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(54) SYSTEM FOR CLEANING A COMPRESSOR

ANLAGE ZUR REINIGUNG EINES KOMPRESSORS

SYSTEME PERMETTANT DE NETTOYER UN COMPRESSEUR

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Description

[0001] The present invention relates to a system for cleaning of compressors that are situated at a difficultly accessible location, e.g. subsea, according to the preamble of the subsequent independent claims.

[0002] In general all compressors will during the operating life experience degradation and fouling from different types of particles and contaminants in the compressed fluid. Particles stick to both static and rotating parts of the compressor flow path, adversely affecting the aerodynamic form leading to a decrease in mass flow, efficiency, pressure ratio and surge margin. This implies an increase in the required electrical power in order to maintain a constant production/delivery rate.

[0003] In recent years it has become desirable to place compressors, especially compressors for compressing natural gas exploited from an offshore hydrocarbon well, at or close to the seabed, or even downhole. Compressing the gas as far upstream in the production line as possible will reduce the required dimensions of risers and flowlines. Especially in deep waters a reduction of required diameter of risers has a great impact and will reduce weight substantially and hence the need for use of sophisticated materials, flotation devices and specially designed installation equipment. All of which have significant cost impact.

[0004] However, maintenance of a compressor placed at such a location has been an obstacle to putting this idea into practice. The maintenance would involve retrieving the compressor at regular intervals. The consequence of this would be not only the costs of retrieving the compressor and replacing it with another, but also a substantial down time in the production.

[0005] The present invention has as its main objective to maintain compressor capacity as high as possible and hence power consumption as low as possible during its entire operating life. As maintenance of subsea compressors is extremely expensive, a further objective is to avoid having to retrieve the compressor due to potentially severe compressor fouling.

[0006] Subsea compressors would typically be located a long distance from the host and the supply of electrical power and utilities would be performed via service lines from the host, offshore platform or onshore facility, at a typical distance of 40 to 180 km. The maintenance and cleaning of the subsea compressors would typically be performed by retrieving the subsea compressor to the surface (topside) in order to be cleaned manually. This is a costly operation that will require compressor system shutdown and an offshore vessels to perform the operation. The operation would not be performed as frequently as it should have been due to the high cost and possible loss of production during intervention. The compressor will therefore experience degradation and reduction of efficiency in the period between the intervention intervals.

[0007] Remotely located and difficultly accessible subsea compressors have a limited power supply system

due to high costs involved in building the power supply line. A relatively small reduction in efficiency for a large compressor will significantly increase the required-compressor power consumption in order to maintain constant production rate. Fouling by different kinds of substances, e.g., particles, sticking to the parts of the compressor in the flow path would therefore relatively quickly lead to an unacceptable reduction of efficiency that cannot be compensated by increasing the power supply to the compressor. An additional object of the invention is therefore to remove these substances adhering to the compressor flow path while the compressor is still in place at the difficultly accessible location.

[0008] It is today common practice for compressors located topside or onshore to utilize specialized cleaning liquids to perform "online" or "offline" washing. However, the topside or onshore located compressors are easily accessible and the system for supply of cleaning liquids is located nearby.

[0009] An example of cleaning of on-shore equipment is shown in US 6872263, which describe a method and a system for cleaning refinery equipment that does not require personnel to enter dangerous areas. Steam is used for this cleaning operation.

[0010] It will not be feasible to use steam as a cleaning agent at a subsea location. First, the steam will have to be generated at the surface. There is no known method described to generate steam at the seabed. Secondly, the steam has to be kept sufficiently hot during the transport from the surface to the seabed. This is a very difficult task, as the surrounding seawater is very cold and will quickly cool the steam until it is no longer steam but water. Thirdly, the pressure of the steam has to be high, in order to be able to pump the steam against the very high pressure at the seabed. The higher the pressure is the higher the temperature must be for the steam to be steam and not water.

[0011] It is therefore not realistic to use the method described in US 6872263 for seabed application.

[0012] US 6273102 also describes cleaning of refinery equipment, where a chemical is supplied via a line and evidently is transported through the whole system. This method for cleaning a land based refinery system is not applicable for cleaning of a compressor at the seabed as the specialized chemicals have to be supplied from the surface. This will take up valuable storage space topside for a chemical tank and pumps for the chemical. An extra line for supplying the chemical to the seabed has to be provided. This makes the system very costly.

[0013] JP 59113300 describes supply of a cleaning liquid to a compressor. It is not described where the compressor is situated, but considering the early filing date, 1982, of the application, it is highly unlikely that it describes a compressor at the seabed.

