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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 March 2012 (15.03.2012)

PCT

(10) International Publication Number
WO 2012/033632 A1

(51) International Patent Classification:
E21B 43/12 (2006.01) *F04F 5/44* (2006.01)
E21B 43/00 (2006.01)

(21) International Application Number:
PCT/US2011/048652

(22) International Filing Date:
22 August 2011 (22.08.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/381,423 9 September 2010 (09.09.2010) US

(71) Applicant *(for all designated States except US)*: **DRESSER-RAND COMPANY** [US/US]; 1101 Paul Clark Drive, P.O. Box 560, Olean, NY 14760 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **MAIER, William, C.** [US/US]; 6959 Schuyler Rd., Almond, NY 14804 (US).

(74) Agents: **NOLTE, N., Alexander** et al.; Edmonds & Nolte, PC, 10411 Westheimer Road, Suite 201, Houston, TX 77042 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

[Continued on next page]

(54) Title: FLUSH-ENABLED CONTROLLED FLOW DRAIN

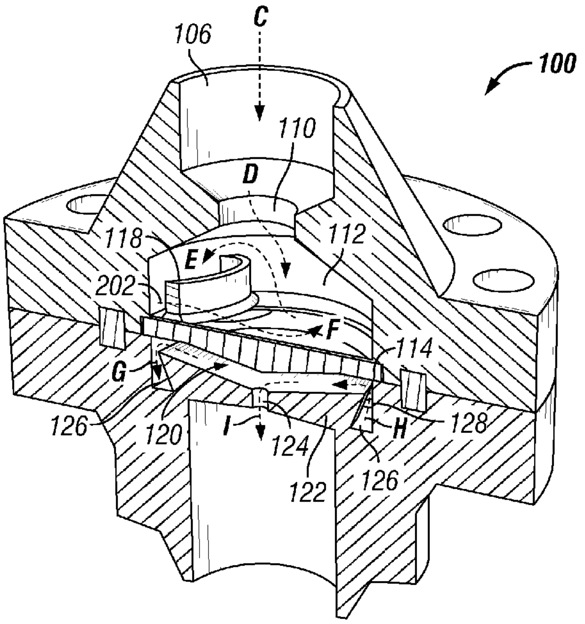

FIG. 3

(57) Abstract: A controlled flow drain having an upper flange coupled to a lower flange. The upper flange defines an inlet cavity and the lower flange defines a swirl chamber. The inlet cavity and swirl chamber are in fluid communication via a swirl nozzle defined within a swirl nozzle plate that separates the inlet cavity from the swirl chamber. After separating debris within the drain fluid, the drain fluid is accelerated through the swirl nozzle and discharged into the swirl chamber, and more debris is thereby separated and eventually settles into an annular groove. The drain fluid may then exit the lower flange via an exit control passage. The swirl chamber may be flushed with a series of flushing liquid injection ports symmetrically-arrayed about the annular groove. Flushing the swirl chamber removes fluidized debris and also remove any built up fouling present on the swirl nozzle and exit control passage.

WO 2012/033632 A1

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

FLUSH-ENABLED CONTROLLED FLOW DRAIN

[0001] This application claims priority to U.S. Provisional Patent Application having Serial No. 61/381,423, filed September 9, 2010. This priority application is incorporated herein in its entirety, to the extent consistent with the present application.

[0002] Motor-compressors are often used in subsea environments to support hydrocarbon recovery applications. Given the high cost of intervention, subsea motor-compressors are generally required to be robust, reliable machines that remain efficient over long periods of uninterrupted service. Operating a motor-compressor in subsea environments, however, can be challenging for a variety of reasons. For example, subsea machines are typically required to survive without maintenance intervention in an environment that promotes severe plugging or fouling and the incidental buildup of liquids in the cavities where the motor and bearing systems are disposed. To avoid damaging the motor and bearing systems, or interrupting hydrocarbon production, this liquid has to be periodically, if not continuously, drained from these liquid-sensitive cavities.

[0003] Draining the liquid, however, promotes fouling of drain orifices and can lead to the buildup of debris which can eventually clog essential drainage ports. Moreover, draining liquid buildup is often accompanied by a loss of gas, commonly referred to as "gas carry-under," such as cooling fluids or working fluid. The amount of gas carry-under leaking through the drainage system has a direct impact on the amount of power used by the compressor, and therefore on the overall efficiency of the compression system.

[0004] In at least one prior drainage system, actively controlled traps or other gas-break systems are employed to allow liquids to be drained while preventing any gas to be leaked through the drainage system. Nonetheless, active trap systems that are suitable for subsea applications are very costly and complex, or otherwise unreliable due to a significant part count.

[0005] Other control flow drainage systems employ passive, limited-flow drain devices. Such devices use a type of flow restrictor or throttle configured to limit undesirable gas egress while allowing all liquids to drain out of the cavities to an appropriate liquid tolerant portion of the system. For these types of systems, however, a minimum flow restrictor size is required, especially where plugging or fouling of the flow restrictor is a concern.

[0006] Another type of control flow drainage system uses a vortex throttle having a purely tangential nozzle configured to impart circumferential velocity to the flow. A drain passage is typically disposed close to the centerline of the vortex throttle, at the bottom of a circular swirl chamber. These devices enjoy a low flow coefficient due to the dissipation of energy in the vortex flow set up in the swirl chamber. Although vortex throttles relax the sensitivity of a passively controlled drain by providing a lower flow coefficient, the flow limiting passages are still subject to fouling or plugging in severe service. In addition, the typical tangential inlet topology of the vortex throttle is not amenable to robust, compact construction for high-pressure subsea applications.

[0007] What is needed, therefore, is a controlled flow drainage system that overcomes these and other limitations of prior control flow drains.

Summary

[0008] Embodiments of the disclosure may provide a controlled flow drain. The drain may include an upper flange coupled to a lower flange, the upper flange defining an inlet fluidly coupled to an upper drain pipe, and the lower flange defining an exit fluidly coupled to a lower drain pipe. The drain may further include a director orifice fluidly coupled to the inlet of the upper flange and in fluid communication with an inlet cavity defined within the upper flange, and a swirl nozzle plate disposed within the upper flange and configured to receive a drain flow via the inlet and director orifice and accommodate accumulation of debris thereon. The drain may also include a debris fence coupled to the swirl nozzle plate within the upper flange, a swirl nozzle defined within the swirl nozzle plate and at least partially surrounded by the debris fence, the swirl nozzle providing fluid communication between the inlet cavity and a swirl chamber, and an annular groove fluidly communicable with the swirl chamber and defined within the lower flange, the annular groove having a series of flushing liquid injection ports symmetrically-arrayed thereabout. The drain may also include an exit control passage defined within the drain restrictor and in fluid communication with the exit and the lower drain pipe.

