(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 459 812 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
22.09.2004 Bulletin 2004/39

(51) Int Cl.[7]: **B08B 7/00**, D06F 43/00

(21) Application number: **03006420.8**

(22) Date of filing: **21.03.2003**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR
Designated Extension States:
AL LT LV MK

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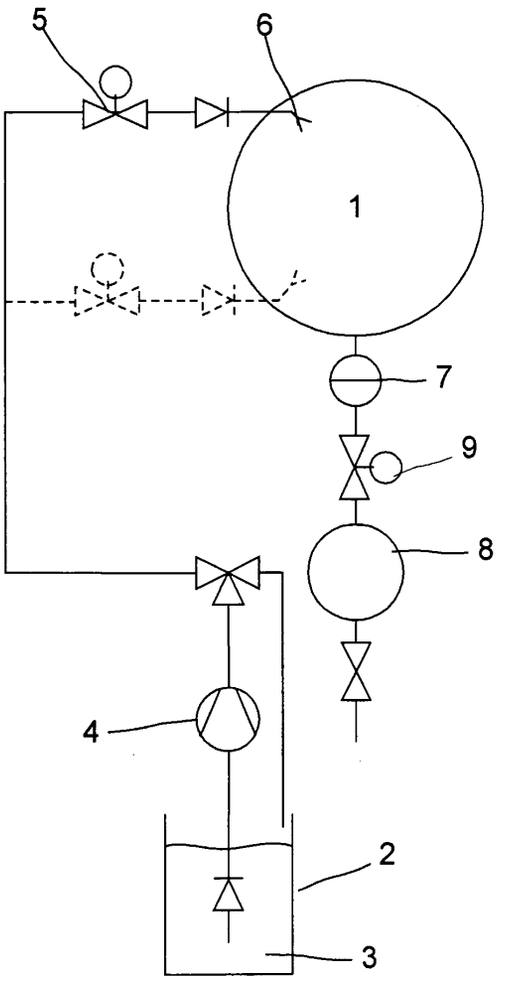
(54) Parts cleaning

(57) The invention relates to a method for cleaning parts wherein a cleaning chamber (1) is at least partly filled with liquid carbon dioxide and wherein said parts are cleaned in said liquid carbon dioxide. Prior to the filling of said cleaning chamber (1) with said liquid carbon dioxide said parts are sprayed with a cleaning fluid (3).

Fig. 1



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Description

[0001] The invention relates to a method for cleaning parts wherein a cleaning chamber is at least partly filled with liquid carbon dioxide and wherein said parts are cleaned in said liquid carbon dioxide.

[0002] Dry-cleaning using liquid carbon dioxide is known as an environmentally friendly cleaning technique with favourable cleaning properties which can be used to remove contaminants from metal, machinery, workpieces or other parts.

[0003] There is always a need to specify the degree of purity which shall be fulfilled for the parts to be cleaned. The degree of purity depends on the cleaning process itself and on the status of the parts prior to cleaning. For example when parts with a higher quality demand than the last cleaned parts shall be treated it is necessary to increase the degree of cleaning performance.

[0004] Consequently, it is an object of the invention to provide a method of cleaning with liquid carbon dioxide which improves the washing performance and which can easily be adapted to different purity demands.

[0005] This object is achieved by a method for cleaning parts wherein a cleaning chamber is at least partly filled with liquid carbon dioxide and wherein said parts are cleaned in said liquid carbon dioxide, wherein prior to the filling of said cleaning chamber with said liquid carbon dioxide said parts are sprayed with a cleaning fluid.

[0006] According to the invention a cleaning fluid is sprayed over the parts placed in the cleaning chamber of the washing machine. The cleaning fluid, which is in particular a detergent or a co-solvent, does not only take away some dirt or impurities from the parts, but also wets the surface of the parts as a concentrate. Thus all the strength of the cleaning fluid is used to brake up or dissolve the impurities. The dirt removed from the parts is then in general transferred to the still. The cleaning chamber is partly or completely filled with liquid carbon dioxide and the parts are cleaned in that liquid carbon dioxide bath which may also contain some additional chemicals

[0007] By removing as much dirt as possible in the inventive manner, that is by spraying with a cleaning fluid, the consumption of detergent in the subsequent cleaning step in the liquid carbon dioxide bath is reduced. Further the re-deposit of dirt which has already been removed from other parts is minimized. According to the invention a lower dirt concentration is reached at an earlier stage of the cleaning process which improves the overall cleaning result.

