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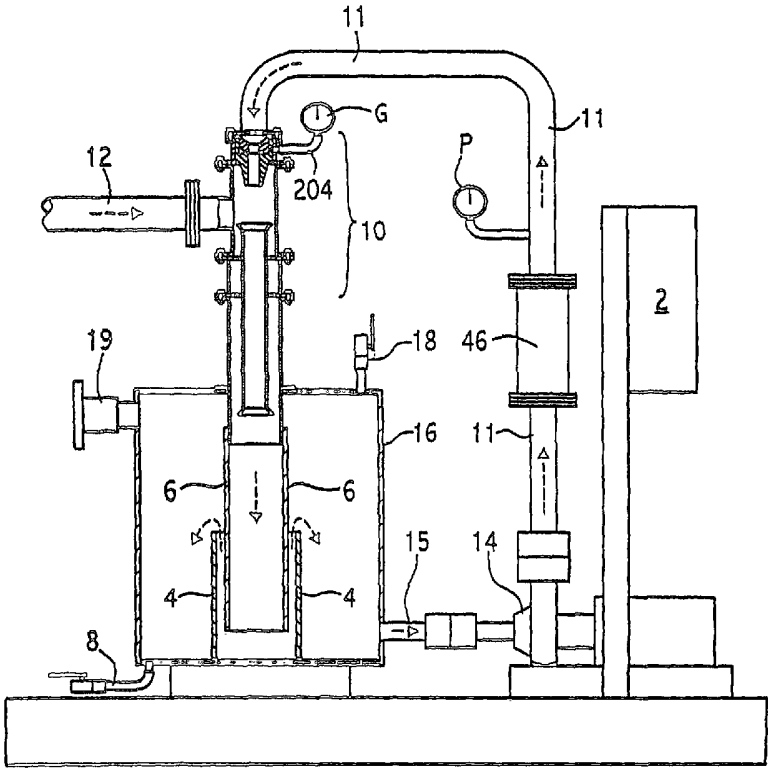
(54) Title: RECIRCULATING JET PUMP AND METHOD OF MOVING MATERIAL



(57) Abstract: A recirculating liquid jet pump and related systems for moving and/or separating a wide variety of materials are described. The system is preferably equipped with a material collection reservoir enabling the placement of material to be suctioned into the collection reservoir without bringing together the material to be suctioned with the motive fluid of the liquid jet pump. The collection reservoir also maybe connected to a separate container for de-watering solid-liquid mixtures to enable mixture liquid to be separated from the solids without bringing the separated liquid into contact with the motive fluid of the jet pump and without the use of excessive amounts of jet pump motive fluid. The collection reservoir also may be connected to a controller and removal means for removing suctioned material from the collection reservoir concurrently with action of the liquid jet pump.

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RECIRCULATING JET PUMP AND METHOD OF MOVING MATERIAL

FIELD OF THE INVENTION

[0001] This invention relates generally to hydraulic nonmechanical pumping devices for transferring material, and specifically, to jet pumps for moving solid, semi-solid and/or liquid materials, as well as related methods.

BACKGROUND

[0002] Previous inventions described in U.S. Patents 6,322,327 B1 and 6,450,775 B1 provide jet pumps with significantly increased vacuum efficiency, resulting in the ability to move greater amounts of solid or slurry materials without a proportionate increase in energy consumption. While those pump configurations have made a significant contribution in the field of pump efficiency and capabilities, the material being vacuumed or suctioned in the pump configurations typically is mixed with the motive fluid of the jet pump. This can present difficulties where the material being pumped might become volatile when placed in contact with the motive fluid or when the material being pumped is preferably kept separate from the motive fluid for other reasons. Also, those previous developments still required significant volumes of motive fluid in many commercial scale pumping operations.

[0003] Thus, a need has continued to exist for a jet pump which does not require a large volume of motive fluid in commercial operations, and which allows a user to keep pumped material separate from the motive fluid of the jet pump. A need also continues to exist for a system and related methods which allow uninterrupted operation of the jet pump while the pumped material is transported elsewhere by the same system.

SUMMARY OF THE INVENTION

[0004] The present invention meets these and other needs by providing, among other things, apparatus comprising:

(a) a jet pump in fluid communication with a passageway for a material to be suctioned, the jet pump being sized and configured to create a vacuum in the passageway when the jet pump is in use;

(b) a motive fluid pump sized and configured to supply a motive fluid to the jet pump; and

(c) a motive fluid reservoir downstream from the jet pump, the motive fluid reservoir

being in fluid communication with the jet pump and the motive fluid pump so that during use the motive fluid pump recirculates at least a portion of the motive fluid from the motive fluid reservoir to the jet pump;

wherein the jet pump is comprised of a nozzle assembly which is sized and configured to (A) receive the motive fluid and a gas, and (B) eject the motive fluid as a liquid flow while feeding the gas into proximity with the periphery of the liquid flow. Preferably, the jet pump in apparatus of this invention is further comprised of a housing defining a suction chamber into which the nozzle assembly may eject the liquid flow, the housing further defining a suction inlet and a suction outlet; and an outlet pipe extending from the suction outlet away from the suction chamber, the outlet pipe being in fluid communication with the suction chamber and being disposed to receive the liquid flow; the outlet pipe defining at least a first inner diameter along a portion of its length and a second inner diameter along another portion of its length, the second inner diameter being less than the first inner diameter. It is particularly preferred in certain applications that the nozzle assembly extend into the suction chamber towards the suction outlet and into the imaginary line of flow of the suction pipe.

[0005] In another embodiment of the invention, the apparatus further comprises a material collection reservoir which is sized and configured to permit the formation of a vacuum therein. In this embodiment, the collection reservoir is intermediate to, and in fluid communication with, the passageway for the material to be suctioned and the jet pump. This collection reservoir allows material which is suctioned to be collected without mixing with or otherwise contacting the motive fluid of the jet pump.

[0006] Yet another embodiment of this invention provides a method of moving material from one location to another. The method comprises:

a. injecting a pressurized fluid into a nozzle assembly to produce a flow of pressurized fluid,

b. providing a gas to the nozzle assembly to surround the flow of pressurized fluid with the gas,

c. directing the flow of pressurized fluid surrounded by the gas into a suction chamber which defines both an inlet in fluid communication with a collection reservoir and an outlet in fluid communication with an outlet pipe, the outlet pipe defining a venturi-like inner surface, and directing the flow of pressurized fluid surrounded by the gas

into the outlet pipe to produce a vacuum in the collection reservoir,

d. suctioning the material to be moved into the collection reservoir using the vacuum produced in step (c.), and

e. recirculating at least a portion of the pressurized fluid directed into the outlet pipe back into the nozzle assembly.

