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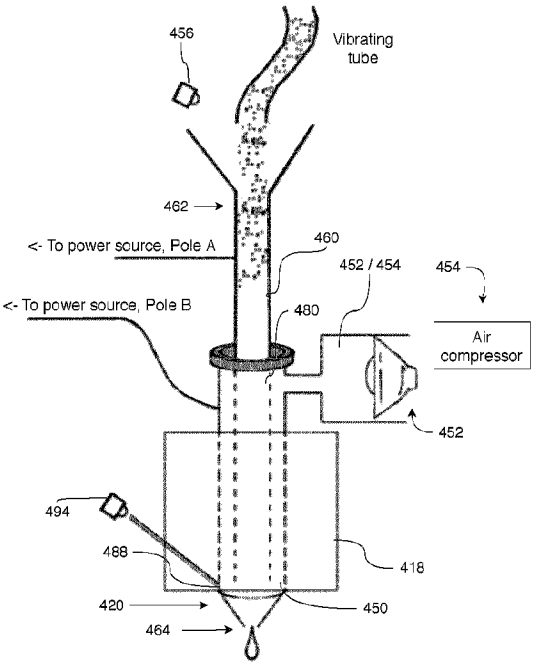
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(54) Titre : IMPRIMANTE DE MODELISATION PAR DEPOT PAR FUSION A AUTO-REPLICATION UTILISANT DES GRANULES

(54) Title: SELF-REPLICATING FUSED DEPOSITION MODELING PRINTER USING GRANULES



(57) Abrégé/Abstract:
A material delivery device for an additive manufacturing device (AMD) adapted for manufacturing objects through deposition of additive material over a build surface. The material delivery device comprises an inner funnel having a large aperture and a small aperture whereby the additive material is guided from the large aperture to the small aperture; wherein the inner funnel is electrically conductive and, upon applying an electrical current to the inner funnel, heat is generated thereby heating the additive material travelling in the inner funnel.

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(54) Title: SELF-REPLICATING FUSED DEPOSITION MODELING PRINTER USING GRANULES

(57) Abstract: A material delivery device for an additive manufacturing device (AMD) adapted for manufacturing objects through deposition of additive material over a build surface. The material delivery device comprises an inner funnel having a large aperture and a small aperture whereby the additive material is guided from the large aperture to the small aperture; wherein the inner funnel is electrically conductive and, upon applying an electrical current to the inner funnel, heat is generated thereby heating the additive material travelling in the inner funnel.

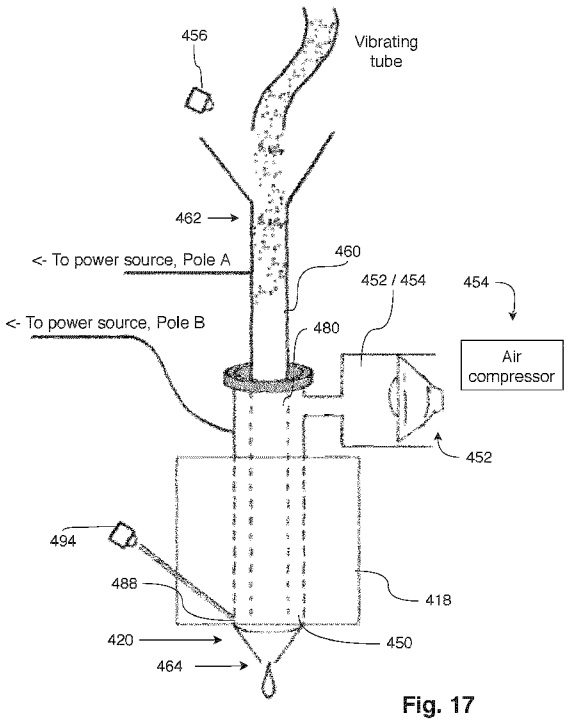


Fig. 17

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SELF-REPLICATING FUSED DEPOSITION MODELING PRINTER USING GRANULES

BACKGROUND

(a) Field

[0001] The subject matter disclosed generally relates to 3D manufacturing tools, and tools adapted to perform additive manufacturing processes through deposition of additive materials. More particularly, the subject matter disclosed relates to 3D printers or other types of additive manufacturing devices.

(b) Related Prior Art

[0002] Existing conventional 3D printers are specialized pieces of equipment that are making their way into the mainstream market. It is currently possible to buy parts to build your own 3D machine, which requires time and knowledge. On the other hand, one can also buy an assembled 3D printing machine that is ready to use. In both cases, in order to build and assemble or repair the 3D printing machine, multiple mechanical parts have to be bought from multiple companies, which increases the cost, complexity and time required for assembling a 3D printing machine while decreases the desire of owners of 3D printing machines to maintain spare parts to respond to wear and tear.

[0003] One supplier, www.RepRap.org, has tried to overcome these shortcomings by designing a general-purpose self-replicating 3D printing machine. However, since the RepRap 3D printer is only capable of producing plastic-made parts, the opportunities provided by the RepRap machine are relatively limited.

[0004] Furthermore, 3D printers are nowadays being actively developed by many other companies and individuals with the object of either trying to make an ever-cheaper 3D printer or a more reliable plastic filament printer, which has a major drawback in the cost of the printing material: plastic beads for 3D printers are expensive, at least about 30$/kg. Alternatively, others develop 3D metal printers with which people shine lasers at expensive metals. Another alternative is using resin as printing material, which, as plastic beads, is also expensive.

[0005] Accordingly, the present subject-matter aims to at least partly address these shortcomings.

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SUMMARY

[0006] According to an embodiment, there is provided an additive manufacturing device (AMD) for manufacturing objects through deposition of additive material over a build surface, the AMD comprising: an electric power source; a material feeding conduit comprising an inner tube, wherein the material feeding conduit feeds the inner tube with the additive material and the inner tube is electrically connected to the electric power source; and a material delivery device is in electrical and mechanical contact with the material feeding conduit, the material delivery device comprising an inner funnel having a large aperture and a small aperture whereby the additive material is guided from the large aperture to the small aperture; wherein the inner funnel is electrically conductive and, upon applying an electrical current to the inner funnel, heat is generated thereby heating the additive material travelling in the inner funnel.

[0007] According to an aspect, the inner tube is in electrical and mechanical contact with the large aperture of the inner funnel.

[0008] According to an aspect, the material delivery device further comprises an outer funnel located external to the inner funnel, the outer funnel having a small aperture, wherein the outer funnel is joined to the inner funnel about the small aperture of the inner funnel and the small aperture of the outer funnel.

[0009] According to an aspect, the outer funnel further comprises a large aperture and the material feeding conduit comprises an outer tube, and further wherein the outer tube is in electrical and mechanical contact with the large aperture of the outer funnel.

[0010] According to an aspect, the AMD further comprises a junction wall extending about the small aperture of the inner funnel, whereby the junction wall joins the outer funnel to the inner funnel.

[0011] According to an aspect, the junction wall divides an interior space concealed by the inner funnel and an exterior space within the outer funnel, wherein the wall comprises slits through which the exterior space is in fluid communication with the interior space.

[0012] According to an aspect, the AMD further comprises a flow-driving means fluidly connected to the outer tube, wherein the flow-driving means is adapted to transmit gas waves to the additive material about the small aperture of the inner funnel through the slits.

[0013] According to an aspect, the flow-driving means is a subwoofer speaker.

[0014] According to an aspect, the flow-driving means is an air compressor.

[0015] According to an aspect, the slits have dimensions and wherein the dimensions of the slits: allow gas from the exterior space into the interior space; and prevent the additive material from travelling from the interior space into the exterior space.

[0016] According to an aspect, the AMD further comprises: a sensor reading one of: temperature in the material delivery device; flow of additive material in the material delivery device; and a physical characteristic of the material delivery device changing with the temperature of the material delivery device, and a power controller electrically connected electric power source, wherein the power controller is adapted to modify the electrical power transmitted to the electrical power source based on readings from the sensor.

[0017] According to an aspect, the AMD further comprises an optical sensor monitoring flow of the additive material in one of: upstream from the material feeding conduit; in the material feeding conduit; and downstream from the material feeding conduit.

[0018] According to an aspect, the material feeding conduit comprises an outer tube, and wherein the material delivery device is made of a first material capable of resisting to a top temperature, and wherein one of the inner tube and the outer tube is made of a second material capable of resisting to a second temperature, wherein the second temperature is below the top temperature, and wherein the first material is different from the second material.

[0019] According to an aspect, the material delivery device is adapted to heat the additive material from a solid state into a fluid state, and wherein the material delivery device deposits the additive material in the fluid state to the build surface upon its exit from the small aperture of the inner funnel.

[0020] According to an embodiment, there is provided a material delivery device for an additive manufacturing device (AMD) adapted for manufacturing objects through deposition of additive material over a build surface, the material delivery device comprising: an inner funnel having a large aperture and a small aperture whereby the additive material is guided from the large aperture to the small aperture; wherein the inner funnel is electrically conductive and, upon applying an electrical current to the inner funnel, heat is generated thereby heating the additive material travelling in the inner funnel.

[0021] According to an aspect, the material delivery device further comprises an outer funnel located external to the inner funnel, the outer funnel having a small aperture, wherein the outer funnel is joined to the inner funnel about the small aperture of the inner funnel and the small aperture of the outer funnel.

[0022] According to an aspect, the material delivery device further comprises a junction wall extending about the small aperture of the inner funnel, whereby the junction wall joins the outer funnel to the inner funnel.

[0023] According to an aspect, the junction wall divides an interior space concealed by the inner funnel and an exterior space within the outer funnel, wherein the wall comprises slits through which the exterior space is in fluid communication with the interior space.

[0024] According to an aspect, the material delivery device is made at least in part of one of a metallic material or a metallic alloy.

[0025] According to an aspect, the material delivery device is made at least in part of one of platinum and a platinum-based alloy.

[0026] According to an aspect, the inner funnel has a varying thickness which results in a variation of an electrical resistance of the inner funnel and hence a variation of the heat which is generated.

[0027] According to an embodiment, there is provided an additive manufacturing device (AMD) for manufacturing objects through deposition of additive material over a build surface, the AMD comprising: an electric power source; a material feeding conduit comprising an inner tube, wherein the material feeding conduit feeds the inner tube with the additive material; and a crucible/nozzle combination (C/NC) connected to the electric power source and the material feeding conduit, the C/NC comprising: an inner funnel comprising a top edge, a bottom edge, a top perimeter about the top edge, a bottom perimeter about the bottom edge, with the top perimeter being greater than the bottom perimeter, and an aperture at the bottom edge operating as a nozzle; a rim extending outwardly from the bottom edge; a first electrical contact located about the top edge of the inner funnel and electrically connected to the electric power source through the material feeding conduit; and a second electrical contact located on the rim distant from the inner funnel and electrically connected to the electric power source; wherein the inner funnel is adapted to receive at the top edge the additive material from the material feeding conduit, to guide the additive material travelling from the top edge to the nozzle, and to heat the additive material therebetween, wherein the C/NC is adapted to heat as current travels between the first electrical contact and the second electrical

contact, thereby heating the additive material travelling in the inner funnel, and wherein the additive material flows out of the C/NC through the nozzle to be deposited to the build surface.

[0028] According to an embodiment, there is provided a crucible/nozzle combination (C/NC) for an additive manufacturing device (AMD) adapted for manufacturing objects through deposition of additive material over a build surface, the crucible/nozzle combination comprising: an inner funnel comprising a top edge, a bottom edge, a top flow area about the top edge, a bottom flow area about the bottom edge, with the top flow area being greater than the bottom flow area, and an aperture at the bottom edge operating as a nozzle; a rim extending outwardly from the bottom edge of the inner funnel; a first electrical contact located about the top edge of the inner funnel; and a second electrical contact located on the rim distant from the inner funnel; wherein the inner funnel is adapted to receive the additive material from its top edge, to guide the additive material travelling from its top edge to its nozzle, and to heat the additive material therebetween, and wherein the C/NC is adapted to heat as current travels between the first electrical contact and the second electrical contact, thereby heating the additive material travelling in the inner funnel.

[0029] According to an embodiment, there is provided a 3D printer for printing 3D objects in a heated chamber comprising a build surface, the 3D printer comprising: a feeding assembly; and a printer block receiving printing material from the feeding assembly, the printer block comprising: a first micro-kiln heating the printing material to a melted condition; and a second micro-kiln fluidly connected to the first micro-kiln and receiving the melted material from the first micro-kiln, the second micro-kiln comprising: a heating component heating the printing material contained in the second micro-kiln to a melted form; a cooling component cooling off the printing material contained in the second micro-kiln to a solid form; and a nozzle fluidly connected to the second micro-kiln, and guiding flow of melted printing material on the build surface to print the 3D object from printing material.

[0030] According to an embodiment, there is provided a feeding system for queueing granules of printing material, the feeding system comprising: an audio amplifier generating audio signals; a speaker comprising a diaphragm, the speaker receiving audio signals from the amplifier with the diaphragm moving accordingly; and an acoustic feeder attached to the diaphragm, the acoustic feeder comprising a receiving area and a feeding hole distant from the receiving area, wherein the receiving area receives the granules which move towards the feeding hole under movements forced by the diaphragm over the acoustic feeder; wherein the feeding system takes raw materials and orders them in a queue.

[0031] According to an embodiment, there is provided an optical sorter for sorting printing material, the optical sorter comprising: a controller receiving signals and generating command signals; an audio amplifier generating audio signals based on command signals received from the controller; horn comprising an upstream extremity and an output hole facing a sorting area where

granules are falling, wherein the output hole is distant from the upstream extremity; a speaker mounted to the upstream extremity of the horn, the speaker comprising a diaphragm generating waves in the horn based on audio signals received from the amplifier, wherein the waves are amplified by the horn and are exiting the horn though the output hole; an optical sensor detecting granules falling towards the sorting area and transmitting signals to the controller accordingly; and sorting bins located about the sorting area, the sorting bins receiving sorted granules, wherein the optical sensor is configured to generate signals that will produce acoustic waves that push the granules as they pass in the sorting area towards the corresponding sorting bin according to the signals generated by the optical sensor.

[0032] According to an embodiment, there is provided a 3D printer for printing 3D objects with a variety of printing materials comprising at least glass, the 3D printer comprising: a feeding assembly; and a micro-kiln receiving printing material from the feeding assembly, the micro-kiln comprising: a heating component heating the printing material at a temperature set based on nature of the printing material to a melted form; a cooling component cooling off the printing material at a temperature set based on nature of the printing material to a solid form; a nozzle guiding flow of melted printing material to print the 3D object from printing material; and a heated chamber comprising a building surface receiving the melted printing material flowing out of the nozzle for printing the 3D objected thereon.

[0033] Features and advantages of the subject matter hereof will become more apparent in light of the following detailed description of selected embodiments, as illustrated in the accompanying figures. As will be realized, the subject matter disclosed and claimed is capable of modifications in various respects, all without departing from the scope of the claims. Accordingly, the drawings and the description are to be regarded as illustrative in nature and not as restrictive and the full scope of the subject matter is set forth in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] Further features and advantages of the present disclosure will become apparent from the following detailed description, taken in combination with the appended drawings, in which:

[0035] Fig. 1 is a schematic view of a 3D printer in accordance with an embodiment;

[0036] Fig. 2 is a schematic view of the components involved in the sorting process in accordance with an embodiment;

[0037] Fig. 3 is schematic top view of the components involved in the feeding of the printer block with granules according to an embodiment;

[0038] Fig. 4 is a schematic side cut view of the printer block of the 3D printer according to an embodiment;

[0039] Fig. 5 is a schematic partial cut view of the printer block of Fig. 4;

[0040] Fig. 6 is a perspective view of an acoustic feeder according to an embodiment;

[0041] Fig. 7 is a side view of a speaker plug used to attach the acoustic feeder of Fig. 6 to a loudspeaker according to an embodiment;

[0042] Fig. 8 is a perspective view of a horn used in the sorting granules according to an embodiment;

[0043] Fig. 9 is perspective view of an insulating brick according to an embodiment;

[0044] Fig. 10 is a perspective view of a rod assembly according to an embodiment;

[0045] Fig. 11 is perspective view of a nozzle used at the output of the printer block according to an embodiment;

[0046] Fig. 12 is a schematic view illustrating the configuration of components of the printer block which are heated or cooled down according to an embodiment;

[0047] Fig. 13 is a perspective view of a heated chamber according to an embodiment;

[0048] Fig. 14 is a perspective view of a Computer Numerical Control (CNC) machine according to an embodiment;

[0049] Figs. 15 and 16 are perspective views of part of 3D printer in accordance with another embodiment;

[0050] Fig. 17 is a schematic of a 3D printer in accordance with an embodiment;

[0051] Fig 18 is a top perspective view of a feeder of a 3D printer in accordance with an embodiment;

[0052] Fig. 19 is a picture of a tube comprising an inner tube and an outer tube in accordance with an embodiment;

[0053] Fig. 20 is a picture of an exemplary power controller adapted for the operation of an embodiment of a 3D printer;

[0054] Fig. 21 is a picture depicting two crucibles in accordance with embodiments of the 3D printer;

[0055] Fig. 22 is a side view of a crucible in accordance with an embodiment;

[0056] Fig. 23 is an elevation view of the crucible of Fig. 22;

[0057] Fig. 24 is a side sectional view of the crucible of Figs. 22 and 23 according to a vertical plan passing through a central axis of the crucible;

[0058] Fig. 25 is a top sectional view along cutting line A-A of the crucible of Figs. 22 to 24;

[0059] Fig. 26 is an elevation view of an embodiment of a crucible with sensing wires; and

[0060] Fig. 27 is a schematic of controlling components of an embodiment of a 3D printer.

