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Pump housing with vertically supported vibration isolators

Abstract

An apparatus can include a housing defining a housing interior, an air pump positioned in the housing interior, and a plurality of resilient connectors connecting the air pump to the housing with the resilient connectors in tension so as to reduce transmission of vibration from the air pump to the housing during operation of the air pump.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
1377556	12/1920	Bridgman	N/A	N/A
2483295	12/1948	Edmund	N/A	N/A
2809005	12/1956	Goode	N/A	N/A
3727865	12/1972	Melrose et al.	N/A	N/A
4644597	12/1986	Walker	N/A	N/A
4766628	12/1987	Greer et al.	N/A	N/A
4788729	12/1987	Greer et al.	N/A	N/A
D300194	12/1988	Walker	N/A	N/A
4829616	12/1988	Walker	N/A	N/A
4864683	12/1988	Herron et al.	N/A	N/A
4890344	12/1989	Walker	N/A	N/A
4897890	12/1989	Walker	N/A	N/A
4901681	12/1989	Pozniak	N/A	N/A
4908895	12/1989	Walker	N/A	N/A
D313973	12/1990	Walker	N/A	N/A
4984971	12/1990	Bergeron	N/A	N/A
4991244	12/1990	Walker	N/A	N/A
5144706	12/1991	Walker et al.	N/A	N/A
5170522	12/1991	Walker	N/A	N/A
D368475	12/1995	Scott	N/A	N/A
5509154	12/1995	Shafer et al.	N/A	N/A
5564140	12/1995	Shoenhair et al.	N/A	N/A
5634225	12/1996	Miller et al.	N/A	N/A
5642546	12/1996	Shoenhair	N/A	N/A
5652484	12/1996	Shafer et al.	N/A	N/A
5765246	12/1997	Shoenhair	N/A	N/A
5903941	12/1998	Shafer et al.	N/A	N/A
5904172	12/1998	Gifft et al.	N/A	N/A
5964579	12/1998	Tang et al.	N/A	N/A
6037723	12/1999	Shafer et al.	N/A	N/A
6108844	12/1999	Kraft et al.	N/A	N/A
6161231	12/1999	Kraft et al.	N/A	N/A
6202239	12/2000	Ward et al.	N/A	N/A
6397419	12/2001	Mechache	N/A	N/A
6483264	12/2001	Shafer et al.	N/A	N/A

6686711	12/2003	Rose et al.	N/A	N/A
6708357	12/2003	Gaboury et al.	N/A	N/A
6763541	12/2003	Mahoney et al.	N/A	N/A
6804848	12/2003	Rose	N/A	N/A
6832397	12/2003	Gaboury	N/A	N/A
D502929	12/2004	Copeland et al.	N/A	N/A
6883191	12/2004	Gaboury et al.	N/A	N/A
7322801	12/2007	Li et al.	N/A	N/A
7389554	12/2007	Rose	N/A	N/A
7865988	12/2010	Koughan et al.	N/A	N/A
8282452	12/2011	Grigsby et al.	N/A	N/A
8336369	12/2011	Mahoney	N/A	N/A
8444558	12/2012	Young et al.	N/A	N/A
D691118	12/2012	Ingham et al.	N/A	N/A
D697874	12/2013	Stusynski et al.	N/A	N/A
D698338	12/2013	Ingham	N/A	N/A
D701536	12/2013	Sakal	N/A	N/A
8672853	12/2013	Young	N/A	N/A
8769747	12/2013	Mahoney et al.	N/A	N/A
8783781	12/2013	McClure et al.	N/A	N/A
8876092	12/2013	Wojcieson	267/141	F16F 15/08
8893339	12/2013	Fleury et al.	N/A	N/A
8931329	12/2014	Mahoney et al.	N/A	N/A
8966689	12/2014	McGuire et al.	N/A	N/A
8973183	12/2014	Palashewski et al.	N/A	N/A
8984687	12/2014	Stusynski et al.	N/A	N/A
D728254	12/2014	Blazar et al.	N/A	N/A
D737250	12/2014	Ingham et al.	N/A	N/A
9314118	12/2015	Blazar et al.	N/A	N/A
9578941	12/2016	MacLachlan et al.	N/A	N/A
9730524	12/2016	Chen et al.	N/A	N/A
9737154	12/2016	Mahoney et al.	N/A	N/A
D809843	12/2017	Keeley et al.	N/A	N/A
D812393	12/2017	Karschnik et al.	N/A	N/A
9924813	12/2017	Basten et al.	N/A	N/A
10143312	12/2017	Brosnan et al.	N/A	N/A
10149549	12/2017	Erko et al.	N/A	N/A
D840732	12/2018	Peterson et al.	N/A	N/A
10194753	12/2018	Fleury et al.	N/A	N/A
10285508	12/2018	Rose et al.	N/A	N/A
10342358	12/2018	Palashewski et al.	N/A	N/A
D857433	12/2018	Kiekhoefer et al.	N/A	N/A
10531745	12/2019	McGuire et al.	N/A	N/A
10539170	12/2019	Peterson et al.	N/A	N/A
10575654	12/2019	Shakal	N/A	N/A
10729253	12/2019	Gaunt	N/A	N/A
10765224	12/2019	Chen et al.	N/A	N/A
10813470	12/2019	Mahoney et al.	N/A	N/A
10888173	12/2020	Shakal et al.	N/A	N/A
10993546	12/2020	Shakal et al.	N/A	N/A

