



(22) **Date de dépôt/Filing Date:** 2008/03/03

(41) **Mise à la disp. pub./Open to Public Insp.:** 2008/09/04

(45) **Date de délivrance/Issue Date:** 2015/12/15

(62) **Demande originale/Original Application:** 2 678 763

(30) **Priorité/Priority:** 2007/03/01 (US11/681,147)

(51) **Cl.Int./Int.Cl.** **B64D 1/16** (2006.01),
B64D 1/00 (2006.01)

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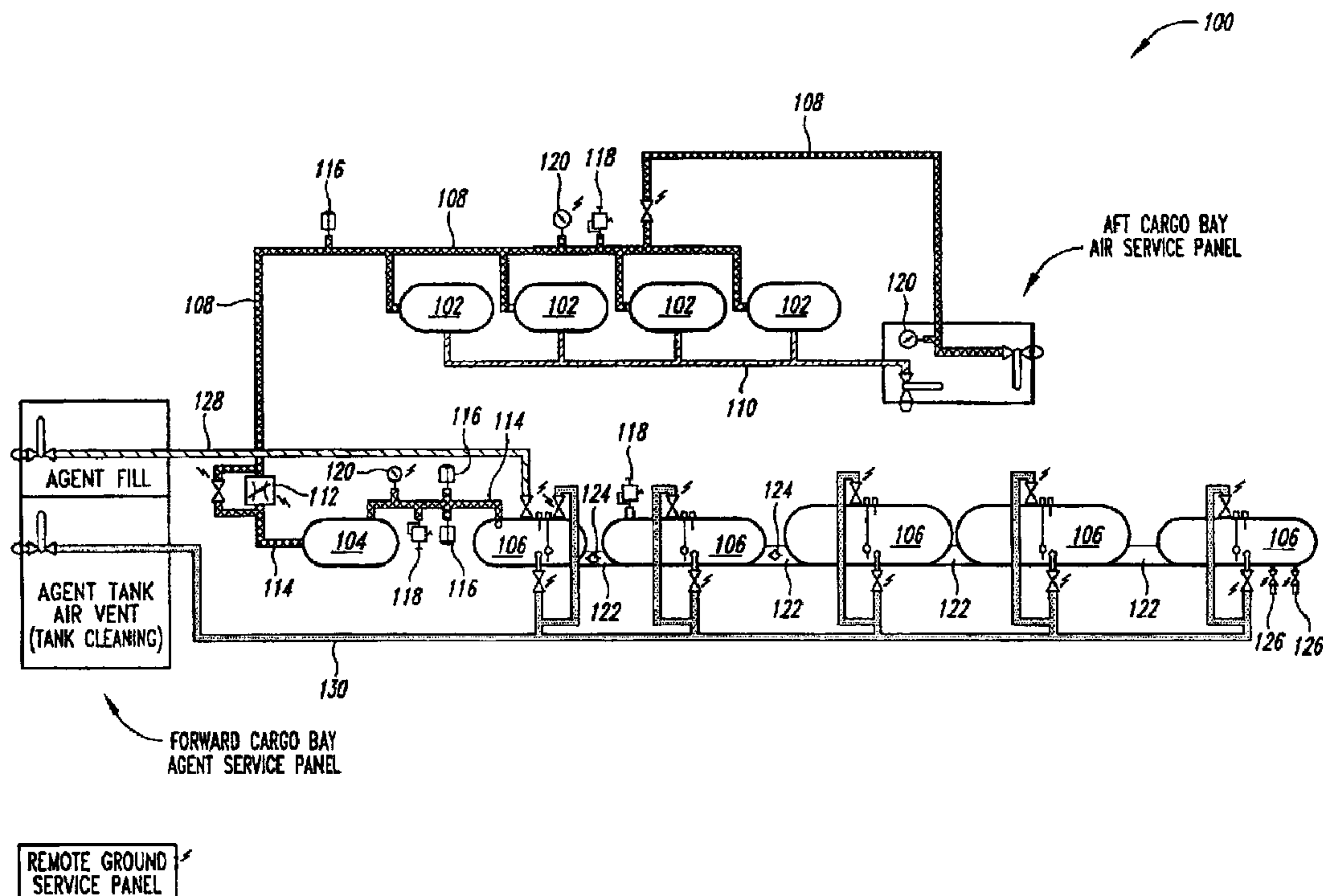
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(54) **Title: ENHANCED AERIAL DELIVERY SYSTEM**



(57) **Abstrégé/Abstract:**

An enhanced aerial delivery system addresses issues raised when large quantities of fluids, powders, and other agent materials are to be transported in and aurally dispersed by aircraft. Some aspects include positioning and securing of tanks aboard the aircraft to facilitate management and safety of the tanks and aircraft. Other aspects address coupling of the tanks and associated piping to lessen structural effects upon the aircraft. Further aspects deal with channeling, containing, and dumping stray agent materials that have escaped from the agent tanks on board the aircraft.

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

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
4 September 2008 (04.09.2008)

PCT

(10) International Publication Number
WO 2008/106693 A1

(51) International Patent Classification:
B64D 1/00 (2006.01)

(21) International Application Number:
PCT/US2008/055725

(22) International Filing Date: 3 March 2008 (03.03.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/681,147 1 March 2007 (01.03.2007) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

(54) Title: **ENHANCED AERIAL DELIVERY SYSTEM**

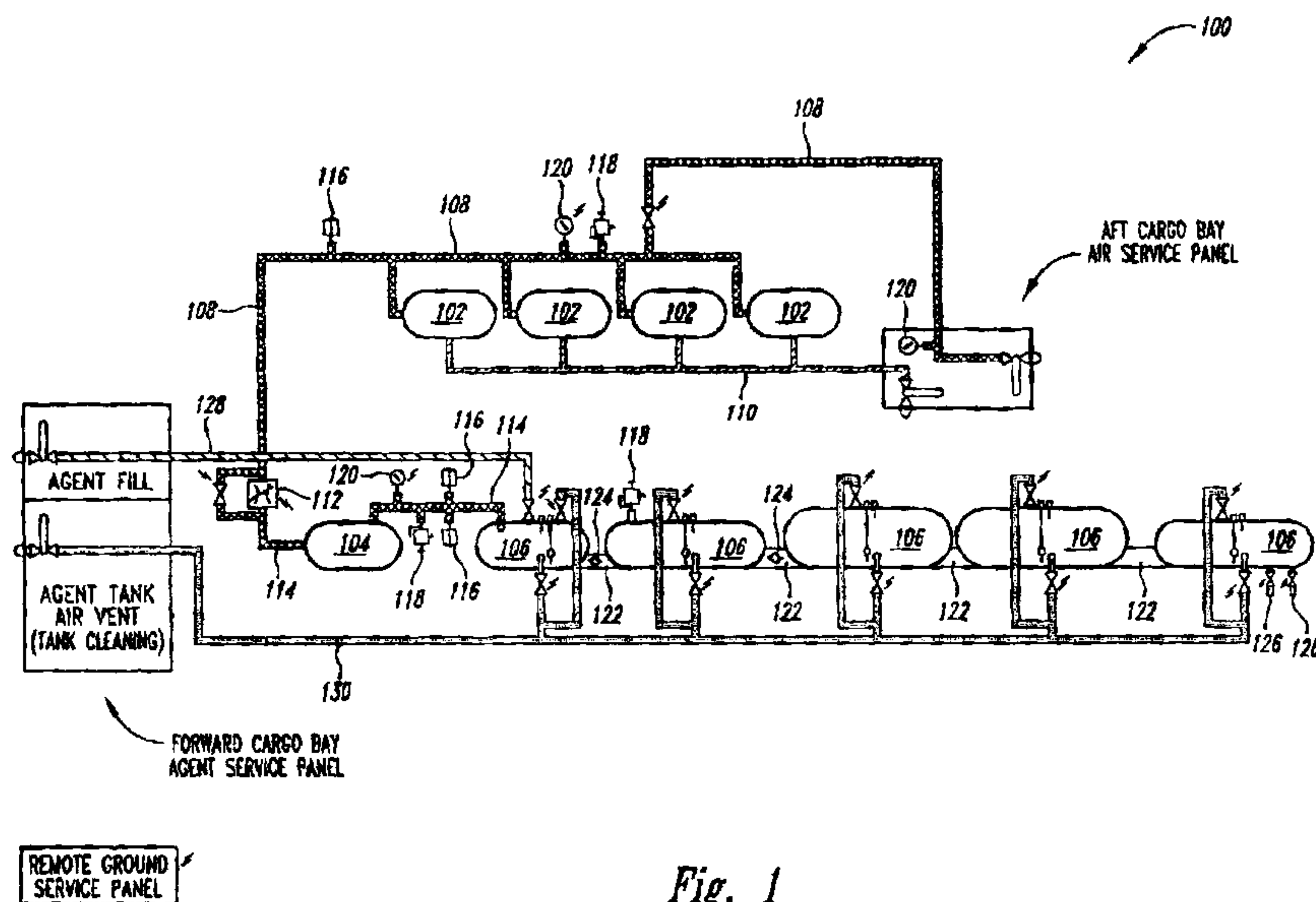


Fig. 1

(57) Abstract: An enhanced aerial delivery system addresses issues raised when large quantities of fluids, powders, and other agent materials are to be transported in and aurally dispersed by aircraft. Some aspects include positioning and securing of tanks aboard the aircraft to facilitate management and safety of the tanks and aircraft. Other aspects address coupling of the tanks and associated piping to lessen structural effects upon the aircraft. Further aspects deal with channeling, containing, and dumping stray agent materials that have escaped from the agent tanks on board the aircraft.

WO 2008/106693 A1

WO 2008/106693

PCT/US2008/055725

ENHANCED AERIAL DELIVERY SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention is directed in general to aerial delivery systems.

