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(54) **BIOCHAR KILN**

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(51) **Int. Cl.**
C10B 1/02 (2006.01)
F23G 5/40 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***C10B 53/02*** (2013.01); ***C10B 1/02*** (2013.01); ***F23G 5/0276*** (2013.01); ***F23G 5/40*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. C10B 53/02; C10B 1/02; C10B 1/04; C10B 1/10; F23G 7/10; F23G 7/105;
(Continued)

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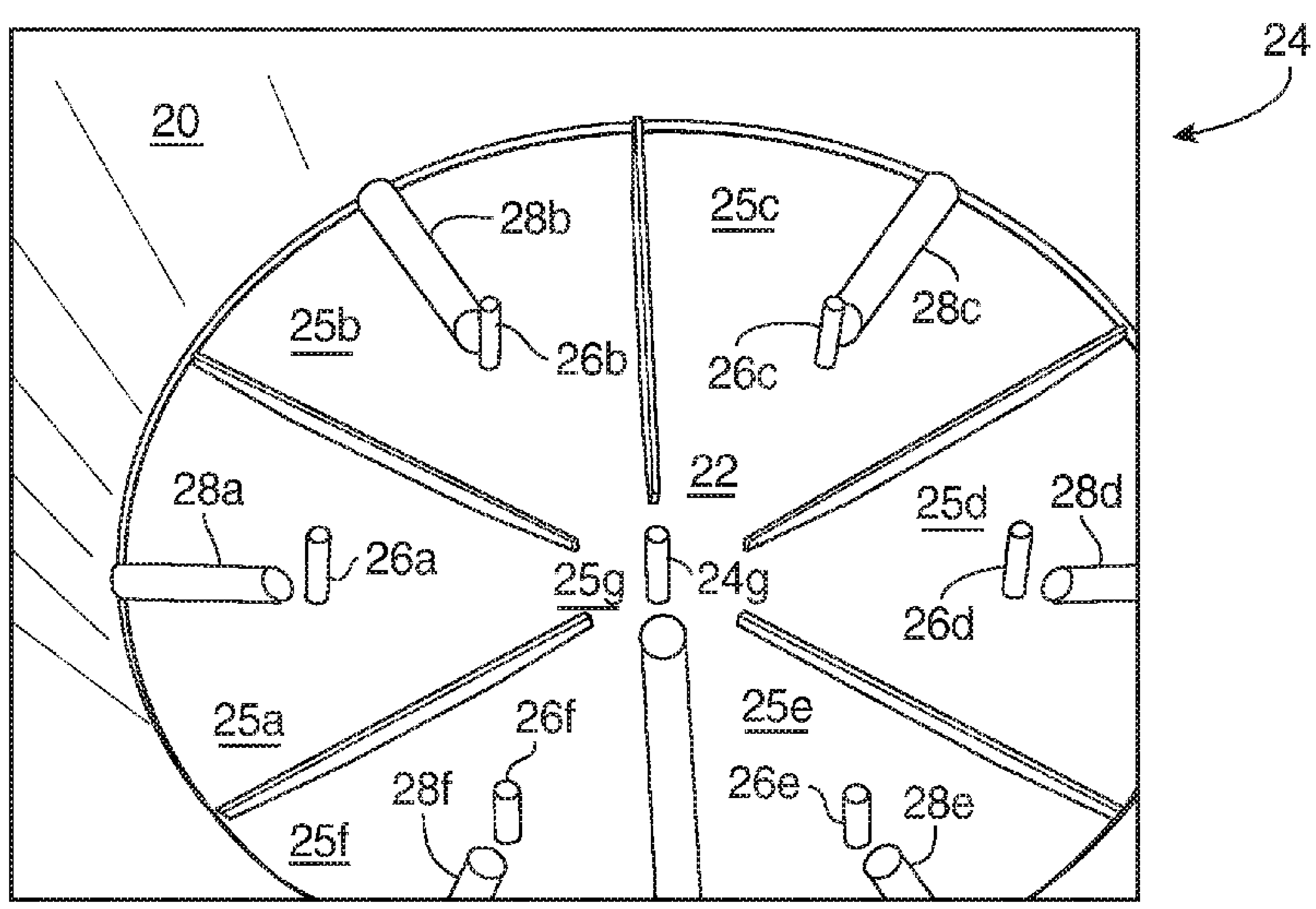
(57) **ABSTRACT**

A biochar kiln is disclosed. An example of the biochar kiln includes a body having a one-piece rolled wall, a curved floor attached to the sidewall by a single weld line, and a removable lid. The example biochar kiln includes a plurality of semi-independent combustion cells. The example biochar kiln also includes a ventilation subsystem, an ember suppression subsystem, and a stack subsystem. A control subsystem may configured to monitor a plurality of zones of the biochar kiln for a plurality of process control variables, to produce a quality biochar product with well-managed emissions.

13 Claims, 14 Drawing Sheets



(51) **Int. Cl.**
F23G 7/10 (2006.01)
F23L 1/02 (2006.01)
C10B 53/02 (2006.01)
F23G 5/027 (2006.01)

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
CPC F23G 2209/26; F23G 2209/261; F23G 2209/262; F23L 1/02
See application file for complete search history.

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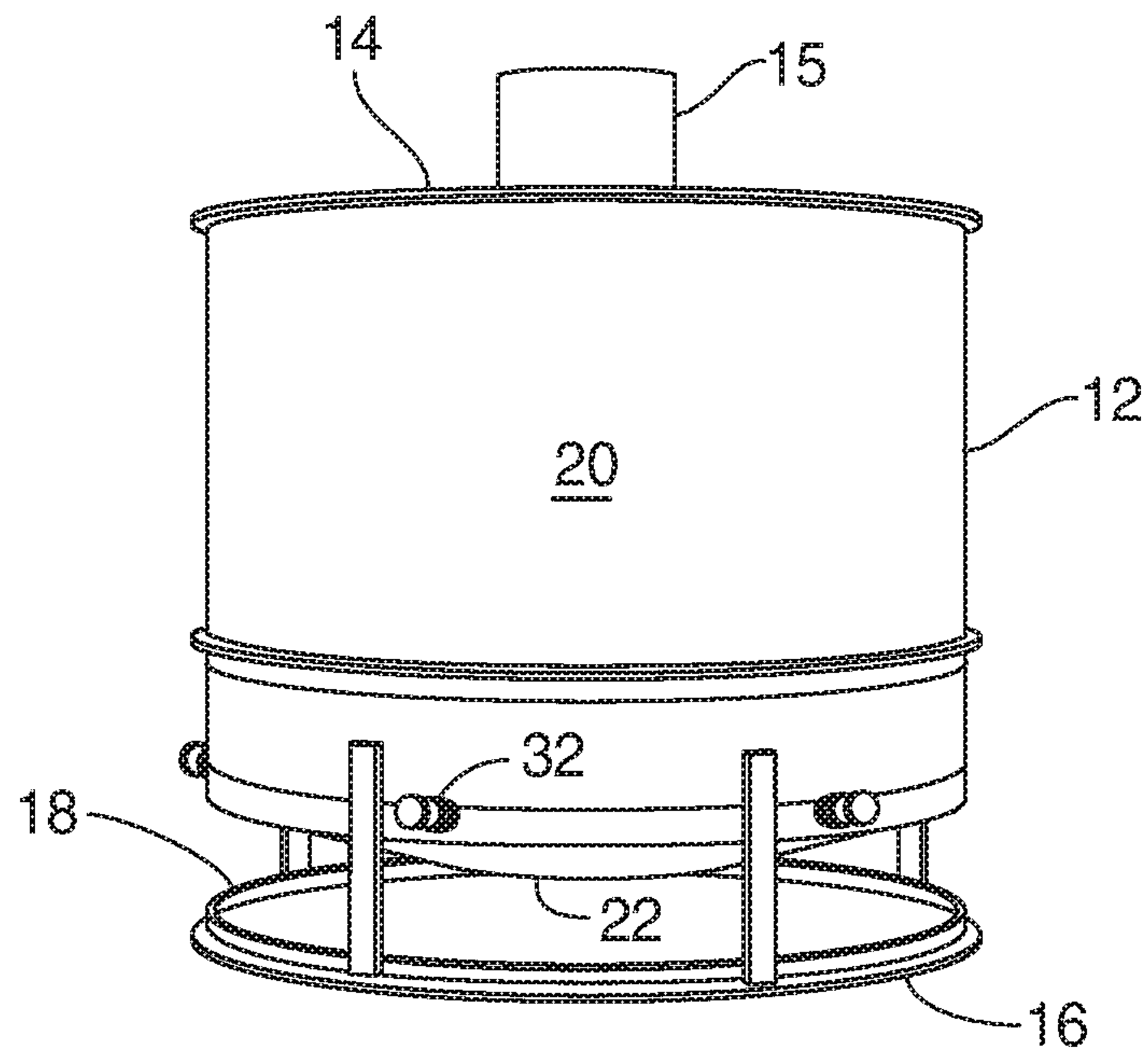
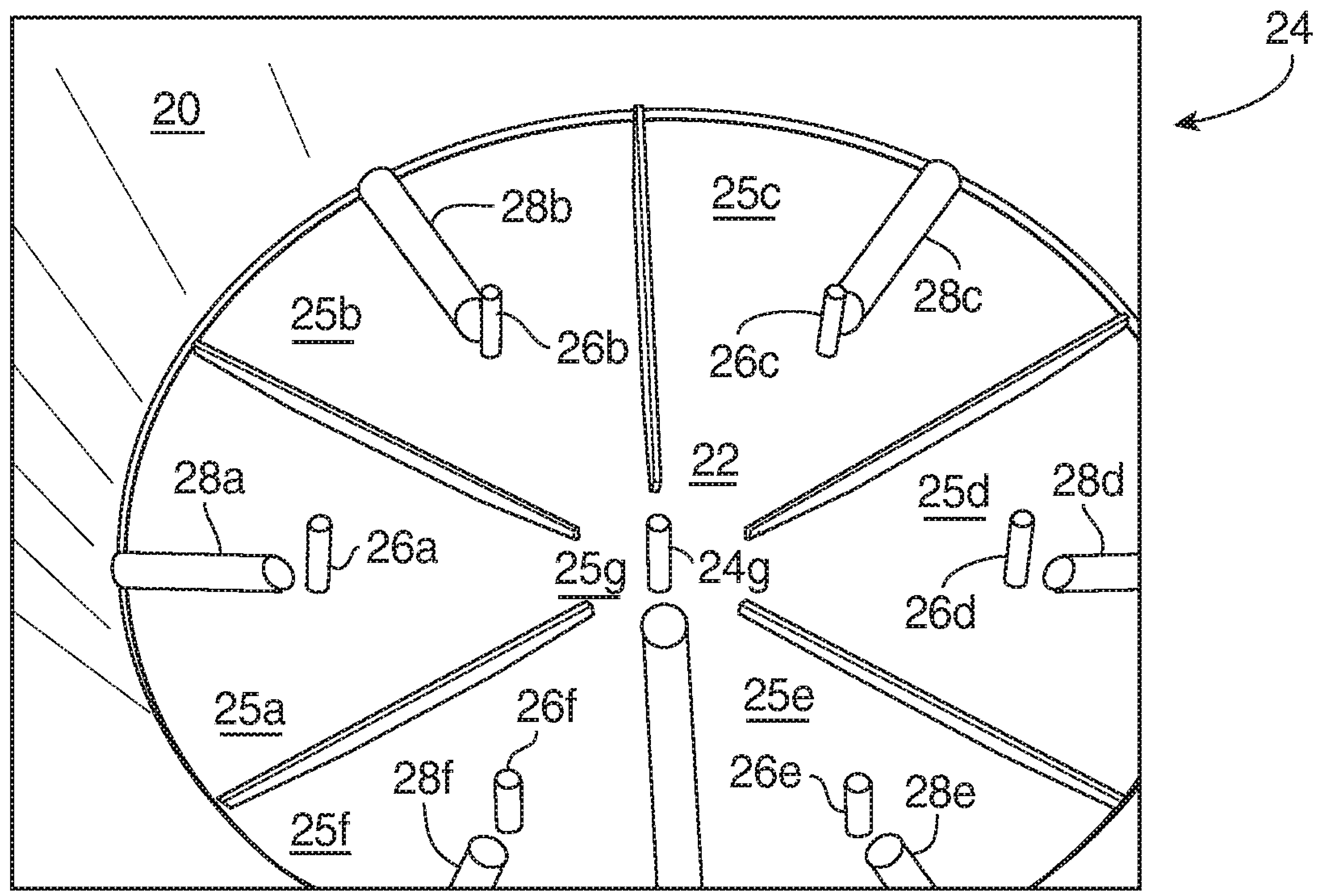


FIG. 1


24
20
28b
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22
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FIG. 2

