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Miller et al.

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(54) **VACUUM PUMP**

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F04C 18/344 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***F04C 27/003*** (2013.01); ***F04C 23/001*** (2013.01); ***F04C 25/02*** (2013.01); ***F04C 27/002*** (2013.01); *F04C 18/3441* (2013.01)

(58) **Field of Classification Search**

CPC F04C 27/003; F04C 23/001; F04C 25/02; F04C 27/002; F04C 2/344; F04C 18/344; F04C 18/3441; F04C 27/001

See application file for complete search history.

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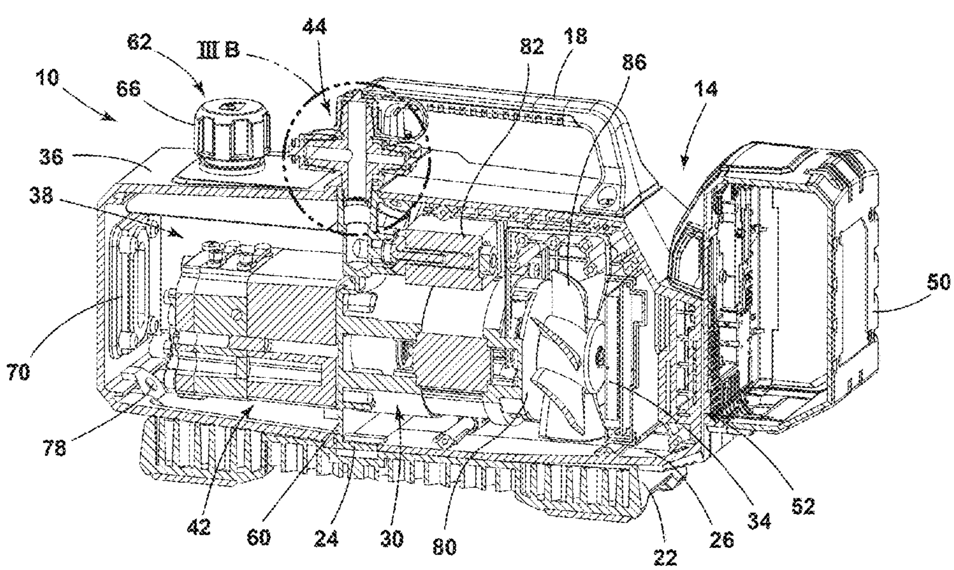
(57) **ABSTRACT**

A vacuum pump, which is connectable to an external system and configured to evacuate material from the external system, includes a main housing defining a motor housing, a pump housing, and a partition wall that separates the motor housing and the pump housing. The pump housing is sealed relative to the motor housing to form a compression chamber that holds a lubrication fluid. The vacuum pump further includes a motor assembly that is positioned within the motor housing and a pump assembly that is positioned within the compression chamber. The pump assembly is driven by the motor assembly and is in fluid communication with the compression chamber. The pump assembly includes a pump chamber, a rotor having vanes that is driven within the pump chamber, and a seal that is in sliding contact with the rotor. The seal is moveable relative to the rotor.

5 Claims, 8 Drawing Sheets



(51) **Int. Cl.**
F04C 23/00 (2006.01)
F04C 25/02 (2006.01)

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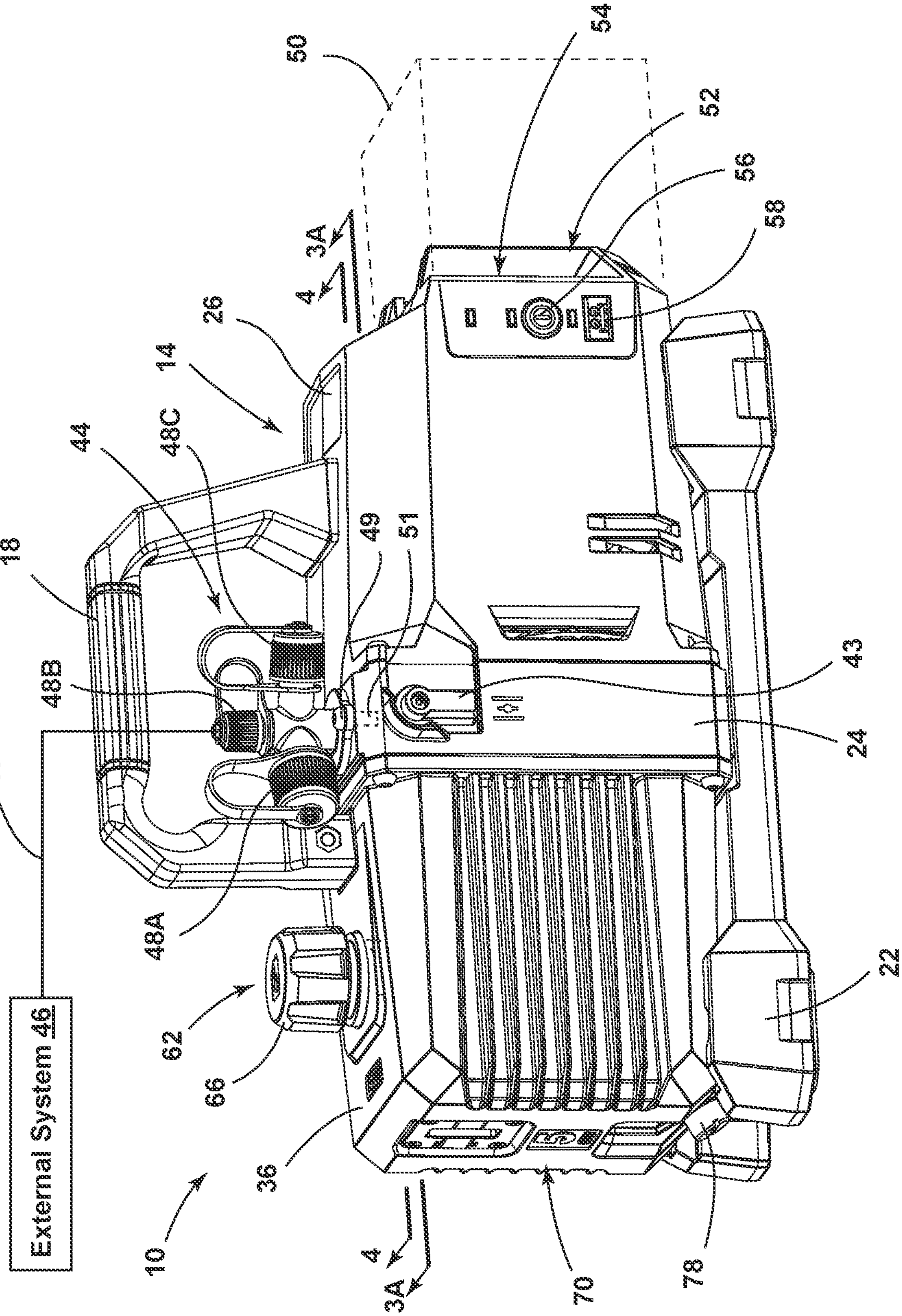
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10
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48A
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FIG. 1