5 Description of the Related Art

In general, aerial delivery systems receive, transport, and disperse fluids, powders, or other substances from aircraft to terrain below for various reasons. In certain cases including fire fighting, weather control, decontamination exercises, and geotechnical applications, it is desirable for large quantities of materials to be dispersed
10 with each trip of the aircraft since areas for dispersion of the materials can be vast, travel distances between receiving and dispersion points can be great and response time to complete a job can be demanding. These and other applications where large quantities of materials are to be aurally dispersed present particular issues regarding aircraft control, safety and other issues that unfortunately conventional approaches
15 have not addressed.

The invention will best be understood by reference to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings. The discussion below is descriptive, illustrative and exemplary and is not to be taken as limiting the scope defined by any appended claims.

20 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a schematic view of an enhanced aerial delivery system.

Figure 2 is a top plan view of the enhanced aerial delivery system shown positioned within an aircraft.

Figure 3 is a side elevational view of the enhanced delivery system of
25 Figure 2.

Figure 4 is an enlarged fragmentary side elevational view of the enhanced delivery system of Figure 3.

WO 2008/106693

PCT/US2008/055725

Figure 5 is an enlarged fragmentary side elevational view of the enhanced delivery system of Figure 3 better showing an outlet assembly.

Figure 6 is a further enlarged fragmentary side elevational view of the enhanced delivery system of Figure 5 better showing detail of the outlet assembly.

5 Figure 7 is an enlarged side elevational view of the outlet assembly.

Figure 8 is a front elevational view of the enhanced delivery system shown positioned within an aircraft taken substantially along lines 8-8 of Figure 2.

Figure 9 is an enlarged fragmentary front elevational view of the enhanced delivery system positioned within the aircraft of Figure 8.

10 Figure 10 is a perspective view of a portion of the outlet assembly of Figure 7 shown in an open position.

Figure 11 is a cross-sectional perspective view of the portion of the outlet assembly of Figure 10 shown in the open position.

15 Figure 12 is a perspective view of the portion of the outlet assembly of Figure 10 shown in a closed position.

Figure 13 is a cross-sectional perspective view of the portion of the outlet assembly of Figure 10 shown in the closed position.

DETAILED DESCRIPTION OF THE INVENTION

20 An enhanced aerial delivery system is described herein that addresses issues raised when large quantities of fluids, powders, and other agent materials are to be transported in and aurally dispersed by aircraft. Some aspects include positioning and securing of tanks aboard the aircraft to facilitate management and safety of the tanks and the aircraft. Other aspects address coupling of the tanks and associated piping to lessen structural effects upon the aircraft. Further aspects deal with
25 channeling, containing, and dumping stray agent materials that have escaped from the agent tanks on board the aircraft.

A tank circuit 100 is shown in Figure 1 to include a set of propellant tanks 102, a proximate propellant tank 104, and a set of agent tanks 106. The propellant tanks 102 can supply propellant, such as compressed air, through high pressure
30 propellant piping 108 while the tank circuit 100 is within accessible distance of an air supply generally on the ground at a servicing airport (not shown). A condensate piping

WO 2008/106693

PCT/US2008/055725

110 is used to carry off condensate from the set of the propellant tanks 102 generally also during a servicing period when the tank circuit 100 is not airborne at a servicing airport.

5 The high pressure propellant piping 108 is also coupled to a pressure regulator 112 that reduces pressure of propellant going into a low pressure propellant piping 114 to feed the proximate propellant tank 104. Additional low pressure propellant piping 114 carries propellant from the proximate propellant tank 104 to the set of the agent tanks 106. Burst disks 116, pressure relief valves 118, and pressure sensors 120 are placed at various points in the tank circuit 100 to guard against
10 dangerous over-pressure conditions.

The agent tanks 106 are coupled together with agent piping 122 with the first two sections of agent piping nearest the proximate propellant tank 104 each containing a one way valve 124 that allows the flow of propellant and agent only away from the proximate propellant tank. Outlet valves 126 are coupled to the agent tank
15 106 in the tank circuit 100 that is farthest from the proximate propellant tank 104. The outlet valves 126 allow agent and propellant to escape from the tank circuit 100 as described further below.

An agent supply piping 128 is coupled to the agent tank 106 nearest the proximate tank 104 to be used for filling the agent tanks 106 with agent material when
20 the tank circuit 100 is being serviced on the ground. Vent piping 130 is coupled to each of the agent tanks 106 to receive left over agent material and/or propellant when the agent tanks are being flushed with propellant. The vent piping 130 is used to vent the tanks during fill, regulating tank fill levels. The vent piping is used during ground cleaning to direct water to valves on lower portions of the agent tanks 106 to route
25 cleaning agent to spray heads located inside the agent tanks.

An aircraft 132 is shown in Figure 2 as having a fuselage 134, center wings 136 (one shown), an upper deck 137 and two of the tank circuits 100 on the upper deck. One of the tank circuits 100 generally occupies a port portion of the aircraft and the other of the two tank circuits occupies a starboard portion of the aircraft. Each
30 of the tanks of the tank circuits 100 are positioned on individual pallets 138, which are secured to the aircraft using conventional pallet handling methods. As shown in Figure 2, flexible couplers 139 are placed along various positions of the high pressure

WO 2008/106693

PCT/US2008/055725

propellant piping 108 and low pressure propellant piping 114, and flexible couplers 140 are coupled with agent piping 122. The flexible couplers 139 and the flexible couplers 140 add structural flexibility to the tank circuits 100 so that the tank circuits impose less of a structural impact upon the aircraft 132.

5 A forward barrier 142 is located on the upper deck 137 forward of the tank circuits 100 and is used to prevent and/or delay stray agent material that has inadvertently escaped from one or more of the agent tanks from moving on the upper deck into a portion of the aircraft 132 that is forward of the forward barrier. A mid-barrier 144 is located just forward of the two most aft of the agent tanks 106 of the two
10 tank circuits 100 and is used to prevent and/or delay stray agent material forward of the mid-barrier from moving on the upper deck 137 aft of the mid-barrier. An aft barrier 146 is located between the set of the propellant tanks 102 and the set of the agent tanks 106 and is used to prevent and/or delay stray agent material from moving on the upper deck 137 forward of the aft barrier.

15 The forward barrier 142, the mid-barrier 144, and the aft barrier 146 are generally made from high strength to weight materials that can divert flow of fluids. These materials can include various plastics, other polymers, fabrics, other sorts of sheeting, and more rigid materials such as metals, composites and combinations thereof. The outlet valves 126 are fluidly coupled to outlet tubes 148 of an outlet
20 assembly 150 located between the two most aft of the agent tanks 106. As better shown in Figure 3 and Figure 4, each of the outlet tubes 148 are large vertically oriented tubular structures that pass from the upper deck 137 through a lower deck 152 out through the aircraft bottom 154.

 One or more upper deck openings 156 are located in the upper deck 137
25 just forward of the mid-barrier 144, and/or located just aft of the aft barrier 146, and/or located between the mid-barrier 144 and the aft barrier 146. The upper deck openings 156 allow stray agent 157 on the upper deck 137 that has been diverted by the mid-barrier 144 and the aft barrier 146 to drain down toward the lower deck 152, as shown in Figure 5 and Figure 6. Lower deck openings 158 are located in the lower deck 152
30 typically below the upper deck openings 156 and/or nearer to the outlet assembly 150 to allow stray agent 157 to pass through to the aircraft bottom 154.

WO 2008/106693

PCT/US2008/055725

A forward ramp 160 and an aft ramp 162 serve to guide stray agent 157 passing through the upper deck openings 156 and the lower deck openings 158 toward the outlet assembly 150. Once the stray agent 157 reaches the aircraft bottom 154, it accumulates having a pool level 164. As the pool level 164 rises, it serves to lift
5 floatable shutters 166 (see Figure 6) or other sorts of door-like members having combined densities to be buoyant relative to the stray agent 157. The shutters 166 serve as portions of the outlet tubes 148 proximate to outlet ends 168.

Consequently, as the floatable shutters 166 are lifted, the stray agent 157 passes through tube wall openings 170 into the outlet tubes 148 to exit from the aircraft
10 132 through the outlet ends 168, as shown in Figures 7 – 9. The floatable shutters 166 include floats 172 coupled to or integrally structured with tube wall portions 173 of the assembly 150. The floats 172 add sufficient buoyancy to the tube wall portions 173 to allow the tube wall portions to be raised up along with a rise of the pool level 164.

Use of large aircraft, such as a Boeing 747, affords greater material
15 carrying capacity so that large amounts can be dumped onto substantial areas of land at high concentrations given the configurations described above. To handle large volume deliveries, the outlet tubes 148 are sized with relatively large pipe diameters such as having 16 inch diameters in some implementations. With large pipe diameters for the outlet tubes 148 and substantially high pressure levels for the propellant tanks
20 102, such as 65 psi, a substantial amount of thrust induced force can result from the material in the material storage agent tanks 106 being shot out from the large diameter outlets at high pressure.

Conventional methods of securing outlets to an aircraft involve common techniques to secure pallets to the aircraft, such as with outer guide locks. Due to the
25 unconventionally high amount of thrust that can result from material being delivered, these conventional outlet securing systems and methods can be inadequate in properly distributing the thrust induced load to an adequately sized portion of the aircraft to safely hold the outlet tubes 148 in place without risking structural damage to the aircraft 132.

30 An outlet securing system 174 is depicted in Figure 8 to properly distribute the unconventionally high thrust induced loads to an adequately sized portion of the aircraft 132. The outlet securing system 174 couples the outlet tubes 148 to the aircraft

WO 2008/106693

PCT/US2008/055725

by coupling to seat tracks 175 originally designed for securing passenger seats to the aircraft when the aircraft is used as a passenger airliner. Coupling the outlet tubes 148 to the aircraft by coupling the outlet tubes to the seat tracks 175 allows for a more secure way of imparting the thrust induced load to the aircraft structure than the conventional methods used involving securing pallets to the aircraft. Consequently, the outlet securing system 174 allows for delivery of greater quantities of material with pressures for the propellant tanks 102 substantially higher than used by conventional delivery systems.

