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(54) **Title:** GRAVITY SEWER DEVICE - SELF-FLUSHING INVERTED SIPHONS, METHOD OF OVERCOMING WATER-COURSES OR SIMILAR UNDERGROUND OBSTACLES AND USE OF THIS DEVICE

FIG. 2

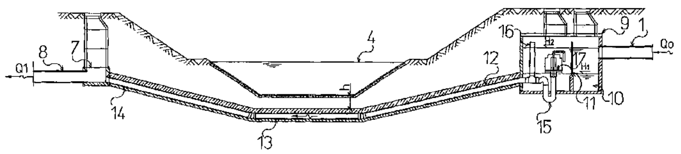
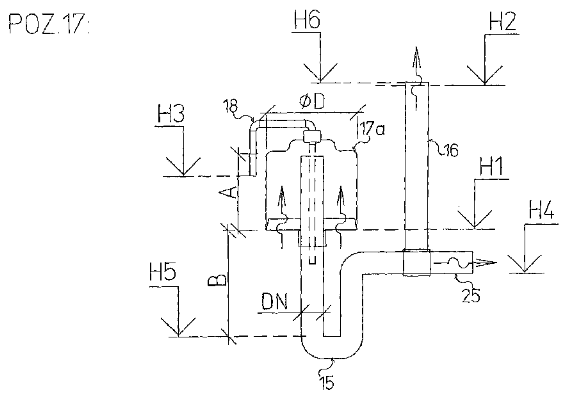


FIG. 3



(57) **Abstract:** The invention relates to a gravity sewer device comprising a self-flushing weir forming a section of gravity sewer that crosses under a watercourse or similar underground obstruction. A self-flushing weir according to the present invention forming a section of gravity sewer which crosses under a watercourse or similar underground obstruction is shown graphically in Figure 2 and compared with the conventional weir design in Figure 1, comprising one or more inlet chambers 9 connected to a (downstream) descending leg 12 of the sewer pipe, a crossing 13, an (upstream) ascensing leg 14 of the sewer pipe and an outlet shaft 7, wherein an automatic flushing bell 17 or 20 is located in the inlet chamber 9. The automatic flushing bell 17 (alternatively in embodiment 20), which includes a siphon conduit 15 and a siphon conduit 16 deaeration, provides a periodic alternation of two phases, accumulation

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Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
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and overflow, wherein the water level in the accumulation inlet chamber 9 varies between HI and H2, the filling rate (or flow rate) is Q(0), and the overflow rate (or flow rate) is Q(l). The level difference H2-H1 is the driving energy of the overflow, it has to be chosen with respect to the length of the header and the local resistances on the pipe so that the effective velocity v(ef) does not fall below 1.0 m.s-1, an indicative value for the correlation calculation can be considered H2-H1=0.5 m.

Gravity sewer device - self-flushing inverted siphons, method of overcoming watercourses or similar underground obstacles and use of this device

Technical Field

The invention relates to a gravity sewer device for overcoming watercourses or similar underground obstacles, so-called inverted siphons consisting of one or more inlet shaft chambers with an automatic flushing bell, connected to a descending leg of a sewer conduit, crossing an ascending leg of a sewer conduit and an outlet shaft, wherein the automatic flushing bell ensures the filling and emptying of the working volume of the shaft, and the waste water is periodically discharged under increased pressure and at high speed into the sewer conduit of the inverted siphon.

Background Art

The most commonly used method and technical equipment for overcoming watercourses or similar underground obstacles is the inverted siphon. When the term "liquid" is used below, this means in particular wastewater or rainwater, however, various other admixtures do not affect the scope of the definition of this term.

The standard arrangement of the sewer inverted siphon is shown in Fig. 1. The wastewater flows through the gravity conduit 1 at the flow rate Q(0) into the upper inlet chamber 2, which forms the transition from the sewer conduit to the inverted siphon. The inverted siphon itself consists of the descending conduit leg 3, a horizontal, resp. slightly inclined part forming the crossing 5 under the watercourse 4 or a similar underground obstacle, and the ascending conduit leg 6. The inverted siphon leads to the lower outlet shaft chamber 7, which must always be located lower than the

upper inlet chamber. The wastewater flows out of the shaft chamber 7 through the gravity conduit 8 at the flow rate Q(0).
From the point of view of physics, the inverted siphon works on the principle of connected vessels and Bernoulli's equation.

From a practical point of view, the usable diameters of the inverted siphon conduits cannot be minimized, particularly due to their possible clogging and subsequent blockage.

After more than a hundred years of operational experience, standardized technical and hydraulic requirements for inverted siphons have been standardised around the world: minimum profile (inner diameter) of inverted siphon DN200, slope of the crossing conduit at least 6.0 ‰ towards the outlet conduit leg, slope of the outlet leg 1:5, however, it must not be greater than 1:3, the velocity of the water flow in the inverted siphon shall not fall below v(ef)=0.75 $m.s^{-1}$ for mixed rainwater and sewage and v(ef)=1.0 $m.s^{-1}$ for sewage water.

These technical and hydraulic conditions determine the use of inverted siphons for crossing watercourses or similar underground obstacles for sewerage systems with a continuous flow of more than Q(0)=25 $l.s^{-1}$, which corresponds to internal diameter DN200 with effective flow velocity v(ef)=0.75 $m.s^{-1}$.

In the case of smaller sewerage systems, the use of an inverted siphon is excluded; instead, a discharging station with a discharge conduit is usually used for crossing, where the wastewater is pumped down the slope only to ensure the passage of the sewage conduit.

Many inventors have tried to solve the problem of low flow velocity and clogging of inverted siphons.

Their solutions can be divided into two basic groups.

The first group consists of solutions that work with the creation of a narrowed point of entry into the inverted siphon and controlled suction of air so as to create a so-called air cushion in the legs of the inverted siphon. This reduces the cross-section of the inverted siphon conduit, which increases the flow rate. The disadvantage of the group of solutions with the air cushion is their technical complexity and thus operational unreliability. Representative of this group of solutions is, for example, JP2006063645A, whose authors are Koda Yoshiharu and Odaka Shiro.

The second group comprises solutions that work with periodic filling of the inlet chamber of the inverted siphon, where the outlet chamber of the inverted siphon has a mechanical conduit closure. It opens in a controlled or automatic manner depending on the state of the water level in the inlet chamber or the water pressure in the outlet chamber. In this group of solutions, the inverted siphon conduit is always filled with water, i.e., without any air cushion. This group is also problematic due to the technical complexity, so it is used mainly for large-diameter inverted siphons.

Representative of the second group of solutions is, for example, CA2529352A1, whose authors are Steinhardt J. M. and Stiehl O.

The objective of the invention is to eliminate the disadvantages of the prior art and to create a simple and operationally reliable sewer system which will be able to function even at a very low flow rate Q(0) without the risk of the crossing conduit clogging under a watercourse or similar underground obstacle.

Summary of the Invention

The shortcomings of the prior art are substantially eliminated and the objective of the invention is fulfilled by the self-flushing inverted siphon according to the invention.

It belongs to the second group of technical solutions of the inverted siphons and works without any air cushion, with a constant cross-section of the conduit and periodic emptying of the inlet chamber of the inverted siphon.

This invention uses a known solution of the Miller flush bell, disclosed in US727990A, US710703A and US761316A.

For the purposes of this invention, the Miller flush bell for use in inverted siphons has been innovatively modified according to exemplary solutions 1 and 2 so as to be able to work in a system of the new technical solution of a self-flushing inverted siphon, which is a modification of the Miller flush bell, hereinafter referred to as the automatic flushing bell 17.

For the purposes of the present invention, the Miller flush bell has been further innovatively modified according to exemplary solutions 3 and 4, which is a variant of the automatic flushing bell, hereinafter referred to as the automatic flushing bell 20.

The self-flushing inverted siphon according to the invention forms a section of a gravity sewer, which crosses a watercourse or a similar underground obstacle, is graphically shown in Fig. 2 and compared with the classic design of the inverted siphon in Fig. 1. It consists of one or more inlet shaft chambers 9 connected to the descending leg 12 of the sewage conduit, the crossing 13, the ascending leg 14 of the sewage conduit and the outlet shaft 7, wherein the automatic flushing bell 17 or 20 is located in the inlet shaft chamber 9. The gravity sewer of the inlet 1 is connected to the inlet of the inlet shaft chamber 9, which is equipped with a space for trapping sand and coarse sediments 10, a bar screen or a screen basket 11. The gravity sewer of the outlet 8 is connected to the outlet shaft 7.

