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Remarks:
Amended claims in accordance with Rule 86 (2) EPC.

(54) **Liquid pump and method for pumping a liquid that may have gas coming out of solution**

(57) The present invention increases the pumping efficiency when pumping liquids whose liquid source is at a temperature and pressure close to the liquidus, or having entrained gas or gas coming out of solution, referred to as vapor, in several ways. First, the pump is oriented to allow liquid flowing into the compression chamber by the natural tendency of liquid to flow downward and residual vapor to return to the supply tank, by the natural tendency of vapor to flow upward. The location of the large smooth inlet line at the top of the pump encourages any vapor to escape and be piped back to the supply tank. The flow of vapor back to the supply tank is also encouraged by the vapor outlets and conduit leading back, at a positive slope, to the supply tank. Second, the inlet chamber located above the inlet valve reduces cavitation because this chamber prepares a new discrete volume of inlet liquid while the current discrete volume is being power-stroked out of the compression chamber. This is furthered by setting the inlet valves in angled pockets which encourages and facilitates the release any released vapor bubbles back to the top of the inlet line during the power stroke. Finally, the current invention discourages cavitation because the unswept volume is minimized. This is critical to the efficiency of the pump as well as reduction of the adverse effects of cavitation because this residual liquid tends to vaporize when subjected to depressurization during the intake stroke.

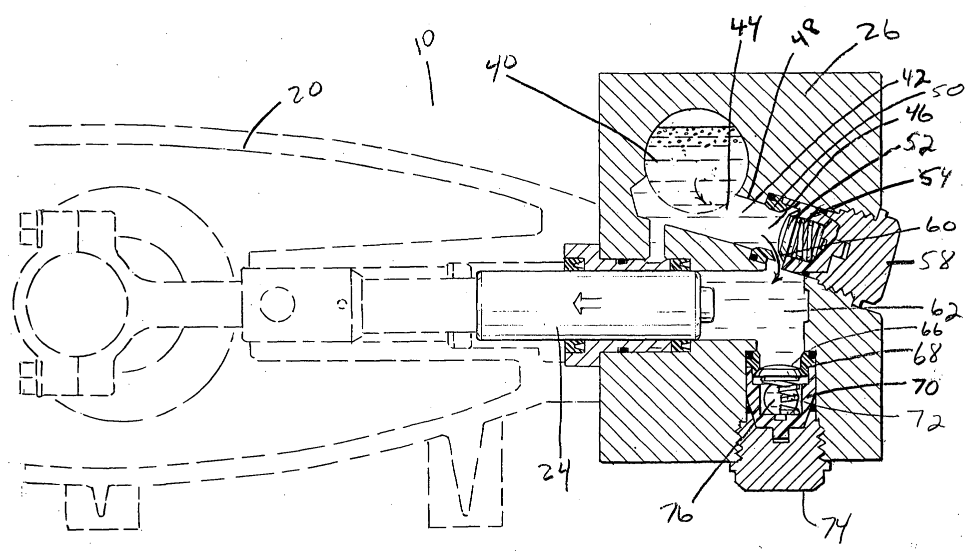

FIG.4

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Description

[0001] This invention relates generally to pumps for pumping a liquid from a source with a temperature and pressure near its liquidus or containing entrained or dissolved gas.

BACKGROUND OF THE PRESENT INVENTION

[0002] The invention relates to the apparatus and methods suitable for either mobile or stationary liquid reciprocating pumping systems whose liquid source is at a temperature and pressure close to its liquidus. Liquid carbon dioxide (CO_2) is an example of this type of liquid source. Liquids having dissolved or entrained gas, may also be pumped using the current invention.

[0003] While a number of pumps are disclosed in the art, such pumps tend to have an overly large unswept volume. The unswept volume is that volume of liquid remaining in the pumping chamber at the end of the power stroke of the pump. The present invention reduces the unswept volume to a minimum by fitting the inlet valves at an angle which allows delivery of the liquid from the inlet valves directly into the pumping chamber. The unswept residual liquid tends to vaporize when subjected to depressurization during the intake stroke, a phenomena known as cavitation which can cause excessive wear on the internal pump components and will reduce the efficiency of the pump.

[0004] Cavitation occurs when vapor bubbles are formed as a result of the lowered pressure of the liquid as it is drawn into the suction of the pump during the intake stroke. Some pumps reduce the liquid's pressure below the vapor pressure of the liquid at the existing temperature, causing it to vaporize. In the extreme situation, the pump can become filled with vapor and may be unable to pump. More importantly, the vapor bubbles will violently recondense into liquid form as the pressure is increased during the liquid's travel during the power stroke of the pump. The pressure pulse from the implosion of the vapor bubble attacks adjacent materials. The effects of cavitation may also combine with corrosion further increasing the speed of wear of the pump materials. In some cases, the original protective layers provided on the pump materials will be destroyed, rendering the exposed metal surface permanently activated for chemical attack.

[0005] The present invention reduces cavitation in several ways. First, the pump is oriented to allow liquid flowing into the compression chamber by the natural tendency of liquid to flow downward and residual vapor to leave the compression chamber, and return to the supply tank, by the natural tendency of vapor to flow upward. The location of the large smooth inlet line at the top of the pump encourages any vapor to escape and be piped back to the supply tank. The flow of vapor back to the supply tank is also encouraged by the conduit leading back, at a positive slope, to the supply tank. This principle will also apply to liquids where dissolved gas can come out of solution or where gas is entrained.