[0008] The invention is preferably useful in cleaning parts or components of glass, metal, plastics, silicone and electronic components of different shape and condition. In cleaning garments the amount of detergent used will normally be so low that if the detergent is sprayed as a concentrate on the garment it will be uneven distributed over the surface, and this might lead to an uneven cleaning result. But in certain cases the inventive pre-cleaning may also be useful in cleaning garments or textiles.

[0009] It has been proven advantageous to spray liquid carbon dioxide onto the parts before filling the cleaning chamber with liquid carbon dioxide. That pre-cleaning step removes dirt and particles from the parts in an easy way. Thus it is assured that less dirt is in the cleaning chamber when it comes to the subsequent cleaning step in the liquid carbon dioxide bath.

[0010] The cleaning performance can further be improved by rotating or moving the parts to be cleaned relative to the jet spray of the cleaning fluid. In that respect it is advantageous to provide a rotatable basket within the cleaning chamber and to place the parts into that basket. When the cleaning fluid is injected into the cleaning chamber the basket and consequently the parts within the basket are rotated in order to subject all surfaces of the parts to the cleaning fluid.

[0011] Instead of or in addition to rotating the basket it is also possible to rotate or move the nozzle which is used to spray the cleaning fluid over the parts. Further it is preferable to provide several nozzles or outlets for the cleaning fluid arranged in different positions relative to the cleaning chamber. The cleaning fluid is then sprayed from different directions over the parts. It is in particular advantageous to use only one nozzle at one time and to switch between different nozzles.

[0012] The invention provides a pre-washing or pre-spotting step which significantly improves the overall cleaning performance. The inventive pre-washing step is not only useful in a one-bath-cleaning process but also in a two-bath process. In the two-bath process the parts are subsequently cleaned in a first bath and a second bath of liquid carbon dioxide with draining of the liquid carbon dioxide between the two steps. As described above prior to the cleaning in the first bath the parts can be sprayed with that cleaning fluid. Then, a first cleaning step in liquid carbon dioxide, with possible additives, is carried out. After that first cleaning step the liquid carbon dioxide is drained from the cleaning chamber. Before the cleaning chamber is re-filled with liquid carbon dioxide in order to perform the second cleaning step, a cleaning fluid, preferably a chemical, is sprayed over the parts. Of course when more than two baths are used the inventive injection of an additional cleaning fluid can be carried out between any of the cleaning steps in those baths.

[0013] After the inventive spraying of the cleaning fluid over the parts there is in general not only liquid carbon dioxide but also a detergent or another additive introduced into the cleaning chamber. Such additives are preferably pumped into the cleaning chamber by means of a high pressure pump. The cleaning chamber is filled with liquid carbon dioxide until a predetermined level is reached. Then a high pressure pump is started and the additive is injected into the liquid carbon dioxide.

[0014] The amount of additive can be reduced if the liquid carbon dioxide is stirred within the cleaning chamber, for example by a propeller, jet streams, rotation of a basket or ultrasonic agitation. The additive is thus easier diluted in the liquid carbon dioxide and is faster and even distributed to all parts in the cleaning chamber. The contact between concentrated particles of additive and the parts is also prevented which otherwise could harm the surface of the parts. Preferably the liquid carbon dioxide is stirred during the injection of the additive and during the following cleaning operation. Thus the additive will not sink down to the bottom of the cleaning chamber and the additive can be utilised to a high degree. The dilution of the additive in the liquid carbon dioxide can be further improved by choosing a proper location of the nozzle which is used to spray the additive into the cleaning chamber. If the parts are sensitive to the concentrated additive the additive could be directly sprayed into liquid CO_2 in the cleaning chamber in order to be diluted as fast as possible.

[0015] It has been found that even if the basket rotates when the bath of liquid carbon dioxide is drained from the cleaning chamber to the still, dirt or particles could be left on the surface of the parts, in particular when the parts are of complicated shape. Therefore, it is preferred to add a washing step wherein the parts are washed with pure liquid carbon dioxide. The parts could either be sprayed with pure liquid carbon dioxide or the cleaning chamber is re-filled with liquid carbon dioxide.

