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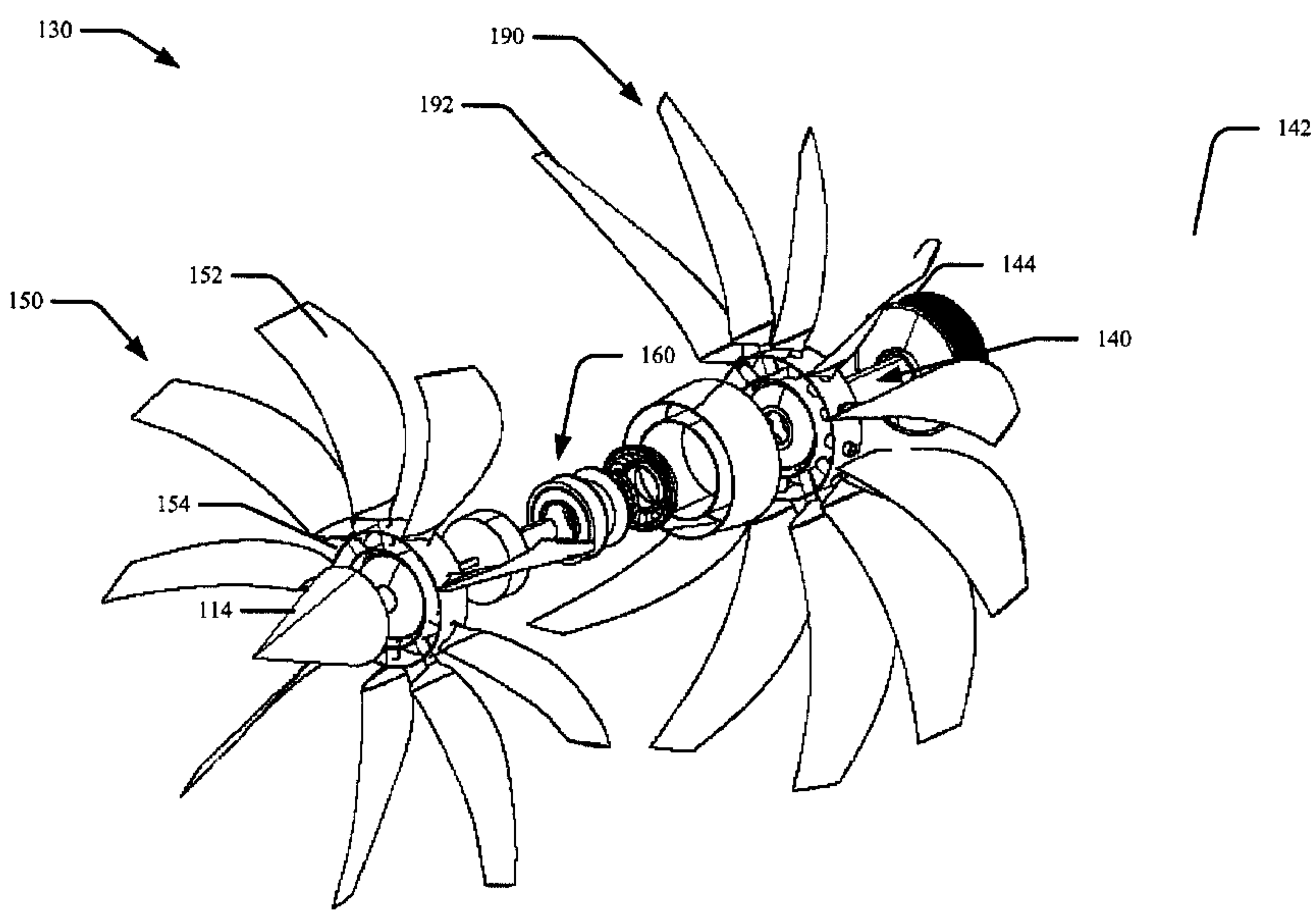

(57) Abrégé/Abstract:
In one aspect a propulsion system comprises an engine and a drive assembly coupled to the engine, comprising a first driveshaft rotatable in a first direction about a first axis, a first fan coupled to the first driveshaft to rotate in the first direction, and a clutch assembly to selectively disengage the first fan from the first driveshaft. Other aspects may be described.

ABSTRACT

In one aspect a propulsion system comprises an engine and a drive assembly coupled to the engine, comprising a first driveshaft rotatable in a first direction about a first axis, a first fan coupled to the first driveshaft to rotate in the first direction, and a clutch assembly to selectively disengage the first fan from the first driveshaft. Other aspects may be described.

CONTRA-ROTATING OPEN FAN PROPULSION SYSTEM

FIELD OF THE DISCLOSURE

[0001] The subject matter described herein relates to aircraft propulsor systems, and more particularly those incorporating a contra-rotating propulsor system which may be incorporated into aircraft engines.

BACKGROUND

[0002] Open fan aircraft engines equipped with contra-rotating propulsor systems continue to generate interest in the aviation industry, particularly as fuel prices increase, due to the efficiency of contra-rotating open fan aircraft engines. Contra-rotating propulsor systems are of particular interest due to their efficiency and ability to generate adequate thrust at high speed.

[0003] Based on previous experience in the industry, the effective perceived noise levels generated by contra-rotating propulsors exceed noise thresholds set by regulatory agencies for aircraft, which renders use of contra-rotating engine systems for commercial applications problematic. Accordingly, techniques to address the reduction of noise levels in contra-rotating engine systems may find utility.

SUMMARY

[0004] In accordance with one disclosed aspect there is provided a drive assembly including a first driveshaft rotatable in a first direction about an axis, a first fan coupled to the first driveshaft to rotate in the first direction, and a hydraulic clutch assembly configured to selectively disengage the first fan from the first driveshaft and to selectively apply resistance to cause rotation of the first fan to spin down. The drive assembly also includes a gearbox coupled to the first driveshaft between an engine and the first fan the

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gearbox is configured to change a direction of rotation of the first fan to a direction opposite to the first direction.

[0005] The drive assembly may include a second driveshaft rotatable in a second direction opposite the first direction, and a second fan coupled to the second driveshaft to rotate in the second direction.

[0006] The first driveshaft and the second driveshaft may be coaxial.

[0006a] The first fan and the second fan may be displaced by a distance that measures between about 0.02 and about 0.35 the distance of an overall front row fan diameter.

[0006b] In accordance with another disclosed aspect there is provided a propulsion system including an engine, and a drive assembly coupled to the engine. The drive assembly includes a first driveshaft rotatable in a first direction about an axis, a first fan coupled to the first driveshaft to rotate in the first direction, and a hydraulic clutch assembly configured to selectively disengage the first fan from the first driveshaft and to selectively apply resistance to cause rotation of the first fan to spin down. The clutch assembly includes a fluid-coupling clutch control circuit. The system further includes a gearbox coupled to the first driveshaft between an engine and the first fan, the gearbox being configured to change a direction of rotation of the first fan to a direction opposite to the first direction.

[0006c] The propulsion system may include a second driveshaft rotatable in a second direction opposite the first direction, and a second fan coupled to the second driveshaft to rotate in the second direction.

[0006d] The first driveshaft and the second driveshaft may be coaxial.

[0006e] The first fan and the second fan may be displaced along the axis by a distance that measures between about 0.02 and about 0.35 the distance of the diameter of the second fan.

[0006f] The fluid-coupling clutch control circuit may be operably configured to cause fluid flow in the circuit to be reversed during spin down of the first fan to increase the applied resistance.

[0006g] The propulsion system may be operably configured for use in an aircraft.

[0007] The features and functions discussed herein can be achieved independently in various embodiments described herein or may be combined in yet other embodiments, further details of which can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The detailed description is described with reference to the accompanying figures.

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[0009] Fig. **1** is a schematic block diagram illustration of an aircraft comprising a contra-rotating open fan propulsion system, according to aspects.

[0010] Figs. **2**A-**2**B are schematic illustrations of a drive assembly, according to a first aspect.

[0011] Fig. **2**C is a schematic illustration of a propulsion system, according to a first aspect.

[0012] Figs. **3**A-**3**B are a schematic illustrations of a drive assembly, according to a second aspect.

[0013] Fig. **3**C is a schematic illustration of a propulsion system, according to a second aspect.

[0014] Figs. **4**A-**4**B are schematic illustrations of a drive assembly, according to a third aspect.

[0015] Fig. **4**C is a schematic illustration of a propulsion system, according to a third aspect.

[0016] Figs. **5**A and **5**B are examples of hydraulic circuits according to aspects.

[0017] Fig. **6** is a schematic view of an aircraft according to aspects.

DETAILED DESCRIPTION

[0018] In the following description, numerous specific details are set forth to provide a thorough understanding of various embodiments. However, it will be understood by those skilled in the art that the various embodiments may be practiced without the specific details. In other instances, well-known methods, procedures, components, and circuits have not been illustrated or described in detail so as not to obscure the particular embodiments.

[0019] As described above, contra-rotating engine systems generate significant noise due at least in part to air turbulence due to interaction between the two rows of contra-rotating blades. For example, noise is generated when the aft row of blades traverse the low pressure wake generated behind the front row of blades.

[0020] The interaction noise is typically comprised of tones resonating at the first blade passage frequency or any integer harmonics of this frequency. Ideal blade passage frequency for a contra-rotating propulsor may be determined using equation **1**:

EQ (1) $$\Omega_{BPF} = n(B_1\Omega_1 - B_2\Omega_2)$$

[0021] In equation (1), Ω_{BPF} denotes blade passage frequency, B_1 denotes front row number of blades, B_2 denotes aft row number of blades, Ω_1 denotes front row rotational speed and Ω_2 denotes the aft row rotational speed. Both Ω_1 and Ω_2 are defined to have positive values in the clockwise direction and negative values in the counter clockwise direction.

[0022] To eliminate the rotor-to-rotor interaction noise, one would ideally prefer the blade passage frequency to tend to zero. By mathematical deduction, one could observe that blade passage frequency will tend to zero if B_1 and B_2 as well as Ω_1 and Ω_2 are equal. This is equivalent to a case where both front and aft row have the same number of blades and rotate with exactly the same rotational speed and in the same direction.

