(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 763 633 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
19.03.1997 Bulletin 1997/12

(51) Int. Cl.[6]: **E03F 1/00**, E03D 5/00

(21) Application number: **95306394.8**

(22) Date of filing: **13.09.1995**

(84) Designated Contracting States:
AT CH DE DK FR IT LI

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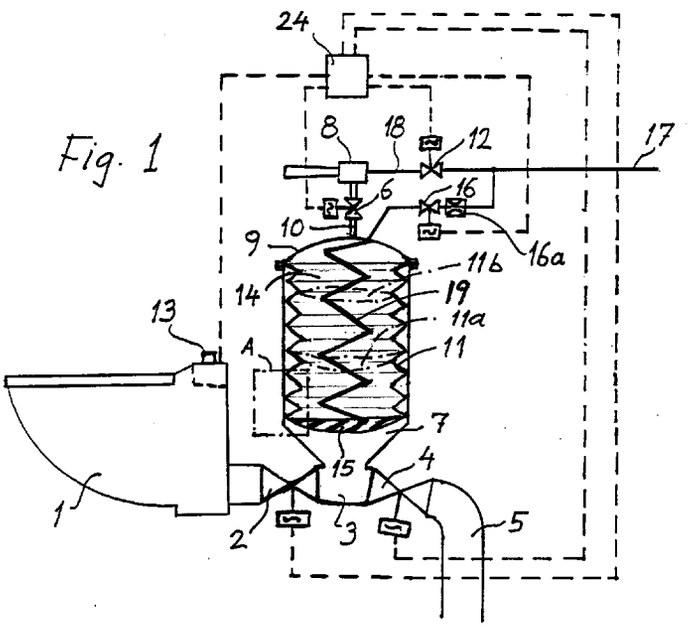
(54) Membrane controlled vacuum sewer system

(57) In a vacuum sewer system the vacuum required for transport of waste material from a waste-producing unit (1) via a sewer valve (2) into a sewer pipe (3) is generated in the sewer pipe (3) by connecting the sewer pipe (3) to a pressure chamber (9) which contains a movable air-impermeable membrane (11). An ejector (8), operated by compressed air, can be used to collapse a bellows-type membrane (11) in the pressure chamber (9) to draw waste material into the sewer pipe (3). Subsequent re-expansion of the membrane (11) can be effected with compressed air or by resilient means (19) to aid in expelling waste material from the sewer pipe (3) into a discharge tube (5).

Fig. 1



EP 0 763 633 A1

Description

This invention relates to a vacuum sewer system of the kind referred to in the preamble of claim 1.

One problem in vacuum sewer systems is that the sewer pipe must be kept under a considerable partial vacuum in order to generate the transport function typical for such sewer systems, whereas the sewage collecting tank should desirably be under atmospheric pressure, because the demands on tank strength are then lower and emptying of such a tank is a simpler procedure. Known solutions for obtaining such an arrangement are relatively complicated and expensive, see US-A-4,184,506, US-A-4,297,751 and US-A-4,034,421.

Another problem in vacuum sewer systems is that air drawn from the sewer pipe has a bad odour. Air filters have been used as a remedy, (EP-A-555984), but such filters are expensive and their effective life-time is relatively short.

An aim of the invention is to simplify the equipment needed in small vacuum sewer systems for toilets, where the collecting tank is kept mainly at atmospheric pressure. This aim is secured by the means disclosed in claim 1. The basic idea is to make the portion of the sewer pipe that is put under partial vacuum very short and to compensate for the radical decrease in available vacuum volume caused by the shortness of the sewer pipe by connecting a pressure chamber containing a movable air-impermeable membrane to the sewer pipe. By means of controlled pressure activation of the membrane every phase of the transport of waste material from a toilet or the like to a collecting tank can be carried out in a convenient manner.