[0016] Further it has been found advantageous to clean the inner surface of the cleaning chamber in the same manner, that is by spraying liquid CO_2 on it. A preferable procedure would be to drain the liquid carbon dioxide out from the cleaning chamber and at the same time to clean the cleaning chamber by spraying liquid CO_2 onto the inner surfaces of the cleaning chamber. Then the parts are sprayed with pure liquid CO_2 with simultaneous draining of any overflow of liquid CO_2. Finally the cleaning chamber is de-pressurized and the parts are unloaded.

[0017] Different types of chemicals can be added to the parts after the cleaning steps in the liquid carbon dioxide bath. The chemicals can be injected into the liquid carbon dioxide bath or sprayed on the surface of the parts after the liquid carbon dioxide is drained from the cleaning chamber.

[0018] If the additional chemicals are injected into liquid carbon dioxide it is preferred to have less liquid carbon dioxide in the cleaning chamber than during the cleaning step. But the amount of liquid carbon dioxide should be sufficient to reach all parts cleaned in the cleaning chamber.

[0019] Preferably chemicals like lubricants, impregnating or anti-static agents are added. It is an advantage if the chemicals have a poor solubility in liquid carbon dioxide since then a higher percentage of the chemicals will add to the parts. These chemicals shall either be added to the surface of the parts or wet through the material of the parts. In general it is important that the chemical is more or less equally distributed on the surface of the parts or in the material. If a chemical has a good solubility in liquid carbon dioxide it might be worth to reuse the chemical by using an additional pressure vessel in which the mixture of liquid carbon dioxide and the chemical is stored from one cleaning cycle to another.

[0020] Normally the parts are below room temperature when they are taken out of the cleaning chamber. There is a certain risk that water could condense at the surface of the parts and damage the parts. This is preferably avoided by heating the parts when they are still in the cleaning chamber.

[0021] That heating can be carried out by an external heating system. For example, after the cleaning step in the liquid carbon dioxide bath the cleaning chamber is emptied and de-pressurized. When the pressure reaches a certain value, for example 10 bar, gaseous carbon dioxide from the cleaning chamber is externally heated, if needed filtered and then returned into the cleaning chamber in order to heat up the parts. Instead of heating gaseous carbon dioxide from the cleaning chamber it is also possible to transfer another hot dry gas into the cleaning chamber. That gas could be nitrogen, compressed air or any other suitable gas.

[0022] Further, the gas in the cleaning chamber and thus the parts can be heated by indirect heat exchange with a hot medium. A hot fluid, for example water or steam, is transferred into a heat exchanger located within the cleaning chamber. The hot medium can be circulated through the heat exchanger or pass it only once.

[0023] The parts can also be heated by an internal heating system. Gas is taken from the cleaning machine, for example from the still, and compressed in order to increase its temperature and then transferred into the cleaning chamber or through a heat exchanger placed in the cleaning chamber. The gas can also be taken from the cleaning chamber during the de-pressurization phase. Then additional heat is added to the carbon dioxide gas before passing it through a heat exchanger in the cleaning chamber. The additional heat added to the gas can for example result from a compressor and/or by passing the gas through a heat exchanger in which heat from an external source is added to the gas. The gas could also be taken from the still and in the same way as above be used to heat the parts in the cleaning chamber.

[0024] The parts have normally a positive or negative charge when they are unloaded from the cleaning chamber after the cleaning process. Thus particles or dirt can easily contaminate the surface of the parts. A cost-efficient way to remove the static charge from the parts is to purge the cleaning chamber by a ionised gas after the cleaning chamber has been de-pressurized The ionised gas, for example air, is injected by nozzles or in any other suitable way. The ionised gas does not only remove the static charge but also takes away particles from the parts which may have been collected during the clean-

ing process.

