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Reuter

(54) **ENHANCED AXIAL AIR MOVER SYSTEM WITH ENCLOSURE PROFILE**

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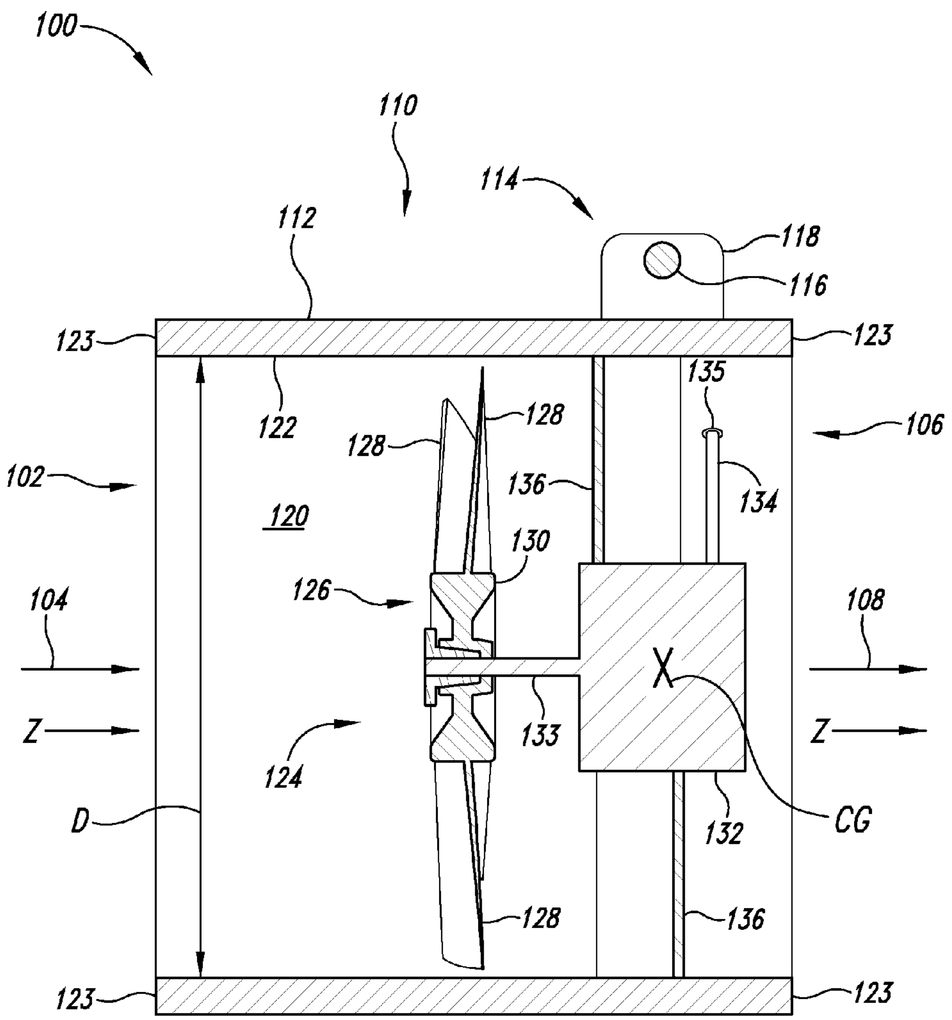
(52) **U.S. Cl.** .... **416/93 R**

(57) **ABSTRACT**

Implementations of an enhanced axial air mover system address various issues such as drying performance, transportability, storage, use, and assembly. Some implementations include ergonomic positioning of a carrying handle relative to positioning of a fan-assembly to make the system easier to carry. Enclosures with variable diameter profiles increase air flow performance. A floor edge allows for flush positioning of the air mover's outlet to improve flow of air. Various supports and engagement members allow for horizontal and/or vertical engagement of a plurality of the air movers for storage or increased air moving capacity for a given application. An alignment guide assists with positioning of the air mover with respect to a room wall to enhance air flow within the room. A cord retaining system provides an enhanced approach for securing the air mover's electrical cord. Grill guards have slotted ends to assist with assembly of the air mover.



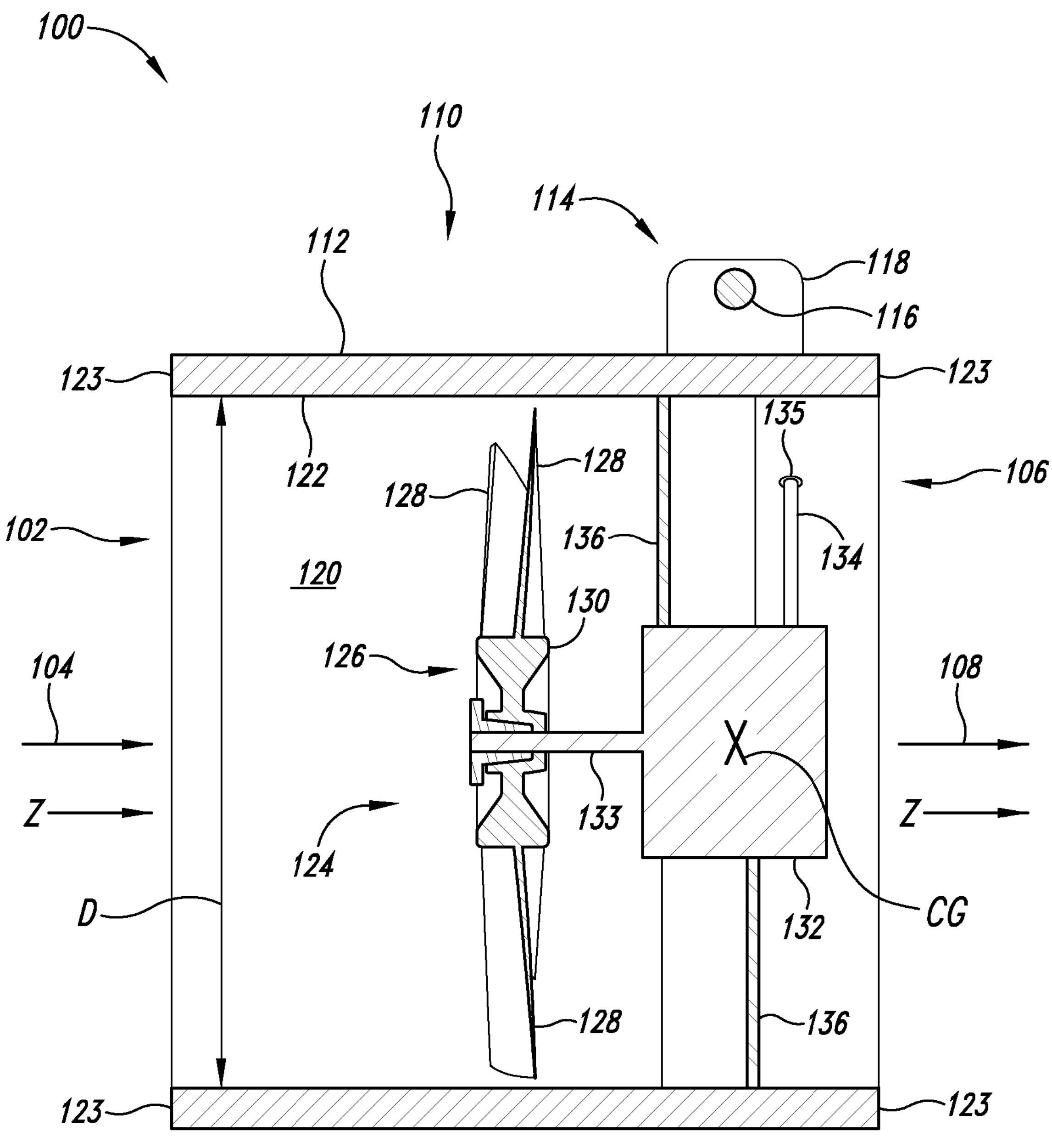

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Fig. 1

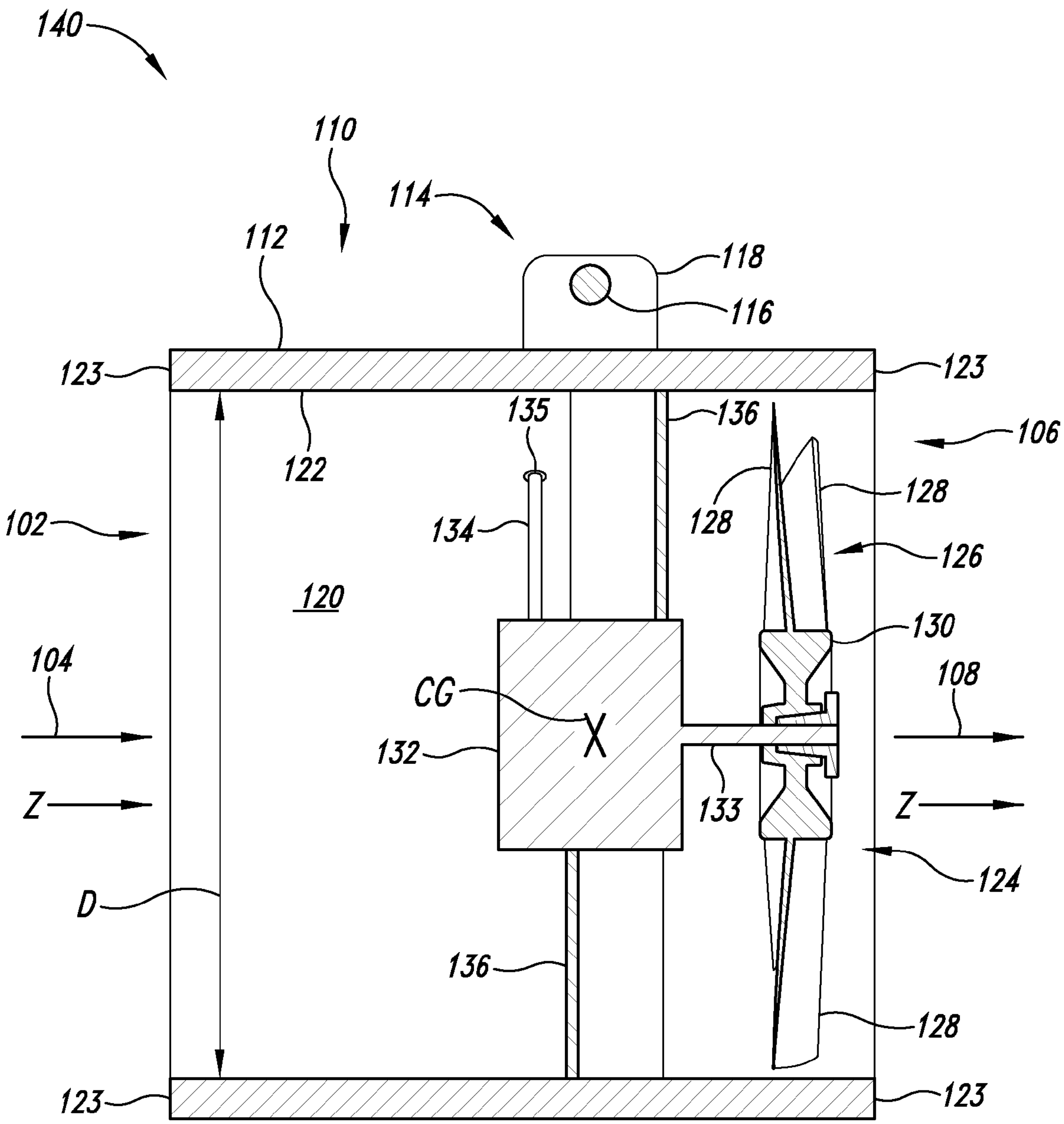
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Fig. 2

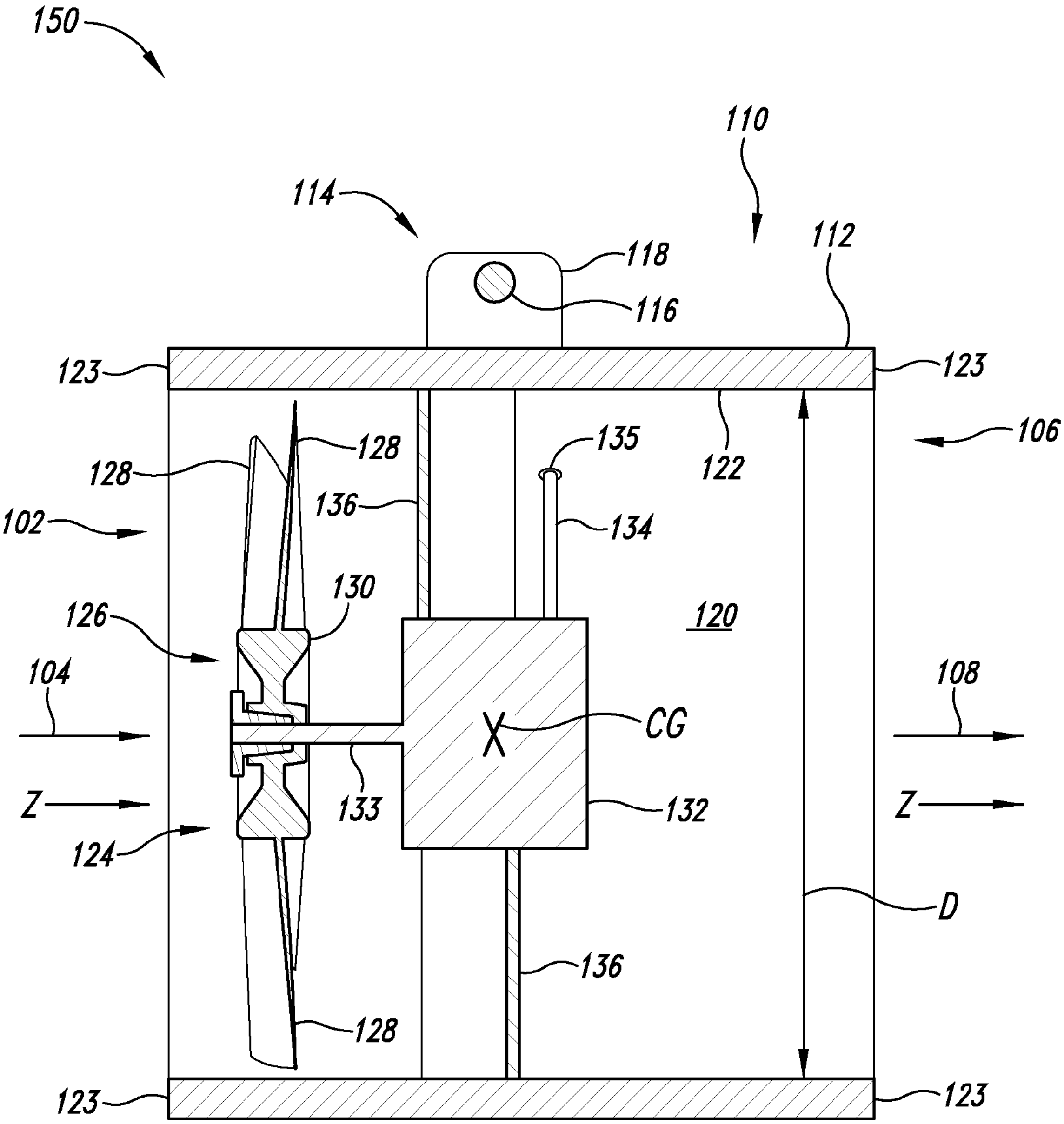
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Fig. 3

