according to any one of claims 1 through 5, wherein the volume ratio of the countercurrent section volume to the total volume of the reactor is a ratio of 1 : N volume units, wherein $1 \leq N \leq 10$.

7. Reactor (100) for gasifying and/or melting feed materials of any one of claims 1 through 6, wherein the cone angle of the conical lower reduction zone and the cone angle of the conical lower oxidation zone are between 50° and 70°.

8. Reactor (100) for gasifying and/or melting feed materials of any one of claims 1 through 7, wherein at least one gas supply means (119) is arranged in the region of the cross-sectional enlargement of the pyrolysis zone.

9. Reactor (100) for gasifying and/or melting feed materials of any one of claims 1 through 8, wherein the tuyeres (117) of the upper oxidation zone (116) are arranged in a plurality of planes.

10. Reactor (100) for gasifying and/or melting feed materials according to any one of claims 1 through 9, wherein at least one further tuyere (139) is arranged in a further plane of the conical lower reduction zone (138) or one further tuyere is arranged in a further plane of the conical lower reduction zone (138) and at least one additional tuyere is arranged in the upper reduction zone (118).

11. Reactor (100) for the gasifying and/or melting of feed materials according to any one of claims 1 through 10, wherein at least one further tuyere is arranged in a further plane of the conical lower oxidation zone (136).

12. Reactor (100) for gasifying and/or melting feed materials according to any one of claims 1 through 11, wherein the internal cross-sectional area of the upper oxidation zone (116) is formed such that the maximum distance from any point within a discharge bed formed from feed materials to an outlet of at least one of the tuyeres (117) is less than a predetermined minimum distance, the minimum distance being

- less than 2.3 m at gas temperatures below 100°C and at gas velocities below 100m/s,
- less than 3.8 m at gas temperatures below 100°C and at gas velocities between 100 m/s and 343 m/s; and
- less than 6.3 m at gas temperatures above 100°C and/or at gas velocities exceeding 343 m/s.

13. Reactor (100) for the gasifying and/or melting of feed materials of any one of claims 1 through 12, wherein an internal cross-sectional area of the upper oxidation zone (116) is formed as a non-circular surface, in particular as a rounded rectangle, stadium, oval, ellipse, epicycloid, multi-circle, super-circle n = 4 or as a polygon with five or more corners, such as a truncated square, a regular polygon or parallelogram.

14. Reactor (100) for gasifying and/or melting feed materials of any one of claims 1 through 13, wherein only one gas outlet (121) is arranged in the gas outlet section (120).

15. Reactor (100) for gasifying and/or melting feed materials of any one of claims 1 through 14, wherein the central vertical longitudinal axis of the co-current section (110) is arranged horizontally offset with respect to the central vertical longitudinal axis of the gas outlet section (120) and the gas countercurrent section (130).

16. Reactor (100) for gasifying and/or melting feed materials of claim 15 with reference to claim 14, wherein the only gas outlet (121) is located closer to the central vertical longitudinal axis of the gas outlet section (120) and the gas countercurrent section (130) than to the central vertical longitudinal axis of the co-current section (110).

17. Reactor (100) for gasifying and/or melting feed materials of any one of claims 1 to 16, wherein gas suction means are arranged in the vicinity of the gas outlet section (120).

18. Reactor (100) for gasifying and/or melting feed materials of any one of claims 1 through 17, wherein high-temperature gate valves are arranged in the vicinity of the tuyeres (117) of the upper oxidation zone (116) and/or the conical lower oxidation zone (136).