[0023] Described herein are exemplary drive assembly configurations for contra-rotating engine systems, and propulsion systems and aircraft incorporating such drive assembly configurations. In various aspects, a drive assembly is provided with a clutch assembly to selectively disengage the aft fan of a contra-rotating fan engine system from the driveshaft which provides power to the aft fan. The clutch assembly may be provided as an integral part of the fan gearbox or installed on the output of the fan gearbox.

[0024] In some aspects the pitch of the aft row blades may be changed to facilitate its passive rotation, i.e., to windmill under the influence of airflow from the forward fan in the same direction as the forward fan. In other aspects the aft fan may be allowed to spin down under the resistance of the clutch assembly, then reengaged to the driveshaft via a gearbox which drives the aft fan in the same direction as the forward fan. In other aspects, a braking system may be incorporated as an integral part of the clutch assembly to facilitate a faster transition between the two modes. Such system would selectively increase the resistance induced by the clutch assembly by hydraulic means, which leads to a shorter spin-down time for the aft rotor. Thus, a drive assembly constructed in accordance with aspects described herein enables the aft fan of a contra-rotating engine system to be selectively disengaged and fan blades re-pitched, e.g., during landing and take off flight segments or other flight segments in which reducing noise from the aircraft may be useful, and subsequently may be reengaged to drive the aft fan in a contra-rotating configuration.

[0025] In this document, a clutch is defined as a device that provides for selective regulation of transmission of torque from the driving component (power source) to the driven component (fan system) when engaged, but it can be disengaged, or partially engaged to allow the continued transmission of a fractional proportion of power. In this application, a clutch could be either a traditional friction clutch (wet or dry) or a fluid coupling device.

[0026] Fig. **1** is a schematic block diagram illustration of an aircraft comprising a contra-rotating open fan propulsion system, according to aspects. Referring to Fig. **1**, an aircraft **100** comprises a fuselage **102** and a propulsion system **110**. Propulsion system **110** comprises at least one engine **120** and drive assembly **130** coupled to the engine **120**. The drive assembly **130** comprises a first driveshaft **140**, a first fan **150**, a clutch assembly **160**, a gearbox **170**, a second driveshaft **180**, and a second fan **190**. In operation the clutch assembly **160** enables the first fan **150** to be selectively engaged and disengaged from the first driveshaft **140**. Specific examples of drive assemblies and propulsion systems will be described with reference to the following figures.

[0027] Figs. **2**A-**2**B are schematic illustrations of a drive assembly, and Fig. **2**C is a schematic illustration of a propulsion system according to a first aspect. Referring to Figs. **2**A-**2**C, in a first example a drive assembly **130** includes a first driveshaft **140** rotatable in a first direction about a first axis **142** and a second driveshaft **180** (see Fig. **2**C) rotatable in a second direction about axis **142**. Driveshafts **140**, **180** may be coaxial, such that driveshaft **140** rotates within driveshaft **180**. Driveshaft **180** is not shown in Figs. **2**A-**2**B.

[0028] Driveshaft **140**, **180** may be coupled to a power source such as engine **120** (Fig. 2C) via a gearbox such as a planetary gearbox **144**. Engine **120** and planetary gearbox **144** power the driveshafts **140**, **180** to rotate the driveshafts **140**, **180** about axis **142**.

[0029] The specific construction of engine **120** is not critical. In some examples engine **120** may be implemented as a gas turbine engine comprising a multi-stage compressor which provides compressed air to a combustor, which turns turbines to rotate an output shaft. Engine **120** may also be comprised of an electric motor or an internal combustion engine of two or four stroke type. Driveshafts **140**, **180** are coupled to the output shaft via planetary gearbox **144**. The fan can be located in front or aft of the engine **120**, allowing for the propulsor to push (i.e. a pusher engine configuration) or pull (i.e., a puller engine configuration) the engine **120** and subsequently the airplane **100**.

[0030] A first fan **150** is coupled to the first driveshaft **140** to rotate in a first direction about axis **142** when the first driveshaft **140** is rotated. First fan **150** may be positioned as the aft fan when the drive assembly **130** is coupled to engine **120**. First fan **150** comprises a plurality of blades **152** coupled to a hub **154**. In some examples the ratio of the diameter of rotor to that of the hub maybe between **0.20** to **0.35**. For many applications, the front rotor may have a diameter between **60** inches (**1.5** meters) to **240** inches (**6.1** meters). Blades **152** may be curved or otherwise contoured to affect the power generation capability of the blades **152**.

[0031] Further, a second fan **190** is coupled to a second driveshaft **180**, visible in Fig. **2C**, to rotate in a second direction, different from the first direction, about axis **142** when the second driveshaft **180** is rotated. Second fan **190** may be positioned as the forward fan when the drive assembly **130** is coupled to engine **120**. Second fan **190** comprises a plurality of blades **192** coupled to a hub **194**.

[0032] In some examples the second fan **190** and fan blades **192** may be designed to generate sufficient thrust at takeoff and climb-out while aft fan **152** is not engaged with the driveshaft **140**. This can be achieved by increasing the diameter of the second fan **190**, as the net thrust generated by a fan is proportional to the forth power of the fan diameter. For example, the thrust generated by fan **190** would be increased by as much as fifty percent (**50**%) if the diameter of fan **190** is increased by nineteen percent (**19**%). In some examples, blades **192** measure between about **40** inches (**1.0** meter) and **200** inches (**5**.1 meters) in length and **4** inches (**10.2** centimeters) and **35** inches (**88.9** centimeters) in width. Blades **192** may be curved or otherwise contoured to affect the propulsive efficiency of the blades **192** at high speed. When assembled the first fan **150** and the second fan **190** are displaced along axis **142** by a distance that measures between **0.02** and **0.35** of the overall front row fan diameter. This distance is typically related to the activity factor of the blades and is determined either (**1**) experimentally, or (**2**) via unsteady computational fluid dynamics analysis.

[0033] A core duct **112** houses the clutch assembly **160** and an exhaust plug **114** is fitted adjacent the second fan **190**.

[0034] A clutch assembly **160** is provided to selectively disengage the first fan **150** from the first driveshaft **140**. In some examples clutch assembly **160** may be a fluid coupling system, or a friction (wet or dry) clutch system. In the example depicted in Figs. **2**A-**2**C clutch drive assembly **160** comprises an impeller **162**, a stator **164**, a turbine **166**, and a casing **168**. Impeller **162** may be coupled to driveshaft **140** such that impeller **162** rotates with driveshaft **140**. Turbine **166** may be coupled to an output shaft which is, in turn, coupled to the hub **154** of first fan **150**. Clutch assembly **160** may be filled with a fluid, typically an oil, to provide a fluid coupling between impeller **162** and turbine **166**. Stator **164** functions to align the direction of fluid flowing from the turbine to the impeller in a manner as is known in the art.

[0035] Clutch assembly **160** may be coupled to a hydraulic circuit system which increases or decreases the pressure of fluid in the clutch assembly **160** to increase or decrease, respectively, the amount of input power that is transmitted by the clutch assembly **160**. Clutch assembly **160** also regulates the resistance applied to the turbine during the spin-down process to facilitate a more rapid change between the two modes of the device. Examples of hydraulic circuits are described below with reference to Figs. **5**A and **5**B.

[0036] In the examples illustrated in Figs. **2**A-**2**C the first fan **150** is free to rotate passively (i.e., to windmill) with an adequate blade pitch angle under the influence of airflow from the second fan **190** after the first fan **150** is disengaged from the driveshaft **140**. In the examples illustrated in Figs. **3**A-**3**C and **4**A-**4**C a gearbox **170** is coupled to the first fan **150** to allow the first fan **150** to be driven in the same direction as the forward fan **190**.

[0037] Referring first to the example illustrated Figs. **3**A-**3**C, the output shaft of the clutch assembly **160** may be provided as an input to a gearbox **170**. Gearbox **170** may be implemented as a reversible gearbox which selectively reverses the direction or rotation of the input shaft. Thus, in the example illustrated in Figs. **3**A-**3**C the clutch assembly **160** may be activated to disengage the first fan **150** from the driveshaft **140**, and the first fan **150** may be allowed to spin down, assisted by the increased viscous resistance acting in the clutch assembly **160**. Subsequently the direction of the output of reversing gearbox **170** may be changed and the clutch assembly **160** may be activated to reengage the second fan with the driveshaft to drive the first fan **150** in the opposite direction while the blades are pitched in the adequate orientation for wind milling, such that the second fan **150** rotates in the same direction as the first fan **150**.

[0038] The remaining components illustrated in Figs. **3**A-**3**C are substantially the same as the corresponding components described with reference to Figs. **2**A-**2**C. In the interest of clarity, the description of these components will not be repeated.

[0039] Referring next to the example illustrated in Figs. **4**A-**4**C, the output shaft of the planetary gearbox **144** may be provided as an input to a gearbox **170**. Again, gearbox

170 may be implemented as a reversible gearbox which selectively reverses the direction or rotation of the input shaft. Thus, in the example illustrated in Figs. 4A-4C the clutch assembly **160** may be activated to disengage the first fan **150** from the driveshaft **140**, and the first fan **150** may be allowed to spin down and come to a full stop under the resistance induced in the clutch assembly **160**. Subsequently the direction of the output of reversing gearbox **170** may be changed and the clutch assembly **160** may be activated to reengage the second fan with the driveshaft to drive the first fan **150** in the opposite direction, such that the first fan **150** rotates in the same direction as the second fan **190**.

[0040] The remaining components illustrated in Figs. 4A-4C are substantially the same as the corresponding components described with reference to Figs. 2A-2C. In the interest of clarity, the description of these components will not be repeated.

