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(54) **EJECTOR AND METHOD**

EJEKTOR UND VERFAHREN

ÉJECTEUR ET PROCÉDÉ ASSOCIÉ

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(73) Proprietor: **Transvac Systems Limited
Alfreton, Derbyshire DE55 4RH (GB)**

(72) Inventor: **SHORT, Gary
Derbyshire DE55 4RH (GB)**

(74) Representative: **Yeadon IP Limited
Nexus
Discovery Way
Leeds LS2 3AA (GB)**

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to ejectors and to a method of ejecting a fluid. In particular but not exclusively the invention relates to ejectors suitable for locating in an underwater environment.

BACKGROUND

[0002] It is known to employ an ejector to pump a fluid. Ejectors employ a high pressure fluid (the 'motive') to compress low pressure fluid ('entrained' fluid or 'suction' fluid) to an intermediate pressure. The fluid at intermediate pressure is then ejected from the ejector as a 'discharge' fluid.

[0003] FIG. 1 is a schematic illustration of a known ejector 1. The ejector 1 has a motive inlet 10 through which a motive fluid may enter the ejector 1. For example, the motive fluid may be pumped by a pump (not shown) through the motive inlet 10.

[0004] The velocity of the motive fluid is increased as it passes through a nozzle portion 40 of the ejector 1 before being injected through an outlet aperture 44 of the nozzle portion 40 at an apex of the nozzle portion 40 into an inlet aperture 52 of a diffuser portion 50. The diffuser portion 50 provides a fluid conduit in the form of a Venturi. That is, a diameter of the conduit initially decreases along a length of the diffuser portion 50 to a diameter less than that of the inlet aperture 52 before increasing in diameter towards an outlet aperture 54 of the diffuser portion 50.

[0005] The outlet aperture 44 of the nozzle portion 40 and the inlet aperture 52 of the diffuser portion 50 are in fluid communication with a suction fluid inlet 20 of the ejector 1. The ejector 1 is arranged such that a flow of motive fluid out from the nozzle portion outlet aperture 44 and into the diffuser portion 50 creates a drop in pressure at the suction fluid inlet 20 such that suction fluid is drawn into the diffuser portion 50 through the suction fluid inlet 20, becoming entrained in the flow of motive fluid through the diffuser portion 50.

[0006] The diffuser portion 50 is arranged to mix the motive and suction fluids and reduce a flow velocity of the fluids thereby increasing a pressure of the fluids. It is to be understood that this is a reverse process to that occurring in the nozzle portion 40 where an increase in motive fluid velocity occurs thereby reducing a pressure of the motive fluid as it exits the nozzle portion 40 through outlet aperture 44.

[0007] Ejectors such as the ejector 1 of FIG. 1 are useful in pumping fluids that may have relatively large amounts of solids contained therein such as suspensions or slurries. Such fluids may be pumped using a motive fluid that has no solids suspended therein or at least a relatively small amount of solids. The motive fluid may be a liquid or a gas or any other suitable fluid. The suction fluid may be a liquid or a gas or any other suitable fluid.

[0008] Ejectors have the advantage that they may be fabricated without moving parts and may therefore enjoy a substantially longer service life than conventional mechanical pumps in many applications. For example, a mechanical pump may experience relatively rapid wear when pumping a slurry due to the relatively high concentration of solids contained in the slurry. In contrast, since the ejector 1 of FIG. 1 has no moving parts it may be used to pump the slurry for a much longer period of time before maintenance is required.

[0009] Thus, it is to be understood that a conventional mechanical pump may be used to pump through the ejector 1 a motive fluid having a relatively low concentration of solids therein. Since the pump need not be exposed to the suction fluid, which may have a relatively high concentration of solids therein, a lifespan of the mechanical pump is not unduly reduced by the presence of solids in the suction fluid.

[0010] US2005/0064255 discloses an electric power generation system in which a fuel cell system is provided with flow cell recirculation. The apparatus has an ejector assembly having two ejectors arranged in parallel with a common suction inlet. The apparatus has two motive flow inlets (one for each ejector) and one discharge outlet. One of the ejectors is optimised for low fluid flow conditions and the other for high fluid flow conditions.

[0011] CN1308991 discloses a steam injector having three ejectors arranged in parallel. The ejectors have a common motive fluid inlet aperture, a common suction fluid inlet aperture and a common discharge fluid outlet aperture.

[0012] JP7167100 discloses a liquid ejector having a pair of diffusers arranged in a parallel configuration. As in the case of the apparatus disclosed in CN1308991 the ejectors have a common motive fluid inlet aperture, a common suction fluid inlet aperture and a common discharge fluid outlet aperture.

[0013] It is desirable to provide ejector apparatus having increased suction fluid pumping speed for a given ejector size. This is because in some applications where space is at a premium such as some underwater applications it is important to reduce an overall installed length of the ejector as much as possible.

[0014] In some applications an ejector is provided for pumping oil or gas from a well head. In some applications use of an ejector can increase the amount of oil or gas that may be drawn from a well by a substantial amount at a relatively low cost. It is therefore desirable to employ ejector technology in oil and gas recovery systems in order to make best use of dwindling natural resources.

[0015] It is therefore an aim of embodiments of the invention to provide ejector apparatus that may be made more compact than known ejector apparatus for a given target pumping rate, such as a given target volumetric or mass flow rate.

STATEMENT OF THE INVENTION

[0016] Embodiments of the invention may be understood with reference to the appended claims.

[0017] According to claim 1 of the invention there is provided fluid pump apparatus comprising a plurality of ejectors, the apparatus having at least one motive fluid inlet arranged to supply motive fluid to the apparatus, at least one suction fluid inlet arranged to supply suction fluid to the apparatus and a common discharge outlet from which motive fluid and suction fluid that have passed through the ejectors is expelled from the apparatus, each ejector having a respective injector portion and a respective diffuser portion, the injector portion being arranged to inject motive fluid from at least one said at least one motive fluid inlet into the diffuser portion thereby to draw suction fluid into the diffuser portion from at least one said at least one suction fluid inlet, the diffuser portion having a Venturi portion, each ejector having a respective flow stabilisation portion downstream of the Venturi portion thereof, the flow stabilisation portion being arranged to stabilise a flow of motive fluid and suction fluid there-through before respective flows of fluid through each ejector meet downstream of the ejectors, wherein the flow stabilisation portion comprises a flow stabilisation conduit of substantially constant diameter and a length substantially equal to at least the diameter thereof.

[0018] It is to be understood that the flow stabilisation conduit may be integrally formed with the Venturi portion, for example by casting, by moulding or by machining from a single piece of material.

[0019] It is to be understood that when fluid passes through a Venturi device it initially passes through a converging portion of the device over which an inner diameter of the Venturi device reduces along the flow direction to a constricted portion and subsequently increases again in a diverging portion downstream of the constricted portion towards an outlet of the Venturi device.

[0020] It is to be understood that the flow velocity of fluid exiting the Venturi device is lower than that of fluid passing through the constricted portion of the Venturi. As fluid passes along the diverging portion the fluid attempts to fill the diverging portion and eddy currents are typically formed as it does so.

[0021] The present inventors have discovered that the distance over which the flow stabilises downstream of the Venturi can be advantageously reduced by providing a flow stabilisation portion immediately downstream of the Venturi portion of each ejector.

[0022] In some arrangements in which laminar flow conditions are assumed downstream of the Venturi, the flow is able to assume laminar flow conditions a shorter distance downstream of the Venturi due to the presence of the flow stabilisation portion.

