US010882059B2

(12) **United States Patent**
Conrad

(10) **Patent No.: US 10,882,059 B2**
(45) **Date of Patent: Jan. 5, 2021**

(54) **MULTI CYCLONE ARRAY FOR SURFACE CLEANING APPARATUS AND A SURFACE CLEANING APPARATUS HAVING SAME**

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(73) Assignee: **Omachron Intellectual Property Inc.**, Hampton (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 232 days.

(21) Appl. No.: **16/201,649**

(22) Filed: **Nov. 27, 2018**

(65) **Prior Publication Data**

US 2020/0094267 A1 Mar. 26, 2020

Related U.S. Application Data

(60) Provisional application No. 62/734,603, filed on Sep. 21, 2018.

(51) **Int. Cl.**
B01D 45/00 (2006.01)
B04C 5/187 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B04C 5/187*** (2013.01); ***A47L 5/00*** (2013.01); ***A47L 9/165*** (2013.01); ***A47L 9/1608*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. B04C 5/187; B04C 9/00; B04C 5/28; B04C 2009/002; B01D 45/16; A47L 9/165;
(Continued)

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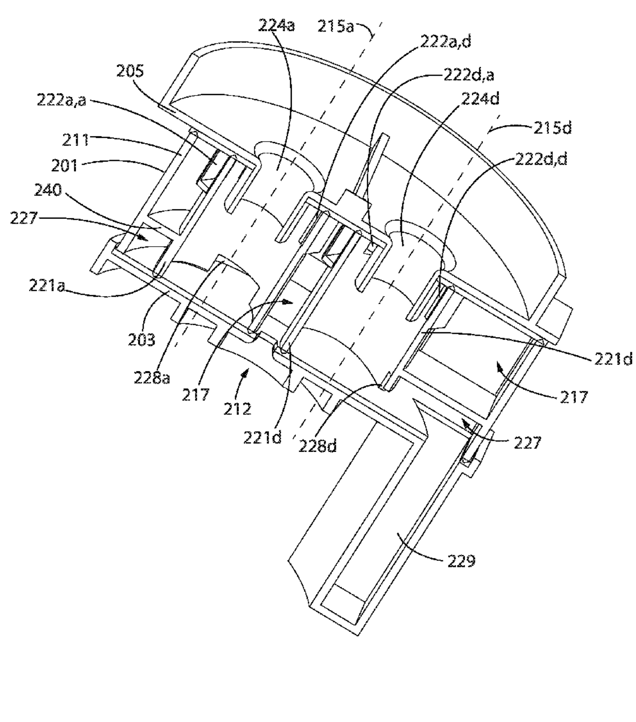
Primary Examiner — Dung H Bui
(74) *Attorney, Agent, or Firm* — Philip C. Mendes da Costa; Bereskin & Parr LLP/S.E.N.C.R.L., s.r.l.

(57) **ABSTRACT**

A surface cleaning apparatus has an upstream air treatment member and a downstream cyclonic cleaning stage that includes a plurality of cyclones in parallel. Each cyclone has a cyclone axis of rotation, a first end, an axially spaced apart second end, a sidewall extending between the first and second ends, an air inlet, an air outlet, and a sideways dirt outlet. The surface cleaning apparatus also includes a dirt collection chamber and a dirt collection plenum.

20 Claims, 42 Drawing Sheets



(51) **Int. Cl.**
B01D 45/16 (2006.01)
B04C 9/00 (2006.01)
B04C 5/28 (2006.01)
A47L 9/16 (2006.01)
A47L 5/00 (2006.01)

(52) **U.S. Cl.**
CPC ***A47L 9/1641*** (2013.01); ***A47L 9/1658*** (2013.01); ***A47L 9/1683*** (2013.01); ***B01D 45/16*** (2013.01); ***B04C 5/28*** (2013.01); ***B04C 9/00*** (2013.01); *B04C 2009/002* (2013.01)

(58) **Field of Classification Search**
CPC A47L 9/1683; A47L 9/1658; A47L 5/00; A47L 9/1608; A47L 9/1641; A47L 9/1625
See application file for complete search history.

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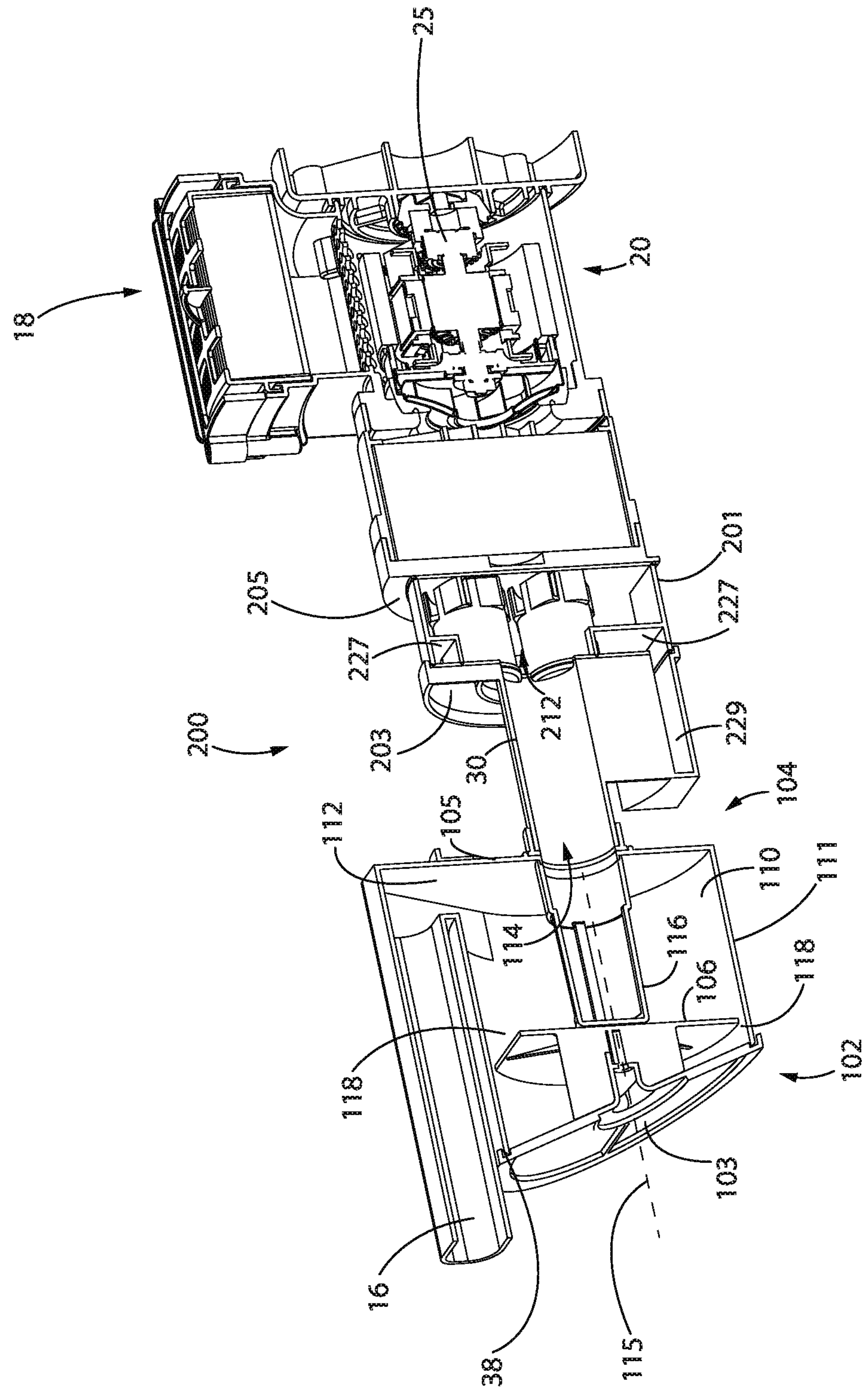
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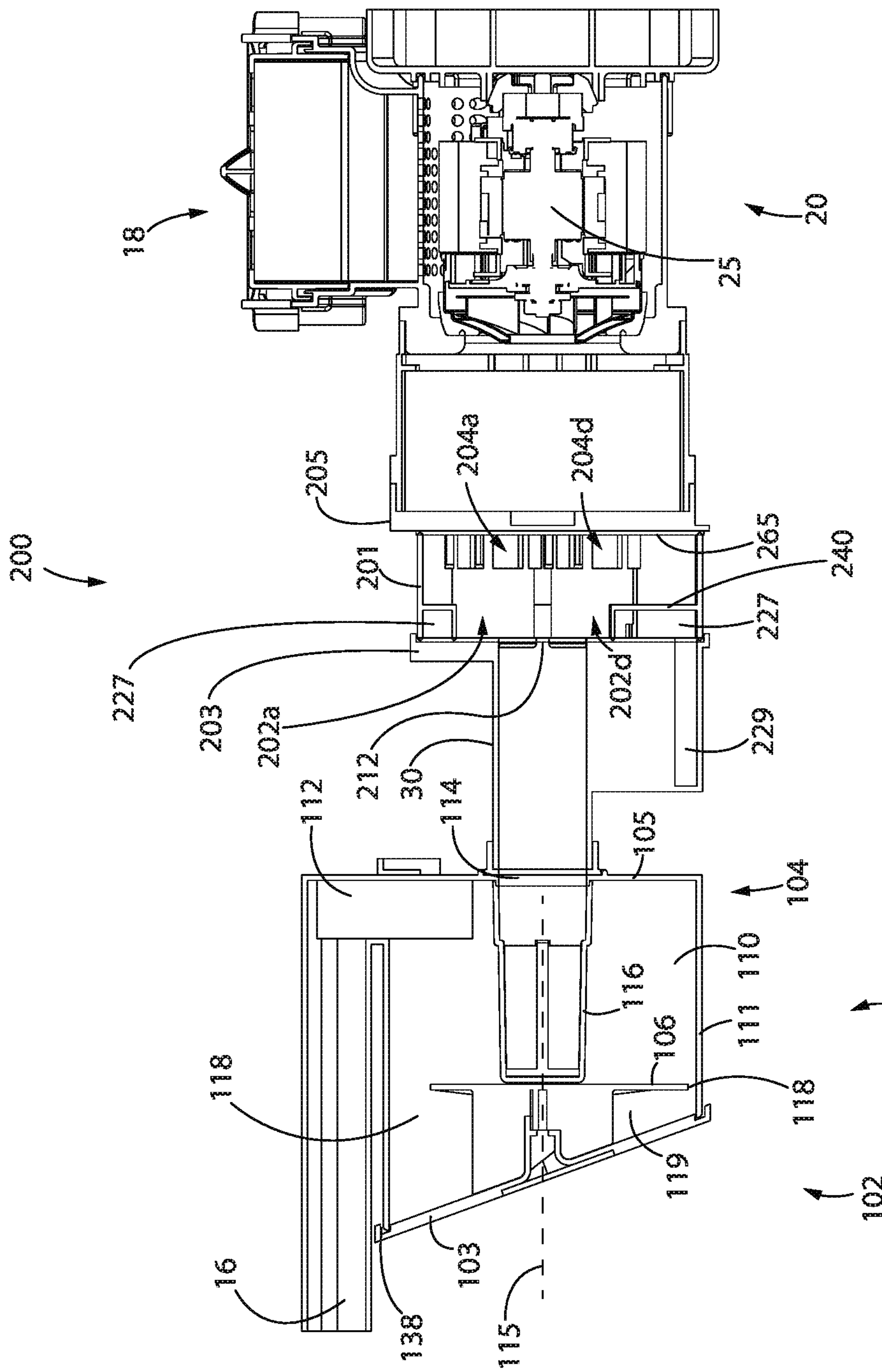
FIG. 1

FIG. 2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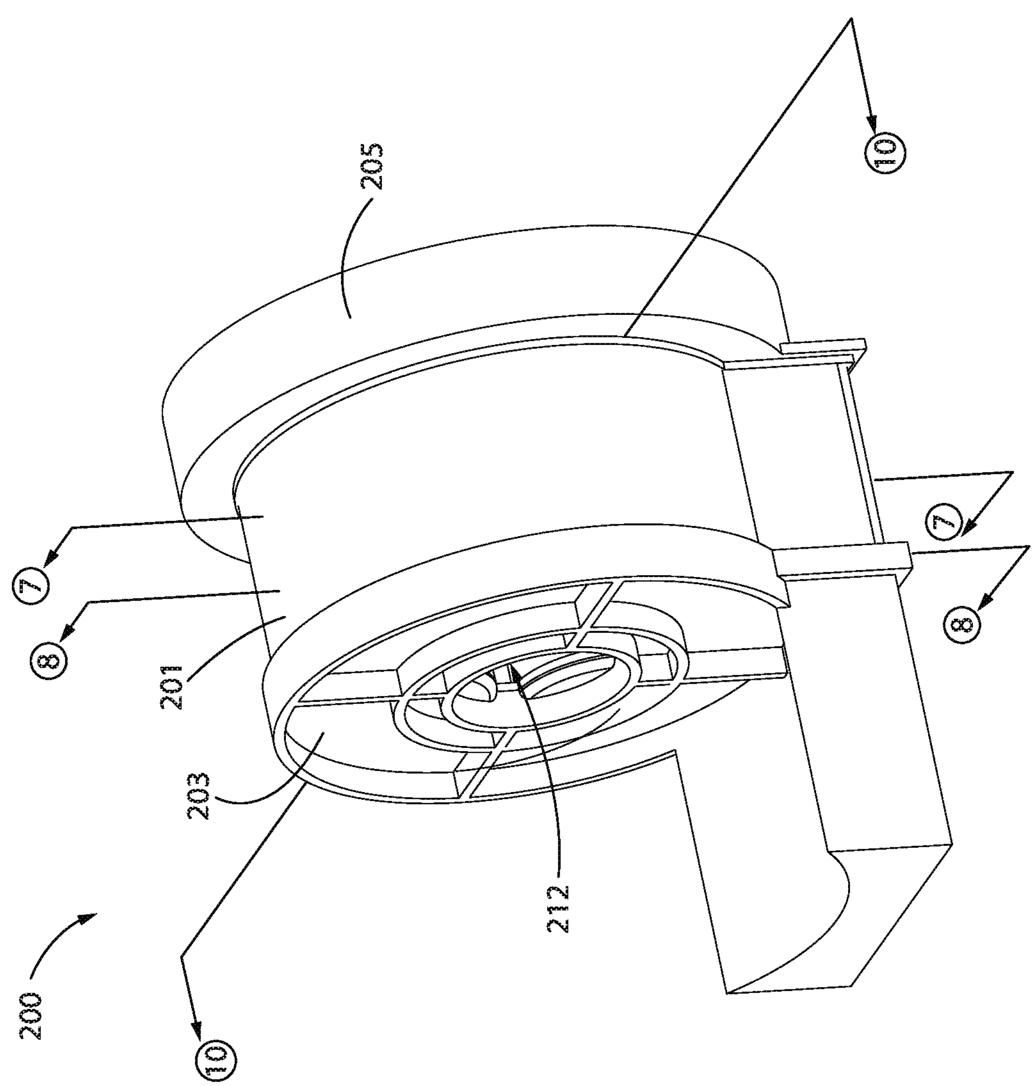

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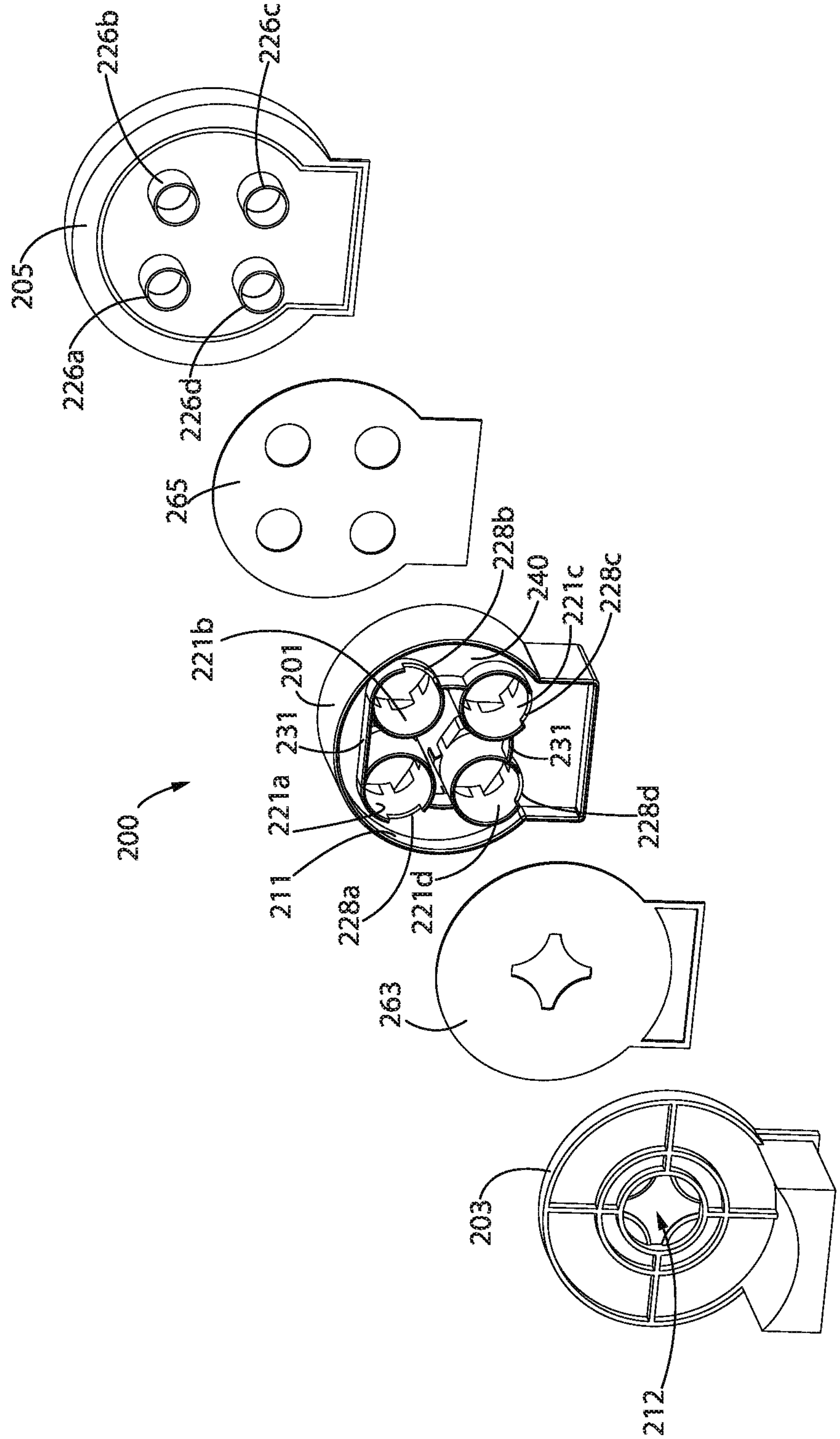
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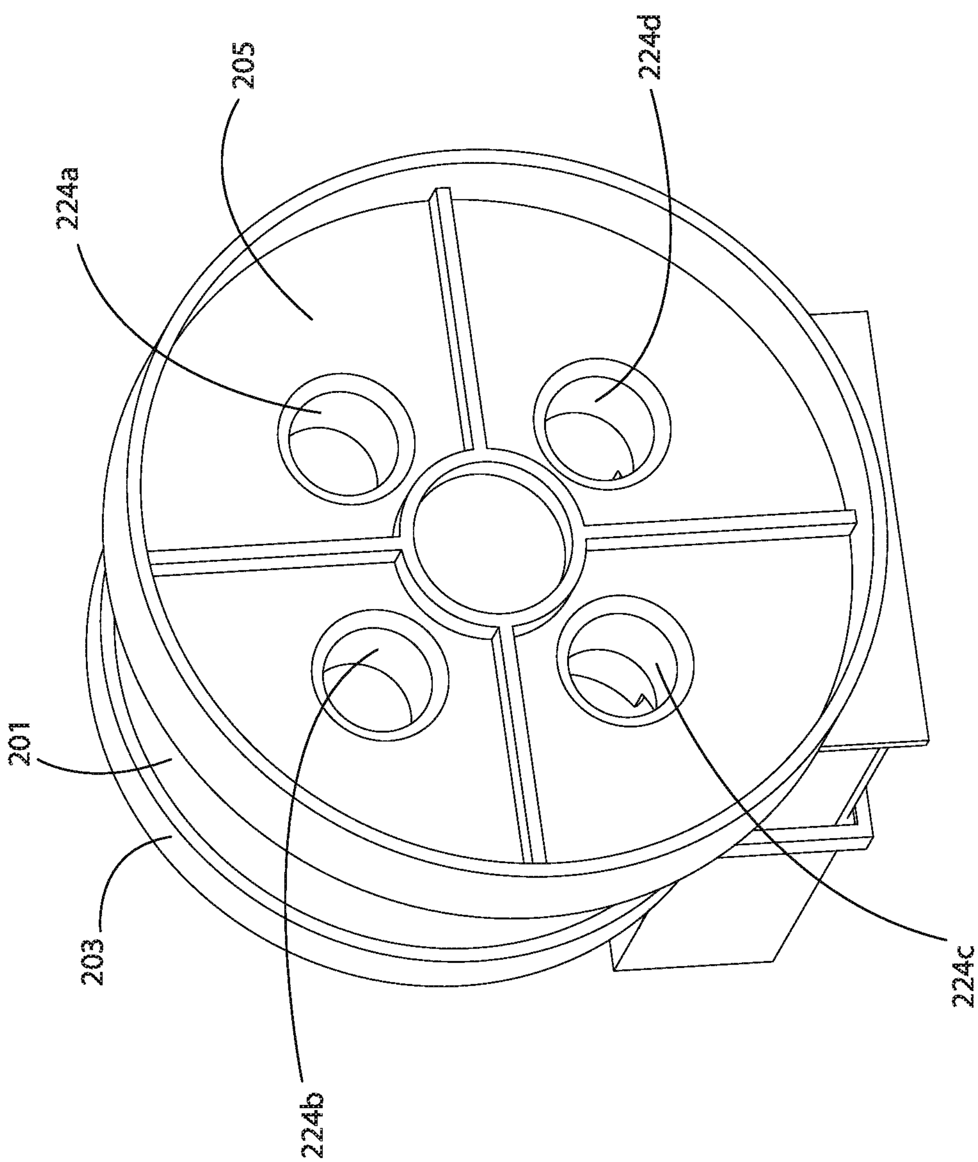
FIG. 4

FIG. 5



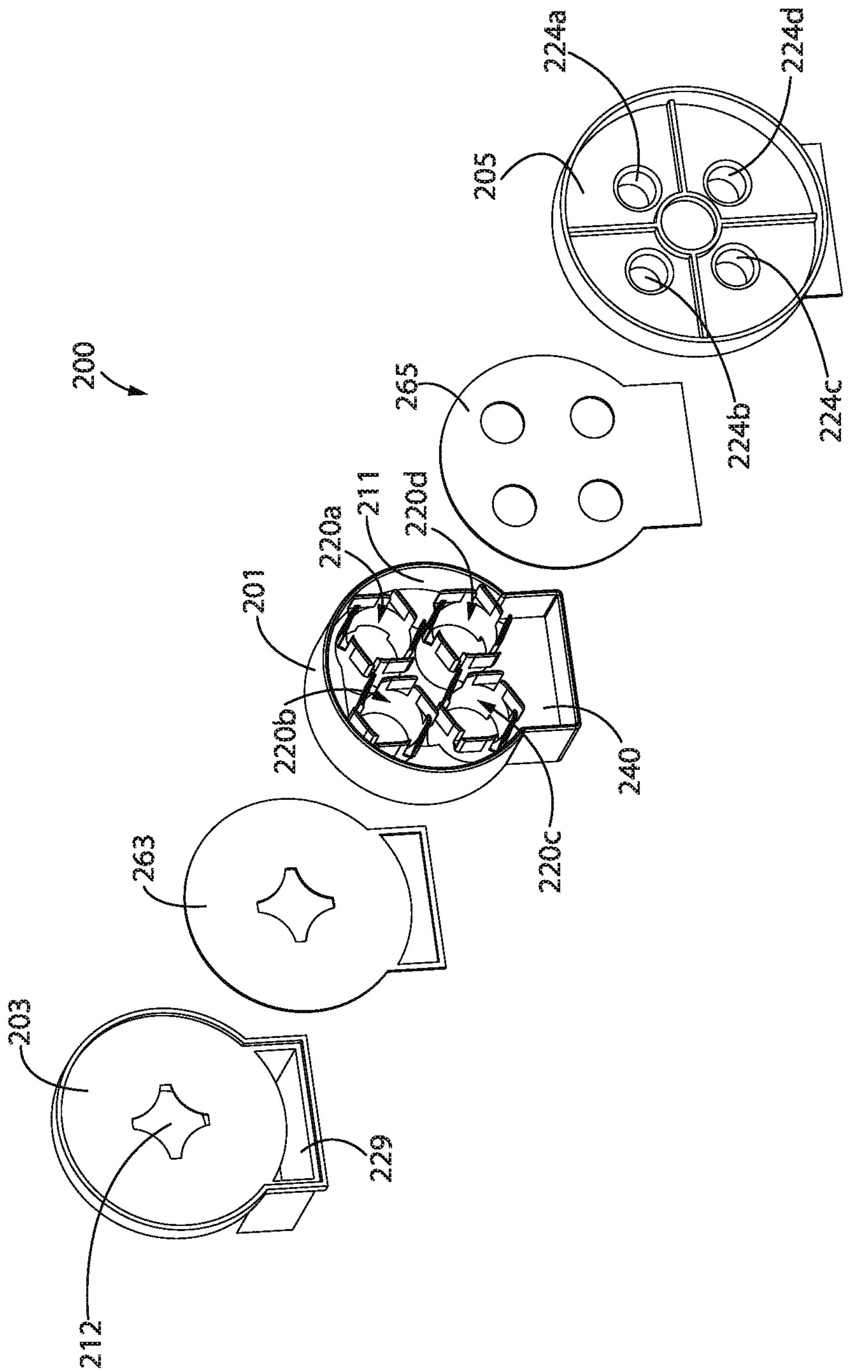

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FIG. 6

FIG. 7

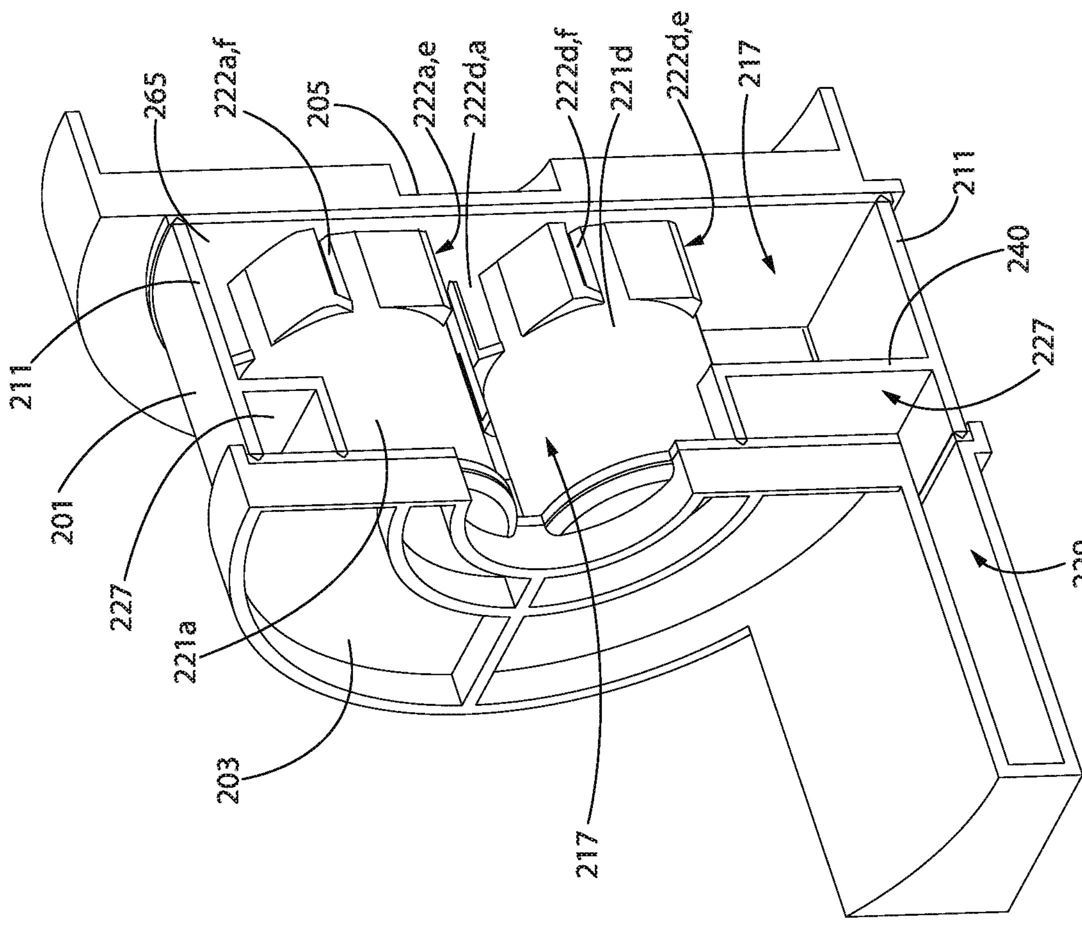
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FIG. 8