[0041] Figs. 5A and 5B are examples of hydraulic circuits which may be used to regulate the clutch assembly **160** to selectively couple and decouple the first fan **150** from the first driveshaft **140**, or decelerate the first fan **150** according to aspects. Referring first to Fig. 5A, in one example a hydraulic circuit **500** comprises a hydraulic accumulator **510** which maintains pressure on a hydraulic fluid. A first supply line **512** couples the hydraulic accumulator **510** to the impeller **162** and to a one-way valve **514** which is switchable between an open position in which hydraulic fluid can flow through the valve **514** and a closed position in which hydraulic fluid cannot flow through the valve **514**.

[0042] A first variable flow rate valve **518** regulates the flow of hydraulic fluid between the impeller **162** and the turbine **166**. Pressure and flow rate sensors **516** monitor the pressure and flow rate of hydraulic fluid on both sides of first variable flow rate valve **518**.

[0043] Hydraulic fluid may exit the turbine **166** via line **520**. A second variable flow rate valve **518** regulates the flow of hydraulic fluid from the impeller **162**. Pressure and flow rate sensors **516** monitor the pressure and flow rate of hydraulic fluid exiting the impeller **162**.

[0044] Hydraulic circuit **500** further includes a heat exchanger **530** to exchange heat from the hydraulic fluid. A reservoir **540** is provided to store hydraulic fluid which overflows from the circuit **500**.

[0045] In operation, power from the power source (e.g., the engine **120**) is applied to the impeller **162** to rotate the impeller **162**. When the valve **514** is closed such that hydraulic fluid cannot flow through valve **514**, the hydraulic fluid flows to the impeller **162**, which drives the turbine **166**, such that the clutch assembly **160** engages the first fan **150** from the driveshaft **140**.

[0046] To disengage the first fan **150** from the engine the variable flow rate valve **518** is closed to reduce the flow of high pressure fluid from impeller **162** to turbine **166**, thereby reducing the amount of power transmitted to the fan **150**. When the amount of fluid passing through impeller **162** drops sufficiently power is no longer transmitted between impeller **162** and the turbine **166**, thereby disengaging the fan **150** from the driveshaft **140**.

[0047] To facilitate a faster spin down of the first fan **150**, the one-way valve **514** may be switched to the open position, thereby allowing pressurized fluid stored in accumulator **510** to flow into the turbine **166** in a direction which is reversed from nominal operation of the turbine **166**. Under the pressure of the reversed flow, the internal resistance induced on turbine **166** will increase, therefore facilitating a more rapid spin-down of the first fan **150**. The transient manner in which the reverse flow from accumulator **510** is applied can be managed via variable flow valve **518**. The reverse flow could continue for such length of time as to allow the accumulator **510** to be fully depressurized and fluid in the circuit attaining ambient pressure. The length of time to depressurize the accumulator **510** would depend on the maximum capacity of the accumulator **510**, maximum allowable pressure in accumulator **510** and line **512**, mass moment of inertia of the fan **150**, the speed of rotation of the fan **150** at the moment when valve **518** was closed, aerodynamic resistance of the fan **150**, and the efficiency of turbine **166**. The design of the hydraulic system is driven by the maximum size and allowable pressure of the accumulator **510** and the desired length of time for fan **150** to reach a full stop. A practical value for the spin-down time may vary from **15** to **80** seconds, depending on operational considerations pertaining to aircraft **100**.

[0048] Fig. 5B is a second example of a hydraulic circuit **500** to selectively couple and decouple the first fan **150** from the first driveshaft **140**, according to aspects. Many components of the circuit **500** depicted in Fig. 5B are the same as the analogous components depicted in Fig. 5A, and in the interest of clarity these components will not be described in detail. Referring first to Fig. 5B, the circuit **500** includes a **3**-way directional valve **550** coupled to lines **520** and **522** that is switchable between an open position in which hydraulic fluid can flow through lines **520** and **522**, a closed position in which hydraulic fluid cannot flow through lines **520** and **522**, and a switch position which lines **520** and **522** are switched at valve **550**.

[0049] In operation, when the valve **550** is in the open position hydraulic fluid flows under pressure from hydraulic accumulator **510** into clutch assembly **160** and to impeller **162** via line **512**. Impeller **162** drives the turbine **166**, such that the hydraulic drive **160** engages the first fan **150** from the driveshaft **140**.

[0050] When the valve **550** is in the closed position hydraulic fluid cannot flow between the impeller **162** and the turbine **166**, thereby disengaging the fan **150** from the driveshaft **140**.

[0051] When the valve **550** is in the switch position hydraulic fluid flows under pressure from the impeller **162** through line **520** into turbine **166** in a reverse direction, effectively acting as a brake on turbine **166**, to facilitate a more rapid spin-down of fan **150**.

[0052] A propulsion system as described herein may be mounted on an aircraft to provide propulsion to the aircraft. By way of example, referring to Fig. **6**, a propulsion system as described herein may be mounted on an aircraft **600** such as an airplane, spacecraft or the like.

[0053] Reference in the specification to "one embodiment" or "some embodiments" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least an implementation. The appearances of the phrase "in one embodiment" in various places in the specification may or may not be all referring to the same embodiment.

[0054] Although embodiments have been described in language specific to structural features and/or methodological acts, it is to be understood that claimed subject matter may not be limited to the specific features or acts described. Rather, the specific features and acts are disclosed as sample forms of implementing the claimed subject matter.

EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A drive assembly comprising:

a first driveshaft rotatable in a first direction about an axis;

a first fan coupled to the first driveshaft to rotate in the first direction;

a hydraulic clutch assembly configured to selectively disengage the first fan from the first driveshaft and to selectively apply resistance to cause rotation of the first fan to spin down; and

a gearbox coupled to the first driveshaft between an engine and the first fan wherein the gearbox is configured to change a direction of rotation of the first fan to a direction opposite to the first direction.

2. The drive assembly of claim **1**, further comprising:

a second driveshaft rotatable in a second direction opposite the first direction; and

a second fan coupled to the second driveshaft to rotate in the second direction.

3. The drive assembly of claim **2**, wherein the first driveshaft and the second driveshaft are coaxial.

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4. The drive assembly of claim **2** or **3**, wherein the first fan and the second fan are displaced by a distance that measures between about 0.02 and about 0.35 the distance of an overall front row fan diameter.

5. A propulsion system comprising:

an engine; and

a drive assembly coupled to the engine, the drive assembly comprising:

a first driveshaft rotatable in a first direction about an axis;

a first fan coupled to the first driveshaft to rotate in the first direction;

a hydraulic clutch assembly configured to selectively disengage the first fan from the first driveshaft and to selectively apply resistance to cause rotation of the first fan to spin down, wherein the clutch assembly comprises a fluid-coupling clutch control circuit; and

a gearbox coupled to the first driveshaft between an engine and the first fan, wherein the gearbox is configured to change a direction of rotation of the first fan to a direction opposite to the first direction.

6. The propulsion system of claim **5**, further comprising:

a second driveshaft rotatable in a second direction opposite the first direction; and

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a second fan coupled to the second driveshaft to rotate in the second direction.

7. The propulsion system of claim **6**, wherein the first driveshaft and the second driveshaft are coaxial.

8. The propulsion system of claim **6** or **7**, wherein the first fan and the second fan are displaced along thc axis by a distance that measures between about 0.02 and about 0.35 the distance of the diameter of the second fan.

9. The system of any one of claims **5** to **8**, wherein the fluid-coupling clutch control circuit is operably configured to cause fluid flow in the circuit to be reversed to during spin down of the first fan increase the applied resistance.

10. The propulsion system of any one of claims **5** to **9** operably configured for use in an aircraft.

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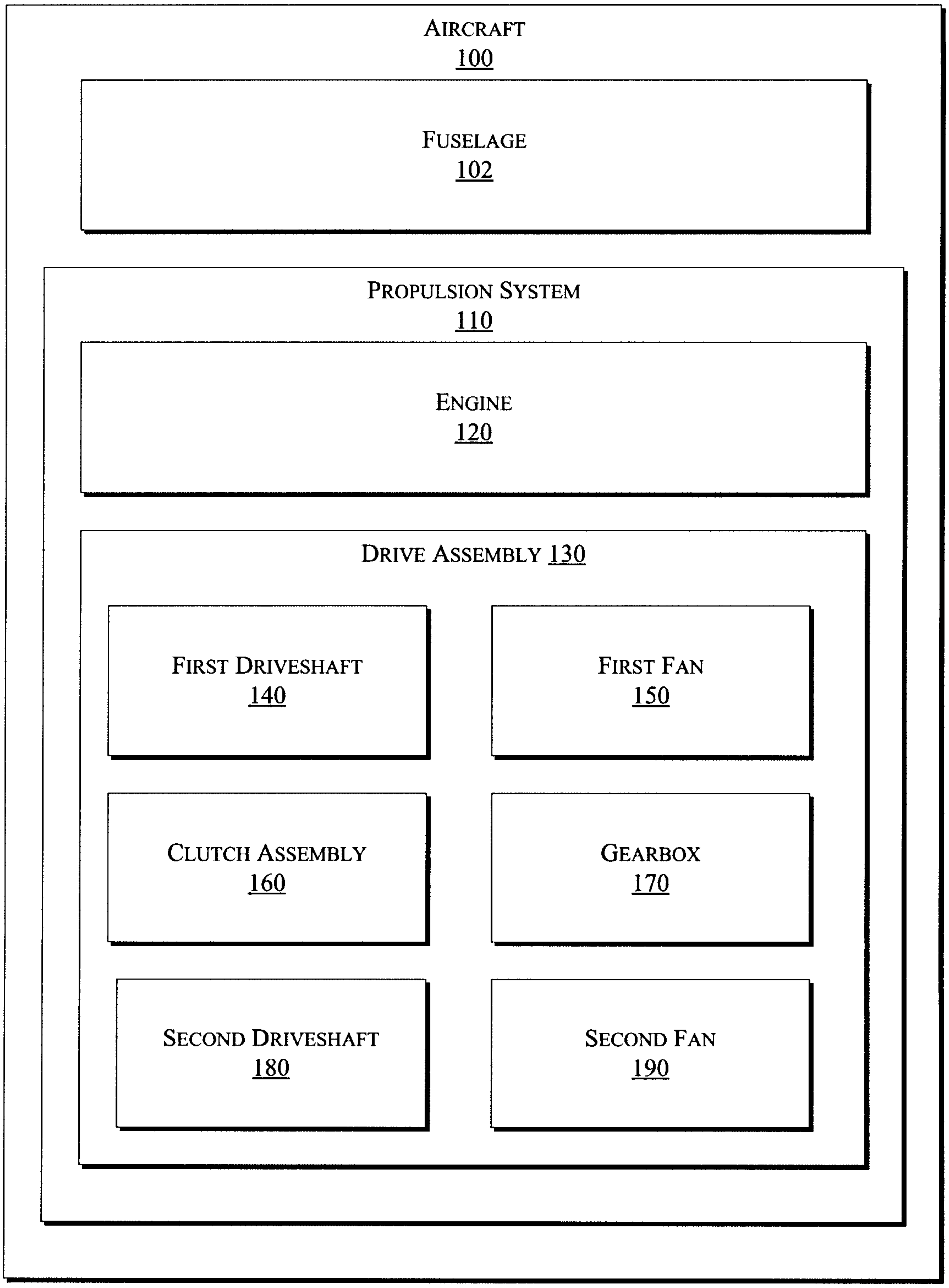
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CLUTCH ASSEMBLY
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GEARBOX
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SECOND DRIVESHAFT
180
SECOND FAN
190