[0023] Embodiments of the invention have the advantage that because flow of fluid through each ejector is stabilised by the flow stabilisation portion of each ejector before the flows are combined, flow stabilisation may be

achieved over a shorter installed length of the apparatus than if each ejector is not provided with its own individual flow stabilisation portion. In other words, if fluid flowing out from the Venturi portion of one ejector is allowed immediately to mix with fluid flowing out from the Venturi portion of another ejector as in the prior art described above, flow stabilisation will occur over a longer length downstream of the Venturi portions than in the case that each ejector has its own flow stabilisation portion immediately downstream of its Venturi portion.

[0024] Thus embodiments of the invention have the advantage that they may be provided having a reduced installed length compared with known ejectors of a comparable pumping efficiency.

[0025] It is to be understood that embodiments of the invention may be provided having a reduced installed length without compromising a flow rate of entrained fluid for a given motive flow rate under a given set of boundary pressures and/or boundary conditions.

[0026] Thus, if apparatus having a design similar to known apparatus identified above was employed, such as JP7167100, where the ejectors are not provided with a flow stabilisation portion, a flow of fluid from the Venturi portion of each ejector into the manifold portion immediately downstream of each ejector is not able to circulate in a stable manner. This has the disadvantage that a reduction in efficiency of the apparatus occurs thereby reducing a pumping rate of the apparatus for a given motive fluid flow rate.

[0027] Embodiments of the present invention have the advantage that a bend portion may be installed a shorter distance downstream of an outlet of the Venturi portion of each ejector and still maintain a required pumping speed compared with ejectors having Venturi portions of similar dimensions but without the flow stabilisation portions associated with each Venturi. If flow of fluid that has not stabilised encounters a bend portion a reduction in efficiency of the system occurs as noted above resulting in a reduced pumping rate under comparable conditions.

[0028] Advantageously the flow stabilisation conduit has substantially the same diameter as a downstream end of the Venturi portion.

[0029] It is to be understood that in some embodiments the flow stabilisation conduit may be of a different diameter to the downstream end of the Venturi portion.

[0030] The flow stabilisation portion preferably has a length equal to at least a diameter thereof.

[0031] More preferably the flow stabilisation portion has a length equal to at least double the diameter thereof.

[0032] The flow stabilisation portion may have a length of substantially at least one selected from amongst three times, four times, five times, six times, seven times, eight times, nine times, ten times, fifteen times, twenty times, fifty times and one hundred times the diameter thereof.

[0033] Preferably the flow stabilisation portion has at length of at least five times the diameter thereof.

[0034] Preferably the flow stabilisation portion has a length in the range from around 6 to around 10 times the

diameter thereof.

[0035] The apparatus may further comprise a manifold portion between the ejectors and the discharge outlet, the manifold portion comprising a conduit arranged to receive fluid flowing out from the diffuser portions of the ejectors of the apparatus.

[0036] The apparatus may be further provided with a bend conduit being a conduit having a bend portion, the bend conduit being provided downstream of the plurality of ejectors.

[0037] The bend conduit may be arranged to turn a direction of the flow of fluid through one selected from at least substantially 45° , at least 90° and substantially 180° .

[0038] The bend conduit may be provided downstream of the manifold portion.

[0039] The apparatus may be provided in combination with a bend conduit being a conduit having a bend portion wherein the conduit bends through an angle θ where θ is nonzero, the bend portion being provided downstream of the common discharge outlet wherein fluid flowing through the plurality of ejectors is directed to flow through the bend conduit.

[0040] The bend conduit may be arranged wherein θ takes a value given by one selected from amongst $30^\circ \leq \theta < 60^\circ$, $60^\circ \leq \theta < 90^\circ$, $90^\circ \leq \theta < 120^\circ$, $120^\circ \leq \theta < 150^\circ$ and $150^\circ \leq \theta \leq 180^\circ$.

[0041] Optionally θ may take a value of one selected from amongst substantially 45° , substantially 90° and substantially 180° .

[0042] The plurality of ejectors may be arranged in a substantially parallel configuration.

[0043] The injector portion of at least one of the ejectors may comprise a plurality of injectors.

[0044] The apparatus may have a separate motive fluid inlet for each ejector whereby a flow of motive fluid to a nozzle portion of the injector portion of one ejector may be prevented from mixing with a flow of motive fluid to the nozzle portion of another ejector.

[0045] The apparatus may have a common motive fluid inlet arranged to supply motive fluid to each of the plurality of ejectors.

[0046] The apparatus may be operable to prevent a flow of fluid through the injector portion of one of the plurality of ejectors.

[0047] This feature has the advantage that a pumping rate of the apparatus may be controlled without adjusting the motive fluid flow rate external to the apparatus.

[0048] Alternatively or in addition the apparatus may be operable to prevent a flow of fluid through the injector portion of each of a plurality of the ejectors.

[0049] This feature has the advantage of allowing a greater range of control of pumping rate.

[0050] The apparatus may be operable to prevent a flow of fluid through the diffuser portion of one of the plurality of ejectors.

[0051] Alternatively or in addition the apparatus may be operable to prevent a flow of fluid through the diffuser

portion of each of a plurality of the ejectors.

[0052] One of the plurality of ejectors may have a portion having a size different from the corresponding portion of another of the ejectors.

5 **[0053]** This feature has the advantage that in some embodiments the pumping rate of the apparatus may be more precisely controlled.

[0054] Said one of the plurality of ejectors may have a portion having a diameter different from the corresponding portion of the other of the ejectors.

10 **[0055]** Alternatively or in addition said one of the plurality of ejectors may have a portion having a length different from the length of the corresponding portion of the other ejector.

15 **[0056]** Said portion may be one selected from amongst the injector portion, the diffuser portion, the Venturi portion and the flow stabilisation portion.

[0057] This has the advantage that ejectors may be provided having components of a size that is optimised for a given application.

20 **[0058]** Optionally the flow stabilisation conduit has substantially the same diameter as a downstream end of the Venturi portion

[0059] Further optionally the flow stabilisation conduit has a length substantially equal to from one to two times or from two to three times the diameter thereof.

25 **[0060]** The flow stabilisation conduit may have a length L to diameter D ratio $R = L/D$ where R is given substantially by one selected from amongst $3 \leq R < 4$, $4 \leq R < 5$, $5 \leq R < 6$, $6 \leq R < 7$, $7 \leq R < 8$, $8 \leq R < 9$, $9 \leq R < 10$, $11 \leq R < 15$, $15 \leq R < 20$, $20 \leq R < 50$, $50 \leq R < 100$, $R \geq 100$.

30 **[0061]** In a further aspect of the invention there is provided apparatus according to the first aspect installed in a subsea system.

35 **[0062]** In a still further aspect of the invention there is provided apparatus according to the first aspect located in an underwater system and arranged to pump a fluid in the underwater system.

40 **[0063]** In an aspect of the invention according to claim 15 there is provided a method of pumping a fluid comprising the steps of: providing a flow of motive fluid to each of a plurality of ejectors thereby to draw suction fluid through each ejector and expel discharge fluid drawn through the ejectors through a common discharge outlet, each ejector having a respective injector portion and a respective diffuser portion, the method comprising injecting motive fluid into the diffuser portion thereby to draw the suction fluid into the diffuser portion, the diffuser portion having a Venturi portion, each ejector having a respective flow stabilisation portion downstream of the Venturi portion thereof, the method further comprising stabilising a flow of fluid from the diffuser portion as it passes through the flow stabilisation portion before respective fluid flows through each ejector meet downstream of the ejectors, the step of passing the fluid through the flow stabilisation portion comprising passing the fluid through a conduit having substantially constant diameter and a length substantially equal to at least the

diameter thereof.