[0014] Cleaning of a land based compressor is basic knowledge for the person of skill, but does not teach the person of skill how he can perform cleaning of a subsea compressor. The feasible maintenance of a subsea com-

pressor, including cleaning, has been an unsolved problem. If the teaching of JP 59113300 were to be followed a dedicated supply line for the cleaning agent, a topside storage tank and pump would be needed.

[0015] The present invention is directed towards cleaning of an underwater compressor. The deep sea environment is a very difficult place for maintenance of any type of equipment, especially rotary equipment, such as a compressor. In a brochure "Taking a Giant Leap in Subsea Technology", issued by Siemens and FMC sometime after 4th November 2005, is presented a newly developed subsea compressor which is denoted as groundbreaking. In the text is stated that the compressor "will operate in a world more alien and less well explored than the moon". It is therefore evident that the subsea environment is something totally different than a land based refinery.

[0016] A system for on-line washing of subsea compressors is not existent today. It is important that the subsea compressor stations system solutions that can show low risk, simplicity, robustness, good efficiency and a minimum of auxiliary systems.

[0017] These objectives are obtained by a system as defined in claim 1.

[0018] A further embodiment is defined in claim 2.

[0019] If the accumulator tank is in communication with the liquid outlet of a gas/liquid separator the accumulator tank can be filled with liquid from the well flow, functioning as cleaning fluid.

[0020] The accumulator tank is in communication with a high pressure line diverting high pressurized gas from the compressor to boost the pressure of the cleaning liquid in the accumulator tank and evacuate the cleaning liquid.

[0021] Thoroughly tested and reliable systems for supply of inhibitors and chemical fluids in pipeline/tubing to subsea production systems exist today, but are not utilized for other purposes than flow assurance.

[0022] Design of subsea processing and boosting systems also includes supply of inhibitors, barrier fluids and other chemical fluids in pipelines/tubing and is based on the existing technology.

[0023] The compressor cleaning liquid can be one of several liquids that are readily available at the location. High pressure oil/gas wells and subsea production systems have some sort of hydrate prevention/control system in order to avoid hydrate formation, especially in flowlines. Hydrates will form when the hydrocarbon wellstream contains water in combination with high pressures and low temperatures. To avoid formation of hydrates, a liquid hydrate inhibitor is normally injected at the wellheads and is a part of the oil production infrastructure. Subsea processing and boosting systems will have means of injecting hydrate inhibitor or other chemical inhibitor supply.

[0024] Using the liquid inhibitor for injection at the compressor inlet (suction) will result in cleaning the fouling on compressor parts that are in direct contact with the

compressed medium and re-establish (at least to a certain extent) the original geometry.

[0025] Also, by injection of a cold liquid (seawater temperature) into the compressor, the compressor performance will improve due to reduced actual volumetric flow rate and increased density of the compressed medium through the compressor.

[0026] The injection of a readily available liquid into the compressor will contribute to

- Maintaining compressor efficiency at a high level during operation without shut down of gas production
- Reduce complexity of the overall system (no need for extra tubing in umbilical and specialized auxiliary systems topside)
- Increase reliability/availability
- Minimize cost (CAPEX and OPEX) for a compressor cleaning system/infrastructure

[0027] The invention will be explained in more detail, referring to the enclosed drawings illustrating exemplary embodiments of the invention, in which:

Figure 1 illustrates schematically a first and preferred embodiment of the invention, with cleaning liquid injected from an inhibitor supply line which also includes an optional interstage injection of cleaning liquid in the compressor,

Figure 2 illustrates a second embodiment of the present invention, with cleaning liquid supplied from an ROV and stored in an accumulator tank, or alternatively supply of cleaning liquid directly from an ROV,

Figure 3 illustrates a third embodiment of the present invention with cleaning liquid supplied from an inhibitor supply line via an accumulator tank with alternative accumulator evacuation systems,

Figure 4 illustrates a fourth embodiment of the present invention with injection of process liquid as cleaning liquid,

[0028] Referring first to figure 1, a compressor 1 is shown. The compressor can be of any type that is capable of compressing dry or wet natural gas, as the types of compressors currently used for this purpose onshore or topside.

[0029] Well fluid is supplied from a wellbore via a well fluid line 2. Unless the well fluid consists entirely of dry, or to a certain extent, wet gas, the well fluid is separated in a subsea or downhole separator 3. The liquid portion (water, condensate and oil) of the well fluid is led from the separator 3 to a liquid line 4. The gas is routed through a gas line 5 to the compressor 1. From the compressor the compressed gas is discharged into line 6 which is extended to a riser or flowline (single phase or mul-

tiphase).