The portion of the pressure chamber between the membrane and the short sewer pipe can be considered as the "unclean portion" and the portion on the opposite side of the membrane can be considered as the "clean portion". The short sewer pipe is normally, at its upstream and downstream ends, closed by shut-off valves. Under these conditions, removing air from the clean portion of the pressure chamber expands the unclean portion to a balanced position, in which the pressure on both sides of the membrane is the same. This produces a partial vacuum in the short sewer pipe. In this state the system is ready to receive a batch of waste material from a toilet or other waste-producing unit connected to the short sewer pipe. The shut-off valve at the upstream end of the short sewer pipe (ie the sewer valve) may now be opened. It is of advantage that there is still some available free space in the clean portion of the pressure chamber, so that continued expansion of the unclean portion of the pressure chamber can take place. Such continued expansion arises when the pressure in the short sewer pipe increases as waste material and air from a toilet bowl or the like flows into the sewer pipe. This continued expansion makes the emptying of a toilet bowl or the like significantly more efficient. The means decreasing the pressure in the clean portion of the pressure chamber should preferably be active during the entire emptying phase, that is, all the time the sewer valve is open. It is feasible and in many cases also desirable that a portion of the waste material drawn from a waste-producing unit is taken up by the unclean portion of the pressure chamber.

When the unclean portion of the pressure chamber has achieved its maximum expansion, the sewer valve may be closed and the shut-off valve at the downstream end of the short sewer pipe may be subsequently opened. The waste material may then flow freely due to gravity or, alternatively, the clean portion of the pressure chamber may be pressurized to drive the material from the sewer pipe. The membrane transmits the pressure existing in the clean portion of the pressure chamber to the unclean portion including the short sewer pipe, where the rising pressure enhances the flow of material out from the short sewer pipe. Such a flow-enhancing pressure may also be obtained by resilient means (eg by having a spring acting on the membrane for urging the membrane back to its initial position).

Since the entire control of the vacuum sewer system is carried out from the clean portion of the pressure chamber, only clean air is used for flow control and the risk for transmitting bad odours to the surroundings is thereby minimized. However, all the advantages typical of a vacuum sewer system are still enjoyed. Typically, the waste transport is rapid and effective, is easy to control and may take place through a small diameter sewer pipe and even in an upward direction, if required. For toilet bowls, a recommended sewer pipe inner diameter is between 40 and 50 mm.

There are known systems which operate in a manner somewhat similar to that of the invention. The Danish company Semco Odense AS markets a vacuum sewer system called SEMLET, in which a pump-like arrangement is used that, like a diaphragm pump or a piston pump, has a moving pump element driven by a mechanical member to cause a pump stroke that expands a space connectable to a toilet bowl on opening of a sewer valve. When a certain expansion of the space has occurred, a substantial vacuum has been created in the space. Then the sewer valve is opened and the toilet bowl is emptied in a manner typical for vacuum sewer systems. The expansion of the space may continue after the sewer valve has been opened. When the toilet bowl has been completely emptied, the sewer valve is closed, and subsequently a closed valve present in the sewer pipe downstream of the pump is opened. The pump element now moves in the opposite direction and carries out a pump stroke compressing the space, thereby pressing sewage out from the space. This kind of pump-like arrangement can be distinguished from an arrangement according to the invention, in which a membrane, controllable by pneumatic forces to take different pressure balance positions, controls the whole process.

In a system according to the invention it is advisable to dimension the pressure chamber and the membrane so that the movement of the membrane causes a

change of volume in a range or about 2 to 15 litres, preferably 5 to 10 litres. This change in volume is well sufficient for a system with one toilet bowl. If two toilet bowls, for example, situated at opposite sides of a separating wall, are connected to one sewer system according to the invention, a somewhat larger change in volume in the pressure chamber is recommended. Alternatively, the emptying functions of the toilet bowls may be controlled so that both toilet bowls cannot be emptied at the same time.

It is recommended to maintain the means for reducing the pressure in the clean portion of the pressure chamber in operation for at least as long as the sewer valve is open. The pressure reducing means may be an ejector driven by compressed air. Such an ejector can, in a few seconds, produce a vacuum causing the desired expansion of the unclean portion of the pressure chamber. Usually, such an ejector is driven by an air pressure of approximately 4 to 6 bar gauge and is able to decrease the pressure in the pressure chamber to less than half an atmosphere, which is quite sufficient for emptying a toilet bowl. The most convenient manner of operating the ejector is to activate it separately for each emptying of a toilet bowl or other waste-producing unit. In a system according to the invention, the ejector needs about 8 to 35 litres of air (the volume being calculated at room temperature and atmospheric pressure). In a well adjusted system, 10 to 15 litres of air are normally sufficient.