As shown in Figure 9, the tube wall portions 173 each have a lower flange 176 that rests against an upper flange 178 of a different one of the outlet ends 168. Sealant 179 is used to seal the upper flange 178 with the fuselage 134. The upper flange 178 and/or the lower flange 176 contain magnets 180 as shown in Figure 10 and Figure 11 that help to seal each floatable shutter 166 in a closed position, such as shown in Figure 12 and Figure 13, when the pool level 164 is not sufficient to raise the floatable shutter. The magnets 180 help prevent the floatable shutters 166 from vibrating and bouncing up and down with aircraft movement.

A pin 182 protrudes from the interior surface of the floatable shutter 166 to engage with a track 184 found in a post 186 of the outlet tube 148. Each of the pins 182 help to prevent one of the floatable shutter 166 from rotating and thereby prevents the floats 172 from hitting each other. A circumferential ring stop 188 of the floatable shutter 166 is used to prevent travel of the floatable shutter beyond a desired vertical height but allows for sufficient vertical travel so that the floatable shutter can be raised to unblock the tube wall openings 170 as the pool level 164 rises.

The tank circuits 100 are self-contained and reusable and enable aircraft, such as but not limited to cargo/utility aircraft, to carry and dump a load, under control. One example of an aircraft among many, is a Boeing 747. The outlet assembly 150 allows a uniform and narrow material drop from relatively high altitudes compared with conventional approaches and a reduction in the amount of time material is suspended in the air due to its capability of delivering pressurized fluid directed substantially straight downward.

By "downward," it is envisioned that the aircraft bottom 154 will generally be the closest side of the fuselage 134 to the ground when the aircraft 132 is being

WO 2008/106693

PCT/US2008/055725

support on the ground by its wheel system. The pressurized fluid or other material delivered from the outlet tubes 148 is directed straight down and exits the aircraft 132 with the material moving further downward away from the aircraft bottom 154. The contents are shot substantially vertically toward the ground not just substantially horizontally away from the aircraft and its turbulence.

Possible agents used in the tank circuits 100 can include those for fire fighting, such as used by a "fire bomber", for chemical decontamination, weather modification and oil spill decontamination, among other uses. The tank circuits 100 and outlet assembly 150 for use with a Boeing 747 can drop approximately 25,000 gallons of fluid in approximately 5 seconds from an altitude of approximately 2,500 feet above the ground.

The quantity of material delivered and duration of the deliveries will be controllable by the pilot at any flight regime the aircraft 132 is capable of operating in (i.e., altitude, airspeed, pressurized or unpressurized). The system's load has the ability to be dispersed in segmented drops or at one time.

A portion of the tank circuits 100 and the outlet assembly 150 can be coupled to the aircraft 132 at what is conventionally known as a wing box since it is a reinforced portion of the aircraft. The wing box typically runs through the lower portion of the fuselage 134 and ties the center wings 136 into the rest of the aircraft 132. Other large aircraft can also be used in addition to the Boeing 747, such as DC 10 aircraft, or Airbus 380 aircraft.

The multiple agent tanks 106 are used to increase the carrying capacity of the aircraft 132 while seeking to maintain a desirable center of gravity of the aircraft. In one aspect, the agent tanks 106 may be made of steel, however, other materials may be used such as polymers, plastics, composites, etc. as conventional practice dictates. Using the two tank circuits 100 provide the capability to premix materials, mix materials on-board or disperse two different materials separately. This would allow for a division of two separate materials, such as a dormant fire retardant material and an activator material. The dormant fire retardant material and the activator would be admixed close to the time of use. The number of valves controlling the outlet tubes 148 that are opened at selected times control the quantity of material ejected.

WO 2008/106693

PCT/US2008/055725

The propellant can be pressurized at different pressures to match requirements of different materials contained in different ones of the agent tanks 106. These materials to be stored in the agent tanks 106 include, but are not limited to, water, gels, powders, chemicals and biological agents used for decontamination, neutralization, weather modification, oil spill treatment and firefighting. The specific agent material is directed by pressurized propellant and is propelled through the outlet tubes 148 straight down or at a forward angle away from the aircraft at variable pressures. Ejected material can strike or interact with its intended target either with forward direction or slow into a rain-like state dependant on which pressures and altitudes are used. The propellant tanks 102 can store pressurized air or other gas as the propellant. The stored air (energy) is the propulsion system allowing fluid and/or materials to exit the aircraft. The propellant tanks 102 can be pressurized with bleed air from the airplane, air from an onboard compressor, or air from a ground supply. The agent tanks 106 are able to withstand any pressure delivered from the proximate propellant tank 104.

The outlet tubes 148 can be dump chutes, nozzles, etc. and can branch out from the outlet assembly 150 and act as the exit mechanism for the material and/or fluids. The outlet valves 126 can open individually, in combination, or all at once to acquire the desired flow rate through the outlet tubes. The control and/or operation of the outlet valves 126 can be by a hydraulic actuator system.

In yet another aspect, a drop controller, such as a microprocessor-based computer device, given flow rate and line length, can be used to calculate how many of the outlet valves 126 to open and at what time to provide exact flow rate management (e.g., levels of coverage, intensity of coverage).

In some implementations, the agent tanks 106 can be progressively sized so that tank size increases the more aft a tank is located. For instance, the forward most tank of each tank circuit 100 can be the smallest, the second forward most tank of each tank circuit can be next largest and so on. In the implementation shown in Figure 2, the forward most one of the tank circuit 100 empties first, then the second most one of the tank circuit empties and so on. Emptying of the tanks continues to follow this sequential order from more forward tank to more aft tank until the most aft tank of the tank circuit 100 is emptied.

WO 2008/106693

PCT/US2008/055725

This particular order of emptying could be re-ordered depending upon how the propellant tanks 102 and/or the proximate propellant tank 104 are coupled to the agent tanks 106. Whatever the implementation, the agent tanks 106 are sized and positioned according to the order of emptying such that the overall center of gravity of the loaded aircraft stays within a forward most center of gravity limit point and an aft most center of gravity limit point. In a particular implementation, the center of gravity of the aircraft when the agent tanks 106 are full is near the forward most center of gravity limit point and is near the aft most center of gravity limit point when the agent tanks 106 are substantially empty.

It has been found that the sequential ordering of emptying of the agent tanks 106 starting from the forward most pair and ending at the aft most pair tends to have less complication involved so tend to have an acceptable level of reliability. Other scenarios involving more complicated ordering of emptying of the agent tanks 106 may not have an acceptable level of reliability given the influence of emptying of the agent tanks on the center of gravity of the aircraft. Consequently, when additional factors of safety are desired, it may be necessary to limit the number of the agent tanks 106 to a number that would allow a more reliable emptying of the tanks such as a sequential forward to aft emptying order rather than using additional of the agent tanks and thereby causing a more complicated emptying order.

The outlet tubes 148 are generally located along the longitudinal dimension of the aircraft 132 relatively near the trailing edge (the most aft edge) of inboard flaps of the aircraft in their extended position. The extended position of the inboard flaps is taken into consideration since the aircraft is generally traveling at reduced speed with the inboard flaps in an extended position at the time of dumping of the contents of the agent tanks 106. It has been found that in this area just aft of the trailing edge of the extended inboard flaps there is a minimal amount of turbulence to be dealt with. If the outlet tubes 148 are moved forward of the trailing edge of the inboard flaps or moved more aft toward the tail of the aircraft, there can be more turbulence, which can reduce the ability to delivery content of the agent tanks 106 to the ground generally below the aircraft in sufficient concentrations.

It has been found that using air pressurized in the propellant tanks 102 at over 40 psi, and preferably at over 50 psi and more preferably at or over 65 psi helps to

WO 2008/106693

PCT/US2008/055725

deliver the contents of the agent tanks 106 to the ground at significantly high levels of concentration. For instance, in test runs, delivery concentrations to the ground as high as 14.8 gallons per square feet have been observed for pressures of 65 psi in the propellant tanks 102 with the positioning and orientation of the outlet tubes 148 as
5 discussed above for drops from the aircraft 132 at 400 feet above the ground. The aerial fluid delivery system may be capable of association with an airplane, helicopter, or balloon. Other aspects can include a faring housed over the outlet ends 168.

The discussion above is descriptive, illustrative and exemplary and is not to be taken as limiting the scope defined by any appended claims.

10

CLAIMS

The invention claimed is

1. A system to be transported on an aircraft, the aircraft having an interior, an exterior, and a bottom, the system comprising:

an agent tank configured to hold material;

an outlet end providing passage from the interior to the exterior of the aircraft through the bottom of the aircraft; and

a member movably coupled to the outlet end, the member having a closed position and an open position, the member configured to be moved from the closed position to the open position through buoyant contact with a portion of the material released from the agent tank into the interior of the aircraft, in the closed position the member being oriented to block access to the outlet end from within the aircraft, and in the open position the member being oriented to allow access to the outlet end from within the aircraft, whereby the material located substantially adjacent the bottom of the aircraft may exit the aircraft through the outlet end.

2. The system of claim 1 wherein the member includes a shutter with a density less than the material so as to be buoyant relative to the material.

3. The system of claim 1 wherein the member includes a door and a float having a combined density, the combined density of the door and the float being less than the material so as to be buoyant relative to the material.

4. The system of claim 1 further including at least one barrier positioned to direct the portion of the material to pool adjacent to the member.

5. The system of claim 1 further including a pin and a track, the pin extending from the member and the track positioned to receive the pin to guide movement of the member between the open and closed positions.

6. The system of claim 5 wherein track is shaped to direct movement by the pin in a linear direction.

7. A system to be transported on an aircraft, the aircraft having an interior, an exterior, an upper deck, a lower deck, and a bottom, the system comprising:
an agent tank configured to hold material;
an outlet tube coupled to the agent tank to receive a portion of the material from the agent tank, the outlet tube extending through the bottom of the aircraft and having a tube end to direct out of the aircraft through the tube end the portion of the material received by the outlet tube from the agent tank, the outlet tube having a tube wall with a tube wall opening in communication with the interior of the aircraft outside of the outlet tube; and

a member movably coupled to the outlet tube to move between a closed position closing the tube wall opening and an open position opening the tube wall opening, the member configured to be moved between the closed position to the open position through contact with a portion of the material released from the agent tank, and located within the interior of the aircraft and outside of the outlet tube, in the closed position the member being configured to inhibit movement of the material portion through the tube wall opening to the outlet end from within the aircraft, and in the open position the member being configured to allow movement of the material portion through the tube wall opening to the outlet end from within the aircraft and outside of the outlet tube, whereby the material portion may exit the aircraft through the outlet end when the member is in the open position.