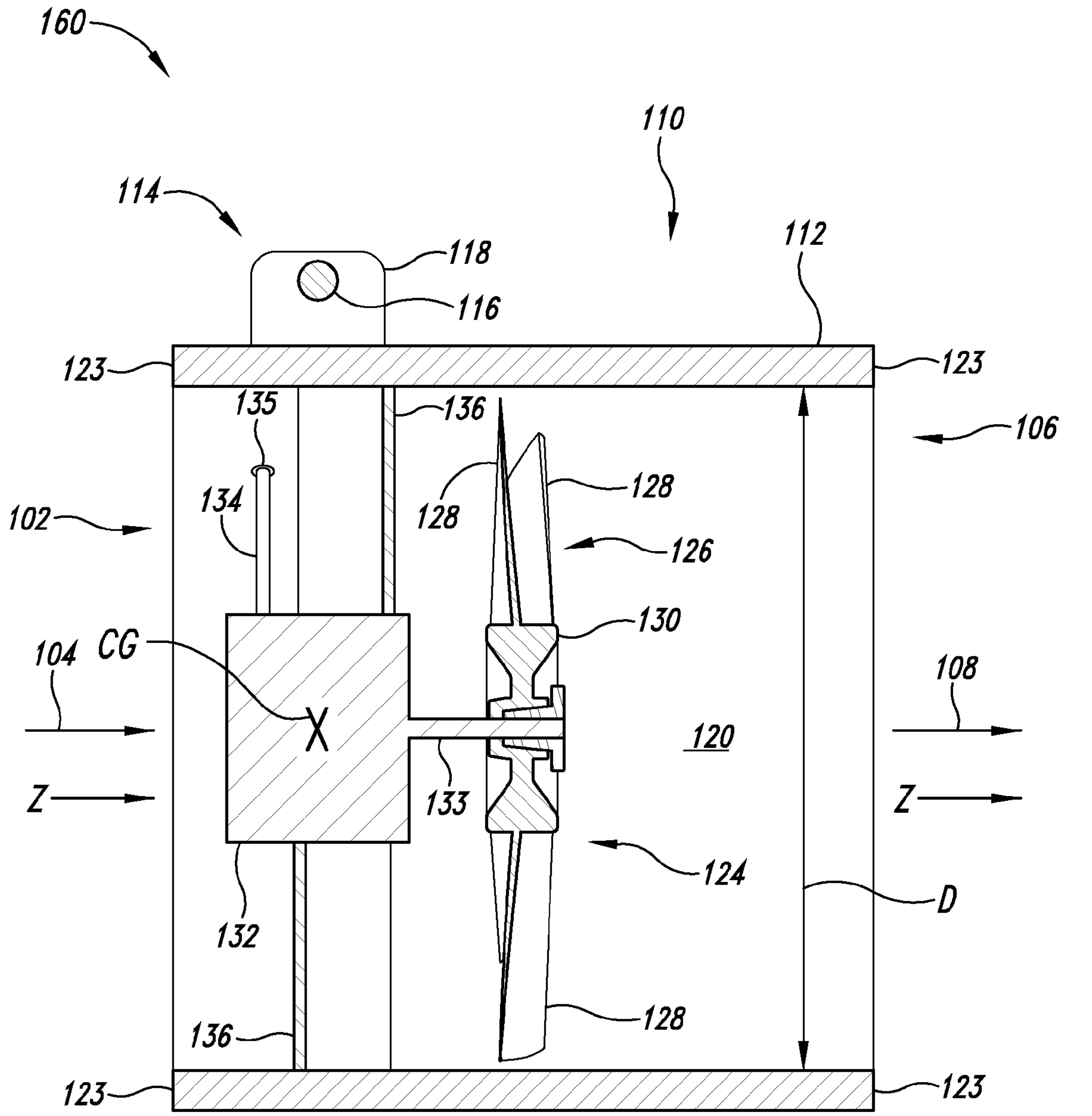
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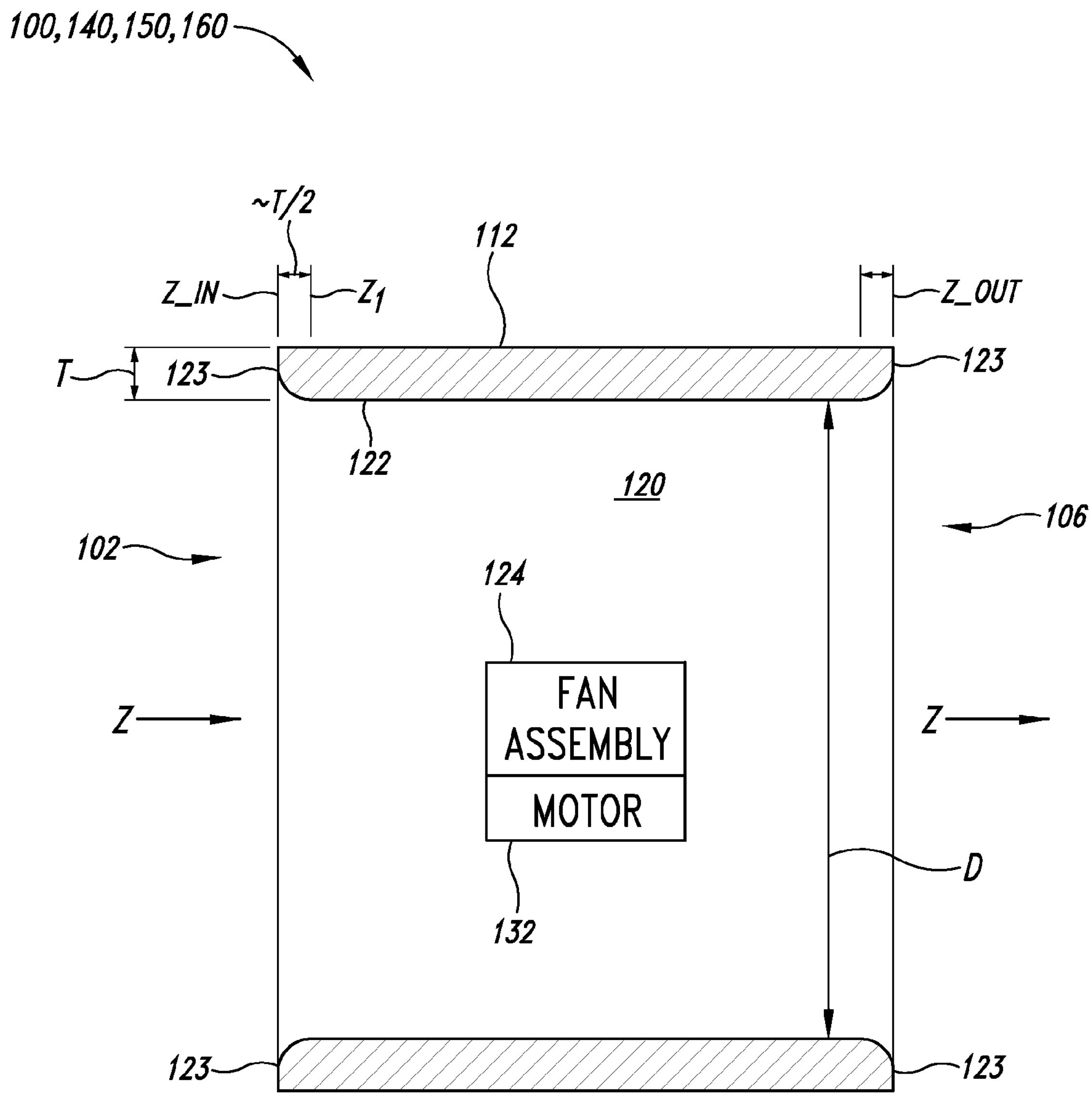
Fig. 4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MOTOR
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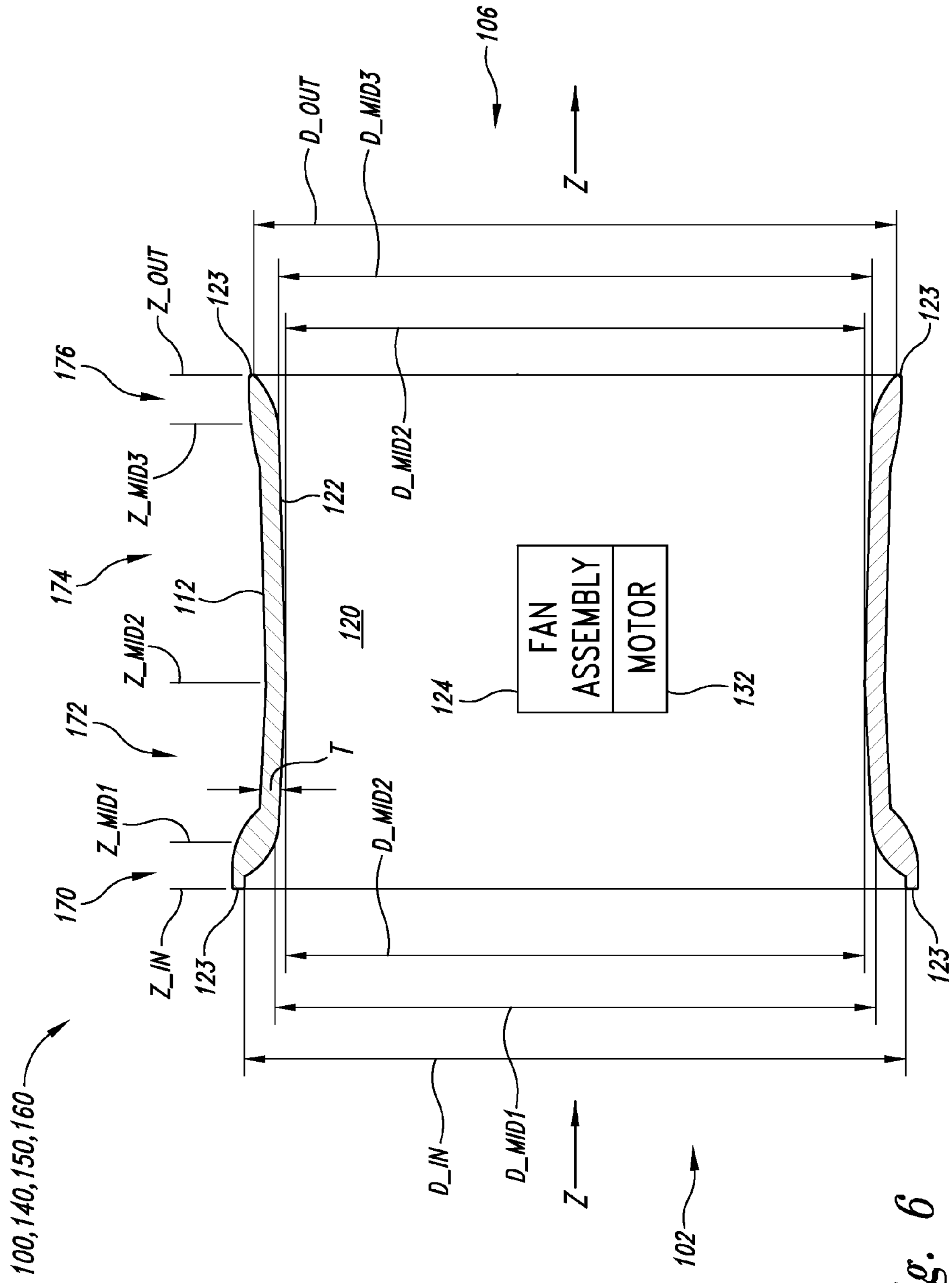
Fig. 5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D_MID2
D_MID1
D_IN
Z_OUT
Z_MID3
Z_MID2
Z_MID1
Z_IN
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176
FAN ASSEMBLY
MOTOR
124
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Fig. 6

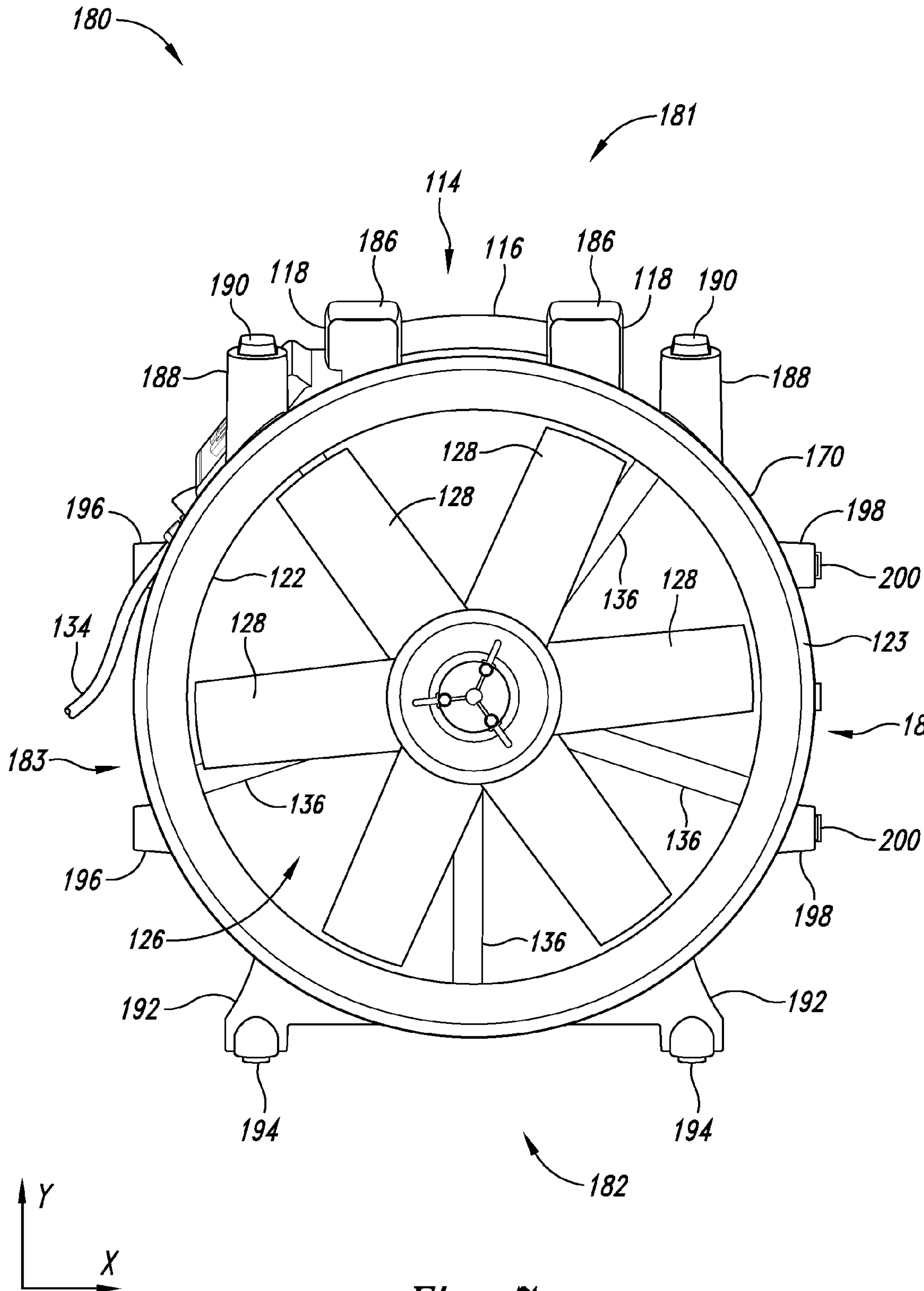
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Fig. 7