[0025] A preferred cleaning cycle would comprise the following steps:

1. loading the parts into the cleaning chamber
2. cleaning of the cleaning chamber with liquid carbon dioxide
3. Pre-washing the parts with a spray of chemicals
4. Vacuum pumping or purging the cleaning chamber with gaseous carbon dioxide
5. Pressurisation of the cleaning chamber with gaseous carbon dioxide to a pressure above about 5 bar
6. Transfer of liquid carbon dioxide into the cleaning chamber in order to compensate for the losses in the washing machine
7. pressurisation of the cleaning chamber, for example to a pressure of about 17 bar
8. pre-washing the parts with liquid carbon dioxide and / or chemicals
9. fill-up of the cleaning chamber with liquid carbon dioxide
10. feeding of chemicals into the cleaning chamber
11. cleaning the parts in the bath of liquid carbon dioxide
12. draining of the liquid carbon dioxide from the cleaning chamber
13. post-cleaning the parts with pure liquid carbon dioxide
14. post-treatment with chemicals
15. de-pressurisation of the cleaning chamber
16. heating of the parts
17. de-ionization of the parts
18. unloading the parts

[0026] It will be apparent to one skilled in the art that there are many ways to combine the specific cleaning steps mentioned above and that some of the above steps, in particular steps 2, 3, 8, 10, 13, 14, 16 and 17, are only optional and may be omitted in certain cases.

[0027] The invention will now be illustrated with reference to the appended drawings. It is obvious for the man skilled in the art that the invention may be modified in various aspects and that the invention is not limited to the specific embodiments enclosed in the following examples.

Figure 1 shows a first system according to the invention to pre-spot the parts to be cleaned by a chemical,

figure 2 an alternative embodiment of the system according to figure 1,

figure 3 an inventive embodiment with a partly reuse of the chemicals and

figure 4 an alternative to the system according to figure 3.

Figure 5 shows a system to pre-spot the parts with liquid carbon dioxide.

[0028] The parts to be cleaned are put into the cleaning chamber 1 of a liquid carbon dioxide dry-cleaning machine. A chemical supply 2 contains a chemical 3, for example a detergent, which shall be used to pre-clean the parts. The chemical 3 is pumped by means of pump 4 to the cleaning chamber 1, valve 5 is put into the open position and the chemical is sprayed over the parts via nozzle 6. Nozzle 6 may be positioned in the upper half of cleaning chamber 1 as illustrated in figure 1 or, as shown in dashed lines, be located in the lower half of cleaning chamber 1.

[0029] To increase the performance of that pre-spotting process the parts within the cleaning chamber might be rotated, for example by placing the parts into a rotatable basket within the cleaning chamber 1. The rotation of the parts is carried out at the same time when the chemical 3 is sprayed into the cleaning chamber 1. The chemical 3 wets the surface of the parts and removes impurities from the parts.

[0030] The chemical 3 is subjected to the parts for a certain time dependent on the desired quality of purity and the status of the parts. Then cleaning chamber 1 is pressurized with gaseous carbon dioxide and partly or completely filled with liquid carbon dioxide. Additional chemicals may also be added at this stage. Then the parts are cleaned in the liquid carbon dioxide bath. When the cleaning operation is finished the liquid carbon dioxide is drained from cleaning chamber 1 via a bottom filter 7 into still 8.

Between the filter 7 and the still 8 a valve 9 is provided which can be used to either keep the chemicals 3 under the whole cleaning cycle or to dump the chemicals 3 to the still 8 before liquid CO_2 is filled into the cleaning chamber 1.

[0031] Figure 2 shows an alternative to figure 1 which allows to reduce the capacity of pump 4. Chemical supply 2 with chemical 3 is not directly connected to the cleaning chamber 1 but to a chemical cylinder 21. By means of pump 4 a portion of the chemical 3 is pumped from chemical supply 2 into chemical cylinder 21. Chemical cylinder 21 is then pressurized by a compressed gas via gas line 22. It is also possible to omit pump 4 and to first de-pressurize chemical cylinder 21 and to use the pressure difference between the chemical supply 2 and the chemical cylinder 21 to transfer the chemical 3 into chemical cylinder 21.