The wastewater flows at the flow rate Q(0) through the gravity conduit 1 into the upper inlet chamber 9, equipped with a sand trap 10 and a floating impurities catcher 11.

The automatic flushing bell 17 (alternatively as variant 20), which includes a siphon conduit 15 and a vent pipe 16, provides periodic alternation between two phases, water accumulation and transfer, when the water level in the storage space of the chamber 9 oscillates between H1 and H2, where the filling velocity (flow rate) is Q(0), and the transfer velocity (resp. flow rate) is Q(1).

The difference in the H2-H1 level height limits is the driving force for the water transfer and must be chosen with respect to the length of the inverted siphon and local flow resistances in the conduit so that the effective velocity v(ef) does not fall below 1.0 $m.s^{-1}$; the approximate value for correlation calculation can be considered H2-H1=0.5 m.

The design of the accumulation volume of the main part of the inlet chamber 9 must be carried out in accordance with the total volume of the sewage conduit of the inverted siphon. It must be at least 1.5 times greater than the inverted siphon volume.

It has proven to be an advantageous solution to use an automatic flushing bell 17 or 20 for the conduit dimensions and the difference between the upper and lower water level height limits H2-H1:

internal diameter DN100	for H2-H1	from 0.2 to 0.6 m
internal diameter DN150	for H2-H1	from 0.6 to 0.7 m

internal diameter DN200 for H2-H1 from 0.7 to 1.0 m

It proved to be an advantageous solution to design the difference in the H2-H1 level height limits so that the effective flush rate of the inverted siphon v(ef) does not fall below 1.0 $m.s^{-1}$, then consider H2-H1 as a reference value for the correlation calculation of the inverted siphon conduit with inner diameter DN100, and then consider H2-H1=0.5 m. A calculation example is given in Example 1.

An advantageous solution has proven to be to design the accumulation volume of the main part of the inlet chamber to be at least 1.5 times greater than the volume of the inverted siphon conduit.

The use of non-corroding materials, e.g., polypropylene, polyethylene, stainless steel AISI 316L, has proven to be a preferred solution for the automatic flushing bell 17 or 20 according to this invention, while materials such as HDPE or cast iron commonly used for pressure conduits can be used for the inverted siphon conduit.

The use of the automatic flushing bell 20 has proven to be another separate advantageous solution.

Units and equations used

g	gravitational acceleration on the Earth´s surface	[$m.s^{-2}$]
v(k)	final velocity	[$m.s^{-1}$]
v(0)	filling velocity at the inlet	[$m.s^{-1}$]
v(ef)	effective velocity	[$m.s^{-1}$]
Q(k)	final flow rate	[$l.s^{-1}$, $m^3.s^{-1}$]
Q(0)	average flow rate at the inlet	[$l.s^{-1}$, $m^3.s^{-1}$]
Q(1)	average flow rate of water being transferred	[$l.s^{-1}$, $m^3.s^{-1}$]
p(hy)	hydrostatic water pressure	[Pa, kPa]

p(A)	atmospheric pressure	[Pa, kPa]
p(PL)	pressure loss in the conduit	[Pa, kPa]
ζ	local flow resistance in the conduit	[Pa, kPa]
T	temperature	[°C]
L	length	[m]
S	cross-section area	[m^2, cm^2]
t	time	[s, hour]
ρ	water density	[$kg.m^{-3}$]
v	kinematic viscosity	[$mm^2.s^{-1}$]
k	conduit roughness	[mm]

Reynolds number (criterion) $Re = \frac{DN.v(ef)}{\nu}$ [-]

$$P(PL) = \frac{\Lambda}{DN} \cdot \rho \cdot \frac{v(ef)^2}{2} \cdot L \qquad [Pa]$$

(*) Colebrook-White equations:_

$$\Lambda = \frac{64}{Re}, \qquad [1]$$

$$\Lambda = \Lambda_{2320} + \frac{\Lambda_{4000} - \Lambda_{2320}}{4000-2320} .(Re - 2320), \qquad [2]$$

$$\frac{1}{\sqrt{\Lambda}} = -2 \cdot \log\left(\frac{2.51}{Re.\sqrt{\Lambda}} + \frac{k}{3.71.DN}\right), \qquad [3]$$

where the empirical equation [1] is used in the laminar flow region, [2] in the transient region and [3] in the turbulent flow region.

The automatic flushing bell 17 is defined as a complete constant device for switching with a constant level described in Examples 1 and 2, the bell 17a being a part of it in the form of a single-stage inverted bell, described in said examples and shown in detail in Fig. 3.

The automatic flushing bell 20 is defined as a complete device for switching with a variable and controlled level described in Examples 3 and 4, the bell 17b being a part of it in the form of a two-stage inverted bell, described in said examples and shown in detail in Fig. 4.

Overview of Figures in the Drawings

The invention will be further explained in the exemplary embodiment according to the accompanying drawings, in which:

Fig. 1 shows a standard technical solution of a sewer inverted siphon under a watercourse;

Fig. 2 shows a technical solution of a self-flushing inverted siphon according to the invention, with an automatic flushing bell 17, described in Example 1;

Fig. 3 shows the individual parts of the automatic flushing bell 17 for the description of its function in Example 2;

Fig. 4 shows the individual parts of the automatic flushing bell 20 for the description of its function in Example 3;

Fig. 5 shows schematically the function of a sequencing batch reactor using the automatic flushing bell 20, the solution being described in Example 4;

Fig. 6 shows the dependence of the pressure loss of the inverted siphon conduit from Example 1 and the flow rate according to the Colebrook-White equations.

Examples of the Embodiments

Example 1:
Self-flushing inverted siphon

The inverted siphon for overcoming a watercourse or similar underground obstacles according to the invention, a self-flushing inverted siphon, is shown in Fig. 2.

The self-flushing inverted siphon consists of an upper inlet chamber 9, to which a gravity sewage pipe 1 is connected. The upper inlet chamber is equipped with a space for collecting sand and coarse sediments 10, with bar screens or a screen basket 11. In the main part of the inlet chamber there is situated an automatic flushing bell 17.

The siphon conduit 15 of the automatic flushing bell 17 is connected to the descending leg 12 of the sewage inverted siphon conduit, then to the crossing conduit 13 of the watercourse 4, the ascending leg of the sewage conduit 14 from where it then leads into the lower outlet sewer shaft 7. The gravity sewage conduit 8 is connected to the sewer shaft 7.

Wastewater flows at the flow rate Q(0) through the gravity conduit 1 into the upper inlet chamber 9, equipped with a sand trap 10 and a floating impurities catcher 11.

The automatic flushing bell 17, which includes a siphon conduit 15 and a vent pipe 16, provides periodic alternation between two phases, water accumulation and transfer, when the water level in the storage space of the chamber 9 oscillates between H1 and H2, where the filling velocity (flow rate) is Q(0), and the water transfer velocity (flow rate) is Q(1). The difference in the H2-H1 level height limits must be chosen with respect to the length of the inverted siphon and local flow resistances in the conduit so that the effective velocity v(ef) does not fall below 1.0 $m.s^{-1}$; the approximate value for correlation calculation can be considered H2-H1=0.5 m.

The design of the accumulation volume of the main part of the inlet chamber 9 must be carried out in accordance with the total volume of the sewage conduit of the inverted siphon. It must be at least 1.5 times greater than the inverted siphon volume.

Fulfilment of these two basic conditions, observance of the effective velocity in the flushing phase and at least 1.5 times the volume of the flushed water compared to the total volume of the inverted siphon, create preconditions for trouble-free operation of the self-flushing inverted siphon.

To understand the essence of the invention, an exemplary calculation is performed.

$$H + \frac{p(A)}{\rho . g} + \frac{v(0)^2}{2.g} = 0 + \frac{p(A)}{\rho . g} + \frac{v(k)^2}{2.g}$$

is a notation of Bernoulli´s equation for the outflow of water from the tank through one conduit, from which, if the filling velocity v(0) is ignored (it is many times lower than the outflow velocity at the end of the conduit v(k), we get to the following for the outflow rate:

$v(k)=\sqrt{(2.g.H)}$, where g is gravitational acceleration $9.81 m.s^{-2}$ and H is the level height difference in the storage tank between the upper and lower-level height limits H2-H1.

