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(54) RAPID HYGROSCOPIC ATMOSPHERIC WATER GENERATOR FOR A CONSTRUCTED ENVIRONMENT

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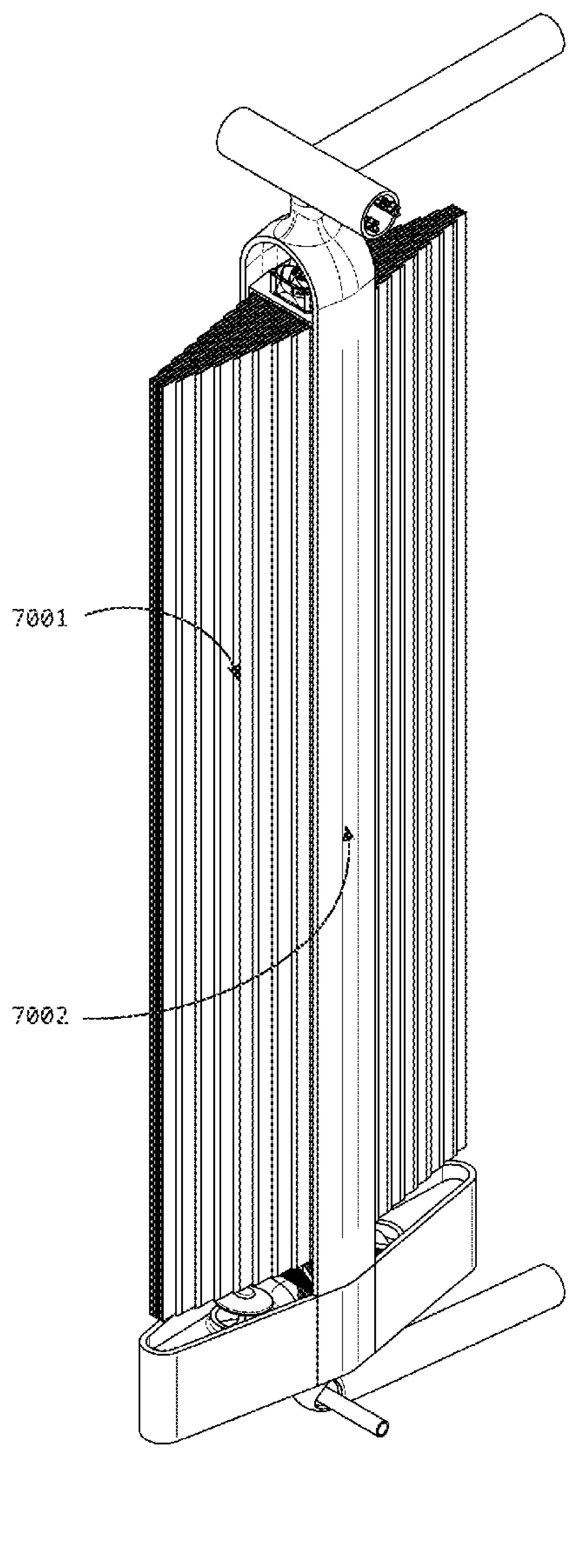
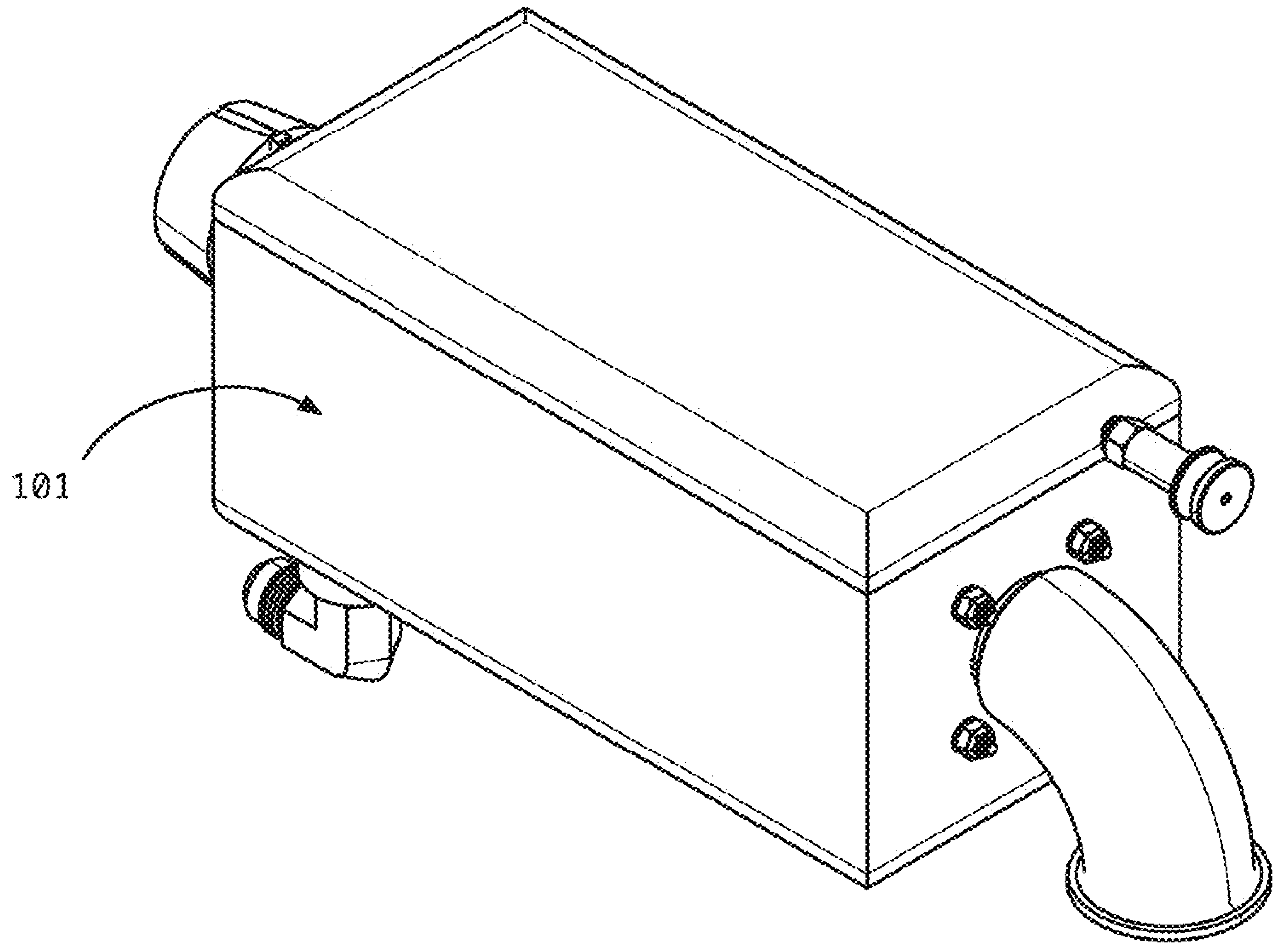
(57) **ABSTRACT**

An atmospheric water generator apparatus is incorporated into a structure within a constructed environment. Example constructed environments include commercial buildings, residential buildings, factories, and infrastructure. Example structures within a constructed environment include sunshades, facades, and walls. The apparatus extracts water vapor from low humidity air using a temperature-responsive hygroscopic material that alternates between hydrophilic and hydrophobic states. The apparatus includes a chamber with a thermal management system for absorption and desorption phases. The chamber can open, permitting air intake and exhaust during the absorption phase. The chamber can close, preventing external air flow during the desorption phase. Fans may assist air flow during both phases. The material is heated during the desorption phase. When heated, the composite material releases water vapor, which is then condensed and collected.





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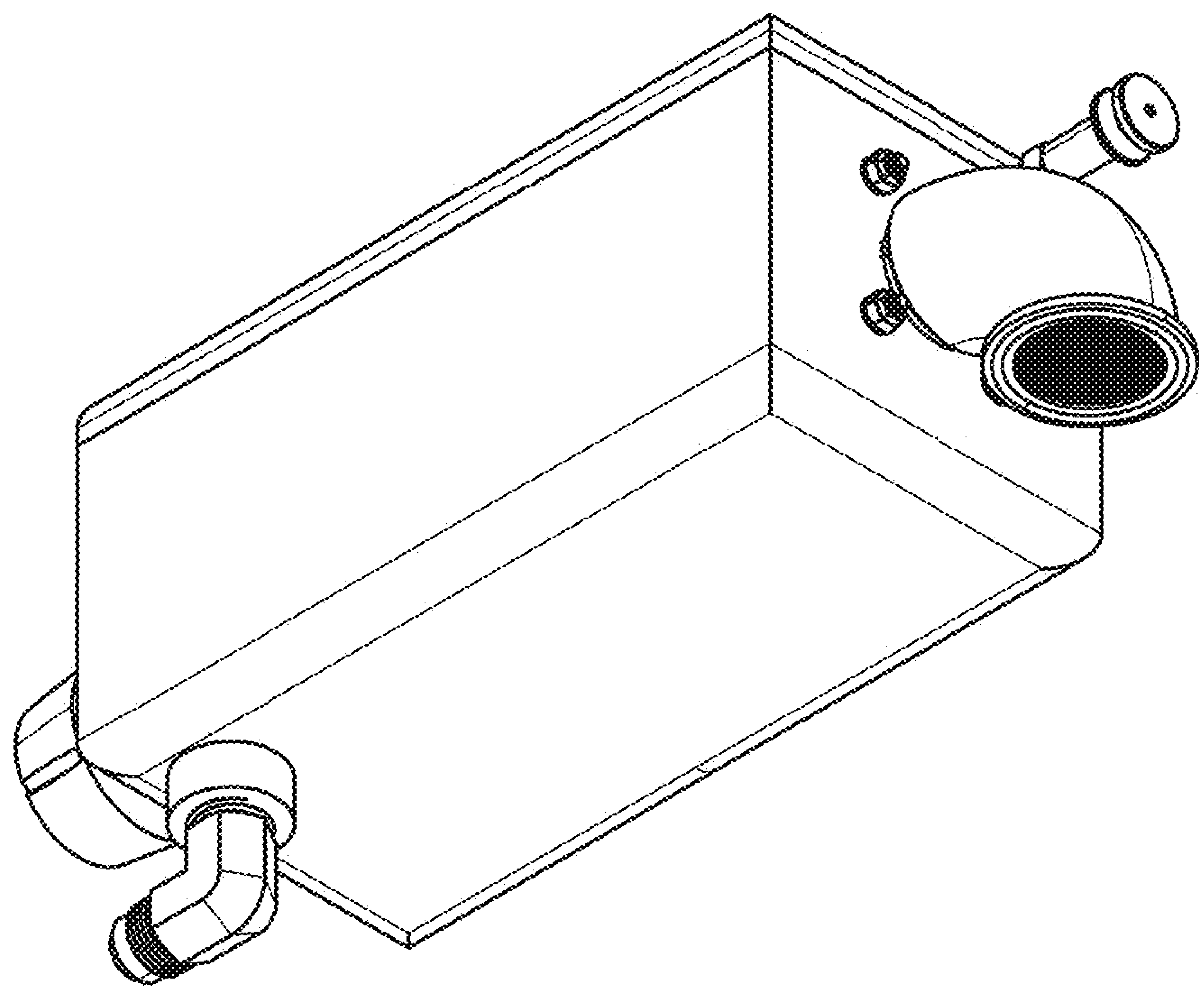

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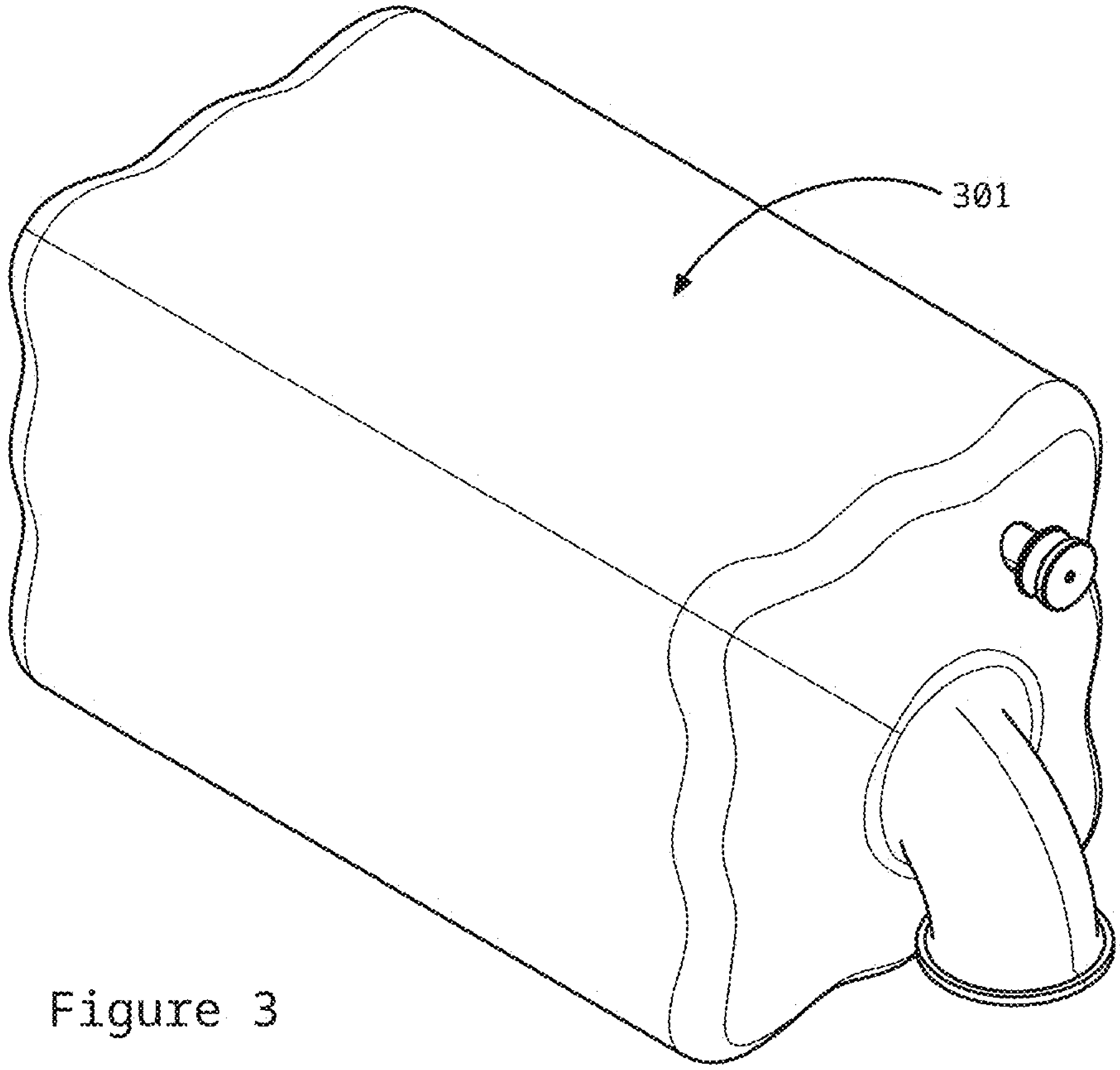

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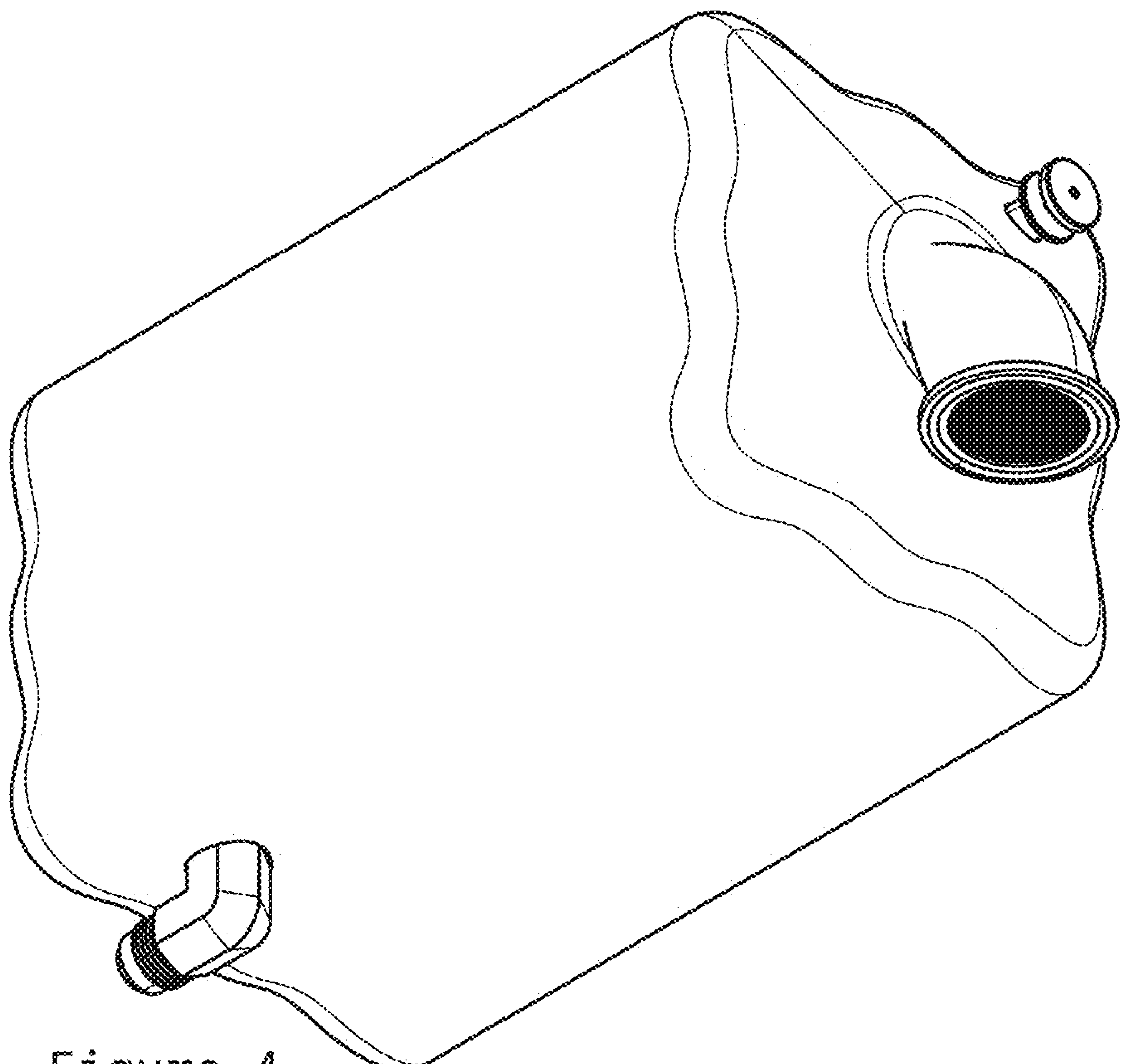

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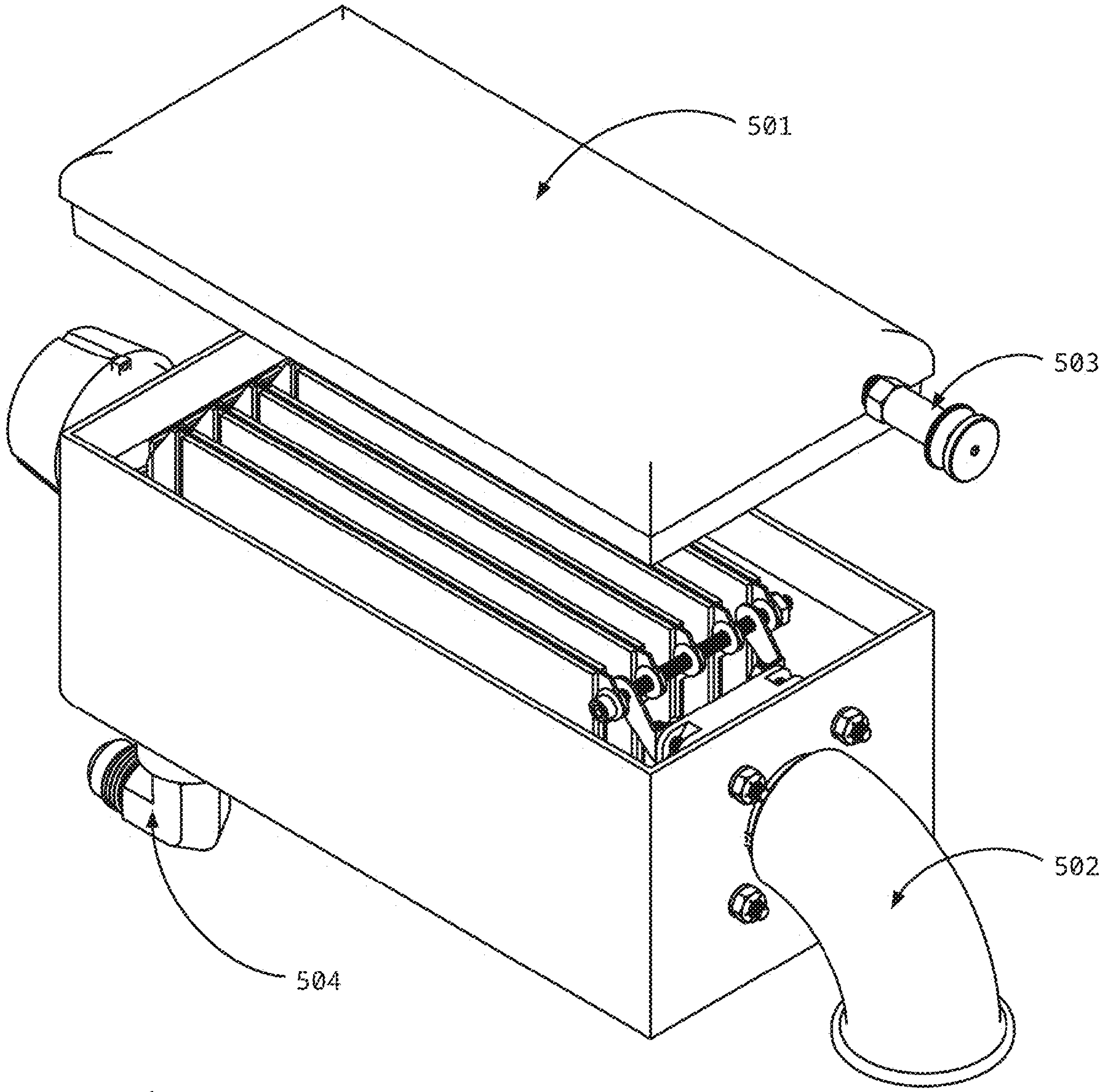

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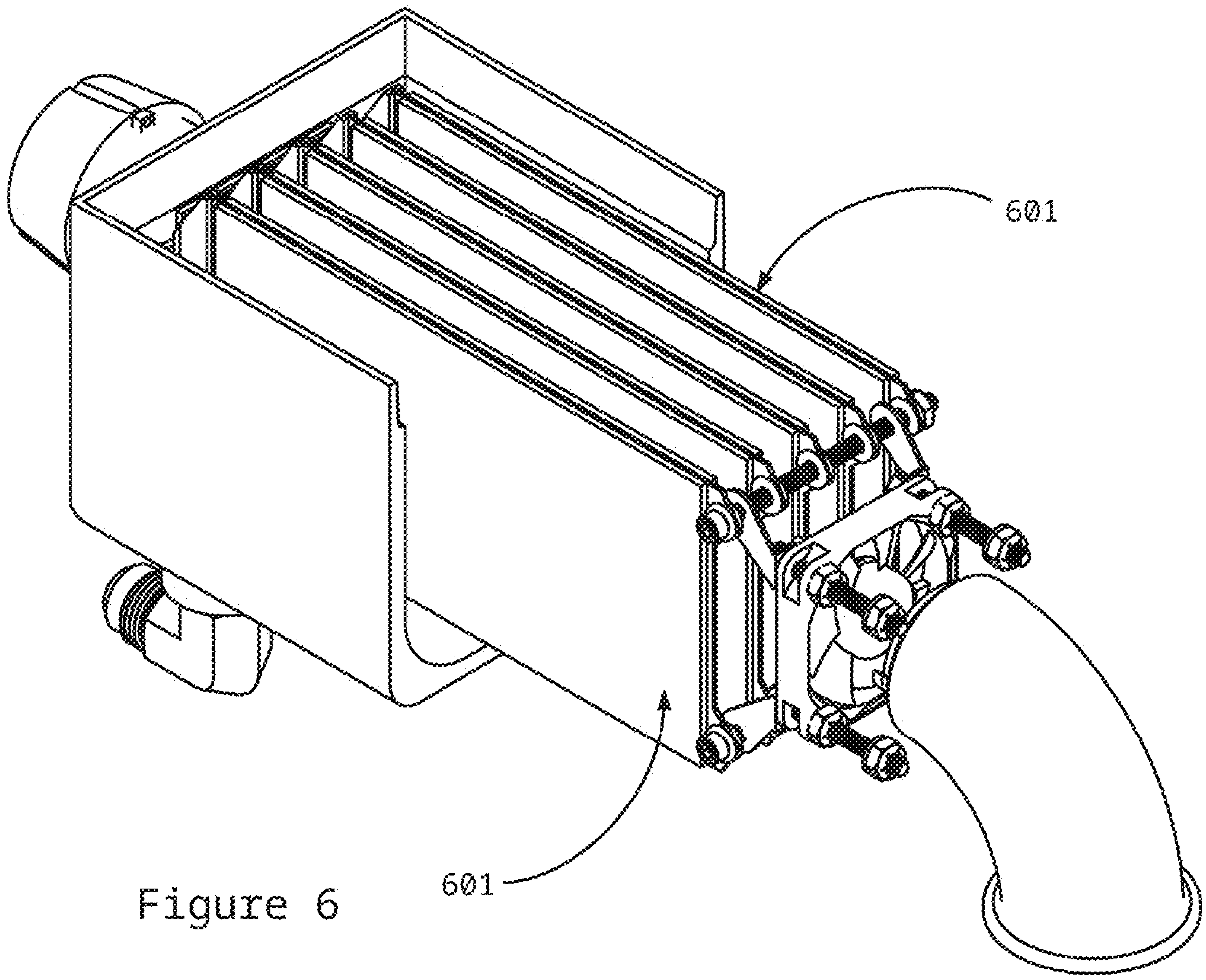

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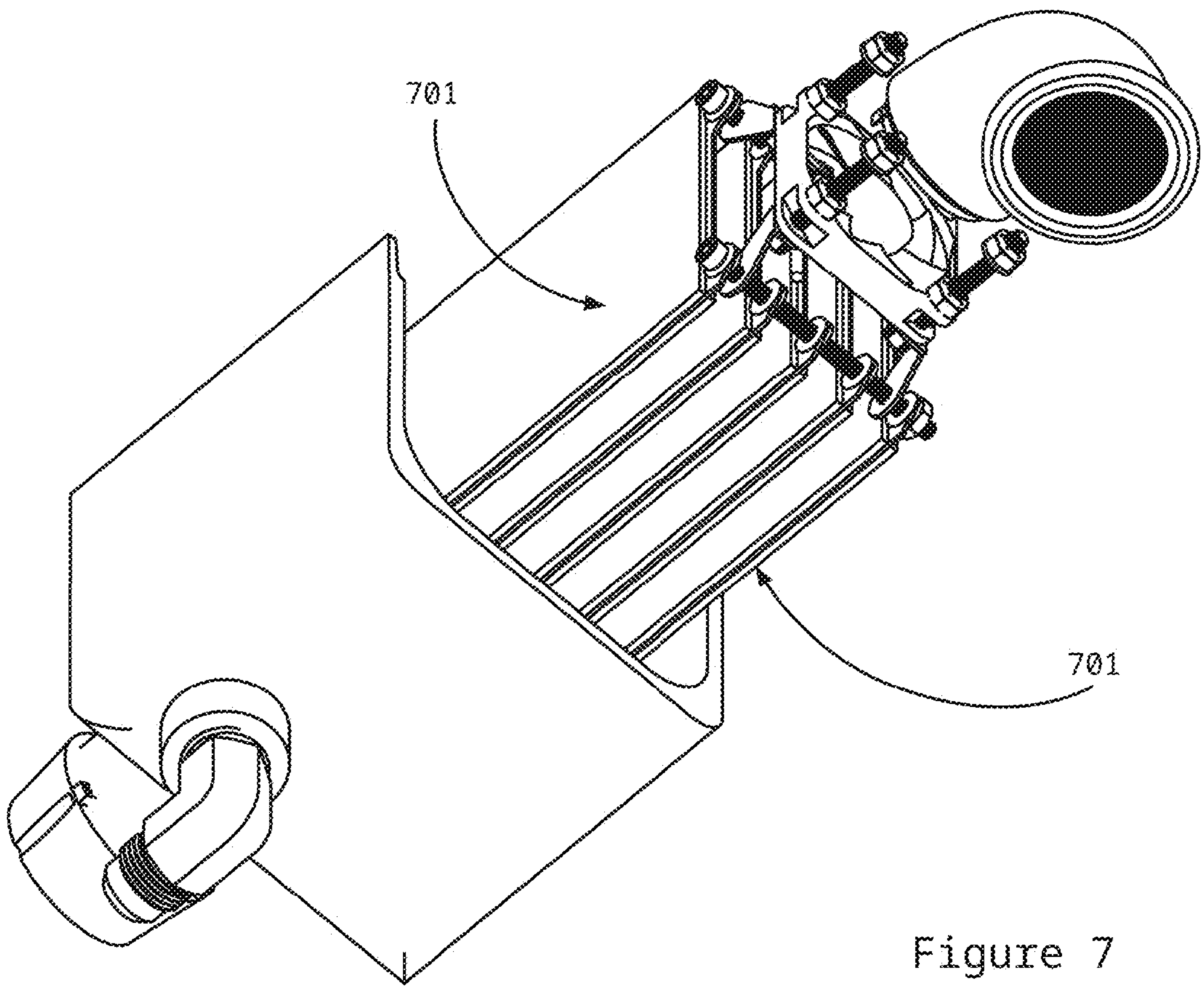

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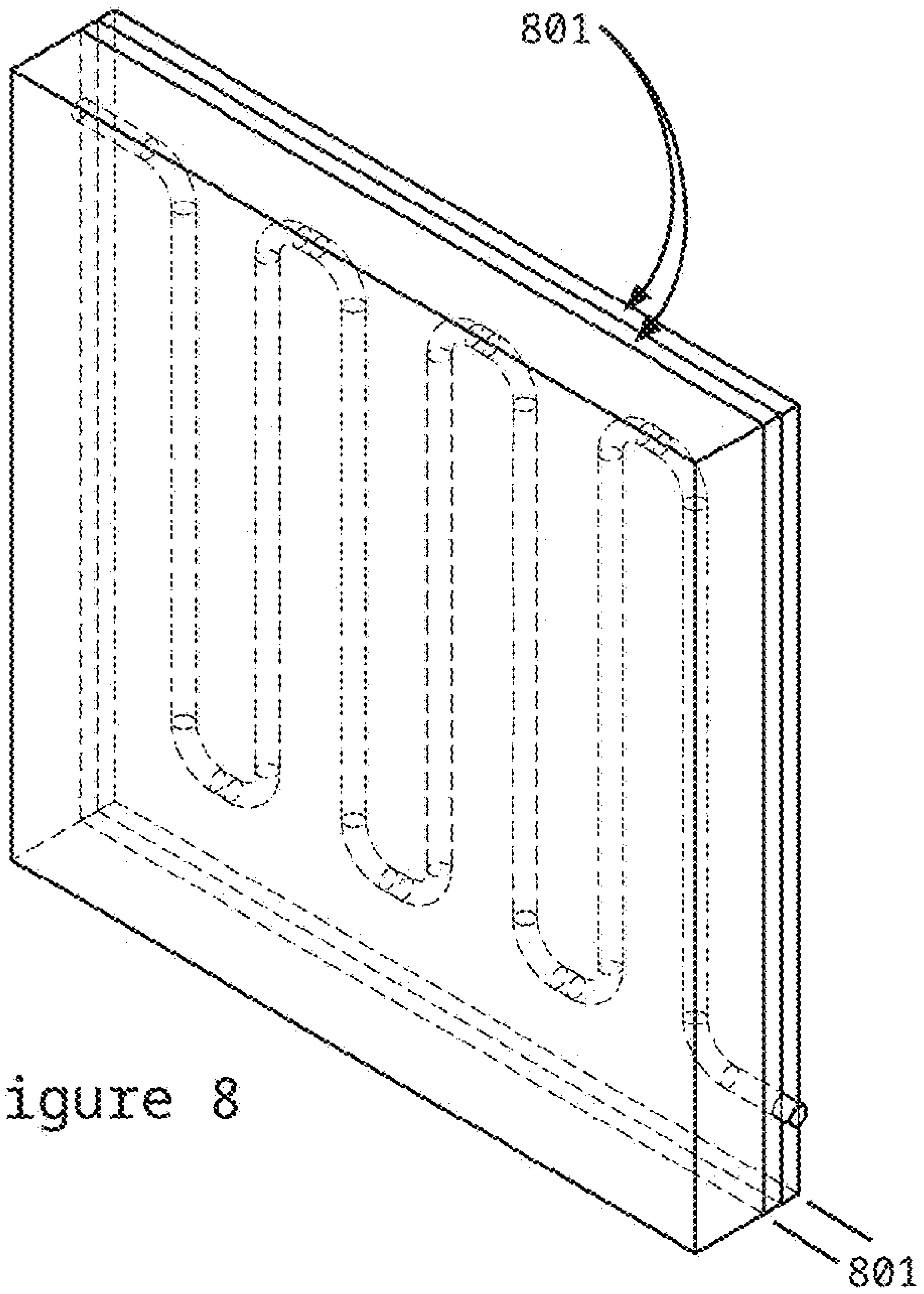

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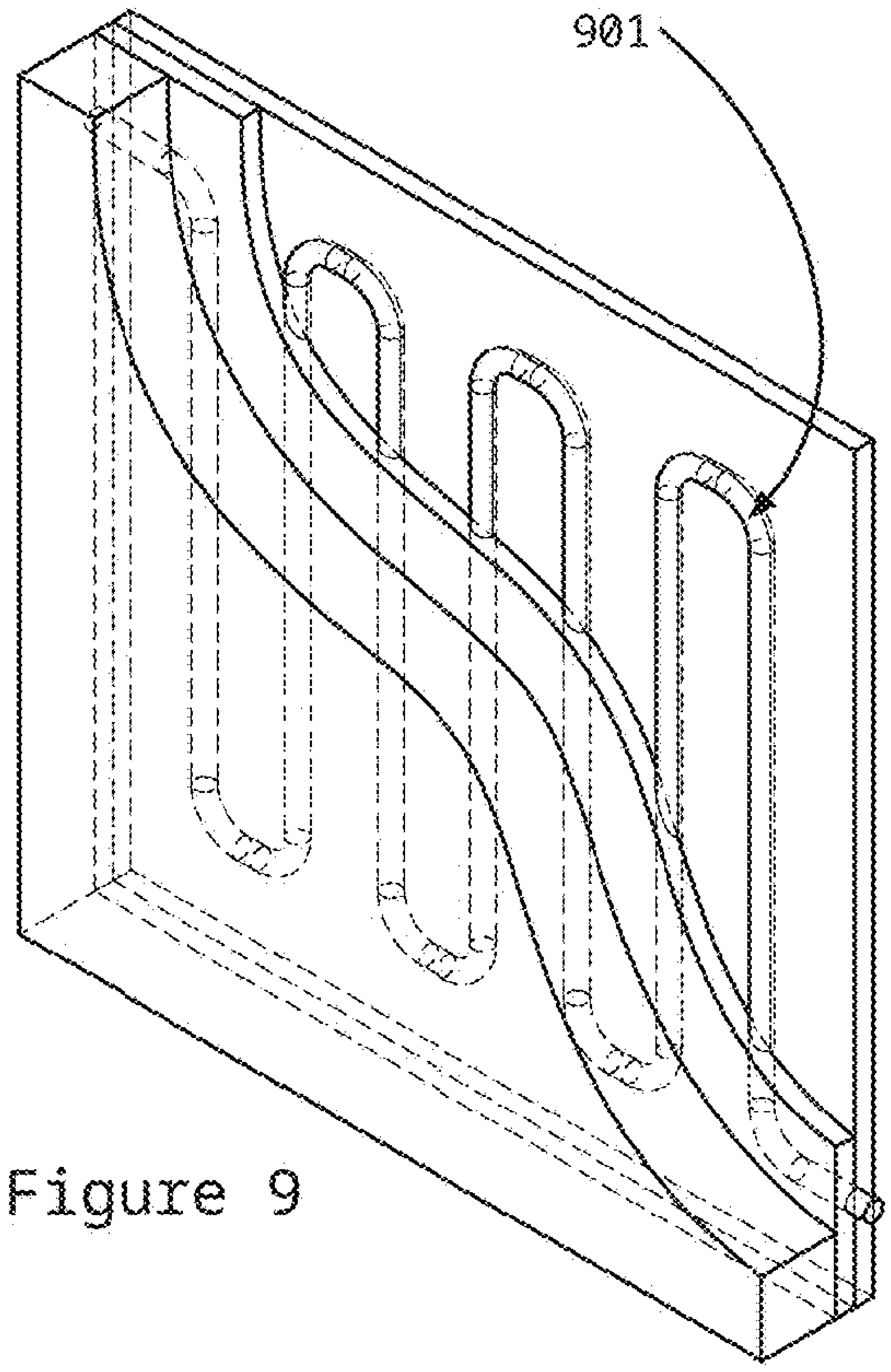

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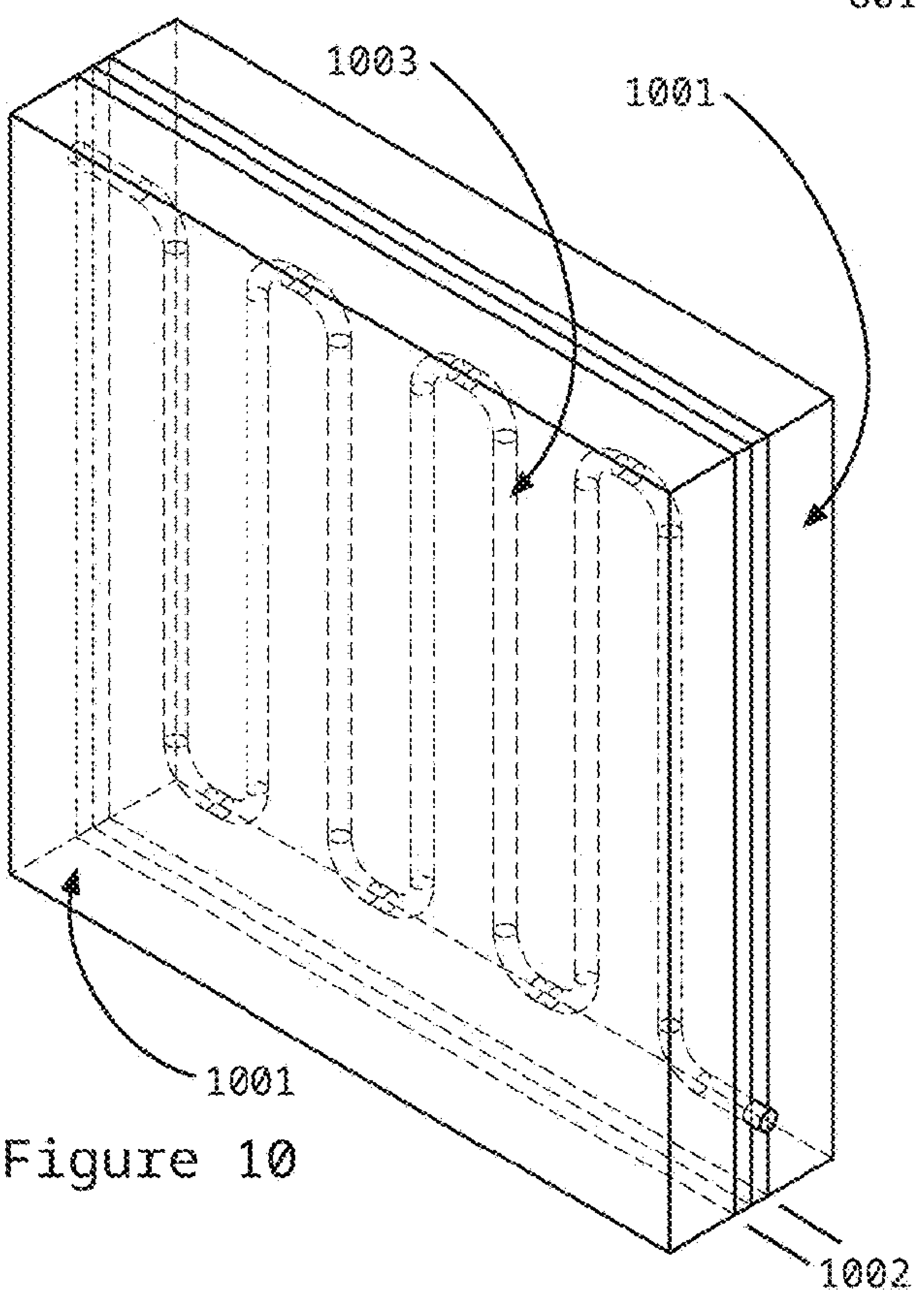

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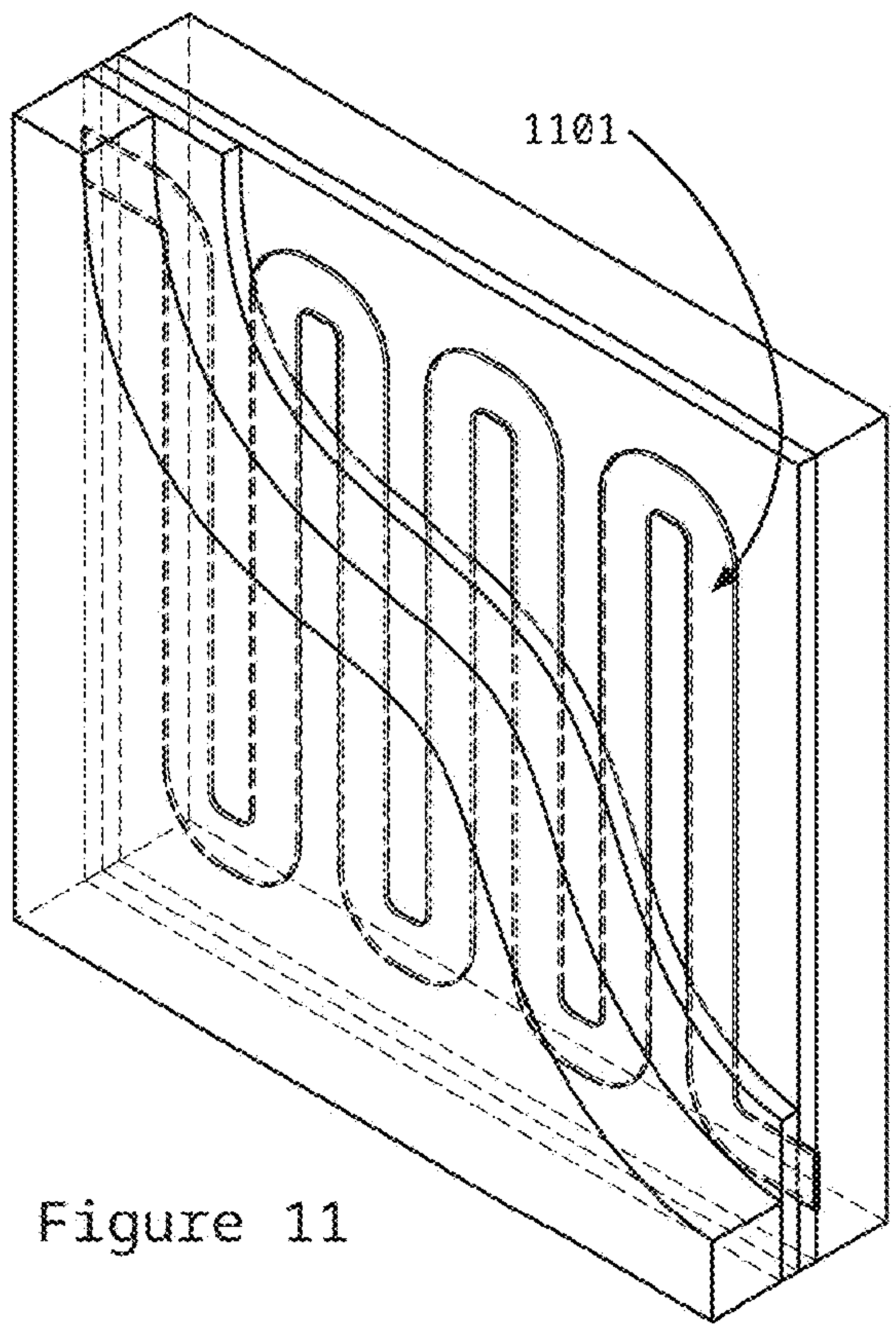

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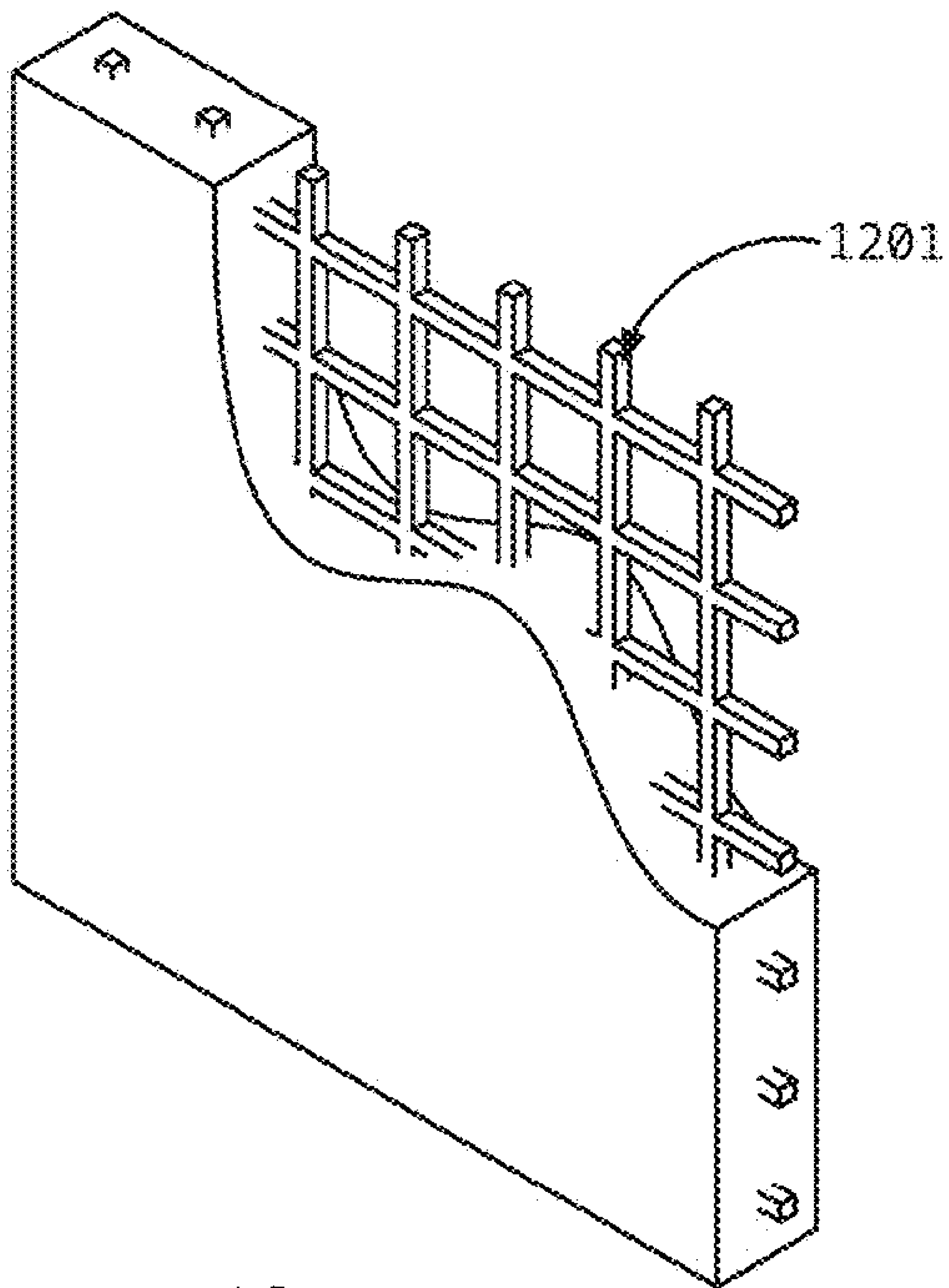

