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(54) Title: USE OF AIRCRAFT WASTE SYSTEM VACUUM GENERATOR TO PROVIDE ELECTRICAL POWER

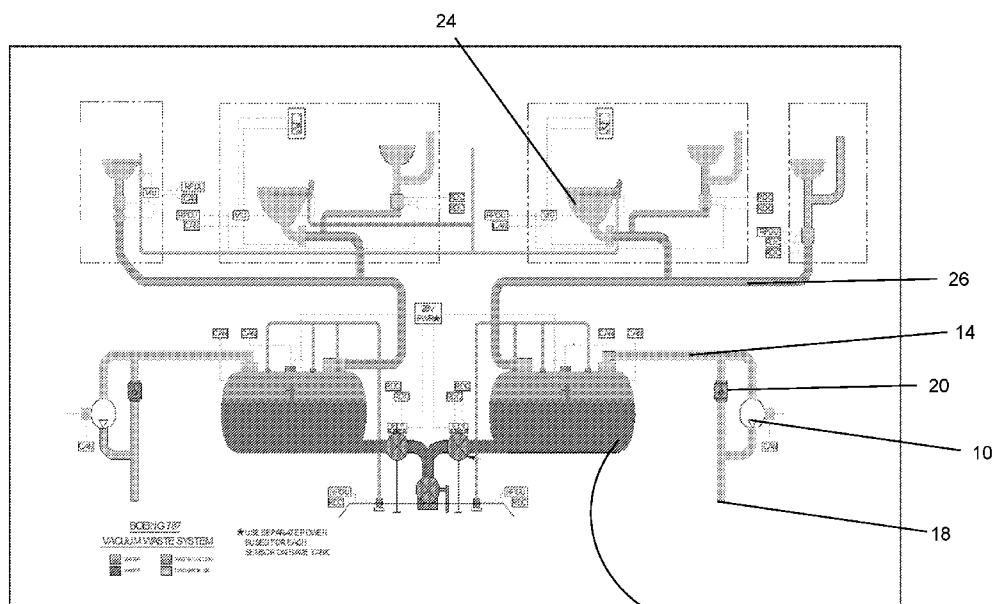


FIGURE 1

(57) Abstract: Use of an aircraft waste system vacuum generator (10) to provide electrical power back to the aircraft. Typically, a vacuum generator is required to create a pressure differential for flushing when an aircraft is on ground or at low altitude. When the aircraft is in flight at higher altitudes, a pressure differential between the cabin and the air outside the aircraft creates the vacuum required for flushing, and the vacuum generator is not needed. This disclosure identifies a way to harvest energy from the vacuum generator when it otherwise would not be in use without increasing the existing burden on the air cabin pressure management system.

EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,  
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,  
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,  
KM, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17:**

— *of inventorship (Rule 4.17(iv))*

**Published:**

— *with international search report (Art. 21(3))*

## **USE OF AIRCRAFT WASTE SYSTEM VACUUM GENERATOR TO PROVIDE ELECTRICAL POWER**

### **CROSS REFERENCE TO RELATED APPLICATIONS**

**[0001]** This application is related to and claims priority benefits from U.S. Provisional Application Serial No. 62/820,781, filed on March 19, 2019, entitled “Using the Waste System Vacuum Generator to Provide Electrical Power Back to the Aircraft,” the entire contents of which is hereby incorporated by this reference.

### **FIELD OF THE INVENTION**

**[0002]** The field of this disclosure relates to use of an aircraft waste system vacuum generator to provide electrical power back to the aircraft. Typically, a vacuum generator is required to create a pressure differential for flushing when an aircraft is on ground or at low altitude. When the aircraft is in flight at higher altitudes, a pressure differential between the cabin and the air outside the aircraft creates the vacuum required for flushing, and the vacuum generator is not needed. This disclosure identifies a way to harvest energy from the vacuum generator when it otherwise would not be in use.