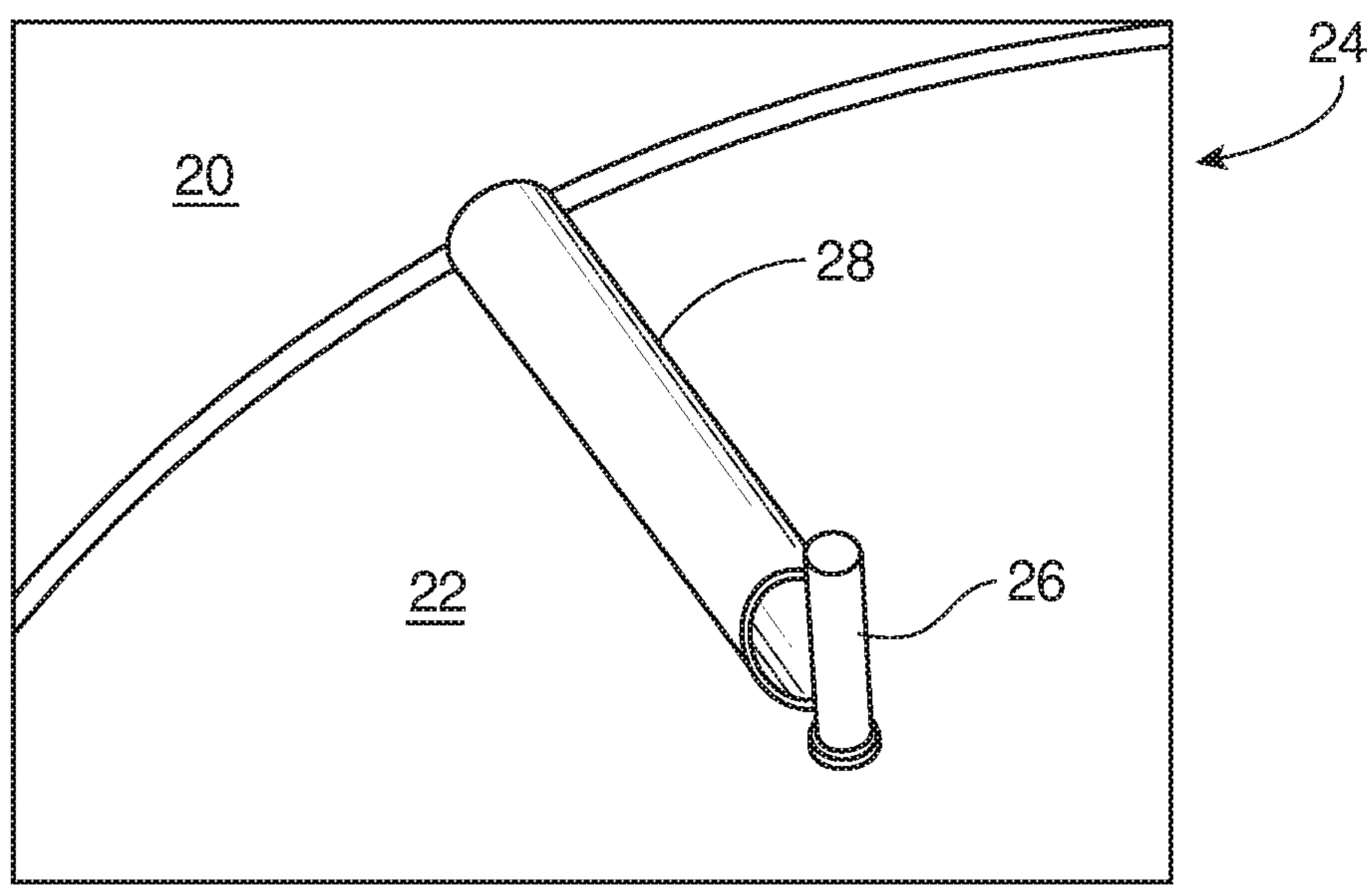
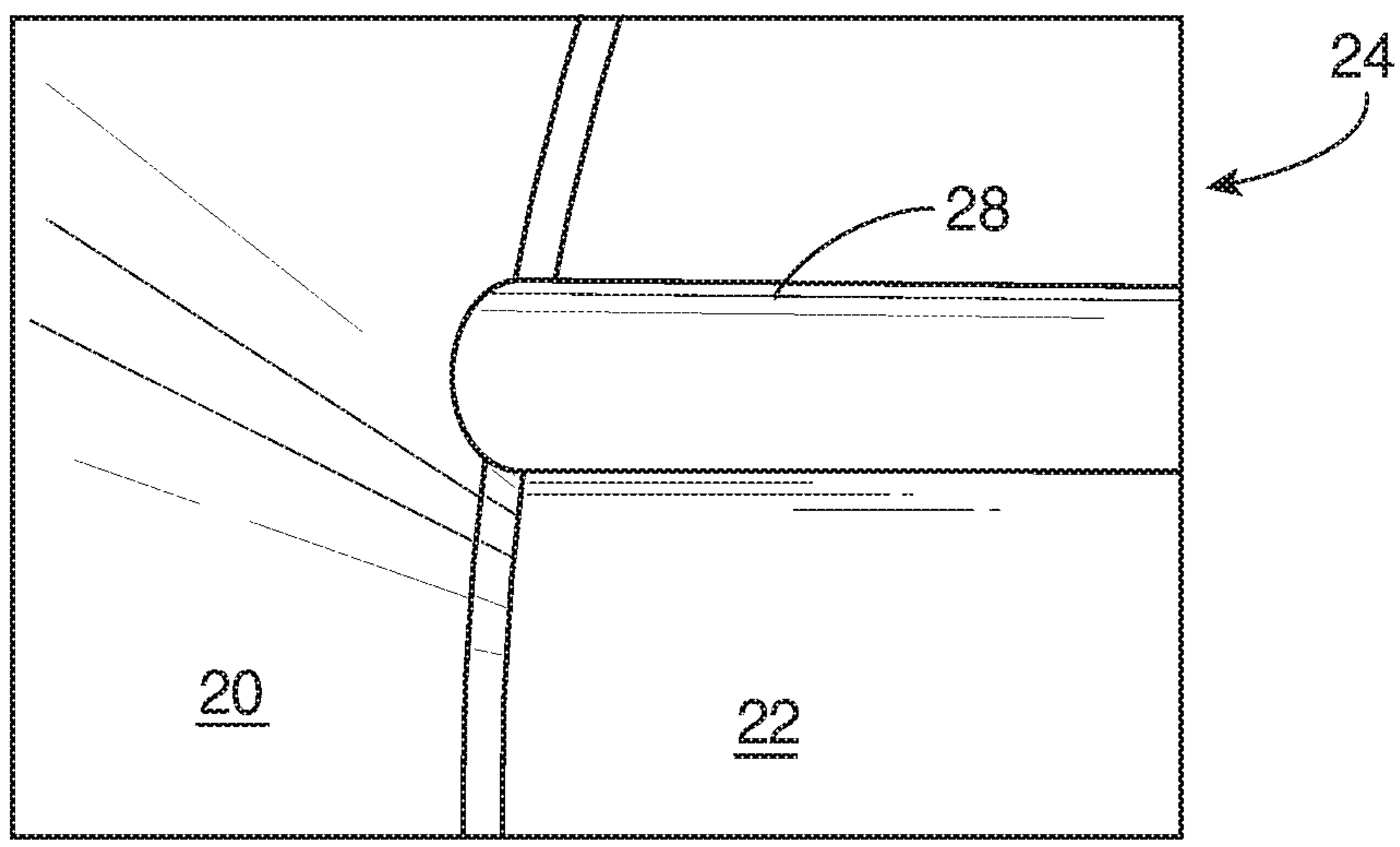

24
20
28
22
26

FIG. 3



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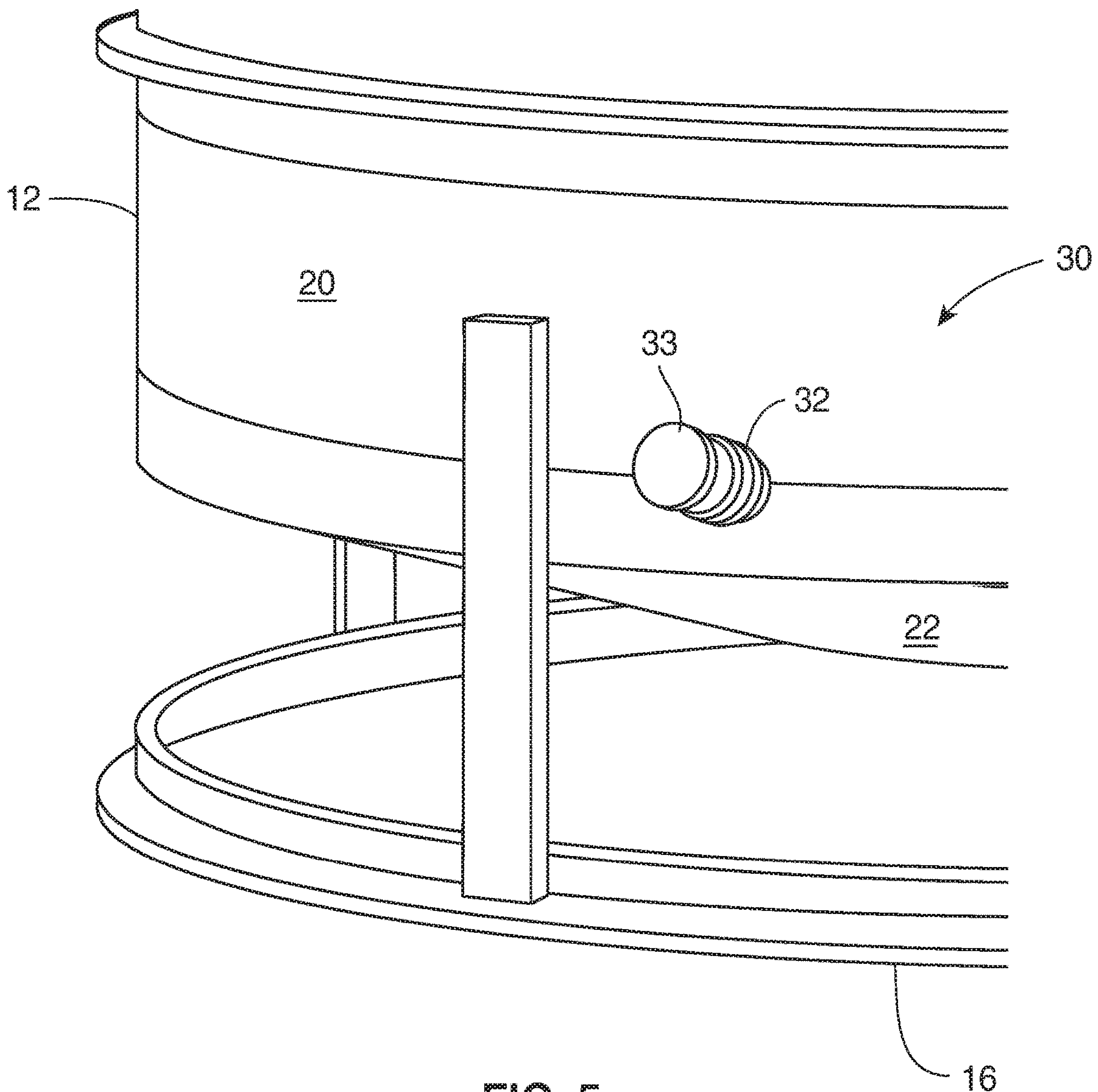