8. The system of claim 7 further including an outlet valve and wherein the outlet tube is coupled to the agent tank through the outlet valve to control release of the material from the agent tank into the outlet tube.

9. The system of claim 7 further including a stop circumferentially extending at least partially about the outlet tube and positioned to prevent travel of the member beyond a predetermined vertical height.

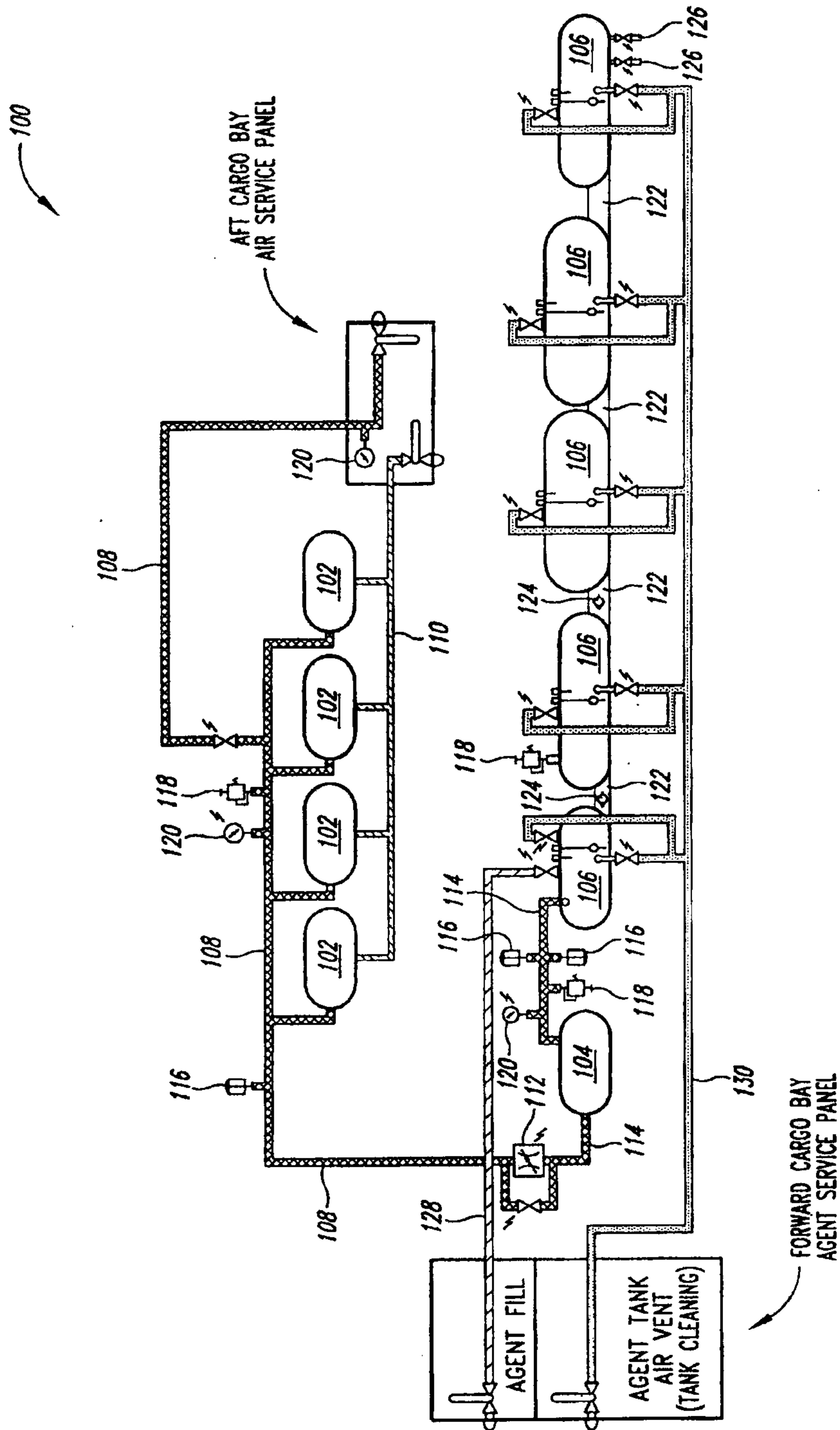


Fig. 1

REMOTE GROUND
SERVICE PANEL

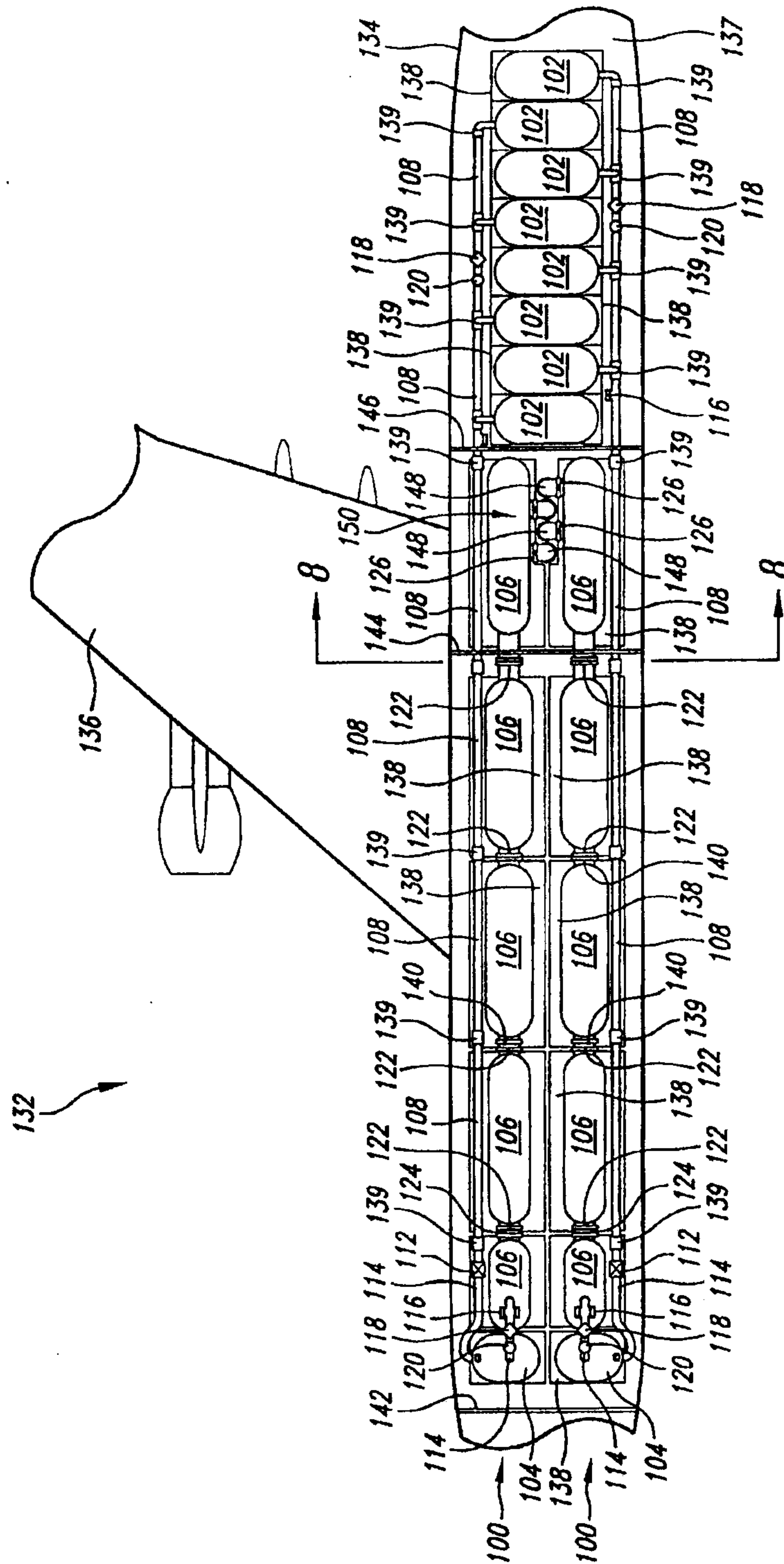