### **BACKGROUND**

**[0003]** Many vehicles such as passenger aircraft, buses, trains, ships, automobiles, and the like include vacuum toilets. A vacuum generator is required to create a pressure differential for a flush to move waste from the toilet bowl to an on-board waste tank. Because aircraft travel occurs at high altitudes, the on-board vacuum generator is required only to create a pressure differential when the aircraft is on ground or flying at low altitudes. When the aircraft is in flight at higher altitudes, a pressure differential between the cabin and the air outside the aircraft creates the vacuum required for flushing. In these instances during

cruise (which is the majority of the duration of the flight), the vacuum generator is disabled because the cabin differential pressure is sufficient to transfer waste materials from the toilet bowl through waste lines to the waste holding tank. In existing systems, when flushing during cruise and the vacuum generator is not powered, a check valve is automatically activated, redirecting the airflow around rather than through the vacuum generator. This prevents the vacuum generator impeller from spinning. This bypass condition is intended to extend the bearing life of the vacuum generator. If sufficient vacuum is not available from the cabin pressure differential in flight, activating the vacuum generator will automatically close the check valve.

### SUMMARY

**[0004]** The present inventor has identified a way to harness energy that is not currently being captured. Rather than preventing the vacuum generator impeller from spinning when the vacuum generator is not in use, this disclosure uses spinning of the vacuum generator impeller during flight in order to generate power.

**[0005]** The terms “invention,” “the invention,” “this invention” “the present invention,” “disclosure,” “the disclosure,” and “the present disclosure,” used in this patent are intended to refer broadly to all of the subject matter of this patent and the patent claims below. Statements containing these terms should be understood not to limit the subject matter described herein or to limit the meaning or scope of the patent claims below. Embodiments of the invention covered by this patent are defined by the claims below, not this summary. This summary is a high-level overview of various aspects of the invention and introduces some of the concepts that are further described in the Detailed Description section below. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in isolation to determine the scope of the claimed

subject matter. The subject matter should be understood by reference to appropriate portions of the entire specification of this patent, any or all drawings and each claim.

[0006] According to certain embodiments of this disclosure, there may be provided a method for generating electrical power through a vacuum generator onboard an aircraft, wherein the vacuum generator comprises an impeller that is managed by a check valve, the method comprising: deactivating the check valve when the aircraft is at a sufficient altitude that a vacuum flush can be activated without the need for activation of the vacuum generator which allows the impeller to spin freely, and harnessing energy created by spinning of the impeller.

[0007] The impeller may be is connected to a motor and airflow entering via the check valve can spin the impeller and cause the motor to become an air-driven electrical generator. In a specific example, the motor is a brushless direct current motor. The energy created by spinning of the impeller can be harnessed by an internal DC link storage capacitor or a battery.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0008] Figure 1 is a diagram of an aircraft waste system.

[0009] Figure 2 shows a schematic of an aircraft waste system.

[0010] Figure 3 shows an exploded perspective view of a vacuum generator.

### **DETAILED DESCRIPTION**

[0011] This disclosure provides a method of harnessing energy that is not currently being captured on an aircraft. Aircraft are generally equipped with a vacuum generator in order to generate sufficient vacuum for toilet flushing when the aircraft is on ground or flying at low altitudes. At these times, the vacuum generator is activated in order to create a pressure differential for a vacuum flush. However, when the aircraft is in flight at altitudes

that are high enough that create a pressure differential between the aircraft cabin and the outside atmosphere, the vacuum generator is not required to create a pressure differential, because the atmospheric pressure differential exists due to the altitude. Accordingly, when an aircraft is in flight, the impeller of the vacuum generator is prevented from spinning via a system check valve. In other words, the vacuum generator is idle for the majority of the flight.

**[0012]** Referring now to Figure 1, a general operation of the vacuum generator system is described for perspective of this disclosure. During ground operation (provided the vacuum waste system is not being serviced), pressing a flush switch will initiate a waste transfer sequence. First, the vacuum generator 10 is started and begins to reduce the pressure in the waste tank 12 through a line 14 connecting the vacuum generator inlet to a water separator on top of the waste tank 12. Tubing 16 connects the vacuum generator outlet 18 to a port that penetrates the aircraft skin. A check valve 20 blocks airflow around the vacuum generator 10 during ground operation. In use, when the waste tank pressure drops, the toilet begins to rinse. After a few seconds, the toilet flush valve opens, providing a path from the toilet bowl 24 to the main waste line 26 that carries the contents to the waste tank 12. The toilet flush valve remains open for a few more seconds and the vacuum generator 10 is then disabled. At sufficiently high cruising altitudes, the check valve 20 is activated, which prevents operation of the vacuum generator 10 by preventing the impeller from spinning.

