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(54) Title: PROVIDING WEAR RESISTANCE IN A REACTOR CONFIGURED TO FACILITATE CHEMICAL REACTIONS AND/OR COMMINUTION OF SOLID FEED MATERIALS USING SHOCKWAVES CREATED IN A SUPERSONIC GASEOUS VORTEX

(57) Abstract: Various wear resistance designs may be applied to a reactor configured to facilitate chemical reactions, and/or comminution using shockwaves created in a supersonic gaseous vortex. The reactor may include a rigid chamber having a substantially circular cross-section. A first gas inlet may be configured to introduce a high-velocity gas stream into the chamber. A first replaceable wear part may be disposed in the chamber to absorb wear impact caused by the gas stream. In some implementations, the first replaceable wear part may be a cylindrical rod continuously fed into the chamber. In some implementations, the first replaceable wear part may be coated with, or composed of, a catalytic material, and/or may be electrically isolated from the rest of the reactor. In some implementations, a second gas inlet may be disposed to steer the gas stream to a desired area within the chamber to even out the wear impact.

PROVIDING WEAR RESISTANCE IN A REACTOR CONFIGURED TO FACILITATE CHEMICAL REACTIONS AND/OR COMMINUTION OF SOLID FEED MATERIALS USING SHOCKWAVES CREATED IN A SUPERSONIC GASEOUS VORTEX

CROSS-REFERENCE TO RELATED APPLICATIONS

(01) This application claims the benefit of U.S. Patent Application Serial No. 14/690,111, filed April 17, 2015, which is hereby incorporated by reference in its entirety.

FIELD OF THE DISCLOSURE

(02) This disclosure relates to providing wear resistance in a reactor configured to facilitate chemical reactions, and/or comminution of solid feed materials using shockwaves created in a supersonic gaseous vortex.

BACKGROUND

(03) Pulverization of solid feed material in a grinding chamber using a gas stream is known in the art. For example, a jet mill is a type of grinding device that relies on high-speed gas streams to grind material inside the grinding chamber. Pulverization may take place in a central toroidal grinding chamber of the jet mill as the process material is driven around the perimeter of the chamber by multiple jets of air or steam. Size reduction via attrition may be a result of high-velocity collisions and resulting compressive forces between particles of the process material itself, and/or between particles of the processes material and interior walls of the grinding chamber of the conventional jet mill. The pulverization in a conventional jet mill may

cause wear to the grinding chamber as the gas streams, carrying pulverized particles, impacts the grinding chamber.

(04) It is known that wear in the conventional jet mill is responsible for limiting the size of the conventional jet mill. As the size (e.g., length, width, and/or radius) of the conventional jet mill increases, the volume of the process material that could pass through the jet mill may increase roughly by a magnitude corresponding to a cube of the size increase, and the surface of the grinding chamber may increase roughly by a magnitude corresponding to a square of the size increase. For example, if the size of the conventional jet mill is doubled, the volume of the process material that could pass through the jet mill may increase as much as by eight times and the wearable surface may only increase as much as by four times. The amount of wear in the conventional jet mill may be proportional to the amount of the process material and thus takes on the level of exponential increase of the process material. Accordingly, the exponential increase of potential wear may be much faster than the increase of wearable surface of the grinding chamber when the size of the conventional jet mill increases. This geometric wear limitation may limit scaling-up of the conventional jet mill. A conventional jet mill typically has an upper size limit of approximately one meter or about forty-two inches.

SUMMARY

(05) One aspect of the disclosure relates to a reactor with a wear resistance design to reduce wear in the reactor in which materials are comminuted via tensive forces resulting from shockwaves induced within a chamber of the reactor. The reactor in accordance with the disclosure may be less constrained from being scaled up as compared to conventional air-flow pulverization devices such as a jet mill. The

reactor may be configured to facilitate chemical reactions, and/or comminution of solid feed materials using shockwaves created in a supersonic gaseous vortex. The reactor may comprise a rigid chamber, a first gas inlet, a material inlet, and an outlet. The chamber may have a substantially circular cross-section centered on a longitudinal axis that is normal to the cross-section. The first gas inlet may be configured to introduce a high-velocity stream of gas into the chamber. The first gas inlet may be disposed and arranged so as to effectuate a vortex of the stream of gas circulating within the chamber. The vortex may rotate at a supersonic speed about the longitudinal axis of the chamber. The first gas inlet may be insulated from the body of the chamber. Various methods of generating a plasma within the gas flow may be employed to effectuate the rotation of the gas vortex, such as glow discharge, travelling wave, radio-frequency, microwave, and/or any other methods for converting gas into a plasma.

(06) The material inlet may be configured to introduce a material to be processed into the chamber. The material inlet may be disposed proximal to the first gas inlet. The material may be processed within the chamber by nonabrasive mechanisms facilitated by shockwaves within the chamber. The outlet may be configured to emit the gas and processed material from the chamber. The outlet may be disposed at an opposite end of the chamber as the gas inlet and the material inlet.

(07) The reactor may comprise a first replaceable wear part configured to protect a first portion of an inner surface of the chamber. The first portion of the inner surface of the chamber may be where the gas stream entrained by the first gas inlet, charged with pulverized particles of the process material, impacts the chamber. The first replaceable wear part may be disposed at the first portion of the inner surface of

the chamber such that a first end of the first replaceable wear part may be adapted to absorb the impacts caused by the pulverized particles in the gas stream entrained by the first gas inlet. As used herein, such a first end of the first replaceable wear part is referred to as a contacting end of the first replaceable wear part. The first replaceable wear part may be made of one or more of tungsten carbide, titanium carbide, titanium nitride, diamond, diamond like carbon, silicon nitride, boron nitride, steel, iron, iron alloys, silicon carbide, partially stabilized zirconia (PSZ), fused alumina, boron nitride, carbides, nitrides, ceramics, silicates, geopolymers, metallic alloys, other alloys and/or any other material for wear resistance (or catalytic activity).

(08) In some implementations, the first replaceable wear part may comprise a rotatable cylindrical rod that rotates as the pulverized particles impact the rod. The rotatable cylindrical rod may control the impact of the pulverized particles on the surface of the rod. In some implementations, the first replaceable wear part may be configured to continuously advance into the chamber as the surface of the contact end is worn.