[0064] In an example there is provided fluid pump apparatus comprising a plurality of ejectors, the apparatus having at least one motive fluid inlet arranged to supply motive fluid to the apparatus, at least one suction fluid inlet arranged to supply suction fluid to the apparatus and a common discharge outlet from which motive fluid and suction fluid that have passed through the ejectors may be expelled from the apparatus, each ejector having a respective injector portion and a respective diffuser portion, the injector portion being arranged to inject motive fluid from at least one said at least one motive fluid inlet into the diffuser portion thereby to draw suction fluid into the diffuser portion from at least one said at least one suction fluid inlet, the diffuser portion having a Venturi portion, each ejector having a respective flow stabilisation portion downstream of the Venturi portion thereof, the flow stabilisation portion being arranged to stabilise a flow of motive fluid and suction fluid therethrough before the respective flows of fluid through each ejector meet downstream of the ejectors, wherein the flow stabilisation portion comprises a flow stabilisation conduit having substantially the same diameter as a downstream end of the Venturi portion and a length substantially equal to at least a diameter thereof.

[0065] In another example there is provided a method of pumping a fluid comprising the steps of: providing a flow of motive fluid to each of a plurality of ejectors thereby to draw suction fluid through each ejector and expel discharge fluid drawn through the ejectors through a common discharge outlet, each ejector having an injector portion and a diffuser portion, the method comprising injecting motive fluid into the diffuser portion thereby to draw the suction fluid into the diffuser portion, the diffuser portion having a Venturi portion, the method further comprising stabilising a flow of fluid from the diffuser portion prior to expulsion from the common discharge outlet.

[0066] It is to be understood that reference to Venturi portion includes reference to any suitable device for inducing the Venturi effect in a flow of fluid through the diffuser portion of the ejectors. That is, a reduction in fluid pressure that results when a fluid flows through a constricted section of a pipe or tube.

BRIEF DESCRIPTION OF THE DRAWINGS

[0067] Embodiments of the invention will now be described with reference to the accompanying figures in which:

FIGURE 1 shows a known ejector;

FIGURE 2 shows ejector apparatus according to an embodiment of the invention;

FIGURE 3 shows the apparatus of FIGURE 2 in cross-section showing a flow path of fluid through the apparatus; and

FIGURE 4 shows the ejector apparatus of FIG. 2 installed in a subsea oil/gas recovery system.

DETAILED DESCRIPTION

[0068] FIG. 2 shows ejector apparatus 100 according to an embodiment of the present invention. The apparatus 100 has a body portion 100B having a single motive fluid inlet 110, a single suction fluid inlet 120 and a single outlet aperture 154. Fluid entering the apparatus 100 through either inlet 110, 120 is arranged to be discharged from the apparatus 100 through the outlet aperture 154.

[0069] The apparatus 100 has four ejectors three of which are shown in FIG. 2 labelled 101, 102 and 103 respectively. Each ejector 101, 102, 103 has an injector 140 having a nozzle portion 140A, 140B, 140C. Each of the nozzle portions 140A, 140B, 140C has a respective inlet aperture 141A, 141B, 141C respectively arranged in fluid communication with the motive fluid inlet 110.

[0070] Each nozzle portion 140A, 140B, 140C has a nozzle outlet aperture 144 arranged to inject inlet fluid from the nozzle portions 140A, 140B, 140C into a corresponding diffuser portion 150 of each ejector 101, 102, 103 labelled 150A, 150B, 150C respectively.

[0071] Each diffuser portion 150 has a Venturi portion 155 and a stabiliser or flow stabilisation portion 157 provided downstream of the Venturi portion 155.

[0072] Each Venturi portion 155 has a converging section 155CON along which a diameter of the Venturi portion decreases, a throat section 155T of substantially constant diameter and a diverging section 155DIV along which the diameter of the Venturi portion increases again.

[0073] The stabiliser portion 157 of each diffuser portion 150A, 150B, 150C is provided immediately downstream of the diverging section 155DIV. The stabiliser portion 157 is in the form of a conduit having a diameter substantially equal to that of the diverging section 155DIV of the Venturi portion 155 at the downstream end of that section 155DIV.

[0074] The stabiliser portions 157 of the ejectors 101, 102, 103 are each of a length of around six times their diameter. A single stabiliser portion 157A is shown in FIG. 2 for clarity, being part of ejector 101.

[0075] In some embodiments the stabiliser portions 157 are each of a length of from around six to around ten times their diameter. Other lengths are also useful.

[0076] At a downstream end of each of the ejectors 101, 102, 103 the stabiliser portions 157 are in fluid communication with the outlet aperture 154 by means of a manifold portion 170.

[0077] The apparatus is arranged to pump suction fluid through the suction fluid inlet 120 and through the diffuser portions 150 of the ejectors 101, 102, 103 when a motive fluid is forced through the motive fluid inlet 110. A decrease in pressure occurs at the entrance aperture to each of the diffuser portions 150 as motive fluid is injected from the injectors 140 into the diffuser portions 150 thereby drawing suction fluid through the suction fluid inlet 120.

[0078] The presence of the stabiliser portions 157 of each of the ejectors 101, 102, 103 causes stable flow conditions to be established in the fluid flowing through each of the ejectors 101, 102, 103 before the fluid is expelled from the apparatus 100. This has the advantage that if a conduit having a bend therein is provided downstream of the apparatus 100 a pumping speed of the apparatus 100 is not reduced to the same extent as corresponding apparatus having ejectors 101, 102, 103 not having the stabiliser portions 157.

[0079] The feature that the presence of a bend portion does not reduce pumping speed to the same extent has the advantage that apparatus may be provided that is more compact. In some embodiments the apparatus has a reduced length compared with prior art apparatus.

[0080] FIG. 3 shows the apparatus 100 of the embodiment of FIG. 2 in cross-section through a pair of ejectors 102, 103 of the apparatus 100. The flow path of motive fluid FM from nozzle portions 140B, 140C is shown, together with the flow path of suction fluid FS into the apparatus 100 through suction fluid inlet 120.

[0081] It can be seen that motive fluid FM injected through nozzle portions 140B, 140C of each ejector 102, 103 is arranged to pass into respective diffuser portions 150B, 150C.

[0082] As described above suction fluid FS is drawn through the suction fluid inlet 120 and becomes entrained in the flow of motive fluid FM passing from the injectors 140 into the diffuser portions 150. Thus, suction fluid entrained in motive fluid, FMS, flows through the diffuser portions 150.

[0083] It can be seen that motive/suction fluid FMS entering the respective stabiliser portions 157B, 157C circulates in a stable manner within the stabiliser portions 157B, 157C before passing out from the apparatus through the outlet aperture 154.

[0084] In some embodiments of the invention a valve is provided in each of the four injectors 140 operable to prevent fluid flow from the respective injector 140A, B, C into the corresponding diffuser portion 150. This feature allows the pumping rate of the apparatus 100 to be varied according to demand and/or the type of suction fluid FS to be pumped.

[0085] In some embodiments the respective ejectors 101, 102, 103 are arranged to provide different respective flow rates therethrough, for example in the ratio 1:2:3:4. Thus in some embodiments the apparatus 100 may be operable to vary a pumping rate from 10% to 100% in 10% increments. It is to be understood that other arrangements are also useful such as other relative flow rates, other numbers of ejectors and so forth.

[0086] In some embodiments the apparatus is arranged to allow fluid to flow in a reverse direction through one of the diffuser portions 150A, B, C of one or more of the four ejectors 101, 102, 103 back to the inlets of the diffuser portions if fluid is not being injected into that diffuser portion 150 from the respective injector 140A, B, C. This has the advantage that flow of fluid through the

apparatus 100 may be manipulated in order to obtain optimum flow conditions for a given application or type of suction fluid FS.