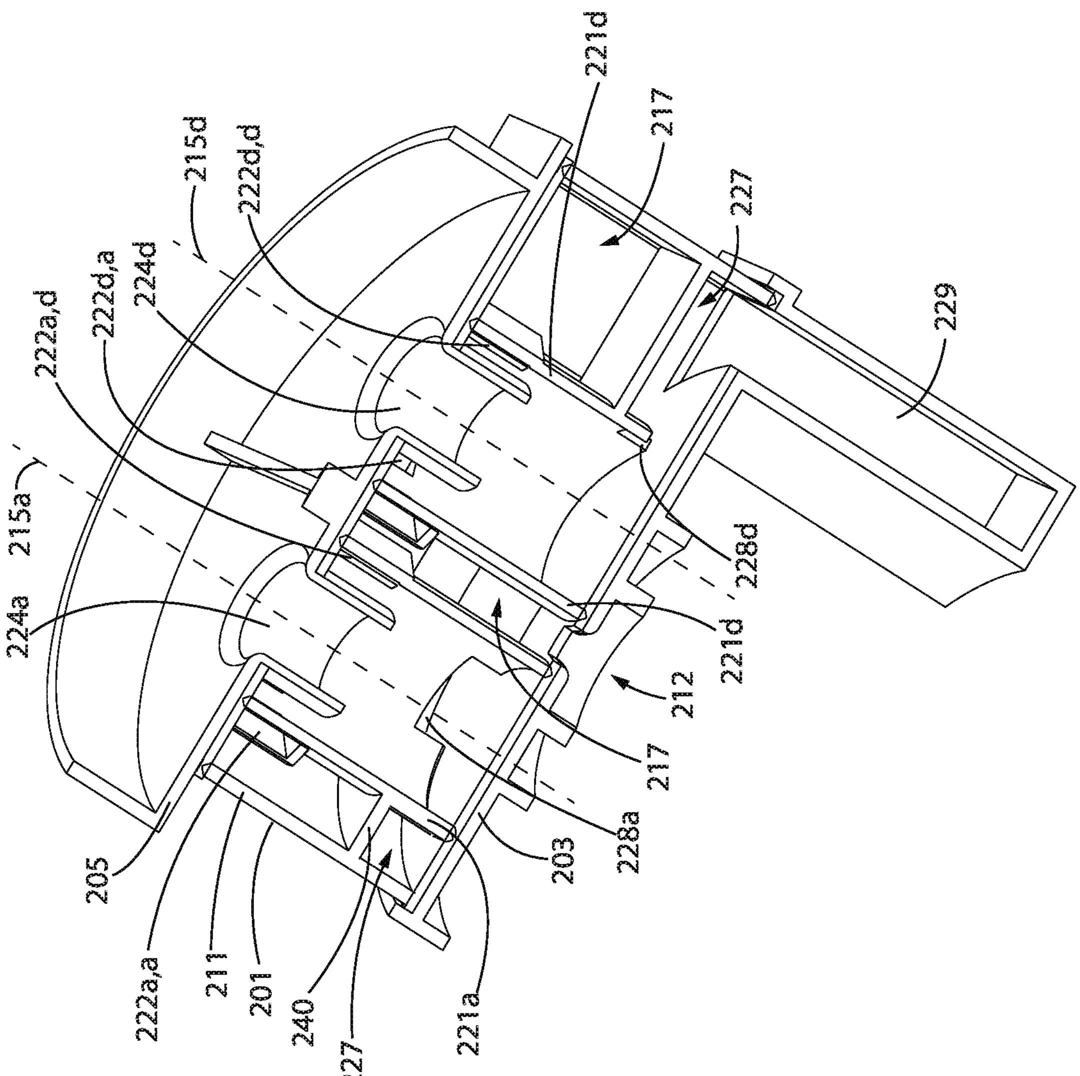
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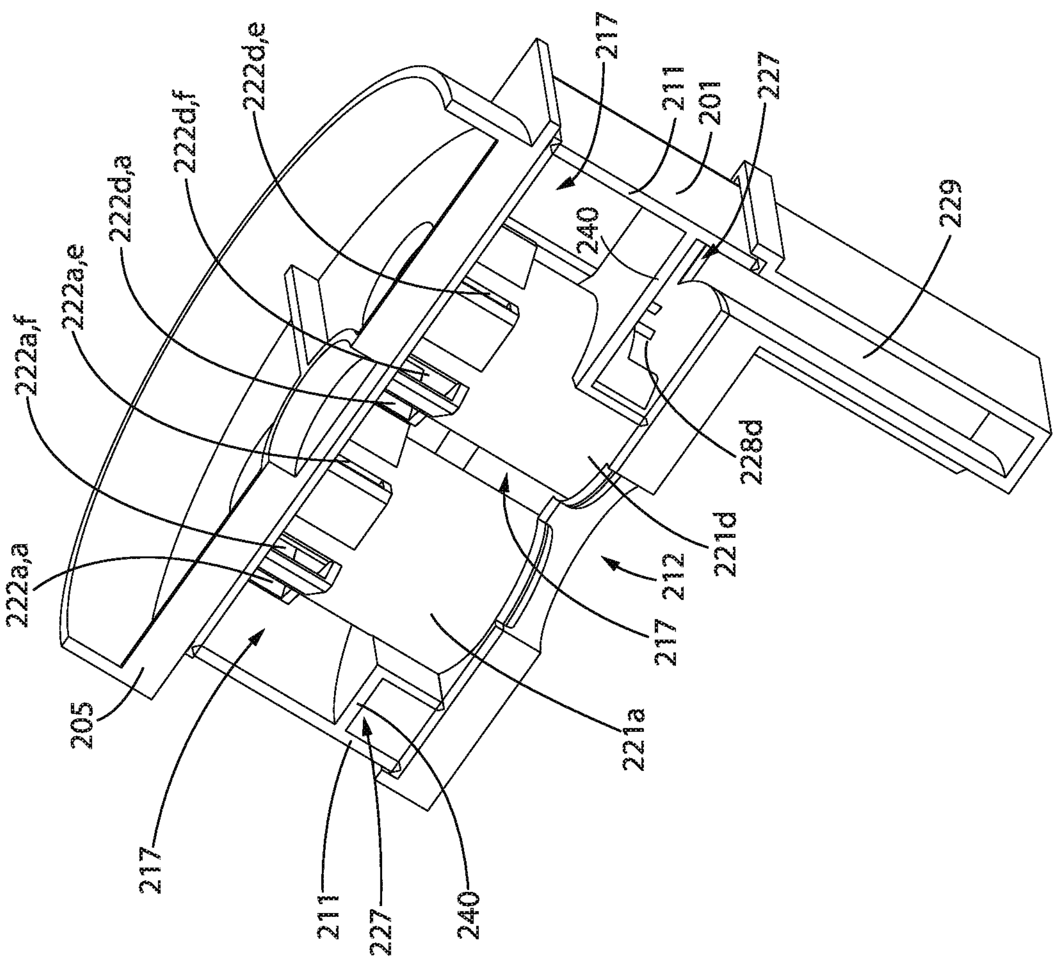
FIG. 9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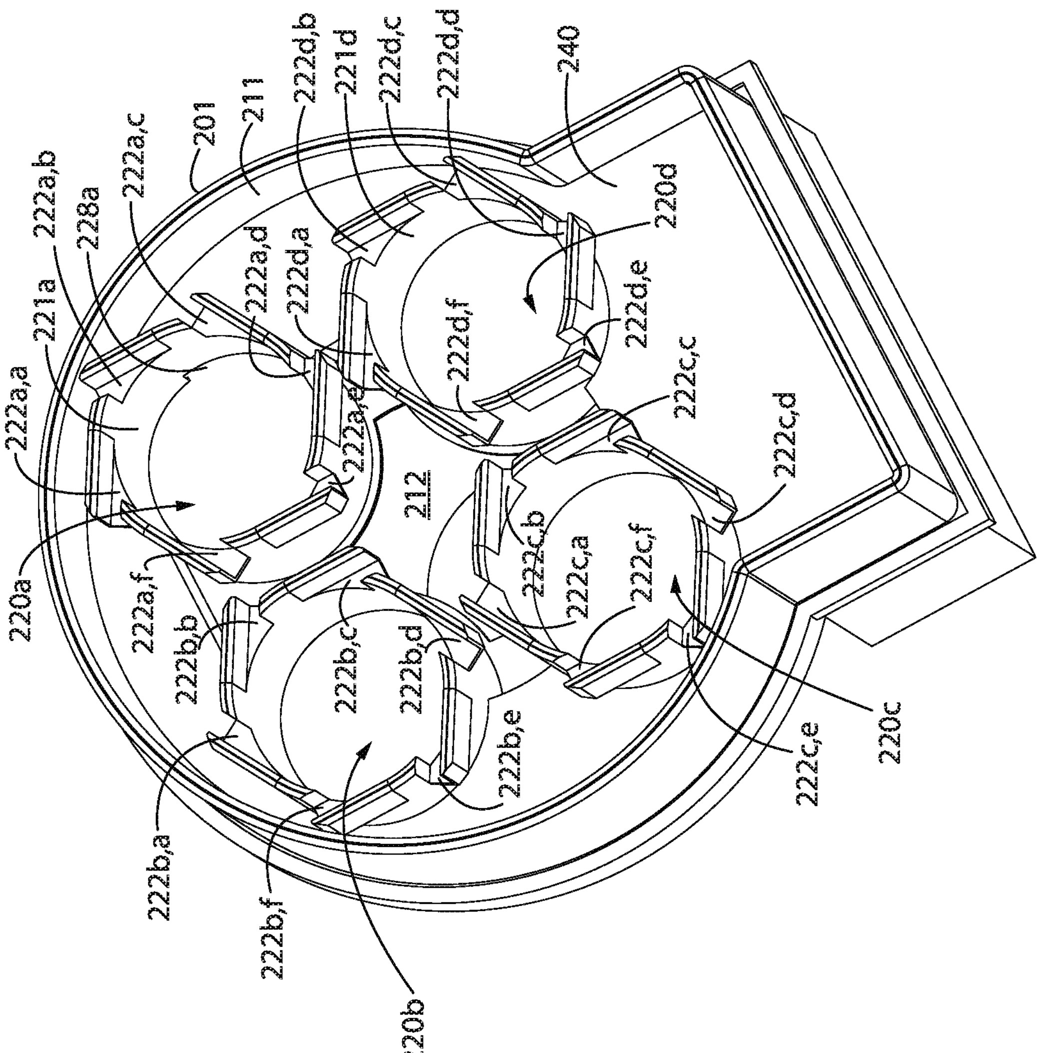
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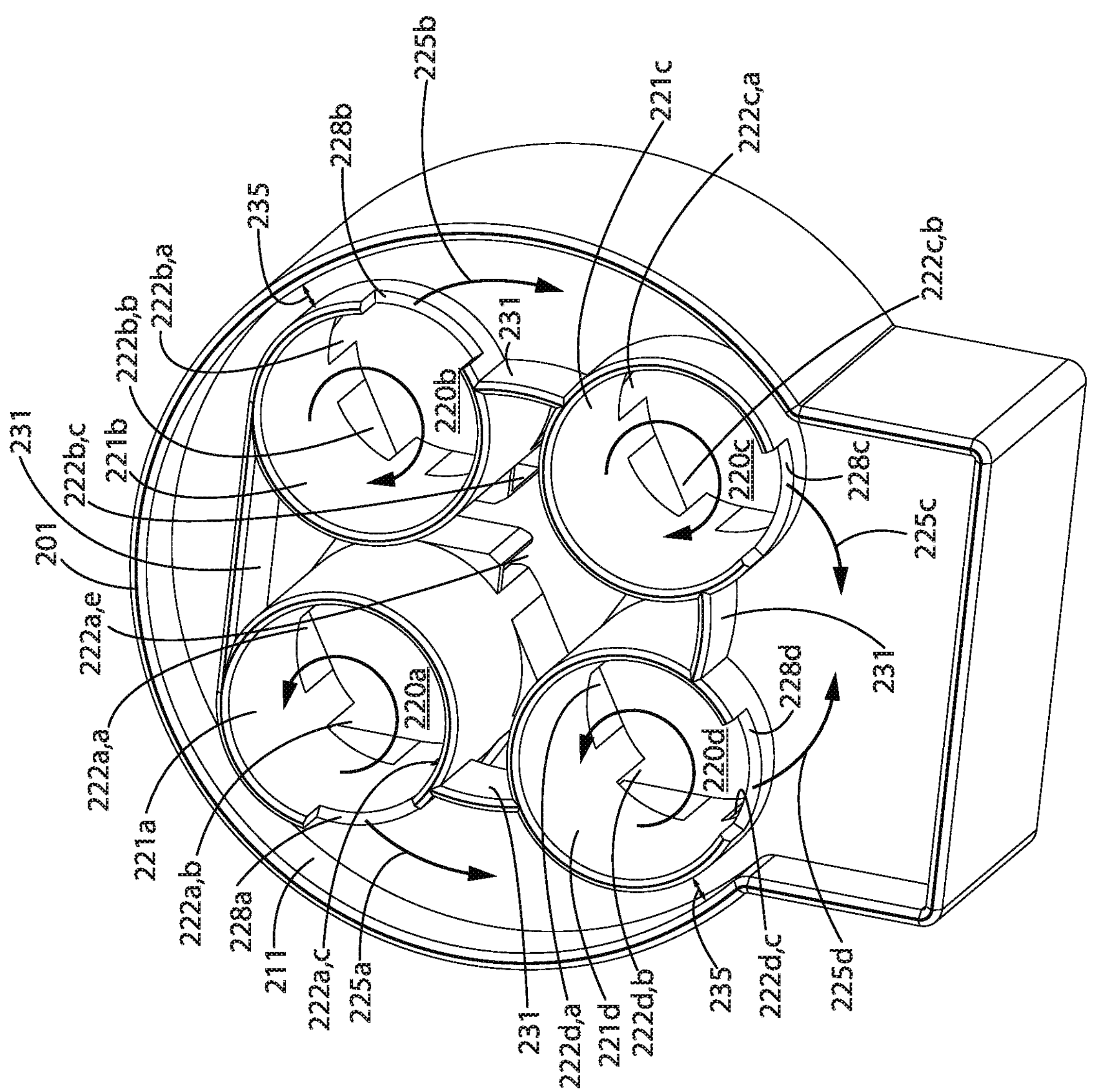
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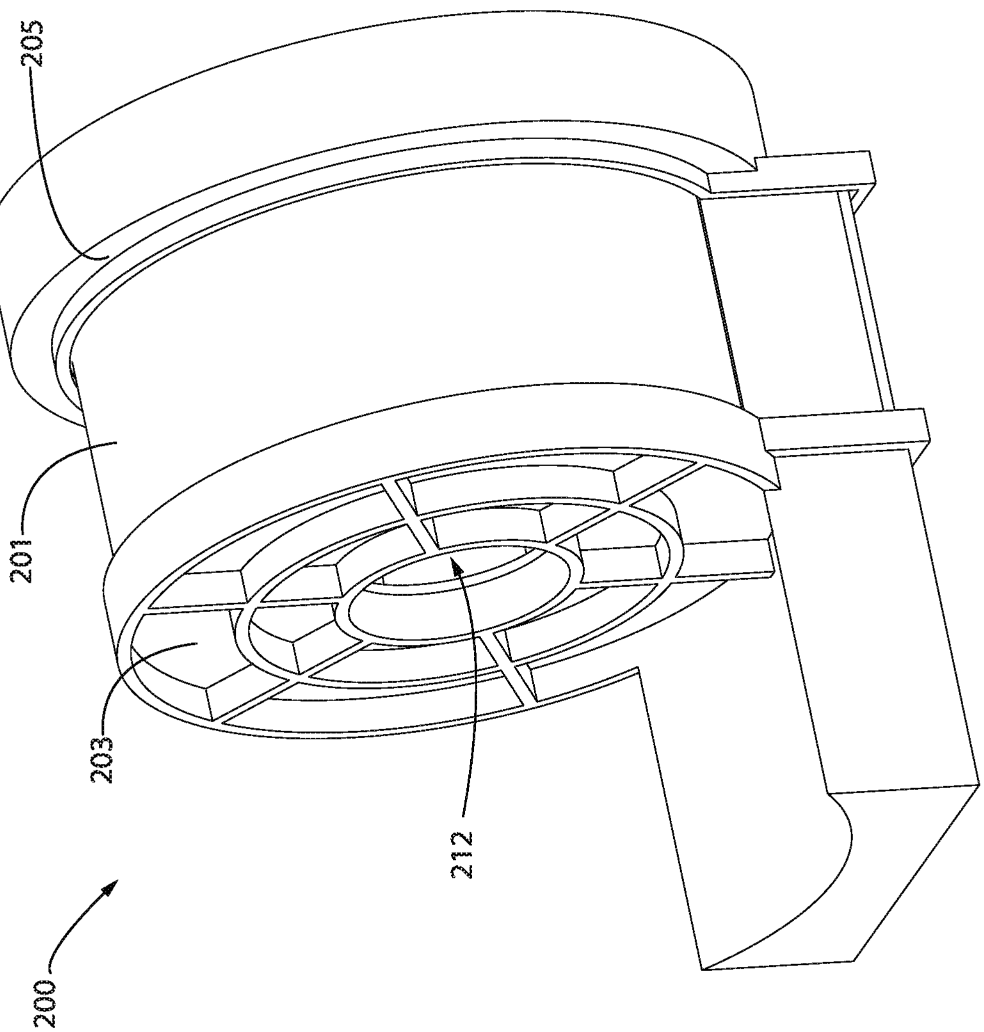
FIG. 11

FIG. 12



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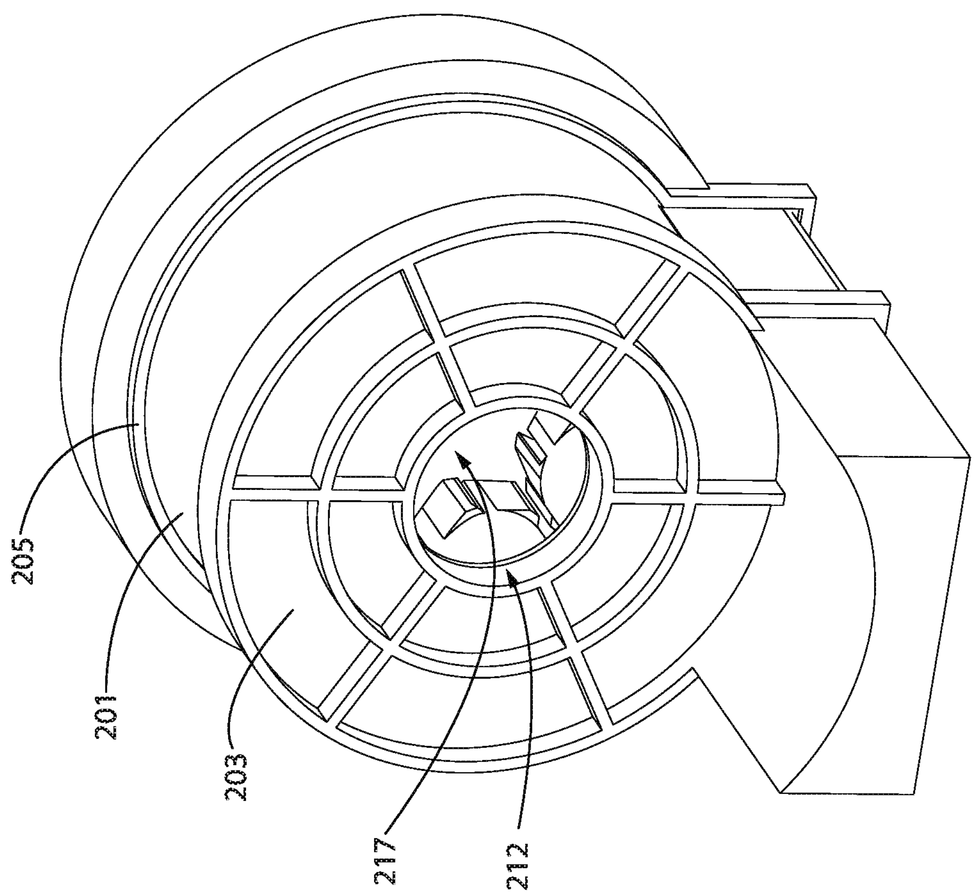

