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CA 2444951 C 2010/07/13

(11)(21) 2 444 951

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(86) Date de dépôt PCT/PCT Filing Date: 2002/04/22
(87) Date publication PCT/PCT Publication Date: 2002/10/31
(45) Date de délivrance/Issue Date: 2010/07/13
(85) Entrée phase nationale/National Entry: 2003/10/21
(86) N° demande PCT/PCT Application No.: SG 2002/000065
(87) N° publication PCT/PCT Publication No.: 2002/085573
(30) Priorité/Priority: 2001/04/21 (SG200102219-3)

(51) Cl.Int./Int.Cl. *B24C 7/00* (2006.01),
B24C 1/04 (2006.01)

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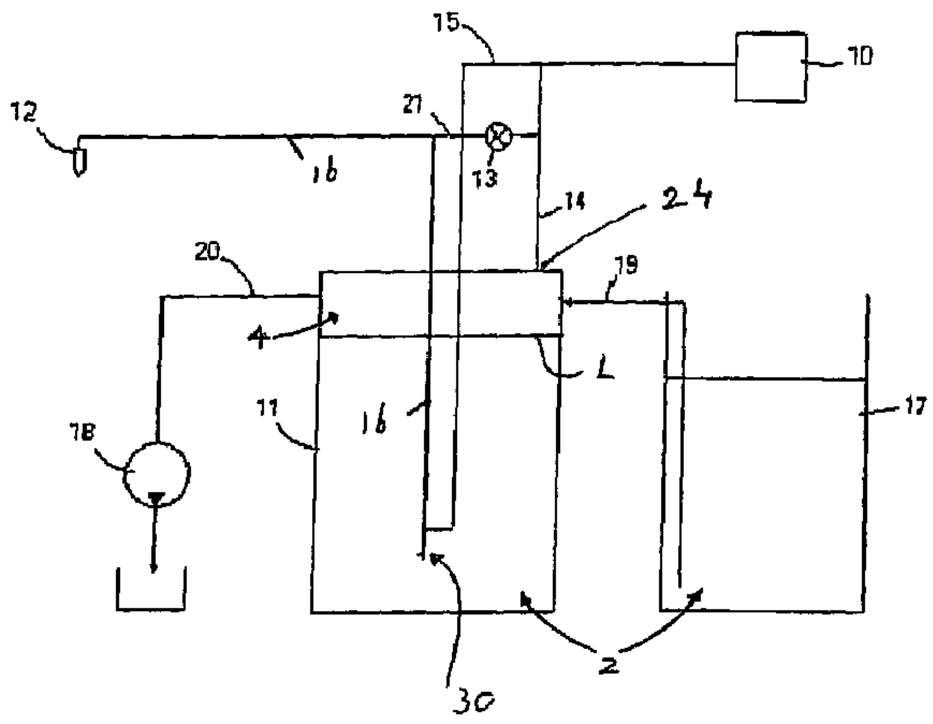
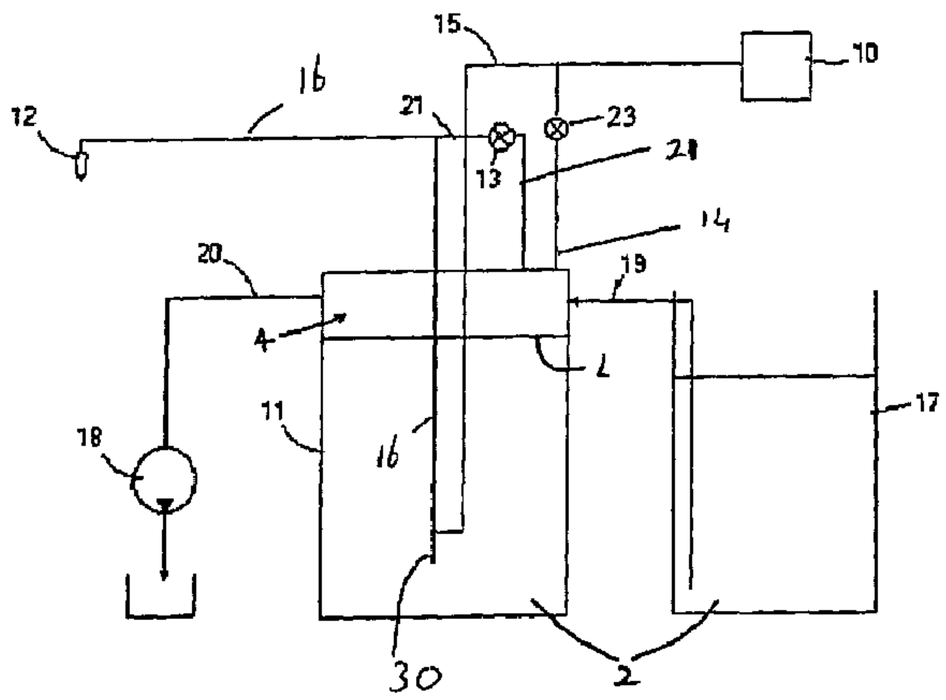
(54) Titre : SYSTEME A JET DE FLUIDE ABRASIF
(54) Title: ABRASIVE FLUID JET SYSTEM





(57) Abrégé/Abstract:
The invention provides an abrasive jet system having a high-pressure fluid supply (10) means supplying fluid to a vessel (11) which includes a layer of abrasive slurry and a top layer that contains substantially of fluid over the layer of abrasive slurry. The system also

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(57) Abrégé(suite)/Abstract(continued):
includes a first conduit (14) which leads from the fluid supply means to the top layer of fluid in the vessel and as high-pressure fluid is fed into the vessel, causes displacement of abrasive slurry from a discharge conduit (16). The system further includes a second conduit (21) which connects at different points to the first conduit and the discharge conduit, and including a fluid valve (13) between the operative connection to the first conduit and the discharge conduit, that controls the fluid flow within the second conduit. The fluid valve is closed once the system is pressurised to displace abrasive slurry through the discharge conduit (16) and is opened upon de-pressurization of the system to allow fluid flow from the first conduit (14) to the second conduit and to stop discharge of the abrasive slurry.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 October 2002 (31.10.2002)

PCT

(10) International Publication Number
WO 02/085573 A1

(51) International Patent Classification[7]: B24C 7/00, 1/04

(21) International Application Number: PCT/SG02/00065

(22) International Filing Date: 22 April 2002 (22.04.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
200102219-3 21 April 2001 (21.04.2001) SG