[0030] In the vicinity of the compressor is a supply line 7 for supplying hydrate inhibitor to the wellhead, or other available and suitable liquid (e.g. MEG, methanol, barrier liquid, demulsifier, anti foam chemicals or different combinations of chemical components required for operation of a subsea production/processing system or to ensure reliable production). From this line extends a branch line 8. The branch line 8 is connected to the gas line at an injection and dosage valve 9. In the branch line 8 is an isolation valve 10.

[0031] When there is a need for cleaning of the compressor a small portion of the inhibitor liquid is tapped from the supply line 7 to the branch line 8 by opening the isolation valve 10. The liquid is fed to the injection nozzle and dosage valve 9. Typically there will be a number of nozzles distributed at optimal locations over the flow area, which is well known from current applications onshore.

[0032] The compressor often comprises more than one compressor stage. The liquid is injected in front of the first compressor stage. The washing liquid will flow through the compressor at high pressure and knock loose particles that have adhered internally in the flow path. The compressor condition monitoring system may make the decision of when to perform washing, based on gas flow measurements, power input measurements or other parameters indicating reduced performance. Alternatively, the cleaning can occur periodically in order to prevent fouling before it degrades the compressor performance significantly and the power supply increase or production is reduced.

[0033] The washing liquid leaves the compressor via the compressed gas line 6 and can be carried with the gas to a subsequent station for separating the washing liquid from the gas.

[0034] Figure 1 also shows a solution for interstage injection of washing liquid. This is represented by a second branch line 11 extending from the first branch line 8 downstream of the isolation valve 10. The second branch line 11 includes a second dosage valve 12.

[0035] The advantage of interstage injection of washing liquid is more efficient cleaning, since fresh cleaning liquid can be introduced at optimal locations into the flow path of the compressor. It is also feasible to have more than one interstage injection, e.g. one for each compressor stage.

[0036] Figure 2 shows an alternative embodiment of the invention where an accumulator tank 13 is supplying the cleaning liquid instead of extracting it from a supply line 7. The cleaning liquid accumulator tank 13 can be filled onshore or topside before installation of the tank 13 and/or it can be filled by an ROV during compressor station operation. The ROV can either access the compressor injection system via a connection line 25 (in which case the accumulator 13 can be omitted) or by filling up the accumulator 13 via a connection system 33. Alternatively, a specialized tube in the umbilical from topside may

be utilized. However, this is not preferred, due to the very high costs involved in manufacturing umbilicals. However, the umbilical tubing used for supply of compressor cleaning liquid does not necessarily have to be sized to be able to supply full cleaning liquid flow rate at the time of injection if a properly sized accumulator tank is installed subsea.

[0037] The advantage of an accumulator tank 13 as illustrated in figure 2 is that it can be filled with specialized cleaning liquids instead of hydrate inhibitors or other available liquids. This is especially advantageously if heavy degradation and compressor fouling is expected and the basic mechanical effect of compressor cleaning by liquid injection has little or no effect. Specialized compressor cleaning liquids may increase the washing effectiveness if the fouling is especially resistant or tough. The special cleaning liquid can be a concentrate mixed with other available subsea liquids (for example barrier liquid) or pre-mixed onshore and delivered to the subsea compression system by an ROV.

[0038] In all other basic features the embodiment of figure 2 is similar to the embodiment of figure 1. Interstage injection may of course also be applicable for the embodiment in figure 2 or all other embodiments described.

[0039] Figure 3 shows another embodiment of the present invention. This embodiment is similar to the embodiment of figure 1, the difference being that an accumulator tank 20 and an additional isolation valve 21 is present in the branch line 8 between the isolation valve 10 and the injection nozzle and dosage valve 9. In order not to disturb other processes requiring this liquid, the accumulator tank 20 may be slowly filled to ensure that the required compressor cleaning liquid flow rate and correct amount can be provided so that cleaning can be performed without disturbing other processes requiring the same liquid at other locations in the subsea production system. In order to evacuate the cleaning liquid from the accumulator tank 20, two options exist where the first mentioned is preferred. A bleed line 22 is routed from the compressor to the accumulator tank 20. The bleed line 22 will extract a small amount of pressurized gas from the compressor 1 and make it possible to evacuate the contents of the accumulator tank 20 by opening the valve 23 while the compressor 1 is running. As a second alternative, it is possible to route a bleed line 33 from upstream of the separator 3 to the accumulator tank 20. Due to the fact that the separator and pipeline between the separator 3 and the compressor 1 will cause a pressure drop, the accumulator pressure will be higher than the compressor 1 suction if valve 26 is open, and hence liquid will be pushed out of the accumulator tank 20 to the injection nozzles 9 in front of the compressor 1.