When using the continuity equation, the flow rate at the end of the conduit amounts to:

$Q(k) = v(k).S$, where S is the cross-section of the conduit.

If, for example, the inverted siphon has a total length L=17 m, the sum of the local flow resistances of the inverted siphon conduit is ζ=3.0 m, water temperature T=20°C, density ρ=998 $kg.m^{-3}$, kinematic viscosity ν=1.004 $mm^{2}.s^{-1}$ and the starting height between the upper and lower level height limits is H=0,7 m, then for DN100 conduit (cross-section S = 78.5 cm^{2}) the theoretical outflow velocity is v(k)=3.71 $m.s^{-1}$ and the flow rate Q(k)=15.55 $l.s^{-1}$. This is a purely theoretical value.

For practical calculation, it is necessary to consider Reynolds numbers for different flow rates and conduit roughness.

If we use computational Colebrook-White(*) equations, we get the curve of dependencies of pressure losses and flow velocity, shown in Fig. 6, for the characteristic behaviour of the particular inverted siphon.

For H=0.7 m and time t=0 it holds that the hydrostatic pressure p(hy)=6.853 kPa, the theoretical outflow velocity v(k)=3.71 $m.s^{-1}$, the actual velocity for the given specific case v(ef)=1.9 $m.s^{-1}$ when meeting the condition p(hy)=p(PL), where p(PL) is the pressure loss at the given operating point of the WP1 diagram.

The level height in the upper chamber of the inverted siphon starts to decrease to the level at which the real velocity $v(ef)=1.0\ m.s^{-1}$ is ensured. This is at the operating point of the WP2 diagram, which corresponds to H=0.2 m.

The working area of a specific inverted siphon is therefore between points WP1 and WP2. The values enable you to approximate the mean outflow velocity, the average flow rate and subsequently to calculate the emptying time of the inlet chamber of the inverted siphon.

Example 2

Automatic flushing bell with constant switching level

The siphon principle, explained by the theory of connected vessels and Bernoulli's equation, was already known in ancient Greece.

Since then, many technical applications and products have been developed using this principle.

The examples given here as an innovative solution according to the invention use the form of a siphon bell, published in 1891 by Mr. S. W. Miller and disclosed in US727990A under the name "SIPHON".

Fig. 3 shows the complete assembly of the automatic flushing bell 17, which consists of the original siphon conduit 15 with the bell 17a fitted.

Innovatively, the assembly was supplemented with a side closing pipe 18 for adjusting the level height H3 and a vent pipe 16.

By this, a variant of the "Miller - Semerád" automatic flushing bell is formed - an automatic flushing bell 17 in a complete assembly for use in a self-flushing inverted siphon.

The principle of operation is as follows:

The tank is filled with water from the water level H1 (lower-level height limit) at the same rate inside and outside the bell 17a, until the water level H3 is reached.

At this level, the rising water covers the side closing pipe 18, the tank continues to fill up to level H2, with different velocities inside and outside the bell 17a, the water level in the storage tank is open to the atmosphere, the water level inside the bell 17a is not. The rise in water between H3 and H2 causes an increase in the air pressure inside the bell 17a, which causes the water to drop towards the siphon 15. When the water in the siphon 15 drops to the H5 level, the H2 level is just reached in the storage tank as the upper-level height limit.

The filling and accumulation phase ends, the water transfer phase begins.

The overpressure in the tank causes the water to be forced into the conduit 25, the excess air escapes into the atmosphere through the pipe 16, the water column and the "siphon effect" start are connected, the tank starts being emptied.

The emptying of the tank continues until the lower-level height limit H1 is reached, which is defined by the edge of the bell 17a. At this moment, air is sucked in by the bell 17a and the column of expelled water in the siphon conduit 15 is interrupted.
A new period, the filling and accumulation phase, begins, from the water level height H1 in the tank.

Example 3

Automatic flushing bell with variable and controlled switching level

The automatic flushing bell 17 in Example 2 is suitable for applications where fixed setting of the switching level H2 is sufficient.

In Example 3 and in Fig. 4 a separate innovative modification is described, which results in a variant according to the second embodiment, i.e., an automatic flushing bell 20 with the variable switching level Hx:

The bell 17b having a cylindrical and a conical part (the bell 17a only has a cylindrical part) is mounted on a siphon conduit 15 with a vent pipe 16 and is supplemented by a side closing tube 18.

In place of the bell´s spherical cap 21a or the bend in the siphon conduit 21b, there is a pipe of small diameter 26a, resp. 26b, on which the solenoid valve 22a, resp. 22b is mounted.

The conical portion of the bell 17b may have a deflector 24 at the bottom, which is a baffle plate with directing lamellas to increase the absorption capacity of the automatic flushing bell and change the direction of water 27 being sucked in. The suction direction 27 is shown in detail on the deflector 24 in Fig. 4.

The principle of operation is as follows:
The tank is filled with water starting from the water level height H1 (lower-level height limit) at the same rate inside and outside the bell 17b, until the water level height H3 is reached, and after the side closing tube 18 has been covered, the tank continues to be filled. Once the level Hx has been reached, it is possible to open

the decompression valve 22 (variants 22a, 22b) at any time up to the level H2. By opening this valve, air is released from the space of the bell 17b and the siphon conduit 15, thus connecting the water continuum. The siphon effect starts immediately, the filling phase ends, and the tank starts being emptied.

With the automatic flushing bell 20 (Example 3), in contrast to the automatic flushing bell 17 (Example 2), it is possible to change the switching level Hx to the H2 level in accordance with current needs.

Example 4
Water discharge for sequencing batch reactor

The automatic flushing bell 20 in Example 3 can be used as a separate technical solution of the invention for discharging water from a sequencing batch reactor, which is shown in Fig. 5:
The tank 19 is equipped with a discharging station 29 for replenishing water in the tank 19, further with a blower 28 for supplying compressed air for the aeration device 31, by means of the device for controlled discharge of separated clean water - the automatic flushing bell 20, described in Example 4.

For normal operation, the sequencing batch reactor is supplemented by a control system 30 with connected digital inputs i1 to i3 for sensing the water level H7, H8 resp. H9, which is ensured by means of a level sensor 23. The control is performed in a combination of volume and time mode via digital outputs o1 to o3, when the output o1 switches on, resp. switches off the blower 28, the outlet o2 switches on/off the discharging station 29, and the outlet o3 carries out decompression in the bell 17b of the automatic flushing bell 20 through the solenoid valve 22, so that the outlet o3 opens the solenoid valve 22, thereby releasing air from the bell space 17b and siphon conduit 15, and subsequently the water continuum is connected. This then triggers the siphon effect when the filling phase ends, and the tank starts being emptied.

The automatic flushing bell 20 in the sequencing batch reactor is always supplemented with a deflector 24 to increase the absorption capacity, to provide water suction 27 direction control and prevent suction of settling particles 24 in the automatic flushing bell 20, and is described in Example 4 and shown in Fig. 4, including the P′-P sectional view in the detailed ground plan.

The principle of operation of the sequencing batch reactor with the automatic flushing bell 20 is as follows:

3 basic phases alternate in the reactor in one cycle: phase F1 - filling and simultaneous biological reaction (pump station 29 and blower 28 are on), phase F2 - sludge sedimentation (blower 28 is off) and phase F3 - decantation and water discharge.

For phases F1 and F3, the volume control of the automatic flushing bell 20 can be successfully used, phase F2 must be strictly time controlled. Usually, a 60-minute sedimentation period is used in one cycle, where sedimentation means switching off the blower 28 and interrupting water discharging from the pumping station 29.

With the proposed modification of the automatic flushing bell 20, it is not a problem to include time control: If the water level is anywhere between H8 and H9, the control system 30 switches off the blower 28 via the digital output o1 for the required 60-minute period, then the control system 30 opens the solenoid valve 22 via the digital output o3 for 10 to 15 seconds. This depressurizes the automatic flushing bell 20 at point 21, via line 26 through the solenoid valve 22 from point 21, which connects the water column inside the bell 17b and at the same time the F3 phase begins, the clean water being discharged until the H7 level is reached. The entire three-phase cycle of the sequencing reactor then starts again.