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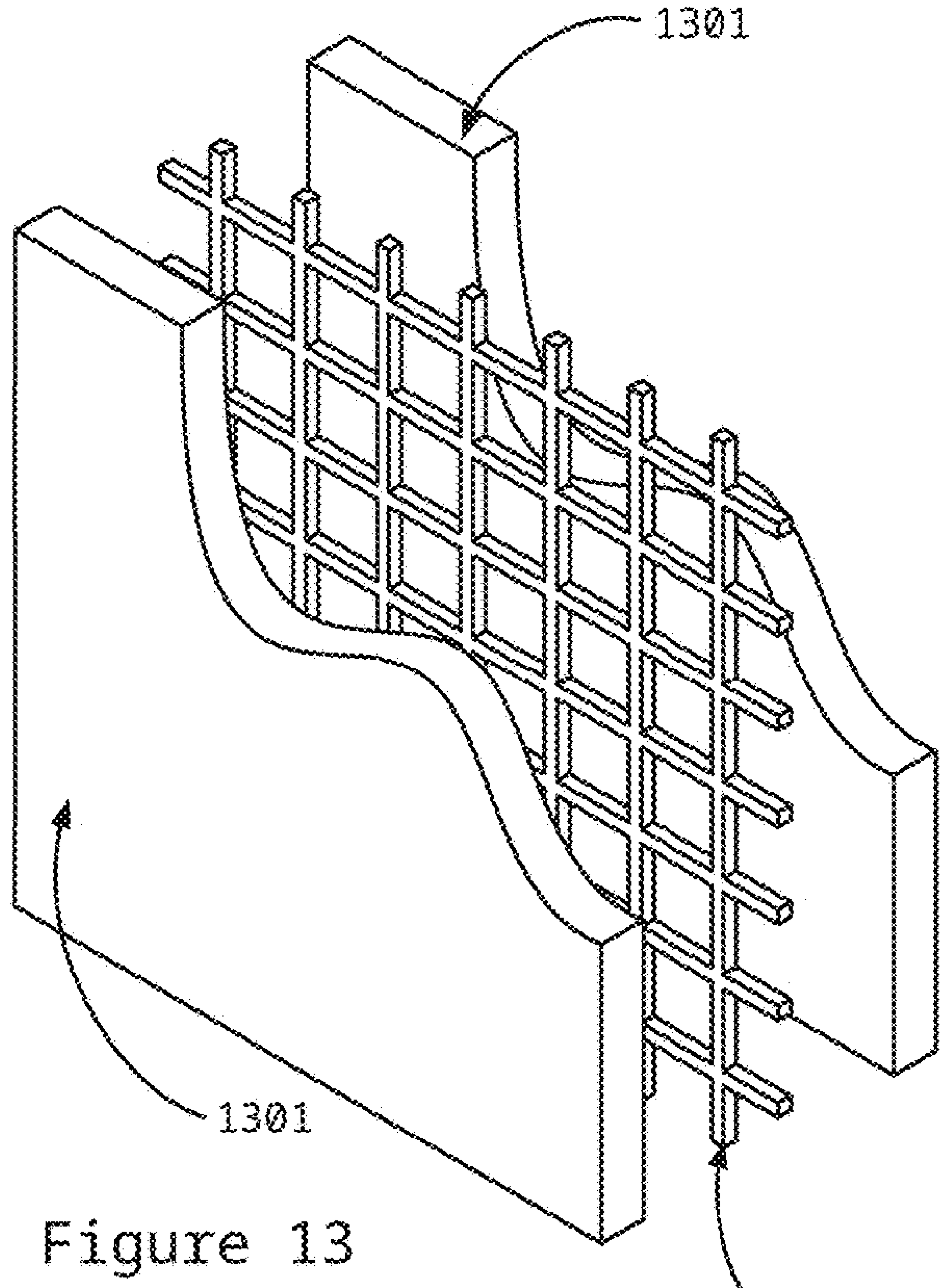

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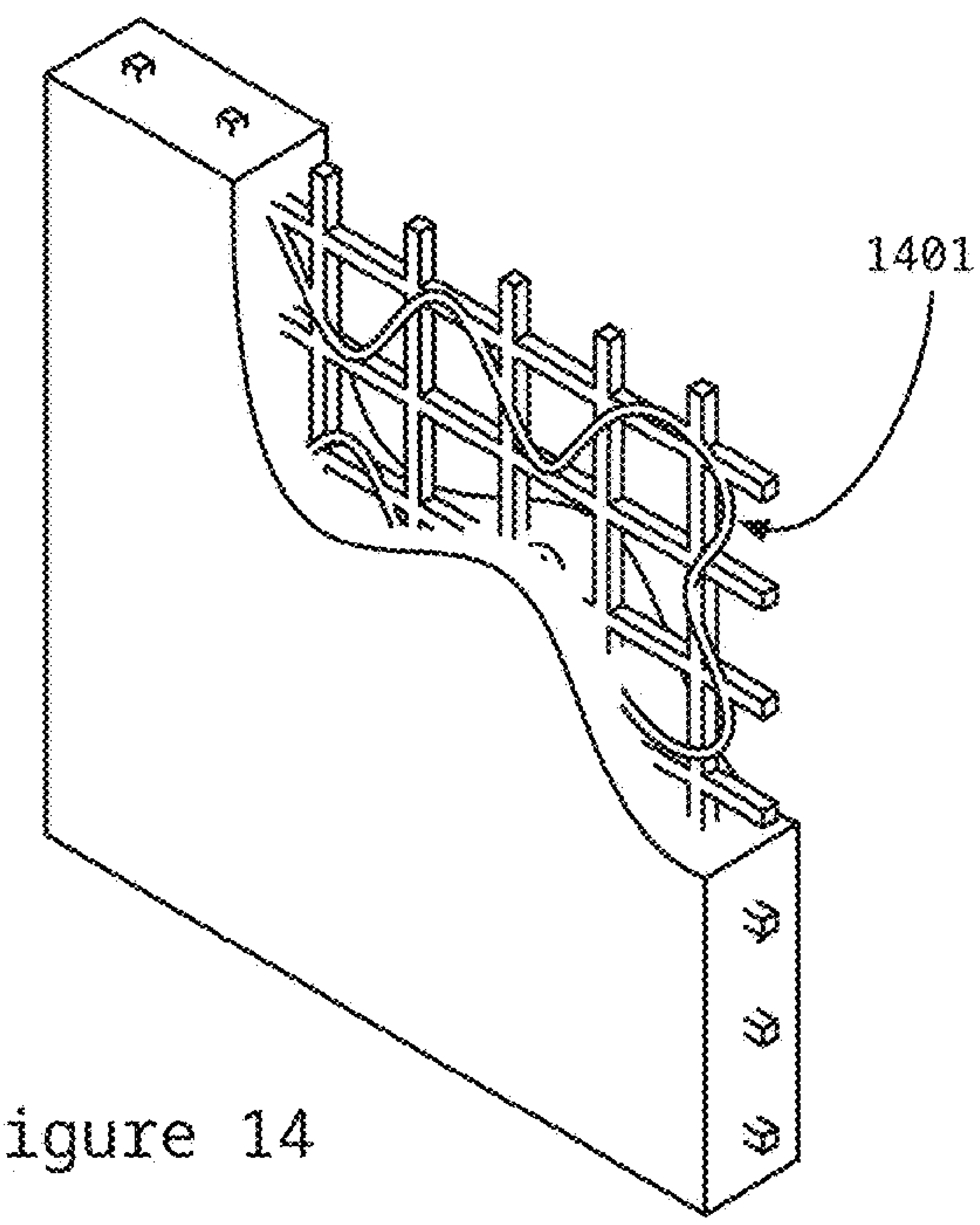

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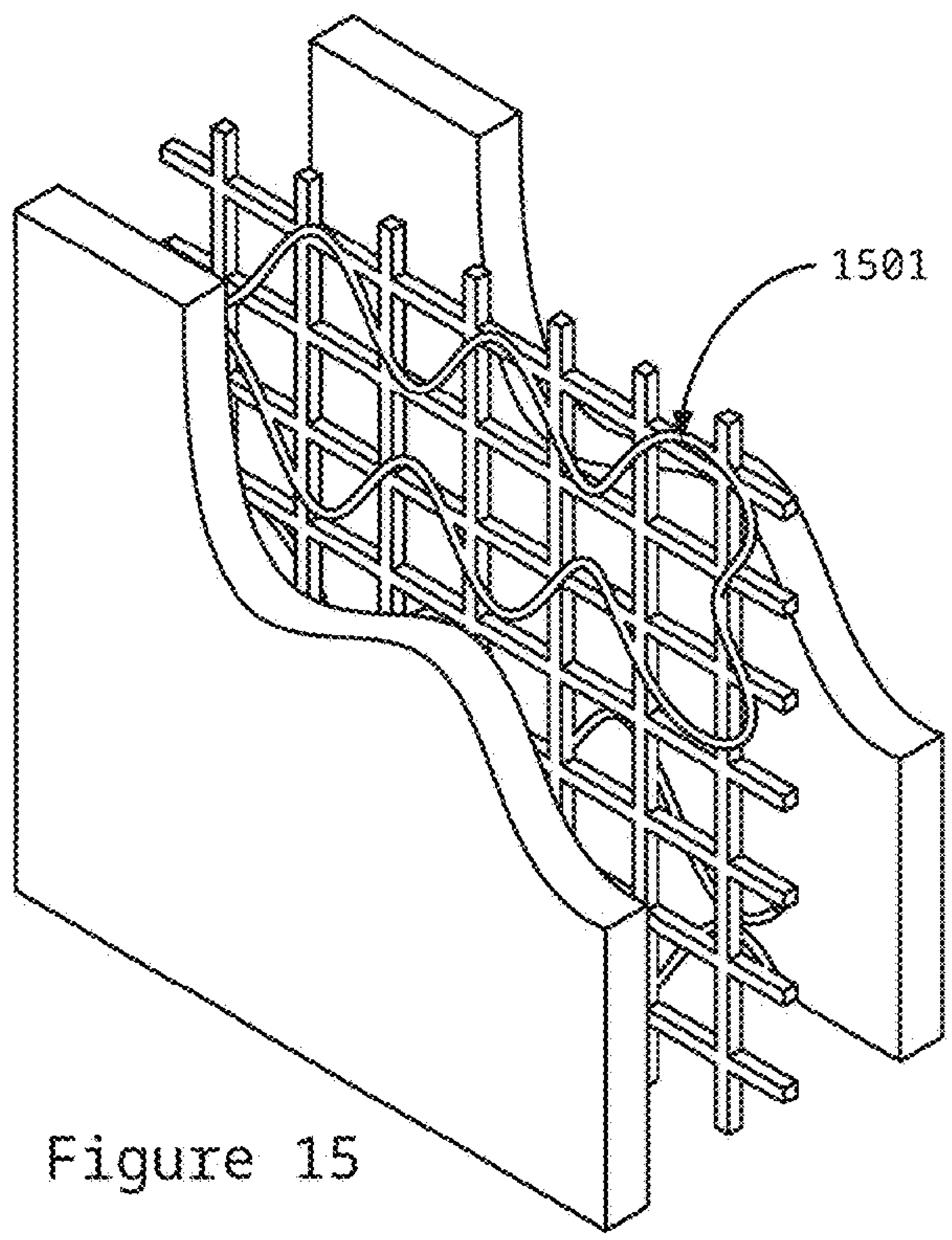

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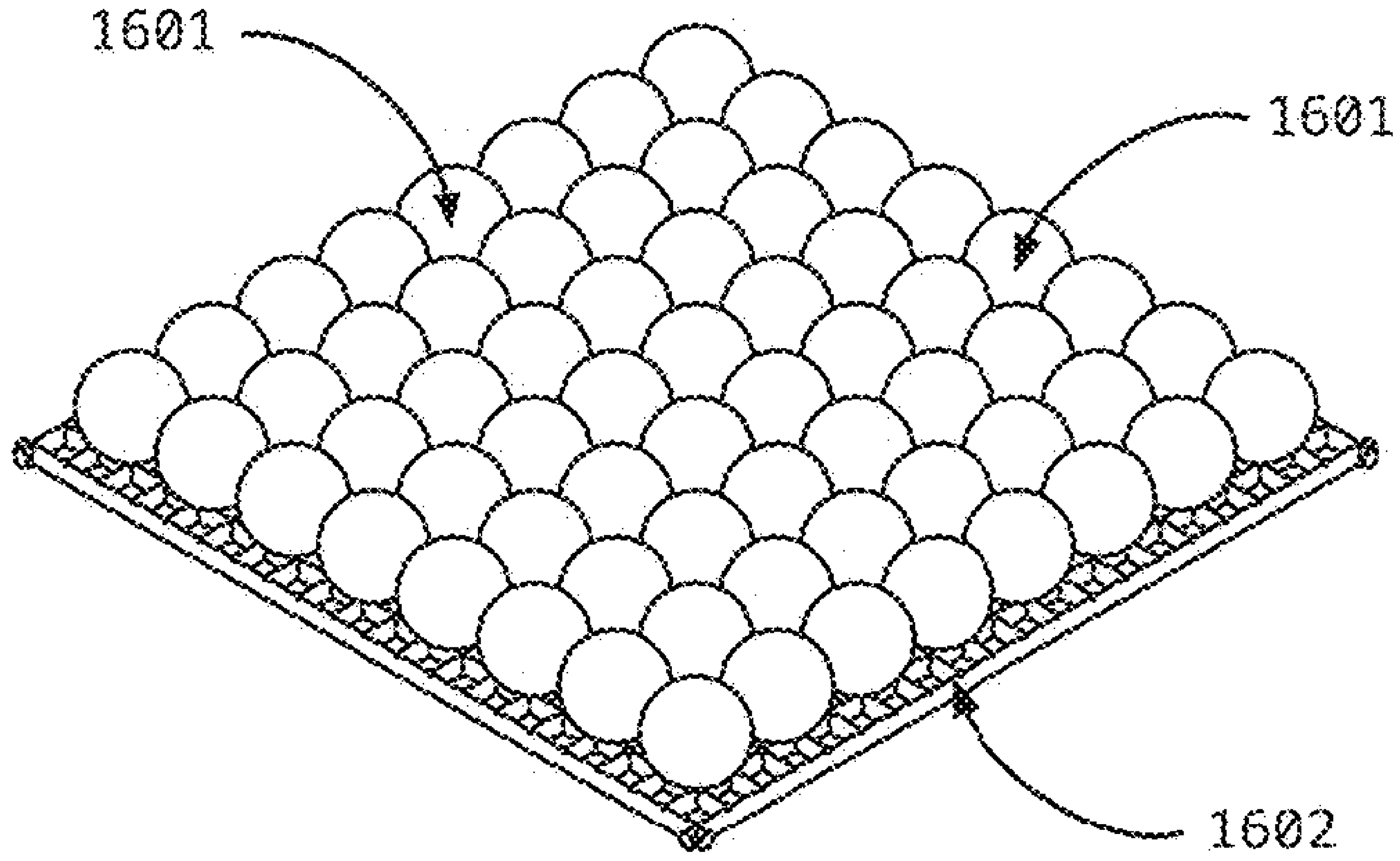

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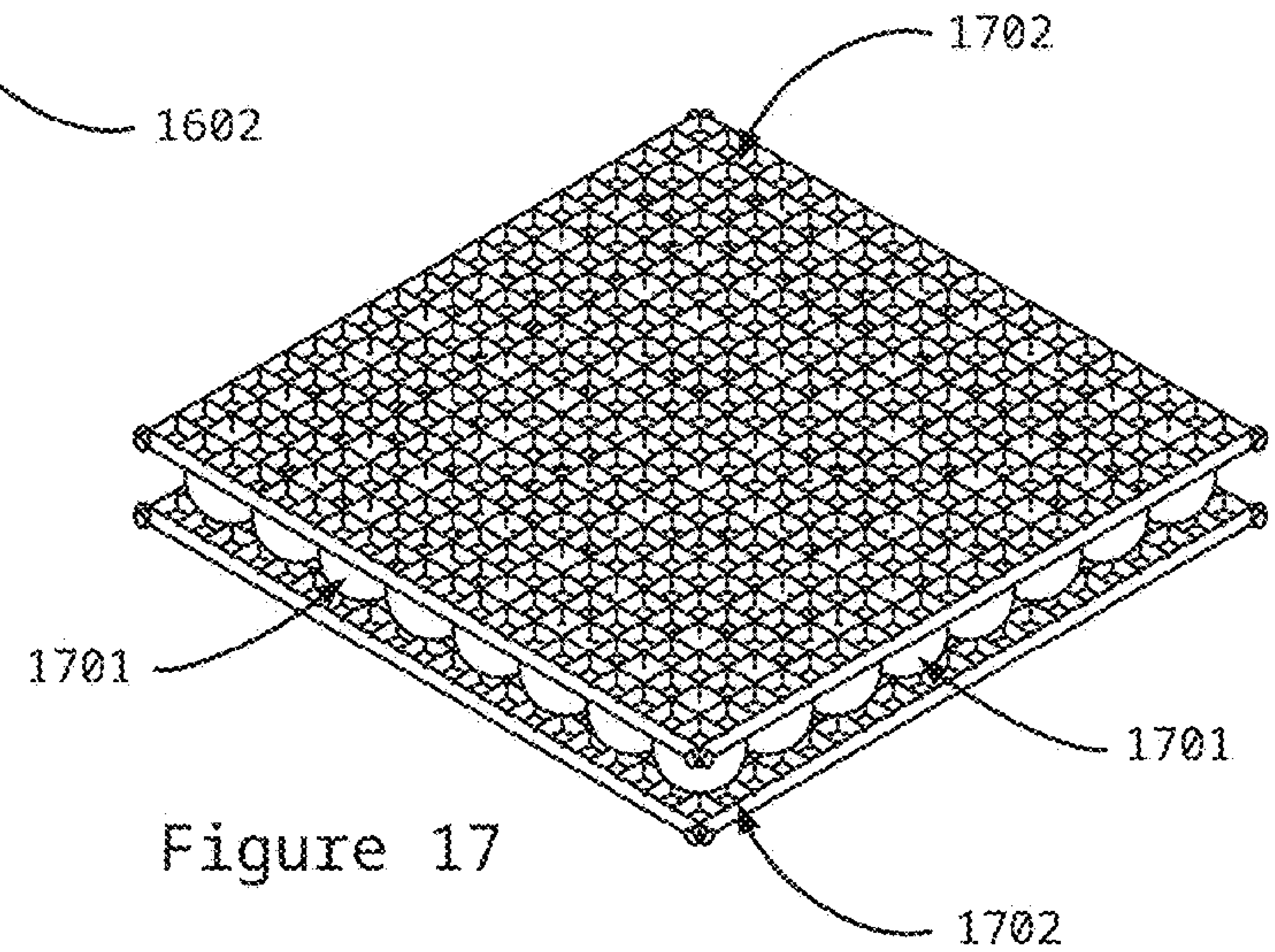

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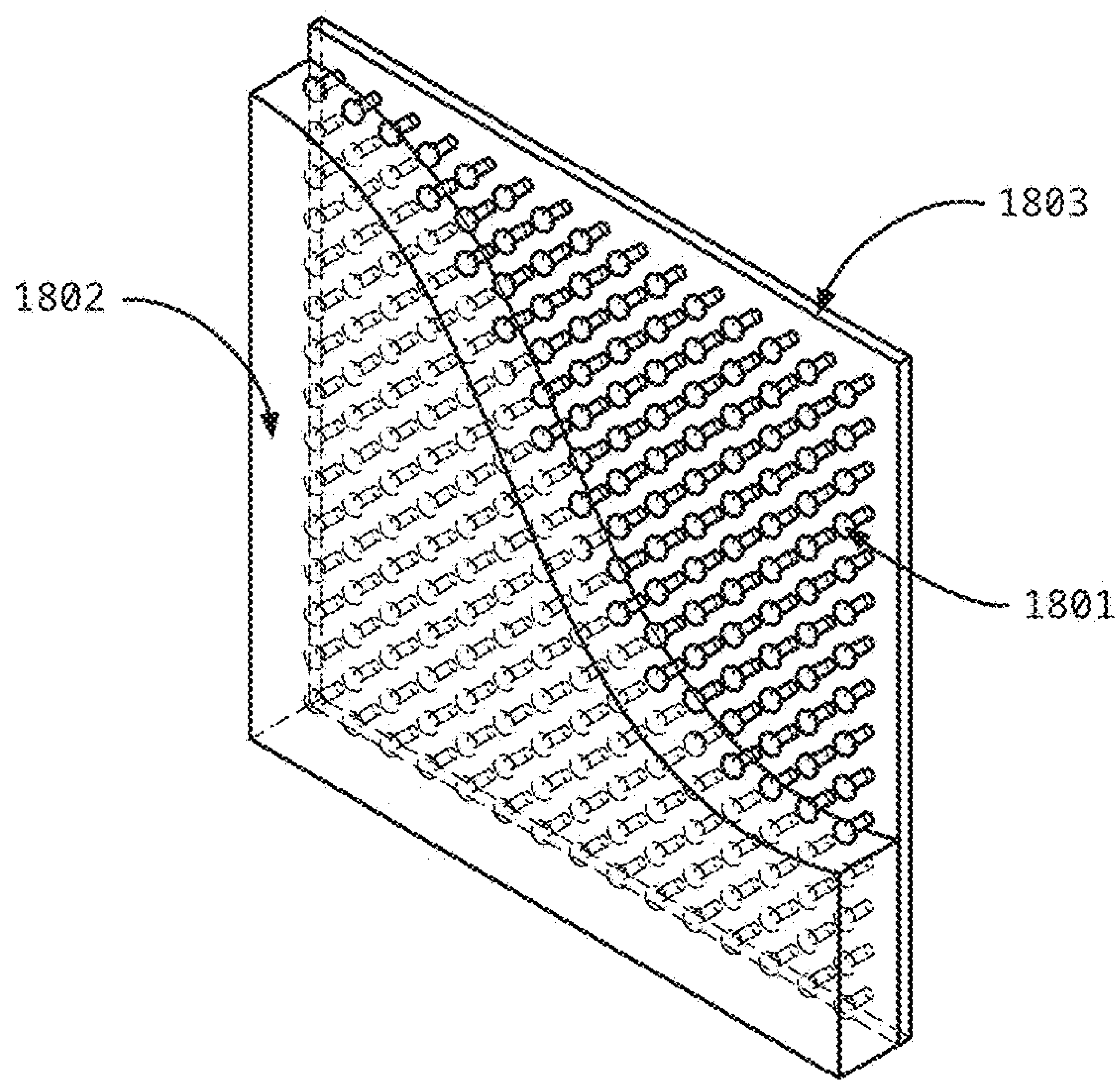

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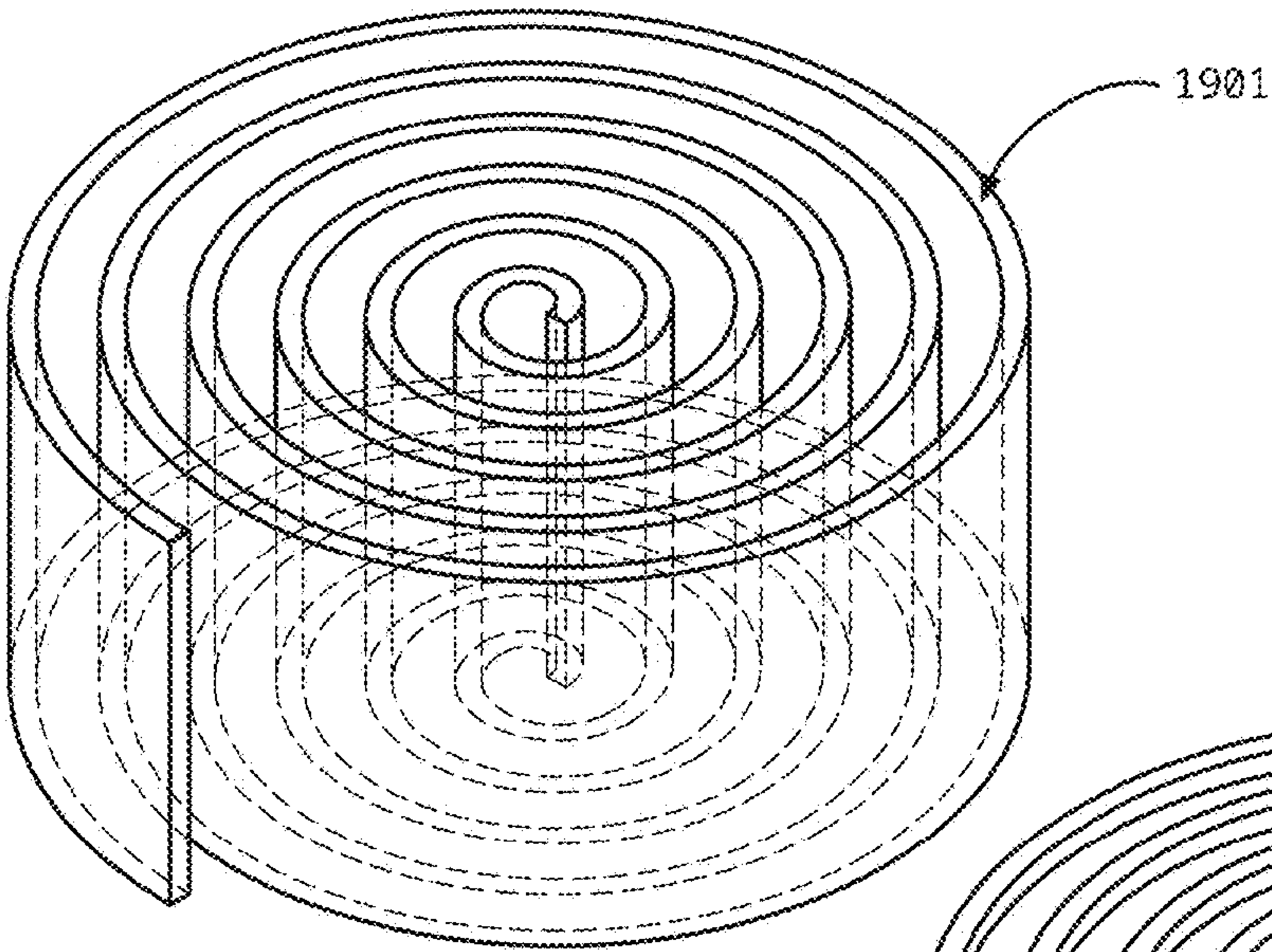

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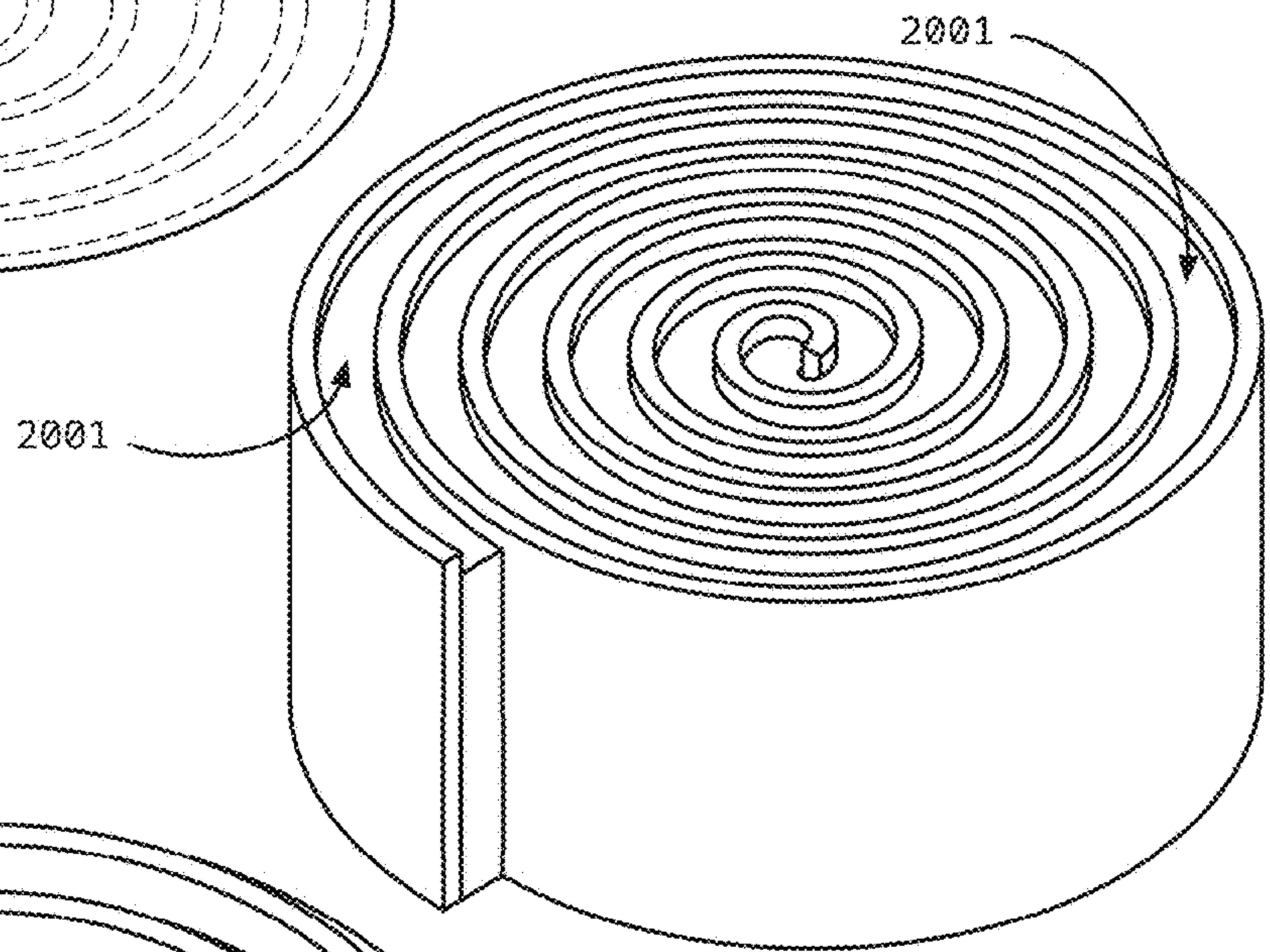

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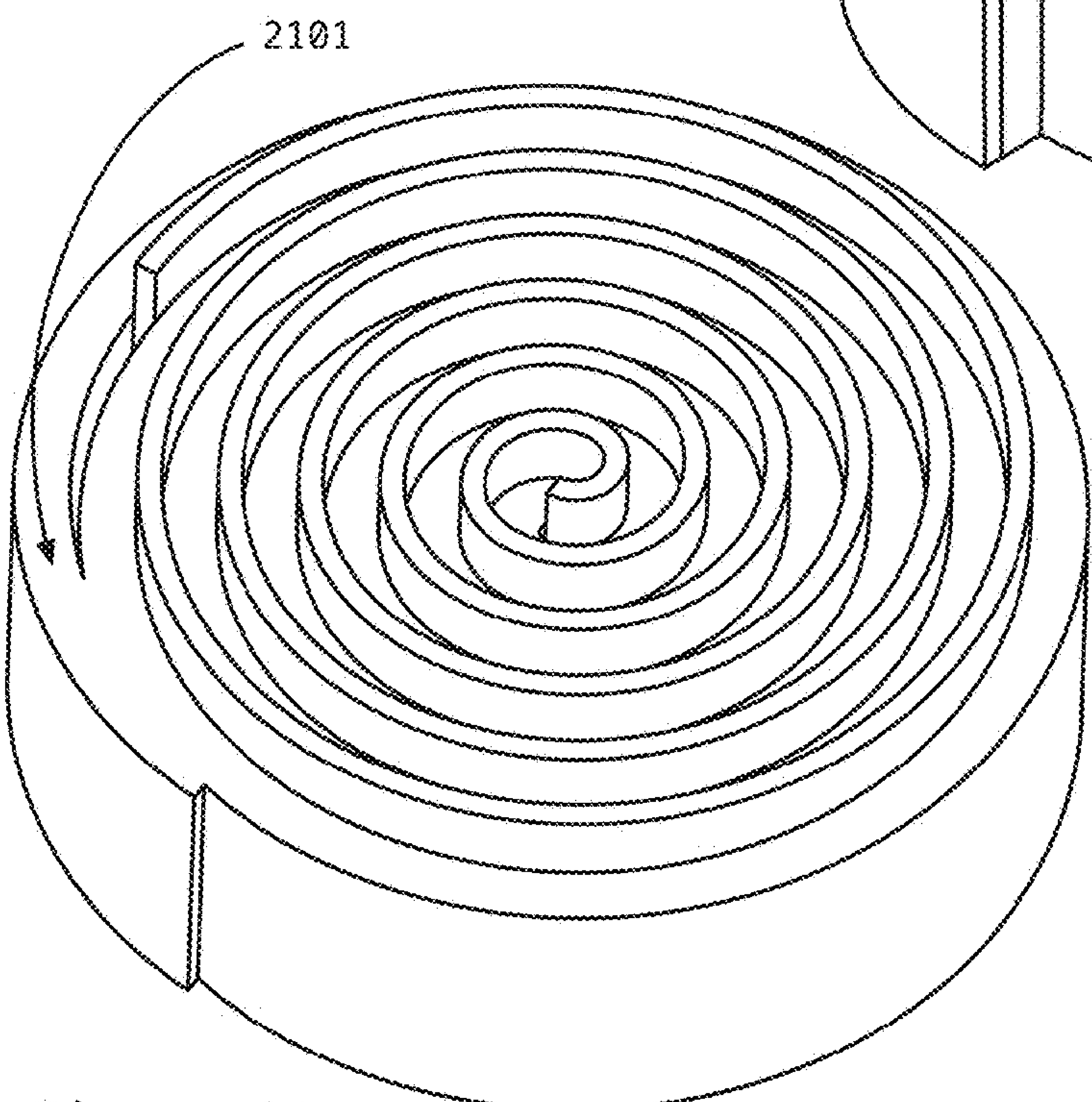

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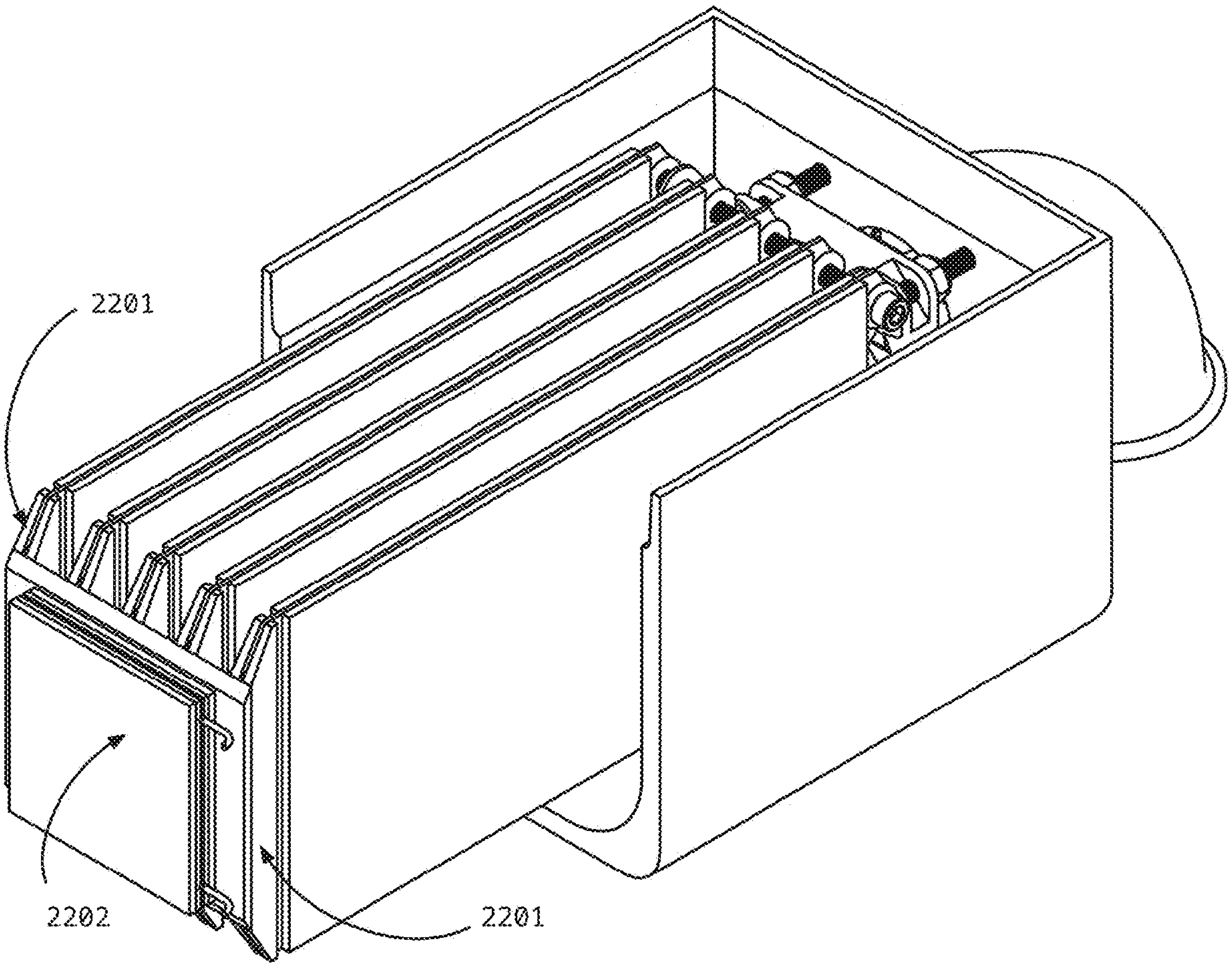

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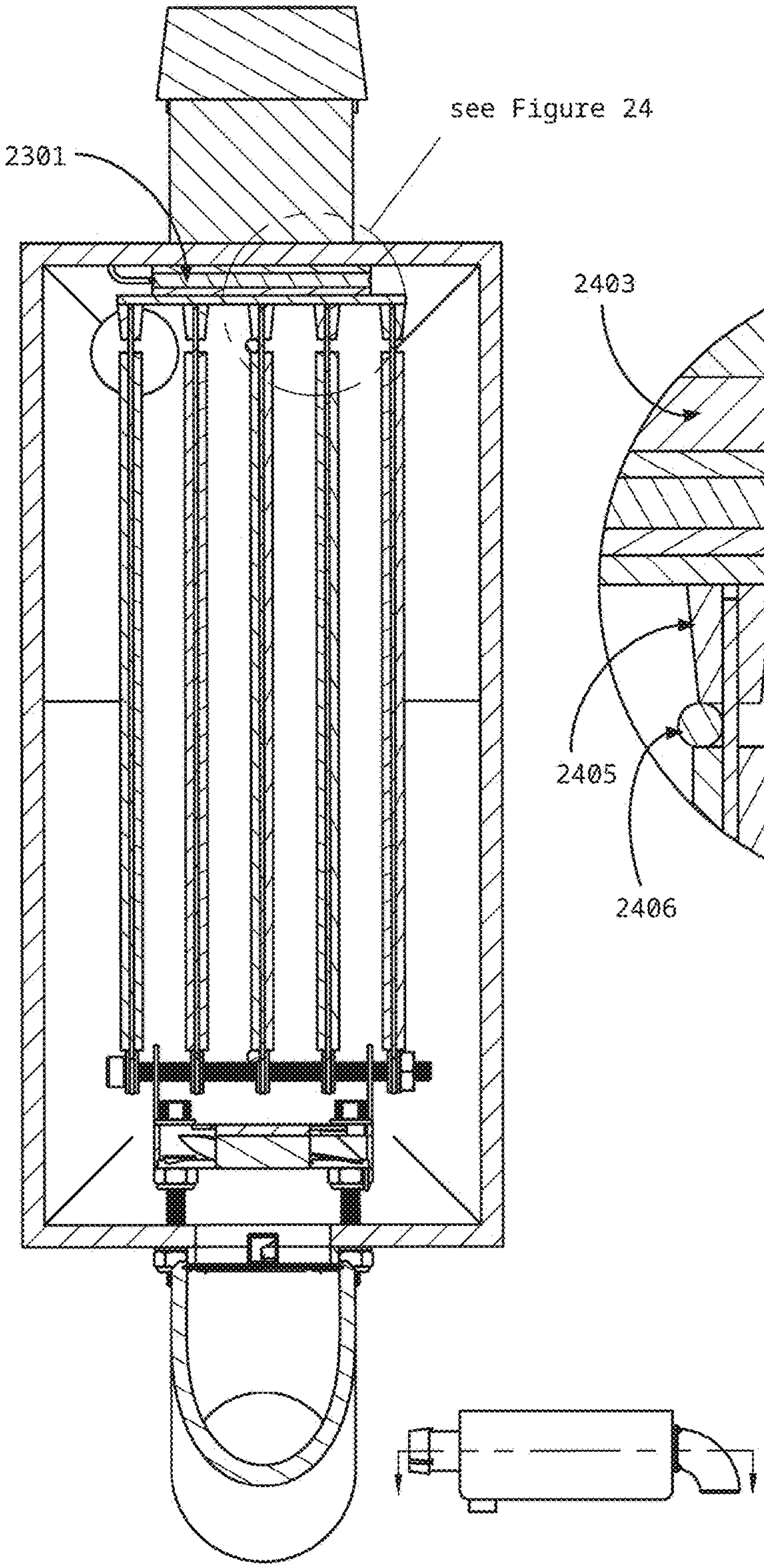

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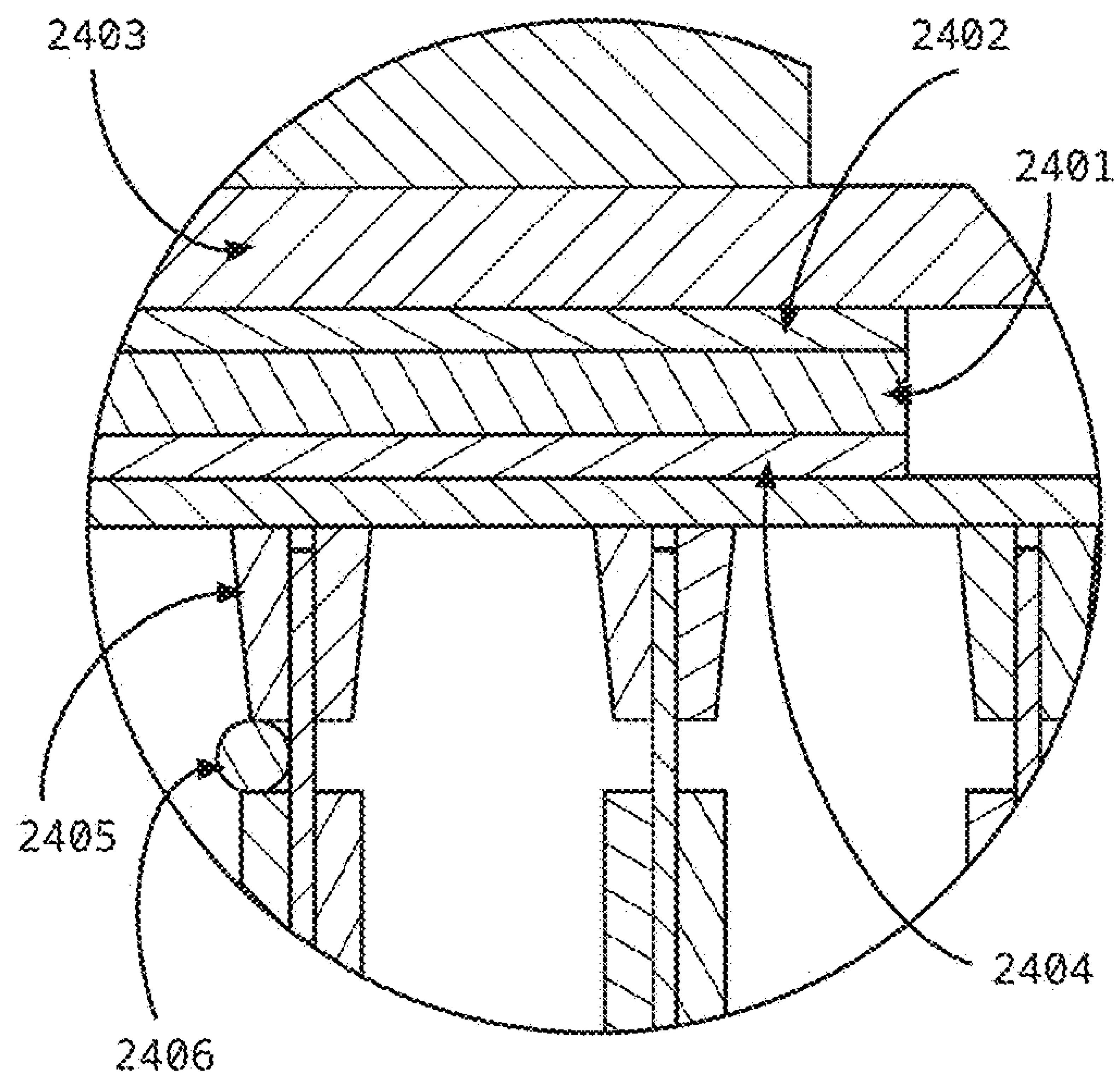