11001447	12/2020	Shutes et al.	N/A	N/A
11085479	12/2020	Griffith et al.	N/A	N/A
11096502	12/2020	Rose et al.	N/A	N/A
D932808	12/2020	Keeley	N/A	N/A
11140999	12/2020	Peterson et al.	N/A	N/A
11229297	12/2021	Gaunt	N/A	N/A
11484128	12/2021	Stusynski et al.	N/A	N/A
D982360	12/2022	Negus	N/A	N/A
2002/0053632	12/2001	Becker	248/610	F16F 15/04
2002/0069462	12/2001	Gaboury et al.	N/A	N/A
2005/0204475	12/2004	Schmitz et al.	N/A	N/A
2005/0235417	12/2004	Koughan et al.	N/A	N/A
2006/0254869	12/2005	Wang	N/A	N/A
2008/0052830	12/2007	Koughan et al.	N/A	N/A
2008/0077020	12/2007	Young et al.	N/A	N/A
2010/0043148	12/2009	Rose et al.	N/A	N/A
2011/0144455	12/2010	Young et al.	N/A	N/A
2012/0022445	12/2011	Jones	N/A	N/A
2012/0153536	12/2011	Coffield et al.	N/A	N/A
2014/0182061	12/2013	Zaiss	N/A	N/A
2014/0250597	12/2013	Chen et al.	N/A	N/A
2014/0257571	12/2013	Chen et al.	N/A	N/A
2014/0259417	12/2013	Nunn et al.	N/A	N/A
2014/0259418	12/2013	Nunn et al.	N/A	N/A
2014/0259431	12/2013	Fleury	N/A	N/A
2014/0259433	12/2013	Nunn et al.	N/A	N/A
2014/0259434	12/2013	Nunn et al.	N/A	N/A
2014/0277611	12/2013	Nunn et al.	N/A	N/A
2014/0277778	12/2013	Nunn et al.	N/A	N/A
2014/0277822	12/2013	Nunn et al.	N/A	N/A
2015/0007393	12/2014	Palashewski	N/A	N/A
2015/0025327	12/2014	Young et al.	N/A	N/A
2015/0026896	12/2014	Fleury et al.	N/A	N/A
2015/0157137	12/2014	Nunn et al.	N/A	N/A
2015/0157519	12/2014	Stusynski et al.	N/A	N/A
2015/0182033	12/2014	Brosnan et al.	N/A	N/A
2015/0182397	12/2014	Palashewski et al.	N/A	N/A
2015/0182399	12/2014	Palashewski et al.	N/A	N/A
2015/0182418	12/2014	Zaiss	N/A	N/A
2015/0290059	12/2014	Brosnan et al.	N/A	N/A
2015/0300345	12/2014	Ansley	N/A	N/A
2015/0366366	12/2014	Zaiss et al.	N/A	N/A
2015/0374137	12/2014	Mahoney et al.	N/A	N/A
2016/0100696	12/2015	Palashewski et al.	N/A	N/A
2018/0119686	12/2017	Shakal	N/A	F04B 39/0044
2018/0125259	12/2017	Peterson et al.	N/A	N/A
2019/0082855	12/2018	Brosnan et al.	N/A	N/A
2020/0187667	12/2019	Shakal	N/A	N/A
2020/0359805	12/2019	Brosnan et al.	N/A	N/A
2020/0375369	12/2019	Negus et al.	N/A	N/A

2021/0145183	12/2020	Negus et al.	N/A	N/A
2021/0145185	12/2020	Negus et al.	N/A	N/A
2021/0177155	12/2020	McGuire et al.	N/A	N/A
2021/0244196	12/2020	Hilden et al.	N/A	N/A
2021/0251392	12/2020	Shakal	N/A	N/A
2021/0330090	12/2020	Shakal et al.	N/A	N/A
2021/0341006	12/2020	Griffith et al.	N/A	N/A
2022/0192388	12/2021	Smith et al.	N/A	N/A
2022/0218116	12/2021	Rose et al.	N/A	N/A
2022/0273118	12/2021	Peterson et al.	N/A	N/A
2022/0322840	12/2021	Gaunt	N/A	N/A
2022/0369827	12/2021	Rose et al.	N/A	N/A
2023/0017015	12/2022	Karschnik et al.	N/A	N/A
2023/0027288	12/2022	Karschnik	N/A	N/A
2023/0031563	12/2022	Molina et al.	N/A	N/A
2023/0057322	12/2022	Shakal	N/A	N/A
2023/0063979	12/2022	Doffing et al.	N/A	N/A
2023/0128215	12/2022	Karschnik et al.	N/A	N/A
2023/0148764	12/2022	Negus et al.	N/A	N/A
2023/0218088	12/2022	Brosnan et al.	N/A	N/A
2023/0389717	12/2022	Yang et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	**Application Date**	**Country**	**CPC**
105909499	12/2015	CN	N/A
105909499	12/2015	CN	N/A
1956263	12/2007	EP	N/A
3086122	12/2015	EP	N/A
3086122	12/2015	EP	N/A