FIG. 5

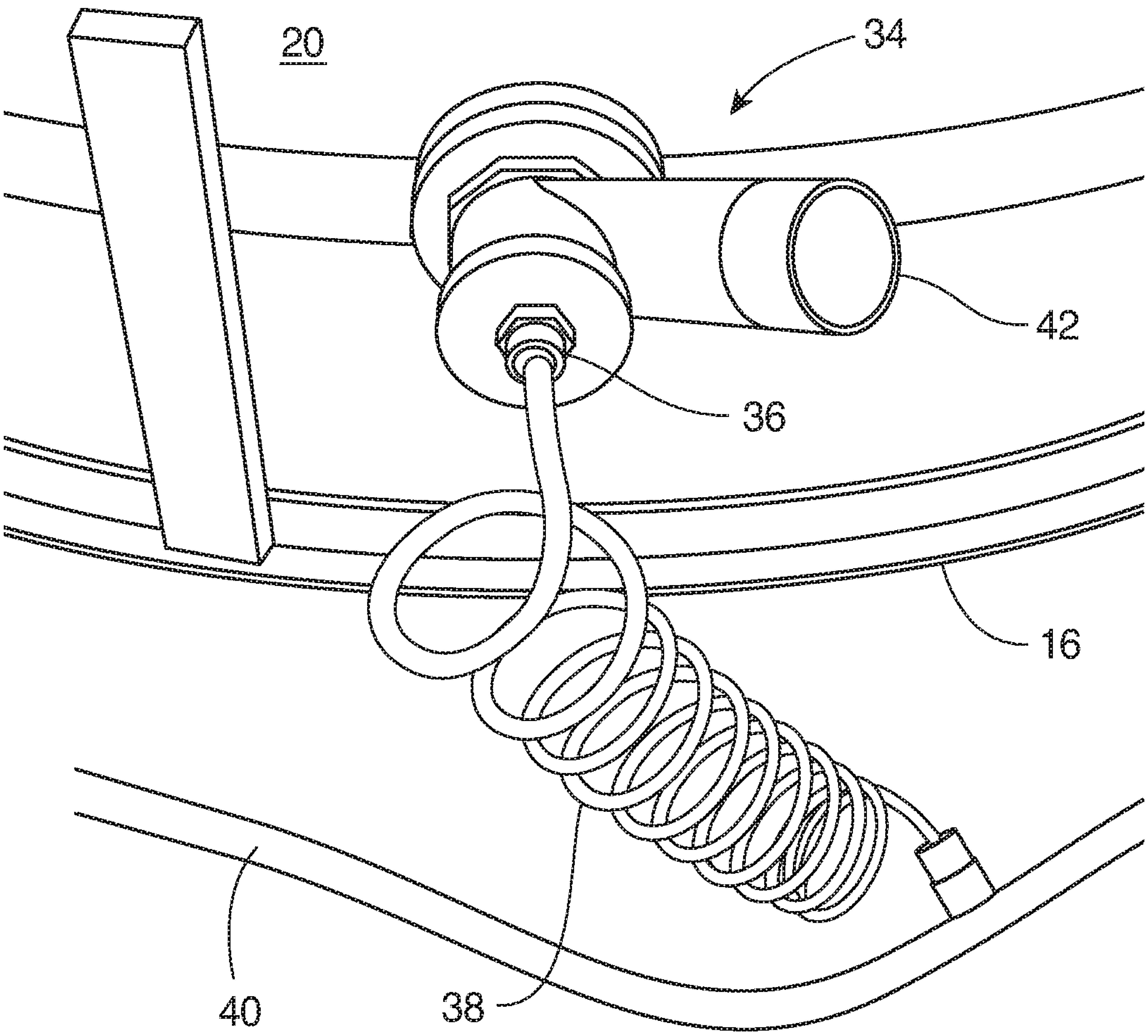


FIG. 6

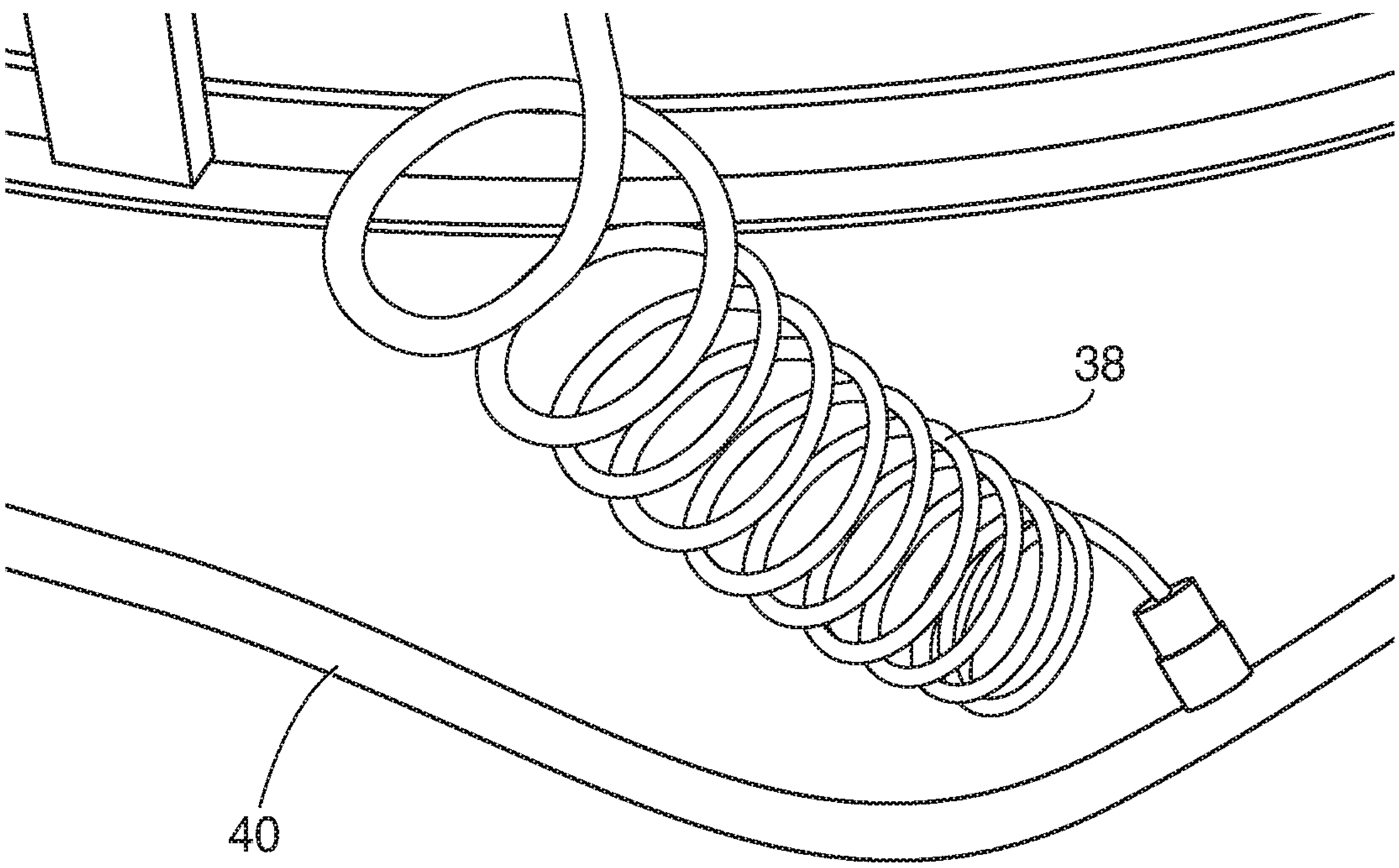


FIG. 7

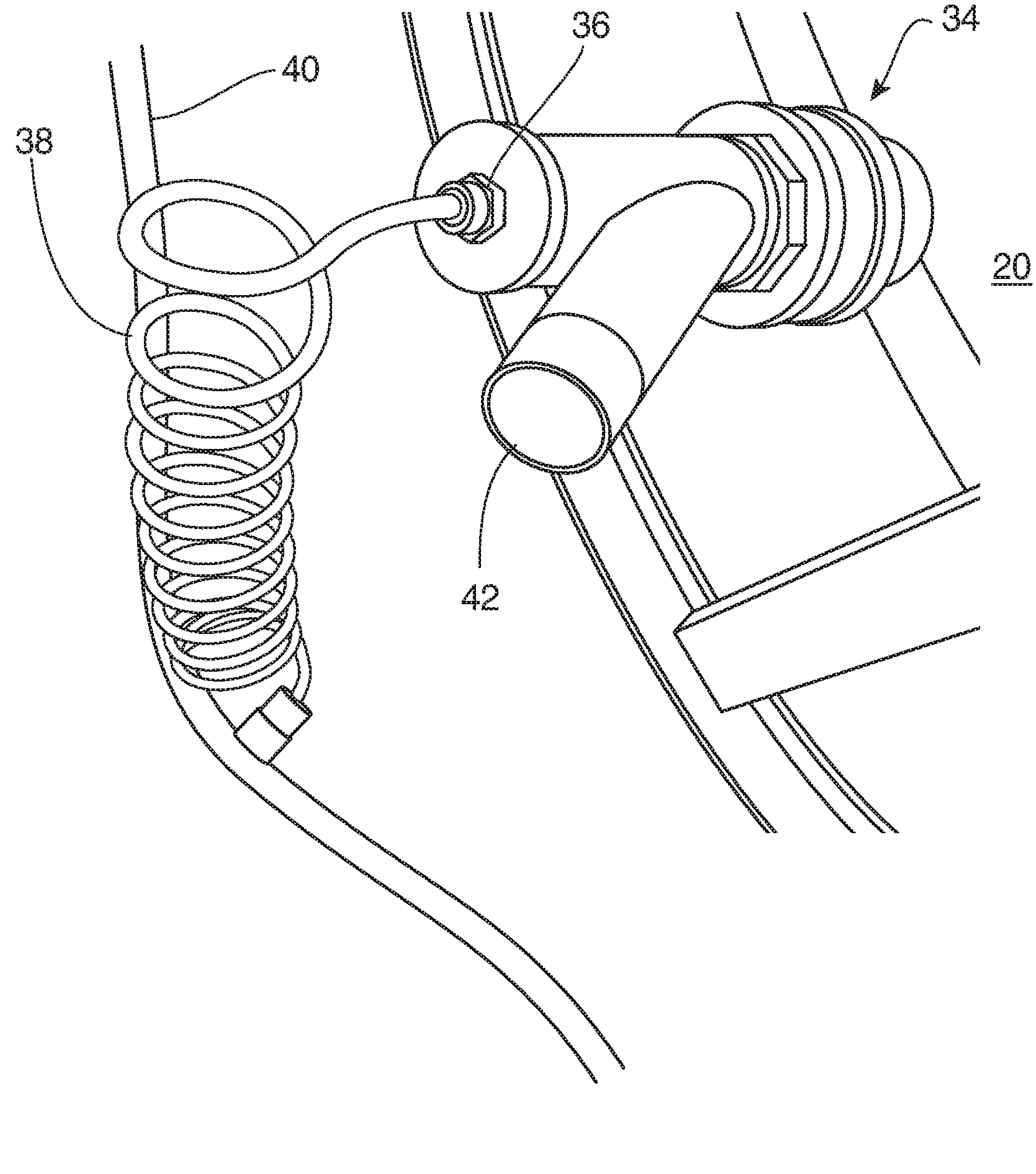


FIG. 8

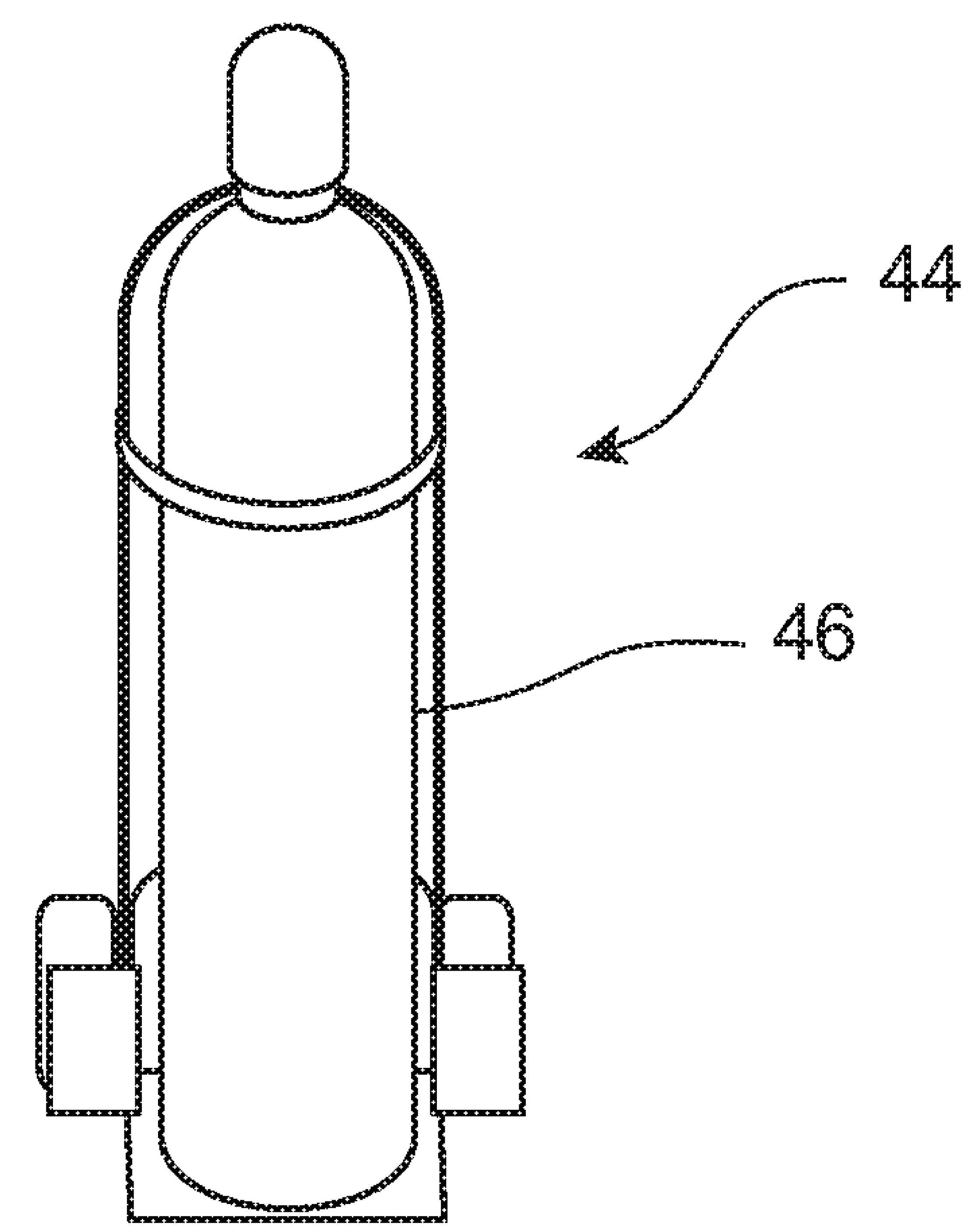


FIG. 9

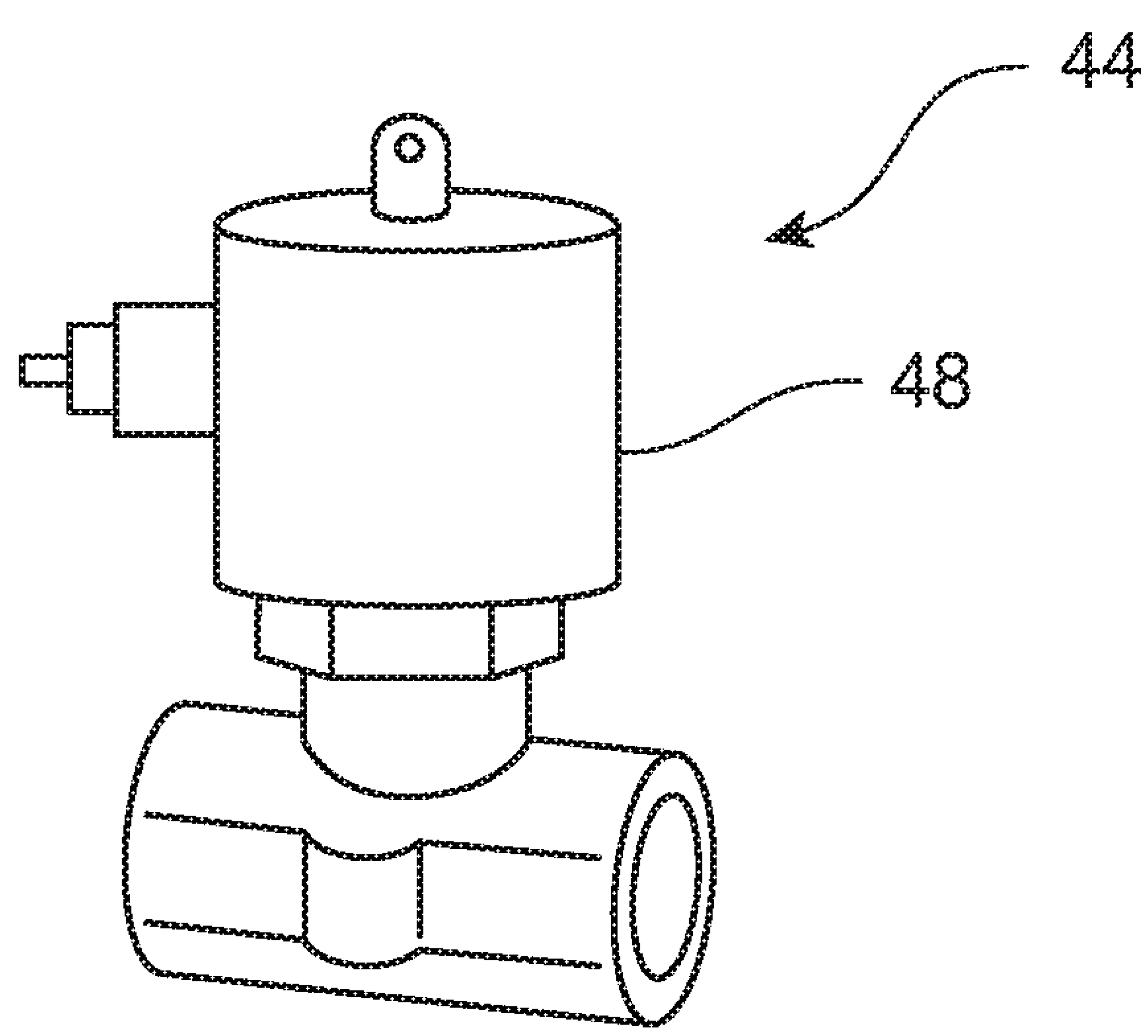
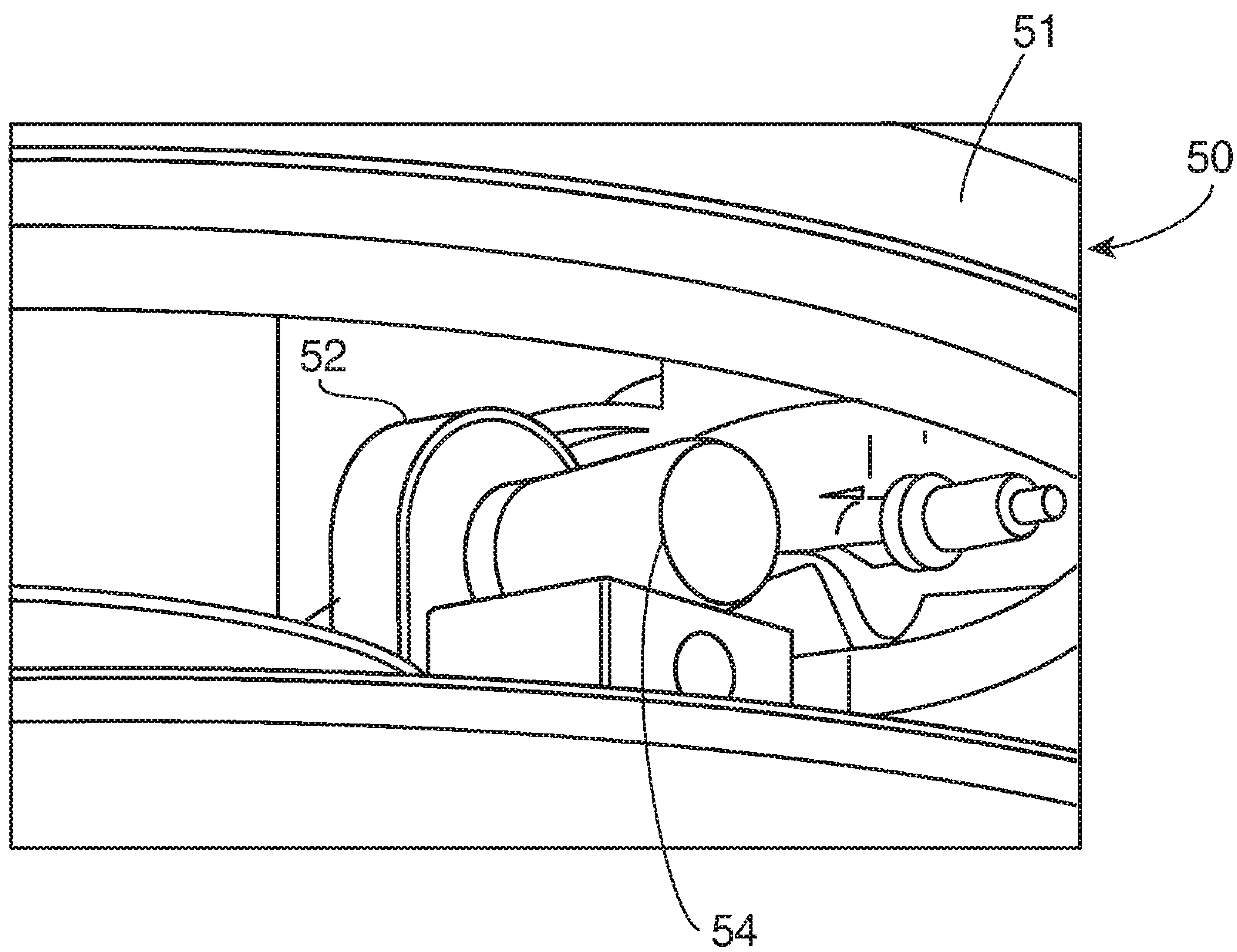