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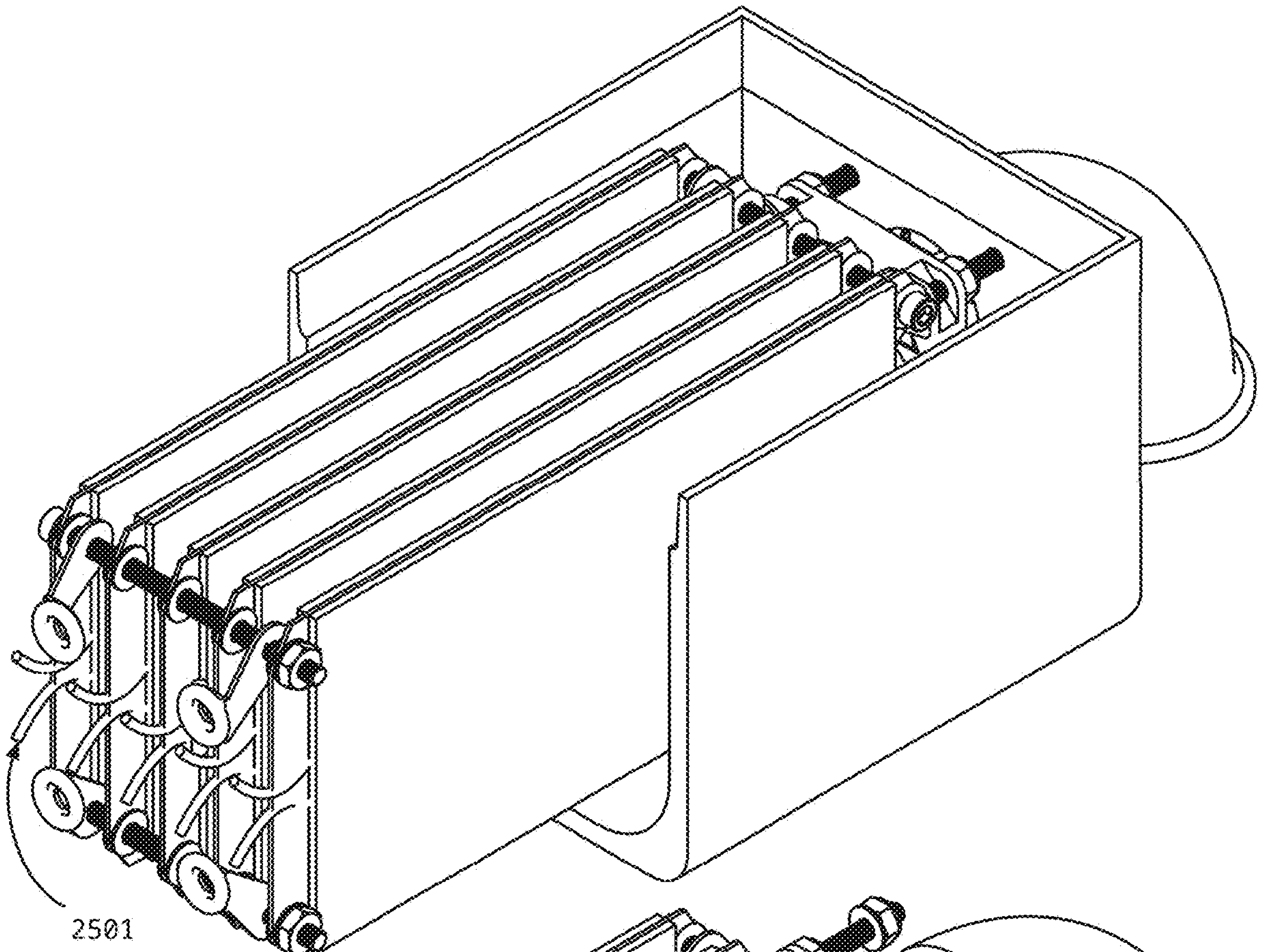

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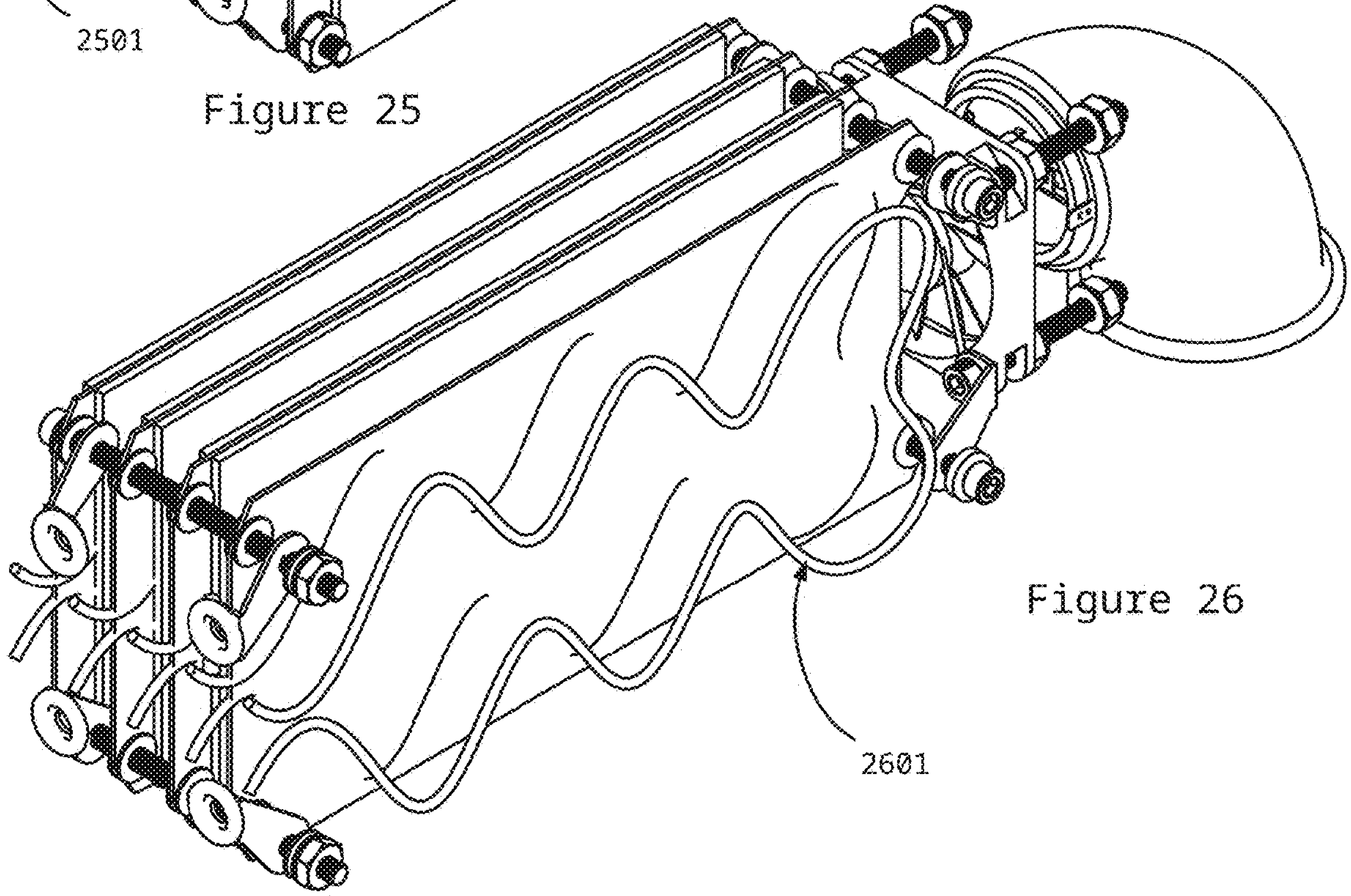

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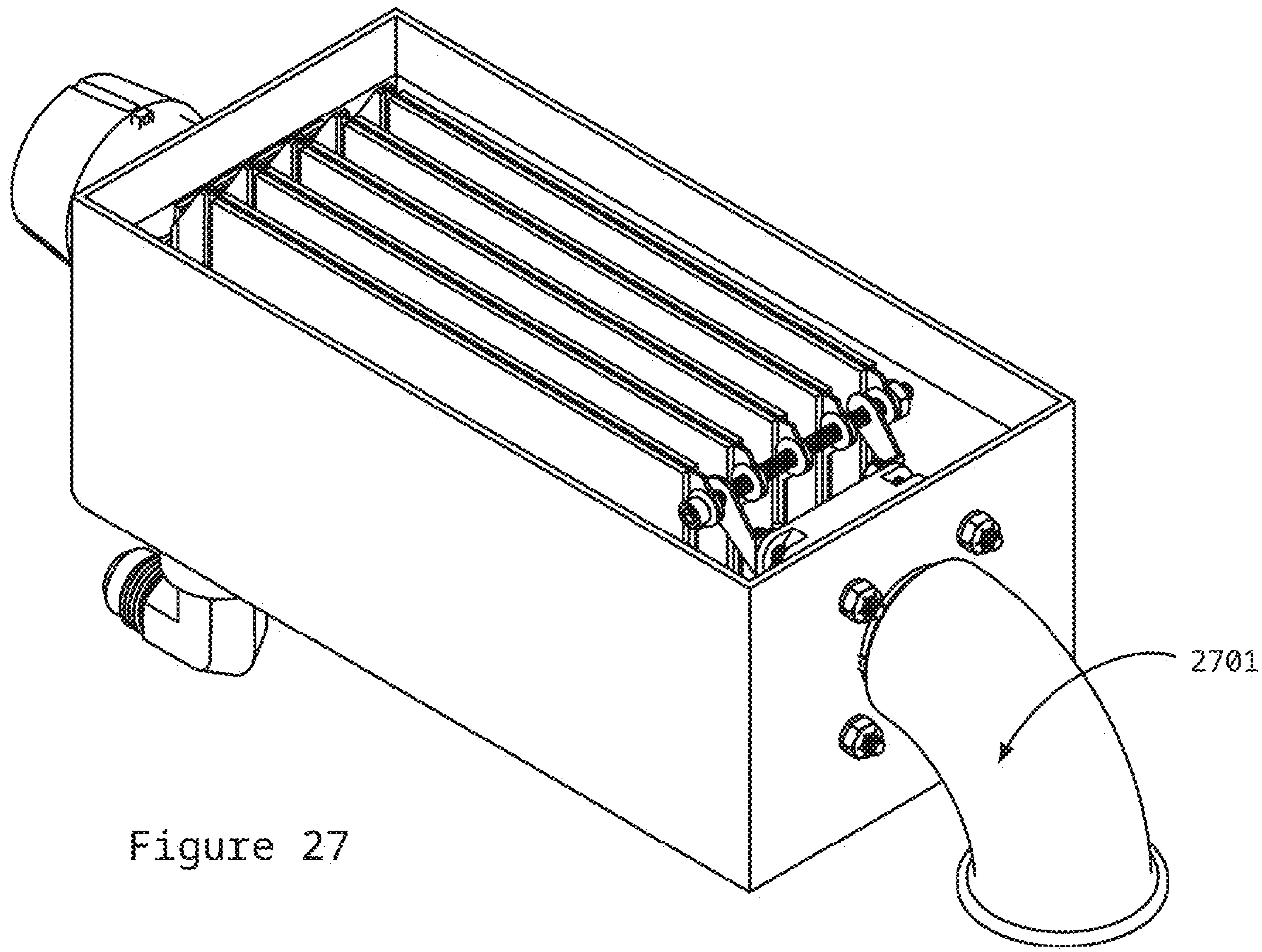

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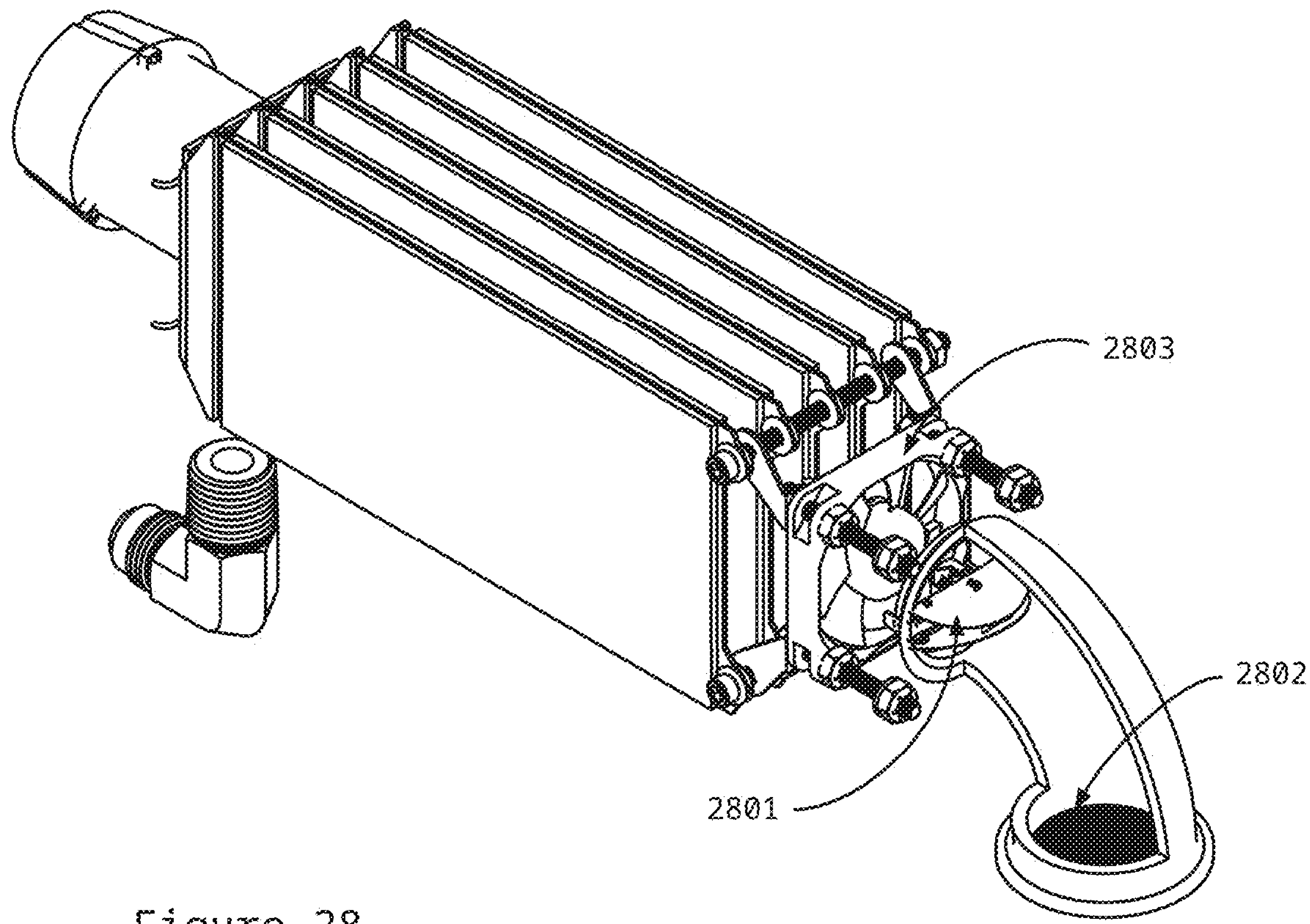

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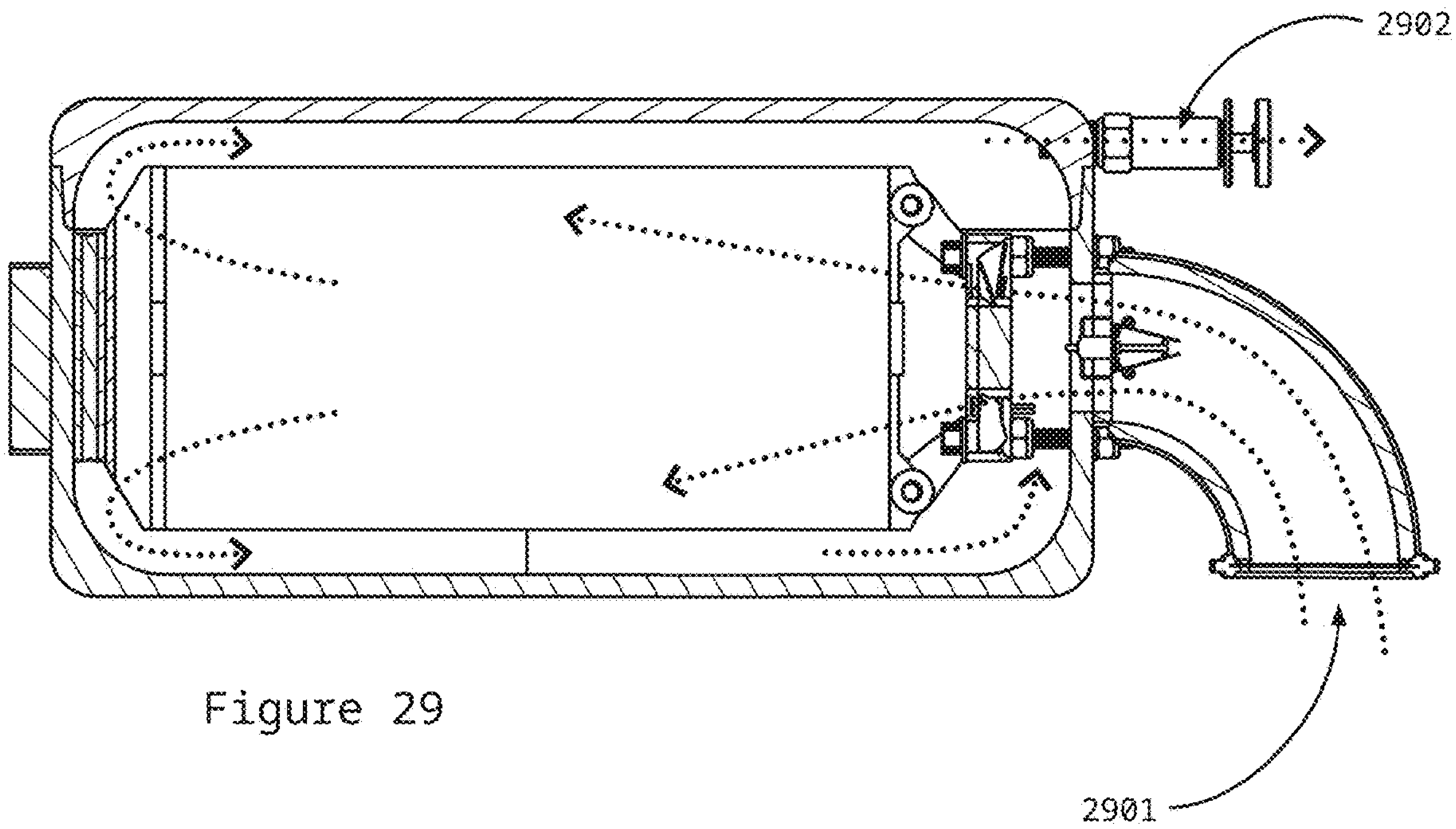

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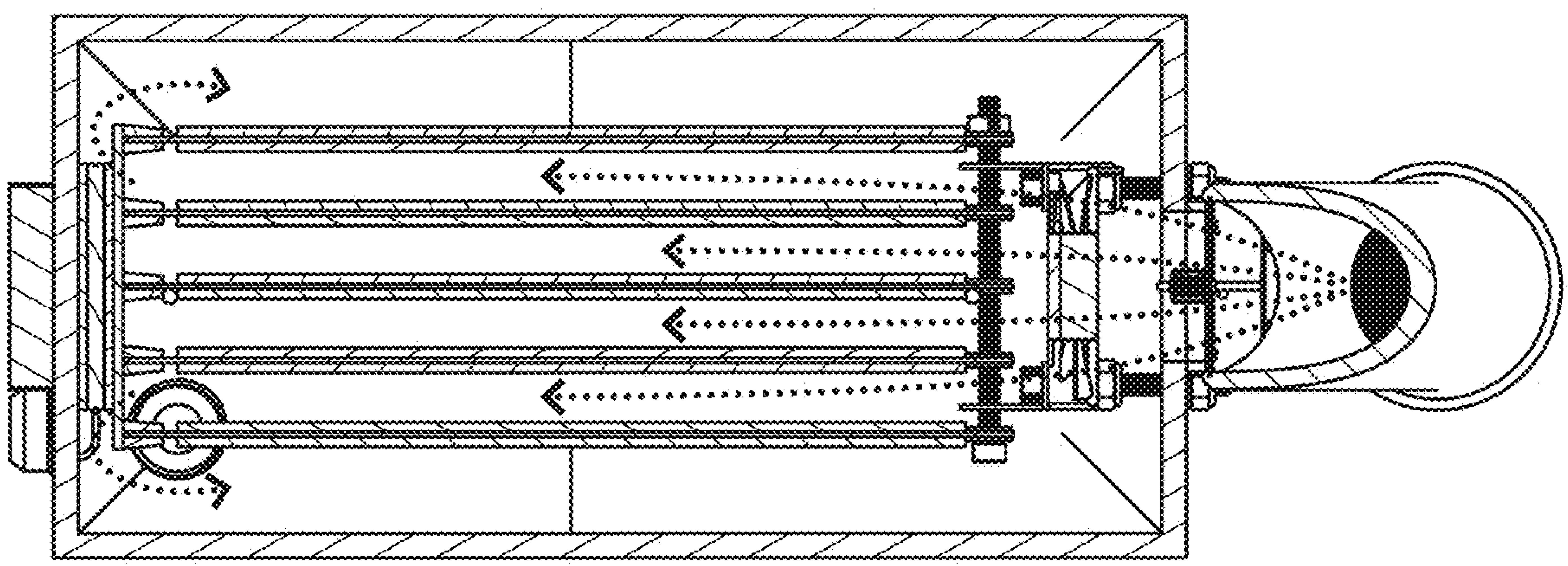

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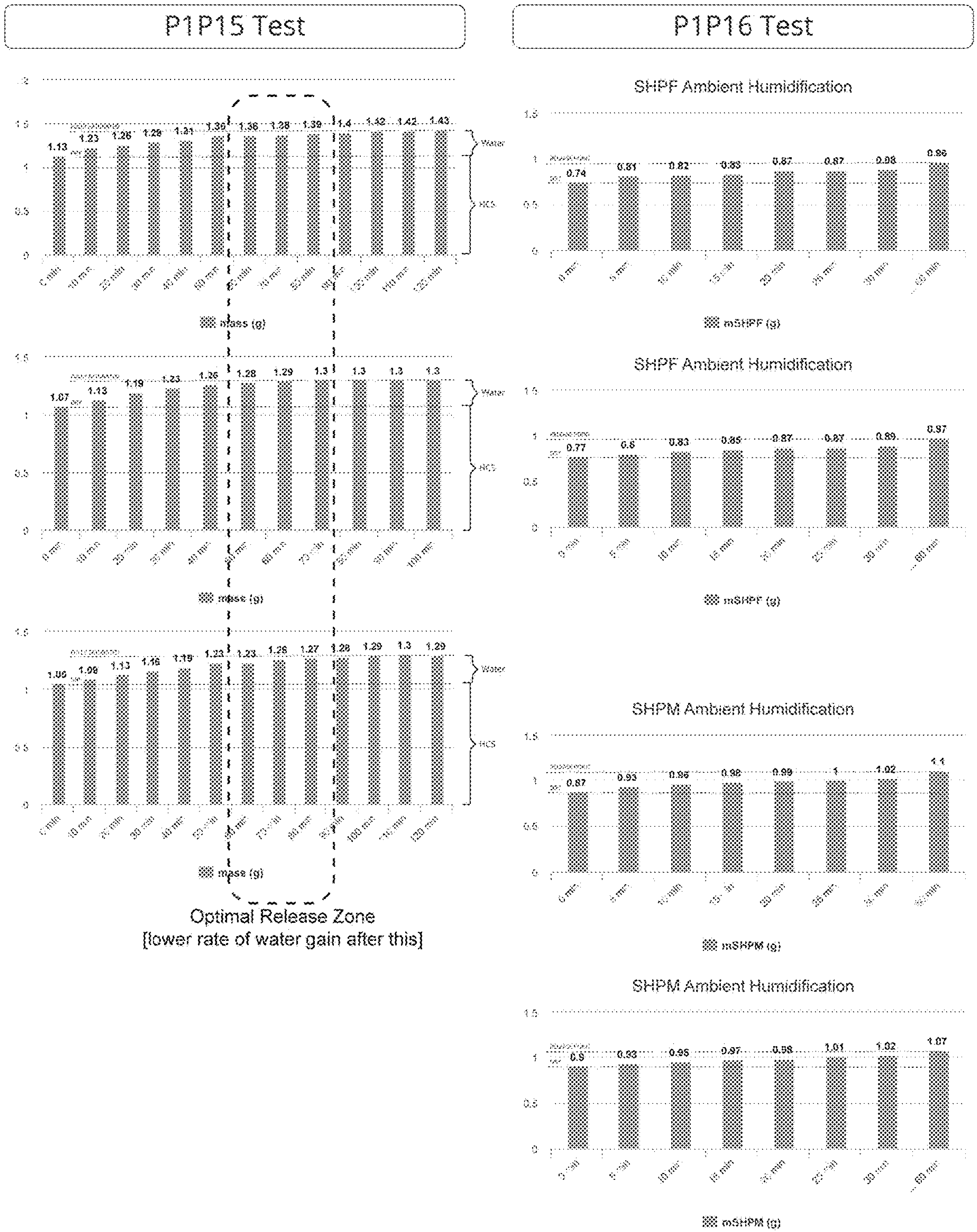
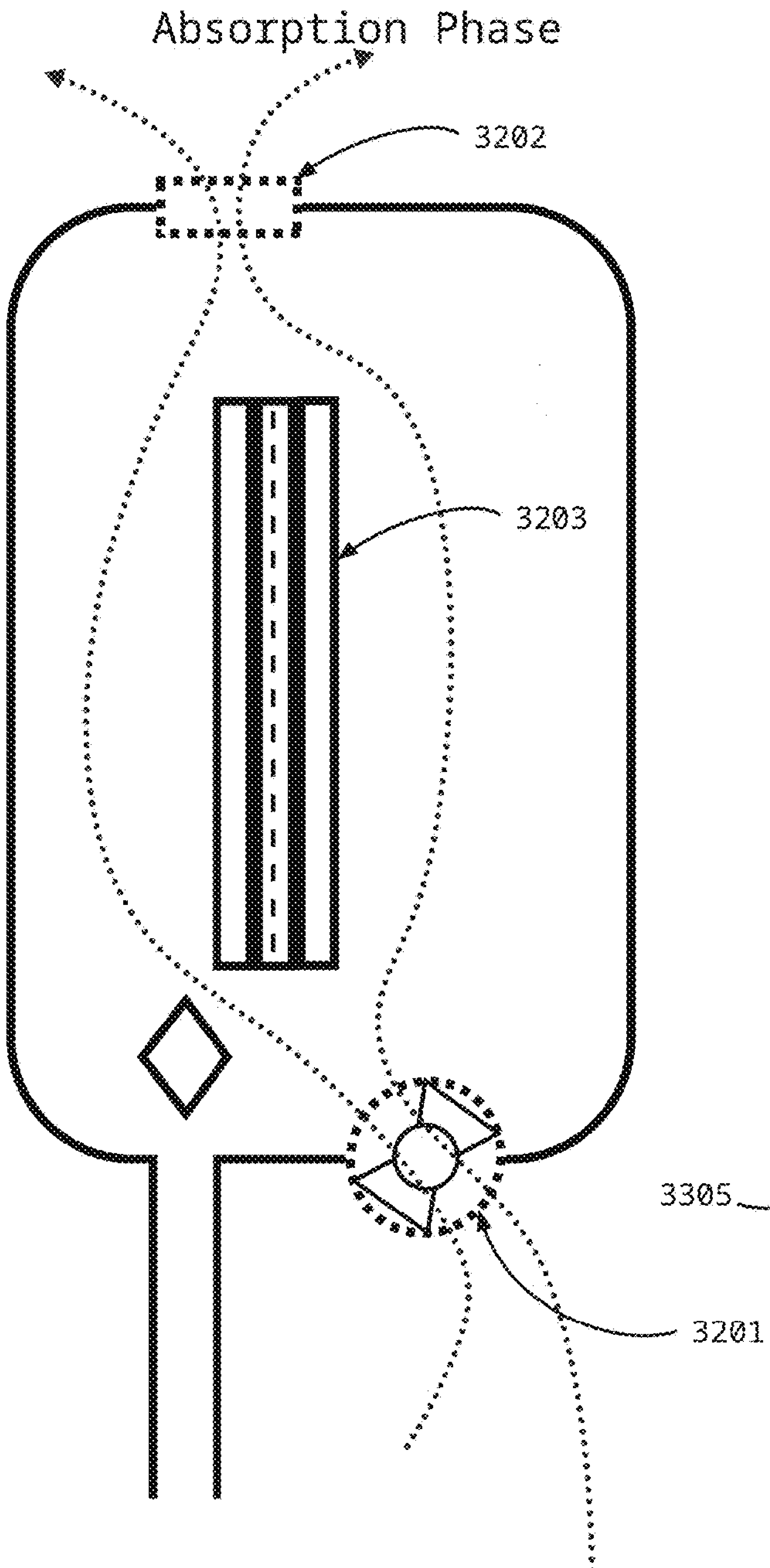

P1P15 Test
P1P16 Test
SHPF Ambient Humidification
SHPF Ambient Humidification
SHPM Ambient Humidification
SHPM Ambient Humidification
Water
HCS
mass (g)
mSHPF (g)
mSHPM (g)
Optimal Release Zone
[lower rate of water gain after this]

Figure 31



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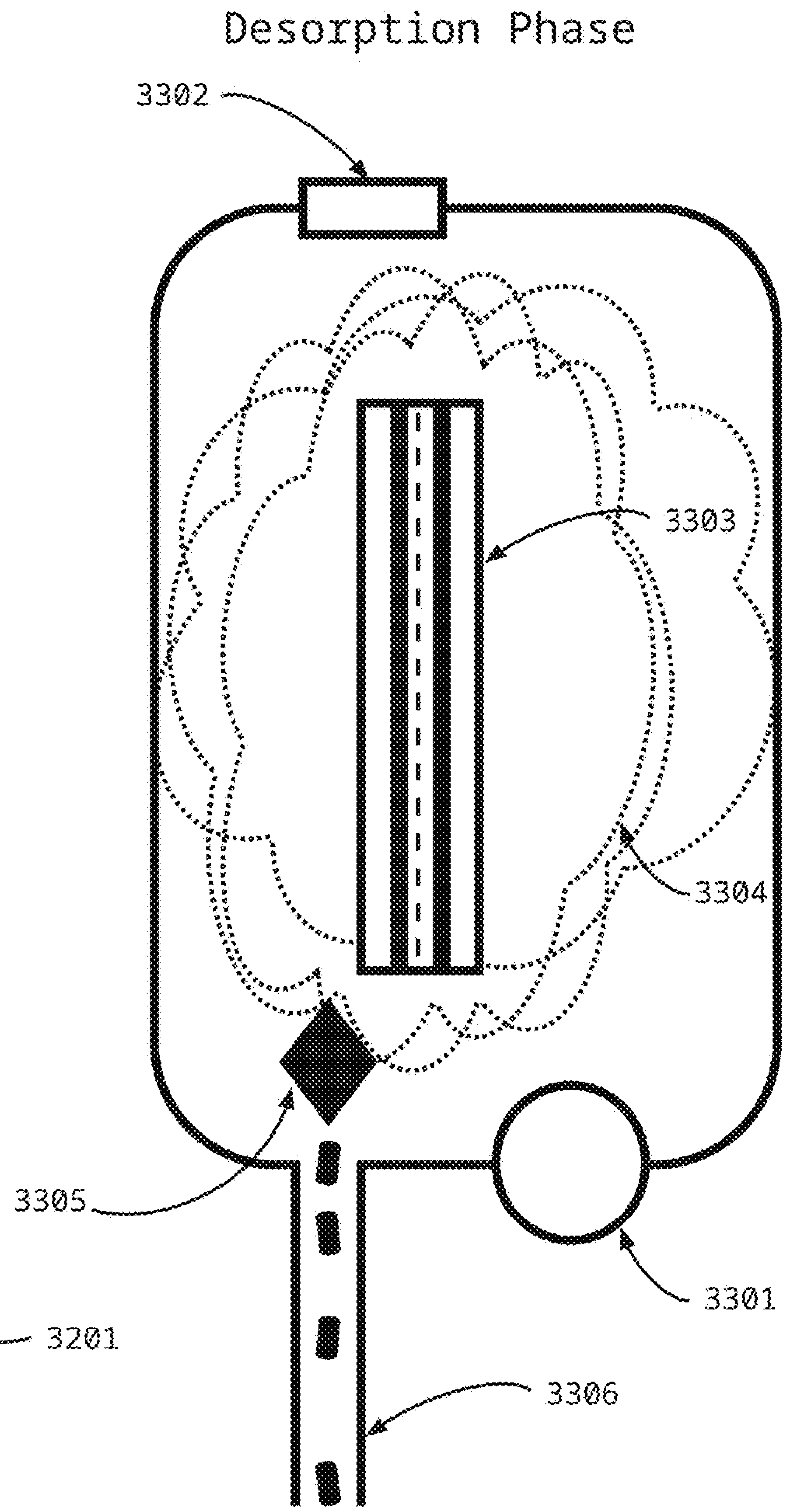

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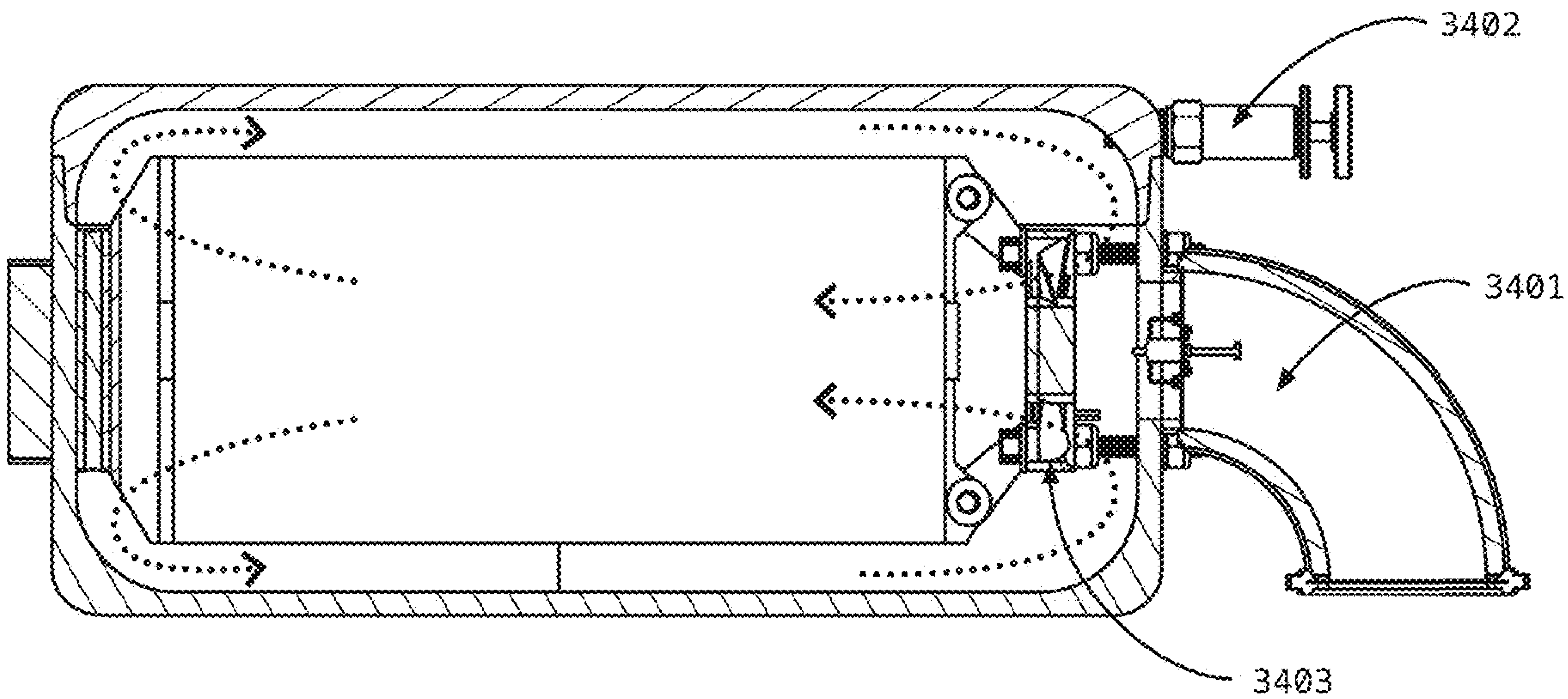

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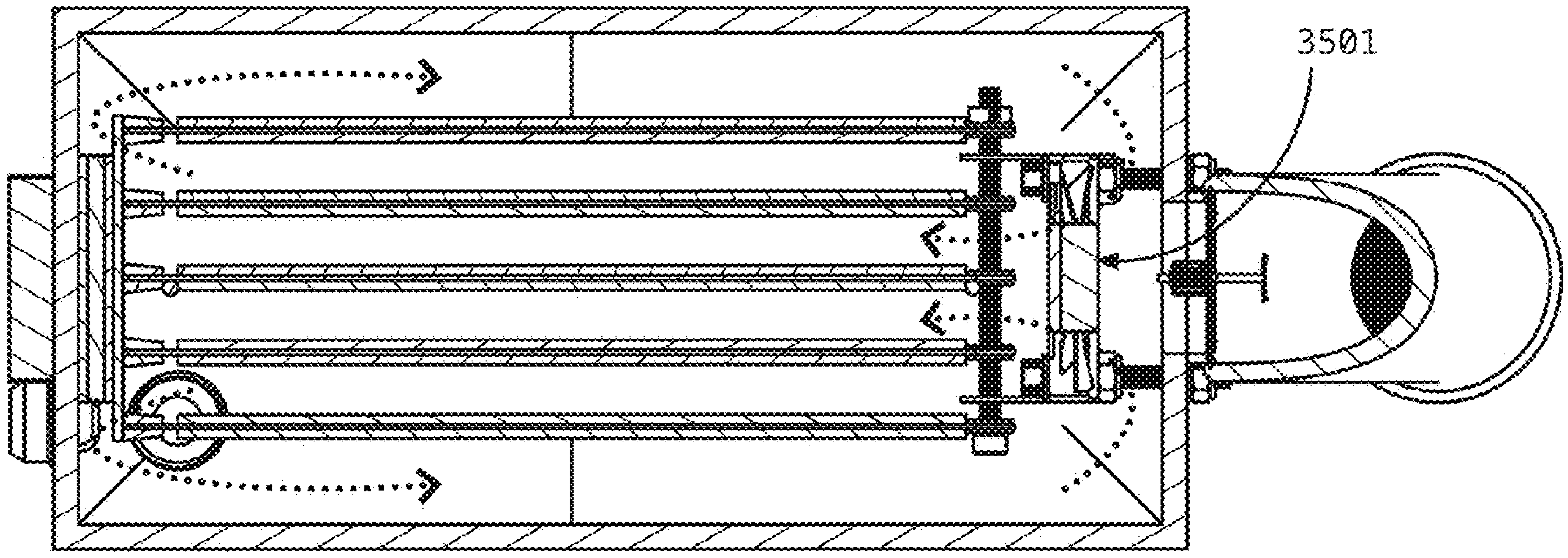

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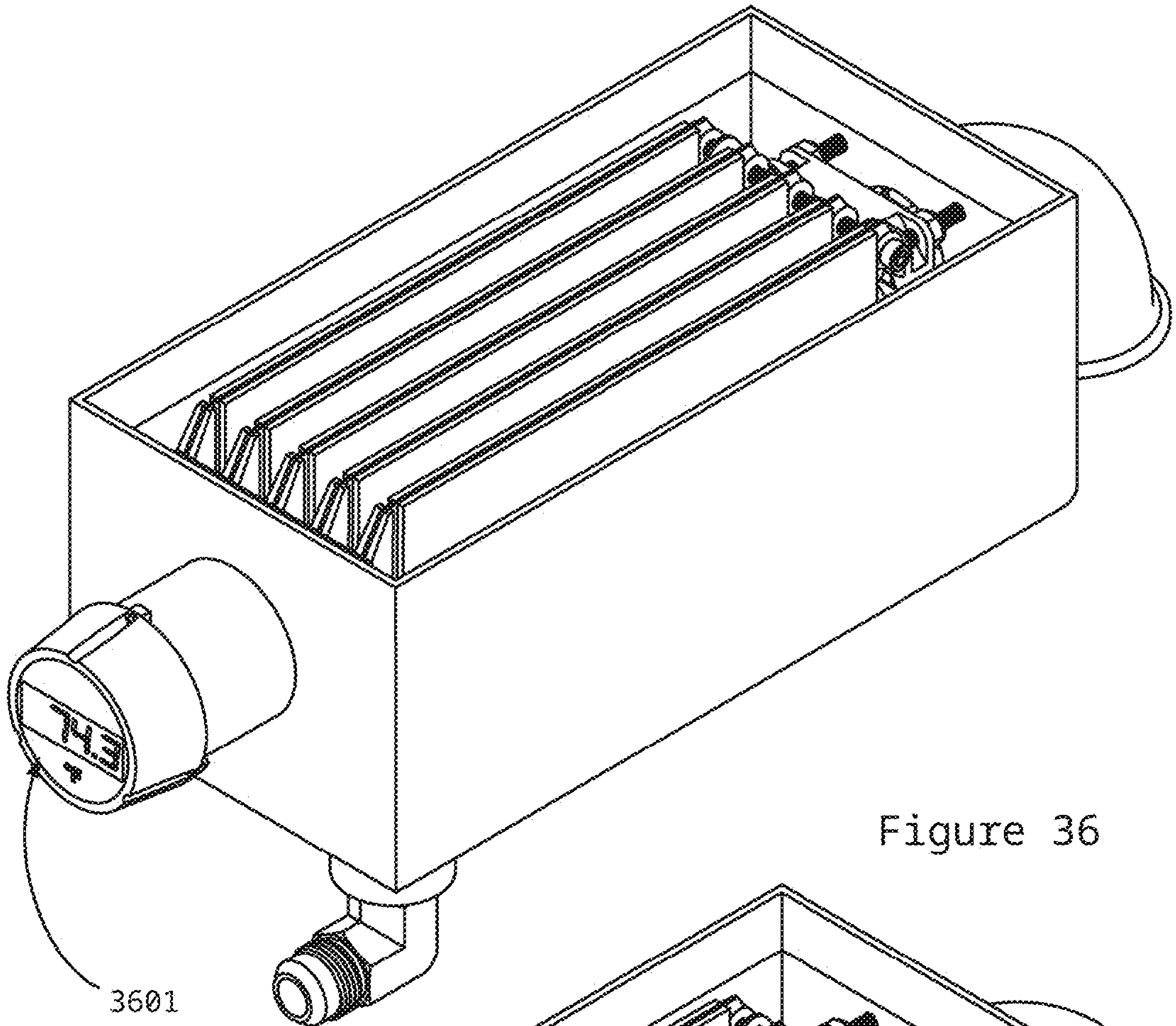

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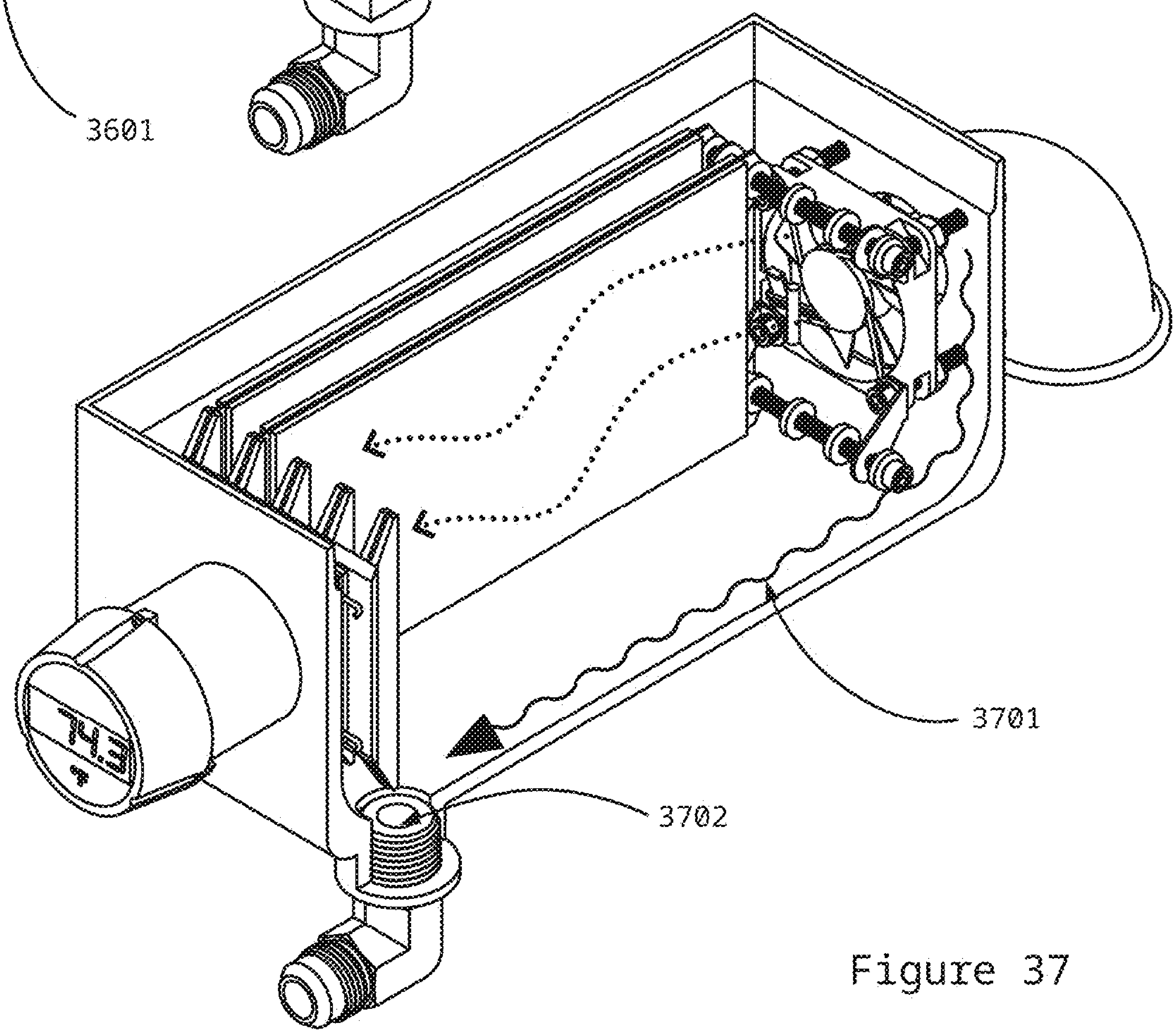