[0061] It will be noted that throughout the appended drawings, like features are identified by like reference numerals.

DETAILED DESCRIPTION

[0062] Nowadays, recycled glass is a widely available and low-cost material. So, in light of the text by John Klein from MIT: Klein, J. (September 2015). Additive Manufacturing of optically transparent Glass. [Master thesis, Massachusetts Institute of Technology], it becomes apparent that there is an opportunity to decrease the cost of operating a 3D printer by both designing a 3D printer capable of manufacturing its own replacement parts; and being able to use a variety of printing materials, including recycled glass material which is widely available at low costs.

[0063] Recycled glass is basically considered garbage these days; recycled glass is currently sold for instance as abrasive, pool filter material, or additive/ingredient for concrete products. Recycled glass can currently be bought in bulk, with a fixed granule size, for less than 0.50$/kg, and in some cases at even lower prices considering that some cities are spending money to get rid of their recycled glass rather than selling it.

[0064] Accordingly, the 3D printer, aka Additive Manufacturing device or AMD, described herein takes advantage of the present situation by using widely available recycled glass as a printing material. Nevertheless, alternative printing materials are considered with respect with the 3D printer of the subject-matter, such as a variety of materials available in powder or granule formats. Using one such alternative printing materials is intended to require simple adjustments to the 3D printer described herein. Alternative printing material suitable for the present 3D printer comprises sugar, PLA granules, ABS granules, PETG granules, metal, sand, Martian regolith, etc. Requirements for these materials comprise that a material is available to serve as a crucible to resist the temperatures associated with printing that printing material when molten.

[0065] With respect to the present description, references to "3D printer" should be understood to reference to a tool or device adapted to perform additive manufacturing processes through deposition of additive materials. Accordingly, the expression "3D printer" encompasses any device or subsystem of a tool adapted to perform such a process, regardless of the nature of the outcome of the process.

[0066] With respect to the present description, references to items in the singular should be understood to include items in the plural, and vice versa, unless explicitly stated otherwise or clear

from the text. Grammatical conjunctions are intended to express any and all disjunctive and conjunctive combinations of conjoined clauses, sentences, words, and the like, unless otherwise stated or clear from the context. Thus, the term "or" should generally be understood to mean "and/or" and so forth.

[0067] Recitation of ranges of values and of values herein or on the drawings are not intended to be limiting, referring instead individually to any and all values falling within the range, unless otherwise indicated herein, and each separate value within such a range is incorporated into the specification as if it were individually recited herein. The words "about," "approximately," or the like, when accompanying a numerical value, are to be construed as indicating a deviation as would be appreciated by one of ordinary skill in the art to operate satisfactorily for an intended purpose. Ranges of values and/or numeric values are provided herein as examples only, and do not constitute a limitation on the scope of the described realizations. The use of any and all examples, or exemplary language ("e.g.," "such as," or the like) provided herein, is intended merely to better illuminate the exemplary realizations and does not pose a limitation on the scope of the realizations. No language in the specification should be construed as indicating any unclaimed element as essential to the practice of the realizations.

[0068] In the following description, it is understood that terms such as "first", "second", "top", "bottom", "above", "below", and the like, are words of convenience and are not to be construed as limiting terms.

[0069] The terms "top", “up”, “upper”, "bottom", “lower”, “down”, “vertical”, “horizontal”, “interior” and “exterior” and the like are intended to be construed in their normal meaning in relation with normal installation of the product.

[0070] Further, in the following description, the term “crucible” should be construed as “a vessel of a very refractory material used for melting and calcining a substance that requires a high degree of heat” (see Merriam-Webster Online Dictionary at https://www.merriam-webster.com/dictionary/).

[0071] Similarly, the term “nozzle” should be construed as “a short tube with a taper or constriction used (as on a hose) to speed up or direct a flow of fluid", or, according to Wikipedia (https://en.wikipedia.org/wiki/Nozzle), “a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe". Thus, “nozzle” should be as commonly construed by person of the art as a type of outlet adapted for delivery of a fluid out of a constrained guided space in a controlled fashion.

[0072] Referring to the drawings in general, to efficiently describe the 3D printer **10** of the present subject-matter, the components of the 3D printer **10** are described following the path of the printing material, from raw material to the printed object.

[0073] Referring now to Fig. 1, the 3D printer **10** comprises a feeder block **12** using a flexible tube **182** to feed a printer block **200** with granules **90**. The printer block **200** is adapted to melt the granules **90** and to lay down, aka to deposit, on a build surface of a kiln assembly **262**, a flow of molted material. Positions in which the material is laid down are controlled by a Computer Numerical Control (CNC) machine **290,** which moves the printer block **200** relative to the build surface of the kiln assembly **262**; the latter being used as a heated chamber **264** to controllably cool down the molten material according to a desired rate. When all the material required to 3D print a piece is laid down on the build surface, the 3D piece is cooled down slowly.

[0074] Referring now more particularly to Fig. 2, the feeder block **12** of Fig. 1 comprises a reservoir **100**, located substantially at the top of the 3D printer **10** in which the printing material, e.g., the recycled glass beads, hereinafter called granules **90**, are placed. The reservoir **100** ends at its base with a tube **102** having an open extremity **104** located inside a feeder **110**, namely an acoustic feeder **112** (see Fig. 6). The open extremity **104** is located above the floor of the acoustic feeder **112**.

[0075] One must note that the acoustic feeder **112**, as most of the other parts, either specifically mentioned or not as such, is designed to be easily printed using the 3D printer **10**.

[0076] The granules **90** are freely fed to the acoustic feeder **112**, with the flow of granules **90** travelling from the reservoir **100** to the acoustic feeder **112** being controlled by the acoustic feeder **112** according to a pull process. More specifically, the acoustic feeder **112** controls the quantity of granules **90** and the movement of the granules **90**, which controls the inflow of granules **90**.

[0077] Movements of the acoustic feeder **112** are driven by a linear motor **120**. According to an embodiment, a speaker such as a loudspeaker **122** is used as linear motor **120** to move the acoustic feeder **112**. An audio amplifier **124** connected to the loudspeaker **122** controls the movements of the acoustic feeder **112** through the movement of the diaphragm **126** of the loudspeaker **122**. By controlling the characteristics (e.g., volume, amplitude, frequency and shape) of the sound waves to be produces by the loudspeaker **122**, desired movements are forced on the acoustic feeder **112** attached to the diaphragm **126** of the loudspeaker **122**.

[0078] Referring particularly to Fig. 6, the acoustic feeder **112** comprises a housing **302** comprising a receiving extremity **304** and a feeding extremity **306**. The housing **302** from the receiving extremity **304** to the feeding extremity **306** has a generally funnel shape leading the granules **90** towards a queueing formation towards the feeding extremity **306**. The walls **308** of the

housing **302** are ribbed to provide resistance to the advancing movement of the granules **90**. The floor **310** of the acoustic feeder **112** is also ribbed and further relatively raised from the receiving extremity **304** to the feeding extremity **306**. At the feeding extremity **306**, a feeding hole **312** allows the passage of a single granule at the time out of the acoustic feeder **112**. Thus, the general shape of the acoustic feeder **112** and characteristics leads the granules **90** under movement forces by the linear motor **120** to a one-by-one passage of the granules **90** out of the acoustic feeder **112** through the feeding hole **312**.

[0079] According to an embodiment, the configuration of the feeder **112** is less complex. The less complex feeder **112** comprises a floor **310** extending from a slope of about zero (0) degrees (thus horizontal) or slightly negative slope relative to the flow of granules, with the slope of the floor **310** increasing gradually to a significant slope (e.g. thirty (30) degrees) near the feeding hole **312**. According to an embodiment depicted on Fig. 18, the feeder **112** features a channel **311** instead of a feeding hole **312**.

[0080] Referring back to Fig. 2. advantages of loudspeakers **122** over other types of linear motors **120** resides in its cost and wide availability, as the ease of controlling the resulting movements forced by the loudspeaker **122** onto the acoustic feeder **112**.

[0081] For operation, the acoustic feeder **112** is attached to the loudspeaker **122** through a speaker plug **116**, with the movement forced onto the acoustic feeder **112** following the axis of the speaker plug **116**. When operating at appropriate parameters set according to the characteristics (e.g. size) of the granules **90**, the movements of the acoustic feeder **112** results in the granules **90** moving towards the exit extremity **119** of the acoustic feeder **112** with the contact of the granules **90** over the walls and floor of the acoustic feeder **112** ordering the granules **90** in a queue formation. According to an embodiment, the acoustic feeder **112** is attached to the loudspeaker **122** using another 3D printed part. i.e., the speaker plug **116** (see Fig. 7), e.g., glued at one extremity to the acoustic feeder **112** and at the other extremity to the diaphragm **126** of the loudspeaker **122**. By attaching the assembly in a slightly off-centered fashion with respect to the diaphragm **126**, the profile of the acoustic/kinetic impulse forced on the acoustic feeder **112** may be slightly changed, in order to provide modifications in the vertical and/or horizontal components of the movements forced to the acoustic feeder **112**.

[0082] Below the acoustic feeder **112**, about the exit extremity **119**, are two (2) infinite screws **132**, **134** on which fall the granules **90**. The two (2) infinite screws **132**, **134** are spinning in opposite directions to slowly move the granules **90** at constant speed over a path along the length of the infinite screws **132**, **134**. Along their travel path, the granules **90** are scanned by optical sensors **142**, detecting the characteristics of the granules **90** to sort them out. Accordingly, granules **90** are either selected or rejected for 3D printing. Reasons for which granules **90** are rejected can be, for example,

that among the raw material are granules of ceramic, which are intended to be removed from the mix since they do not present the same characteristics. This sorting process removes the rejected granules from the raw material; thus, sorting the rejected granules and the granules **90** to be used for 3D printing.

[0083] According to an embodiment depicted on Fig. 18, an optical sensor **448** is placed directly on the moving acoustic feeder **112**, above the downward slope near the exit. The granules **90** are sensed optically, e.g., observed using a camera while lit by a light source in front a color-coded background **313**. A condition for contrasts is therefore reached, that condition helping for classification of the granules **90**.

[0084] According to embodiments, other components and alternative algorithms may be used to detect, sort, and identify characteristics of granules **90** without departing from the object of the present 3D printer **10**.

[0085] According to an embodiment, a magnet (not shown) is mounted along the path of the granules **90** preceding the optical sensors **142**. The magnet allows detecting the presence of metal in the raw material. The magnetic force produced by the magnet is used to remove the metallic material from the granules **90** when metallic material passes close to the magnet.

[0086] Configuration of the infinite screws **132**, **134** further results in smaller size material (smaller than the nominal granule size), such as powder falling through the space between the infinite screws **132**, **134** as the granules **90** are forced to travel via the infinite screws **132**, **134**, with the smaller size material being collected below.

[0087] To sort the granules and thus reject unwanted material from the raw material and to obtain the desired quality of granules **90** in a low-cost fashion, an optical sorter **150** comprising a subwoofer loudspeaker **152** with a horn **154** (see Fig. 8) is used. The sorting process concentrates air waves towards the granules **90** falling in the sorting area **170** in front of the horn **154** and sends a sound pulse at the appropriate moment to push out material in the appropriate bin **160**. When an inverse saw-tooth wave is sent by the audio amplifier **124** to the subwoofer loudspeaker **152**, the shock wave is mostly sent to the output hole **324**, while the slower return of the diaphragm **126** of the subwoofer loudspeaker **152** to its rest position can breathe through the extra holes **326**. Using various amplitudes, the granules **90** are pushed into different bins **160** according to their size, thus sorting the granules **90**.

[0088] A controller **175** (illustrated in two separate parts on Fig. 2) is connected to the audio amplifier **124** and to the optical sensors **142**. The controller **175** controls the signals to be generated by the loudspeaker **122** and the subwoofer loudspeaker **152**. As one task, the controller **175** controls the movement of the acoustic feeder **112**. Additionally, the controller **175**, based on signals received

from the optical sensors **142**, controls the subwoofer loudspeaker **152** to generate sound pulses in a timely manner to sort the falling granules based upon identification of their characteristics.

[0089] Such an optical sorter **150** sorting the granules **90** one by one is ill-designed to sort large amounts of material. However, since such an optical sorter **150** is so cheap to produce using a 3D printer **10**; comprising a few parts that can printed, and two (2) loudspeakers, one (1) 2-channels audio amplifier (or two 1-channel amplifiers), one (1) electronic chip, one (1) 2-channels DAC (digital-to-analog converter) (or two 1-channel DACs), and a few sensors, which are all mass-produced components easily available nowadays, one may simply make a plurality of these optical sorters **150** to increase the material processing capability, thus increasing the amount of material processed per hour at a low cost.

[0090] Of course, one using source material that is pure, in powder, or pre-sorted, can skip the steps involving the optical sorters **150**, including the displacement of the material using the two (2) infinite screws **132**, **134** and the rejection operation. Accordingly, one would just keep the acoustic feeder **112**.

[0091] Further advantage of the present embodiment of the acoustic feeder **112** is that, in addition to ordering the granules **90** to process them one-by-one, the acoustic feeder **112** regulates the flow into the flexible tube **182** (see Fig. 1) after the optical sorting process. The flexible tube **182** extends from the acoustic feeder **112** to the moving head, a.k.a. printer block **200** of the 3D printer **10**, leading the granules **90** therethrough. The connecting flexible tube **182** is further driven to vibrate to prevent granules **90** from getting stuck when the hot end is positioned in such a way that part of the flexible tube **182** is close to a horizontal position. The vibration of the flexible tube **182** participates in a controlled flow of granules **90** therethrough.

[0092] Referring additionally to Fig. 4, at the top of the printer block **200** is the flexible tube **182** feeding a transparent tube **183** with the granules **90**, with an optical sensor **184** measuring the level of granules **90** in the transparent tube **183**. The optical sensor **184** is responsible for commands to be sent to the acoustic feeder **112** to keep the level of granules **90** at the desired height in the transparent tube **182**. The height of the granules **90** can be arbitrarily increased to increase pressure to the lower parts.

[0093] According to an embodiment, to respond to situations when the pressure requirements would result in a required height of granules **90** in the transparent tube **183** that would be unreasonable, or when the granules **90** tend to self-support themselves, and when these issues cannot be fixed by using a transparent tube **183** of a proper diameter, an acoustic hammer (not shown, see hammering controller **522** from Fig. 27 that would control an acoustic hammer as an example of driving means) is placed on top of the transparent tube **183** using a similar part as for

the sorting process (see Figs. 2 and 8) with the diameter of the output hole being about the size of the transparent tube **183**.

[0094] Referring additionally to Fig. 12, further along the path of the granules **90**, the granules **90** enter a radiator **192** that cools off heat generated below as explained after, so the parts above the radiator **192** can work at appropriate temperature.

[0095] To 3D print high-quality objects, one challenge resides in controlling the flow of molten printing material. Such control requires the ability to stop the flow of molten printing material on demand, to move the printing head, and then to restart the flow of printing material. Such a level of control with the prior art usually requires pure printing material. The present 3D printer **10** used a liquid/solid printing material solution to overcome these drawbacks.

[0096] Referring particularly to Figs. 4 and 5, after the radiator **192**, and some extra tubing (not shown) for thermal gradient, the granules **90** enter a cylinder **212** made from a material suitable to operate as a crucible for the material of the granules **90**. This cylinder **212**, or main micro-kiln **212**, is located inside an electrical insulator **214** (e.g., comprising at least one of air, vacuum, quartz, etc.) wrapped with a heating wire **216** (e.g., made of katlan, tungsten, etc.) capable of heating the granules **90** so that they melt at the material-specific temperature. The temperature is measured by a thermal sensor **222**, with the whole assembly being kept inside an appropriate thermal insulator **218** (e.g., alumina, fiber glass, etc.). The granules **90,** once melted, pour from the main micro-kiln **212** into a smaller second micro-kiln **232** (which comprises its own heater **234** and thermal sensor **242**) which has thermal mass that is designed for a desired nozzle output size; i.e., minimized for the desired nozzle output size. That second micro-kiln **232** is equipped with a cooling assembly **244** that can actively cool down (using for instance gas or liquid) the melted material, allowing to solidify the material close to the output nozzle **252**, or in other words practically just at the output nozzle **352** of Fig. 11.

[0097] According to an embodiment, for a particular range of sizes of the output nozzle **252**, i.e., small sizes of output nozzles, an optical pyrometer (not shown) and infrared heating component (not shown) are used instead of the thermocouple and of the heating wire described before with respect to at least the second micro-kiln **232**.

[0098] For the operation of the 3D printer **10**, controlling the flow and viscosity of the molten material **260** in a precise manner is possible through:

- varying the amplitude and frequency of the acoustical hammer;

- varying quickly the output temperature;

- controlling the overall pressure with the granules level; and

- controlling the temperature of the main kiln **212**.