[0009] Embodiments of the disclosure may further provide a method of controlling a drain flow. The method may include receiving the drain flow into an upper flange coupled to a lower flange, the upper flange defining an inlet and the lower flange defining an exit, centralizing the drain flow into an inlet cavity defined within the upper flange, and segregating debris within the drain flow from a swirl nozzle defined within a swirl nozzle plate, the swirl nozzle providing fluid communication between the inlet cavity and a swirl chamber defined in the lower flange. The method may further include accelerating the drain flow through the swirl nozzle to generate a

vortical fluid flow that forces dense debris within the drain flow to a radially outer extent of the swirl chamber, and accumulating the dense debris within an annular groove fluidly coupled to the swirl chamber and defined within the lower flange. The drain flow may then be drained from the lower flange via an exit control passage.

[0010] Embodiments of the disclosure may further provide another controlled flow drain. The drain may include an upper flange coupled to a lower flange, the upper flange defining an inlet fluidly coupled to an upper drain pipe, and the lower flange defining an exit fluidly coupled to a lower drain pipe. The drain may further include an inlet cavity fluidly coupled to the inlet, a swirl chamber fluidly coupled to the exit, and a swirl nozzle plate disposed between the inlet cavity and the swirl chamber and having a debris fence coupled thereto, the debris fence being disposed within the inlet cavity. The drain may also include a swirl nozzle defined within the swirl nozzle plate and providing fluid communication between the inlet cavity and the swirl chamber, and an annular groove defined within the lower flange and in fluid communication with the swirl chamber, the annular groove having a curved radius defined about its upper periphery where the annular groove meets the swirl chamber. The drain may also include an exit control passage defined within lower flange and in fluid communication with the exit and the lower drain pipe.

Brief Description of the Drawings

[0011] The present disclosure is best understood from the following detailed description when read with the accompanying Figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

[0012] Figure 1 illustrates a cross-sectional view of an exemplary drain, according to one or more embodiments disclosed.

[0013] Figure 2A illustrates a side view of a debris fence and swirl nozzle, according to one or more embodiments disclosed.

[0014] Figure 2B illustrates a plan view of a debris fence and swirl nozzle, according to one or more embodiments disclosed.

[0015] Figure 3 illustrates a cross-sectional isometric view of the drain shown in Figure 1.

[0016] Figure 4 illustrates a close-up cross-sectional view of a portion of the drain shown in Figure 1, according to one or more embodiments of the disclosure.

[0017] Figure 5 illustrates a schematic method of controlling a drain flow, according to one or more embodiments of the disclosure.

Detailed Description

[0018] It is to be understood that the following disclosure describes several exemplary embodiments for implementing different features, structures, or functions of the invention. Exemplary embodiments of components, arrangements, and configurations are described below to simplify the present disclosure; however, these exemplary embodiments are provided merely as examples and are not intended to limit the scope of the invention. Additionally, the present disclosure may repeat reference numerals and/or letters in the various exemplary embodiments and across the Figures provided herein. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various exemplary embodiments and/or configurations discussed in the various Figures. Moreover, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact. Finally, the exemplary embodiments presented below may be combined in any combination of ways, *i.e.*, any element from one exemplary embodiment may be used in any other exemplary embodiment, without departing from the scope of the disclosure.

[0019] Additionally, certain terms are used throughout the following description and claims to refer to particular components. As one skilled in the art will appreciate, various entities may refer to the same component by different names, and as such, the naming convention for the elements described herein is not intended to limit the scope of the invention, unless otherwise specifically defined herein. Further, the naming convention used herein is not intended to distinguish between components that differ in name but not function. Additionally, in the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to." All numerical values in this disclosure may be exact or approximate values unless otherwise specifically stated. Accordingly, various embodiments of the disclosure may deviate from the numbers, values, and ranges disclosed herein without departing from the intended scope. Furthermore, as it is used in the claims or specification, the term "or" is intended to encompass both exclusive and inclusive cases, *i.e.*, "A or B" is intended to be synonymous with "at least one of A and B," unless otherwise expressly specified herein.

[0020] Figure 1 illustrates a cross-sectional view of an exemplary controlled flow drain 100, according to one or more embodiments disclosed herein. The drain 100 may be used to remove unwanted fluids and/or contaminants away from one or more contamination-sensitive cavities within a turbomachine (not shown), such as a motor-compressor. The drain 100 may be configured to simultaneously limit or otherwise preclude undesirable exiting of gas from the contamination-sensitive cavities. In at least one embodiment, the drain 100 may be employed in conjunction with a subsea motor-compressor configured to receive and compress a working fluid, such as a hydrocarbon gas, including but not limited to natural gas or methane.

[0021] The drain 100 may be embedded or otherwise defined within a modified high-pressure pipe flange, including an upper flange 102 and a lower flange 104. In at least one embodiment, the upper and lower flanges 102, 104 may form a single-piece pipe flange. In the depicted embodiment, however, the upper and lower flanges 102, 104 may be coupled together as known by those skilled in the art, such as by mechanical fasteners (*i.e.*, bolts), welding, brazing, or combinations thereof. An annular seal 103 may be disposed between the flanges 102, 104 and configured to sealingly engage the flanges 102, 104, thereby creating a fluid-tight seal therebetween. In one embodiment, the annular seal 103 may be an O-ring, but may also include other types of seals without departing from the scope of the disclosure.

[0022] The upper and lower flanges 102, 104 may be coupled to upper and lower drain pipes (not shown), respectively, of the accompanying turbomachine in order to channel and remove the unwanted fluids and/or contaminants from the liquid-sensitive cavities within the turbomachine. The unwanted fluids and/or contaminants may include liquids, such as water or hydrocarbon-based liquids, but may also include gases derived from the interior of the contamination-sensitive cavities described above.

[0023] To minimize plugging, the connecting upper and lower drain pipes may provide at least four times the flow area of the drain 100. In at least one embodiment, the connecting upper and lower drain pipes provide ten or more times the flow area of the drain 100. As depicted, the drain 100 may be oriented with respect to gravity having an inlet 106 at its upper extent defined within the upper flange 102, and an exit 108 at its bottom extent defined within the lower flange 104. Accordingly, drain fluid flow proceeds in a generally axial direction with respect to the drain's axis of symmetry Q, and as depicted by arrows A and B.