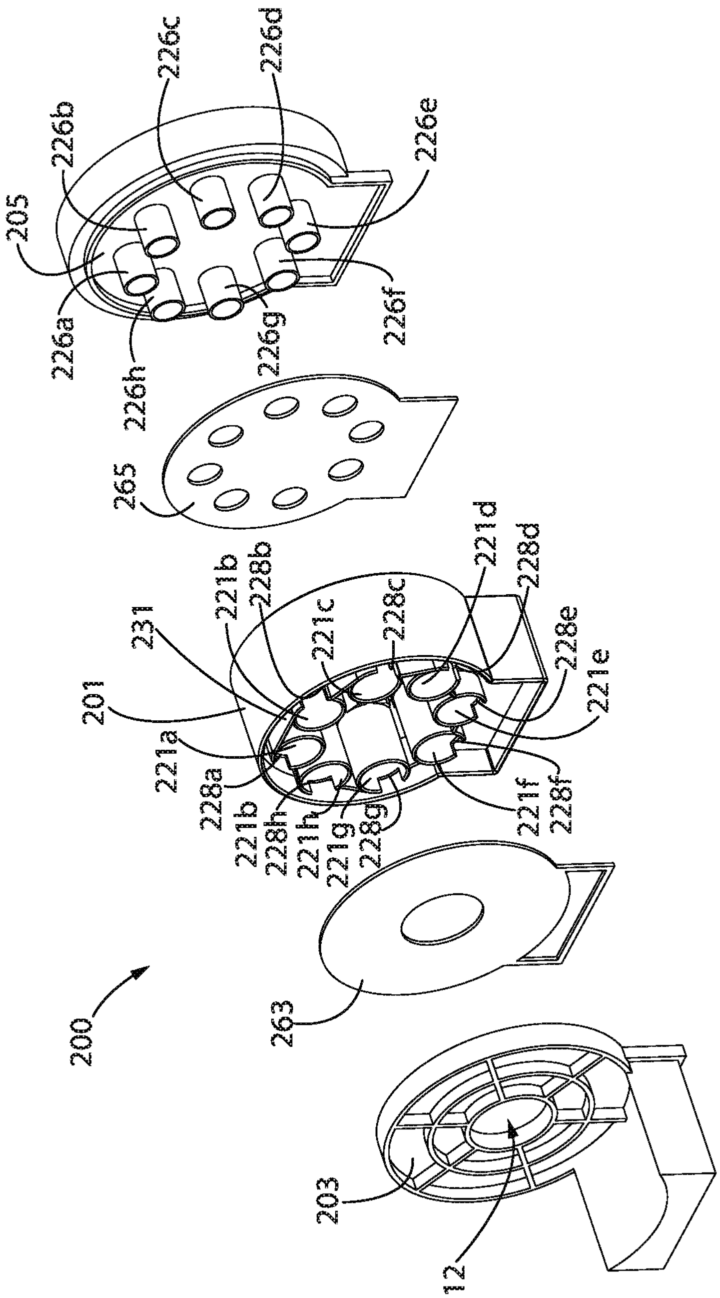
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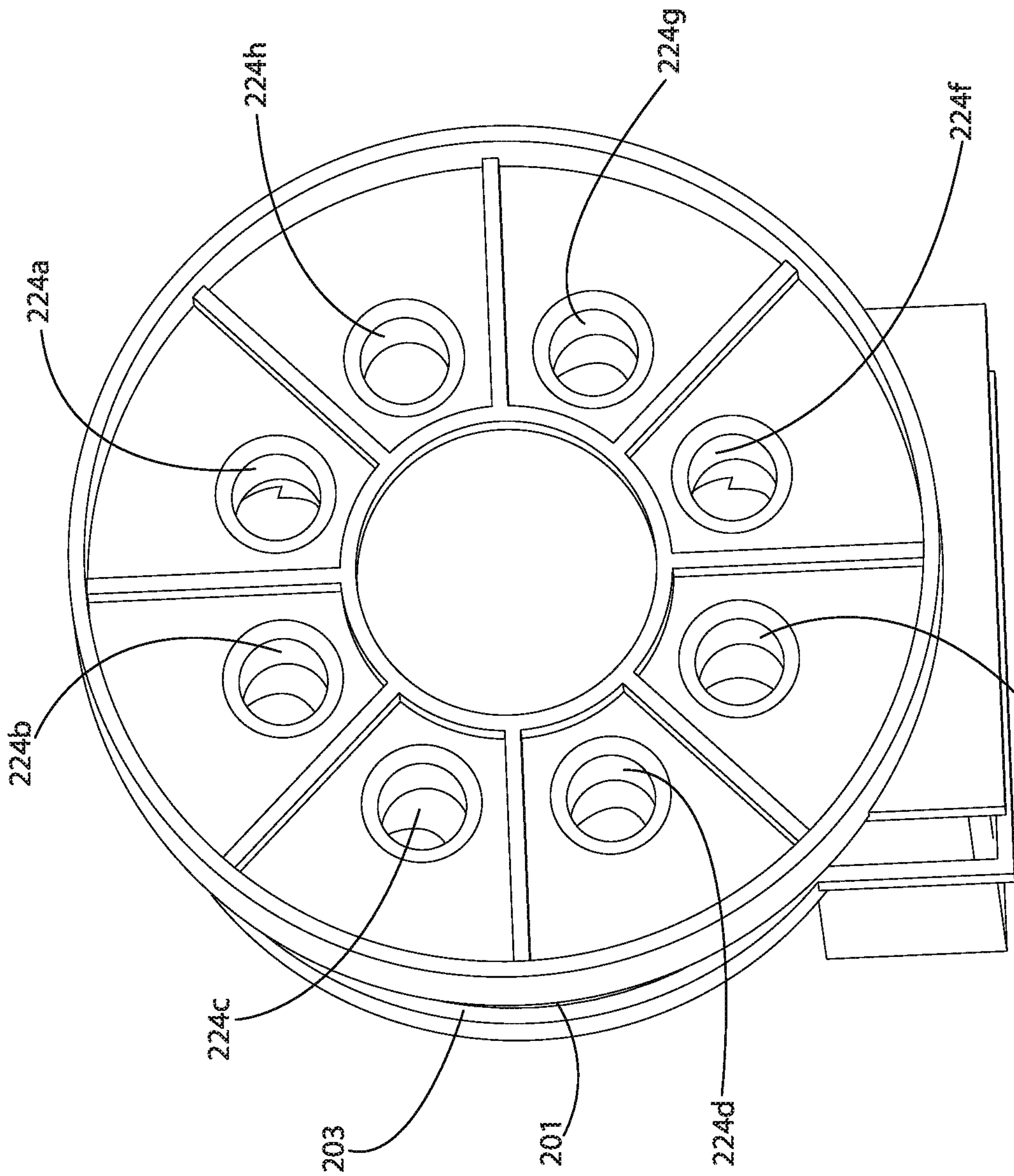
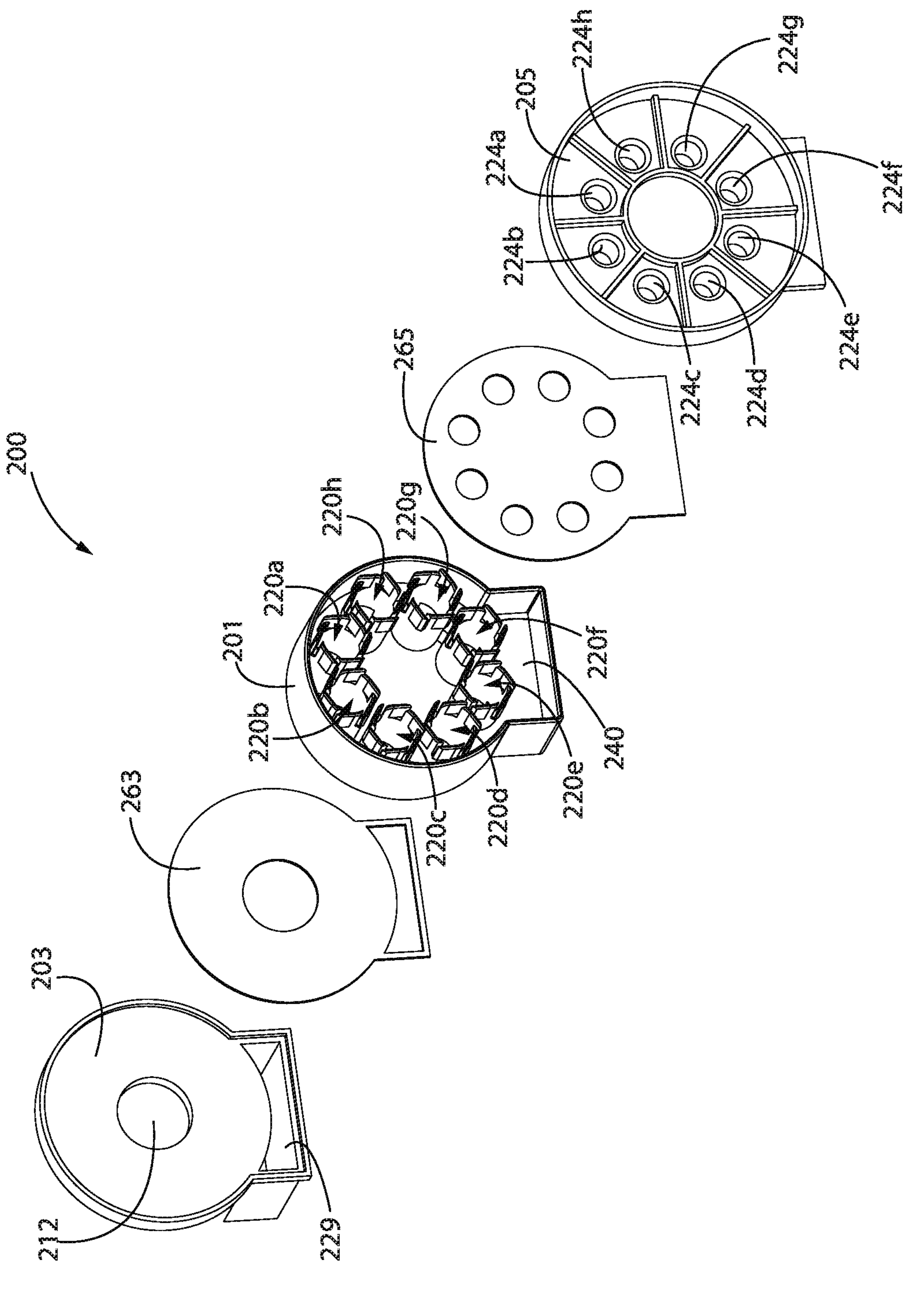
FIG. 14

FIG. 15

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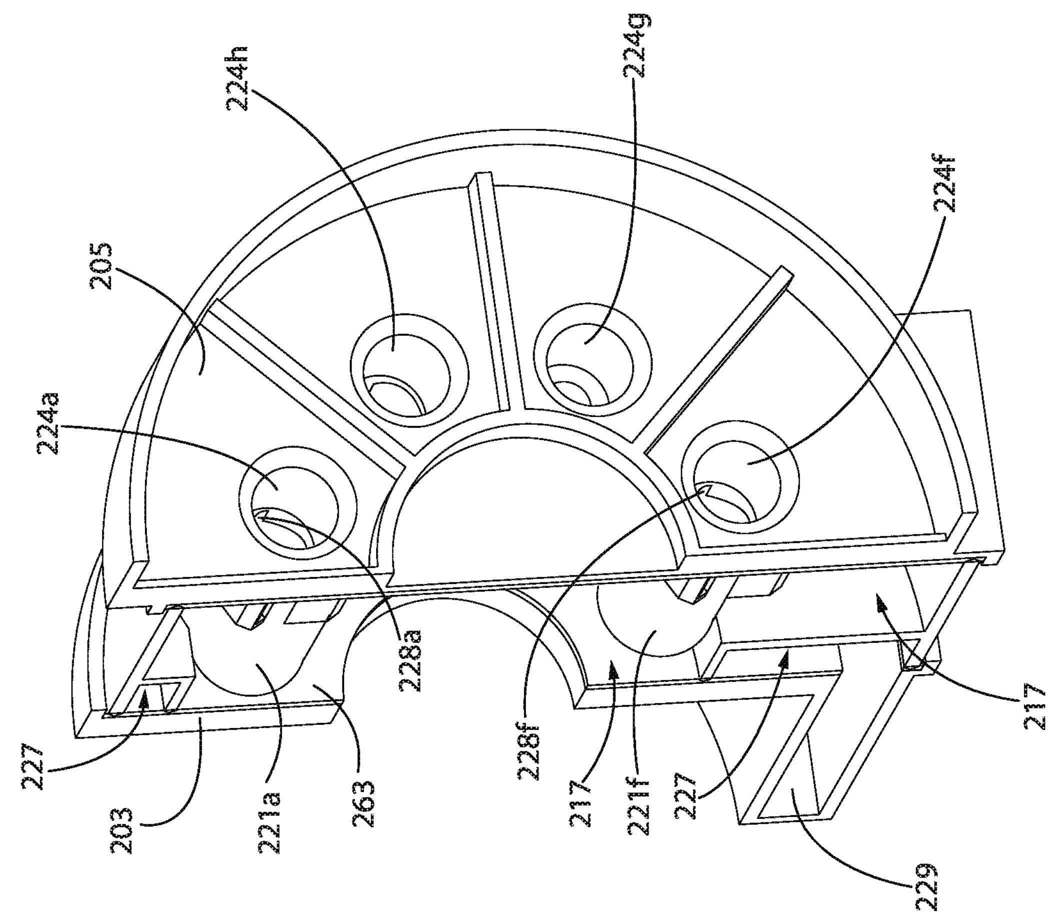
224b
224c
224d
224e
224f
224g
224h

FIG. 16

FIG. 17



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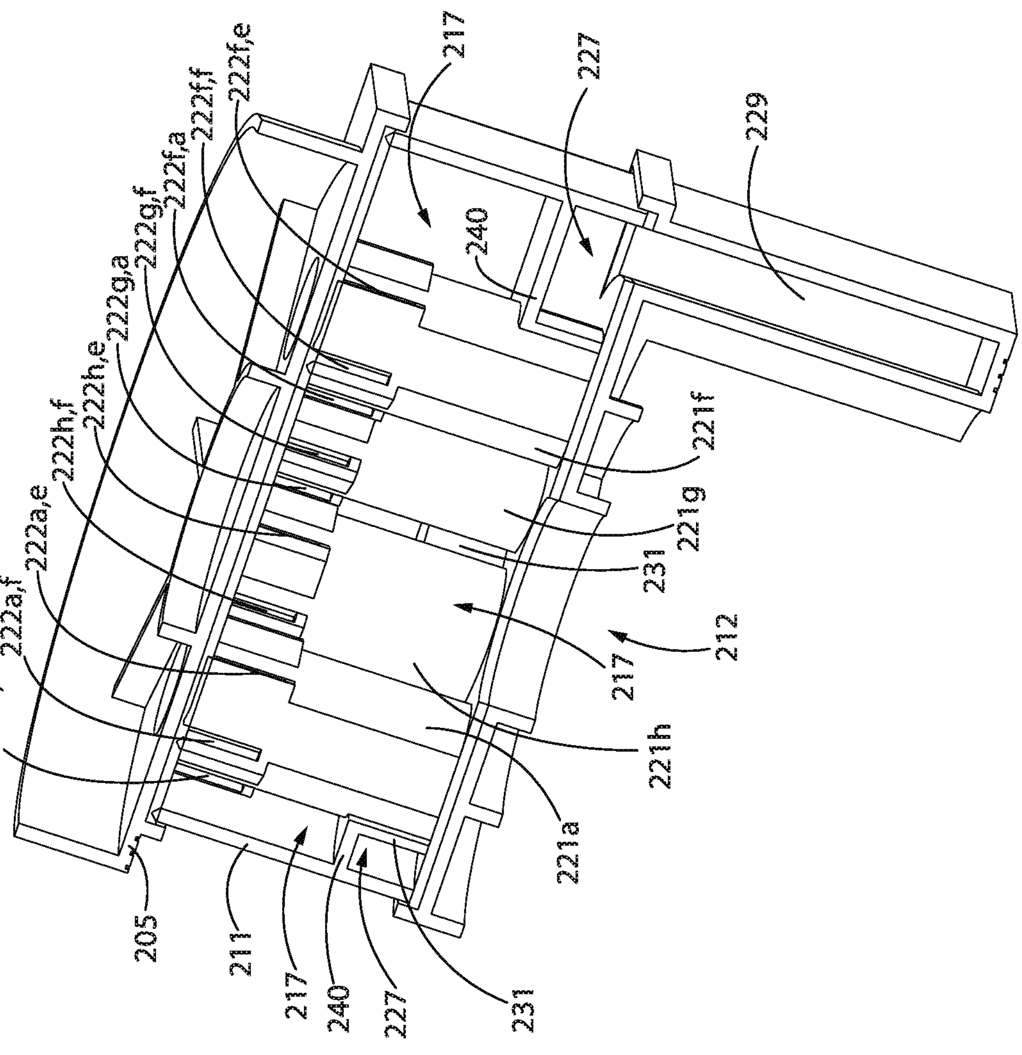
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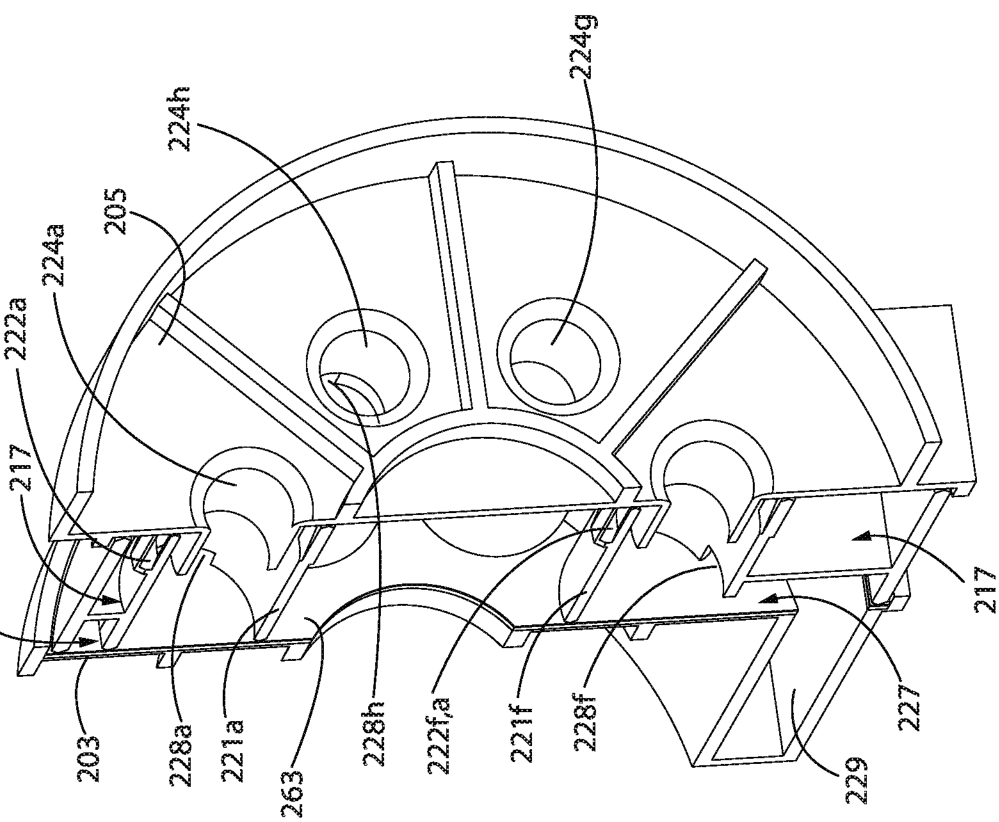
227
231

FIG. 18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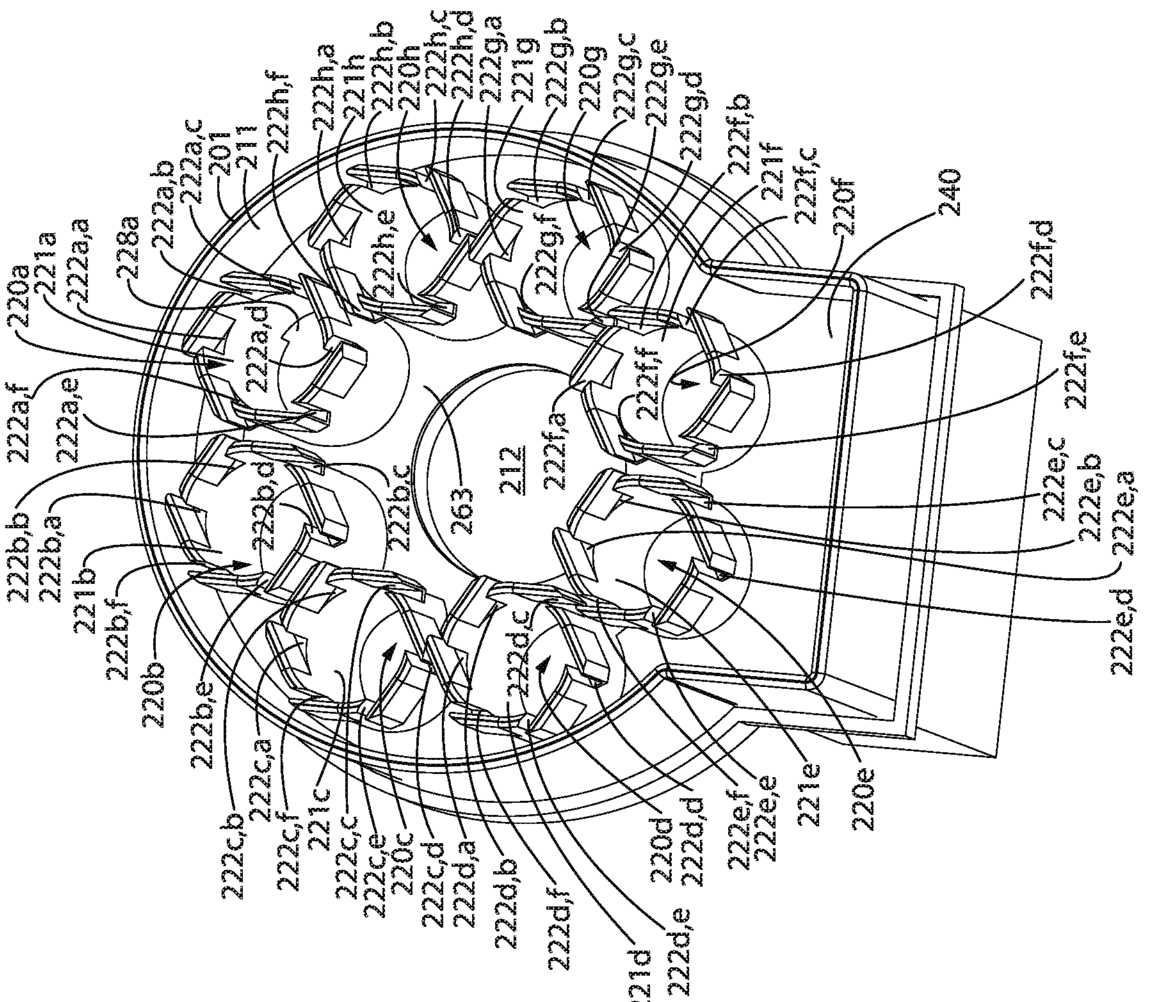
227
217

FIG. 19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221c
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222c,b
222c,a
222b,e
220b
222b,f
221b
222b,a
222b,b
222a,f
222a,e
222a,d
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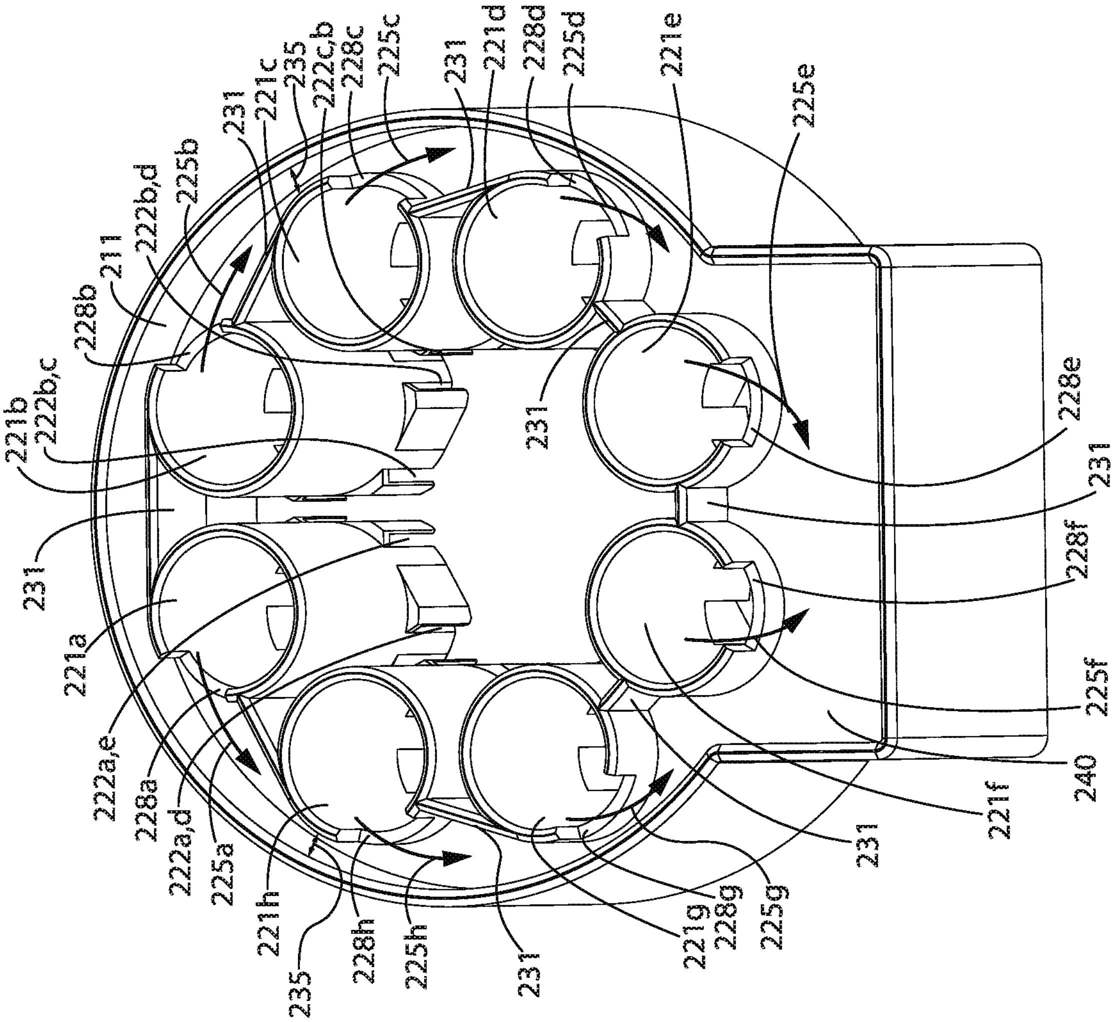
222f,f
222g,f
222h,e
222d,c

FIG. 20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231
228e
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221e
225d
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225b
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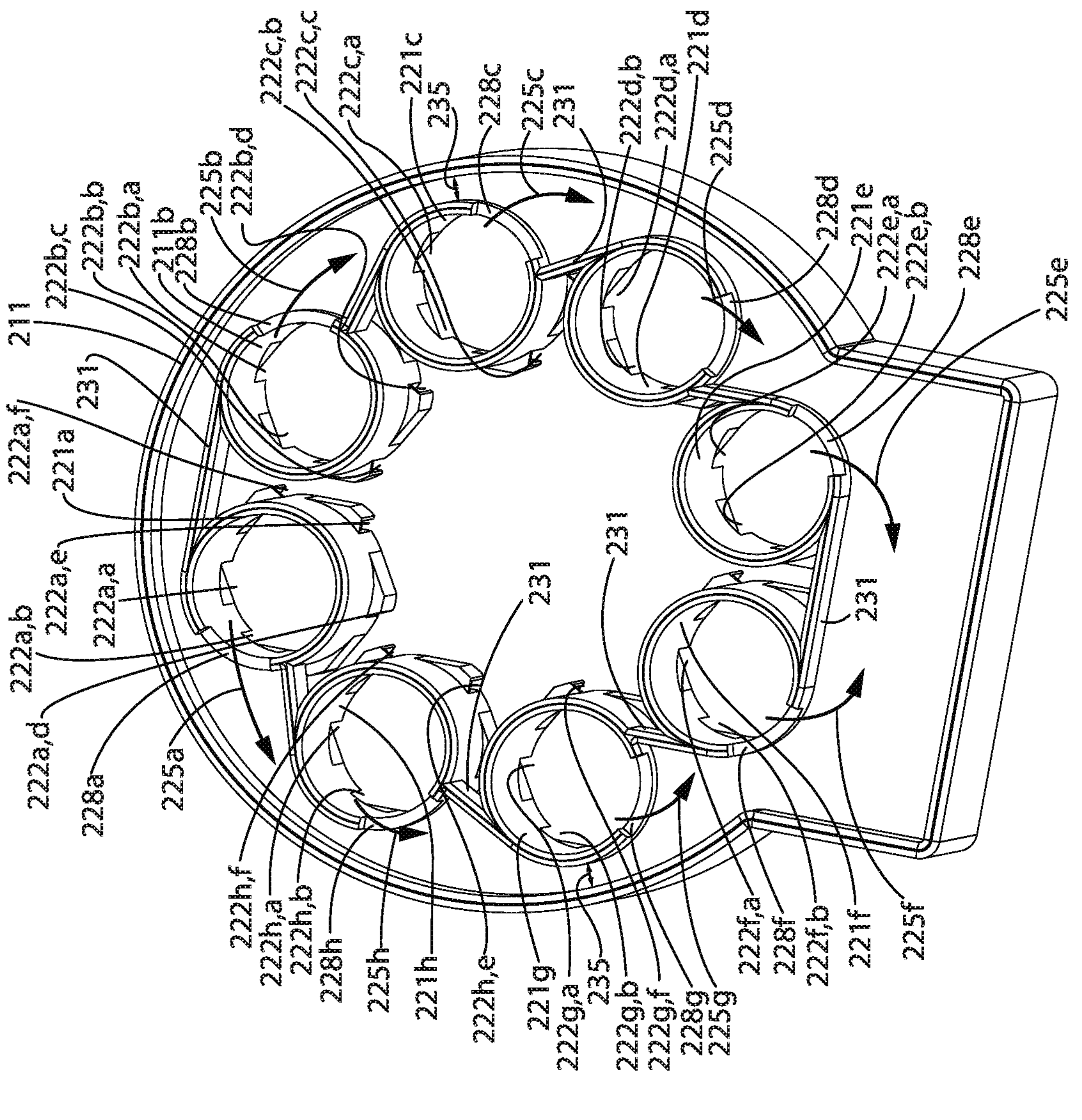
211
228b
231