[0099] Hence the flow is precisely controlled which is and improvement over the prior art which usually attempt to obtain the same result by moving the filament. The flow of material can be approximated by the present characteristics of the sound waves sent to the acoustic feed required to keep the current desired granules height level, as the flow of a given material for a specific sound wave shape, volume, and frequency, can be measured in advance.

[00100] By reducing the temperature of the output while slightly continuously moving the printer block **200**, the operator of the 3D printer **10** can detach a filament of molten material **260** from the 3D printed object and move the printer block **200** to a next position with no stringing, oozing, or other issues that occur typically with most prior art 3D printers, even when they are properly tuned with retraction settings meant to avoid these issues.

[00101] Afterwards, as shown in Fig. 1 and additionally in Fig. 13. the molten material **260** is deposited on a build surface of the kiln assembly **262** (e.g., steel plate, glass, kiln wash, etc.), in a heated chamber **264** (a kiln, heated at a temperature of, for example, 500 °C for glass, 100 °C for ABS, 60 °C for PLA, etc.) that can also serve as a lehr for slowly reducing the temperature of the molten material **260** and the whole printed object.

[00102] According to an embodiment, the top part of the 3D printer **10** can be moved above another heated chamber (not shown) once a first object is 3D printed, to print another object, while the completed printed object slowly cools down. This two-chamber solution contributes to optimize throughput.

[00103] Now referring to Fig. 3 there is shown a plurality of feeder blocks **12** around a single printer block **200**. The foregoing description provides the path of a given granule **90**. According to other embodiments, multiple printing materials can each have their own acoustic feeder **112** that pours into the flexible tube **182** toward the printer block **200**, providing a method of, for example, mixing colors, incorporating additives in the mix, etc. Fig. 3 illustrates a series of individual paths **190** in a star-like shape, comprising each an acoustic feeder **112** and other previously described components, enabling an embodiment in which a plurality of printing materials are fed individually and mixed before reaching the printer block **200**.

[00104] By using dual extruders (not shown), the 3D printer **10** can be operated with a variety of different materials, such as glass and aluminum.

[00105] The present design can further work with granules **90** or powder material as described, with the use of powder instead of granules **90** requiring minimal changes to the design of the 3D printer **10**.

[00106] The 3D printer **10**, using such a variety of printing materials as discussed before, allows potentially to 3D print motors and circuit boards for the price of the raw material in granules and the operating energy.

[00107] According to an embodiment, the 3D printer **10** can be bootstrapped to an external Computer Numerical Control (CNC) machine **290** (see Figs. 1 and 14) and a kiln assembly **262**, the 3D printer **10** can print components of its own kiln assembly **262** and the frame of the CNC machine **290**. Indeed, using glass, the operator of the 3D printer **10** can print an insulating brick **330** (see Fig. 9) based on a custom design. Since for glass material, the kiln assembly **262** needs to resist to a temperature of about 500 °C (while the glass material is printed at about 1000 °C), it is possible for the 3D printer **10** to print the insulating bricks **330** making a kiln assembly **262** enclosing a similar brick as the one being printed. Likewise, many parts of the rest of the 3D printer **10** can be 3D printed by the 3D printer **10**. As discussed before, RepRap™ printers (http://reprap.org) use this principle, with the limitation of printing only plastic parts. Since stiffness of printed plastic parts is relatively low, that characteristic limits severely the components and thus the proportion of the RepRap™ printer that can be 3D printed on the same printer or a similar one. In comparison, stiffness of the glass is substantially higher, hence usable to print more robust parts, including gears (which will have to be adjusted for that material in comparison to metal).

[00108] According to another embodiment of a 3D printer, with at least parts depicted on Figs. 15 to 26, alternatives to the insulating bricks **330** may comprise bricks comprising at least a layer of foam or made of foam material manufactured with the 3D printer.

[00109] Referring to Fig. 10, the present 3D printer **10** also allows to print rods **340** that can potentially be larger than the maximum build volume of the 3D printer **10**; such by printing a plurality of smaller rods **342**, one or more connecting piece(s) **344**, and screwing the printed rods **342** and the connecting piece(s) **344** together as an assemblage (not shown). Such adaptations are available for a variety of parts, including actual frame parts.

[00110] Alternatively, other configurations may be used such as tubes (e.g., square tubes and cylindrical tubes) that may comprise for example insert portions to join. The joint can be fixed to each other using glue, being weld or using alternative methods known in the art.

[00111] Finally, the present design of a 3D printer **10** is well adapted or requires small adaptations for harsh environments where procurement is difficult, expensive or almost impossible.

[00112] For instance, the 3D printer **10** can be adapted to 3D print objects using Martian regolith (with potentially the use of additives to lower the melting point of the Martian regolith). Accordingly, one such 3D printer could be shipped on Mars, with the capability of being operated to replicate itself for maintenance, for production improvements or specific operations. It may further

be used to gradually increase the production capabilities and the size of the printed objects. The design of the present 3D printer **10** can thus be optimized to minimize the mass of the printer components that cannot in current conditions be 3D printed with the current 3D printer **10**.

[00113] This particular feature is, of course, still very useful here on Earth. The operator of a 3D printer **10** can use regular sand when recycled glass is too complex to obtain, for instance in countries lacking the appropriate infrastructures allowing easy procurement of recycled glass.

[00114] Electronics components that cannot in current conditions be 3D printed are lightweight and are available at low costs nowadays. The remaining parts that cannot in current conditions be 3D printed are the motors, which are the remaining costly and/or heavy parts that need to be bought instead of printing them. Therefore, such a 3D printer would be widely accessible for everyone wishing to own one at a reasonable price. Further, the process of building it, maintaining it and operating it in terms of printing material would also be accessible to a wide proportion of the population.

[00115] Referring now to Figs. 15 to 17, parts of another embodiment of a 3D printer is illustrated. The 3D printer comprises an alternative feeding, heating and deposition assembly comprising a feeding tube **450** (i.e., a material feeding conduit, depicted on Fig. 19) comprising an inner tube **460** fed at the top extremity **462** with granules **90** and connected to a material delivery device **420**, which may sometimes be referred to as a crucible, at the bottom extremity **464**. The feeding tube **450** further comprises an outer tube **480** also connected to the material delivery device **420** at its bottom extremity **464**. It is to be noted that the material delivery device **420** can be interpreted to comprise a crucible portion and a nozzle portion as described herein.

[00116] Other components such as thermal insulator **418** (similar to thermal insulator **218**), and granule feeding components up flow from the feeding tube **450** comprising an optical sensor **456** monitoring flow of material (similar to optical sensor **184**, part of feeding sensors **512)** remain similar as with the 3D printer 10.

[00117] Regarding the thermal insulator **418**, a variety of material may be used for that part, with the selection of the material as the dimensions of the thermal insulator **418** being based on the operating temperature of the 3D printer. Examples of materials for the thermal insulator **418** comprise plaster, concrete and castable alumina. Further alternative materials are listed at https://www.zircarceramics.com/product/alumina-castable-type-ziralcast-94/.

[00118] Referring additionally to Figs. 21 to 25, the material delivery device **420** is made of, or at least comprises, electrical and thermal conductive material, e.g., stainless steel or for very high temperature platinum. The material delivery device **420** is adapted to perform a plurality of functions typically performed by separated components in known 3D printers. The material delivery device

420 operates as a nozzle for depositing material and as a heating element for changing the phase of the granules **90** from a solid state into a liquid state. The material delivery device **420** has female inner fitting **422** about its top edge **423**; the top edge **423** being characterized by an associated perimeter (i.e., a top perimeter), a corresponding circumference and a corresponding flow area. The female inner fitting **422** is adapted for connecting the inner tube **460**. The female inner fitting **422** operates as a cylindrical contact face with the inner tube **460**. The material delivery device **420** is adapted to lead and pour granules **90** to the material delivery device **420** from its bottom edge **425**; the bottom edge **425** being characterized by an associated perimeter (i.e. a bottom perimeter which is smaller than the top perimeter), a corresponding circumference and a corresponding flow area. The interface of the inner tube **460** with the material delivery device **420** further operates as an electrical connector, aka electrical contact, used to polarize the inner fitting **422**. The material delivery device **420** has female outer fitting **432** for connecting to the outer tube **480**; the passage between the inner tube **460** and the outer tube **480** provides fluid communication between inlet **498** and the bottom end of the outer tube **480** for purposes explained hereinbelow. The interface of the outer tube **480** with the material delivery device **420** further operates as an electrical connector, aka electrical contact, used to polarize the outer fitting **432**.

[00119] One should note that the reference to materials of the material delivery device **420** should include related materials and platinum should include related alloys. Relatively to the use of platinum, one should understand that platinum comprises platinum-based alloys such as platinum-iridium alloys, and platinum-rhodium alloys. It further encompasses other material and allows, wherein the selection of the material or alloy is based on at least its thermal and electrical characteristics. Examples of materials and alloys to select from are provided through Fischer, B., Behrends, A., Freund, D., Lupton, D. F., Merker, J. (1999). High Temperature Mechanical Properties of the Platinum Group Metals. Stress-Rupture Strength and Creep Behaviour at Extremely High Temperatures. Platinum Metals Rev, 43, 18-28. Other characteristics that may influence the selection comprises the chemical inertia ort lack of reactiveness with other chemical compounds.

[00120] The inner tube **460** and the outer tube **480** are joined with the material delivery device **420** using according to a first non-limiting method a pressure conical fitting, or according to a second non-limiting method by friction welding. Alternatively, the tube **450** and the crucible may be made using the same method or as a single component.

[00121] The material delivery device **420** comprises an inner funnel **424** extending from the inner fitting **422**, and an outer funnel **434** extending in periphery of the inner funnel **424**. The inner funnel **424** has a large aperture at its top and a small aperture at its bottom. The additive material therefore flows (i.e., is guided) from the large aperture to the small aperture.

[00122] The outer funnel **434** ends at its bottom (small) extremity with an aperture **438** (i.e., the small aperture of the outer funnel **434**) operating as a delivery nozzle for material deposition, aka liquid resulting from melted granules **90**. A junction wall **440** joins and at least partially divides the inner funnel **424** to the outer funnel **434**. Thus, the interior space **435** in the inner funnel **424** is at least partially concealed from the exterior space **445**; a space enclosed by the outer funnel **434**.

[00123] According to an embodiment, the junction wall **440** features slits **442** that are sized to obstruct flow of molten material from within the enclosure defined by the junction wall **440** toward to outer funnel **434**, wherein the outward flow is prevented by the viscosity of the molten material, but wherein the size of the slits **442** allows air movement to be directly coupled to the molten enclosed in the junction wall **440**. Thus, the slits **442** provide openings through which fluid communication is provided between the interior space and the exterior of the inner funnel **424** above the connection of the inner funnel **424** with the outer funnel **434**.

[00124] According to an embodiment, no slits **442** are present in a realization where the influence of air pressure on the molten material is unnecessary and/or when structural and thermal characteristics for the material delivery device **420** are the utmost important characteristics to obtain and/or when the presence of slits **442** would work against these desired characteristics for the material delivery device **420** or the desired operating conditions.

[00125] Thermal characteristics of the material delivery device **420** depend on the material(s) composing the material delivery device **420** and on design parameters, e.g., diameter, thickness, length, etc., of the material delivery device **420** since the crucible heats based on electricity travelling between the polarized inner fitting **422** and the polarized outer funnel **434**.

[00126] In the depicted realization, the material delivery device **420** is designed in such a manner that the portion with highest electrical resistance, i.e., the biggest voltage drop / power output, is near the portion operating as a delivery nozzle, near the aperture **438**. That characteristic is due to the electrical resistance increasing with the decrease of the diameter, in other words the bigger the circular diameter of the funnel / cone diameter, the smaller the electrical resistance. Further, the higher the electrical resistance, the higher the heat generated and thus the temperature of the corresponding surface or portion. So, it results that, with the depicted material delivery device **420**, most heat is generated near the bottom, and the portion connecting both funnels **424**, **434**, namely the junction wall **440**, has the greatest resistance, heat most where the most needed.

[00127] Practically, the resistance profile of the material delivery device **420**, thus the heating profile of the material delivery device **420**, can be adjusted by varying sizes and thicknesses to generate increase or decrease electrical resistance where it is needed.

[00128] According to an embodiment, a plating solution may be used to modify electrical resistance on desired surfaces.

[00129] Referring now particularly to Fig. 21, the left material delivery device **420**' is made of stainless steel. The right material delivery device **420**" is made of platinum. The platinum material delivery device **420**" features high electric resistivity, thus heats to high temperatures. Accordingly, tubes **460** and **480** are made of platinum on contacting sections to resist to these high temperatures. Above, the materials of the tubes **460** and **480** may be modified through for example sectional tubes joined together as the temperature decrease. For example, a stainless-steel tube portion may be joined to a platinum tube portion farther from the material delivery device **420**, and a copper tube portion may be joined even farther.

[00130] Referring additionally to Fig. 20, the tubes **460** and **480** are connected to a transformer **490** able to provide high current / low voltage / high power necessary for the current circulating in the material delivery device **420** to heat to the temperature needed. According to realizations, the reached temperature is up to about two thousand (~2000) degrees Celsius for a material delivery device **420** made of platinum and about nine hundred (~900) degrees Celsius for a material delivery device **420** made of stainless steel. Since the heat / temperature drops with the diameter, as explained above, only the small exit diameter will reach that peak temperature. Further, the material delivery device **420** may be designed with diameters for the fittings **422**, **432** that are big enough for the temperature at the fittings **422**, **432** to be low enough for refractory material (e.g. plaster/alumina) to be used to hold the tubes **460**, **480** to the material delivery device **420**.

[00131] Referring now additionally to Fig. 27, since the electric power source is of a known voltage, a current sensor (flow sensor **514**) can be used to measure the resistivity of the material delivery device **420** which doubles as a temperature measurement since the electrical resistance of the material delivery device **420** changes with temperature. Accordingly, the electrical power controller **524** and the flow sensor **514** define a feedback temperature control system.

[00132] Referring to Fig. 26, a contemplated solution to measure the temperature of the material delivery device **420** comprises a Kelvin sensing (see reference https://en.wikipedia.org/wiki/Four-terminal_sensing) using a plurality of wires **458** contacting the material delivery device **420** at one extremity and plugged in a sensor (not shown) at the other extremity to sense changes in electrical characteristics of the material delivery device **420** as the temperature of the crucible changes, and thus to deduct the current temperature of the material delivery device **420**. As above, a signal is transmitted to the electrical power controller **524** to perform live control of the temperature of the material delivery device **420**.

[00133] The entire material delivery device **420** can be, for example, connected as part of an assembly comprising a line noise filter connected to a relay, the latter connected to a current transformer, with the latter connected to the material delivery device **420**. One can use a controller **502** to perform duty cycles to vary the average heating power. An alternative sophisticated approach would have to have multiple relays using a multi-tap current transformer to allow multiple heating levels, or a servo-controlled variac in front of the current transformer.

[00134] The present solution solves multiple major issues occurring with previous 3D printers comprising heating wires. Such previous solutions do not allow to operate according to similar temperature limits as the present material delivery device **420**. Further the use of heating wires results in a delay between the wires being powered and the metal being heated due to in-between components. Such a delay practically complicates the manufacturing process about and at the delivery nozzle.

[00135] One should note that, according to the 3D printer operating with the material delivery device **420**, the use of a heat sink or radiator (similar to radiator **192**), a cooling assembly (similar to cooling assembly **244**), and heating wires (similar to heating wire **216** and heater **234**) are either optional of completely prevented since the granules **90** are heated when in the material delivery device **420**.

[00136] According to the depicted realization, the outer tube **480** has a small hole **488** that allows the passage from the outside of a sensor wire ending about the nozzle output between the two inner funnel **424** and the outer funnel **434**. Accordingly, an optical sensor **494** or a pyrometer, and in case of low temperature operation a thermocouple or thermistor (with any of these being in the category of flow sensors **514**, Fig. 27) can sense the nozzle output, and thus, directly measure its temperature.

[00137] Referring now particularly to Figs. 17 and 19, the outer tube **480** comprises about its top extremity a T fitting **486**, for a gas/air flow driving means to be paired through the side connection to provide power and help with the control of the flow.

[00138] According to the depicted realization, the T fitting **486** provides a seal between the inner tube **460** and the outer tube **480.** Accordingly, power provided by the driving means, (i.e. flow-driving means), which is thus fluidly connected to the material delivery device **420** at the extremity of the feeding tube **450,** travels through that space to reach the material delivery device **420**. According to a realization, the seal may be made of plastic, ceramic, plaster, or glass, with the selection of the material used for the seal being based at least on the temperature that reach the seal when in operation, thus based on the characteristics of the molten material.

[00139] According to a realization, a subwoofer loudspeaker **452**, aka loudspeaker **526** from Fig. 27, is paired to the assembly. According to another realization, an air compressor **454** is connected to the inlet **498**. According to realizations, driving means influencing flow of material **90** in the material delivery device **420** may comprise an arrangement comprising a subwoofer loudspeaker **452** or an acoustic hammer.