Industrial utilisation

The devices according to the invention can be particularly used in the field of wastewater transport and treatment.

List of reference marks

1 - gravity sewer conduit, inverted siphon inlet
2 - shaft, upper inlet chamber of the inverted siphon
3 - descending leg of the sewage conduit of the inverted siphon
4 - watercourse or other obstacle to be overcome by the inverted siphon
5 - sewage conduit crossing a watercourse
6 - ascending leg of the sewage conduit of the inverted siphon
7 - lower output shaft of the inverted siphon
8 - gravity sewer conduit, inverted siphon outlet
9 - upper inlet chamber of the inverted siphon with an automatic flushing bell installed
10 - space for accumulation of sand and coarse sediments
11 - bar screen or screen basket
12 - descending leg of the sewage conduit of the inverted siphon
13 - sewage conduit crossing a watercourse
14 - ascending leg of the sewage conduit of the inverted siphon
15 - siphon conduit of the automatic flushing bell
16 - siphon conduit deaeration
17 - automatic flushing bell according to the first embodiment
17a - bell as a part of the equipment 17
17b - bell as a part of the equipment 20
18 - side closing pipe of the automatic flushing bell
19 - tank of the sequencing batch reactor
20 - automatic flushing bell according to the second embodiment
21 - connection of the pipe to the automatic flushing bell 20
22 - valve for controlled decompression of the bell 17b for Examples 3 and 4
23 - water level sensor H7, H8 and H9 for the control system 30
24 - deflector to increase absorption capacity and direct the flow of water
25 - discharge conduit of the automatic flushing bell 17, 20

26 - decompression pipe for venting air through the valve 22

27 - flow direction, water suction into the bell 17b

28 - blower for the sequencing batch reactor, Example 4

29 - pumping station for the sequencing batch reactor, Example 4

30 - control system for the sequencing batch reactor, Example 4

31 - aeration device for the sequencing batch reactor, Example 4

i1, i2, i3 - digital inputs of the control system 30

o1, o2, o3 - digital outputs of the control system 30

A	height of the bell 17a in Fig.3	[mm]
B	distance between the edge of the bell 17a and the bend of the siphon pipe	[mm]
D	inner diameter of the bell 17a (Fig. 3) or 17b (cylindrical part)	[mm]
D1	inner diameter of the bell 17b (lower conical part)	[mm]
DN	conduit inner diameter	[mm]
B	structural height	[m]
H1	lower height limit	[m]
H2	upper height limit	[m]
H3	water level when the side pipe 16 is covered	[m]
H4	lower edge of the discharge conduit 25	[m]
H5	upper edge of the siphon conduit 15	[m]
H6	upper level of the deaeration pipe 16	[m]
H7	lower water level for the sequencing batch reactor	[m]
H8	bell cap level 17b (Example 4)	[m]
H9	maximum water level for the sequencing batch reactor	[m]
H	water level in the tank, in general	[m]
H2-H1	distance between lower and upper-level height limits	[m]
Hx	water level when opening the decompression valve 22	[m]

CLAIMS

1. A gravity sewer device comprising a self-flushing inverted siphon forming a part of the gravity sewer, which crosses under a watercourse or some other underground obstacle, **characterised in that** it consists of one or more inlet shafts (9) connected to a descending leg (12) of a sewer conduit, a crossing (13), an ascending leg (14) of a sewer conduit and an outlet shaft (7), where an automatic flushing bell (17) or an automatic flushing bell (20) is situated in the inlet shaft chamber (9), wherein the gravity sewer of an inlet (1) is connected to an inlet into the inlet shaft chamber (9), which is equipped with a space for trapping sand and coarse sediments (10) by a bar screen or a screen basket (11), the gravity sewer of an outlet (8) is further connected to the outlet shaft (7), wherein the device includes a side closing pipe (18) for setting the level height (H3) and a vent pipe (16), wherein the device is further configured so that:
- the level in the inlet shaft chamber (9) automatically moves between the lower height limit (H1) and the upper height limit (H2;
- the difference between the upper height limit (H2) and the lower height limit (H1) is the driving force for the transfer of water to the outlet shaft (7);
- the lower height limit (H1) is situated higher than the level height (H4) in the inlet conduit;
- the data on all the levels and height limits (H1, H2, H3, H4) are derived from the height of the upper edge (H5) of the siphon conduit (15), which is defined as the initial level height of zero;
- the lower height limit (H1) is defined as the difference between the upper height limit (H2) and the level (H3) and at the same time it is equal to the value representing the optional design height (B) between the lower edge of the automatic flushing bell (17) and the bend of the siphon conduit (15), wherein the upper height limit (H2) is calculated as the difference between the value of the structural

height (B) and the level (H3) and the structural height (B) is designed so that the minimum flow velocity is ensured for the particular inverted siphon.

2. The device according to claim 1, **characterised in that** the accumulation volume of the main part of the inlet chamber (9) is 1.5 times greater than the total volume of the sewer inverted siphon conduit.

3. The device according to claim 1 or 2, **characterised in that** the inner diameter of the conduit ranges from 100 to 200 mm.

4. The device according to claim 1, 2 or 3, **characterised in that** the height difference between the upper-level height limit (H2) and the lower-level height limit (H1) ranges from 0.2 to 0.6 m for conduits with a diameter of 100 mm.

5. The device according to claim 1, 2 or 3, **characterised in that** the height difference between the upper-level height limit (H2) and the lower-level height limit (H1) ranges from 0.6 to 0.7 m for conduits with a diameter of 150 mm.

6. The device according to claim 1, 2 or 3, **characterised in that** the height difference between the upper-level height limit (H2) and the lower-level height limit (H1) ranges from 0.7 to 1.0 m for conduits with a diameter of 200 mm.

7. The device according to any of claims 1 to 6, **characterised in that** the automatic flushing bell (17) or (20) is equipped with a siphon conduit (15) and a vent pipe (16).

8. The device according to any of claims 1 to 7, **characterised in that** the automatic flushing bell (20) with variable switching level

Hx is fitted on the siphon conduit (15) with the vent pipe (16), which is supplemented by a side closing pipe (18), wherein the bell (17b) has a cylindrical and conical section.

9. The device according to any of claims 1 to 8, **characterised in that** the automatic flushing bell (20) is formed in such a way that a small diameter pipe (26a) or (26b) is connected at the location of the bell cap (21a) or bend (21b) of the siphon pipe, on which small diameter pipe a solenoid valve (22a) or (22b) is mounted.

10. The device according to claim 7 or 8, **characterised in that** the conical part of the bell (17b) is equipped in its lower part with a deflector (24) in the form of a baffle plate with directing lamellas to increase the absorption capacity of the automatic flushing bell and change the direction of water (27) being sucked in.

11. The device according to any of claims 8 to 10, **characterised in that** the automatic flushing bell (20) is provided with a deflector (24) for increasing the absorption capacity.

12. The device according to any of claims 1 to 11, **characterised in that**, in connection with the automatic flushing bell (20), the device is further provided with a sequencing batch reactor, a pumping station (29) for replenishing water in a tank (19) and a blower for supplying compressed air for oxygenation by means of an aeration device (31).

13. The device according to claim 12, **characterised in that** the sequencing batch reactor is supplemented with a control system (30) with connected digital inputs (i1) to (i3) for sensing level heights (H7, H8 and/or H9) by means of a level sensor (23), wherein for control performed in a combination of volume and time mode it comprises digital outputs (o1) to (o3) to control the blower (28),

the pumping station (29) and the decompression of the bell (17b) of the automatic flushing bell (20) via the solenoid valve (22).

14. The device according to any of claims 1 to 13, **characterised in that** the automatic flushing bell (20) is made of a noncorroding material, particularly polypropylene, polyethylene or stainless steel AISI 316L.

15. The device according to any of claims 1 to 7, **characterised in that** the automatic flushing bell (17) is made of a noncorroding material, particularly polypropylene, polyethylene or stainless steel AISI 316L.

16. The device according to any of claims 1 to 15, **characterised in that** the inverted siphon conduit is made of cast iron or HDPE.