[0006] Second, the inlet chamber located above the inlet valve reduces cavitation because this chamber prepares a new discrete volume of inlet liquid while the current discrete volume is being power-stroked out of the compression chamber. This is furthered by setting the inlet valves in angled pockets that encourage and facilitate the buoyancy and upward movement of any released bubbles back to the top of the inlet line during the power stroke.

[0007] Third, the current invention discourages cavitation because the unswept volume, as discussed above, is minimized. This is critical to the efficiency of the pump as well as reduction of the adverse effects of cavitation because this residual liquid tends to vaporize when subjected to depressurization during the intake stroke.

[0008] Although the foregoing art addresses some of the various needs of the industry, the devices and methods described present an improvement in cavitation reduction and pump efficiency.

SUMMARY OF THE INVENTION

[0009] The present invention increases the pumping efficiency of liquids whose liquid source is at a temperature and pressure close to its liquidus, or liquids with entrained or dissolved gas, referred to as a vapor in several ways. First, the pump is oriented to allow liquid flowing into the compression chamber by the natural tendency of liquid to flow downward and residual vapor to return to the supply tank, by the natural tendency of vapor to flow upward. The location of the large smooth inlet line at the top of the pump encourages any vapor to escape and be piped back to the supply tank. The flow of vapor back to the supply tank is also encouraged by the vapor outlet and conduit leading back, at a positive slope, to the supply tank. The vapor outlet can be slightly higher than the liquid inlet to improve the purging of the vapor. Second, the inlet chamber located above the inlet valve reduces cavitation because this chamber prepares a new discrete volume of inlet liquid while the current discrete volume is being power-stroked out of the compression chamber. This is furthered by setting the inlet valves in angled pockets which encourages and facilitates the release of any released vapor bubbles back to the top of the inlet line during the power stroke. Finally, the current invention discourages cavitation because the unswept volume is minimized. This is critical to the efficiency of the pump as well as reduction of the adverse effects of cavitation because this residual liquid tends to vaporize when subjected to depressurization during the intake stroke. The effects of liquid compressibility are reduced with reduced unswept volume.

[0010] An object and advantage of the invention is to provide an improved apparatus and method of pumping liquids that removes vapor from the pump and returns the vapor to the supply tank in a more efficient manner.

[0011] Another object and advantage of the invention allows the pumping of liquids whose liquid source is at a temperature and pressure close to its liquidus or has entrained gas or gas coming out of solution.

[0012] An object and advantage of the invention is to provide an apparatus and method of pumping liquids that decreases the unswept volume of the pump.

[0013] Yet another object and advantage of the invention is to provide an apparatus and method of pumping liquids with reduced cavitation.

[0014] Another object and advantage of the invention is to provide an apparatus and method of pumping liquids that increases the efficiency of the pump.

[0015] The foregoing objects and advantages of the invention will become apparent to those skilled in the art when the following detailed description of the invention is read in conjunction with the accompanying drawings and claims. Throughout the drawings, like numerals refer to similar or identical parts.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Figure 1 is a front view of the pumping system, showing inlet and outlet lines, the supply tank and the driving means.

Figure 2 is a perspective view of the pump.

Figure 3 is a front view of the pump with arrows indicating fluid direction.

Figure 4 is a side cross sectional view of the pump as it aspirates fluid into the compression chamber.

Figure 5 is a side cross sectional view of the pump as it pumps fluid out of the compression chamber.

DETAILED DESCRIPTION OF THE INVENTION

[0017] With reference to the accompanying figures, Figure 1 illustrates a preferred pumping system using the inventive pump. The pump 10, shown in detail in Figures 2 to 5, is in fluid communication with a downwardly declining inlet conduit 14 which is connected to the bottom of a supply tank 12, an upwardly inclining vapor release conduit 16 which communicates with the top of the supply tank 12. The supply tank 12 is shown in Figure 1 with a level of liquid 13 contained therein. Since the liquid is held near its liquidus, vapor bubbles will tend to form in the liquid when either the temperature rises beyond the liquid's liquidus or the pressure decreases below the liquidus. The inlet conduit 14 is preferably connected at the bottom of the supply tank 12 and the vapor release conduit 16 in fluid communication with the supply tank 12, preferably connected at the top of the supply tank 12. In an alternative embodiment not shown in the Figures, an automatic vent valve can replace the vapor release conduit 16 when the gas can be safely and economically vented to atmosphere or alternative vessel. The inlet conduit 14 is further preferably downwardly declining in slope and the gas release conduit 16 preferably upwardly inclining. This configuration facilitates the natural tendency of liquid to flow downwardly and vapor upwardly.

[0018] As Figure 1 illustrates, the fluid in the supply tank 12 is primarily liquid under vapor, however the liquid may contain some vapor bubbles, with the vapor bubbles being more prevalent at the top of the liquid than at the bottom. Thus, the inlet conduit 14, communicating with the bottom of the supply tank 12, is generally composed of liquid but some vapor bubbles may move into the downwardly declining inlet conduit 14. Further, as the liquid progresses down the inlet conduit 14, additional vapor bubbles may form due to increased temperature or decreased pressure. The vapor release conduit 16 is shown in Figure 1 to be filled with a liquid and vapor mixture to the level of liquid contained in the supply tank 12. A fluid equilibrium level 19 is shown across the vapor release conduit 16 and the fluid level 13 in the supply tank. The vapor release conduit 16 contains vapor above the fluid equilibrium level 19.

[0019] The pump 10 is drivingly connected to a drive means, e.g., an electric motor 11. Actuation of the pump 10 by the motor 11 will result in liquid being drawn from the bottom of the supply tank 12 into the pump 10 with the liquid ultimately being pumped out of the pump 10 through a liquid outlet conduit 18. Any vapor released inside the pump 10 will tend, as a result of the invention, to be released into the upwardly inclined vapor outlet conduit 16, thus preventing the bubbles from moving through the internal valved chambers of the pump 10. Thus, cavitation is minimized and volumetric efficiency maximized.