FIG. 1

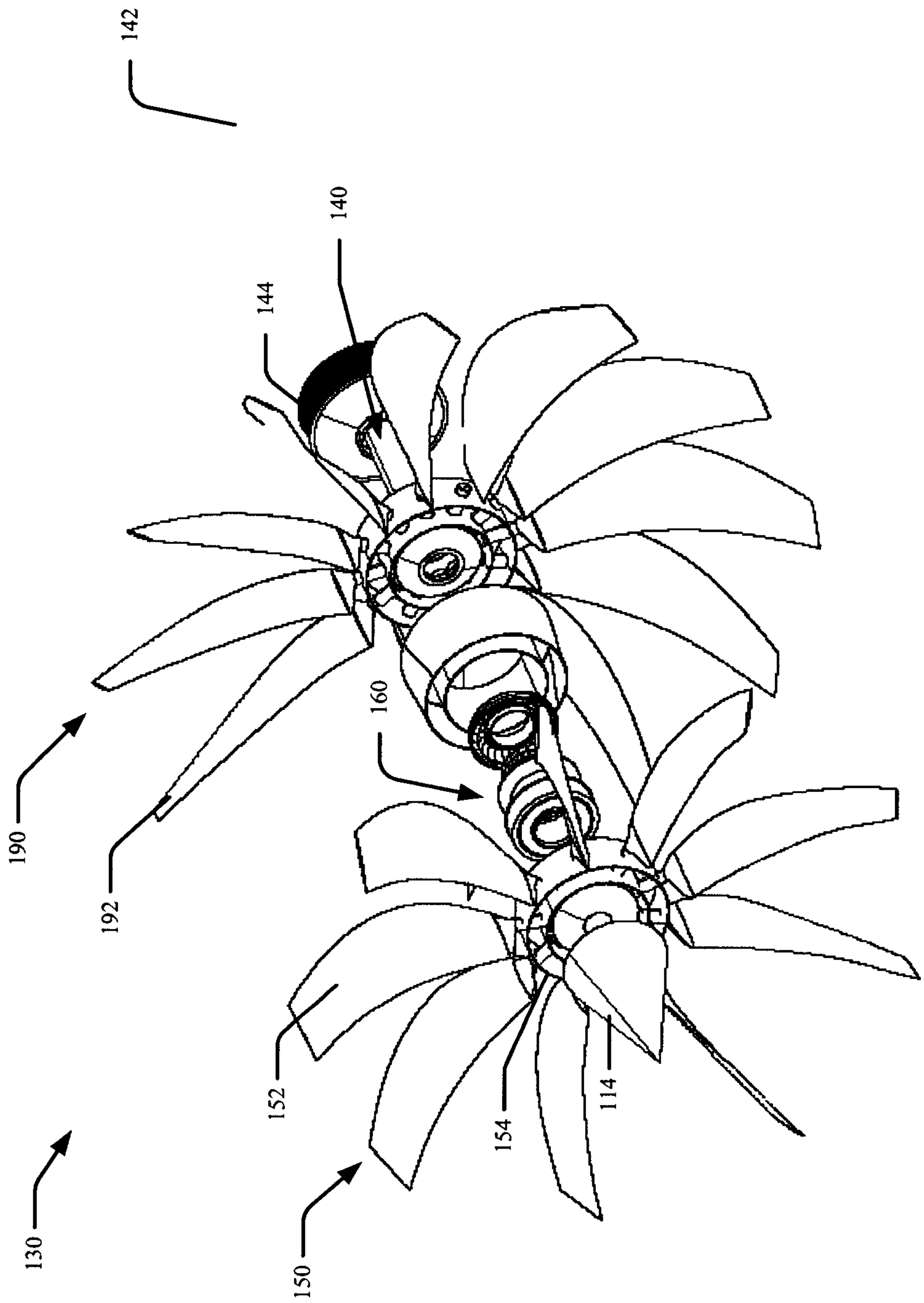


FIG. 2A

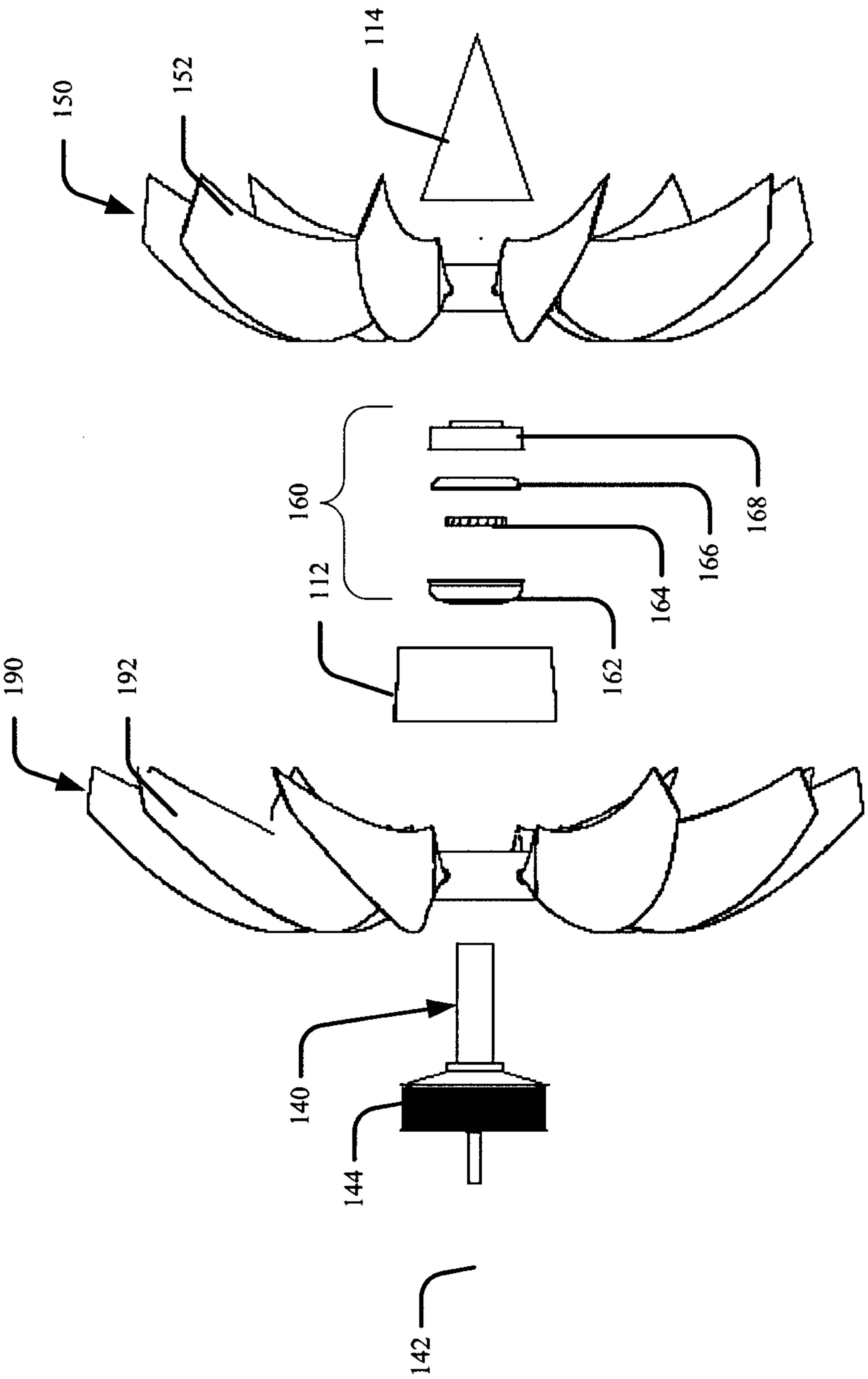


FIG. 2B

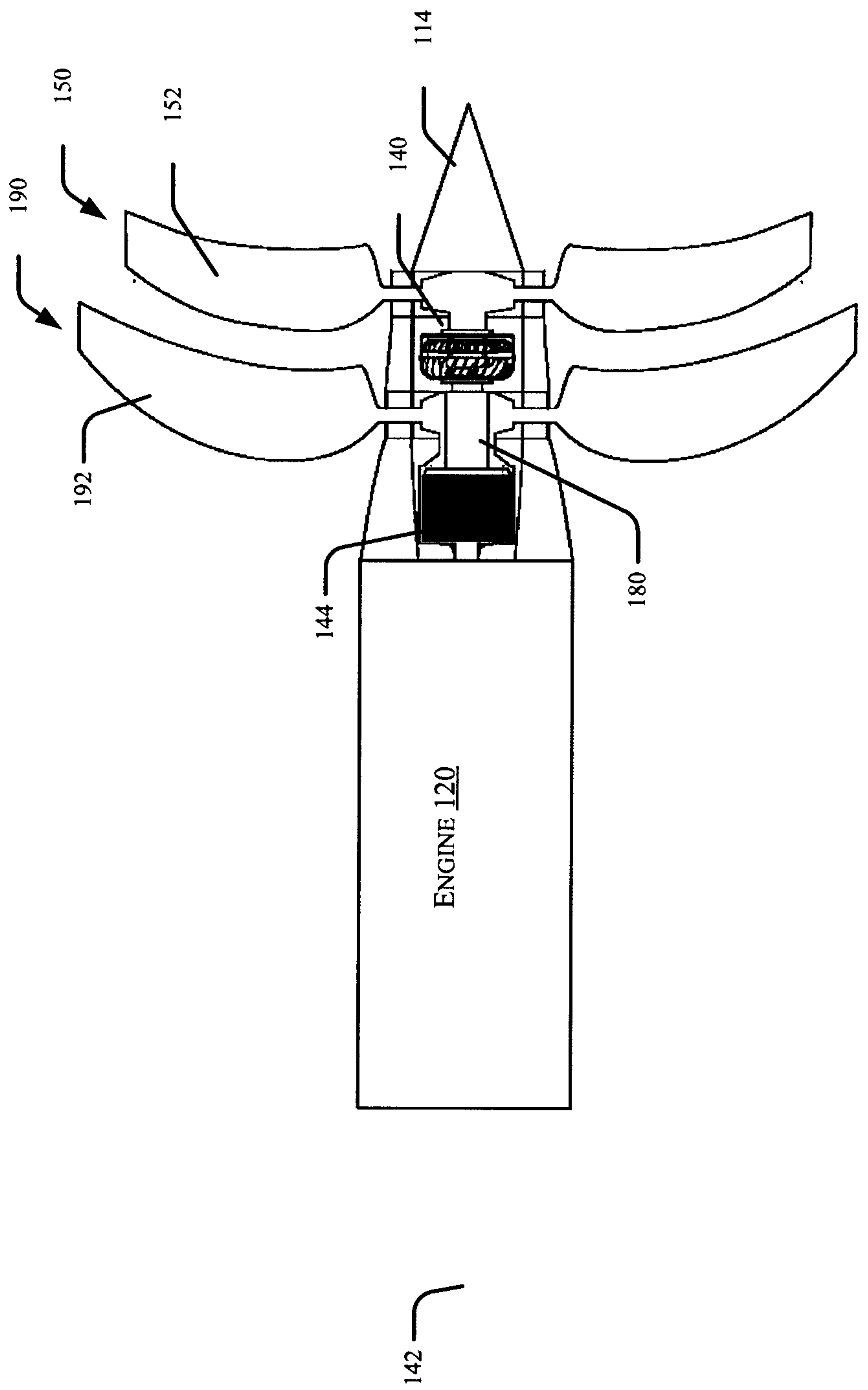


FIG. 2C