[0087] The apparatus may be arranged to allow this reverse direction of fluid flow by terminating a supply of fluid to one or more of the injectors 140A, B, C such that motive fluid is not injected into the corresponding diffuser 150.

[0088] It is to be understood that as described above this may be accomplished by providing a valve within the respective injector 140A, B, C or by providing a valve upstream of the injector 140A, B, C to prevent a flow of fluid into the injector 140A, B, C.

[0089] Thus, it is to be understood that for a given motive fluid inlet pressure at the motive inlet 110, suction fluid inlet pressure at the suction inlet 120 and discharge fluid pressure at the outlet aperture 154 the rate of fluid flow through the suction inlet 120 and out through the outlet aperture 154 may be reduced by preventing flow of fluid through one or more of the injectors 140A, B, C and allowing recirculation of some discharge fluid back through one or more of the diffuser portions 150B, C before it passes through the fluid outlet aperture 154.

[0090] It is to be understood that such embodiments of the invention have the advantage that a valve (such as a throttle valve) is not required to be provided in a flowpath of suction fluid FS (which may be a slurry in some applications) or suction fluid entrained in motive fluid FMS (being a diluted slurry in some applications). Provision of a valve in a flow of slurry is undesirable due to issues in respect of valve movement and valve closure in addition to wear of the valve. By providing the valve in the flow of motive fluid (typically liquid not being a slurry, or a gas) this problem may be avoided.

[0091] Furthermore, by allowing fluid to flow in a reverse direction through a diffuser 150 the need to provide a separate return path for suction fluid entrained in motive fluid FMS from (say) the manifold portion 170 back to inlets of the diffuser portion 150 in order to reduce the motive, suction and discharge fluid flow rates may be eliminated. This return path would require a valve therein which would be exposed to the suction and motive fluids (such as slurry) and the apparatus would therefore have the associated disadvantages. However it is to be understood that such an arrangement may be employed in some embodiments of the invention.

[0092] Thus some embodiments of the invention have the advantage that control of suction fluid flow rate may be effected without changing the pressure of fluid at either the motive fluid inlet, the suction fluid inlet or the discharge fluid outlet of the apparatus. Furthermore some embodiments have the advantage that control of fluid flow rate may be made without a requirement to position a valve in a flowpath of suction fluid or suction fluid entrained in motive fluid.

[0093] Other arrangements are also useful.

[0094] FIG. 4 shows the apparatus 100 of FIG. 2 installed in an underwater oil recovery system in which the

apparatus is arranged to pump slurry from an outlet of a separator 105. The separator 105 may be arranged to separate solids and liquids pumped from a subsea oil well, an outlet of the separator being coupled to a suction fluid inlet 120 of the apparatus 100.

[0095] A motive inlet 110 of the apparatus 100 is coupled to a motive fluid pump 171 arranged to pump motive fluid therethrough. The apparatus 100 is thereby arranged to pump fluid from the separator 105 entrained in motive fluid out from the apparatus 100 through the fluid outlet 154.

[0096] It can be seen that a fluid conduit 185 is coupled to the fluid outlet 154 of the apparatus 100. A bend 185B is provided in the conduit 185.

[0097] It is to be understood that an installed length of the apparatus 100 from the motive inlet 110 to the bend 185B for a given pumping efficiency may be made less than that which would be possible in a known ejector not having a flow stabilisation portion downstream of the Venturi portion 155B, C of each ejector 101A, B, C. This has the advantage of enabling a reduction in a size and cost of the apparatus 100 and in turn the underwater oil recovery system.

[0098] In some embodiments apparatus according to an embodiment of the invention may be employed to pump a fluid such as a liquid, gas or slurry from a source to a separator. Other arrangements are also useful.

[0099] Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of the words, for example "comprising" and "comprises", means "including but not limited to", and is not intended to (and does not) exclude other moieties, additives, components, integers or steps.

[0100] Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

[0101] Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith.

Claims

1. Fluid pump apparatus (100) comprising a plurality of ejectors (101, 102, 103), the apparatus (100) having at least one motive fluid inlet (110) arranged to supply motive fluid to the apparatus (100), at least one suction fluid inlet (120) arranged to supply suction fluid to the apparatus (100) and a common discharge outlet (154) from which motive fluid and suction fluid that have passed through the ejectors (101, 102, 103) is expelled from the apparatus (100),

each ejector (101, 102, 103) having a respective injector portion (140) and a respective diffuser portion (150), the injector portion (140) being arranged to inject motive fluid from at least one said at least one motive fluid inlet (110) into the diffuser portion (150) thereby to draw suction fluid into the diffuser portion (150) from at least one said at least one suction fluid inlet (120), the diffuser portion (150) having a Venturi portion (155),

characterised in that each ejector (101, 102, 103) has a respective flow stabilisation portion (157) downstream of the Venturi portion (155) thereof, the flow stabilisation portion (157) being arranged to stabilise a flow of motive fluid and suction fluid therethrough before respective flows of fluid through each ejector (101, 102, 103) meet downstream of the ejectors (101, 102, 103), wherein the flow stabilisation portion (157) comprises a flow stabilisation conduit of substantially constant diameter and having a length substantially equal to or greater than the diameter thereof.

2. Fluid pump apparatus (100) as claimed in claim 1 wherein the plurality of ejectors (101, 102, 103) are arranged in a substantially parallel configuration.
3. Fluid pump apparatus (100) as claimed in claim 1 or claim 2 wherein the injector portion (140) of at least one of the ejectors (101, 102, 103) comprises a plurality of injectors (140).
4. Fluid pump apparatus (100) as claimed in any preceding claim having a common motive fluid inlet (110) arranged to supply motive fluid to each of the plurality of ejectors (101, 102, 103).
5. Fluid pump apparatus (100) as claimed in any one of claims 1 to 4 having a separate motive fluid inlet (110) for each ejector (101, 102, 103) whereby a flow of motive fluid to a nozzle portion (140) of the injector portion (140) of one ejector (101, 102, 103) may be prevented from mixing with a flow of motive fluid to a nozzle portion (140) of the injector portion (140) of another ejector (101, 102, 103).
6. Fluid pump apparatus (100) as claimed in any preceding claim operable to prevent a flow of fluid through the injector portion (140) of one or more of the plurality of ejectors (101, 102, 103).
7. Fluid pump apparatus (100) as claimed in any preceding claim operable to prevent a flow of fluid through the diffuser portion (150) of one or more of the plurality of ejectors (101, 102, 103), and/or operable to allow a reverse flow of fluid through the diffuser portion (150) of one or more of the plurality of ejectors (101, 102, 103).