[00140] The subwoofer loudspeaker **452** performs three different functions:

[00141] 1- Creating a temporary vacuum in the outer tube **480** and thus about the slits **442**. Where a typical 3D printer would retract the filament to create a vacuum to immediately stop the flow of material, application of negative Direct Current (DC) voltage to the subwoofer loudspeaker **452** creates a temporary vacuum combined with a temperature drop that participate in temporarily stopping the flow of molten material at the delivery nozzle;

[00142] 2- Accelerating the restauration of flow of molten material at the delivery nozzle. inversely, when the temperature is increased to restart the flow, application of positive DC voltage to the subwoofer loudspeaker **452** creates an overpressure that kickstarts the extrusion process.

[00143] 3- Temperature stabilization. By using acoustic waves instead of other options, the subwoofer loudspeaker **452** avoids providing a temperature inhibiting the flow of material and thus keeps the temperature stable, thus practically close to the point where capillary effect balances internal pressure / viscosity of the molten material. The acoustic waves can be used to control the flow by going slightly over and under the threshold where the capillary effect holds the molten material

[00144] Using an air compressor **454** as a flow-driving means involves high pressure air or another gas. With such a configuration, one can make the delivery nozzle spray the molten material in a way that creates foam or another type of materials wherein the molten material and the gas are mixed in the outcome material.

[00145] One should note that the 3D printer will be able to operate not only with glass, but with sugar, salt, plastic, even metal. The size of the delivery nozzle (aperture **438**) will be designed for a specific viscosity range of a material. For materials that have a broad viscosity range (i.e. glass), a broad range of sizes of delivery nozzles can be used since temperature can be adjusted. For materials with a narrower viscosity range (e.g. water, metal), the possible nozzle size will be decided based on the capillary effect, therefore having very delivery nozzles that have a very small diameter with low viscosity materials. The material delivery device **420'**, made of platinum, can operate in high temperatures quite above the temperature requires to operate with the glass, comprising with quartz, sand, and regolith (e.g. lunar regolith, Martian regolith or Earth regolith). The material delivery device

420", made of stainless steel, is less expensive to produce and allows to operate with almost anything requiring operating temperatures under the molting glass temperature.

[00146] According to a realization, a material delivery device **420** comprises an inner funnel **424** adapted at its top to be joined to a feeding tube similar to inner tube **460** feeding the material delivery device **420** with granules **90**, wherein the material delivery device **420** comprises at its top an electrical contact (similar to interface of the inner tube 460). The material delivery device **420** comprises at its bottom an aperture similar to aperture **438** operating as a nozzle for the deposition of material, and a rim (similar to outer funnel **434** but rather without the conic shape) extending outwardly from the crucible. The rim comprises distant to the inner funnel **424** a periphery about which is defined a second electrical contact (similar to interface of the outer funnel **434)**. Accordingly, the material delivery device **420** is powered through current provided through both electrical contacts and, wherein the electrical contacts being located far from small-diameter portions of the inner funnel **424** have their temperature increased less than the small-diameter portions of the inner funnel 424 through the travelling of current therethrough.

[00147] One should further note that operation of the present 3D printers may be involved in plans for extra-terrestrial 3d printed habitations that focus mainly on extruding concrete/cement which might not be easy to make on another planet, or requite a lot of material to be brought there (at a very high cost), while our solution do not require any additives and can 3d print directly with whatever available. This also allows for integrating larger 3d printed blocks of quartz or sand or other material into architectural buildings.

[00148] While preferred embodiments have been described above and illustrated in the accompanying drawings, it will be evident to those skilled in the art that modifications may be made without departing from this disclosure. Such modifications are considered as possible variants comprised in the scope of the disclosure.

CLAIMS:

1. An additive manufacturing device (AMD) for manufacturing objects through deposition of additive material over a build surface, the AMD comprising:

- an electric power source;
- a material feeding conduit comprising an inner tube and an outer tube, wherein the material feeding conduit feeds the inner tube with the additive material and the inner tube and the outer tube are electrically connected to the electric power source; and
- a material delivery device is in electrical and mechanical contact with the material feeding conduit, the material delivery device comprising an inner funnel having a large aperture and a small aperture whereby the additive material is guided from the large aperture to the small aperture, wherein the material delivery device further comprises an outer funnel located external to the inner funnel in electrical and mechanical contact with the inner funnel, the outer funnel having a large aperture which is in electrical and mechanical contact with the outer tube and wherein the large aperture of the inner funnel is in electrical and mechanical contact with the inner tube;

wherein the inner funnel is electrically conductive and, upon applying an electrical current to the inner funnel through the inner tube and the outer tube, heat is generated thereby heating the additive material travelling in the inner funnel.

2. The AMD of claim 1, wherein the inner tube is in electrical and mechanical contact with the large aperture of the inner funnel.

3. The AMD of claims 1 or 2, wherein the outer funnel further comprises a small aperture, wherein the outer funnel is joined to the inner funnel about the small aperture of the inner funnel and the small aperture of the outer funnel.

4. The AMD of claim 3, further comprising a junction wall extending about the small aperture of the inner funnel, whereby the junction wall joins the outer funnel to the inner funnel.

5. The AMD of claim 4, wherein the junction wall divides an interior space concealed by the inner funnel and an exterior space within the outer funnel, wherein the wall comprises openings through which the exterior space is in fluid communication with the interior space.

6. The AMD of claim 5, further comprising a flow-driving means fluidly connected to the outer tube, wherein the flow-driving means is adapted to transmit gas waves to the additive material about the small aperture of the inner funnel through the openings.

7. The AMD of claim 6, wherein the flow-driving means is a subwoofer speaker.

8. The AMD of claim 6, wherein the flow-driving means is an air compressor.

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9. The AMD of any one of claims 5 to 8, wherein the openings have dimensions and wherein the dimensions of the openings:

allow gas from the exterior space into the interior space; and

prevent the additive material from travelling from the interior space into the exterior space.

10. The AMD of any one of claims 1 to 9, further comprising:

- a sensor reading one of:
  - temperature in the material delivery device;
  - flow of additive material in the material delivery device; and
  - a physical characteristic of the material delivery device changing with the temperature of the material delivery device, and
- a power controller electrically connected to the electric power source,

wherein the power controller is adapted to modify the electrical power transmitted from the electrical power source based on readings from the sensor.

11. The AMD of any one of claims 1 to 10, further comprising an optical sensor monitoring flow of the additive material in one of:

- upstream from the material feeding conduit;
- in the material feeding conduit; and
- downstream from the material feeding conduit.

12. The AMD of any one of claims 1 to 10, wherein the material delivery device is made of a first material capable of resisting to a top temperature, and wherein one of the inner tube and the outer tube is made of a second material capable of resisting to a second temperature, wherein the second temperature is below the top temperature, and wherein the first material is different from the second material.

13. The AMD of any one of claims 1 to 12, wherein the material delivery device is adapted to heat the additive material from a solid state into a fluid state, and wherein the material delivery device deposits the additive material in the fluid state to the build surface upon its exit from the small aperture of the inner funnel.

14. A material delivery device for an additive manufacturing device (AMD) adapted for manufacturing objects through deposition of additive material over a build surface, the material delivery device comprising:

- an inner funnel having a large aperture at a top edge and a small aperture at a bottom edge whereby the additive material is guided from the large aperture to the small aperture;
- an outer funnel located external to the inner funnel, the outer funnel having a large aperture at a top edge and a small aperture extending outwardly from the bottom edge of the inner

funnel, wherein the outer funnel and the inner funnel are joined about the small aperture of the inner funnel and the small aperture of the outer funnel;

- a first electrical contact located about the top edge of the inner funnel; and
- a second electrical contact located about the top edge of the outer funnel;

wherein the inner funnel is electrically conductive and, upon applying an electrical current from an electric power source between the first electrical contact and the second electrical contact, heat is generated thereby heating the additive material travelling in the inner funnel.

15. The material delivery device of claim 14, further comprising a junction wall extending about the small aperture of the inner funnel, whereby the junction wall joins the outer funnel to the inner funnel.

16. The material delivery device of claim 15, wherein the junction wall divides an interior space concealed by the inner funnel and an exterior space within the outer funnel, wherein the wall comprises openings through which the exterior space is in fluid communication with the interior space.

17. The material delivery device of any one of claims 14 to 16, wherein the material delivery device is made at least in part of one of a metallic material or a metallic alloy.

18. The material delivery device of any one of claims 14 to 17, wherein the material delivery device is made at least in part of one of platinum and a platinum-based alloy.

19. The material delivery device of any one of claims 14 to 18, wherein the inner funnel has a varying thickness which results in a variation of an electrical resistance of the inner funnel and hence a variation of the heat which is generated.