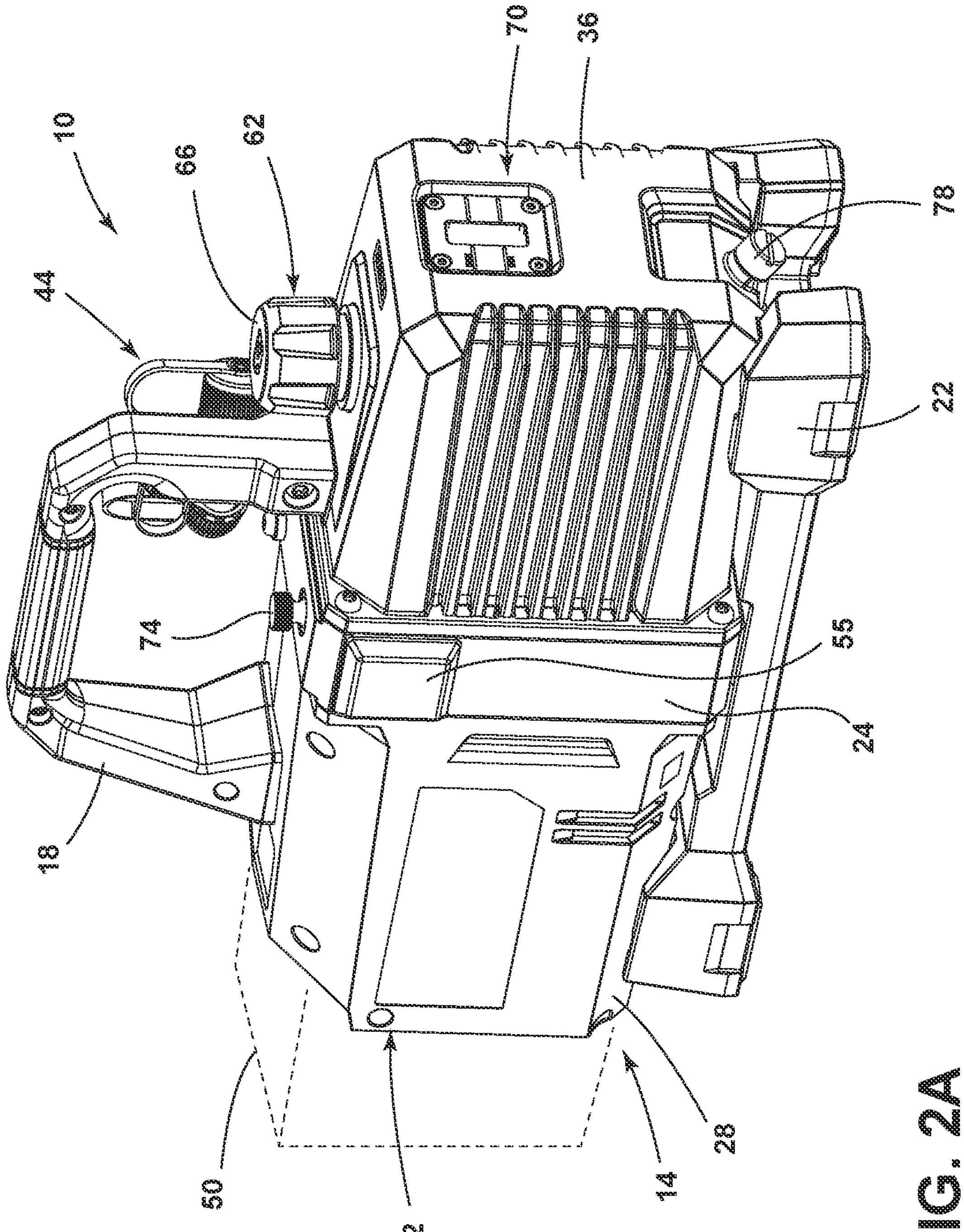


FIG. 2A

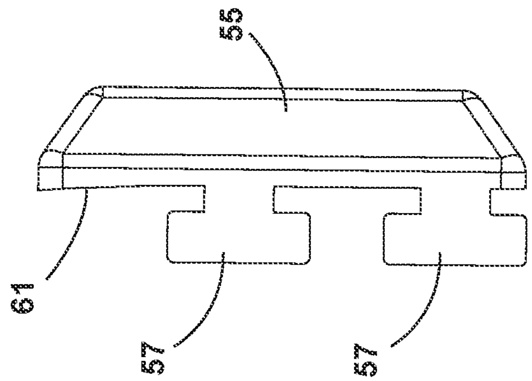


FIG. 2C

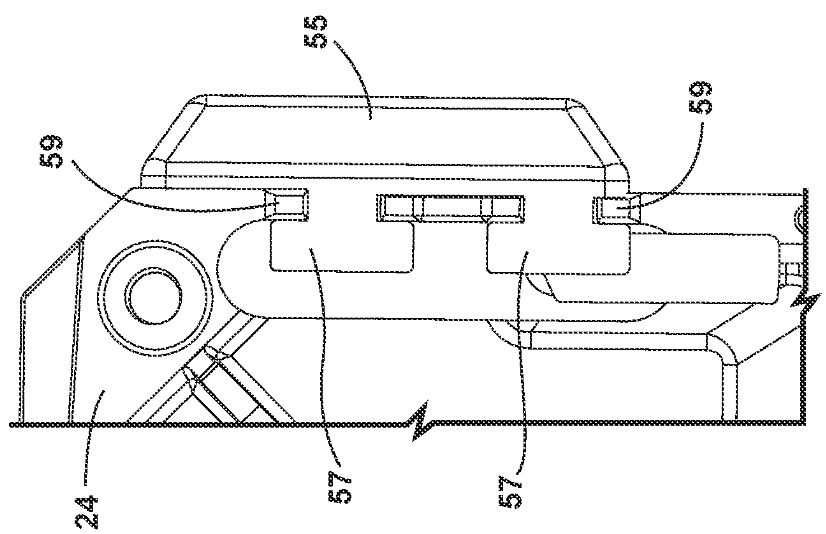


FIG. 2B