[0024] As the drain flow enters the inlet 106, it is directed through a director orifice 110 configured to centralize the incoming drain flow and direct it into an inlet cavity 112 and subsequently to the center of a succeeding swirl nozzle plate 114. The inlet cavity 112 may be an axisymmetric, profiled cavity formed within the upper flange 102 and partially defined at its base by the upper surface of the swirl nozzle plate 114. As the inlet cavity 112 receives the drain flow, particulate contamination or debris 116 contained within the drain flow is deposited or otherwise collected on the upper surface of the swirl nozzle plate 114. Typical debris 116 can include metallic pieces, rust, rock, sand, corrosion particles, sediment deposits, and/or combinations thereof.

[0025] A debris fence 118 is disposed within the inlet cavity 112 and may be welded to or otherwise milled into the swirl nozzle plate 114. As shown and described below with reference to Figures 2A and 2B, the debris fence 118 may surround a nozzle inlet 204 of a swirl nozzle 202. In operation, the debris fence 118 is at least partially configured to segregate the swirl nozzle 202 inlet area 204 from the debris 116 accumulating on the upper surface of the swirl nozzle plate 114. At the same time, the debris fence 118 allows drainage fluids to flow over the top of the debris fence 118 and into the swirl nozzle 202. Accordingly, the swirl nozzle 202 may provide fluid communication between the inlet cavity 112 and a swirl chamber 120, as will be described below.

[0026] Referring to Figures 2A and 2B, illustrated is the swirl nozzle 202 having a nozzle inlet 204 and a nozzle outlet 206. Figure 2A depicts a side view of the swirl nozzle 202 and Figure 2B depicts a plan view of the swirl nozzle 202. As illustrated, the swirl nozzle 202 may be defined or otherwise formed in the swirl nozzle plate 114, and the debris fence 118 may at least partially surround the nozzle inlet 204. The swirl nozzle 202 may include a prismatic cylindrical passage having a central axis R.

[0027] In one or more embodiments, the swirl nozzle 202 may be defined or otherwise arranged using compound declination angles. For example, as shown in Figure 2A, the central axis R of the swirl nozzle 202 may be arranged at an angle α with respect to the horizontal X axis, thereby imparting a downward pitch to the swirl nozzle 202 with respect to horizontal. In at least one embodiment, the angle α may be about 20° or less. Moreover, as shown in Figure 2B, the swirl nozzle 202 may be further arranged at an angle β with respect to the Z axis, thereby positioning the central axis R at an angle β with respect to a tangential discharge pitch circle in the radial plane. In other words, disposing the central axis R at an angle β effectively rotates the central axis R away from a purely tangential discharge position with respect to the sub-regions disposed below the swirl nozzle plate 114. In at least one embodiment, the angle β may be about 15°. As will be appreciated, however, the angle β may be adjusted in accordance with the desired diameter of the swirl nozzle 202. Accordingly, a broad range of diameters for the swirl nozzle 202 may be had simply by adjusting the angle β.

[0028] The use of double compound declination angles α and β allow for a compact geometry with both the nozzle inlet 204 and outlet 206 of the swirl nozzle 202 being contained within the same concentric circular boundary. Such a design maintains over 90% of the theoretical tangential swirl velocity as compared to the bulkier prior art designs described above that use a purely tangential swirl nozzle design.

[0029] In one or more embodiments, the overall thickness T (Figure 2A) of the swirl nozzle plate 114 allows for the fully-cylindrical portion of the swirl nozzle 202 between its nozzle inlet 204 and outlet 206 breakout regions to be approximately equal to the nozzle 202 passage diameter in length. When concern about gas carry-under is the controlling constraint, the size of the swirl nozzle 202 may be fixed at the minimum diameter deemed acceptable by those skilled in the art for proof against blockage by possible fouling particles and debris. In at least one embodiment, an industrially-acceptable size of the swirl nozzle 202 may range from about 1/8 inch to about ¼ inch in diameter.

[0030] Referring again to Figure 1, the drain 100 may further include a swirl chamber 120 formed or otherwise defined within the lower flange 104, the swirl chamber having its upper extent defined by the frustoconical, lower surface of the swirl nozzle plate 114 and its lower extent defined by a drain restrictor 122. The drain restrictor 122 may also have a generally frustoconical shape and include an exit control passage 124 centrally-defined therein. In at least one embodiment, the frustoconical, lower surface of the swirl nozzle plate 114 and the generally frustoconical shape of the drain restrictor 122 may be opposing parallel surfaces that are slightly angled to mirror each other. In one embodiment, the declination angle of the frustoconical, lower surface of the swirl nozzle plate 114 and the generally frustoconical shape of the drain restrictor 122 may be about 10°, but such angle may be modified to suit varying applications where fluids with differing flow coefficients are used. The frustoconical shape of the drain restrictor 122 may further generate a low point in the swirl chamber 120 where drain flow will accumulate and drain via the exit control passage 124. The frustoconical shape may also prevent incidental buildup of solids and/or liquids on the surface of the drain restrictor 122. This may be especially important for drainage when liquid is present with little or no pressure difference imposed across the drain restrictor 122.

[0031] The exit control passage 124 may be configured to minimize through-flow, and therefore act as a restrictor. In one embodiment, the exit control passage 124 includes sharp edges adapted to permit liquid drainage therethrough but concurrently control or otherwise restrict gas carry-under. The exit control passage 124 is in fluid communication with the downstream exit 108 discharge, which in turn fluidly communicates with the downstream exit piping system (not shown). In operation, the amount of flow through exit control passage 124 is generally controlled by the series combination of the pressure drops required to force the drain fluids through the swirl nozzle 202, the vortex flow generated by the swirl nozzle 202, and the general configuration of the exit control passage 124. In at least one embodiment, the diameter of the exit control passage 124 may be the same as the diameter of the swirl nozzle 202. As will be appreciated, however, the diameter of the exit control passage 124 may be greater than or less than the diameter of the swirl nozzle 202, without departing from the scope of the disclosure.

[0032] The swirl chamber 120 may be a generally cylindrical space configured to allow the drain flow exiting the swirl nozzle 202 (Figures 2A and 2B) to develop into a fully vortical fluid flow. Several novel features of the geometry of the swirl chamber 120 are directed at facilitating long service in difficult unattended subsea conditions. For example, in at least one embodiment, the geometry of the swirl chamber 120 includes a height roughly equal to the swirl nozzle 202 diameter. As can be appreciated, however, the height of the swirl chamber 120 may be modified to be greater or less than the swirl nozzle 202 diameter, without departing from the scope of the disclosure. In addition, to minimize the flow coefficient, the diameter of the swirl chamber 120 may be from about 5 to about 10 times the swirl nozzle 202 diameter.