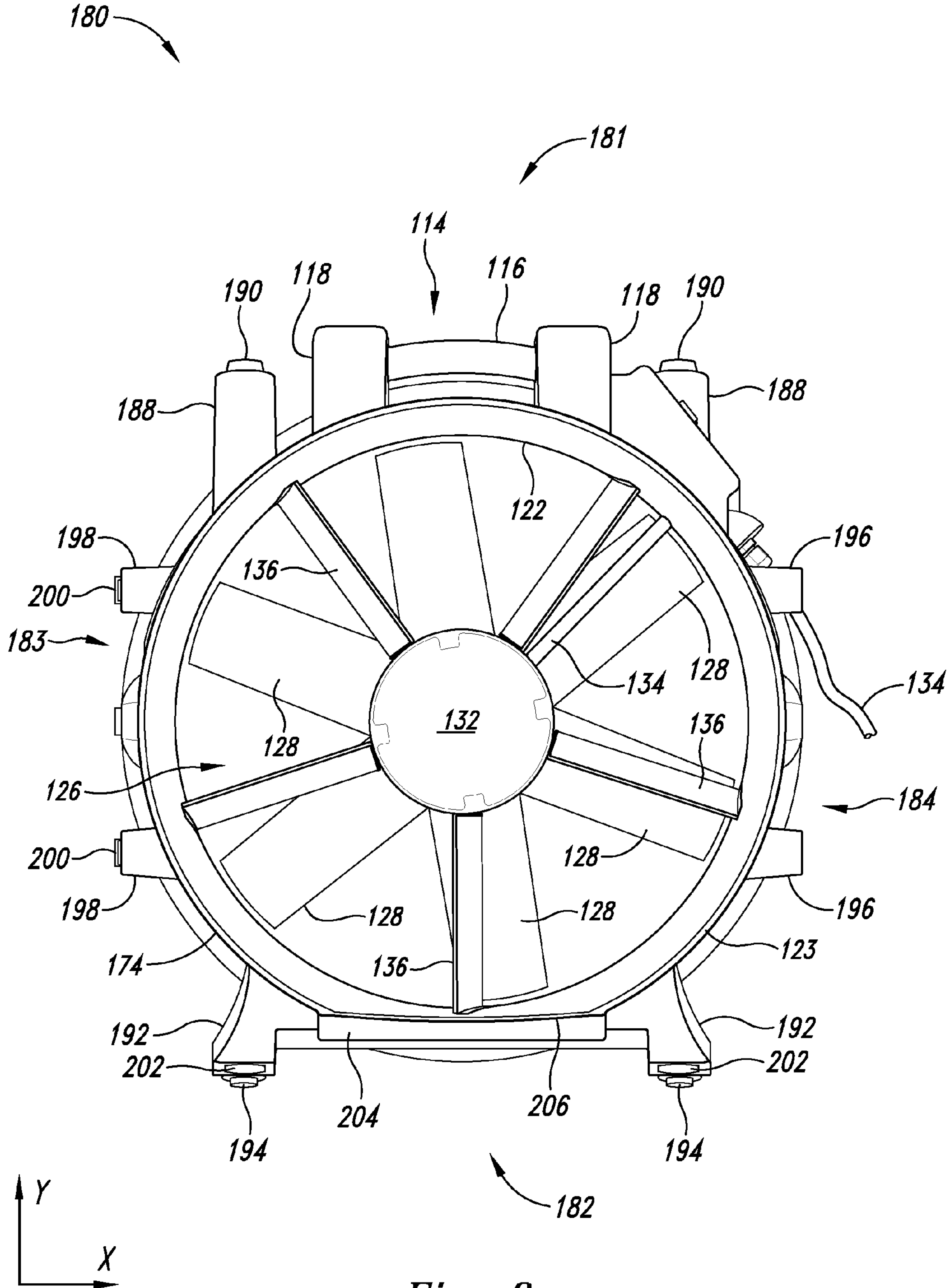
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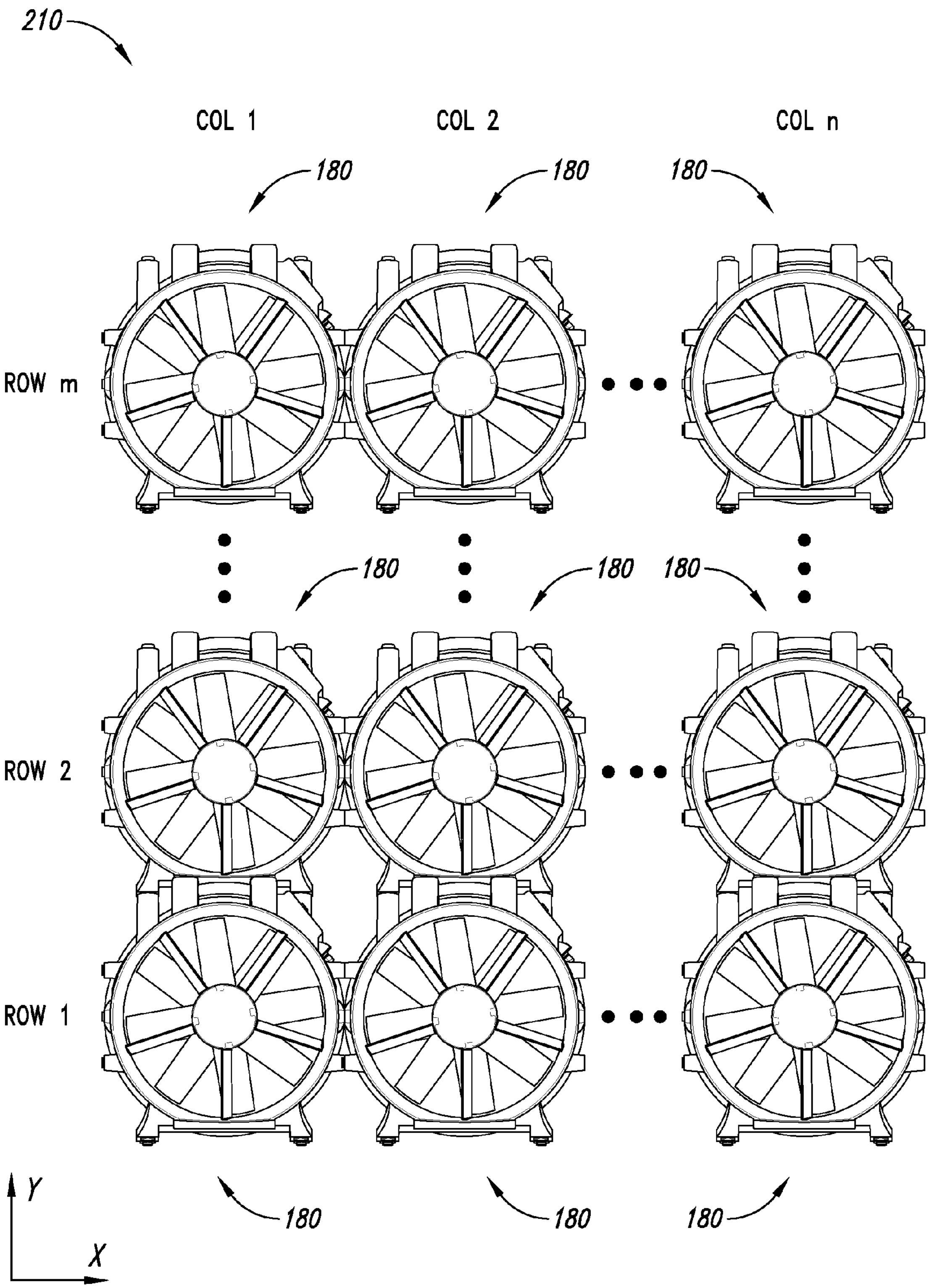
Fig. 8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COL 2
COL n
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ROW 2
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Fig. 9

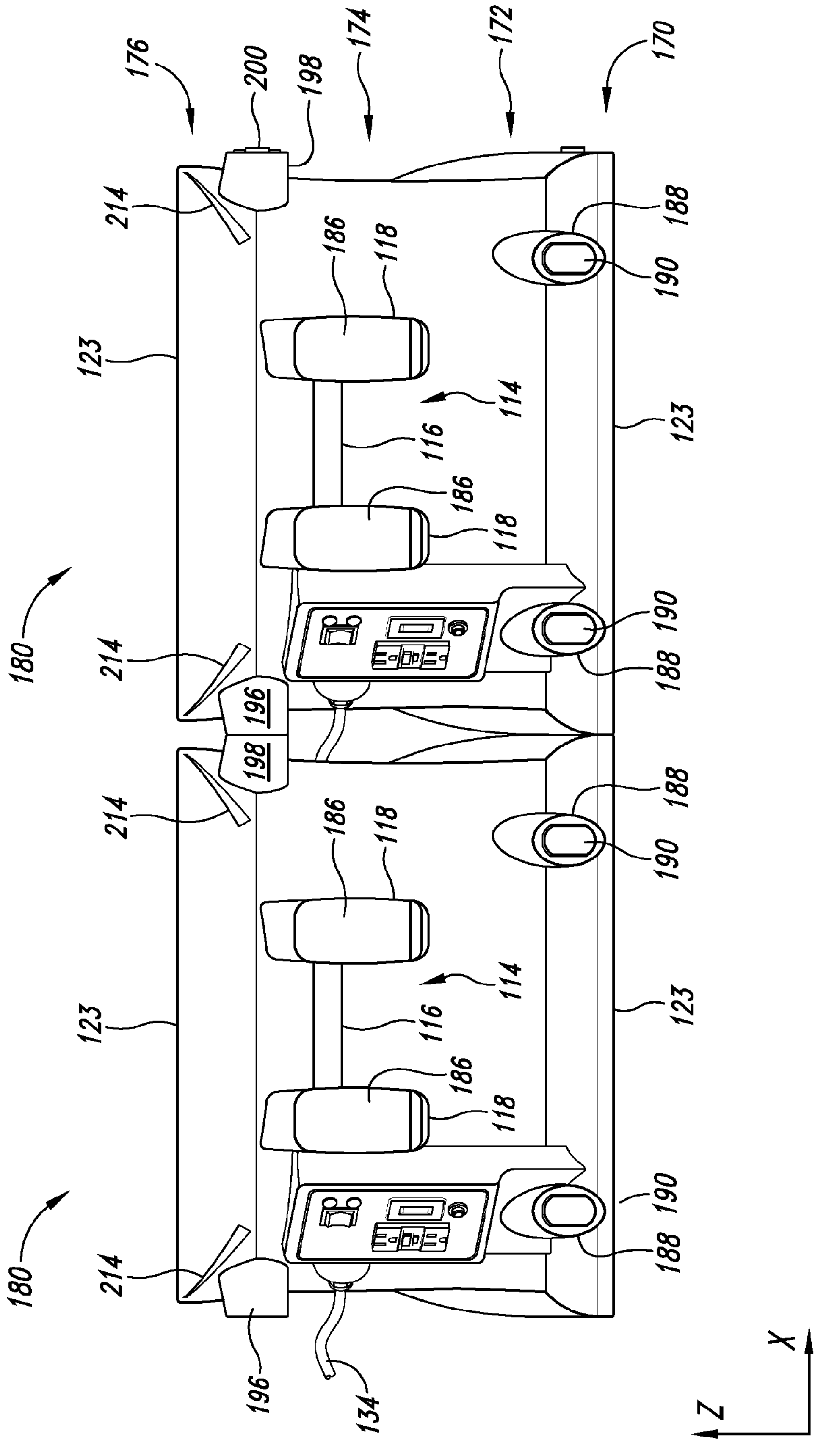
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Fig. 10

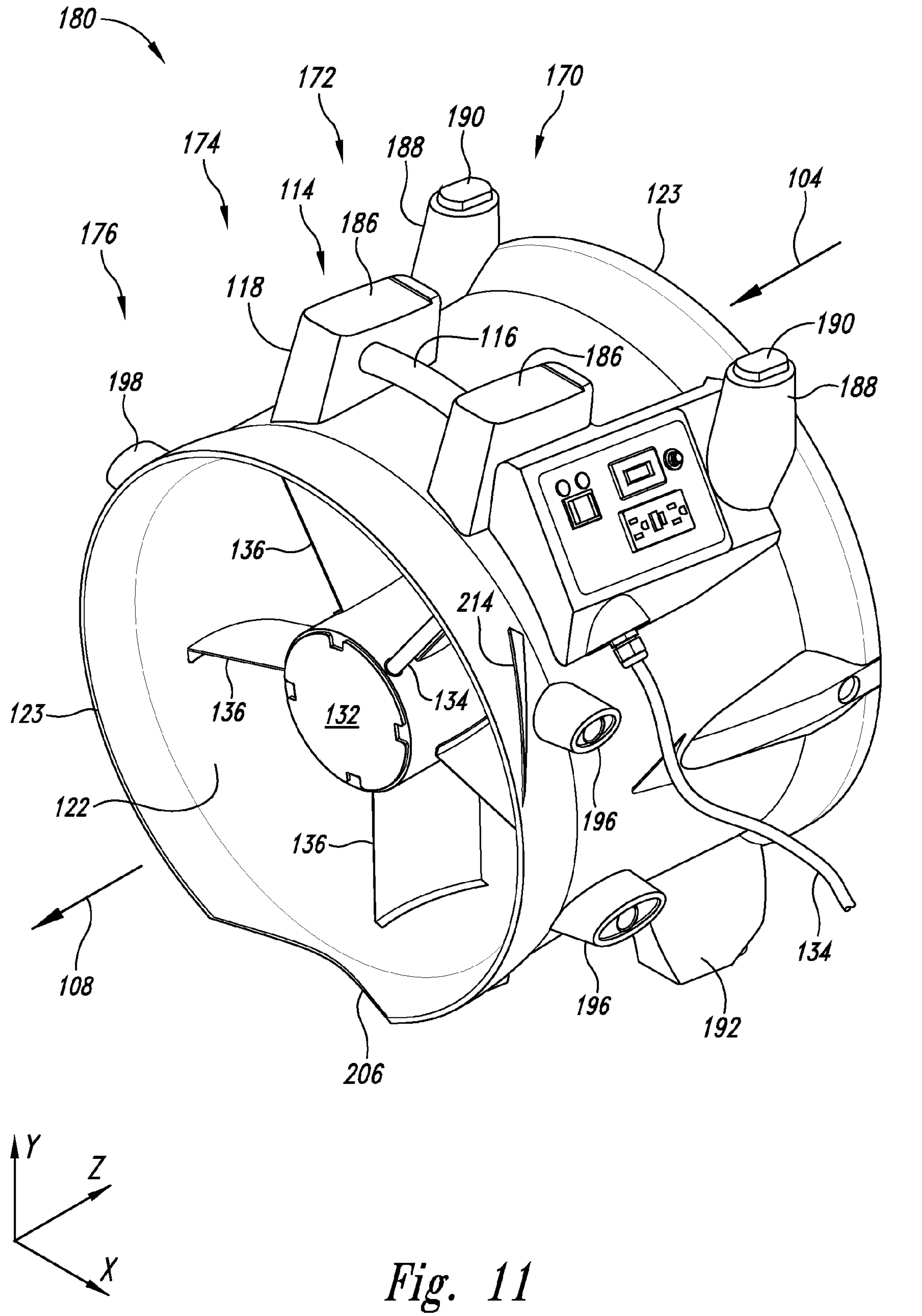
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Fig. 11

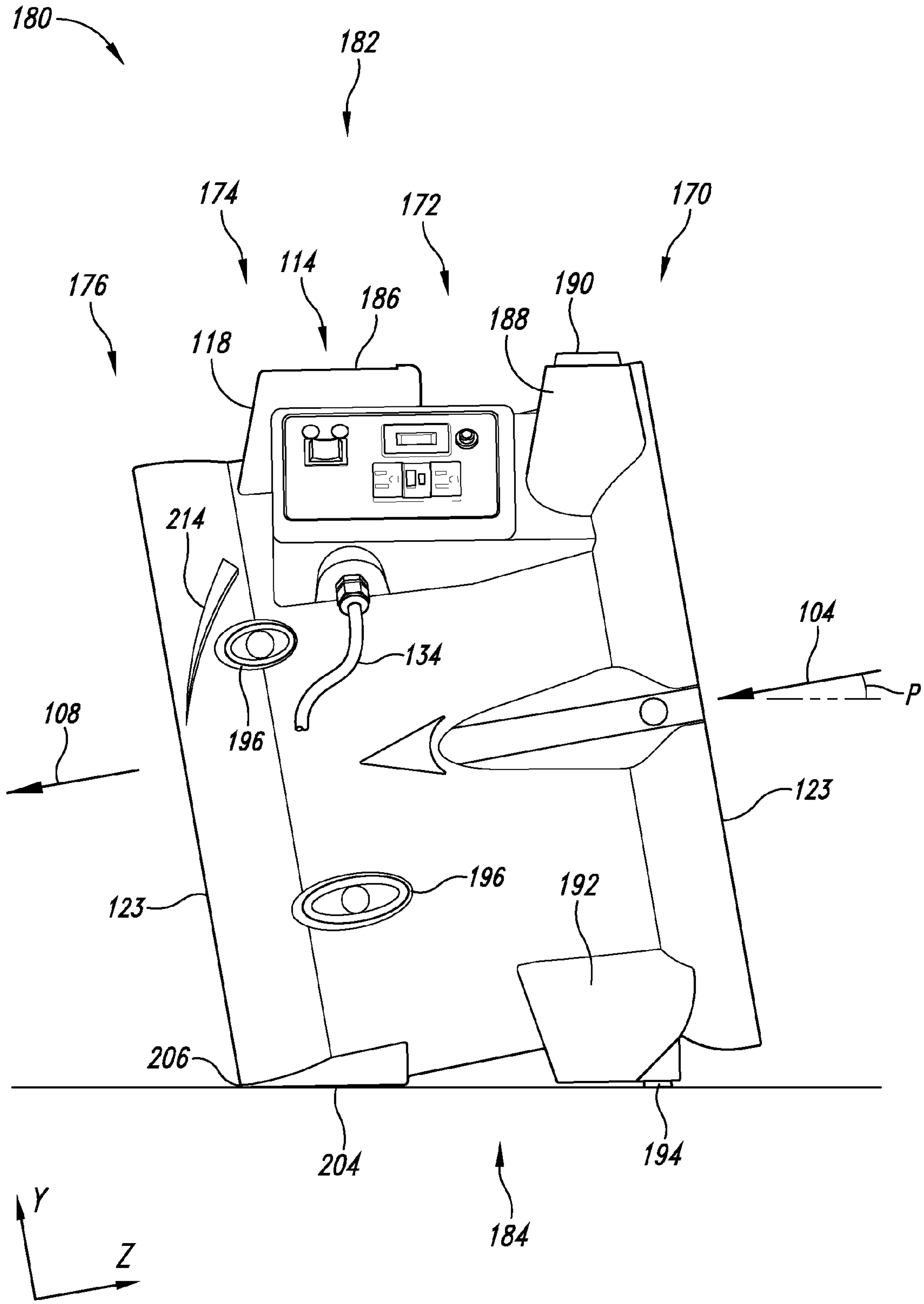
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Fig. 12