17. A method of overcoming watercourses or similar underground obstacles by means of the device according to claims 1 to 16, **characterised in that** it includes the phase of filling and accumulating the liquid and subsequently transferring it, wherein the waste liquid flows at the flow rate Q(0) through the gravity conduit (1) to the first inlet chamber (9), equipped with a sand trap 10 and a floating impurities catcher 11, wherein the automatic flushing bell (17) or (20) ensures periodic alternation between two phases consisting of filling and accumulation of liquid in phase one and its subsequent transfer in phase two, when the water level in the storage space of the chamber (9) moves between the lower height limit (H1) and the upper height limit (H2), whose height difference does not exceed 0.5 m.

18. The method according to claim 17, **characterised in that** the effective velocity v(ef) of the liquid flow through the conduit amounts to at least 1.0 $m.s^{-1}$.

19. The method according to claim 17 or 18, **characterised in that** the filling and accumulation phase of the liquid includes filling of the tank with the liquid from the lower-level height limit H1 at the same rate inside and outside the bell 17a, until the level height H3 is reached, wherein at the level height (H3) the rising liquid level covers the side closing pipe (18) and the tank is further filled up to the level (H2) with different velocities inside and outside the bell (17a), while the water level in the accumulation tank is open to the atmosphere and the water level inside the bell (17a) is not.

20. The method according to claim 17 or 18, **characterised in that** the accumulation phase of the liquid lasts until the level (H2) in the storage tank is reached so that the rise of water between the level (H3) to the level (H2) causes an increase in air pressure inside the bell (17a), which causes the water to drop towards the siphon (15), wherein the level height (H2) is achieved due to the drop in the liquid level in the siphon (15) down to the level (H5).

21. The method according to claim 17 or 18, **characterised in that** the transfer phase comprises emptying of the tank, which is achieved by forcing water into the conduit (25) while releasing excess air into the atmosphere through the pipe (16) and connecting the water column and starting the siphon effect, wherein the tank is emptied until the lower level height limit (H1) is reached, which is defined by the edge of the bell (17a), whereby air is sucked in by the bell (17a) and the column of the liquid being forced into the siphon conduit (15) is interrupted.

22. The method according to claim 17 or 18, **characterised in that** the phase of filling and accumulating the liquid comprises filling of the tank with liquid from the lower level height limit (H1) at the same rate inside and outside the bell (17b) until the level (H3)

is reached and subsequently filling of the tank after closing of the side closing tube (18), the decompression valve (22) being open at any time from reaching the level Hx up to the level (H2) and subsequently the air is discharged from the space of the bell (17b) and the siphon conduit (15) to connect the water column and start the siphon effect.

23. The method according to claim 22, **characterised in that** the switching level (Hx) is adjustable even up to the level (H2) as necessary.

24. The method according to claim 17 or 18, **characterised in that** the transfer phase comprises the use of a combination of the sequencing batch reactor and the automatic flushing bell (20) in one cycle in three phases, the first phase (F1) representing liquid filling and biological reaction with the pumping station (29) and the blower (28) switched on, the second phase (F2) representing the sludge sedimentation with the blower (28) switched off and the third phase (F3) consists in the decantation and discharge of the liquid.

25. The method according to claim 24, **characterised in that** the phases (F1) and (F3) are controlled depending on the liquid volume, while the phase (F2) is time controlled.

26. The device according to any of claims 24 to 25, **characterised in that** at the liquid level between (H8) and (H9), the blower (28) is disconnected via the digital output (o1) for a specified interval of the phase (F2), and then the control system (30) opens for a short time, usually 10 to 15 seconds, via the digital output (o3), a solenoid valve (22) to depressurize the bell (17b) of the automatic flushing bell (20) at the location (21) through the pipe (26) via the solenoid valve (22) from the location (21), which connects the

water column inside the bell (17b) and the phase (F3) begins when the clean liquid is admitted to the level (H7).

27. The method according to claim 26, **characterised in that** the phase (F2) runs in a 60-minute interval.

28. A use of the device according to claims 1 to 16 for overcoming watercourses or similar underground obstacles.

AMENDED CLAIMS
received by the International Bureau on 20 December 2021 (20.12.21)

1. A gravity sewer device comprising a self-flushing inverted siphon forming a part of a gravity sewer, wherein the gravity sewer device crosses under a watercourse or other underground obstacle, **characterised in that** the device consists of one or more inlet shaft chambers (9) connected to a descending leg (12) of a sewer conduit, a crossing (13), an ascending leg (14) of a sewer conduit and an outlet shaft (7), wherein an automatic flushing bell (17) or an automatic flushing bell (20) is situated in the inlet shaft chamber (9), wherein the gravity sewer of an inlet (1) is connected to an inlet of the inlet shaft chamber (9), which is equipped with a space for trapping sand and coarse sediments (10) by a bar screen or a screen basket (11), an outlet (8) gravity sewer is further connected to the outlet shaft (7), wherein the device includes a side closing pipe (18) for setting the level height (H3) and a vent pipe (16), wherein the device is further configured so that:
- the level in the inlet shaft chamber (9) automatically moves between the lower height limit (H1) and the upper height limit (H2;
- the difference between the upper height limit (H2) and the lower height limit (H1) is the driving force for the transfer of water to the outlet shaft (7);
- the lower height limit (H1) is situated higher than the level height (H4) in the inlet conduit;
- the data on all the levels and height limits (H1, H2, H3, H4) are derived from the height of the upper edge (H5) of the siphon conduit (15), which is defined as the initial level height of zero;
- the lower height limit (H1) is defined as the difference between the upper height limit (H2) and the level (H3) and at the same time it is equal to the value representing the optional design height (B) between the lower edge of the automatic flushing bell (17) and the bend of the siphon conduit (15), wherein the upper height limit (H2) is calculated as the difference between the value of the structural

height (B) and the level (H3) and the structural height (B) is designed so that the minimum flow velocity is ensured for the particular inverted siphon,
wherein the accumulation volume of the main part of the inlet chamber (9) is 1.5 times greater than the total volume of the sewer inverted siphon conduit and
wherein the automatic flushing bell (17) or (20) is equipped with a siphon conduit (15) and a vent pipe (16).

2. The device according to claim 1, **characterised in that** the height difference between the upper-level height limit (H2) and the lower-level height limit (H1) ranges from 0.2 to 0.6 m for conduits with a diameter of 100 mm and
the height difference between the upper-level height limit (H2) and the lower-level height limit (H1) ranges from 0.6 to 0.7 m for conduits with a diameter of 150 mm and
the height difference between the upper-level height limit (H2) and the lower-level height limit (H1) ranges from 0.7 to 1.0 m for conduits with a diameter of 200 mm.

3. The device according to any of claims 1 or 2, **characterised in that** the automatic flushing bell (20) with variable switching level Hx is fitted on the siphon conduit (15) with the vent pipe (16), which is supplemented by a side closing pipe (18), wherein the bell (17b) has a cylindrical and conical section.

4. The device according to any of claims 1 to 3, **characterised in that** the automatic flushing bell (20) is formed in such a way that a small diameter pipe (26a) or (26b) is connected at the location of the bell cap (21a) or bend (21b) of the siphon pipe, on which small diameter pipe a solenoid valve (22a) or (22b) is mounted.

5. The device according to claim 3, **characterised in that** the conical part of the bell (17b) is equipped in its lower part with a deflector (24) in the form of a baffle plate with directing lamellas to increase the absorption capacity of the automatic flushing bell and change the direction of water (27) being sucked in.

6. The device according to any of claims 3 to 5, **characterised in that** the automatic flushing bell (20) is provided with a deflector (24) for increasing the absorption capacity.

7. The device according to any of claims 1 to 6, **characterised in that,** in connection with the automatic flushing bell (20), the device is further provided with a sequencing batch reactor, a pumping station (29) for replenishing water in a tank (19) and a blower for supplying compressed air for oxygenation by means of an aeration device (31).

8. The device according to claim 7, **characterised in that** the sequencing batch reactor is supplemented with a control system (30) with connected digital inputs (i1) to (i3) for sensing level heights (H7, H8 and/or H9) by means of a level sensor (23), wherein for control performed in a combination of volume and time mode it comprises digital outputs (o1) to (o3) to control the blower (28), the pumping station (29) and the decompression of the bell (17b) of the automatic flushing bell (20) via the solenoid valve (22).

9. The device according to any of claims 1 to 8, **characterised in that** the automatic flushing bell (20) or automatic flushing bell (17) is made of a noncorroding material, particularly polypropylene, polyethylene or stainless steel AISI 316L.