Fig. 2

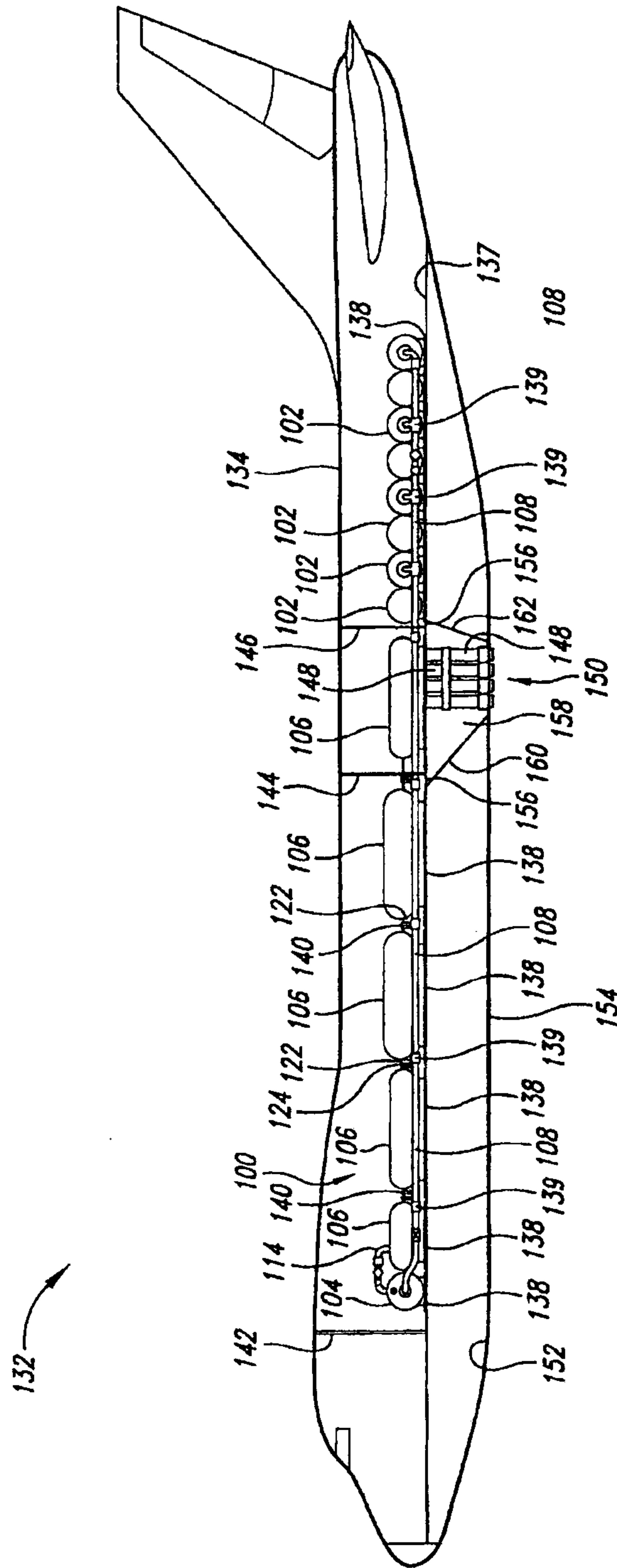


Fig. 3

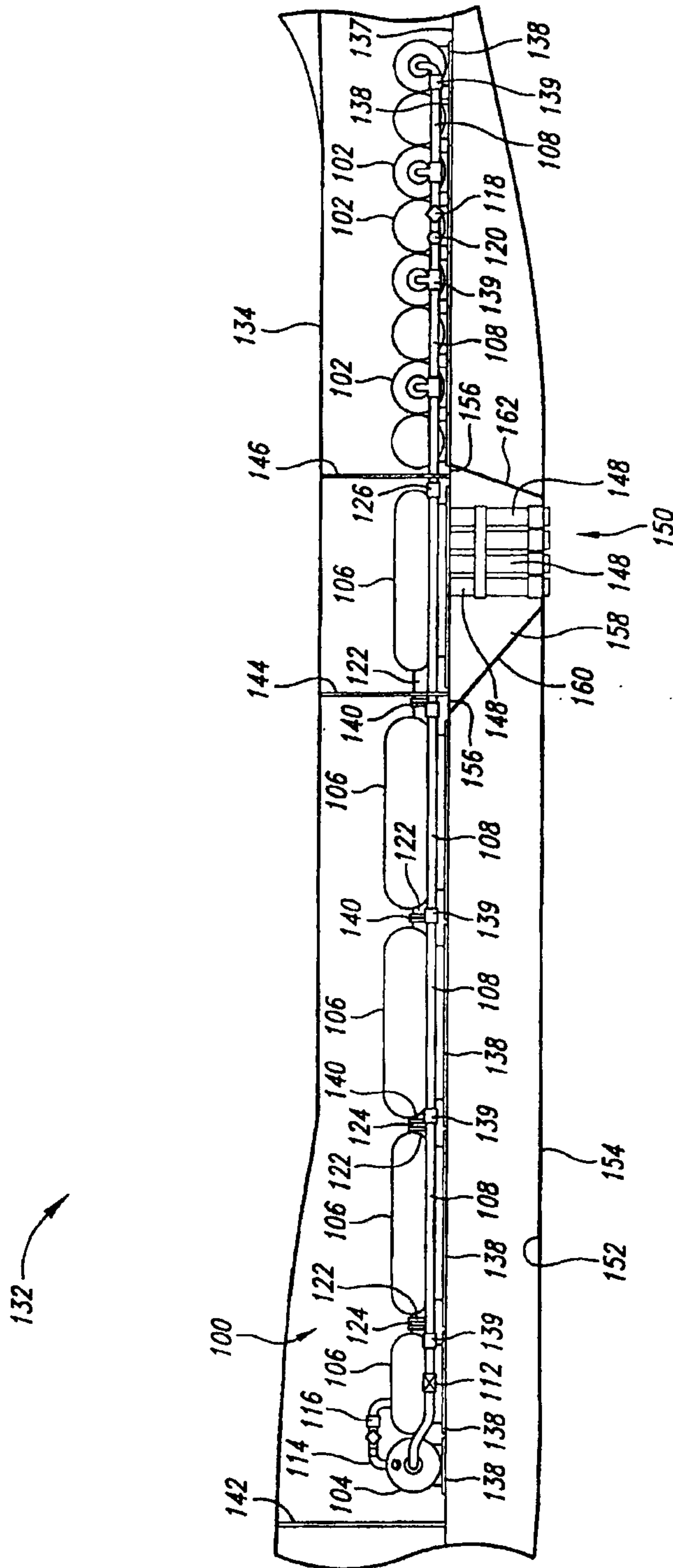


Fig. 4

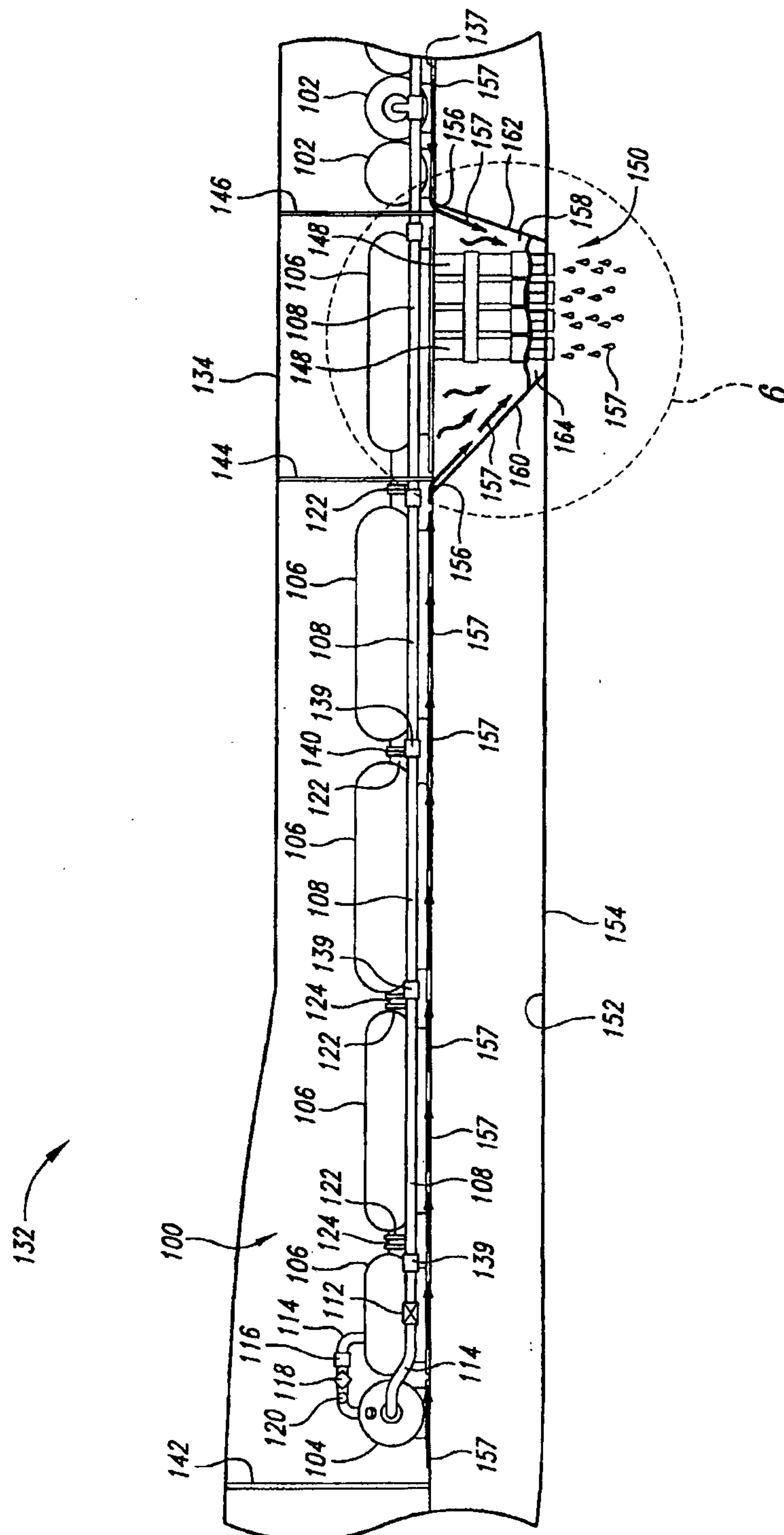


Fig. 5

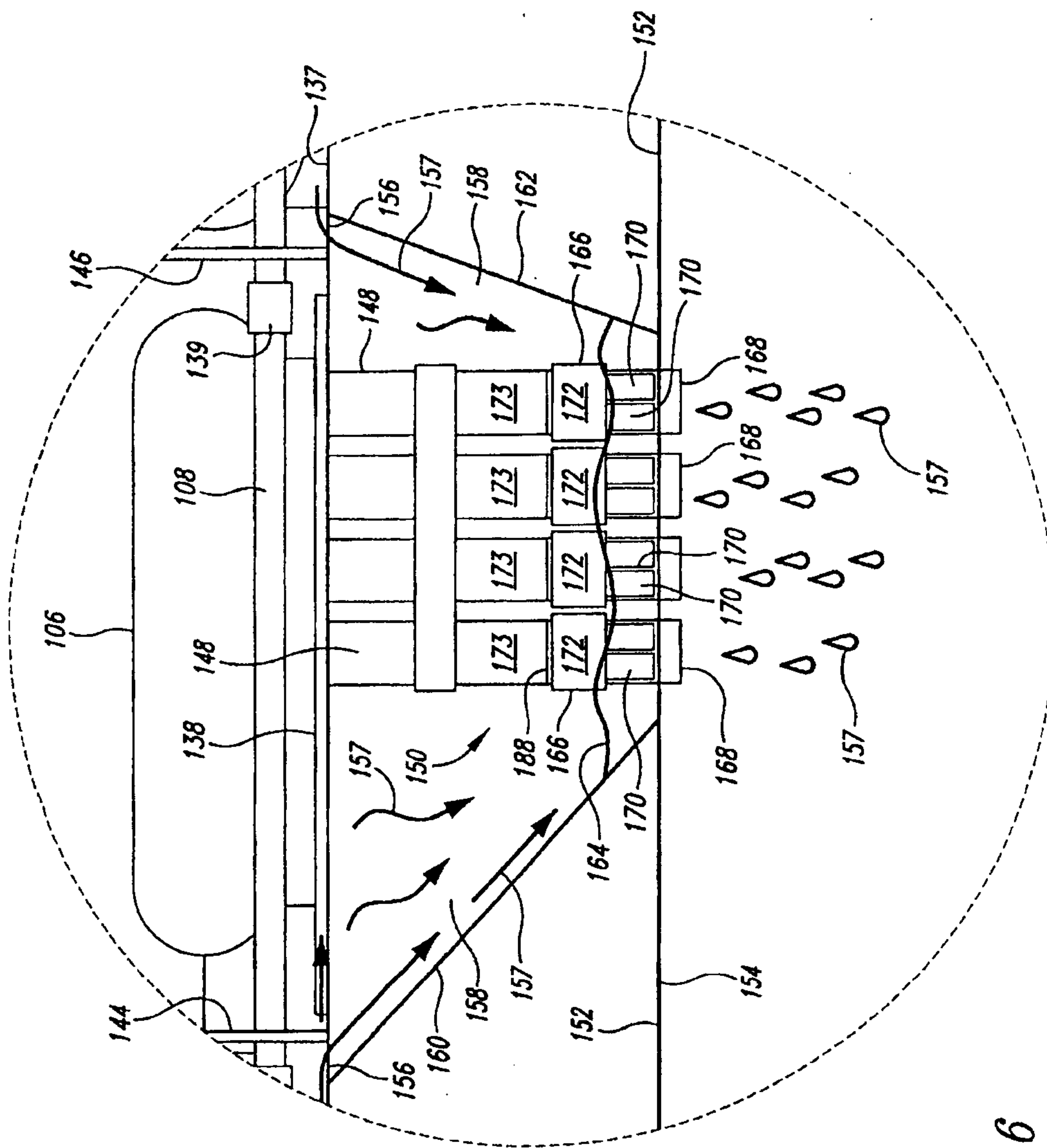
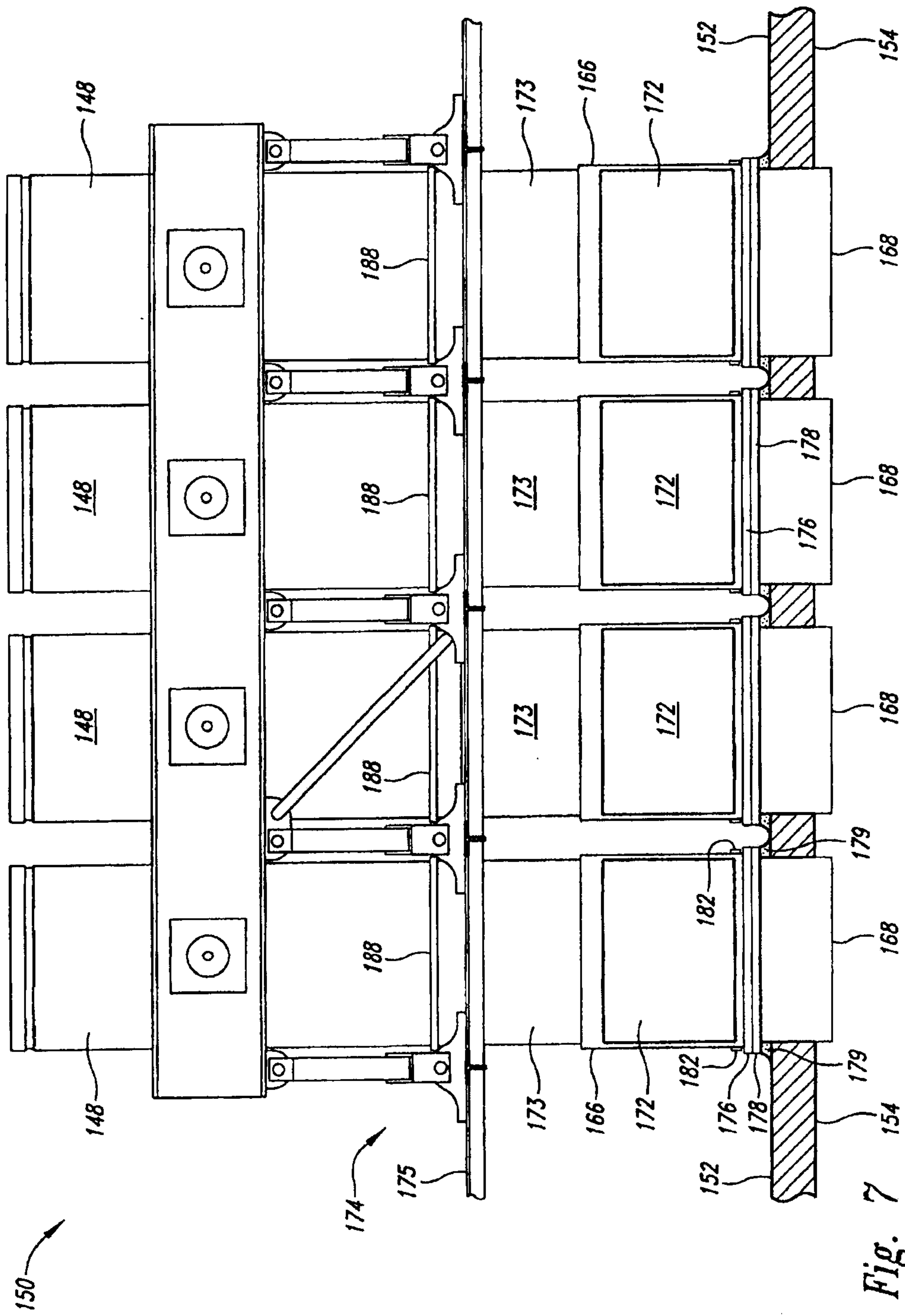