In a preferred embodiment of this invention, the material to be moved is liquid material from a slurry comprised of a mixture of solid material and liquid material. The suctioning of step (d.) is carried out after placing the collection reservoir in fluid communication with a slurry container equipped with a filter so that, when a vacuum is created in the collection reservoir, a vacuum is created in the slurry container and liquid material from slurry within the slurry container is suctioned through the filter and into the collection reservoir while solid material remains in the slurry container. This preferred embodiment thus enables the removal of liquid from the slurry without mixing or otherwise bringing together the separated liquid material with the motive fluid of the jet pump. In another preferred embodiment of this invention, the method further comprises the step of controlling the flow rate of the gas into the nozzle assembly to thereby control the level of vacuum produced in the suction chamber.

[0007] Yet another embodiment of the present invention provides a system comprising:

(a) a material collection reservoir in fluid communication with a passageway for suctioned material, the collection reservoir being sized and configured to permit formation of a vacuum within the collection reservoir,

(b) a jet pump in fluid communication with the collection reservoir and the passageway, the jet pump being sized and configured to form a vacuum within the collection reservoir so as to enable collection of the suctioned material in the collection reservoir without permitting suctioned material to directly enter the jet pump, and

(c) removal means for removing at least a portion of the suctioned material from the collection reservoir, the removal means being configured to enable removal of at least a portion of the suctioned material from the collection reservoir while the jet pump is in use.

Preferably the jet pump is comprised of a nozzle assembly which is sized and configured to (1) receive the motive fluid and a gas, and (2) eject the motive fluid as a liquid flow while feeding the gas into proximity with the periphery of the liquid flow. In another embodiment,

the system further comprises a controller which controls the operation of the removal means based upon the level of suctioned material in the collection reservoir.

[0008] Yet another embodiment of this invention provides a method for moving material from one location to another. The method comprises:

a. creating a vacuum in a material collection reservoir by action of a jet pump, the collection reservoir being in fluid communication with a passageway for a material to be moved and with the jet pump, and

b. suctioning the material through the passageway into the collection reservoir while controlling the amount of material in the collection reservoir so as to prevent the material from entering the jet pump.

[0009] These and other embodiments, advantages, and features of this invention will be apparent from the following description, accompanying drawings and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 is a partial cross-sectional, side view of a preferred embodiment of the present invention.

[0011] Figure 2 is a side view of another preferred embodiment of the present invention.

[0012] Figure 3 is an enlarged view in cross-section of the jet pump component of the device of Figure 1.

[0013] Figure 4 is a side view of another preferred embodiment of the present invention.

[0014] In each of the above figures, like numerals or letters are used to refer to like parts among the several figures.

DETAILED DESCRIPTION OF THE INVENTION

[0015] It will now be appreciated that the re-circulation of motive fluid for the jet pump component in apparatus of this invention coupled with a collection reservoir intermediate in series to the targeted material to be suctioned enables vacuum collection of the material to be moved into the collection reservoir without moving parts contacting the material and without the material contacting motive fluid of the jet pump. Thus solids, liquids, gases and all mixtures of two or more of those which are subject to being moved by a vacuum can be moved, collected and/or separated without vacuum pump contact, and the jet pump driving

the vacuum is self-contained in that it only requires a fixed amount of motive fluid to operate. When using the preferred jet pumps of this invention, the foregoing can be accomplished without pump cavitation so as to maintain a stable level of vacuum during pump operation regardless of the material being suctioned.

[0016] Turning now to the drawings, Figure 1 illustrates one preferred embodiment of this invention. There, a re-circulating jet pump apparatus is shown to include a jet pump **10**, a pipe **12** which defines a passageway in fluid communication with pump **10**, a motive fluid pump **14**, a motive fluid reservoir **16**, and a heat exchanger **46**. Pump **14** is a centrifugal or other type of pump, controlled at a control panel **2**. Pump **14** forces motive fluid, *e.g.*, liquid water or another inert fluid, into a pipe loop **11** which feeds the pressurized motive fluid into a nozzle assembly (see Fig. 3) of jet pump **10**. A pressure gauge **P** is provided to allow monitoring of the motive fluid pressure. Loop **11** places the re-circulating motive fluid in thermal communication with heat exchanger **46** by directing the motive fluid through exchanger **46** to remove accumulated heat from the motive fluid during its re-circulation.

[0017] The motive fluid reservoir **16** further comprises a drain valve **8**, a breather valve **18** and an exhaust port **19**. Valve **18** and port **19** exhaust gas built up in reservoir **16** during use of the vacuum created by jet pump **10**, in order to maintain a level of motive fluid in reservoir **16** sufficient to feed a pipe **15** at the lower portion of reservoir **16**. Pipe **15** in turn feeds motive fluid to motive fluid pump **14**. Reservoir **16** further comprises vertical baffles **4** and **6** for diverting the flow of a mixture of motive fluid and gas suctioned into and expelled out of jet pump **10**. By diverting the flow in this way, baffles **4** and **6** facilitate the separation of liquid from gas within reservoir **16** to minimize gas in the motive fluid exiting reservoir **16** at pipe **15**. This in turn minimizes the amount of gas fed into pump **14**. While this configuration of the motive fluid reservoir is preferred, other reservoir configurations or labyrinth-like structures may be employed so long as the configuration minimizes the amount of gas transferred from the motive fluid reservoir to the motive fluid pump.

[0018] As seen in another preferred embodiment illustrated in Figure 2, the apparatus of Figure 1 is placed in fluid communication with a material collection reservoir **50**. Collection reservoir **50** defines a collection reservoir inlet **52** through which suctioned material enters reservoir **50**. In the particular embodiment depicted, the material enters inlet **52** from a slurry container **T** which is in fluid communication with reservoir **50** through inlet **52** and is lined

with a filter **F**. As a vacuum is created in reservoir **50**, the fluid communication between reservoir **50** and container **T** causes a vacuum to be formed in container **T** to draw liquid material from slurry therein through filter **F** and into material collection reservoir **50**. This particular de-watering configuration is more particularly described in our co-filed and commonly owned U.S. Patent Application No. 10/199,777. A collection reservoir outlet **54** is connected to pipe **12** to place the interior of reservoir **50** in fluid communication with the passageway defined by pipe **12**. A discharge port **56** at a lower portion of reservoir **50** may be closed to allow suctioned material which enters reservoir **50** to accumulate, or opened to drain reservoir **50** of suctioned material. Draining through port **56** can be facilitated during jet pump operation by placing discharge port **56** of reservoir **50** in fluid communication with another vacuum pump (not shown in Fig. 2), or other pump capable of pulling or removing accumulated material from the lower portion of reservoir **50**. Collection reservoir **50** should be constructed in such a way that it structurally withstands the vacuum produced by the pump(s) with which it is in fluid communication during operation of the apparatus.