[0033] Another significant feature of the swirl chamber 120 is the provision for the collection and removal of debris 116 from the swirl chamber 120 by flushing the debris 116 and any other fouling matter away from the swirl chamber 120. To accomplish this, the swirl chamber 120 may fluidly communicate with an annular groove 126 and a series of flushing liquid injection ports 128 (two shown in Figure 1) symmetrically-arrayed about the annular groove 126. As illustrated, the annular groove 126 may be formed about the drain restrictor 122 on the lower surface and outer extent of the swirl chamber 120. The flushing liquid injection ports 128 may be configured to feed a flushing liquid from external piping connections (not shown) into the swirl chamber 120. In one embodiment, the flushing liquid may be water, but may also include liquids derived from hydrocarbons or other liquid sources known in the art. Until needed for flushing, the flushing liquid injection ports 128 are sealed and no fluid flow passes therethrough.

[0034] The vortical fluid flow exiting the swirl nozzle 202 into the swirl chamber 120 will force dense debris 116 disposed within the drain flow to the radially outer extent of the swirl chamber 120, where the debris 116 eventually settles into the annular groove 126 without obstructing the general area of swirl chamber 120 itself. At some point, during a duty cycle of the turbomachine, for example, the debris 116 accumulated within the annular groove 126 may be flushed out by injecting flushing liquid into the annular groove 126 via the flushing liquid injection ports 128. When flushing is carried out, the flushing liquid flows uniformly from these ports 128, pressurizes the swirl chamber 120, and thereby forces accumulated debris 116 out of the swirl chamber 120 and through the exit control passage 124. As can be appreciated, pressurizing the swirl chamber 202 may serve to fluidize at least a portion of the solid contaminants or debris settled in the annular ring 126. Once fluidized, the debris more easily exits the exit control passage 124.

[0035] The pressurized flushing liquid also serves to remove fouling that may have built up on the edges of the exit control passage 124. Moreover, because the swirl chamber 120 becomes pressurized, a fraction of the flushing liquid is simultaneously forced through the swirl nozzle 202 at a significant pressure. Consequently, flushing the swirl chamber 120 also dislodges debris 116 or fouling matter formed on the swirl nozzle 202, and such dislodged debris 116 and/or fouling matter can then be removed from the drain 100 via the exit control passage 124.

[0036] Referring now to Figure 3, illustrated is a cross-sectional isometric view of the drain 100 shown in Figure 1. As such, Figure 3 may be best understood with reference to Figure 1, where like numerals correspond to like elements and therefore will not be described again in detail. In exemplary operation, drain fluid enters the drain 100 via the inlet 106, as shown by arrow C. The director orifice 110 centralizes the incoming drain flow and directs it into the inlet cavity 112 and the succeeding swirl nozzle plate 114, as shown by arrow D. While the more dense debris 116 (Figure 1) and other contaminating materials accumulate on the upper surface of the swirl nozzle plate 114, the less dense fluid flows over the top of the debris fence 118 and toward the swirl nozzle 202, as shown by arrow E.

[0037] As the drain flow channels through the swirl nozzle 202, it is accelerated and develops into a fully vortical fluid flow within the swirl chamber 120, as shown by arrow F. The vortical fluid flow exiting the swirl nozzle 202 forces dense debris and other contaminants within the drain flow to the radially outer extent of the swirl chamber 120 where they eventually settle into the annular groove 126, as shown by arrow G. By injecting flushing fluid via the flushing liquid injection ports 128 (one shown in Figure 3), the debris and contaminants are removed or otherwise flushed from the annular groove 126 and to the frustoconical surface of the drain restrictor 122, as shown by arrow H. Flushing the swirl chamber 120 also serves to pressurize the swirl chamber, thereby forcing drain flow and unwanted contaminants down the exit control passage 124, as shown by arrow I. In at least one embodiment, a valve (not shown) located upstream from the inlet 106 to the drain 100 may be closed during flushing operations, thereby promoting the full pressurization of the drain and the consequential removal of debris 116 (Figure 1) via the exit control passage 124.

[0038] Referring now to Figure 4, illustrated is a partial cross-sectional view of the drain 100, and in particular a sectional view of the swirl chamber 120 and its interaction or fluid communication with the annular groove 126. In at least one embodiment, the upper periphery of the annular groove 126 where it meets the swirl chamber 120 may include a curved radius 402 about the circumference of the swirl chamber 120. As can be appreciated, the curved radius 402 may be configured to generally direct any flushed debris or contaminants toward the exit control passage 124, as shown by arrow J, and minimize potential reverse flow of collected debris through the swirl nozzle 202, as shown by arrow K.

[0039] It will be appreciated that the drain 100 as generally disclosed herein provides several advantages. For example, the combination of the inlet flow director orifice 110, the swirl nozzle plate 114, and the debris fence 116 allow prolonged operation in severe fouling or plugging service by shunting potential blocking matter away from the smaller downstream flow control passages, such as the exit control passage 124. Also, the compact topology of the swirl nozzle 202, including its unique compound angling, allows the drain 100 to be conveniently contained within a standard piping flange. Moreover, the integration of the annular ring 126 and uniformly-arrayed flushing liquid injection ports 128 disposed about the circumference of the annular ring 126 further extends severe service application of the drain 100, especially in subsea applications. Lastly, the conical endwalls on the swirl chamber 120 actively promote gravity assisted liquid drainage when little or no pressure differential exists across the drain 100, while simultaneously limiting deleterious gas migration through the exit control passage 124. Accordingly, this present disclosure allows reliable and efficient long-term operation of subsea devices requiring drainage maintenance.

[0040] Referring now to Figure 5, depicted is a schematic method 500 of controlling a drain flow. The method 500 may include receiving a drain flow in a drain, as at 502. The drain flow may include an upper flange coupled to a lower flange, where the upper flange defines an inlet and the lower flange defines an exit. The drain flow may then be centralized within an inlet cavity with a director orifice, as at 504. The director orifice may be fluidly coupled to the inlet of the upper flange. Any debris within the incoming drain flow may then be segregated from a swirl nozzle, as at 506. The swirl nozzle may be defined within a swirl nozzle plate and provide fluid communication between the inlet cavity and a swirl chamber. The swirl chamber may be defined in the lower flange.