FIG. 21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228e
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228h
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221h
222h,e
221g
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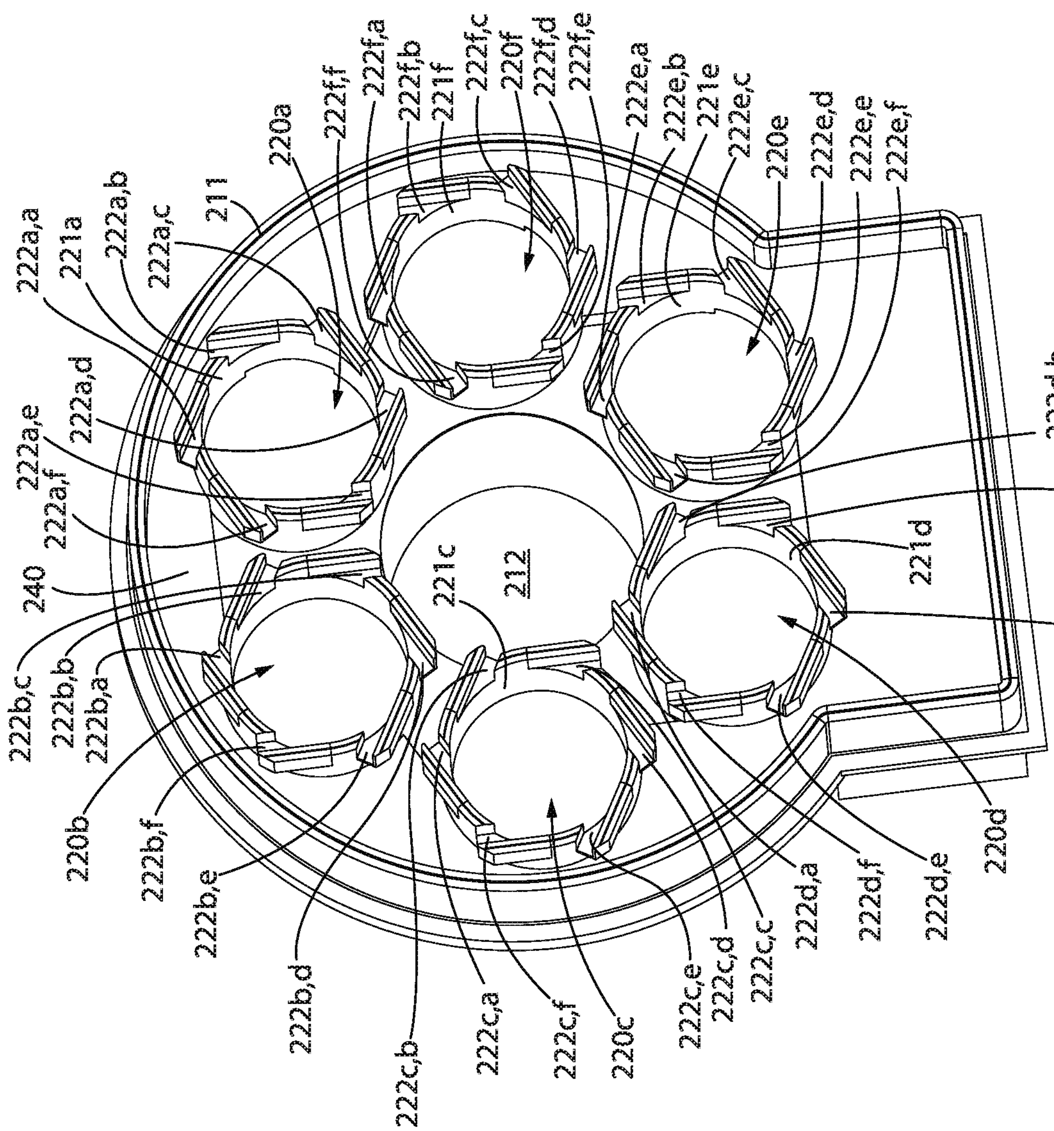
228f
222f,b
221f
225f

FIG. 22

FIG. 23



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212
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221c
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221f
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222b,b
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222c,c
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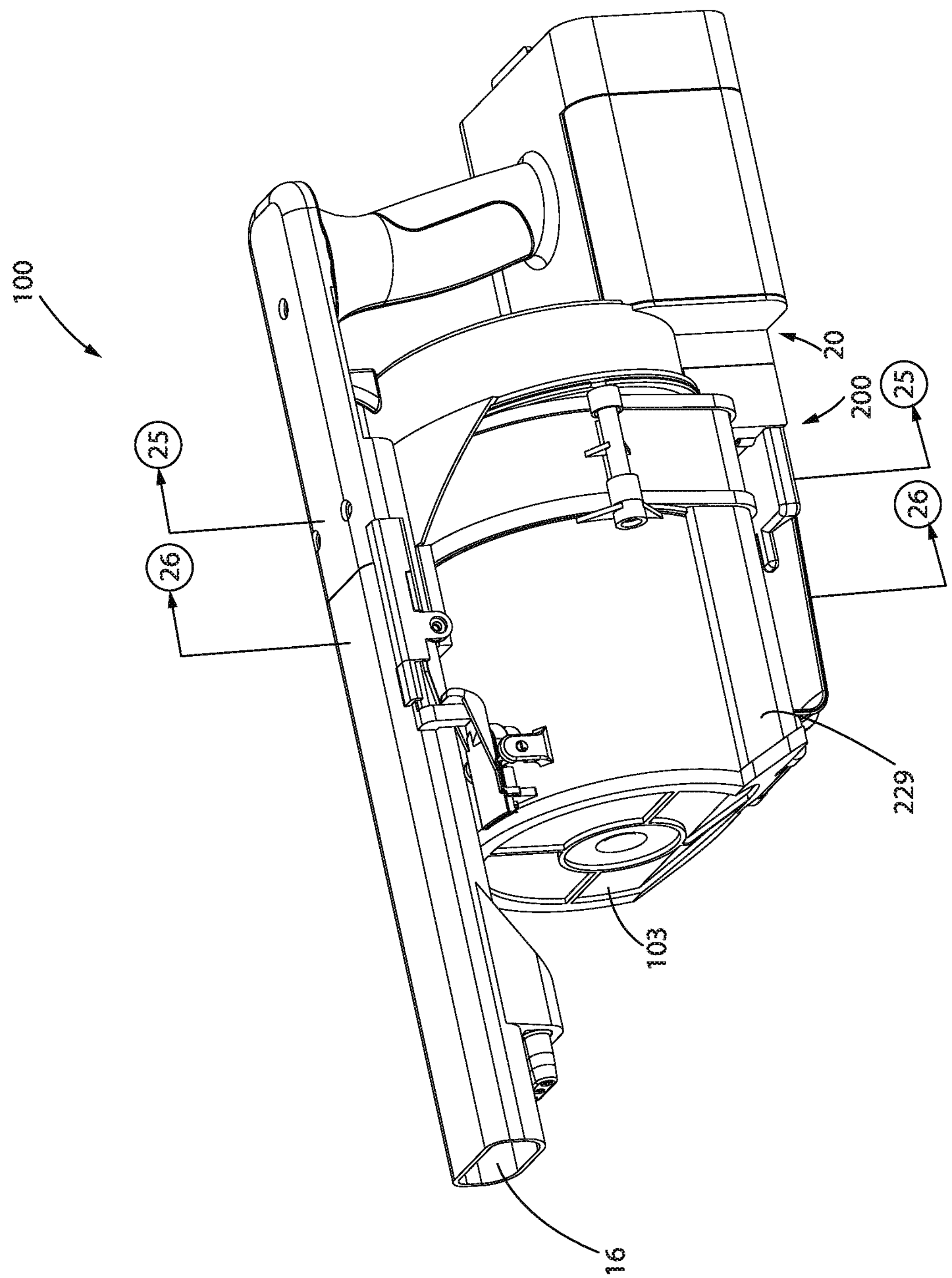
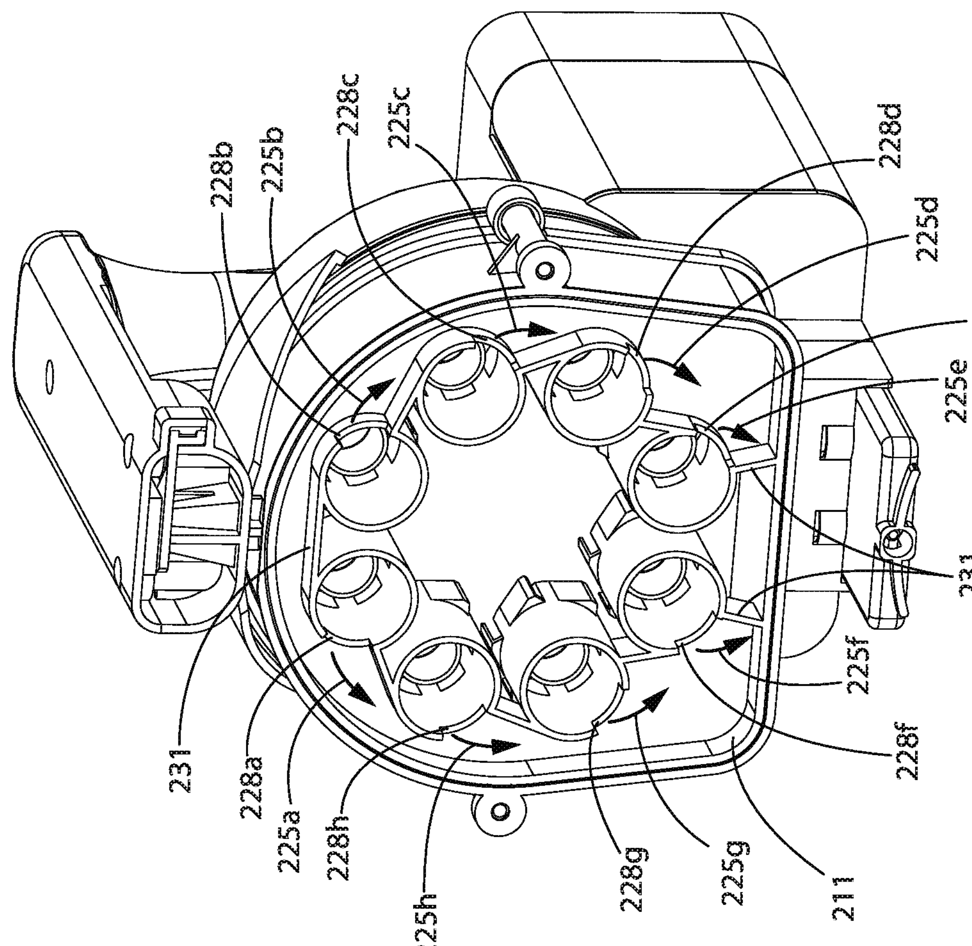


FIG. 24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225c
228d
225d
228e
225e
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225f
228f
211
225g
228g
225h
228h
225a
228a
231

FIG. 25

FIG. 26

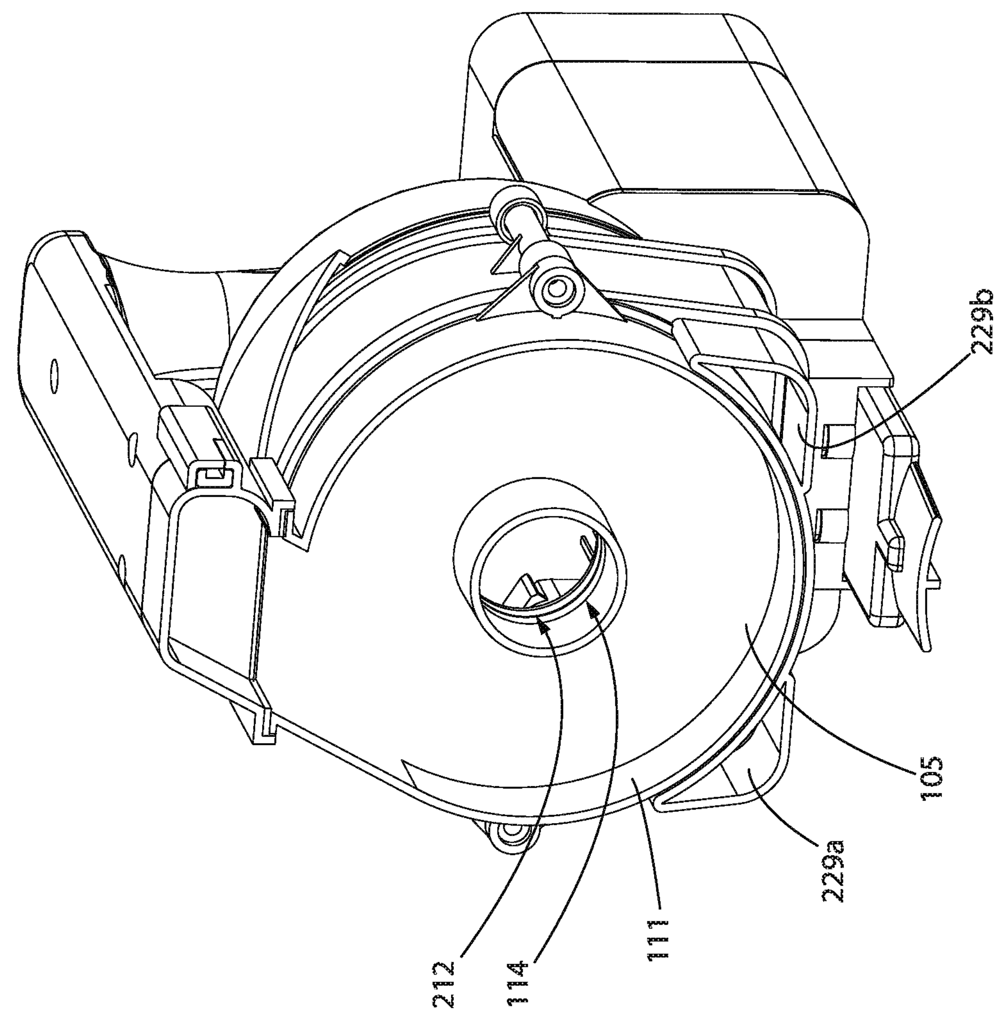
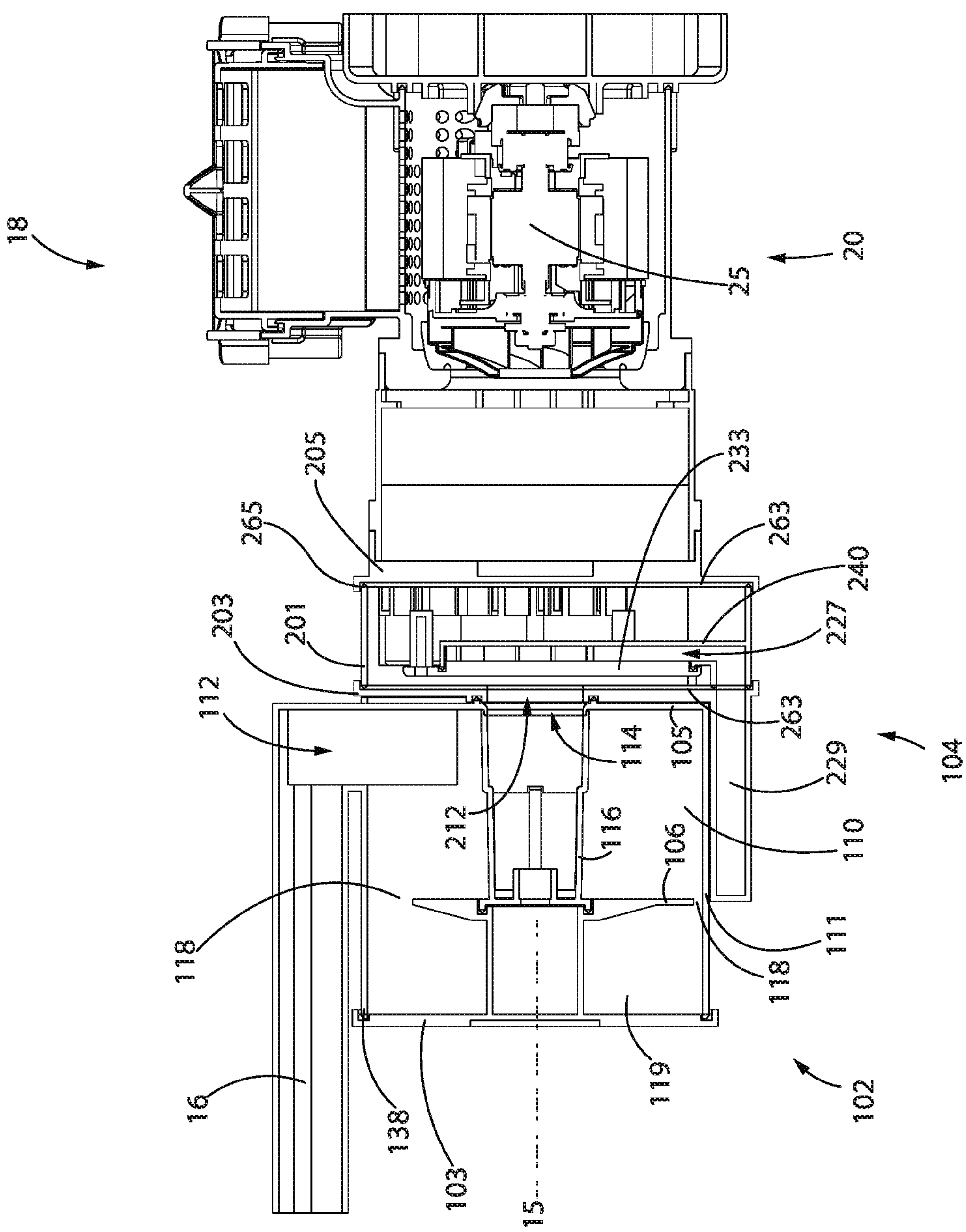


FIG. 27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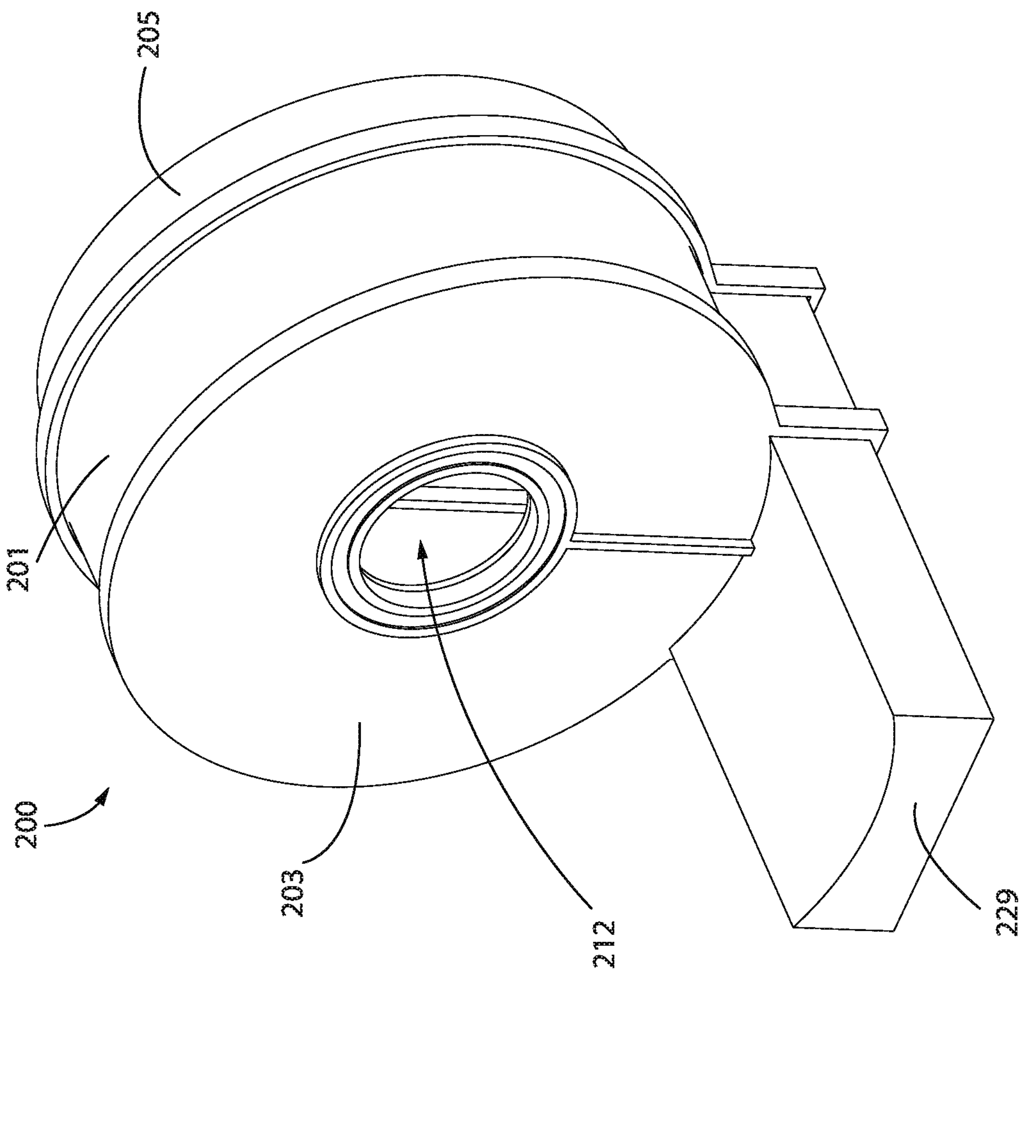
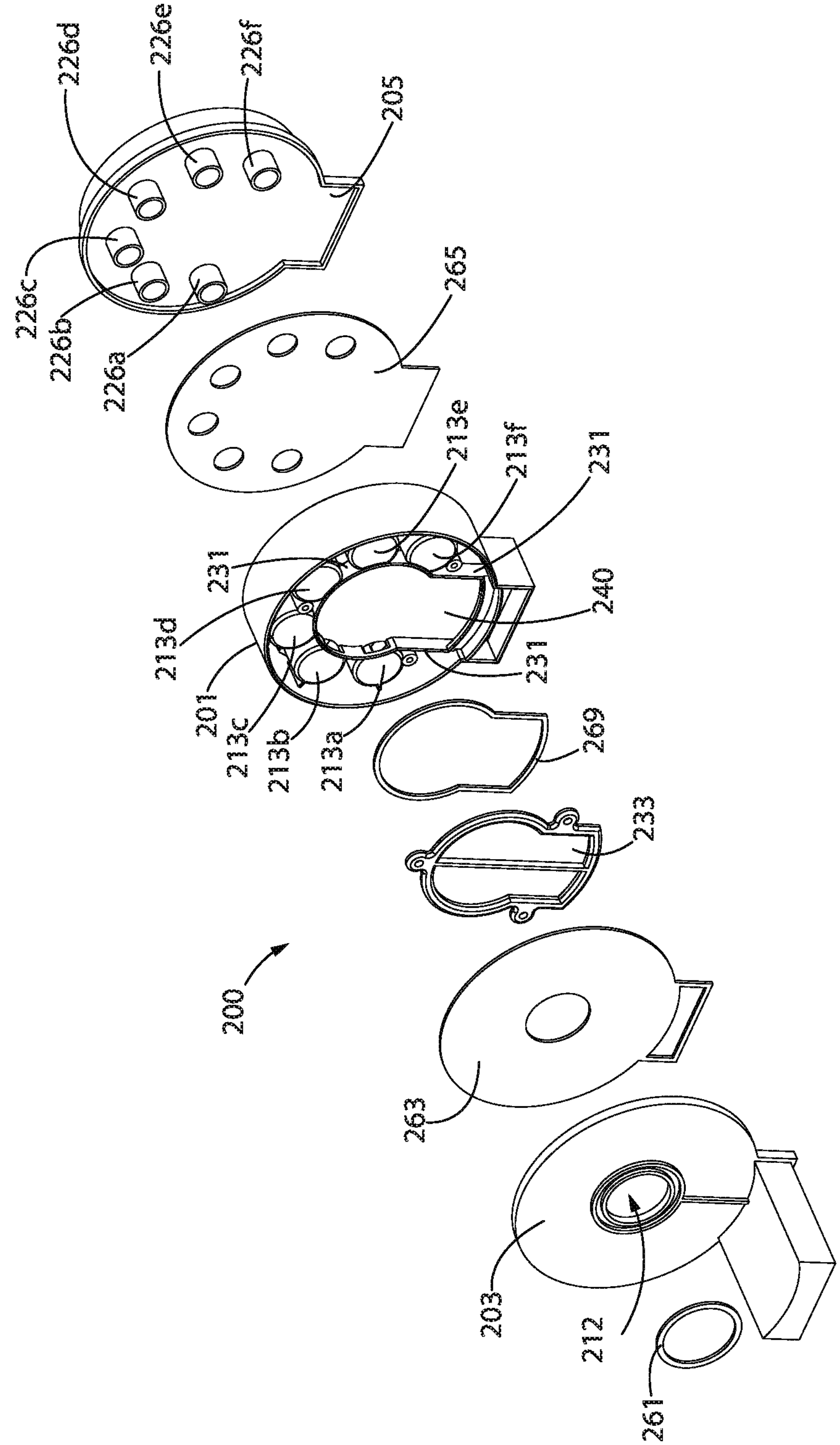