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent

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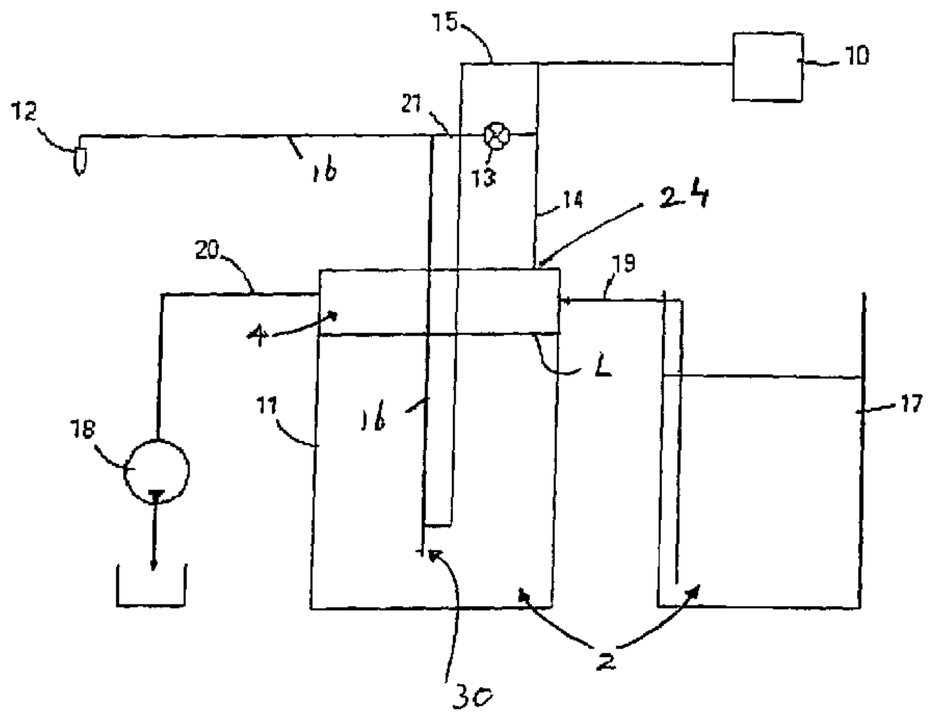

(57) Abstract: The invention provides an abrasive jet system having a high-pressure fluid supply (10) means supplying fluid to a vessel (11) which includes a layer of abrasive slurry and a top layer that contains substantially of fluid over the layer of abrasive slurry. The system also includes a first conduit (14) which leads from the fluid supply means to the top layer of fluid in the vessel and as high-pressure fluid is fed into the vessel, causes displacement of abrasive slurry from a discharge conduit (16). The system further includes a second conduit (21) which connects at different points to the first conduit and the discharge conduit, and including a fluid valve (13) between the operative connection to the first conduit and the discharge conduit, that controls the fluid flow within the second conduit. The fluid valve is closed once the system is pressurised to displace abrasive slurry through the discharge conduit (16) and is opened upon de-pressurization of the system to allow fluid flow from the first conduit (14) to the second conduit and to stop discharge of the abrasive slurry.

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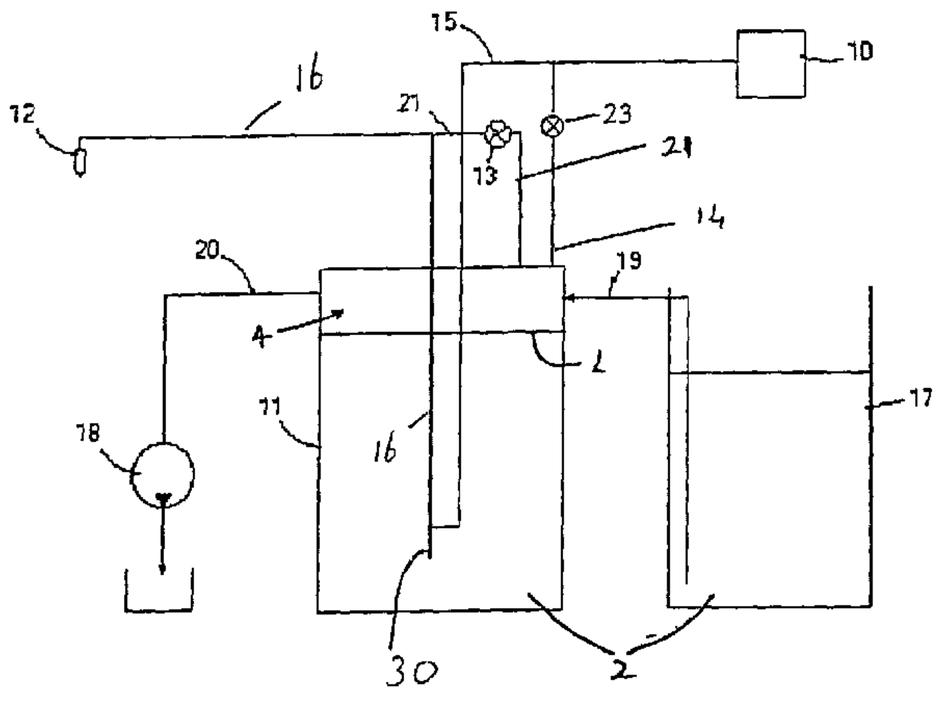

WO 02/085573 A1

(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

ABRASIVE FLUID JET SYSTEM

Field of the invention

The present invention relates to an abrasive fluid jet cutting system and in particular although not solely to a system for supplying a pressurised slurry from a pressurised abrasive slurry containing vessel to an abrasive-jet nozzle(s) to enable cutting or other abrasive-fluid jet machining operations to be carried out.

Background and Prior Art

Abrasive fluid jet systems in the art are used in many applications where precision-cutting is required. An example of such an application is the singulation of substrates. One type of abrasive jet system utilizes abrasive that is stored and discharged under pressure from a pressure vessel to mix with the driving fluid immediately before the nozzle to form an abrasive slurry. Such mixing is achieved by a venturi effect. The slurry is normally then accelerated through a nozzle to form an abrasive fluid jet tool for cutting substrates.

Such existing systems require the separate and independent delivery of abrasive for each of the nozzles where a multi-nozzle cutting head is to be provided. Such independent delivery requires independent control and increases the chances of one or more nozzles of the multi-nozzle cutting head operating in a less than ideal condition.

An alternative configuration of mixing an abrasive with a fluid is for example shown in WO 95/29792. In the system of WO 95/29792, a pressure vessel is provided within which an abrasive and a fluid under pressure are able to mix prior to being delivered via a conduit to the nozzle.

WO 00/52679 describes a fluid supply system having a high pressure fluid supply (31, 32) which provides fluid under pressure via an inlet (6) to an entrainment vessel (1) in which the fluid can take up another component such as an abrasive material. An outlet (51) from the vessel leads to a nozzle (54). A jet pump (61) has an outlet (64) which is connected via a valve (65) to the junction between the vessel discharge tube (51) and the system outlet (54). When the valve (65) is closed, pressurized fluid supplied to the high pressure inlet (62) of the jet pump (61) passes via the lower pressure inlet (63) of the jet pump, to the inlet (6) of the vessel (1), then through the vessel entraining the abrasive material, before flowing through the vessel discharge tube (51) to the nozzle (54). The valve (65) is opened to allow isolation valve (52) to be flushed and closed to stop the flow to the nozzle. This arrangement does not dilute the abrasive discharge by introducing a diluting flow near the lower end of the discharge tube, nor allow this diluting flow to flush the vessel discharge tube (51) when the abrasive discharge is stopped.