[0040] The line similar to the bleed line 22 can also be used for boosting the pressure of the accumulator tank 13 and evacuate its content according to the embodiment of figure 2.

[0041] Figure 4 shows a further alternative embodiment that is feasible if a separation unit 3 is present. The

figure shows a liquid booster pump 14 that normally is present to boost the pressure of oil, condensate and/or water after separation and before transporting. A branch line 15 is extending from the liquid line 31 after the booster pump 14. The branch line 15 includes an isolation valve 16, which is opened to let fluid into an accumulator and settling tank 17. From the accumulator and settling tank 17 a washing liquid line 8, having an isolation valve 27, extends to the injection nozzles and dosage valve 9, which is generally of the same type as in figure 1.

[0042] In order to fill the accumulator tank 17 with liquid from the pump 14 through the line 15, it may be necessary to bleed off fluid already present in the tank 17 (which can be a mixture of gas, liquid and settled particles). Preferably this fluid should be routed to a location upstream of the separator 3. This can be done from the settling vessel 17 via a return line 18, having an isolation valve 19, and a flowline 30 to an upstream location of the separator 3, or a flowline 29 into the pipeline 4 upstream of the pump 14. The particles will be transported through line 18 and line 29 or 30. Line 18 is therefore connected to the bottom of the accumulator 17 in order to ensure evacuation of any settled particles and route them through the liquid pump 14.

[0043] Any gas in the accumulator tank 17 can be evacuated through a line 28, having an isolation valve 32, extending from the top of the accumulator tank 17 to a location upstream of the separator 3. The line 28 can also serve as a means for evacuating the liquid in the settling tank 17 when the valves 19 and 16 are closed (valve 27 and 32 open). This can be done during operation due to the fact that there is a dynamic pressure drop over the separator 3. By opening valve 32, the pressure in tank 17 will be higher than at the compressor suction side so that injection of the liquid in the settling tank 17 is possible. An additional pressure increase in the liquid line 8 can be obtained by placing the settling tank 17 at a physically higher location than the compressor.

[0044] In the accumulator and settling tank 17 the liquid coming from the branch line 15, which often will contain particles of sand etc, can settle for some time before it is injected as a cleaning liquid into the compressor on one or more locations as described in connection with figure 1. After injection in the compressor the remaining fluid (and particles) in the settling vessel 17 can be re-injected into the suction side of the pump 14 or separator 3 and boosted back through the pump and to the receiving facility through line 31. This evacuation of particles and remaining liquid from the settling tank 17 can be done using the return line 18 to either upstream of the separator (through line 29) or upstream of the separator 3 (through line 30). The line 18 contains an isolation valve 19, to selectively return liquid and particles to a chosen one of these locations.

[0045] The injected inhibitor liquid must be injected in front of the first compressor impeller but the injection nozzle and dosage valve does not have to be a part of the compressor casing. The injected liquid should as far as

practically possible be distributed evenly over the flow area in order to be carried with the gas flow and gain momentum and increase washing effectiveness.

[0046] In general, the injection device 9 may also be used as an injection point for hydrate inhibitor during planned or unplanned shutdown of the compressor.

Claims

1. System for cleaning compressors (1) that are situated on or near the seabed or downhole in a well bore, **characterized in that** it comprises a cleaning liquid line (8) extending between a readily accessible liquid source (7, 13, 17, 20) on the seabed and the compressor (1), and that the liquid source is a line (7) for supply of hydrate inhibitor, anti foam chemicals, barrier liquid, demulsifier or other types of chemicals to a subsea production or processing activity.
2. System according to claim 1, **characterized in that** the liquid source is an accumulator tank (13, 20) situated between and communicating with the line and the compressor.
3. System according to claim 2, **characterized in that** the accumulator tank (13, 20) is in communication with a supply line (7) for hydrate inhibitor, anti foam chemicals, barrier liquid, demulsifier or other types of chemicals to a subsea production or processing activity.
4. System according to claim 3, **characterized in that** the accumulator tank (13, 20) is in communication with the liquid outlet of a gas/liquid separator (3).
5. System according to any of the claims 2 - 4, **characterized in that** the accumulator tank (20) is in communication with a high pressure line (22) diverting high pressurized gas from the compressor (1) to boost the pressure of the cleaning liquid in the accumulator tank (20) and evacuate the cleaning liquid.