(09) In some implementations, the contacting end of the first replaceable wear part may be composed of or doped with a catalytic material. The catalyst material may ablate as the pulverized particles impact the contacting end of the first replaceable wear part. The catalyst material may be configured to enhance the chemical reactions and/or comminution that take place in the reactor. In some implementations, the first replaceable wear part may be electrically isolated from the rest of the reactor. This may facilitate an electrical field to be imparted on the first replaceable wear part. As such, the first replaceable wear part may enable the Non-

Faradaic Electrochemical Modification of Catalytic Activity (NEMCA), also known as Electrochemical Promotion of Catalysis (EPOC), for reducing energy required for comminution, and/or the chemical reactions inside the chamber.

(10) In some implementations, a second gas inlet corresponding to the first gas inlet may be employed. The second gas inlet may be configured to introduce a steering gas stream into reactor for controlling the direction(s) of the gas flow introduced by the first gas inlet. This “steering” effect by the second gas inlet may help control the impact area of the wear to be limited to a desired area, such as the first portion, of the inner surface of the chamber. The “steering” effect by the second gas inlet may be employed to introduce eddy current, and/or interference current to vary the shockwaves in the reactor. For achieving the “steering” effect, the second gas inlet may be disposed proximal to the first gas inlet.

(11) In some implementations, the inner surface of the reactors may be configured to comprise pockets (e.g., disruptors). The pockets may be configured to have appropriate sizes so as to be packed with the pulverized particles. This may create a layer of a “material wall” inside the reactor. The “material wall” may facilitate “material on material wear resistance”. This approach is used in the comminution industry where it is known as a rock box. The material being processed forms a barrier to protect the machinery from wear.

(12) In some implementations, multiple sets of a first gas inlet, a second gas inlet, and a replaceable wear part may be employed to enhance wear resistance of the reactor and as well as to increase the throughput of the reactor. The multiple sets of the gas inlets and replaceable wear parts may be disposed within the chamber of the reactor at various desired locations around the periphery of the chamber. This may

reduce or control the wear caused by drag as the processed material travels in a long flight path before exiting. In some implementations, the shape of the chamber may be configured to have the continuously decreasing radius of the substantially circular cross-section is shaped as a cone, a hemisphere, or a horn-shape. This may advantageously limit the wear in the reactor in certain areas.

(13) These and other features and characteristics of the present technology, as well as the methods of operation and functions of the related elements of structure and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention. As used in the specification and in the claims, the singular form of “a”, “an”, and “the” include plural referents unless the context clearly dictates otherwise.

BRIEF DESCRIPTION OF THE DRAWINGS

(14) FIG. 1 illustrates a top view of a reactor, in accordance with one or more implementations.

(15) FIG. 2 illustrates a side view of the reactor, in accordance with one or more implementations.

(16) FIG. 3 illustrates one example of first replaceable wear part of the reactor shown in FIGS. 1 and 2 in a detailed view.

(17) FIG. 4 illustrates one example of including multiple gas inlets and replaceable wear parts in the reactor shown in FIGS. 1 and 2.

(18) FIG. 5 illustrates one example of a shape of the interior volume of chamber designed to control the wear impact.

DETAILED DESCRIPTION

(19) FIGS 1 and 2 illustrate a top and a side view of a reactor, respectively, in accordance with one or more implementations. With continuous reference to FIGS. 1 and 2, reactor 100 will be described. Reactor 100 may be configured to facilitate processing including chemical reactions, and/or comminution of solid feed materials using shockwaves created in a supersonic gaseous vortex. Such a reactor is described U.S. Non-provisional Application Serial Number 14/298,868 entitled "A Reactor Configured To Facilitate Chemical Reactions, and/or Comminution Of Solid Feed Materials Using Shockwaves Created In A Supersonic Gaseous Vortex", which is incorporated herein by reference. As shown, reactor 100 may include one or more of a chamber 102, a first gas inlet 104, a material inlet 106, an outlet 108, a second gas inlet 110, a first replaceable wear part 112, and/or other components.

(20) Chamber 102 may be configured to provide a volume in which material processing occurs. Chamber 102 may have a substantially circular cross-section centered on a longitudinal axis 124 that is normal to the cross-section. The substantially circular cross-section may facilitate a vortex rotating within chamber 102. A radius of the substantially circular cross-section of chamber 102 may continuously decrease at an end of chamber 102 proximal to outlet 108. The continuous decrease of the radius of the substantially circular cross-section of chamber 102 may be configured to cause an acceleration of a rotational speed of the

gaseous vortex. As the continuous decrease of the radius of the substantially circular cross-section of chamber 102 may be shaped as a cone (illustrated in FIG. 2), a hemisphere, a horn-shape, and/or other shapes.

(21) Chamber 102 may be formed of various materials. Chamber 102 may be formed of a rigid material. Chamber 102 may be formed of a thermally conductive material. Chamber 102 may be formed of an electrically conductive material. According to some implementations, chamber 102 may be formed wholly or partially of steel, iron, iron alloys, silicon carbide, partially stabilized zirconia (PSZ), fused alumina, tungsten carbide, boron nitride, carbides, nitrides, ceramics, silicates, geopolymers, metallic alloys, other alloys, and/or other materials. In some implementations, an internal surface 116 of chamber 102 may be coated with one or more coatings. An exemplary coating may be configured to prevent physical or chemical wear to internal surface 116 of chamber 102. In some implementations, a coating or composition may be configured to promote a chemical reaction within chamber 102. An example of a coating or composition that may promote a chemical reaction may include one or more of iron; nickel; ruthenium; rhodium; platinum; palladium; cobalt; other transition metals and their alloys, compounds, and/or oxides (e.g., the lanthanide series and their compounds, alloys, and/or oxides); and/or other materials.

(22) The first gas inlet 104 may be configured to introduce a high-velocity stream of gas into chamber 102. The first gas inlet 104 may be disposed and arranged so as to effectuate a vortex of the stream of gas circulating within chamber 102. The vortex may rotate about longitudinal axis of chamber 102. The gas inlet may be disposed so that the gas stream 116 is directed substantially perpendicular to

longitudinal axis 124 of chamber 102. The first gas inlet 104 may be disposed so that the gas stream 116 is directed substantially tangent to a portion of the internal surface 126 of the substantially circular cross-section of chamber 102. The first gas inlet 104 may be disposed proximal to material inlet 106.

(23) According to some implementations, the first gas inlet 104 may comprise inlet gas nozzle (not depicted in this example) disposed within the first gas inlet 104. In those implementations, the inlet nozzle may be configured to accelerate the stream of gas being introduced into chamber 102, to emit the stream of gas at a supersonic speed, to emit shockwaves in the stream of gas emitted from inlet nozzle, and/or for any other purposes. U.S. Application Serial Number 14/298,868 describes some exemplary implementations of the first gas inlet 104 in detail, incorporated *supra*.