Fig. 1

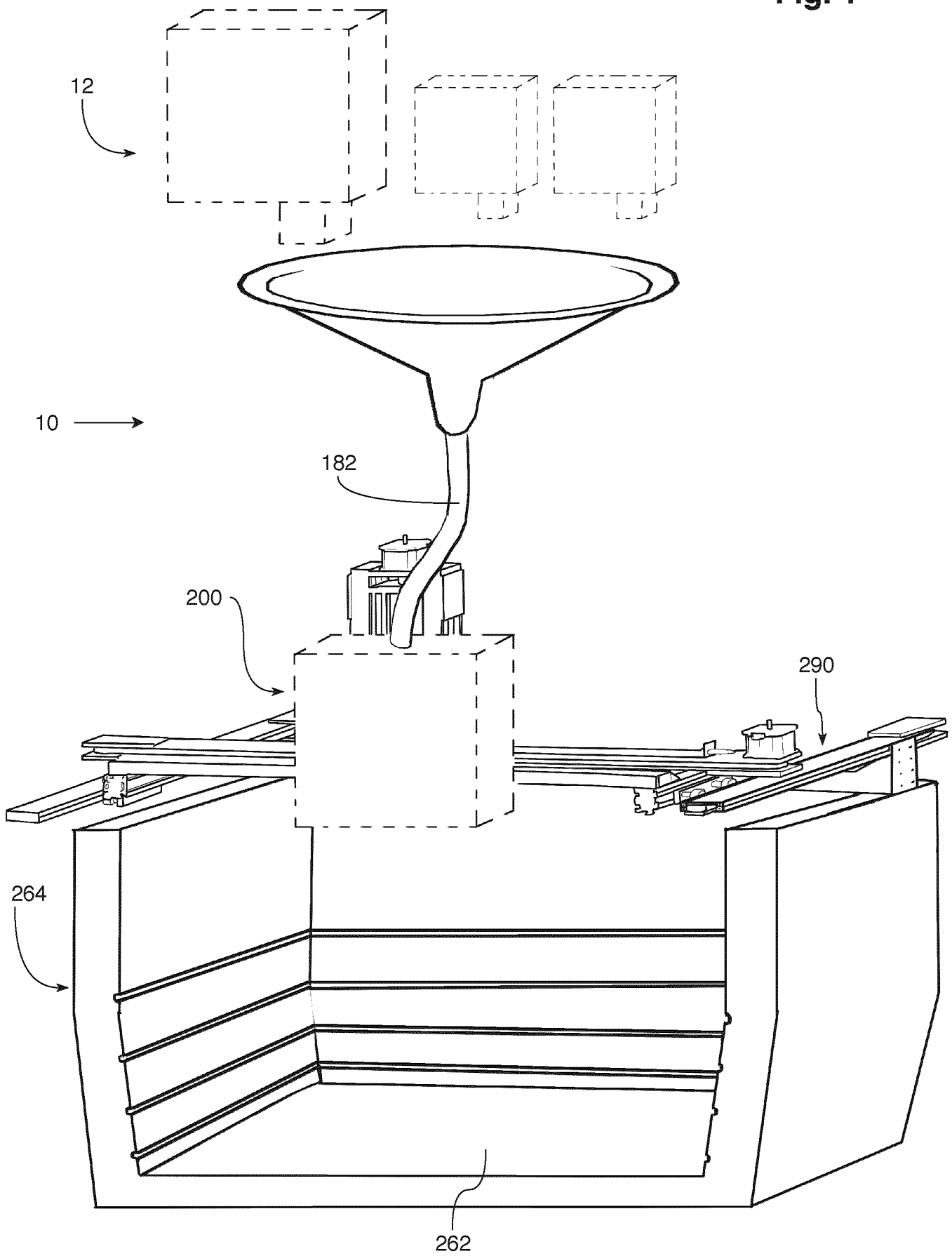


Fig. 2

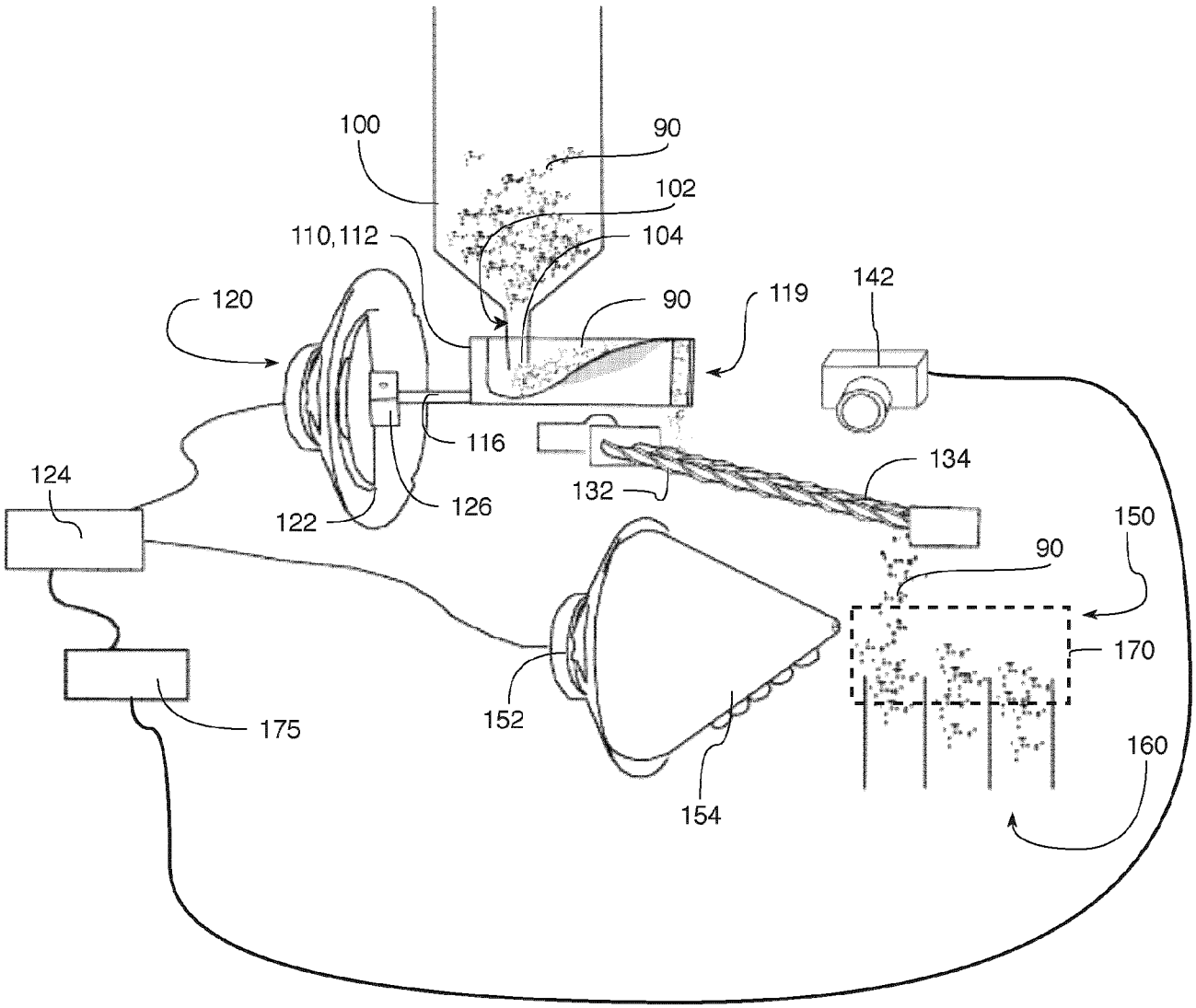

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Fig. 3

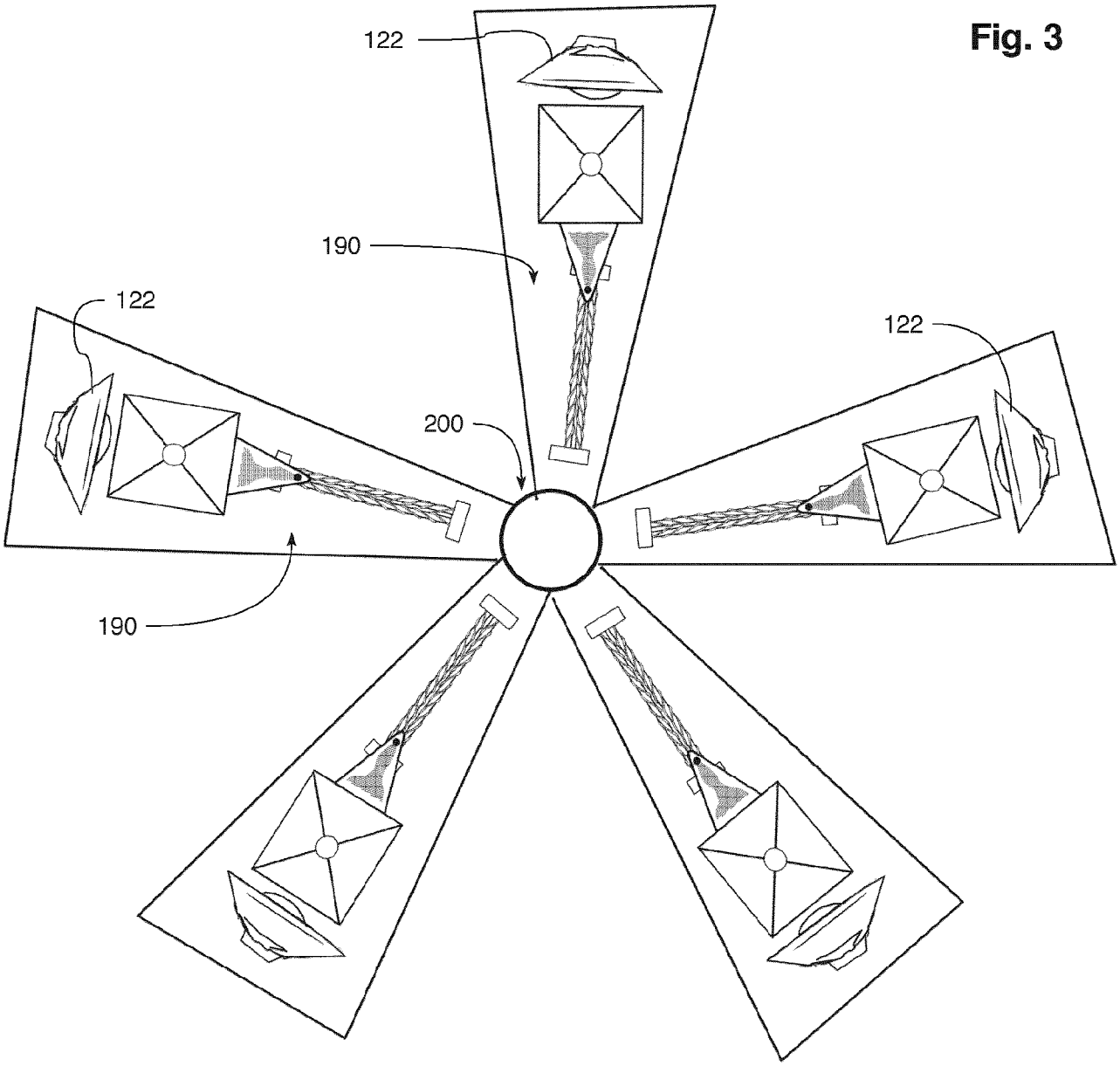


Fig. 4

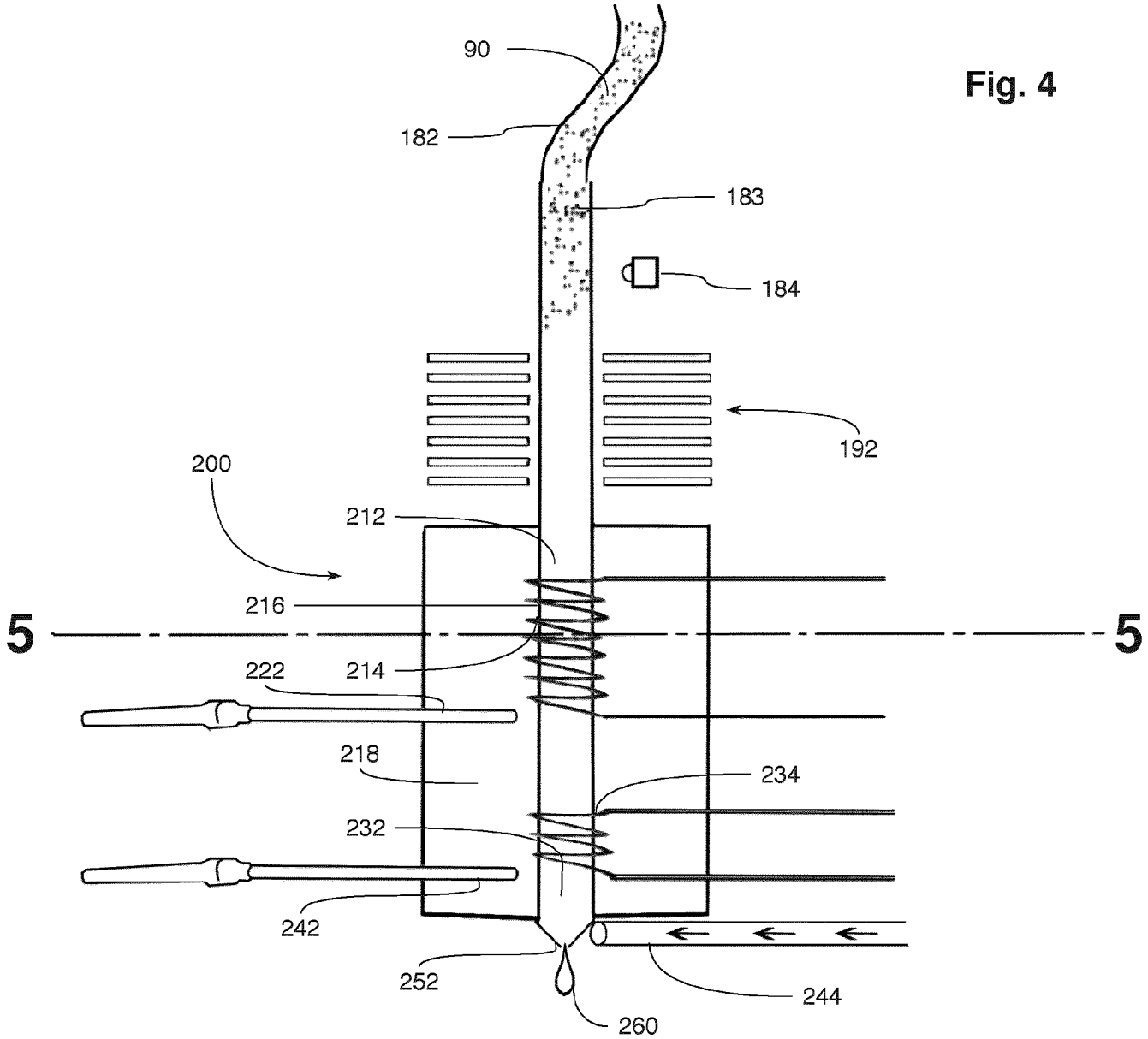

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Fig. 5

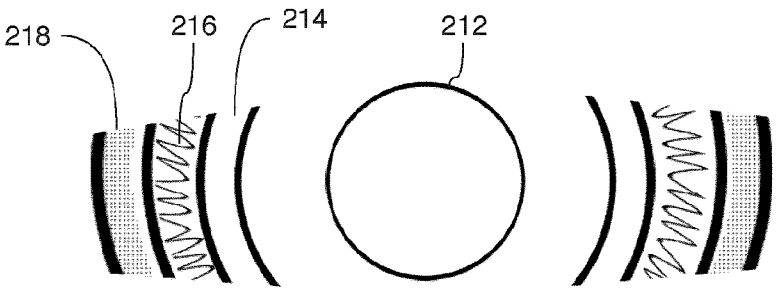

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Fig. 6

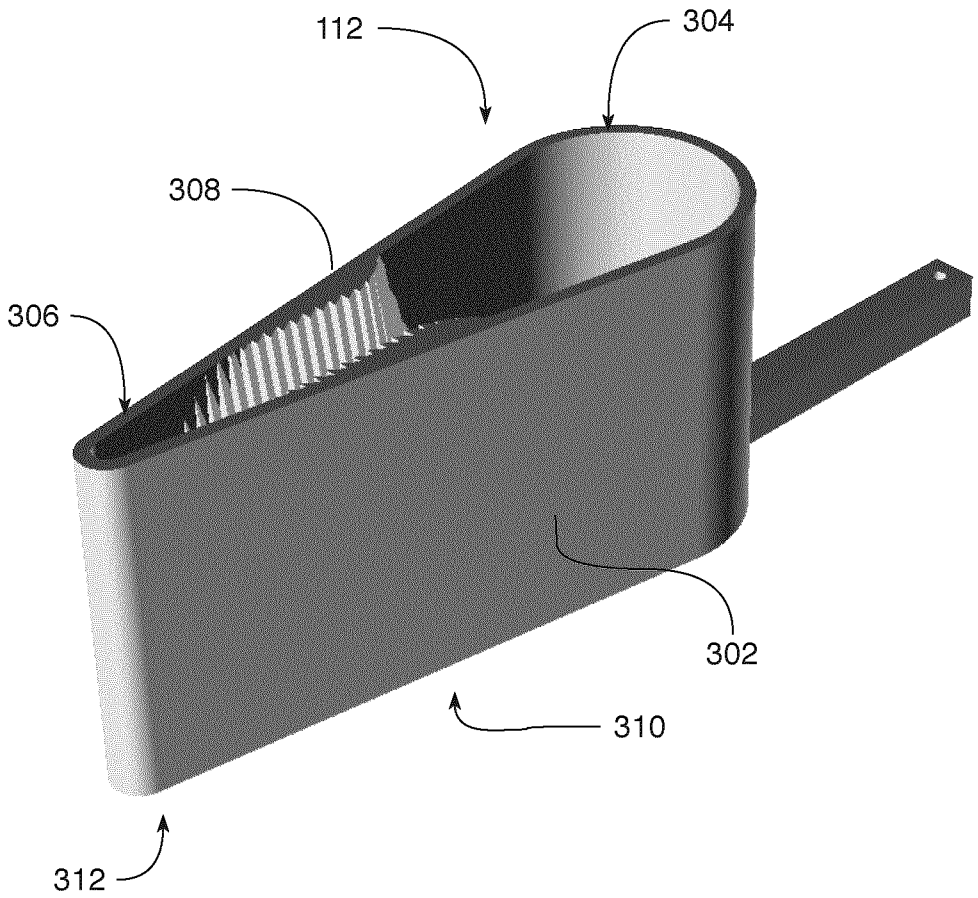


Fig. 7

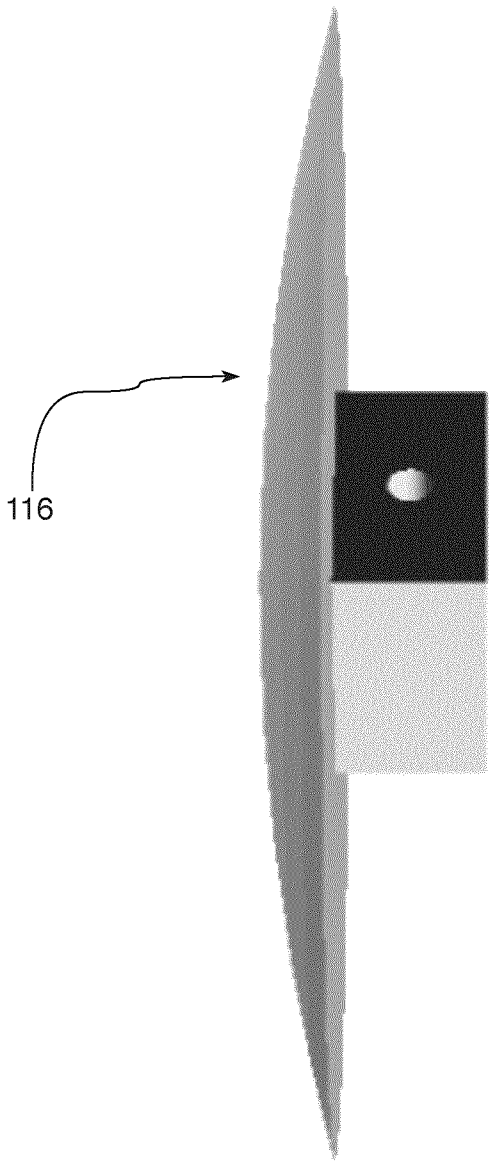


Fig. 8

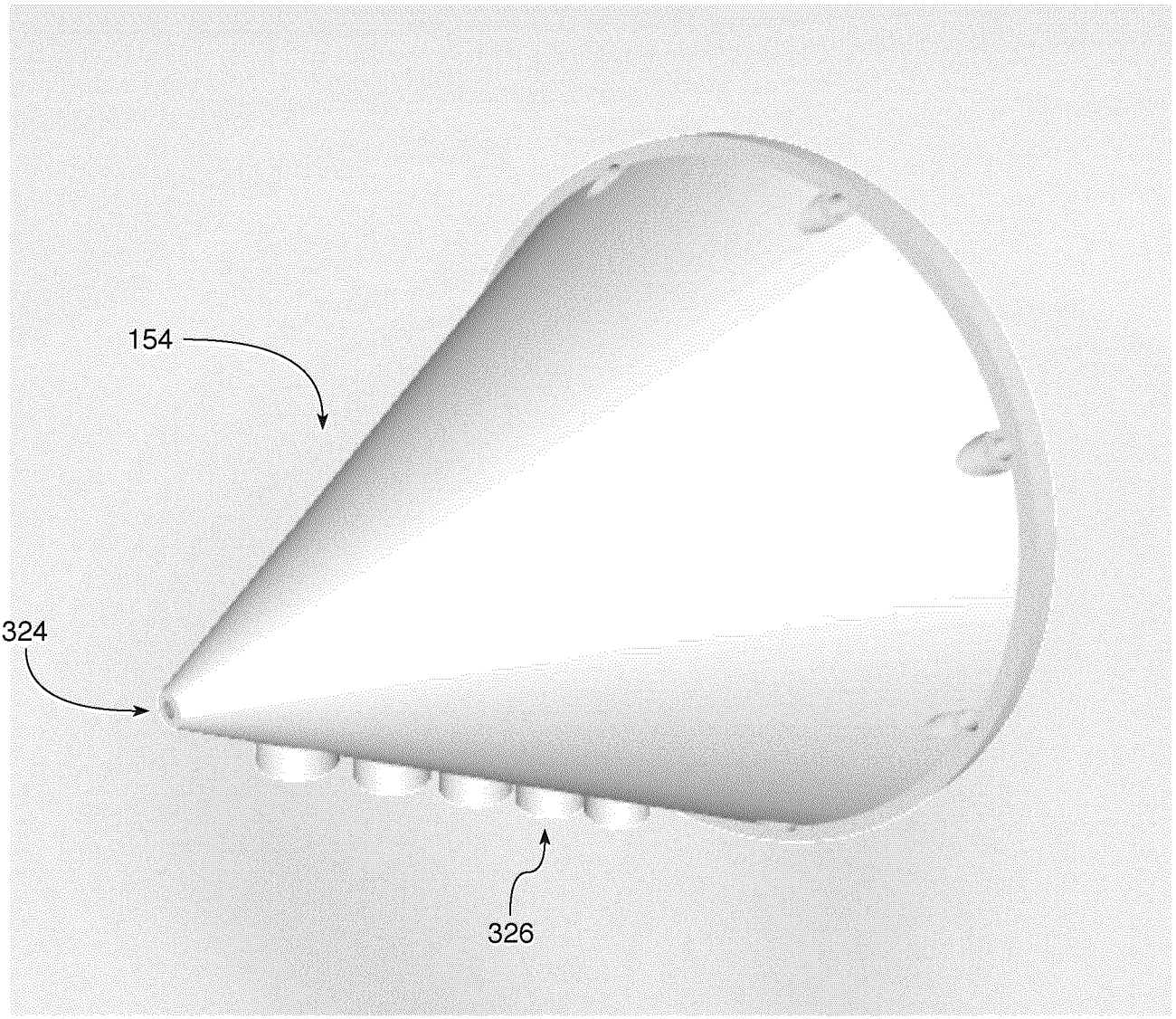