Fig. 6

7/11



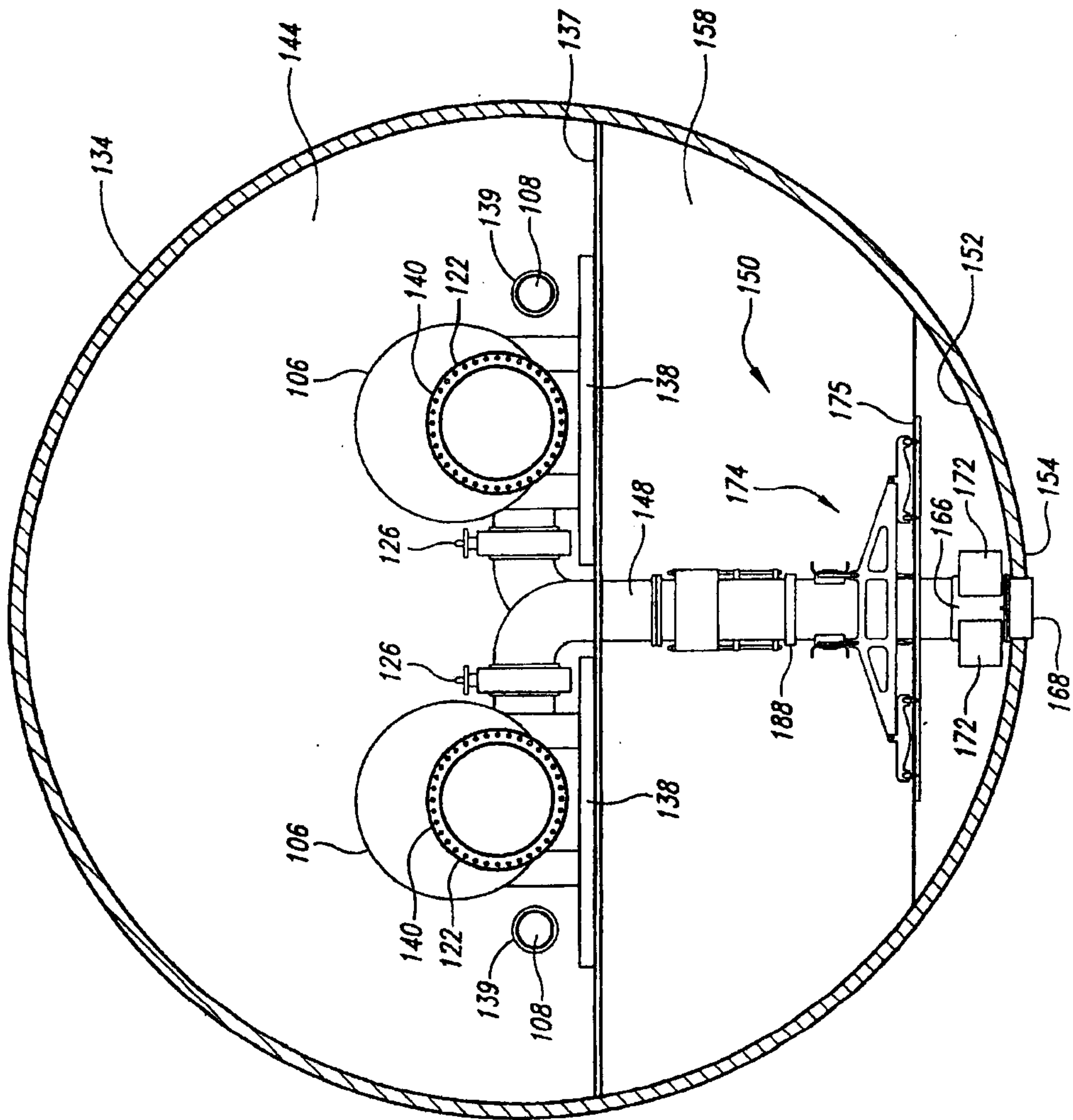


Fig. 8

9/11

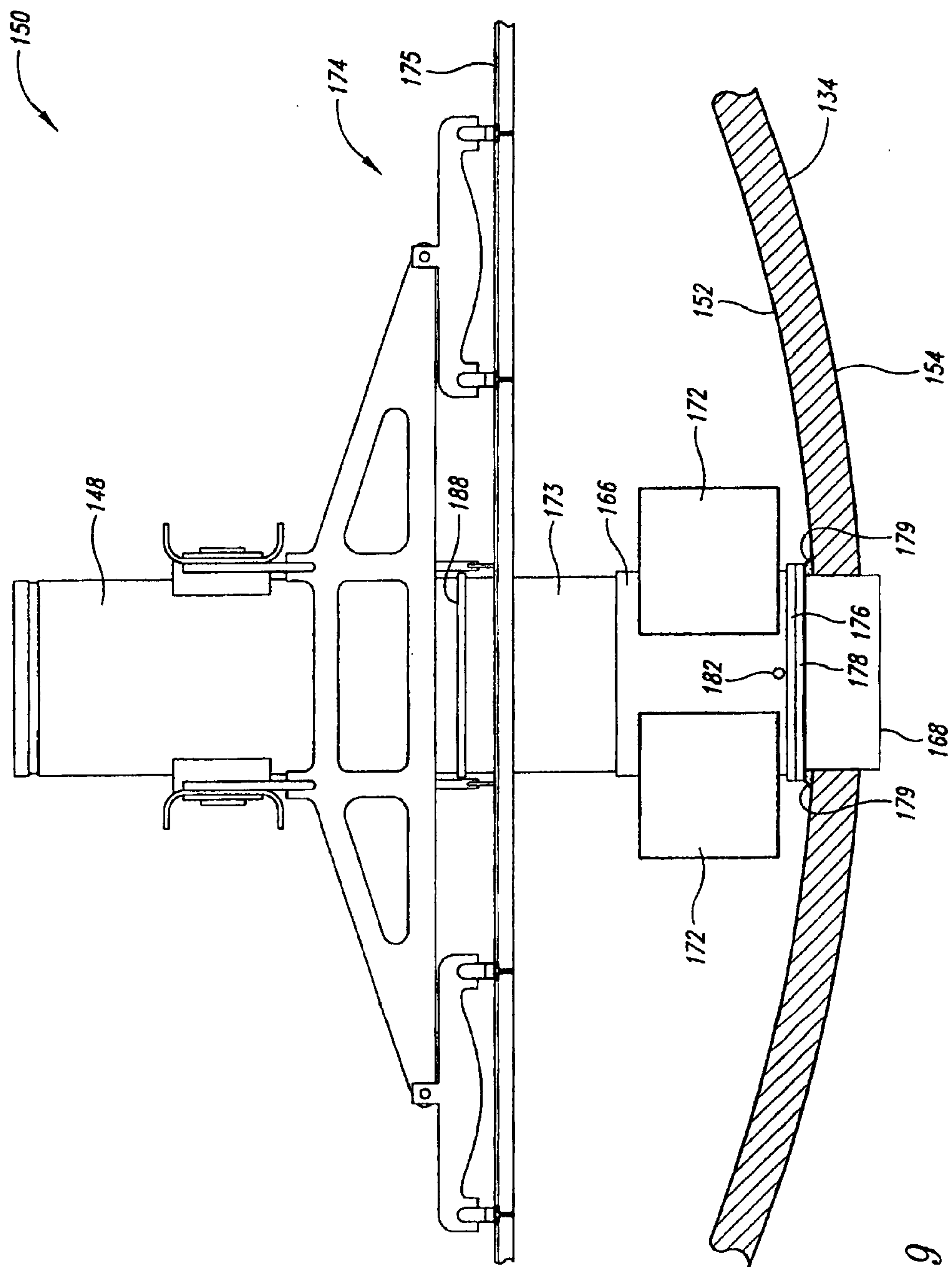


Fig. 9

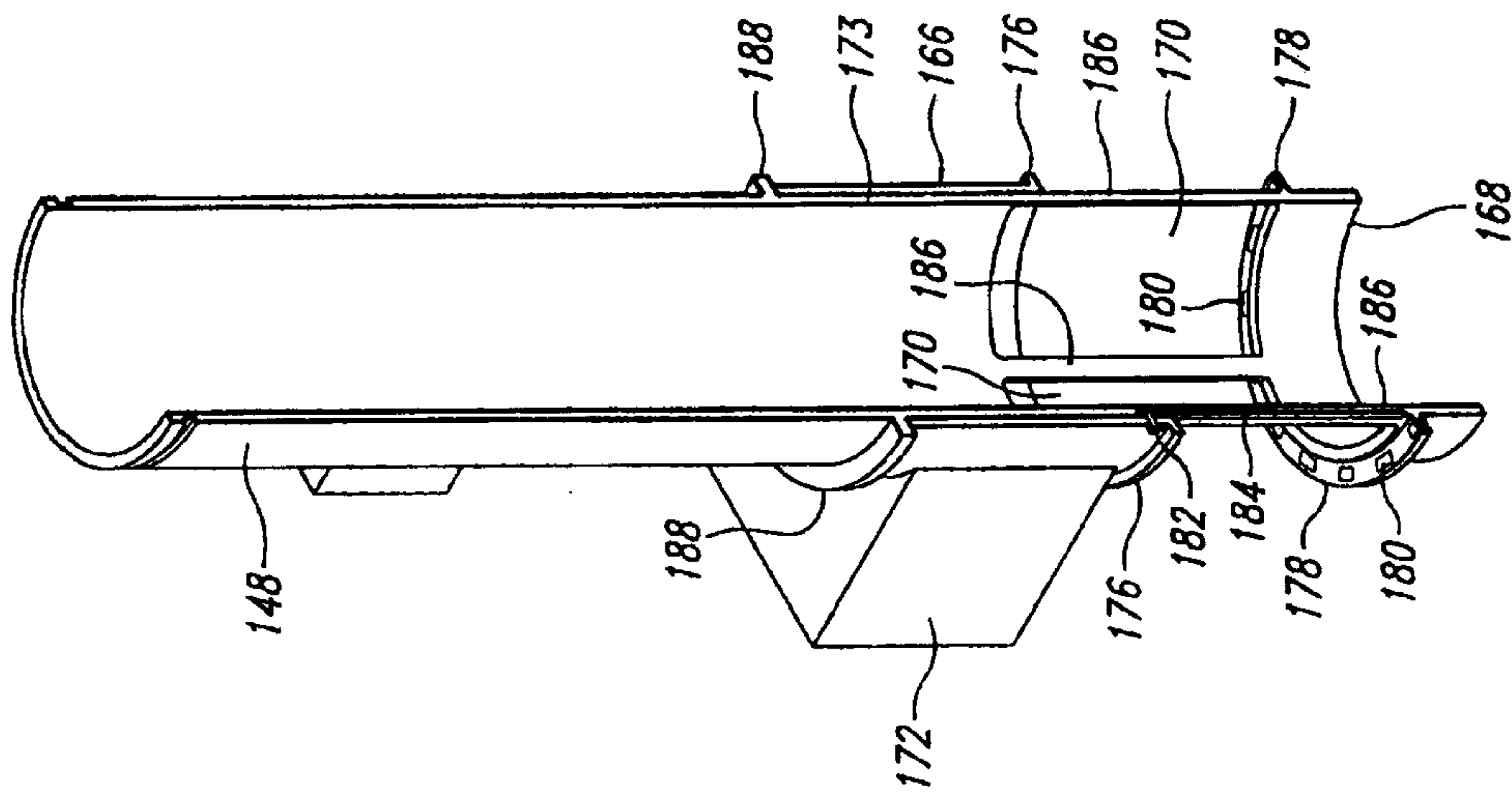