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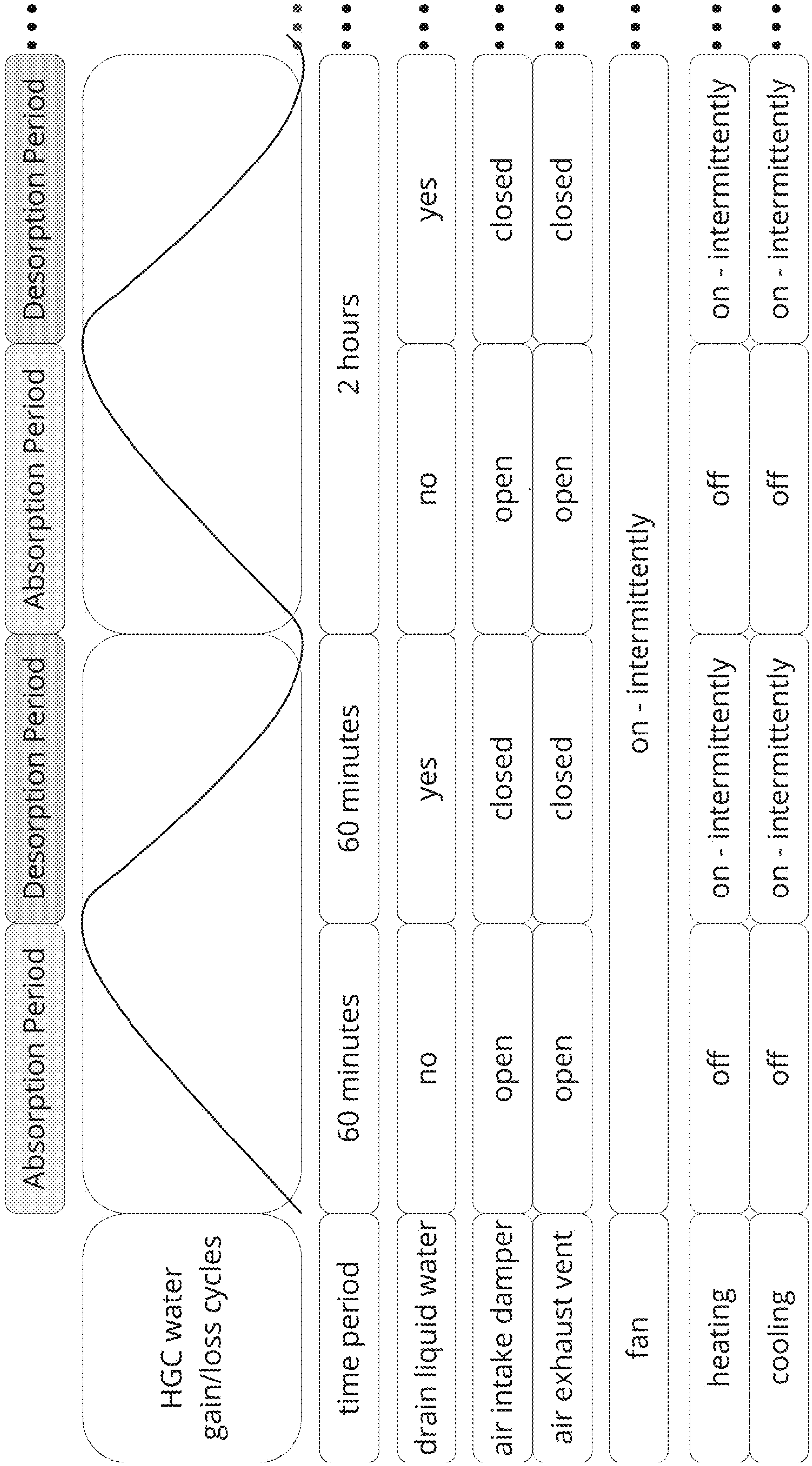

Absorption Period
Desorption Period
Absorption Period
Desorption Period
HGC water gain/loss cycles
time period
60 minutes
60 minutes
2 hours
drain liquid water
no
yes
no
yes
air intake damper
open
closed
open
closed
air exhaust vent
open
closed
open
closed
fan
on - intermittently
heating
off
on - intermittently
off
on - intermittently
cooling
off
on - intermittently
off
on - intermittently

Figure 38

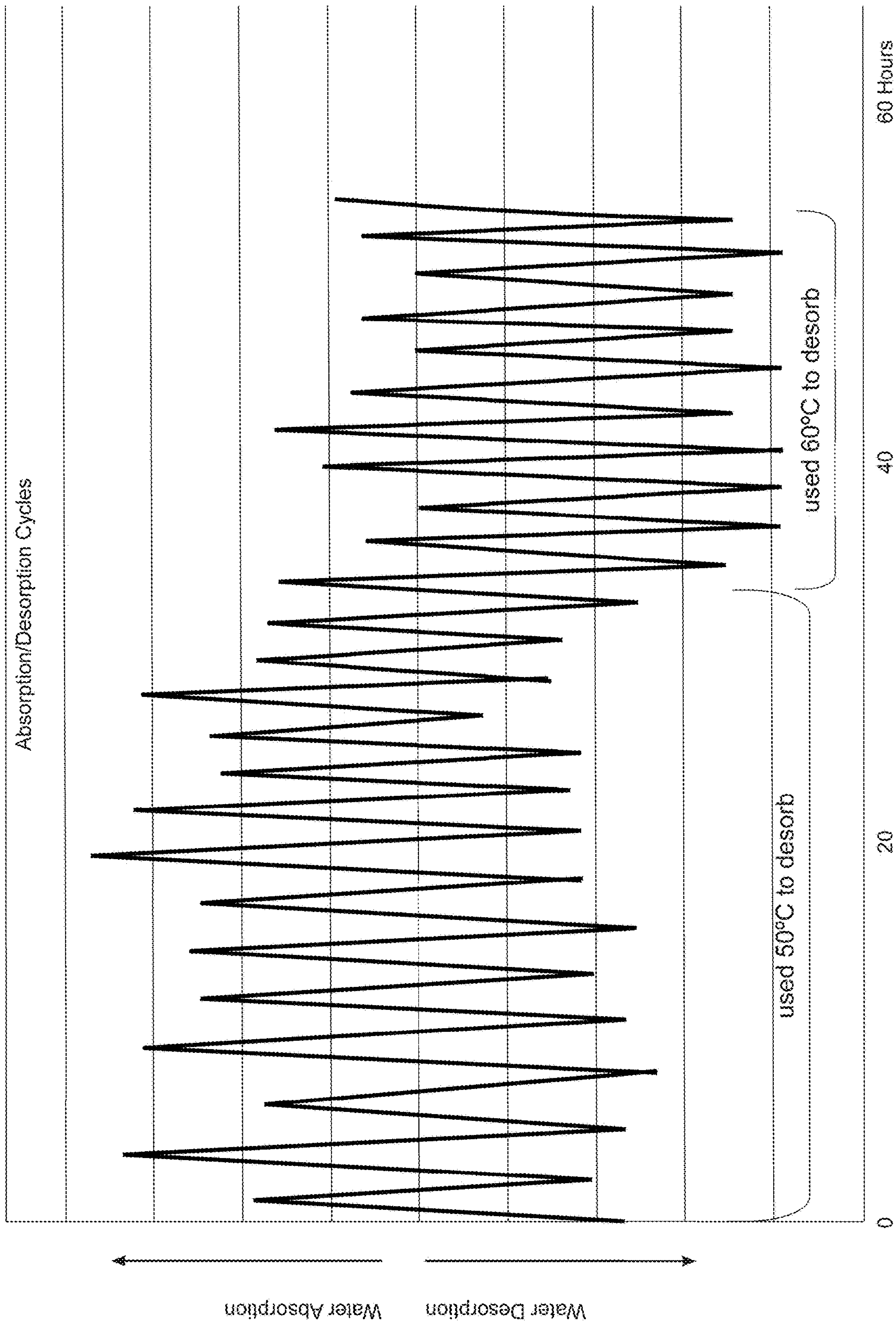
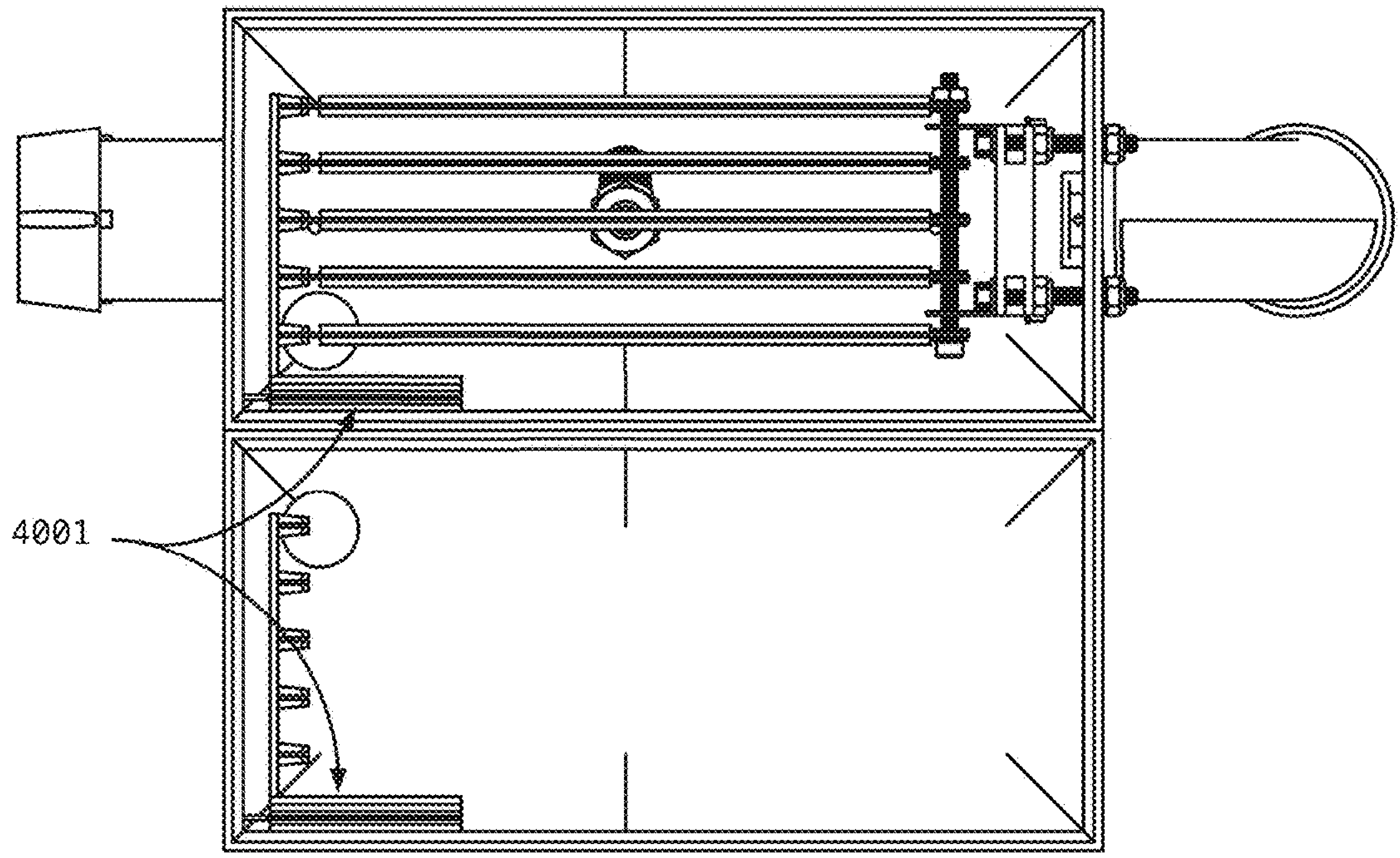

Absorption/Desorption Cycles
used 50°C to desorb
used 60°C to desorb
0
20
40
60 Hours
Water Absorption
Water Desorption

Figure 39



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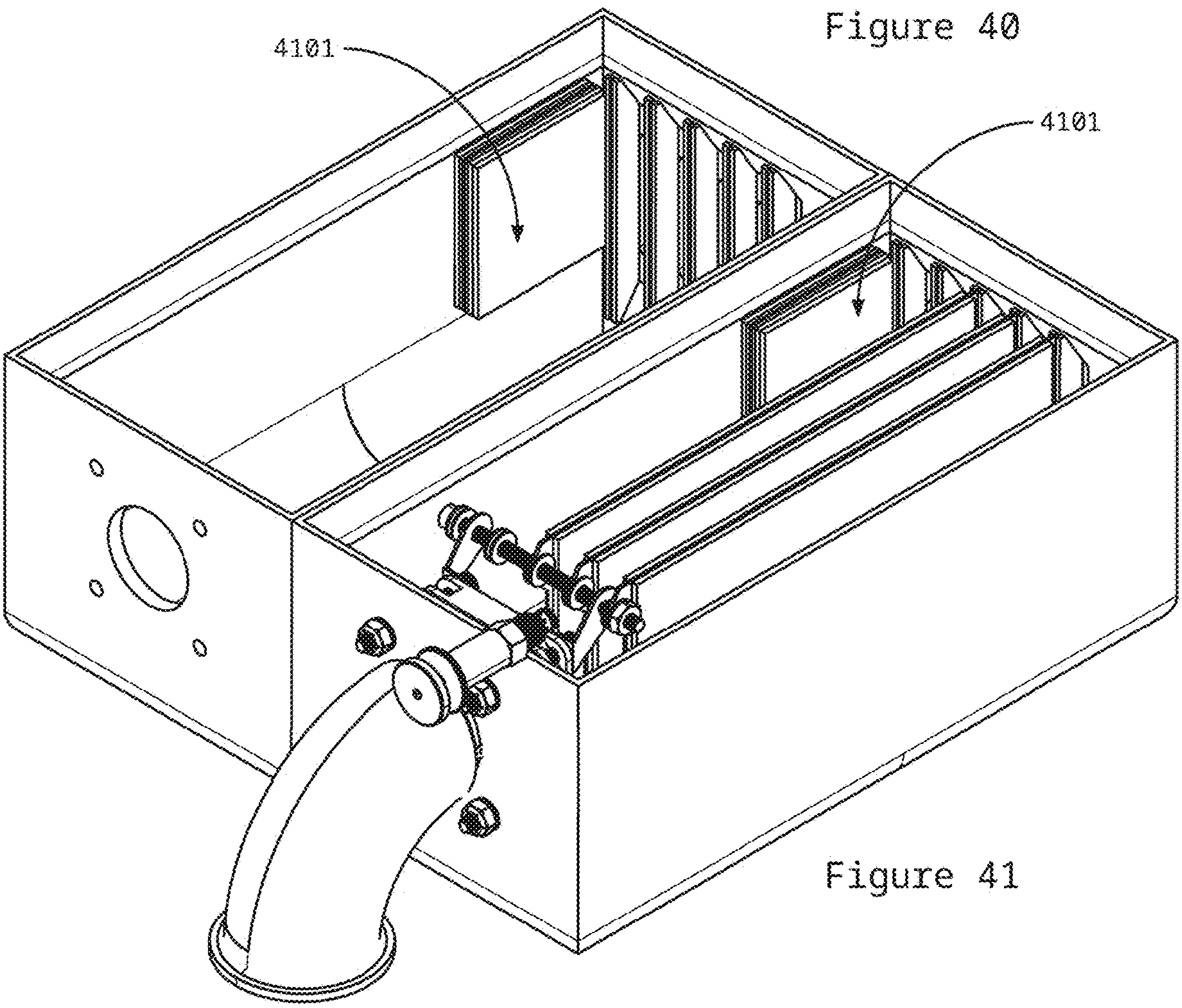

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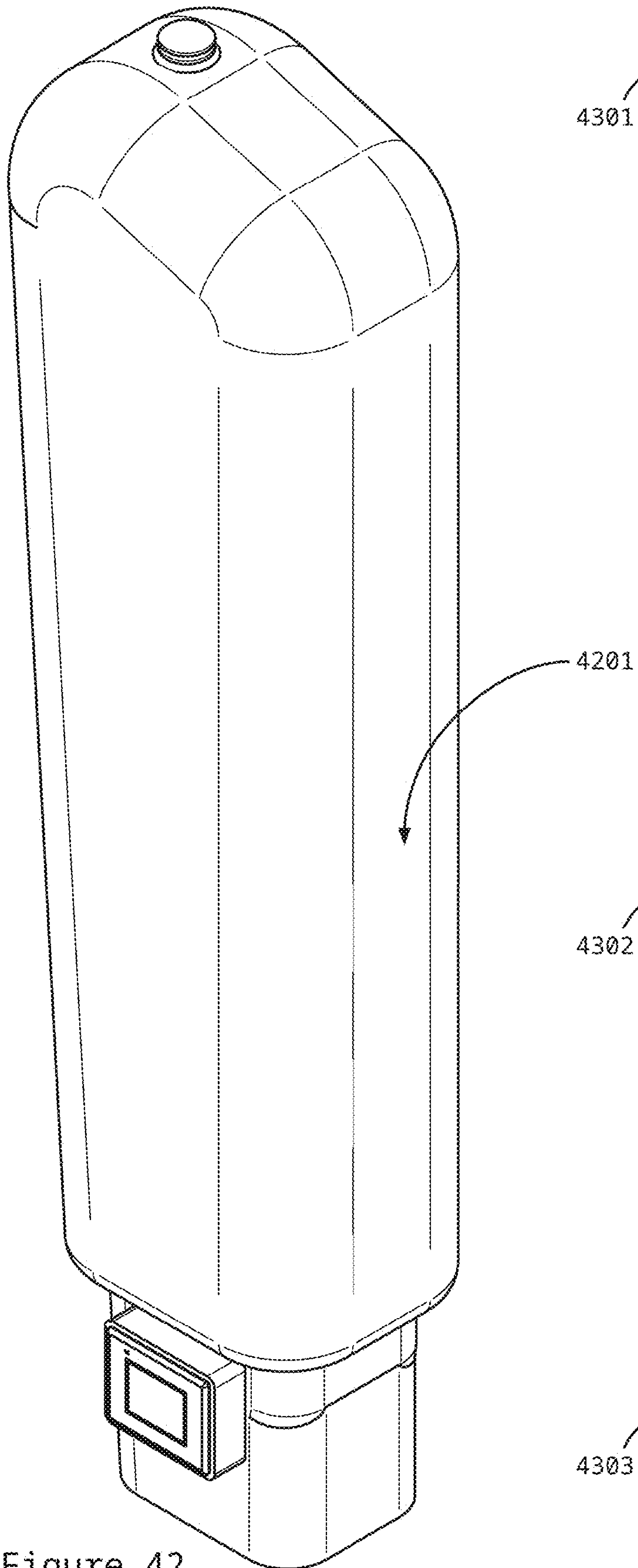

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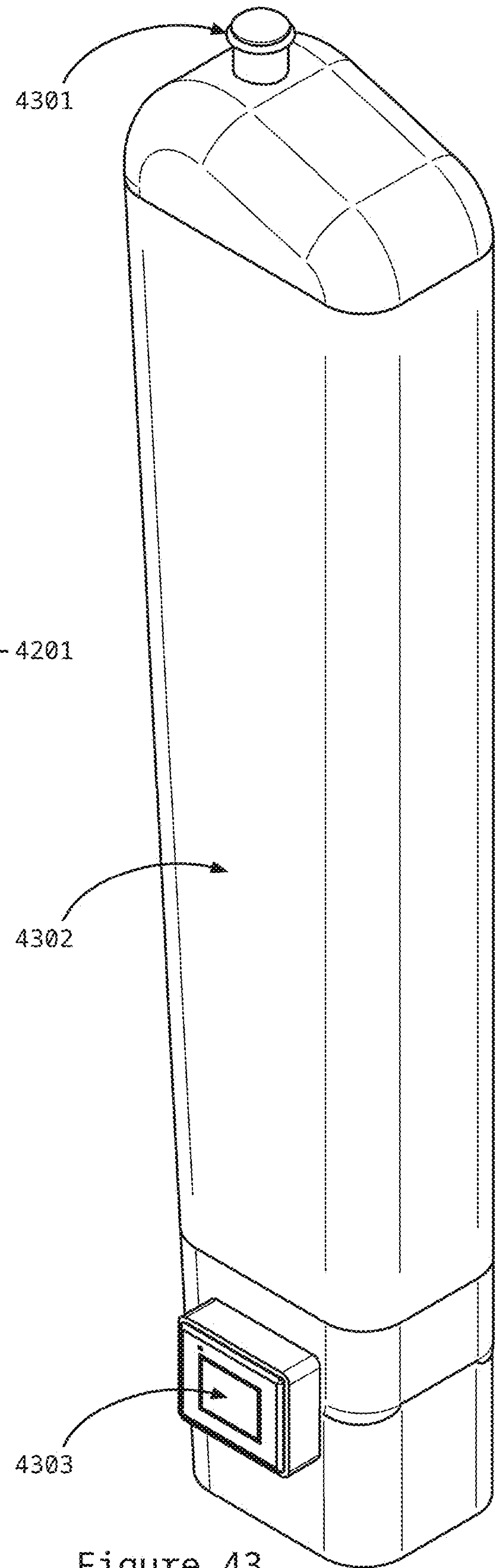

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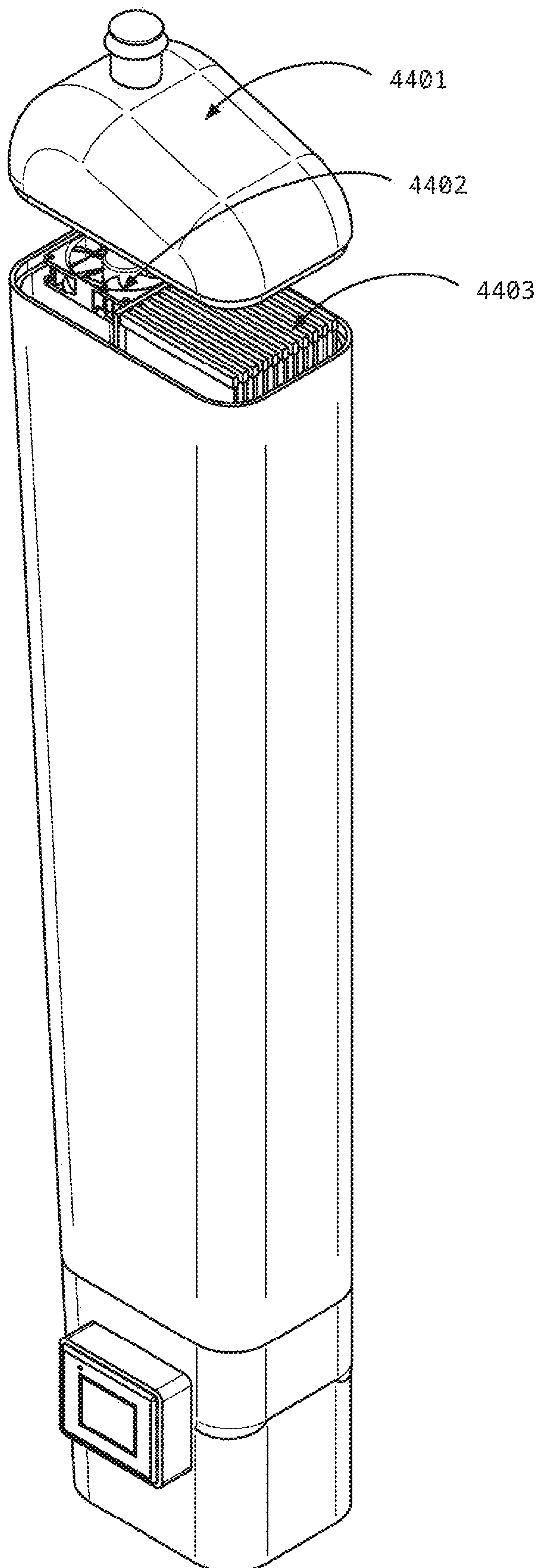

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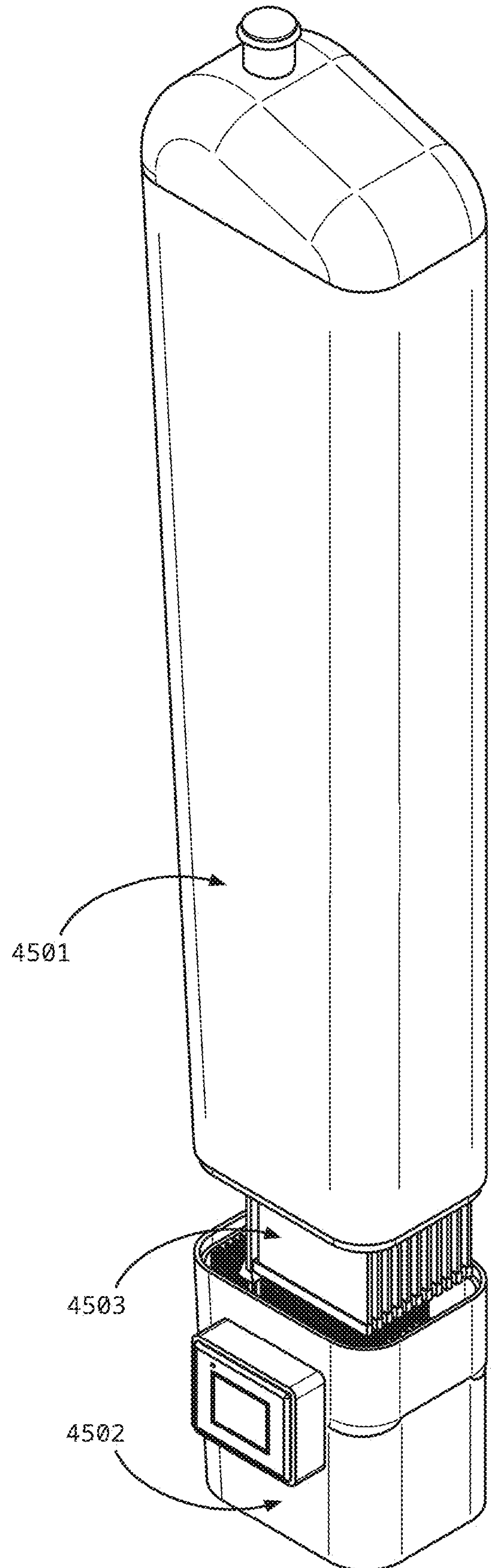

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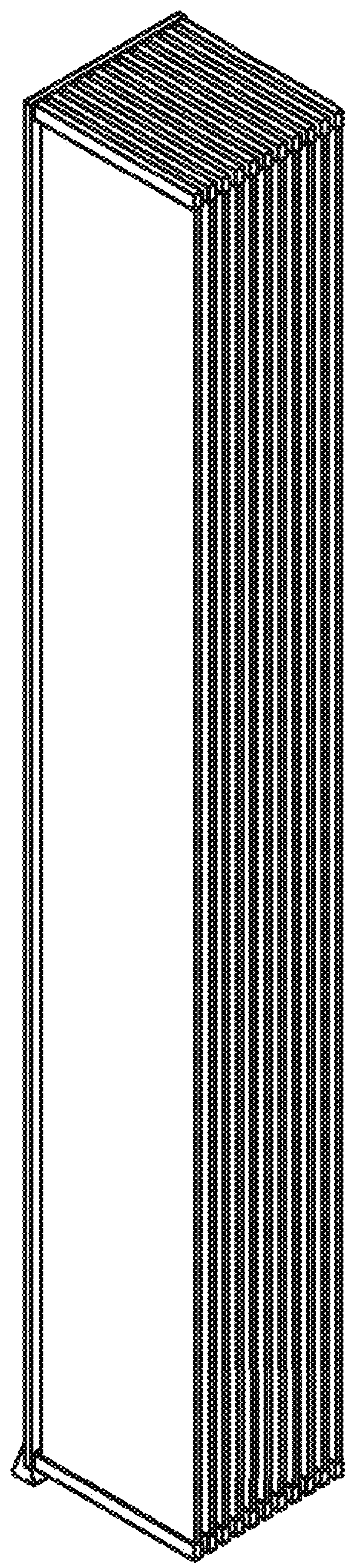

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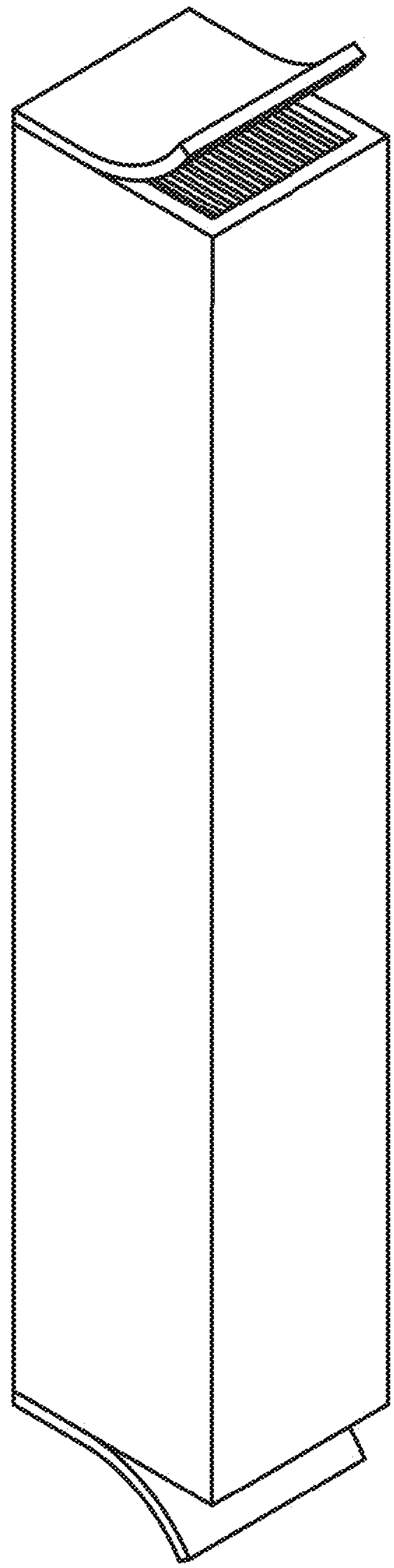

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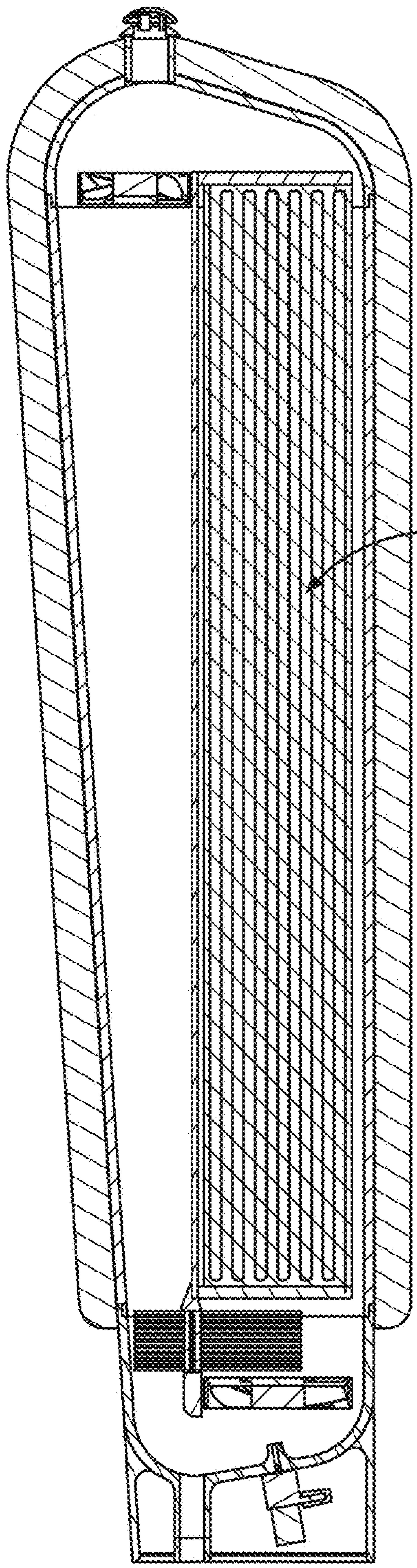

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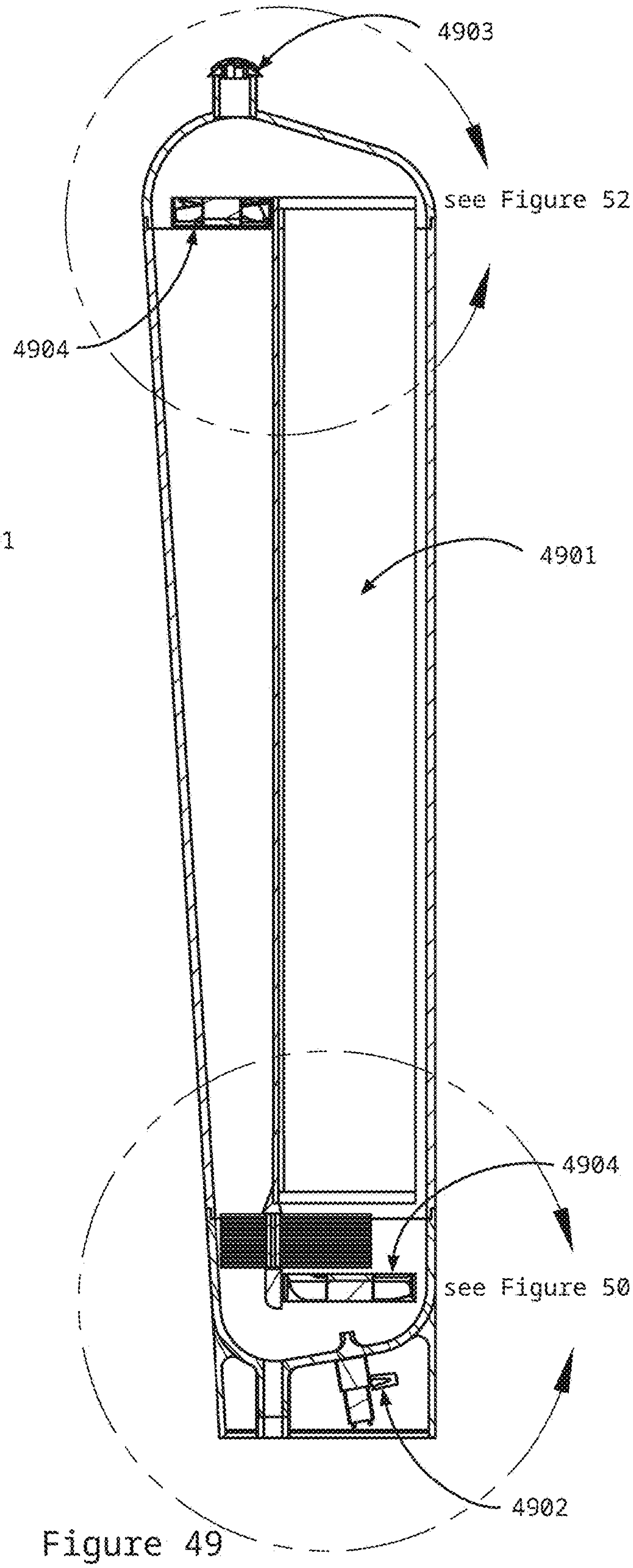

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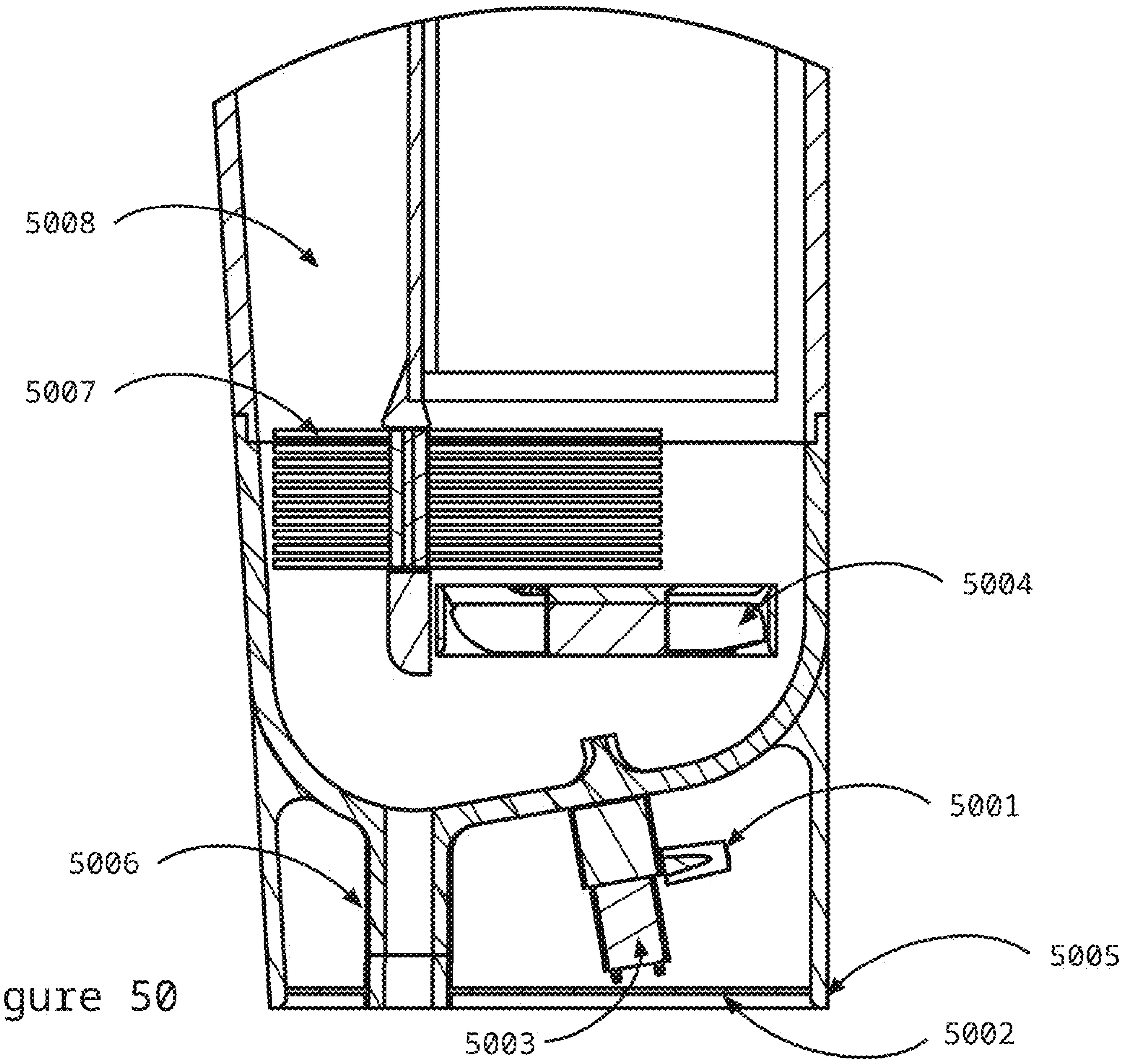

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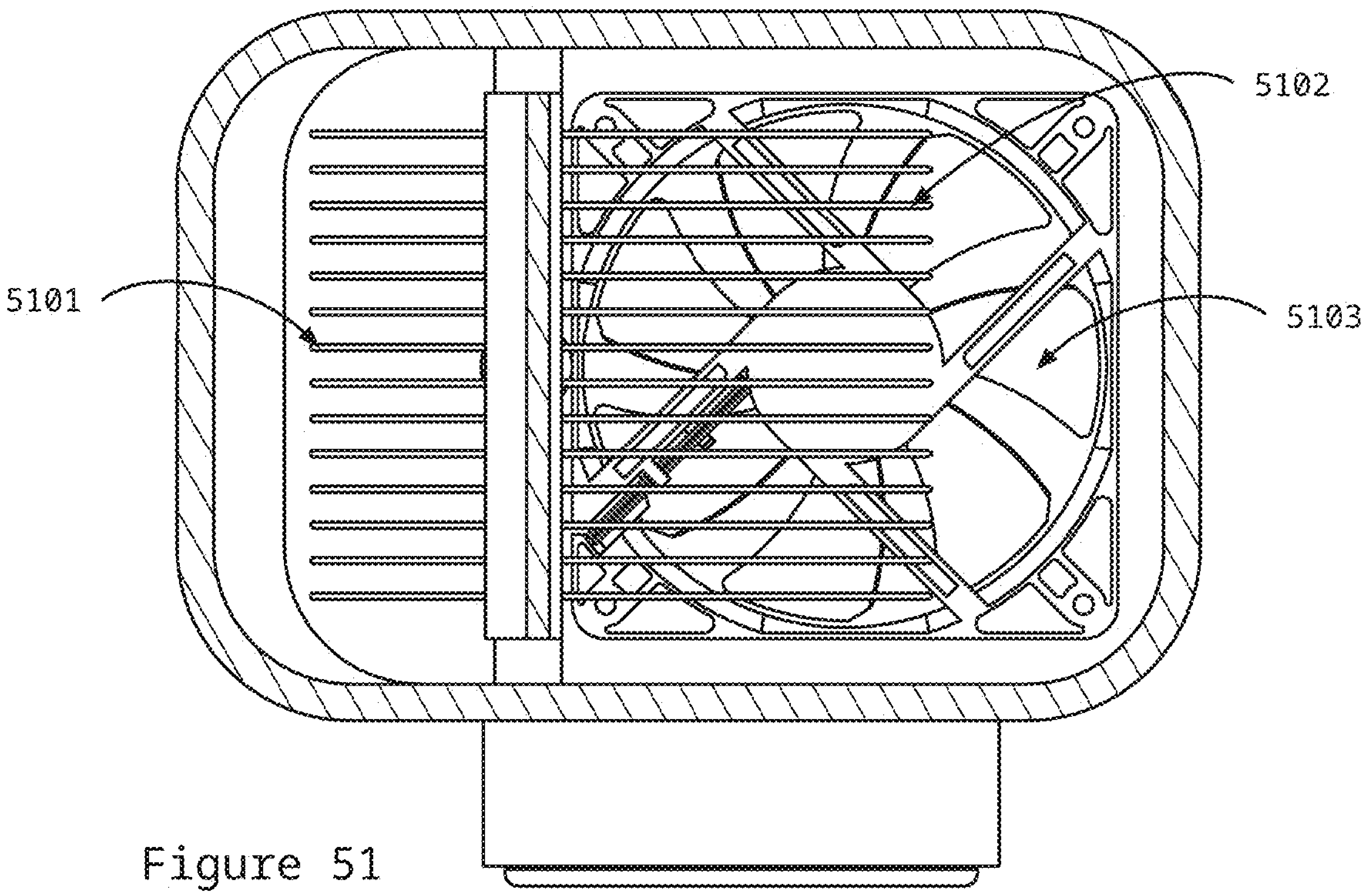

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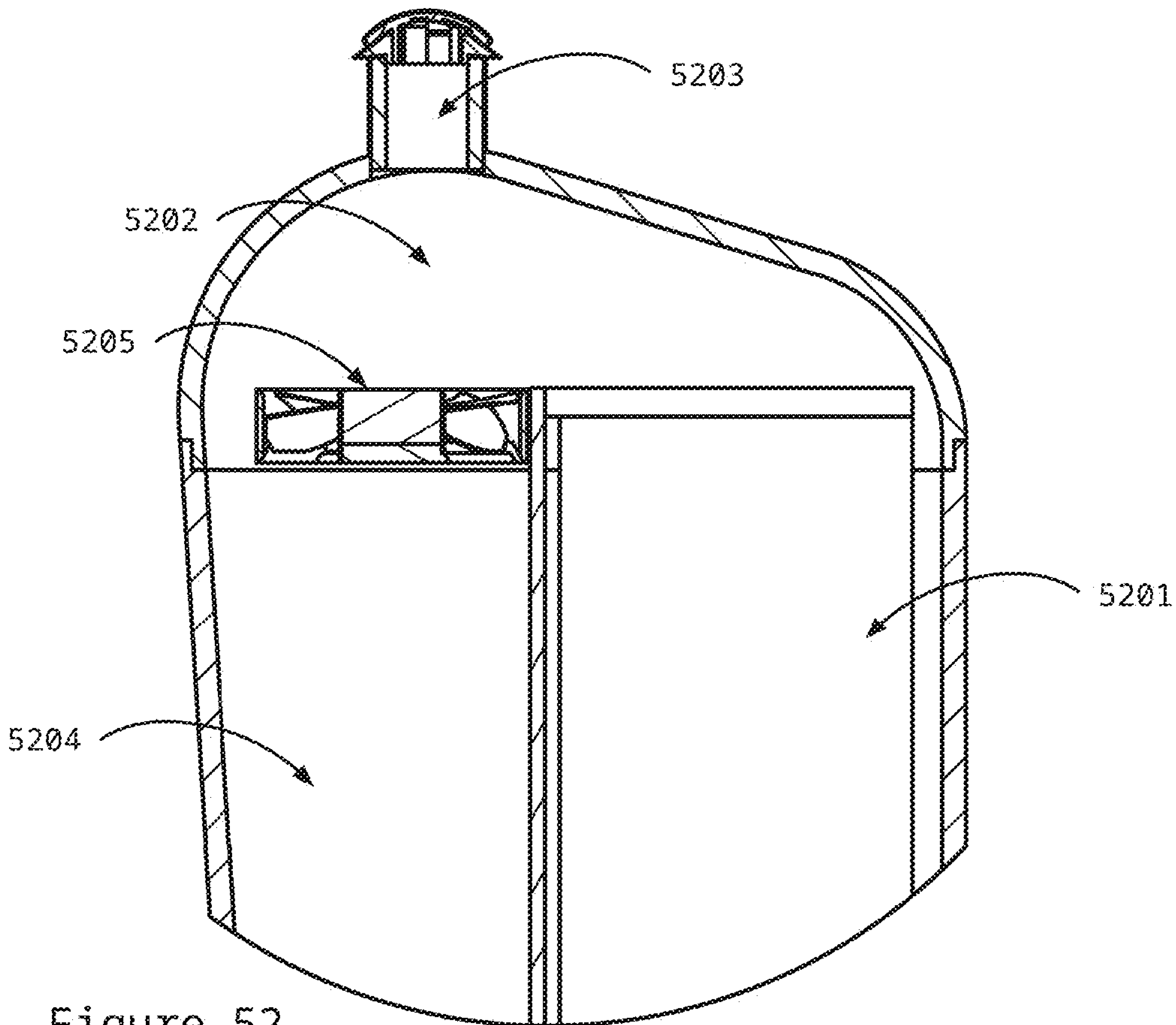

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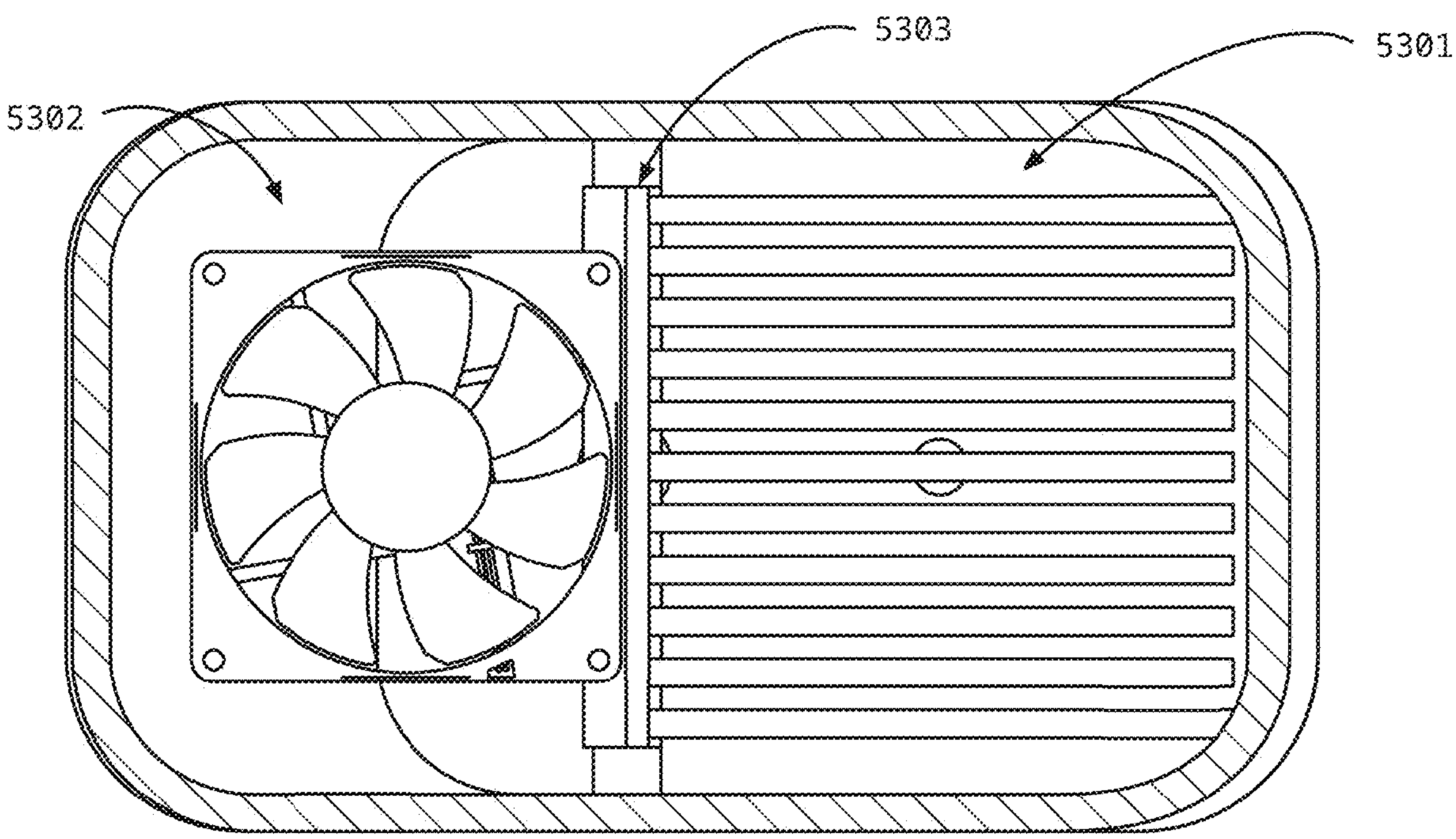