FIG. 10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50
52
54

FIG. 11

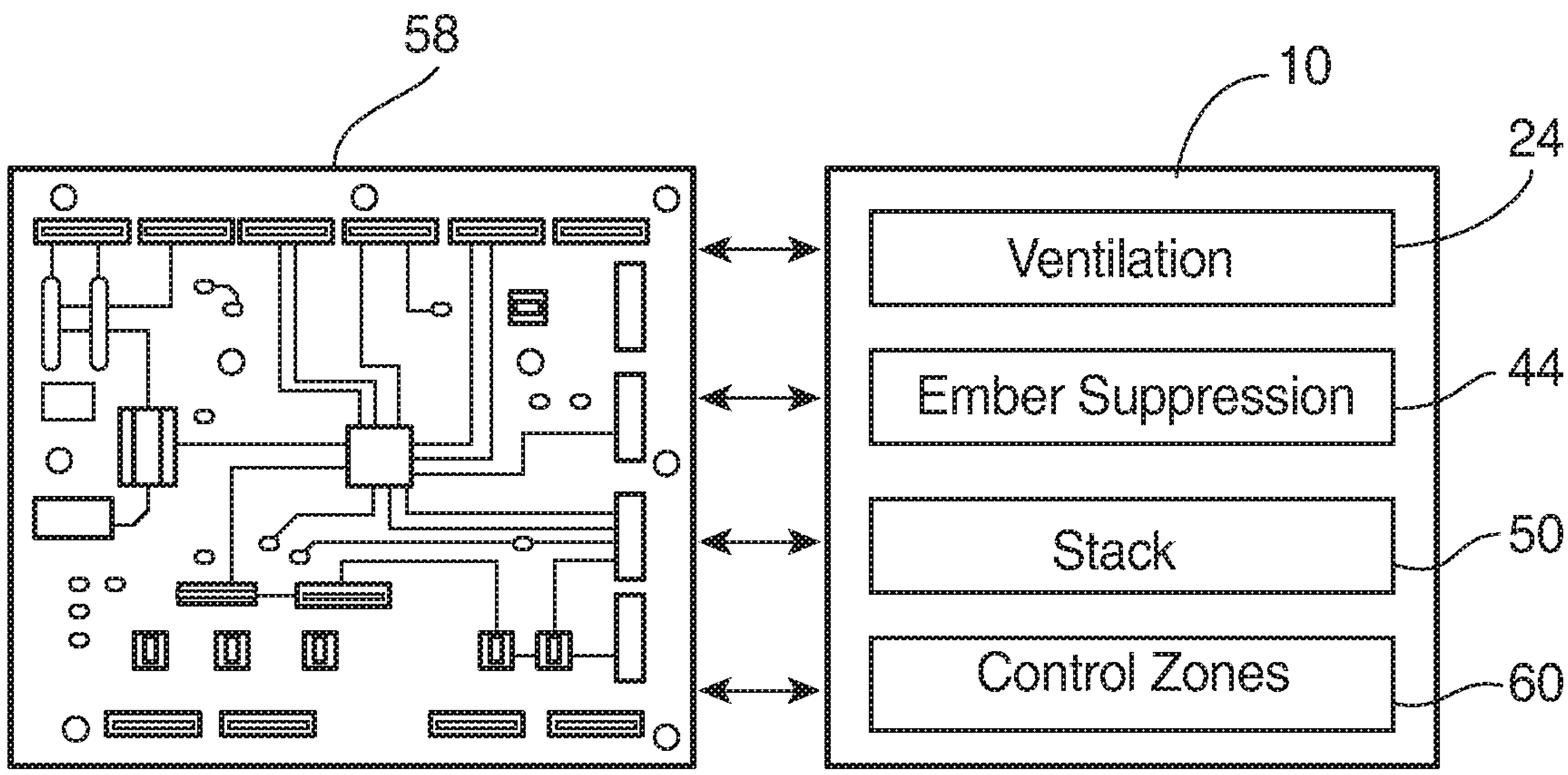

58
10
24
Ventilation
Ember Suppression
44
Stack
50
Control Zones
60

FIG. 12

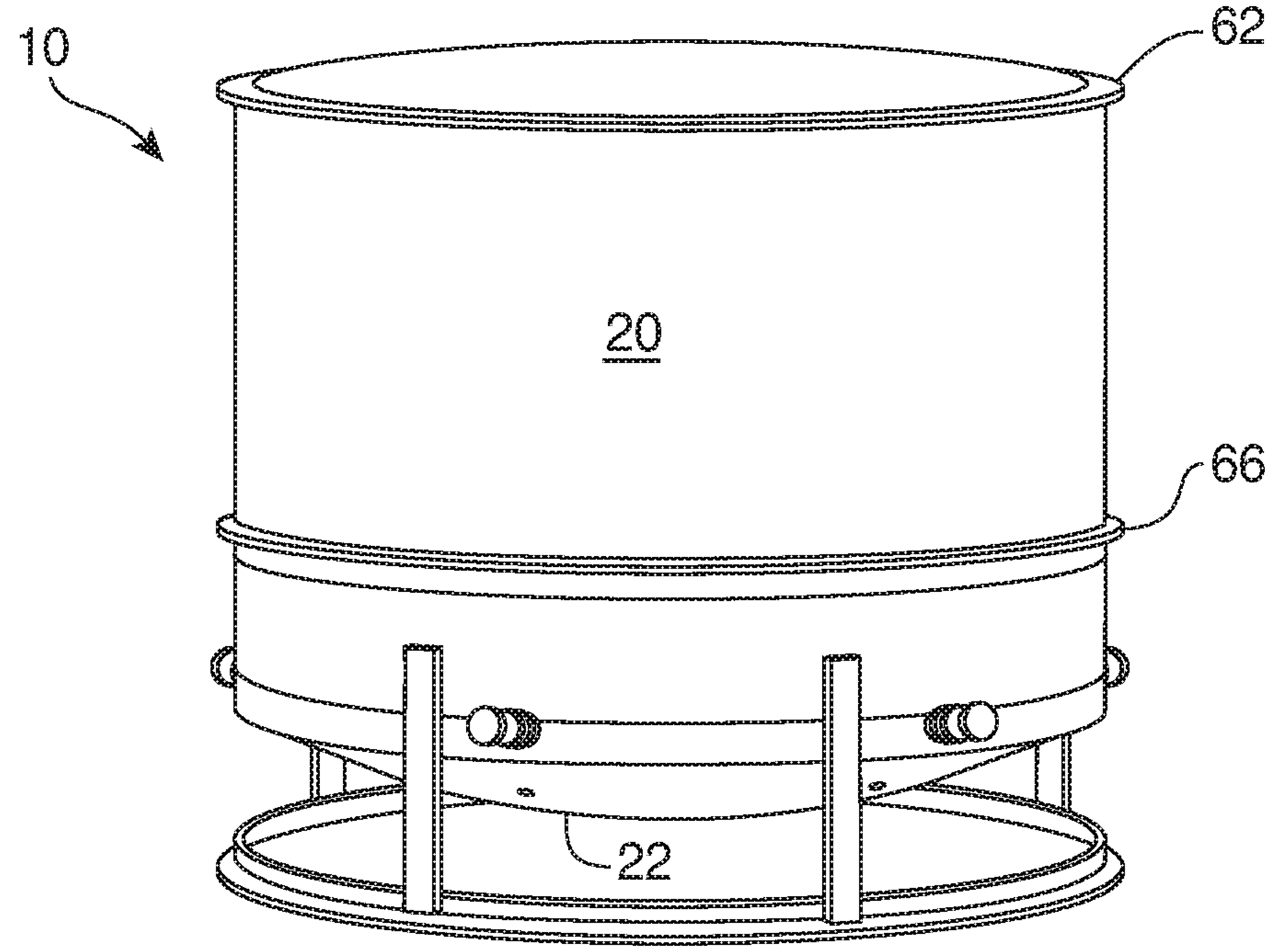