**[0013]** The present disclosure modifies the way that the check valve 20 is operated during flight cruising altitudes, during times when the vacuum generator 10 does not need to operate (because the waste flush system operates via pressure differential created during flight at certain altitudes). If the system check valve is omitted, or activation of the system check valve(s) 20 is inhibited, a significant mass of air at a high velocity will pass overboard

through the vacuum generator 10 during flushing at cruising altitude. This flow is due to the high differential pressure present at altitude due to the narrow flow path (which is typically about 2" diameter) of the waste tank vent lines. This airflow will spin the impeller 30 of the vacuum generator 10 and its connected motor 32 to create rotational energy. The motor 32 then becomes an air-driven electrical generator. In certain embodiments, the motor 32 is a brush-less direct current (BLDC) motor. Impulses from the rotor magnets passing by the stator coils of the motor may be rectified and present to the internal DC link storage capacitors.

**[0014]** Accordingly, rather than inhibiting the vacuum generator impeller 30 from spinning when the vacuum generator 10 would typically not be in use, this disclosure uses spinning of the vacuum generator impeller 30 during flight in order to generate power. Without release of the impeller 30 from its locked position, the potential energy that could be created during toilet flushing is not collected. By releasing the impeller 30 from its locked position, the energy harvested from the force of the cabin to atmosphere differential pressure across the vacuum generator 10 is not otherwise wasted or simply sent overboard. Instead, the energy can be captured and used for performing functions in relation to the waste system components or elsewhere on the aircraft. This is energy that would otherwise not be available and can be considered "free." This waste energy can be recovered, allowing for reduction of overall power consumption by the system. Because this airflow is normally wasted, there is no additional burden on the ECS (environmental control system) or cabin pressurization systems to recover it. Further, because the vacuum generator is standard equipment required for passenger service, very little modification is required to the design in order to accomplish this energy harvest and conditioning for export to connected systems. Primarily, removal of the system check valve 20 or a system that can release the check valve

20 is provided. This allows the vacuum generator system to function as an electrical power generator.

**[0015]** In one example, the peak power generated during toilet flushing is estimated to be in the range of about 3kW to 5kW for about 6 seconds. The peak power generated during a sink flushing may be about 1kW because the sink flush is a shorter cycle and the orifice is smaller. The energy produced by this configuration is several orders of magnitude greater than the flea power available from distributed piezo MEMS harvesters which depend on aircraft vibrations for motivation. In the typical embodiment, exported power could be conditioned for distribution to devices powered by 28VDC.

**[0016]** Frequency of flushing depends on the flight profile, but given a means of energy storage, the total energy recovered could potentially power the waste system in flight including all toilets, sink drains, and sensors in the waste system.

**[0017]** Synchronization and delivery back to the aircraft AC bus may not be possible with the existing Vienna Rectifier topology of the B787 VG. However, DC/DC conversion from the DC link is possible and straightforward. There are other energy harvesting devices that may be used to store the energy created. Given sufficient energy storage, the waste system 28VDC could be unburdened from the aircraft bus excepting the B787 VG 235VAC bus use on ground.

**[0018]** Application of this technology is practical with little risk or impact to existing system conventions. Development and installation on board can be supported by existing devices and known power topologies / technologies. Additionally, waste energy recovery appeals to green sensibilities and corporate responsibility.

**[0019]** The subject matter of certain embodiments of this disclosure is described with specificity to meet statutory requirements, but this description is not necessarily intended to

limit the scope of the claims. The claimed subject matter may be embodied in other ways, may include different elements or steps, and may be used in conjunction with other existing or future technologies. This description should not be interpreted as implying any particular order or arrangement among or between various steps or elements except when the order of individual steps or arrangement of elements is explicitly described.

**[0020]** It should be understood that different arrangements of the components depicted in the drawings or described above, as well as components and steps not shown or described are possible. Similarly, some features and sub-combinations are useful and may be employed without reference to other features and sub-combinations. Embodiments of the invention have been described for illustrative and not restrictive purposes, and alternative embodiments will become apparent to readers of this patent. Accordingly, the present invention is not limited to the embodiments described above or depicted in the drawings, and various embodiments and modifications may be made without departing from the scope of the claims below.