(24) The gas stream 116 introduced by the first gas inlet 104 may include any number of gaseous materials. In some implementations, the gas may include a reduced gas, i.e., a gas with a low oxidation number (or high reduction), which is often hydrogen-rich. The gas may include one or more of steam, methane, ethane, propane, butane, pentane, ammonia, hydrogen, carbon monoxide, carbon dioxide, oxygen, nitrogen, chlorine, fluorine, ethene, hydrogen sulphide, acetylene, and/or other gases. The gas may be a vapor. The gas may be superheated. In some implementations, the gas may be heated beyond a critical point, and/or compressed above a critical pressure so that the gas becomes a superheated gas, compressible fluid, and/or a super critical fluid.

(25) The material inlet 106 may be configured to introduce material 132 (illustrated in FIG. 2) to be processed into chamber 102. As shown, the material inlet 106 may be disposed proximal to the first gas inlet 104. The material inlet 106 may be

disposed on a flat surface of chamber 102 that is perpendicular to longitudinal axis 124 of chamber 102. The material inlet 106 may be disposed so that material 132 introduced into chamber 102 is directed parallel to longitudinal axis 124 of chamber 102. The material inlet 106 may be coupled to an auger (not depicted) that advances material through material inlet 106 into chamber 102.

(26) Any number of material 132 may be processed by reactor 100. According to some implementations, the material to be processed may include a solid, a fluid, a liquid, a vapor, a gas, a plasma, a supercritical fluid, a mixture including one or more of the aforementioned materials, and/or other types of materials. By way of non-limiting example, material 132 to be processed within chamber 102 may include one or more of soil, coal, woodchips, food scraps, ore, and/or ore concentrate, mine tailings, tar sands, shale, an organic material, an inorganic material, and/or other materials.

(27) Material 132 processed by reactor 100 may be processed by nonabrasive mechanisms facilitated by shockwaves 128 within chamber 102. For example, material 132 may be processed by tensile forces caused by shockwaves within chamber. Material 132 may be processed by cavitation in the stream of gas within chamber 102. As described below, material 132 may be processed in chamber 102 by direct impingement on the first replaceable part wear part 112. For example, material 132 may be fragmented by collision with the first replaceable part wear part 112. Material 132 may undergo a chemical transformation due to the catalytic effect built into the first replaceable part wear part 112, and/or due to the electric field imparted on the first replaceable part wear part 122.

(28) The outlet 108 may be configured to emit the gas and processed material from chamber 102. The outlet 108 may be disposed at an end of chamber 102 opposite to the first gas inlet 104 and material inlet 106. The outlet may be disposed on longitudinal axis 124 of chamber 102. As particle size of the processed material is reduced, those particles may migrate toward outlet 108. The outlet 108 may be coupled to a vacuum chamber (not depicted) configured to trap processed material emitted from outlet 108.

(29) In some implementations, outlet 108 may include one or more of an outlet nozzle 130 (illustrated in FIG. 2) disposed within outlet 108. The outlet nozzle 130 may be configured to pressurize chamber 102. The outlet nozzle 130 may be configured to effectuate a rapid cooling of processed material exiting chamber 102. According to some implementations, such rapid cooling may reduce or minimize back reactions of metals, and/or other chemicals susceptible to back reactions. In some implementations, the outlet nozzle 130 may include a venturi tube (not depicted).

(30) For resisting wear in reactor 100, a first replaceable wear part 112 may be disposed at a first portion 122 of the inner surface 126 of chamber 102. The first portion 122 may be an area on the inner surface 126 where the stream 116, charged with pulverized particles from process material, contacts the surface 126. As such, the first portion 122 may be opposite to the first gas inlet 104 within chamber 102. The first replaceable wear part 112 may be disposed at the first portion 122 in a way to absorb impacts to first portion 122 on the inner surface 126 caused by the pulverized particles from the process material entrained by the gas stream 116 introduced by the first gas inlet 104. The first replaceable wear part 112 may be

made of hard material such as tungsten carbide, titanium carbide, titanium nitride, diamond, polycrystalline diamond, diamond like carbon, silicon nitride, boron nitride, steel, iron, iron alloys, silicon carbide, partially stabilized zirconia (PSZ), fused alumina, boron nitride, carbides, nitrides, ceramics, silicates, geopolymers, metallic alloys, other alloys and/or any other materials for wear resistance. In some implementations, the first replaceable wear part 112 may be partially or wholly composed of one or more of iron; nickel; ruthenium; rhodium; platinum; palladium; cobalt; other transition metals and their alloys, compounds, and/or oxides (e.g., the lanthanide series and their compounds, alloys, and/or oxides); and/or other catalytic materials known to those skilled in the art and used to promote chemical reactions within the chamber 102.

(31) In some implementations, the first replaceable wear part 112 may be configured to continuously advance into the chamber as the surface of the contact end is worn. FIG. 3 illustrates one example of a first replaceable wear part 112 in a detailed view. It will be described with reference to FIGS 1 and 2. As shown in this example, the first replaceable wear part 112 may comprise a first end 112A, e.g., the contacting end of the first replaceable wear part 112, and a second end 112B that is opposite to the first end 112A. As shown, the first replaceable wear part 112 may comprise a thruster 136 configured to continuously feed the first replaceable wear part 112 into chamber 102 as the surface of the first replaceable wear part 112 is worn by the impacts caused by the pulverized particles. As also shown in this example, casing 138 may be employed to be lined around chamber 102 and serve as a support to the first replaceable wear part 112. As shown, around the casing 138 where the first replaceable wear part 112 enters chamber 102, seals 140 may be employed. Seals 140 may facilitate removal of the first replaceable wear part 112

for maintenance or replacement. The facilitated removal of first replaceable wear part 112 may reduce scheduled downtime as compared to the conventional jet mill. As shown, a second replaceable wear part 150 may be coupled to the first replaceable wear part 112 at the second end 112B of the first replaceable wear part 112. This may facilitate continuous feeding of replaceable wear parts into chamber 102.

(32) In some implementations, the first replaceable wear part 112 may comprise a rotatable cylindrical rod adapted to control impacts of the pulverized particles. In those implementations, the cylindrical rod may rotate about the axis of its cylinder when the pulverized particles contact the rod. The rotation of the rod may allow the wear to be controlled on the surface of the rod.