The membrane of the pressure chamber is preferably arranged in a pressure vessel of substantially circular cylindrical form. It is convenient to use a membrane in the form of a sack with bellows-like folds. The open end of the sack can be attached to the end of the pressure vessel that is remote from the sewer pipe. The folds of a bellows-type membrane may lightly touch the cylindrical inner surface of the pressure vessel. In this way the folds provide a scraping function that keeps the cylinder wall clean. In order to enhance this function, the outwardly directed folds may be provided with stiffening rings or the like, the purpose of which is to prevent a reduction in the outer diameter of the folds during the movement of the membrane, so that the contact between the folds and the cylinder wall is maintained in all positions of the membrane. In order to additionally improve the efficiency of the scraping function of the membrane, the closed end of the sack may be provided with a peripheral flexible lip sliding with some outward pressure against the cylinder wall.

The membrane may be so rigid that by itself it has a spring function, but it may also be urged towards its expanded condition by a separate spring member. Other embodiments of the membrane are also feasible. The membrane may, for example, be formed as a partition wall or as an expansive pipe. It may be expansive, foldable or rollable. For obtaining a suitable guided movement of the membrane, it may be provided with some stiffer portions reducing the flexibility of the membrane at points where less movement is desired.

The sewer pipe may be so short that its connection to the pressure chamber takes up almost the full length of the pipe. In that case the unclean portion of the pressure chamber will partly act as a temporary waste-collecting chamber for at least a portion of the waste material drawn from a waste-producing unit during an emptying cycle.

The invention will now be described in more detail with reference to the accompanying drawing, in which

Fig. 1 shows a schematical illustration of a vacuum toilet system according to the invention,
and Fig. 2 shows the portion A of Fig. 1 on a larger scale.

The vacuum toilet system shown is intended for installation in a passenger transport unit such as a railroad car, a bus or the like. Vacuum is generated separately just before each emptying of the toilet bowl. The system includes a toilet with a toilet bowl 1 that is connected to a short sewer pipe 3 through a normally-closed sewer valve 2. The sewer pipe 3 is in free connection with a portion 7 of variable volume in a chamber 9 and is closed at its downstream end by a valve 4 that separates the short sewer pipe 3 from an extension 5 thereof that leads to a collection tank, an outlet or the like (not shown).

The vacuum generator of the system is an ejector 8 that extracts air from a pressure chamber 9 through an evacuation duct 10. The inner space of the pressure chamber is divided by a movable rubber membrane 11 into two portions. The portion 7 (which is an unclean portion) and a clean portion 14. The ejector 8 is driven by pressurized air received from a compressed air network 17 via a solenoid valve 12. The compressed air network 17 is also connected to another solenoid valve 16 operable to pressurize the clean portion 14 of the pressure chamber with compressed air. The air feed duct 18 of the ejector is controlled by the valve 12 and the evacuation duct 10 is controlled by a solenoid valve 6. For avoiding excessive pressurization of the pressure chamber 9, the flow duct passing through the valve 16 is provided with a pressure reduction means 16a. All the valves mentioned are remote controlled. A flush button 13 arranged at or near the toilet bowl 1 is connected to a control unit 24 that controls the different functions of the system by operating the remote controlled valves of the system.

A toilet emptying sequence is started by operating the flush button 13. Thereby an impulse is sent to the control unit 24 which opens the valve 12 and allows compressed air to flow through the ejector 8. This creates, in a few seconds, a partial vacuum of approximately 60% of atmospheric pressure (absolute pressure approximately 0,4 bar) in the clean portion 14 of the pressure chamber, which moves the membrane 11 upwards to a pressure balance position 11a creating essentially the same vacuum in the space portion 7. The sewer valve 2 is now rapidly opened and the waste present in the toilet bowl 1 is instantaneously pressed by the atmospheric pressure into the sewer pipe 3. This

causes a rise in pressure in the pipe 3 and in the space portion 7, that causes the membrane 11 to move further upwards to a position 11b. This second movement will be faster and more positive if the ejector 8 is still operating during this phase. A less favourable alternative is to disconnect the ejector 8 when the maximum vacuum level has been reached and the valves 6 and 16 are kept closed.