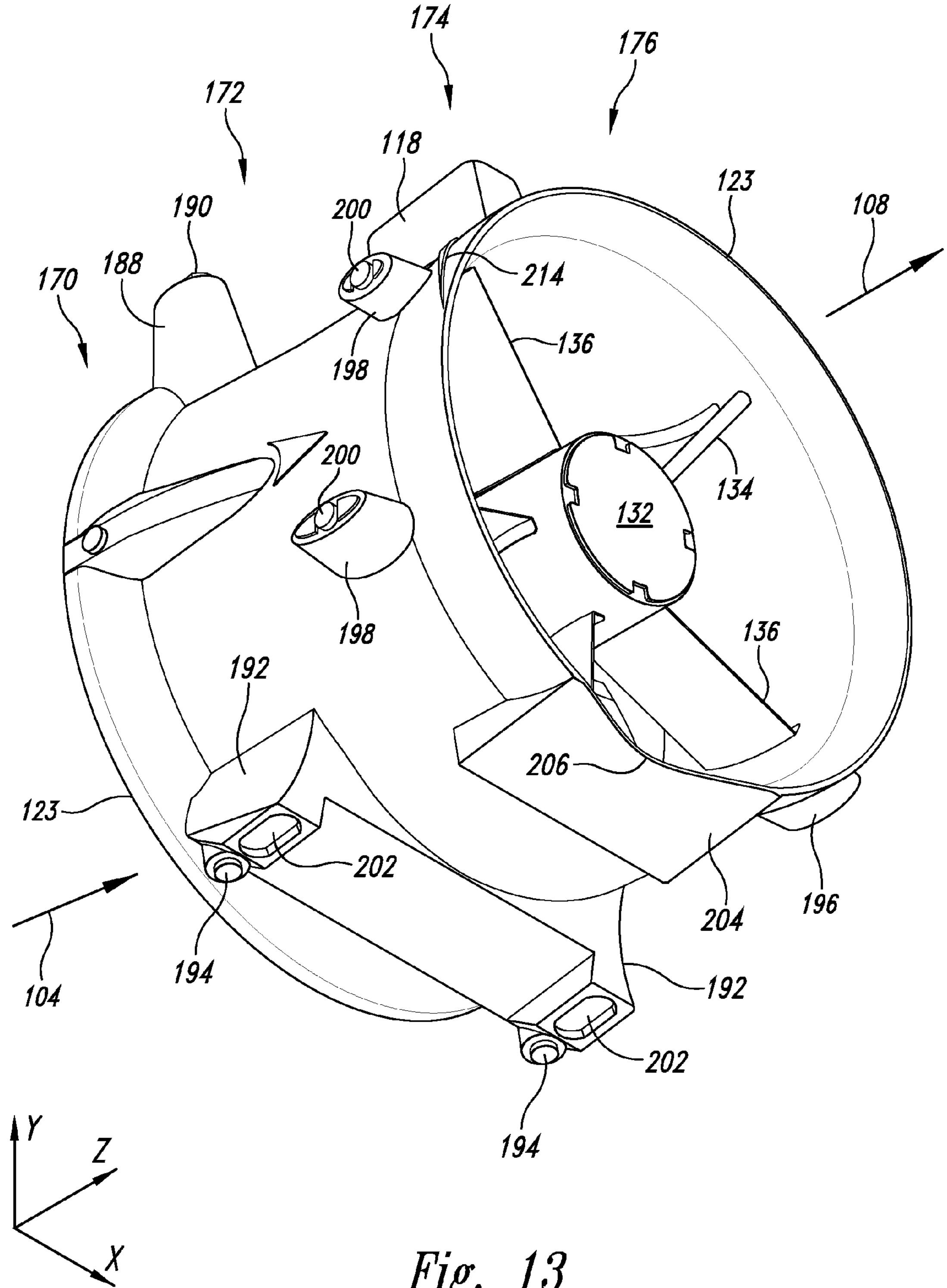
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Fig. 13

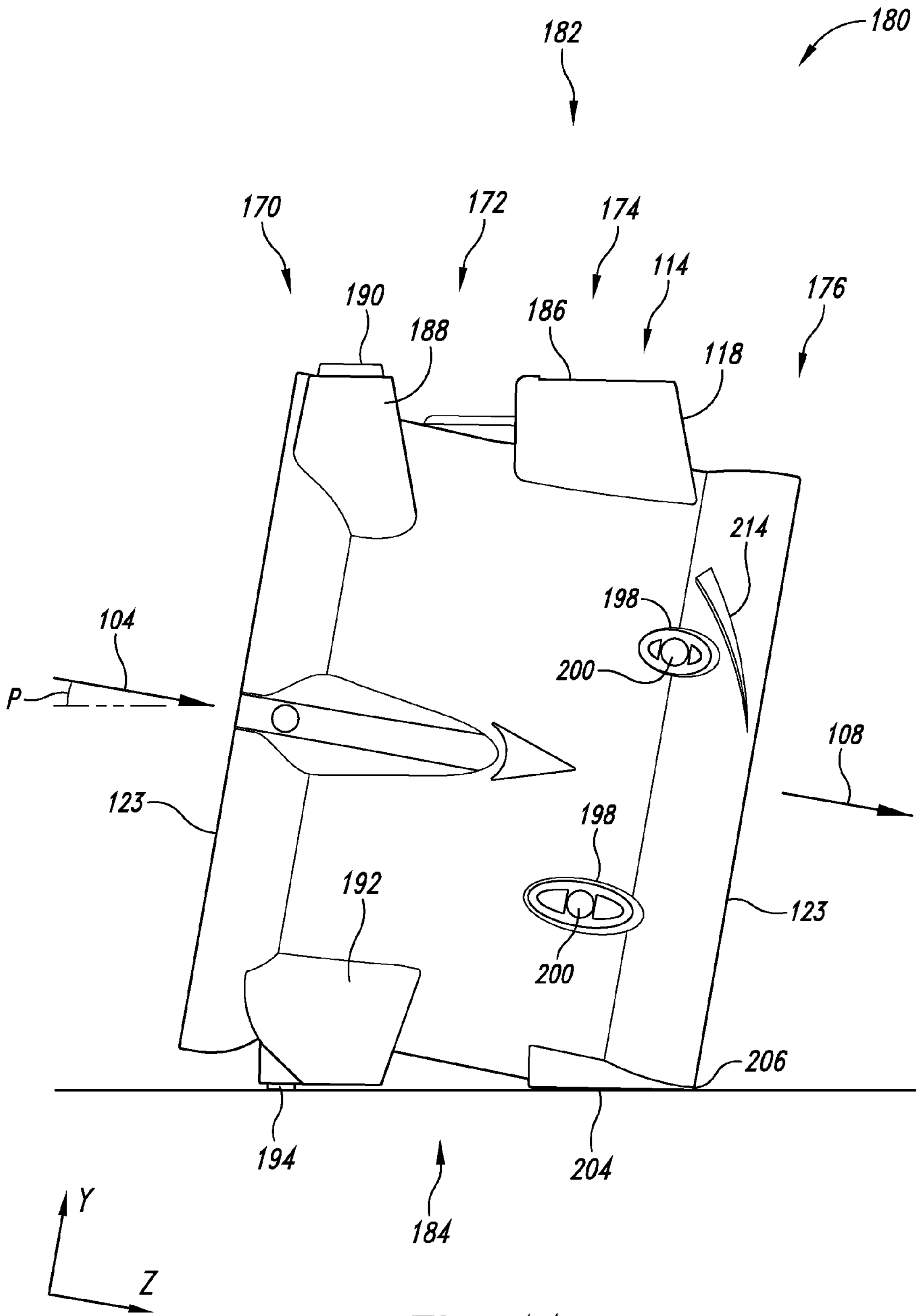
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Fig. 14

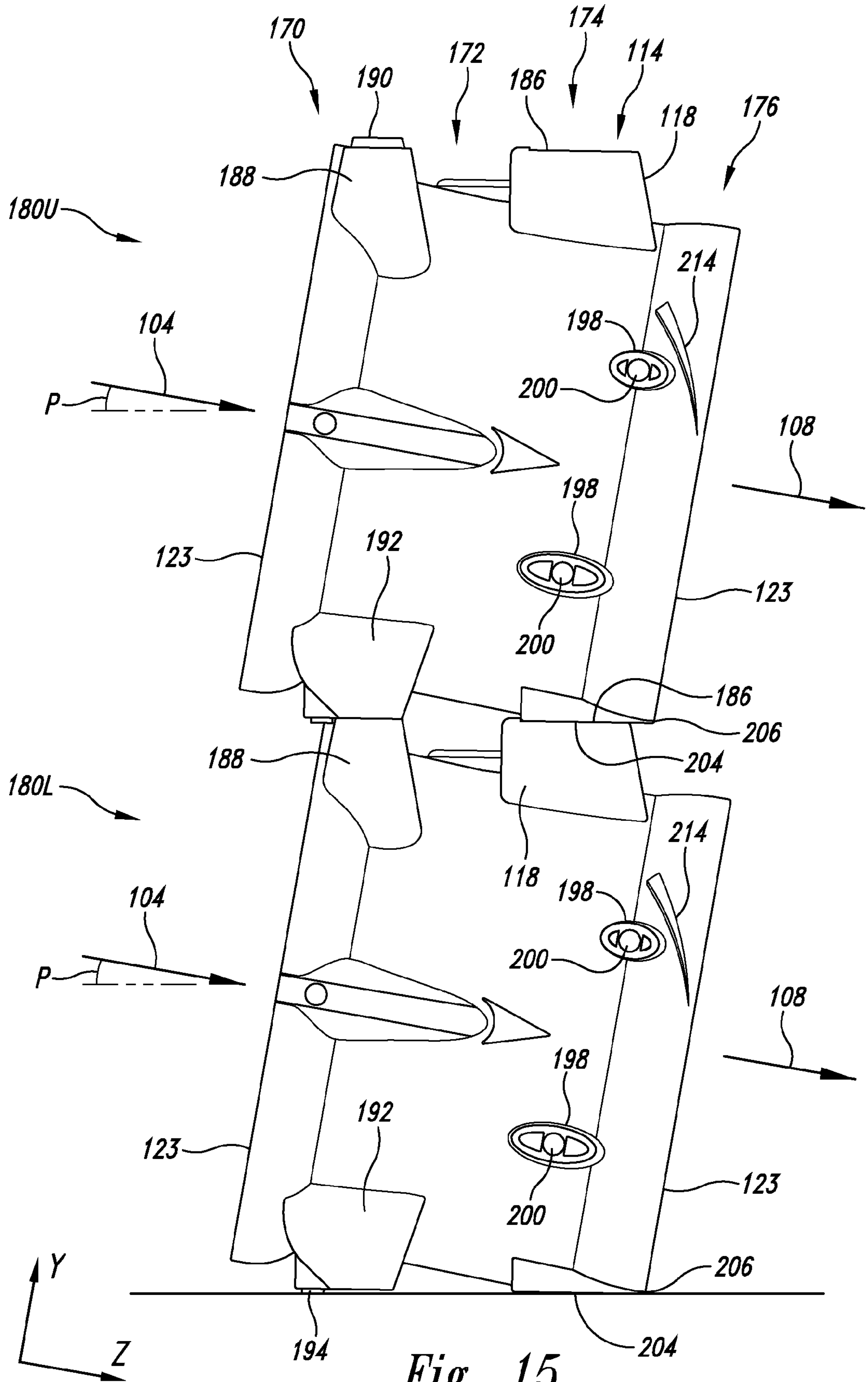
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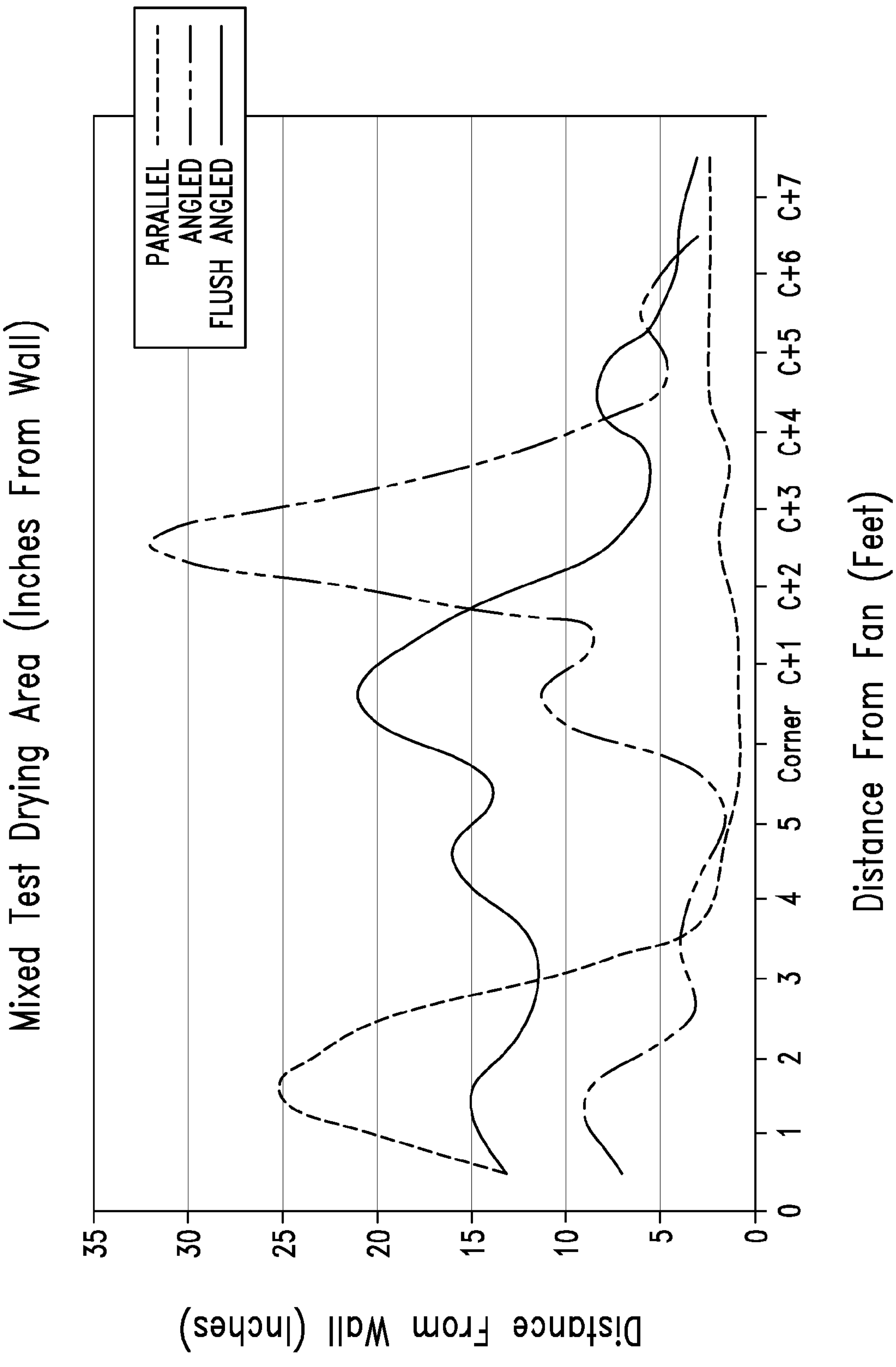
Fig. 15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Distance From Wall (Inches)
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25
20
15
10
5
0
Distance From Fan (Feet)
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1
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3
4
5
Corner
C+1
C+2
C+3
C+4
C+5
C+6
C+7
PARALLEL
ANGLED
FLUSH ANGLED