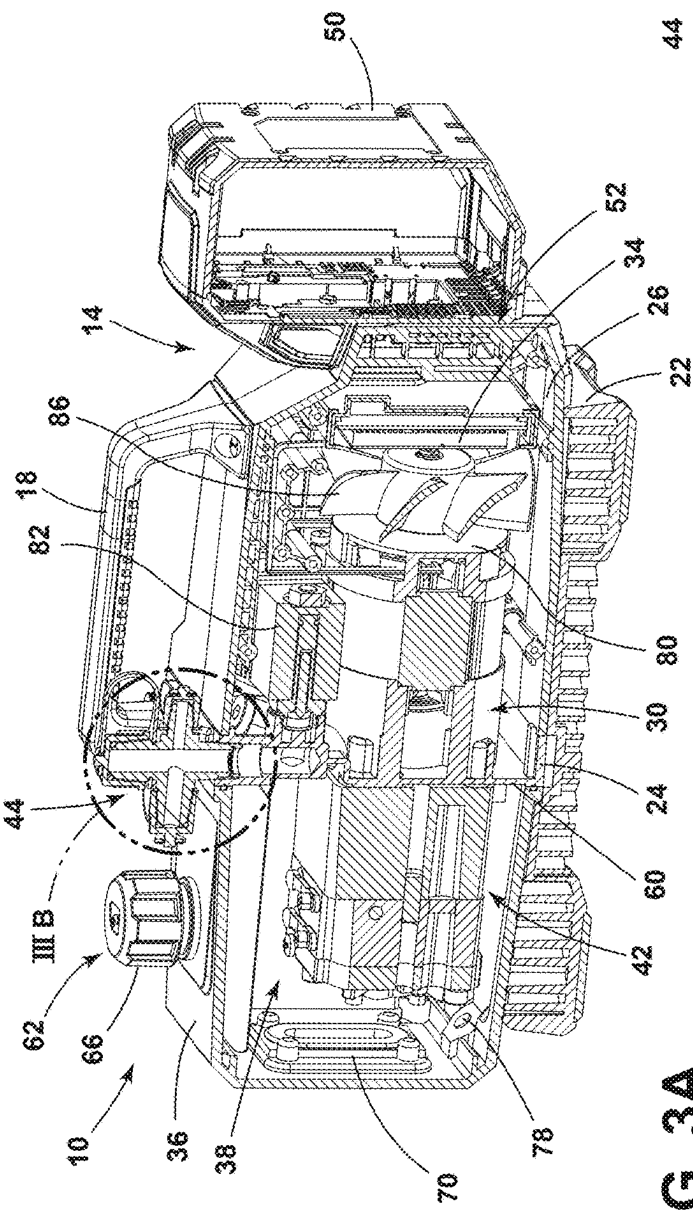


FIG. 3A

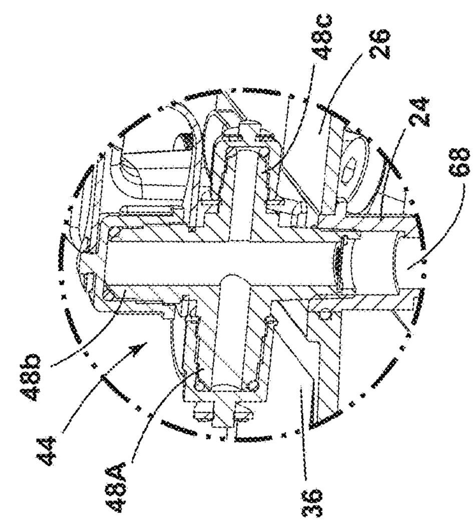


FIG. 3B

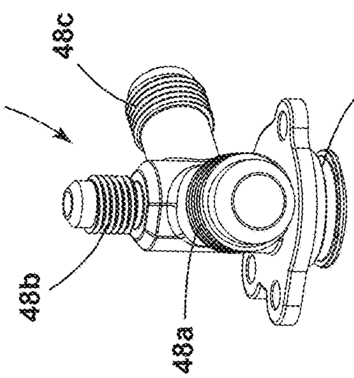
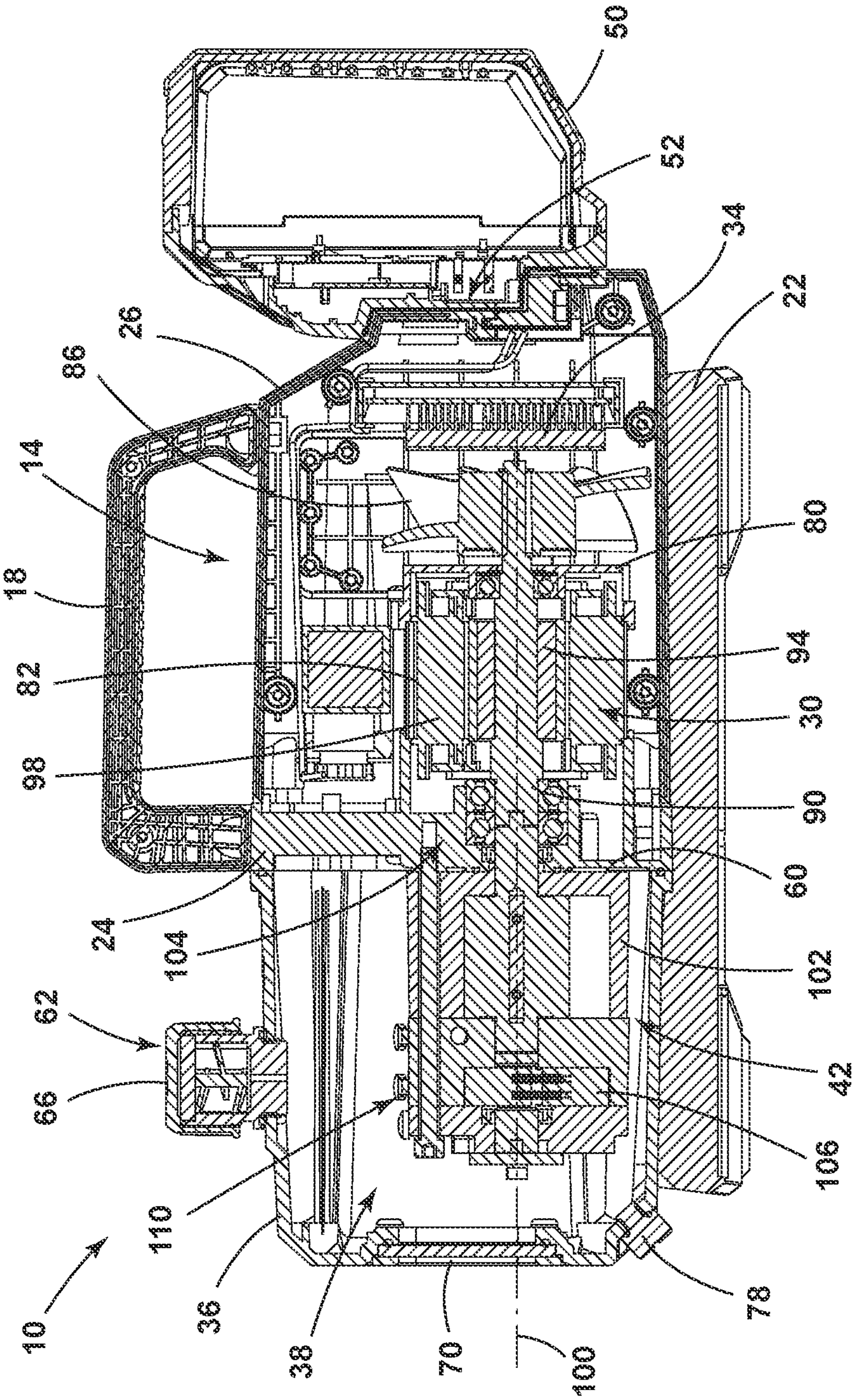