[0019] In the preferred embodiments depicted, the jet pump is configured in accordance with our previously developed jet pump described in commonly-owned U.S. Patents 6,322,327 B1 and 6,450,775 B1. Figure 3 illustrates in cross-section jet pump **10** of Figures 1 and 2. Jet pump **10** includes nozzle assembly **307**, which in turn is comprised of a constricted throat **301** formed by fluid nozzle **201**, an air injection nozzle **202** which forms a nozzle opening **303**, and a nozzle housing **203**. Nozzle housing **203** is a flanged member which is attached to and maintains the proper position of fluid nozzle **201** adjacent to air injection nozzle **202**. Air intake **211** is a passage through nozzle housing **203**. In the embodiment depicted, a single air intake **211** is shown although a plurality of intakes also may be provided. A gas conduit in the form of an air hose **204** allows a gas to enter jet pump **10** through intake **211**. The gas enters the nozzle assembly through intake **211** and an aperture **304** in nozzle **202**, then into an annular air gap **302** to form an air bearing around fluid flow ejected from nozzle **201** as the gas passing through gap **302** between the tip of nozzle **201** and the upstream side of nozzle **202**. The amount of gas allowed into jet pump **10** is controlled by a valve **V** which includes a gauge **G** (Fig. 1). By using valve **V** to control the level of gas entering jet pump **10**, it is possible to increase or decrease the level of vacuum produced by jet pump **10**.

[0020] Water or other motive fluid from loop pipe **11** passes through fluid nozzle **201** and air injection nozzle **202** of nozzle assembly **307** and into a housing **200** which defines a suction chamber **205**, a suction inlet **210** and a suction outlet **220**. In suction chamber **205**, the fluid in the form of a liquid flow combines with gas or gaseous material entering from pipe **12** through inlet **210**, and the combined stream enters an outlet pipe **207** through outlet **220**, pipe **207** being comprised of an outlet pipe segment **207a** which is detachable from the apparatus and which itself comprises a concentric wear segment in the form of a venturi target tube **206**. The combined stream then passes through target tube **206** into outlet pipe **207** and into motive fluid reservoir **16** (see Fig. 1).

[0021] Although not depicted in these drawings and typically less important when the material being suctioned does not include solid material, the nozzle assembly **307**, and in particular the downstream end of air injection nozzle **202** may be extended into suction chamber **205** and into an imaginary line of flow of material from pipe **12** through suction inlet **210** to increase the vacuum created by jet pump **10**. This feature is more particularly described in the previously referenced U.S. Patent 6,322,327 B1 and U.S. Patent 6,450,775 B1.

[0022] Target tube **206** of outlet pipe **207** defines a first inner diameter **Q** of outlet pipe **207**, and outlet pipe **207** also defines a second inner diameter **R** which is less than inner diameter **Q**. It should be appreciated that outlet pipes of this invention may also be fabricated without a target tube but with a non-uniform inner surface so as to define a narrowing passage providing a venturi-like effect to the material exiting the suction chamber through the outlet pipe.

[0023] The gas employed in the jet pump component of preferred embodiments of this invention will preferably be under no more than atmospheric pressure, to reduce risk of operations and cost. The gas preferably will be an inert gas, *e.g.*, nitrogen or argon, when the liquid or other material being pumped could be volatile in the presence of certain atmospheric gases, *e.g.*, oxygen. When such volatility is not an issue, the gas employed will be most conveniently atmospheric air.

[0024] Typically, as depicted, the motive fluid pump is an electrically powered centrifugal pump or the like. However, the motive fluid pump alternatively may be any pump that is otherwise compatible with the motive fluid being pumped and is otherwise capable of causing

the motive fluid to re-circulate back into the jet pump sufficiently to cause the jet pump to form a vacuum. The motive fluid of this invention may be any fluid which is capable of being used in the jet pump to create a vacuum. Typically, the motive fluid will be liquid water or some other aqueous liquid solution, but the motive fluid also may be a gas or another liquid if the circumstances of use dictate that water is less preferred as the motive fluid. Preferably, the motive fluid is inert to the material being moved or suctioned, to reduce hazardous condition risks in the event that the motive fluid comes into contact with the suctioned material.

[0025] The heat exchanger in preferred embodiments of this invention may be any device which reduces the temperature of the motive fluid of the jet pump, and its location along the re-circulation path of the motive fluid may vary. The heat exchanger may, for example, be a set of copper coils located along the piping which extends from the motive fluid pump to the nozzle assembly of the jet pump. Or, it could be located within or attached to the motive fluid reservoir. The location and configuration of the heat exchanger may vary as long as the heat exchanger reduces the temperature of the motive fluid during use.

[0026] While it is understood that at least one preferred jet pump described herein is characterized by certain component features, the foregoing description of specific embodiments can be readily adapted for various applications without departing from the general concept or spirit of this invention. Thus, for example, the inner surface of the outlet pipe (which provides the venturi effect feature of the outlet pipe) alternatively can be defined by the pipe itself, rather than a detachable wear plate. These and other adaptions and modifications are intended to be comprehended within the range of equivalents of the presently disclosed embodiments. Also, while specific embodiments have been described above, several other applications and embodiments of the presently described invention may be contemplated in view of this disclosure. Thus, for example, while the accompanying drawings illustrate the pumping system of this invention as used for separating liquid material from a slurry, the system may be used for virtually any application in which liquids, solids as agglomerate or particulate matter, or a slurry comprised of a mixture of liquid and solid material, must be separated or moved from one location to another. The system also may be employed to remove liquids from such slurry mixtures, thereby permitting solid particulate matter to be rapidly separated from the liquid and dried, if desired. In each of the above

examples, small batch operations as well as large commercial batch, semi-continuous and continuous operations are possible using pumping methods and systems of this invention. The present invention can be used in any application requiring significant suction effect of solid material in a liquid or gaseous environment. The invention can also be used for suction in gaseous or liquid environments without solids present, and maintain a significant suction effect. Thus, as noted extensively herein, the invention can also be used in closed loop de-watering applications to remove excess water or moisture from material.