Fig. 16

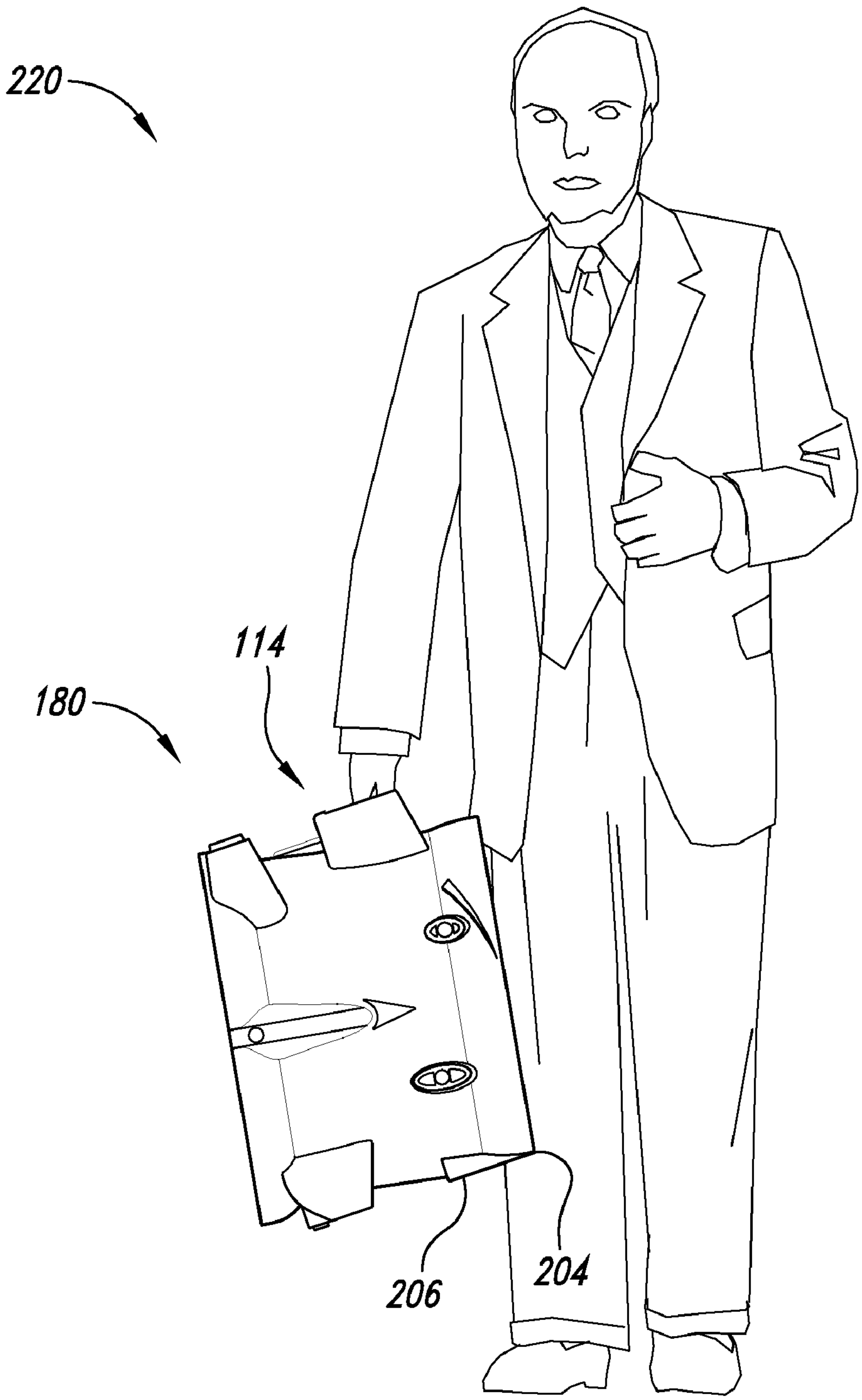

Fig. 17

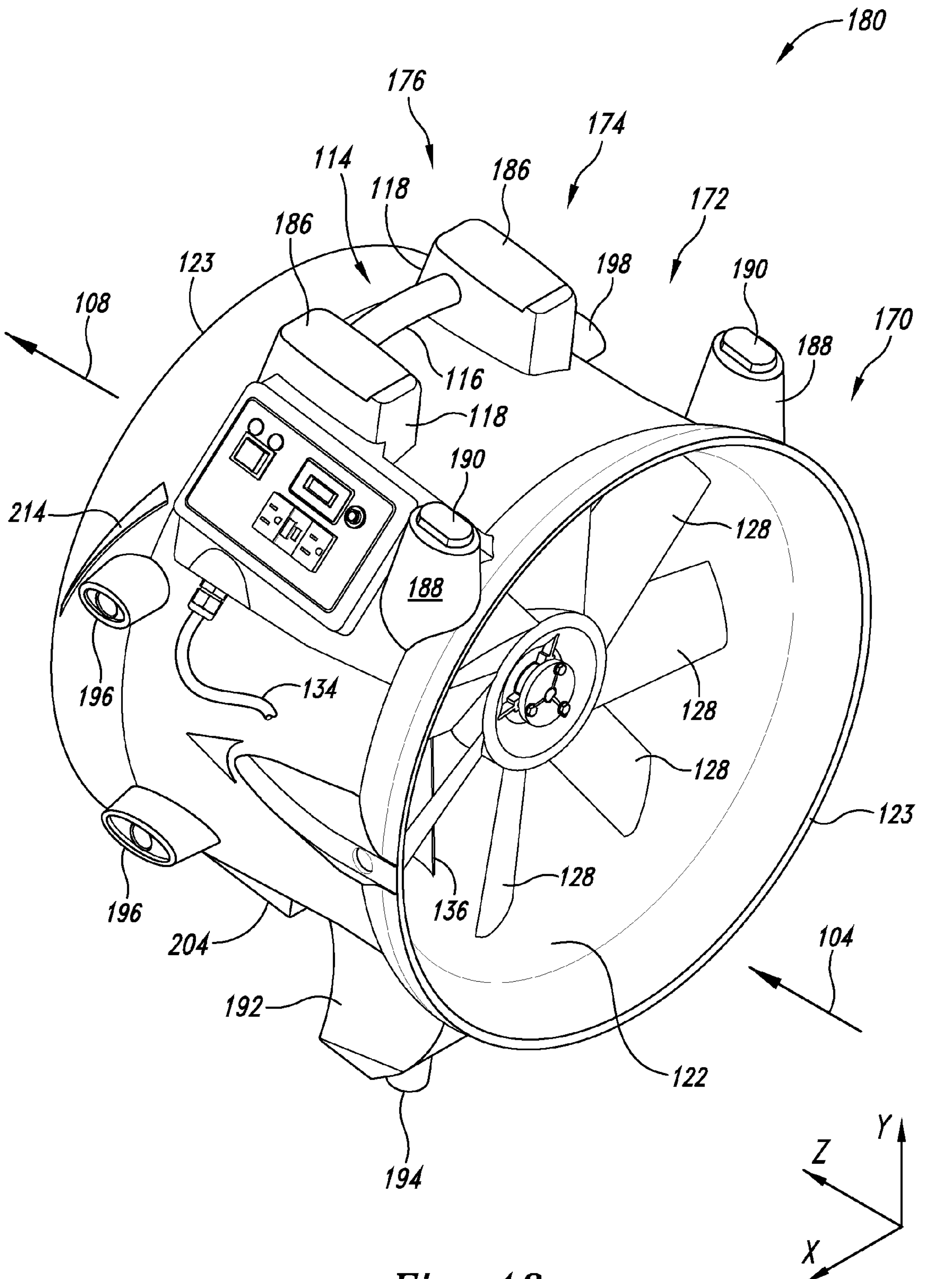
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Fig. 18

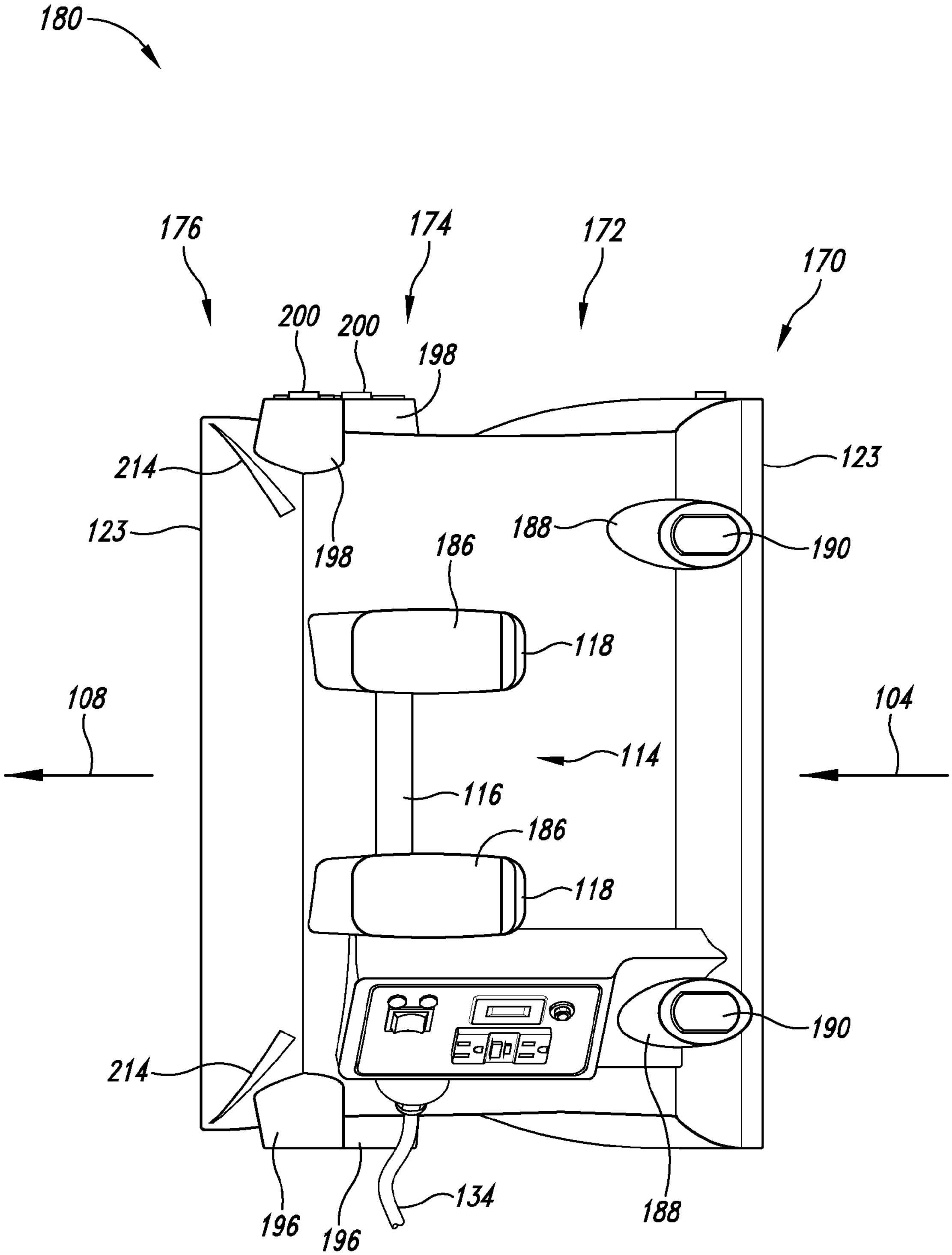
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Fig. 19

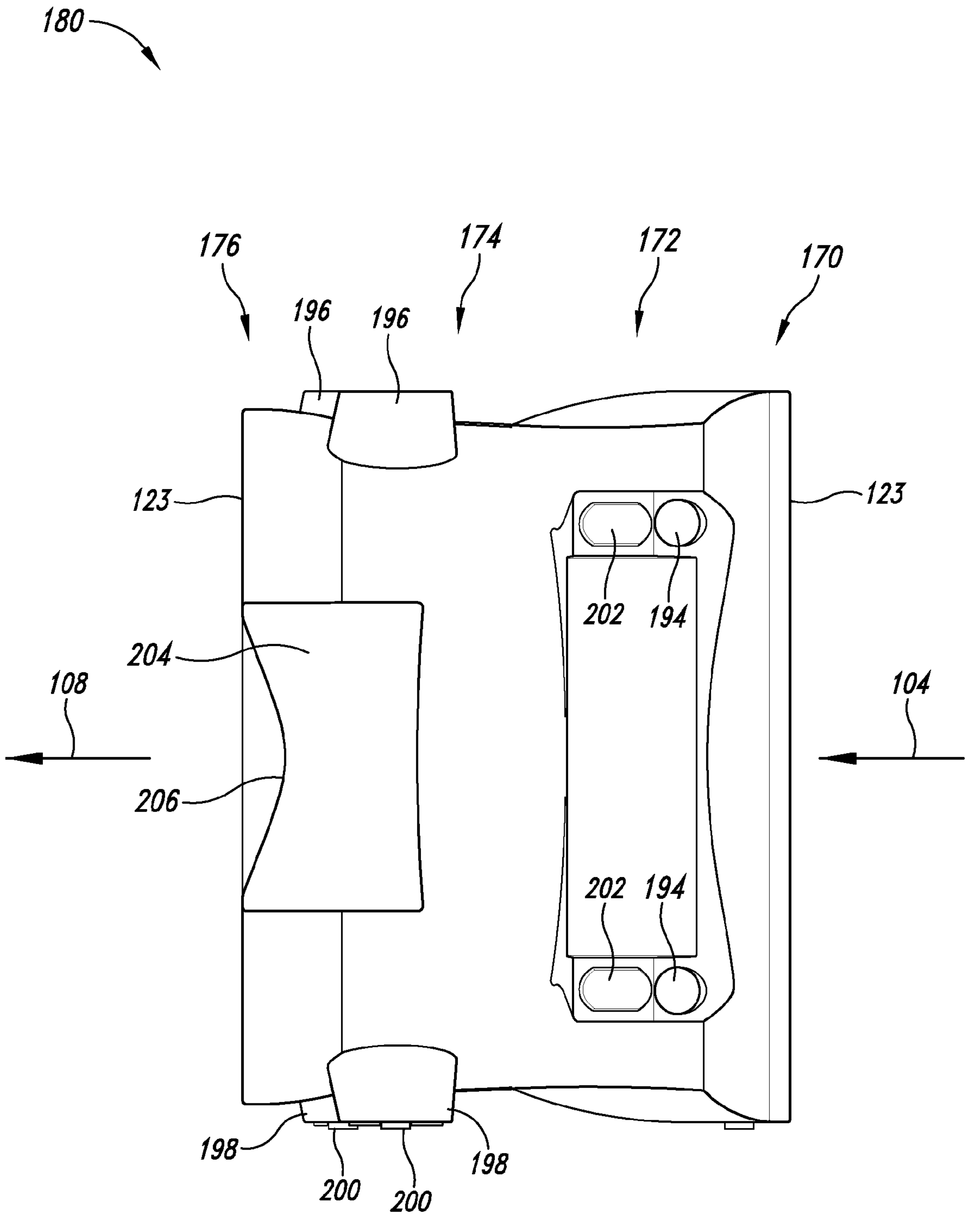
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Fig. 20

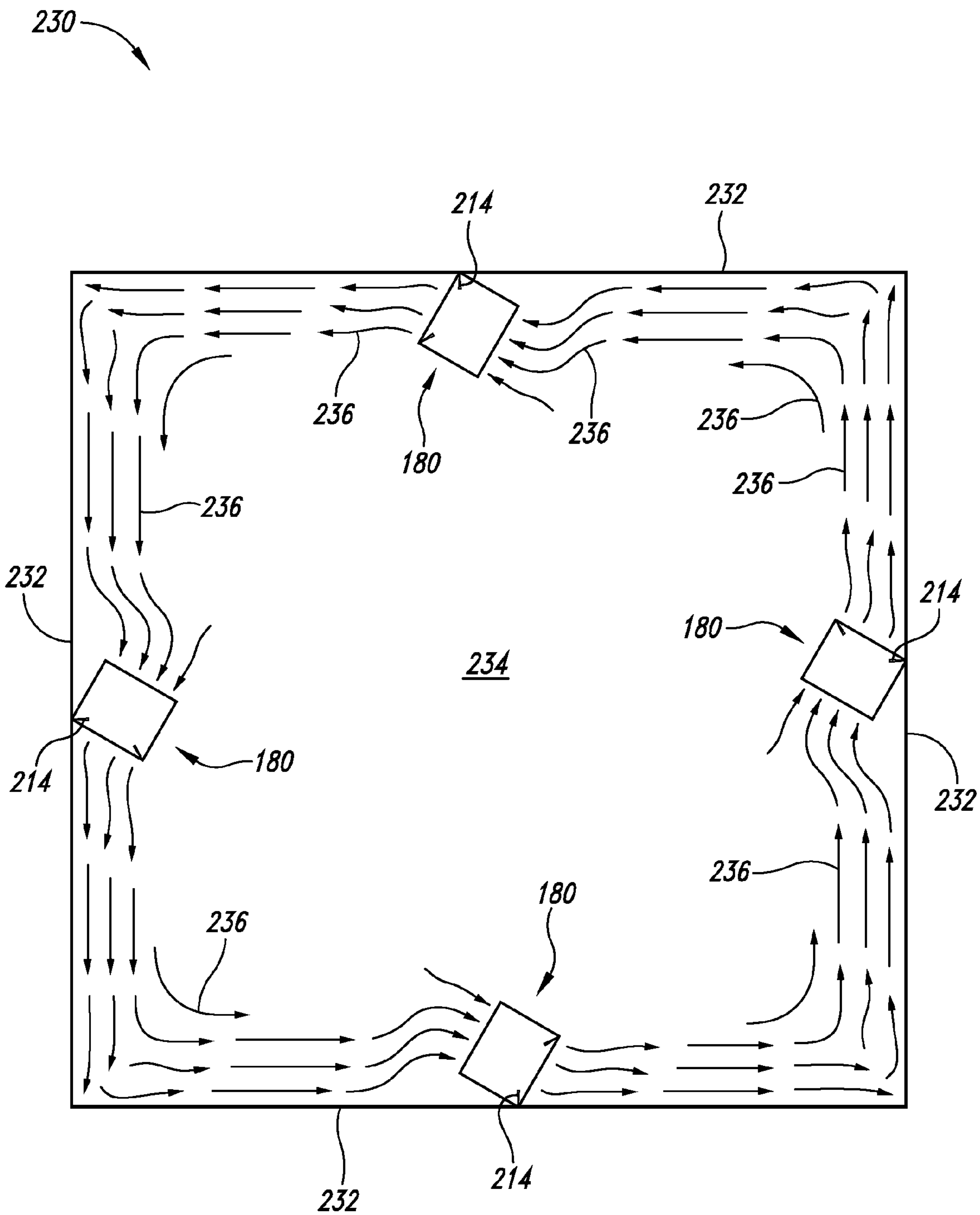
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Fig. 21