[0020] Turning now to Figures 2 and 3, the pump 10 is comprised of a crankcase assembly 20 and a manifold 26. A crankshaft 22 is disposed through the crankcase assembly 20 and, as illustrated in Figure 1, is drivingly connected to an electric motor 11 or the equivalent.

[0021] The downwardly declined liquid-vapor inlet conduit 14, shown in Figure 1, is connected to the pump 10 via the inlet pipe stub 30 and inlet flange 32. The upwardly inclined vapor release conduit 16 is connected to the pump 10 via the vapor outlet pipe stub 36 and vapor outlet flange 38. In an alternate embodiment, the vapor outlet pipe 36 can be slightly higher than the liquid inlet pipe 30, either by design or by tilting the pump. The liquid outlet conduit 18 is connected to the pump 10 via the liquid outlet pipe stub 78 and the liquid outlet flange 80. The arrows in Figures 1 and 3 indicate the direction of flow of the fluid when the pump is operational. The vapor release conduit 16 is of sufficient diameter to allow the buoyant vapor to percolate upwardly.

[0022] Figure 4 illustrates a cross section of the manifold 26 and crankcase assembly 20. An upper inlet chamber 40 is in fluid communication with a valve chamber 42 that is configured in an angled pocket. The first upper end of the valve chamber 44 is preferably higher with respect to the second lower end of the chamber 46. The second lower end of the valve chamber 44 is in valved fluid communication with the compression chamber 62. An inlet valve 52 controls the flow of liquid from the valve chamber 42 into the compression chamber 62. The inlet valve 52 consists preferably of a valve seat 50, a spring retainer 54, a valve spring 56 and a valve plug 58. The inlet valve 52 is biased in the closed position by the valve spring 56.

[0023] A displacement element, shown as a plunger 24, an alternate embodiment may be a piston, is in communication with the compression chamber 62 and is drivingly connected to the crankshaft 22 which is, in turn, driven by the motor 11. The plunger 24 moves backward in a suction stroke to draw liquid into the compression chamber 62 and forward in a power stroke to push liquid out of the compression chamber 62. The preferred embodiment provides a valve chamber 42 volume that is greater than the volume vacated by the plunger 24 after completing a full suction stroke in the compression chamber 62.

[0024] The lower portion of the compression chamber 62 is in valved fluid communication with the liquid outlet chamber 76. The outlet valve 66 consists preferably of a valve seat 68, a spring retainer 70, a valve spring 72 and a valve plug 74. Figure 4 shows the valve spring 72 partially cut away to expose the liquid outlet chamber 76. The outlet valve 66 is biased in the closed position by the valve spring 72. The preferred embodiment includes three sets of valve chambers 42, inlet valves 50, compression chambers 62, plungers 24 and outlet valves 66. It is understood that any number of these components may be employed depending on the particular requirements.

[0025] Operation of the preferred embodiment may now be described. Initially, it is ensured that the liquid is in equilibrium through the pumping system. When this is achieved, liquid is allowed to substantially fill the upper inlet chamber 40, the vapor release conduit 16 up to the fluid equilibrium level 19, and the valve chambers 42. Figures 1 and 3 illustrate the general flow of liquid and vapor during operation of the pump.

[0026] Once equilibrium is achieved, the liquid resident in the upper inlet chamber 40 and in the valve chambers 42 is prepared by the invention design by allowing time for any released vapor bubbles to move upwardly. The natural tendency for vapor to move upward is facilitated by the angling of the valve chamber 42. The preferred embodiment further includes a substantially smooth upper surface 48 within the valve chamber 42 to allow the released vapor bubbles to move more readily upwardly along the upper surface 48 and ultimately, into the upper inlet chamber 40.

[0027] Actuation of the crankshaft 22 by the motor 11 results in the plunger 24 moving either forward in a power stroke or backward in a suction stroke. Figure 4 illustrates the plunger 24 moving backward in a suction stroke. As the plunger 24 moves back, the compression cylinder pressure is reduced. This pressure drop actuates the inlet valve 52, causing the valve 52 to compress the valve spring 56 against the spring retainer 54, creating a valved liquid inlet aperture 60. The liquid flows through the inlet aperture 60 into the compression chamber 62, which is empty on the initial stroke, primarily from the valve chamber 42, and to some extent the upper inlet chamber 40. The suction pressure created during the filling process along with the bias of the valve spring 72 causes the outlet valve 66 to remain seated and closed while the compression chamber 62 is filled. Pressure in the discharge side makes this more positive on subsequent strokes. When the plunger 24 is completely pulled back and the compression chamber 62 filled with liquid, the pressure in the compression chamber 62 balances with the pressure of the valve chamber 42 and upper liquid inlet chamber 40 and the inlet valve 52 closes.

[0028] As illustrated in Figure 5, the crankshaft 22 then causes the plunger 24 to push forward in a power stroke, increasing the pressure on the liquid in the compression chamber 62. This pressure causes the inlet valve 50 to remain closed, but forces the outlet valve 66 to compress the outlet valve spring 72 creating a valved liquid outlet aperture 64. The liquid is forced out of the compression chamber 62 through the liquid outlet aperture 64 and into the liquid outlet chamber 76. Ultimately, the liquid flows out of the pump 10 and into the liquid outlet conduit 18.