(33) In some implementations, the contacting end of the first replaceable wear part 112 may be coated with or composed of catalyst material. The catalyst material may be configured to protect the surface of the contacting end of the first replaceable wear part 112, and/or to promote a chemical reaction within chamber 102. For example, the catalyst material may be incorporated into the matrix of the first replaceable wear part 112 during manufacturing of the first replaceable wear part 112. A number of factors may contribute to including catalyst material in the first wear part. For example, in situations where the reaction in the chamber 102 involves mostly comminution, very little or none of catalyst material may be added to the first replaceable wear part 112. In situations where it is desired to have catalytic activity in the chamber 102, the rate at which catalyst material added to the first replaceable wear part 112 would ablate due to wear, how much of poisoning of the catalyst is needed in the chamber 102, and/or any other consideration may be taken

into account. Accordingly, the catalyst material that may be coated on the contacting end, or embedded in the matrix, of the first replaceable wear part 112 may include one or more of platinum, palladium, iron; nickel; ruthenium; rhodium; platinum; palladium; cobalt; other transition metals and their alloys, compounds, and/or oxides (e.g., the lanthanide series and their compounds, alloys, and/or oxides); and/or any other catalyst material for aiding the chemical reaction(s), and/or the comminution inside chamber 102. The coating on, or composition of, the first replaceable wear part 112 may be configured such that the coated catalyst material ablates from the surface of the first replaceable wear part 112 at a rate that exposes a new clean surface of the first replaceable wear part 112. The ablated catalyst material may increase the throughput, and/or activity in chamber 102 by increasing the rate of reactions without a need to physically scale the size of reactor 100. The throughput value may be a value between ten kilos per hour to a thousand tons per hour. For example, the throughput value may be 850 tons per hour or 11 kilos per hour.

(34) In some implementations, the first replaceable wear part 112 may be configured to be electrically isolated from chamber 102, and/or other components of reactor 100. This may facilitate an electrical field on the first replaceable wear part 112 having a variable voltage, amperage, frequency, waveform, and/or any other type(s) electrical potential to aid chemical reaction in chamber 102. In those implementations, the first replaceable wear part 112 may enable the Non-Faradaic Electrochemical Modification of Catalytic Activity (NEMCA), also known as Electrochemical Promotion of Catalysis (EPOC), for reducing energy required for comminution, and/or the chemical reactions inside chamber 102.

(35) Returning to FIGS 1 and 2, in some implementations, reactor 100 may comprise a second gas inlet 110 for controlling the direction of the gas stream 116. As shown, the second gas inlet 110 may be arranged proximal to the first gas inlet 104. The second gas inlet 110 may comprise a nozzle configured to introduce a gas stream 118 to produce a "steering effect" to the gas stream 116. That is, the gas stream 118 may be introduced to control the direction of the first gas stream 116 such that the first gas stream 116 may be directed to a particular direction to even out wear in chamber 102. To achieve this, the second gas inlet 110 may be disposed such that the gas stream 118 may have an axial flow configured to intercept the gas stream 116 introduced by the first gas inlet 104. As illustrated, the second gas inlet 110 may be employed to "steer" the gas stream 116 towards a desired area on the inner surface 126 of chamber 102. For example, without limitation, the second gas inlet 110 may be employed to steer the gas stream towards the first replaceable wear part 112 for limiting wear impact to the first replaceable wear part 112. In another example, the second gas inlet 118 may be disposed such that the gas stream 116 is directed to a second portion of the inner surface 126 of reactor 100 to even out wear inside chamber 102. In some implementations, gas stream 118 may be configured to introduce eddy current and interference currents into chamber 102 to vary the shock wave effects of reactor 100. In another example, the second gas stream may be composed of a different gas to the first gas stream and may be designed to affect a chemical reaction. For instance, the first gas stream may be composed of hydrogen, and the second gas stream may be composed of nitrogen. With a suitable catalyst included in the composition of the first replaceable wear part 112, ammonia may be produced at certain temperatures and pressures.

(36) In some implementations, inner surface 126 of chamber 102 may comprise pockets (e.g., disruptors) around the periphery of the chamber 126. The pockets may be configured with appropriate sizes to receive some or all of the process material such that it is packed into the inner surface 126. FIG. 2 illustrates such pockets 134 on the inner surface 126 of chamber 102. The process material that is packed by the pockets may form a layer on the inner surface 126 to effect "material on material" wear resistance. That is, the process material packed into the pockets on the inner surface 126 may form a "new surface" of chamber 102 with the same hardness as the process material impacting the chamber 102.

(37) In some implementations, additional gas inlets and replaceable wear part may be included in reactor 100 to reduce and control effects caused by drag or boundary layers in reactor 100 as process material is required to travel a long flight path before existing. FIG. 4 illustrates one example of including multiple gas inlets and replaceable wear parts in reactor 100. It will be described with reference to FIGS. 1-2. As shown, in addition to the first gas inlet 104, the second gas inlet 110 and the first replaceable wear part 112, reactor 100 may further comprise a third gas inlet 144, a fourth gas inlet 146, and a second replaceable wear part 142 arranged similarly to the arrangement of the first gas inlet 104, the second gas inlet 110 and the first replaceable wear part 112. That is, the fourth gas inlet 138 may be disposed proximal to the third gas inlet 144 such that gas stream 146 introduced by the fourth gas inlet 128 may "steer" the supersonic gas stream 144 introduced by the third gas inlet 144. As shown, the second replaceable wear part 140 may be disposed at a second portion 142 of inner surface 126 of chamber 102. The second portion 142 may be an area of inner surface 126 where gas stream 144, charged with pulverized particles from the process material, impacts the inner surface 126.

(38) Returning to FIGS. 1 and 2, in some implementations, the shape of the interior volume of chamber 102 may be configured to control wear impact to be on desired areas within chamber 102. FIG. 5 illustrates one example of a shape of the interior volume of chamber 102 designed to control the wear impact. It will be described with reference to FIGS 1 and 2. As shown in this example, reactor 100 may comprise casings 138 that may "partition" chamber 102 into multiple sections. In this example, the casings 138 "partitions" chamber 102 into sub-chambers in which majority of the gaseous vortex takes place as illustrated. In this way, the wear impact during the pulverization process may be restricted to desired areas within chamber 102.