[0027] The dimensions of the various component parts of, the pressure under which motive fluid is fed to the jet pump of, and the level of vacuum produced by, devices of this invention may vary depending upon the circumstances in which the device will be employed, so long as the dimensions, pressures and vacuum permit the apparatus to function as described. Except where specifically noted otherwise herein, the component parts may be fabricated from a wide variety of materials, the selection of which will depend again upon the circumstances in which the device will be employed. Preferably, metals, metal alloys or resilient plastics, for example, will be employed to insure that points of mechanical contact or abrasive wear in the systems and pumps will be resilient enough to withstand the forces placed upon them during pump operation.

[0028] It also should be appreciated that virtually any material which can be suctioned or vacuumed can serve as the material to be moved in the practice of this invention. Thus, for example, agricultural products, liquid products or side-products, liquid waste, slurries of waste, mixtures of liquids and solids and particulate solids alone can all be suctioned using the apparatus and method of this invention.

[0029] As seen in another preferred embodiment of this invention illustrated in Figure 4, a system for removal of material comprises a material collection reservoir **50** in fluid communication with a passageway, defined by pipe **12**. Collection reservoir **50** is sized and configured to permit formation of a vacuum within reservoir **50**. The system also comprises a jet pump **10**, which is in fluid communication with a collection reservoir outlet **54** of collection reservoir **50** by way of the passageway defined by pipe **12**. Action of jet pump **10** causes a vacuum to be formed in collection reservoir **50** so that suctioned material **M** is drawn into collection reservoir **50** through collection reservoir inlet **52** from a source not shown. The system also comprises removal means for removing at least a portion of suctioned material

M from collection reservoir **50**. As depicted, the removal means is a removal pump **110**. Operation of removal pump **110** is controlled by a controller **112**. The removal of suctioned material **M** is controlled based upon a level **L** of suctioned material in collection reservoir **50**. Controller **112** as depicted comprises an ultrasonic sensor which is configured to collect and transmit real time information regarding level **L** of suctioned material **M** present in collection reservoir **50**. This allows controller **112** to activate removal pump **110** when material level **L** reaches some predetermined value, causing suctioned material **M** to pass from collection reservoir **50** into discharge pipe **120**. Controller **112** further activates a reservoir discharge valve actuator **118** to open (and close) a reservoir discharge valve **116**. Actuator **118** operates to open and close discharge valve **116** to allow removal of suctioned material out of collection reservoir **50**. In a preferred embodiment of the invention, controller **112** controls activation of removal pump **110** concurrently with operation of actuator **118** in a manner to remove suctioned material from collection reservoir **50** and prevent level **L** of suctioned material **M** from reaching and passing into collection reservoir outlet **54** and thus entering jet pump **10**. In addition controller **112** controls removal of suctioned material so as to ensure that a minimum level of suctioned material is maintained in the collection reservoir. This maintenance of a minimum material level in the collection reservoir prevents air from being drawn into the removal pump which could cause cavitation and loss of prime of the removal pump. A clean out port **114** is provided to allow access to discharge line **120** should discharge line **120** become plugged.

[0030] Thus, in a preferred embodiment of the invention, controlled removal of suctioned material from the collection reservoir is carried out by removal means for removing the material such as, for example, a removal pump. The controller ensures that the level of material in the collection reservoir is maintained within a pre-selected range. This pre-selected range should preferably have a maximum level of material which, if reached, would cause controller to activate the removal means and the discharge valve actuator to drain at least a portion of the suctioned material present in the collection reservoir. The pre-selected range also includes a minimum level of suctioned material which, when reached in the process of draining the collection reservoir, would cause the controller to de-activate the removal pump and the discharge valve actuator to prevent any further draining of suctioned material. Optimal benefit of the system of this invention is attained by use of the jet pump to provide

vacuum for drawing suctioned material into the collection reservoir while also allowing optional concurrent use of the removal means to simultaneously drain suctioned material out of the collection reservoir. Such continuous or semi-continuous operation of the jet pump with concurrent use of the removal pump avoids the necessity of stopping material movement operation to draw down the collection reservoir. In particularly preferred embodiments, the use of certain types of removal means, for example, mechanical reciprocating pumps, allow the automated movement and disposal of suctioned material over long distances that is not possible with systems which do not employ such removal means.

[0031] The jet pump component of the system of the invention is understood to be preferably that which has been described in detail previously, although other jet pumps, *e.g.*, nozzle-driven pumps which employ a venturi tube, can be used. The collection reservoir should be constructed so that it is capable of withstanding the vacuum produced by the pumps with which it is in fluid communication during operation of the system.

[0032] The removal means of this invention can be any device which provides for adequate removal of the suctioned material. Such removal means can include, but are not limited to, pumps, rotary valves and tilt mechanisms. The removal means of this invention is preferably a removal pump and more preferably either a positive displacement pump or a mechanical pump.

[0033] The controller of the invention can be any device which allows controlling the amount of suctioned material present in the collection reservoir. Such devices can include, but are not limited to devices which employ sensors in operative connection with a switch for controlling removal pump and/or valve operations. Exemplary sensors include, *e.g.*, ultrasonic sensors, laser sensors, radar sensors, mechanical sensors, magnetic sensors, and photoelectric sensors, though an ultrasonic sensor has been depicted. In addition, though the controller has been shown as an ultrasonic sensor located on top of the collection reservoir, it is to be understood that the location of the controller can be at other region of the collection reservoir. One alternative embodiment of the invention, though not shown, can comprise a controller comprised of at least two magnetic or photoelectric sensors located along a side of the collection reservoir for sensing high and low level conditions of the suctioned material. Another alternative embodiment of the invention can comprise a controller comprised of a sight glass for manual inspection of the level of suctioned material within the collection

reservoir, together with a manual switch for activation of the removal pump.

[0034] As shown, the reservoir discharge valve is an actuated valve, though numerous other valve mechanisms, *e.g.*, check valves or the like, can be envisioned by those of skill in the art which could alternatively serve the same purpose of controlling the flow of suctioned material from the collection reservoir. the reservoir discharge valve can be replaced by a check valve. It should also be appreciated that the material collection reservoir of this invention may be affixed to the other components of the system in a permanent or semi-permanent fashion, or may be configured for easy detachment from those components so that the reservoir may be made mobile.

[0035] This invention is susceptible to considerable variation in its practice. Therefore, the foregoing description is not intended to limit, and should not be construed as limiting, the invention to the particular exemplifications presented hereinabove.