As increasingly higher liquid pressures are being used to take advantage of the increases in cutting power, liquid compressibility becomes an important factor. When it is required to stop discharging abrasive slurry and depressurise the abrasive slurry pressure vessel to pause the operational process or to facilitate abrasive recharge, as a result of the high pressures generated, there remains within the pressure vessel a volume of compressed fluid. With conventional state of the art systems, as the compressed volume is de-pressurised its only route of escape is through the discharge conduit, the inlet of which is positioned within the slurry confinement. Hence a volume of slurry continues to be discharged giving rise to problems with nozzle blockages. Such blockage comes about because the discharged slurry is under a lower than normal operational pressure and lacks sufficient momentum to settle in the delivery pipe or nozzle in a manner to avoid blockage.

Such undesired discharge may for example occur if the slurry containment pressure vessel pressurising pump fails. Since the slurry in the pressure vessel is

under high pressure and is compressed by the pump, upon failure of the pump the compressed slurry will expand and continue, for at least for a short period, to deliver the slurry through the delivery pipe to continue to discharge an abrasive slurry from the nozzle.

In designing a solution it is important to avoid problems, including high wear rates and reliability concerns brought about by the high pressures and the working medium itself which contains abrasives.

It is an object of the present invention to mitigate the above disadvantages and to avoid nozzle blockage or to provide the public with a useful choice.

Summary of the Invention

In a first aspect the present invention may be broadly said to be a fluid supply system for delivery of an abrasive slurry, the fluid supply system including;

a vessel for containing an abrasive slurry at a lower layer and a substantially abrasive-free fluid at a higher layer,

a pressurizing supply conduit having a first end which is connected to the vessel and a second end which is for connection to a source of high pressure fluid, for delivering high pressure fluid to the vessel,

a slurry uptake and delivery conduit having a slurry uptake end which is located at the lower layer of the vessel and a delivery end which is connected to an abrasive discharge outlet, for delivery of slurry to the discharge outlet upon displacement by high pressure fluid delivered to the vessel,

a pressure relief conduit having a first end connected to the higher layer of the vessel and a second end connected to a pressure relief outlet, the pressure relief conduit also having a valve for control of fluid flow through the pressure relief conduit, and

a second supply conduit having a first end connected to the pressurizing supply conduit and a second end connected to the slurry uptake and delivery conduit,

wherein the second end of the second supply conduit connects to the slurry uptake and delivery conduit in the vicinity of the slurry uptake end.

Preferably the second end of the pressure relief conduit is connected to the slurry uptake and delivery conduit, the pressure relief outlet being provided by the abrasive discharge outlet.

Preferably the first end of the pressurizing supply conduit is located at the higher layer of the vessel. The first end of the pressure relief conduit may be connected to the pressurizing supply conduit, thereby connecting to the higher layer of the vessel via the first end of the pressurizing supply conduit.

Alternatively, the first end of the pressurizing supply conduit is located at the lower layer of the vessel.

The first end of the pressure relief conduit may be connected directly to the higher layer of the vessel. The pressurizing conduit may include a flow control valve.

In a second aspect the present invention may be broadly said to be a method of delivering an abrasive slurry including;

supplying high pressure fluid to a vessel, the vessel containing an abrasive slurry at a lower layer and a substantially abrasive-free fluid at a higher layer,

delivering high pressure fluid to a slurry uptake and delivery conduit, the high pressure fluid being connected to the conduit in the vicinity of a slurry uptake end located at the lower layer of the vessel,

displacing the slurry, by the supplied high pressure fluid, via the slurry uptake and delivery conduit,

diluting the slurry displaced via the slurry uptake and delivery conduit with fluid delivered to the conduit at the connection in the vicinity of the slurry uptake end,

discharging the displaced and diluted slurry at an abrasive discharge outlet, and

opening and closing a valve in a conduit connected to the vessel to respectively relieve and restore pressure in the vessel and to thereby stop and start the displacement and the discharge of the slurry.

Preferably pressure in the vessel is relieved via the slurry uptake and delivery conduit and the discharge outlet.

Preferably the high pressure fluid supplied to the vessel is introduced at the higher layer of the vessel.

Alternatively the high pressure fluid supplied to the vessel is introduced at the lower layer of the vessel.

The pressure relief may be via a conduit by which the high pressure fluid is supplied to the vessel.

The pressure relief may be via a conduit which is connected directly to the higher layer of the vessel.

Preferably, upon initially supplying high pressure fluid to the vessel and delivering high pressure fluid to the slurry uptake and delivery conduit, the valve is open to allow fluid flow through the pressure relief conduit to pressurize the system and thereafter the valve is closed to displace and discharge slurry at the abrasive discharge outlet.

Brief description of the Drawings

Figure 1 is a system diagram illustrating a first embodiment of the invention.

Figure 2 is a system diagram illustrating a second embodiment of the invention.

Figure 3 is a system diagram illustrating a third embodiment of the invention.

Figure 4 is a system diagram illustrating a fourth embodiment of the invention.

Detailed Description of the Preferred Embodiments of the Invention

The present invention relies on the natural tendency for fluid to take the path of least resistance to enable compressed fluid volume to be released into a discharge conduit with the design being such that the discharge is absent of abrasive.

With reference to Figure 1 which is a diagram illustrating a first embodiment of the invention, there is provided a pressure vessel 11 which provides a compartment for retaining an abrasive slurry. An abrasive slurry is a mixture of an abrasive material which is entrained within a fluid such as for example water or a liquid composition containing water. The vessel 11 contains the abrasive slurry 2 above which a layer of liquid 4 is provided. This liquid 4 is the same liquid used to entrain the abrasive particles to provide the slurry but which above a certain level "L" in the vessel is not mixed with abrasive.

A source of pressurised fluid 10 which incorporates a pressurising pump feeds fluid to the vessel 11. Feeding of fluid from the source 10 is through delivery conduits 14 and 15. Conduit 15 is provided to deliver fluid to the uptake and delivery conduit 16 to thereby provide the appropriate dilution to the slurry being displaced through

the opening 30. This dilution may be necessary to avoid blockage of the uptake and delivery conduit.

Conduit 14 is the main delivery and vessel pressurising conduit. In the configuration of the invention shown in figure 1, the conduit 14 has its outlet opening 24, defining a first opening in the vessel 11 within the fluid only region of the pressure vessel (ie above L)

A hopper 17 feeds abrasive slurry 2 to the vessel 11 through conduit 19.