OTHER PUBLICATIONS

U.S. Appl. No. 09/471,592, filed Dec. 23, 1999, Shafer. cited by applicant
U.S. Appl. No. 14/594,843, filed Jan. 12, 2015, Rose et al. cited by applicant
U.S. Appl. No. 18/196,658, filed May 12, 2023, Herman et al. cited by applicant
U.S. Appl. No. 18/221,628, filed Jul. 13, 2023, Karschnik et al. cited by applicant
U.S. Appl. No. 18/222,104, filed Jul. 14, 2023, Shakal et al. cited by applicant
U.S. Appl. No. 18/367,634, filed Sep. 13, 2023, Gaunt. cited by applicant
U.S. Appl. No. 18/377,932, filed Oct. 9, 2023, VerBockel et al. cited by applicant
U.S. Appl. No. 18/382,902, filed Oct. 23, 2023, Doffing et al. cited by applicant
U.S. Appl. No. 18/512,568, filed Nov. 17, 2023, Stusynski et al. cited by applicant
U.S. Appl. No. 29/719,090, filed Dec. 31, 2019, Negus et al. cited by applicant
U.S. Appl. No. 29/821,785, filed Jan. 3, 2022, Negus et al. cited by applicant

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of U.S. Utility application Ser. No. 16/518,344, filed Jun. 8, 2020, which is a continuation of U.S. Application Serial No. U.S. application Ser. No. 15/337,470 (now U.S. Pat. No. 10,677,232), filed Oct. 28, 2016. The disclosures of the prior applications are considered part of (and are incorporated by reference in) the disclosure of this application.

TECHNICAL FIELD

(1) This invention relates to pumps, and more particularly to vibration of pumps for use in beds.

BACKGROUND

(2) People have traditionally used beds that come in many shapes, sizes, and styles. Such beds can range from extremely simple designs to rather complex designs that include a variety of features. For example, some beds can have one or more inflatable air chambers. Some of such beds can include an inflation system including a number of mechanical and electrical components. For example, some beds can include one or more pumps for inflating the air chambers.

SUMMARY

(3) Some embodiments of a pump system can include one or more of the features and functions disclosed herein. Some embodiments can include the pump within a larger housing and can include vibration isolators connecting the pump to the housing. This can allow the pump to vibrate during operation while reducing noise resulting from that operation. The vibration isolators can be elongated, resilient connectors extending from the housing to the pump in tension. The resilient connectors can suspend the pump within the housing so that the pump has little or no contact with the housing during operation. The pump can be an air pump for inflating air chambers of an air mattress, which can benefit from reduced noise from vibration if the pump is to be operated while a user sleeps. The housing can contain a printed circuit board and one or more stops that limit movement of the pump so as to limit or prevent the pump from hitting and damaging the printed circuit board if the pump moves too far in that direction. Various embodiments can be configured with components having particular shapes and features.

(4) In one aspect, an apparatus includes a housing defining a housing interior, an air pump positioned in the housing interior, and a plurality of resilient connectors connecting the air pump to the housing with the resilient connectors in tension so as to reduce transmission of vibration from the air pump to the housing during operation of the air pump.

(5) Some of the implementations described herein may optionally include one or more of the following features. The resilient connectors comprise elastomer bands each having a first end connected to the housing and a second end connected to the air pump. The housing comprises a plurality of housing mounting structures, the air pump comprises a plurality of pump mounting structures, and the resilient connectors each extends from one of the pump mounting structures to the housing mounting structures. The housing mounting structures each comprise a vertical standoff that defines a shoulder and wherein each of the resilient connectors has a first end configured for connecting to the vertical standoff adjacent the shoulder such that the air pump is suspended from the vertical standoff via the resilient connectors. The pump mounting structures each comprise a hole. Each of the resilient connectors has a second end configured for extending into the hole and pulling against the pump mounting structure. The second end of the resilient connector has a cross section with a first wide portion adjacent a narrow neck. The narrow neck is adjacent a second wide portion. The second wide portion tapers to a second narrow portion at a tip of the second end of the resilient connector. The resilient connectors comprise first, second, third, and fourth resilient connectors with the first and third resilient connectors connected so as to pull in tension in substantially opposite directions and the second and fourth resilient connectors are connected so as to pull in tension in substantially opposite directions. The apparatus further includes a printed circuit board comprising a plurality of electronic components positioned in the housing and a stop positioned between the air pump and the printed circuit board and spaced from

the air pump. The stop is spaced and the resilient connectors are configured such that the resilient connectors dampen vibration of the motor enough to prevent contact between the motor and the stop during normal operation. The stop is sized to limit movement by the air pump when motion of the air pump toward the printed circuit board exceeds a threshold. The printed circuit board is positioned below the air pump and the stop extends through a hole in the printed circuit board toward the air pump. The apparatus further includes a printed circuit board comprising a plurality of electronic components positioned in the housing and a stop extending from the air pump toward the printed circuit board and that is sized to contact a structure when motion of the air pump toward the printed circuit board exceeds a threshold. The resilient connectors extend laterally outward from the air pump in a substantially horizontal direction. The apparatus further includes a pump manifold fluidically connected to the pump. The pump manifold is mounted to the housing and is spaced from the pump such that pump vibration is substantially isolated from the pump manifold. The apparatus further includes a pump manifold fluidically connected to the pump, an air mattress comprising at least one air chamber fluidically connected to the pump manifold, and a pump controller positioned in the housing and configured to control operation of the air pump to selectively inflate the air chamber of the air mattress. The resilient connectors extend between 0.5 and 1.5 inches between mounting structures of the housing and the air pump. Each of the resilient connectors has a first connection portion defining a hole that extends over a portion of a standoff of the housing and a second connection portion that extends through a hole of a mounting structure of the pump.
(6) The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