Claims:

1. Apparatus comprising:

   (a) a jet pump in fluid communication with a passageway for a material to be suctioned, the jet pump being sized and configured to create a vacuum in the passageway when the jet pump is in use;

   (b) a motive fluid pump sized and configured to supply a motive fluid to the jet pump; and

   (c) a motive fluid reservoir downstream from the jet pump, the reservoir being in fluid communication with the jet pump and the motive fluid pump so that during use the motive fluid pump recirculates at least a portion of the motive fluid from the motive fluid reservoir to the jet pump;

wherein the jet pump is comprised of (1) a nozzle assembly which is sized and configured to (A) receive the motive fluid and a gas, and (B) eject the motive fluid as a liquid flow while feeding the gas into proximity with the periphery of the liquid flow.

2. Apparatus according to Claim 1 wherein the jet pump is further comprised of:

   (2) a housing defining a suction chamber into which the nozzle assembly may eject the liquid flow, the housing further defining a suction inlet and a suction outlet; and

   (3) an outlet pipe extending from the suction outlet away from the suction chamber, the outlet pipe being in fluid communication with the suction chamber and being disposed to receive the liquid flow; the outlet pipe defining at least a first inner diameter along a portion of its length and a second inner diameter along another portion of its length, the second inner diameter being less than the first inner diameter.

3. Apparatus according to Claim 2, wherein the nozzle assembly extends into the suction chamber towards the suction outlet and into the imaginary line of flow of the suction pipe.

4. Apparatus according to Claim 2 wherein the nozzle assembly defines a constricted throat, an annular gap surrounding the constricted throat, at least one aperture in fluid communication with the gap, and a nozzle opening, the constricted throat terminating at the nozzle opening.

5. Apparatus according to Claim 2 wherein the gas is air.

6. Apparatus according to Claim 2 wherein the gas is an inert gas.

7. Apparatus according to Claim 2 wherein the nozzle assembly receives the gas from a gas conduit, and wherein the gas flow rate through the gas conduit is controlled.

8. Apparatus according to Claim 7 wherein the gas flow rate is controlled by a valve, to thereby control the level of vacuum produced by the jet pump.

9. Apparatus according to Claim 2 wherein the outlet pipe is comprised of an outlet pipe segment, at least a portion of the outlet pipe segment defining an inner surface, at least a portion of the inner surface in turn defining the second inner diameter of the outlet pipe.

10. Apparatus according to Claim 9 wherein the outlet pipe segment is detachable from the apparatus.

11. Apparatus according to Claim 10 wherein the outlet pipe segment is comprised of a detachable concentric wear segment which defines the inner surface.

12. Apparatus according to Claim 11 further comprising a heat exchanger in thermal communication with the motive fluid.

13. Apparatus according to Claim 1 further comprising a heat exchanger in thermal communication with the motive fluid.

14. Apparatus according to Claim 1 further comprising a material collection reservoir which is sized and configured to permit the formation of a vacuum therein, the collection reservoir being intermediate to, and in fluid communication with, the passageway for the material to be suctioned and the jet pump.

15. Apparatus according to Claim 14 wherein the jet pump is comprised of:

(1) a nozzle assembly which is sized and configured to (A) receive the motive fluid and a gas, and (B) eject the motive fluid as a liquid flow while feeding the gas into proximity with the periphery of the liquid flow;

(2) a housing defining a suction chamber into which the nozzle assembly may eject the liquid flow, the housing further defining a suction inlet and a suction outlet; and

(3) an outlet pipe extending from the suction outlet away from the suction chamber, the outlet pipe being in fluid communication with the suction chamber and being disposed to receive the liquid flow; the outlet pipe defining at least a first inner diameter along a portion of its length and a second inner

diameter along another portion of its length, the second inner diameter being less than the first inner diameter.

16. Apparatus according to Claim 15, wherein the nozzle assembly extends into the suction chamber towards the suction outlet and into the imaginary line of flow of the suction pipe.

17. Apparatus according to Claim 16 wherein the nozzle assembly defines a constricted throat, an annular gap surrounding the constricted throat, at least one aperture in fluid communication with the gap, and a nozzle opening, the constricted throat terminating at the nozzle opening.

18. Apparatus according to Claim 15 wherein the gas is air.

19. Apparatus according to Claim 15 wherein the gas is an inert gas.

20. Apparatus according to Claim 15 wherein the nozzle assembly receives the gas from a gas conduit, and wherein the gas flow rate through the gas conduit is controlled.

21. Apparatus according to Claim 20 wherein the gas flow rate is controlled by a valve, to thereby control the vacuum produced by the jet pump.

22. Apparatus according to Claim 15 wherein the outlet pipe is comprised of an outlet pipe segment, at least a portion of the outlet pipe segment defining an inner surface, at least a portion of the inner surface in turn defining the second inner diameter of the outlet pipe.

23. Apparatus according to Claim 22 wherein the outlet pipe segment is detachable from the apparatus.

24. Apparatus according to Claim 23 wherein the outlet pipe segment is comprised of a detachable concentric wear segment which defines the inner surface.

25. Apparatus according to Claim 24 further comprising a heat exchanger in thermal communication with the motive fluid.

26. Apparatus according to Claim 14 further comprising a heat exchanger in thermal communication with the motive fluid.

27. Apparatus according to Claim 15 further comprising a heat exchanger in thermal communication with the motive fluid.

28. A method of moving material from one location to another, the method comprising:

a. injecting a pressurized fluid into a nozzle assembly to produce a flow of pressurized fluid,

b. providing a gas to the nozzle assembly to surround the flow of pressurized fluid with

the gas,

c. directing the flow of pressurized liquid surrounded by the gas into a suction chamber in fluid communication with a collection reservoir and in fluid communication with an outlet pipe, the outlet pipe defining a venturi-like inner surface, and directing the flow of pressurized fluid surrounded by the gas into the outlet pipe to produce a vacuum in the collection reservoir,

d. suctioning the material to be moved into the collection reservoir using the vacuum produced in step (c.), and

e. recirculating at least a portion of the pressurized fluid directed into the outlet pipe back into the nozzle assembly.

29. A method according to Claim 28, further comprising the step of controlling the flow rate of the gas into the nozzle assembly to thereby control the level of vacuum produced by in the suction chamber.

30. A method according to Claim 29, wherein the material to be moved is liquid material from a slurry comprised of a mixture of solid material and liquid material, and wherein the suctioning of step (d.) is carried out after placing the collection reservoir in fluid communication with a slurry container equipped with a filter so that, when a vacuum is created in the collection reservoir, a vacuum is created in the slurry container and liquid material from slurry within the slurry container is suctioned through the filter and into the collection reservoir while solid material remains in the slurry container.