[0032] The pressure difference between chemical cylinder 21 and cleaning chamber 1 is used to push chemical 3 via line 23 to cleaning chamber 1. At the end of line 23 a closed circular pipeline 24 is provided which comprises several nozzles 25. Each nozzle 25 is provided with a valve 26. Instead of using a rotatable basket as described with reference to figure 1 the chemical 3 is sprayed over the parts to be cleaned by switching between the nozzles 25. Thus it is also possible to spray different surfaces of the parts.

[0033] In figure 3 another altemative of the invention is shown. The parts are again loaded into cleaning

chamber 1. Chemical vessel 31 is filled from chemical supply 2 by means of pump 4. Pump 33 is started, valves 34, 35, 36 are put in the open position and chemical 3 is pumped via line 38 into cleaning chamber 1 and sprayed over the parts. As mentioned above the parts may be rotated during the spraying of the chemical 3 and / or several nozzles 6 may be used and / or the nozzle 6 may be rotated.

[0034] Any overflow of chemical 3 passes bottom filter 38 of cleaning chamber 1 and flows back into chemical vessel 31. The bottom part 39 of chemical vessel 31 is designed to collect dirt heavier than the chemical 3. Such dirt is taken out of chemical vessel 31 via waste line 32. Thus a partly re-use of chemical 3 is possible.

[0035] Figure 4 shows an inventive system which is similar to the system according to figure 3, but without the need of pump 33. Chemical 3 is pumped into chemical vessel 31 as described above. Then valves 34 and 35 are opened. Line 40 is connected to a gaseous carbon dioxide supply, for example gaseous carbon dioxide is taken from the washing machine. Valve 41 is put in the open position. Valve 42 is closed at this stage. Gaseous carbon dioxide under pressure flows from line 40 via line 43 into the chemical vessel 31 and pressurizes chemical vessel 31. Thus the chemical 3 is pushed from chemical vessel 31 via line 37 and nozzle 6 into cleaning chamber 1.

[0036] When the spraying is finished the pressure in chemical vessel 31 is equalized with the pressure in cleaning chamber 1. For that reason valve 41 is closed and valve 42 opened. After equalizing the pressures cleaning chamber 1 is drained into chemical vessel 31 by opening valve 36. Any dirt drained from cleaning chamber 1 into chemical vessel 31 which is heavier than the chemical 3 is again collected in the bottom portion 39 of chemical vessel 31 and taken out as waste 32.

[0037] In another altemative not shown in the figures two chemical vessels are provided, one to supply chemical for spraying over the parts, the other to collect used chemical.

[0038] Instead of or in addition to pre-spotting the parts with a chemical, for example a detergent, it is also advantageous to spray the parts with liquid carbon dioxide prior to cleaning them in a bath of liquid carbon dioxide. Figure 5 shows an inventive embodiment to provide a spray of pure liquid carbon dioxide to the parts.

[0039] The parts to be cleaned are placed into cleaning chamber 1. Gaseous carbon dioxide is withdrawn from the top of still 8 and fed to the vaporizer (not shown in figure 5) of the still 8 in order to maintain the desired pressure and temperature in the still. Then the gas is pumped by means of compressor 50 into the working tank 51 of the washing machine. The gaseous carbon dioxide may either be introduced into the top of working tank 51 via lines 52 or 53 or to the bottom of working tank 51 via line 54. When necessary the gaseous carbon dioxide is passed through a cooler 55 prior to its introduction into working tank 51. This is in particular advantageous in order to keep a defined overpressure in the working tank 51 compared to the pressure in cleaning chamber 1.

[0040] Instead of withdrawing gaseous carbon dioxide from the top of still 8 it is also possible to use gas from the top of cleaning chamber 1 in order to pressurize the working tank 51. In that case valve 56 is closed, valve 57 opened and compressor 50 sucks gaseous carbon dioxide from the cleaning chamber 1 to working tank 51.

[0041] After pressurization of working tank 51 valve 5 is put in an open position and liquid carbon dioxide is sprayed via line 58 through nozzle 6 into the cleaning chamber 1 and over the parts. To ensure that the parts are subjected to pure liquid carbon dioxide a filter 59 may be provided in line 58 downstream valve 5.

Claims

1. Method for cleaning parts wherein a cleaning chamber is at least partly filled with liquid carbon dioxide and wherein said parts are cleaned in said liquid carbon dioxide, **characterized in that** prior to the filling of said cleaning chamber (1) with said liquid carbon dioxide said parts are sprayed with a cleaning fluid (3).