19. Method for gasifying and/or melting feed materials using a reactor (100) according to any one of claims 1 through 18, the method comprising the following steps:

- Providing feed materials into the co-current section (110), wherein the feed materials are fed via the feed zone with a sluice (112), wherein the feed materials are preheated and pre-dried in the buffer zone (113), wherein by the providing of the feed materials in the pyrolysis zone (114), a discharge bed having a discharge cone is formed, wherein the cross-section of the pyrolysis zone (114) is enlarged with respect to the buffer zone (113) ;
- Heating the discharge bed in the pyrolysis zone (114) to at least 800°C by supplying air and/or oxygen and/or combustion gas in order to initiate pyrolysis at the surface of the feed materials or in the feed materials, the feed materials being fully pyrolyzed and fully dried in the subsequent intermediate zone;
- Providing a lower lying hot upper oxidation zone by supplying oxygen and/or air, and
- Burning the pyrolysis products and feed materials, melting of metallic and mineral constituents, if any, and further coking the feed material residues in the hot upper oxidation zone;
- Converting thermal energy into chemical energy in the upper reduction zone (118);
- Providing a lower lying hot lower oxidation zone by supplying oxygen and/or air and collecting any metal and/or slag melts present in the conical lower oxidation zone;
- Discharging the gases generated in the co-current section (110) through the at least one gas outlet (121) of the gas outlet section (120); and
- Discharging the gases generated in the countercurrent section (130) through the at least one gas outlet (121) of the gas outlet section (120), the gases formed in the conical lower oxidation zone of the countercurrent section (130) flowing via the conical lower reduction zone (138) to the gas outlet section (120).

20. Method of claim 19, wherein the gases generated in the co-current section and the gases generated in the countercurrent section are discharged by suction.

21. Method of claim 19, wherein an overpressure is generated in the co-current section, wherein the gases generated in the co-current section are discharged by overpressure.