31. A method according to Claim 28, wherein the material to be moved is liquid material from a slurry comprised of a mixture of solid material and liquid material, and wherein the suctioning of step (d.) is carried out after placing the collection reservoir in fluid communication with a slurry container equipped with a filter so that, when a vacuum is created in the collection reservoir, a vacuum is created in the slurry container and liquid material from slurry within the slurry container is suctioned through the filter and into the collection reservoir while solid material remains in the slurry container.

32. A system comprising:

(a) a material collection reservoir in fluid communication with a passageway for suctioned material, the collection reservoir being sized and configured to permit formation of a vacuum within the collection reservoir,

(b) a jet pump in fluid communication with the collection reservoir and the

passageway, the jet pump being sized and configured to form a vacuum within the collection reservoir so as to enable collection of the suctioned material in the collection reservoir without permitting suctioned material to directly enter the jet pump, and

(c) removal means for removing at least a portion of the suctioned material from the collection reservoir, the removal means being configured to enable removal of at least a portion of the suctioned material from the collection reservoir while the jet pump is in use.

33. A system according to Claim 32 wherein the jet pump is comprised of (1) a nozzle assembly which is sized and configured to receive a motive fluid and a gas, and (2) eject the motive fluid as a liquid flow while feeding the gas into proximity with the periphery of the liquid flow.

34. A system according to Claim 32 wherein the system further comprises a controller which controls the operation of the removal means based upon the level of suctioned material in the collection reservoir.

35. A system according to Claim 34 wherein the removal means comprises a removal pump.

36. A system according to Claim 35 wherein the controller is configured to maintain at least a level of material which prevents loss of prime of the removal pump.

37. A system according to Claim 35 wherein the removal pump is a positive displacement pump.

38. A system according to Claim 35 wherein the removal pump is a mechanical pump.

39. A method for moving material from one location to another, the method comprising:

a. creating a vacuum in a material collection reservoir by action of a jet pump, the collection reservoir being in fluid communication with a passageway for a material to be moved and with the jet pump, and

b. suctioning the material through the passageway into the collection reservoir while controlling an amount of material in the collection reservoir so as to prevent the material from entering the jet pump.

40. A method according to Claim 39 wherein the jet pump is comprised of (1) a nozzle assembly which is sized and configured to receive a motive fluid and a gas, and (2) eject the motive fluid as a liquid flow while feeding the gas into proximity with the periphery of the

liquid flow.

41. A method according to Claim 39 wherein in step b the amount of material in the collection reservoir is maintained by removing at least a portion of the material from the collection reservoir.

42. A method according to Claim 41 wherein removal of the material is controlled based upon the level of suctioned material in the collection reservoir.

43. A method according to Claim 42 wherein the controlled removal is carried out by removal means for removing the material from the collection reservoir and a controller which ensures that the level of material in the collection reservoir is maintained within a pre-selected range.

44. A method according to Claim 43 wherein the removal means is a removal pump and wherein the level of material in the collection reservoir is maintained so as to prevent a loss of prime in the removal pump.