Description

DESCRIPTION OF DRAWINGS
(1) FIG. **1** shows an example air bed system.
(2) FIG. **2** is a block diagram of an example of various components of an air bed system.
(3) FIG. **3** is a perspective view of an air controller for use in an air bed system.
(4) FIG. **4**A is a perspective view of the air controller of FIG. **3** with a top of a housing removed.
(5) FIG. **4**B is a perspective view of a pump of the air controller of FIG. **3**.
(6) FIG. **5** is a top view of the air controller of FIG. **3** with the top of the housing removed.
(7) FIG. **6** is a side view of the air controller of FIG. **3** with the top of the housing removed.
(8) FIG. **7** is a top view of a connector.
(9) Like reference symbols in the various drawings indicate like elements.
DETAILED DESCRIPTION
(10) An air controller, such as for inflatable air beds, can have a pump and other components positioned inside a housing. The pump can be mounted in the housing by suspending the pump with multiple resilient connectors. These resilient connectors can reduce noise from vibration of the pump. This can be desirable in applications where noise is undesirable, such as for an air controller for an air bed.
(11) FIG. **1** shows an example air bed system **100** that includes a bed **112**. The bed **112** includes at least one air chamber **114** surrounded by a resilient border **116** and encapsulated by bed ticking **118**. The resilient border **116** can comprise any suitable material, such as foam.
(12) As illustrated in FIG. **1**, the bed **112** can be a two chamber design having first and second fluid chambers, such as a first air chamber **114**A and a second air chamber **114**B. In alternative embodiments, the bed **112** can include chambers for use with fluids other than air that are suitable for the application. In some embodiments, such as single beds or kids' beds, the bed **112** can

include a single air chamber **114**A or **114**B or multiple air chambers **114**A and **114**B. The first and second air chambers **114**A and **114**B can be in fluid communication with a pump **120**. The pump **120** can be part of an air controller **124**, which can be in electrical communication with a remote control **122**. The air controller **124** can include a wired or wireless communications interface for communicating with one or more devices, including the remote control **122**. The air controller **124** can be configured to operate the pump **120** to cause increases and decreases in the fluid pressure of the first and second air chambers **114**A and **114**B based upon commands input by a user using the remote control **122**. In some implementations, the pump **120** and the air controller **124** can be integrated into a common housing. In other embodiments, the air controller **124** and the pump **120** can be in separate housings.

(13) The remote control **122** can include a display **126**, an output selecting mechanism **128**, a pressure increase button **129**, and a pressure decrease button **130**. The output selecting mechanism **128** can allow the user to switch air flow generated by the pump **120** between the first and second air chambers **114**A and **114**B, thus enabling control of multiple air chambers with a single remote control **122** and a single pump **120**. For example, the output selecting mechanism **128** can by a physical control (e.g., switch or button) or an input control displayed on display **126**. Alternatively, separate remote control units can be provided for each air chamber and can each include the ability to control multiple air chambers. Pressure increase and decrease buttons **129** and **130** can allow a user to increase or decrease the pressure, respectively, in the air chamber selected with the output selecting mechanism **128**. Adjusting the pressure within the selected air chamber can cause a corresponding adjustment to the firmness of the respective air chamber. In some embodiments, the remote control **122** can be omitted or modified as appropriate for an application. For example, in some embodiments the bed **112** can be controlled by a computer, tablet, smart phone, or other device in wired or wireless communication with the bed **112**.

(14) FIG. **2** is a block diagram of an example of various components of an air bed system. For example, these components can be used in the example air bed system **100**. As shown in FIG. **2**, the air controller **124** can include the pump **120**, a power supply **134**, a processor **136**, a memory **137**, a switching mechanism **138**, and an analog to digital (A/D) converter **140**, a air manifold **143** (having valves **144**, **145**A, and **145**B), and one or more pressure transducers **146**. The switching mechanism **138** can be, for example, a relay or a solid state switch.

(15) The pump **120** can include a motor **142**. The pump **120** can be fluidly connected to the pump manifold, which is fluidically connected with the first air chamber **114**A and the second air chamber **114**B via a first tube **148**A and a second tube **148**B, respectively. The first and second control valves **145**A and **145**B can be controlled by switching mechanism **138**, and are operable to regulate the flow of fluid between the pump **120** and first and second air chambers **114**A and **114**B, respectively.

(16) In some implementations, the pump **120** and the air controller **124** can be provided and packaged as a single unit. In some alternative implementations, the pump **120** and the air controller **124** can be provided as physically separate units. In some implementations, the air controller **124**, the pump **120**, or both are integrated within or otherwise contained within a bed frame or bed support structure that supports the bed **112**. In some implementations, the air controller **124**, the pump **120**, or both are located outside of a bed frame or bed support structure (as shown in the example in FIG. **1**).