When all the waste has been removed from the toilet bowl 1, the sewer valve 2 is closed and the valve 4 is opened. The sewage present in the pipe 3 and the space portion 7 may now flow into the pipe 5. Further transport of the waste material may be enhanced by pressurizing the portion 14 of the pressure chamber space. An alternative is to provide a pressure spring 19 urging the membrane downwards and/or to use a membrane that itself functions as a pressure spring. In that case pressurizing of the space 7 is obtained merely by closing down the ejector 8 and by keeping the valve 6 open, provided that the ejector 8 allows ambient air to flow into the portion 14 when the ejector is closed down. If this is not possible, another air flow duct must be provided. If the portion 7 is not pressurized, or is pressurized only by means of a spring force, the valve 6 may be totally omitted as well as the valve 16 and its piping.

A bottom portion 15 of the membrane 11, forming the upper boundary of the space portion 7, is preferably made of thicker material. It may then provide a suitable support for a pressure spring 19 arranged to urge the membrane 11 downwards should such a spring be required.

The presence of a spring 19 and/or the inherent rigidity of the membrane 11 results in the pressure on opposite sides of the membrane 11 not being exactly the same in the pressure balanced positions of the membrane but this usually has no significance for the functioning of the arrangement.

Fig. 2 shows how each outer fold of the membrane 11 can be provided with a strengthening ring 20 of steel or some other suitable material. Without such rings, the outer diameter of the folds can decrease during axial expansion of the membrane so that contact between the membrane folds and the wall of the pressure chamber 9 will be lost. The rings 20 keep the outer diameter of the folds practically constant. At the lowermost outwardly directed fold there is a peripheral lip 21 that slides against the inner surface of the pressure chamber and clears it of any impurities drawn in from the sewer pipe 3.

In connection with an emptying sequence, the toilet bowl 1 is provided with a desired amount of rinse liquid for rinsing and cleaning the inner surface of the bowl. This arrangement is not illustrated because it is known art and is not part of the inventive concept.

The invention is not to be considered as being limited to the embodiment illustrated since several variations thereof are feasible including variations which have features equivalent to, but not necessarily literally within the meaning of, features in any of the following claims.

Claims

1. A vacuum sewer system including at least one waste-producing unit (1), for instance a toilet bowl, with an outflow opening and a normally-closed sewer valve (2) near the outflow opening, which sewer valve directly connects the unit (1) to the upstream end of a short sewer pipe (3) having at its downstream end another normally-closed valve (4) and being, between the valves (2,4), in connection with a chamber (7) of variable volume, which chamber together with the sewer pipe (3) is provided with means for generating therein, when said valves (2,4) are closed, a partial vacuum of such a magnitude, that waste material from the unit (1), in a momentary manner, is pressed into the sewer pipe (3) by the pressure of ambient air when the sewer valve (2) is opened, **characterized in that** the means for generating partial vacuum includes a flexible membrane (11) movable in a pressure chamber (9), of which a first portion (7) forms the chamber of variable volume, said membrane (11) being on its side remote from the first portion (7) of the pressure chamber subjected to the influence of operating pressure fluctuations causing, when the operating pressure is reduced and said valves (2,4) are closed, the membrane (11) to move to a pressure balance position basically determined by the pressure difference prevailing across opposite sides of the membrane (11) thereby creating said partial vacuum in the first portion (7) of the pressure chamber, and in the sewer pipe (3) and in that, subsequently, when said operating pressure is again increased and the sewer valve (2) is closed said another valve (4) at the downstream end of the sewer pipe (3) is open, the membrane (11) is caused to move back towards its initial position, thereby, if the membrane is loaded, generating an overpressure in the sewer pipe (3) for enhancing further transport of waste material present in the sewer pipe (3) by means of said over pressure.