Fig. 11

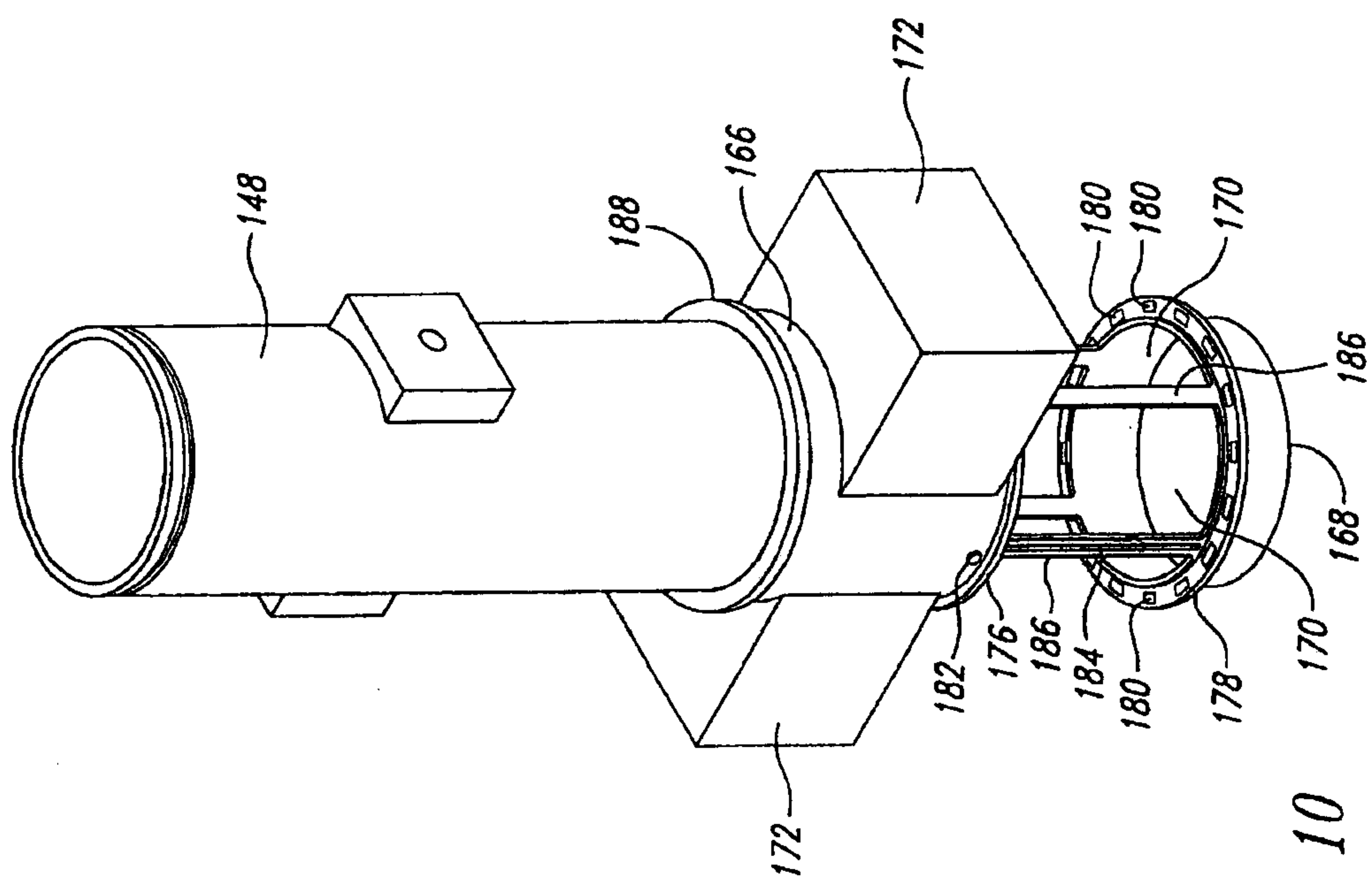


Fig. 10

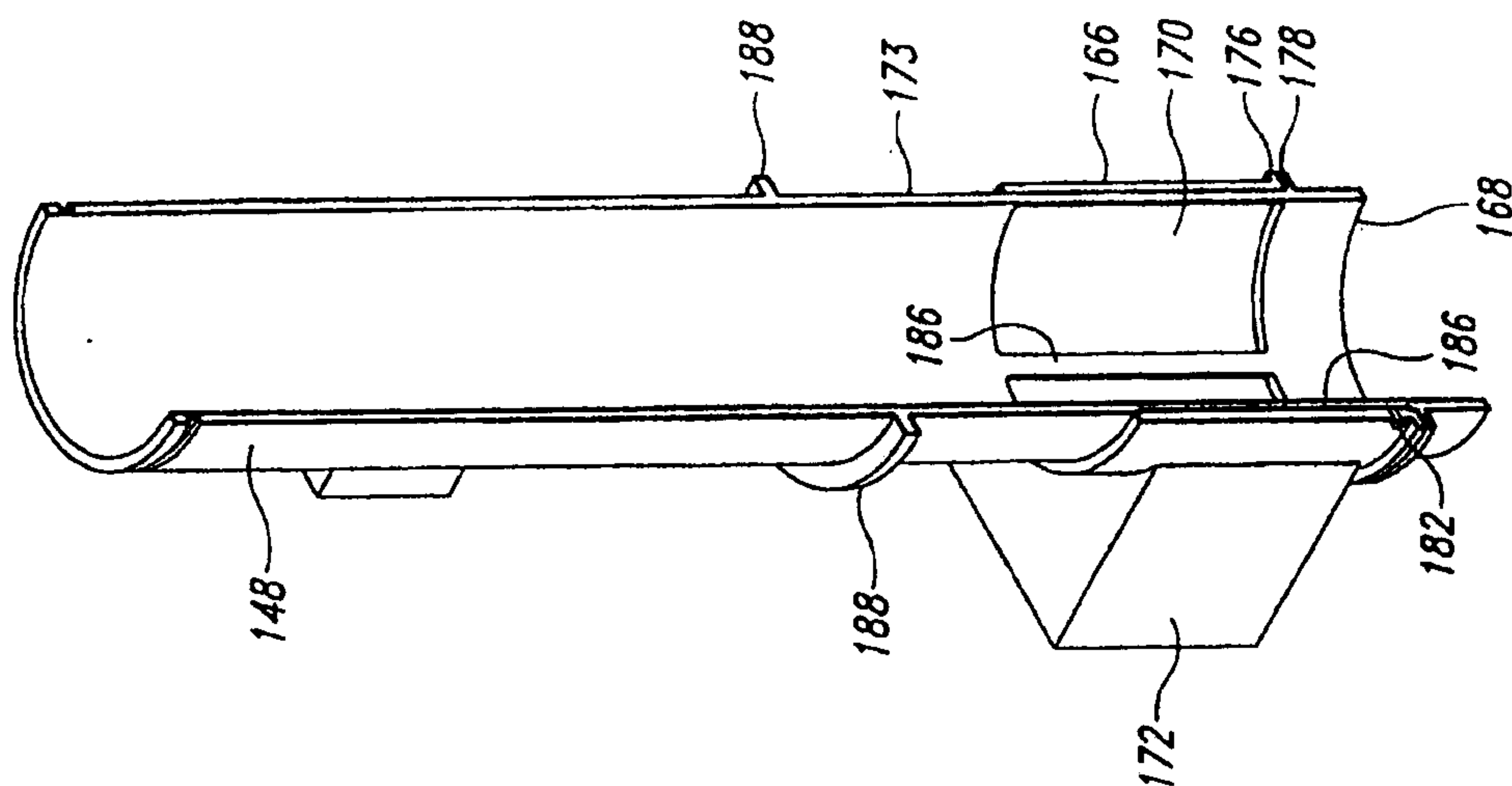


Fig. 13

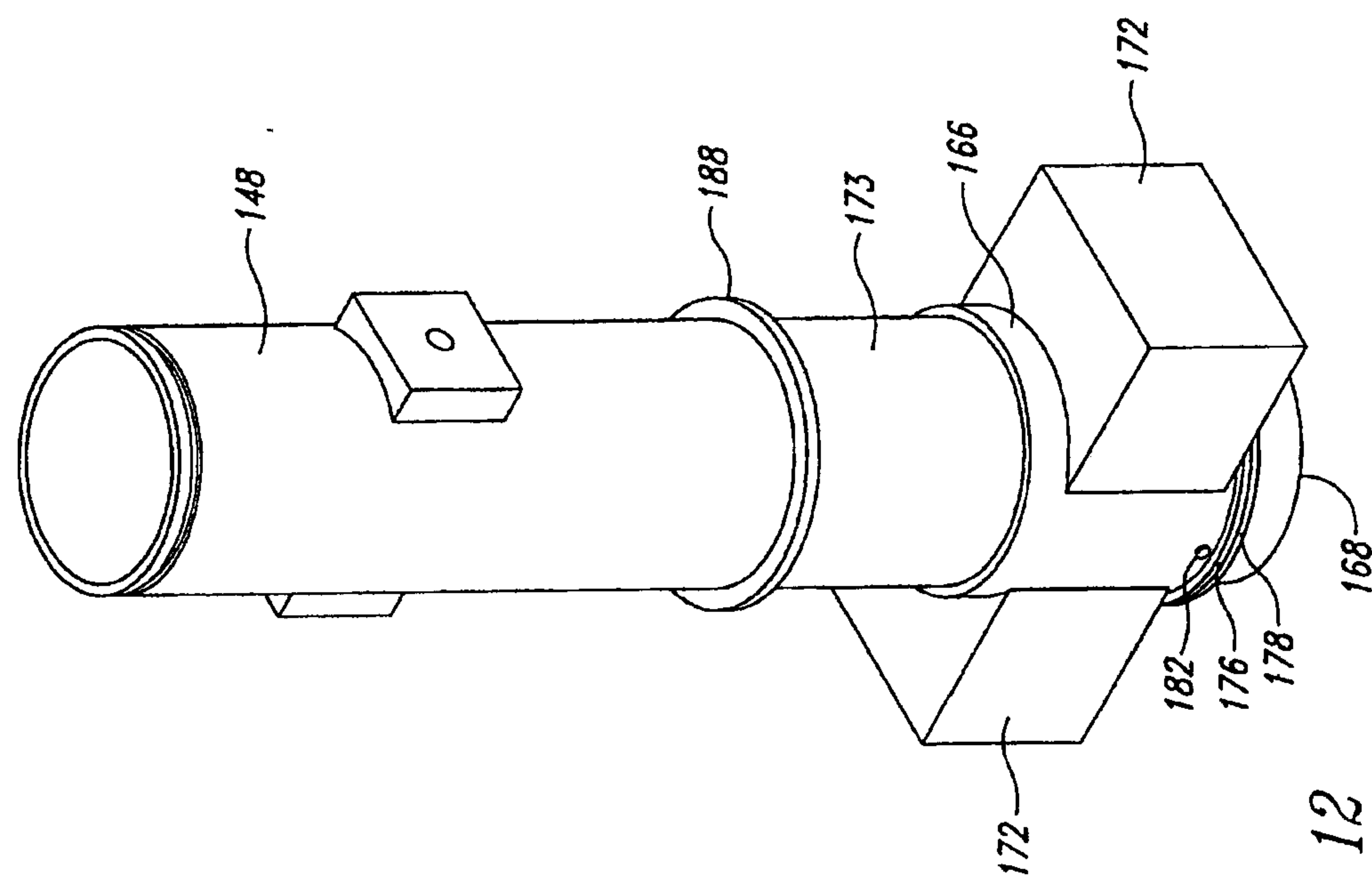


Fig. 12