Fig. 9

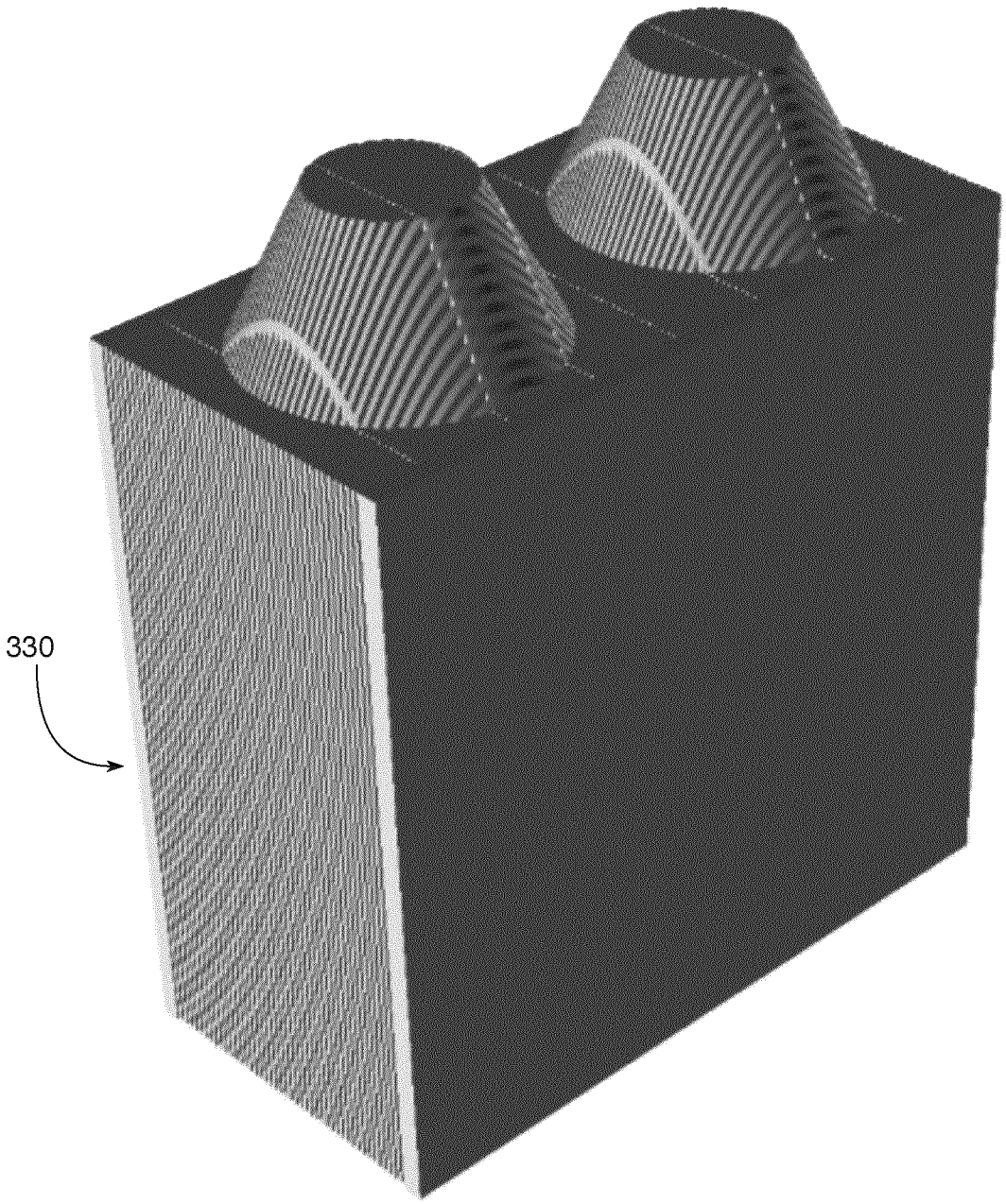


Fig. 10

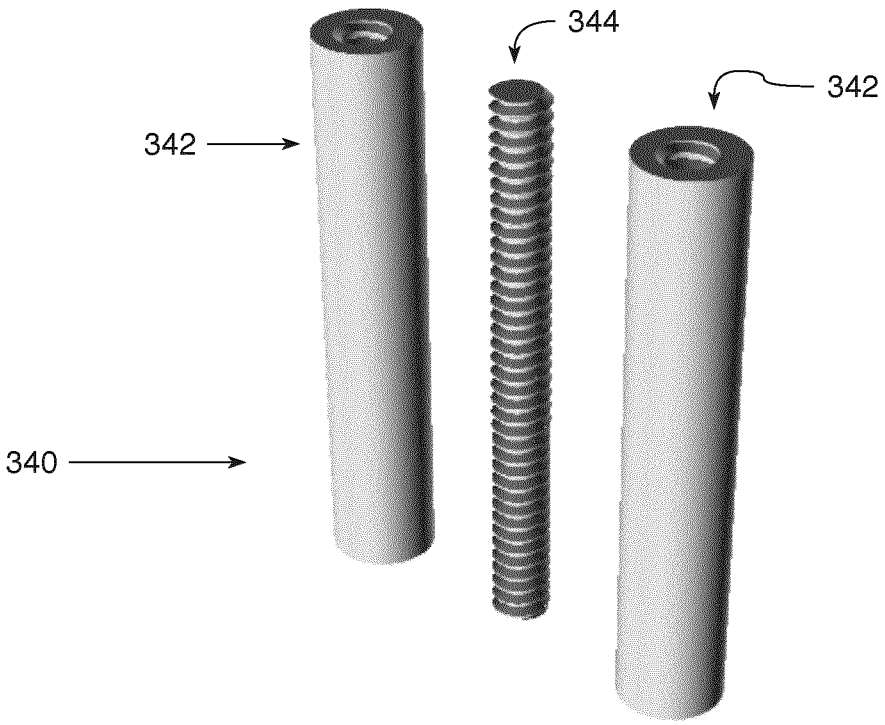


Fig. 11

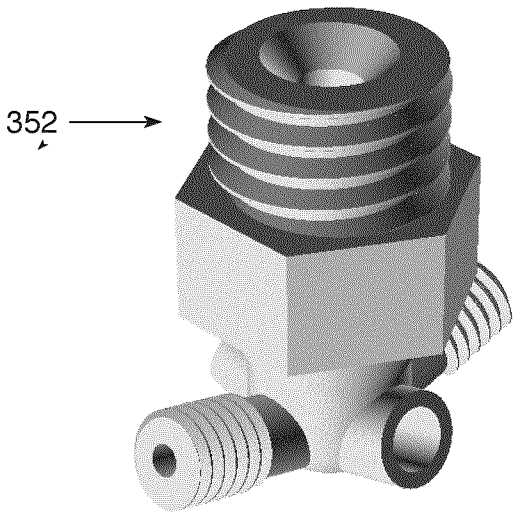


Fig. 12

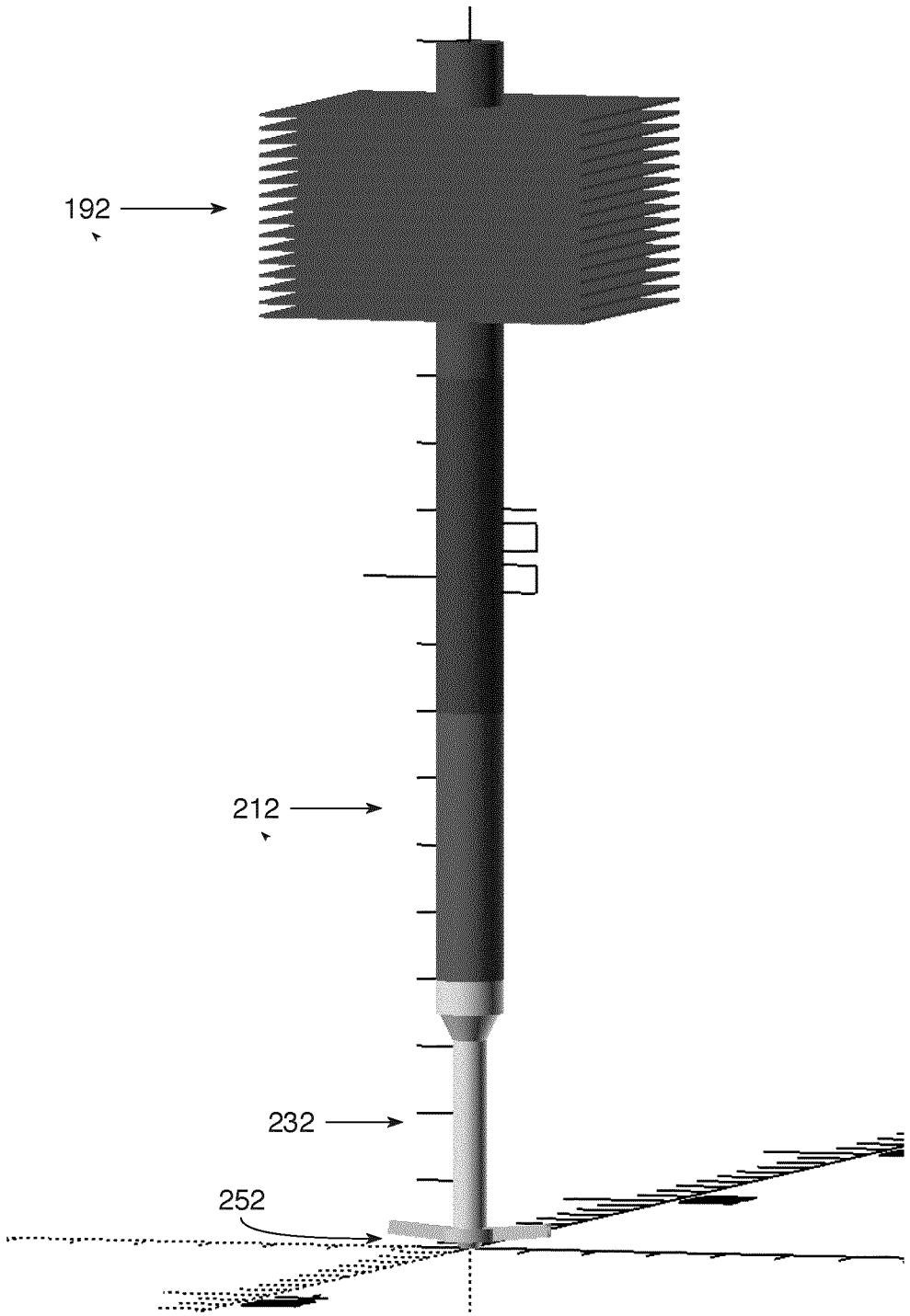


Fig. 13

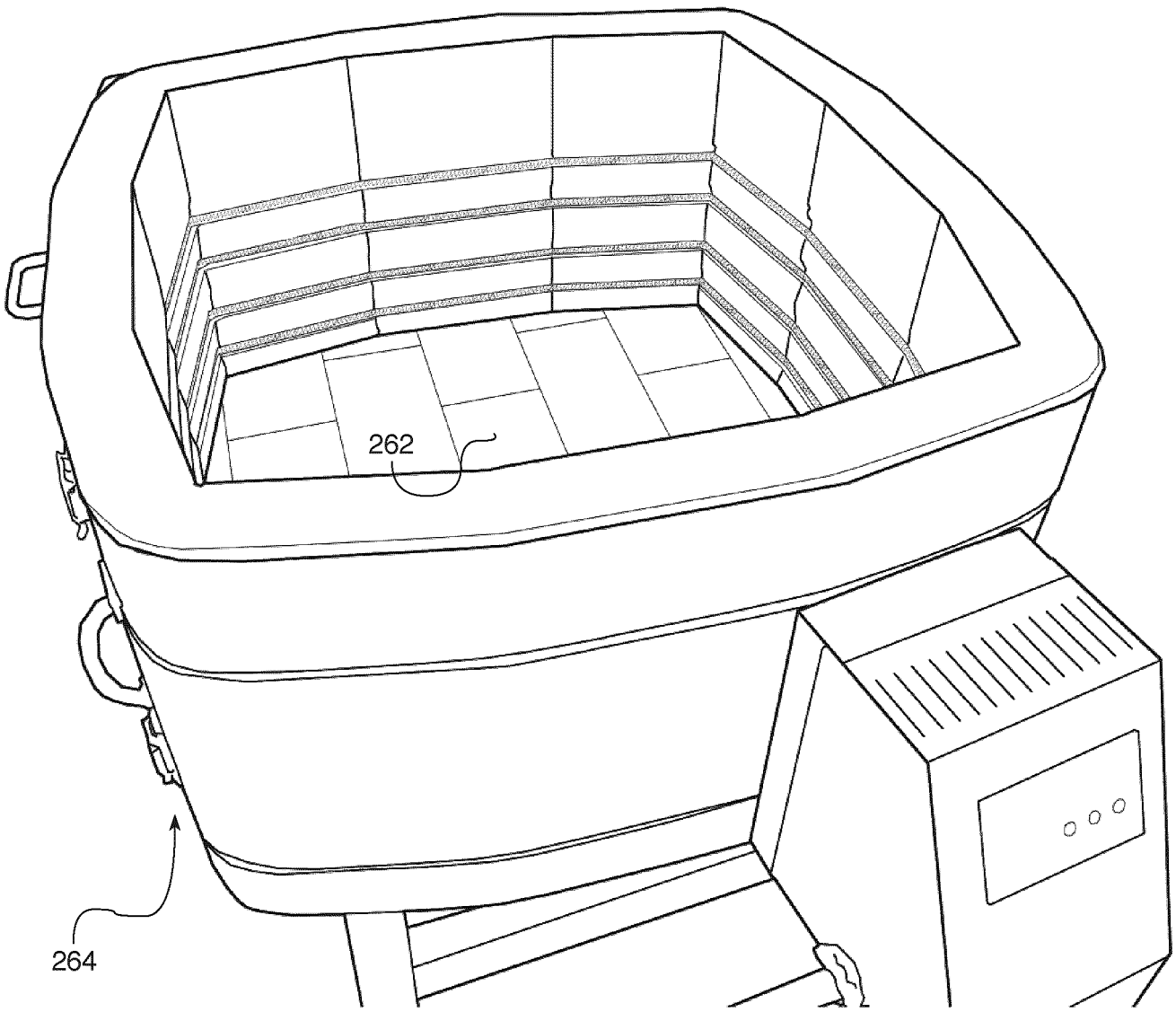


Fig. 14

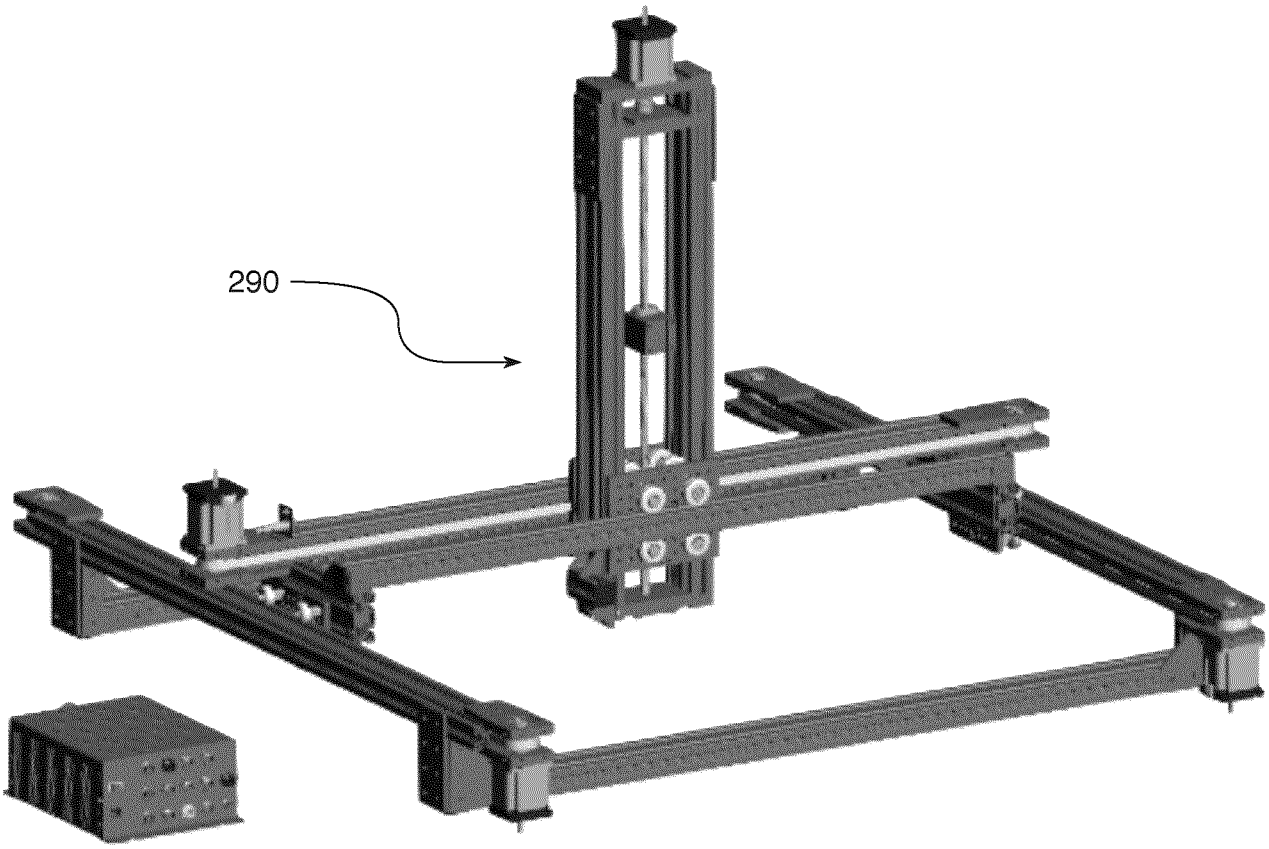




Fig. 15



Fig. 16

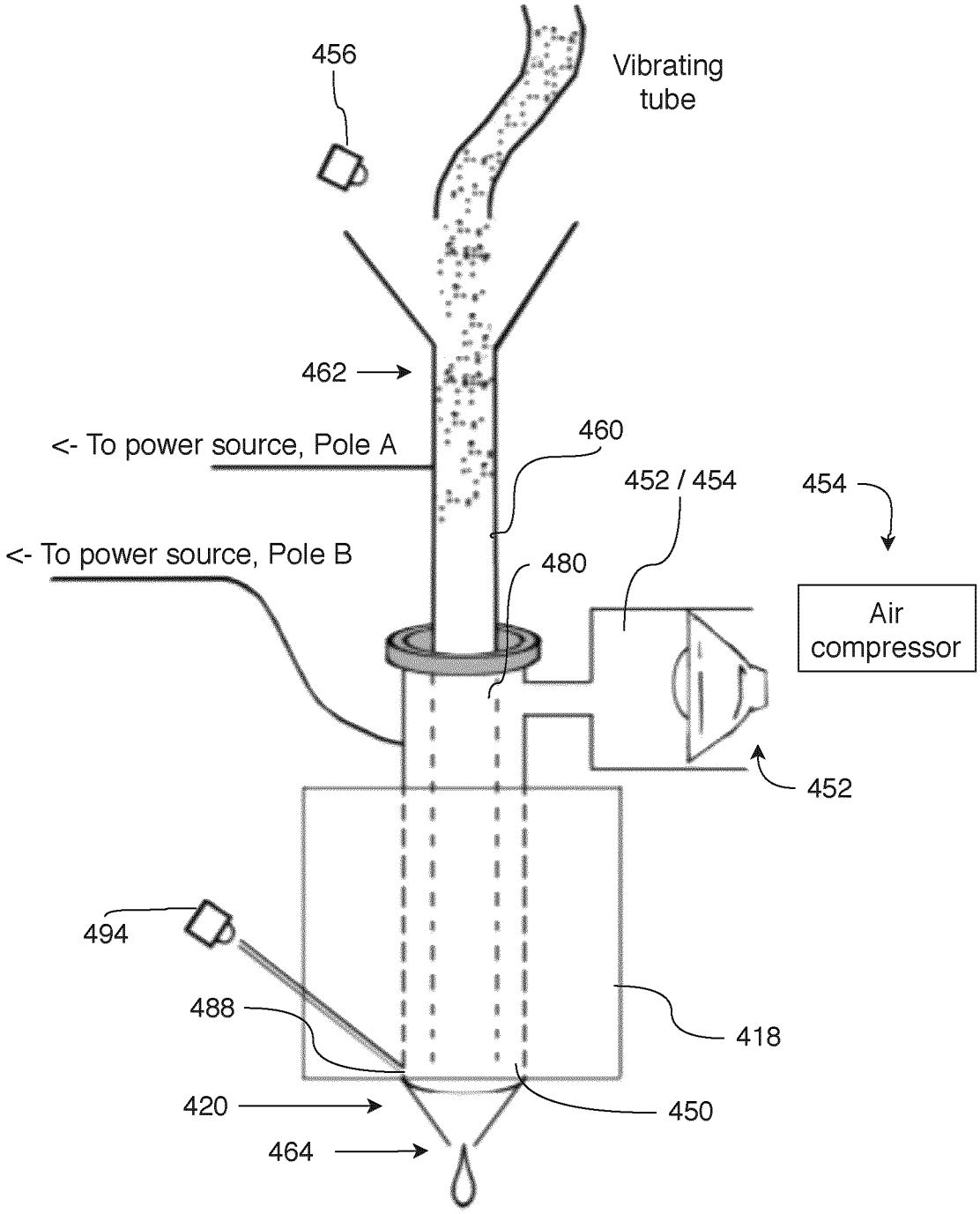

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Vibrating tube
462
<- To power source, Pole A
460
452 / 454
454
<- To power source, Pole B
480
Air compressor
452
494
488
418
420
450
464