FIG. 3C



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36
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42
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106
110

FIG. 4

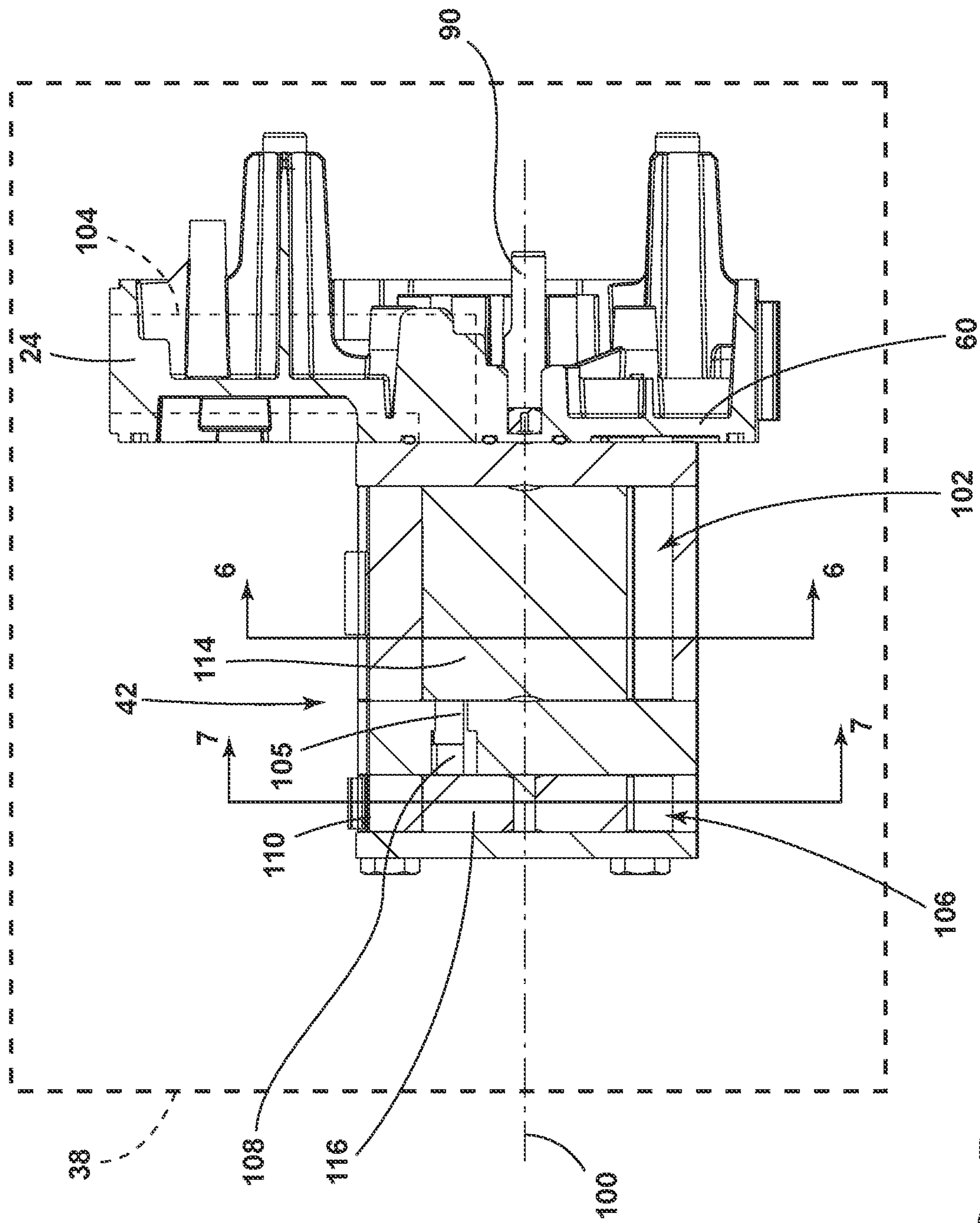
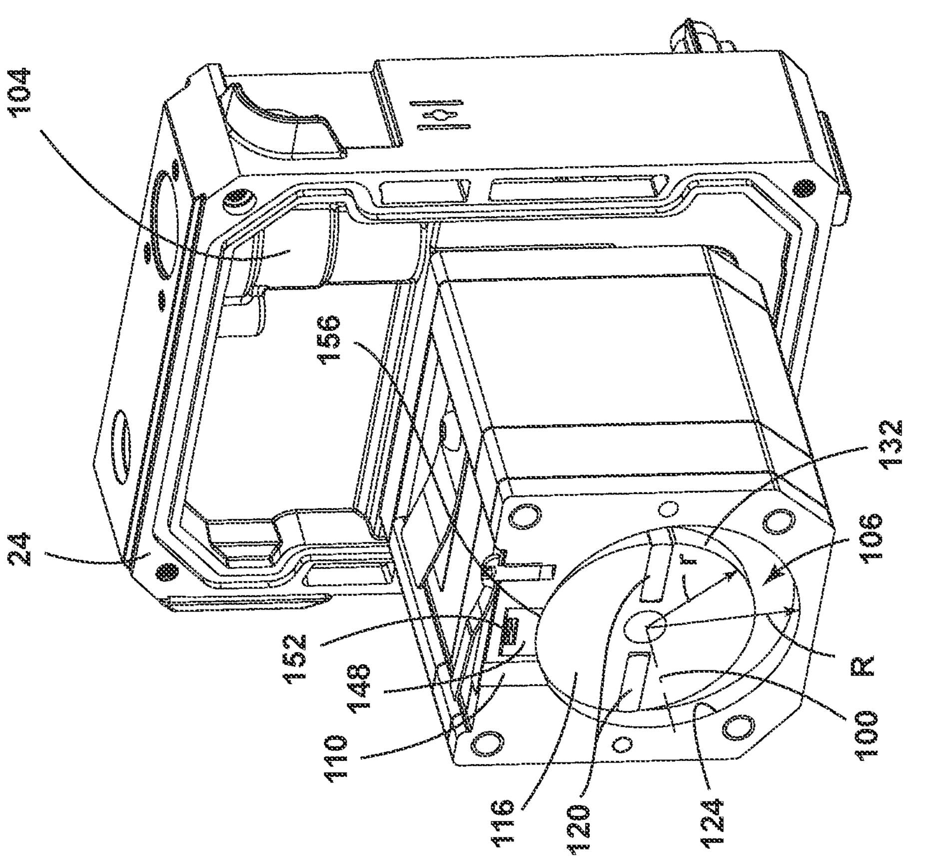