FIG. 28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213e
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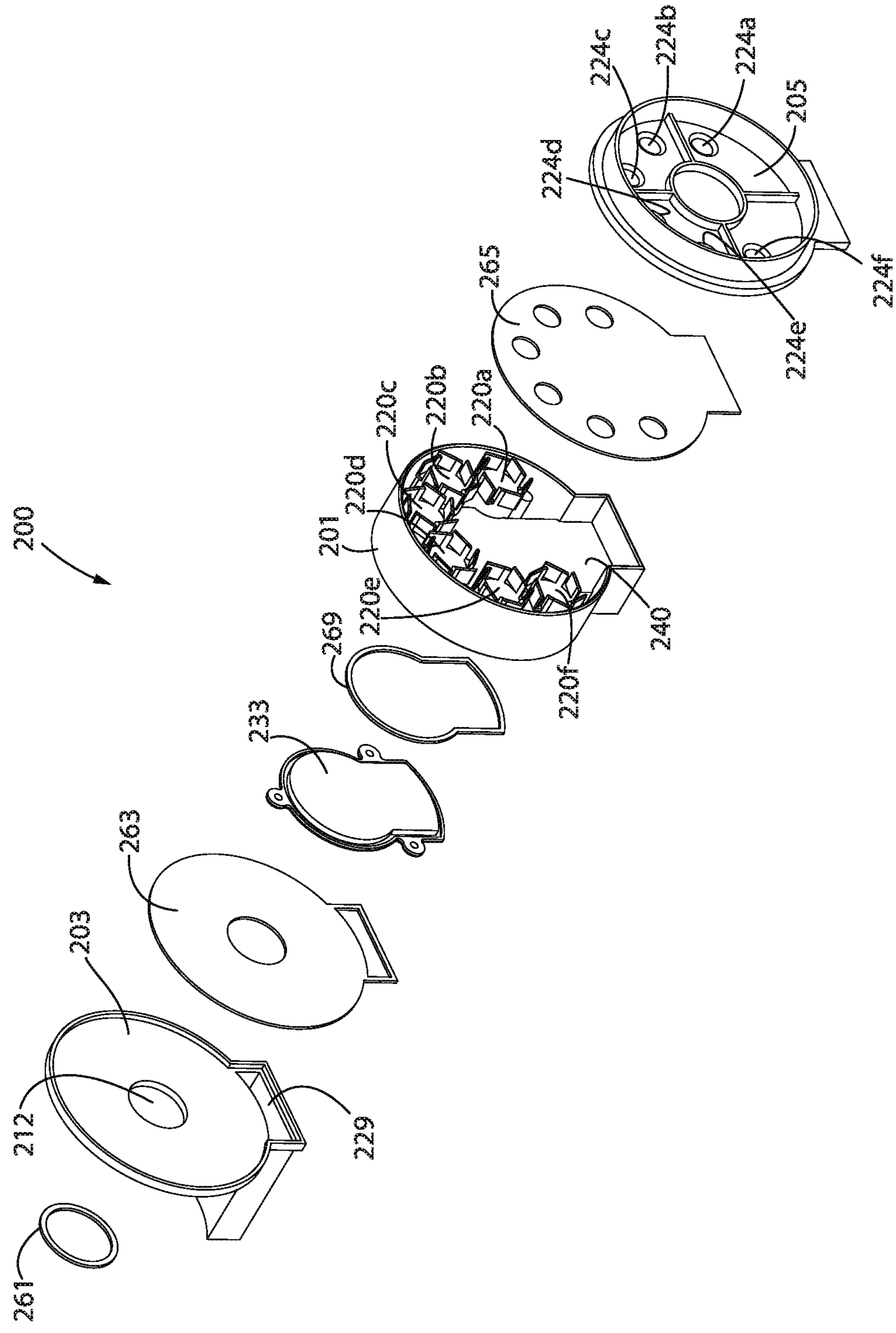
213c
213b
213a
269
233
200
263
203
212
261

FIG. 29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224e
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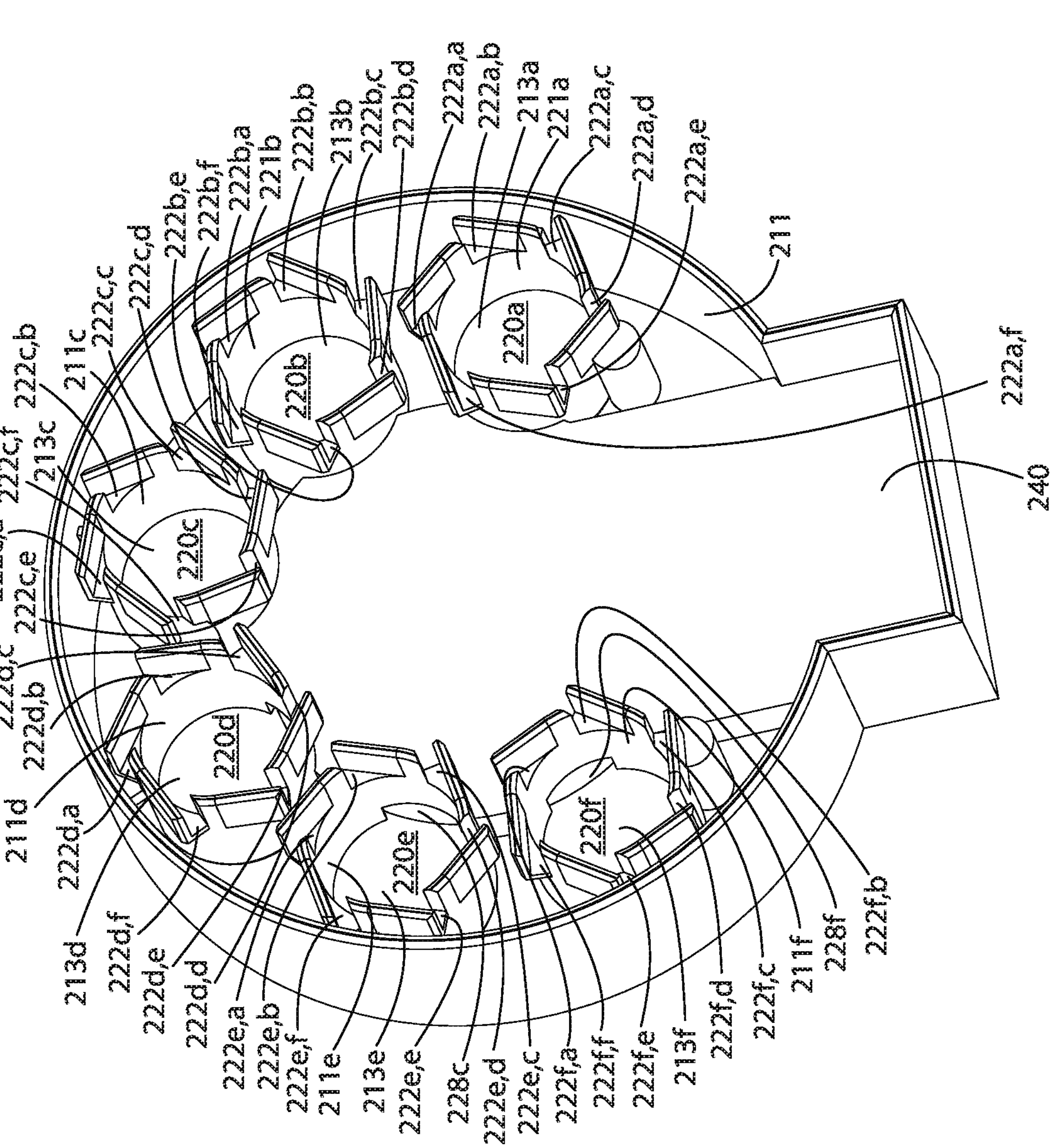
FIG. 30

FIG. 31



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222b,d
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220b
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222d,f
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222e,c
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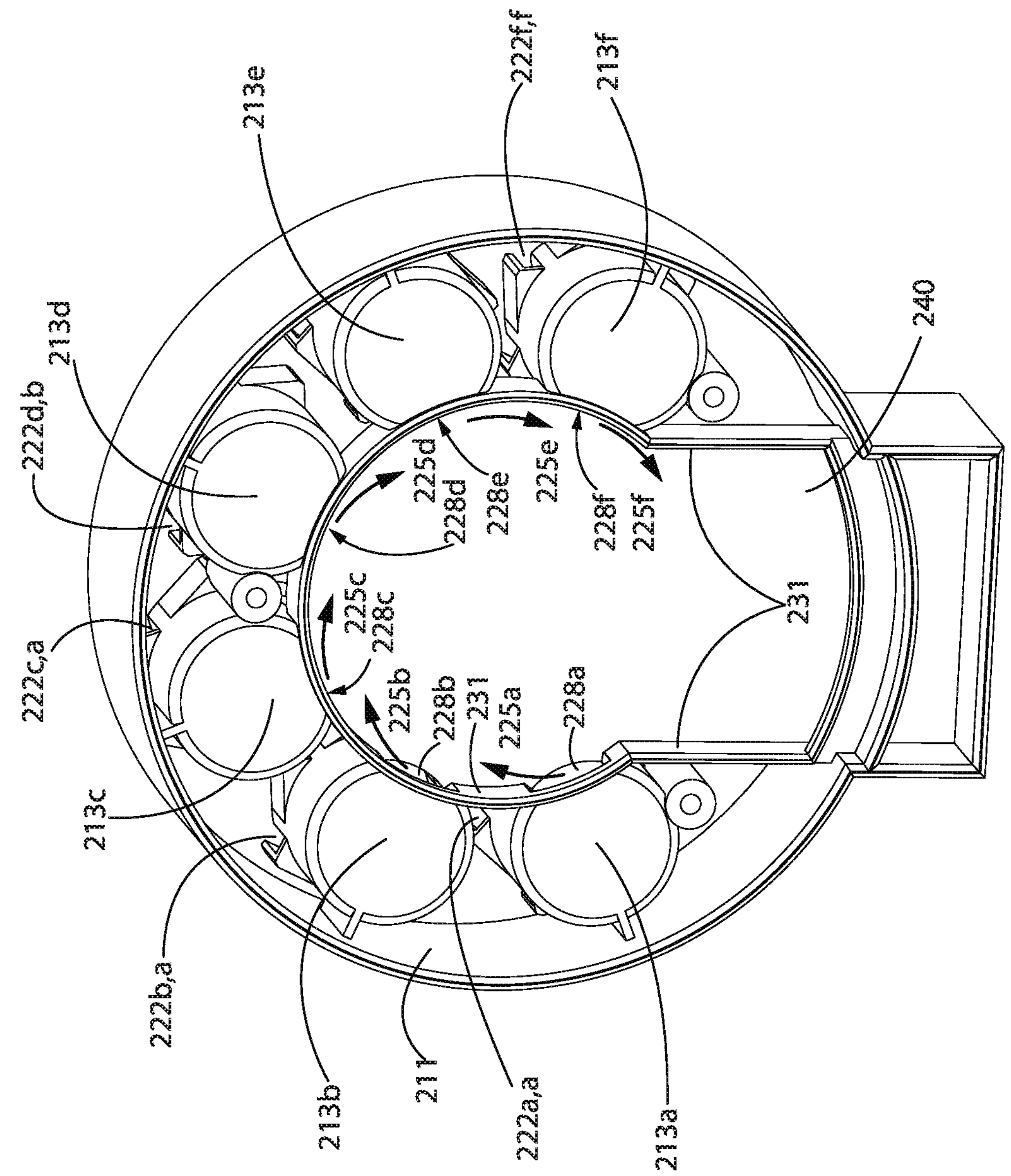
220f

FIG. 32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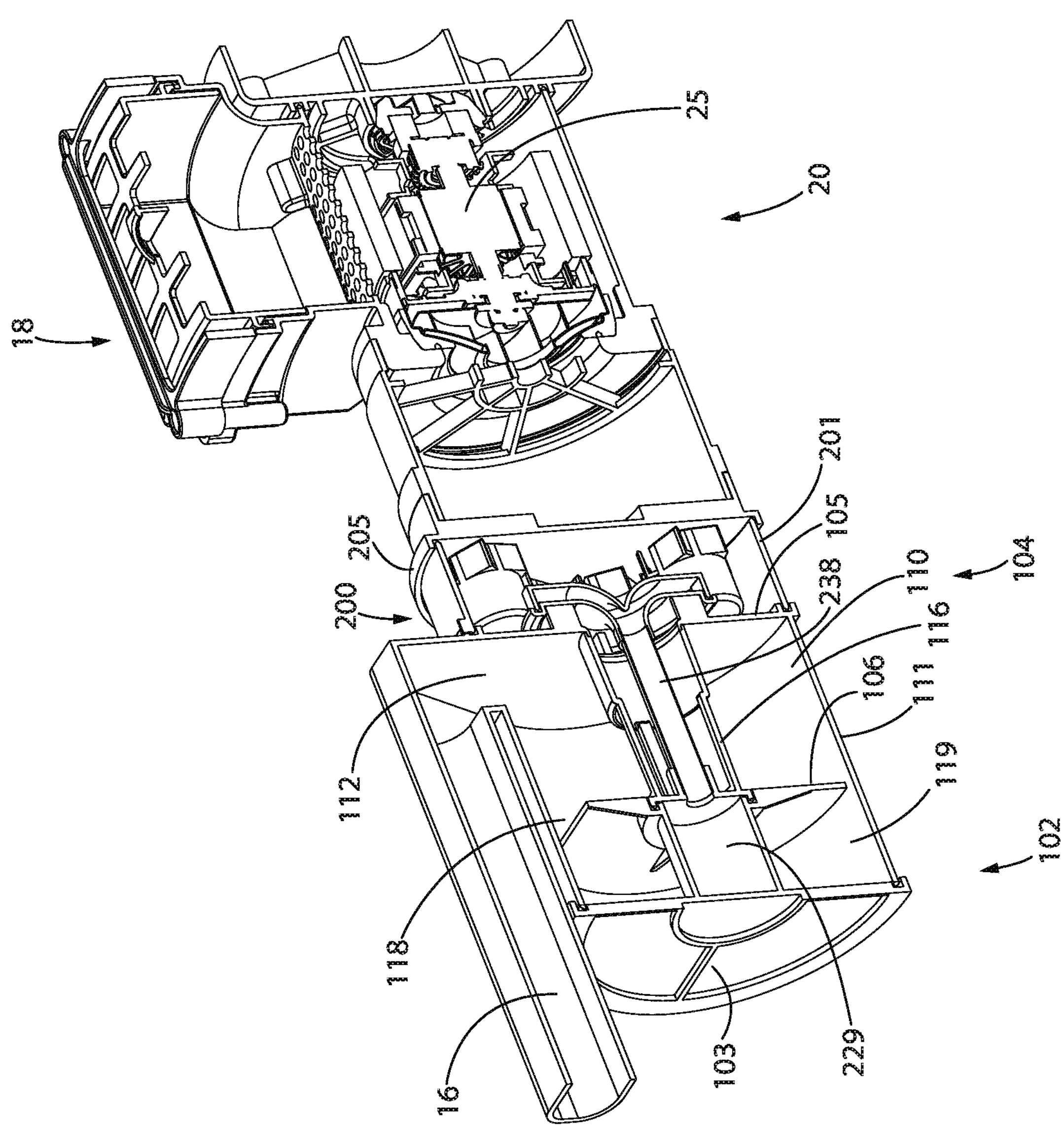
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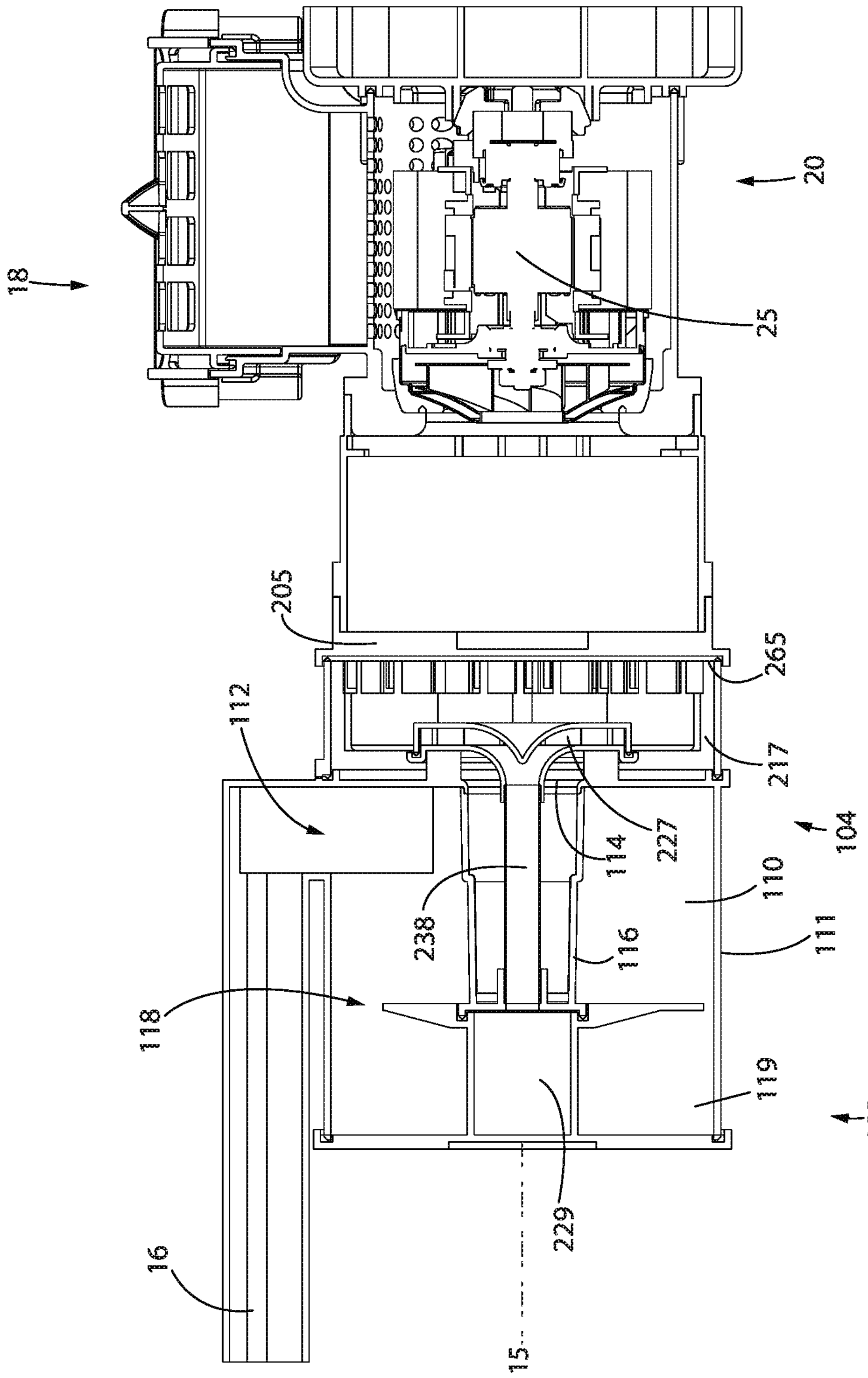
FIG. 33

FIG. 34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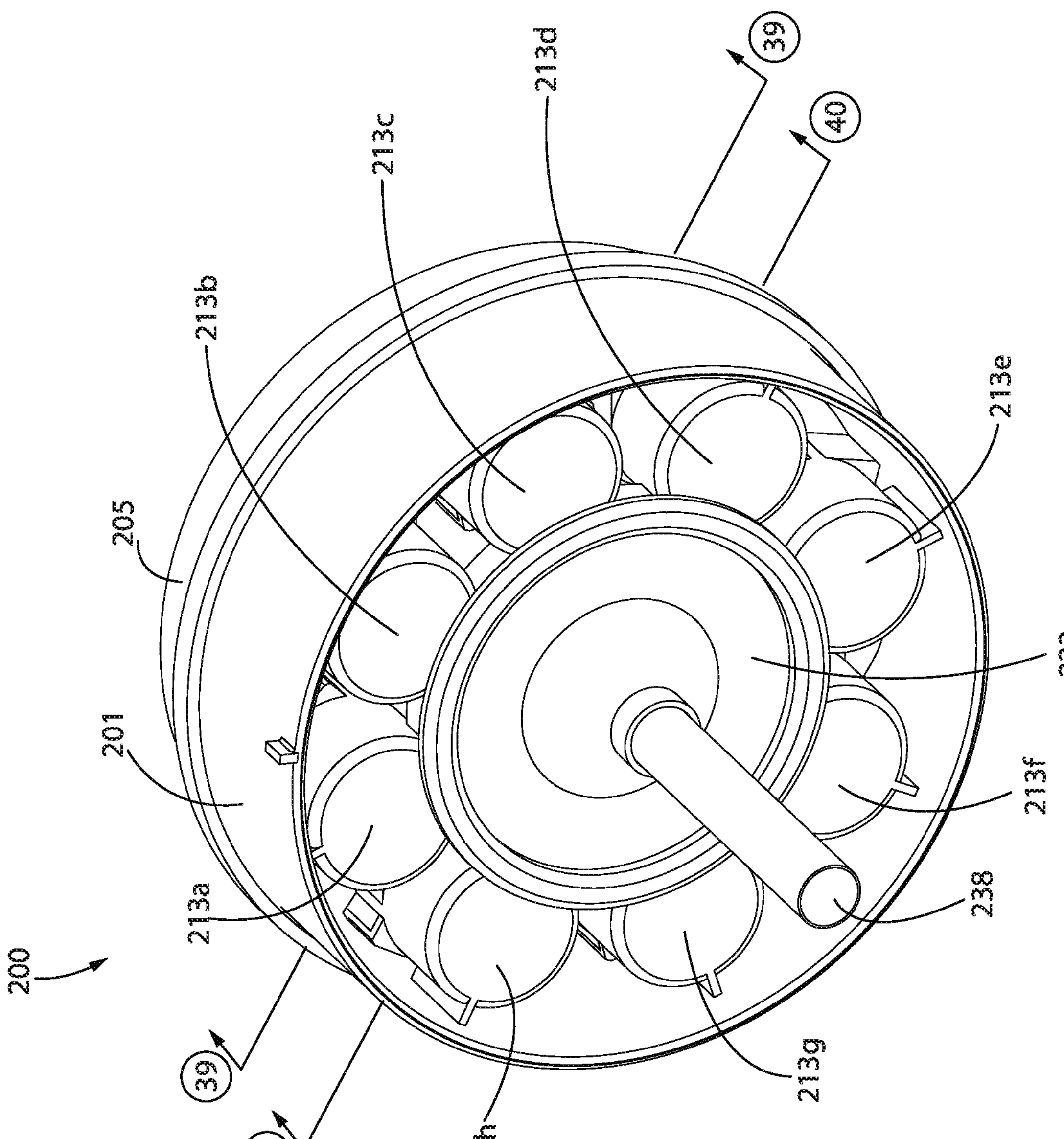
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213a
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213h
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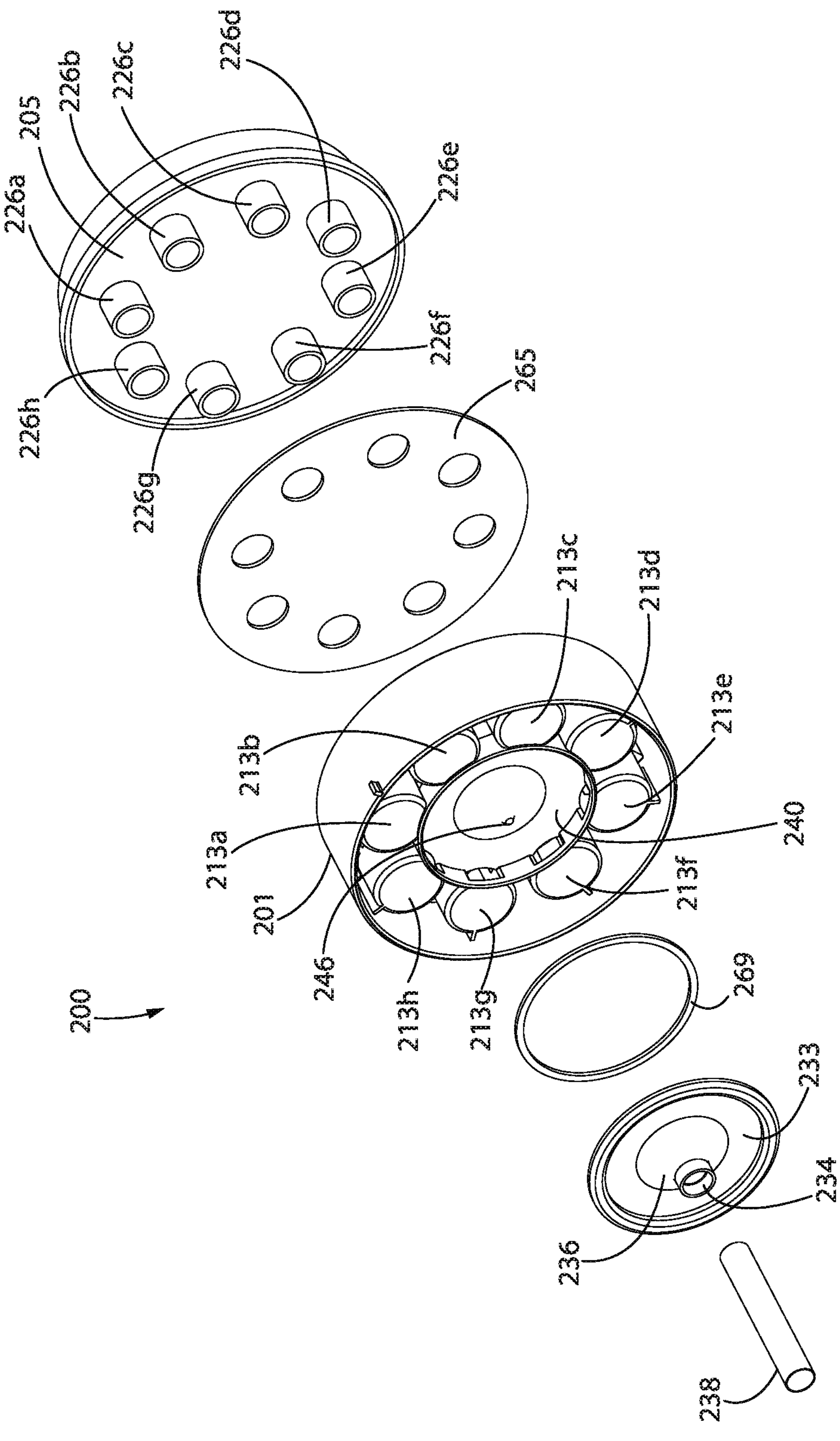
238
39
40
39
40

FIG. 35



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213g
213h
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226g
226h
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234
236
238
240
246
265
269