A pressure relief conduit 21 is provided to be in fluid communication with the volume in vessel and be in flow contact with the fluid absent of abrasive. In the configuration of figure 1, the flow contact is provided via part of said delivery conduit 14. A fluid valve 13 controls the flow of fluid across pressure control conduit 21.

In normal operation of the system the pump system delivers pressurised fluid to the vessel and this causes the displacement of abrasive slurry 2 via the inlet opening 30 of the slurry uptake and delivery conduit 16 to nozzle 12. The inlet opening is positioned below L and preferably near the bottom of the vessel 11.

The pressure relief conduit 21 can be considered a by pass conduit to by pass the flow of volume of the vessel which contains abrasive. The control of the bypass is achieved by a fluid flow control valve 13 which is closable to close the conduit 21.

In the configuration of Figure 1, the conduit 14 is connected to the top of the vessel 11 where there is no abrasive 2 present. On depressurisation (when for example the fluid source 10 fails, is or is about to be turned off) the fluid valve 13 connecting conduit 21 to the delivery conduit 14 outside of the vessel is opened. The volume of the content inside the vessel 11 will remain compressed but will wish to expand. Two openings are available but such expansion will have a preference to discharge

through conduit 21, instead of through the opening 30 of the delivery conduit 16. This is because expansion of the volume by displacement of slurry flow through the opening 30 of the conduit 16 whose internal diameter, length and most predominantly because of the density and viscosity of the slurry bed 2 leads to a higher flow resistances.

On start-up and pressurisation of the system, fluid valve 13 will initially be open. The fluid will flow from source 10 into the vessel 11 through conduit 14. With fluid valve 13 open some of the fluid flow will enter conduit 21. Pressurisation of the vessel will also occur but this is reduced because of the partial flow diversion. In the preferred form where the pressure relief conduit 21 is connected to the slurry uptake and delivery conduit 16 upstream of the second opening 30 (and preferably outside of said vessel) the combination of resistance of slurry flow up through the opening 30 and the fact that the flow of fluid through the conduit 21 and into the uptake and delivery conduit 16 creates a back pressure in that part of the uptake and delivery conduit towards the opening 30, no slurry will travel to the nozzle. Upon closing of the valve 13 there will then be sufficient mass flow into the slurry pressure vessel 11 to cause a displacement of abrasive into the inlet opening 30 of conduit 16.

With valve 13 closed, the fluid flow from source 10 enters the vessel 11 through conduit 14 thus causing displacement of abrasive slurry into the inlet opening 30 of the uptake and delivery conduit 16 where it mixes with the main flow from conduit 15 and is carried to the nozzle through the uptake and delivery conduit 16 to the nozzle 12.

Abrasive flow can also at any time be halted by opening valve 13. On de-pressurisation, fluid valve 13 is open to provide an alternative and preferred route through conduit 21 for the compressed fluid. Upon expansion of the contents in the vessel such expansion is via the relief conduit 21. Conduit 14 has its opening in the vessel above level L, which ensures that the abrasive slurry is not able to reach

fluid valve 13 and it hence normally operates on clean water and with a minimal pressure differential hence its service life-time will be generally higher than would otherwise be the case. In addition the inner diameter of conduit 21 should be sufficiently large to ensure that the velocity of the escaping fluid is well below the settling velocity of the abrasive slurry 2 used. In this way any abrasive particles in the vessel above Level "L" will further be prejudiced not to enter or travel along the conduit 14 and enter the conduit 21 through the fluid valve 13.

Figure 2 illustrates a second embodiment of the invention where a separate relief conduit 21 is provided. Unlike the first embodiment shown in Figure 1, conduit 21 is not connected to conduit 15, and serves purely as a route of escape for the compressed volume in vessel 11. The second fluid valve 23 always operates on clean fluid, and the fluid valve 13 operates less frequently, ie. only at pressurisation and depressurisation stages. As a result, wear on valve 13 is decreased. The provision of the second fluid valve 23 is preferred but not essential.

In situation where a flow diversion is required when the pump pressurising the source 10 fails, a loss in pressure in the conduit 14 or at the pump may be detected by a pressure sensor thereby automatically opening valve 13 to provide pressure relief within the vessel through the conduit 21. In situation where the flow of abrasive slurry is desired to be stopped but where the pump pressurising the source 10 continues to operate, the valve 13 may merely be opened and fluid may continue to flow into the vessel 11 through the conduit 14 and 15 (if this is not separately closed) but since the path of least resistance of the pressurised material within the vessel is through the conduit 21, water will enter and merely exit above L thereby ensuring only water will exhaust through the conduit 21 out towards the nozzle 12. This flow will continue as long as the pump pressurising at the fluid source 10 continues to operate, the equilibrium of pressure of the compressed fluid is not reach and the valve 13 remains open.

A diaphragm pump 18 is used to draw fluid 4 from conduit 20, which creates a pressure drop in vessel 11 which in turn draws in abrasive slurry 2 from hopper 17 to vessel 11. In the particular embodiment in Figure 2, with fluid valve 13 and second fluid valve 23 closed, the diaphragm pump 18 is used to withdraw fluid through conduit 20 from the vessel creating a vacuum to draw in abrasive slurry 2 from the hopper 17 through conduit 19.

It would be appreciated that the system avoids fluid compressibility problems leading to unwanted discharging of abrasives to the nozzle at system pressurising and depressurising states. By providing an alternative route of less resistance for expansion of the compressed fluid volume from within the vessel from a point where no abrasive is carried to the nozzle and so the invention helps prevent nozzle blockages.

With reference to Figure 3, an alternative configuration is shown wherein the delivery conduit is positioned to have the first opening submerged in the slurry. In this configuration a separate opening provided by the pressure relief conduit is required to be positioned above L. The provision of the first opening 24 near the second 30 is that better mixing of the abrasive with the water to form the slurry is achieved nearer the second opening.

A further alternative is shown in figure 4 wherein the pressure relief conduit exhausts not into the uptake and delivery conduit but to a different location. This is a less preferred option in that the pressure from the fluid in the conduit 21 can not be used to provide a back pressure to fluid in the uptake and delivery conduit 16 and hence some slurry (during expansion in volume of the contents of the vessel) may travel into the uptake and delivery conduit through the opening.

The invention described herein is susceptible to variations, modifications and/or additions other than those specifically described and it is to be understood that the

invention includes all such variations, modifications and/or additions which fall within the spirit and scope of the above description.