Patentansprüche

1. System zum Reinigen von Kompressoren (1), welche sich am oder in der Nähe des Meeresgrunds oder unten in einem Bohrloch befinden, **dadurch gekennzeichnet, dass** es eine Reinigungsflüssigkeitsleitung (8) umfasst, welche sich zwischen einer leicht zugänglichen Flüssigkeitsquelle (7, 13, 17, 20) am Meeresgrund und dem Kompressor (1) erstreckt, und dass die Flüssigkeitsquelle eine Leitung (7) zur Zufuhr eines Hydratinhibitors, von Antischaumchemikalien, einer Sperrflüssigkeit, eines Demulgators oder anderer Arten von Chemikalien zu einer Produktions- oder Bearbeitungsaktivität unter Wasser

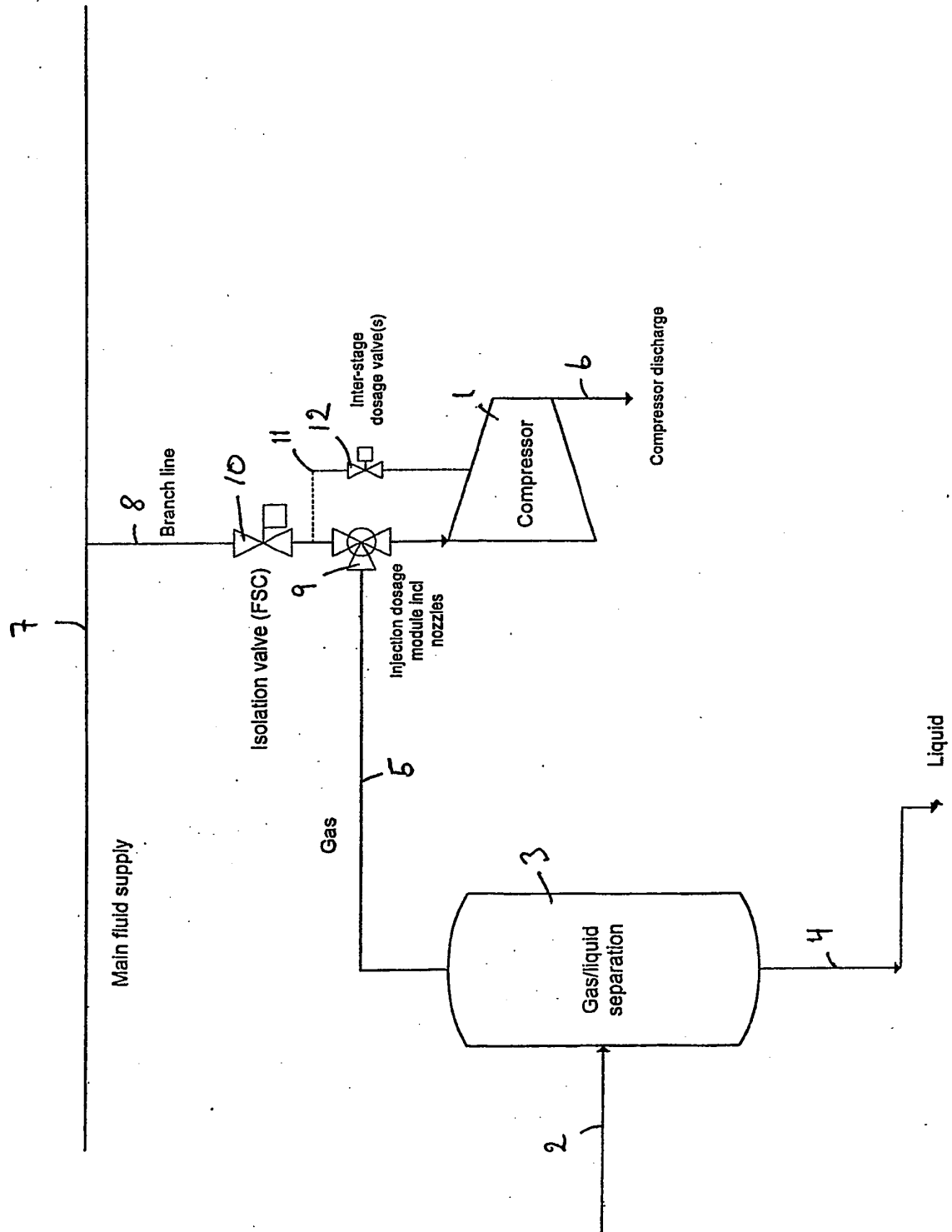
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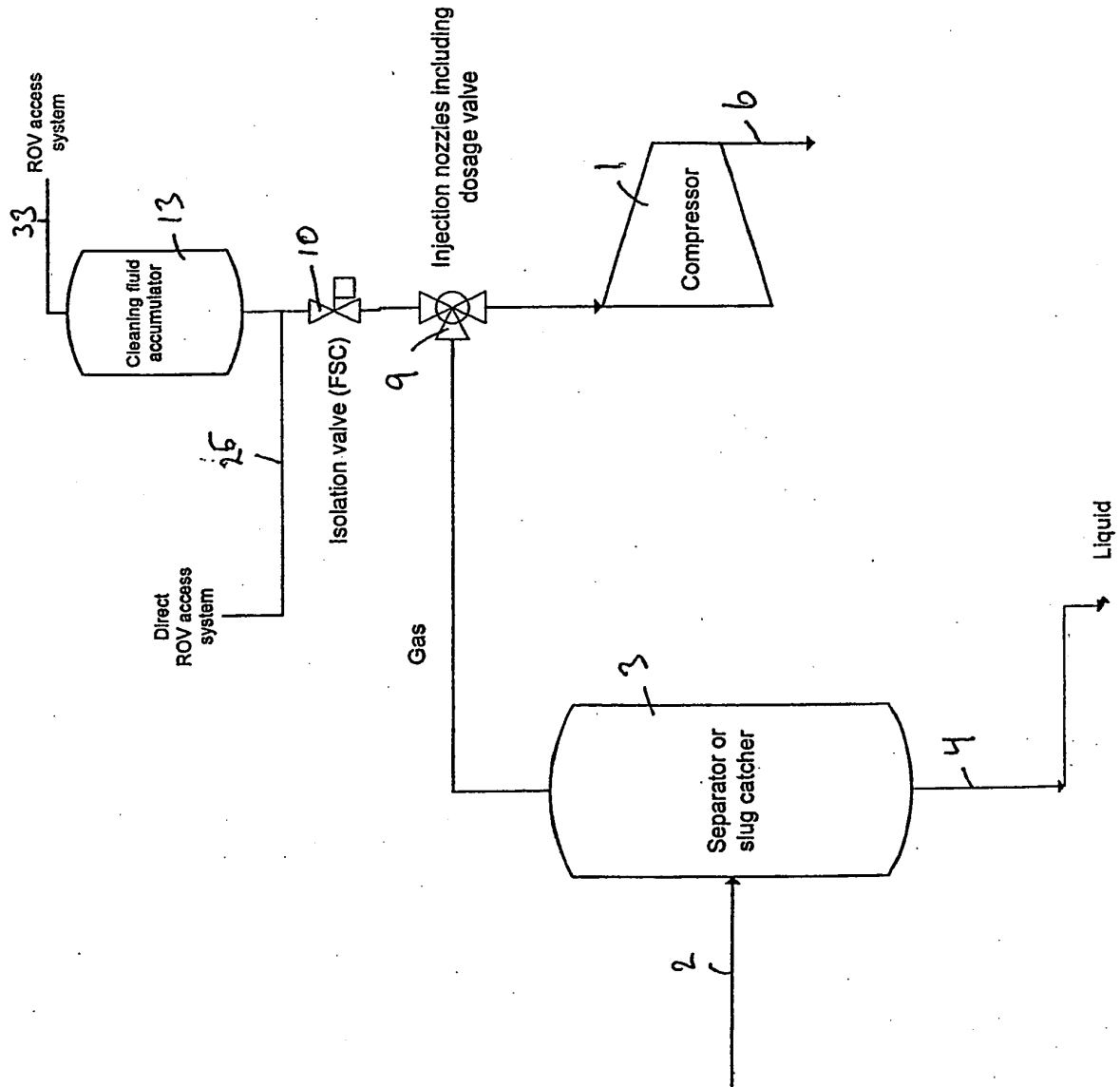
2. System nach Anspruch 1, **dadurch gekennzeichnet, dass** die Flüssigkeitsquelle ein Speicherbehälter (13, 20) ist, welcher sich zwischen der Leitung und dem Kompressor befindet und mit diesen verbunden ist. 5
3. System nach Anspruch 2, **dadurch gekennzeichnet, dass** der Speicherbehälter (13, 20) in Verbindung mit einer Zuführleitung (7) für Hydratinhibitor, Antischaumchemikalien, Sperrflüssigkeit, Demulgator oder andere Arten von Chemikalien zu einer Produktions- oder Bearbeitungsaktivität unter Wasser steht. 10 15
4. System nach Anspruch 3, **dadurch gekennzeichnet, dass** der Speicherbehälter (13, 20) in Verbindung mit dem Flüssigkeitsauslass eines Gas-/Flüssigkeitstrenners (3) steht. 20
5. System nach einem der Ansprüche 2 bis 4, **dadurch gekennzeichnet, dass** der Speicherbehälter (20) in Verbindung mit einer Hochdruckleitung (22) steht, welche Hochdruckgas vom Kompressor (1) umleitet, um den Druck der Reinigungsflüssigkeit im Speicherbehälter (20) zu erhöhen und die Reinigungsflüssigkeit zu evakuieren. 25 30