Fig. 17

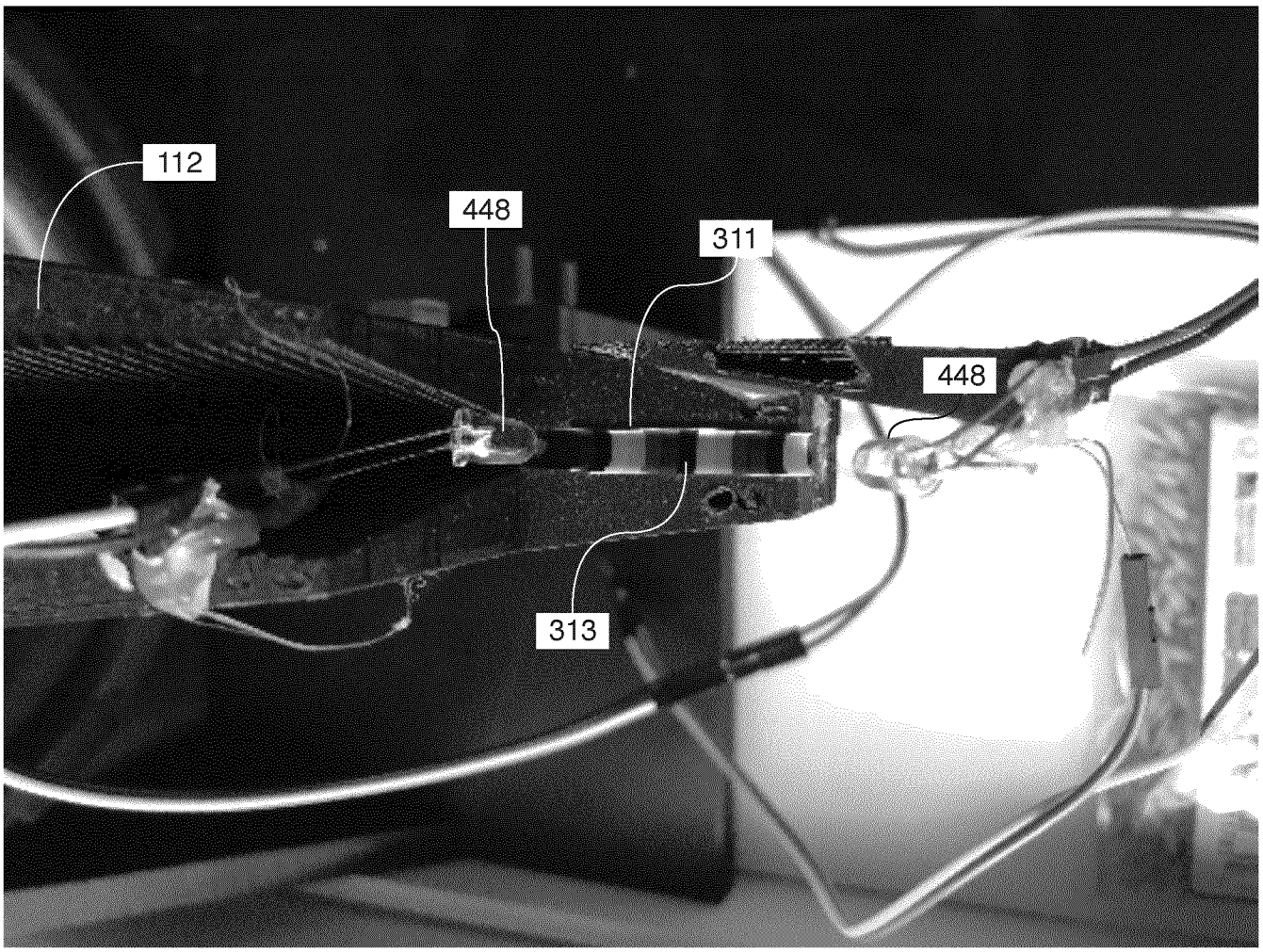


Fig. 18

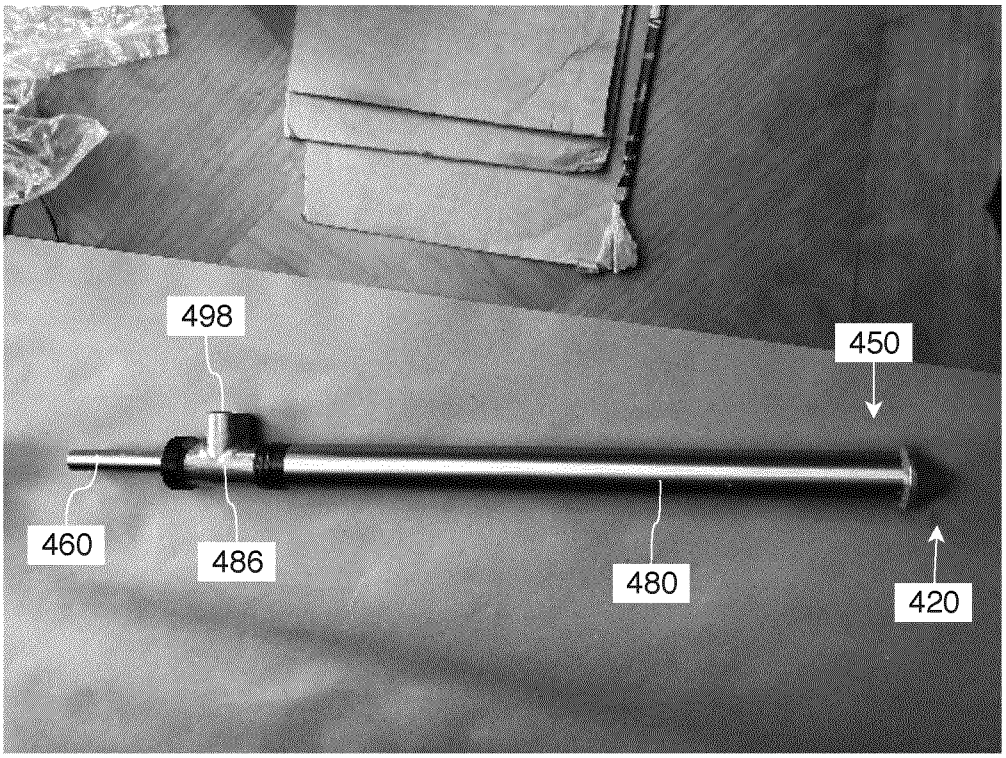


Fig. 19

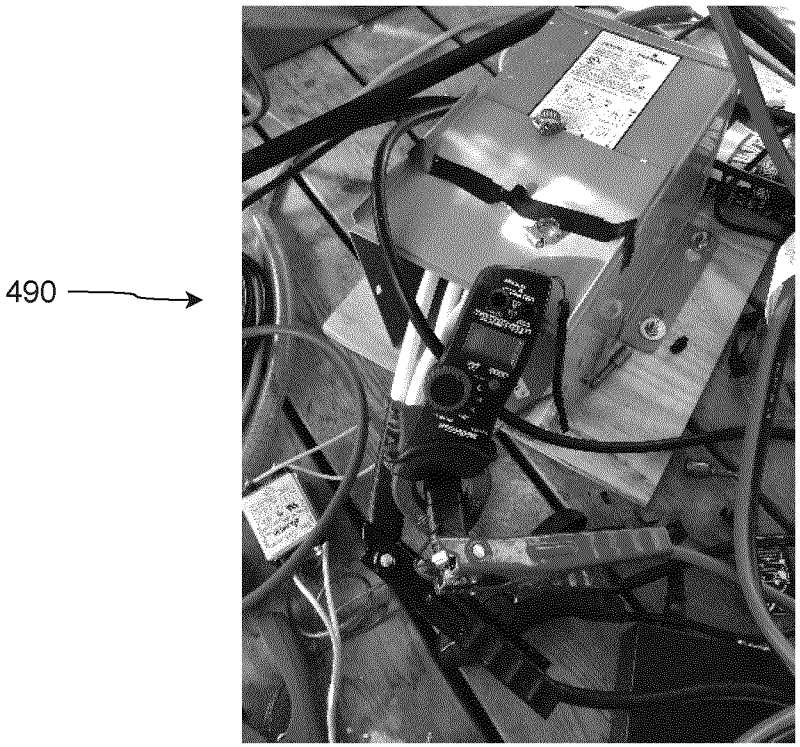


Fig. 20

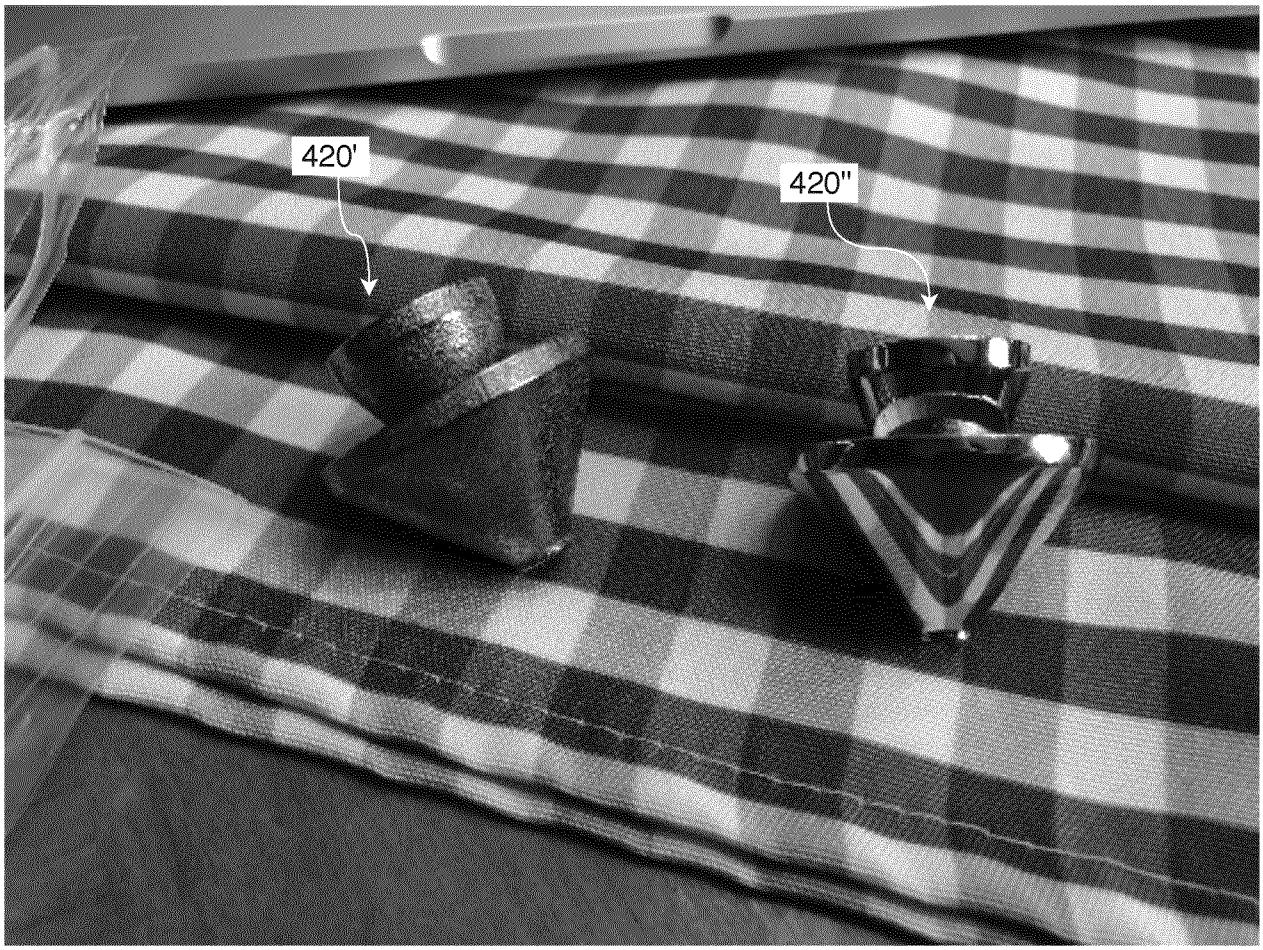


Fig. 21

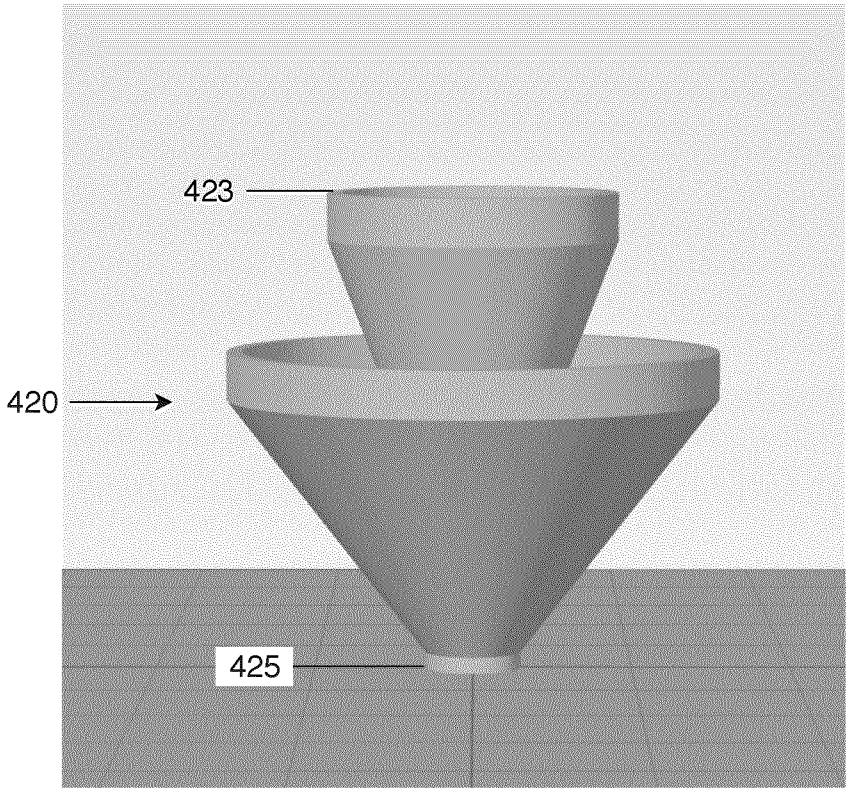


Fig. 22

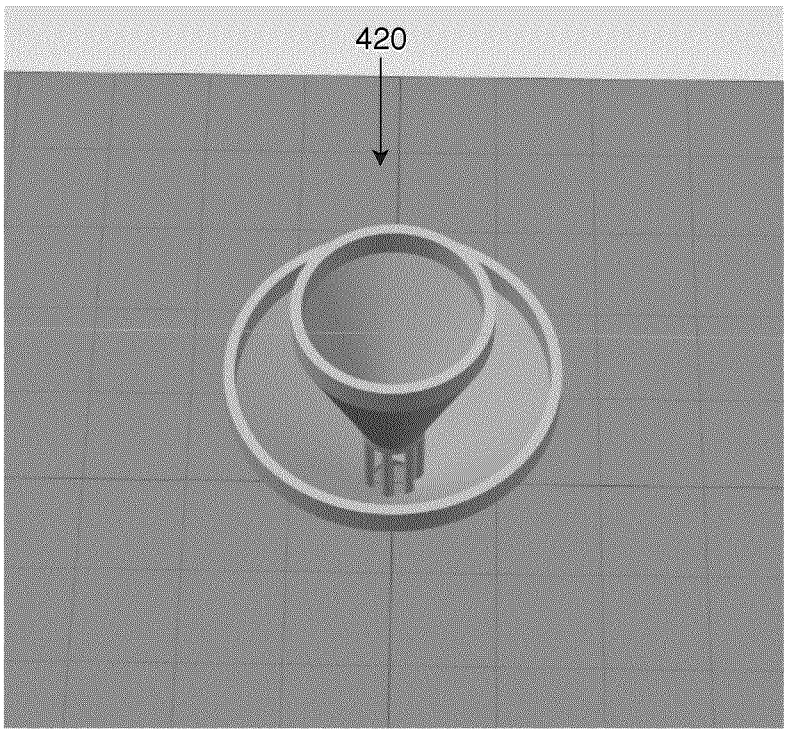


Fig. 23

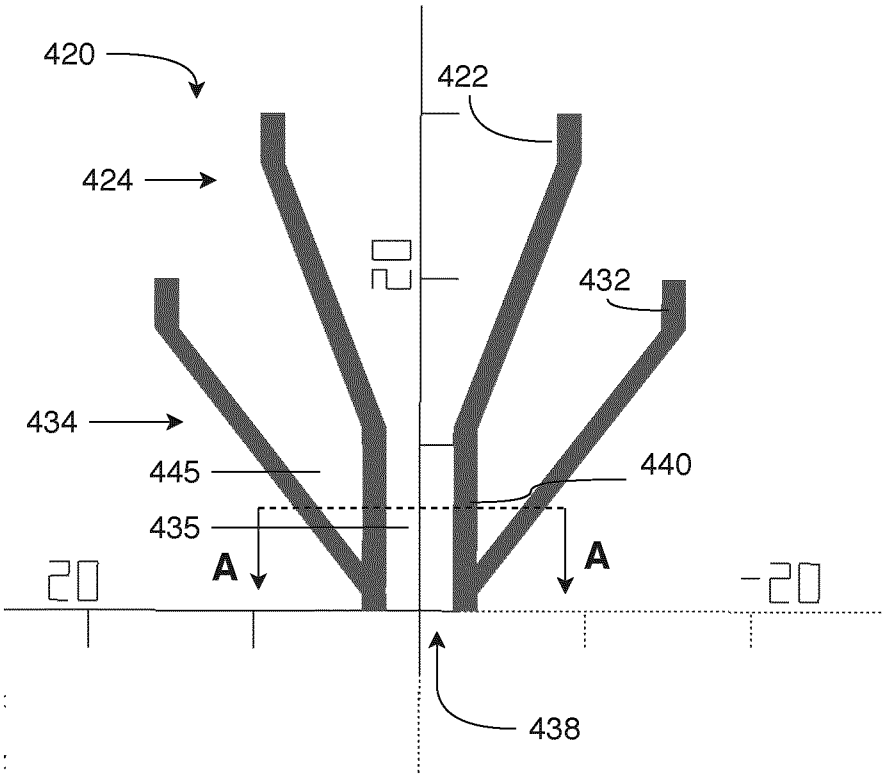

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422
424
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432
434
445
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435