(39) Other components that may be included in reactor 100 may include, a heating component configured to provide heat to chamber 102, a ventilation component 160 configured to vent gas from a region surrounding chamber 102, one or more sensors configured to provide a signal conveying information related to one or more parameters associated with reactor 100, and/or any other components. U.S. Application Serial Number 14/298,868, incorporated *supra,* describes some exemplary implementations of these components in reactor 100 in detail.

(40) Although the present technology has been described in detail for the purpose of illustration based on what is currently considered to be the most practical and preferred implementations, it is to be understood that such detail is solely for that purpose and that the technology is not limited to the disclosed implementations, but, on the contrary, is intended to cover modifications and equivalent arrangements that are within the spirit and scope of the appended claims. For example, it is to be understood that the present technology contemplates that, to the extent possible,

one or more features of any implementation can be combined with one or more features of any other implementation.

What is claimed is:

1. A reactor configured to facilitate chemical reactions, and/or comminution therein using shockwaves created in a supersonic gaseous vortex, the reactor being further configured to resist wear caused by the chemical reactions, and/or comminution, the reactor comprising:

a rigid chamber having a substantially circular cross-section centered on a longitudinal axis that is normal to the cross-section;

a first gas inlet configured to introduce a high-velocity stream of gas into the chamber, the first gas inlet being disposed and arranged so as to effectuate a vortex of the stream of gas circulating within the chamber, the vortex rotating at a supersonic speed about the longitudinal axis of the chamber;

a material inlet configured to introduce a material to be processed into the chamber, the material inlet being disposed proximal to the first gas inlet, the material being processed within the chamber by nonabrasive mechanisms facilitated by shockwaves within the chamber;

an outlet configured to emit the gas and processed material from the chamber; and

a first replaceable wear part configured to protect an inner surface of the chamber, the first replaceable wear part corresponding to the first gas inlet such that the first replaceable wear part being disposed at the first portion of the inner surface of the chamber, wherein a first end of the first wear part is adapted to contact processed material particles at an first portion of the inner surface of the chamber; and, wherein

processing of the material within the chamber causes a wear impact to the first portion of the inner surface of the chamber due to the stream of gas introduced by the first gas inlet

2. The reactor of claim 1, wherein the first replaceable wear part is made of tungsten carbide, titanium carbide, or titanium nitride, and/or diamond.

3. The reactor of claim 1, wherein the first wear part includes a cylindrical rod configured to rotate about a longitudinal axis of the cylindrical rod, the rod being disposed such that a first end of the rod forms a portion of or the entire first end of the wear part.

4. The reactor of claim 3, wherein the rod includes a catalytic material to enhance a throughput of the reactor.

5. The reactor of claim 4, wherein the catalytic material includes platinum, and/or palladium.

6. The reactor of claim 3, wherein the first replaceable wear part is electronically isolated from the rest of the reactor.

7. The reactor of claim 1, wherein the first replaceable wear part is further configured such that the first replaceable wear part is continuously fed into the chamber.

8. The reactor of claim 1, wherein the first replaceable wear part is further configured such that another replaceable wear part can be coupled to a second end of the first replaceable wear part for continuous feed into the chamber, the second end being opposite of the first end of the first replaceable wear part.

9. The reactor of claim 1, wherein the first portion of the inner surface of the chamber is located opposite to the first gas inlet within the chamber.

10. The reactor of claim 1, further comprising a second gas inlet configured to introduce a gas flow into the chamber, the second gas inlet being disposed proximal to the first gas inlet such that the gas flow introduced by the second gas inlet alters the direction of the gas flow introduced by the first gas inlet.

11. The reactor of claim 10, wherein the second gas inlet is disposed such that the gas flow introduced by the second gas inlet introduces eddy current, and/or interface current to vary the shockwaves within the chamber.

12. The reactor of claim 1, wherein the chamber is configured such that the inner surface of the chamber comprises pockets adapted to pack processed material particles into the inner surface of the chamber.

13. The reactor of claim 1, wherein the first gas inlet includes an inlet nozzle disposed within the first gas inlet, the inlet nozzle being configured to emit the stream of gas at a supersonic speed.

14. The reactor of claim 11, wherein the inlet nozzle is configured to emit shockwaves in the stream of gas emitted from the inlet nozzle.

15. The reactor of claim 1, wherein a portion of the chamber, having a continuously decreasing radius of the substantially circular cross-section, is shaped as a cone, a hemisphere, or a horn-shape.

16. The reactor of claim 1, further comprising:

a third gas inlet configured introduce a high-velocity stream of gas into the chamber, the third gas inlet being disposed and arranged so as to effectuate a vortex of the stream of gas circulating within the chamber, the vortex rotating at a supersonic speed about the longitudinal axis of the chamber;

a fourth gas inlet configured to introduce a gas flow into the chamber, the fourth gas inlet being disposed proximal to the third gas inlet such that the gas flow introduced by the fourth gas inlet alters the direction of the gas flow introduced by the third gas inlet;

a second replaceable wear part configured to protect the inner surface of the chamber, the second replaceable wear part corresponding to the third gas inlet such that the second replaceable wear part is disposed at a second portion of the inner surface of the chamber, wherein first end of the second wear part is adapted to contact processed material particles at the second portion of the inner surface of the chamber; and, wherein processing of the material within the chamber causes a wear impact to the second portion of the inner surface of the chamber due to the stream of gas introduced by the third gas inlet.

17. The reactor of claim 1, wherein the reactor has a throughput value range from 10 kilos per hour to one thousand tons per hour.