22. Method of any one of claims 19 through 21, wherein nitrogen is injected to start the reactor.

23. Tuyere, wherein the tuyere is made of ceramic.

Fig. 1

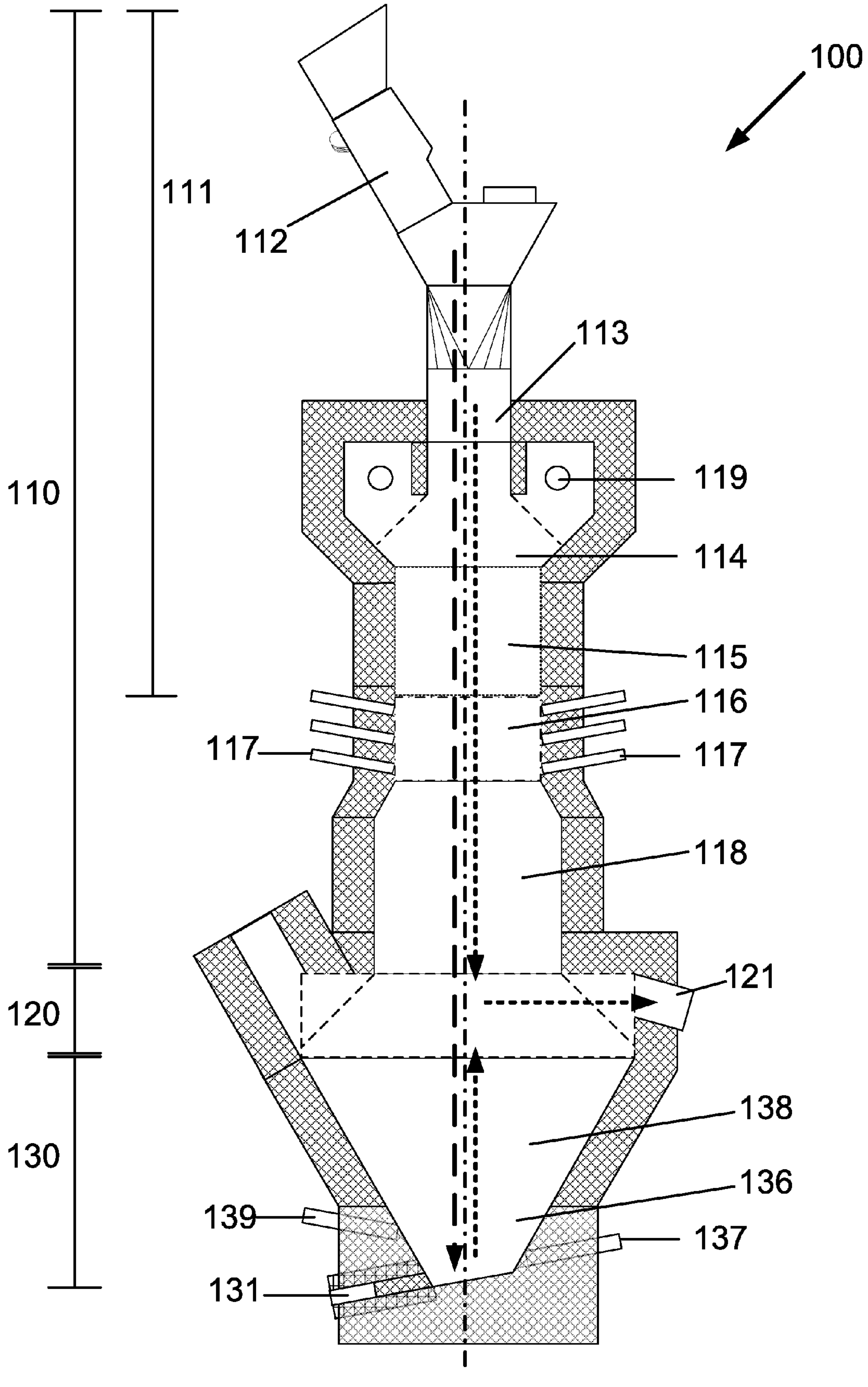

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Fig. 2

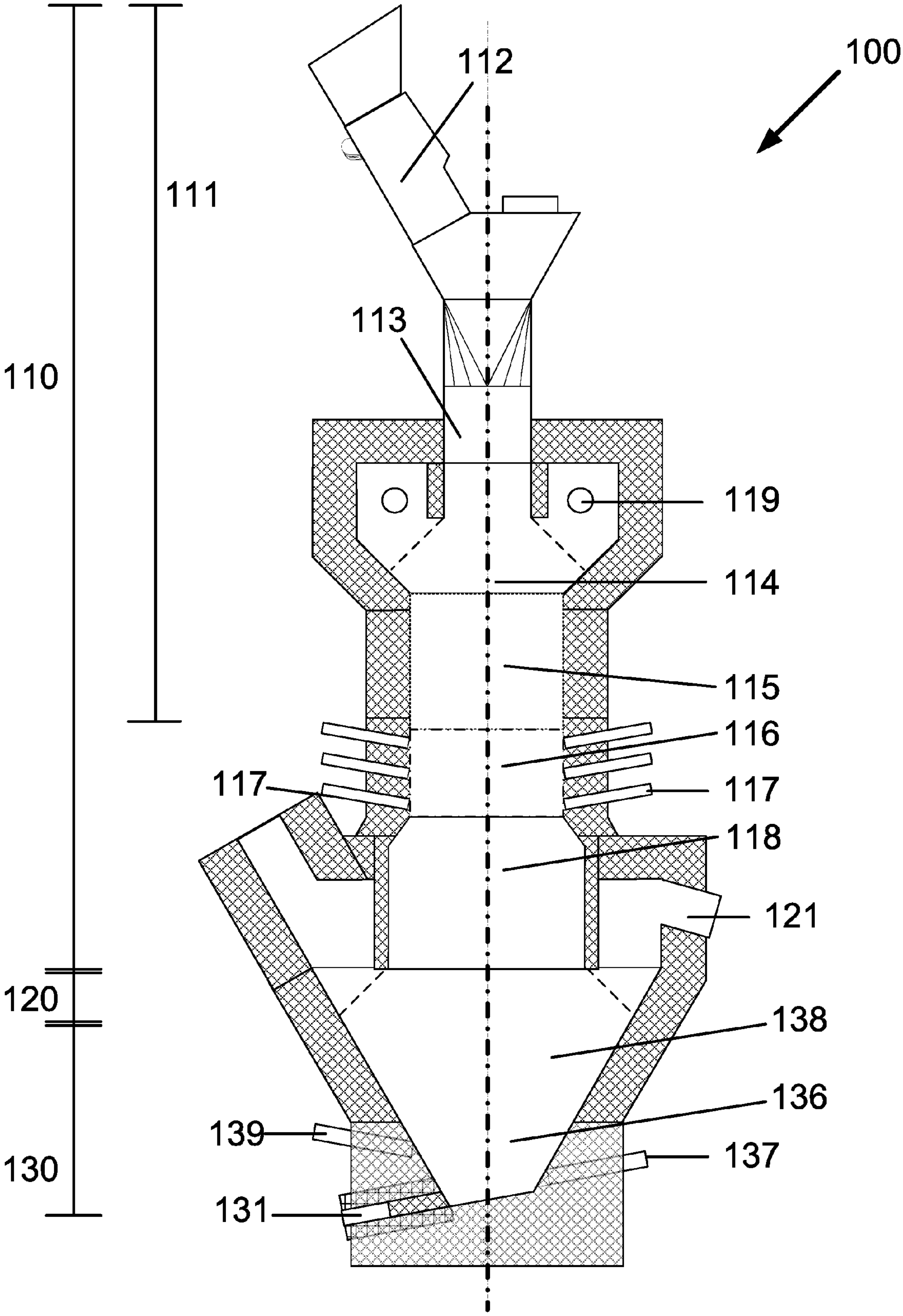
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Fig. 3