FIG. 36

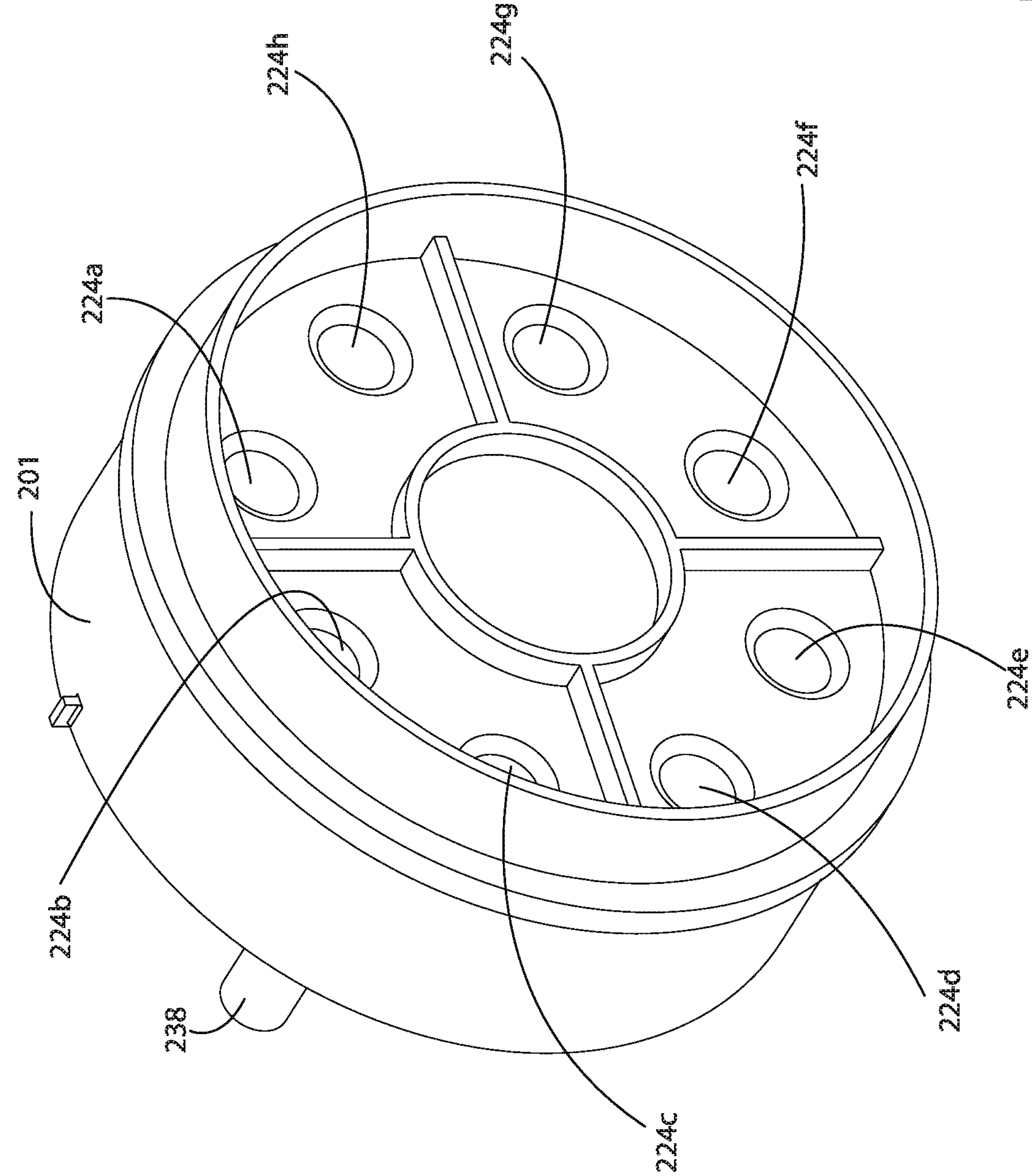
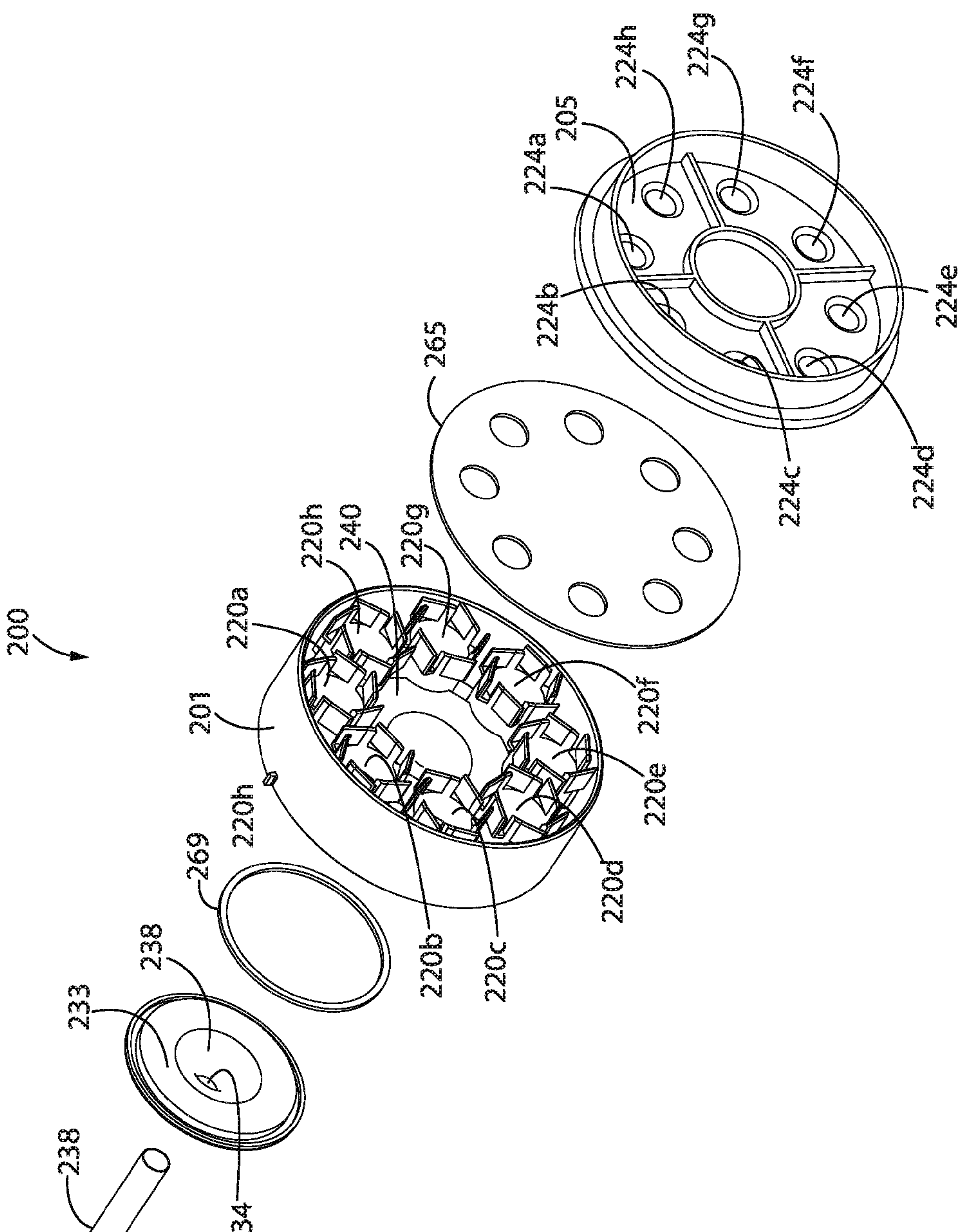


FIG. 37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220h
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238
240
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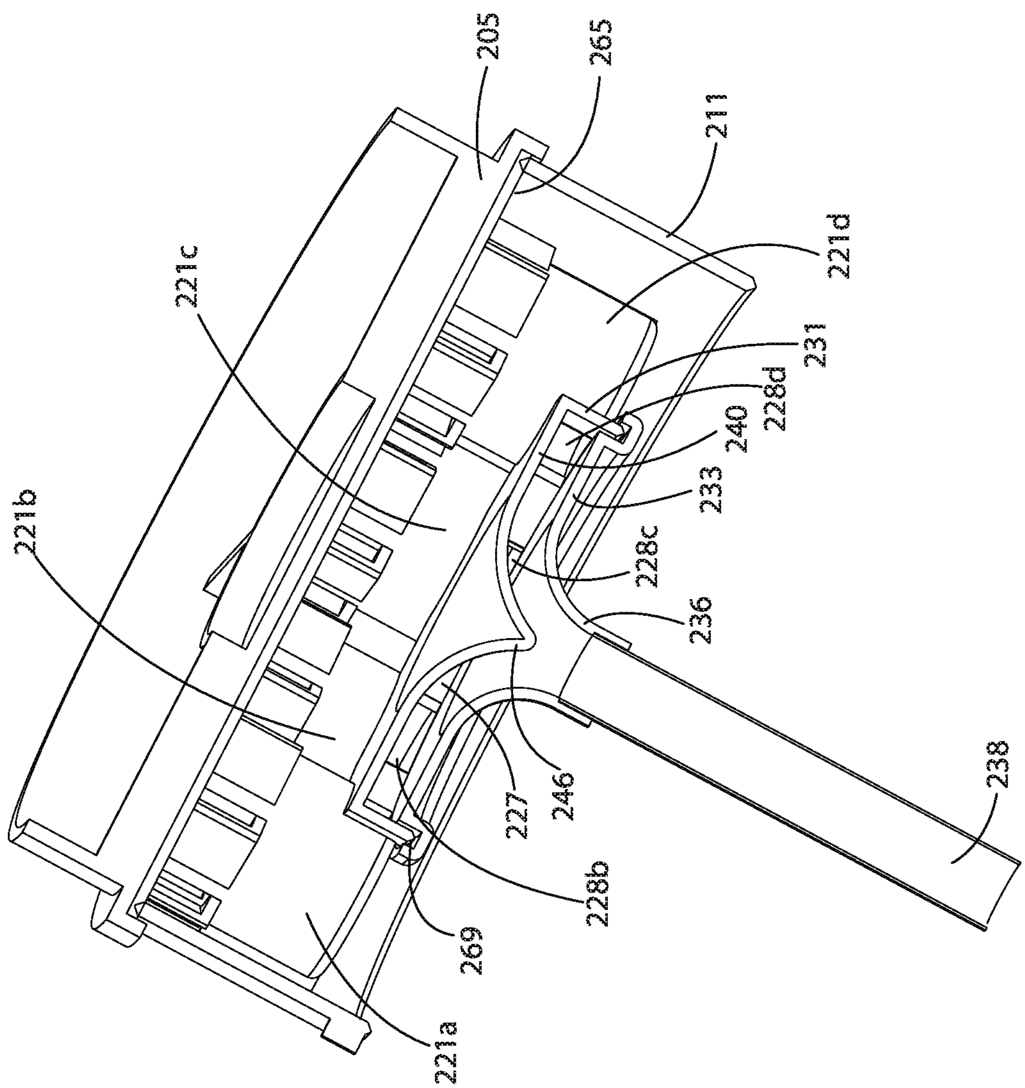
269

FIG. 38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265
211
221d
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221b
228c
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246
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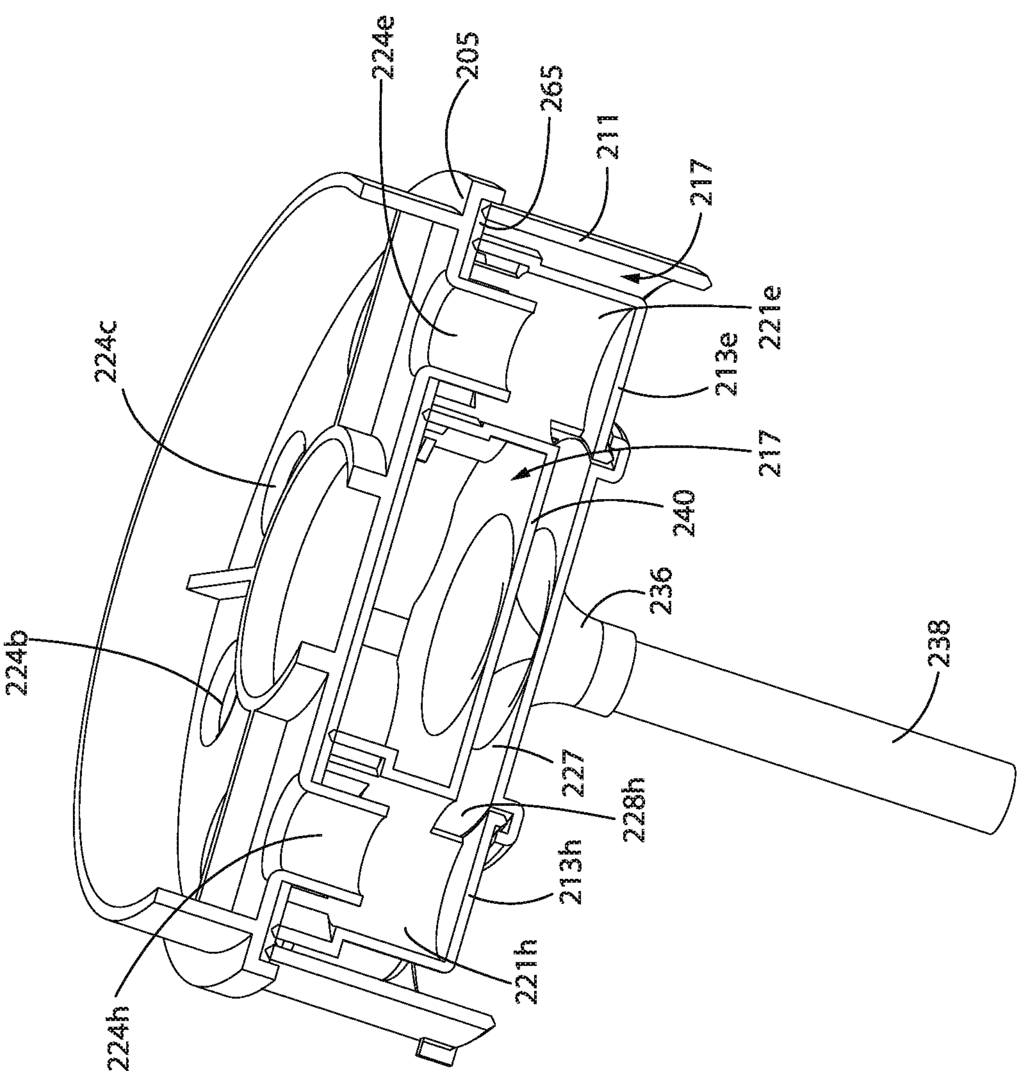
269
221a

FIG. 39

FIG. 40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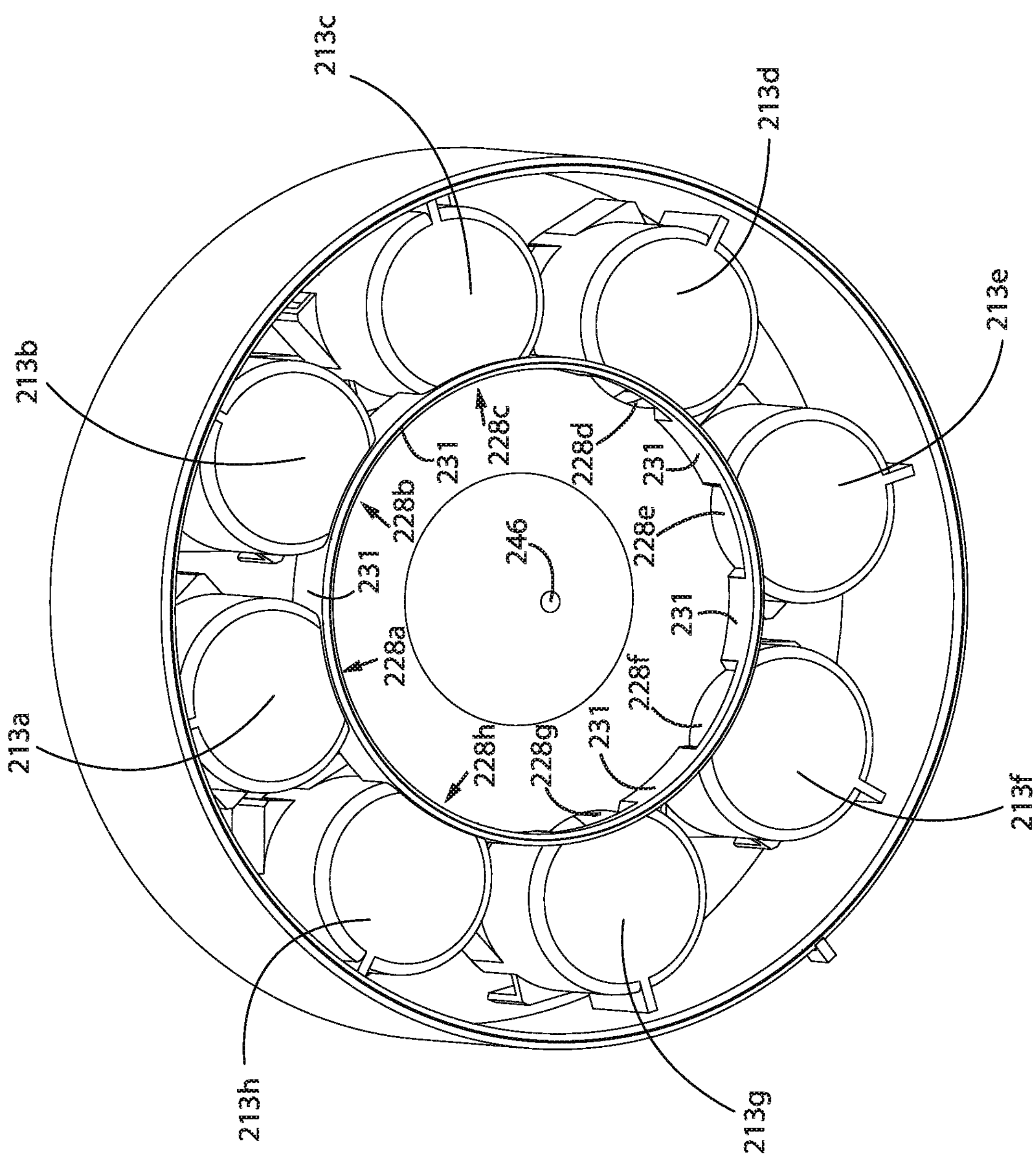
224c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228h
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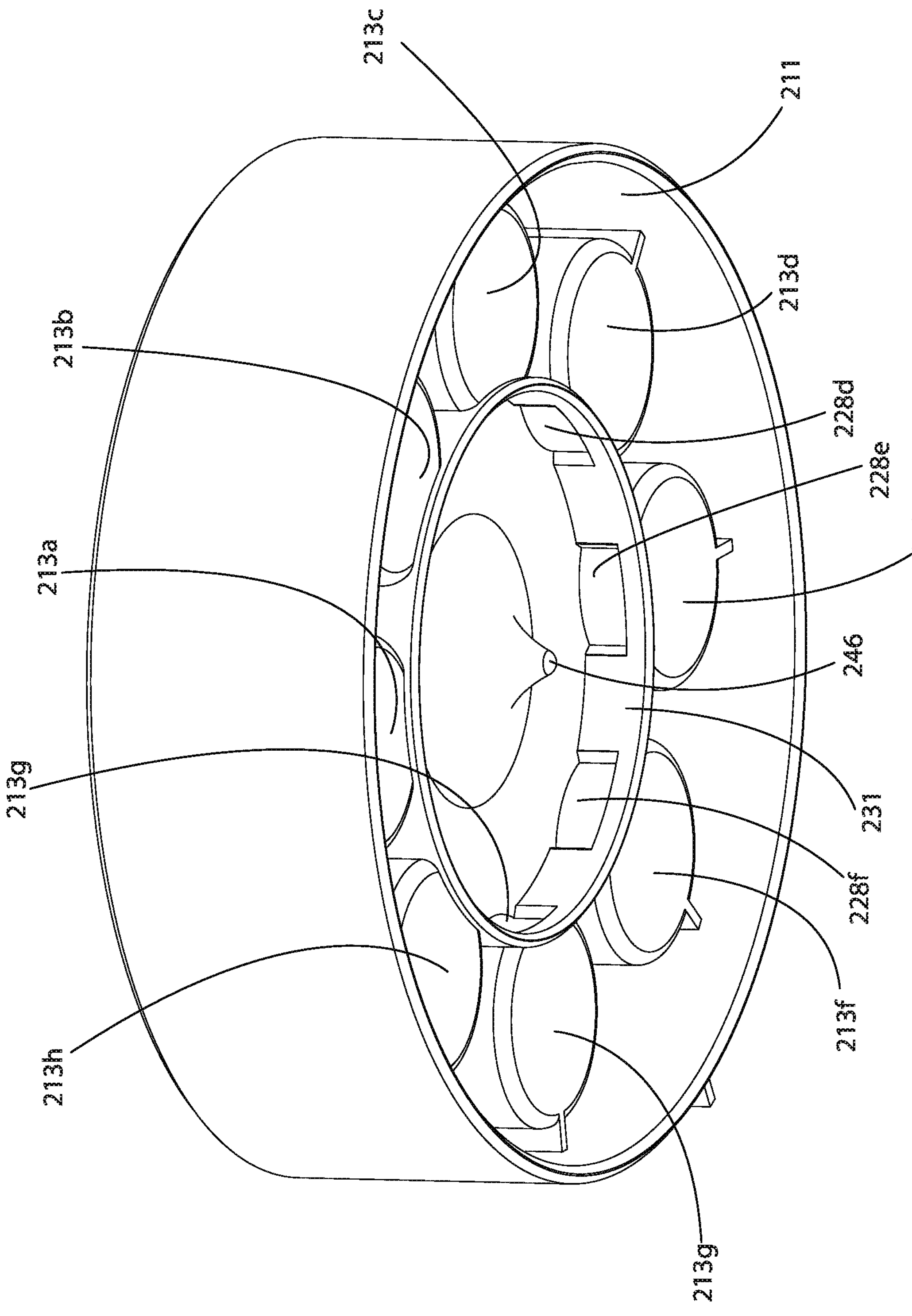
246

FIG. 41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213a
246
231
213g
228f
213f
213h
213g

FIG. 42

MULTI CYCLONE ARRAY FOR SURFACE CLEANING APPARATUS AND A SURFACE CLEANING APPARATUS HAVING SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit under 36 U.S.C. 119(e) of U.S. Provisional Application Ser. No. 62/734,603, filed on Sep. 21, 2018, entitled MULTI CYCLONE ARRAY FOR SURFACE CLEANING APPARATUS AND A SURFACE CLEANING APPARATUS HAVING SAME, the content of which is incorporated herein by reference.

FIELD

This disclosure relates generally to cyclone assemblies for surface cleaning apparatus, and more specifically to cyclone assemblies that have a cyclonic cleaning stage that includes a plurality of cyclones arranged in parallel.

INTRODUCTION

Various types of surface cleaning apparatus are known, including upright surface cleaning apparatus, canister surface cleaning apparatus, stick surface cleaning apparatus, hand carriable surface cleaning apparatus, and central vacuum systems.

Surface cleaning apparatus that use one or more cyclonic cleaning stages to remove particulate matter (e.g. dust and dirt) from an airstream are known.

A second cyclonic cleaning stage, which may comprise a plurality of cyclones in parallel, may be provided downstream of a first air treatment member (e.g. a first cyclonic cleaning stage) and upstream of the suction motor. The second cyclonic cleaning stage is typically provided to remove particulate matter from the airstream exiting the first air treatment member and was not removed from the airstream by the first air treatment member.

SUMMARY

The following introduction is provided to introduce the reader to the more detailed discussion to follow. The introduction is not intended to limit or define any claimed or as yet unclaimed invention. One or more inventions may reside in any combination or sub-combination of the elements or process steps disclosed in any part of this document including its claims and figures.

In accordance with one aspect of this disclosure, a cyclonic cleaning stage (which may be referred to as a downstream cyclonic cleaning stage or as a second cyclonic cleaning stage if an upstream air treatment member such an upstream cyclonic cleaning stage is provided) may be used as an air treatment member downstream of a primary air treatment member to remove particulate matter (e.g. dirt, dust) from an airflow exiting the first air treatment member. The cyclonic cleaning stage includes a plurality of second stage cyclone chambers arranged in parallel. Each second stage cyclone chamber has a dirt outlet configured such that at least a portion of, and preferably most or substantially all of the dirt exiting a second stage cyclone travels in a radial direction (i.e. approximately perpendicular to the cyclone axis of the second stage cyclone chamber). Such a dirt outlet may be characterized as a 'sideways' dirt outlet. A dirt

collection plenum may be provided between the dirt outlets of two or more second stage cyclone chambers and a second stage dirt collection region.

Providing sideways dirt outlets for the second stage cyclone chambers may facilitate a more compact design of the cyclonic cleaning stage. For example, the cyclonic cleaning stage may have an overall length that is about the same as the length of the second stage cyclone chambers.

In accordance with this broad aspect, there is provided a surface cleaning apparatus comprising:

(a) an upstream air treatment member;

(b) a downstream cyclonic cleaning stage comprising a plurality of cyclones in parallel, each cyclone having a cyclone axis of rotation, a first end, an axially spaced apart second end, a sidewall extending between the first and second ends, an air inlet, an air outlet and a sideways dirt outlet;

(c) a dirt collection chamber; and

(d) a dirt collection plenum positioned between at least some of the dirt outlets and the dirt collection chamber.

In some embodiments, the cyclone air inlets may have a radial outward extent and the dirt collection plenum may have a radial outer extent that is spaced radially outwardly of the radial outward extent of the cyclone air inlets.

In some embodiments, a plane that is transverse to the cyclone axis of rotation may extend through the cyclone and the dirt collection plenum.

In some embodiments, the plane may extend through the sideways dirt outlets.

In some embodiments, the cyclone air inlets may comprise a passage having an inlet end and an outlet end, and the dirt collection plenum may have a radial outer extent that is spaced radially outwardly of the inlet end of the cyclone air inlets.

In some embodiments, a plane that is transverse to the cyclone axis of rotation may extend through the cyclone and the dirt collection plenum.

In some embodiments, the plane may extend through the sideways dirt outlets.

In some embodiments, the sideways dirt outlet may comprise an opening in the sidewall.

In some embodiments, at least a portion of the sidewall may be spaced from the second end wall, whereby the sideways dirt outlet comprises a space between the sidewall and the second end wall.

In some embodiments, the sideways dirt outlet may direct dirt outwardly in a plane generally transverse to the cyclone axis of rotation into the dirt collection plenum.

In some embodiments, the plurality of cyclones may comprise a first cyclone and a second cyclone and a portion of the dirt collection plenum may be positioned between the first and second cyclones and the sideways dirt outlet of the first cyclone may direct dirt towards the portion.

In some embodiments, each cyclone may have a radially inner side, a radially outer side and lateral sides provided between the radially inner and radially outer sides and the sideways dirt outlet may be provided in one of the lateral sides.