8. Fluid pump apparatus (100) as claimed in any preceding claim wherein one of the plurality of ejectors (101, 102, 103) has a portion having a size different from the corresponding portion of another of the ejectors (101, 102, 103). 5
9. Fluid pump apparatus (100) as claimed in any preceding claim wherein one of the plurality of ejectors (101, 102, 103) has a portion having a diameter and/or a length different from the corresponding portion of another of the ejectors (101, 102, 103). 10
10. Fluid pump apparatus (100) as claimed in any one of claims 8 or 9 wherein said portion is one selected from amongst the injector portion (140), the diffuser portion (150), the Venturi portion (155) and the flow stabilisation portion (157). 15
11. Fluid pump apparatus (100) as claimed in any preceding claim coupled to a separation system operable to separate liquid from solids. 20
12. Fluid pump apparatus (100) as claimed in any preceding claim wherein the flow stabilisation conduit (157) has substantially the same diameter as a downstream end of the Venturi portion (155). 25
13. Fluid pump apparatus (100) as claimed in any preceding claim further comprising a manifold portion (170) between the ejectors (101, 102, 103) and the discharge outlet (154), the manifold portion (170) comprising a conduit arranged to receive fluid flowing out from the the respective flow stabilisation portions (157) of the ejectors (101, 102, 103) and to direct the fluid to the discharge outlet (154). 30 35
14. Fluid pump apparatus (100) as claimed in any preceding claim in combination with a bend conduit being a conduit having a bend portion wherein the conduit bends through an angle θ where θ is nonzero, the bend portion being provided downstream of the common discharge outlet wherein fluid flowing through the plurality of ejectors is directed to flow through the bend conduit. 40
15. A method of pumping a fluid comprising the steps of: 45
 - providing a flow of motive fluid to each of a plurality of ejectors (101, 102, 103) thereby to draw suction fluid through each ejector (101, 102, 103) and expel discharge fluid drawn through the ejectors (101, 102, 103) through a common discharge outlet (154), 50
 - each ejector (101, 102, 103) having a respective injector portion (140) and a respective diffuser portion (150), the method comprising injecting motive fluid into the diffuser portion (150) thereby to draw the suction fluid into the diffuser por-

tion (150), the diffuser portion (150) having a Venturi portion (155),

characterised in that each ejector (101, 102, 103) has a respective flow stabilisation portion (157) downstream of the Venturi portion (155) thereof, the method further comprising stabilising the flow of fluid from the diffuser portion (155) as it passes through the flow stabilisation portion (157) before respective fluid flows through each ejector (101, 102, 103) meet downstream of the ejectors (101, 102, 103), the step of passing the fluid through the flow stabilisation portion (157) comprising passing the fluid through a conduit having a substantially constant diameter and a length substantially equal to or greater than the diameter thereof.

Patentansprüche

1. Fluidpumpenvorrichtung (100), die eine Vielzahl von Ejektoren (101, 102, 103) beinhaltet, wobei die Vorrichtung (100) mindestens einen Arbeitsfluideinlass (110), der eingerichtet ist, um der Vorrichtung (100) Arbeitsfluid zu liefern, mindestens einen Saugfluideinlass (120), der eingerichtet ist, um der Vorrichtung (100) Saugfluid zu liefern, und einen gemeinsamen Ableitungsauslass (154), von dem Arbeitsfluid und Saugfluid, die durch die Ejektoren (101, 102, 103) hindurch gelaufen sind, von der Vorrichtung (100) ausgestoßen werden, wobei jeder Ejektor (101, 102, 103) einen jeweiligen Injektorabschnitt (140) und einen jeweiligen Diffusorabschnitt (150) aufweist, wobei der Injektorabschnitt (140) eingerichtet ist, um Arbeitsfluid von mindestens einem des mindestens einen Arbeitsfluideinlasses (110) in den Diffusorabschnitt (150) zu injizieren, um dadurch von mindestens einem des mindestens einen Saugfluideinlasses (120) Saugfluid in den Diffusorabschnitt (150) zu ziehen, wobei der Diffusorabschnitt (150) einen Venturiabschnitt (155) aufweist, **dadurch gekennzeichnet, dass** jeder Ejektor (101, 102, 103) einen jeweiligen Flussstabilisierungsabschnitt (157) stromabwärts von dem Venturiabschnitt (155) von diesem aufweist, wobei der Flussstabilisierungsabschnitt (157) eingerichtet ist, um einen Fluss von Arbeitsfluid und Saugfluid dort hindurch zu stabilisieren, bevor jeweilige Flüsse von Fluid durch jeden Ejektor (101, 102, 103) hindurch stromabwärts von den Ejektoren (101, 102, 103) zusammentreffen, wobei der Flussstabilisierungsabschnitt (157) eine Flussstabilisierungsleitung mit im Wesentlichen konstantem Durchmesser und mit einer Länge, die im Wesentlichen gleich dem oder größer als der Durchmesser von dieser ist, beinhaltet.

2. Fluidpumpenvorrichtung (100) gemäß Anspruch 1, wobei die Vielzahl von Ejektoren (101, 102, 103) in einer im Wesentlichen parallelen Konfiguration eingerichtet sind.
3. Fluidpumpenvorrichtung (100) gemäß Anspruch 1 oder Anspruch 2, wobei der Injektorabschnitt (140) von mindestens einem der Ejektoren (101, 102, 103) eine Vielzahl von Injektoren (140) beinhaltet.
4. Fluidpumpenvorrichtung (100) gemäß einem vorhergehenden Anspruch, die einen gemeinsamen Arbeitsfluideinlass (110) aufweist, der eingerichtet ist, um jedem der Vielzahl von Ejektoren (101, 102, 103) Fluid zu liefern.
5. Fluidpumpenvorrichtung (100) gemäß einem der vorhergehenden Ansprüche 1 bis 4, die einen getrennten Arbeitsfluideinlass (110) für jeden Ejektor (101, 102, 103) aufweist, wodurch verhindert werden kann, dass ein Fluss von Arbeitsfluid zu einem Düsenabschnitt (140) des Injektorabschnitts (140) von einem Ejektor (101, 102, 103) mit einem Fluss von Arbeitsfluid zu einem Düsenabschnitt (140) des Injektorabschnitts (140) von einem anderen Ejektor (101, 102, 103) vermischt wird.
6. Fluidpumpenvorrichtung (100) gemäß einem vorhergehenden Anspruch, die betriebsfähig ist, um einen Fluss von Fluid durch den Injektorabschnitt (140) von einem oder mehreren der Vielzahl von Ejektoren (101, 102, 103) hindurch zu verhindern.
7. Fluidpumpenvorrichtung (100) gemäß einem vorhergehenden Anspruch, die betriebsfähig ist, um einen Fluss von Fluid durch den Diffusorabschnitt (150) von einem oder mehreren der Vielzahl von Ejektoren (101, 102, 103) hindurch zu verhindern, und/oder betriebsfähig ist, um einen Rückfluss von Fluid durch den Diffusorabschnitt (150) von einem oder mehreren der Vielzahl von Ejektoren (101, 102, 103) hindurch zu erlauben.
8. Fluidpumpenvorrichtung (100) gemäß einem vorhergehenden Anspruch, wobei einer der Vielzahl von Ejektoren (101, 102, 103) einen Abschnitt aufweist, der eine Größe aufweist, die sich von dem entsprechenden Abschnitt von einem anderen der Ejektoren (101, 102, 103) unterscheidet.
9. Fluidpumpenvorrichtung (100) gemäß einem vorhergehenden Anspruch, wobei einer der Vielzahl von Ejektoren (101, 102, 103) einen Abschnitt aufweist, der einen Durchmesser und/oder eine Länge aufweist, die sich von dem entsprechenden Abschnitt von einem anderen der Ejektoren (101, 102, 103) unterscheiden.
10. Fluidpumpenvorrichtung (100) gemäß einem der vorhergehenden Ansprüche 8 oder 9, wobei der Abschnitt einer ist, der aus dem Injektorabschnitt (140), dem Diffusorabschnitt (150), dem Venturiabschnitt (155) und dem Flussstabilisierungsabschnitt (157) ausgewählt ist.
11. Fluidpumpenvorrichtung (100) gemäß einem vorhergehenden Anspruch, das mit einem Trennungssystem gekoppelt ist, das funktionsfähig ist, um Flüssigkeit von Feststoffen zu trennen.
12. Fluidpumpenvorrichtung (100) gemäß einem vorhergehenden Anspruch, wobei die Flussstabilisierungsleitung (157) im Wesentlichen den gleichen Durchmesser wie ein stromabwärtiges Ende des Venturiabschnitts (155) aufweist.
13. Fluidpumpenvorrichtung (100) gemäß einem vorhergehenden Anspruch, die ferner einen Verteilerabschnitt (170) zwischen den Ejektoren (101, 102, 103) und dem Ableitungsauslass (154) beinhaltet, wobei der Verteilerabschnitt (170) eine Leitung beinhaltet, die eingerichtet ist, um Fluid, das von den jeweiligen Flussstabilisierungsabschnitten (157) der Ejektoren (101, 102, 103) herausfließt, zu empfangen und das Fluid an den Ableitungsauslass (154) zu leiten.
14. Fluidpumpenvorrichtung (100) gemäß einem vorhergehenden Anspruch in Kombination mit einer gebogenen Leitung, die eine Leitung ist, die einen gebogenen Abschnitt aufweist, wobei die Leitung in einem Winkel θ gebogen ist, wobei θ nicht Null ist, wobei der gebogene Abschnitt stromabwärts von dem gemeinsamen Ableitungsauslass bereitgestellt ist, wobei das Fluid, das durch die Vielzahl von Ejektoren hindurch fließt, geleitet wird, um durch die gebogene Leitung hindurch zu fließen.
15. Verfahren zum Pumpen eines Fluids, das die folgenden Schritte beinhaltet:

Bereitstellen eines Flusses von Arbeitsfluid für jeden von einer Vielzahl von Ejektoren (101, 102, 103), um dadurch Saugfluid durch jeden Ejektor (101, 102, 103) hindurch zu ziehen und durch die Ejektoren (101, 102, 103) hindurch gezogenes Ableitungsfluid durch einen gemeinsamen Ableitungsauslass (154) hindurch auszustoßen, wobei jeder Ejektor (101, 102, 103) einen jeweiligen Injektorabschnitt (140) und einen jeweiligen Diffusorabschnitt (150) aufweist, wobei das Verfahren das Injizieren von Arbeitsfluid in den Diffusorabschnitt (150) beinhaltet, um dadurch Saugfluid in den Diffusorabschnitt (150) zu ziehen, wobei der Diffusorabschnitt (150) einen

Venturiabschnitt (155) aufweist, **dadurch gekennzeichnet, dass** jeder Ejektor (101, 102, 103) einen jeweiligen Flusstabilisierungsabschnitt (157) stromabwärts von dem Venturiabschnitt (155) von diesem aufweist, wobei das Verfahren ferner das Stabilisieren des Flusses von Fluid von dem Diffusorabschnitt beinhaltet, wenn es durch den Flusstabilisierungsabschnitt (157) hindurch läuft, bevor jeweilige Fluidflüsse durch jeden Ejektor (101, 102, 103) hindurch stromabwärts von den Ejektoren (101, 102, 103) zusammentreffen, wobei der Schritt des Laufenlassens des Fluids durch den Flusstabilisierungsabschnitt (157) hindurch das Laufenlassen des Fluids durch eine Leitung mit im Wesentlichen konstantem Durchmesser und mit einer Länge, die im Wesentlichen gleich dem oder größer als der Durchmesser von dieser ist, beinhaltet.

Revendications

1. Appareil de pompe à fluide (100) comprenant une pluralité d'éjecteurs (101, 102, 103), l'appareil (100) ayant au moins une entrée de fluide moteur (110) agencée de façon à fournir un fluide moteur à l'appareil (100), au moins une entrée de fluide d'aspiration (120) agencée de façon à fournir un fluide d'aspiration à l'appareil (100) et une sortie de décharge commune (154) à partir de laquelle un fluide moteur et un fluide d'aspiration qui ont passé à travers les éjecteurs (101, 102, 103) sont expulsés de l'appareil (100),

chaque éjecteur (101, 102, 103) ayant une portion injecteur respective (140) et une portion diffuseur respective (150), la portion injecteur (140) étant agencée de façon à injecter un fluide moteur à partir d'au moins une ladite au moins une entrée de fluide moteur (110) dans la portion diffuseur (150) afin d'aspirer ainsi un fluide d'aspiration dans la portion diffuseur (150) à partir d'au moins une ladite au moins une entrée de fluide d'aspiration (120), la portion diffuseur (150) ayant une portion venturi (155),

caractérisé en ce que chaque éjecteur (101, 102, 103) a une portion de stabilisation d'écoulement respective (157) en aval de la portion venturi (155) de celui-ci, la portion de stabilisation d'écoulement (157) étant agencée de façon à stabiliser un écoulement de fluide moteur et de fluide d'aspiration à travers celle-ci avant que des écoulements respectifs de fluide à travers chaque éjecteur (101, 102, 103) se rencontrent en aval des éjecteurs (101, 102, 103), dans lequel la portion de stabilisation d'écoule-

ment (157) comprend un conduit de stabilisation d'écoulement d'un diamètre substantiellement constant et ayant une longueur substantiellement égale ou supérieure au diamètre de celui-ci.

2. Appareil de pompe à fluide (100) tel que revendiqué dans la revendication 1 dans lequel la pluralité d'éjecteurs (101, 102, 103) sont agencés suivant une configuration substantiellement parallèle.
3. Appareil de pompe à fluide (100) tel que revendiqué dans la revendication 1 ou la revendication 2, dans lequel la portion injecteur (140) d'au moins un des éjecteurs (101, 102, 103) comprend une pluralité d'injecteurs (140).
4. Appareil de pompe à fluide (100) tel que revendiqué dans n'importe quelle revendication précédente ayant une entrée de fluide moteur commune (110) agencée de façon à fournir un fluide moteur à chaque éjecteur de la pluralité d'éjecteurs (101, 102, 103).
5. Appareil de pompe à fluide (100) tel que revendiqué dans l'une quelconque des revendications 1 à 4 ayant une entrée de fluide moteur séparée (110) pour chaque éjecteur (101, 102, 103) en vertu de quoi un écoulement de fluide moteur vers une portion buse (140) de la portion injecteur (140) d'un éjecteur (101, 102, 103) peut être empêché de se mélanger avec un écoulement de fluide moteur vers une portion buse (140) de la portion injecteur (140) d'un autre éjecteur (101, 102, 103).
6. Appareil de pompe à fluide (100) tel que revendiqué dans n'importe quelle revendication précédente apte à fonctionner pour empêcher un écoulement de fluide à travers la portion injecteur (140) d'un ou plusieurs éjecteurs de la pluralité d'éjecteurs (101, 102, 103).
7. Appareil de pompe à fluide (100) tel que revendiqué dans n'importe quelle revendication précédente apte à fonctionner pour empêcher un écoulement de fluide à travers la portion diffuseur (150) d'un ou plusieurs éjecteurs de la pluralité d'éjecteurs (101, 102, 103), et/ou apte à fonctionner pour autoriser un écoulement inverse de fluide à travers la portion diffuseur (150) d'un ou plusieurs éjecteurs de la pluralité d'éjecteurs (101, 102, 103).
8. Appareil de pompe à fluide (100) tel que revendiqué dans n'importe quelle revendication précédente dans lequel un éjecteur de la pluralité d'éjecteurs (101, 102, 103) a une portion ayant une taille différente de la portion correspondante d'un autre des éjecteurs (101, 102, 103).