The invention described herein is susceptible to variations, modifications and/or additions other than those specifically described and it is to be understood that the invention includes all such variations, modifications and/or additions which fall within the spirit and scope of the above description.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A fluid supply system for delivery of an abrasive slurry, the fluid supply system comprising:

a vessel for containing an abrasive slurry at a lower layer and a substantially abrasive-free fluid at a higher layer;

a pressurizing supply conduit having a first end which is connected to the vessel and a second end which is for connection to a source of high pressure fluid, for delivering high pressure fluid to the vessel;

a slurry uptake and delivery conduit having a slurry uptake end which is located at the lower layer of the vessel and a delivery end which is connected to an abrasive discharge outlet, for delivery of slurry to the discharge outlet upon displacement by high pressure fluid delivered to the vessel;

a pressure relief conduit having a first end connected to the higher layer of the vessel and a second end connected to a pressure relief outlet, the pressure relief conduit also having a valve for control of fluid flow through the pressure relief conduit; and

a second supply conduit having a first end connected to the pressurizing supply conduit and a second end connected to the slurry uptake and delivery conduit,

wherein the second end of the second supply conduit connects to the slurry uptake and delivery conduit in the vicinity of the slurry uptake end.

2. A fluid supply system as claimed in claim 1, wherein the second end of the pressure relief conduit is connected to the slurry uptake and delivery conduit, the pressure relief outlet being provided by the abrasive discharge outlet.

3. A fluid supply system as claimed in claim 1 or 2, wherein the first end of the pressurizing supply conduit is located at the higher layer of the vessel.

4. A fluid supply system as claimed in claimed 2, wherein the first end of the pressurizing supply conduit is located at the lower layer of the vessel.

5. A fluid supply system as claimed in claim 3, wherein the first end of the pressure relief conduit is connected to the pressurizing supply conduit, thereby connecting to the higher layer of the vessel via the first end of the pressurizing supply conduit.

6. A fluid supply system as claimed in claim 3 or 4, wherein the first end of the pressure relief conduit is connected directly to the higher layer of the vessel.

7. A fluid supply system as claimed in claim 6, wherein the pressurizing conduit includes a flow control valve.

8. A method of delivering an abrasive slurry comprising:

supplying high pressure fluid to a vessel, the vessel containing an abrasive slurry at a lower layer and a substantially abrasive-free fluid at a higher layer;

delivering high pressure fluid to a slurry uptake and delivery conduit, the high pressure fluid being connected to the conduit in the vicinity of a slurry uptake end located at the lower layer of the vessel;

displacing the slurry, by the supplied high pressure fluid, via the slurry uptake and delivery conduit;

diluting the slurry displaced via the slurry uptake and delivery conduit with fluid delivered to the conduit at the connection in the vicinity of the slurry uptake end;

discharging the displaced and diluted slurry at an abrasive discharge outlet; and

opening and closing a valve in a pressure relief conduit connected to the vessel to respectively relieve and restore pressure in the vessel and to thereby stop and start the displacement and the discharge of the slurry.

9. A method of delivering an abrasive slurry as claimed in claim 8, wherein the pressure in the vessel is relieved via the slurry uptake and delivery conduit and the discharge outlet.

10. A method of delivering an abrasive slurry as claimed in claim 8 or 9, wherein the high pressure fluid supplied to the vessel is introduced at the higher layer of the vessel.

11. A method of delivering an abrasive slurry as claimed in claim 9, wherein the high pressure fluid supplied to the vessel is introduced at the lower layer of the vessel.

12. A method of delivering an abrasive slurry as claimed in claim 10, wherein the pressure relief is via a conduit by which the high pressure fluid is supplied to the vessel.

13. A method of delivering an abrasive slurry as claimed in claim 10 or 11, wherein the pressure relief is via a conduit which is connected directly to the higher layer of the vessel.

14. A method of delivering an abrasive slurry as claimed in any one of claims 8 to 13, wherein, upon initially supplying high pressure fluid to the vessel and delivering high pressure fluid to the slurry uptake and delivery conduit, the valve is open to allow fluid flow through the pressure relief conduit to pressurize the system and thereafter the valve is closed to displace and discharge slurry at the abrasive discharge outlet.

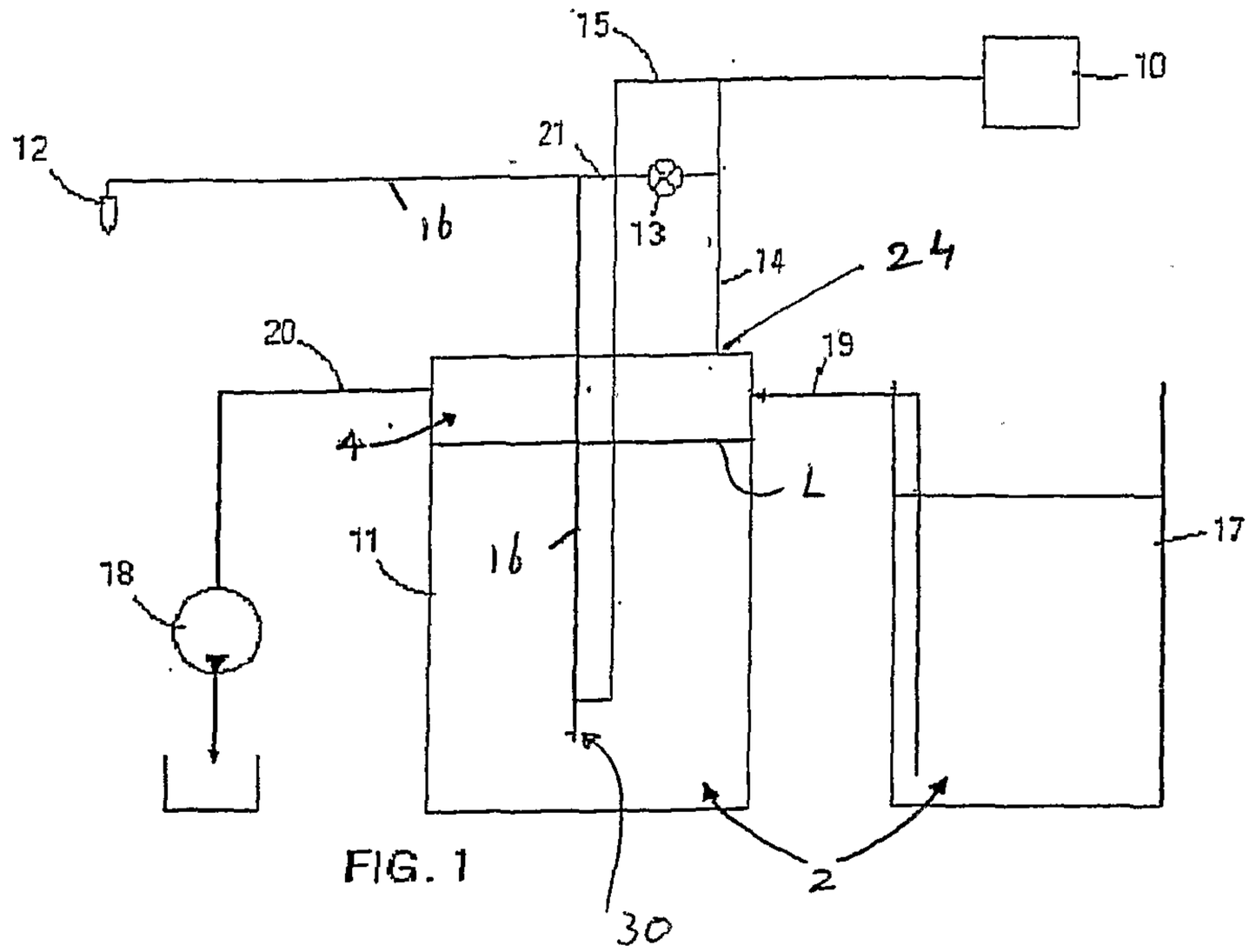
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FIG. 1