2. A system according to claim 1, **characterized in that**, when the membrane (11) is in its pressure balance position, there is a free space portion (14) at the operating pressure side of the membrane allowing the membrane (11) to move further in a direction enlarging the first portion (7) of the pressure chamber, when the pressure in the first portion (7) increases under the influence of waste material and air entering the sewer pipe (3) while the sewer valve (2) is open.

3. A system according to claim 1 or 2, **characterised in that** the membrane (11) has a freedom of movement which allows volume changes in the pressure chamber (9), on each side of the membrane (11), in

the range 2 to 15 litres, preferably 5 to 10 litres.

4. A system according to any preceding claim, **characterised in that** the means providing pressure operation of the membrane includes a device (8) for providing partial vacuum, which device (8) is arranged to be in operation for at least substantially the whole time the sewer valve (2) is open and preferably is arranged to decrease the operating pressure acting on the membrane (11) to at least approximately half the pressure of the ambient air.

5. A system according to any preceding claim, **characterised in that** the means (8) for generating partial vacuum in the sewer pipe (3) is arranged to be activated immediately before each desired emptying of the unit (1).

6. A system according to any preceding claim, **characterised in that** the system includes an air driven ejector (8) as the source of partial vacuum.

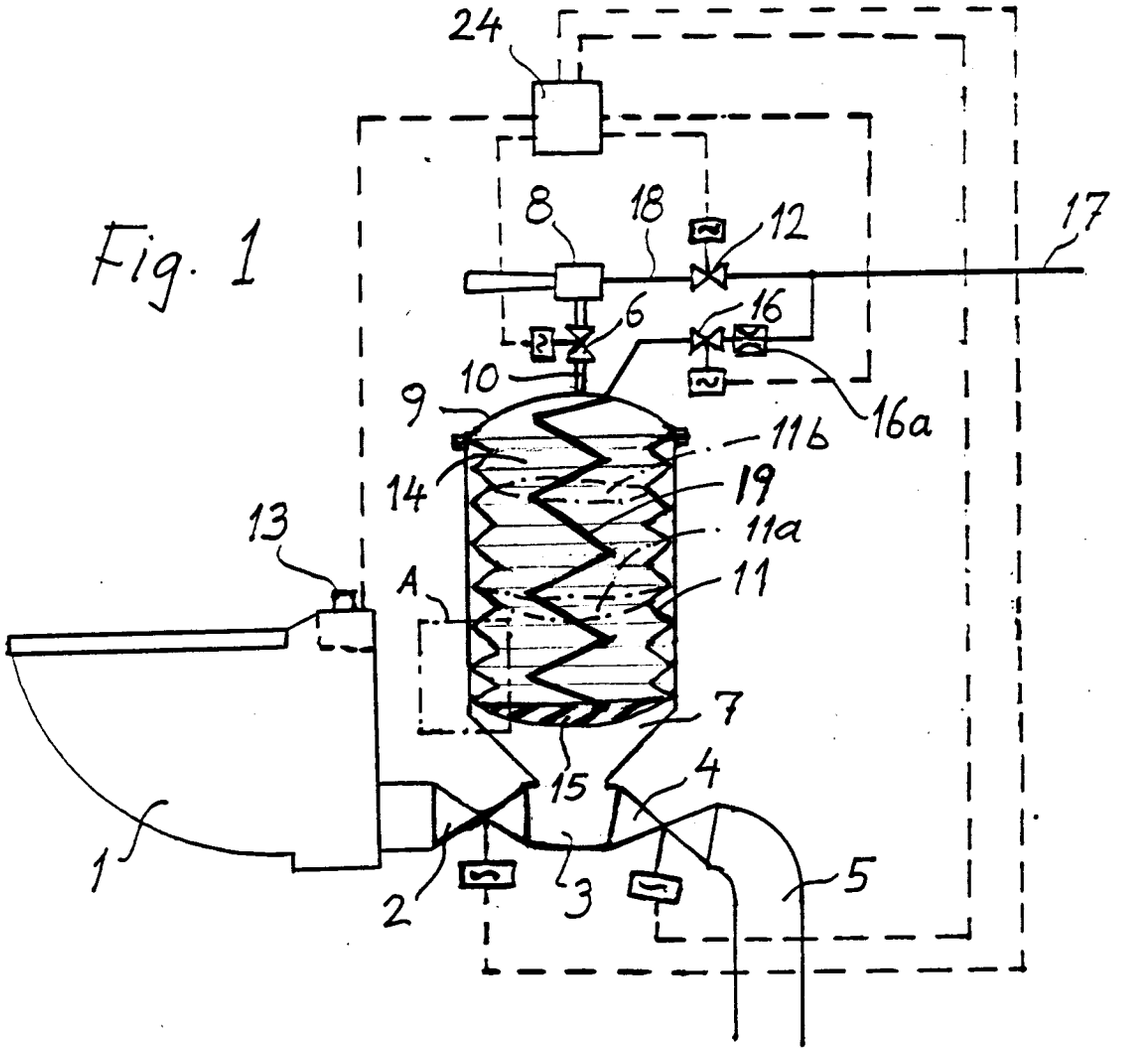
7. A system according to any preceding claim, **characterised in that** the membrane has the form of a folded bellows (11) moving axially in a substantially cylindrical pressure chamber (9), the folds of the bellows preferably receiving guidance by contacting the cylindrical inner surface of the pressure chamber (9).