In accordance with another aspect of this disclosure, at least a portion of, and preferably most or substantially all of a second stage dirt collection plenum may be positioned radially outwardly of the second stage cyclone chambers. Providing a dirt collection plenum radially outwardly of the second stage cyclone chambers may facilitate a more compact design of the second cyclonic cleaning stage. For example, such a design may allow an air inlet for the second cyclonic cleaning stage to be provided radially inward of the second stage cyclone chambers.

In accordance with this broad aspect, there is provided a surface cleaning apparatus comprising:

(a) an upstream air treatment member;

(b) a downstream cyclonic cleaning stage comprising a plurality of cyclones in parallel, each cyclone having a cyclone axis of rotation, a first end, an axially spaced apart second end, a sidewall extending between the first and second ends, an air inlet, an air outlet and a dirt outlet;

(c) a dirt collection chamber; and,

(d) a dirt collection plenum positioned between at least some of the dirt outlets and the dirt collection chamber,

wherein the cyclone air inlets have a radial outward extent and the dirt collection plenum has a radial outer extent that is spaced radially outwardly of the radial outward extent of the cyclone air inlets.

In accordance with another aspect of this disclosure, a cyclonic cleaning stage may be configured such that a plane perpendicular to a cyclone axis of a cyclone chamber that extends through a dirt outlet of that cyclone chamber also extends through a dirt collection plenum. Such a design may have one or more advantages. For example, providing a portion of a dirt collection plenum on the same plane as the cyclone chamber dirt outlets may result in a more compact design of a cyclonic cleaning stage.

In accordance with this broad aspect, there is provided a surface cleaning apparatus comprising:

(a) an upstream air treatment member;

(b) a downstream cyclonic cleaning stage comprising a plurality of cyclones in parallel, each cyclone having a cyclone axis of rotation, a first end, an axially spaced apart second end, a sidewall extending between the first and second ends, an air inlet, an air outlet and a dirt outlet;

(c) a dirt collection chamber; and,

(d) a dirt collection plenum positioned between at least some of the dirt outlets and the dirt collection chamber,

wherein a plane that is transverse to the cyclone axis of rotation extends through the sideways dirt outlets and the dirt collection plenum.

In accordance with either of these aspects, there is provided a surface cleaning apparatus comprising:

(a) an air flow path extending from a dirty air inlet to a clean air outlet with a suction motor provided in the air flow path;

(b) a cyclonic cleaning stage provided in the air flow path, the cyclonic cleaning stage comprising a plurality of cyclones in parallel, each cyclone having a cyclone axis of rotation, a first end, an axially spaced apart second end, a sidewall extending between the first and second ends, an air inlet, an air outlet and a sideways dirt outlet;

(c) a dirt collection chamber; and,

(d) a dirt collection plenum located between first and second axially spaced apart walls and positioned radially from the dirt outlets, wherein the second wall has a first opening communicating with the dirt collection chamber.

In some embodiments, the air inlets and the air outlets may be provided at the first end of the cyclones and the dirt outlet may be provided at the second end of the cyclones.

In some embodiments, the sideways dirt outlets may comprise openings in the sidewalls.

In some embodiments, the sideways dirt outlets may direct dirt outwardly in a plane generally transverse to the cyclone axis of rotation into the dirt collection plenum.

In some embodiments, the plurality of cyclones may comprise a first cyclone and a second cyclone and a portion of the dirt collection plenum may be positioned between the first and second cyclones and the sideways dirt outlet of the first cyclone directs dirt towards the portion.

In some embodiments, each cyclone may have a radially inner side, a radially outer side and lateral sides provided between the radially inner and radially outer sides and the sideways dirt outlet may be provided in one of the lateral sides.

In some embodiments, a portion of the air flow path may extend along the length of the cyclones from second end to the first end wherein the portion of the air flow path extends through the first and second axially spaced apart walls of the dirt collection plenum.

In some embodiments, the dirt collection plenum may be located radially outwardly from the dirt outlets.

In some embodiments, a portion of the air flow path may extend through the first and second axially spaced apart walls of the dirt collection plenum and may extend through a radial inner central portion of the cyclonic cleaning stage.

In some embodiments, the dirt collection plenum may be located radially inwardly from the dirt outlets.

In some embodiments, a portion of the air flow path may extend along an axially extending passage surrounding at least a portion of the cyclonic cleaning stage.

In some embodiments, a portion of the air flow path may extend along an axially extending passage surrounding the cyclonic cleaning stage.

In some embodiments, a plane that is transverse to the cyclone axes of rotation may extend through the cyclones and the dirt collection plenum.

In some embodiments, the plane may extend through the sideways dirt outlets.

In some embodiments, the air inlets may produce a direction of rotation in the cyclones and, for at least some of the cyclones of the plurality of cyclones, the dirt outlet may be located, based on the direction of rotation, to direct dirt towards the first opening.

In some embodiments, some of the cyclones of the plurality of cyclones have a clockwise direction of rotation and a remainder of the cyclones of the plurality of cyclones have a counterclockwise direction of rotation.

In some embodiments, for at least some of the cyclones, the air inlet may be configured to produce a direction of rotation such that dirt exiting the sideways dirt outlet travels in a direction towards the first opening.

In some embodiments, when the surface cleaning apparatus is used to clean a floor, the first opening may be located at a lower end of the dirt collection plenum.

In some embodiments, the second wall may have a second opening and, for some of the cyclones of the plurality of cyclones, the dirt outlet may be located based on a direction of rotation of the cyclone to direct dirt towards the first opening and, for a remainder of the cyclones of the plurality of cyclones, the dirt outlet may be located based on a direction of rotation of the cyclone to direct dirt towards the second opening.

In some embodiments, the surface cleaning apparatus may further comprise an upstream air treatment member and the dirt collection chamber may extend axially along at least a portion of the upstream air treatment member.

In some embodiments, the surface cleaning apparatus may be a hand vacuum cleaner having a front end and a rear end and the dirt collection chamber may have a front openable door.

In some embodiments, the front openable door may be openable concurrently with a dirt collection region of the upstream air treatment member.

In some embodiments, the air inlets may be provided at the first end of the cyclones, the dirt outlet may be provided at the second end of the cyclones and the first wall may be located between the first and second ends of the cyclones.

In some embodiments, the first wall may have a dirt collection plenum face facing the dirt collection plenum and an opposed face that is part of an air inlet plenum for the plurality of cyclones.

It will be appreciated by a person skilled in the art that an apparatus or method disclosed herein may embody any one or more of the features contained herein and that the features may be used in any particular combination or sub-combination.

These and other aspects and features of various embodiments will be described in greater detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the described embodiments and to show more clearly how they may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

FIG. **1** is a perspective cross-section view of a surface cleaning apparatus comprising a first cyclonic cleaning stage and a second cyclonic cleaning stage in accordance with one embodiment;

FIG. **2** is a cross-section view of the surface cleaning apparatus of FIG. **1**;

FIG. **3** is a perspective view of the upstream end of the second cyclonic cleaning stage of the surface cleaning apparatus of FIG. **1**;

FIG. **4** is an exploded view of the second cyclonic cleaning stage of FIG. **3**;

FIG. **5** is a perspective view of the downstream end of the second cyclonic cleaning stage of the surface cleaning apparatus of FIG. **1**;

FIG. **6** is an exploded view of the second cyclonic cleaning stage of FIG. **5**;

FIG. **7** is a perspective section view of the second cyclonic cleaning stage of FIG. **3**, taken along line **7-7** shown in FIG. **3**;

FIG. **8** is a perspective section view of the second cyclonic cleaning stage of FIG. **3**, taken along line **8-8** shown in FIG. **3**;

FIG. **9** is another perspective section view of the second cyclonic cleaning stage of FIG. **3**, taken along line **7-7** shown in FIG. **3**;

FIG. **10** is a perspective section view of the second cyclonic cleaning stage of FIG. **3**, taken along line **10-10** shown in FIG. **3**;

FIG. **11** is a perspective end view of the second stage cyclones of the second cyclonic cleaning stage of FIG. **3**;

FIG. **12** is a perspective view of the upstream end of a second cyclonic cleaning stage in accordance with another embodiment;

FIG. **13** is another perspective view of the upstream end of the second cyclonic cleaning stage of FIG. **12**;

FIG. **14** is an exploded view of the second cyclonic cleaning stage of FIG. **12**;

FIG. **15** is a perspective view of the downstream end of the second cyclonic cleaning stage of FIG. **12**;

FIG. **16** is an exploded view of the second cyclonic cleaning stage of FIG. **15**;

FIG. **17** is a perspective section view of the second cyclonic cleaning stage of FIG. **12**, taken along line **17-17** shown in FIG. **12**;

FIG. **18** is another perspective section view of the second cyclonic cleaning stage of FIG. **12**, taken along line **17-17** shown in FIG. **12**;

FIG. **19** is a perspective section view of the second cyclonic cleaning stage of FIG. **12**, taken along line **19-19** shown in FIG. **12**;

FIG. **20** is a perspective end view of the inlet plenum of the second stage cyclones of the second cyclonic cleaning stage of FIG. **12**;

FIG. **21** is a perspective end view of the first ends of the second stage cyclones of the second cyclonic cleaning stage of FIG. **12**;

FIG. **22** is a perspective end view of the first ends of the second stage cyclones of a second cyclonic cleaning stage in accordance with another embodiment;

FIG. **23** is a perspective end view of the inlet plenum of the second stage cyclones of a second cyclonic cleaning stage in accordance with another embodiment;

FIG. **24** is a perspective view of a surface cleaning apparatus comprising a first cyclonic cleaning stage and a second cyclonic cleaning stage in accordance with another embodiment;

FIG. **25** is a section view of the surface cleaning apparatus of FIG. **24**, taken along line **25-25** shown in FIG. **24**;

FIG. **26** is a section view of the surface cleaning apparatus of FIG. **24**, taken along line **26-26** shown in FIG. **24**;

FIG. **27** is a perspective cross-section view of a surface cleaning apparatus comprising a first cyclonic cleaning stage and a second cyclonic cleaning stage in accordance with another embodiment;

FIG. **28** is a perspective view from the front end of the surface cleaning apparatus of the second cyclonic cleaning stage of the surface cleaning apparatus of FIG. **27**;

FIG. **29** is an exploded view from the front end of the surface cleaning apparatus of the second cyclonic cleaning stage of FIG. **28**;

FIG. **30** is exploded view from the air inlet and outlet end of the second cyclonic cleaning stage of FIG. **28**;

FIG. **31** is a perspective end from the air inlet and outlet end view of the first ends of the second stage cyclones of the second cyclonic cleaning stage of FIG. **27**;

FIG. **32** is a perspective end from the front end of the surface cleaning apparatus view of the inlet ends of the second stage cyclones of the second cyclonic cleaning stage of FIG. **27**;

FIG. **33** is a perspective cross-section view of a surface cleaning apparatus comprising a first cyclonic cleaning stage and a second cyclonic cleaning stage in accordance with another embodiment;

FIG. **34** is a cross-section view of the surface cleaning apparatus of FIG. **33**;

FIG. **35** is a perspective view from the front end of the surface cleaning apparatus of the second cyclonic cleaning stage of the surface cleaning apparatus of FIG. **33**;

FIG. **36** is an exploded view from the front end of the surface cleaning apparatus of the second cyclonic cleaning stage of FIG. **35**;

FIG. **37** is a perspective view of the downstream end of the second cyclonic cleaning stage of the surface cleaning apparatus of FIG. **33**;

FIG. **38** is an exploded view from the downstream end of the second cyclonic cleaning stage of FIG. **37**;

FIG. **39** is a perspective section view of the second cyclonic cleaning stage of FIG. **33**, taken along line **39-39** shown in FIG. **35**;

FIG. **40** is a perspective section view of the second cyclonic cleaning stage of FIG. **33**, taken along line **40-40** shown in FIG. **35**;

FIG. **41** is a perspective end view from the front end of the surface cleaning apparatus of the first ends of the second stage cyclones of the second cyclonic cleaning stage of FIG. **35**; and

FIG. **42** is another perspective end view from the front end of the surface cleaning apparatus of the first ends of the second stage cyclones of the second cyclonic cleaning stage of FIG. **35**.

The drawings included herewith are for illustrating various examples of articles, methods, and apparatuses of the teaching of the present specification and are not intended to limit the scope of what is taught in any way.

DESCRIPTION OF EXAMPLE EMBODIMENTS

Various apparatuses, methods and compositions are described below to provide an example of an embodiment of each claimed invention. No embodiment described below limits any claimed invention and any claimed invention may cover apparatuses and methods that differ from those described below. The claimed inventions are not limited to apparatuses, methods and compositions having all of the features of any one apparatus, method or composition described below or to features common to multiple or all of the apparatuses, methods or compositions described below. It is possible that an apparatus, method or composition described below is not an embodiment of any claimed invention. Any invention disclosed in an apparatus, method or composition described below that is not claimed in this document may be the subject matter of another protective instrument, for example, a continuing patent application, and the applicant(s), inventor(s) and/or owner(s) do not intend to abandon, disclaim, or dedicate to the public any such invention by its disclosure in this document.

Furthermore, it will be appreciated that for simplicity and clarity of illustration, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the example embodiments described herein. However, it will be understood by those of ordinary skill in the art that the example embodiments described herein may be practiced without these specific details. In other instances, well-known methods, procedures, and components have not been described in detail so as not to obscure the example embodiments described herein. Also, the description is not to be considered as limiting the scope of the example embodiments described herein.

General Description of a Surface Cleaning Apparatus

Referring to FIGS. **1** and **2**, a surface cleaning apparatus is shown generally as **10**. The surface cleaning apparatus **10** includes an inlet conduit **16** downstream of a dirty air inlet (not shown), a clean air outlet **18** and an air flow path or passage extending therebetween. An upstream air treatment member **100**, a downstream cyclonic cleaning stage **200** and at least one suction motor **25** are provided in the air flow path. Preferably, the cyclone assembly is provided upstream from a suction unit **20** that contains the suction motor(s) **25**, but alternatively may be provided downstream from the suction motor(s).

In addition to the cyclone assembly, the surface cleaning apparatus may also include one or more pre-motor filters (preferably positioned in the air flow path between the downstream cyclonic cleaning stage and the suction motor) and/or one or more post-motor filters (positioned in the air flow path between the suction motor and the clean air outlet).

Preferably, the surface cleaning apparatus includes one or more handles (not shown) for a user to support and/or direct the surface cleaning apparatus above a surface to be cleaned. For example, the surface cleaning apparatus may be an upright vacuum cleaner that has a surface cleaning head and an upper portion that is movably and drivingly connected to the surface cleaning head, wherein the surface cleaning head may be supported by any suitable support members, such as, for example wheels and/or rollers, to allow the surface cleaning head to be moved across a floor or other surface being cleaned. In alternative embodiments, the surface cleaning apparatus may be another suitable type of surface cleaning apparatus, such as a canister type vacuum cleaner, a hand vacuum cleaner, a stick vac, a wet-dry type vacuum cleaner, a carpet extractor, and the like.

General Description of an Upstream Air Treatment Member

FIGS. **1** and **2** illustrate an embodiment of an upstream air treatment member, referred to generally as **100**. In the illustrated example, the air treatment member **100** comprises a first cyclonic cleaning stage located upstream of the cyclonic cleaning stage **200**. Alternatively, or additionally, the upstream air treatment member may comprise a filter bag or any other suitable air treatment apparatus. Alternatively, or additionally, in some embodiments, an upstream air treatment member may not be provided.

In the illustrated example, the first cyclonic cleaning stage includes a first stage cyclone chamber **110** that has a first end **102**, a second end **104**, and extends along a cyclone axis **115** and includes a generally cylindrical sidewall **111** extending between a first or front end wall **103** and second or rear end wall **105**. In the illustrated embodiment, a plate (which may be referred to as an arrestor plate) **106** is provided at the first end **102**. Alternatively, or in addition, the first cyclonic cleaning stage may comprise a plurality of cyclone chambers.

In the illustrated embodiment, the first stage cyclone chamber **110** includes a first stage cyclone air inlet **112** and a first stage cyclone air outlet **114**. Optionally, an external dirt chamber **119** may be provided. Accordingly, as exemplified, first stage cyclone chamber **110** also includes at least one dirt outlet **118**, through which dirt and debris that is separated from the air flow can exit the cyclone chamber **110**. While it is preferred that most or all of the dirt exit the first stage cyclone chamber via the dirt outlet **118**, some dirt may be entrained in the air exiting the first stage cyclone chamber via the air outlet **114**, and/or may settle on the arrestor plate **106** (e.g. if the surface cleaning apparatus is oriented such that the cyclone axis **115** is generally vertical).

In the illustrated example, the first stage cyclone dirt outlet **118** is in the form of a gap between the cyclone side wall **111** and the arrestor plate **106**, and is located toward the first end **102** of the cyclone chamber **110**. Alternatively, the dirt outlet may be of any other suitable configuration, and may be provided at another location in the cyclone chamber, including, for example as a hole in the sidewall **111**, or as a hole or gap between the sidewall and an end wall of the cyclone chamber.

Preferably, the first stage cyclone air inlet **112** is located toward one end of the cyclone chamber **110** (the second end in the illustrated example) and may be positioned adjacent the corresponding cyclone chamber end wall **105**. Alternatively, the cyclone air inlet **112** may be provided at another location within the first stage cyclone chamber **110**. Preferably, the air inlet **112** is positioned so that air flowing through the inlet and into the first stage cyclone chamber is travelling generally tangentially relative to, and preferably adjacent, the sidewall **111** of the cyclone chamber **110**.

Air can exit the first stage cyclone chamber **110** via the first stage air outlet **114**. Preferably, the cyclone air outlet is positioned in one of the cyclone chamber end walls and, in the example illustrated, is positioned in the same end as the air inlet **112**. Accordingly, as exemplified, air inlet **112** and air outlet **114** may be positioned adjacent or at the second end wall **105**. In the illustrated embodiment the air outlet **114** is generally circular in cross-sectional shape. Preferably, the cross-sectional area in a direction transverse to a direction of flow of air through the outlet **114** or flow area of the first stage cyclone air outlet **114** is generally equal to the cross-sectional area in a direction transverse to a direction of flow of air through the air inlet **112** or flow area of the first stage cyclone air inlet **112**. In the illustrated example, the cyclone air outlet **114** comprises a vortex finder **116**.

Referring to FIGS. **1** and **2**, first stage dirt collection chamber **119** is in communication with dirt outlet **118** to collect the dirt and debris as it exits first stage cyclone chamber **110**. Dirt collection chamber **119** may be of any suitable configuration. In the illustrated example, the dirt collection chamber **119** is bounded by the first stage cyclone side wall **111**, end wall **103**, and arrestor plate **106**.

In use, air enters the first stage cyclone chamber **110** via air inlet **112** and exits the chamber **110** via air outlet **114**, while separated dirt and debris exits the cyclone chamber **110** via dirt outlet **118**, where it collects in the first stage dirt collection chamber **119**.

To help facilitate emptying the dirt collection chamber **119**, the end walls **103**, which may be the front wall of a hand vacuum cleaner, may be openable. Preferably, end wall **103** is moveable between a closed position (FIGS. **1** and **2**) and an open position (not shown). When the end wall **103** is in the open position, the first stage dirt collection chamber **119** and the first stage cyclone chamber **110** may be emptied.

End wall **103** is preferably configured so that when it is in the closed position, the surface facing the cyclone chamber **110** cooperatively engages an end surface of the sidewall **111**. For example, as shown in FIGS. **1** and **2**, the end wall surface may have one or more channels or grooves **138** configured to receive the ends of sidewall **111** when the end wall **103** is in the closed position. Optionally, one or more sealing or gasketing elements may be provided between groove(s) **138** and the sidewall ends.

In the illustrated embodiment, air exiting the first stage air outlet **114** is directed along a conduit **30** to a second stage air inlet **212**. From there, the air is directed into a chamber or manifold **217** of the downstream cyclonic cleaning stage **200**. Alternatively, conduit **30** may not be provided (or may have a de minimus length) such that air exiting the first stage air outlet **114** passes directly through second stage air inlet **212** and into manifold **217**. Optionally, a manifold may not be provided and outlet **114** may be directly connected to the inlets of the inlets of the cyclones second cyclonic stage.

General Description of a Downstream Cyclonic Cleaning Stage

FIGS. **1** to **11** illustrate an embodiment of a downstream cyclonic cleaning stage, referred to generally as **200**. The cyclonic cleaning stage includes a plurality of second stage cyclone chambers **220** arranged in parallel. In the embodiment illustrated in FIGS. **1** to **11**, four cyclone chambers **220** are shown, referred to as **220***a*, **220***b*, **220***c*, and **220***d*, respectively. It will be appreciated that an upstream air treatment member need not be provided. Also, it will be appreciated that the plurality of second stage cyclones may comprise any number of cyclones.

In the illustrated embodiment, each cyclone chamber **220** extends along a respective cyclone axis **215** (see e.g. FIG. **8**) and includes a sidewall **221** that extends between a first end wall **203** and a second end wall **205**.

In the illustrated embodiment, each cyclone chamber **220** includes one or more cyclone air inlets **222** and a cyclone air outlet **224**. Each cyclone chamber **220** also includes at least one dirt outlet **228**, through which dirt and debris that is separated from the air flow can exit the cyclone chamber **220**. While it is preferred that most or all of the dirt entrained in the air exiting the first air treatment member (e.g. cyclone **100**) exits the cyclone chambers **200** via the dirt outlets **228**, some dirt may be entrained in the air exiting the second stage cyclone chambers via the air outlets **224**, and/or may settle on the end wall **203** of the cyclone chambers **220** (e.g. if the surface cleaning apparatus is oriented such that the cyclone axes **215** are generally vertical).

In some embodiments, all or substantially all of the dirt entrained in the air exiting the first cyclonic cleaning stage may be removed from the airflow by the second cyclonic cleaning stage. This may, for example, obviate the need to provide a pre-motor filter in the surface cleaning apparatus **10**.

In the illustrated example, each cyclone dirt outlet **228** is in the form of a slot bounded by the cyclone side wall **221** and the first or front end wall member **203** (and/or an optional inlet sealing member **263**, discussed further below), and is located toward the first or front end **202** of the cyclone chamber **220**. An advantage of this design is that at least a portion of, and preferably most or substantially all of the dirt exiting a second stage cyclone travels in a radial direction (e.g., approximately perpendicular to the cyclone axis of the second stage cyclone chamber). Such a dirt outlet may be characterized as a 'sideways' dirt outlet. This preferred orientation for the dirt collection outlets may facilitate a more compact design of the cyclonic cleaning stage **200**. It will be appreciated that the dirt outlet may be of any configuration that permits dirt to exit sideways into dirt plenum for two or more of the cyclone of the second cyclonic cleaning stage if a common dirt plenum is provided.

Preferably, each second stage cyclone has one or more air inlets **222** located toward one end of the cyclone chamber **220** (the second end **204** in the illustrated example). For example, in the illustrated embodiments the inlets **222** are positioned adjacent the corresponding first end wall member **205**. Alternatively, the cyclone air inlets **222** may be provided at another location within the cyclone chamber **220**. Preferably, each air inlet **222** is positioned so that air flowing through the inlet and into a cyclone chamber **220** is travelling generally tangentially relative to, and preferably adjacent, the sidewall **221** of the cyclone chamber **220**.

In the embodiment illustrated in FIGS. **1-10**, each second stage cyclone chamber **220***a-d* includes six airflow inlets (i.e. air inlets **222***a,a-f*, **222***b,a-f*, **222***c,a-f*, and **222***d,a-f*), and one cyclone air outlet **224***a-d*. In the illustrated embodiment, the air inlets of each cyclone chamber **220** are positioned radially equidistantly at the second end of each second cyclonic cleaning stage (see e.g. FIGS. **7-10**). Alternatively, the air inlets of the second cyclonic stage may be arranged in any suitable manner. Also, while six air inlets are illustrated for each second stage cyclone chamber, it will be appreciated that, alternatively, two or three or four or five or seven or more air inlets may be provided per cyclone chamber.

Also, in the illustrated embodiment, the air inlets **222** of the cyclone chambers **220** are in communication with a common manifold or header **217**. Having the second stage cyclone air inlets in communication with the air outlet **114** of the first air treatment stage via manifold **217** may have one or more advantages. For example, it may facilitate airflow to the second cyclonic cleaning stages with reduced bends in an air flow conduit thereby reducing the back pressure through the cyclone assembly. In addition, the use of a common manifold may enable the air to be distributed to the inlets of a plurality of cyclones with reduced back pressure.

The cross-sectional shape of each air inlet **222** can be any suitable shape. In the illustrated example each air inlet has a cross-sectional shape that is generally rectangular. The total cross-sectional area of the second stage air inlets (i.e. the sum of the cross-sectional areas of each inlet **222**) can be referred to as the total cross-sectional area or total flow area of the second cyclonic cleaning stage.

Air can exit each cyclone chamber **220** via an air outlet **224** provided for each cyclone chamber **220**. Preferably, the cyclone air outlets **224***a-d* are positioned in one of the end walls of each cyclone chamber **220** and, in the example illustrated, are positioned in the same ends as the air inlets **222***a-f*. As exemplified, the air inlets and air outlets may be at the rear end of the second cyclonic cleaning stage.

In the illustrated embodiment the air outlets **224***a-d* are generally circular in cross-sectional shape. Preferably, the cross-sectional area in a direction transverse to a direction of flow of air through the air outlets **224***a-d* or flow area of each second stage cyclone air outlet **224** is generally equal to the flow area of the air inlets **222** in a direction transverse to a direction of flow of air through the air inlets **224** for that cyclone chamber. As exemplified, each cyclone air outlet **224** may comprise a vortex finder **226**.

As illustrated in FIGS. **4** and **6**, the cyclonic cleaning stage **200** may include a central body member **201**, a first or front end wall member **203**, and a second or rear end wall member **205**. As in the illustrated example, an inlet sealing member **263** may be provided between the first end wall member **203** and the central body member **201**, and an outlet sealing member **265** may be provided between the second end wall member **205** and the central body member **201**. The sealing members **263**, **265** may reduce or inhibit air leakage between the central body member **201** and the end wall members **203**, **205** when the cyclonic cleaning stage **200** is assembled. Alternatively, the central body member **201** may be joined to one or both end wall members **203**, **205** using a process that results in a relatively air-impermeable seal (e.g. sonic welding, adhesive, or the like), in which case one or both sealing members **263**, **265** may not be provided.

Dirt Collection Plenum for Second Stage Cyclones Positioned Radially Outward of the Second Stage Cyclones

The following is a description of the positioning of a dirt collection plenum for second stage cyclones that may be used by itself in any surface cleaning apparatus or in any combination or sub-combination with any other feature or features disclosed herein.