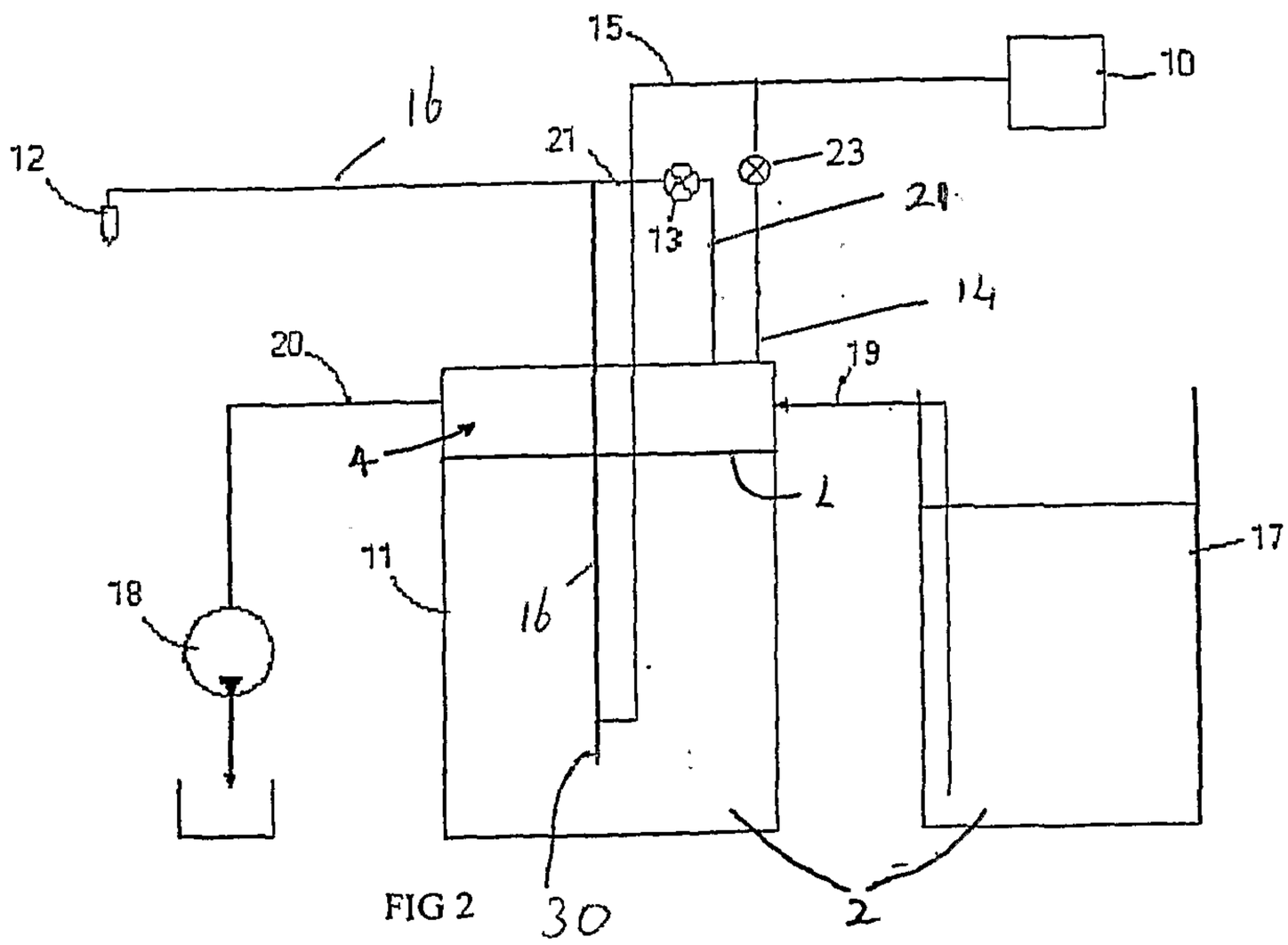
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FIG 2

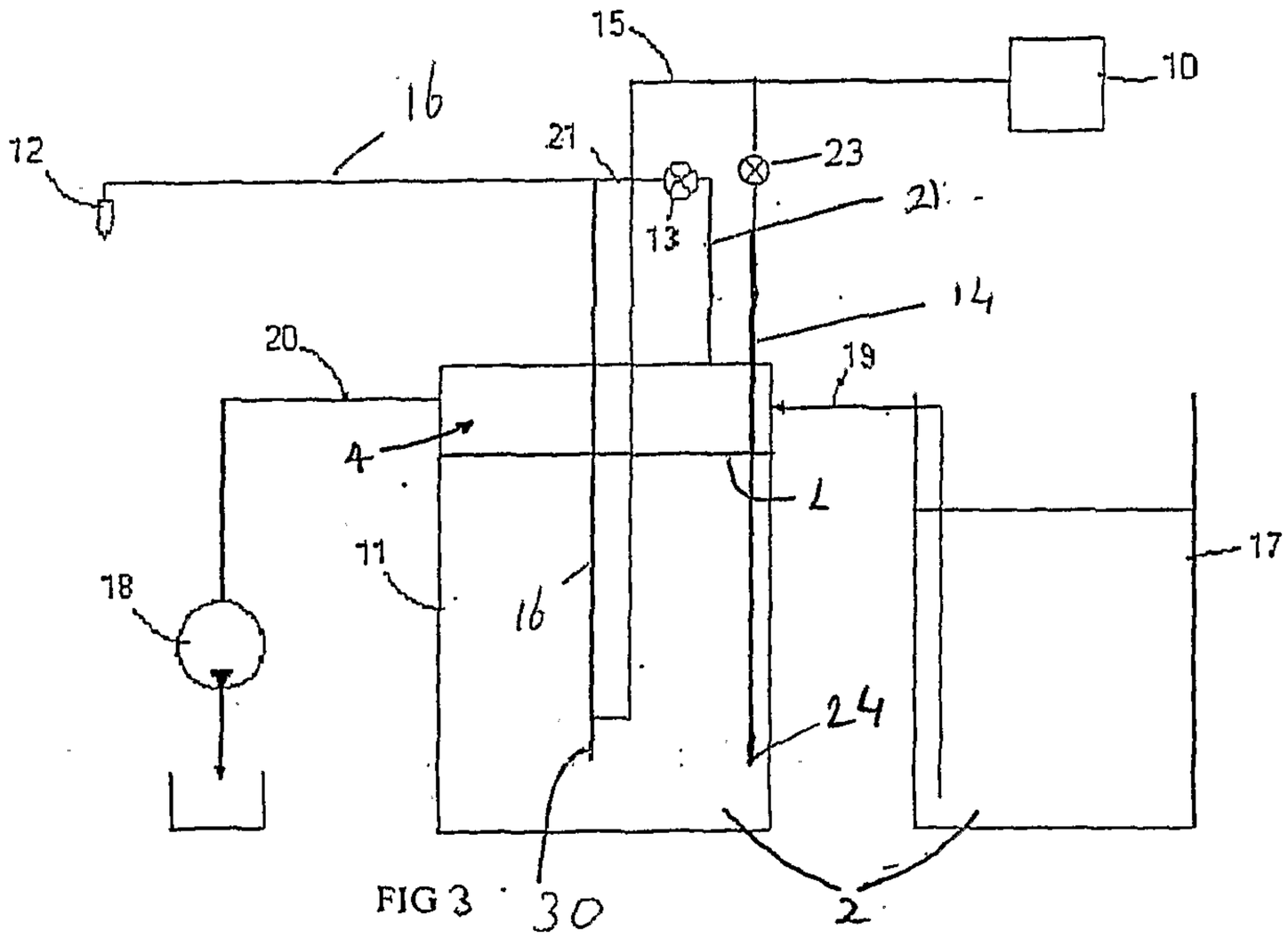
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FIG 3