[0029] As discussed above, during the power stroke, the liquid that is in contact with the valve chamber 42 has time to allow any released vapor bubbles to flow upwardly which will occur since the bubbles are lighter than the liquid. The upwardly angled valve chamber 42 then facilitates the escape of the bubbles into the upper inlet chamber 40. When the pump is operating, the natural flow of the bubbles will be upward and toward the region of least pressure. Since the flow will be sustained from the downwardly declining liquid inlet conduit 14 that connects with the bottom of supply tank 12 there will be a natural tendency for the bubbles to move to the upwardly inclining gas outlet conduit 16 which connects with the tank 12 at a point above the fluid equilibrium level 19. As a result, the bubbles are released from the pump system and returned to the supply tank 12.

[0030] The angling of the valve chamber 42 also reduces cavitation by reducing the unswept volume of the compression chamber 62. The unswept volume is the volume of liquid remaining in the compression chamber 62 when the plunger 24 is at the end of its power stroke. Vaporization of the liquid remaining unswept in the compression chamber 62 when subjected to depressurization during the suction stroke results in cavitation and reduces the efficiency of the pump 10. The present invention places the valved liquid inlet aperture 60 as near to the plunger as possible by angling the second end of the valve chamber 46 downwardly with respect to the first end of the valve chamber 44. As seen in Figure 5, the valved inlet aperture 60 is configured so that it is immediately adjacent to the fully extended plunger 24. Thus, the incoming liquid is placed directly into the compression chamber 62 with as little intervening space as possible.

[0031] The above specification describes certain preferred embodiments of this invention. This specification is in no way intended to limit the scope of the claims. Other modifications, alterations, or substitutions may now suggest themselves to those skilled in the art, all of which are within the spirit and scope of the present invention. It is therefore intended that the present invention be limited only by the scope of the attached claims below:

Claims

1. A pump for pumping a liquid that may have gas coming out of solution, comprising:

a manifold having an upper inlet chamber connected to at least one lower valve chamber with first and second ends, the first end adjacent and below the upper inlet chamber and the second end adjacent and above a compression chamber with an inlet valve between the second end of the at least one valve chamber and the compression chamber;

a plunger displaceable in the compression chamber; and

an outlet valve in a lower portion of the compression chamber.

2. The pump of claim 1, further comprising downwardly angling the at least one valve chamber such that the second end of the valve chamber is positioned lower than the first end of the valve chamber to facilitate the upward escape of released vapor and the downward flow of liquid.

3. The pump of claim 1, further comprising the valve chamber having a substantially smooth upper side.

4. The pump of claim 1, wherein the volume of the at least one valve chamber is greater than the volume vacated by the plunger in moving its full stroke in the compression chamber.

5. The pump of Claim 1, further comprising:

a downwardly declining inlet conduit in fluid communication with the upper inlet chamber;

an upwardly inclining vapor release conduit in fluid communication with the upper inlet chamber; and

a supply tank containing liquid in liquid communication with the inlet conduit and vapor with the vapor release conduit, wherein the pump is at a lower level than the level of liquid in the supply tank to facilitate the downward flow of liquid and the upward escape of released vapor, the inlet conduit and vapor release conduits being in fluid communication with the upper inlet chamber.

6. A pump, for pumping liquids that may have gas coming out of solution, comprising:

a manifold having an upper inlet chamber connected to at least one lower valve chamber with a substantially smooth upper side and having first and second ends, the first end adjacent to the upper inlet chamber and the second end adjacent and above a compression chamber with an inlet valve between the second end of the at least one valve chamber and the compression chamber, then at least one valve chamber being downwardly angled by positioning the second end of the valve chamber lower than the first end of the valve chamber;

a plunger displaceable in the compression chamber;

an outlet valve in a lower portion of the compression chamber;

a downwardly declining inlet conduit in fluid communication with the upper inlet chamber;

an upwardly inclining vapor release conduit in fluid communication with the upper inlet chamber; and

a supply tank in fluid communication with the inlet conduit and vapor release conduit, the supply tank containing liquid, wherein the pump is at a lower level than the level of liquid in the supply tank.

7. A method for reducing cavitation in a pump, for pumping liquids that may have gas coming out of solution, the method comprising:

locating the upper inlet chamber adjacent to and above the valve chamber;

locating the valve chamber adjacent to and above a compression chamber with an inlet valve therebetween;

locating an outlet valve in a lower portion of the compression chamber;

facilitating the removal of vapor released by the liquid while held in the upper inlet chamber and valve chamber; and

providing an upwardly inclined conduit for vapor released by the liquid while held in the upper inlet chamber and valve chamber to return to the liquid supply tank.

8. The method of claim 7, further comprising facilitating the removal of vapor released by the liquid while held in the upper inlet chamber and valve chamber by downwardly angling the valve chamber so that the second end of the valve chamber is lower with respect to the first end of the valve chamber.

9. The method of claim 8, further comprising ensuring the upper side of the valve chamber is substantially smooth.

10. The method of claim 9, further comprising placing the pump lower than the level of liquid in the supply tank.

11. A method for reducing cavitation in a pump for pumping a liquid that may have gas coming out of solution, the method comprising:

locating the upper inlet chamber adjacent to and above the valve chamber ;

locating the valve chamber above a compression chamber with an inlet valve therebetween, wherein the valve chamber is downwardly angled so that the second end of the valve chamber is lower with respect to the first end of the valve chamber and the upper side of the valve chamber is substantially smooth;

facilitating the removal of vapor released by the liquid while held in the upper inlet chamber and valve chamber; and

providing an upwardly inclined conduit for vapor released by the liquid while held in the upper inlet chamber and valve chamber to return to the supply tank, wherein the pump is placed at a lower level than the liquid in the supply tank.