FIG. 13

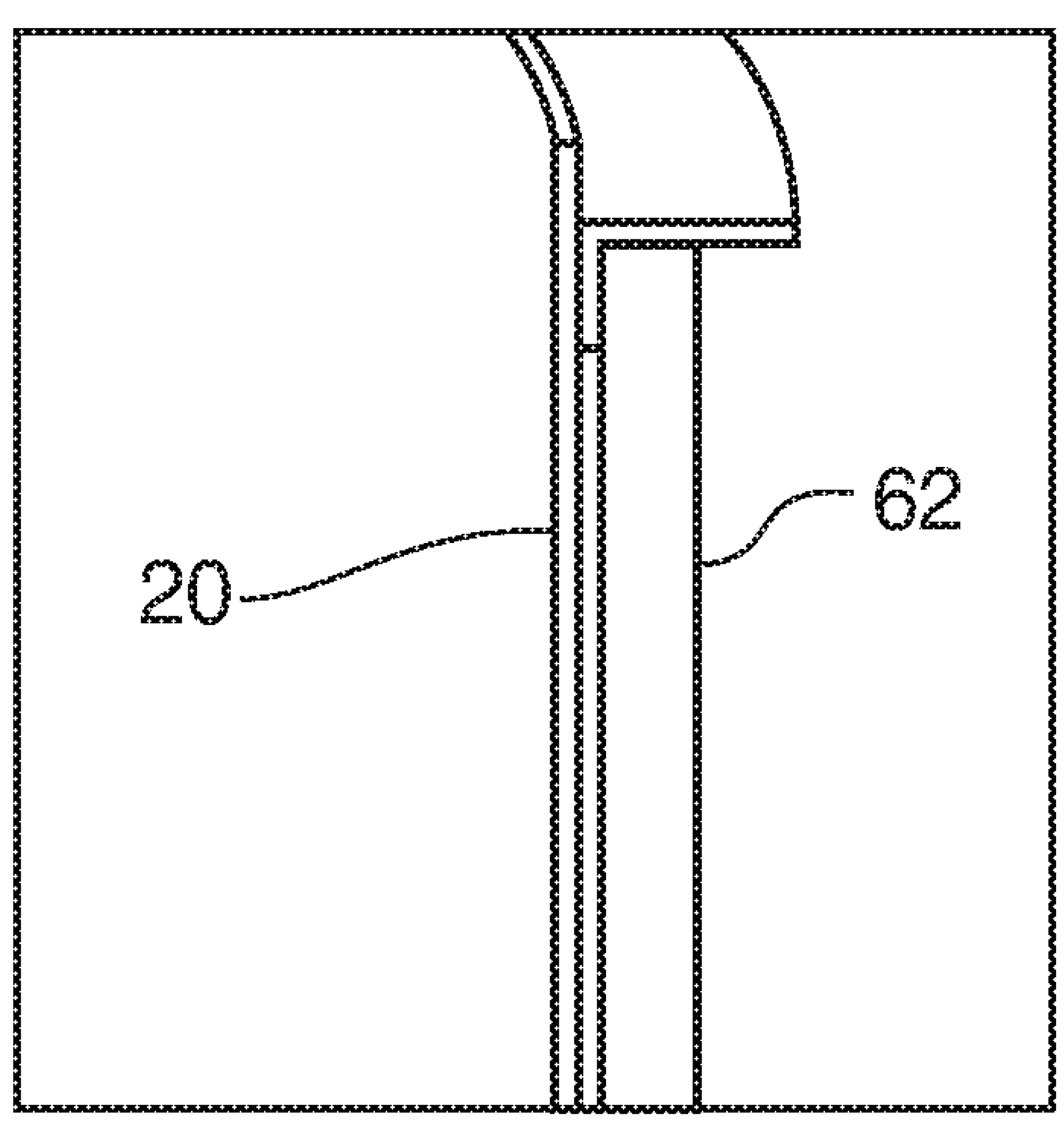


FIG. 14

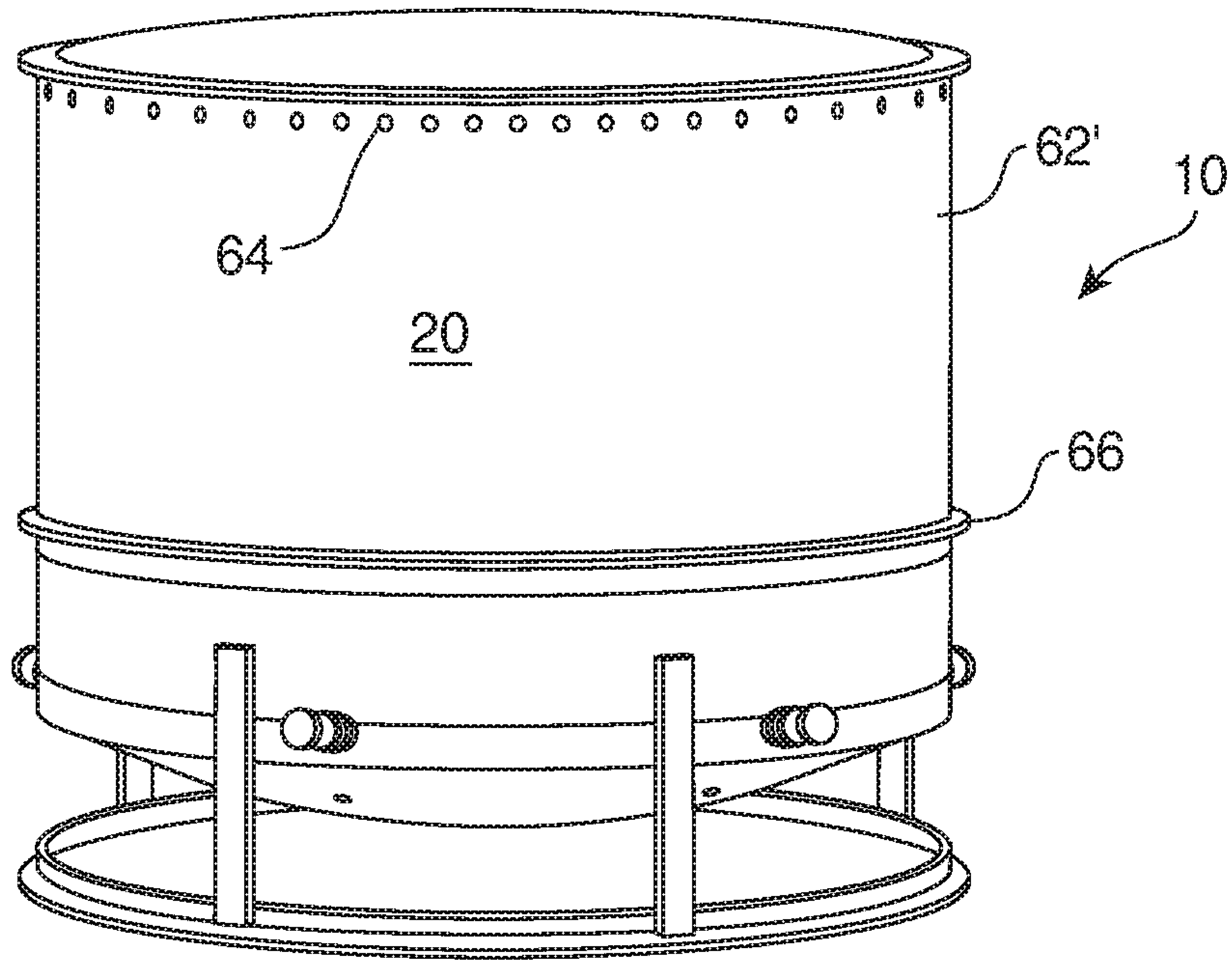


FIG. 15

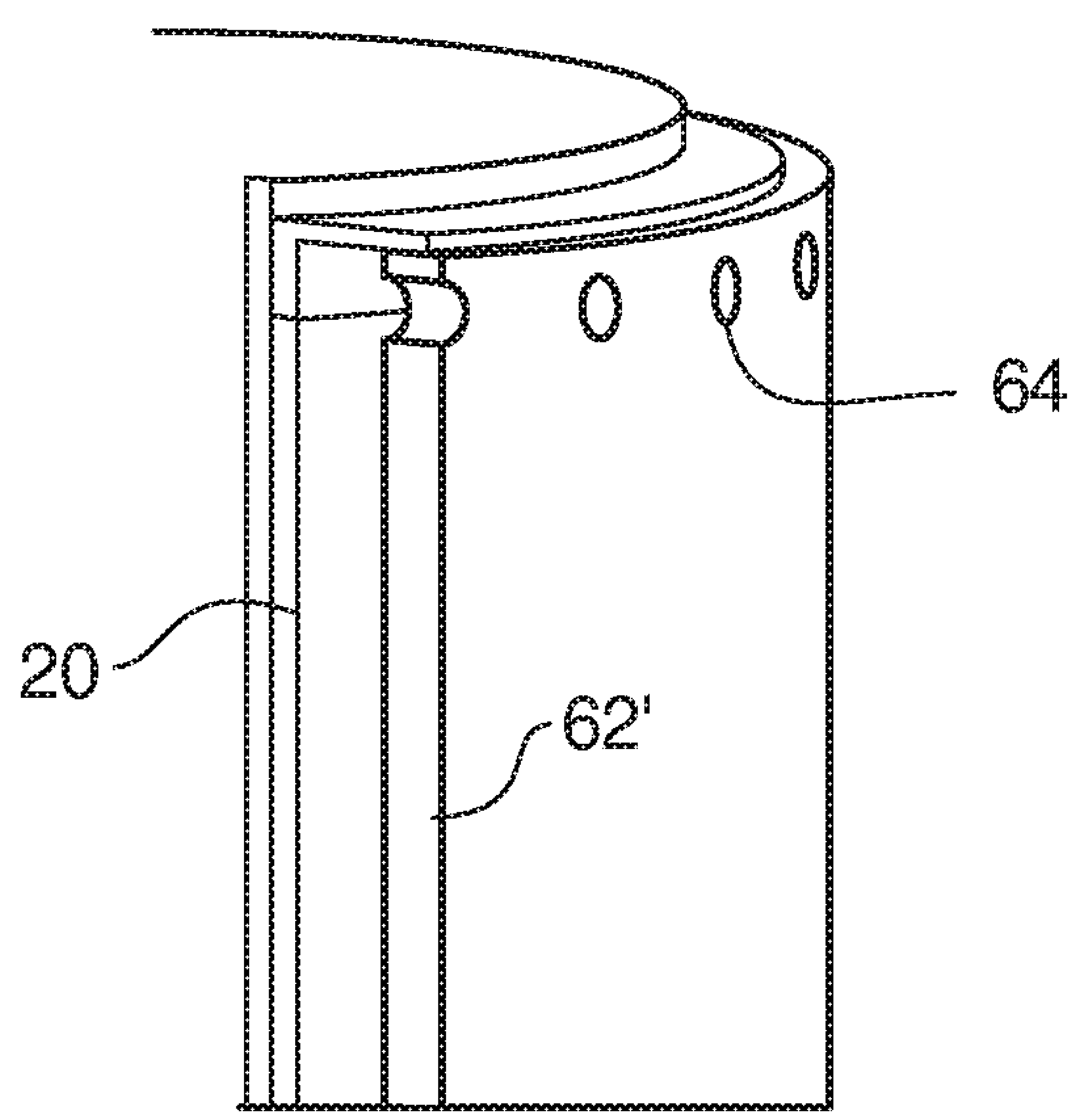


FIG. 16

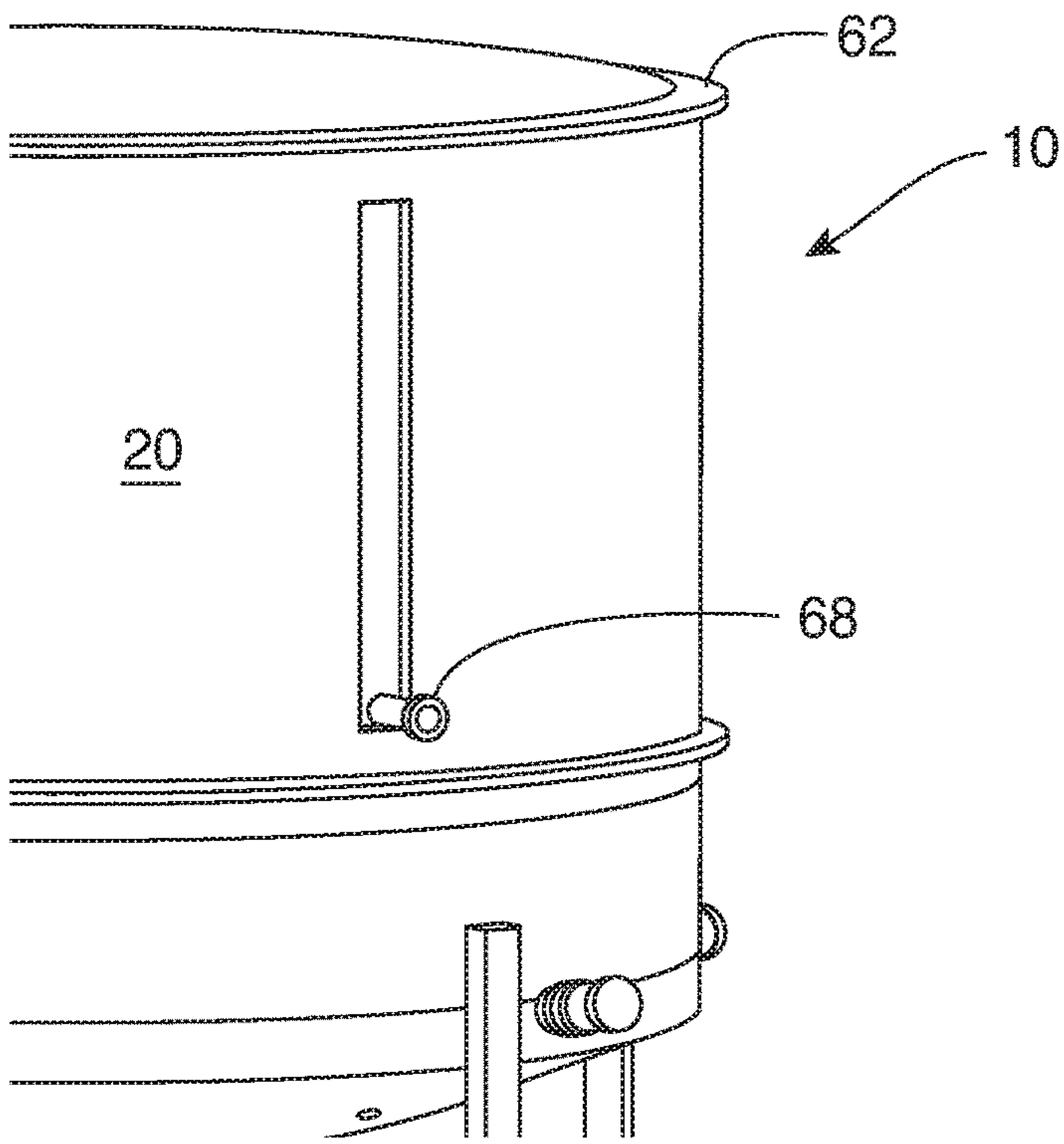
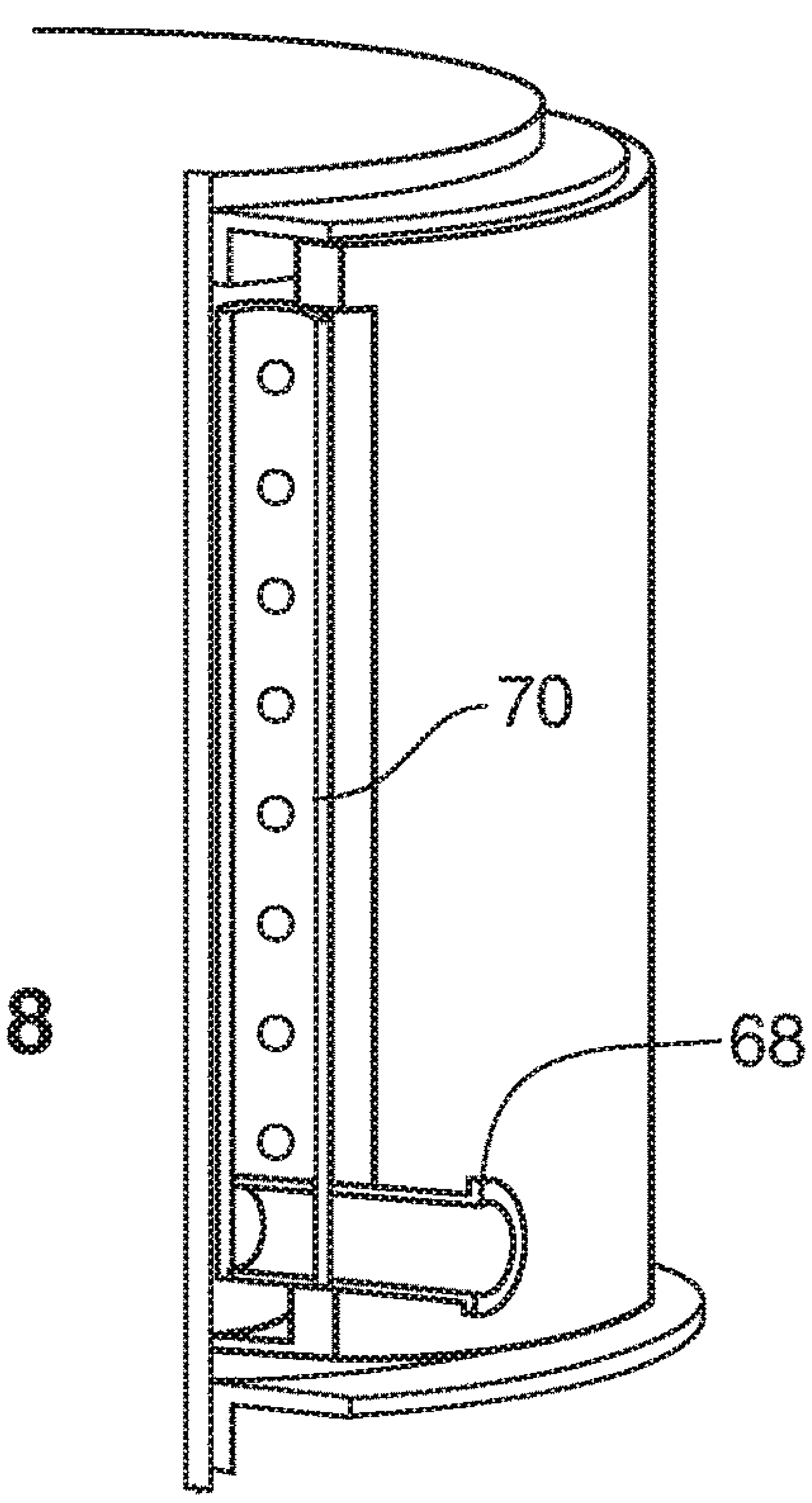