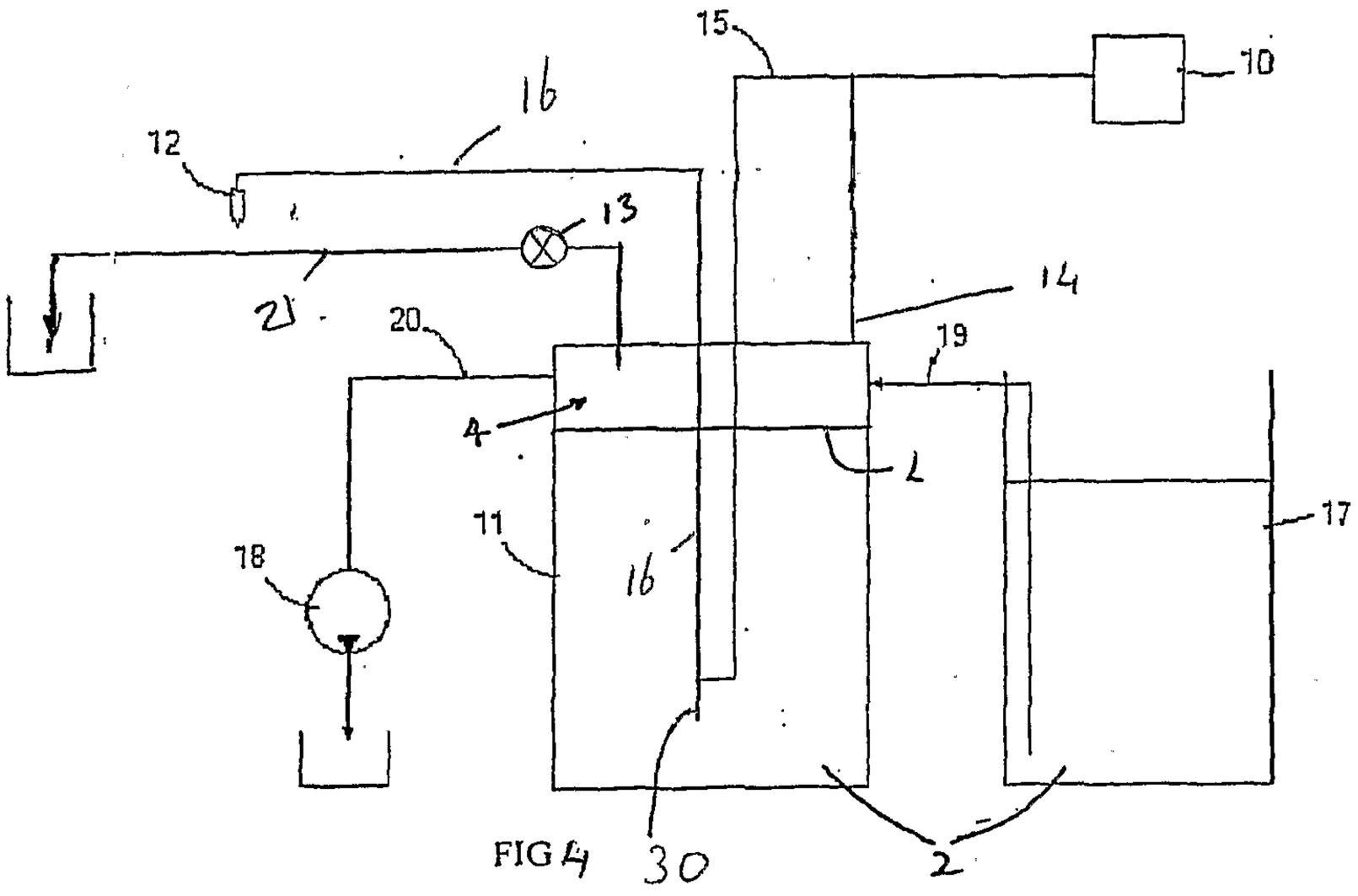
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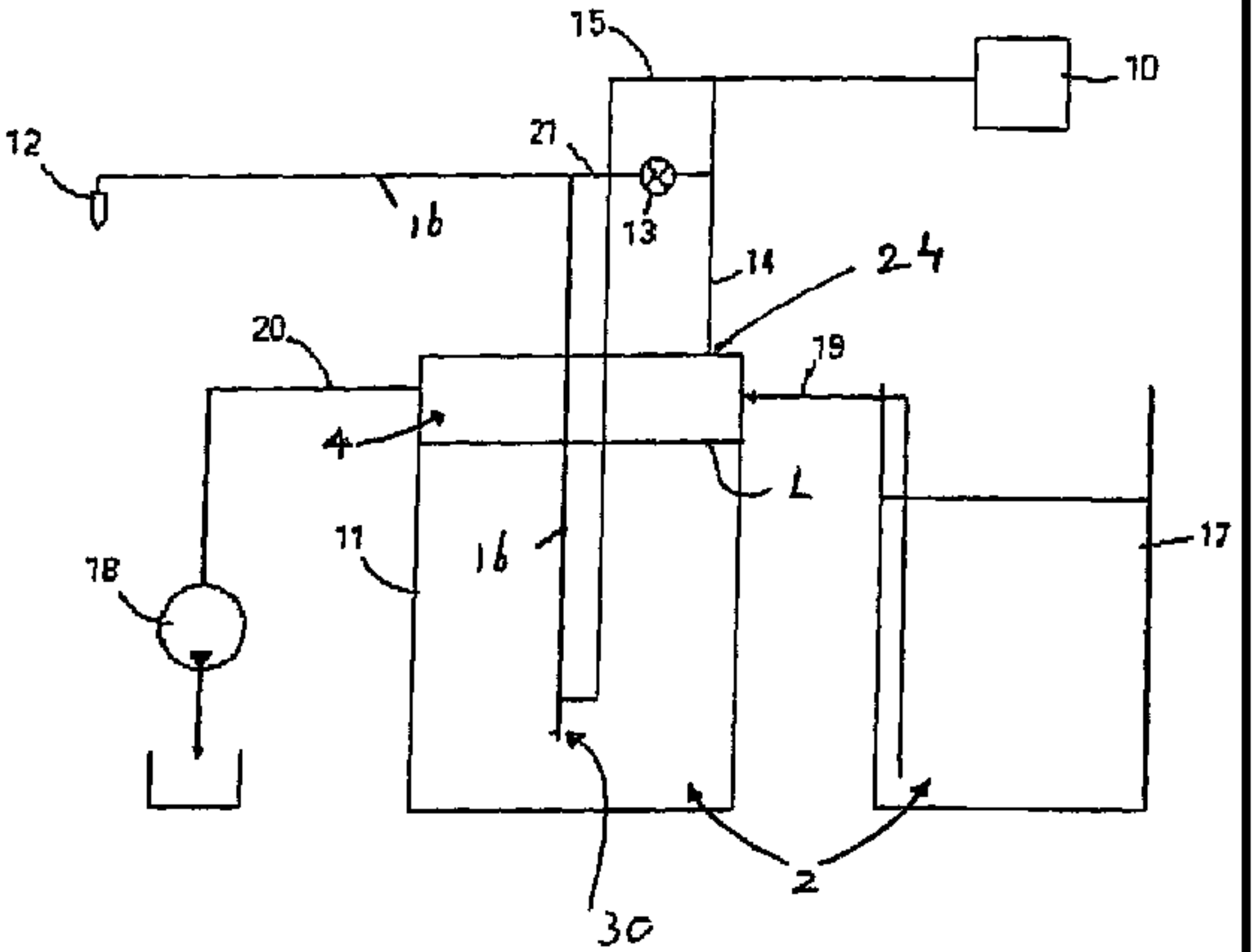