12. A method for reducing the unswept volume in a pump for pumping a liquid that may have gas coming out of solution, the method comprising:

locating the upper inlet chamber adjacent to and above the valve chamber;

locating the valve chamber above a compression chamber with an inlet valve therebetween;

minimizing the distance between the inlet valve and the compression chamber by downwardly angling the inlet valve;

facilitating the removal of vapor released by the liquid while held in the upper inlet chamber and valve chamber; and

providing an upwardly inclined conduit for vapor released by the liquid while held in the upper inlet chamber and valve chamber to return to the liquid supply tank, wherein the pump is lower than the level of liquid in the supply tank.

13. A method for increasing the efficiency of a pump for pumping liquids a liquid source that may have gas coming out of solution, the method comprising:

locating the upper liquid gas inlet chamber adjacent to and above the valve chamber;

locating the valve chamber above a compression chamber with an inlet valve therebetween, wherein the valve chamber is downwardly angled so that the second end of the valve chamber is lower with respect to the first end of the valve chamber and the upper side of the valve chamber is substantially smooth;

facilitating the removal of vapor released by the liquid while held in the upper inlet chamber and valve chamber;

minimizing the distance between the inlet valve and the compression chamber by downwardly angling the inlet valve; and

providing an upwardly inclined conduit for vapor released by the liquid while held in the upper inlet chamber and valve chamber to return to the supply tank, wherein the pump is placed at a lower level than the liquid in the supply tank.

Amended claims in accordance with Rule 86(2) EPC.

1. A pump for pumping a liquid that may have gas coming out of solution, comprising:

a manifold having an upper inlet chamber valvelessly connected to at least one lower valve chamber with first and second ends, the first end adjacent and below the upper inlet chamber and the second end adjacent and above a compression chamber with an inlet valve between the second end of the at least one valve chamber and the compression chamber;

a plunger displaceable in the compression chamber; and

an outlet valve in a lower portion of the compression chamber.

2. The pump of claim 1, further comprising downwardly angling the at least one valve chamber such that the second end of the valve chamber is positioned lower than the first end of the valve chamber to facilitate the upward escape of released vapor into the upper inlet chamber and the downward flow of liquid.

3. The pump of claim 1, further comprising the valve chamber having a substantially smooth upper side.

4. The pump of claim 1, wherein the volume of the at least one valve chamber is greater than the volume vacated by the plunger in moving its full stroke in the compression chamber.

5. The pump of Claim 1, further comprising:

a downwardly declining inlet conduit in fluid communication with the upper inlet chamber;

an upwardly inclining vapor release conduit in fluid communication with the upper inlet chamber; and

a supply tank containing liquid in liquid communication with the inlet conduit and vapor with the vapor release conduit, wherein the pump is at a lower level than the level of liquid in the supply tank to facilitate the downward flow of liquid and the upward escape of released vapor, the inlet conduit and vapor release conduits being in fluid communication with the upper inlet chamber.

6. A pump, for pumping liquids that may have gas coming out of solution, comprising:

a manifold having an upper inlet chamber connected to at least one lower valve chamber with a substantially smooth upper side and having first and second ends, the first end adjacent to the upper inlet chamber and the second end adjacent and above a compression chamber with an inlet valve between the second end of the at least one valve chamber and the compression chamber, the at least one valve chamber being downwardly angled by positioning the second end of the valve chamber lower than the first end of the valve chamber;

a plunger displaceable in the compression chamber;

an outlet valve in a lower portion of the compression chamber;

a downwardly declining inlet conduit in fluid communication with the upper inlet chamber;

an upwardly inclining vapor release conduit in fluid communication with the upper inlet chamber; and