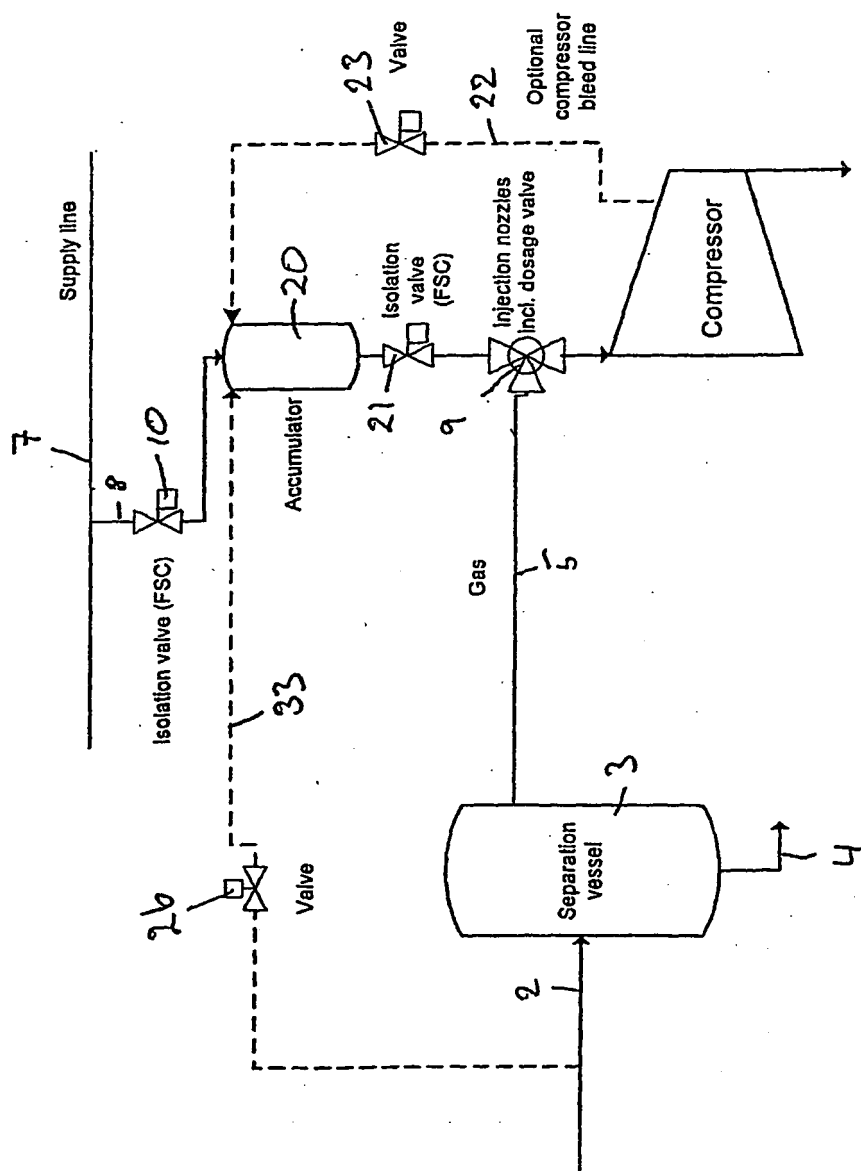
Revendications

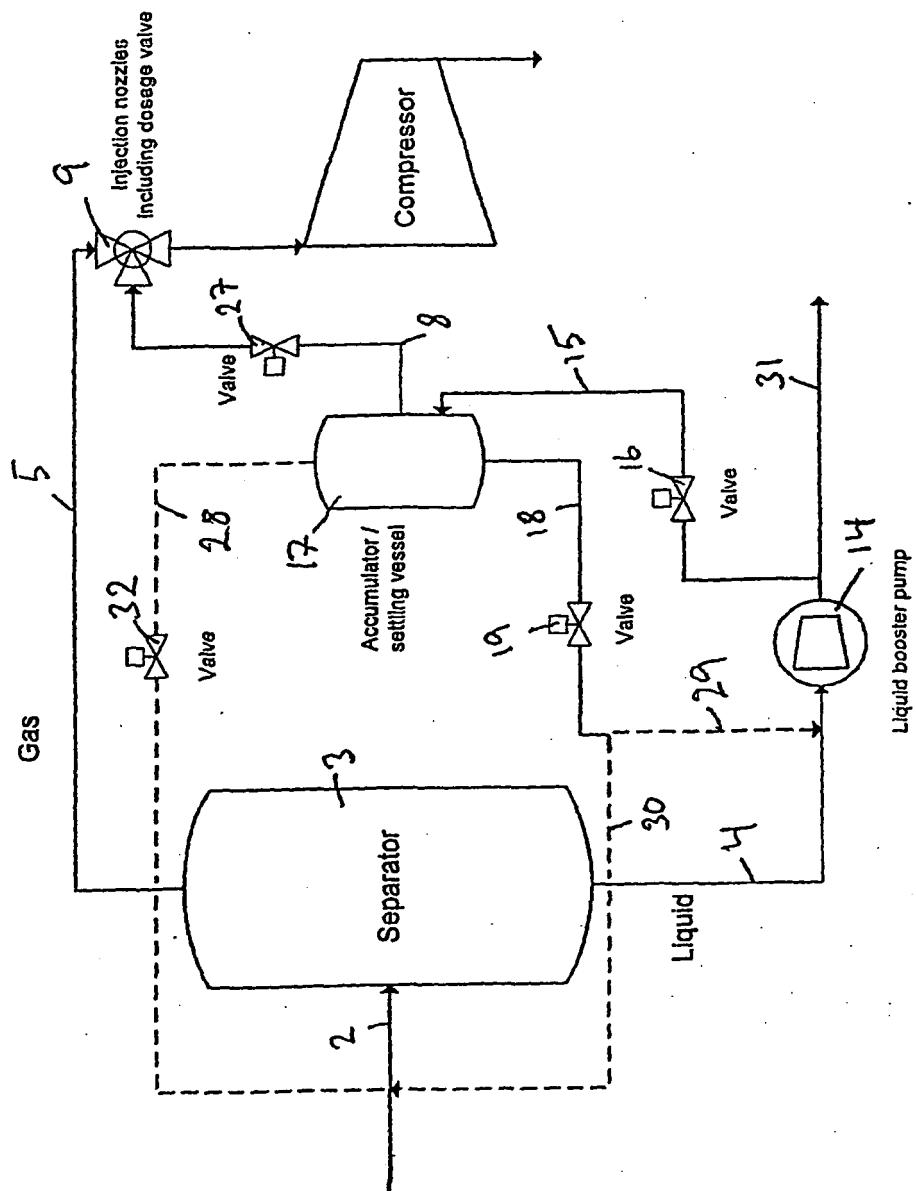
1. Système pour nettoyer des compresseurs (1) qui sont situés sur le fond de la mer ou un fond de puits d'un puits de forage, ou à proximité de ceux-ci, **caractérisé en ce qu'il** comprend une ligne de liquide de nettoyage (8) s'étendant entre une source de liquide facilement accessible (7, 13, 17, 20) située sur le fond de la mer et le compresseur (1), et **en ce que** la source de liquide est une ligne (7) destinée à alimenter un inhibiteur d'hydrate, des produits chimiques anti mousse, un liquide de barrière, un désémulsionnant ou d'autres types de produits chimiques pour une activité immergée de production ou de traitement. 35 40 45
2. Système selon la revendication 1, **caractérisé en ce que** la source de liquide est un réservoir accumulateur (13, 20) situé entre la ligne et le compresseur et communiquant avec ceux-ci. 50
3. Système selon la revendication 2, **caractérisé en ce que** le réservoir accumulateur (13, 20) est en communication avec une ligne d'alimentation (7) d'inhibiteur d'hydrate, de produits chimiques anti mousse, de liquide de barrière, de désémulsionnant ou d'autres types de produits chimiques pour une activité immergée de production ou de traitement. 55

4. Système selon la revendication 3, **caractérisé en ce que** le réservoir accumulateur (13, 20) est en communication avec la sortie de liquide d'un séparateur gaz/liquide (3).
5. Système selon l'une quelconque des revendications 2 à 4, **caractérisé en ce que** le réservoir accumulateur (20) est en communication avec une ligne haute pression (22) dérivant du gaz haute pression provenant du compresseur (1) pour accroître la pression du liquide de nettoyage dans le réservoir accumulateur (20) et évacuer le liquide de nettoyage.









REFERENCES CITED IN THE DESCRIPTION

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