FIG. 17

FIG. 18



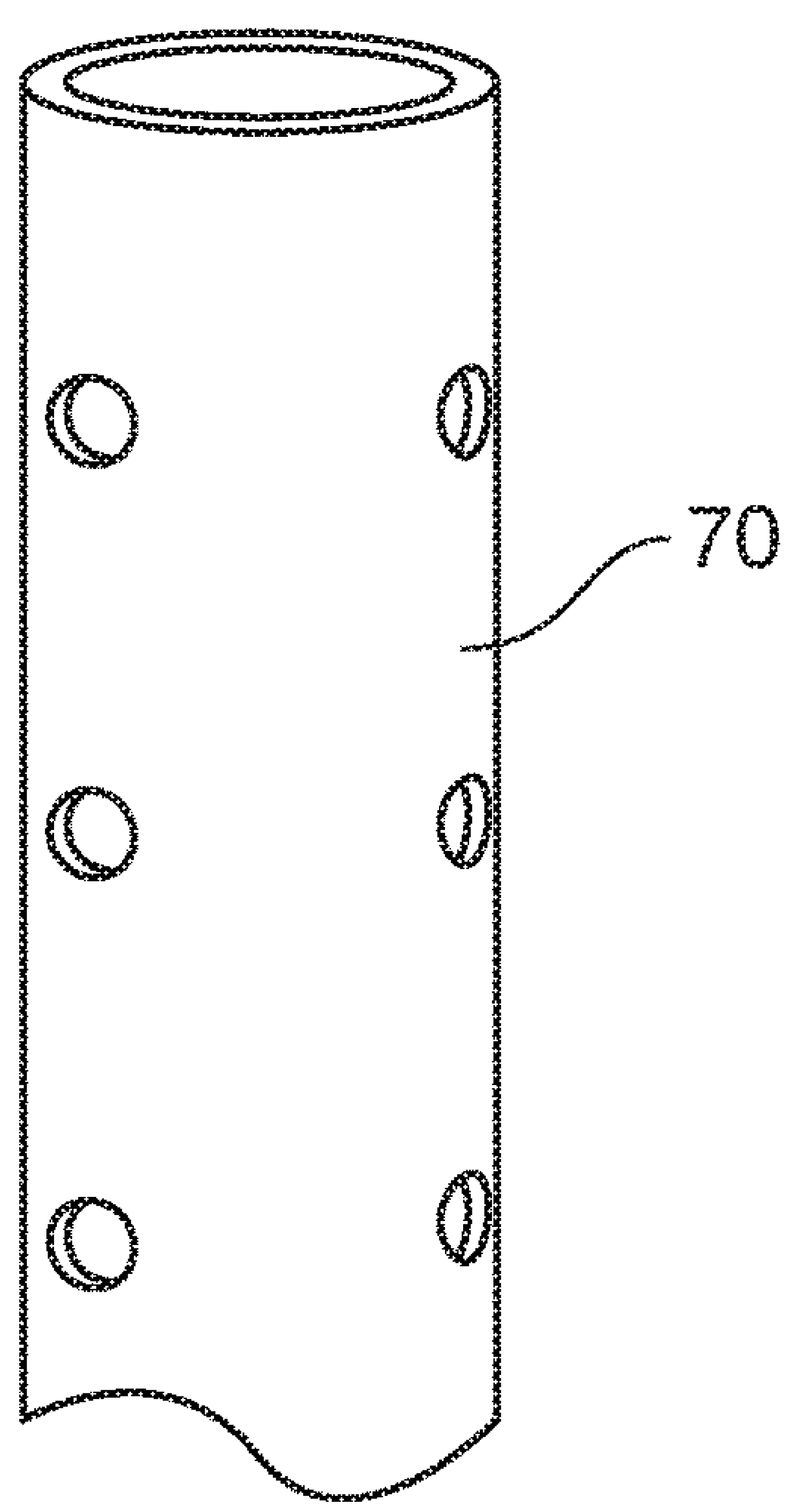


FIG. 19

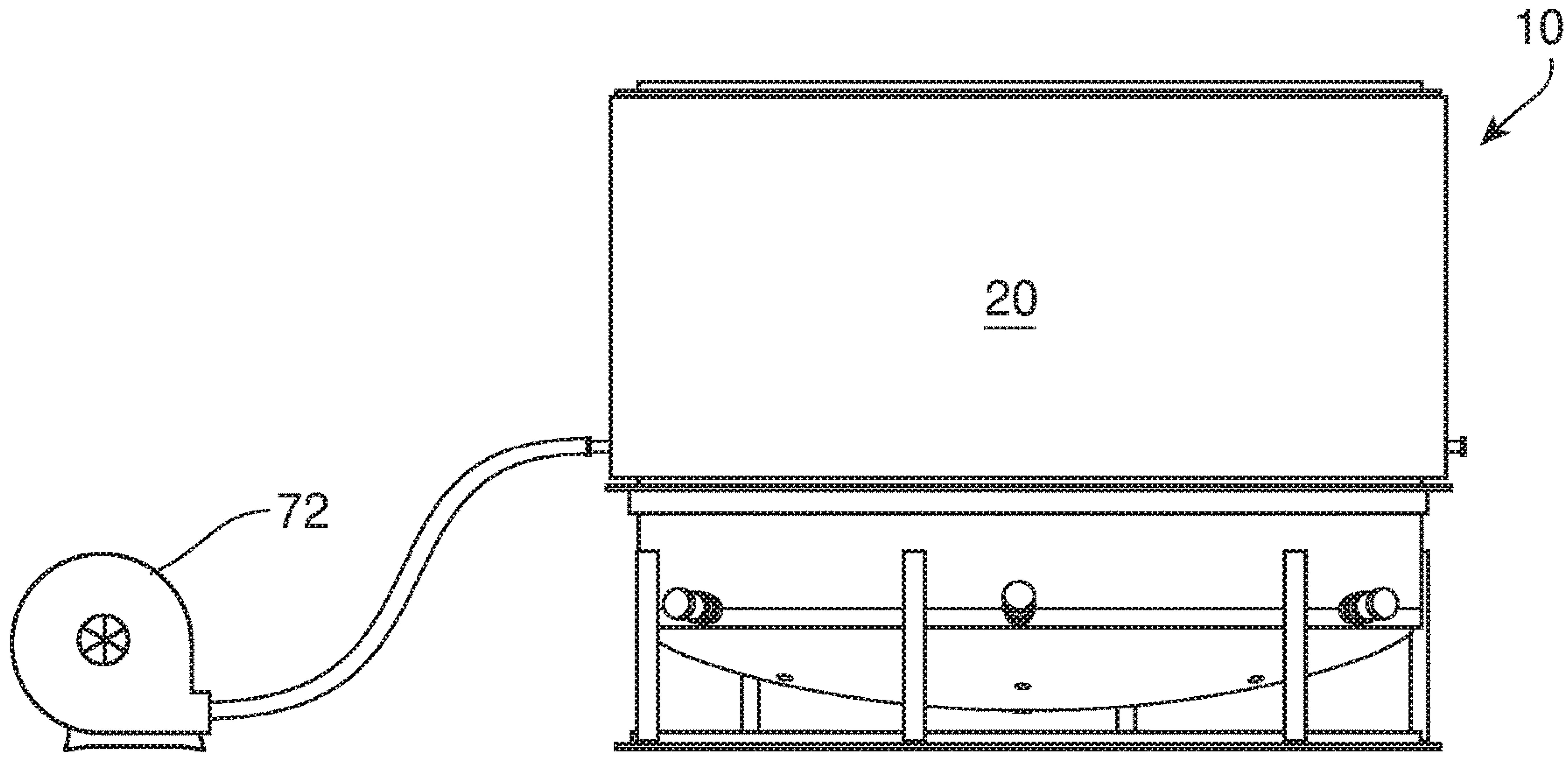


FIG. 20

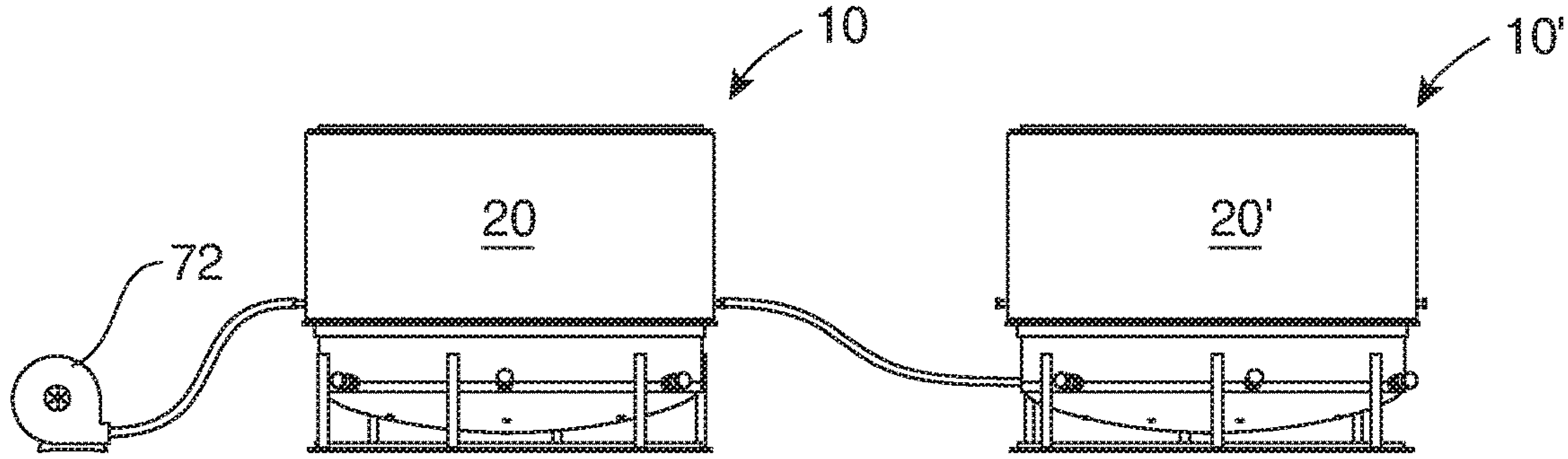


FIG. 21

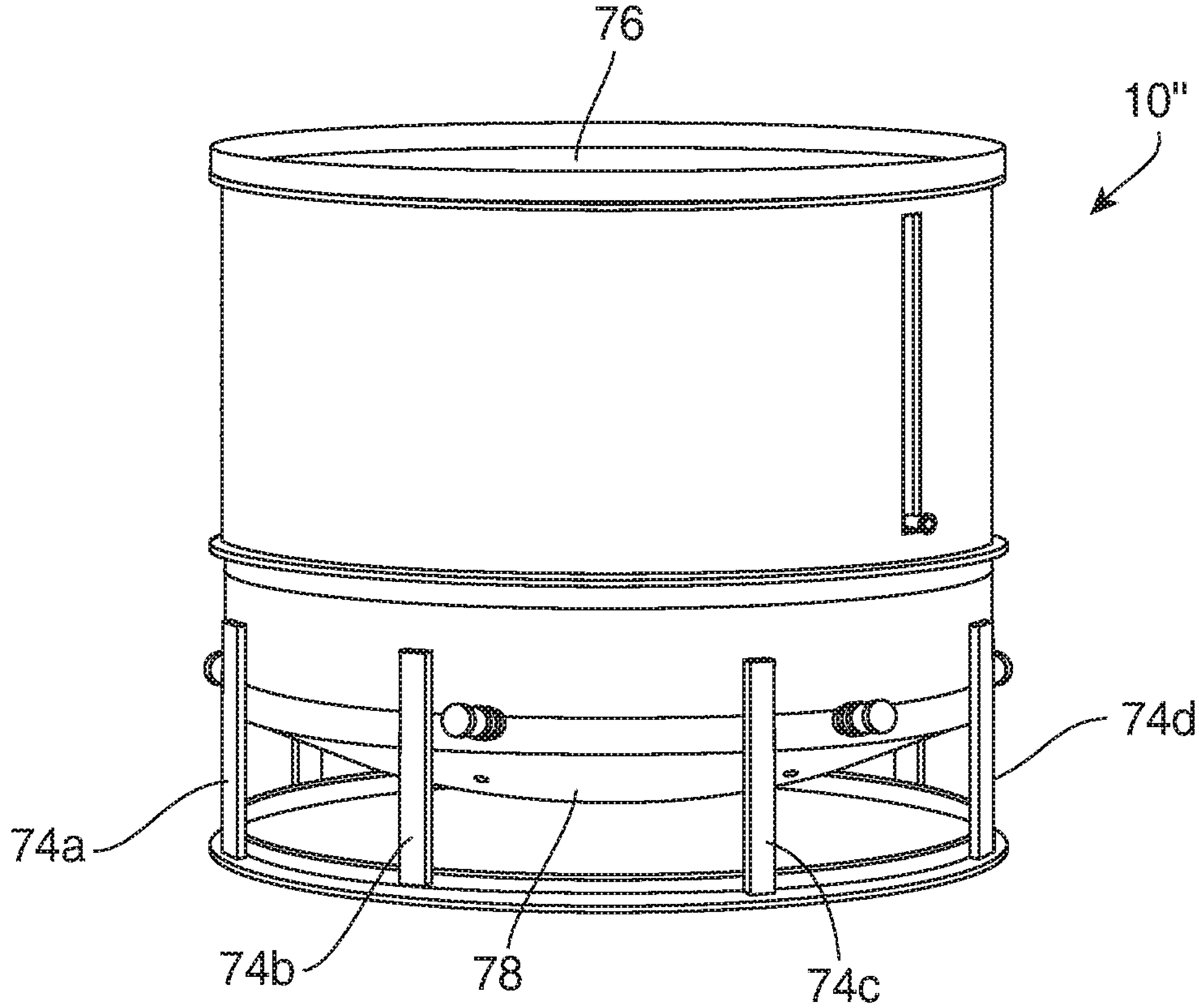


FIG. 22

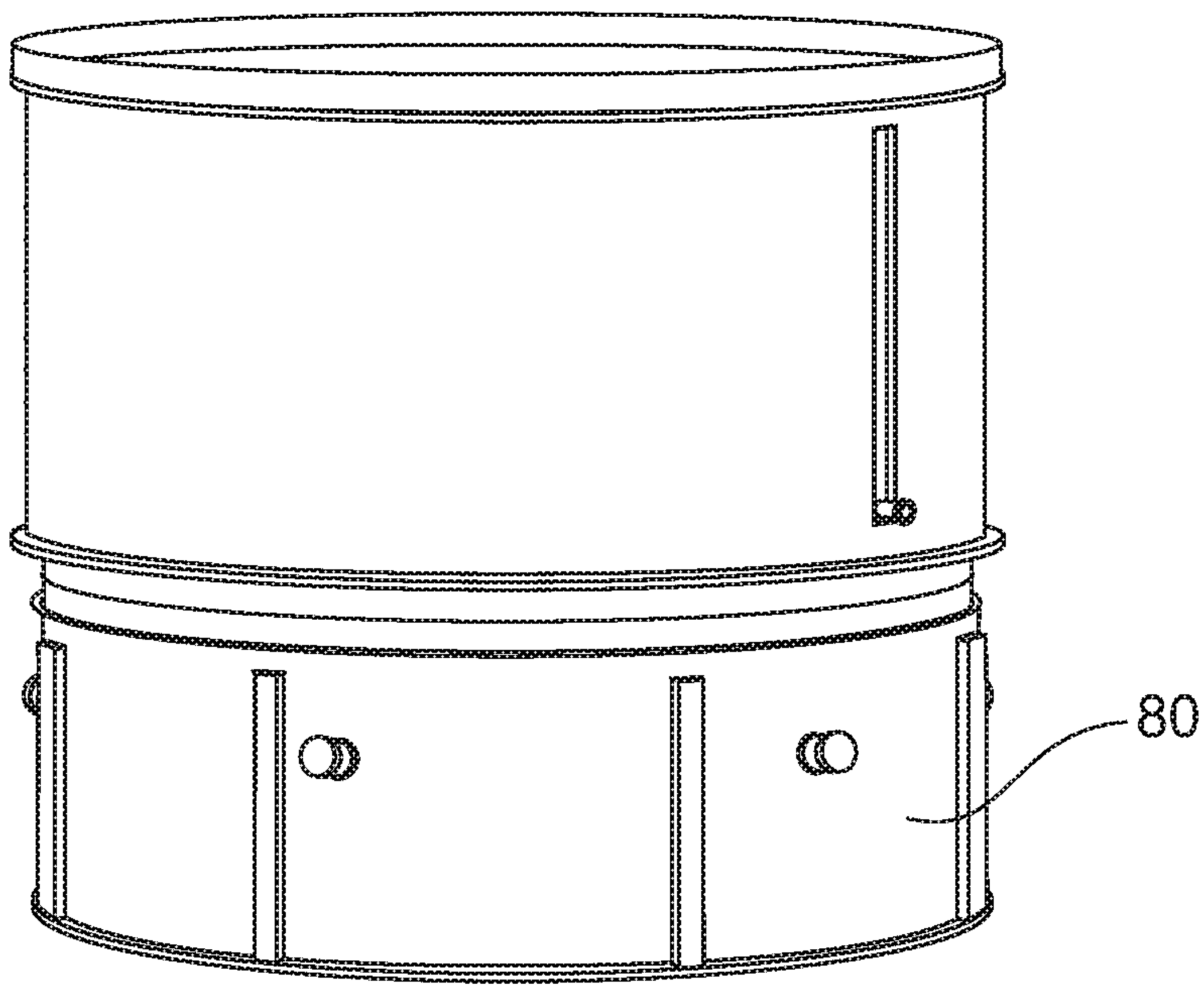


FIG. 23

BIOCHAR KILN

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the priority benefit of U.S. Provisional Patent Application No. 62/317,573 filed Apr. 3, 2016 for "Biochar Kiln," hereby incorporated by reference in its entirety as though fully set forth herein.

BACKGROUND

Biochar is made from biomass (trees, agricultural waste, etc.) in an oxygen deprived, high temperature environment. Quality biochar has high purity, absorptivity and cation exchange capacity. This can provide significant benefits to several large markets including, but not limited to, agriculture, pollution remediation, odor sequestration, separation of gases, and oil and gas clean up.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an example biochar kiln.

FIG. **2** is an interior view of a floor of the example biochar kiln, illustrating a ventilation subsystem.

FIG. **3** is a close-up view of the ventilation subsystem shown in FIG. **2**.

FIG. **4** is another close-up view of the ventilation subsystem shown in FIG. **2**.

FIGS. **5-8** are close-up views of the exterior of the example biochar kiln, illustrating the ventilation subsystem.

FIGS. **9-10** are perspective views of example components of an ember suppression subsystem of the biochar kiln.

FIG. **11** is a perspective view of an example stack subsystem of the biochar kiln.

FIG. **12** is a high-level block diagram of an example control subsystem of the biochar kiln.

FIG. **13-23** are illustrations of example insulation of the biochar kiln shown in FIG. **1**.

DETAILED DESCRIPTION

A biochar kiln is disclosed, including construction of the kiln and various subsystems such as, but not limited to, ventilation, stack, control, insulation, and ember suppression. The kiln may be implemented to produce biochar.

In an example, the kiln is configured for internal combustion and heat generation as needed, to convert biomass into biochar. During operation, the kiln may experience frequent and wide thermal cycling. For example, every 2 days, the kiln temperatures can vary between −30 and +1300 degrees Fahrenheit (e.g., stack temperature ranges from −30 F to 1850 F).

The biochar kiln is configured to support slow pyrolysis and can accommodate a number of variables. Variables include, but are not limited to, a "green" and/or dry feedstock, large and/or small pieces of the feedstock, various and multiple different species of the feedstock, and operation according to variable processing times. The biochar kiln is robust in that it may be operated under a number of variable operating conditions, while still producing a consistent and high quality biochar product.

The biochar kiln may include a local and dedicated process control system. The control system may be implemented with a ventilation subsystem, an ember suppression subsystem, and airflow management or "stack" subsystem,

to help ensure high quality and high yield biochar is produced while simultaneously complying with emissions standards.

In an example, the biochar kiln has multi-zone combustion cells that are computer-controlled to maintain target temperatures while creating faster burns. Multi-zone servo dampers are computer-control to manage inlet air flows to the combustion cells to support optimum heating. The biochar kiln may also have removable stacks and a stack hole sealing mechanism. The kiln may also be configured for negative flue gas pressure to eliminate fugitive emissions.

Before continuing, it is noted that as used herein, the terms "includes" and "including" mean, but is not limited to, "includes" or "including" and "includes at least" or "including at least." The term "based on" means "based on" and "based at least in part on."

FIG. **1** is a perspective view of an example biochar kiln **10**. The biochar kiln **10** may include a main body portion **12** and a lid **14**. The main body portion **12** is configured to receive a feedstock (not shown) by removing the lid **14** and loading the feedstock before replacing the lid **14**. In an example, the biochar kiln further includes a base portion **16**. The base portion **16** may be configured such that it is raised off of the ground. This enables airflow under the main body portion **12**. A ring **18** may also be implemented to lift the biochar kiln **10**, e.g., using a loader tractor, forklift or other suitable machinery.

In an example, the kiln wall **20** may be made of a one-piece, rolled wall. Body welds, where needed (e.g., between the floor **222** and wall **20**, and various ports), are made on curved surfaces to lower structural and thermal stress to those joints.

The floor **24** may also be a one-piece heavy gauge, high strength steel. The floor **24** may be downward elliptical-shaped (the shape being visible in FIG. **1** and FIG. **5**) to withstand heavy falling wood chunks during filling. The surface of the floor **24** is curved and has only one weld joint along the perimeter where it joins with the wall **20**. The floor **20** and walls **20** may anneal with use, which also serves to relieve stress.

Before continuing, it should be noted that the examples described above are provided for purposes of illustration, and are not intended to be limiting. Other devices and/or device configurations may be utilized to carry out the operations described herein.