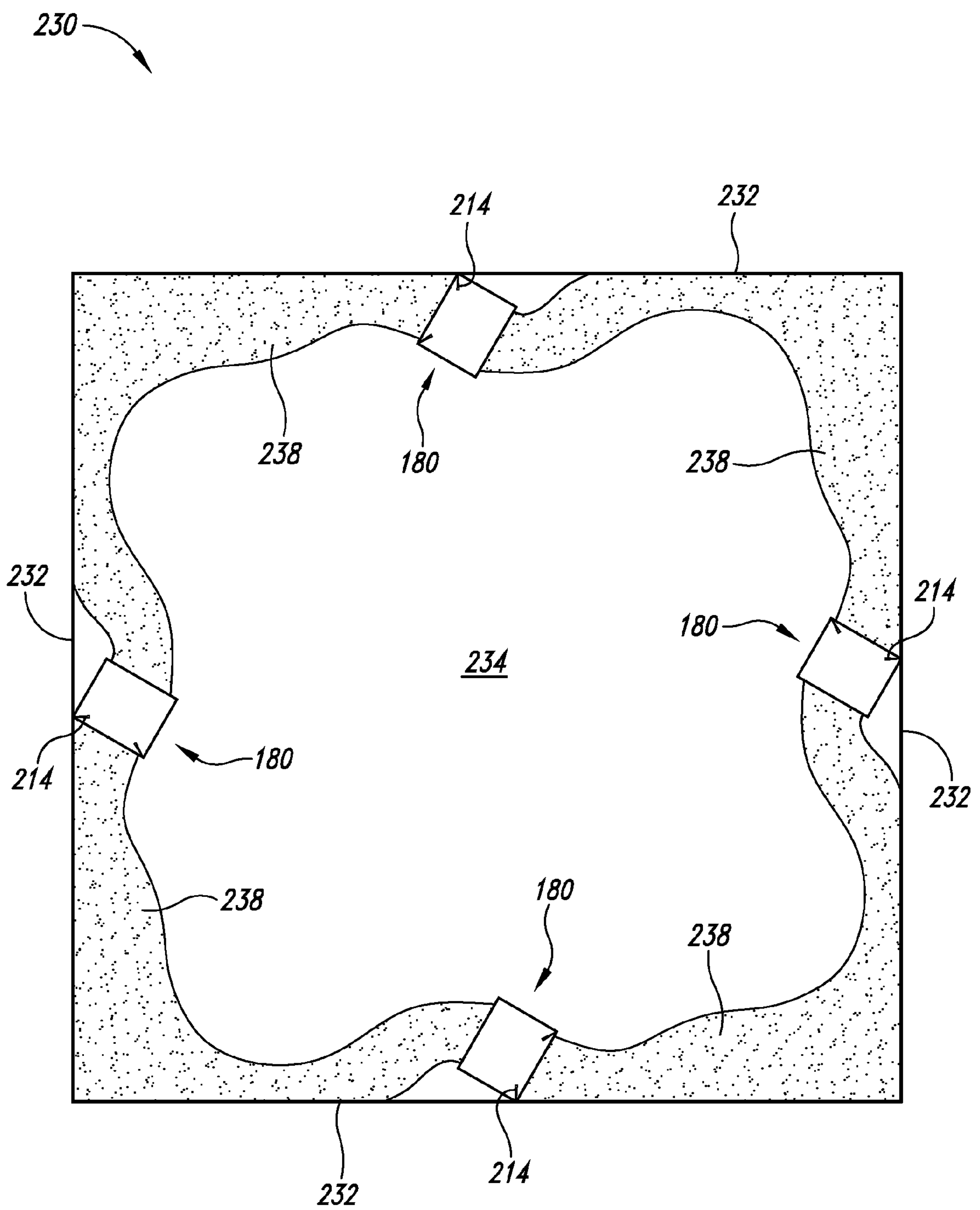
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Fig. 22

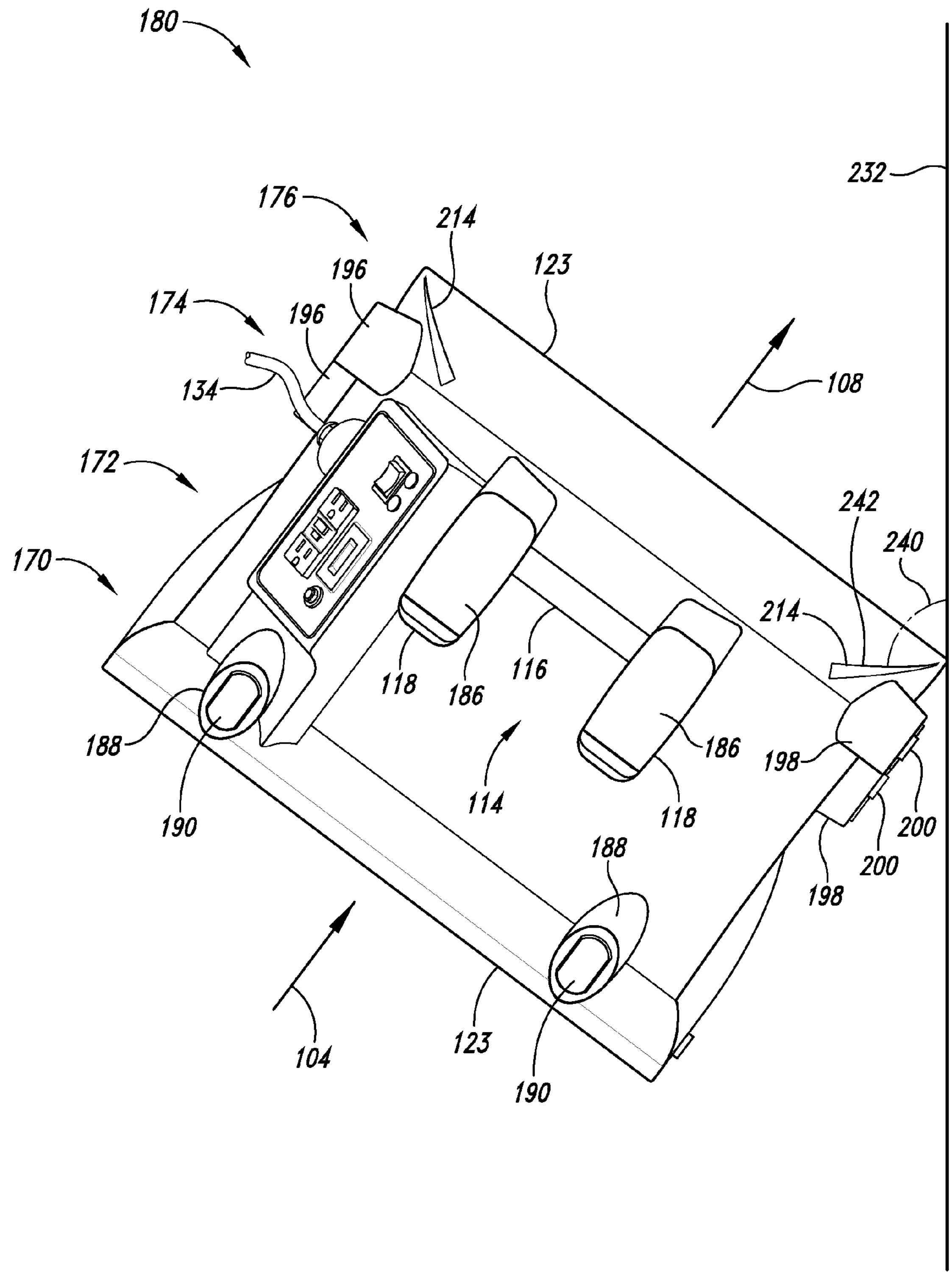
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Fig. 23

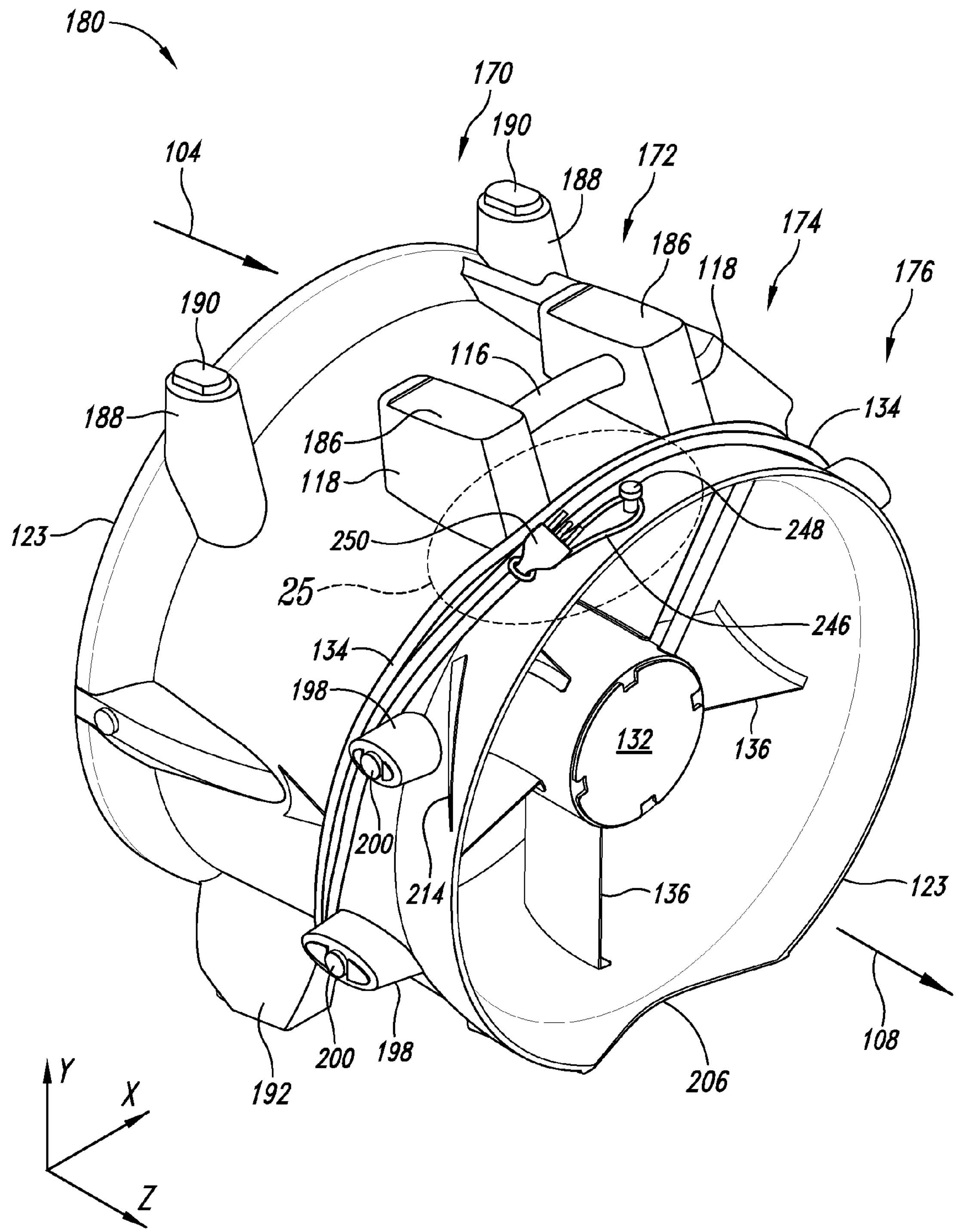
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Fig. 24