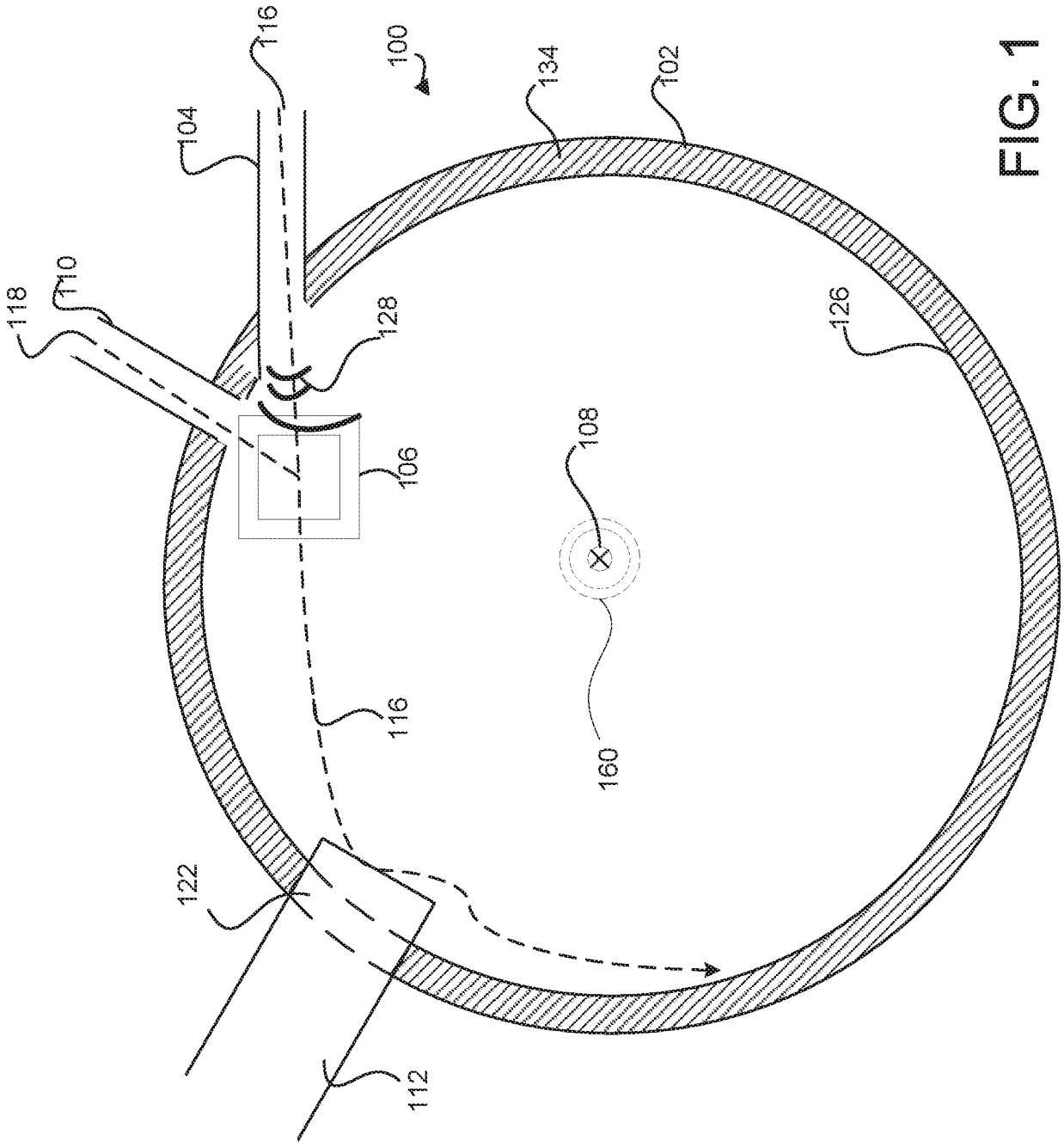


FIG. 1