(17) The example air bed system **100** depicted in FIG. **2** includes the two air chambers **114**A and **114**B and the single pump **120**. However, other implementations can include an air bed system having two or more air chambers and one or more pumps incorporated into the air bed system to control the air chambers. For example, a separate pump can be associated with each air chamber of the air bed system or a pump can be associated with multiple chambers of the air bed system. Separate pumps can allow each air chamber to be inflated or deflated independently and simultaneously. Furthermore, additional pressure transducers can also be incorporated into the air

bed system such that, for example, a separate pressure transducer can be associated with each air chamber.

(18) In use, the processor **136** can, for example, send a decrease pressure command for one of the air chambers **114**A or **114**B, and the switching mechanism **138** can be used to convert the low voltage command signals sent by the processor **136** to higher operating voltages sufficient to operate the relief valve **144** of the pump **120** and open the control valve **145**A or **145**B. Opening the relief valve **144** can allow air to escape from the air chamber **114**A or **114**B through the respective air tube **148**A or **148**B. During deflation, the pressure transducer **146** can send pressure readings to the processor **136** via the A/D converter **140**. The A/D converter **140** can receive analog information from pressure transducer **146** and can convert the analog information to digital information useable by the processor **136**. The processor **136** can send the digital signal to the remote control **122** to update the display **126** in order to convey the pressure information to the user.

(19) As another example, the processor **136** can send an increase pressure command. The pump motor **142** can be energized in response to the increase pressure command and send air to the designated one of the air chambers **114**A or **114**B through the air tube **148**A or **148**B via electronically operating the corresponding valve **145**A or **145**B. While air is being delivered to the designated air chamber **114**A or **114**B in order to increase the firmness of the chamber, the pressure transducer **146** can sense pressure within the air manifold **143**. Again, the pressure transducer **146** can send pressure readings to the processor **136** via the A/D converter **140**. The processor **136** can use the information received from the A/D converter **140** to determine the difference between the actual pressure in air chamber **114**A or **114**B and the desired pressure. The processor **136** can send the digital signal to the remote control **122** to update display **126** in order to convey the pressure information to the user.

(20) FIG. **3** is a perspective view of the air controller **124** in a housing **150**. The housing **150** can include a housing top **152** and a housing bottom **154** and can substantially enclose components of the air controller **124**. One or more nozzles **156** and **158** can extend through the housing **150** and can be detachably connected to the air tubes **148**A and **148**B (shown in FIG. **2**) for inflating the air chambers **114**A and **114**B (shown in FIG. **2**).

(21) FIG. **4**A is a perspective view of the air controller **124** with the housing top **152** (shown in FIG. **3**) removed so as to show internal components. As shown in FIG. **4**A, the housing **150** of the air controller **124** contains the pump **120** and its motor **142**, the air manifold **143**, and a printed circuit board **160** (which can include some or all of the power supply **134**, the processor **136**, the memory **137**, the switching mechanism **138**, the A/D converter **140**, and the pressure transducer **146** shown in FIG. **2**).

(22) A tube **162** can extend from a nozzle **164** of the pump **120** to the air manifold **143** for fluidly connecting the pump **120** to the air manifold **143**. One or more additional tubes **166** and **168** can extend from the air manifold **143** to one or more pressure transducers **146** (shown in FIG. **2**) on the printed circuit board **160**.

(23) A plurality of resilient connectors **170**, **172**, **174**, and **176** connect the pump **120** to the housing **150**. The resilient connectors **170**, **172**, **174**, and **176** can extend from the pump **120** to the housing **150** in tension so as to reduce transmission of vibration from the pump **120** to the housing **150** during operation of the pump **120**. The housing **150** can include mounting structures **180**, **182**, **184**, and **186** (such as vertical posts) for connecting to the resilient connectors **170**, **172**, **174**, and **176**, respectively.

(24) The resilient connectors **170**, **172**, **174**, and **176** can support the pump **120** so as to be suspended in the housing **150** with the pump **120** spaced from the printed circuit board **160**. This can allow the pump **120** to vibrate while partially or totally isolating the vibration of the pump **120** such that the vibration of the pump **120** has little to no effect on the printed circuit board **120** and the housing **150**. This can reduce damage to the printed circuit board **150** and can reduce the