FIG. 5


104
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156
152
148
110
116
120
124
100
R
106
132
r

FIG. 7

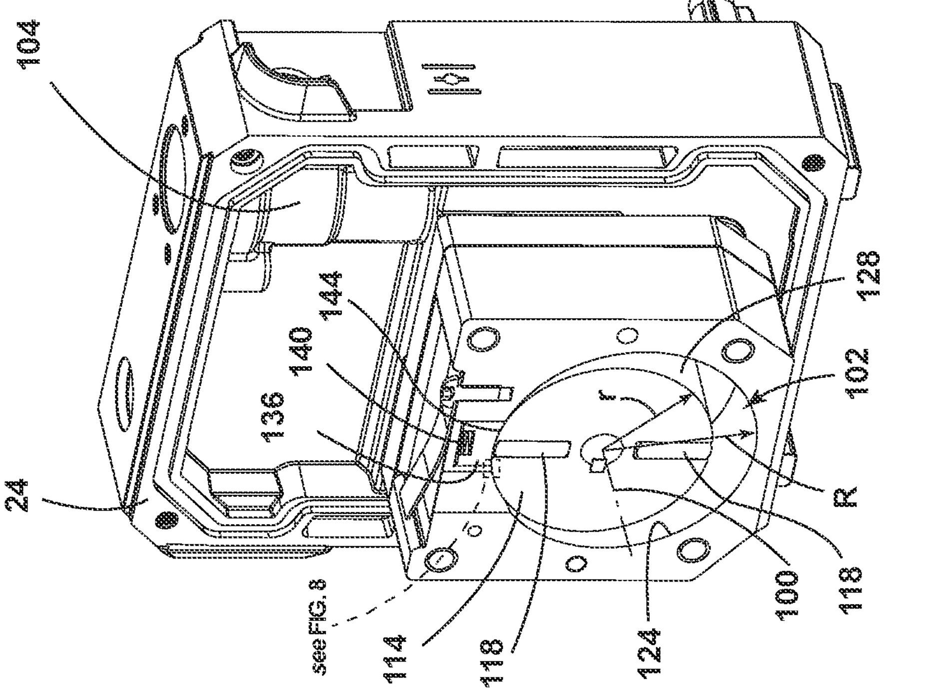
104
24
144
140
136
see FIG. 8
114
118
124
100
118
R
102
128
r