## CLAIMS

That which is claimed is:

1. A method for generating electrical power through a vacuum generator (10) onboard an aircraft, wherein the vacuum generator comprises an impeller (30) that is managed by a check valve (20), the method comprising:

deactivating the check valve (20) when the aircraft is at a sufficient altitude that a vacuum flush can be activated without the need for activation of the vacuum generator (10) which allows the impeller (30) to spin freely, and

harnessing energy created by spinning of the impeller (10).

2. The method of claim 1, wherein the impeller (30) is connected to a motor (32) and wherein airflow entering via the check valve spins the impeller and causes the motor to become an air-driven electrical generator.

3. The method of claim 2, wherein the motor is a brushless direct current motor.

4. The method of claim 1, wherein the energy created by spinning of the impeller is harnessed by an internal DC link storage capacitor or a battery.

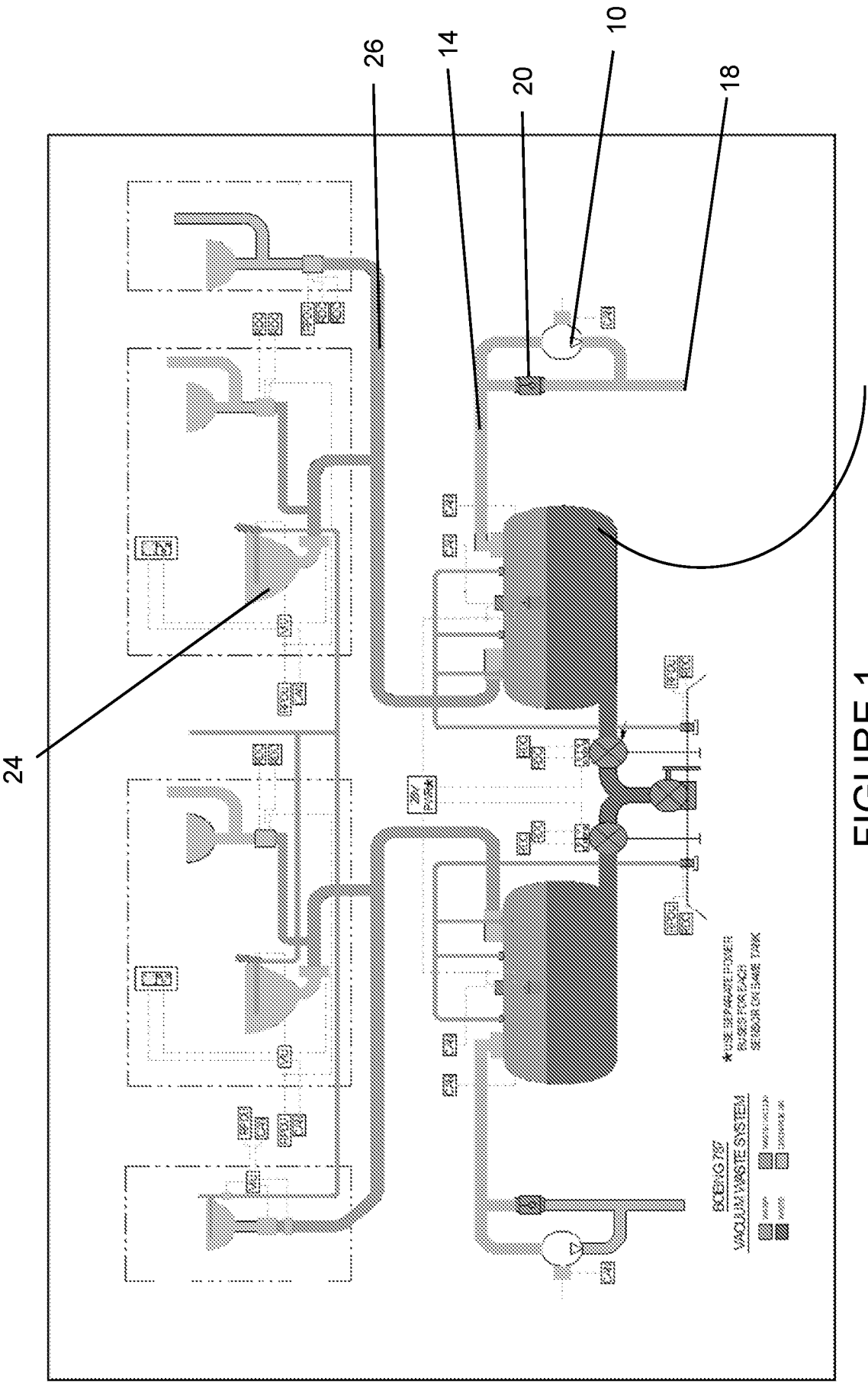


FIGURE 1

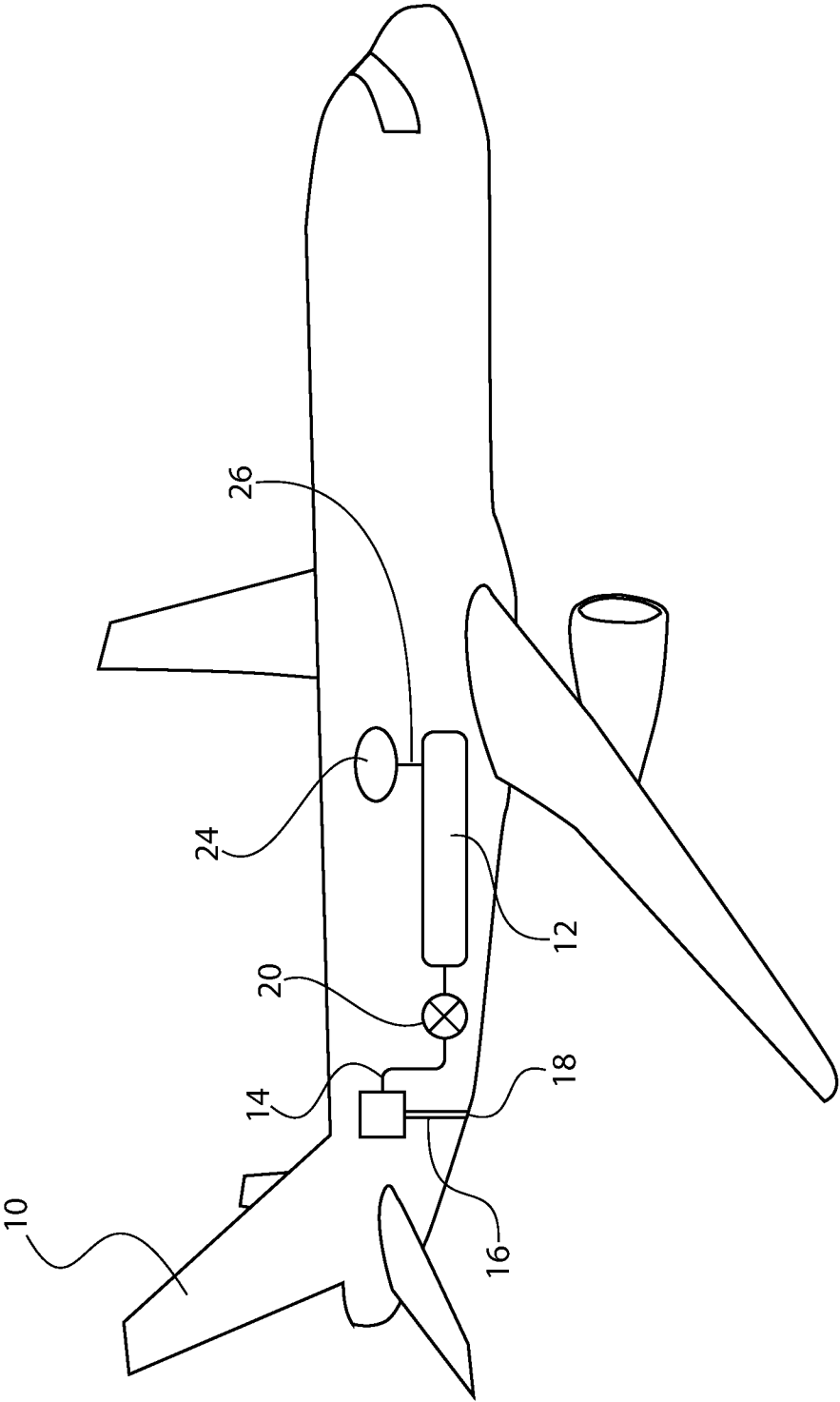


FIG. 2

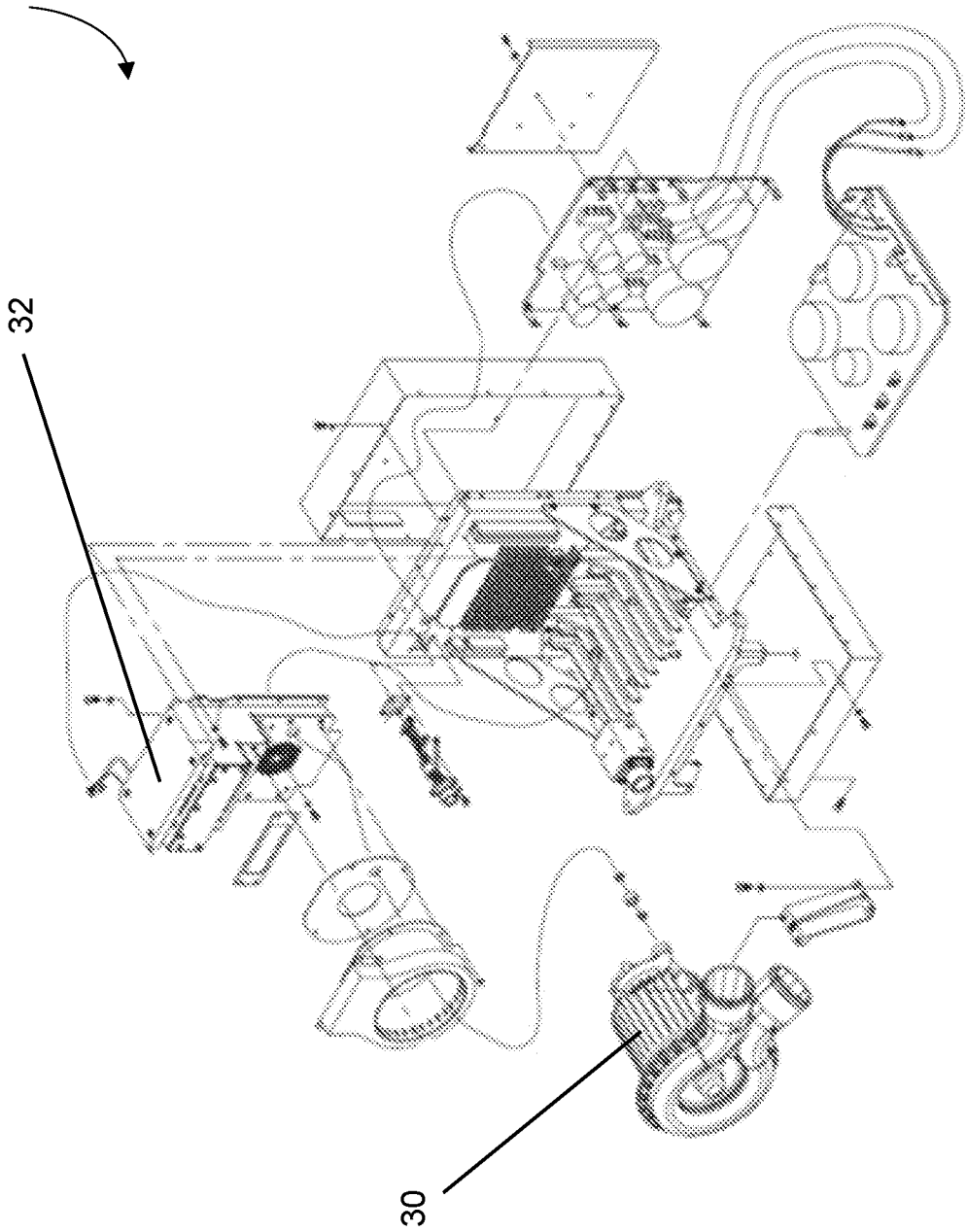


FIGURE 3

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2020/023512

A. CLASSIFICATION OF SUBJECT MATTER  
INV. B64D11/02 B64D41/00  
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
B64D F04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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|-----------|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | US 2017/341770 A1 (HILLER NATHAN D [US])<br>30 November 2017 (2017-11-30)<br>figures 1, 2, 3A, 3B<br>-----                                 | 1-4                   |
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Further documents are listed in the continuation of Box C.



See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

5 June 2020

Date of mailing of the international search report

29/06/2020

Name and mailing address of the ISA/

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## INTERNATIONAL SEARCH REPORT

International application No  
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| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                       |                       |
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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2020/023512

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