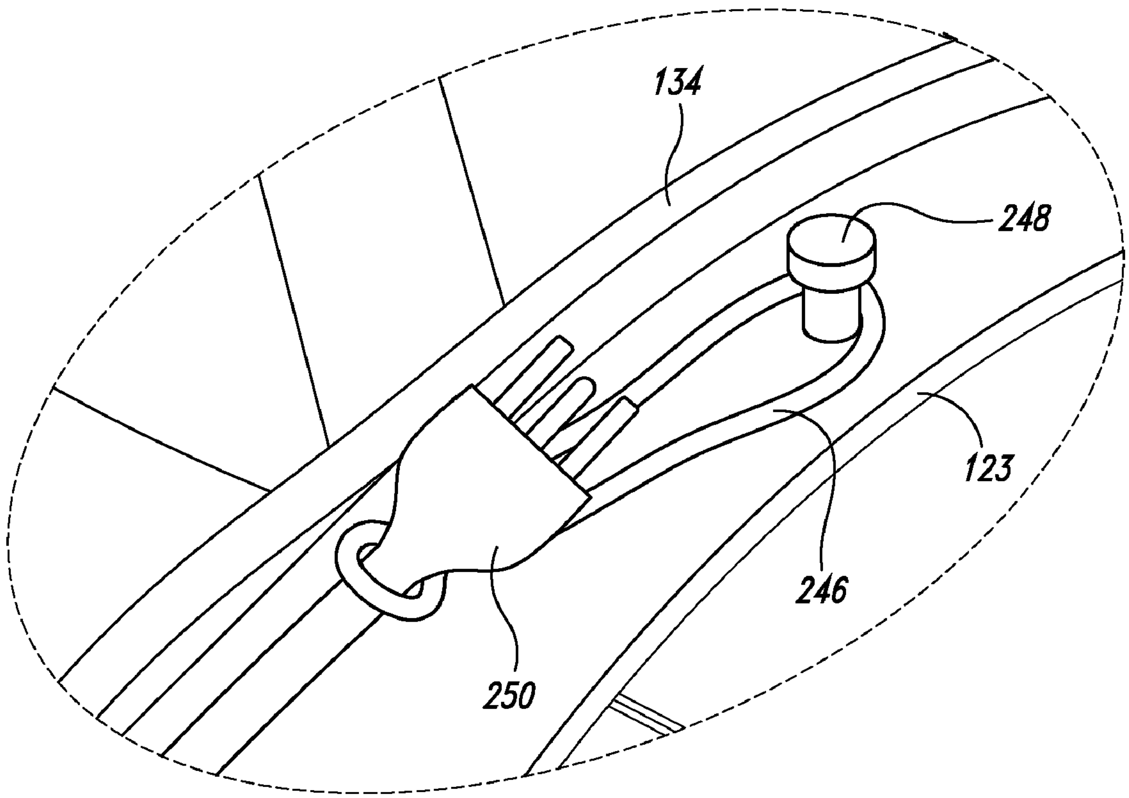

Fig. 25

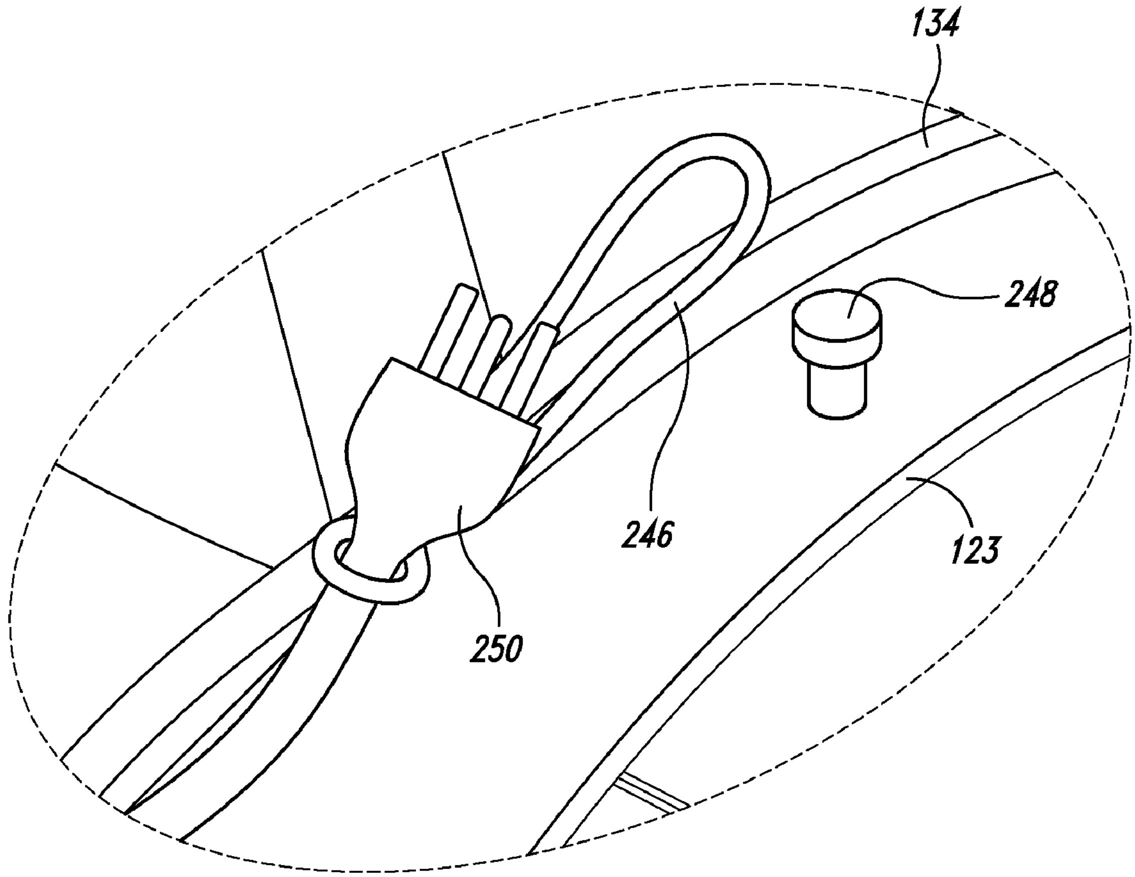

Fig. 26

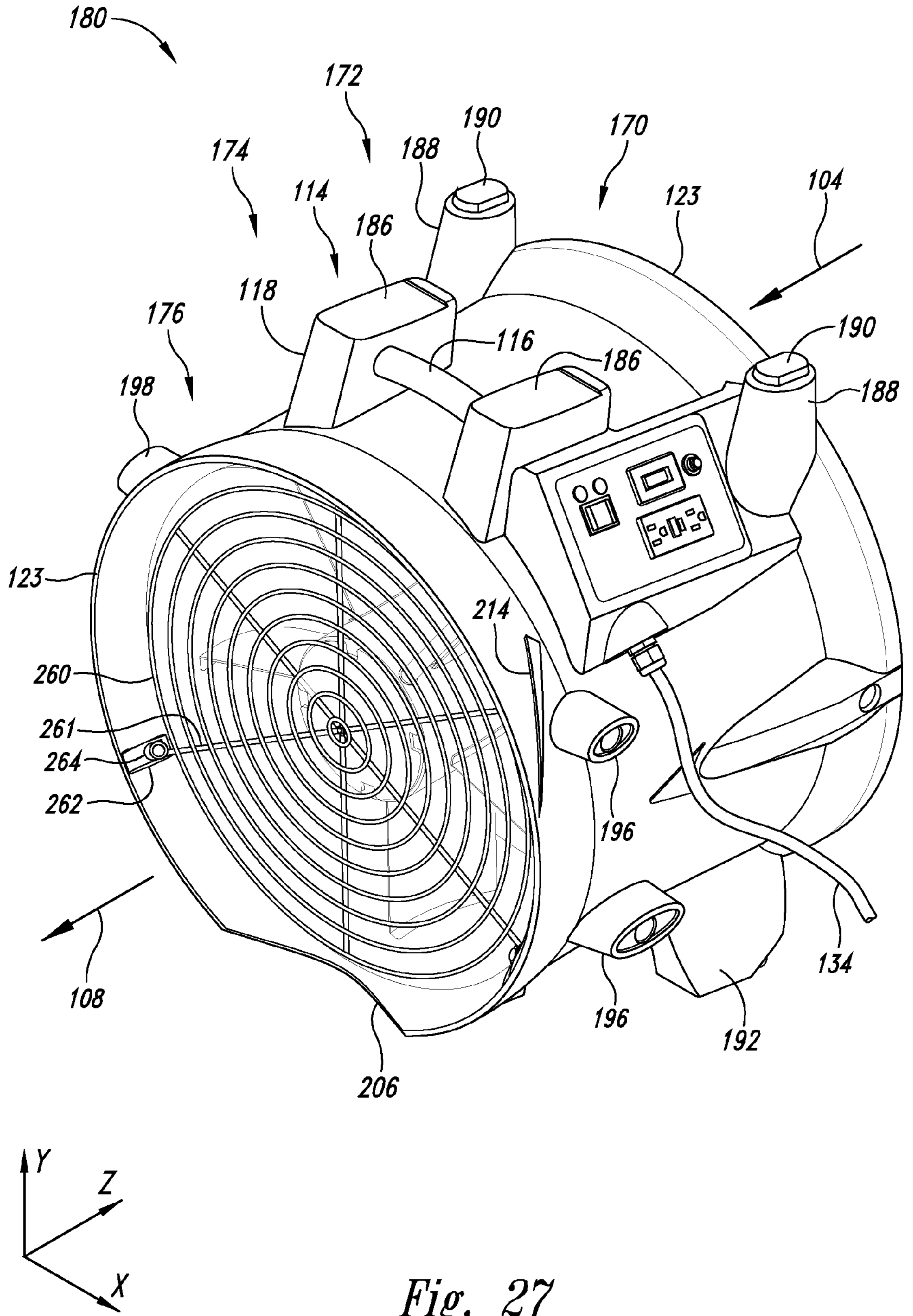
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Fig. 27

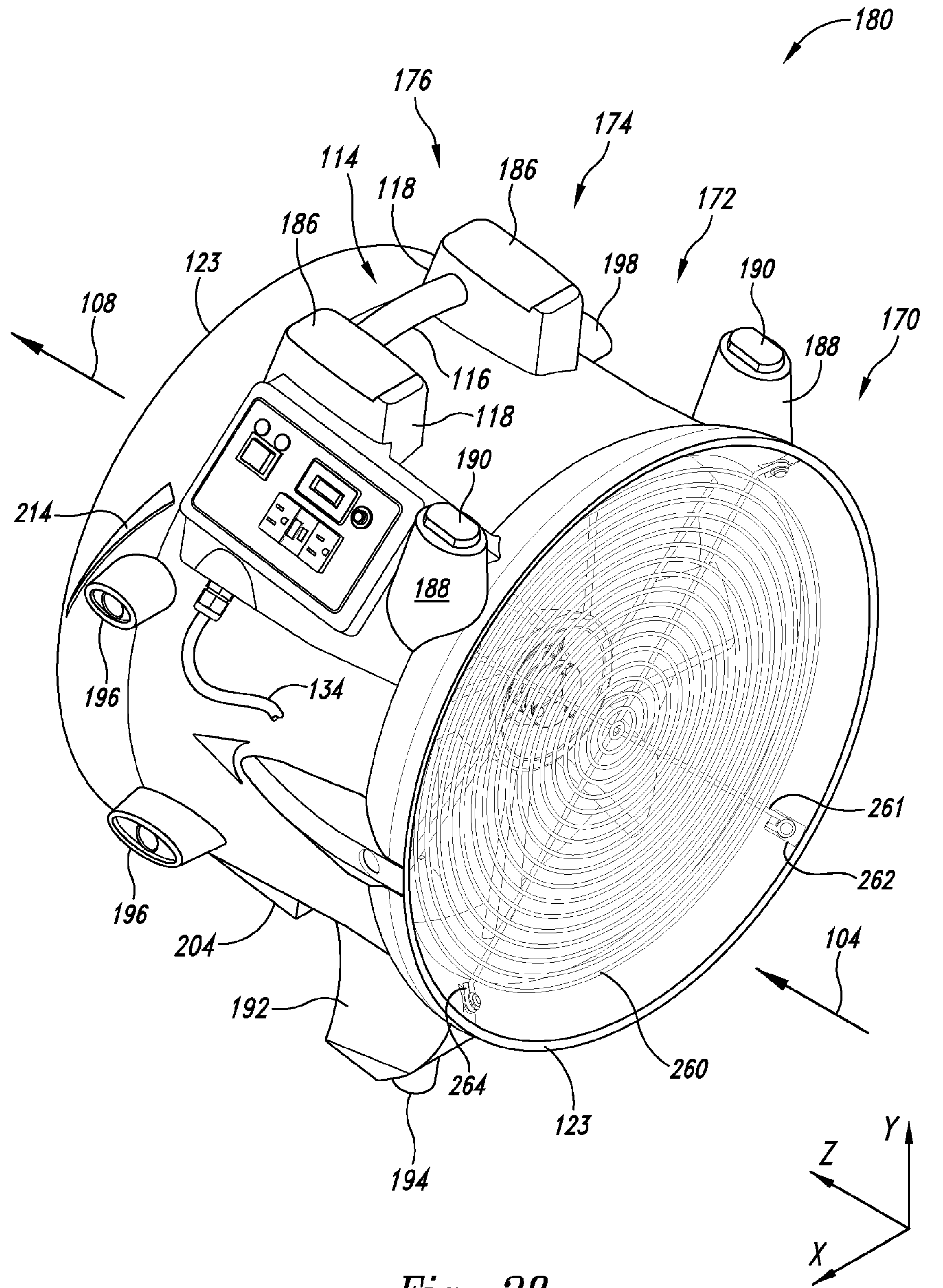
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Fig. 28

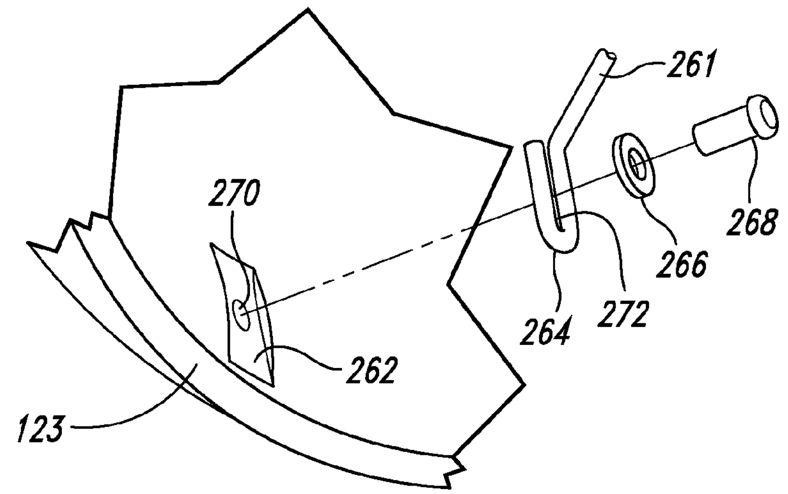

Fig. 29

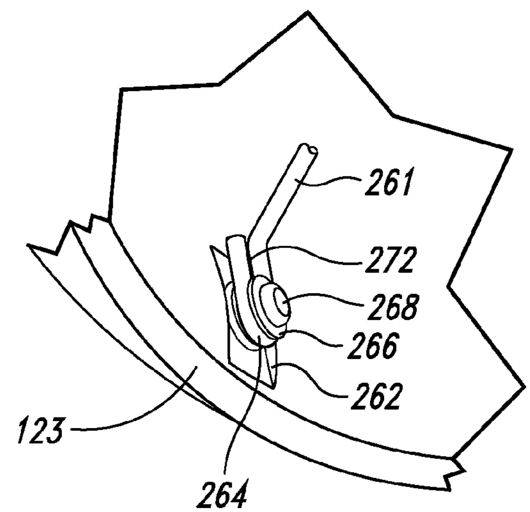

Fig. 30

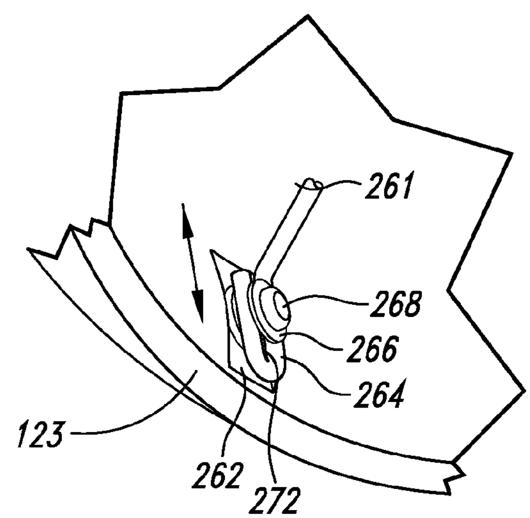

Fig. 31

ENHANCED AXIAL AIR MOVER SYSTEM WITH ENCLOSURE PROFILE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention is related to axial air movers.

[0003] 2. Description of the Related Art

[0004] Air movers are used for such applications as to dry buildings and other structures when accidents have occurred causing areas in the buildings and other structures to become wet. Unfortunately, conventional air movers can be noisy, can waste energy, and can raise difficulties in transport, use, storage, and assembly of the units.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0005] FIG. **1** is a cross-sectional elevational side view of a first fan-assembly version of an enhanced axial air mover system.

[0006] FIG. **2** is a cross-sectional elevational side view of a second fan-assembly version of the enhanced axial air mover system.

[0007] FIG. **3** is a cross-sectional elevational side view of a third fan-assembly version of the enhanced axial air mover system.

[0008] FIG. **4** is a cross-sectional elevational side view of a fourth fan-assembly version of the enhanced axial air mover system.

[0009] FIG. **5** is a cross-sectional elevational side view of the enhanced axial air mover system having radiused edges.

[0010] FIG. **6** is a cross-sectional elevational side view of the enhanced axial air mover system having tapered edges.

[0011] FIG. **7** is an elevational inlet view of an augmented implementation of the first fan-assembly version of the enhanced axial air mover system.

[0012] FIG. **8** is an elevational outlet view of the augmented implementation of the enhanced axial air mover system of FIG. **7**.

[0013] FIG. **9** is an elevational outlet view of a matrix configuration of a plurality of the augmented implementations of FIG. **7**.

[0014] FIG. **10** is a top plan view of an engaged pair of the augmented implementations of FIG. **7**.

[0015] FIG. **11** is a top-outlet perspective port side view of the augmented implementation of FIG. **7**.

[0016] FIG. **12** is an elevational port side view of the augmented implementation of FIG. **7**.

[0017] FIG. **13** is a bottom-outlet perspective starboard side view of the augmented implementation of FIG. **7**.

[0018] FIG. **14** is an elevational starboard side view of the augmented implementation of FIG. **7**.

[0019] FIG. **15** is an elevational starboard side view of a vertically stacked pair of the augmented implementations of FIG. **7**.

[0020] FIG. **16** is a drying performance chart.

[0021] FIG. **17** is an elevational front view of person carrying the augmented implementation of FIG. **7**.

[0022] FIG. **18** is a top-inlet perspective port side view of the augmented implementation of FIG. **7**.

[0023] FIG. **19** is a top plan view of the augmented implementation of FIG. **7**.

[0024] FIG. **20** is a bottom plan view of the augmented implementation of FIG. **7**.

[0025] FIG. **21** is a top view of a room being dried by four of the augmented implementations of FIG. **7** showing airflow.

[0026] FIG. **22** is a top view of the room being dried by the four augmented implementations of FIG. **7** showing drying area.

[0027] FIG. **23** is a top plan view of the augmented implementation of FIG. **7** showing alignment with a wall of the room of FIG. **21**.

[0028] FIG. **24** is a top-outlet perspective starboard side view of the augmented implementation of FIG. **7** with a cord restraint system.

[0029] FIG. **25** is an enlarged fragmentary view of FIG. **24** showing engagement detail of the court restraint system.

[0030] FIG. **26** is an enlarged fragmentary view of FIG. **24** showing disengagement detail of the cord restraint system.

[0031] FIG. **27** is a top-outlet perspective port side view of the augmented implementation of FIG. **7** with an attached grill guard.

[0032] FIG. **28** is a top-inlet perspective port side view of the augmented implementation of FIG. **7** with an attached grill guard.

[0033] FIG. **29** is an enlarged exploded fragmentary view of one either of the grill guards of FIG. **27** and FIG. **28** showing engagement detail with the augmented implementation of FIG. **7**.

[0034] FIG. **30** is an enlarged fragmentary view of the grill guards of FIG. **29** with the grill being attached in a first position.

[0035] FIG. **31** is an enlarged fragmentary view of the grill guards of FIG. **29** with the grill being attached in a second position.

DETAILED DESCRIPTION OF THE INVENTION

[0036] As discussed herein, implementations of an enhanced axial air mover system address various issues such as drying performance, transportability, storage, use, and assembly. Some implementations include ergonomic positioning of a carrying handle relative to positioning of a fan-assembly to make the system easier to carry. Implementations have enclosures with variable diameter profiles to increase air flow performance through the air mover. A floor edge allows for flush positioning of the air mover's outlet to improve flow of air after exhausted from the air mover. Various supports and engagement members allow for horizontal and/or vertical engagement of a plurality of the air movers for storage or increased air moving capacity for a given application. An alignment guide assists with positioning of the air mover with respect to a room wall to enhance air flow within the room. A cord retaining system provides an enhanced approach for securing the air mover's electrical cord. The air mover's grill guards have slotted ends to assist with assembly of the air mover.