[0041] At least a portion of the drain flow may be accelerated through the swirl nozzle to generate a vortical fluid flow, as at 508. The vortical fluid flow may be configured to force any dense debris within the drain flow to a radially outer extent of the swirl chamber. Once separated from the drain flow, the dense debris may accumulate within an annular groove, as at 510. The annular groove may be fluidly coupled to the swirl chamber and defined within the lower flange. The drain flow may then be drained from the lower flange via an exit control passage, as at 512.

[0042] As used herein, “about” refers to a degree of deviation based on experimental error typical for the particular property identified. The latitude provided the term “about” will depend on the specific context and particular property and can be readily discerned by those skilled in the art. The term “about” is not intended to either expand or limit the degree of equivalents which may otherwise be afforded a particular value. Further, unless otherwise stated, the term “about” shall expressly include “exactly,” consistent with the discussion below regarding ranges and numerical data.

[0043] The foregoing has outlined features of several embodiments so that those skilled in the art may better understand the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

Claims

We claim:

1. A controlled flow drain, comprising:

an upper flange coupled to a lower flange, the upper flange defining an inlet fluidly coupled to an upper drain pipe, and the lower flange defining an exit fluidly coupled to a lower drain pipe;

a director orifice fluidly coupled to the inlet of the upper flange and in fluid communication with an inlet cavity defined within the upper flange;

a swirl nozzle plate disposed within the upper flange and configured to receive a drain flow via the inlet and director orifice and accommodate accumulation of debris thereon;

a debris fence coupled to the swirl nozzle plate within the upper flange;

a swirl nozzle defined within the swirl nozzle plate and at least partially surrounded by the debris fence, the swirl nozzle providing fluid communication between the inlet cavity and a swirl chamber;

an annular groove fluidly communicable with the swirl chamber and defined within the lower flange, the annular groove having a series of flushing liquid injection ports symmetrically-arrayed thereabout; and

an exit control passage defined within the drain restrictor and in fluid communication with the exit and the lower drain pipe.

2. The controlled flow drain of claim 1, wherein the debris fence segregates the swirl nozzle from the debris accumulating on the swirl nozzle plate.

3. The controlled flow drain of claim 3, wherein the debris fence allows the drain flow to flow over a top of the debris fence and into the swirl nozzle.

4. The controlled flow drain of claim 1, wherein the swirl nozzle has a central axis extending from a nozzle inlet to a nozzle outlet.

5. The controlled flow drain of claim 4, wherein the central axis is arranged at an angle α with respect to horizontal, thereby imparting a downward pitch to the swirl nozzle.

6. The controlled flow drain of claim 5, wherein the central axis is arranged at an angle β with respect to the Z axis.

7. The controlled flow drain of claim 5, wherein the angle α may be about 20° or less.

8. The controlled flow drain of claim 6, wherein the angle β may be about 15°.

9. The controlled flow drain of claim 1, wherein the swirl chamber is defined in the lower flange by a lower surface of the swirl nozzle plate and a drain restrictor.

10. The controlled flow drain of claim 9, wherein the lower surface of the swirl nozzle plate and the drain restrictor are opposing parallel surfaces that are respectively frustoconical.

11. The controlled flow drain of claim 1, wherein the exit control passage includes sharp edges adapted to permit liquid drainage therethrough but concurrently restrict gas carry-under.

12. A method of controlling a drain flow, comprising:

receiving the drain flow into an upper flange coupled to a lower flange, the upper flange defining an inlet and the lower flange defining an exit;

centralizing the drain flow into an inlet cavity defined within the upper flange;

segregating debris within the drain flow from a swirl nozzle defined within a swirl nozzle plate, the swirl nozzle providing fluid communication between the inlet cavity and a swirl chamber defined in the lower flange;

accelerating the drain flow through the swirl nozzle to generate a vortical fluid flow that forces dense debris within the drain flow to a radially outer extent of the swirl chamber;

accumulating the dense debris within an annular groove fluidly coupled to the swirl chamber and defined within the lower flange; and

draining the drain flow from the lower flange via an exit control passage.

13. The method of claim 12, further comprising flushing the swirl chamber with a flushing fluid ejected from a series of flushing liquid injection ports symmetrically-arrayed about the annular groove.

14. The method of claim 13, further comprising pressurizing the swirl chamber with the flushing fluid to force the drain fluid through the exit control passage.

15. The method of claim 14, further comprising fluidizing at least a portion of the dense debris such that the dense debris can be drained through the exit control passage.

16. The method of claim 14, further comprising removing built up fouling from the swirl nozzle and exit control passage with the flushing fluid.

17. A controlled flow drain, comprising:

an upper flange coupled to a lower flange, the upper flange defining an inlet fluidly coupled to an upper drain pipe, and the lower flange defining an exit fluidly coupled to a lower drain pipe;

an inlet cavity fluidly coupled to the inlet;

a swirl chamber fluidly coupled to the exit;

a swirl nozzle plate disposed between the inlet cavity and the swirl chamber and having a debris fence coupled thereto, the debris fence being disposed within the inlet cavity;

a swirl nozzle defined within the swirl nozzle plate and providing fluid communication between the inlet cavity and the swirl chamber;

an annular groove defined within the lower flange and in fluid communication with the swirl chamber, the annular groove having a curved radius defined about its upper periphery where the annular groove meets the swirl chamber; and

an exit control passage defined within lower flange and in fluid communication with the exit and the lower drain pipe.

18. The controlled flow drain of claim 17, further comprising a series of flushing liquid injection ports symmetrically-arrayed about the annular groove.

19. The controlled flow drain of claim 18, wherein the swirl nozzle has a central axis arranged at an angle α with respect to horizontal, thereby imparting a downward pitch to the swirl nozzle.

20. The controlled flow drain of claim 19, wherein the central axis is arranged at an angle β with respect to the Z axis.

21. The controlled flow drain or method of any of the preceding claims, wherein the debris fence segregates the swirl nozzle from the debris accumulating on the swirl nozzle plate.

22. The controlled flow drain or method of any of the preceding claims, wherein the debris fence allows the drain flow to flow over a top of the debris fence and into the swirl nozzle.

23. The controlled flow drain or method of any of the preceding claims, wherein the swirl nozzle has a central axis extending from a nozzle inlet to a nozzle outlet.