45. A method according to Claim 44 wherein the removal pump is a positive displacement pump.

46. A method according to Claim 44 wherein the removal pump is a mechanical pump.

47. A method according to Claim 43 wherein the jet pump and the removal means are used concurrently.

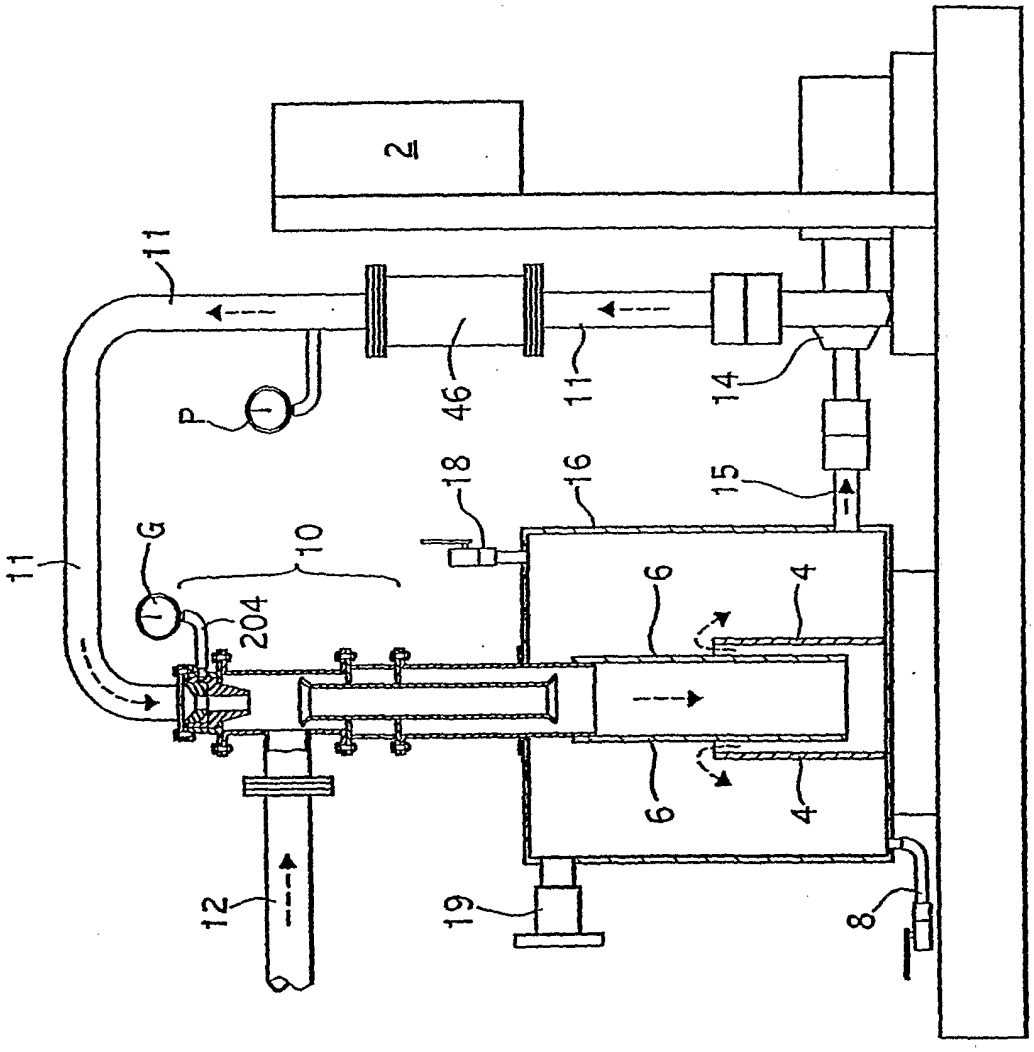

FIG. 1

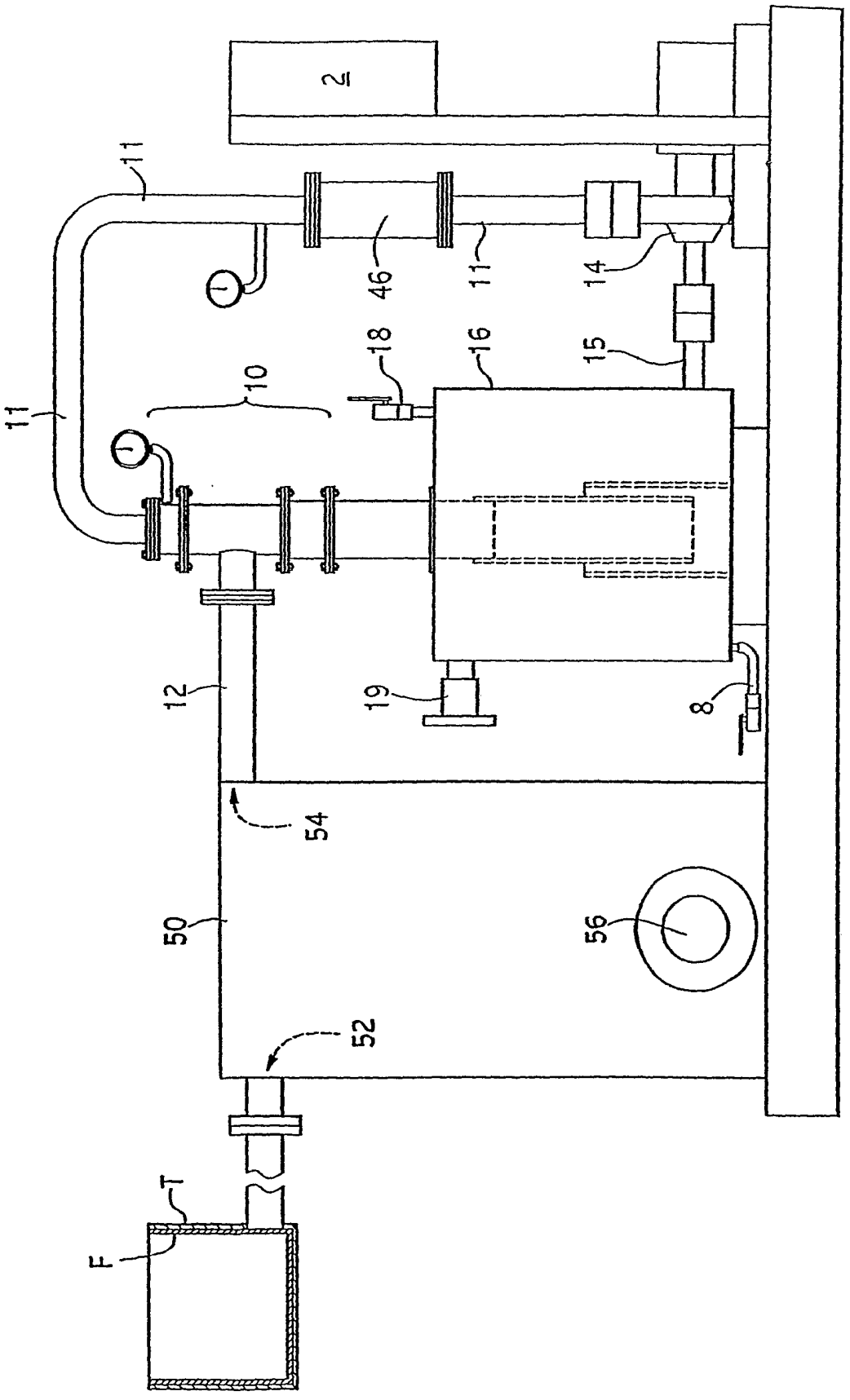

FIG. 2

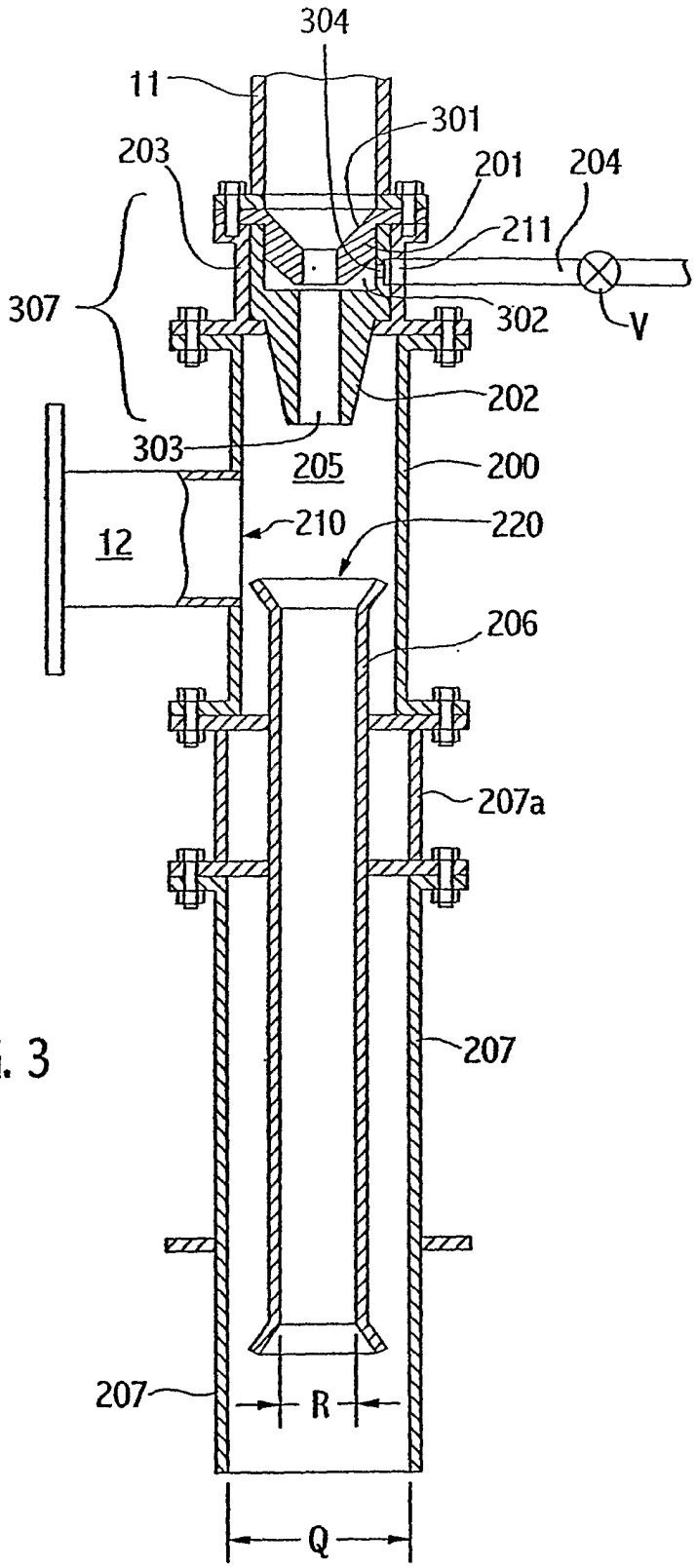
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FIG. 3