amount of noise noticed by a user.
(25) The air controller **124** can include one or more stops **188** and **190** configured for limiting movement of the pump **120** within the housing **150**. The stop **188** can extend downward from the pump **120** toward the printed circuit board **160**. In some embodiments, the stop **188** can be sized to contact the stop **190** when motion of the pump **120** toward the printed circuit board **160** (and/or toward other components) exceeds a threshold. In other embodiments, the stop **188** can be sized to contact another suitable structure. In some embodiments were limited contact with the printed circuit board **160** is suitable, the stop **188** can be sized to contact the printed circuit board **160** at a portion of the printed circuit board that has little or no electronic components that can be damaged as a result of being struck by the stop **188** when motion of the pump **120** toward the printed circuit board **160** exceeds a threshold.
(26) The stop **190** can extend through a hole extending through the printed circuit board **160** toward the pump **120**. The stop **190** can be sized and configured to limit movement of the pump **120** when motion of the pump **120** toward the printed circuit board **160** exceeds a threshold.
(27) In some embodiments, the stops **188** and **190** can work in conjunction to limit movement of the pump **120**. In other embodiments, movement of the pump **120** can be suitably limited by one of the stops **188** and **190** and the other can be omitted.
(28) For example, during normal operation, the pump **120** can vibrate in a limited way such that the pump **120** is supported by the resilient connectors **170**, **172**, **174**, and **176**, without requiring the stop **188** to bump or otherwise contact the printed circuit board **160**. During other conditions, such as during shipment of the air controller **124**, the pump **120** can be substantially shaken such that movement of the pump **120** exceeds a threshold. In such conditions, the stop **188** can bump against a structure (such as a relatively durable portion of the printed circuit board **160** or another structure) before the pump **120** bumps against fragile components on the printed circuit board **160**, such as the processor **136**, the memory **137**, etc.
(29) Similarly, during normal operation, the pump **120** can vibrate in a limited way such that the pump **120** is supported by the resilient connectors **170**, **172**, **174**, and **176**, without requiring the stop **190** to bump or otherwise contact the pump **120**. During other conditions, such as during shipment of the air controller **124**, the pump **120** can be substantially shaken such that movement of the pump **120** exceeds a threshold. In such conditions, the stop **190** can bump against a portion of the pump **120** before the pump **120** bumps against fragile components on the printed circuit board **160**, such as the processor **136**, the memory **137**, etc.
(30) FIG. **4**B is a perspective view of the pump **120** and the resilient connectors **170**, **172**, **174**, and **176**, with the other features of the air controller **124** removed for clarity.
(31) FIG. **5** is a top view of the air controller **124** with the housing top **152** removed. As shown in FIG. **5**, the resilient connectors **170** and **174** are connected so as to pull in tension in substantially opposite directions and the resilient connectors **172** and **176** are connected so as to pull in tension in substantially opposite directions.
(32) FIG. **6** is a side view of the air controller **124** with the housing top **152** removed.
(33) As shown in FIG. **6**, a distal end of the stop **188** is spaced from the printed circuit board **160** (shown better in FIGS. **4**A and **5**) and a distal end of the stop **190** is spaced from the pump **120**. This can allow the pump **120** to vibrate with slight to moderate movement without any contact from the stops **188** and **190** until movement of the pump **120** exceeds a threshold amount of movement.
(34) FIGS. **5** and **6** show the resilient connectors **170**, **172**, **174**, and **176** extending from the pump **120** to the mounting structures **180**, **182**, **184**, and **186** to support and isolate the pump **120**. In the illustrated embodiment, the size, shape and function of the resilient connectors **170**, **172**, **174**, and **176** are substantially similar. Additionally, the size, shape, and function of the mounting structures **180**, **182**, **184**, and **186** are also substantially similar in the illustrated embodiments. In other embodiments, one or more of the resilient connectors **170**, **172**, **174**, and **176** and/or the mounting

structures **180**, **182**, **184**, and **186** can be modified as suitable for the application. For example, one or more of the resilient connectors **170**, **172**, **174**, and **176** could be modified to be longer or shorter than as illustrated or to be connected in a different way.

(35) As shown in FIG. **6**, the mounting structures **180**, **182**, **184**, and **186** can be substantially vertical posts that have different widths at different portions along their lengths. For example, the mounting structure **180** has a section **192** near its proximal end and a section **194** near its distal end. The section **192** can have a greater diameter than the section **194** and a shoulder **196** can be defined at the junction between the section **192** and section **194**. The shoulder **196** allows the mounting structure **180** to function as a standoff to vertically support and align the resilient connector **170** when connected to the mounting structure **180**. The mounting structure **180** can also have a tapered distal tip **198**. During assembly, the resilient connector **170** can slide over the tapered distal tip **198** and along the section **194** to stop at or near the shoulder **196**.

(36) The resilient connector **170** can be an elongated structure with first and second ends **200** and **202**. The resilient connector **170** can have a first connection portion **204** proximate the first end **200** for connecting to the mounting structure and a second connection portion **206** proximate the second end **202** for connecting to the pump **120**. A resilient middle section **208** can extend between the connection portions **204** and **206** to perform dampening and isolation of vibration of the pump **120**.

(37) In the illustrated embodiment, the pump **120** includes a mounting structure **210** defining a hole for receiving the second end **202** of the resilient connector **170**. The second end **202** of the resilient connector **170** can extend through the hole in the mounting structure **210** with connection portion **206** of the resilient connector **170** held fast against the mounting structure **210** of the pump **120**. The resilient connector **170** can have a tapered portion **212** between the connection portion **206** and the second end **202** which can facilitate insertion of resilient connector **170** through the hole in the mounting structure **210** and resist removal of the resilient connector **170** from the mounting structure **210**.