FIG 4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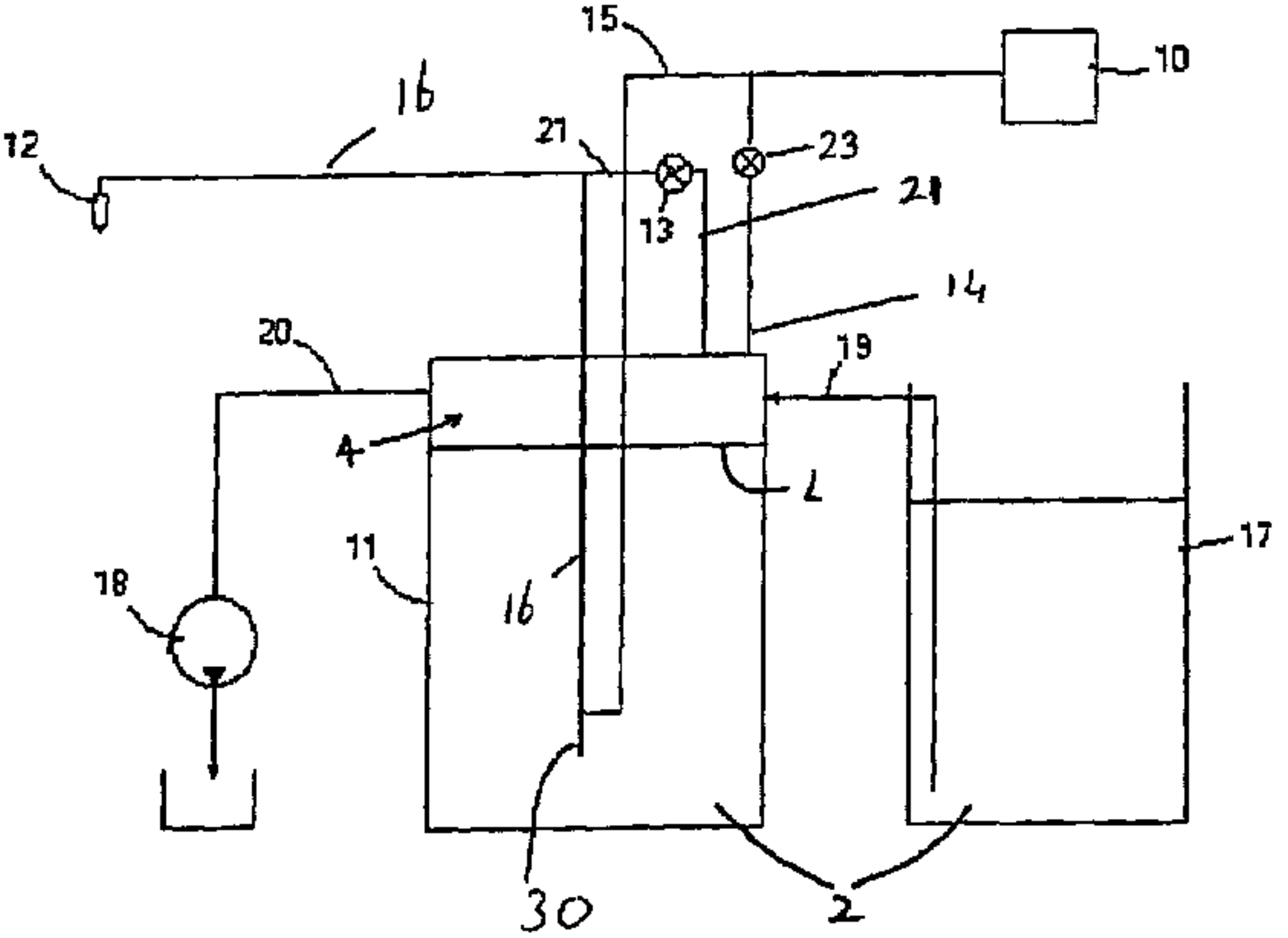
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