24. The controlled flow drain or method of any of the preceding claims, wherein the central axis is arranged at an angle α with respect to horizontal, thereby imparting a downward pitch to the swirl nozzle.

25. The controlled flow drain or method of any of the preceding claims, wherein the central axis is arranged at an angle β with respect to the Z axis.

26. The controlled flow drain or method of any of the preceding claims, wherein the angle α may be about 20° or less.

27. The controlled flow drain or method of any of the preceding claims, wherein the angle β may be about 15°.

28. The controlled flow drain or method of any of the preceding claims, wherein the swirl chamber is defined in the lower flange by a lower surface of the swirl nozzle plate and a drain restrictor.

29. The controlled flow drain or method of any of the preceding claims, wherein the lower surface of the swirl nozzle plate and the drain restrictor are opposing parallel surfaces that are respectively frustoconical.

30. The controlled flow drain or method of any of the preceding claims, wherein the exit control passage includes sharp edges adapted to permit liquid drainage therethrough but concurrently restrict gas carry-under.

31. The controlled flow drain or method of any of the preceding claims, further comprising flushing the swirl chamber with a flushing fluid ejected from a series of flushing liquid injection ports symmetrically-arrayed about the annular groove.

32. The controlled flow drain or method of any of the preceding claims, further comprising pressurizing the swirl chamber with the flushing fluid to force the drain fluid through the exit control passage.

33. The controlled flow drain or method of any of the preceding claims, further comprising fluidizing at least a portion of the dense debris such that the dense debris can be drained through the exit control passage.

34. The controlled flow drain or method of any of the preceding claims, further comprising removing built up fouling from the swirl nozzle and exit control passage with the flushing fluid.

35. The controlled flow drain or method of any of the preceding claims, further comprising a series of flushing liquid injection ports symmetrically-arrayed about the annular groove.

36. The controlled flow drain or method of any of the preceding claims, wherein the swirl nozzle has a central axis arranged at an angle α with respect to horizontal, thereby imparting a downward pitch to the swirl nozzle.

37. The controlled flow drain or method of any of the preceding claims, wherein the central axis is arranged at an angle β with respect to the Z axis.

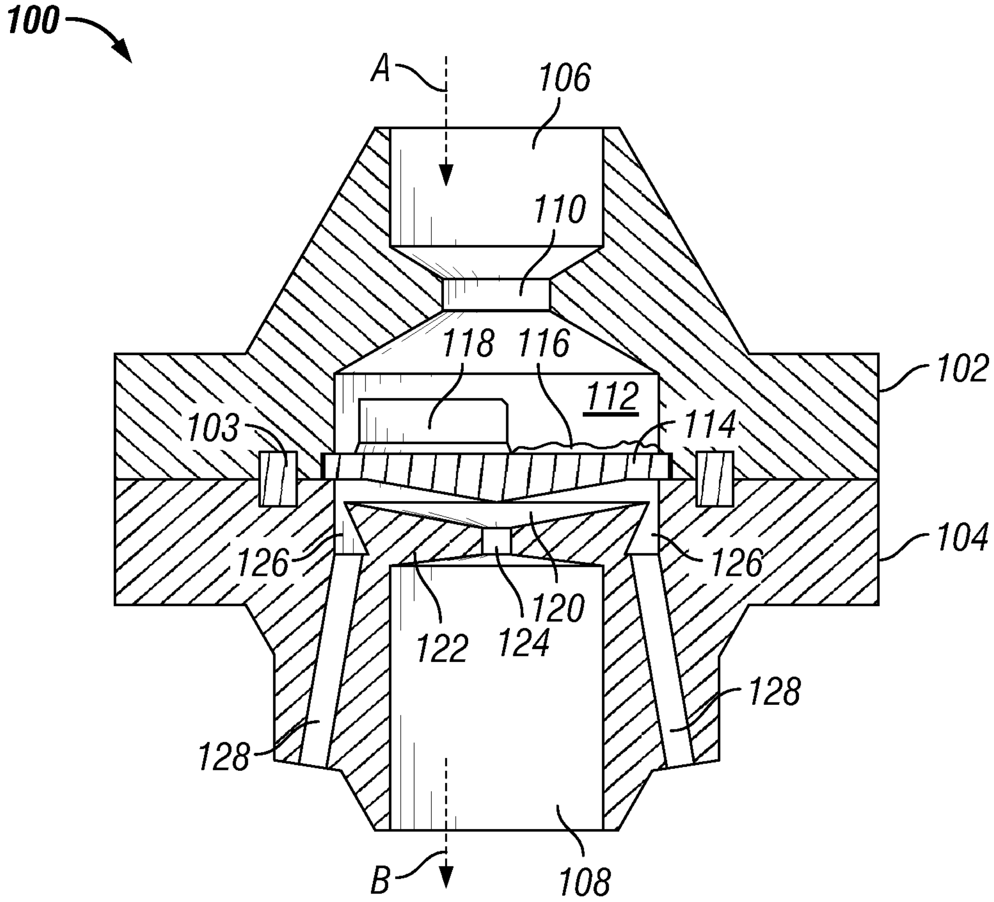
100
A
106
110
118
116
112
102
103
114
104
126
126
120
122
124
128
128
B
108