9. Appareil de pompe à fluide (100) tel que revendiqué dans n'importe quelle revendication précédente dans lequel un éjecteur de la pluralité d'éjecteurs (101, 102, 103) a une portion ayant un diamètre et/ou une longueur différente de la portion correspondante d'un autre des éjecteurs (101, 102, 103). 5
10. Appareil de pompe à fluide (100) tel que revendiqué dans n'importe laquelle des revendications 8 ou 9 dans lequel ladite portion est une portion sélectionnée parmi la portion injecteur (140), la portion diffuseur (150), la portion venturi (155) et la portion de stabilisation d'écoulement (157). 10
11. Appareil de pompe à fluide (100) tel que revendiqué dans n'importe quelle revendication précédente couplé à un système de séparation apte à fonctionner pour séparer un liquide de solides. 15
12. Appareil de pompe à fluide (100) tel que revendiqué dans n'importe quelle revendication précédente dans lequel le conduit de stabilisation d'écoulement (157) a substantiellement le même diamètre qu'une extrémité aval de la portion venturi (155). 20
25
13. Appareil de pompe à fluide (100) tel que revendiqué dans n'importe quelle revendication précédente comprenant en outre une portion collecteur (170) entre les éjecteurs (101, 102, 103) et la sortie de décharge (154), la portion collecteur (170) comprenant un conduit agencé de façon à recevoir un fluide s'écoulant hors des portions de stabilisation d'écoulement respectives (157) des éjecteurs (101, 102, 103) et à diriger le fluide vers la sortie de décharge (154). 30
35
14. Appareil de pompe à fluide (100) tel que revendiqué dans n'importe quelle revendication précédente en combinaison avec un conduit à coude qui est un conduit ayant une portion à coude, le conduit fléchissant par un angle θ où θ est non nul, la portion à coude étant prévue en aval de la sortie de décharge commune, le fluide s'écoulant à travers la pluralité d'éjecteurs étant dirigé de façon à s'écouler à travers le conduit à coude. 40
45
15. Procédé de pompage d'un fluide comprenant les étapes consistant à :
- fournir un écoulement de fluide moteur à chaque éjecteur d'une pluralité d'éjecteurs (101, 102, 103) afin d'aspirer ainsi un fluide d'aspiration à travers chaque éjecteur (101, 102, 103) et d'expulser un fluide de décharge aspiré à travers les éjecteurs (101, 102, 103) à travers une sortie de décharge commune (154), 50
55
- chaque éjecteur (101, 102, 103) ayant une portion injecteur respective (140) et une portion dif-

fuseur respective (150), le procédé comprenant l'injection de fluide moteur dans la portion diffuseur (150) afin d'aspirer ainsi le fluide d'aspiration dans la portion diffuseur (150), la portion diffuseur (150) ayant une portion venturi (155), **caractérisé en ce que** chaque éjecteur (101, 102, 103) a une portion de stabilisation d'écoulement respective (157) en aval de la portion venturi (155) de celui-ci, le procédé comprenant en outre la stabilisation de l'écoulement de fluide à partir de la portion diffuseur (155) au fur et à mesure qu'il passe à travers la portion de stabilisation d'écoulement (157) avant que des écoulements respectifs de fluide à travers chaque éjecteur (101, 102, 103) se rencontrent en aval des éjecteurs (101, 102, 103), l'étape de passage du fluide à travers la portion de stabilisation d'écoulement (157) comprenant le passage du fluide à travers un conduit ayant un diamètre substantiellement constant et une longueur substantiellement égale ou supérieure au diamètre de celui-ci.

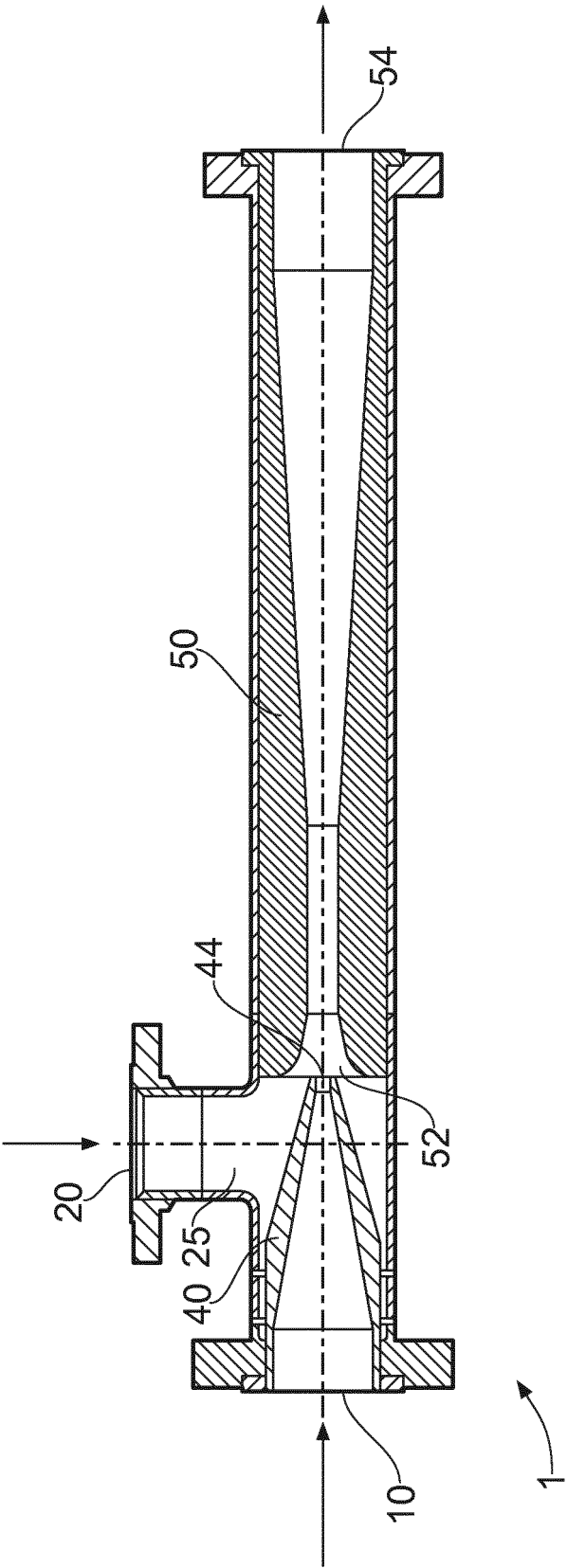


FIG. 1 (Prior Art)