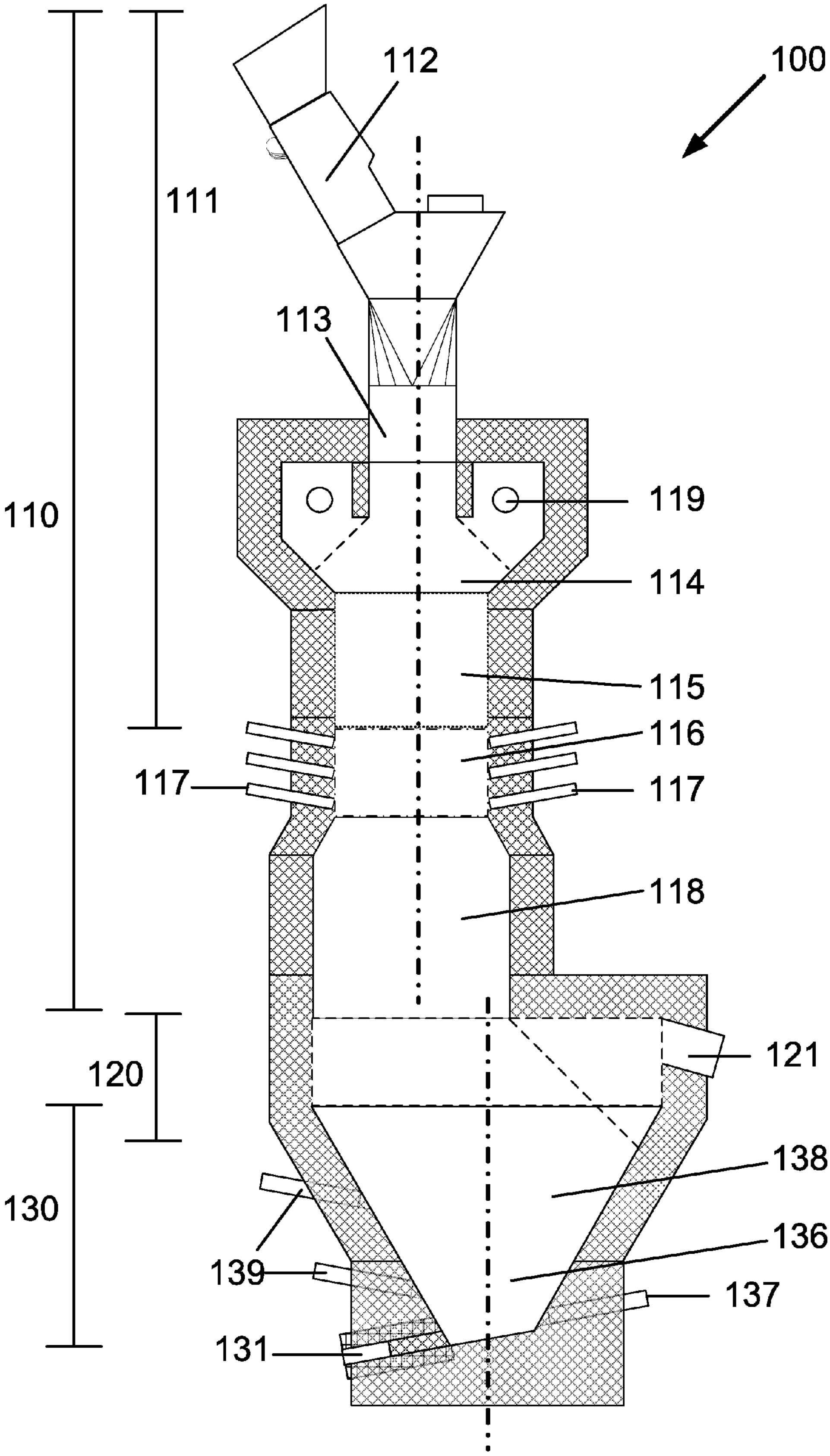
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Fig. 4