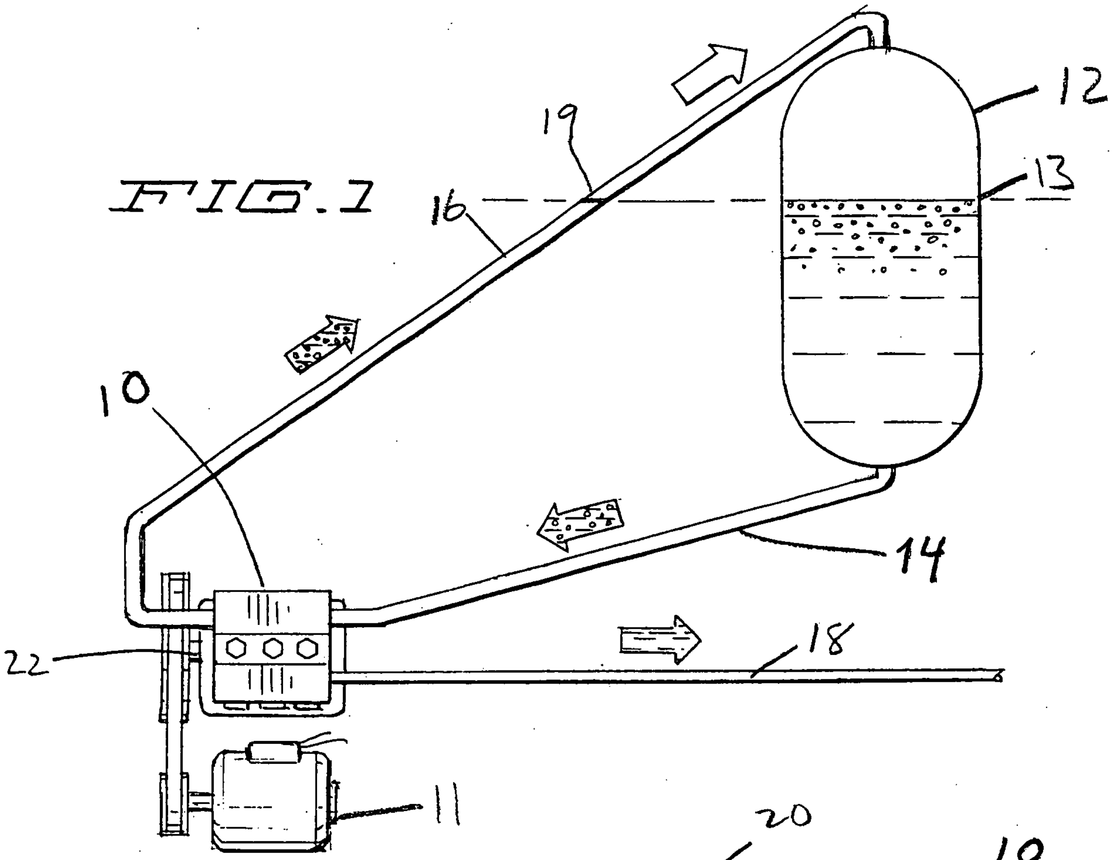

FIG. 1

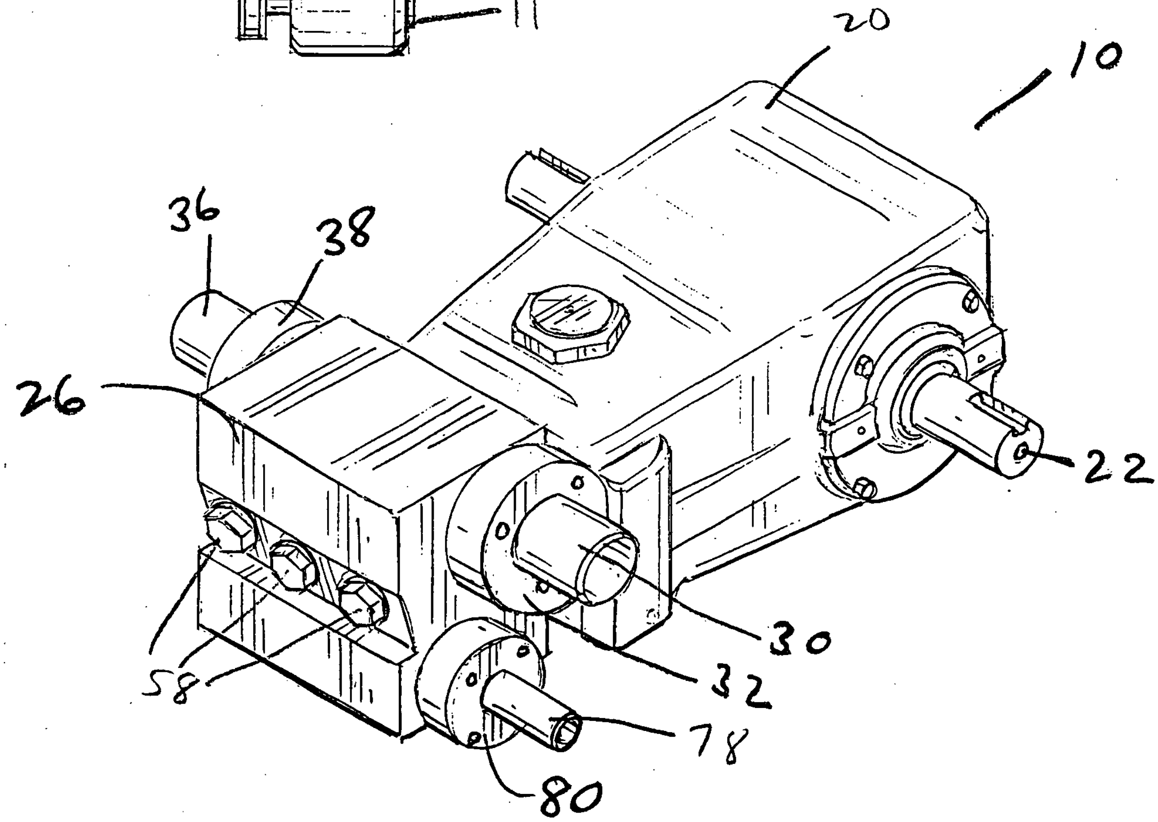

FIG. 2

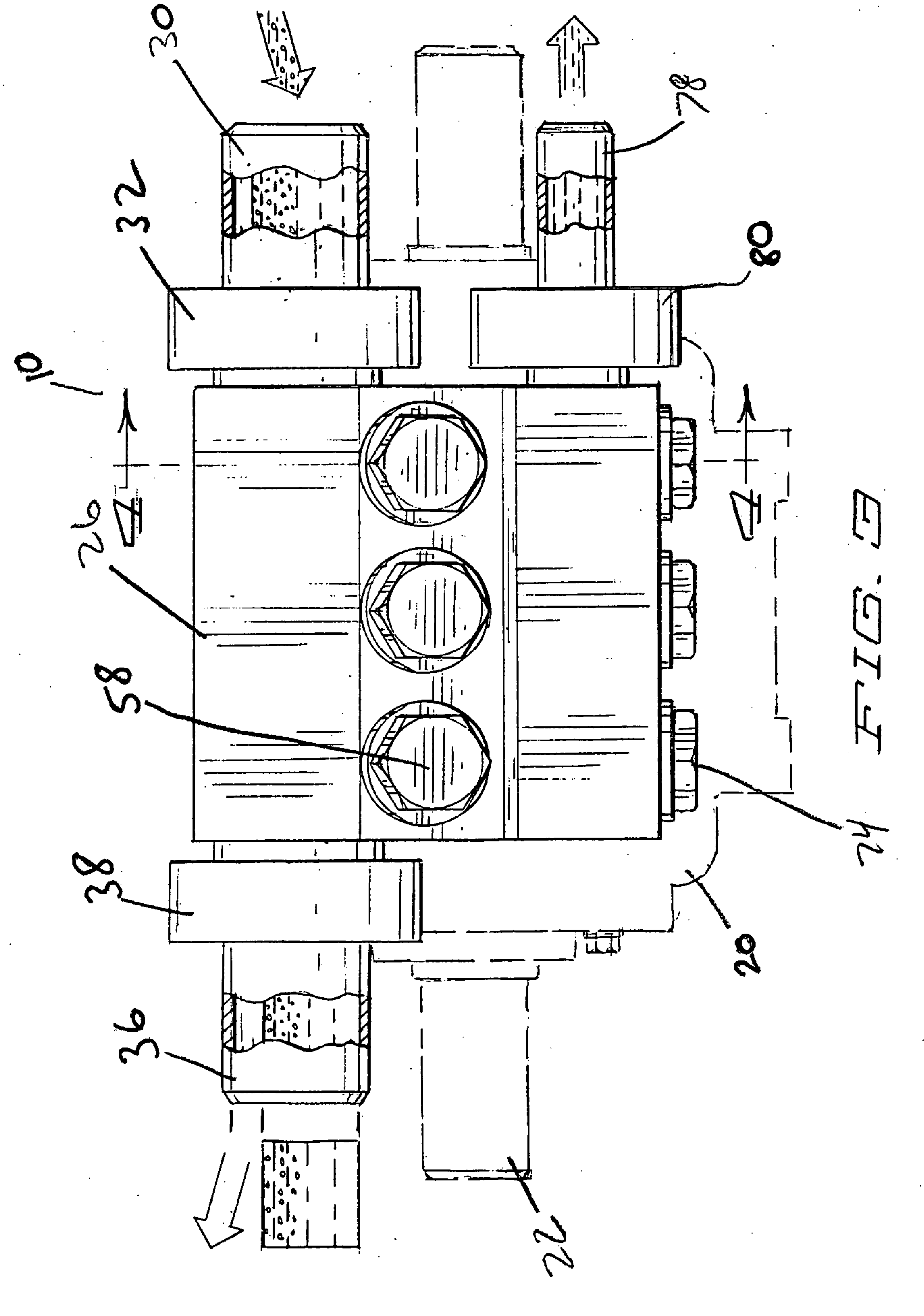

FIG. 3

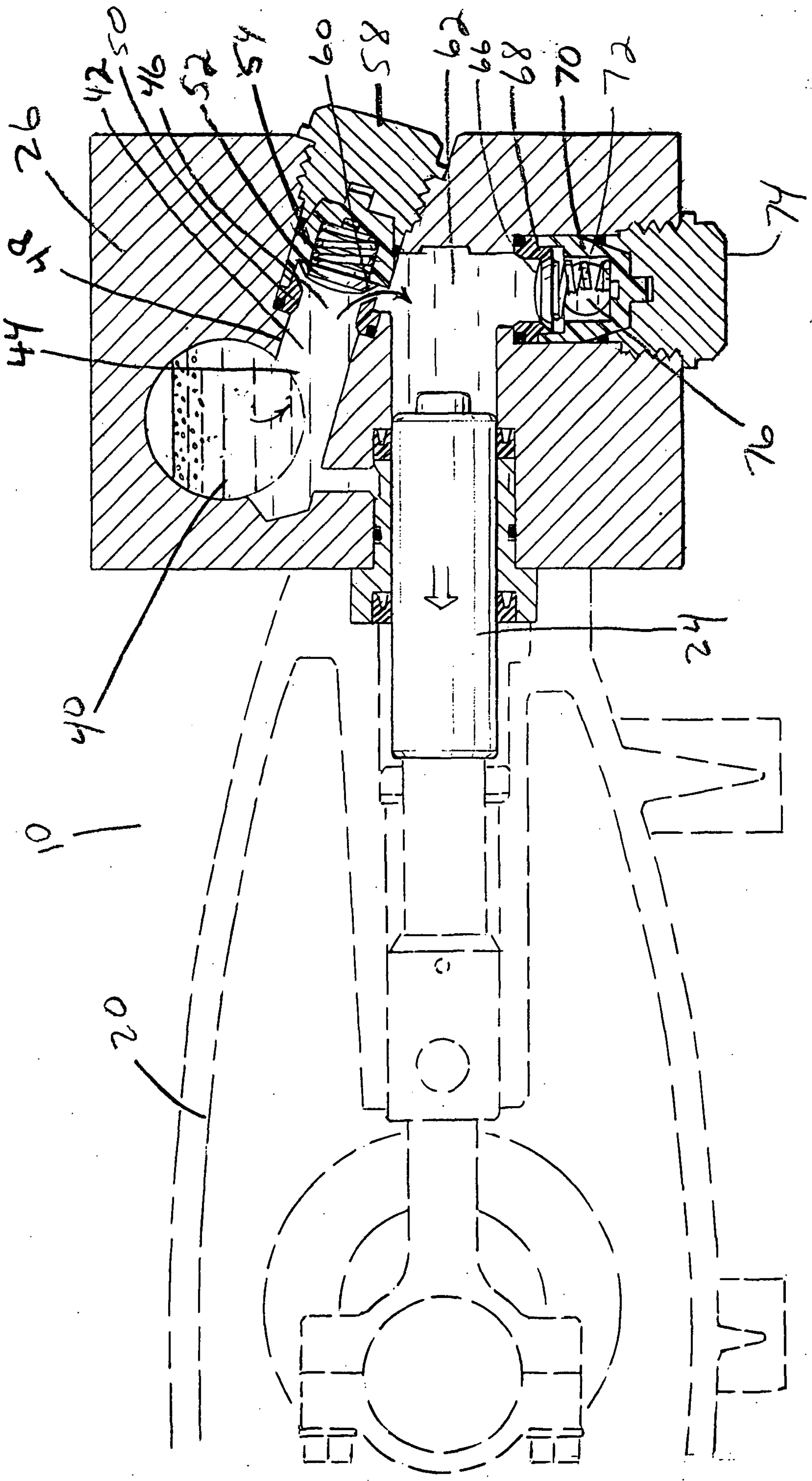

FIG. 4

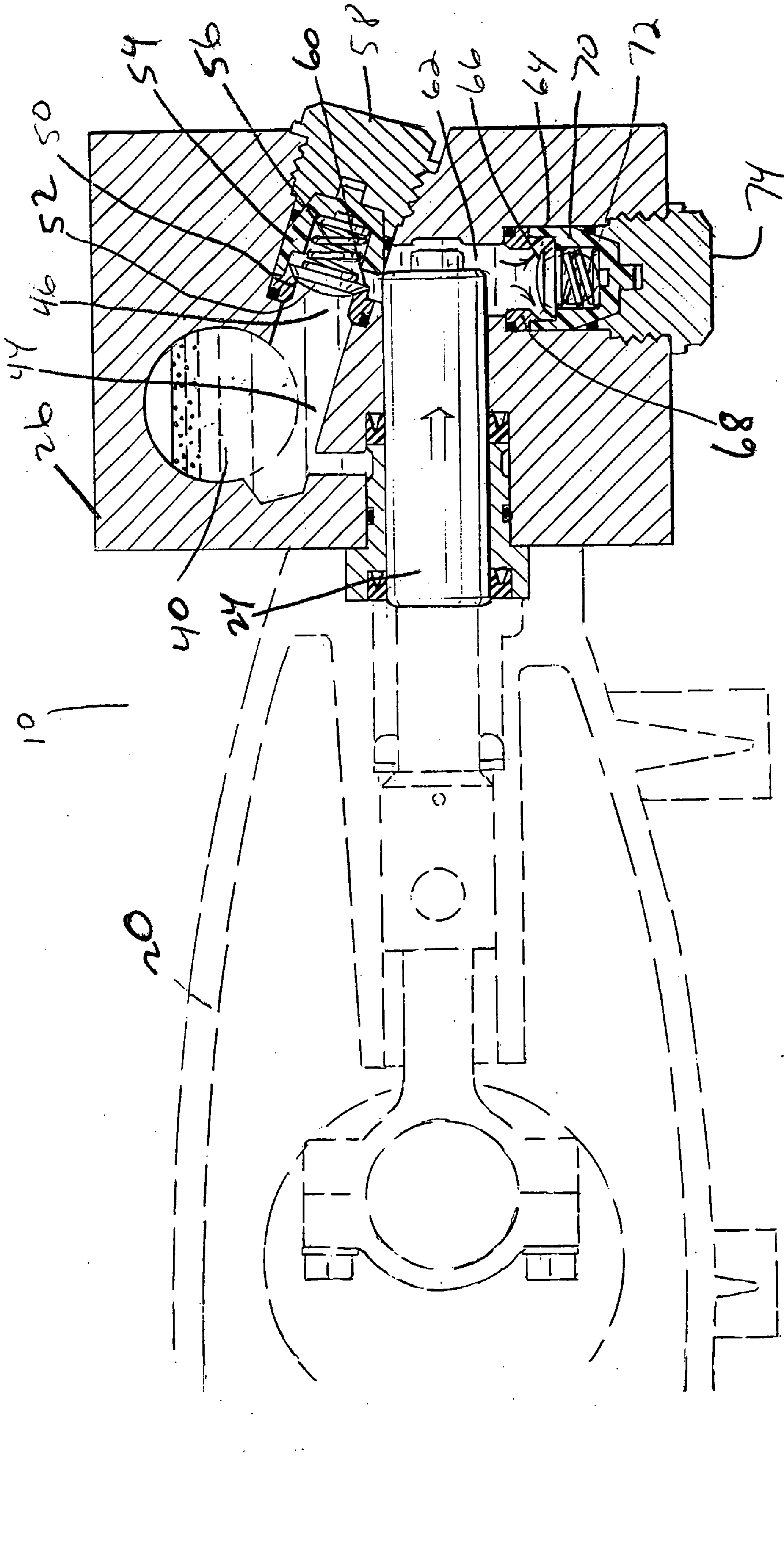

FIG. 5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 01 5611

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 6 227 818 B1 (WILSON GREATBATCH LTD.) 8 May 2001 (2001-05-08) * column 1, line 20 - line 22 * * column 3, line 3 - column 13, line 38 *	1	F04B11/00 F04B3/00 F04B15/00
A	* figures 1-4 *	6,7, 11-13	
X	US 6 015 270 A (AIR CONDITION TECHNOLOGIES) 18 January 2000 (2000-01-18) * column 2, line 63 - column 3, line 20 *	1	
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A	US 4 239 460 A (SOCSIL S.A.) 16 December 1980 (1980-12-16) * column 1, line 38 - column 2, line 29 * * figures 1,2 *	1,6,7, 11-13	TECHNICAL FIELDS SEARCHED (Int.Cl.7) F04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	13 September 2004	Gnüchtel, F

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 04 01 5611

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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