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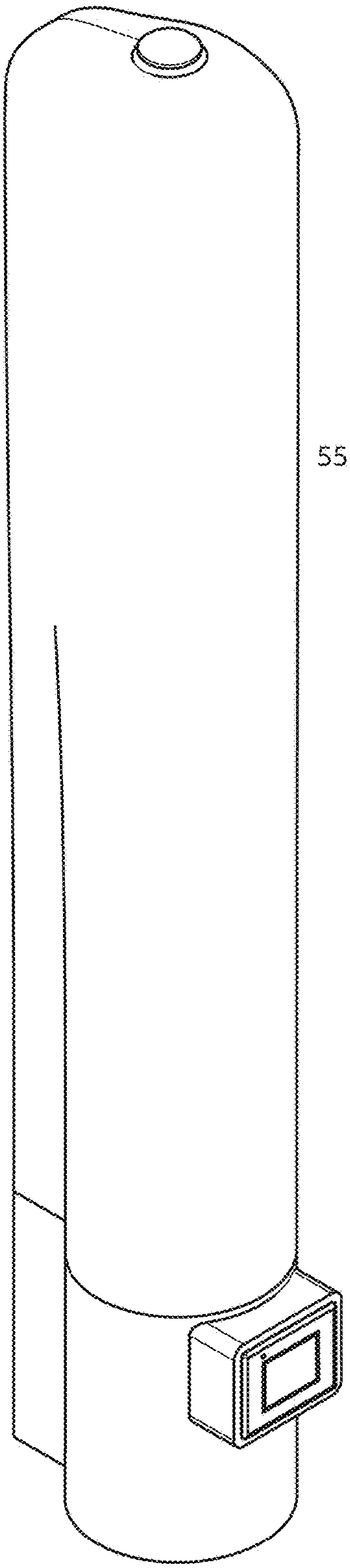

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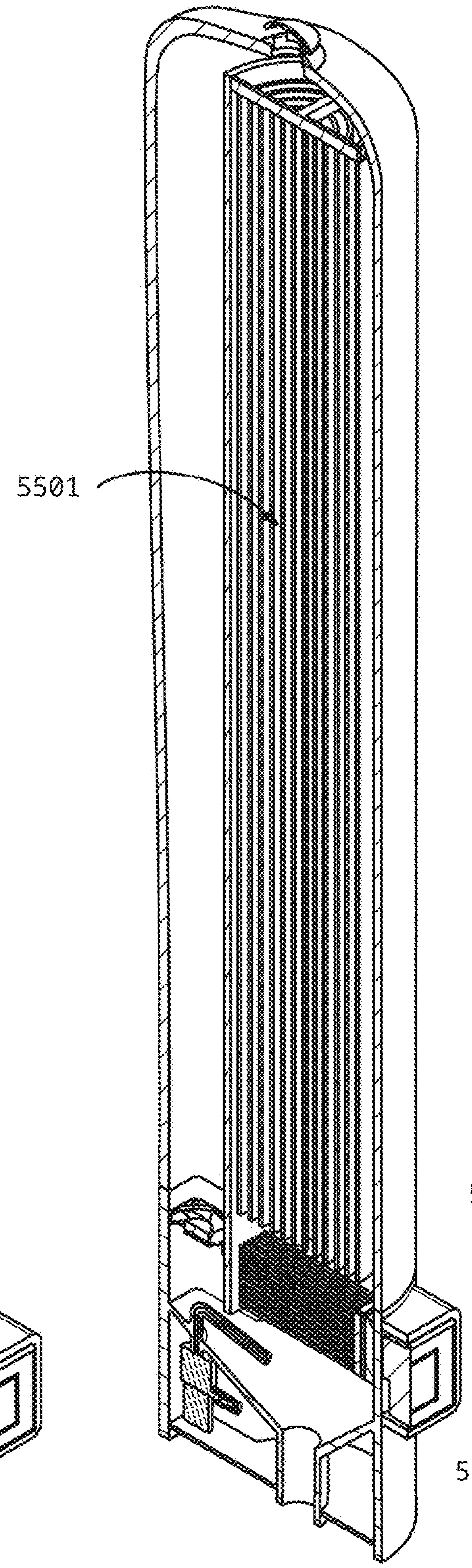

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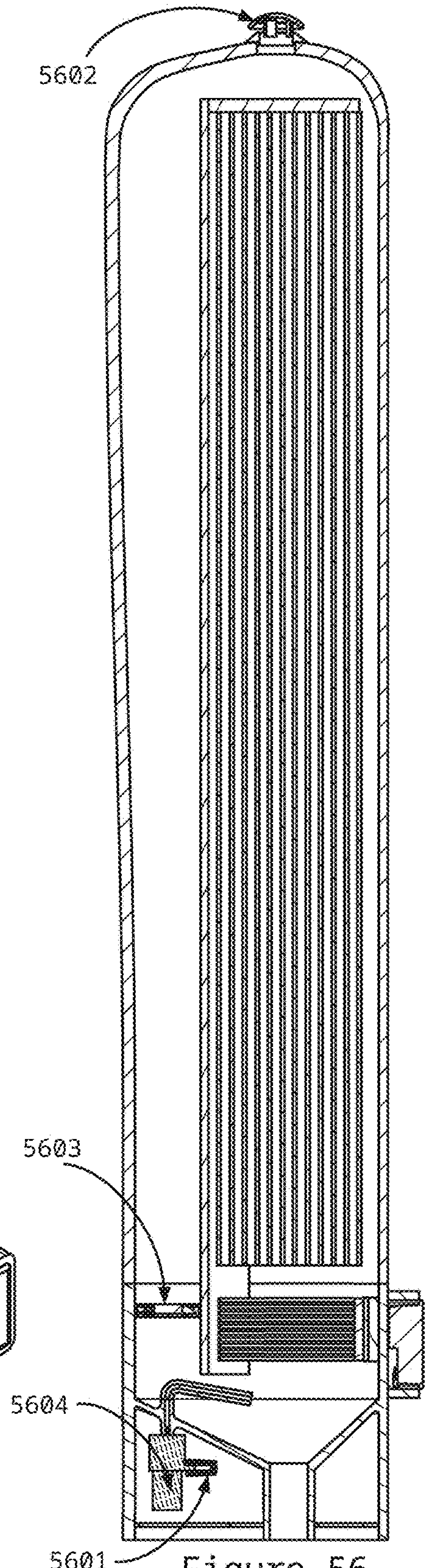

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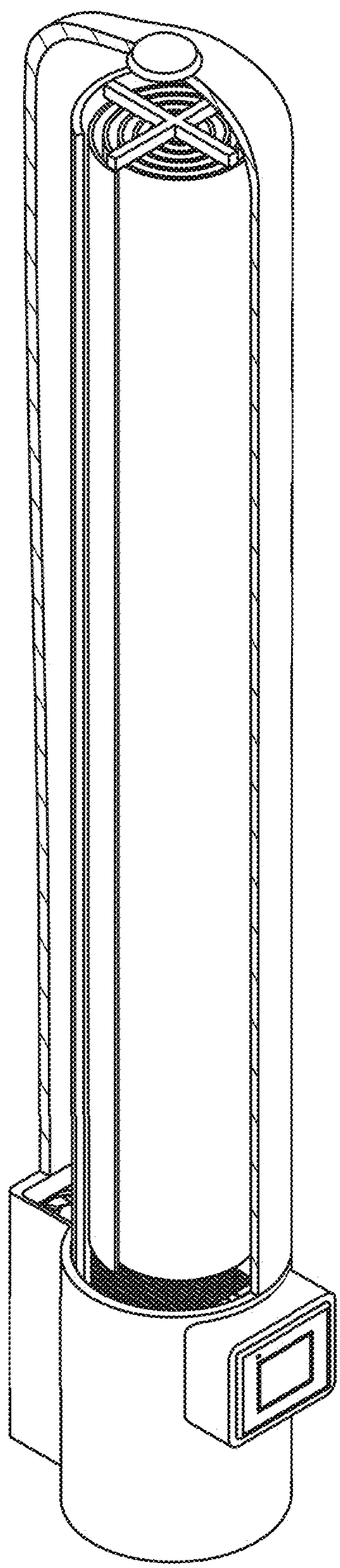

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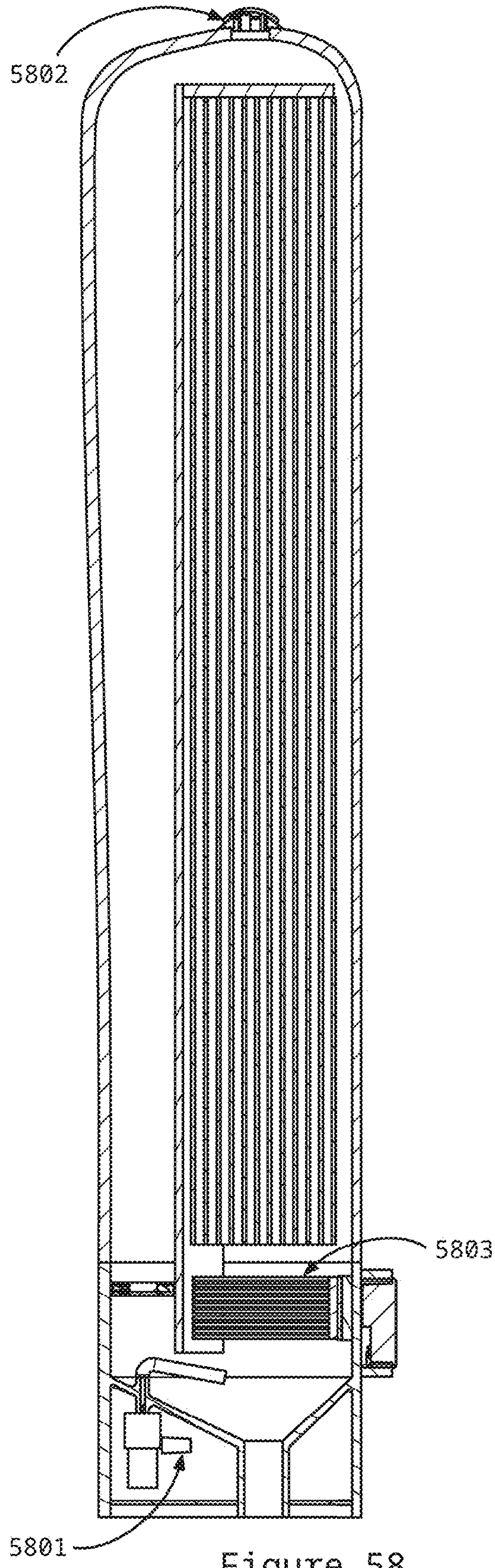

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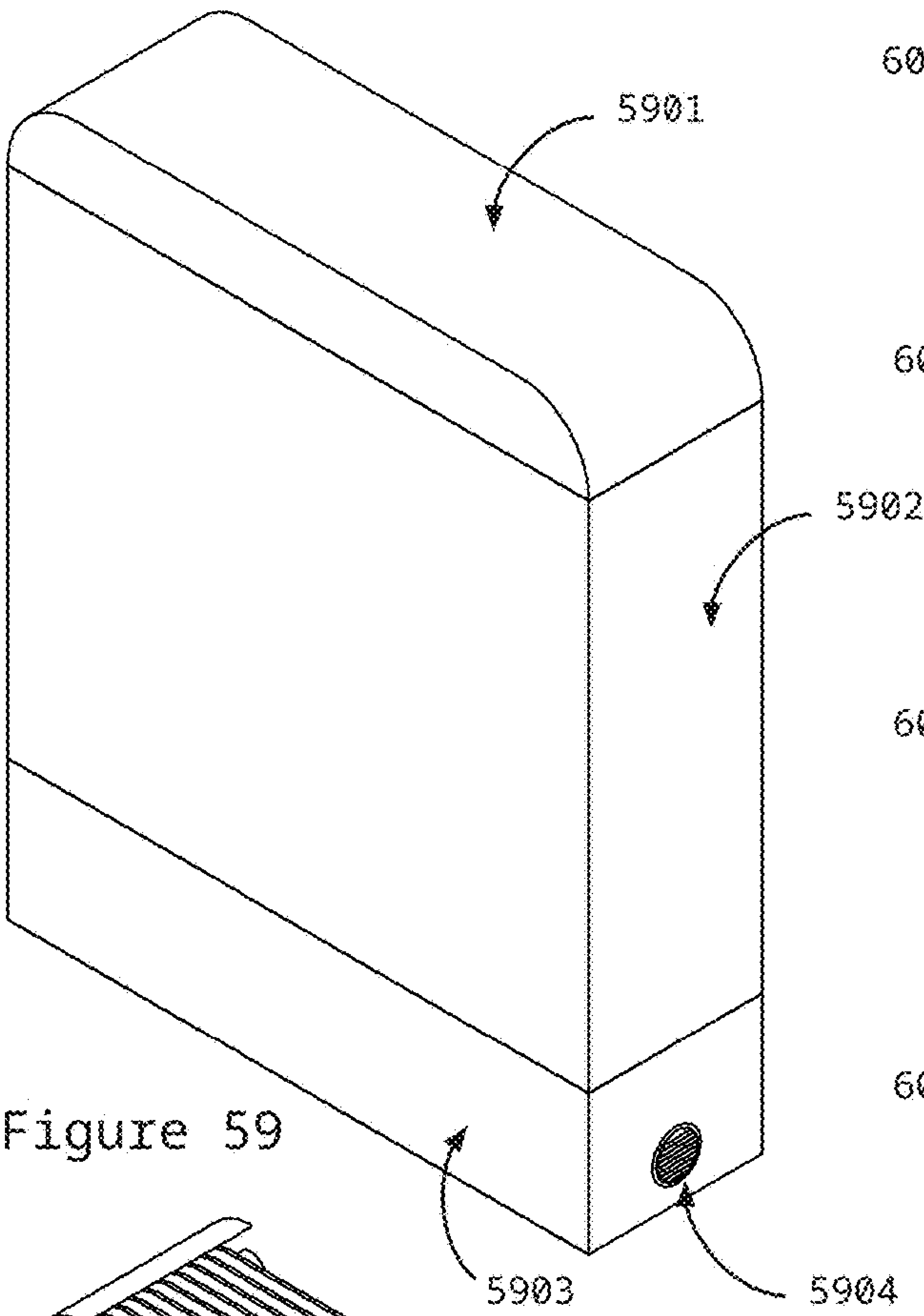

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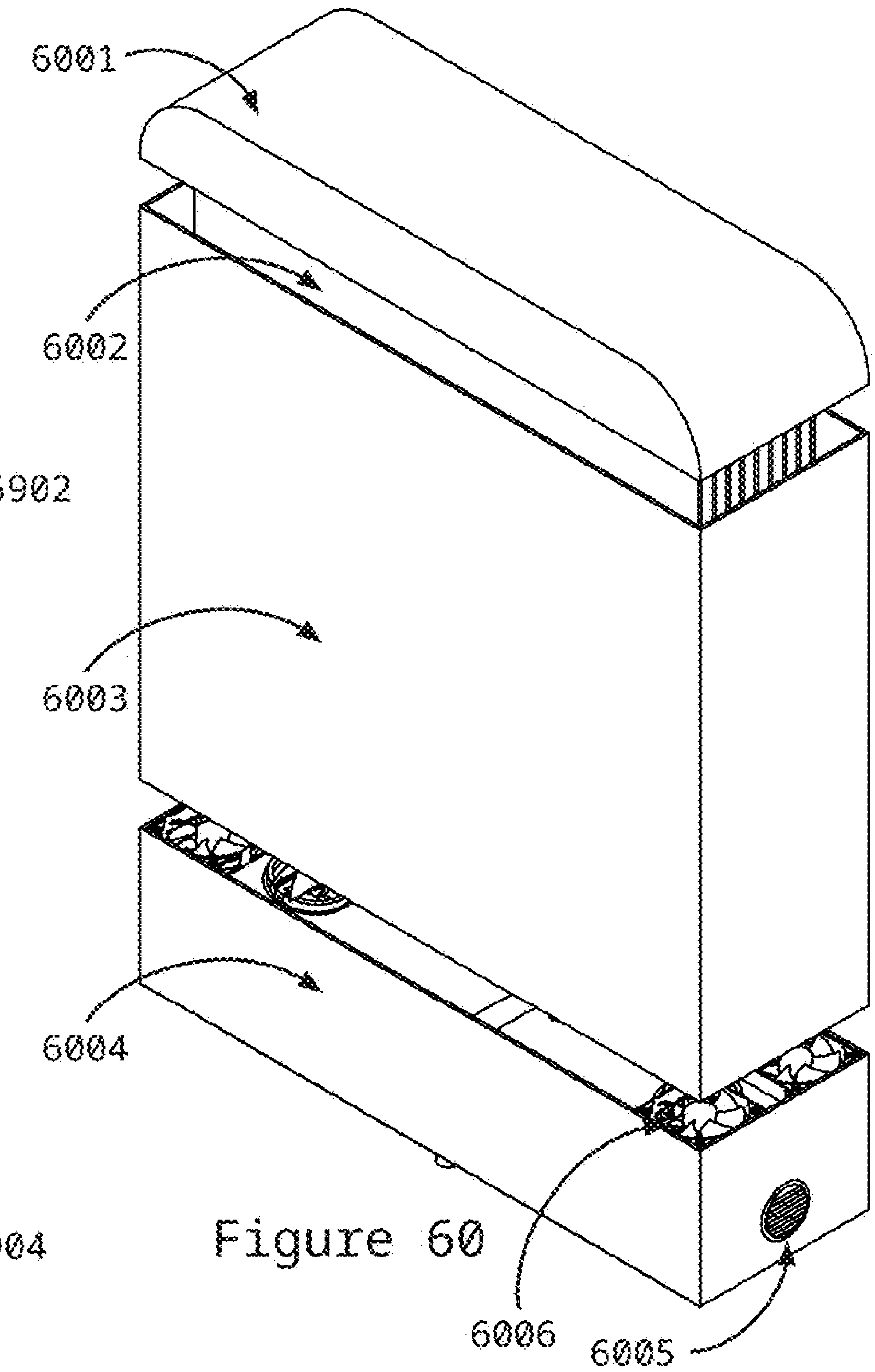

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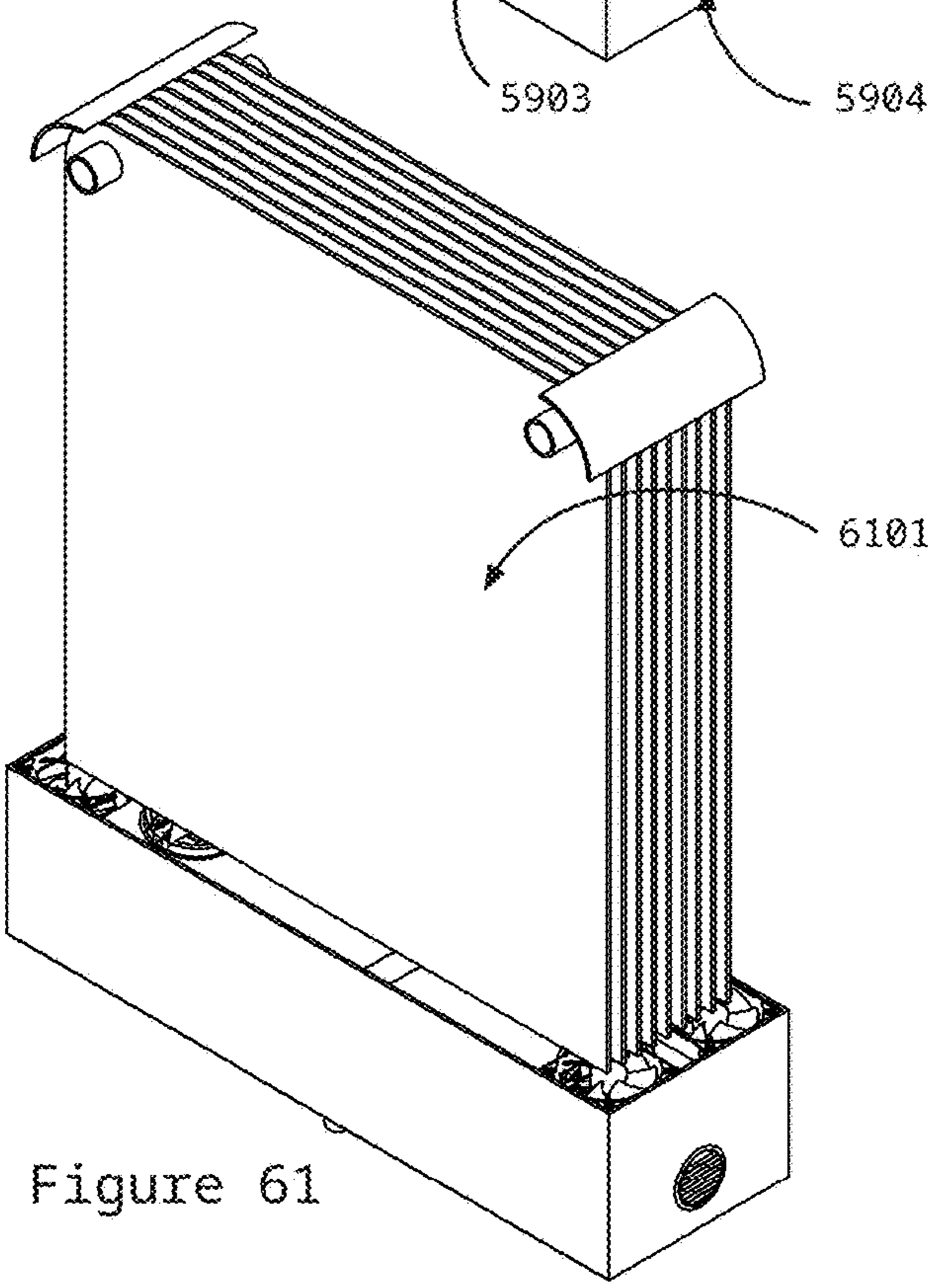

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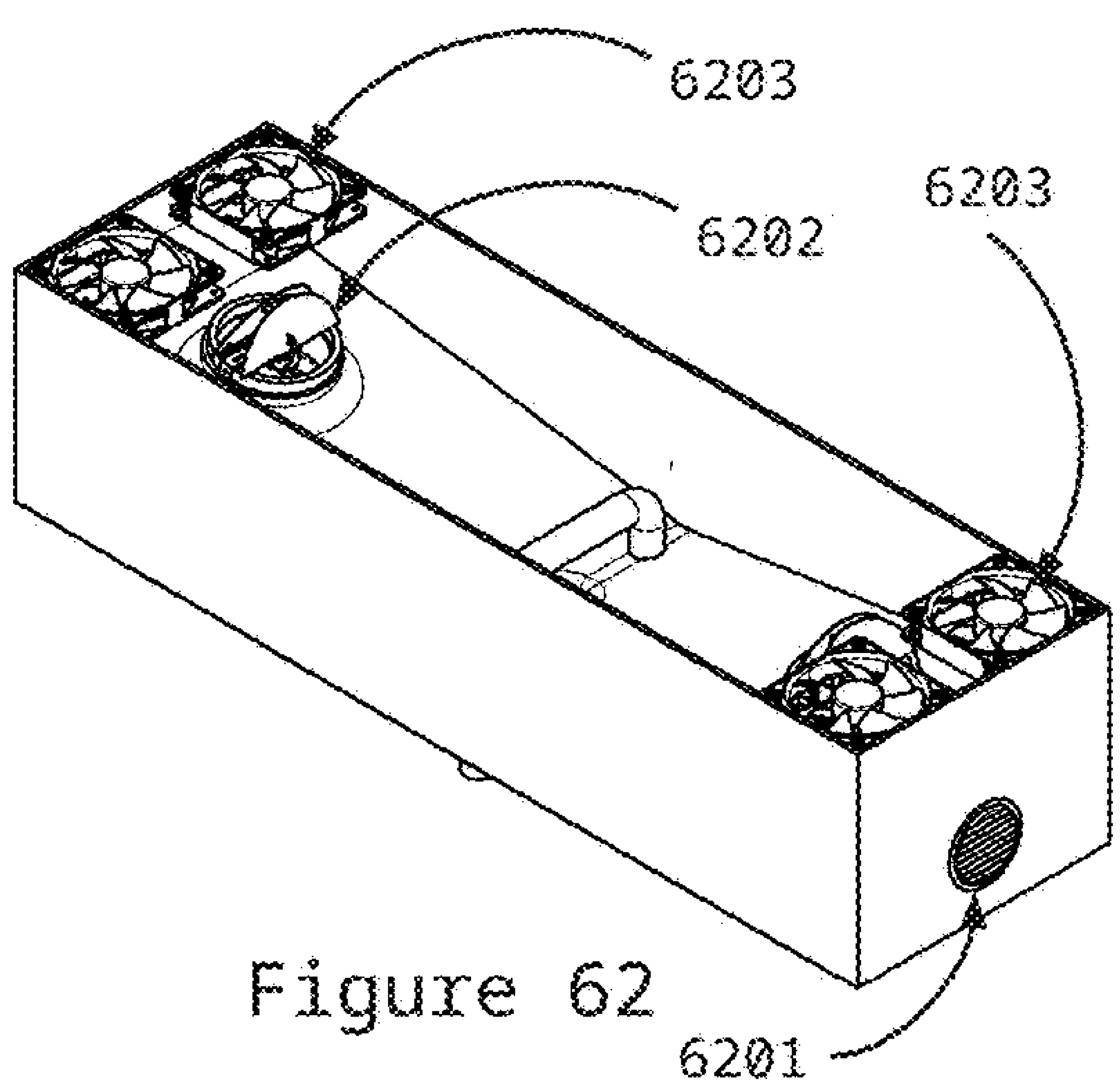

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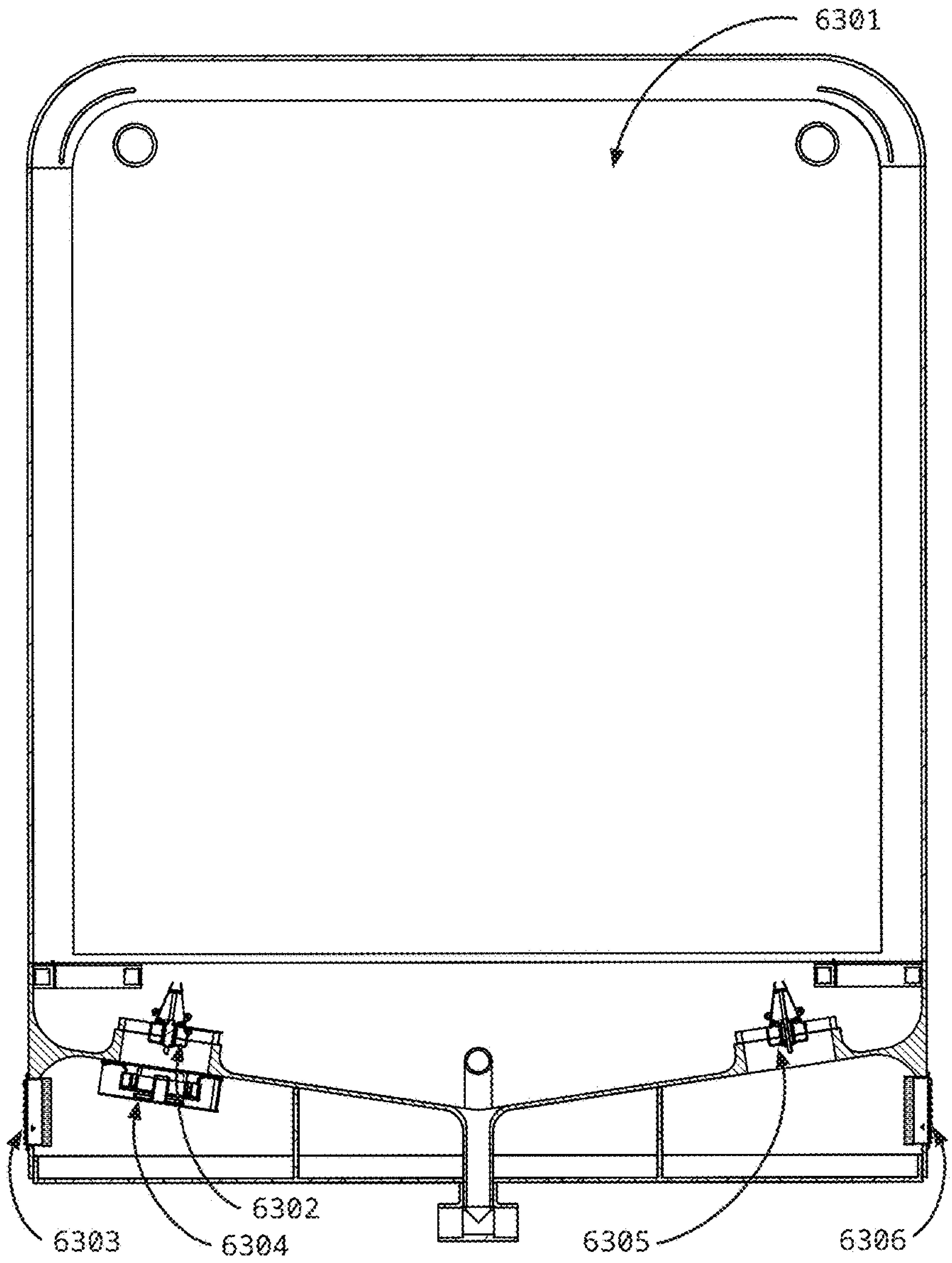

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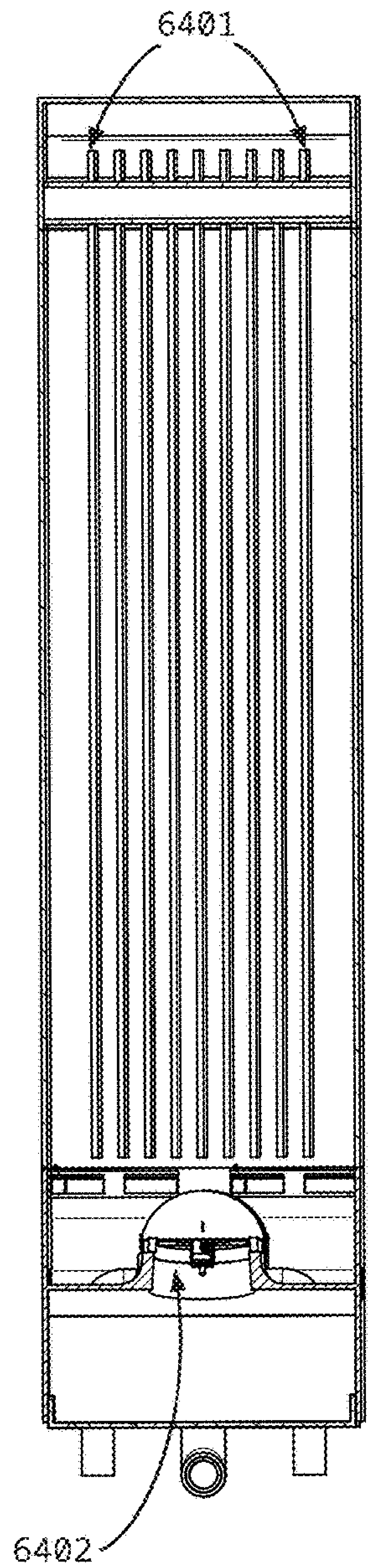

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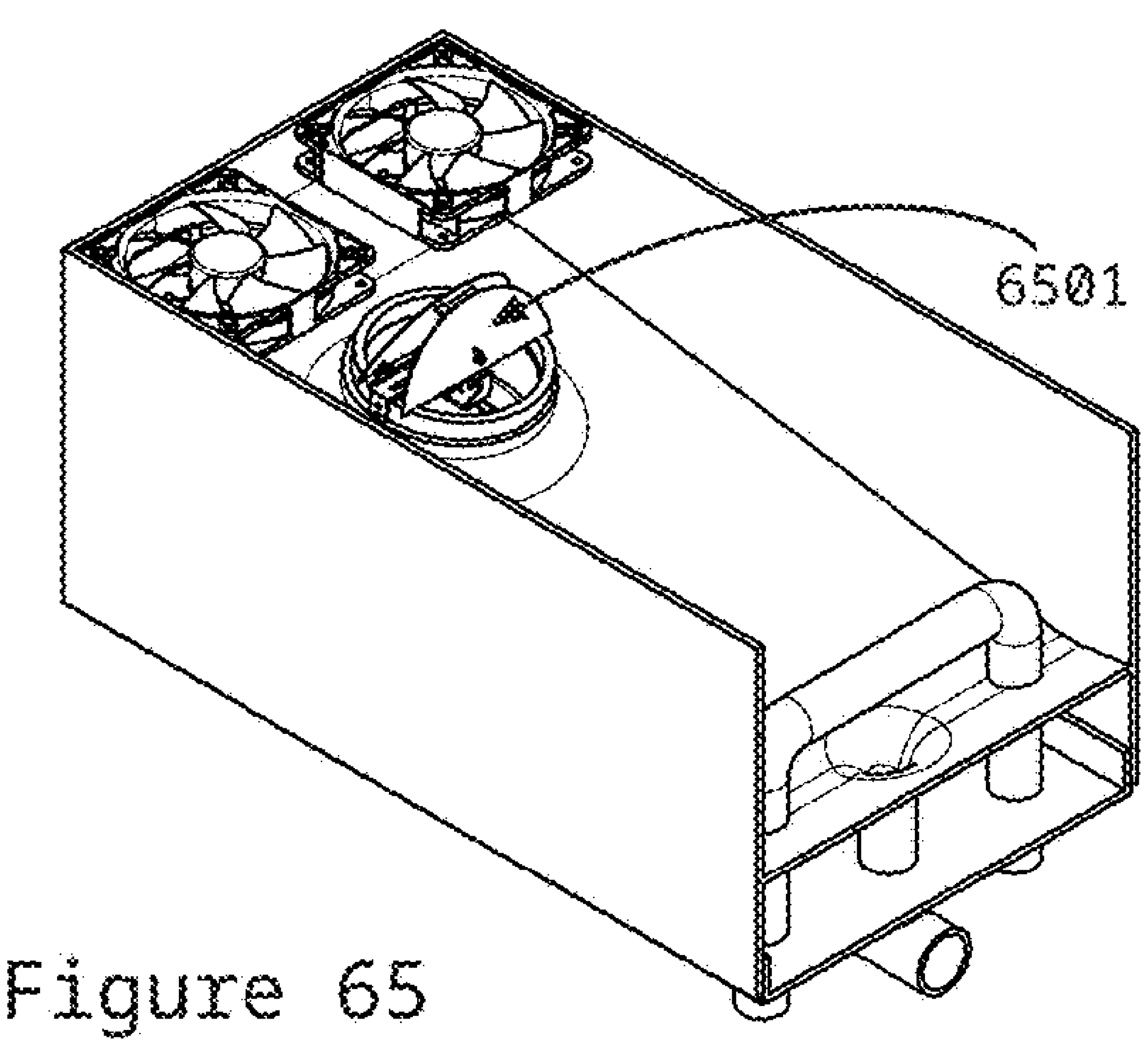

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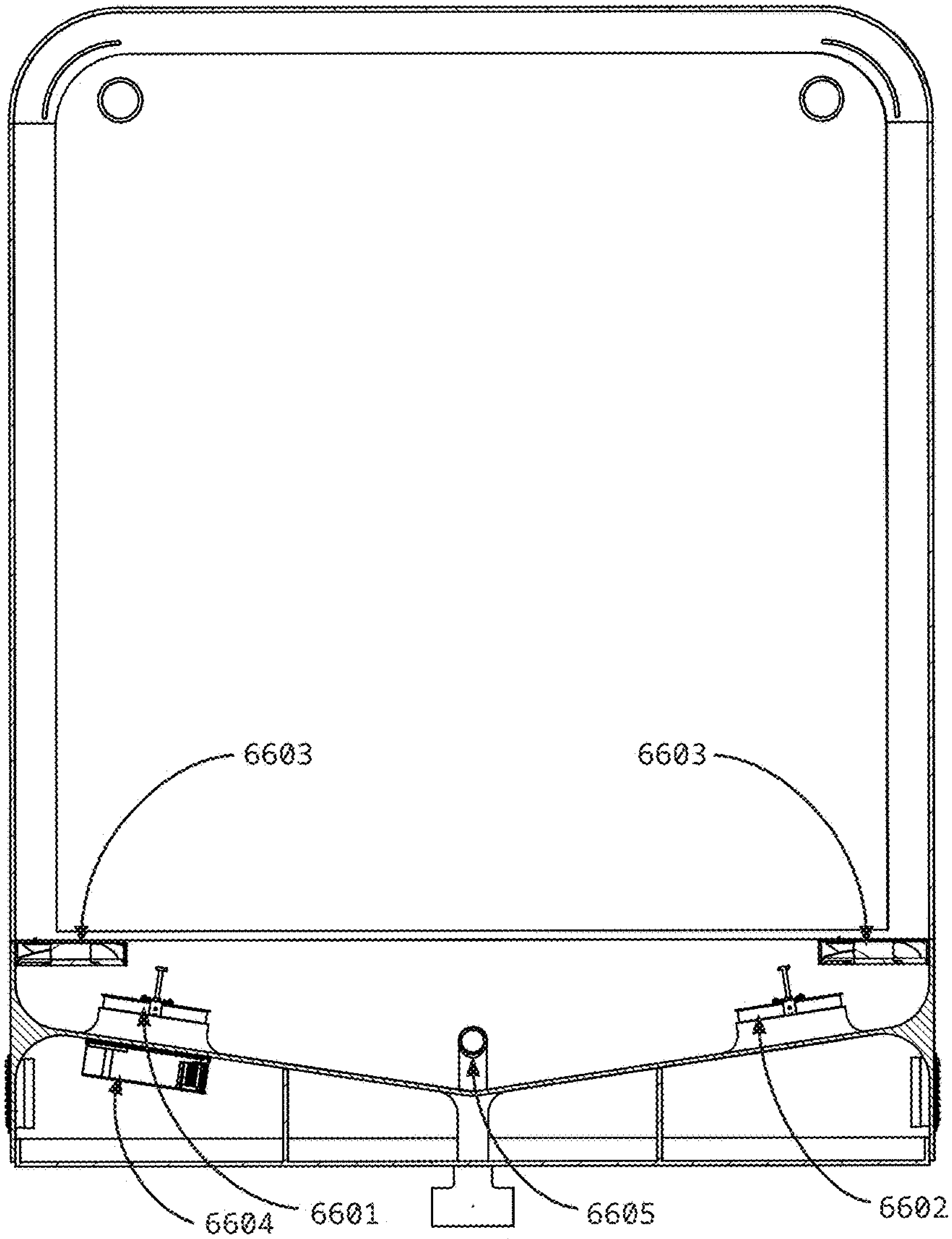

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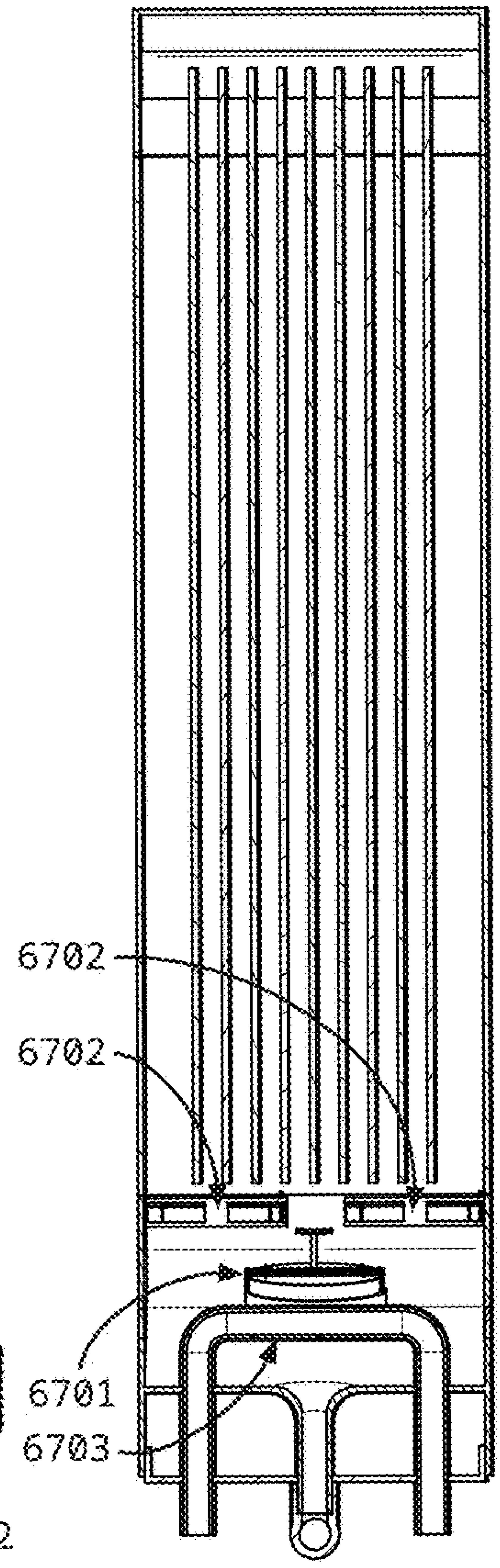
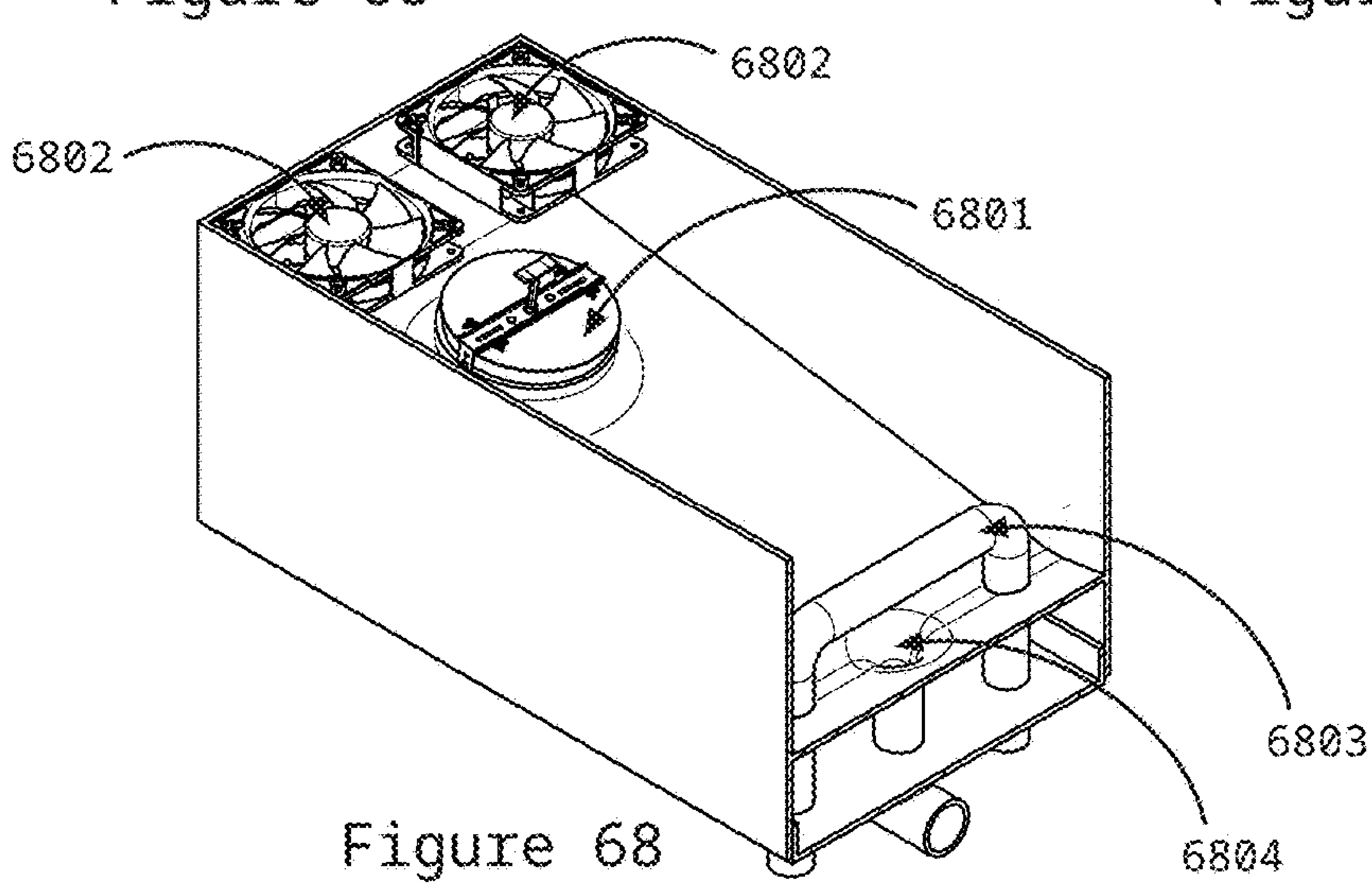