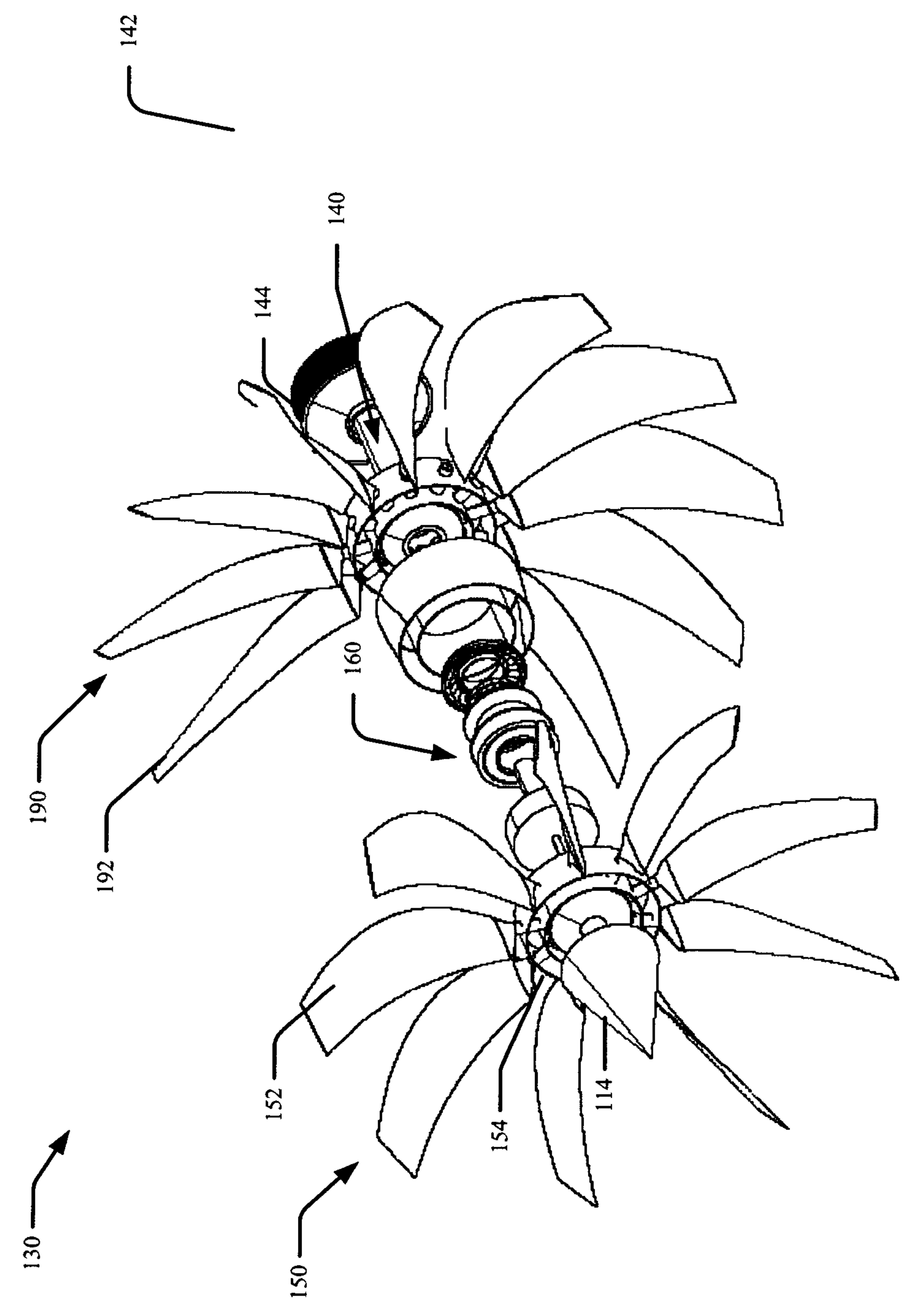


FIG. 3A

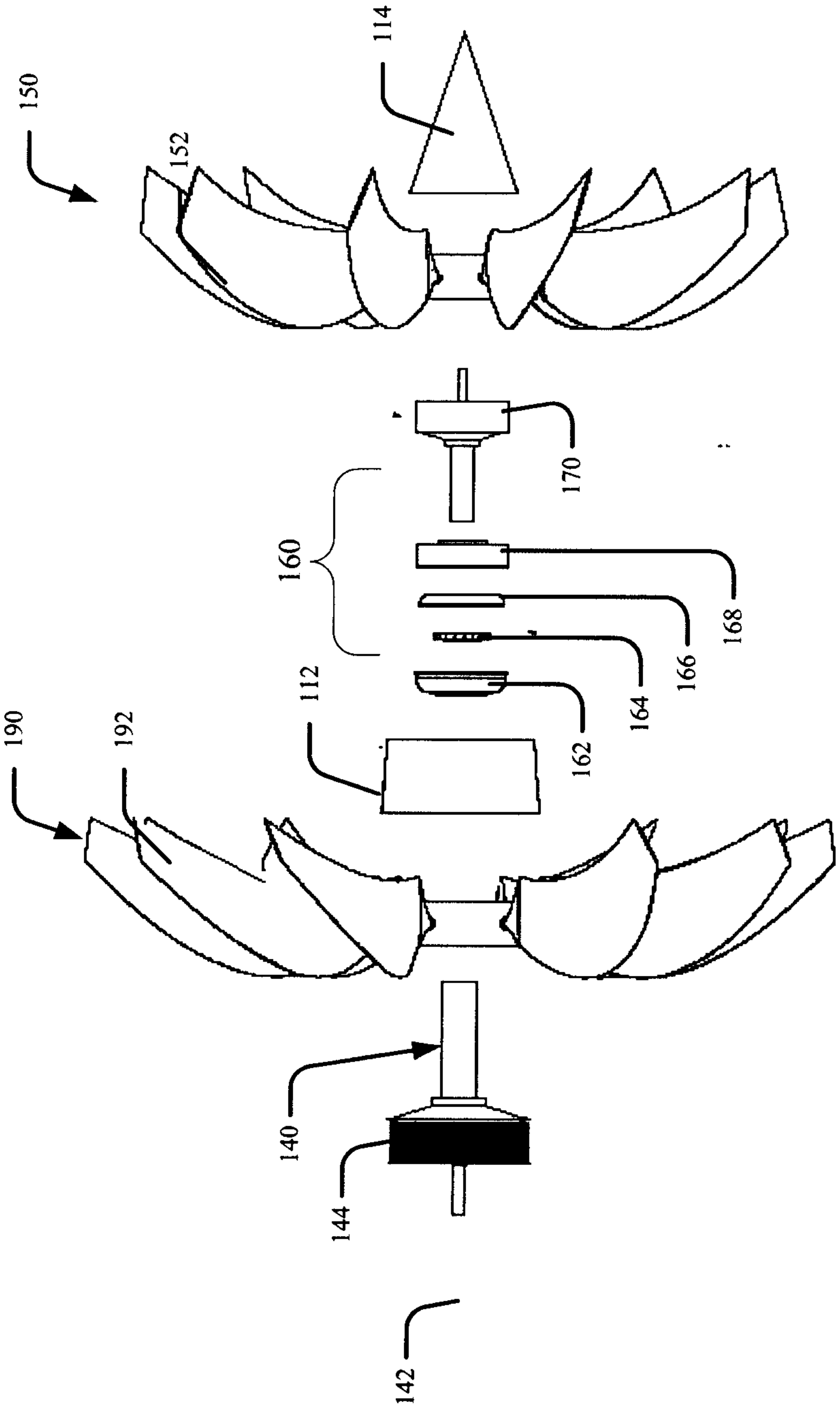


FIG. 3B

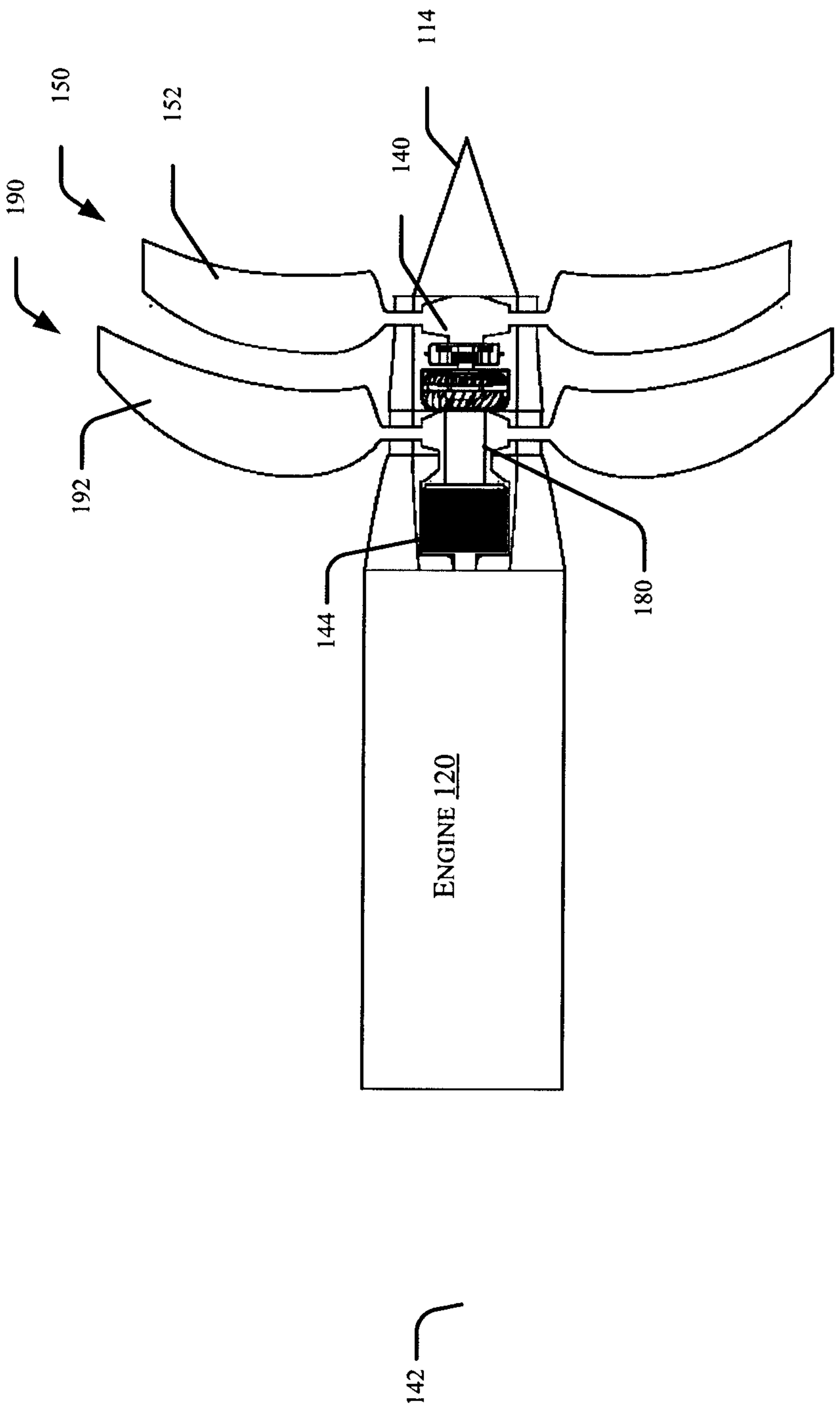


FIG. 3C

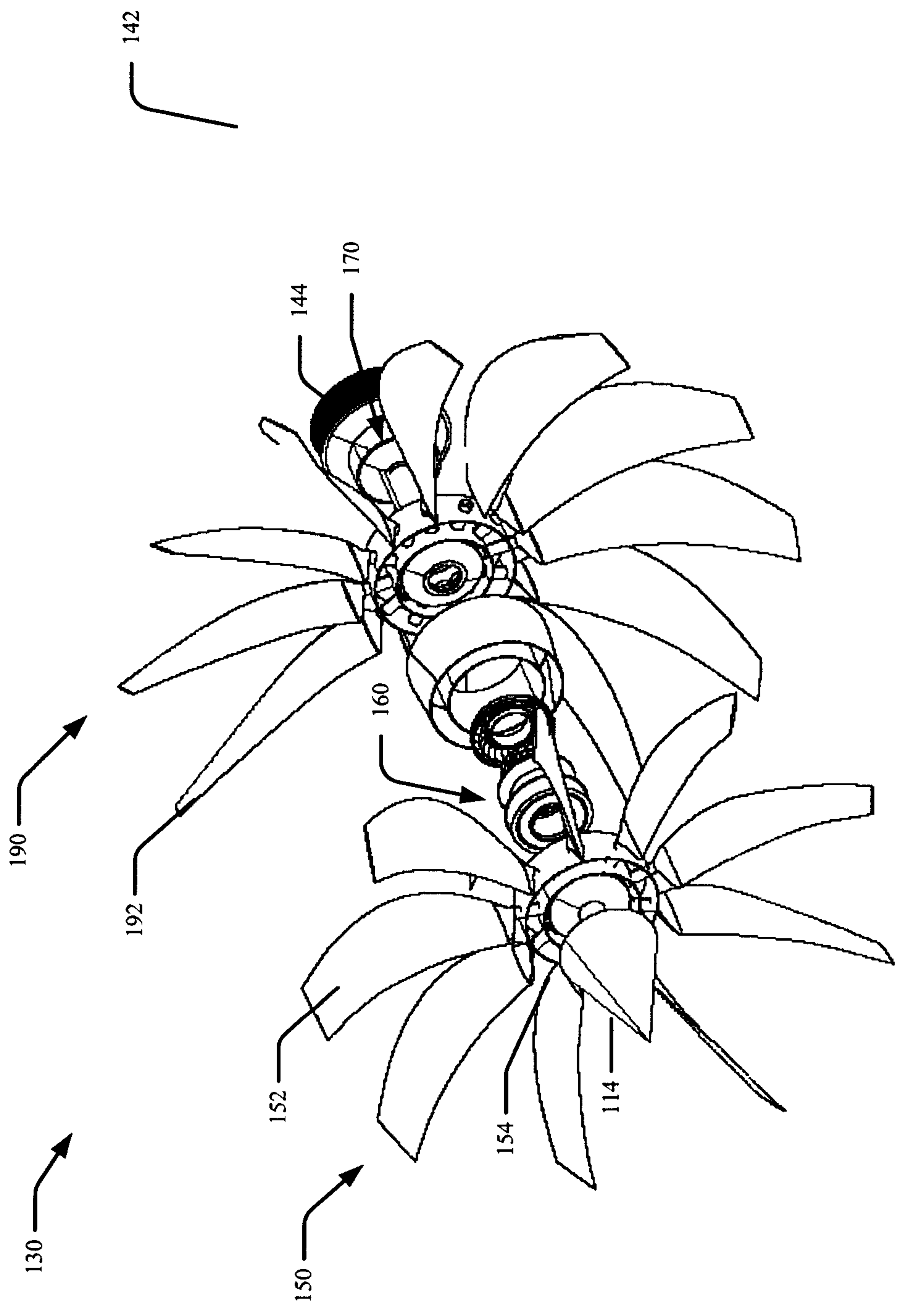