FIG. 6

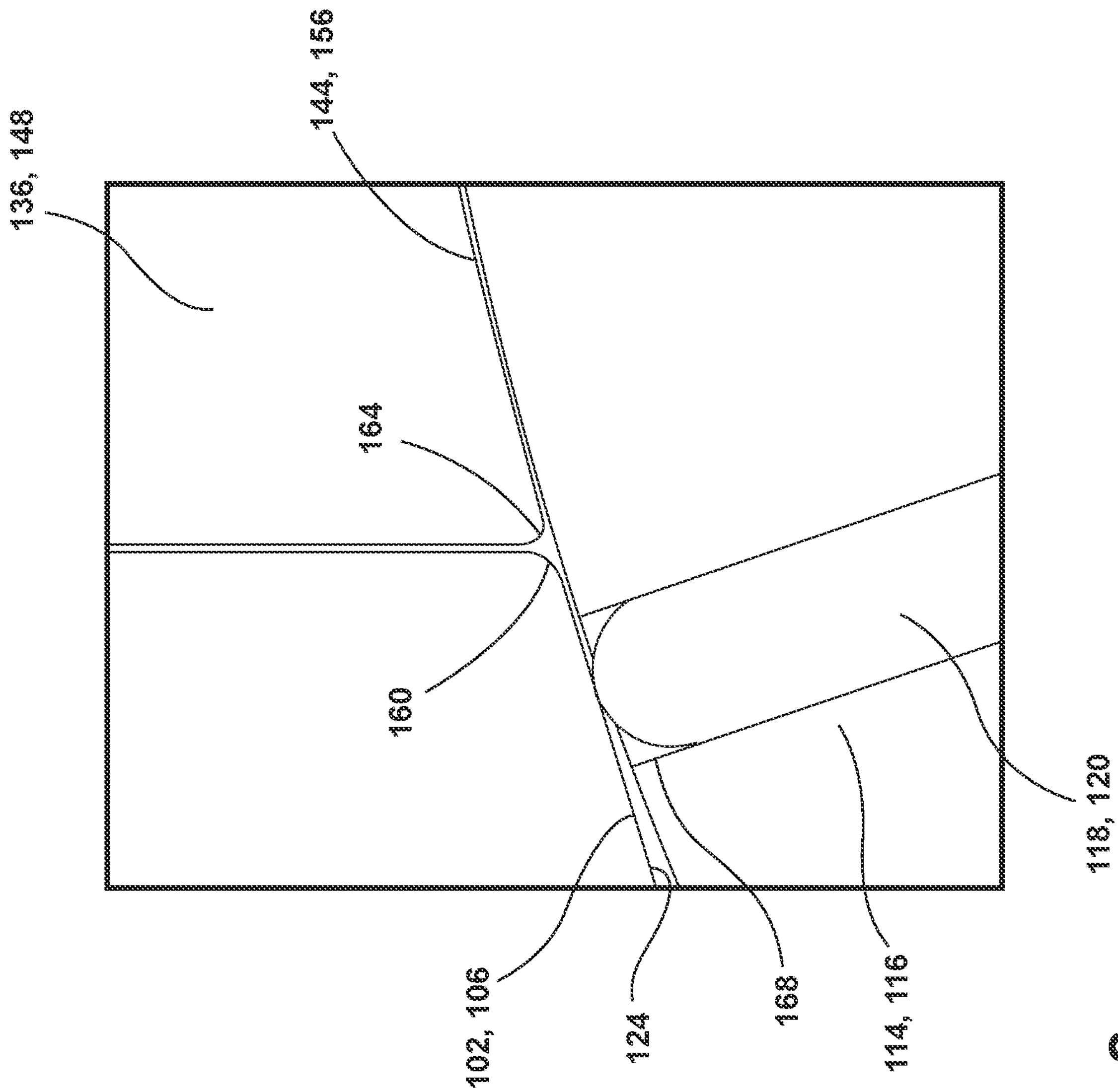

FIG. 8

VACUUM PUMP

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application No. 63/476,240, filed on Dec. 20, 2022, and U.S. Provisional Patent Application No. 63/327,599, filed on Apr. 5, 2022, the entire contents of both of which are incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates to a pump, and more particularly to a vacuum pump.

BACKGROUND OF THE INVENTION

Vacuum pumps may be used to remove or evacuate material such as unwanted air, gas, and non-condensables (e.g., water vapor), from an external system (e.g., an air conditioning system, a refrigeration system, etc.). Vacuum pumps may be used to evacuate the external system before the system is charged with refrigerant or when the existing system is undergoing repair (e.g., the refrigerant is already recovered). The vacuum pump may be connected to high- and low-pressure sides of the external system via hoses and a manifold. During operation, the vacuum pump creates a low-pressure zone that draws the unwanted materials such as air and non-condensables out of the external system, which has a high pressure, and into the vacuum pump.

SUMMARY OF THE INVENTION

The present disclosure provides, in one aspect, a vacuum pump that is connectable to an external system and configured to evacuate material from the external system. The vacuum pump includes a main housing defining a motor housing, a pump housing, and a partition wall that separates the motor housing and the pump housing. The pump housing is sealed relative to the motor housing to form a compression chamber that holds a lubrication fluid. The vacuum pump further includes a motor assembly that is positioned within the motor housing of the main housing, a battery that is coupled to the main housing and configured to supply electrical current to the motor assembly, and a pump assembly that is positioned within the compression chamber. The pump assembly is driven by the motor assembly and is in fluid communication with the compression chamber. The pump assembly includes a pump chamber, a rotor having vanes that is driven within the pump chamber, and a seal that is in sliding contact with the rotor. The seal is moveable relative to the rotor.

The present disclosure provides, in another aspect, a vacuum pump that is connectable to an external system and configured to evacuate material from the external system. The vacuum pump includes a motor assembly that is positioned within a motor housing, a battery that is coupled to the motor housing and configured to supply electrical current to the motor assembly, and a pump assembly that is positioned within a pump housing. The pump housing is sealed relative to the motor housing to form a compression chamber storing a lubrication fluid. The pump assembly is driven by the motor assembly and is in fluid communication with the compression chamber. The vacuum pump further includes a trestle that separates the motor housing and the pump housing, and an inlet manifold coupled to the trestle

that fluidly connects the pump assembly to the external system. The vacuum pump further includes a bumper composed of an elastomeric material and coupled to the trestle to protect the vacuum pump from damage when inadvertently dropped.

Other features and aspects of the invention will become apparent by consideration of the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a left perspective view of a vacuum pump according to an embodiment of the invention.

FIG. **2**A is a right perspective view of the vacuum pump of FIG. **1**.

FIG. **2**B is a cross-sectional view along line FIG. **2**B-**2**B of FIG. **2**A, illustrating a bumper attached to a housing of the vacuum pump.

FIG. **2**C is a side view of the bumper of FIG. **2**B removed from the housing of the vacuum pump.

FIG. **3**A is a cross-sectional perspective view of the vacuum pump along line **3**A-**3**A of FIG. **1**.

FIG. **3**B is an enlarged view of an inlet manifold of the vacuum pump.

FIG. **3**C is a perspective view of the inlet manifold of FIG. **3**B.

FIG. **4** is a cross-sectional plan view of the vacuum pump along line **4**-**4** of FIG. **1**.

FIG. **5** is an enlarged cross-sectional view of FIG. **4**, illustrating a pump assembly that is disposed within the vacuum pump.

FIG. **6** is a cross-sectional perspective view of the pump assembly along line **6**-**6** of FIG. **5**, illustrating a first spring-loaded seal disposed adjacent a first pump chamber.

FIG. **7** is a cross-sectional perspective view of the pump assembly along line **7**-**7** of FIG. **5**, illustrating a second spring-loaded seal disposed adjacent a second pump chamber.

FIG. **8** is an enlarged view of the interface between the seal and a rotor of the pump assembly.

Before any embodiments of the present subject matter are explained in detail, it is to be understood that the present subject matter is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The present subject matter is capable of other embodiments and of being practiced or of being carried out in various ways.

DETAILED DESCRIPTION

FIGS. **1**-**4** illustrate a vacuum pump **10** including a housing **14**, a handle **18** coupled to an upper portion of the housing **14**, and a base **22** coupled to a lower portion of the housing **14** to support the vacuum pump **10** relative to a support surface. The housing **14** includes (FIG. **3**A) a trestle **24**, a motor housing **26** that houses, protects, and/or conceals a motor assembly **30**, an electronic control unit **34**, and other electronic components. The housing **14** further includes a pump housing **36** that houses a pump assembly **42** within a compression chamber **38**. The trestle **24** is disposed between the motor housing **26** and the pump housing **36**.

With continued reference to FIGS. **1**-**4**, an inlet manifold **44** is positioned on an upper portion of the trestle **24** and is in communication with the pump assembly **42** via a valve switch **43** (FIG. **1**). The inlet manifold **44** is fluidly connected to a hose **40** that connects the vacuum pump **10** to an external system **46** (e.g., an air conditioning system, a refrigeration system, etc.). In the illustrated embodiment, the inlet manifold **44** includes multiple connection ports **48***a*, **48***b*, **48***c* that are sized to connect to the hose **40** of the external system **46**. For example, the connection ports **48***a*, **48***b*, **48***c* may have various sizes (e.g., ½ inch, ⅜ inch, ¼ inch, etc. In the illustrated embodiment, of FIG. **1** and **3**C, the inlet manifold **44** is a flange-style manifold that removes the need for thread locking and thread sealant. Instead, the inlet manifold **44** of FIG. **3**C includes a flange **45** with an O-ring (not shown), providing a watertight connection between the inlet manifold **44** and the trestle **24** which allows for ease of assembly and servicing of the compression chamber **38**. Specifically, the O-ring is disposed on an outer periphery of the flange **45** such that the inlet manifold **44** is in sealed fluid communication with the pump assembly **42**. The inlet manifold **44** is fastened to the trestle **24** using a plurality of threaded fasteners **49** (FIG. **1**) received within corresponding threaded bores **51** within the trestle **24**.