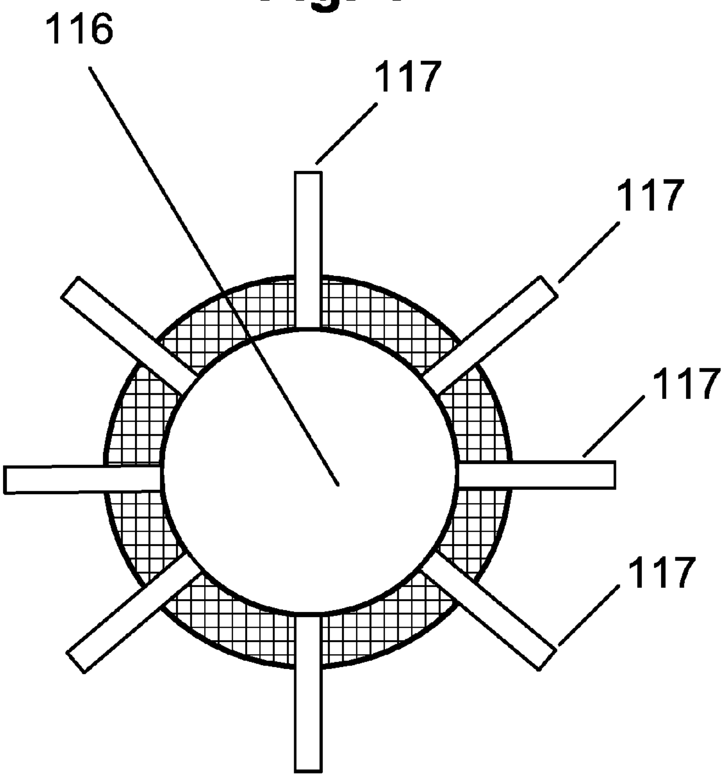
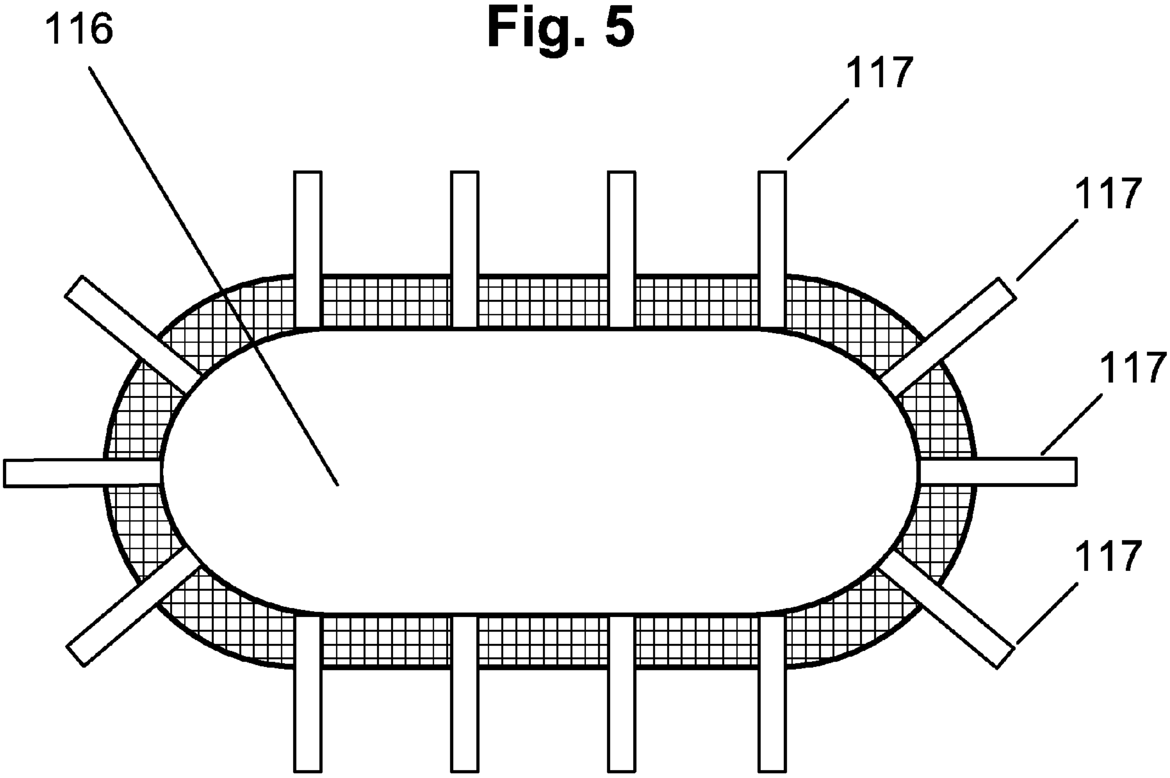