10. The device according to any of claims 1 to 9, **characterised in that** the inverted siphon conduit is made of cast iron or HDPE.

11. A method of overcoming watercourses or similar underground obstacles by means of the device according to claims 1 to 10, **characterised in that** it includes the phase of filling and accumulating the liquid and subsequently transferring it, wherein the waste liquid flows at the flow rate Q(0) through the gravity conduit (1) to the first inlet chamber (9), equipped with a sand trap (10) and a floating impurities catcher (11), wherein the automatic flushing bell (17) or (20) ensures periodic alternation between two phases consisting of filling and accumulation of liquid in phase one and its subsequent transfer in phase two, when the water level in the storage space of the chamber (9) moves between the lower height limit (H1) and the upper height limit (H2), whose height difference does not exceed 0.5 m and the effective velocity v(ef) of the liquid flow through the conduit amounts to at least 1.0 m.s-1.

12. The method according to claim 11, **characterised in that** the filling and accumulation phase of the liquid includes filling of the tank with the liquid from the lower-level height limit (H1) at the same rate inside and outside the bell (17a), until the level height (H3) is reached, wherein at the level height (H3) the rising liquid level covers the side closing pipe (18) and the tank is further filled up to the level (H2) with different velocities inside and outside the bell (17a), while the water level in the accumulation tank is open to the atmosphere and the water level inside the bell (17a) is not, and wherein the accumulation phase of the liquid lasts until the level (H2) in the storage tank is reached so that the rise of water between the level (H3) to the level (H2) causes an increase in air pressure inside the bell (17a), which causes the water to drop towards the siphon (15), wherein the level height (H2) is achieved due to the drop in the liquid level in the siphon (15) down to the level (H5) and

the transfer phase comprises emptying of the tank, which is achieved by forcing water into the conduit (25) while releasing excess air into the atmosphere through the pipe (16) and connecting the water column and starting the siphon effect, wherein the tank is emptied until the lower level height limit (H1) is reached, which is defined by the edge of the bell (17a), whereby air is sucked in by the bell (17a) and the column of the liquid being forced into the siphon conduit (15) is interrupted.

13. The method according to claim 11, **characterised in that** the phase of filling and accumulating the liquid comprises filling of the tank with liquid from the lower level height limit (H1) at the same rate inside and outside the bell (17b) until the level (H3) is reached and subsequently filling of the tank after closing of the side closing tube (18), the decompression valve (22) being open at any time from reaching the level Hx up to the level (H2) and subsequently the air is discharged from the space of the bell (17b) and the siphon conduit (15) to connect the water column and start the siphon effect,
wherein the switching level (Hx) is adjustable even up to the level (H2) as necessary.

14. The method according to claim 11, **characterised in that** the transfer phase comprises the use of a combination of the sequencing batch reactor and the automatic flushing bell (20) in one cycle in three phases, the first phase (F1) representing liquid filling and biological reaction with the pumping station (29) and the blower (28) switched on, the second phase (F2) representing the sludge sedimentation with the blower (28) switched off and the third phase (F3) consists in the decantation and discharge of the liquid,
wherein the phases (F1) and (F3) are controlled depending on the liquid volume, while the phase (F2) is time controlled,
wherein at the liquid level between (H8) and (H9), the blower (28) is disconnected via the digital output (o1) for a specified interval of the phase (F2), and then the control system (30) opens for a short time, usually 10 to 15 seconds, via the digital output (o3), a solenoid

valve (22) to depressurize the bell (17b) of the automatic flushing bell (20) at the location (21) through the pipe (26) via the solenoid valve (22) from the location (21), which connects the water column inside the bell (17b) and the phase (F3) begins when the clean liquid is admitted to the level (H7) and
wherein the phase (F2) runs in a 60-minute interval.

15. A use of the device according to claims 1 to 10 for overcoming watercourses or similar underground obstacles by crossing the watercourse or obstacle from under.