A battery pack **50** is removably coupled to an end portion of the housing **14** via a battery receptacle **52**. The battery pack **50** provides electrical current to the motor assembly **30** that drives the pump assembly **42** to remove or evacuate material such as air, gas, and non-condensables (e.g., water vapor) from the external system **46**. The vacuum pump **10** includes a control panel **54** on one sidewall of the housing **14** and a bumper **55** (FIG. **2**A) on an opposite sidewall of the housing **14**. In the illustrated embodiment, the control panel **54** is disposed on the motor housing **26** and includes a power switch **56** that selectively activates the vacuum pump **10** and a Universal Serial Bus (USB) port **58**. In some embodiments, an external display may be connected to the USB port **58** to display information related to the operation of the vacuum pump **10** (e.g., battery life remaining, micron gauge, etc.). In other embodiments, the control panel **54** may include a display (e.g., an LCD display). The bumper **55** is composed of an elastomeric material (e.g., rubber) and is intended to protect the pump **10** from damage when inadvertently dropped or tipped from the upright orientation shown in FIG. **2**A. As shown in FIG. **2**B, the bumper **55** is coupled to the trestle **24** and includes a pair of T-ribs **57** that are received within a pair of corresponding slots **59** of the trestle **24**. In other words, the T-ribs **57** retain the bumper **55** to the trestle **24**. As shown in FIG. **2**C, the bumper **55** also includes a concave face **61** from which the T-ribs **57** project. The concave face **61** bends or deforms when laid flat (i.e., flush) against the housing **14** as the T-ribs **57** are received in the slots **59**.

With reference to FIG. **3**A, the compression chamber **38** is sealed relative to the motor housing **26** via the trestle **24** so the compression chamber **38** can hold lubrication fluid (e.g., oil). Specifically, the trestle **24** includes a partition wall **60** that seals the compression chamber **38** from the motor housing **26**. The trestle **24** defines a fluid pathway **68** that extends between the inlet manifold **44** and the pump assembly **42**. The lubrication fluid positioned within the compression chamber **38** is used to lubricate and cool the pump assembly **42** during operation of the vacuum pump **10**.

With reference to FIGS. **2**A and **3**A, the compression chamber **38** further includes a fluid port **62** having a removable cap **66**, a fluid gauge **70** positioned on a sidewall of the pump housing **36**, a release valve **74** positioned on the upper portion of the trestle **24**, and a fluid drain valve **78** positioned at the bottom of the compression chamber **38** adjacent the base **22**. In the illustrated embodiment, a user may remove the removable cap **66** to fill the compression chamber **38** with lubrication fluid via the fluid port **62**. The fluid port **62** and the removable cap **66** may also function as an exhaust during operation of the vacuum pump **10**. The fluid gauge **70** may be transparent to allow a user to determine the amount of lubrication fluid that is held within the compression chamber **38**. Also, the fluid drain valve **78** allows the user to drain the lubrication fluid from the compression chamber **38**.

With reference to FIG. **4**, the motor assembly **30** is positioned within the motor housing **28** and is coupled to the partition wall **60** of the trestle **24** via a support bracket **80**. The motor assembly **30** includes a motor **82** and a fan **86** driven by the motor **82**. In the illustrated embodiment, the motor **82** is a brushless direct current (BLDC) motor that has a motor shaft **90** having a first end coupled to the fan **86** and a second end coupled to the pump assembly **42**, a rotor **94** coupled to the motor shaft **90**, and a stator **98** surrounding the rotor **94**. During operation of the motor **82**, an electrical current flows through coils of the stator **98** to produce a magnetic field around the rotor **94**, causing the rotor **94** and the motor shaft **90** to rotate about a drive axis **100** and drive the pump assembly **42**. The fan **86** is positioned between the electronic control unit **34** and the motor assembly **30**. The fan **86** removes heat from the electronic control unit **34** and provides air to the motor assembly **30** to prevent overheating of each of the electronic control unit **34** and the motor assembly **30**. Although the motor **82** of the illustrated embodiment is a BLDC motor, in other embodiments, the motor **82** may alternatively be a brushed direct current motor or any other type of DC motor.

With reference to FIGS. **4** and **5**, the pump assembly **42** is a two-stage pump that has a first pump chamber **102** and a second pump chamber **106** in series with the first pump chamber **102**. The first pump chamber **102** has a first pump inlet **104** in communication with the fluid pathway **68** and a first pump outlet **105** that is in fluid communication with a second pump inlet **108** of the second pump chamber **106**. The second pump chamber **106** has a second pump outlet **110** that releases the pressure from the pump assembly **42** to the compression chamber **38**. Although the illustrated pump assembly **42** is a two-stage pump (e.g., has first and second pump chambers), in other embodiments, the pump assembly **42** may only include a single stage or chamber.

With reference to FIGS. **6** and **7**, the first pump chamber **102** includes a first rotor **114** and the second pump chambers **106** includes a second rotor **116**. The first and second rotors **114**, **116** each include a pair of vanes **118**, **120** that are biased outward toward an interior surface **124** of the pump chambers **102**, **106** (FIGS. **6** and **7**) via centrifugal forces. In other embodiments, the vanes **118**, **120** may be biased outward via springs or some other biasing member. As a result, the rotation of the eccentrically mounted rotors **114**, **116** create low-pressure zones within the pump assembly **42**, which draws material out of the external system **46** (FIG. **1**) and into the pump assembly **42**. The evacuated material is transferred from the first pump chamber **102** to the second pump chamber **106**, at which point the evacuated material is discharged into the compression chamber **38** via the second pump outlet **110**. In the illustrated embodiment, the second pump outlet **110** includes a valve (e.g., a reed valve, etc.) that selectively releases the evacuated material into the compression chamber **38** before being released from the vacuum pump **10** through the exhaust (e.g., via the cap **66**) of the compression chamber **38**.