Figure 67



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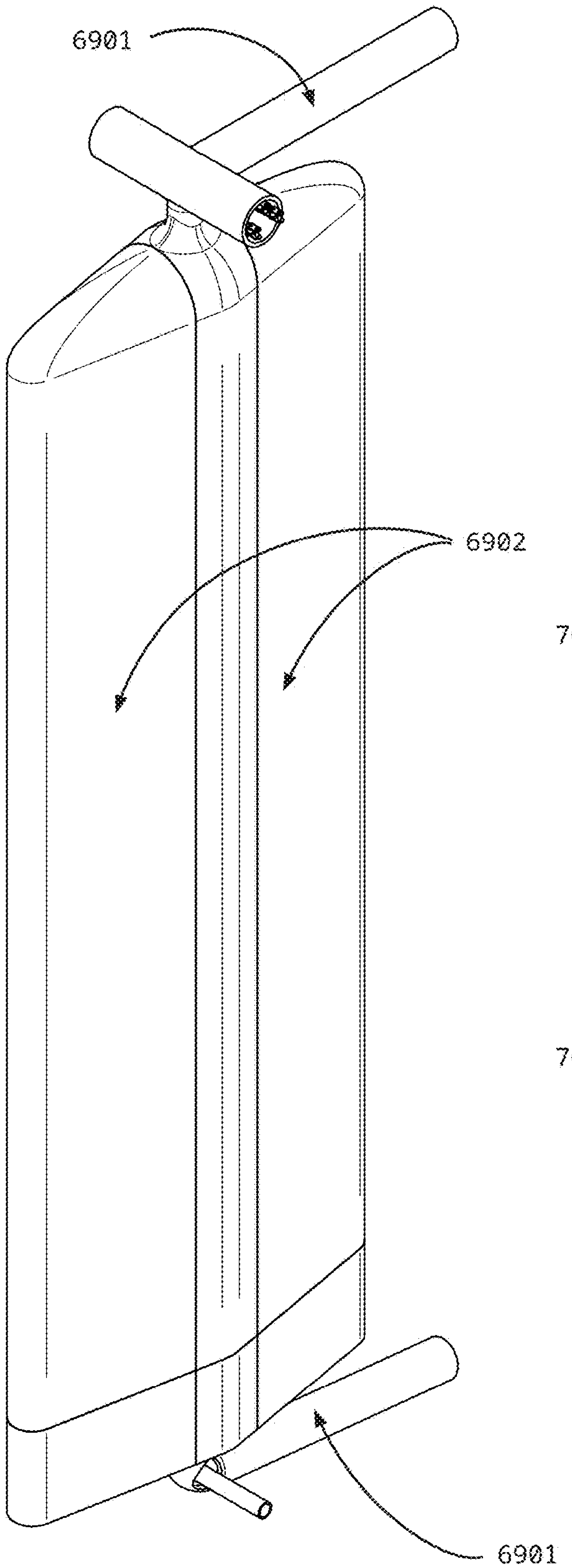

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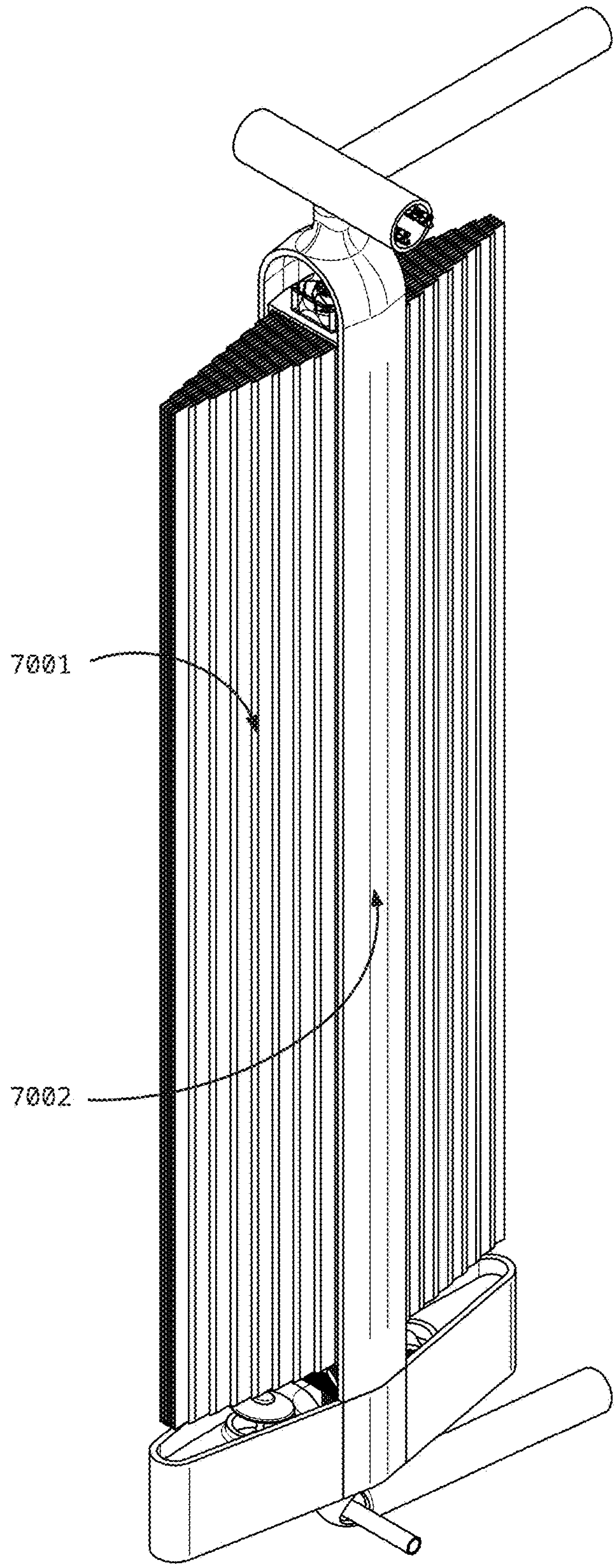

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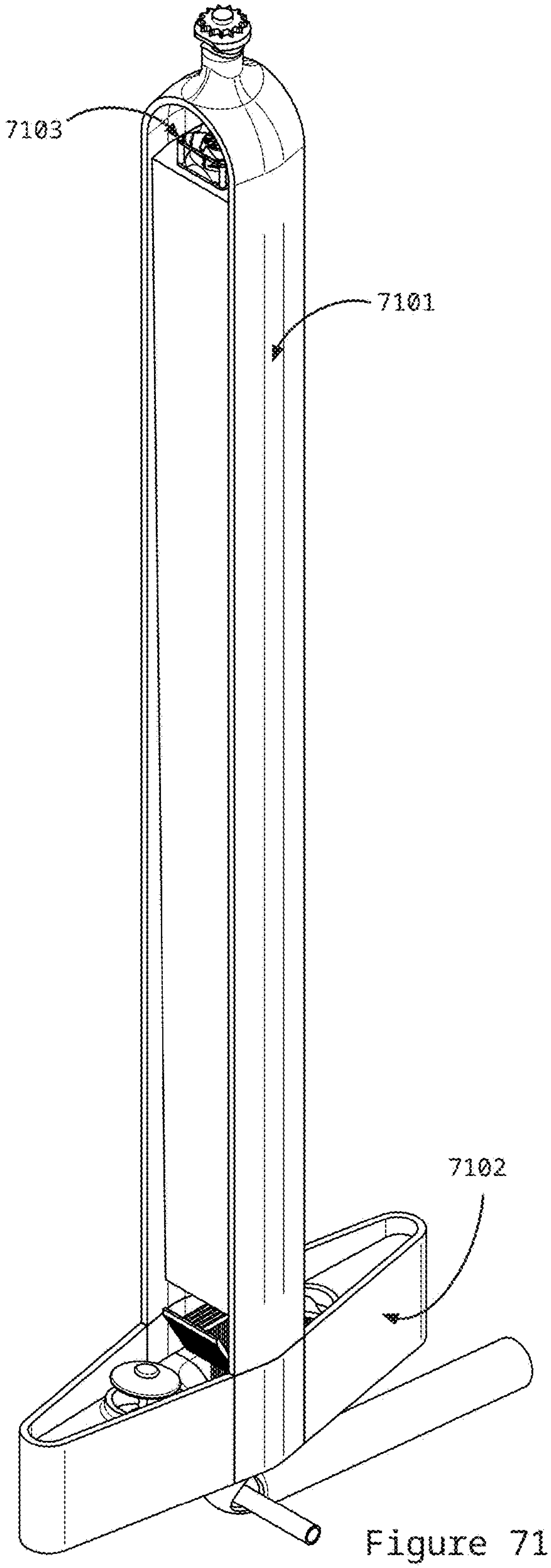

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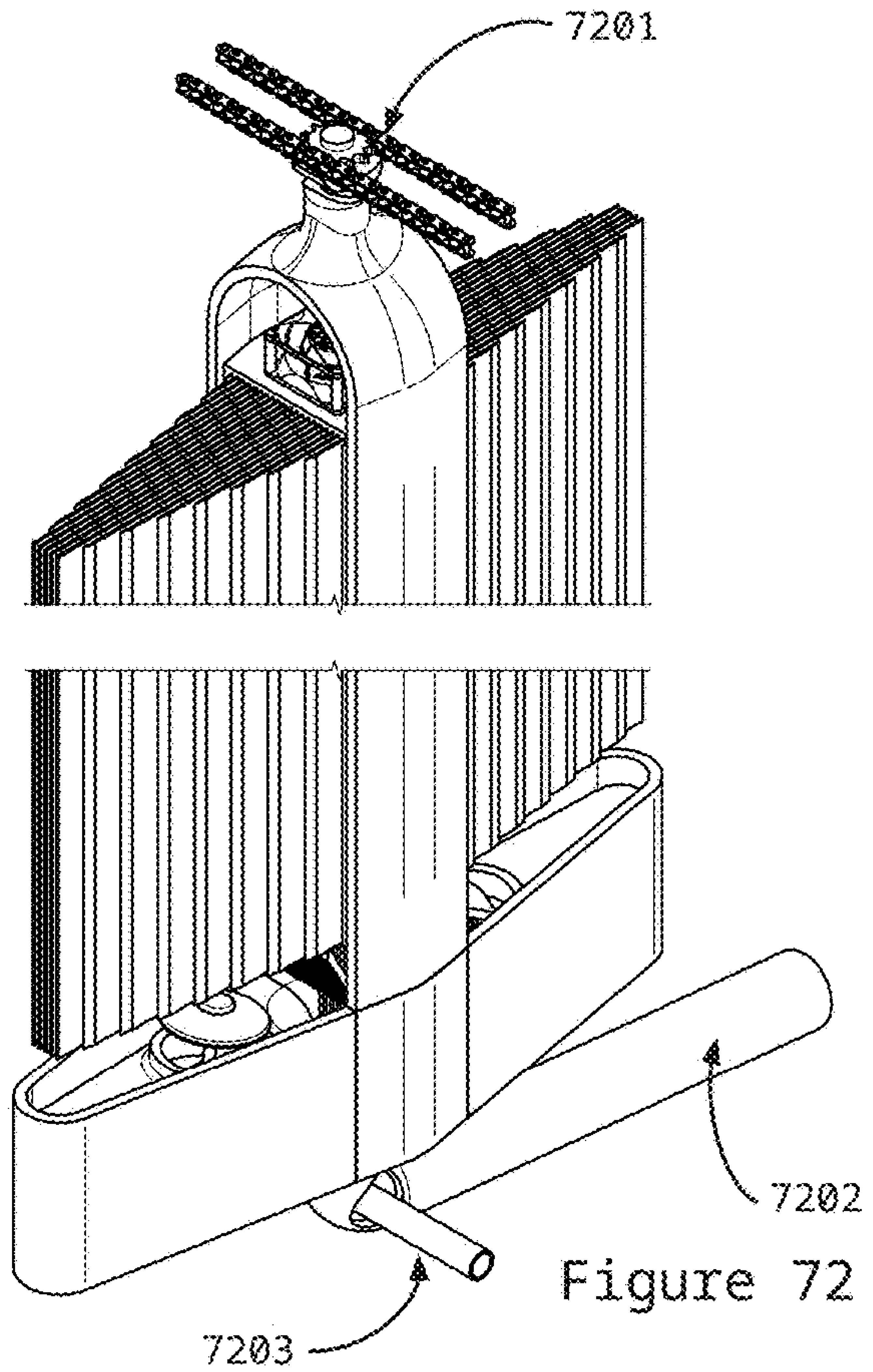

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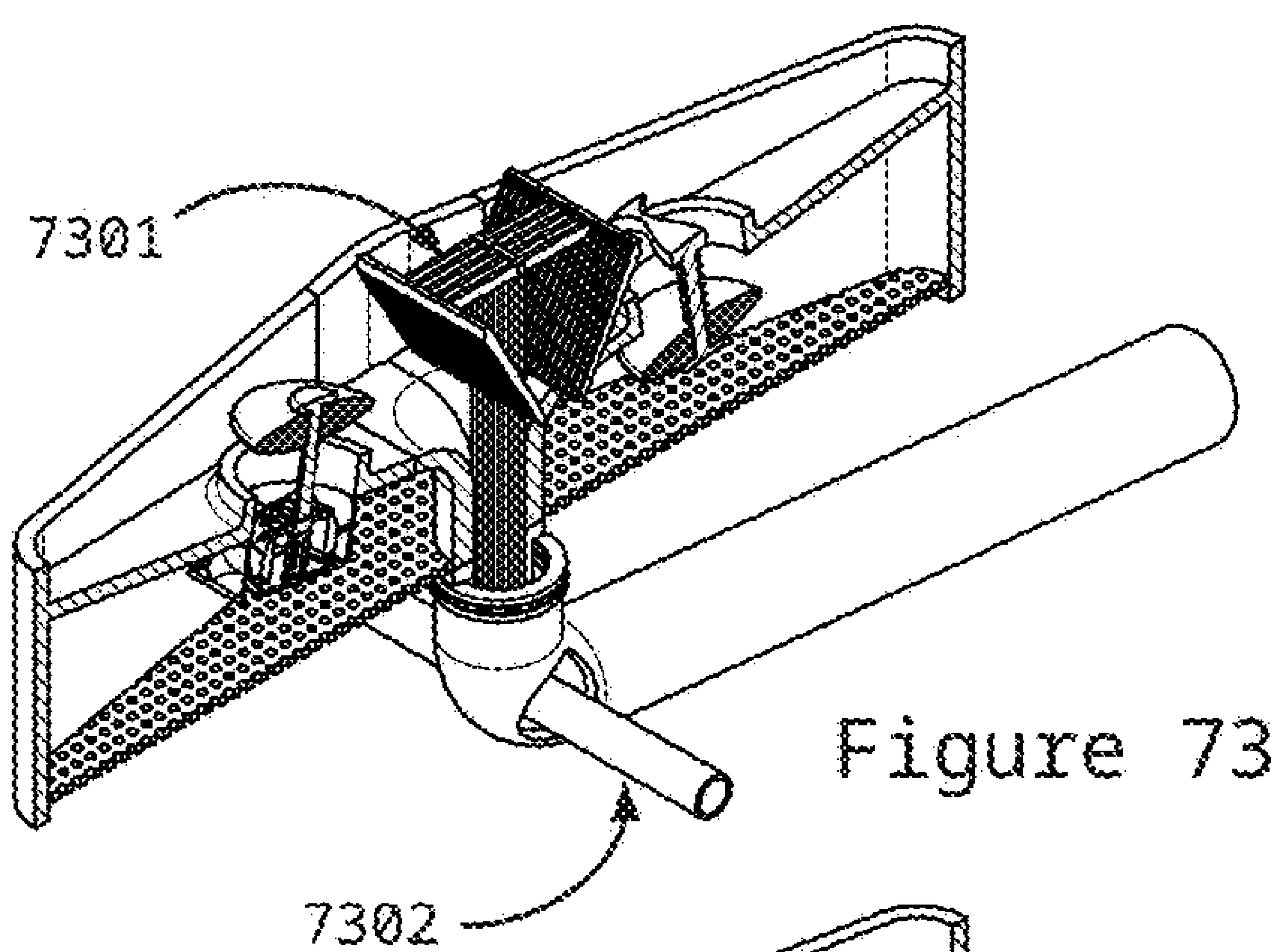

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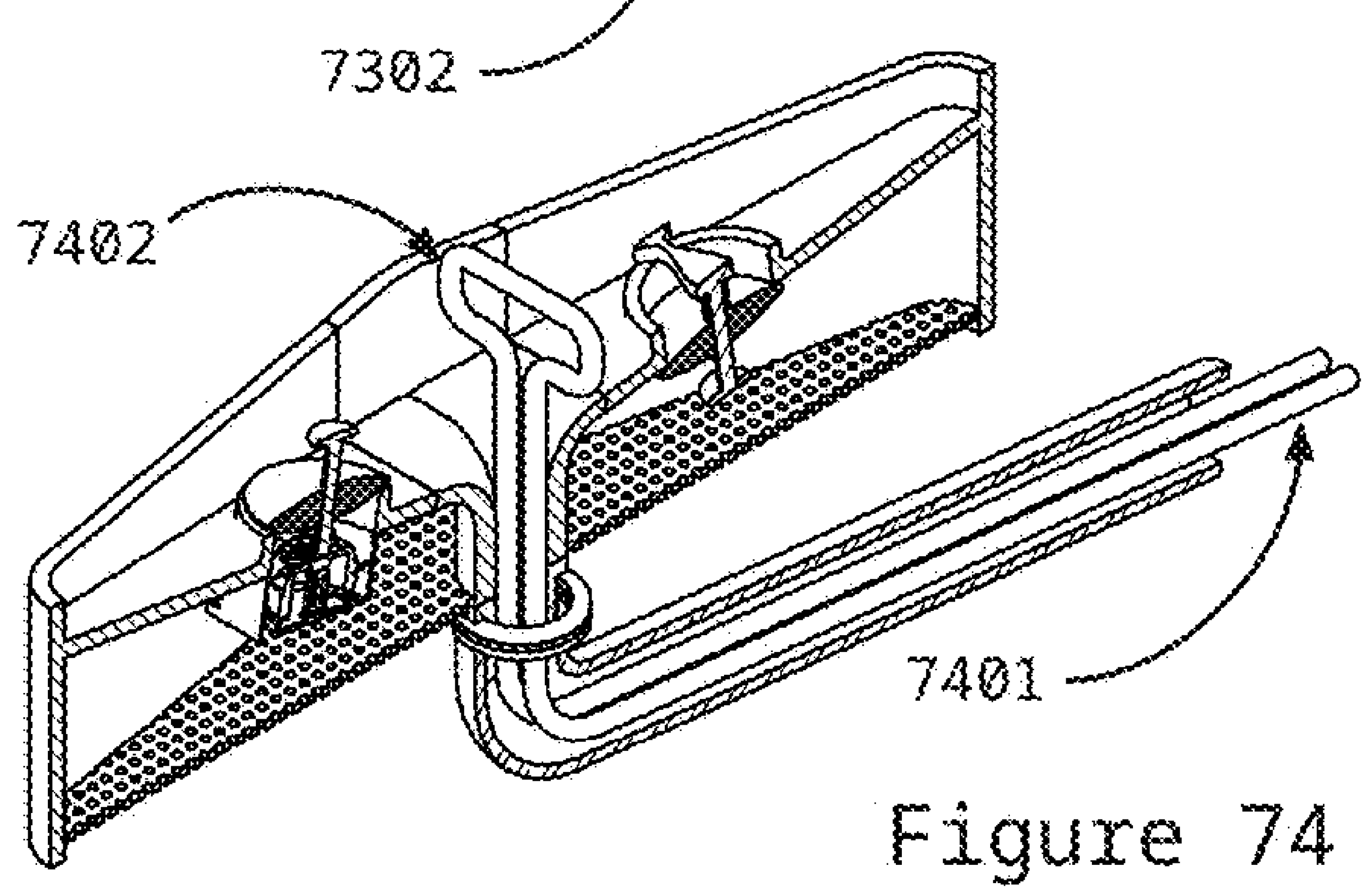

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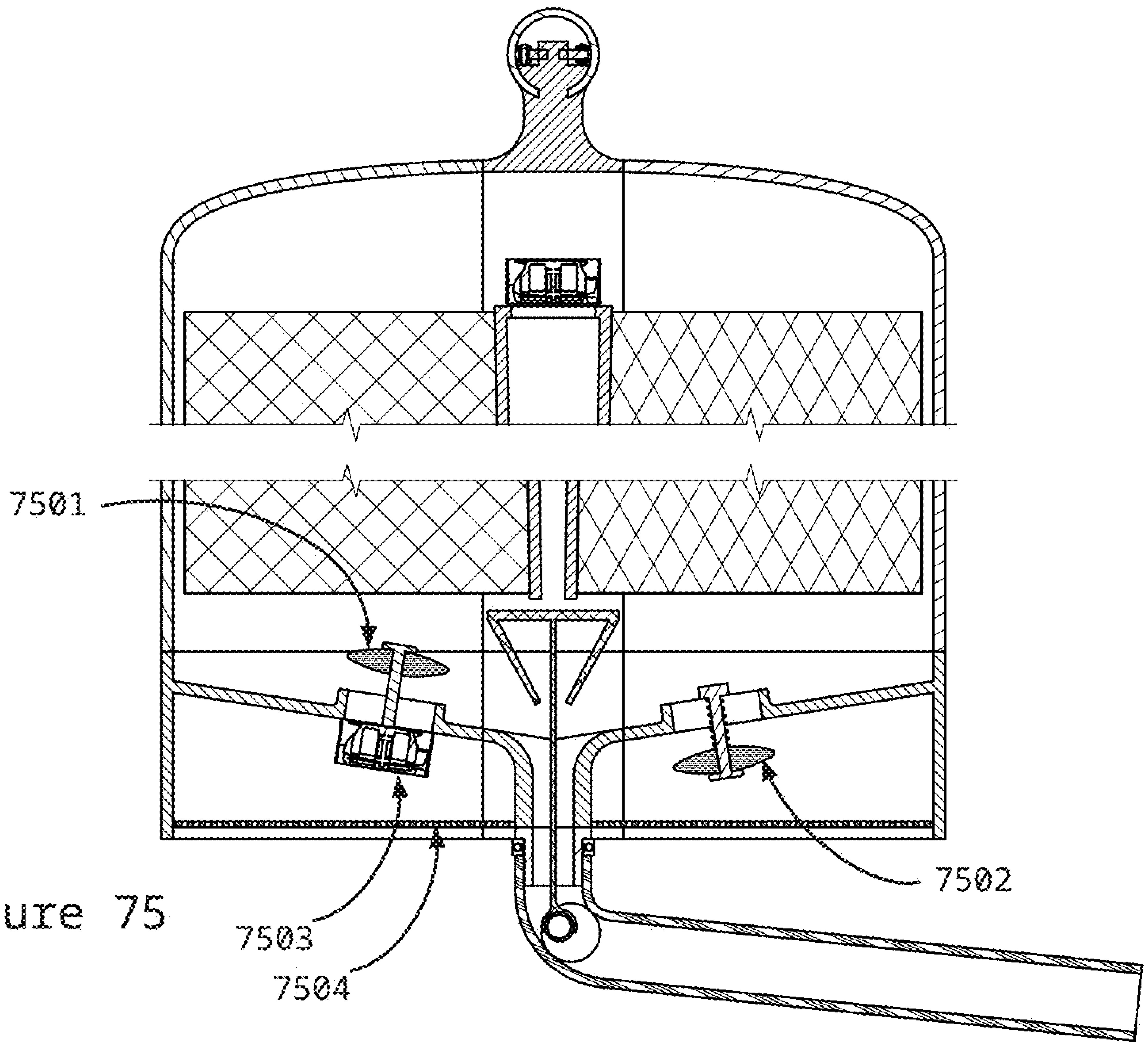

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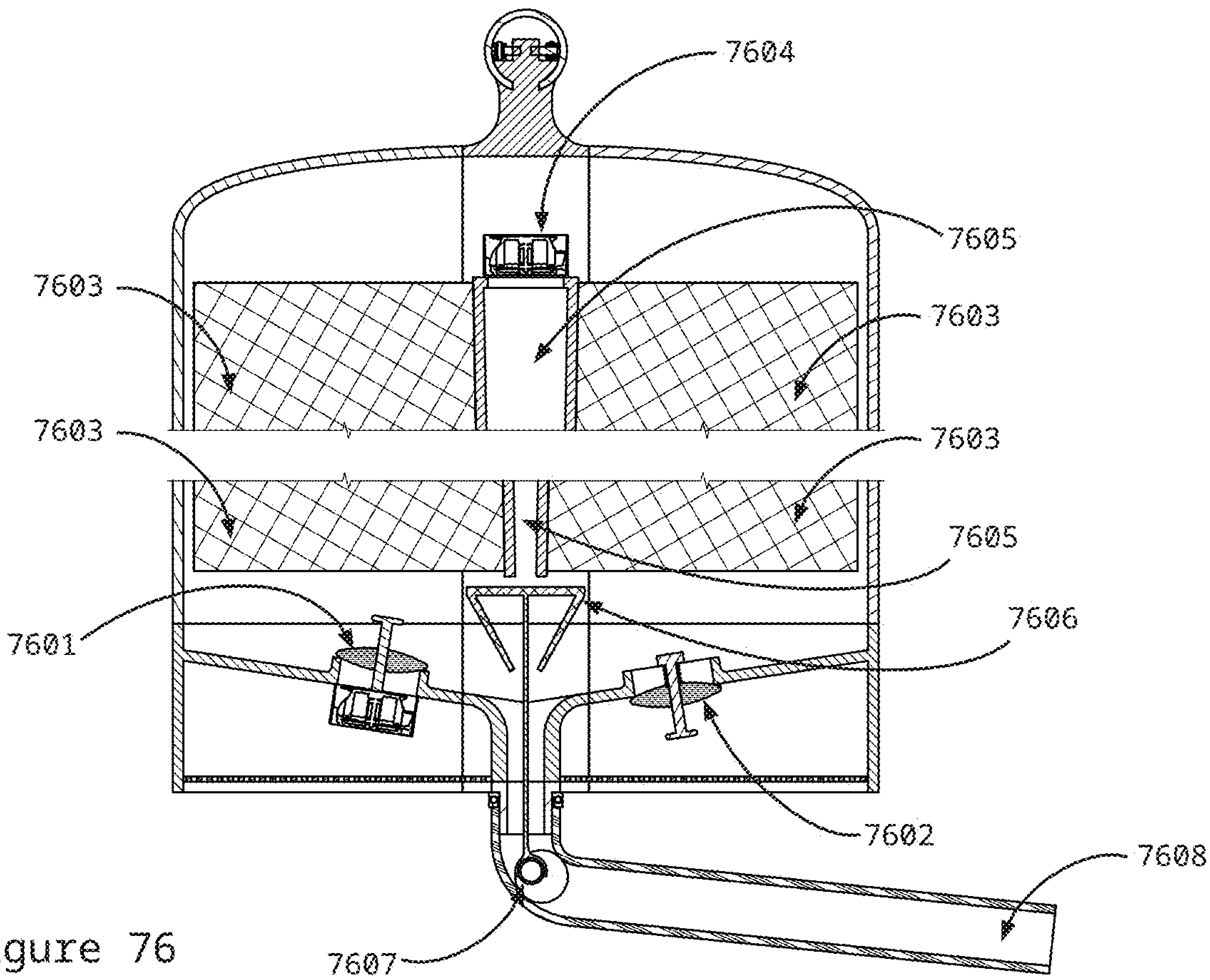

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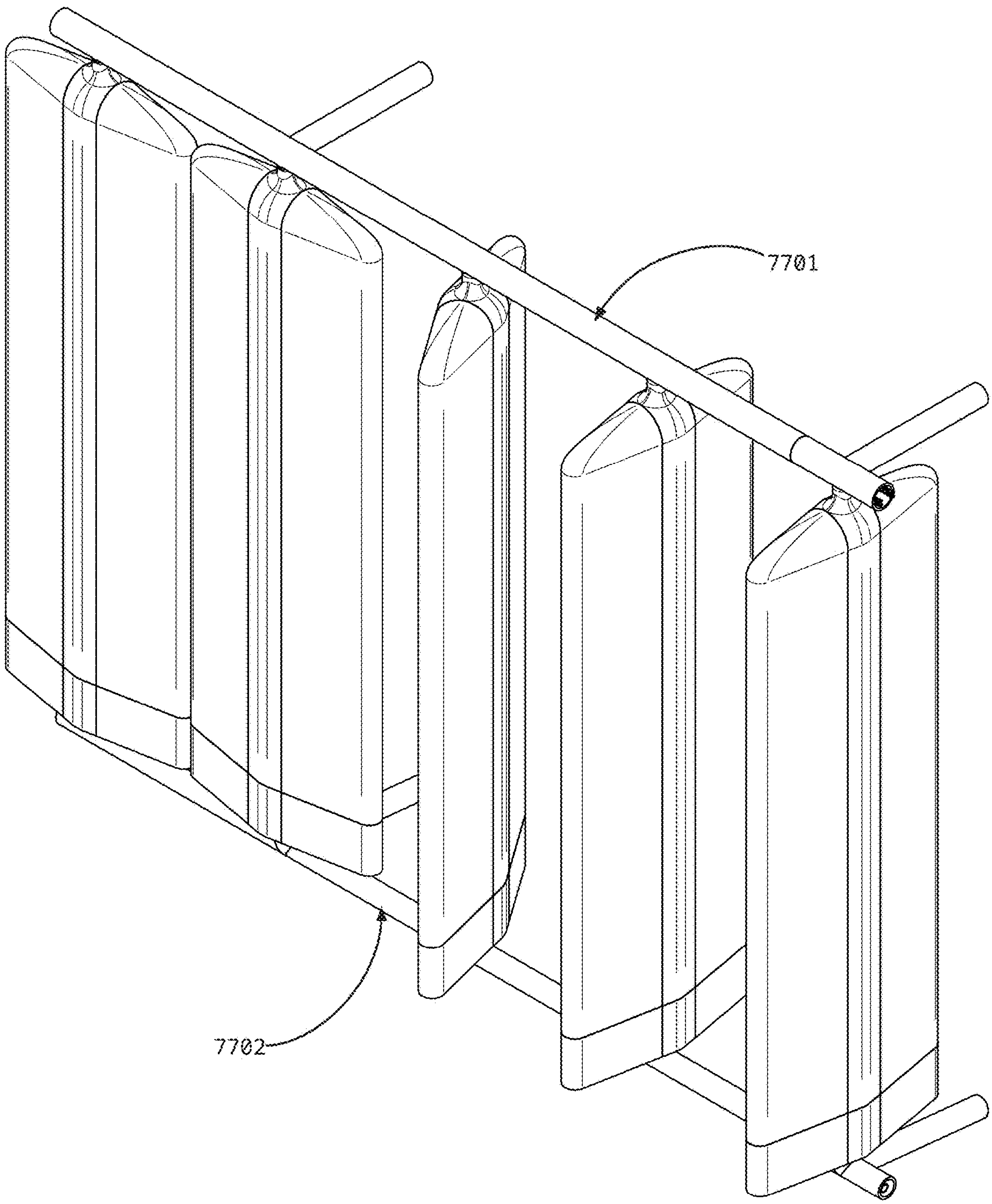

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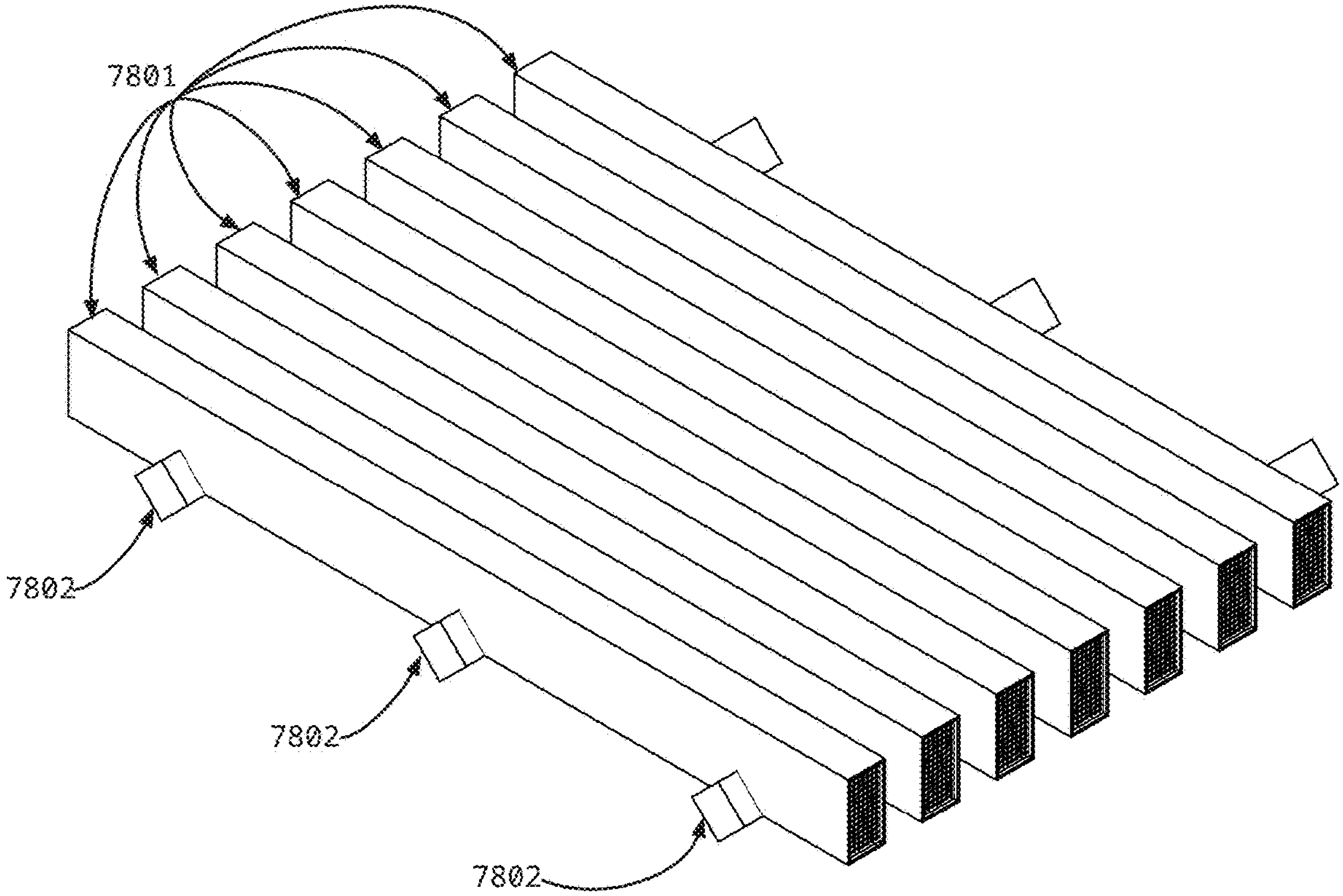

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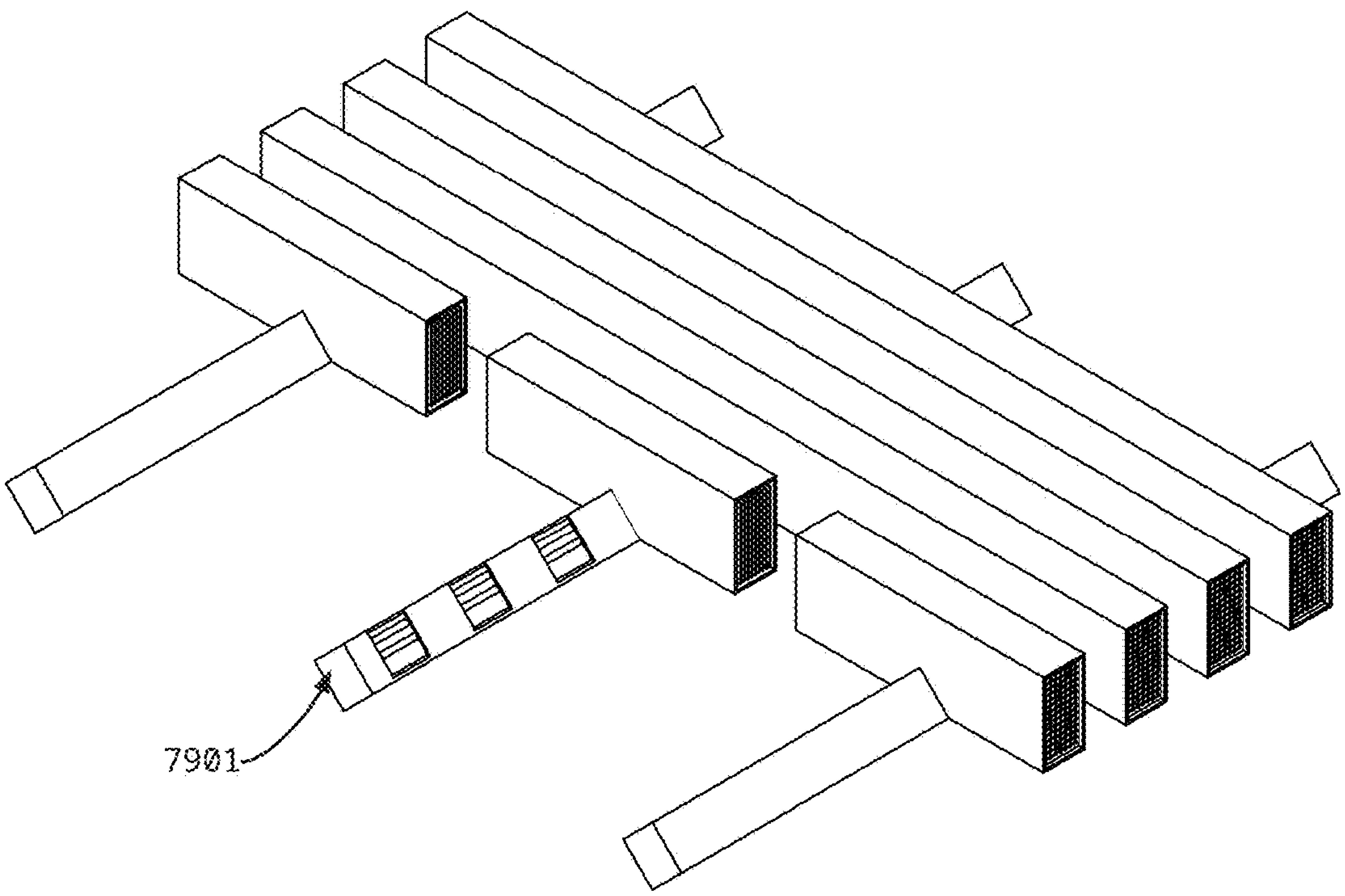

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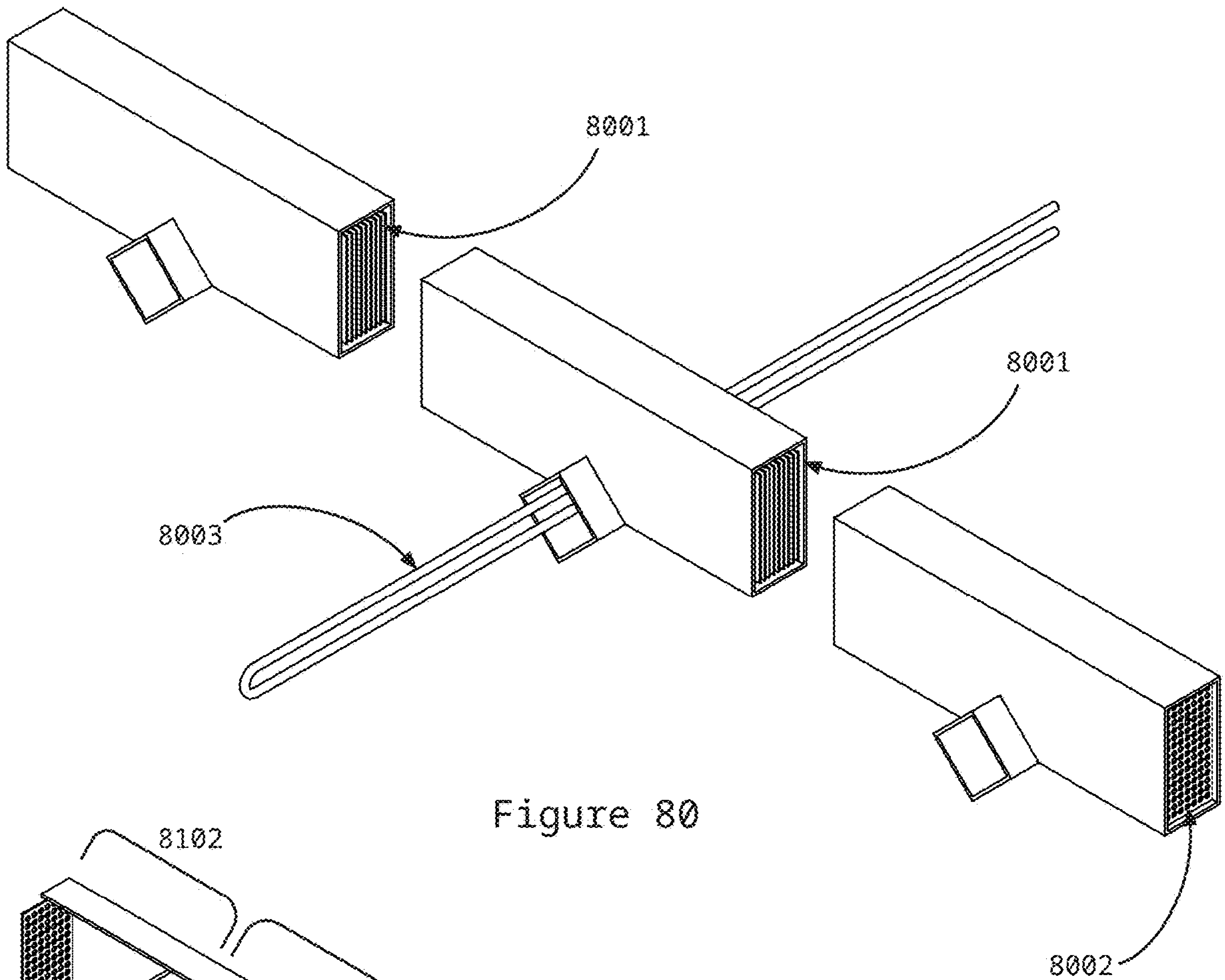

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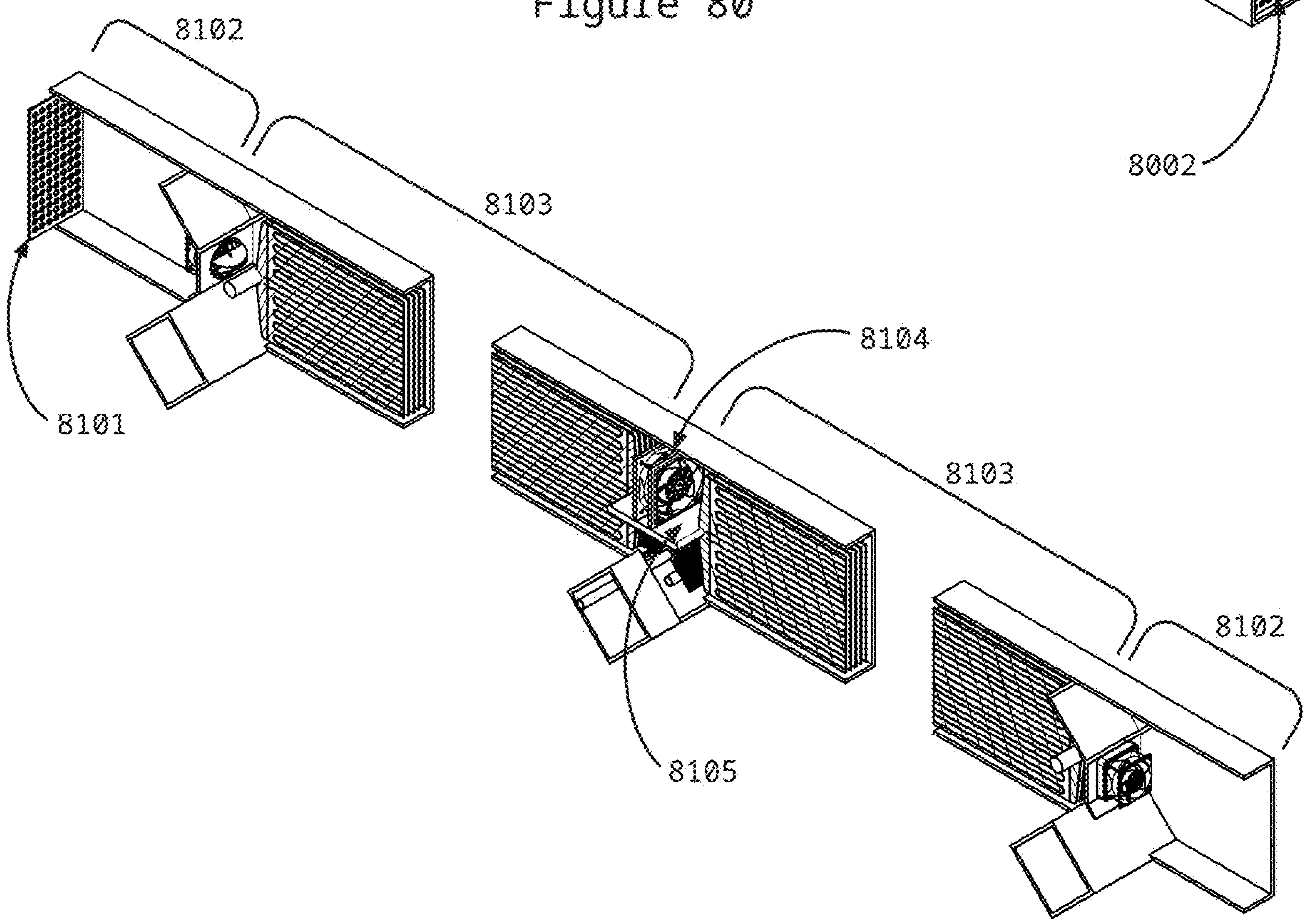

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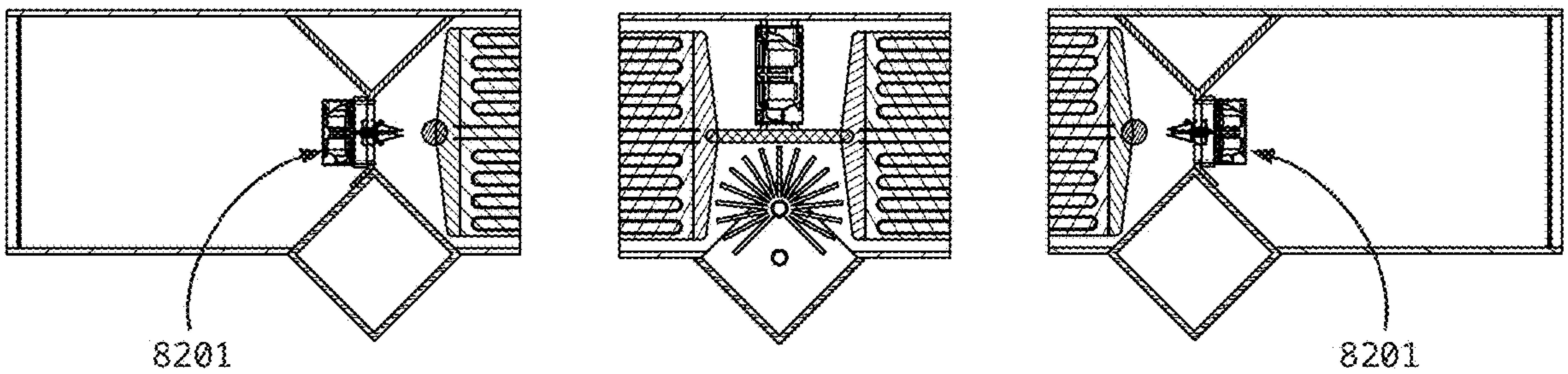