8. A system according to claim 7, **characterized in that** at least some of the outwardly directed folds of the bellows (11) are provided with strengthening rings (20) or the like, which cause the outer diameter of the folds to remain substantially constant during the movement of the bellows.

9. A system according to claim 7 or 8, **characterized in that** the bellows, at its movable end facing the first portion (7) of the pressure chamber, is provided with a flexible peripheral lip (21) sliding against the inner surface of the pressure chamber (9).

10. A system according to any preceding claim, **characterised in that** the membrane (11) itself acts as a spring member, or is loaded by a spring member (19), in a direction towards the first portion (7) of the pressure chamber, thereby causing overpressure therein and in the sewer pipe (3), when the operating pressure acting on the membrane (11) is the same or closely the same as the pressure of the ambient air.

Fig. 1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16a
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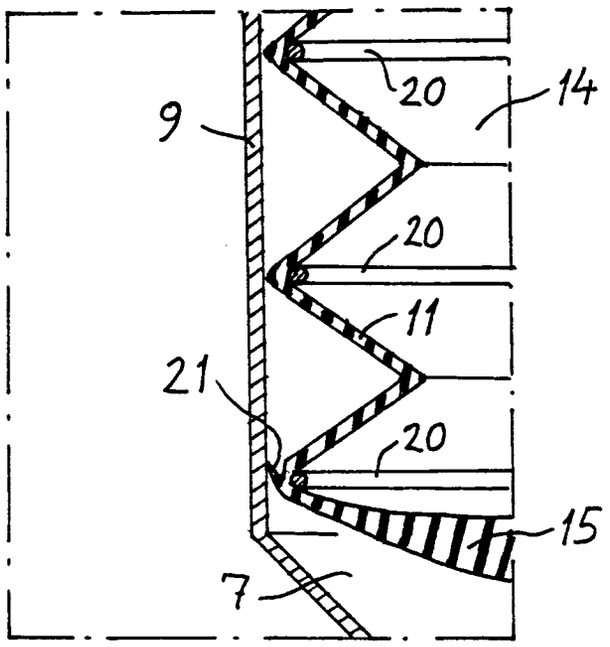
Fig. 2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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 30 6394

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DE-U-91 11 247 (SEMCO) * page 3, line 1 - page 4, line 16; figure 1 *	1	E03F1/00 E03D5/00
A	FR-A-2 516 119 (SOTERKENOS) * page 4; figure 2 *	10	
A	US-A-2 865 028 (PATENAUDE)		
A,D	US-A-4 297 751 (OLIN)		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

E03F
E03D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 February 1996	Hannaart, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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