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Fig. 24

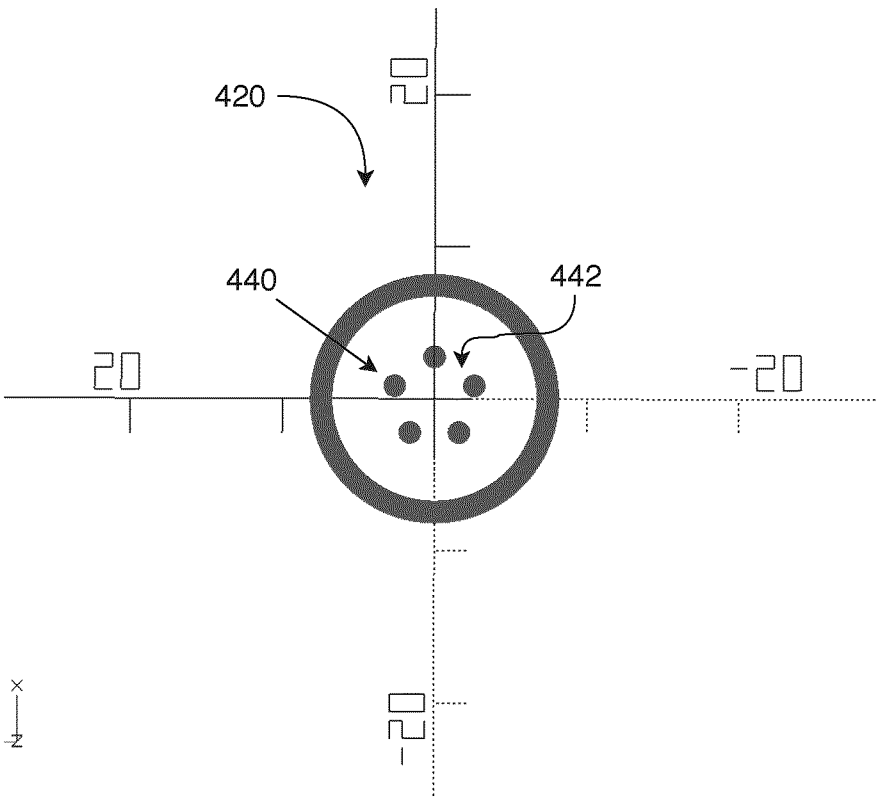

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Fig. 25

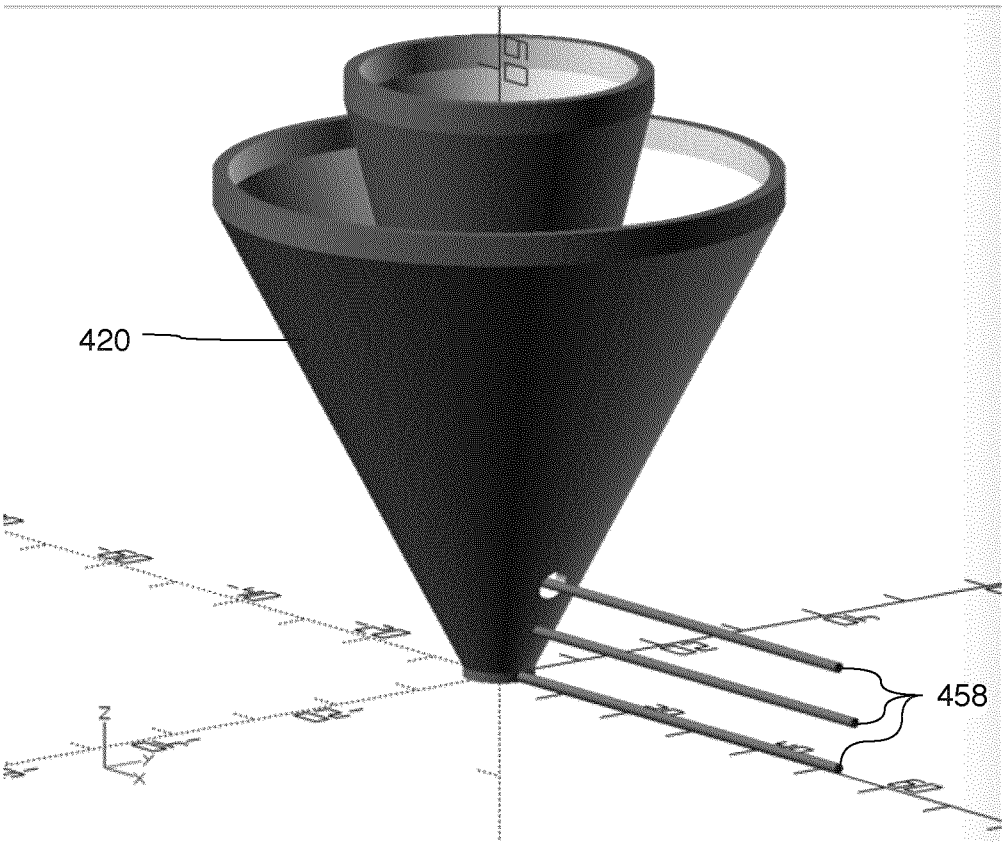


Fig. 26

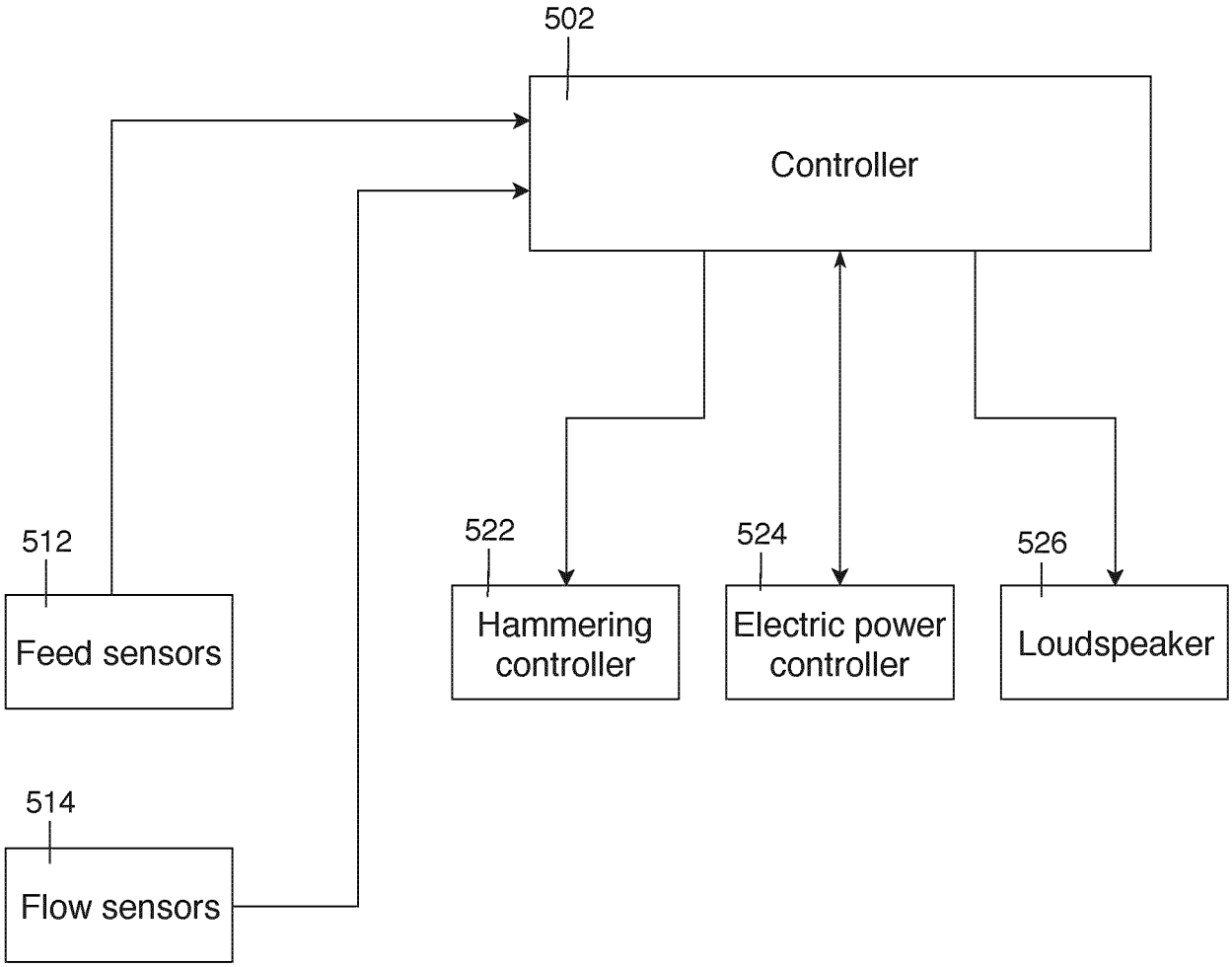
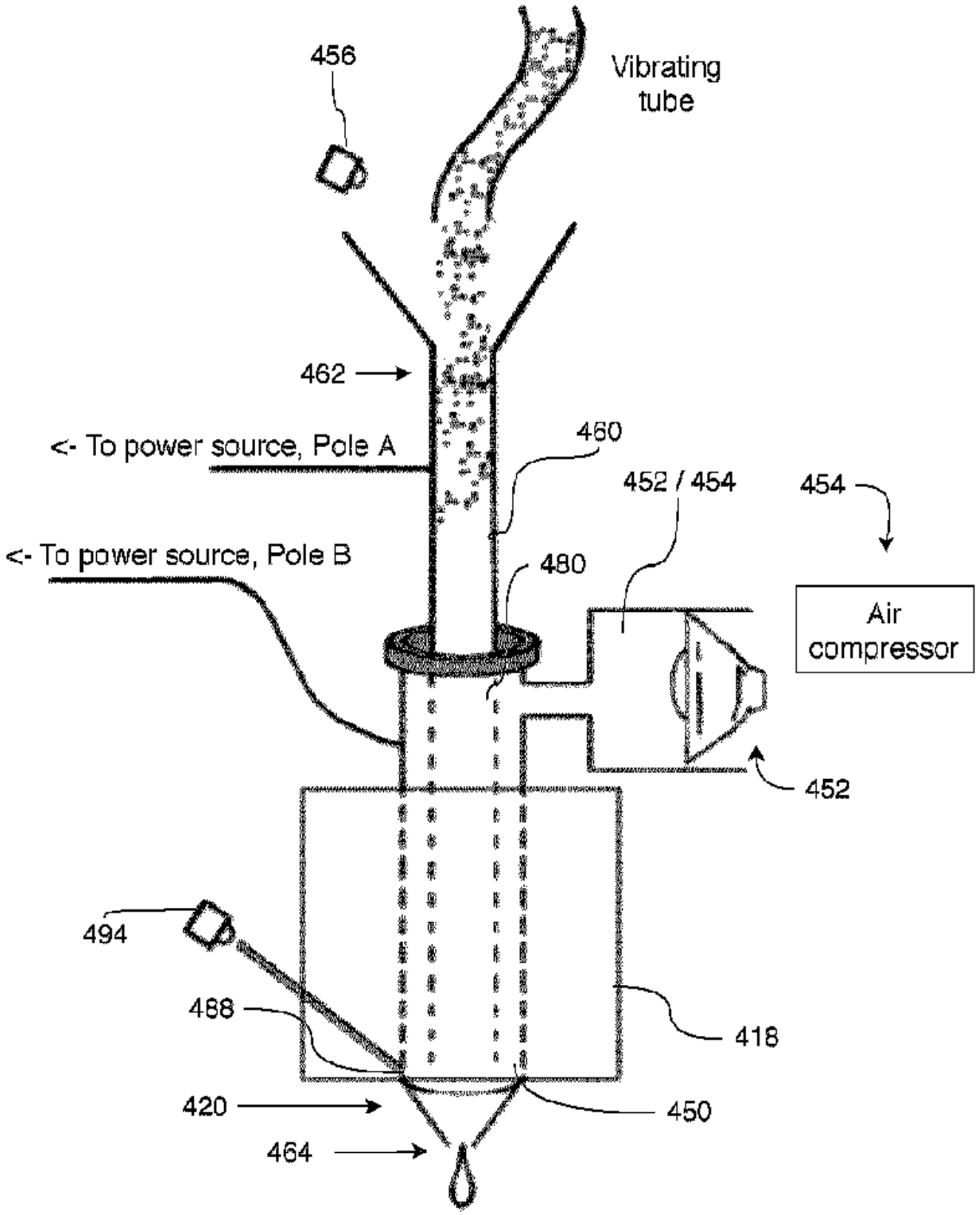

502
Controller
512
Feed sensors
514
Flow sensors
522
Hammering controller
524
Electric power controller
526
Loudspeaker

Fig. 27


456
Vibrating tube
462
<- To power source, Pole A
460
452 / 454
454
<- To power source, Pole B
480
Air compressor
452
494
488
418
420
450
464