(38) FIG. **7** is a top view of the resilient connector **170**, which further illustrates the features of the resilient connector **170**. As shown in FIG. **7**, the resilient connector **170** becomes thicker from the second end **202** to the connection portion **206**, becomes thinner at a neck portion **214**, and becomes thicker again at a pad portion **216**. When assembled, the neck portion **214** can be aligned with the mounting structure **210** of the pump **120** (shown in FIGS. **5** and **6**), with the connection portion **206** and the pad portion **216** positioned on opposite sides of the mounting structure **210** to hold the resilient connector **170** in place.

(39) In some embodiments, the middle section **208** of the resilient connector **170** can be shaped and function as an elastomer band (e.g. a rubber band), defining a hole in its center between two elongated strips **218** and **220** which can elastically stretch to dampen vibration during operation of the pump **120**. The resilient connector **170** can be formed from a thermoplastic vulcanizate or another elastomer suitable for the application. The elongated strips **218** and **220** can extend at an angle with respect to each-other. The elongated strips **218** and **220** can also extend angled with respect to that portion of the resilient connector extending from the second end **202** and the pad **216**. The shape and configuration of the resilient connector **170** can allow the resilient connector **170** to suitably connect the mounting structure **210** to the mounting structure **180** (shown in FIGS. **4**A, **5**, and **6**) so as to suspend the pump **120** to reduce vibration. In other embodiments, the resilient connector **170** can be modified as suitable for the application, such as if the shape or location of the mounting structures **180** and **210** were varied.

(40) In some embodiments, the resilient connector **170** can be sized with a length between the mounting structures **180** and **210** of about an inch. In some embodiments, the resilient connector **170** can be sized with a length between the mounting structures **180** and **210** in excess of an inch. In some embodiments, the resilient connector **170** can be sized with a length between the mounting structures **180** and **210** of between 0.5 and 1.5 inches.

(41) A number of embodiments of the invention have been described. Nevertheless, it will be

understood that various modifications may be made without departing from the spirit and scope of the invention. For example, various components illustrated in the air controller **124** can be modified, such as the air manifold **143** being modified as suitable for an application with more or less than two air chambers. Additionally, the mounting structures **180**, **182**, **184**, and **186** can be formed integrally with the housing **150** such as via injection molding or can be formed as separate components. Similarly, one or more features present on one or more of the various embodiments can be considered optional, and need not necessarily be included in all embodiments. Accordingly, other embodiments are within the scope of the following claims.

Claims

1. An apparatus comprising: a housing defining a housing interior; a plurality of vertical posts extending vertically and positioned in the housing interior, wherein each of the plurality of vertical posts comprise a bottom end and a top end opposite the bottom end, each of the vertical posts coupled to a bottom portion of the housing only at the bottom end; an air pump positioned in the housing interior, wherein the air pump comprises a mounting structure defining a plurality of horizontally-oriented holes; and a plurality of resilient connectors connecting the air pump to the vertical posts with the resilient connectors in tension so as to reduce transmission of vibration from the air pump to the housing during operation of the air pump, wherein each of the vertical posts is coupled to one of the resilient connectors, wherein one or more of the resilient connectors has a first end that defines a vertically-oriented hole positioned over one of the vertical posts and has a second end extending through one of the plurality of horizontally-oriented holes of the mounting structure of the air pump.
2. The apparatus of claim 1, wherein each of the plurality of vertical posts are further defined by a diameter, the diameter decreasing between the bottom end and the top end.
3. The apparatus of claim 1, wherein each of the plurality of vertical posts comprise a proximal portion and a distal portion, the proximal portion coupled to the bottom portion of the housing at the bottom end of each of the vertical posts, the distal portion extending from the proximal portion toward the top end of each of the vertical posts, the proximal portion defined by a proximal portion-diameter and a proximal portion-length, the distal portion defined by a distal portion-diameter and a distal portion-length, the distal portion-diameter is constant along the distal portion-length between the proximal portion and the top end.
4. The apparatus of claim 3, wherein each of the plurality of vertical posts comprise a shoulder positioned at a junction between the proximal portion and the distal portion.
5. The apparatus of claim 4, wherein the shoulder is configured to receive and support the respective resilient connector.
6. The apparatus of claim 4, wherein each of the plurality of vertical posts comprise a tapered distal tip positioned at the top end.
7. An apparatus comprising: a housing defining a housing interior; a plurality of vertical posts extending vertically and positioned in the housing interior, wherein each of the plurality of vertical posts comprise a bottom end and a top end opposite the bottom end, each of the vertical posts coupled to a bottom portion of the housing only at the bottom end, wherein each of the plurality of vertical posts comprise a proximal portion and a distal portion, the proximal portion coupled to the bottom portion of the housing at the bottom end of each of the vertical posts, the distal portion extending from the proximal portion toward the top end of each of the vertical posts, the proximal portion defined by a proximal portion-diameter and a proximal portion-length, the proximal portion-diameter is an outer diameter which is constant along the proximal portion-length from the bottom end of the vertical post to an opposite end of the proximal portion that is closer to the distal portion of the vertical post, the distal portion defined by a distal portion-diameter and a distal portion-length, the distal portion-diameter is an outer diameter which is constant along the distal