FIG. 1

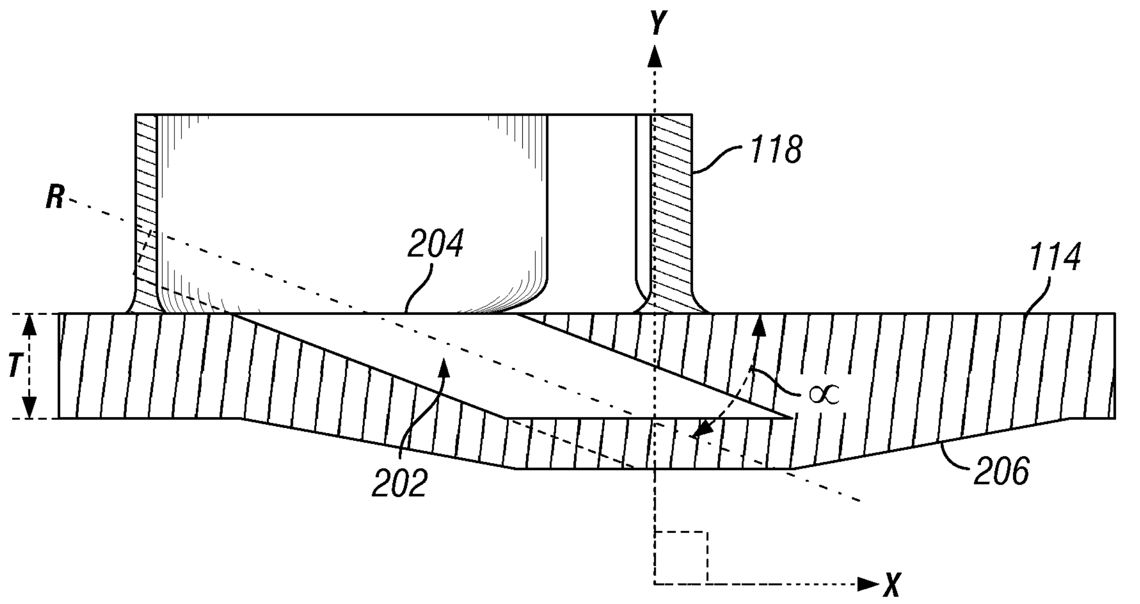
Y
118
R
204
114
T
∝
202
206
X

FIG. 2A

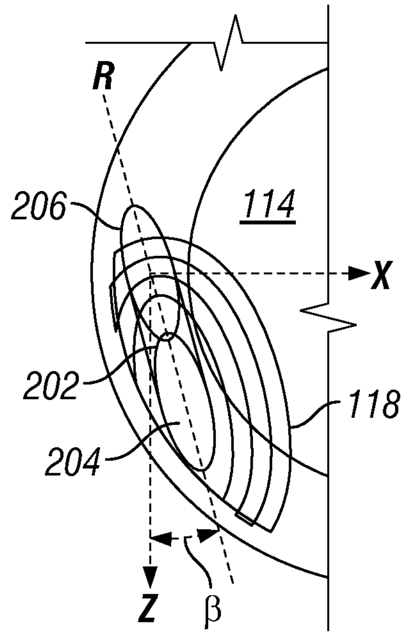
R
206
114
X
202
118
204
Z
β

FIG. 2B

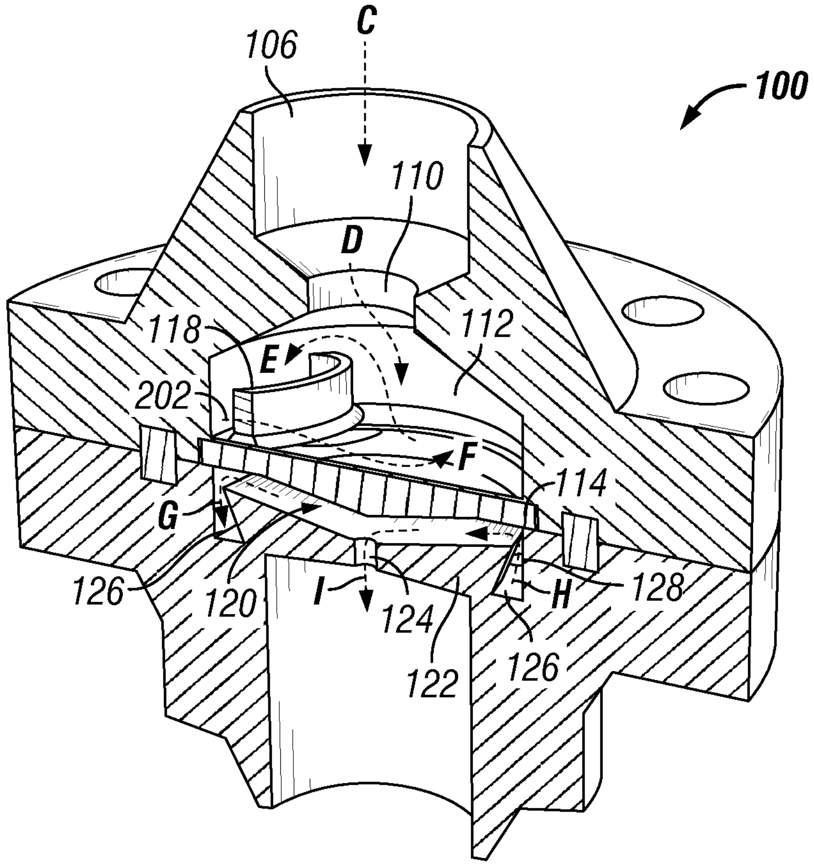
C
106
100
110
D
118
112
E
202
F
114
G
126
120
I
124
H
128
122
126