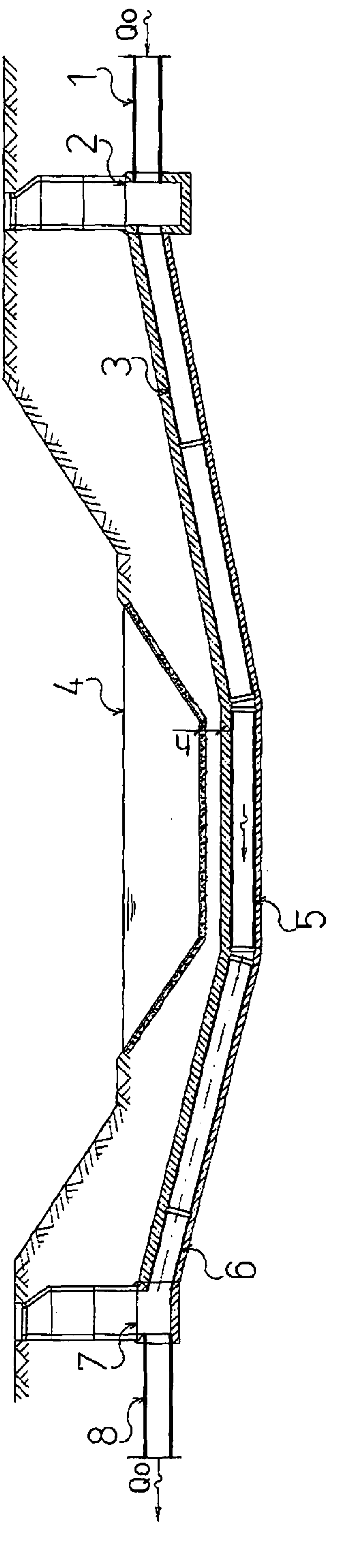


FIG. 1

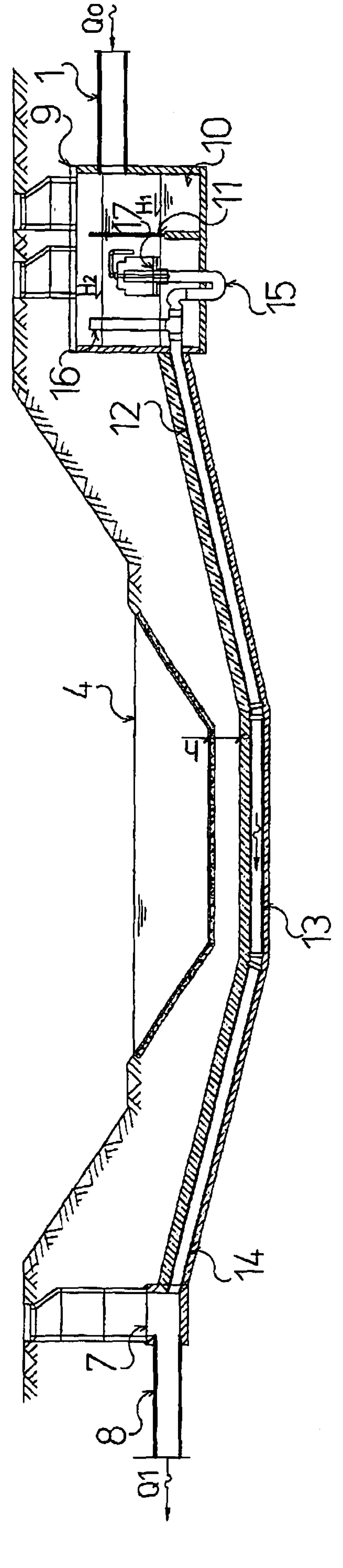


FIG. 2

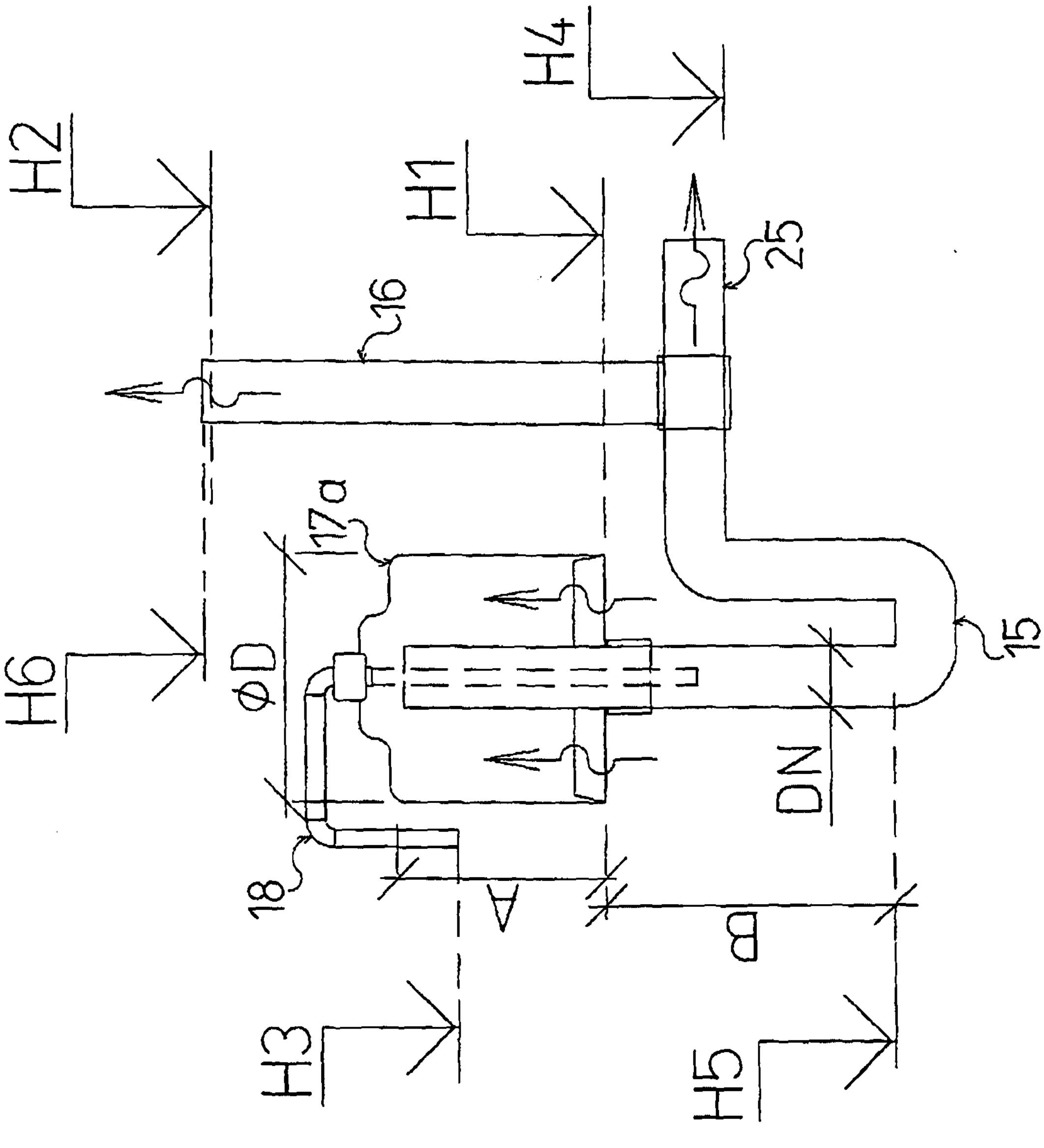
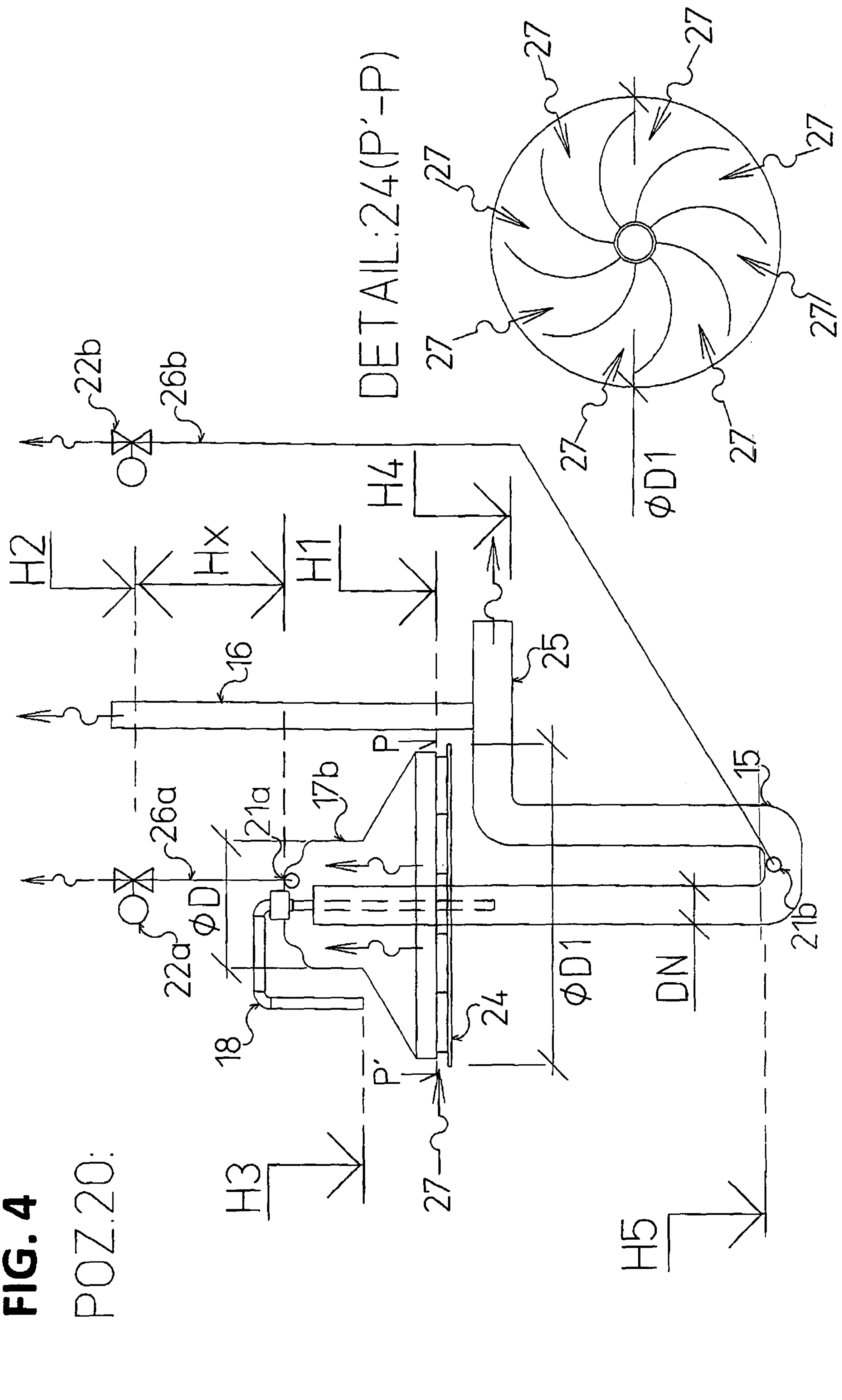


FIG. 3
POZ.17.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H2
Hx
H1
16
25
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17b
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26a
ΦD
22a
18
P'
H3
H5