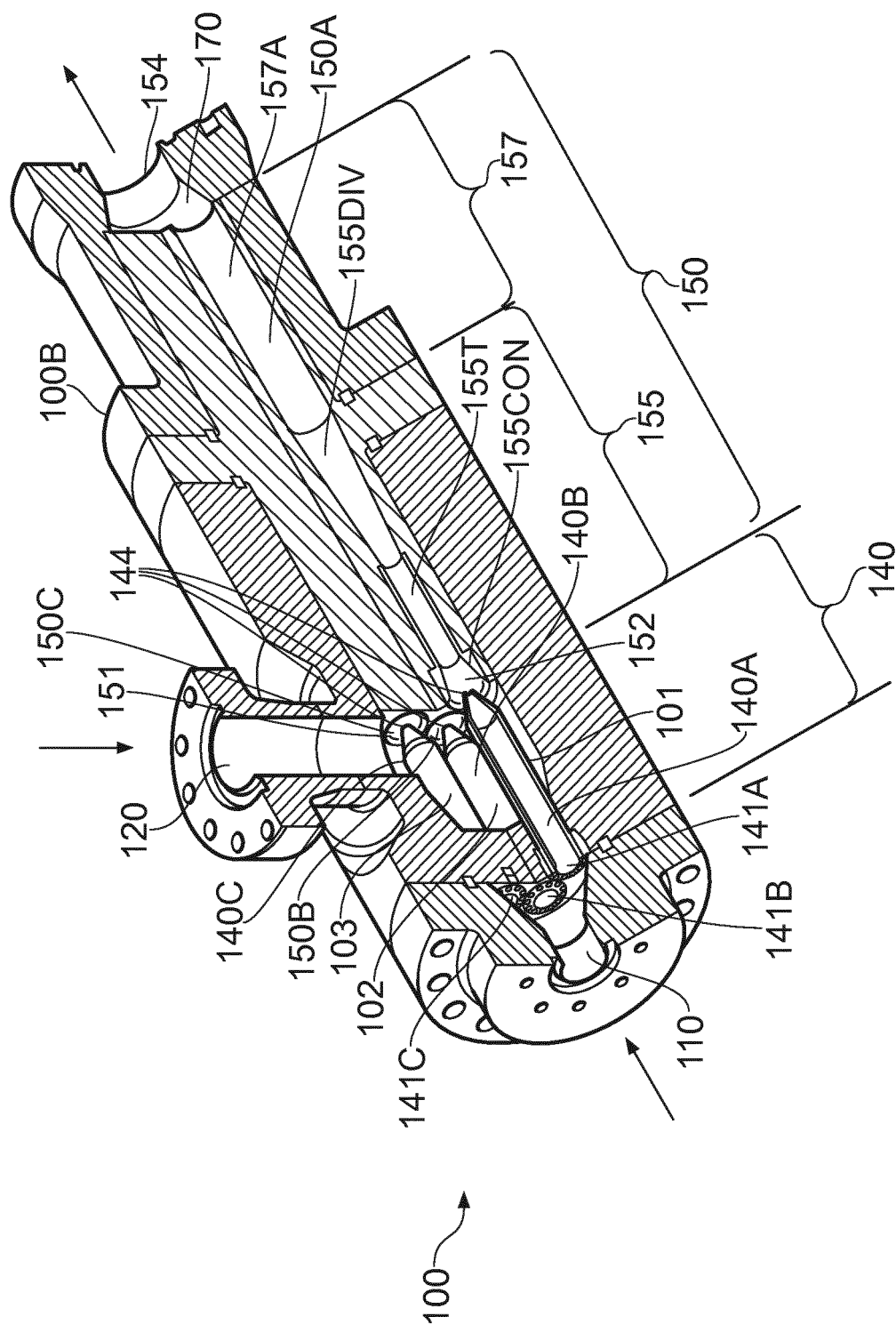


FIG. 2

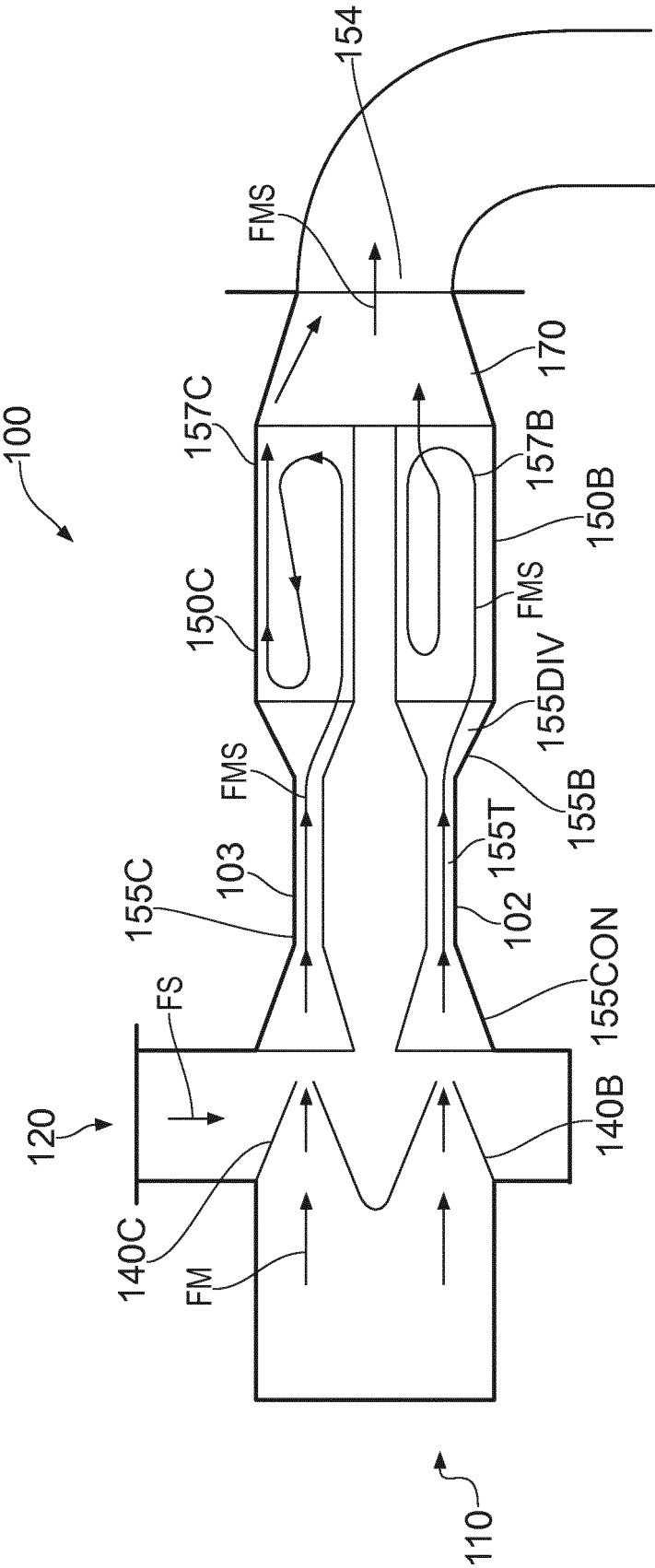


FIG. 3

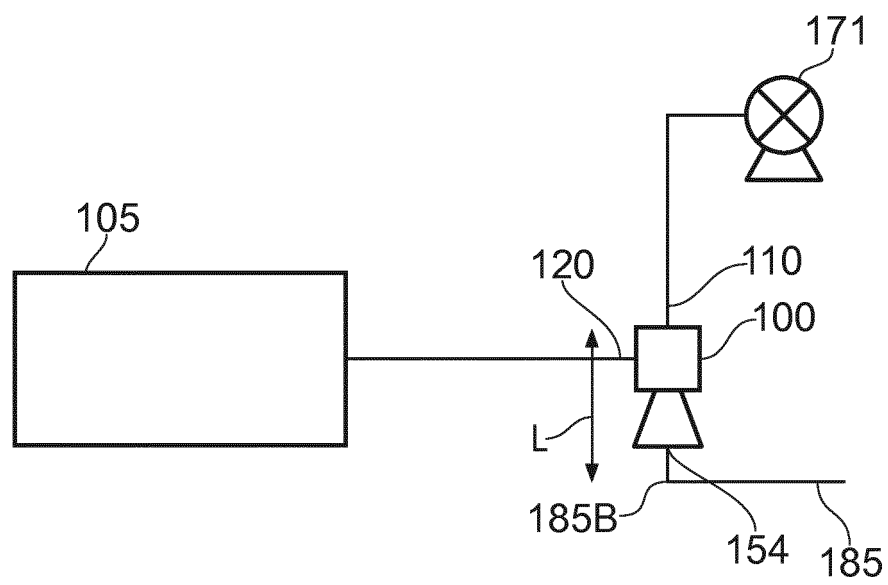


FIG. 4

REFERENCES CITED IN THE DESCRIPTION

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