FIG. 3

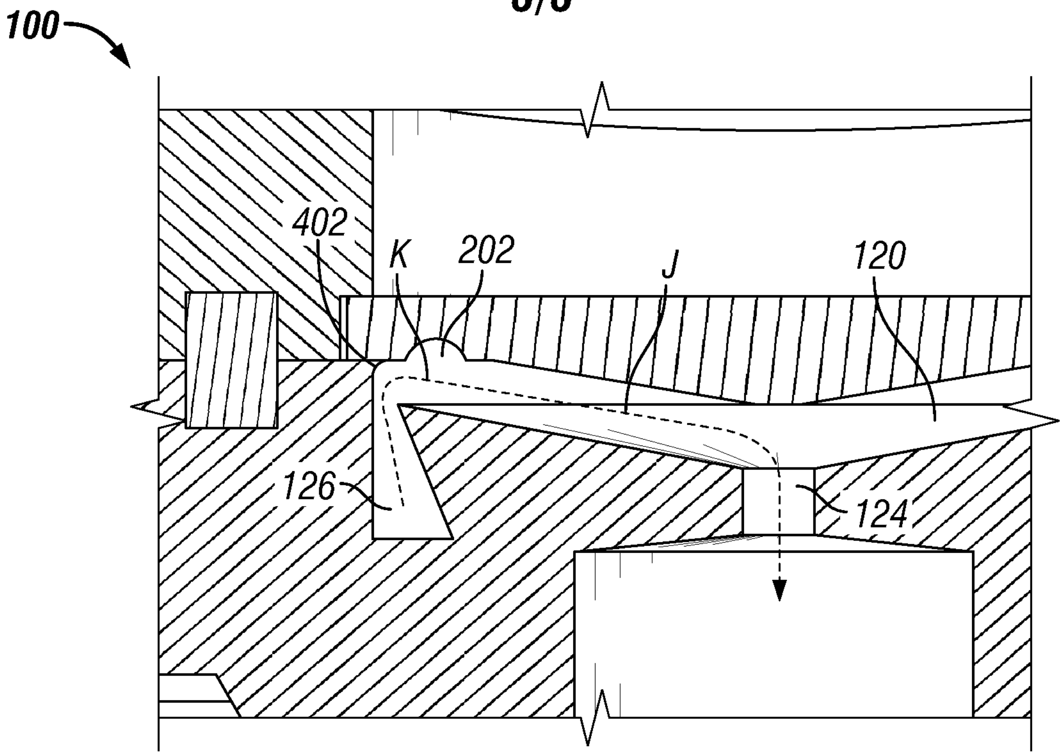
100
402
K
202
J
120
126
124

FIG. 4

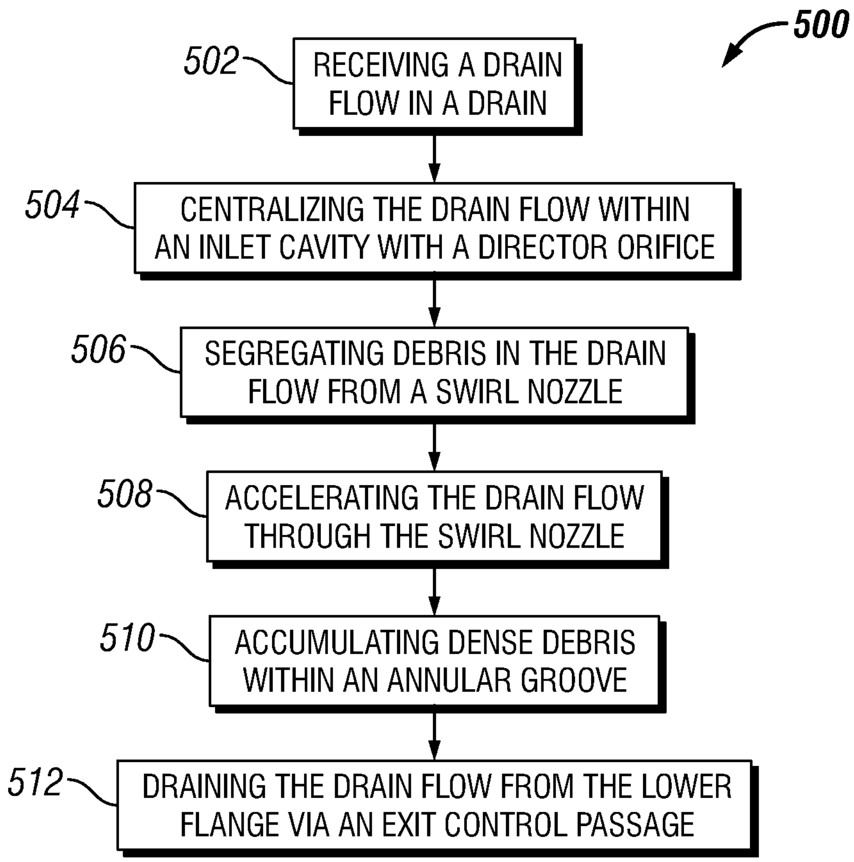
500
502
RECEIVING A DRAIN FLOW IN A DRAIN
504
CENTRALIZING THE DRAIN FLOW WITHIN AN INLET CAVITY WITH A DIRECTOR ORIFICE
506
SEGREGATING DEBRIS IN THE DRAIN FLOW FROM A SWIRL NOZZLE
508
ACCELERATING THE DRAIN FLOW THROUGH THE SWIRL NOZZLE
510
ACCUMULATING DENSE DEBRIS WITHIN AN ANNULAR GROOVE
512
DRAINING THE DRAIN FLOW FROM THE LOWER FLANGE VIA AN EXIT CONTROL PASSAGE

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/048652

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/12(2006.01)i, E21B 43/00(2006.01)i, F04F 5/44(2006.01)i

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)
E21B 43/12; B01D 21/26; F04D 13/12; E21B 7/18; F04D 13/16; A01K 63/04; B01D 19/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: drain, flush, nozzle, spray, inject, swirl, turbulent, vortex, vortical, remove, empty, withdraw, debris, groove, recess, submersible, subsea, motor, pump, compressor, loss, leak, cuttings, waste, build up, annular

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6187208 B1 (WHITE; THEODORE BAXTER) 13 February 2001 See abstract, columns 3,4 and figures 1,3,4	1,2,4-20
A	US 2003-0192718 A1 (WILLIAM, G. BUCKMAN et al.) 16 October 2003 See abstract, paragraph 25 and figure 3a	1,2,4-20
A	US 7288139 B1 (SHOWALTER,STEPHEN) 30 October 2007 See abstract, columns 3,4 and figure 2	1,2,4-20
A	EP 2233745 A1 (SIEMENS AKTIENGESELLSCHAFT) 29 September 2010 See abstract, paragraphs 15,16 and figure 1	1,2,4-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 JANUARY 2012 (06.01.2012)	**09 JANUARY 2012 (09.01.2012)**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon, 189 Cheongsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea	BAHNG, Seung Hoon
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-8444

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6187208 B1	13.02.2001	AU 2000-12545 A1	19.06.2000
		CA 2351635 A1	08.06.2000
		CA 2351635 C	04.12.2007
		EP 1137336 A1	04.10.2001
		NO20012662A	30.07.2001
		NO20012662D0	30.05.2001
		NO313311B1	16.09.2002
		US 06093320 A	25.07.2000
		WO 00-32038 A1	08.06.2000
US 2003-0192718 A1	16.10.2003	AU 2003-226330 A1	27.10.2003
		AU 2003-226330 B2	31.05.2007
		CA 2390466 A1	12.12.2003
		CA 2480249 A1	23.10.2003
		CA 2480249 C	15.09.2009
		EP 1499789 A2	26.01.2005
		US 6668948 B2	30.12.2003
		WO 03-087522A2	23.10.2003
		WO 03-087522A3	15.07.2004
US 7288139 B1	30.10.2007	CA 2662573 A1	13.03.2008
		CN 101511442 A	19.08.2009
		EP 2059317 A2	20.05.2009
		WO 2008-029262 A2	13.03.2008
		WO 2008-029262 A3	29.05.2008
EP 2233745 A1	29.09.2010	WO 2010-102905 A1	16.09.2010

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/048652

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 3,21-37
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

Claim 3 refers to itself. Hence, the claim does not clearly define the matter for which protection is sought (PCT Article 6).
Claims 21-37 have more than one subject matter, thereby rendering the subject matter unclear. (Rule 6.1(a))

3. ☒ Claims Nos.: 22-37
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.