With continued reference to FIGS. **6** and **7**, the first and second rotors **114**, **116** are eccentrically mounted within the first and second pump chambers **102**, **106**, respectively. Specifically, the first rotor **114** is smaller in diameter relative to the first pump chamber **102** and positioned such that an outer surface **128** of the first rotor **114** is approximately tangent to the interior surface **124** of the first pump chamber **102** adjacent the first pump inlet **104**. Similarly, the second rotor **116** is smaller in diameter relative to the second pump chamber **106** and positioned such that an outer surface **132** of the second rotor **116** is approximately tangent to the interior surface **124** of the second pump chamber **106** adjacent the second pump inlet **108**. As explained in further detail below, it is important for the first and second rotors **114**, **116** to be approximately tangent to the first and second pump chambers **102**, **106** to ensure a proper seal within the pump assembly **42**.

To provide some background, if either of the rotors **114**, **116** are spaced too far away from the interior surface **124** of the pump chambers **102**, **106**, then the pump assembly **42** fails to make a low-pressure zone because a proper seal cannot be made between the first pump inlet **104** and the second pump outlet **110**. Now, if either of the rotors **114**, **116** are spaced too close to the interior surface **124** of the pump chambers **102**, **106**, then excessive frictional forces are generated between the rotors **114**, **116** and the pump chambers **102**, **106** causing undue wear on the vacuum pump **10**.

Returning to FIGS. **6** and **7**, the first pump chamber **102** includes a first seal **136** that is disposed between the first pump inlet **104** and the first pump outlet **105** for creating a moveable seal with the first rotor **114**. The first seal **136** is in continuous engagement with the first rotor **114** and moveable toward the first rotor **114** along a direction perpendicular to the drive axis **100**. Also, the first seal **136** is in sliding contact with the first rotor **114** and the vanes **118** as the first rotor **114** rotates. A first spring **140** biases the first seal **136** toward the first rotor **114**. As illustrated, the first seal **136** includes a wall section **144** that has a radius equal to a radius R of the first pump chamber **102**, while the first rotor **114** includes a radius r that is less than the radius R of the first pump chamber **102**. That said, the wall section **144** of the first seal **136** remains approximately tangentially engaged with the outer surface **128** of the first rotor **114**.

Now, the second pump chamber **106** also includes a seal (i.e., a second seal **148**) that is disposed between the second pump inlet **108** and the second pump outlet **110** for creating a moveable seal with the second rotor **116**. The second seal **148** is in continuous engagement with the second rotor **116** and moveable toward the second rotor **116** along a direction perpendicular to the drive axis **100**. Also, the second seal **148** is in sliding contact with the second rotor **116** and the vanes **120** as the second rotor **116** rotates. A second spring **152** biases the second seal **148** toward the second rotor **116**. As illustrated, the second seal **148** includes a wall section **156** that has a radius equal to the radius R of the second pump chamber **106**, while the second rotor **116** includes the radius r that is less than the radius R of the second pump chamber **106**. That said, the wall section **156** of the second seal **148** remains approximately tangentially engaged with the outer surface **132** of the second rotor **116**. The spring stiffness of each spring **140**, **152** is configured to apply a sufficient force on the first and second seals **136**, **148** to create a proper seal within the first and second pump chambers **102**, **106** while avoiding excessive friction forces being generated that may otherwise damage the vacuum pump **10**. Although the first and second seals **136**, **148** of the illustrated embodiments are composed of steel, in other embodiments, the first and second seals **136**, **148** may be composed of a variety of other types of material, such as plastics, ceramics, or flexible elastomers.

With reference to FIG. **8**, the interior surface **124** of the first and second pump chambers **102**, **106** include a fillet edge **160** that is adjacent another fillet edge **164** of the first and second seals **136**, **148**. The fillet edge **164** ensures that the first and second seals **136**, **148** avoid catching a shoulder **168** of the first and second rotors **114**, **116** adjacent the vanes **118**, **120**. The fillet edges **160**, **164** also reduce wear on the vanes **118**, **120** as the vanes **118**, **120** slide from the interior surface **124** of the first and second pump chambers **102**, **106** to the wall sections **144**, **156** of the first and second seals **136**, **148**.

During operation, a user may attach the battery pack **50** to the battery receptacle **52** of the vacuum pump **10**, and fluidly connect the external system **46** to the vacuum pump **10** via the inlet manifold **44** (e.g., with the hose **40**). The user may activate the vacuum pump **10** with the control panel **54** (e.g., by depressing the power switch **56**) to activate the motor assembly **30** and begin evacuating material from the external system **46**. When the vacuum pump **10** is activated, the first and second rotors **114**, **116** begin rotating within the first and second pump chambers **102**, **106**, which creates a low-pressure zone to evacuate material from the external system **46**. As the first and second rotors **114**, **116** rotate, the first and second seals **136**, **148** are biased toward the first and second rotors **114**, **116**, respectively, and remain in continuous contact with the outer surface **128**, **132** of the first and second rotors **114**, **116**. Also, the first and second seals **136**, **148** remain in constant contact with the vanes **118**, **120** as the vanes **118**, **120** slide past the first and second seals **136**, **148**.

Various features of the invention are set forth in the following claims.

What is claimed is:

1. A vacuum pump that is connectable to an external system and configured to evacuate material from the external system, the vacuum pump comprising:

- a housing including a motor housing, a pump housing, and a trestle that separates the motor housing and the pump housing;
- a base coupled to a lower portion of the housing;
- a motor assembly that is positioned within the motor housing;
- a control panel disposed on a first sidewall of the housing;
- a battery that is coupled to the motor housing and configured to supply electrical current to the motor assembly;
- a pump assembly that is positioned within the pump housing, the pump housing is sealed relative to the motor housing to form a compression chamber storing a lubrication fluid, wherein the pump assembly is driven by the motor assembly and is in fluid communication with the compression chamber;
- an inlet manifold coupled to the trestle and configured to fluidly connect the pump assembly to the external system; and
- a bumper composed of an elastomeric material and coupled to the trestle on a second sidewall of the housing that is opposite the first sidewall, the bumper is configured to protect the vacuum pump from damage when inadvertently dropped, and wherein the first sidewall and the second sidewall extend upward from the base.

2. The vacuum pump of claim **1**, further comprising an O-ring that is disposed on an outer periphery of the inlet manifold such that the inlet manifold is sealingly coupled to the trestle.

3. The vacuum pump of claim **1**, wherein the inlet manifold is fastened to the trestle using a plurality of threaded fasteners that are received within corresponding threaded bores of the trestle.

4. The vacuum pump of claim **1**, wherein the bumper includes a pair of T-ribs that are received within a pair of corresponding slots of the trestle, wherein the T-ribs retain the bumper to the trestle.

5. The vacuum pump of claim **4**, wherein the bumper includes a concave face from which the T-ribs project, wherein the concave face deforms and lays flat against the trestle as the T-ribs are received in the slots.

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