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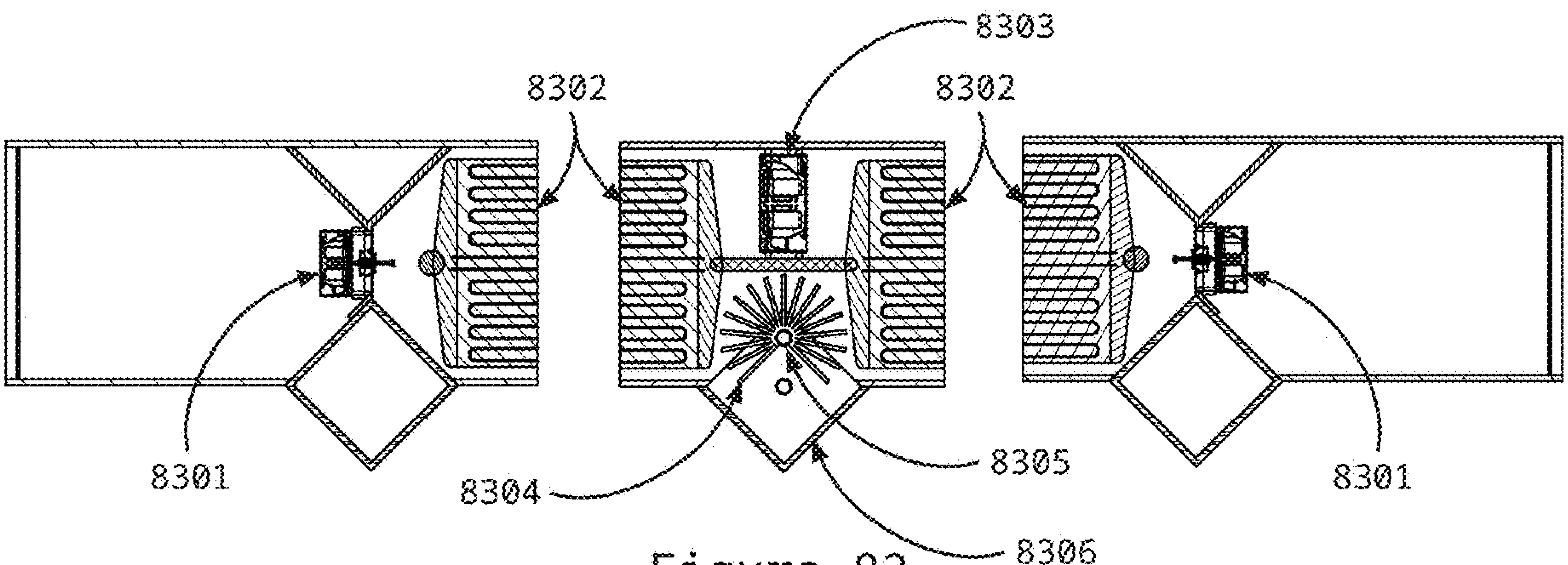

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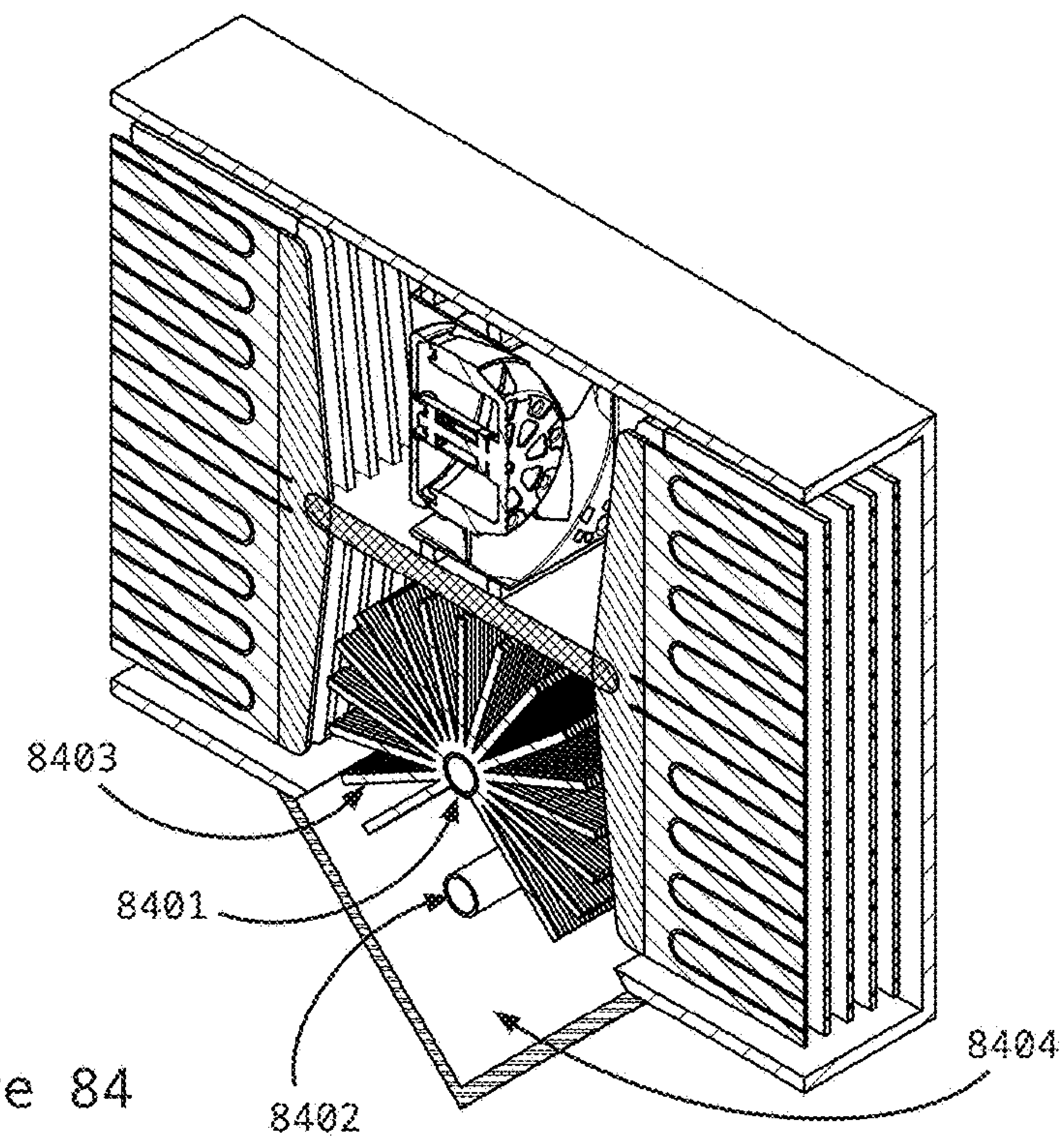

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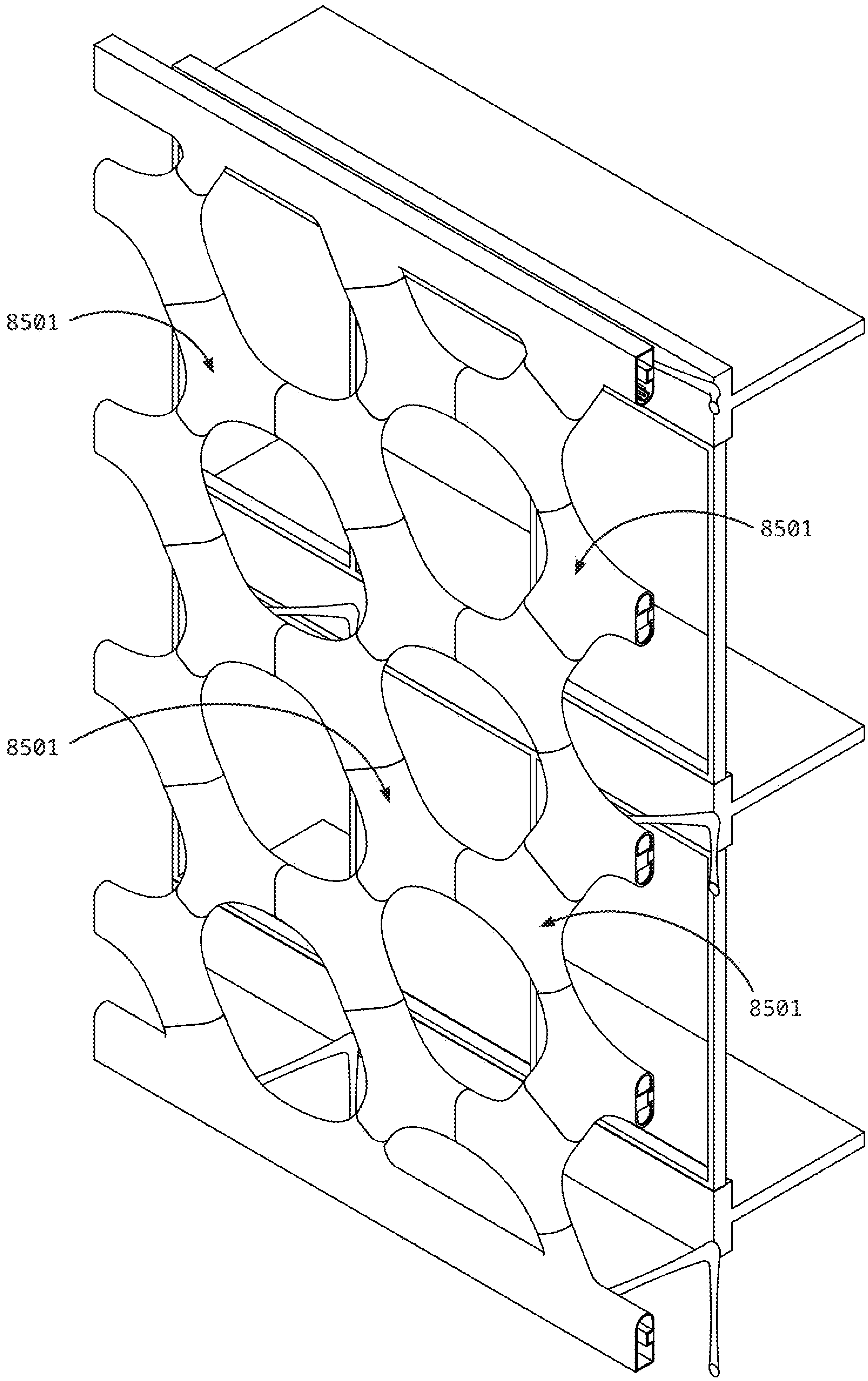

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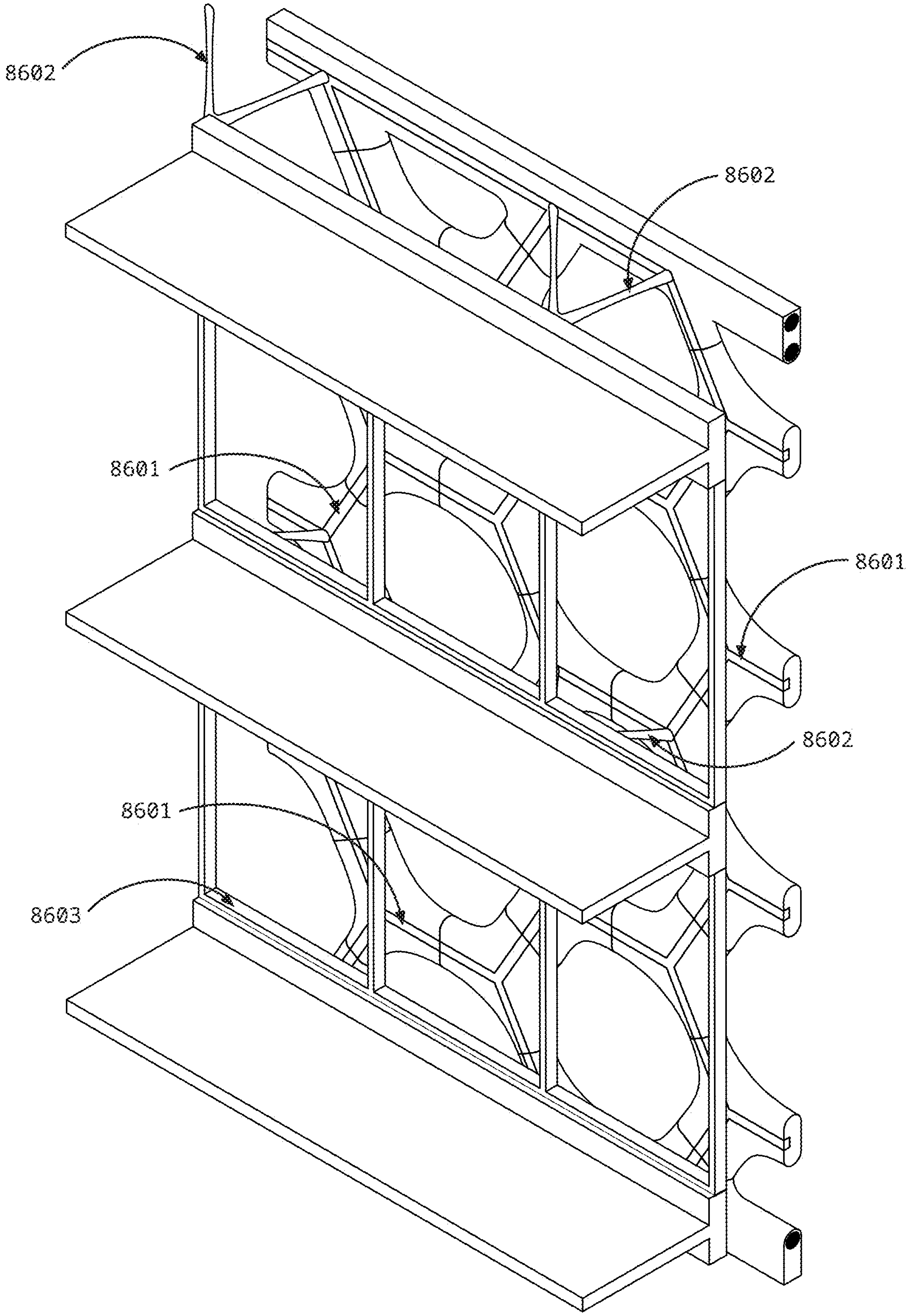

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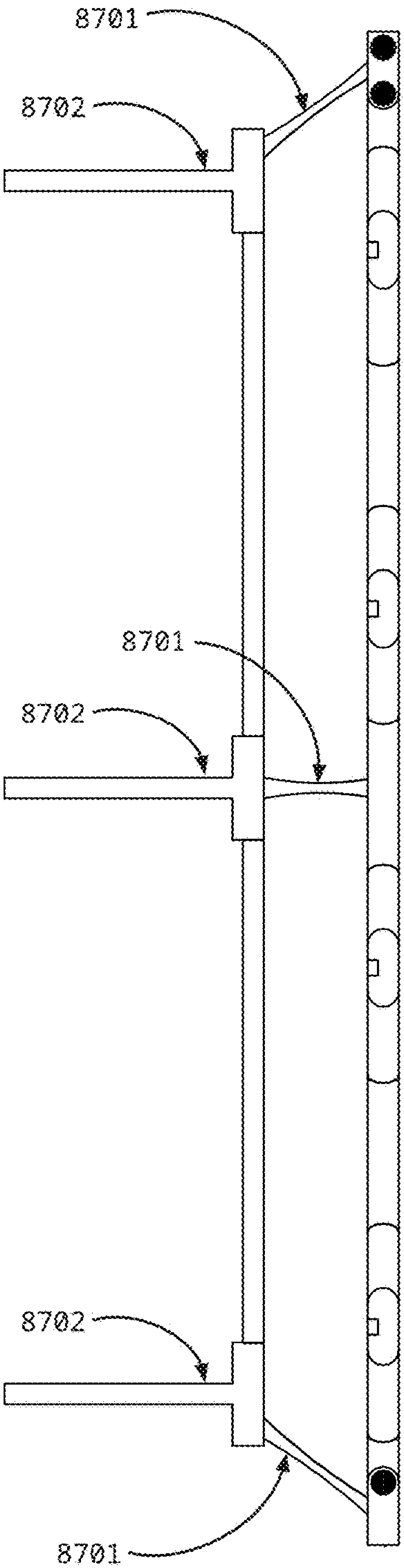
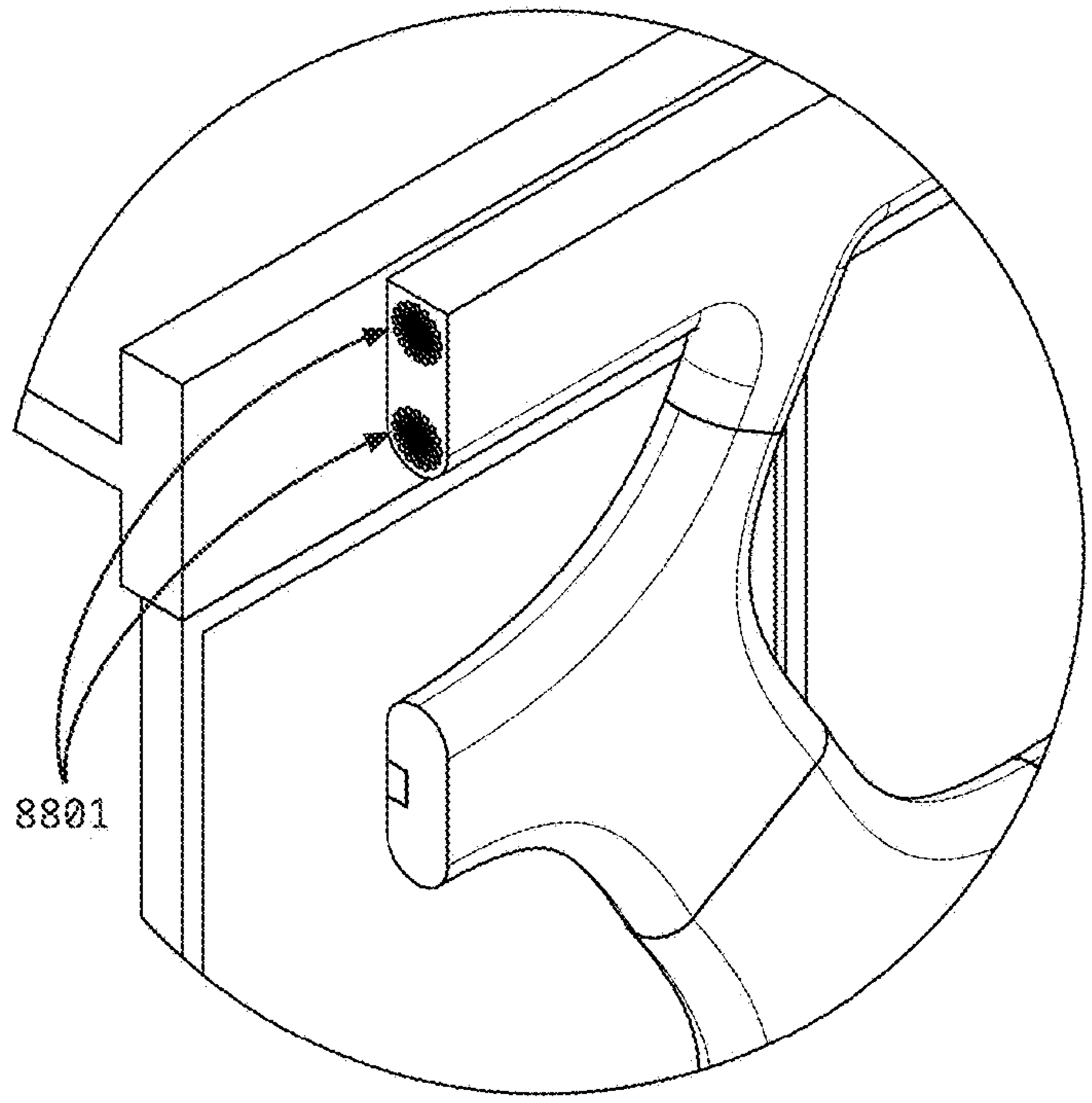


Figure 87



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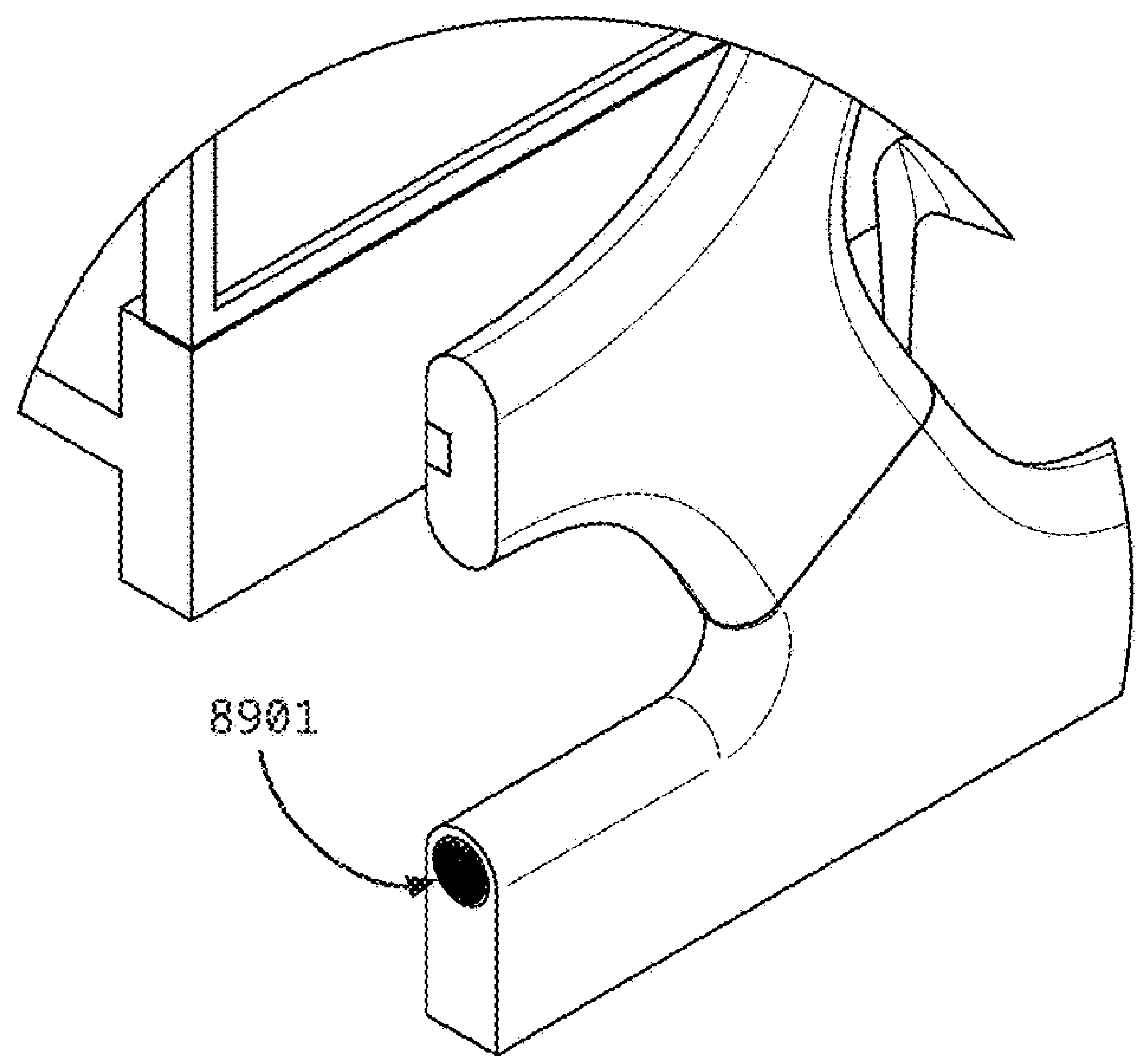

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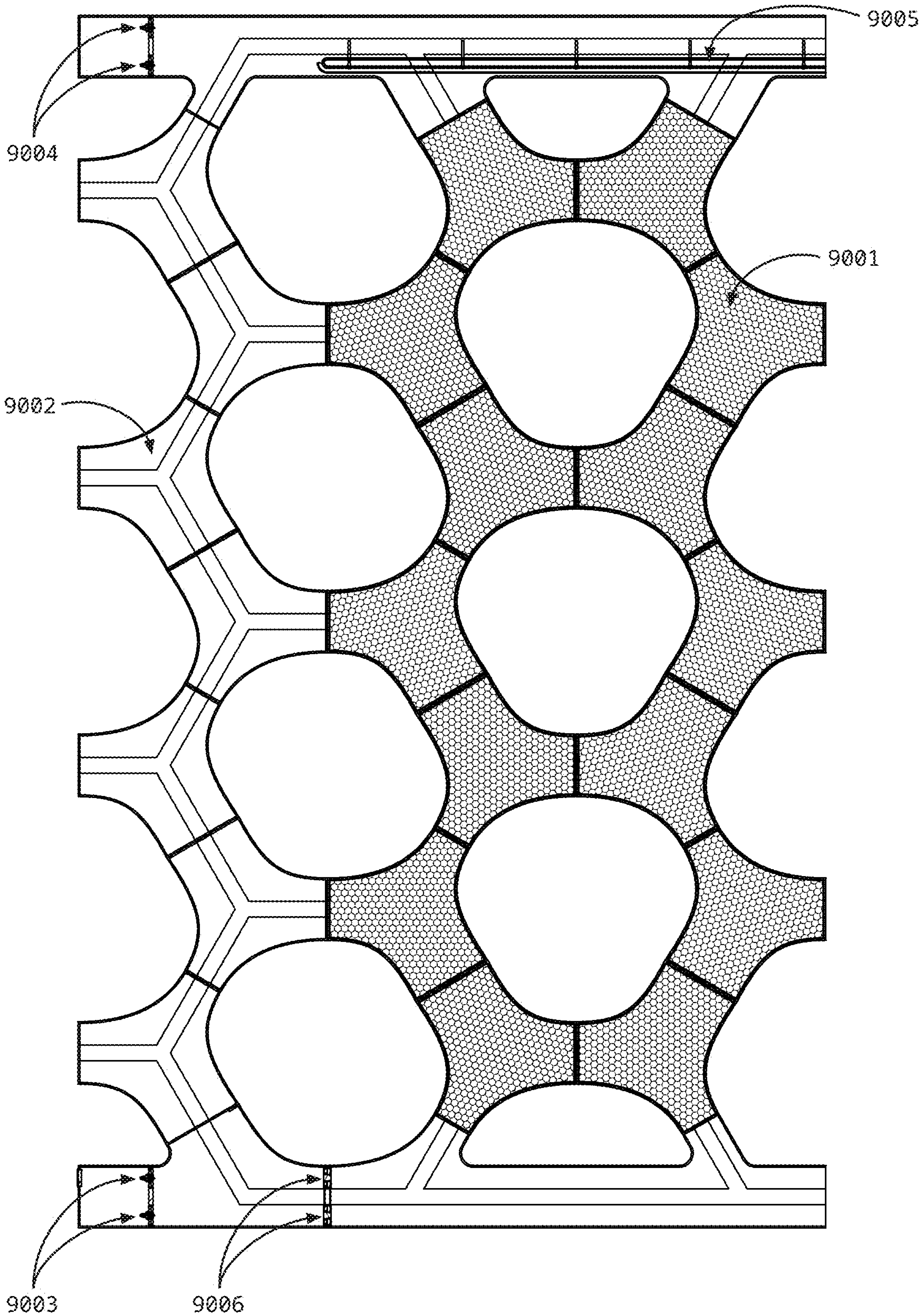

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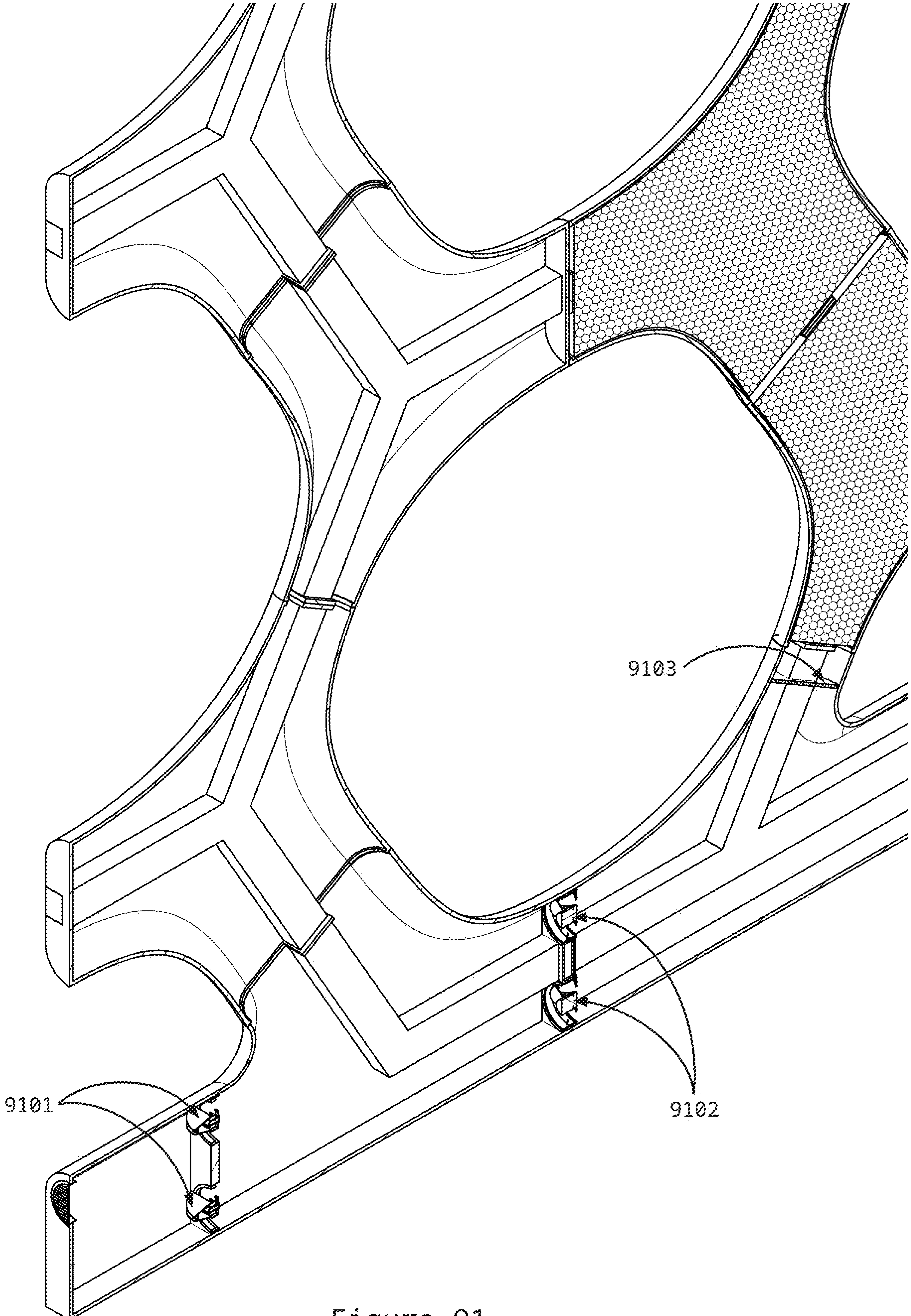

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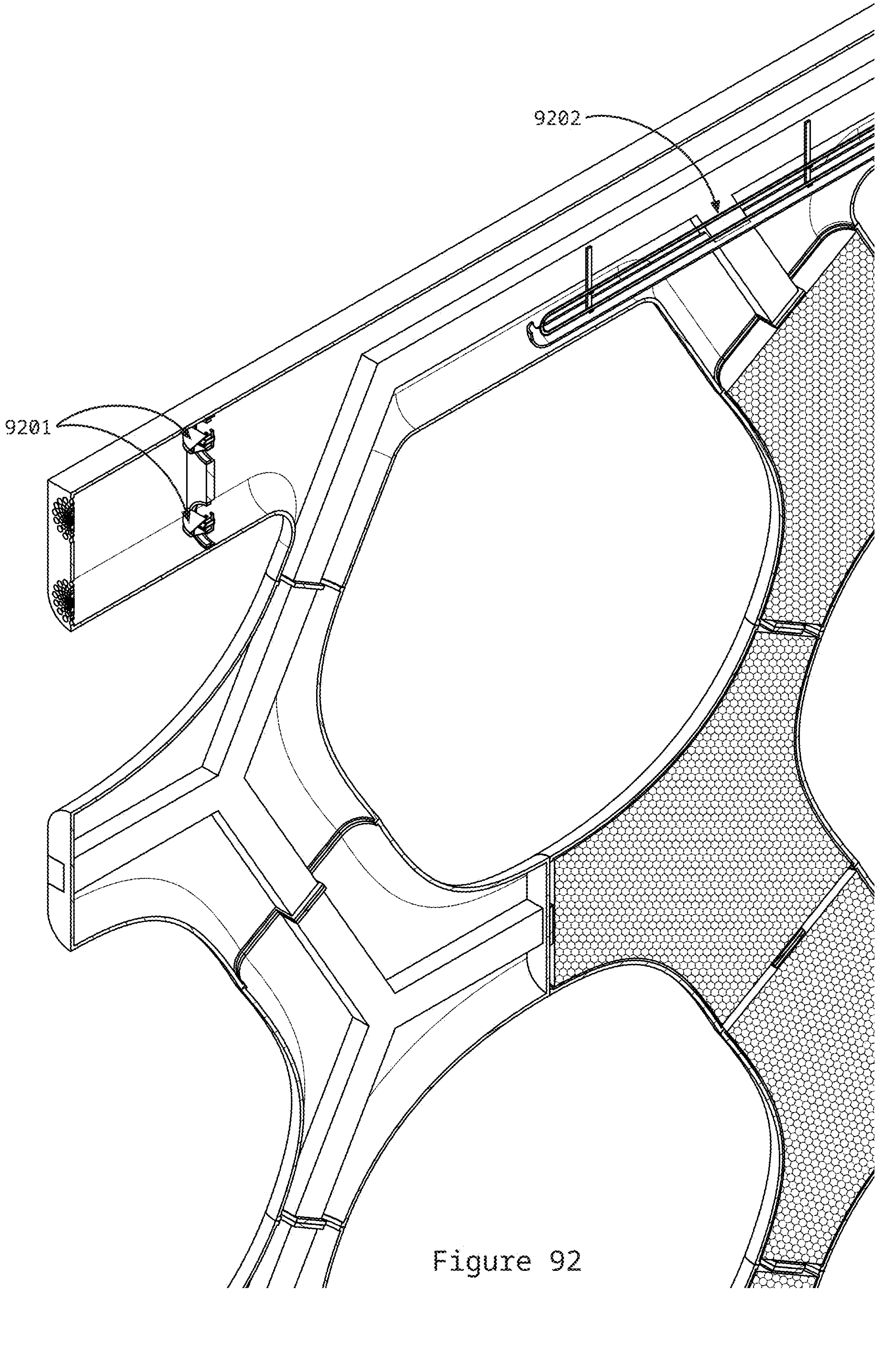

Figure 92

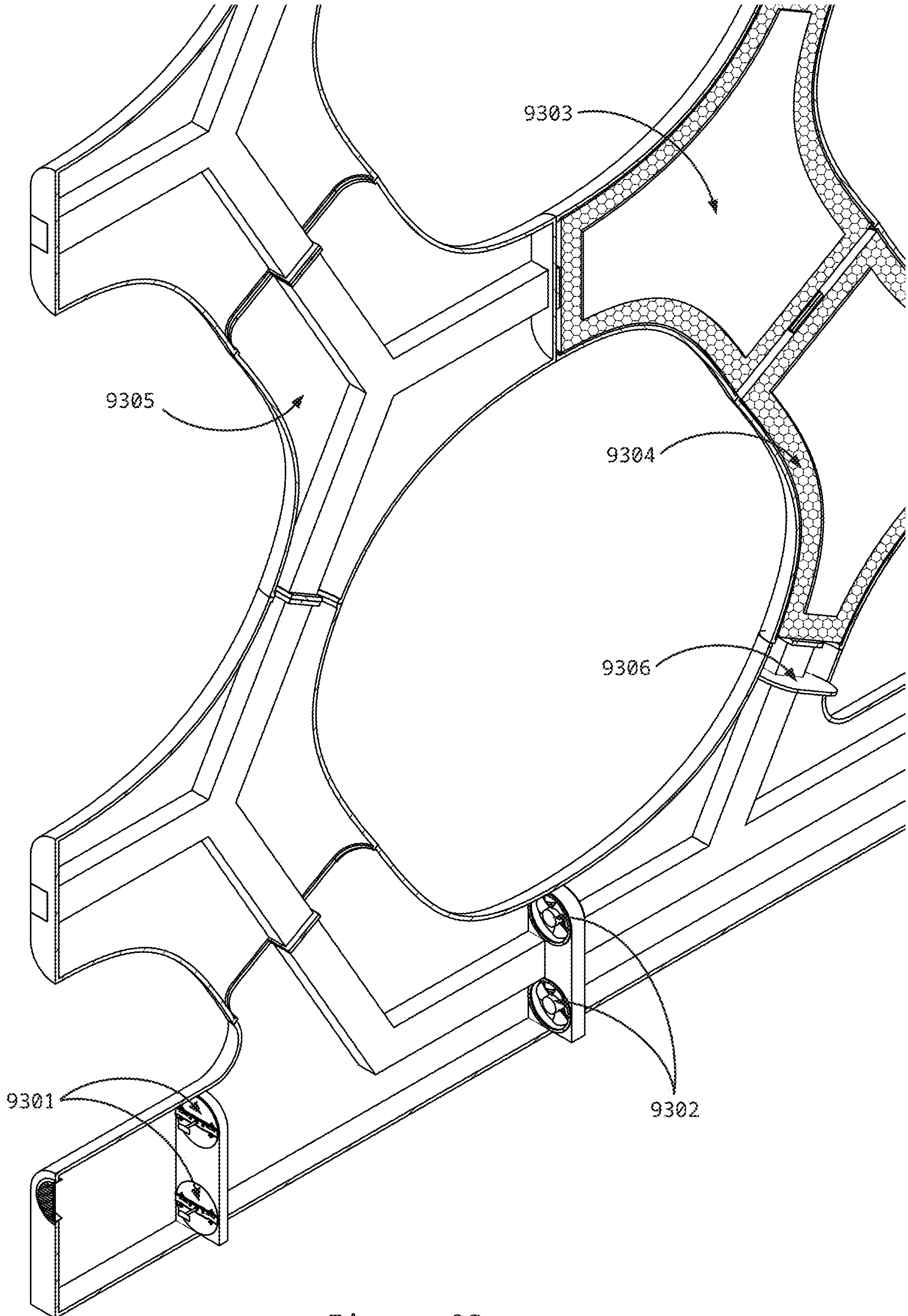

Figure 93

RAPID HYGROSCOPIC ATMOSPHERIC WATER GENERATOR FOR A CONSTRUCTED ENVIRONMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a non-provisional application, which claims the benefit of provisional patent application No. 63/548,586, filed on Feb. 1, 2024.

FIELD

[0002] The present disclosure generally relates to atmospheric water generation, and more specifically to an apparatus and process utilizing temperature-responsive hygroscopic materials for absorbing and desorbing atmospheric water.

BACKGROUND

[0003] People rely on fresh water for agriculture, industry, and consumption. Many communities around the world lack access to fresh water. Population growth and climate change are increasing the problem.

[0004] Global warming is causing more water to evaporate and remain in the atmosphere as water vapor. This increased evaporation diminishes some freshwater resources. The increase in atmospheric water vapor also shifts weather patterns, causing increased rainfall in some areas and droughts in others.

[0005] Furthermore, some communities were built in locations without a sustainable freshwater source and are experiencing diminished supply. Water scarcity can also arise during disasters, when infrastructure is damaged, and when water systems become polluted.

[0006] There are several current approaches to provide water to areas with no freshwater access. One approach collects water from the sea. Desalination is the conversion of saltwater to freshwater. It requires access to the saltwater and a large amount of energy.

[0007] Other approaches convert non-potable water to freshwater through evaporation. A solar still uses sunlight to heat and evaporate polluted water or salt water. The vapor is then condensed into purified liquid water. Solar stills require access to non-potable water and ample sunlight.

[0008] Other approaches collect water from the air. Fog catchers and dew harvesters capture water vapor from the atmosphere with hydrophilic materials. These are location-dependent and need specific high-humidity climate conditions.

[0009] An atmospheric water generator ("AWG") also collects water from the air. It uses condensation or desiccants to capture and collect water vapor. AWGs work well in moderate-to-high humidity, but not in arid conditions.

[0010] Some AWGs use hygroscopic materials, that absorb water vapor under certain humidity conditions. Common hygroscopic materials used in AWGs include polymers and salts, which may have temperature-dependent variability in degree of hydrophilicity or hydrophobicity. For example, the hygroscopic material may absorb water vapor in lower temperatures and desorb water vapor in higher temperatures.

[0011] Some devices using hygroscopic AWGs are intended for use in arid environments and utilize solar radiation as a heat source. One example places hygroscopic material in a container. During the cool night, low humidity air enters the container through openings and is absorbed by the hygroscopic material. During the warm day, the sun heats the hygroscopic material within the container and causes the hygroscopic material to turn hydrophobic. The water vapor is emitted from the material into the container for condensation and collection.

[0012] These hygroscopic AWG's require access to sunlight and are constrained to one cycle of absorption and desorption every twenty-four hours. Direct sunlight may also have detrimental effects, like overheating.

[0013] A hygroscopic AWG independent of the solar cycle would provide a more efficient means of harvesting water vapor from the atmosphere.

SUMMARY

[0014] A hygroscopic AWG apparatus is designed to extract water vapor from the atmosphere in low humidity environments. The AWG utilizes hygroscopic materials that alternate between hydrophilic and hydrophobic states based on temperature changes. The apparatus consists of a container housing a chamber with a thermal management system, allowing for the optimization of absorption and desorption cycles.

[0015] In one embodiment, the hygroscopic material is an interpenetrating polymer network composite, consisting of a hygroscopic polymer (e.g., konjac glucomannan or sodium alginate) and a thermoresponsive polymer (e.g., hydroxypropyl cellulose). The hygroscopic polymer absorbs water vapor at a lower temperature. As the temperature rises, the thermoresponsive polymer changes from hydrophilic to hydrophobic, causing the composite to emit water vapor during desorption.

[0016] The apparatus may include salts such as calcium chloride, providing hygroscopic and antimicrobial properties. Alternative embodiments may incorporate dopants, additives, and nanomaterials to enhance performance, absorption/desorption, antimicrobial properties, thermal properties, electrical properties, or biodegradability.

[0017] The chamber housing the hygroscopic material can be of various sizes and shapes, with surfaces that may be opaque for light protection. Insulation and reflective surfaces may be included for temperature control. A removable lid allows access to interior components. The chamber includes a means for air intake, exhaust, and circulation, and water collection.

[0018] The hygroscopic material can be in the form of a hygroscopic composite sheet ("HCS"), offering a structured format for easy insertion, removal, and efficient use of both sides for absorption and desorption. In one embodiment, the HCS may be made by casting the composite around a reinforcement material. In another embodiment, the HCS is attached to the surface of a reinforcement material.

[0019] The apparatus includes a heating system for the HCS, using methods like conduction, convection, or radiation. Thermoelectric modules, heating fins, or integrated resistance heating wires are among the heating elements.

[0020] The operation involves two phases: absorption and desorption. During absorption, air enters and circulates through the chamber, and the hygroscopic material absorbs water vapor. The desorption phase follows, during which the temperature is increased, turning the hygroscopic material hydrophobic. Water vapor is expelled from the composite, and condensed for collection.

[0021] Some embodiments are further comprised of a condensation surface to aid water collection during the desorption phase. The condensation surface possesses certain characteristics that attract water vapor for condensation. Characteristics may include a surface cooler than the temperature of the chamber, hydrophilic and or hydrophobic materials, and the ability to vibrate.

[0022] Some embodiments include various fans to aid air flow. These include fans to aid air intake, exhaust, as well as circulation within the chamber during absorption and/or desorption.

[0023] Various controls, sensors, and meters are incorporated into some embodiments, including temperature sensors, weight sensors, hygrometers, and electronic components for remote operation.

[0024] The temperature-controlled chamber allows for optimized absorption/desorption cycles, increasing efficiency over devices affected by day/night cycles or weather conditions. The apparatus can perform multiple cycles throughout the day, and night, resulting in higher water generation. Optimization can be achieved by adjusting heating temperatures and monitoring individual HCS performance.

[0025] Alternative embodiments consider antimicrobial features, using materials like copper or silver. The apparatus is scalable, allowing for the customization of size and multiple units operating in unison or tandem to ensure a continuous water supply.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Particular descriptions of the principles briefly described above are rendered by specific embodiments illustrated in the drawings. These drawings depict only exemplary embodiments of the disclosure and are not limiting of its scope. The principles and advantages herein are described and explained with additional specificity and detail by the accompanying drawings in which:

[0027] FIG. **1** shows a top, front, right perspective view of one embodiment of an AWG.

[0028] FIG. **2** shows a bottom, front, right perspective view of one embodiment of an AWG.

[0029] FIG. **3** shows a top, front, right perspective view of one embodiment of an AWG with insulation coating.

[0030] FIG. **4** shows a bottom, front, right perspective view of one embodiment of an AWG with insulation coating.

[0031] FIG. **5** shows a top, front, right perspective view of one embodiment of an AWG with a removable lid.

[0032] FIG. **6** shows a top, front, right perspective view of one embodiment of an AWG with the chamber cut away to show the interior components.

[0033] FIG. **7** shows a bottom, front, right perspective view of one embodiment of an AWG with the chamber cut away to show the interior components.

[0034] FIG. **8** shows a hygroscopic composite sheet with one layer of hygroscopic polymer film, two layers of reinforcement material, and a resistance heating wire.

[0035] FIG. **9** shows the hygroscopic composite sheet of FIG. **8** with the layer of hygroscopic polymer film and one layer of reinforcement material cut away.

[0036] FIG. **10** shows a hygroscopic composite sheet with two layers of hygroscopic polymer film, two layers of reinforcement material, and a resistance heating wire.

[0037] FIG. **11** shows a hygroscopic composite sheet with two layers of hygroscopic polymer film, two layers of reinforcement material, and flat ribbon resistance heating wire, with one layer of film and one layer of reinforcement material cut away.

[0038] FIG. **12** shows a hygroscopic composite sheet formed by embedding reinforcing material in the polymer composite.

[0039] FIG. **13** shows a hygroscopic composite sheet formed by attaching two layers of polymer composite to both sides of reinforcing material.

[0040] FIG. **14** shows a hygroscopic composite sheet formed by embedding reinforcing material in the polymer composite, with a resistance heating wire providing heat during the desorption phase.

[0041] FIG. **15** shows a hygroscopic composite sheet formed by attaching two layers of polymer composite to both sides of reinforcing material, with a resistance heating wire providing heat during the desorption phase.

[0042] FIG. **16** shows a hygroscopic composite sheet formed by attaching polymer composite spheres to the surface of reinforcing material.

[0043] FIG. **17** shows a hygroscopic composite sheet formed by encasing polymer composite spheres between two surfaces of reinforcing material.

[0044] FIG. **18** shows a hygroscopic composite sheet formed by attaching the hygroscopic polymer composite to reinforcement material with several protrusions.

[0045] FIG. **19** shows a hygroscopic composite sheet coiled into a spiral form.

[0046] FIG. **20** shows the hygroscopic composite sheet of FIG. **19** with additional spacer media between the surfaces of the coil.

[0047] FIG. **21** shows the hygroscopic composite sheet of FIG. **19** with additional spacer media between the surfaces of the coil and around the perimeter.

[0048] FIG. **22** shows a top, front, left perspective view of one embodiment of an AWG with the chamber cut away to show the interior components and thermoelectric device.