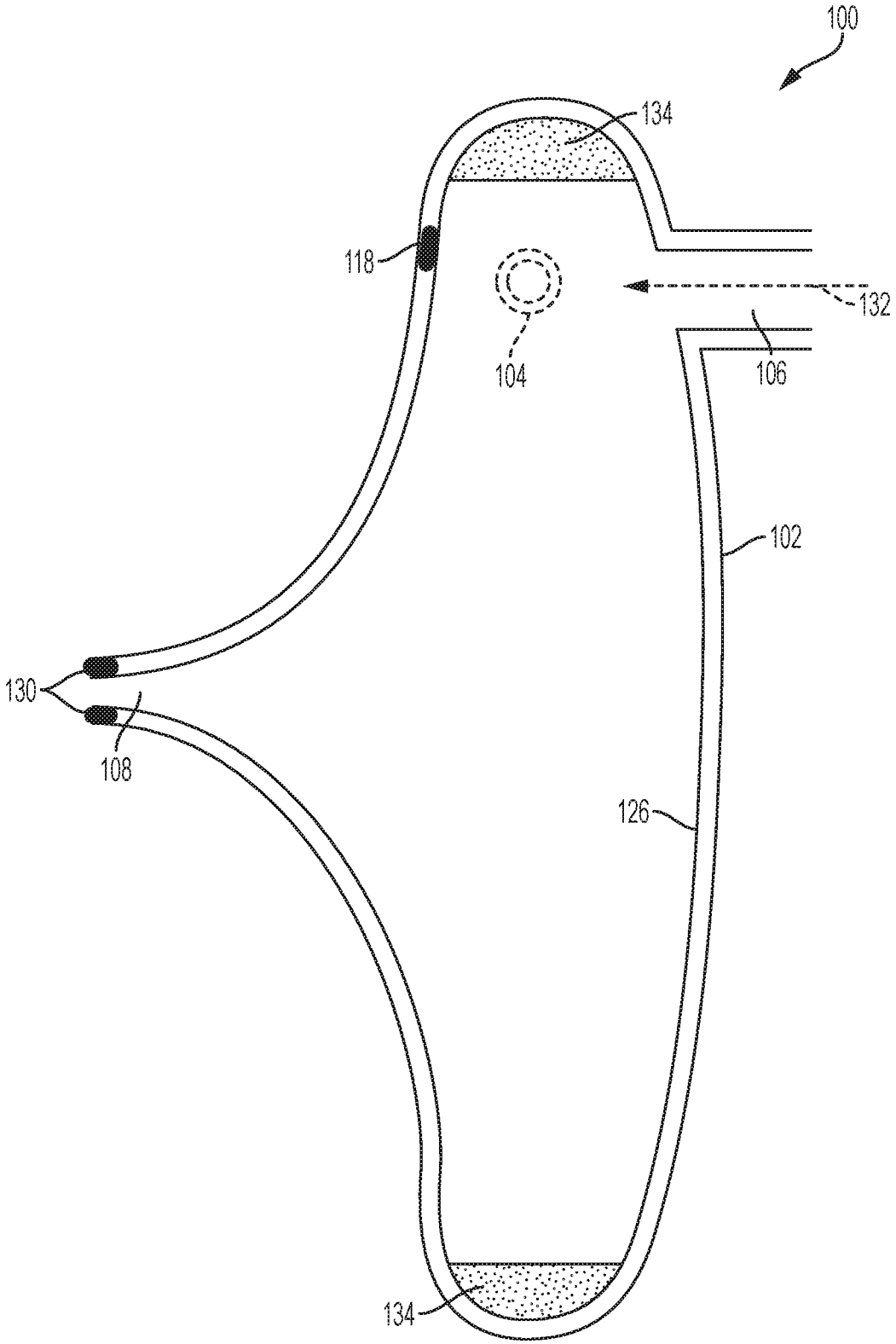
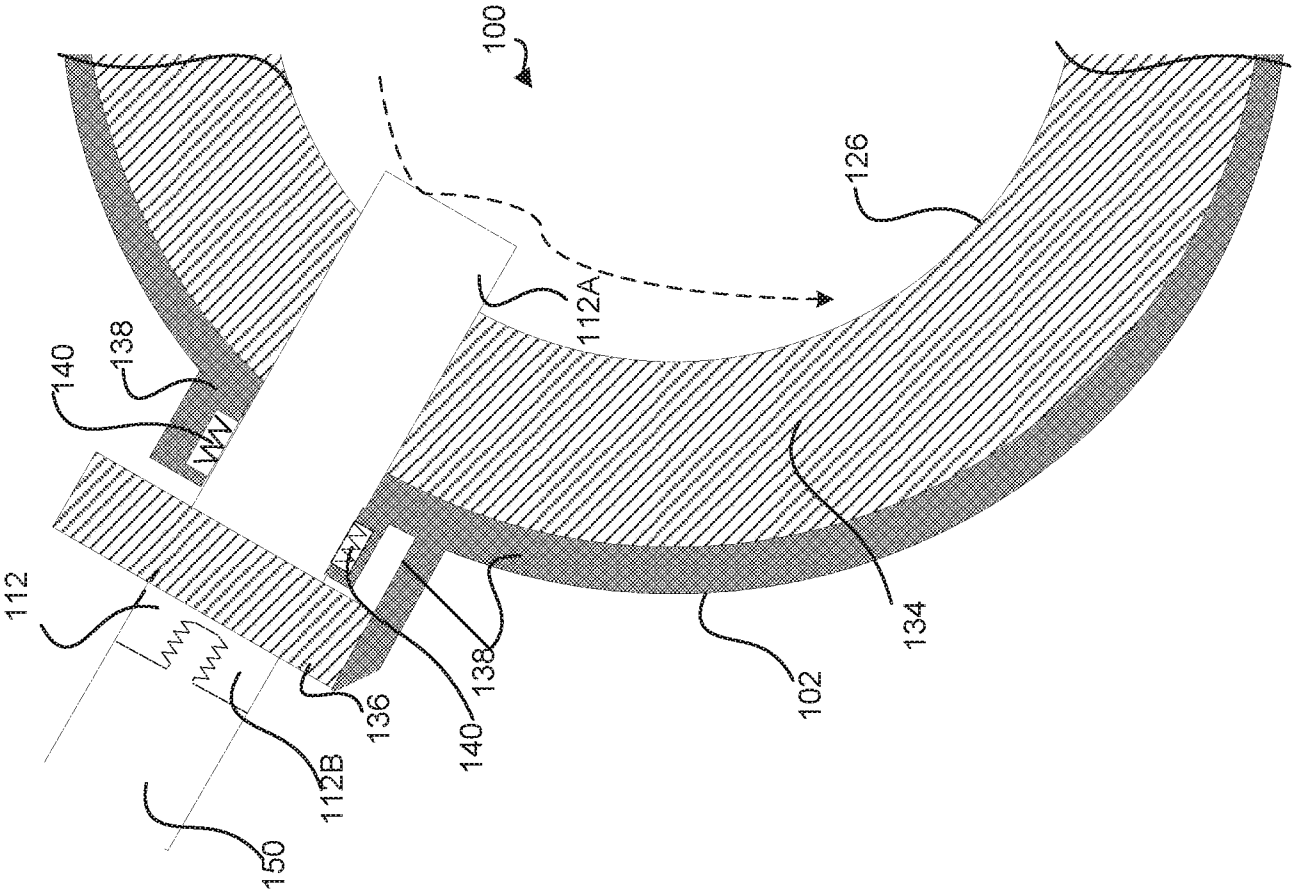