In accordance with one feature, a second stage dirt collection plenum may be provided between the dirt outlets of two or more second stage cyclone chambers and a second stage dirt collection region (or the dirt plenum may be the second stage dirt collection region). In one or more preferred embodiments, at least a portion of, and preferably most or substantially all of the second stage dirt collection plenum may be positioned radially outwardly of the second stage cyclone chambers. In such an embodiment, this preferred location for the second stage dirt collection plenum may facilitate a more compact design of the cyclonic cleaning stage **200**.

As exemplified in FIGS. **1**, **2**, and **7-9**, two or more second stage cyclone chambers **220** may be associated with a single second stage dirt collection chamber **229**. Accordingly, for example, a single second stage dirt collection chamber **229** may be provided. Collectively, the second stage dirt collection chamber(s) **229** may be referred to generally as a second stage dirt collection region.

As exemplified in FIG. **8**, in use air enters each second stage cyclone chamber **220** (e.g. chamber **220***a*) via one or more air inlets **222** (e.g. inlets **222***a,a*, **222***a,b*, **222***a,c*, **222***a,d*, **222***a,e*, and **222***a,f*) and exits each chamber **220** (e.g. chamber **220***a*) via an air outlet **224** (e.g. outlet **224***a*), while separated dirt and debris exits each cyclone chamber **220** (e.g. chamber **220***a*) via a dirt outlet **228** (e.g. outlet **228***a*), where it enters a dirt collection plenum **227**. Dirt collection plenum **227** is also in communication with the second stage dirt collection region **229**.

In the illustrated example, dirt collection plenum **227** is defined, in the radial direction, between an outer wall **211** of the central body member **201** and second stage cyclone chamber sidewalls **221**, and a plurality of inner walls **231** extending between the second stage cyclone chamber sidewalls **221**. Dirt collection plenum **227** is also defined, in the longitudinal direction, between an intermediate wall **240** of the central body member **201** and an inner surface of the first end wall member **203**. The second stage cyclone chamber sidewalls **221** and the plurality of inner walls **231** extend between the intermediate wall **240** and first end wall member **203**.

Notably at least part, and optionally all, of dirt collection plenum **227** is positioned radially outwardly from the second stage cyclone chambers **220***a-d*, and also radially outwardly from the second stage air inlet **212** of the second cyclonic cleaning stage **200** (see e.g. FIG. **11**). Accordingly, as exemplified, a plane perpendicular to a cyclone axis **215** of a second stage cyclone chamber **220** that extends through a dirt outlet **228** of that cyclone chamber **220** may therefore extend through the dirt collection plenum **227**. Such a design may have one or more advantages. For example, providing the plenum **227** radially outwardly from the second stage cyclone chambers **220***a-d* may result in a more compact design of a second cyclonic cleaning stage. In addition, less dirt may be re-entrained back into the cyclone chamber since the dirt may be collected distal to the dirt outlet. Alternatively, or in addition, the dirt may exit the dirt outlet and be directed into a void region which does not have a wall that may reflect the dirt back towards the dirt outlet, from where it could be re-entrained.

Preferably, the dirt outlets **228***a-d* of the second stage cyclone chambers **220***a-d* are oriented such that dirt is ejected outwardly into the dirt collection plenum **227** in a plane generally transverse to the cyclone axis of rotation **215** and preferably in a direction towards the second stage dirt collection region **229**. For example, as illustrated in FIG. **11**, in operation air within the second stage cyclone chambers **220***a* and **220***d* may rotate in a counter-clockwise direction, when viewed from the dirt outlet end. Accordingly, most if not all of the dirt ejected from the second stage cyclone chamber dirt outlets **228***a* and **228***d* may travel towards the dirt collection region **229**, e.g. in directions **225***a* and **225***b*, respectively. Air may be induced to flow counter clockwise in second stage cyclone chambers **220***a* and **220***d* by using air inlets that will create a counter clockwise flow. As exemplified, air inlets **222***a* and **222***d* define a passage that will introduce air flowing in a counter clockwise direction into second stage cyclone chambers **220***a* and **220***d*.

Similarly, in operation air within the second stage cyclone chambers **220***b* and **220***c* may rotate in a clockwise direction, when viewed from the outlet end. Accordingly, most if not all of the dirt ejected from the second stage cyclone chamber dirt outlets **228***b* and **228***c* may travel towards the dirt collection region **229**, e.g. in directions **225***b* and **225***c*, respectively. In the illustrated embodiments, a single dirt collection region **229** is provided. Air may be induced to flow clockwise in second stage cyclone chambers **220***b* and **220***c* by using air inlets that will create a clockwise flow. As exemplified, air inlets **222***b* and **222***c* define a passage that will introduce air flowing in a clockwise direction into second stage cyclone chambers **220***b* and **220***c*.

Alternatively, as exemplified in FIGS. **25** and **26**, two or more dirt collection regions may be provided. For example, a dirt collection region in communication with cyclone chamber dirt outlets **228***a* and **228***d* (the dirt outlets on the left side of the second cyclonic cleaning stage **200** when viewed from the front of the hand vacuum cleaner), and another dirt collection region in communication with cyclone chamber dirt outlets **228***b* and **228***c* (the dirt outlets on the right side of the second cyclonic cleaning stage **200** when viewed from the front of the hand vacuum cleaner).

Orienting the cyclone chamber dirt outlets such that dirt is ejected outwardly into the dirt collection plenum and in a direction towards a second stage dirt collection region may have one or more advantages. For example, by orienting the direction of the ejected dirt a relatively small gap **235** (e.g. less than 10 mm, less than 5 mm, or about 3 mm) may be provided between the second stage cyclone chamber sidewalls **221** and the outer wall **211** of the central body member **201**, which may result in a more compact design of a second cyclonic cleaning stage.

As discussed previously, in the illustrated embodiment, air exiting the first stage air outlet **114** is directed along a conduit **30** to a second stage air inlet **212** and into manifold **217** of the downstream cyclonic cleaning stage **200**. Alternatively, conduit **30** may not be provided (or may have a de minimus length) such that air exiting the first stage air outlet **114** passes directly through second stage air inlet **212** and into manifold **217**. In such embodiments, the second stage dirt collection chamber **229** may be provided alongside of the first stage air treatment member (e.g. radially outward of cyclone chamber **110**). In such a configuration, the dirt collection chamber **119** and the second stage dirt collection region **229** may be configured to be concurrently openable. For example, end wall **103** may be configured so that when it is in the closed position, the surface facing the cyclone chamber **110** cooperatively engages an end surface of the sidewall **111** and also cooperatively engages an end surface of the second stage dirt collection region **229**.

FIGS. **12** to **21** illustrate an embodiment of a cyclonic cleaning stage, referred to generally as **200**. In this example embodiment, eight second stage cyclone chambers **220** are shown, referred to as **220***a*, **220***b*, **220***c*, **220***d*, **220***e*, **220***f*, **220***g*, and **220***h*, respectively. Elements having similar structure and/or performing similar function as those in the example cyclonic cleaning stage illustrated in FIGS. **1** to **11** are numbered similarly, and will not be discussed further.

The embodiment illustrated in FIGS. **12** to **21** is generally similar to the embodiment illustrated in FIGS. **1** to **11**, with the exception of the number of second stage cyclone chambers. Notably, in the eight-cylinder embodiment of FIGS. **12** to **21**, the second stage air inlet **212** has a circular cross-section, which is possible due to the space resulting from the generally circular arrangement of the eight second stage cyclone chambers **220***a-h*. This is in contrast to the generally cross-shaped air inlet **212** of the four-cylinder embodiment of FIGS. **1** to **11**, which results from the reduced spacing of the four second stage cyclone chambers **220***a-d*.

In this example embodiment, the location and/or angle of the inner walls **231** that extend between adjacent second stage cyclone chamber sidewalls **221** is different than in the embodiment illustrated in FIG. **11**. In the embodiment of FIG. **21**, some of the walls **231** extend from a position adjacent the downstream end of a dirt outlet of one cyclone to the sidewall **221** of an adjacent cyclone chamber. In contrast, in the embodiment of FIG. **11**, walls **231** extend from a position spaced from the dirt outlet of one cyclone chamber to a portion of the sidewall **221** of an adjacent cyclone chamber that is also spaced from the dirt outlet of that cyclone chamber.

FIG. **22** illustrates another eight cyclone embodiment of a cyclonic cleaning stage. In this example embodiment, the location and/or angle of the inner walls **231** that extend between the adjacent second stage cyclone chamber sidewalls **221** located at the portion of the dirt plenum facing the dirt chamber **229** is different than in the embodiment illustrated in FIG. **21**. As exemplified in FIG. **22**, walls **231** that extend between cyclone chambers **228***f* and **228***g*, and between **228***c* and **228***d* also extend from a position adjacent the downstream end of a dirt outlet of one of the cyclone chambers. In addition, a wall **231** extends from a position adjacent the downstream end of the dirt outlet of cyclone chamber **228***f* to a position adjacent the downstream end of the dirt outlet of cyclone chamber **228***c*. Altering the position and/or angle of the inner walls **231** may inhibit or prevent debris from accumulating in the areas of the plenum **227** between the cyclone chamber sidewalls (e.g. the area adjacent wall **231** between sidewalls **221***b* and **221***c*).

FIG. **23** illustrates an embodiment of a cyclonic cleaning stage having six second stage cyclone chambers **220***a-f*. Elements having similar structure and/or performing similar function as those in the example cyclonic cleaning stage illustrated in FIGS. **1** to **11** are numbered similarly. This embodiment is generally similar to the embodiment illustrated in FIGS. **12** to **22**, with the exception of the number of second stage cyclone chambers.

FIGS. **24** to **26** illustrate a surface cleaning apparatus **100**, in this case a hand vacuum, having an embodiment of a cyclonic cleaning stage, referred to generally as **200**. Elements having similar structure and/or performing similar function as those in the example cyclonic cleaning stage illustrated in FIGS. **1** to **11** are numbered similarly, and will not be discussed further.

The embodiment illustrated in FIGS. **24** to **26** is generally similar to the embodiment illustrated in FIGS. **12** to **21**, with the exception of the number of dirt collection regions and the configuration of the dirt collection plenum. Notably, in the embodiment of FIGS. **24** to **26**, two second stage dirt collection regions **229** are provided.

As illustrated in FIG. **26**, a first second stage dirt collection region **229***a* is provided on one side of cyclone chamber **110**, and another (or second) second stage dirt collection region **229***b* is provided on another side of cyclone chamber **110**. The illustrated locations of the dirt collection regions may facilitate a more compact design of the surface cleaning apparatus. It will be appreciated that the dirt collection regions may be positioned elsewhere in alternative embodiments.

As illustrated in FIG. **25**, the dirt outlets **228***a*, **228***f*, **228***g*, and **228***h* of the second stage cyclone chambers **220***a*, **220***f*, **220***g*, and **220***h* are oriented such that dirt is ejected outwardly into the dirt collection plenum **227** in a direction towards the dirt collection region **229***a*. For example, as illustrated in FIG. **25**, the air inlets **222***a,a-f*, **222***f,a-f*, **222***g,a-f*, and **222***h,a-f* may be oriented such that, in operation, air is directed into the second stage cyclone chambers **220***a*, **220***f*, **220***g*, and **220***h* such that air within the cyclone chamber may rotate in a counter-clockwise direction, when viewed from the outlet end. Accordingly, most if not all of the dirt ejected from the second stage cyclone chamber dirt outlets **228***a*, **228***f*, **228***g*, and **228***h* may be directed towards the dirt collection region **229***a*, e.g. in directions **225***a*, **225***f*, **225***g*, and **225***h*, respectively.

The dirt outlets **228***b*, **228***c*, **228***d*, and **228***e* of the second stage cyclone chambers **220***b*, **220***c*, **220***d*, and **220***e* are oriented such that dirt is ejected outwardly into the dirt collection plenum **227** in a direction towards the dirt collection region **229***b*. For example, as illustrated in FIG. **25**, the air inlets **222***b,a-f*, **222***c,a-f*, **222***d,a-f*, and **222***e,a-f* may be oriented such that, in operation, air is directed into the second stage cyclone chambers **220***b*, **220***c*, **220***d*, and **220***e* such that air within the cyclone chamber may rotate in a clockwise direction, when viewed from the outlet end. Accordingly, most if not all of the dirt ejected from the second stage cyclone chamber dirt outlets **228***b*, **228***c*, **228***d*, and **228***e* may be directed towards the dirt collection region **229***b*, e.g. in directions **225***b*, **225***c*, **225***d*, and **225***e*, respectively.

Dirt Collection Plenum for Second Stage Cyclones Positioned Radially Inward of the Second Stage Cyclones

The following is a description of the positioning of a dirt collection plenum for second stage cyclones that may be used by itself in any surface cleaning apparatus or in any combination or sub-combination with any other feature or features disclosed herein.

In accordance with one feature, a second stage dirt collection plenum is provided between the dirt outlets of two or more second stage cyclone chambers and a second stage dirt collection region. In accordance with this feature, the air flow path to the air inlets **222** of the cyclone chambers is provided radially outwardly from the dirt collection plenum. Accordingly, at least a portion of, and preferably all or substantially all of the second stage dirt collection plenum may be positioned radially inwardly of the second stage cyclone chambers. In such an embodiment, this preferred location for the second stage dirt collection plenum may facilitate a more compact design of the cyclonic cleaning stage **200**.

FIGS. **27** to **32** illustrate an embodiment of a cyclonic cleaning stage, referred to generally as **200**. In this example embodiment, six second stage cyclone chambers **220** are shown, referred to as **220***a*, **220***b*, **220***c*, **220***d*, **220***e*, and **220***f*, respectively. Elements having similar structure and/or performing similar function as those in the example cyclonic cleaning stage illustrated in FIGS. **1** to **11** are numbered similarly, and will not be discussed further.

In the illustrated embodiments, air entering the downstream cyclonic cleaning stage **200** via second stage air inlet **212** is directed into a chamber or manifold **217**, which is in communication with the air inlets **222** of the cyclone chambers **220**.

In the embodiments illustrated in FIGS. **1** to **26**, air directed through second stage air inlet **212** enters a central portion of the manifold **217** (e.g., a portion axially aligned with conduit **30**), and a portion of the air flow may diffuse radially outwardly towards the outer wall **211** of the central body member **201** to surround the air inlets **222** of the cyclone chambers **220**.

In contrast, in the embodiments illustrated in FIGS. **27** to **32**, air passing through second stage air inlet **212** is directed radially outwardly towards the outer wall **211** of the central body member **201** (i.e. a radially outward portion of the manifold **217**), and a portion of the air flow may diffuse radially inwardly towards a central portion of the manifold **217** to surround the air inlets **222** of the cyclone chambers **220**.

Since the air flow path to the manifold **217** is centrally located in the embodiments illustrated in FIGS. **1** to **26**, each cyclone chamber **220** may extend along a respective cyclone axis **215** and includes a sidewall **221** that extends between a first end wall **203** and a second end wall **205** of the second cyclonic stage. In contrast, in the embodiments illustrated in FIGS. **27** to **32**, a plenum may be provided at the front end of the second cyclonic stage to distribute the air towards the outer wall **221**. Therefore, instead of the second stage cyclones extending from the front end wall **203** of the second cyclonic stage, the forwardly positioned wall of the second stage cyclones (which is designated as first end wall **213**) is spaced from front end wall **203** of the second cyclonic stage to accommodate an air flow plenum at the front end of the second cyclonic cleaning stage. Accordingly, each cyclone chamber **220** extends along a respective cyclone axis **215** and includes a sidewall **221** that extends between the first end wall **213** and a second end wall **205**.

As illustrated in FIG. **31**, dirt collection plenum **227** is defined by an intermediate wall **240** of the central body member **201**, an inner surface of an intermediate plate **233**, and an inner wall **231** (which may be characterized as a dirt plenum side wall **231**) extending between the intermediate wall **240** and the intermediate plate **233**.

Accordingly, as exemplified, a majority of dirt collection plenum **227** may be positioned radially inwardly from the second stage cyclone chambers **220***a-f*. As shown in the illustrated example, dirt outlets **228***a-f* are oriented such that dirt is ejected inwardly into the dirt collection plenum **227** in a plane generally transverse to the cyclone axis of rotation **215**. Put another way, substantially all of the portion of dirt collection plenum **227** in direct communication with dirt outlets **228***a-f* of the second stage cyclone chambers **220***a-f* is positioned radially inwardly from the second stage cyclone chambers **220***a-f*.

As exemplified, the air inlets **222***a,a-f*, **222***b, a f*, **222***c,a-f*, **222***d,a f*, **222***e,a-f*, and **222***f,a-f* may be oriented such that, in operation, air is directed into the second stage cyclone chambers **220***a-f* such that air within the cyclone chambers may rotate in a counter-clockwise direction, when viewed from the outlet end. Accordingly, most if not all of the dirt ejected from the second stage cyclone chamber dirt outlets

228*a*, 228*b*, 228*c*, 228*d*, 228*e*, and 228*f* may travel in generally the same direction towards the dirt collection region 229, e.g. in directions 225*a*, 225*b*, 225*c*, 225*d*, 225*e*, and 225*f*, respectively. An advantage of this design is that it may promote a cyclonic air flow within the dirt collection plenum 227.

Alternatively, some or all of the air inlets 222 for a cyclone chamber 220 may be oriented such that, in operation, air within some cyclone chambers may rotate in a clockwise direction. For example, cyclone chambers 220*a*, 220*b*, and 220*c* may be configured to promote air rotation in a counter-clockwise direction, and cyclone chambers 220*d*, 220*e*, and 220*f* may be configured to promote air rotation in a counter-clockwise direction. An advantage of this design is that dirt may be ejected from the cyclone chamber dirt outlets 228 into the dirt collection plenum in a direction towards the second stage dirt collection region 229.

In the illustrated embodiments, a single dirt collection region 229 is provided. Alternatively, two or more dirt collection regions may be provided (e.g.

a dirt collection region in communication with cyclone chamber dirt outlets 228*a*, 228*b*, and 228*c*, and another dirt collection region in communication with cyclone chamber dirt outlets 228*d*, 228*e*, and 228*f*.)

FIGS. 33 to 42 illustrate an embodiment of a cyclonic cleaning stage, referred to generally as 200. In this example embodiment, the second stage dirt collection region 229 is located within the first stage cyclone and a conduit 238 connecting the second stage dirt collection plenum and the second sage dirt collection region 229 extends within the air flow passage from the first cyclonic stage to the second cyclonic stage. As exemplified, eight second stage cyclone chambers 220 are shown, referred to as 220*a*, 220*b*, 220*c*, 220*d*, 220*e*, 220*f*, 220*g*, and 220*h*, respectively. Elements having similar structure and/or performing similar function as those in the example cyclonic cleaning stage illustrated in FIGS. 27 to 32 are numbered similarly, and will not be discussed further.

Similar to the embodiments illustrated in FIGS. 27 to 32, in the embodiments illustrated in FIGS. 33 to 42, air passing through second stage air inlet 212 is directed radially outwardly towards the outer wall 211 of the central body member 201 (i.e. a radially outward portion of the manifold 217), and a portion of the air flow diffuses radially inwardly towards a central portion of the manifold 217 to surround the air inlets 222 of the cyclone chambers 220.

In the embodiments illustrated in FIGS. 33 to 42, dirt collection plenum 227 is defined by an intermediate wall 240 of the central body member 201, an inner surface of an intermediate plate 233, and an inner wall 231 (which may be characterized as a dirt plenum side wall 231) extending between the intermediate wall 240 and the intermediate plate 233.

As illustrated in FIG. 39, the intermediate plate 233 has a central recessed portion 236, with an aperture 234 located at a lower end of the recessed portion. As illustrated in FIG. 34, a conduit 238 extends from aperture 234 through the cyclone air outlet 114 of the first stage cyclone chamber 110, and to the second stage dirt collection region 229, which in this example is located below an arrestor plate 106 and at the first end 102 of the cyclone chamber 110.

In the embodiments illustrated in FIGS. 33 to 42, substantially all of dirt collection plenum 227 is positioned radially inwardly from the second stage cyclone chambers 220*a*-*h*. Such a design may have one or more advantages. For example, providing substantially all of the plenum 227 radially inwardly of the second stage cyclone chambers may result in a more compact design of a second cyclonic cleaning stage.

In the illustrated example, the intermediate wall 240 has a projection 246 that overlies the central recessed portion 236 of the intermediate plate 233. As a result, the distance between the intermediate wall 240 and the intermediate plate 233 (which may be characterized as the height of the dirt collection plenum 227 is substantially constant. Also, since the second stage cyclone chambers are provided with 'sideways' dirt outlets (i.e. at least a portion of, and preferably most or substantially all of the dirt exiting a second stage cyclone travels in a radial direction), the projection 246 may deflect dirt ejected from the second stage cyclone chambers towards the conduit 238 (e.g. towards the second stage dirt collection region 229).

As used herein, the wording "and/or" is intended to represent an inclusive—or. That is, "X and/or Y" is intended to mean X or Y or both, for example. As a further example, "X, Y, and/or Z" is intended to mean X or Y or Z or any combination thereof.

While the above description describes features of example embodiments, it will be appreciated that some features and/or functions of the described embodiments are susceptible to modification without departing from the spirit and principles of operation of the described embodiments. For example, the various characteristics which are described by means of the represented embodiments or examples may be selectively combined with each other. Accordingly, what has been described above is intended to be illustrative of the claimed concept and non-limiting. It will be understood by persons skilled in the art that other variants and modifications may be made without departing from the scope of the invention as defined in the claims appended hereto. The scope of the claims should not be limited by the preferred embodiments and examples, but should be given the broadest interpretation consistent with the description as a whole.

The invention claimed is:

1. A vacuum cleaner comprising:

(a) an air flow path extending from a dirty air inlet to a clean air outlet with a suction motor provided in the air flow path;

(b) a cyclonic cleaning stage provided in the air flow path, the cyclonic cleaning stage comprising a plurality of cyclones in parallel and an air inlet manifold having a radial outer wall and an inner volume, each cyclone having a cyclone axis of rotation, a first end, an axially spaced apart second end, a sidewall extending between the first and second ends, an air inlet in communication with the inner volume of the air inlet manifold, an air outlet and a sideways dirt outlet;

(c) a dirt collection chamber; and,

(d) a dirt collection plenum located between first and second axially spaced apart walls and positioned radially from and in communication with the dirt outlets,

wherein the second wall has a first opening communicating with the dirt collection chamber and the first wall is positioned between the dirt collection plenum and the air inlet manifold,

wherein at least a portion of the dirt collection plenum is positioned radially outwardly of at least some of the cyclones, and

wherein a plane that is transverse to the cyclone axis of rotation of one of the cyclones extends through the dirt collection plenum, at least one of the dirt outlets and at least one cyclone.

2. The vacuum cleaner of claim **1** wherein the air inlets and the air outlets are provided at the first end of the cyclones and the dirt outlet is provided at the second end of the cyclones.

3. The vacuum cleaner of claim **2** wherein a portion of the air flow path extends along the length of the cyclones from second end to the first end wherein the portion of the air flow path extends through the first and second axially spaced apart walls of the dirt collection plenum and the dirt collection plenum extends around at least a portion of the air flow path.

4. The vacuum cleaner of claim **1** wherein the sideways dirt outlets comprise openings in the sidewalls.

5. The vacuum cleaner of claim **4** wherein the sideways dirt outlets direct dirt outwardly in the plane.

6. The vacuum cleaner of claim **4** wherein each cyclone has a radially inner side, a radially outer side and lateral sides provided between the radially inner and radially outer sides and the sideways dirt outlet is provided in one of the lateral sides.

7. The vacuum cleaner of claim **1** wherein at least a portion of the dirt collection plenum comprises an annular volume that is located radially outwardly from at least some of the dirt outlets.

8. The vacuum cleaner of claim **7** wherein a portion of the air flow path extends through the first and second axially spaced apart walls of the dirt collection plenum and extends through a radial inner central portion of the cyclonic cleaning stage.

9. The vacuum cleaner of claim **1** wherein the air inlets produce a direction of rotation in the cyclones and, for at least some of the cyclones of the plurality of cyclones, the dirt outlet is located, based on the direction of rotation, to direct dirt towards the first opening.

10. The vacuum cleaner of claim **1** wherein, when the vacuum cleaner is used to clean a floor, the first opening is located at a lower end of the dirt collection plenum.

11. The vacuum cleaner of claim **1** wherein the second wall has a second opening and, for some of the cyclones of the plurality of cyclones, the dirt outlet is located based on a direction of rotation of the cyclone to direct dirt towards the first opening and, for a remainder of the cyclones of the plurality of cyclones, the dirt outlet is located based on a direction of rotation of the cyclone to direct dirt towards the second opening.

12. The vacuum cleaner of claim **1** further comprising an upstream air treatment member and the dirt collection chamber extends axially along at least a portion of the upstream air treatment member.

13. The vacuum cleaner of claim **12** wherein the vacuum cleaner is a hand vacuum cleaner having a front end and a rear end and the dirt collection chamber has a front openable door.

14. The vacuum cleaner of claim **13** wherein the front openable door is openable concurrently with a dirt collection region of the upstream air treatment member.

15. The vacuum cleaner of claim **1** wherein the air inlets are provided at the first end of the cyclones, the dirt outlet is provided at the second end of the cyclones and the first wall is located between the first and second ends of the cyclones.

16. The vacuum cleaner of claim **15** wherein the first wall has a dirt collection plenum face facing the dirt collection plenum and the dirt collection plenum comprises an opposed face that is part of an air inlet plenum for the plurality of cyclones.

17. The vacuum cleaner of claim **1** wherein air exiting the outlets of the plurality of cyclones passes through the first wall of the dirt collection plenum.

18. A vacuum cleaner comprising:

(a) an air flow path extending from a dirty air inlet to a clean air outlet with a suction motor provided in the air flow path;

(b) a cyclonic cleaning stage provided in the air flow path, the cyclonic cleaning stage comprising a plurality of cyclones in parallel, each cyclone having a cyclone axis of rotation, a first end, an axially spaced apart second end, a sidewall extending between the first and second ends, an air inlet, an air outlet and a sideways dirt outlet, wherein a first set of cyclones of the plurality of cyclones have a clockwise direction of rotation and a second set of cyclones of the plurality of cyclones have a counterclockwise direction of rotation;

(c) a first dirt collection chamber; and,

(d) a dirt collection plenum located between first and second axially spaced apart walls, the dirt collection plenum comprising a first annular volume and a second annular volume, the first annular volume surrounding a portion of the first set of cyclones and in communication with each dirt outlet of the first set of cyclones and the second annular volume surrounding a portion of the second set of cyclones and in communication with each dirt outlet of the second set of cyclones,

wherein the first annular volume is in communication with the first dirt collection chamber.

19. The vacuum cleaner of claim **18** wherein the second annular volume is in communication with the first dirt collection chamber.

20. The vacuum cleaner of claim **18** wherein the second annular volume is in communication with a second dirt collection chamber.

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