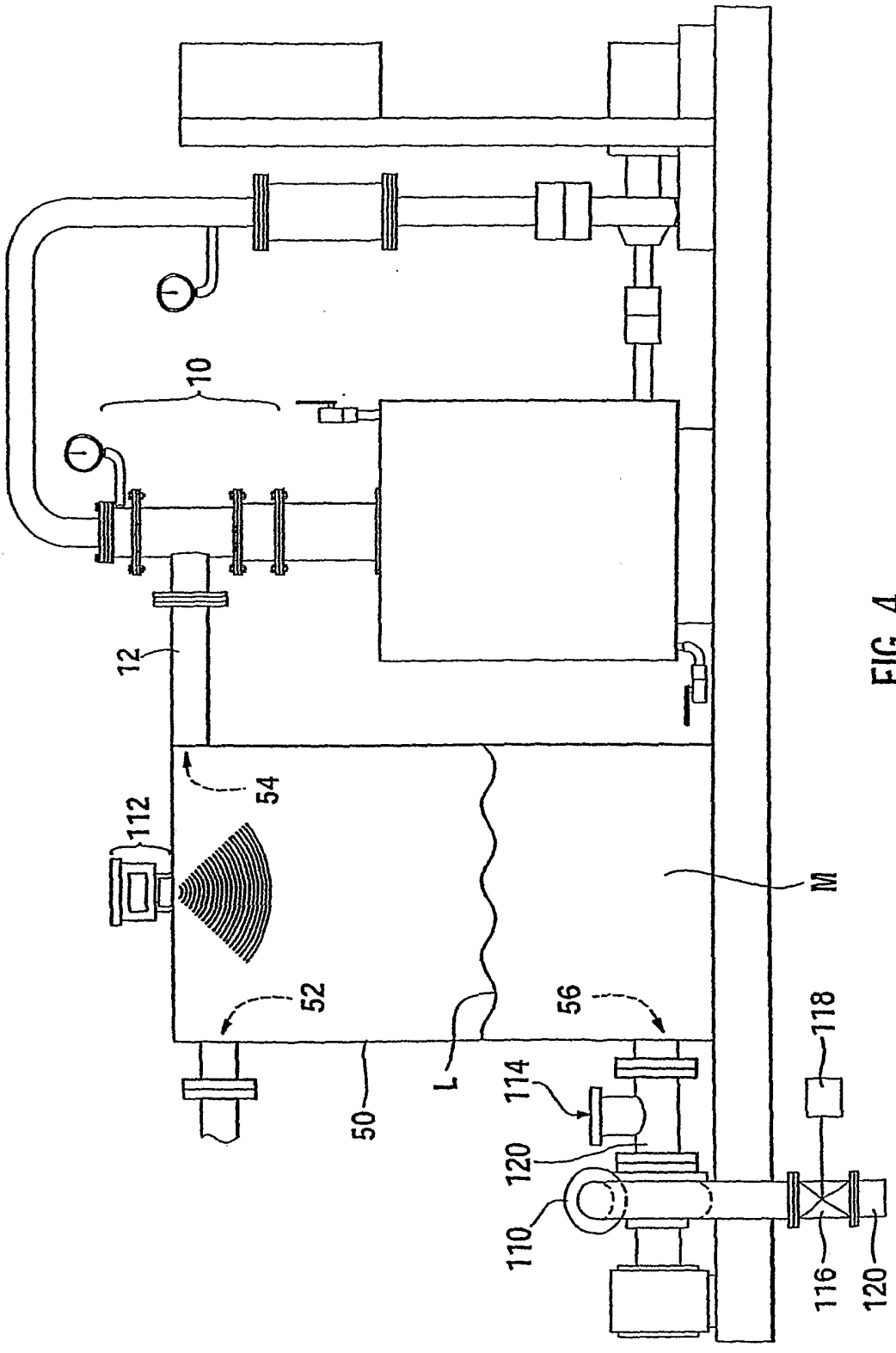

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/22384

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F04F5/04 F04F5/46 F04F3/00 F04F5/54 F04F5/52

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)
IPC 7 F04F

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 practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 179 643 A (EVAC INTERNAT OY) 13 February 2002 (2002-02-13)	32,34, 35,38, 39,41,42
A	abstract	1,2,14, 28,33, 36,40, 41,43, 44,46
	column 3, line 31 -column 6, line 39 figures 1,2	
X	EP 0 555 984 A (EVAC AB) 18 August 1993 (1993-08-18)	32,34, 39,41-43
A	abstract	1,2,14, 28,35
	column 3, line 48 -column 4, line 43 figure 1	

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

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 December 2003	29/12/2003

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, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Kolby, L

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INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	abstract column 3, line 66 -column 6, line 62 figures 1-7	1,28,32, 34-36
A	EP 0 882 480 A (TSEGELSKY VALERY GRIGORIEVICH) 9 December 1998 (1998-12-09) abstract page 6, line 30 -page 7, line 49 figure 1	1-3, 12-14, 16, 25-28, 32,39
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A	US 6 322 327 B1 (HUTCHINSON ROBERT J ET AL) 27 November 2001 (2001-11-27) cited in the application the whole document figures	1-5, 9-11, 15-18, 22-24, 28,32, 33,39,40
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