FIG. **2** is an interior view of a floor **20** of the example biochar kiln **10**, illustrating a ventilation subsystem **24**. The ventilation subsystem **24** may include a plurality of semi-independent combustion cells **25***a-g*. In the example shown, there is a combustion cell **25***g* in the center, and six combustion cells **25***a-f* between the center cell **25***g* and the kiln wall **20**. An outside vent pipe **28***a-f* leads to the center of each cell to provide combustion air. FIG. **3** is a close-up view of the ventilation subsystem **24** shown in FIG. **2**. FIG. **4** is another close-up view of the ventilation subsystem **24** shown in FIG. **2**.

In an example, upward facing thermowell tubes **26***a-g* may be built into the floor **20** for each combustion cell **25***a-f*. The thermowell tubes **26***a-f* may be positioned adjacent vent pipes or air inlets **28***a-f*. Another thermowell tube **26***g* may be positioned substantially in the center of the floor **20**, e.g., for combustion cell **25***g*. The thermowell tubes **26***a-g* may be configured with monitors to enable interior biochar temperature sensing while the biochar is cooking.

FIGS. **5-8** are close-up views of the exterior of the example biochar kiln, illustrating a ventilation subsystem **30**. The ventilation subsystem **30** includes ports **32** around the perimeter of the body **12** of the biochar kiln **10**. Each of the ports **32** is connected to the internal air inlets **28***a-f*. These ports may be closed (e.g., as shown in FIG. **5**) and opened manually, or via computer control.

In FIGS. **6-8**, an automatic control is shown including dampers **34** with air inlet **36** which can be connected to a gas line **38** to a main line **40** to supply ignition gas into the chamber formed in the body **12** of the biochar kiln **10**.

The dampers **34** are each attached to the outside portion of the corresponding vent pipes **28***a-f* to provide computer-controlled airflow. Each damper has a servo-controlled butterfly valve **42** to regulate airflow. Damper airflow results from negative pressure in the kiln (the vacuum sucks air in), or can be blown in by an external blower or both.

In an example, the ventilation subsystem **30** may be implemented with the control system described herein to provide a controlled airflow, thus enabling a carefully controlled burn and emissions control. In an example, each servo is computer-controlled and provides physical position feedback to the computer to confirm the valve's position. The feedback enables the computer control to determine whether a valve is working, blocked or failed. In an example, servo accuracy is about +/−0.5 degrees to permit precise control.

In an example, the kiln is equipped with one or more pressure transducer(s) to insure negative kiln pressure. Air vent pipes for each combustion cell may also pass through the floor flange. After a burn, the vent pipes can be sealed with cam-lock caps to help cut off oxygen, stop combustion and cool the biochar.

At the end of a burn, dampers **34** are removed from the vent pipe openings **32** and replaced with airtight, gasket cam-lock caps **33** (shown in FIG. **4**) over the vent pipe openings **32**. The dampers **34** are then temporally secured to the kiln wall during kiln transit or moved to another kiln for further use.

Damper wiring may be routed to a kiln-mounted control board to eliminate the need to unplug and plug damper wiring when the kiln travels to and from the workstations.

In addition to airflow control, the damper assembly **34** provides a computer-controlled gas-start system to ignite the wood during a fresh burn. Gas flow is turned by the computer via a gas solenoid.

During operation gas is piped into the assembly where it flows through a venturi pulling in air to the air/gas mix tube before being exposed to a preheated glow plug igniter. The ignited gas then travels by a thermocouple probe to verify its ignition and down the vent pipe to start the wood fire at its combustion cell.

FIGS. **9-10** are perspective views of example components **46** and **48** of an ember suppression subsystem **44** of the biochar kiln **10**. An ember suppression subsystem **44** is provided in the event ember suppression is needed after a burn. In an example, a gas **46** (e.g., nitrogen, carbon dioxide, and/or other inert gases) can be injected into the kiln **10** (e.g., at one or more ports **32**, the exhaust stack **51**, or other suitable location) to purge and/or dilute residual oxygen in the chamber of kiln **10**. In an example, carbon dioxide is utilized because it is about two times heavier than air, which enables the biochar to flood a kiln from the bottom up so it can be processed the next morning. Without oxygen, there is no combustion and the embers are put out (stop burning) to allow the biochar to cool down.

The introduction of suppression gases can be managed by a regulator **48** (FIG. **10**) at port **32** or other suitable location, to maintain a low, positive kiln pressure. This helps keep fresh air from entering the kiln. After the heat is reduced to a safe level, the control system can turn off the gas supply. In an example, a safe temperature is about 300 F to 400 F (e.g., it is noted that the auto ignition temperature of wood is about 570 F). By using suppression gases, instead of a water quench, the biochar can be processed in its dry state.