[0049] FIG. **23** shows a top section cut view of one embodiment of an AWG.

[0050] FIG. **24** shows a detail of a thermoelectric device connected to the container wall and heating fins.

[0051] FIG. **25** shows a top, front, left perspective view of one embodiment of an AWG with the chamber cut away to show the interior components and an integrated resistance heating wire.

[0052] FIG. **26** shows a top, front, left perspective view of one embodiment of an AWG with the chamber and polymer composite removed to show the interior components and an integrated resistance heating wire.

[0053] FIG. **27** shows a top, front, right perspective view of one embodiment of an AWG with the lid removed.

[0054] FIG. **28** shows a top, front, right perspective view of the interior components of one embodiment of an AWG.

[0055] FIG. **29** shows a front section cut view of one embodiment of an AWG showing air flow during the absorption phase.

[0056] FIG. **30** shows a top section cut view of one embodiment of an AWG showing air flow during the absorption phase.

[0057] FIG. **31** shows multiple charts demonstrating absorption rates.

[0058] FIG. **32** shows a diagram of the absorption phase.

[0059] FIG. **33** shows a diagram of the desorption phase.

[0060] FIG. **34** shows a front section cut view of one embodiment of an AWG showing air flow during the desorption phase.

[0061] FIG. **35** shows a top section cut view of one embodiment of an AWG showing air flow during the desorption phase.

[0062] FIG. **36** shows a top, front, left view of one embodiment of an AWG with a display and the lid removed.

[0063] FIG. **37** shows a top, front, left view of one embodiment of an AWG with the front wall of the container, lid, and several hygroscopic composite sheets removed.

[0064] FIG. **38** shows a chart showing two absorption/desorption cycles.

[0065] FIG. **39** shows line graph showing multiple absorption/desorption cycles at two desorption temperatures.

[0066] FIG. **40** shows a top view of two AWGs with lids removed operating in a system, one AWG has several hygroscopic composite sheets removed.

[0067] FIG. **41** shows a top, front, left view of two AWGs with lids removed operating in a system.

[0068] FIG. **42** shows a perspective view of a dual chamber embodiment with an insulation cover.

[0069] FIG. **43** shows a perspective view of a dual chamber embodiment without an insulation cover.

[0070] FIG. **44** shows a perspective view of a dual chamber embodiment with the lid removed.

[0071] FIG. **45** shows a perspective view of a dual chamber embodiment with the body removed.

[0072] FIG. **46** shows a removable cartridge with twelve hygroscopic polymer sheets.

[0073] FIG. **47** shows a removable cartridge in packaging.

[0074] FIG. **48** shows a side section cut of the dual chamber embodiment with an insulation cover.

[0075] FIG. **49** shows a side section cut of the dual chamber embodiment without an insulation cover.

[0076] FIG. **50** shows a side section cut detail of the base of the dual chamber embodiment.

[0077] FIG. **51** shows a top section cut view of the base of the dual chamber embodiment.

[0078] FIG. **52** shows a side section cut detail of the top of the dual chamber embodiment.

[0079] FIG. **53** shows a top section cut view of the top of the dual chamber embodiment.

[0080] FIG. **54** shows a perspective view of a curved dual chamber embodiment.

[0081] FIG. **55** shows a section cut of the perspective view of the curved dual chamber embodiment.

[0082] FIG. **56** shows a section cut side view of the curved dual chamber embodiment during the absorption phase.

[0083] FIG. **57** shows a perspective view of the curved dual chamber embodiment with part of the container removed.

[0084] FIG. **58** shows a section cut side view of the curved dual chamber embodiment during the desorption phase.

[0085] FIG. **59** shows a top, front, right perspective view of a constructed environment embodiment.

[0086] FIG. **60** shows a top, front, right perspective view of a disassembled constructed environment embodiment.

[0087] FIG. **61** shows a top, front, right perspective view of a constructed environment embodiment with the lid and middle portion removed.

[0088] FIG. **62** shows a top, front, right perspective view of the base of a constructed environment embodiment.

[0089] FIG. **63** shows a front section cut view of a constructed environment embodiment.

[0090] FIG. **64** shows a right section cut view of a constructed environment embodiment.

[0091] FIG. **65** shows a top, front, right perspective section cut view of the base of a constructed environment embodiment.

[0092] FIG. **66** shows a front section cut view of a constructed environment embodiment.

[0093] FIG. **67** shows a right section cut view of a constructed environment embodiment.

[0094] FIG. **68** shows a top, front, right perspective section cut view of the base of a constructed environment embodiment.

[0095] FIG. **69** shows a top, front, right perspective view of a vertical brise soleil embodiment.

[0096] FIG. **70** shows a top, front, right perspective view of a vertical brise soleil embodiment with the covers removed.

[0097] FIG. **71** shows a top, front, right perspective view of the central shaft and base of a vertical brise soleil embodiment.

[0098] FIG. **72** shows a top, front, right perspective view of the top and bottom sections of a vertical brise soleil embodiment with the covers removed.

[0099] FIG. **73** shows a top, front, right perspective section cut view of the bottom of a vertical brise soleil embodiment.

[0100] FIG. **74** shows a top, front, right perspective section cut view of the bottom of a vertical brise soleil embodiment.

[0101] FIG. **75** shows a right section cut view of the top and bottom sections of a vertical brise soleil embodiment.

[0102] FIG. **76** shows a right section cut view of the top and bottom sections of a vertical brise soleil embodiment.

[0103] FIG. **77** shows a top, front, right perspective view of several vertical brise soleil embodiments.

[0104] FIG. **78** shows a top, front, right perspective view of a horizontal brise soleil embodiment.

[0105] FIG. **79** shows a top, front, right perspective view of a horizontal brise soleil embodiment with some devices removed and some devices cut into sections.

[0106] FIG. **80** shows a top, front, right perspective view of one horizontal brise soleil embodiment device cut into sections.

[0107] FIG. **81** shows a top, front, right perspective section cut view of one horizontal brise soleil embodiment device cut into sections.

[0108] FIG. **82** shows a front section cut view of one horizontal brise soleil embodiment device cut into sections.

[0109] FIG. **83** shows a front section cut view of one horizontal brise soleil embodiment device cut into sections.

[0110] FIG. **84** shows a top, front, right section cut view of a portion of one horizontal brise soleil embodiment device.

[0111] FIG. **85** shows a top, front, right perspective view of a patterned brise soleil embodiment.

[0112] FIG. **86** shows a top, back, left perspective view of a patterned brise soleil embodiment.

[0113] FIG. **87** shows a left side view of a patterned brise soleil embodiment.

[0114] FIG. **88** shows a top, front, left perspective view of a detail of a patterned brise soleil embodiment.

[0115] FIG. **89** shows a top, front, left perspective view of a detail of a patterned brise soleil embodiment.

[0116] FIG. **90** shows a front section cut view of a patterned brise soleil embodiment.

[0117] FIG. **91** shows a top, front, left perspective section cut view of the bottom of a patterned brise soleil embodiment.

[0118] FIG. **92** shows a top, front, left perspective section cut view of the top of a patterned brise soleil embodiment.

[0119] FIG. **93** shows a top, front, left perspective section cut view of the bottom of a patterned brise soleil embodiment.

DETAILED DESCRIPTION

[0120] A hygroscopic AWG apparatus extracts atmospheric water vapor in low humidity environments. The apparatus is comprised of a container with a closable chamber and a thermal management system, allowing the optimization of absorption and desorption cycles.

AWG & Hygroscopics

[0121] AWGs harvest water vapor from the surrounding atmosphere. The current apparatus includes a hygroscopic material for absorbing the water vapor. Furthermore, the hygroscopic material alternates between hydrophilic and hydrophobic with changes in temperature. In one embodiment, the hygroscopic material is hydrophilic at temperatures below 45-Celcius and hydrophobic above 45-Celcius. Alternative temperature ranges are envisioned.

[0122] In one embodiment, the hygroscopic material is comprised of an interpenetrating polymer network composite. The composite is comprised of at least two polymers. One polymer is hygroscopic, capable of absorbing water vapor from the air, and one is a thermoresponsive polymer that can reversibly change between hydrophilic and hydrophobic.

[0123] In one embodiment, the hygroscopic hydrogel polymer is konjac glucomannan ("KGM"). An alternative hygroscopic polymer is sodium alginate ("SA"). KGM is a natural polymer found in konjac roots, and SA is a natural polymer extracted from brown seaweed or bacteria. Any hygroscopic hydrogel polymer that can form a film, sheet, or coating is suitable.

[0124] In one embodiment, the thermoresponsive polymer is hydroxypropyl cellulose ("HPC"). HPC is derived from the cellulose of fibrous plant material, or bacterial cellulose, and is soluble in water. Alternative thermoresponsive polymers that change in their hydrophilicity/hydrophobicity include Poly (N-substituted acrylamide) s, such as poly (N-isopropylacrylamide ("PNIPAM"), and poly (N-substituted acrylamide) derivatives; ethylene glycol-based polymers, such as Poly (oligoethylene glycol methacrylate) ("POEGMA"), and POEGMA derivatives; poly (N-vinylcaprolactam) ("PNVCL"); and poly (oxazoline) s.

[0125] When the temperature is low, the hygroscopic polymer absorbs and holds atmospheric water vapor. The hygroscopic polymer becomes damp and then wet as it approaches saturation. As the temperature rises, the thermoresponsive polymer reversibly changes from hydrophilic to hydrophobic and repels water from the interpenetrating polymer network composite. The water is emitted as a higher concentration of water vapor during desorption.

[0126] Alternative embodiments may further be comprised of a salt, which is hygroscopic and antimicrobial. One embodiment used Calcium Chloride ($CaCl_2$)), which is derived from natural brines found in stone formations. It is the most abundant salt found in seawater. Alternative salts include magnesium chloride, sodium chloride, and lithium chloride. Others may include zinc chloride, lithium bromide, and potassium chloride.

[0127] Alternative embodiments of the hygroscopic material may also include dopants and additives to improve performance. The addition of nanomaterials may improve antimicrobial properties, thermal properties, electrical properties, porosity, or biodegradability.

[0128] In one embodiment, the interpenetrating polymer network composite is made by dissolving HPC in distilled water and adding the $CaCl_2$) salt. Its pH is balanced (to 8.5) by adding minute amounts of citric acid (e.g., from lemons or limes or other fruit). KGM is then added, and the solution is immediately cast, sprayed, or deposited on the reinforcement material, because gelation occurs very quickly.

[0129] Dopants may be added to the solution before pH balancing and before gelation occurs, although it may be possible to soak them up from a dopant brine after gelation.

[0130] After the gel sets, the composite is frozen and then dried in a freeze dryer or with an air dryer. This produces a porous composite with increased active surface area.

[0131] In addition to interpenetrating polymer network composites, other hygroscopic materials are envisioned. In an alternative embodiment, a metal-organic framework (MOF) provides a material for absorbing water vapor under certain conditions, which can then be released with the application of heat. Any hygroscopic material capable of absorbing water vapor and then releasing it after a change in conditions is envisioned.

Chamber

[0132] The apparatus is comprised of a container, with the hygroscopic material inside a closable chamber. See FIGS. **1** and **2**. The container **101** could be any size or shape. One embodiment utilizes a container about the size of a shoebox. The surfaces of the container may be opaque to protect against external light.

[0133] Some embodiments of the apparatus may include insulation surrounding the container to control the temperature inside the chamber. See FIGS. **3** and **4**. Some embodiments may include a reflective surface to repel sunlight and its associated heat.

[0134] The container may be composed of various materials. The following factors may impact the choice of material: hydrophobicity and hydrophilicity, water absorption and desorption efficiency, thermal properties, electrical properties, manufacturability, cost, weight, durability, recyclability and disposability, albedo, etc.

[0135] The container and components may be composed of materials that resist microbial growth and contamination. Antimicrobial materials include copper, silver, and salt. In one embodiment, the hygroscopic material is further comprised of antimicrobial copper, silver, or carbon nanomaterials.

[0136] Some embodiments of the apparatus have a removable lid **501** for accessing the interior of the chamber. See FIG. **5**.

[0137] The apparatus allows air to enter and exit the chamber. Some embodiments have a separate air intake **502** and exhaust valve **503**. One embodiment is further comprised of a microporous filter on the air intake and exhaust vent, to prevent microbes, spores, and other contaminants from entering the chamber. The apparatus is comprised of a means for withdrawing the water **504**. One embodiment collects and drains water at the bottom of a sloped surface.

[0138] FIGS. **6** and **7** show two views of one embodiment of an apparatus with portions of the chamber cut away to show the interior. A series of parallel HCS's **601**, **701** hold the hygroscopic material.

Hygroscopic Composite Sheet

[0139] The hygroscopic material is housed inside the chamber. One embodiment uses an HCS. An HCS is comprised of a reinforcement material providing structure to a hygroscopic polymer composite. See FIGS. **8**-**21**, showing multiple embodiments of HCS's.

[0140] The reinforcement material may be solid or perforated, a woven or non-woven mesh, a network of wires and/or fibers and/or tubes, a fabric, or a porous solid (e.g., open cell rigid foam). The reinforcement material may be composed of metals, metals combined with natural fibers (e.g., hemp, flax, cotton), carbon nanomaterials (nanoparticles, graphene, nanotubes and nanofibers, etc.), conductive polymers, ceramics, or glass (e.g., highly porous metal-organic framework glasses). The reinforcement material is chosen for suitable properties, including strength, thermal conductivity, electrical conductivity, durability, workability/handling, manufacture, scalability, configuration, shipping, modification, replacement, reuse, recyclability, and/or disposal.

[0141] FIG. **8** shows one embodiment of an HCS. A flat sheet of hygroscopic polymer composite is attached to two layers of reinforcement material **801**. The purpose of a sheet format is to maximize surface area of the hygroscopic polymer composite. Greater surface area provides an increased rate of absorption, and any embodiment providing additional surface area is envisioned. Multiple thin HCS's may be placed in a single apparatus. This embodiment has one side of the hygroscopic polymer composite exposed to the air.

[0142] One embodiment uses an adhesive to attach the composite to the reinforcement material. In one embodiment the reinforcement material may be a copper sheet, with electrical and thermal conductivity. In an alternative embodiment, the reinforcement material is a double-sided tape with thermally conductive and electrically insulative properties. This double-sided tape may be attached to copper sheet or another reinforcement material.

[0143] FIG. **9** shows an HCS with the hygroscopic polymer composite and one layer of reinforcement material cut away. A resistance heating wire **901** runs between the two layers of reinforcement material. The wire resists electricity causing it to heat up. In one embodiment, the wire is nichrome. In other embodiments, the wire is an iron-chromium-aluminum alloy, copper-nickel alloy, nickel-iron alloy, nichrome V, stainless steel, or copper-manganese-nickel alloy.

[0144] One embodiment is an HCS with polymer composite on both sides. FIG. **10** shows an alternative embodiment with two sheets of hygroscopic polymer composite **1001** covering both sides. There are two layers **1002** of reinforcement material between the polymer sheets. A resistance heating wire **1003** runs between the two layers of reinforcement material. The benefit of this embodiment is that both sides of the HCS can absorb/desorb water, greatly increasing efficiency with each cycle.

[0145] FIG. **11** shows an alternative embodiment with hygroscopic polymer composite on both sides. This embodiment is comprised of a flat ribbon resistance heating wire **1101** running between the two layers of reinforcement material.

[0146] The HCS may be made by casting the composite around the reinforcement material. See FIG. **12**. In one embodiment, a mesh reinforcement material **1201** is laid into a bed of solution that has not yet fully gelled. In an alternative embodiment, the HCS is formed by casting two layers of composite **1301** and attaching them to both sides of the reinforcement material **1302**. See FIG. **13**.

[0147] FIGS. **14** and **15** show embodiments with a resistance heating wire **1401**, **1501** running along the reinforcement material.

[0148] In an alternative embodiment, several spheres of hygroscopic polymer composite **1601** are attached to the reinforcement material **1602**. See FIG. **16**. The spherical shape increases surface area of the composite. FIG. **17** shows an alternative embodiment where the spheres **1701** are encased between two layers of reinforcement material **1702**.

[0149] FIG. **18** shows an alternative embodiment where the hygroscopic polymer composite is attached to reinforcement material through a mechanical means. In this embodiment, several protrusions **1801** create anchors to hold the composite **1802** to the reinforcement material **1803**.

[0150] Alternative embodiments are comprised of sheets coiled in a spiral, and pleated/folded sheets (origami-like). FIG. **19** shows one embodiment where the HCS **1901** is coiled into a spiral. The HCS may be comprised of the hygroscopic polymer composite, reinforcement material, and a means of heating the HCS. Space between the coils permits air flow across both sides of the HCS.

[0151] FIG. **20** shows a spiral embodiment with additional spacer media **2001** between the coils of HCS. The spacer media is an open-celled porous material permitting air flow. The spacer media may also serve as the reinforcement material for the HCS and/or it could be a means to heat the HCS. FIG. **21** is another spiral embodiment comprised of additional spacer media **2101** surrounding the perimeter of the HCS to prevent damage to the HCS, ensure air flow along the outside, and prevent contact with chamber walls.

[0152] One benefit of an HCS format is for easy insertion and removal of hygroscopic polymer composite from the apparatus, for cleaning or replacement. Salts in the polymer may degrade over time, thus lowering effectiveness, requiring replacement. In one embodiment, all components of the polymer composite are water soluble and biodegradable, allowing the sheets to be rinsed clean and allowing the washed reinforcement materials to be reused or repurposed.

Heat

[0153] The apparatus is comprised of a means of heating the HCS. Conduction, convection, and radiation are envisioned. One embodiment uses solar radiation as the heat source. Various means of heating may operate independently or in conjunction. The heat source may directly heat the HCS through conduction or heat the interior of the chamber and ambiently heat the HCS through convection. In one embodiment, the HCS's are thermally separated from the walls of the chamber. See FIG. **22**.

[0154] In some embodiments, the reinforcement material facilitates the transfer of heat across the HCS. In one embodiment the reinforcement material is comprised of copper, silver, aluminum, and/or thermally conductive tape. In one embodiment, the HCS is comprised of a layer of hygroscopic polymer composite, a sheet of copper, a layer of double-sided thermally conductive tape, a resistance heating metal wire, a second layer of double-sided thermally conductive tape, and a second sheet of copper. See FIGS. **8** and **9**. An alternative embodiment includes a second layer of hygroscopic polymer composite. See FIGS. **10** and **11**. The tape allows heat, but not electricity, to pass from the wire to the copper sheet. This facilitates the spread of heat across the HCS without shorting the current in the wire.

[0155] In one embodiment, each HCS is attached to a heating fin **2201**. The reinforcement material is composed of resistance heating wires that are attached to the heating fin. As the heating fin increases in temperature, the sheet heats as well, increasing the temperature of the hygroscopic polymer composite.

[0156] In one embodiment, a thermoelectric module (e.g., Peltier module) **2202**, **2301**, **2401** on one end of the chamber heats the heating fins. See also FIGS. **23** and **24**. The cold side **2402** of the thermoelectric module cools the wall **2403** of the chamber. Simultaneously, the hot side **2404** of the thermoelectric module heats the heating fins **2405** attached to the HCS. Some embodiments also have a heat sensor on each HCS to measure temperature **2406**.

[0157] In one embodiment, the HCS is equipped with an integrated resistance heating wire **2501**, **2601**. See FIGS. **25** and **26**. The integrated resistance heating wire **2501**, **2601** runs throughout the reinforcement material of the HCS, supplying heat to the polymer composite.

Absorption Phase

[0158] The apparatus operates in two phases: absorption and desorption. The absorption phase occurs at a lower temperature, and the desorption phase occurs at a higher temperature.

[0159] In one embodiment, the apparatus is comprised of an air intake **2701**, and an exhaust vent. See FIG. **27**. One embodiment includes a valve on the air intake and a valve on the exhaust vent. Both are open during the absorption phase to allow air to circulate through the chamber, and across the surface of the hygroscopic polymer composite. See FIG. **28**, showing an open valve **2801** on the air intake.

[0160] Some embodiments include a filter **2802** on the air intake. The filter may prohibit dust, particulates, spores, seeds, insects and other animals, and microbes from entering the apparatus.

[0161] Some embodiments include a fan **2803** to aid circulation. The fan may be inside the chamber, or at the air intake. As the fan operates, it pulls air through the air intake. One embodiment has a valve, which opens automatically with air flow. Some embodiments are comprised of reversable fans to adjust air flow during different phases. Other embodiments utilize impeller fans. Alternative embodiments may circulate air through wind or convection.

[0162] Air **2901** circulates within the chamber and exits through the exhaust vent **2902**. See FIGS. **29** and **30**. As the air circulates, it crosses over the surface of one or more HCS's. See FIG. **30**. The larger volume of air that passes through the chamber, the greater the opportunity for the hygroscopic polymer composite to absorb water vapor.

[0163] Over time, the rate of absorption diminishes as the polymer composite becomes more saturated. FIG. **31** shows several tests where the absorption rate decreases substantially around sixty minutes. In some embodiments, it may take several hours to reach the full saturation point (100% saturated), but only several minutes to reach the half saturation point (50% saturated). In one embodiment, the hygroscopic polymer composite reaches around 50% of full saturation at thirty minutes, and 75% saturation at fifty minutes. Absorption rates depend on relative humidity and other environmental conditions.

[0164] FIG. **32** shows a diagram of one embodiment of the apparatus during the absorption phase. In some embodiments, the air intake **3201** and the exhaust vent **3202** are positioned on opposite ends of the chamber to facilitate air flow across the HCS **3203**. The air intake and the exhaust vents are open and air flows through the chamber. As the air flows through the chamber and across the HCS, the hygroscopic polymer composite absorbs moisture from the air.

Desorption Phase

[0165] FIG. **33** shows a diagram of one embodiment of the apparatus during the desorption phase. The air intake **3301** and the exhaust vent **3302** are closed. The HCS **3303** is heated causing the hygroscopic polymer composite to desorb moisture in the form of water vapor **3304**. Some embodiments are equipped with a condensation surface **3305**. This surface collects and condenses water vapor, which then exits through a drain **3306** as liquid water.

[0166] The desorption phase follows the absorption phase. See FIG. **34**. The air intake **3401** and the exhaust vent **3402** are closed to prohibit any water vapor from leaving the chamber. The polymer composite is heated, bringing the temperature to the point where the hygroscopic material becomes hydrophobic and starts expelling water vapor.

[0167] The water vapor fills the interior of the chamber. Some embodiments include a fan **3403**, **3501** to help the air circulate throughout the interior. See also FIG. **35**. Alternative embodiments may not require a fan, as the air circulates via convection. Some embodiments include a heat sensor and display **3601**. See FIG. **36**.

[0168] The water vapor is condensed and collected. See FIG. **37**. In one embodiment one or more surfaces are cooled inside the chamber to facilitate condensation. One surface could be the interior of the chamber itself. A thermoelectric device, used for heating the HCS's, has a cold side which could provide a means of cooling the surface.

[0169] Alternative embodiments do not require active cooling, as the condensation surface temperature is already suitable. Alternative embodiments use a hydrophobic surface for condensation in place of, or in addition to, a cool surface. This hydrophobic surface may include interspersed hydrophilic regions that attract water vapor to aid collection. Another embodiment may include a means of shaking/vibrating the condensation surface to aid drainage.

[0170] In one embodiment, the water **3701** is collected in the bottom of the chamber and drained out of the apparatus. The bottom of the chamber may be sloped to allow gravity to carry condensed water to the drain. Some embodiments include a water filter, P-trap, and/or valve at the drain **3702**.

[0171] A desorption cycle may last several minutes. In one embodiment, the desorption cycle lasts sixty minutes. Once the polymer composite is sufficiently desorbed, the apparatus can transition to an absorption cycle.

[0172] FIG. **38** shows two complete absorption/desorption cycles. In this embodiment, the absorption and desorption phases are each set to sixty minutes. Alternative phase lengths are envisioned and are dependent on HCS performance and environmental factors. FIG. **39** shows several absorption/desorption cycles over the course of more than two days. The heating temperature during the desorption phases was increased from 50-Celsius to 60-Celsius to demonstrate changes in cycle times and saturation levels. As the temperature was increased, desorption rates increased, but overall saturation levels dropped.

[0173] Heating temperature during the desorption phase may be adjusted for individual devices to improve performance. In one embodiment, the heating temperature is at or above 50 C. The target absorption temperature may be below 40 C. The range between the heating temperature for desorption and the lower temperature for absorption is variable dependent upon atmospheric and material conditions.

Additional Elements

[0174] Some embodiments include various controls and meters to manage the apparatus. One embodiment is further comprised of electronics, including a processor, memory, receiver, transceiver, sensors, transformers, and power source. The electronics include a means of opening and closing the air intake, exhaust vent, and drainage valves and turning the heating/cooling elements on and off. The receiver/transceiver sends signals providing information and receives signals for remote operation of controls.

[0175] In one embodiment, a power source is a photovoltaic solar cell. The solar cell could also serve as means of shading the apparatus from solar radiation in addition to generating electricity.

[0176] One embodiment includes temperature sensors and controls. Locations of temperature sensors include the HCS, ambient air inside the chamber, air outside the chamber, and the condensation surface. One embodiment includes weight sensors to monitor the weight of HCS's, to assess saturation levels. One embodiment is also equipped with hygrometers on the interior and exterior of the apparatus.

[0177] The apparatus may include a means of displaying the status of measurements and operation of the absorption/desorption cycles.

Optimizing Cycles

[0178] One advantage of utilizing a temperature-controlled chamber with a heating element, is that hygroscopic absorption/desorption cycles can be optimized to greater efficiency over devices subject to the day/night cycle. Additionally, seasonal sunlight, cloudy weather, shadows cast upon the container, or adverse temperatures are eliminated as factors.

[0179] Additionally, the frequency of heating and reheating on successive desorption cycles could help reduce microbial growth.

[0180] During the absorption phase, the rate of absorption can be increased through monitoring of performance. The rate of absorption diminishes as the hygroscopic material becomes saturated. It is more efficient over time to transition to desorption prior to full saturation.

[0181] Likewise, the desorption cycle may be optimized by increasing heat to a specific temperature and controlling the temperature of the condensation surface.

[0182] Many absorption/desorption cycles can occur throughout a single day, and continue throughout the night, resulting in the highest possible water generation. In one embodiment, the apparatus can perform twelve absorption and desorption cycles in a single 24-hour period.

[0183] Additionally, absorption/desorption may be optimized over time by monitoring the performance of individual HCS's in a single apparatus. As one HCS starts to degrade, it can be replaced.

[0184] Some embodiments may utilize an artificial intelligence ("AI") system to continuously determine the optimal heat during the desorption phase and the optimal time to switch between absorption and desorption phases. The continuous inputs to the AI system may include the water generated from each cycle, the weight of each HCS, the internal and exterior temperature, the internal and exterior humidity, internal and exterior pressure, the target heat of the HCS during desorption, fan speed, and the energy expenditures for the heating, fans, and other controls. The system will record performance of water generation according to the various parameters. As conditions change the AI may predict the optimal heat to apply during the desorption phase and the optimal times to change to the next phase in the generation cycle.

[0185] The apparatus is scalable as an individual unit or as a system. The larger a single apparatus, the greater amount of hygroscopic material it can possess and the more water it can harvest in a single cycle.

[0186] Additionally, multiple apparatuses can operate in unison. They can share resources, such as the electronics, fan, drainage, and power source.

[0187] Alternatively, two or more apparatuses could operate in tandem, with one operating an absorption phase while the other is in a desorption phase. This would ensure a continuous supply of water and would reduce surges in power demand because they are not all being heated at the same time.

[0188] Furthermore, when operating in tandem, two apparatuses could share a chamber wall, where one surface is hot and the other is cool. This could be accomplished using a thermoelectric device and/or hydronics (liquid heating and cooling). FIGS. **40** and **41** show one embodiment of a system with two apparatuses. The thermoelectric devices **4001**, **4101** are placed on common walls, increasing overall efficiency of resources.

[0189] In a system configuration, an individual apparatus could be replaced while the others maintain operation.

Dual Chamber Embodiment

[0190] FIG. **42** shows one embodiment of an apparatus, that utilizes dual chambers for air flow. An insulation cover **4201** over the container aids temperature control. FIG. **43** shows the dual chamber embodiment with the insulation cover removed. An exhaust vent **4301** is positioned at the top of the chamber **4302**. A display/control panel **4303** is shown at the bottom of the apparatus.

[0191] FIG. **44** shows the dual chamber embodiment with the lid **4401** removed. An internal fan **4402** and a cartridge of HCS's **4403** are visible. FIG. **45** shows the ability to remove the body of the container **4501** from the base of the apparatus **4502**. The bottom of a cartridge of HCS's **4503** is visible. The ability to remove the lid and body of the container facilitates the replacement of HCS's and other components.

[0192] FIG. **46** shows one embodiment of a removable cartridge. This embodiment shows a cartridge with eleven HCS's. Each HCS is separated by space to permit air flow vertically across the surfaces of the hygroscopic polymer composite. FIG. **47** shows a removable cartridge in packaging material for safe transport.

[0193] FIG. **48** shows a side section cut view of the dual chamber embodiment with the insulation cover. The cartridge **4801** is shown on the right chamber, with the section cut running through the HCS showing the internal resistance heating wires. FIG. **49** shows the side section cut view with the insulation cover removed and the side of one HCS **4901**. The dual chamber embodiment is designed to utilize convection air flow and water flow.

[0194] During the absorption phase, the air intake **4902** and the exhaust vent **4903** are open. Air flows from the bottom up through the right chamber and out through the exhaust vent. Circulation fans **4904** are positioned at the top and bottom to facilitate air flow.

[0195] FIG. **50** shows a detail of the base of the dual chamber embodiment. In this embodiment, the air intake **5001** is protected by an insect screen **5002**, which filters air before entering the chamber. An impeller fan **5003** pulls air in through the air intake. An internal fan **5004** may facilitate air circulation during the absorption phase.

[0196] The exterior of the container is further comprised of a drip edge **5005** to prevent rainwater from entering the air intake. A drain **5006** is position at the nadir of curved surfaces to facilitate drainage during the desorption phase.

[0197] During the desorption phase, the air intake **5001** is closed. The fan **5004** moves air up through the right chamber up and across the surface area of the HCS's. One embodiment is comprised of a thermoelectric module **5007** that cools the left side and heats the right side. Air flows up through the heated right side of the thermoelectric module and continues up through the right chamber. The air then descends the left chamber **5008**. As the air crosses the cool left side of the thermoelectric module it condenses and drips to the bottom of the chamber, and into the drain.

[0198] FIG. **51** shows a top section cut view of the base of the apparatus. The cool side **5101** of the thermoelectric module is in the left chamber, and the heated side **5102** of the thermoelectric module is in the right chamber. The fan **5103** facilitates air flow up through the right chamber.

[0199] FIG. **52** shows a detail of the top of the dual chamber embodiment. During the absorption phase, air flows up the right chamber **5201**, through the top chamber **5202**, and out the exhaust vent **5203**. During the desorption phase, the HCS's expel water vapor which travels up through the right chamber, through the top chamber, and down the left chamber **5204**. A circulation fan **5205** and curved surface across the top chamber facilitates air flow.

[0200] FIG. **53** shows a top section cut view of the top chamber of the dual chamber embodiment. The HCS's are shown in the right chamber **5301** and a fan is shown in the left chamber **5302**. A divider **5303** forms the dual chambers within the container.

[0201] FIG. **54** shows a perspective view of an alternative embodiment with dual chambers. This embodiment utilizes a curved container. FIG. **55** shows a section cut of the perspective view. The HCS **5501** is in a spiral format in the right chamber. FIG. **56** shows a section cut side view of the alternative dual chamber embodiment during the absorption phase. The air intake **5601** and exhaust vent **5602** are open. This embodiment has one internal circulation fan **5603** at the bottom of the left chamber, and one impeller fan **5604** at the air intake.

[0202] FIG. **57** shows a perspective view of the alternative dual chamber embodiment with a portion of the container removed. FIG. **58** shows a section cut side view of the embodiment in the desorption phase. The air intake **5801** and exhaust vent **5802** are closed. The thermoelectric module **5803** provides cooling surfaces to facilitate condensation during the desorption phase. The heated side of the module is sunk into the exterior wall or outside of the container.

Constructed Environment Embodiment

[0203] The AWG may be incorporated into a building system or other constructed environments. Several constructed environments are imagined, including residential, commercial, industrial, institutional, public facilities, stadiums, transportation infrastructure, and landscaping. Incorporating the device into a constructed environment has the dual benefit of utilizing aspects of the constructed environment while providing it with water.

[0204] The device may utilize the physical components of the structure to form the chamber. Structures often have empty spaces which are otherwise unused. The device may also coordinate with the building's existing plumbing, mechanical, electrical, and communications systems.

[0205] Additionally, the device may utilize a building's heating and cooling systems to create a condensation surface inside the container. One embodiment runs a cold-water pipe from a building's plumbing system or hydronics system into the chamber of the device. The cold-water pipe provides a cool surface for the desorption phase. The pipe may be located near a drain, facilitating condensation close to, or even within, the drain. Any cold fluid running through a pipe is envisioned.

[0206] FIG. **59** shows one embodiment of a device incorporated into a building. This device may be placed on the roof of a building, or on the ground next to the building. Additionally, the device may be incorporated into the structure of the building. The shape of the device is adaptable, as long as it is capable of comprising an interior chamber to perform the water generation. The embodiment in FIG. **59** is rectangular and could be incorporated into a wall. The device is split into three areas, a top **5901**, a middle portion **5902**, and a base **5903**. The base has at least one air intake port (not seen) and at least one air exhaust port **5904** on either side.

[0207] FIG. **60** shows how the embodiment may be disassembled. The top portion **6001**, or lid, may be removed. In this embodiment, the HCS's **6002** are attached to the lid. The middle portion **6003** is a housing, creating the chamber. The base portion **6004** is comprised of the at least one air intake port (not seen) and at least one air exhaust port **6005**, as well as internal fans **6006**.

[0208] FIG. **61** shows the HCS's **6101** inside the device with the lid and middle portion removed. FIG. **62** shows the base, comprised of at least one air intake port (not seen), and at least one air exhaust port **6201**. An open valve **6202** shows how air enters the chamber during the absorption phase.

Fans **6203** may facilitate air flow during both the absorption phase and the desorption phase.

[0209] FIG. **63** shows a front section view of the embodiment. The HCS's **6301** nearly span the length of the chamber, but do not touch the sides to allow air flow within the chamber. FIG. **64** shows a side section view of the embodiment. The HCS's **6401** are parallel with gaps between them, allowing air flow across the surface of the HCS's interpenetrating polymer network compound.

[0210] FIGS. **63** and **64** show the device in the absorption phase. Air intake valve **6302** is open, allowing air to enter the chamber from the air intake port **6303**. A fan **6304** draws the outside air through port **6303** and pushes it through valve **6302**. Air exhaust port **6305**, **6402** opens and allows air to vent out of the chamber and through the air exhaust port **6306** to the outside. FIG. **65** shows a section of the base in the absorption phase. This figure shows the air intake valve **6501** open.

[0211] FIGS. **66**, **67**, and **68** show the embodiment in the desorption phase. The air intake valve **6601**, **6701**, **6801** is closed. The air exhaust valve **6602** is also closed. Air intake fan **6604** is off. The HCS's are heated to release water vapor from the interpenetrating polymer network compound. Fans **6603**, **6702**, **6802** circulate the water vapor around the interior of the chamber.

[0212] A cold-water pipe **6605**, **6703**, **6803** flows into and out of the base, creating a cool surface for condensation. In some embodiment the pipe is comprised of copper. As the water vapor encounters the cold-water pipe, the water vapor condenses into liquid water and drips down into a drain **6804** at the bottom of a sloped surface.

[0213] Another embodiment is the incorporation of the device into a brise soleil, or sunshade. The sunshade may be placed on the exterior of a building, on the roof, in front of a window, above a skylight, or in any location to shade humans, animals, plants, vehicles, equipment, or other objects from the sun. Some brise soleil systems are fixed, while others may move to accommodate the sun's changing position during the day or throughout the year. Brise soleil solar shades may serve as a good location for the device as they are easily accessible, there is direct access to air input, and they are exposed solar radiation for an energy source, directly heating the HCS or after converting to electricity.

[0214] FIG. **69** shows one embodiment of a brise soleil in a vertical orientation. This embodiment is capable of rotating around a central vertical axis. Support struts **6901** at the top and bottom of the device attach to a building façade or directly to a building structure. FIG. **70** shows this embodiment with two outside covers **6902** removed to reveal the interior chamber. Several HCS's **7001** run parallel up and down the length of the device, on either side of a central shaft **7002**.

[0215] FIG. **71** shows the central shaft **7101** and the base **7102**. A fan **7103** at the top of the shaft may circulate air and vapor down through the central shaft and throughout the interior chamber. FIG. **72** shows top and bottom section cuts of the device with the cover removed. A chain and sprocket system **7201** provides a means of rotating a series of devices. Other means are envisioned, including individual devices/units having their own dedicated motors. A support strut **7202** attached to a building structure also provides an interior drainage pipe, which delivers water to the building. In some embodiments a cold-water pipe **7203** may provide a means of cooling a condensation surface inside the chamber.

[0216] FIG. **73** shows a section cut of the base. One embodiment of a condensation surface **7301** is shown. This embodiment is designed to have a large surface area for condensation. In some embodiments the condensation surface may be made of aluminum or copper. It is cooled by connecting to a cold-water pipe **7302**. FIG. **74** shows an alternative embodiment, where a cold-water pipe **7401** is run in and out through a drainage pipe. The cold-water pipe runs up into the chamber, forming a loop **7402** and providing a condensation surface that facilitates drainage.

[0217] FIG. **75** shows a section cut of the top and bottom of a vertical brise soleil in the absorption phase. An air intake valve **7501** and air exhaust valve **7502** are open. An air intake fan **7503** pulls air into the chamber first through an insect screen with an air filter **7504**, and then through the air intake valve **7501**.

[0218] FIG. **76** shows a section cut of the top and bottom of a vertical brise soleil in the desorption phase. The air intake valve **7601** and the air exhaust valve **7602** are closed. The HCS's **7603** are heated, and a circulation fan **7604** directs air down through a central shaft **7605** towards a condensation surface **7606**. The condensation surface is connected to a cold-water pipe **7607** running through a horizontal support tube that connects a series of devices. The condensation surface attracts water vapor and condenses it into liquid water, which drips down towards the drain **7608**, and out of the device towards a building's plumbing system.

[0219] FIG. **77** shows several vertical brise soleil devices as they may appear on the façade of a building. Each brise soleil device may rotate individually or collectively, depending on the changing sun shading needs. In this embodiment, top and bottom support tubes connect the top and bottom of each device. The top support tube **7701** provides a means of rotating the devices, while the bottom support tube **7702** provides a cold-water pipe to cool a condensation surface and a drainage pipe to deliver condensed water from each device.

[0220] FIG. **78** shows a horizontal brise soleil embodiment. In this embodiment the devices are fixed. Alternative embodiments of moveable and fixed devices are envisioned for both vertical and horizontal brise soleil systems. This embodiment shows seven devices **7801** supported by three cantilevered support struts **7802**.

[0221] FIG. **79** shows the embodiment with three devices removed, and sections cut in one of the devices. The center support strut **7901** serves as drainage for all devices. FIG. **80** shows the device with cuts from FIG. **79**. Parallel HCS's **8001** fill the chamber. Permeable screens **8002** allowing air intake and exhaust enclose both ends. In this embodiment, a cold-water pipe **8003** is shown traveling out and back through the center support strut.

[0222] FIG. **81** shows the device from FIG. **80** with sections cut from the front panels of the device. A permeable screen **8101** is shown on the left side of the device, while the right side's screen is removed. The device is divided into four regions: two filter regions **8102** on the left and right side, and two HCS regions **8103** within a closable chamber. Fans and valves are located between the filter regions and the HCS regions, to facilitate air flow during the absorption phase. A circulation fan **8104** is shown in the middle to facilitate air flow during the absorption phase and desorption phase. A divider **8105** separates the chamber holding the HCS zones into a top and bottom portion. This ensures that air flows across both the top and bottom portions of the chamber during desorption.

[0223] FIG. **82** shows front section cuts of one device. Fans and valves **8201** are located on either side between the filter zones and the HCS zones. These valves are shown open, to represent the absorption phase. Air flows in from one side and out the other, across the HCS's in the chamber.

[0224] FIG. **83** shows the same front section cuts of the device in the desorption phase. The air intake and exhaust fans and valves **8301** are turned off and closed. The HCS's **8302** are heated and begin to expel water vapor into the chamber. The circulation fan **8303** is turned on to move water vapor around the chamber. As the water vapor traverses the bottom portion of the chamber, it crosses a condensation surface **8304**. In one embodiment, the condensation surface is made of aluminum or copper and is connected to a cold-water pipe **8305** running through the center support strut **8306**.

[0225] FIG. **84** shows a detail of the center portion of the device. In one embodiment, a cold-water pipe **8401** exits from the building and continues out through the center support strut. The cold-water pipe turns at the end of the center support strut and returns to the building as an inbound pipe **8402**. The cold-water pipe may lose heat during the journey out and back, with the outbound pipe slightly cooler. The condensation surface **8403** has a large cool surface area and is in contact with the outbound cold-water pipe **8401**. As water vapor contacts the condensation surface, it will condense and form liquid water, which drips down to the nadir of the center support strut **8404**. The center support strut is sloped at a slight grade, allowing water to drain out of the center support strut.

[0226] FIG. **85** shows one embodiment for a patterned brise soleil. This embodiment is comprised of multiple units **8501** fixed to a façade or side of building. The modular units may scale to fit any size or shape. FIG. **86** shows the reverse side of the patterned brise soleil. The units are supported by a structure **8601**, such that each unit may be removed individually for repair or replacement. The structure is attached to support struts **8602** connecting to a building's facade or structure **8603**. Other embodiments may attach to other structural components.

[0227] FIG. **87** shows a side view of the patterned brise soleil. The struts **8701** connect the patterned brise soleil to three floors of building structure **8702**, but this embodiment may span any number of floors. The top and bottom of the patterned brise soleil contains special functionality to facilitate the absorption and desorption phases.

[0228] FIG. **88** is a detail of the top of the patterned brise soleil. Two exhaust vents **8801**, covered with insect screens, allow air to flow out of the patterned brise soleil at the top. FIG. **89** is a detail of the bottom of the patterned brise soleil. One exhaust vent **8901**, covered with an insect screen and air filter, allows air to flow into the patterned brise soleil at the bottom.

[0229] FIG. **90** shows a front section cut of the patterned brise soleil embodiment. The units are comprised of two types. One unit type **9001** contains hygroscopic composite. In one embodiment, the units are filled with several hygroscopic composite spheres. A second unit type **9002** is empty, to allow unimpeded air flow. Air intake valves **9003** are positioned at the bottom, and air exhaust valves **9004** are positioned at the top. A condensation surface in the form of a cold-water pipe **9005** runs along the top of the patterned brise soleil embodiment, with a water collection trough positioned directly below the cold-water pipe. During the absorption phase, the valves are open, and air runs from the bottom up through the hygroscopic composite and then out through the top. Air flow may occur naturally through a chimney effect, or with the aid of fans **9006**. During the desorption phase, the valves are closed and fans **9006** circulate air to run up through the hygroscopic composite **9001**, across the condensation surface **9005**, and back down through the empty units **9002**.

[0230] FIG. **91** shows a detail section cut of the bottom of the patterned brise soleil. The valves **9101** are open to allow air intake during the absorption phase. Fans **9102** may facilitate air flow during both the absorption and desorption phases. FIG. **91** also shows a section cut through a porous heating element **9103** that may be used during the desorption phase.

[0231] FIG. **92** shows a detail section cut of the top of the patterned brise soleil. The valves **9201** are open to allow air exhaust during the absorption phase. A condensation surface, in the form of a cold-water pipe **9202** condenses water vapor during the desorption phase, which collects in a trough for drainage.

[0232] FIG. **93** shows a section cut of the patterned brise soleil during the desorption phase. The valves **9301** are closed, and a heating element **9303** heats the hygroscopic polymer composite. The fans **9302** circulate air up through the composite units **9304**. The air with water vapor reaches the top for condensation, then circulates back down through the empty units **9305**. FIG. **93** also shows a porous heating element **9306** that may be used during the desorption phase.

CONCLUSION

[0233] While there have been shown and described illustrative examples of a hygroscopic AWG, it is to be understood that various other adaptations and modifications may be made within the spirit and scope of the embodiments herein. Thus, while the foregoing description has been directed to specific embodiments, it will be apparent that other variations and modifications may be made to the described embodiments, with the attainment of some or all their advantages. Accordingly, this description is to be taken only by way of example and not to otherwise limit the scope of the embodiments herein.

1. An apparatus fixed to a constructed environment for harvesting water from the air,

a. comprising:

- a container with at least one chamber configured to be open or closed,
- a temperature-responsive hygroscopic material inside the at least one chamber, and
- a means for heating the temperature-responsive hygroscopic material,

b, wherein:

- the temperature-responsive hygroscopic material absorbs water vapor from the air when the at least one chamber is open, and
- the temperature-responsive hygroscopic material desorbs water vapor into the at least one chamber when the temperature-responsive hygroscopic material is heated and the at least one chamber is closed.

2. The apparatus of claim **1**, wherein the at least one chamber is integrated within the structure of a constructed environment.

3. The apparatus of claim **1**, wherein the apparatus is incorporated into a component of the constructed environment designed to provide shade from light.

4. The apparatus of claim **3**, wherein the component of the constructed environment designed to provide shade is configured to move, accommodating changing light conditions.

5. The apparatus of claim **3**, wherein the component of the constructed environment designed to provide shade from light is vertically oriented.

6. The apparatus of claim **3**, wherein the component of the constructed environment designed to provide shade from light is horizontally oriented.

7. The apparatus of claim **6**, wherein the horizontally oriented component is further divided into at least two horizontal chambers to facilitate airflow.

8. The apparatus of claim **3**, wherein the component of the constructed environment designed to provide shade from light is comprised of at least two modular units attached to a support structure.

9. The apparatus of claim **8**, wherein the at least two modular units are scalable to cover a portion of the constructed environment.

10. The apparatus of claim **9**, wherein at least one of the at least two modular units is configured to facilitate air flow.

11. The apparatus of claim **8**, wherein the at least two modular units are attached to a base unit with an air intake valve at the bottom and a top unit with an air exhaust valve at the top,

and are configured to facilitate air flow in from the intake valve at the bottom, up through the modular units, and out of the air exhaust valve at the top.

12. The apparatus of claim **1**, wherein temperature-responsive hygroscopic material is an interpenetrating polymer network composite comprised of at least one hydrophilic polymer and one thermo-responsive polymer.

13. The apparatus of claim **1**, wherein temperature-responsive hygroscopic material is a metal-organic framework.

14. The apparatus of claim **1**, further comprised of a condensation surface.

15. The apparatus of claim **14**, wherein the condensation surface is comprised of a pipe transporting cold fluid.

16. The apparatus of claim **1**, further comprised of at least one air intake valve allowing air flow into the at least one chamber and at least one air exhaust valve allowing air flow out of the at least one chamber.

17. The apparatus of claim **1**, further comprised of a fan inside the at least one chamber.

18. The apparatus of claim **1**, wherein the means for heating the temperature-responsive hygroscopic material is conduction from a heated material.

19. The apparatus of claim **1**, wherein the means for heating the temperature-responsive hygroscopic material is convection.

20. The apparatus of claim **1**, wherein the means for heating the temperature-responsive hygroscopic material is radiation.

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