FIG. 4

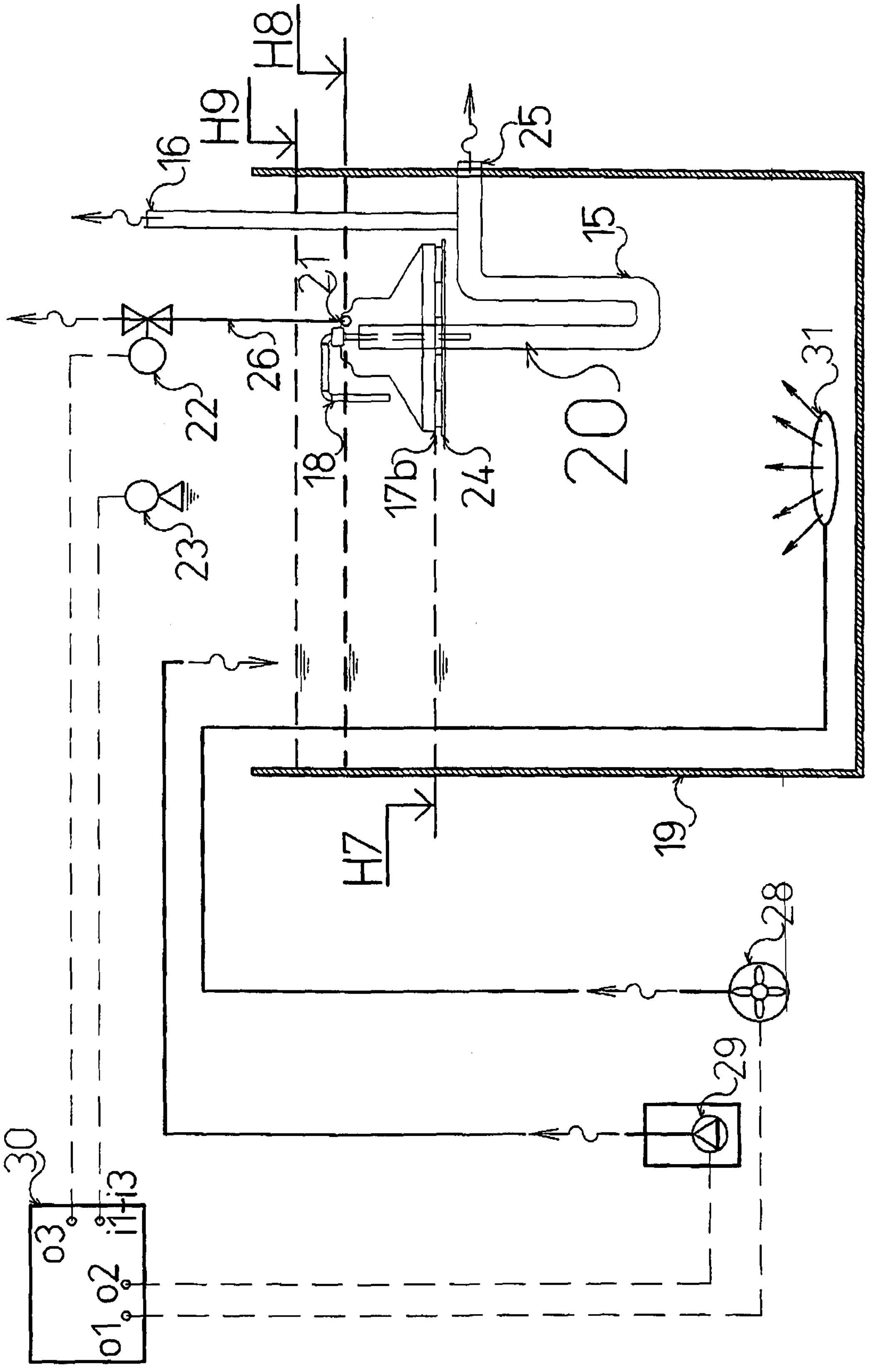
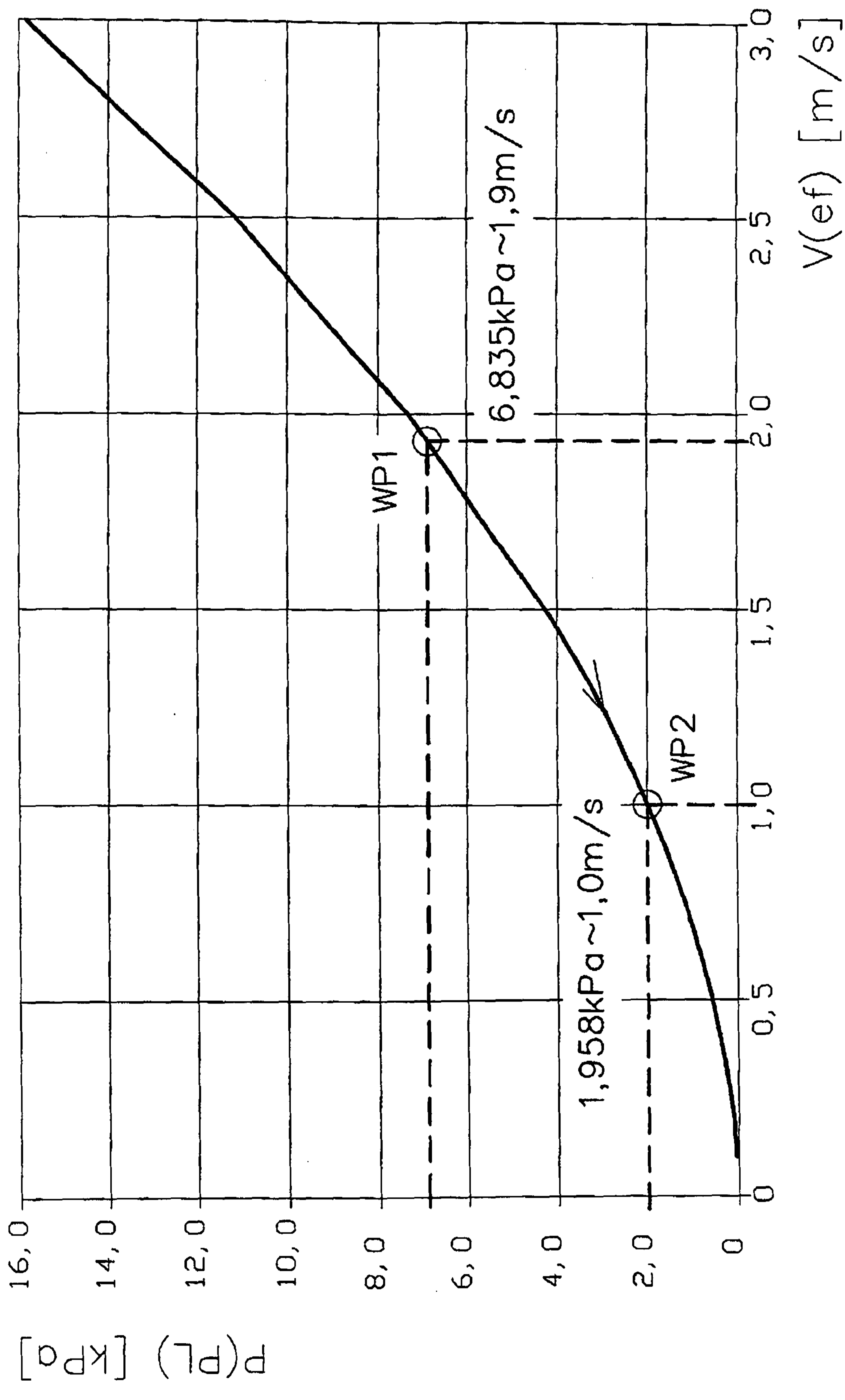


FIG. 5

FIG. 6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0
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2,5
3,0
WP1
WP2
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1,958kPa~1,0m/s

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2021/000437

A. CLASSIFICATION OF SUBJECT MATTER
INV. E03F3/02 E03F5/10 E03F5/20
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)
E03F E03D

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 727 990 A (MILLER SIDNEY W [US]) 12 May 1903 (1903-05-12) columns 1-3; figure 1	1-28
Y	WO 2019/147526 A1 (BRYANT GRAHAM J [US]) 1 August 2019 (2019-08-01) paragraphs [0025], [0030]; figure 1	1-28
Y	US 2003/024874 A1 (WALLACE SCOTT D [US] ET AL) 6 February 2003 (2003-02-06) paragraphs [0016], [0017]; figure 9	12,13, 24-27
A	US 5 898 375 A (PATTERSON DONALD J [US]) 27 April 1999 (1999-04-27) figure 1	1-28

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 October 2021	19/10/2021

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Posavec, Daniel

2

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 761 316 A (MILLER SIDNEY W [US]) 31 May 1904 (1904-05-31) figure 1	1-28
A	EP 2 283 188 A1 (STEINHARDT JOERG-MICHAEL [DE]) 16 February 2011 (2011-02-16) figures 1-3	1-28
A	DE 27 10 478 A1 (STAHN ROLF) 14 September 1978 (1978-09-14) figures 1-3	1-28
A	DE 296 738 C (HEINRICH GREBE) 27 February 1917 (1917-02-27) figures 1-3	1-28
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2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2021/000437

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			WO 2009135640	A1	12-11-2009
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			SE 416981	B	16-02-1981
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			WO 8002855	A1	24-12-1980