The ember suppression subsystem may also be implemented at least in part in the lid. In an example, the lid has a gasket attached to it at the perimeter. The gasket gets squeezed between lid flange located above the gasket and the flange on the kiln rim below. The gasket reduces or prevents air leaks during ember suppression. During the burn, the gasket also helps retain fugitive smoke in the kiln (e.g., in case of a short term negative pressure drop).

FIG. **11** is a perspective view of an example stack subsystem **50** of the biochar kiln **10**. In FIG. **11**, a portion of the stack **51** (shown in FIG. **1**) is illustrated in detail. In an example, a stack **51** sits on top of the lid **14** of the biochar kiln **10**.

In an example, a reflector/flow director is attached to the underside of the lid. This reflects radiant heat back into the kiln and biochar while also directing the flue gas to the out perimeter of the kiln, which improves heat distribution in the kiln.

The stack may be anchored by gravity and/or other attachment(s). In an example, the base of the stack is wide enough to provide stability (e.g., up to about 90 mph wind loads). At the bottom of the stack **51**, a smoke chamber **52** funnels kiln gases into the stack **50**. A stack blower **54** moves the smoke first horizontally and then curves straight up and through the top of the stack **51**.

During example operation, the stack blower **54** moves combustion air through the duct **52** where the smoke then enters a venturi mix tube. Air from the blower **54** entrains nearby flue gas to pull it up into the mix tube of the stack **51**. At the top end of the mix tube (see FIG. **1**), the air and flue gas combine on their way to a secondary or exhaust burner (not shown).

As the air and flue gas pass through the burner (natural gas or propane), it ignites volatile gases (if any), which lowers emission pollution, burns particulates, heats the vapors and spirals the smoke upward to heat refractory material above the burner. The spiral effect is cause by vanes placed just after the burner. The spiraling hot vapors spend more time heating the refractory than a straight upward flow.

In an example, the target refractory temperature is about 1650 F, and is managed by adjusting the burner fuel flow rate and/or the blower flow rate. At 1650 F, CO combines with radical Oxygen to make CO_2, which is an acceptable emission gas (whereas CO is highly regulated). In addition, at 1650 F, thermal NOX is also kept low.

An added stack extension (not shown) may be provided to help increase flow rate due to stronger convection flow. Less entrainment air is required, for less cooling, less use of burner gas. This may reduce or eliminate the need for refractory material, thus reducing cost.

The blower **54** provides a negative kiln pressure (e.g., by reducing or altogether eliminating fugitive smoke, and providing suction to pull air in from the dampers). The blower **54** also provides oxygen for emission conversion and burner combustion, and helps control stack temperatures by adding cooling air.

FIG. **12** is a high-level block diagram of an example control subsystem **56** of the biochar kiln **10**. The control subsystem **56** may include one or more controller **58**. In an example, the controller **58** may be implemented as a PLC (programmable logic array). The controller **58** may be mounted in any suitable location (e.g., on a pole near the kiln). The PLC has enough computing power to run multiple kilns. In an example, the cable between the kiln and the PLC has 4 conductors (2 for DC power and 2 for data) which make plugging and unplugging easy. In another example, a controller **58** may be provided for each kiln where and can travel with the kiln.

The controller **58** may receive input and/or feedback from the kiln (e.g., the ventilation subsystem **24**, the ember suppression subsystem **44**, and/or the stack subsystem **50**). The controller **58** may also provide output or control of the various subsystems.

In addition, the kiln and stack may also be considered to include a plurality of control zones **60**. The control zones **60** are independent, horizontal and/or vertical zones within the kiln body **12** and stack **51**. The zones each have one or more process control variable (e.g., temperature, oxygen level). The zones **60** may be physical component(s) and/or area(s) (both physical and virtual) of the kiln body **12** and/or stack **14** itself, and/or a process component, such as the feedstock, product (including intermediary product), air, gas(es), and smoke within the kiln body **12** and/or stack **14**.

Examples zones **60** include, but are not limited to, floor combustion cells, the kiln feedstock itself, the produced biochar itself, the kiln lid **14**, the stack smoke chamber, stack mix venturi, the stack burner, Flue gas spiral vanes, Stack refractory, Stack extension. The zones **60** may be equipped with one or more sensor and/or dampers. These zones **60** may be managed by the controller **58**.

In an example, each kiln **10** has its own computer control board (e.g., for easy transit and improved individual kiln reliability). The control board may be wirelessly linked to a site controller to accept site-wide remote commands (e.g., fire start), to provide archive data and to send status alarms.

To integrate multiple zones across multiple kilns **10**, and/or multiple zones within a single kiln **10**, the control subsystem **56** can apply one or more group state machines on top of individual zone state machines to insure even burns across individual zones. For example, group state machines may include a program to ask individual zones to stop at intermediate temperatures to permit slower zones to catch up. When all zones arrive at the temperature, the group is then released to continue the process.

The control board may be accessed via tablet, smart phone, and laptop devices, e.g., which provide the user interface and control. The control board may also control work lights and strobe alarms at the site and/or individual kiln(s).

In an example, the controller **58** implements state machine software and device controllers to independently manage each of the various subsystems (e.g., **24**, **44**, and **50**) and zones **60** (e.g., a floor combustion cell). To integrate zones **60**, the controller **58** can be implemented as one or more group state machines on top of individual state machines to ensure optimal group performance (e.g., to ensure consistent or even burns across all cells).

The controller **58** may enable non-programmers to develop advanced control logic and algorithms without making changes to its lower level program code. Unique control instructions (e.g., "recipes") can be generated for unique customer needs, feedstock type, emissions requirements, biochar attributes, etc.

In an example, the control subsystem **56** provides higher yields, higher biochar quality, greater consistency, optimized flow rates, vapor pressure control, end of cycle detection, lower emissions and shorter burn cycles. By way of illustration, each floor combustion cell may be provided with an optimal amount of combustion air for maximum temperature rise while working to reach a preset temperature goal. The burn control can use Boolean logic and/or PID (proportional, integral and derivative) control or other techniques for fastest temperature attainment.

FIG. **13-23** are illustrations of example insulation of the biochar kiln **10** shown in FIG. **1**. On cold, windy days, over 80% of the kiln's heat can be lost through the steel shell (e.g., lid **14**, walls **20**, and floor **22**) of the biochar kiln **10**. On a windless, warm day, heat loss can be under 30%. If the kiln is insulated with a ceramic blanket (or other types), heat loss can be reduced by as much as 95%. When insulation is used, internal temperatures climb more quickly for shorter burn times, yield improvement (less wood burned), reduced emissions (less wood burned), improved consistency (soak heats are more evenly distributed), and improved quality. Exposing the ceramic blanket to rain and snow quickly transforms it into a poor insulator. To protect the blanket, it may be encapsulated in a high temperature weatherproof skin.

In an example, a cylindrical insulator **62** (FIG. **13**) is provided that follows the shape of the kiln wall **20**. FIG. **14** is a close up of the upper side edge of the wall **20** showing the cylindrical insulator **62** in detail.

In another example, the insulating cylinder **62'** may stand away from the kiln wall **20** to allow forced airflow through a gap between the kiln wall **20** and the insulating cylinder **62**, and optionally through openings or vents **64** (e.g., after a burn). In an example, (not shown), a ring or band with similar sized and spaced openings can be fit snugly to the insulation. During processing, the band can be rotated so that the vents **62** are at least partially or fully covered. To aid in cooling, the band can be rotated so that openings in the ring line up with the vents **64**. By natural convection, the air inside the space is heated by the Kiln wall. It then rises out the vent openings, drawing cool air into the air space from the bottom.

Ambient air (or chilled air) blowers may be provided to force air to pass between the kiln wall and insulation for cooling before it exits on the far side. Sensing the existing air temperature and internal thermowell temperatures can indicate when the kiln is safe to open.

In an example, the insulation is about 1.5 inches thick, although other sizes may be provided. The insulator **62** and **62'** can detach from the kiln to permit replacement and maintenance as needed.

There may be provided a clearance between a gripper ring **66** and the bottom of the insulation so that gripping the gripper ring **66** (e.g., with a forklift or other machinery to raise/lower the kiln **10**) does not pinch or otherwise harm the insulation. This distance may depend on the dimensions of the gripper and the expected accuracy of the loader driver while picking up the Kiln.

The insulation **62** and **62'** holds significantly more heat inside the Kiln during processing, and is expected to reduce the amount of wood burned (increasing efficiency) with increased yield of char.

If using natural convection doesn't allow cooling of the Kiln in a short enough time, forced convection may be provided. One way to accomplish forced convection is by mounting a pipe **68** vertically to the kiln **10**, as shown in FIG. **17**. The pipe **68** can direct air into the space between the kiln wall **20** and the insulation. It may be possible to leave this pipe **68** uncapped during processing, since little air will escape. If desired, the pipe(s) **68** can be capped.

The pipe(s) **68** distribute forced air both ways (e.g., left and right) into the air space on one side of the kiln **10**. If it is desired to "collect" the air on the opposite side of the kiln

10, another similar pipe can be installed. If faster cooling is desired, 4 pipes can be used, 2 for inlet and 2 for "exhaust", though the complexity increases significantly. These are only exemplary configurations. Other configurations are also contemplated.

As shown in FIGS. **18-19**, plenum walls **70** may be provided inside the air space to keep the cooling coverage more even than if the forced air could flow vertically inside the air space. These plenum walls **70** may be welded to the Kiln wall in a circular direction and could be full or partial walls.

FIG. **20** shows a blower **72** attached to the inlet of the forced air system. Forced convection possibly will require an additional blower for each kiln **10** in the cool-down cycle.

FIG. **21** shows how to use the "waste" heat from the kilns **10**. If the heated air from cooling a processed kiln **10** is piped into the inlet air pipes of a waiting kiln **10'**, some amount of drying of the wood might be accomplished while waiting to process the loaded kiln. This may reduce the time needed to evaporate all the moisture in the wood during processing.

The heated air may be forced into 2 or 3 inlets, as illustrated by FIG. **21**. Or a manifold of sorts could be attached to the waiting kiln, where hot air could enter all air inlets and would exit through the lid (some venting mechanism might be provided on the lid if general air leaks are not enough).

FIGS. **22-23** show a kiln **10"** having six 2×2 inch legs (legs **74***a-d* are visible in FIG. **22**) and a rolled angle bottom with top insulation **76** and bottom insulation **78**. Bottom insulation **78** may not be provided if the bottom area is enclosed with insulation or insulation sections **78**.

In this example, there may be no air blown into/out of the bottom for cooling to reduce the need for plumbing through the insulation **80**. As the heat rises, and when the walls and inside air were cooled, the bottom may lose heat to the Kiln air. If forced air cooling is desired for the bottom, a small diameter pipe may be attached to the blower, and cool air can be blown into the bottom chamber which exits from vents in the bottom insulation sections.

A similar air space/insulation configuration may be used for the lid. The stack blower may be used to provide the forced air for cooling. It may implement a switched damper to divert the air from the stack to the lid and/or kiln. It is noted that the kiln and lid may be hot if plumbing needs to be connected. In another example, a blower is attached to the lid that is used for cooling.

In an example, the kiln insulation is provided in sections to make it easier to install. Overlapped sheet metal joints may hold sections together and help prevent air loss during cooling.

In an example, the kiln wall insulation is enclosed in a "box" (e.g., of 1/16" or 16-gauge (or thinner) sheet metal). For the kiln walls and bottom sections, these may be rolled to fit, with bent or welded ends for fastening the "front" and "back" sides together. An attachment mechanism/bracket may be welded to the kiln. In other examples, these insulation sections may be fastened to the brackets.

If the insulation section dimensions are about half or whole multiples of about 14.5 inches, fiberglass rolls may fill the inside of the insulation sections (e.g., 16 inch stud spacing less 1.5 inch stud is about 14.5 inches). It is noted that careful dimensioning may lead to more efficient use of the insulation.

It is noted that the examples shown and described are provided for purposes of illustration and are not intended to be limiting. Still other examples are also contemplated.

The invention claimed is:

1. A biochar kiln, comprising:

a body having a one-piece rolled wall, a curved floor attached to the sidewall by a single weld line, and a removable lid;

a plurality of semi-independent combustion cells, wherein a center combustion cell is provided in the center of the body and six perimeter combustion cells are provided between the center combustion cell and the wall;

an outside vent pipe loading to a center of each of the perimeter combustion cells to provide combustion air;

a plurality of thermowell tubes built into the curved floor for each of the combustion cells, wherein the thermowell tubes are positioned adjacent the vent pipes;

a ventilation subsystem;

an ember suppression subsystem;

a stack subsystem; and

a control subsystem.

2. The biochar kiln of claim **1**, wherein the ventilation subsystem includes ports around the perimeter of the body of the biochar kiln, each of the ports connected to internal air inlets.

3. The biochar kiln of claim **1**, further comprising an automatic control including computer-controlled dampers to regulate airflow into the body of the biochar kiln.

4. The biochar kiln of claim **3**, wherein damper airflow is by negative pressure in the kiln or blown in by an external blower or both.

5. The biochar kiln of claim **1**, wherein the stack subsystem includes a stack blower to move combustion air through a duct where smoke then enters a venturi mix tube.

6. The biochar kiln of claim **5**, wherein air from the blower entrains nearby flue gas to pull up into the venturi mix tube, and the air and flue gas combine en route a secondary burner.

7. The biochar kiln of claim **1**, wherein the ember suppression subsystem includes a gas injected into the body of the biochar kiln to purge and/or dilute residual oxygen in the body.

8. The biochar kiln of claim **7**, wherein carbon dioxide gas is utilized to enable produced biochar to flood the body of the biochar kiln from bottom-up.

9. The biochar kiln of claim **1**, wherein the control subsystem manages a plurality of zones within the body.

10. The biochar kiln of claim **9**, wherein the zones include independent horizontal and vertical zones.

11. The biochar kiln of claim **9**, wherein the zones include at least one of a plurality of floor combustion cells.

12. The biochar kiln of claim **9**, wherein the zones are managed for variable kiln wood, kiln biochar, stack smoke, stack mix, stack burner temperature, and flue gas.

13. The biochar kiln of claim **9**, wherein the zones are monitored by one or more sensor and/or dampers.

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