FIG. 4A

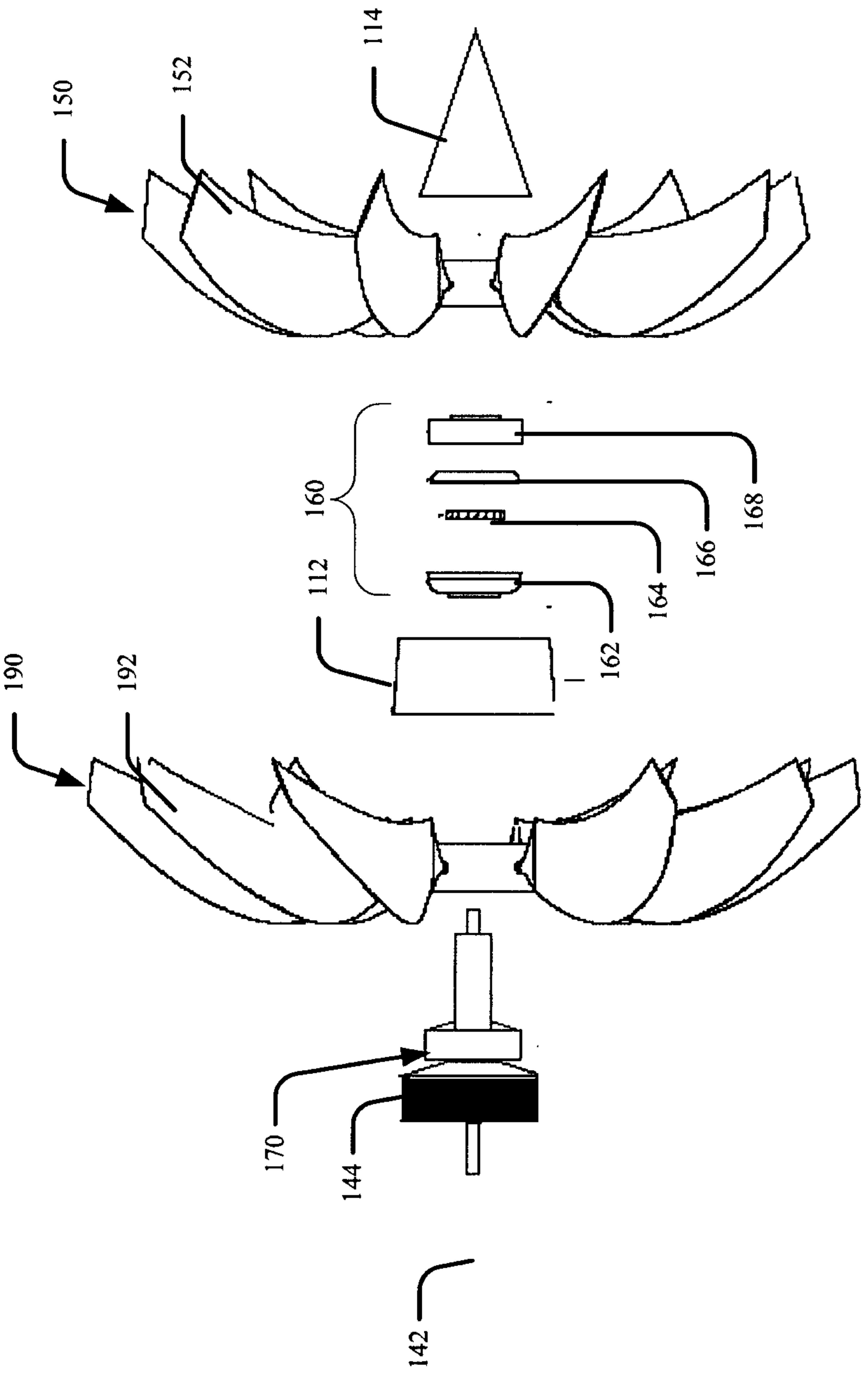


FIG. 4B

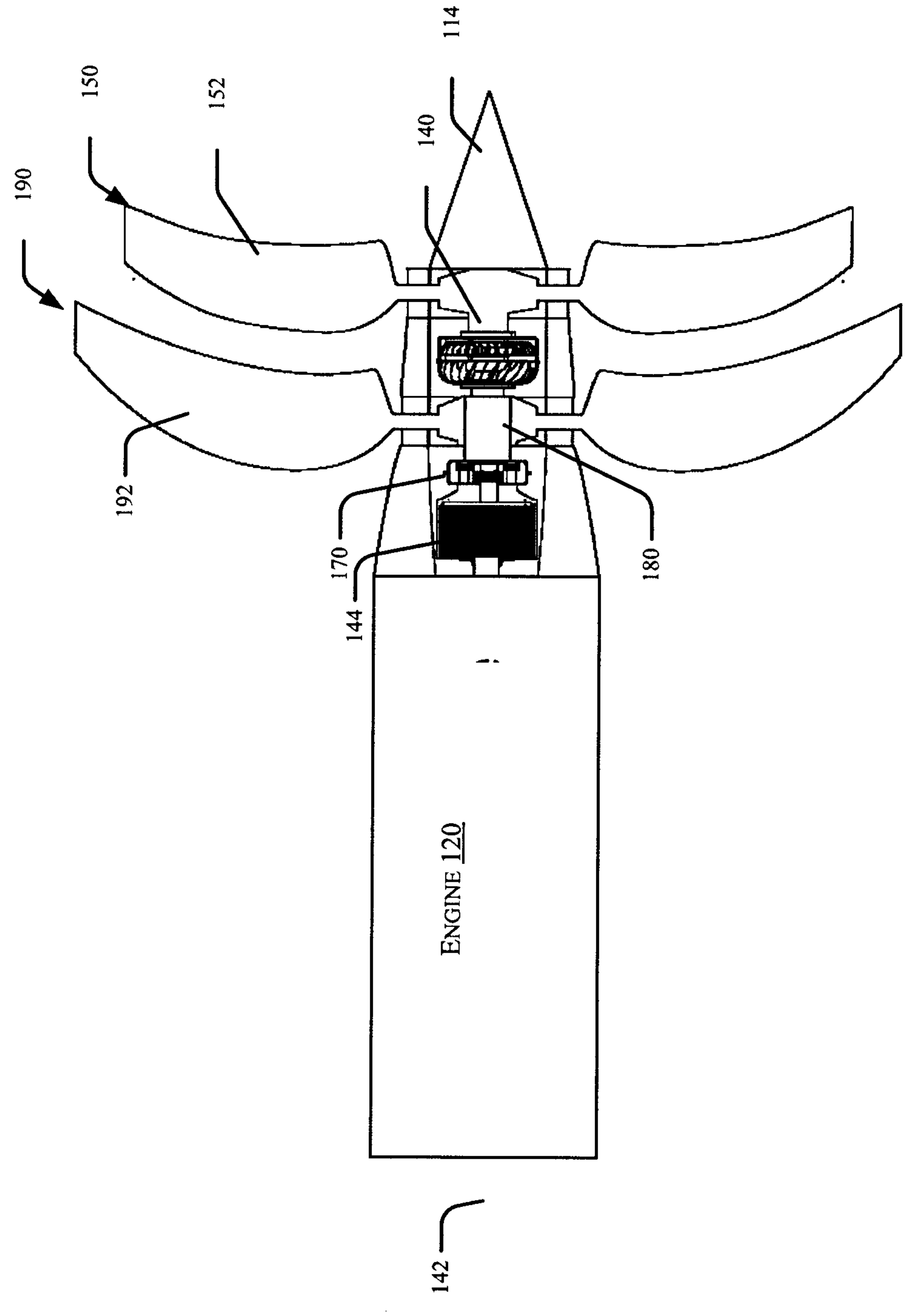


FIG. 4C

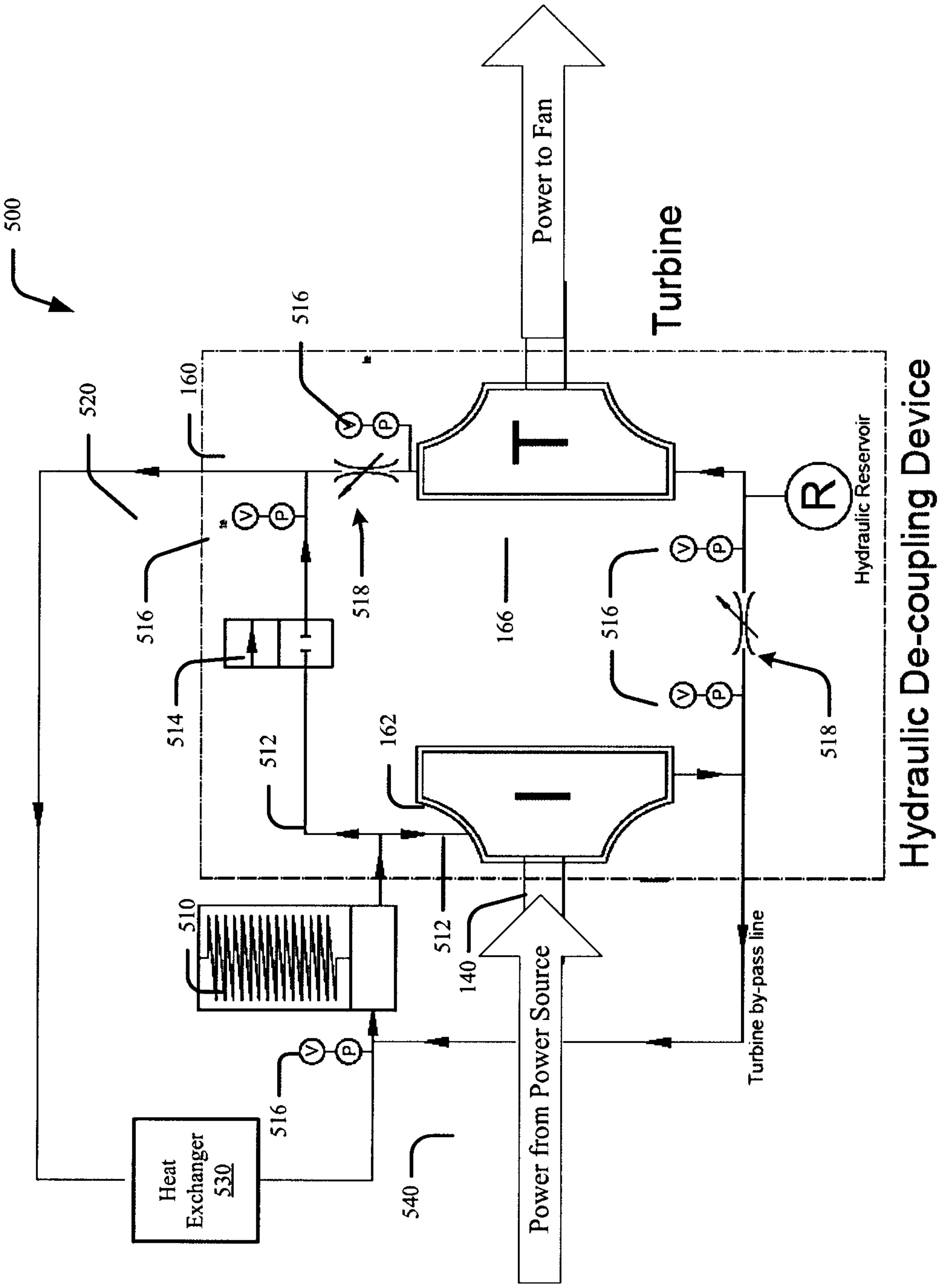

500
Power to Fan
Turbine
516
520
160
T
518
166
R
Hydraulic Reservoir
514
512
162
I
510
512
140
Power from Power Source
Turbine by-pass line
Heat Exchanger 530
540
Hydraulic De-coupling Device