FIG. 2

FIG. 3



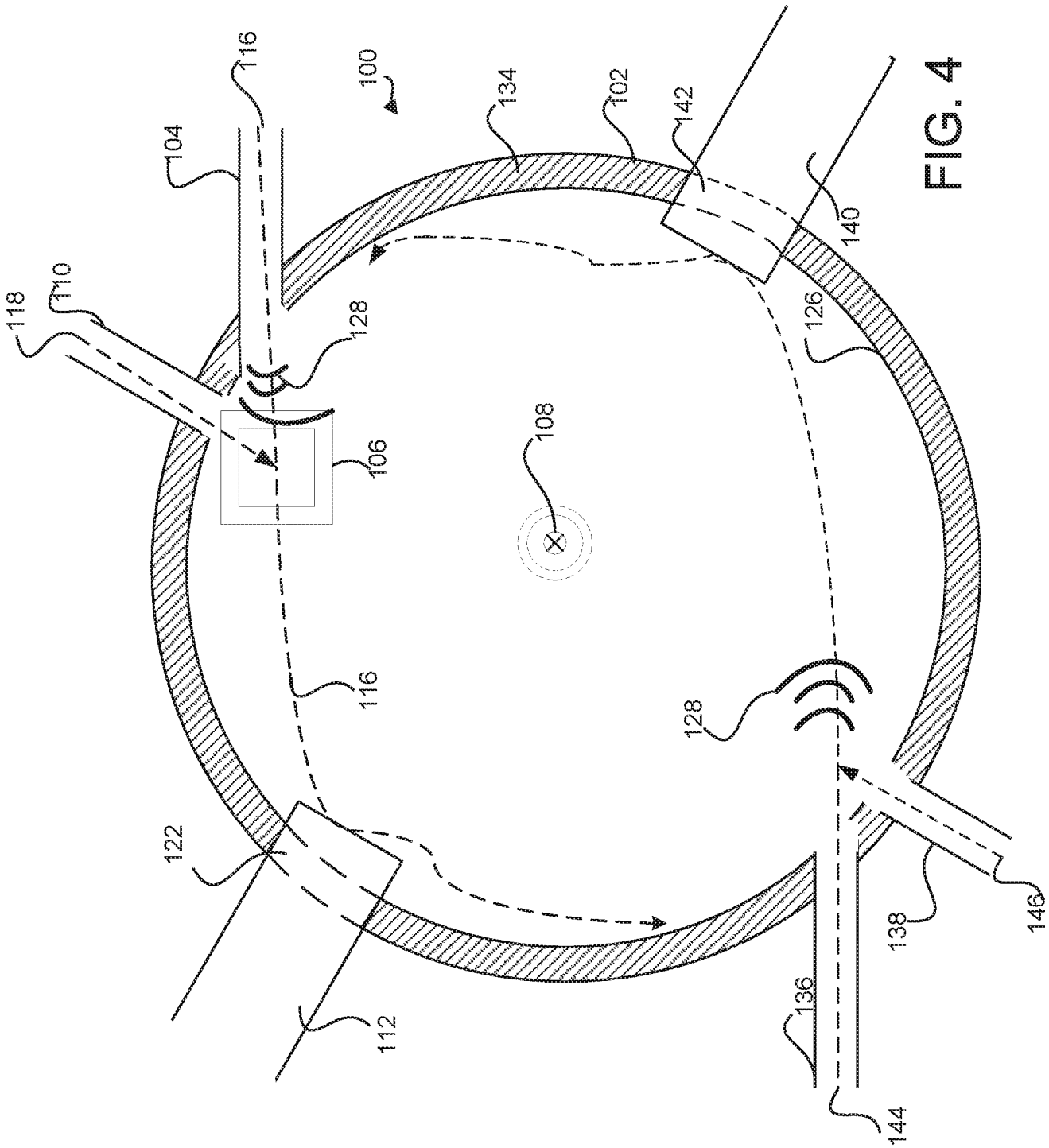

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FIG. 4

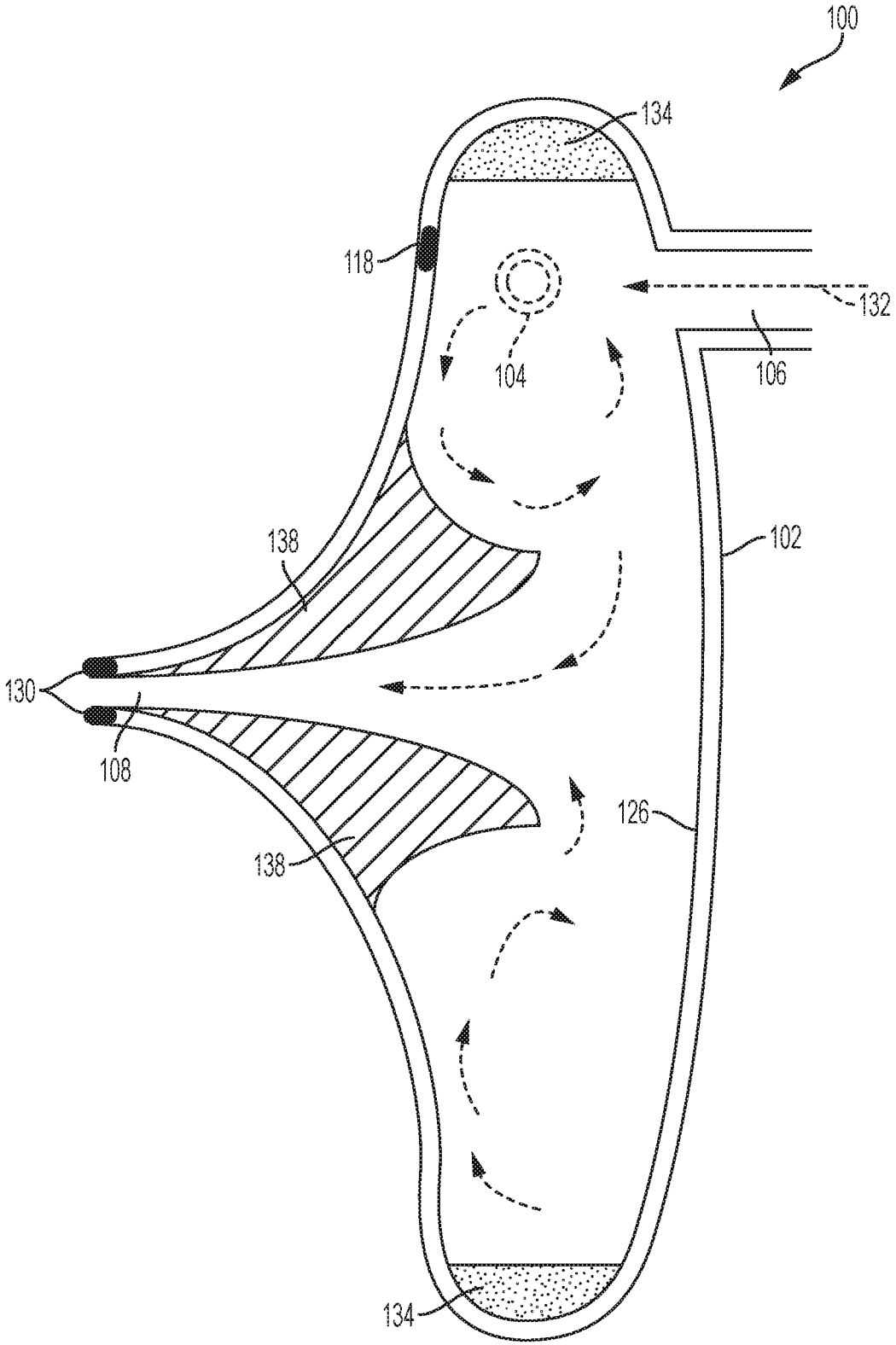


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US16/28167

A. CLASSIFICATION OF SUBJECT MATTER
IPC: **B02C 19/06**(2006.01)

USPC: 241/39
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)
U.S. : 241/39, 40; IPC: B02C 2210/02

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GB 1,037,770 (E.I. DU PONT DE NEMOURS AND COMPANY) 03 August 1966 (03.08.1966), entire document.	1-5 and 9-17
Y	US 5,277,369 A (MORIYA et al.) 11 January 1994 (11.01.1994), entire document.	1-5 and 9-17
Y	US 4,354,641 (SMITH) 19 October 1982 (19.10.1982), entire document.	1-5 and 9-17
Y --- A	US 2004/0063874 A1 (MUHLE et al.) 01 April 2004 (01.04.2004), entire document.	4 and 5 --- 6-8
Y --- A	US 4,921,173 (BARTLEY) 01 May 1990 (01.05.1990), entire document.	12 --- 6-8

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 May 2016 (17.05.2016)	25 JUL 2016
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Tom Barrett Telephone No. (571) 272-4300