portion-length between the proximal portion and a tapered distal tip, the proximal portion-diameter being different than the distal portion-diameter, wherein each of the plurality of vertical posts comprise a shoulder positioned at a junction between the proximal portion and the distal portion, the shoulder separating the proximal portion-diameter from the distal portion-diameter, wherein each of the plurality of vertical posts comprises the tapered distal tip positioned at the top end, wherein the tapered distal tip comprises a chamfer between an outer surface of the distal portion and a top surface of the vertical post; an air pump positioned in the housing interior; and a plurality of resilient connectors connecting the air pump to the vertical posts with the resilient connectors in tension so as to reduce transmission of vibration from the air pump to the housing during operation of the air pump, wherein each of the vertical posts is coupled to one of the resilient connectors.
8. The apparatus of claim 7, wherein the tapered distal tip is sized such that the respective resilient connector slides along the distal portion to stop at the shoulder.
9. The apparatus of claim 7, wherein the tapered distal tip is sized such that the respective resilient connector slides along the distal portion to stop near the shoulder.
10. The apparatus of claim 7, wherein the air pump comprises a mounting structure defining tabs, each tab defining a hole extending therethrough, each of plurality of resilient connectors comprise: a first end portion defining a hole configured to fit about the top end of the respective vertical post; and a second end portion coupled to the first end portion, the second end portion defining a tapered portion configured to pass through the respective tab and couple the second end portion to the respective tab.
11. The apparatus of claim 10, wherein the first end portion defines a first end portion-center axis, the second end portion defines a second end portion-center axis, and the first end portion-center axis is angled not parallel relative to the second end portion-center axis.
12. The apparatus of claim 11, wherein the first end portion-center axis intersects a center axis of the vertical post.
13. The apparatus of claim 11, wherein the second end portion-center axis is perpendicular to the respective tab.
14. The apparatus of claim 10, wherein the second end portion comprises a void extending from a top surface of the resilient connector to a bottom surface of the resilient connector.
15. The apparatus of claim 14, wherein the void is positioned between the hole and the tapered portion.
16. The apparatus of claim 14, wherein the void is triangular-shaped.
17. The apparatus of claim 16, wherein two surfaces of the triangular-shaped void are generally parallel to two outer side surfaces, respectively, of the resilient connector.
18. The apparatus of claim 16, wherein corners of the triangular-shaped void are filleted.
19. An apparatus comprising: a housing comprising: a housing top comprising a housing top surface and a housing top side wall extending from the housing top surface; and a housing bottom comprising a housing bottom surface and a housing bottom side wall extending from the housing bottom surface, the housing top side wall configured to couple to the housing bottom side wall, the housing top and the housing bottom defining a housing interior; a plurality of vertical posts positioned in the housing interior, wherein each of the vertical posts extend perpendicularly from at least one of the housing top or the housing bottom; a pump positioned in the housing interior with a pump outlet facing a sideways direction that is parallel to at least one of the housing top or the housing bottom; and a plurality of resilient connectors connecting the pump to the vertical posts with the resilient connectors in tension so as to reduce transmission of vibration from the pump to the housing during operation of the pump, wherein each of the resilient connectors extends parallel to at least one of the housing top surface or the housing bottom surface, wherein each resilient connector comprises a first connection portion and a second connection portion coupled to the first connection portion, the first connection portion defining a longitudinal axis, wherein a first pair of resilient connectors of the plurality of resilient connectors are positioned on and coupled to a first

set of opposite vertical posts, the longitudinal axes of the first connection portions of the first pair of resilient connectors co-linear with an axis extending between the first set of opposite vertical posts, and wherein a second pair of resilient connectors of the plurality of resilient connectors are positioned on and coupled to a second set of opposite vertical posts, the longitudinal axes of the first connection portions of the second pair of resilient connectors co-linear with an axis extending between the second set of opposite vertical posts.

20. The apparatus of claim 19, wherein the pump includes a plurality of tabs each configured to allow a portion of a respective one of the resilient connectors to pass through a respective one of the tabs.

21. The apparatus of claim 19, wherein each of the plurality of vertical posts comprise a tapered distal tip positioned at a top end and the tapered distal tip comprises a chamfer between an outer surface of the tapered distal tip and a top surface of the vertical post.

22. An apparatus comprising: a housing comprising: a housing top comprising a housing top surface and a housing top side wall extending from the housing top surface; and a housing bottom comprising a housing bottom surface and a housing bottom side wall extending from the housing bottom surface, the housing top side wall configured to couple to the housing bottom side wall, the housing top and the housing bottom combinable to enclose and define a housing interior; a plurality of vertical posts positioned in the housing interior, wherein each of the vertical posts extend perpendicularly from at least one of the housing top or the housing bottom; a pump positioned in the housing interior, wherein the pump includes a pump body and a pump outlet, wherein a cylindrical portion of the pump body has a center axis that is parallel to at least one of the housing top or the housing bottom; and a plurality of resilient connectors connecting the pump to the vertical posts with the resilient connectors in tension so as to reduce transmission of vibration from the pump to the housing during operation of the pump, wherein each of the resilient connectors extends parallel to at least one of the housing top surface or the housing bottom surface, wherein the cylindrical portion of the pump body includes a plurality of tabs, at least two tabs of the plurality of tabs extending horizontally in a plane, each tab of the plurality of tabs defining a respective hole that is configured to allow a portion of a respective one of the resilient connectors to pass therethrough.