Fig. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 18 20 8810

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	WO 02/46331 A1 (EMERY RECYCLING CORP [US]; HASSETT SCOTT [US]) 13 June 2002 (2002-06-13) * figures 1-2 * * the whole document * * page 7, line 12 - page 16, line 33 * * page 9, line 30 - page 10, line 16 * * page 15, line 28 - page 16, line 9 * -----	1-22	INV. C10J3/26 C10J3/72 C10J3/08 C10J3/66
A	WO 01/62873 A1 (MITTELDEUTSCHE FEUERUNGS UND U [DE]; FEUSTEL HANS ULRICH [DE] ET AL.) 30 August 2001 (2001-08-30) * figure 1 * * the whole document * -----	1-22	
A	DE 196 40 497 A1 (FEUSTEL HANS ULRICH DIPL ING [DE] ET AL.) 9 April 1998 (1998-04-09) * the whole document * * figure 1 * -----	1-22	
			TECHNICAL FIELDS SEARCHED (IPC)
			C10J

~~The present search report has been drawn up for all claims~~

1

Place of search	Date of completion of the search	Examiner
The Hague	10 May 2019	Lachmann, Richard

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)

Europäisches Patentamt
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Application Number

EP 18 20 8810

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-22

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION SHEET B

Application Number

EP 18 20 8810

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-22

   Reactor and method for gasifying and/or melting of feed materials

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2. claim: 23

   Tuyere, wherein the tuyere is made of ceramic

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 20 8810

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
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10-05-2019

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

REFERENCES CITED IN THE DESCRIPTION

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