[0037] A first fan assembly version **100** of the enhanced axial air mover system is shown in FIG. **1** as having an inlet **102** to receive intake air **104** flowing toward the system in the direction of the Z-axis and an outlet **106** to release exhaust air **108** flowing from the system in the direction of the Z-axis. The first version **100** has a housing assembly **110** including an enclosure **112** and a handle **114** extending therefrom. The handle **114** includes a grip **116** and a bracket **118**. The enclosure **112** has an interior **120** with an inner surface **122** depicted in FIG. **1** with a straight profile. The enclosure **112** has edges **123** on both the inlet **102** and the outlet **106** depicted in FIG. **1** as blunt. The first version **100** further includes a fan assembly **124** having a propeller **126** with blades **128** extending from a hub **130**. The fan assembly also includes a motor **132** with a shaft **133** extending therefrom with the hub **130** attached thereto. The motor **132** has a power cord **134** protruding through a passageway **135** in the enclosure **112**. The motor **132** is held in place relative to the enclosure **112** with support vanes **136** extending from the enclosure. The support vanes **136** are shaped to help guide the exhaust air **108** leaving the system.

[0038] As shown in FIG. **1**, the motor **132** is located along the Z-axis substantially near the outlet **106**. The propeller **126** is positioned in the interior **120** farther from the outlet **106** than the motor **132** is from the outlet. Since the motor **132** weighs significantly more than the propeller **126**, the combined center of gravity (CG) of the motor and the propeller as the fan assembly **124** is located approximately near the center of the motor along the Z-axis as shown in FIG. **1**. The grip **116** of the handle **114** is positioned along the Z-axis to be substantially aligned along a second dimension substantially perpendicular to the Z-axis with the center of gravity (CG) of the fan assembly **124** to allow for greater ease in transport of the system. In many implementations, the Z-axis is substantially horizontally oriented and the second dimension substantially perpendicular to the Z-axis is substantially vertically oriented with the system is being carried.

[0039] A second fan assembly version **140** is shown in FIG. **2** in which the propeller **126** is located substantially near the outlet **106** and the motor **132** is located farther from the outlet. The position of the grip **116** of the handle **114** along the Z-axis is changed in the second fan assembly version **140** to be aligned with the center of gravity (CG) of the fan assembly **124** of the second fan assembly version **140**.

[0040] A third fan assembly version **150** is shown in FIG. **3** in which the propeller **126** is located substantially near the inlet **102** and the motor **132** is located farther from the inlet. The position of the grip **116** of the handle **114** along the Z-axis is changed in the third fan assembly version **150** to be aligned with the center of gravity (CG) of the fan assembly **124** of the third fan assembly version **150**.

[0041] A fourth fan assembly version **160** is shown in FIG. **4** in which the motor **132** is located substantially near the inlet **102** and the propeller **126** is located farther from the inlet. The position of the grip **116** of the handle **114** along the Z-axis is changed in the fourth fan assembly version **160** to be aligned with the center of gravity (CG) of the fan assembly **124** of the fourth fan assembly version **160**.

[0042] The enclosure **112** is shown in FIG. **5** as having a version of the edges **123** curved with a substantially constant radius such that the curve of the edge is sized approximately half the thickness, T, of the enclosure. The enclosure **112** of FIG. **5** is shown to house any one of the first fan assembly version **100**, the second fan assembly version **140**, the third fan assembly version **150**, and the fourth fan assembly version **160**. The enclosure **112** has a version of the inner surface **122** with a substantially straight profile.

[0043] The enclosure **112** is shown in FIG. **6** as having a version of the edges **123** as tapered. The tapering of the edges **123** is such that for an inlet portion **170** of the enclosure, the diameter of the inner surface **122** changes from D_in at the inlet **102** to D_mid**1** at the Z_mid**1** location along the Z axis in from the inlet along the Z-axis. The change of diameter between D_in and D_mid**1** for the inlet portion **170** can be at least as much as twice the average thickness, T, of the enclosure **112** in some implementations. In other implementations the change in diameter for the inlet portion **170** between D_in and D_mid**1** is at least as much as five to ten percent of the diameter, D_in, at the inlet.

[0044] The diameter of the enclosure **112** continues to decrease along the Z-axis for a first mid-portion **172** of the enclosure from a diameter of D_mid**1** at the Z_mid**1** location to D_mid**2** at the Z_mid**2** location approximately near a mid location along the Z-axis so that the inner surface **122** has a substantially variable profile for the inlet portion **170** and the first mid-portion **172**. Farther toward the outlet **106** along the Z-axis for a second mid-portion of the enclosure **112** from the Z_mid**2** location to a Z_mid**3** location, the diameter of the enclosure **112** increases gradually from D_mid**2** at the Z_mid**2** location to D_mid**3** at the Z_mid**3** location. For an outlet portion **176** of the enclosure **112** the diameter of the enclosure increases more abruptly from D_mid**3** at the Z_mid**3** location to D out at the outlet **106** so that the inner surface **122** has a substantially variable profile between the second mid-portion **174** and the outlet portion **176**. In some implementations, the change in diameter between D_mid**3** and D_out can be at least half as great as the change in diameter between D_in and D_mid**1**. The enclosure **112** of FIG. **6** is shown to house any one of the first fan assembly version **100**, the second fan assembly version **140**, the third fan assembly version **150**, and the fourth fan assembly version **160**.

[0045] An augmented implementation **180** of the first fan-assembly version **100** is shown in FIG. **7** as having a top **181**, a bottom **182**, a port **183**, and a starboard **184**. The bracket **118** of the handle **114** has a platform **186** to support an additional one of the augmented implementation **180** positioned above the depicted augmented implementation as further described below. Two vertical supports **188** extend upward from the top **181** to further support the additional above-positioned one of the augmented implementation **180**. Each of the vertical supports **188** has a peg **190** to engage with the additional above-positioned one of the above augmented implementation **180**.

[0046] Extending from the bottom **182** are two legs **192** each having a floor guard **194** to support the inlet portion **170** and the first mid-portion **172** on a floor. Extending from the port **183** are port supports **196**. Extending from the starboard **184** are starboard supports **198**. The starboard support **198** is further shown to have a peg **200** for engagement with the port support of another of the augmented implementations **180**.

[0047] In FIG. **8**, the augmented implementation **180** is shown to have an opening **202** in each of the legs **192** to receive the peg **190** of one of the vertical supports **188** of a lower-positioned one of the augmented implementations **180**. The augmented implementation **180** has a support pad **204** that rests on the platform **186** of a lower-positioned augmented implementation. The augmented implementation **180** has a floor edge to allow for a more flush positioning of the inlet portion **102** with a floor of a room. As discussed herein, a more flush positioning allows for enhanced flow of the exhaust air **108**.

[0048] The matrix **210** having m rows by n columns of a plurality of instances of the augmented implementation **180** is shown in FIG. **9**. The port supports **196** of the first column of the augmented implementations **180** are engaged with respective ones of the starboard supports **198** of the second column of the augmented implementations and so on for other adjacent columns of the augmented implementations of the matrix **210**.

[0049] The support pads **204** of the second row of the augmented implementations **180** rest upon the respective platforms **186** of the first row of the augmented implementations and so on for other adjacent rows of the matrix **210**. The pegs **190** of the vertical supports **188** of the first row of the augmented implementations **180** engage with the respective openings **202** of the legs **192** of the augmented implementations of the second row of the matrix **210**.

[0050] Various subsets of the matrix **210** can be implemented such as having a single row or a single column. For instance, a single row could have as little as two of the augmented implementations **180** coupled together as shown in FIG. **10**. Alignment guides **214**, further discussed herein, are shown on the top of the outlet portion **176** of the augmented implementations **180**.

[0051] The floor edge **206** and associated downward pitch of the outlet portion **176** relative to the inlet portion **170** of the augmented implementation **180** is better shown in FIG. **11** through FIG. **14**. The floor edge **206** allows the outlet portion **176** of the augmented implementation to be pitched down toward a floor surface relative to the inlet portion **170**. Instead of the outlet portion **176** being completely circular near the outlet **106**, a section of the outlet portion is missing. The missing section forming the floor edge **206** of the outlet portion **176** is shaped as though a horizontal slice is taken through the outlet portion near the bottom **182** of the augmented implementation **180** as the outlet portion is being pitched downward relative to the inlet portion **170**. The floor edge **206** allows more of the outlet portion **276** to be flush with a floor, in comparison to a case in which the outlet **106** was completely circular thereby allowing an increase in air flow near the floor surface of the exhaust air **108** leaving the outlet.

[0052] As shown in FIG. **15**, for a column of a pair of an upper one **180***u* of the augmented implementations **180** of the pair and a lower one **180***l* of the augmented implementations of the pair, the legs **192** and the support pad **204** of the upper one are sized and positioned relative to the platform **186** and the vertical supports **188** of the lower one so that the pitch angle, P, for each of the augmented implementations of the column pair is substantially the same.

[0053] A drying performance graph of FIG. **16** shows total floor area dried as area under a curve for three configurations: 1.) parallel, 2.) angled, and 3.) flush angled. The parallel configuration is similar to the augmented implementation **180**, however, without the outlet portion **176** pitched downward relative to the inlet portion **170** and without the floor edge **206**. The angled configuration is similar to the augmented implementation **180** having the outlet portion **176** being pitched downward relative to the inlet portion **170**, but without the floor edge **206**. The flush angled configuration is similar to the augmented implementation **180** having the outlet portion **176** being pitched downward relative to the inlet portion **170** and having the floor edge **206**.

[0054] As shown by the graph of FIG. **16**, the parallel configuration has the least amount of area under its curve indicating that the least amount of floor area was dried with this configuration. The angled configuration has about the same amount of drying area as the parallel configuration except for a large drying area away from the angled configuration air blower as airflow turns a corner of a room. The flush angled configuration has the most area under the curve indicating that the flush angled configuration has the most drying area. The flush angled configuration also has relatively even drying area and the most drying area near the air blower of the three configurations depicted.

[0055] As shown in previous figures such as FIG. **13**, to conform with a plane of the floor when the outlet portion **176** is pitched, the floor edge **206** is shaped as a curvilinear cut of the circular outlet **106**. The curvilinear cut of the floor edge **206** can be used to another advantage for carrying the augmented implementation **180** as shown in FIG. **17**. Since both the handle **114** and the floor edge **206** are located near or at the outlet **106**, the curvilinear aspect of the floor edge can be used to position the augmented implementation **180** in a more ergonomic position for transport. By allowing the floor edge **206** to be positioned near the leg or other portion of an individual carrying the augmented implementation, the arm used to carry can be brought closer to the torso resulting in a more comfortable position for carrying the augmented implementation.

[0056] The variable profile for the inlet portion **170** of the augmented implementation **180** is indicated in FIG. **18**. The variable profiles for the inlet portion **170**, the first mid-portion **172**, the second mid-portion **174**, and the outlet portion **176** are indicated in FIG. **19** and FIG. **20**.

[0057] An example of placement of the augmented implementation **180** in a room **230** with walls **232** and a floor **234** to be dried is shown in FIG. **21** and FIG. **22**. By placing each of the augmented implementations **180** at a predetermined angle such as an acute angle, (such as approximately 30° for a version of the augmented implementation) with a different one of the walls **232**, air flow **236** is distributed in a relatively uniform manner along the walls **232** and across the floor **234**. The relatively uniform distribution of the air flow **236** results in a relatively large and evenly distributed dried area **238** of the floor **234** as shown in FIG. **22**.

[0058] For various versions of the augmented implementation **180**, there will generally be a particular acute angle **240** for aligning the augmented implementation relative to the wall **232**. As shown in FIG. **23**, the alignment guide **214** can be arranged to have a perpendicular instance **242** to be used to align the augmented implementation **180** relative to the wall **232**. For the case in which the alignment guide **214** is used as the perpendicular instance **242**, the augmented implementation **180** is aligned relative to the wall **232** such that the alignment guide **214** is approximately perpendicular to the wall. In other versions of the augmented implementation **180** other instances of the alignment guide **214** having other position angles relative to the wall **232** can be used.

[0059] The power cord **134** is shown in a secured position in FIG. **24** and FIG. **25** by using an elastic member **246**, having a capability of resuming original shape after being stretched or expanded, to fasten the power cord to a protruding member such as a post **248** extending from the augmented implementation **180**. As shown, the post **248** extends from the outlet portion **176** although in other versions of the augmented implementation **180**, the post could extend from other locations of the augmented implementation.

[0060] The location of the post **248**, expanded length and contracted length of the elastic member **246**, length of the power cord **134**, and location of the power cord passageway **135** are synergistically adjusted so that the elastic member **246** can be stretched to give sufficient tension to hold the power cord in place after the power cord has been wrapped around a portion of the augmented implementation **180** (such as being wrapped around the outlet portion **176** as depicted) when the elastic member is coupled with the post **248**, or other protruding member. The elastic member **246** is also secured around a head portion **250** of the power cord **134** as depicted, however, in other versions, the elastic member can be coupled to the power cord in some other manner. To use the augmented implementation **180**, the elastic member **246** is uncoupled from the post **248** as shown FIG. **26**.

[0061] A grill guard **260** having support members **261** is shown in FIG. **27** with the support members coupled to the outlet portion **176** and is shown in FIG. **28** with support members coupled to the inlet portion **170** through brackets **262**. As shown in FIGS. **29-31**, the grill guard **260** has slotted end portions **264** that receive a washer **266** and screw **268** to couple with a threaded hole **270** in the bracket **262**. The slotted end portion **264** has an elongated opening **272** that allows the slotted end portion **264** to be positionally adjusted relative to the screw **268** when the screw is coupled to the threaded hole **270** to account for dimension differences in the inlet portion **170** and the outlet portion **176** due to variation in manufacturing conditions. Consequently, use of the slotted end portions **264** on the grill guard **260** reduce assembly problems due to manufacturing variations.

[0062] Conventional air movers used in water damage restoration have been centrifugal type fans of dual inlet design. While there is a range of sizes and power configurations the vast majority fall in the ¼ to ½ horsepower (HP) range with ⅓ HP being typical. This type of fan would generate about 1250 cubic feet per minute (CFM) and have a static pressure capacity at zero flow at around 3 inches of water column. This type fan would draw about 5 amps at 115V. When multiple fans were used to do structural drying work finding enough available power became as issue. Contractors were using more and more fans on a job in an effort to speed the drying process. We looked at adapting axial fans that had been used for ventilation of confined spaces to this type of structural drying.

[0063] Items that had to be balanced in the design included the Diameter of the axial fan, the number of blades, the pitch of the blades, motor HP, RPM, blade tip clearance, barrel length and inlet and outlet design.

[0064] A vane axial fan with a 16" blade diameter in the correct housing could produce around 2000 CFM with a static pressure at zero flow of 1.3 inches of water column. This performance level required 1.4 HP which would draw 2.5 amps. This setup gave the contractor more airflow per unit running at half the amps. A given structural drying job would now dry quicker with less setup issues.

[0065] As we looked at how the fans were drying the structure we saw some opportunity for improvement. The air outlet of the fan is directed at the wall at an angle so that the air flows down the wall but also maintains a higher air pressure zone against the wall. If we ran the fan at no angle to the wall the air velocity down the wall increased but the amount of structural material, walls and floors, that was being dried decreased. We looked at angles from 5 to 55 degrees and found that angles between 25 and 35 degrees produced the largest drying area. We recommend a 30 degree angle against the wall.

[0066] We changed from a 8 blade 35 degree pitch to a 6 blade 30 pitch because we found that the inherent static load at the 30 degree angle to the wall would allow us to run the 6 blade configuration and increase flow and the overall drying area without adding more load, it still ran at 2.5 amps.

[0067] We also found that by shaping the air outlet to direct the flow down at floor level increased the amount of drying area. The original shell design was from a vane axial fan model line that we produced which used duct connection rings for the attachment of long runs of flexible ducting. This left a sharp edge at both the inlet and outlet that created some level of shock loss in the airflow. Because the structural drying application did not require any type of duct connection we changed the shape of the inlet and outlet in minimize the transition at the opening. This gave us much cleaner flow coming into the blade area and increased overall flow numbers. We were able to increase the size of the diameter of the blade to 17 inches without increasing the amp draw above the 2.5 amps in the smaller shell.

[0068] From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. For instance in some implementations Further, in some instances, Likewise, Accordingly, the invention is not limited except as by the appended claims.

The invention claimed is:

1. An air mover system comprising:

a fan assembly including a propeller and a motor, the propeller coupled to the motor; and

a housing assembly including an enclosure, the enclosure having an interior bounded by an inlet and an outlet, the fan assembly positioned within the interior, the enclosure having a variable diameter including a first diameter at the inlet, a second diameter at the outlet and a third diameter at a mid-point on a first dimension extending from the inlet and outlet, the difference between the first diameter and the third diameter is at least five percent of the first diameter.

2. The air mover system of claim **5** wherein the difference between the first diameter and the third diameter is at least ten percent of the first diameter.

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