FIG. 5A

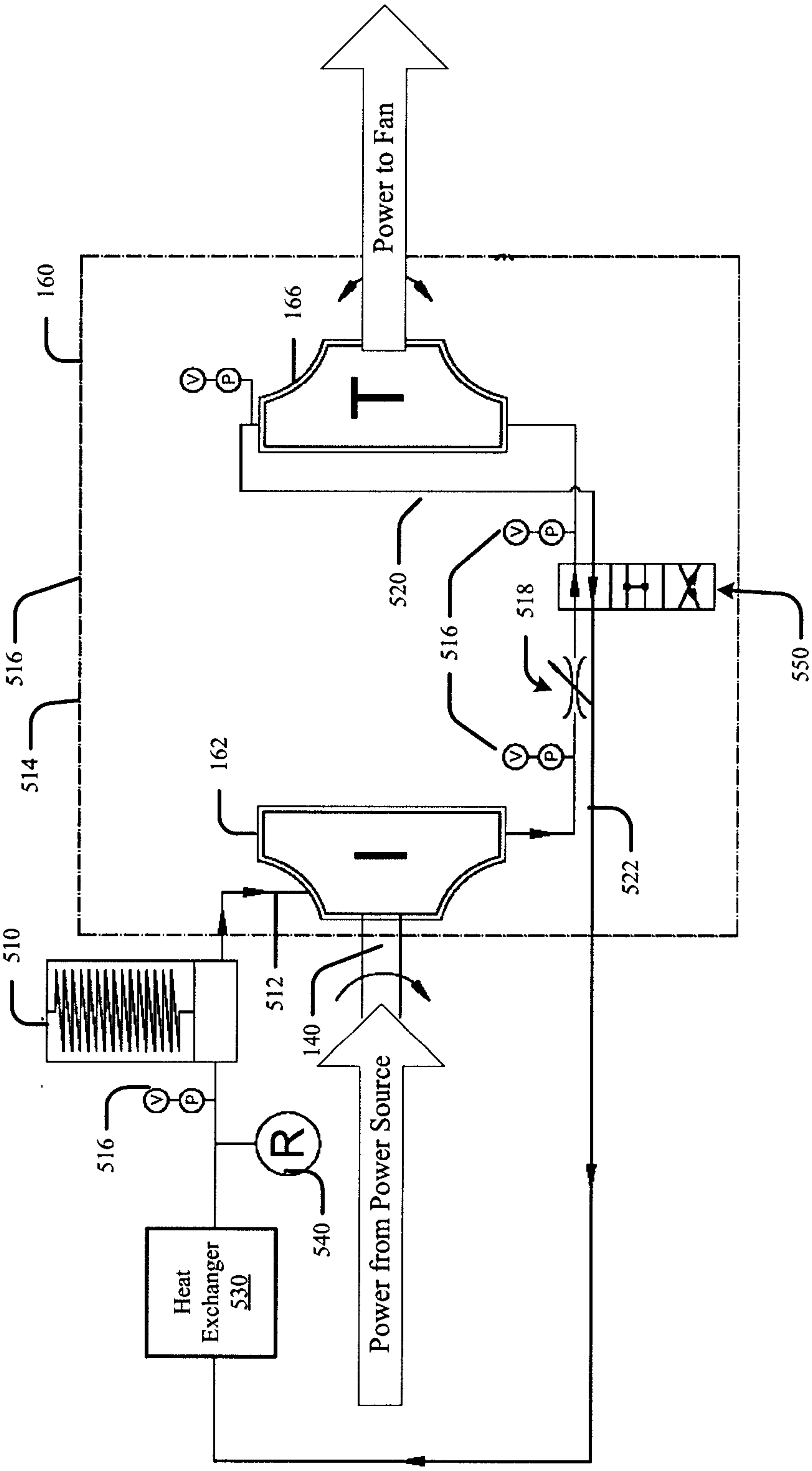

Power to Fan
160
166
T
520
516
518
550
516
514
162
I
522
510
512
140
Power from Power Source
516
540
R
Heat Exchanger 530
V
P

FIG. 5B

600

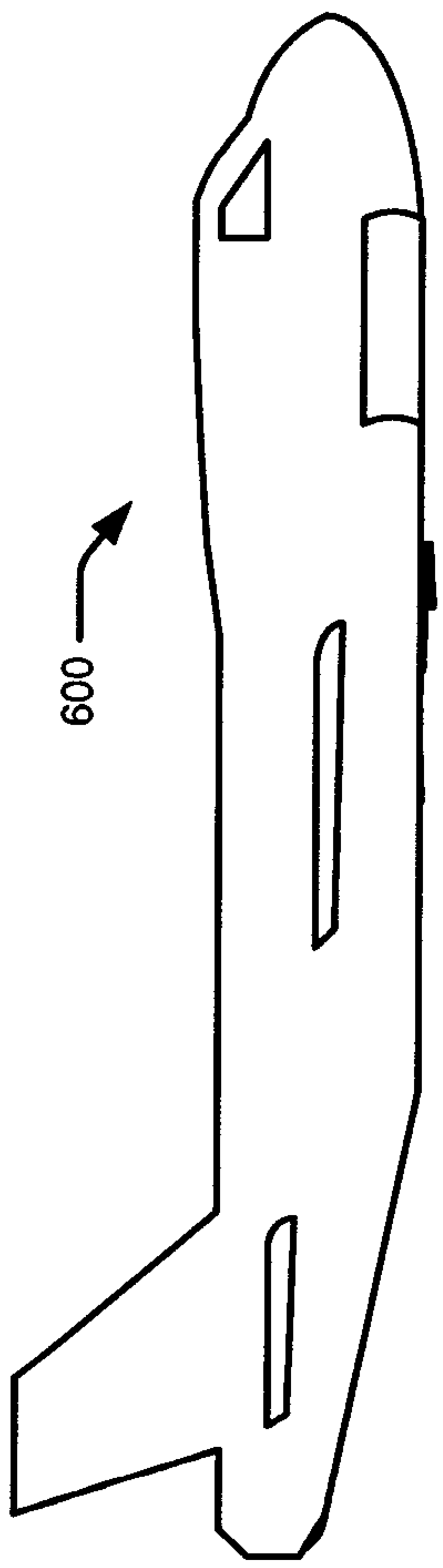
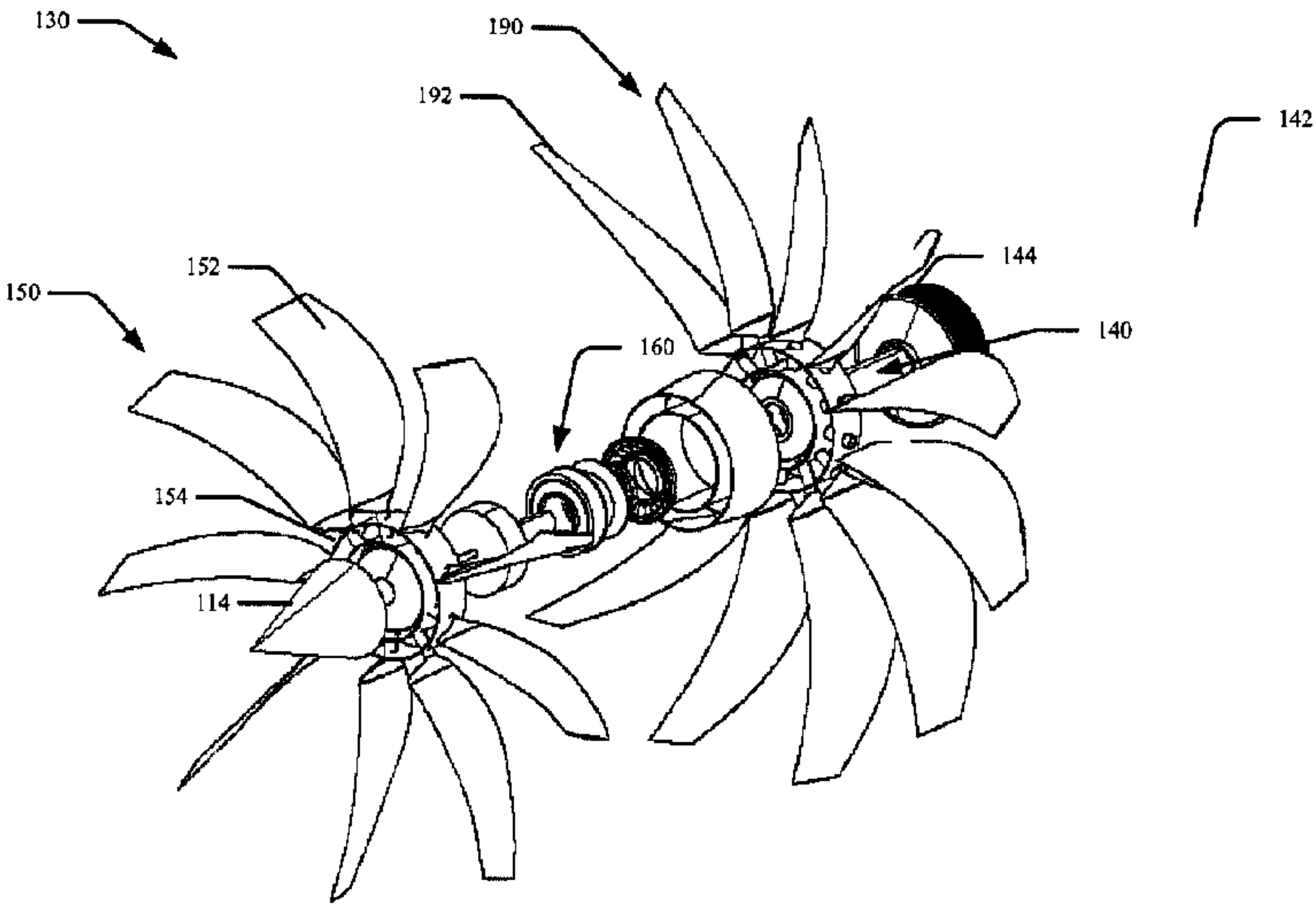


FIG. 6



130
190
192
142
144
140
160
152
150
154
114