2. Method according to claim 1 **characterized in that** said parts are sprayed with liquid carbon dioxide as said cleaning fluid.

3. Method according to any of claims 1 or 2 **characterized in that** said parts are sprayed with a chemical (3), in particular with a detergent or a co-solvent.

4. Method according to any of claims 1 to 3 **characterized in that** said parts are rotated during said spraying of said cleaning fluid (3).

5. Method according to any of claims 1 to 4 **characterized in that** said cleaning fluid (3) is subsequently sprayed through several nozzles (25).

6. Method according to any of claims 1 to 5 **characterized in that** a first and a second cleaning operation in liquid carbon dioxide is carried out and that prior to said first and / or said second cleaning operation said parts are sprayed with said cleaning fluid (3).

7. Method according to any of claims 1 to 6 **characterized in that** a chemical, in particular a detergent, is injected into said cleaning chamber which is at least partly filled with liquid carbon dioxide by means of a high pressure pump.

8. Method according to any of claims 1 to 7 **charac-**

terized in that after said parts have been cleaned in said liquid carbon dioxide said parts are once more cleaned in pure liquid carbon dioxide.

9. Method according to any of claims 1 to 8 **characterized in that** said cleaning chamber (1) is sprayed with liquid carbon dioxide.

10. Method according to any of claims 1 to 9 **characterized in that** after said parts have been cleaned in said liquid carbon dioxide an additional chemical, in particular an impregnating or anti-static agent or a lubricant, is added to said parts.

11. Method according to any of claims 1 to 10 **characterized in that** said parts are heated before they are unloaded from said cleaning chamber (1).

12. Method according to any of claims 1 to 11 **characterized in that** an ionised gas is introduced into said cleaning chamber (1) before said parts are unloaded from said cleaning chamber.

Fig. 1

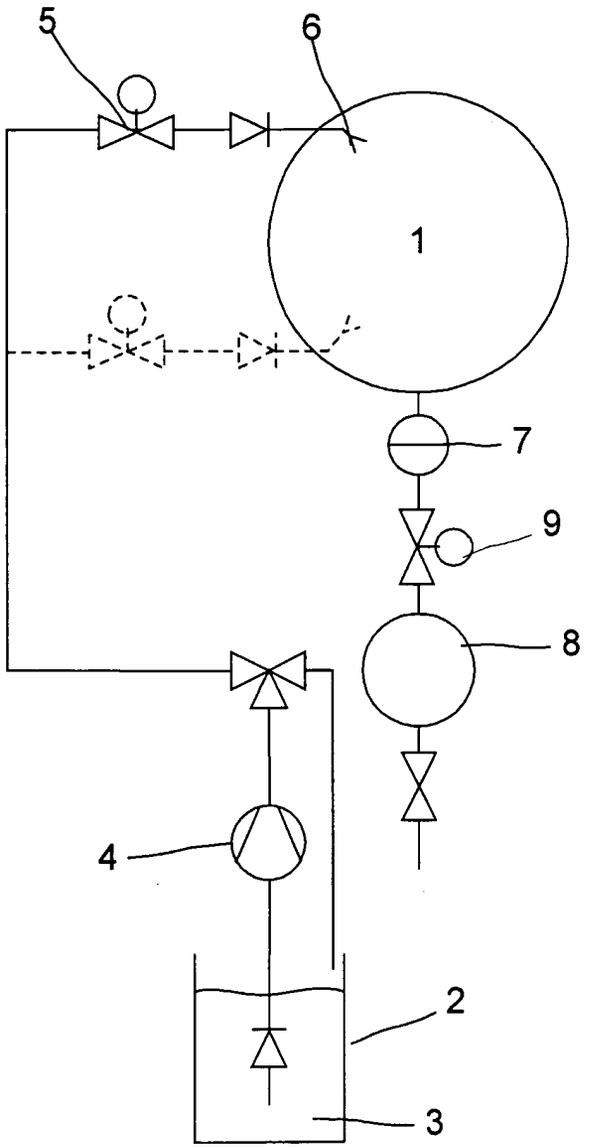


Fig. 2

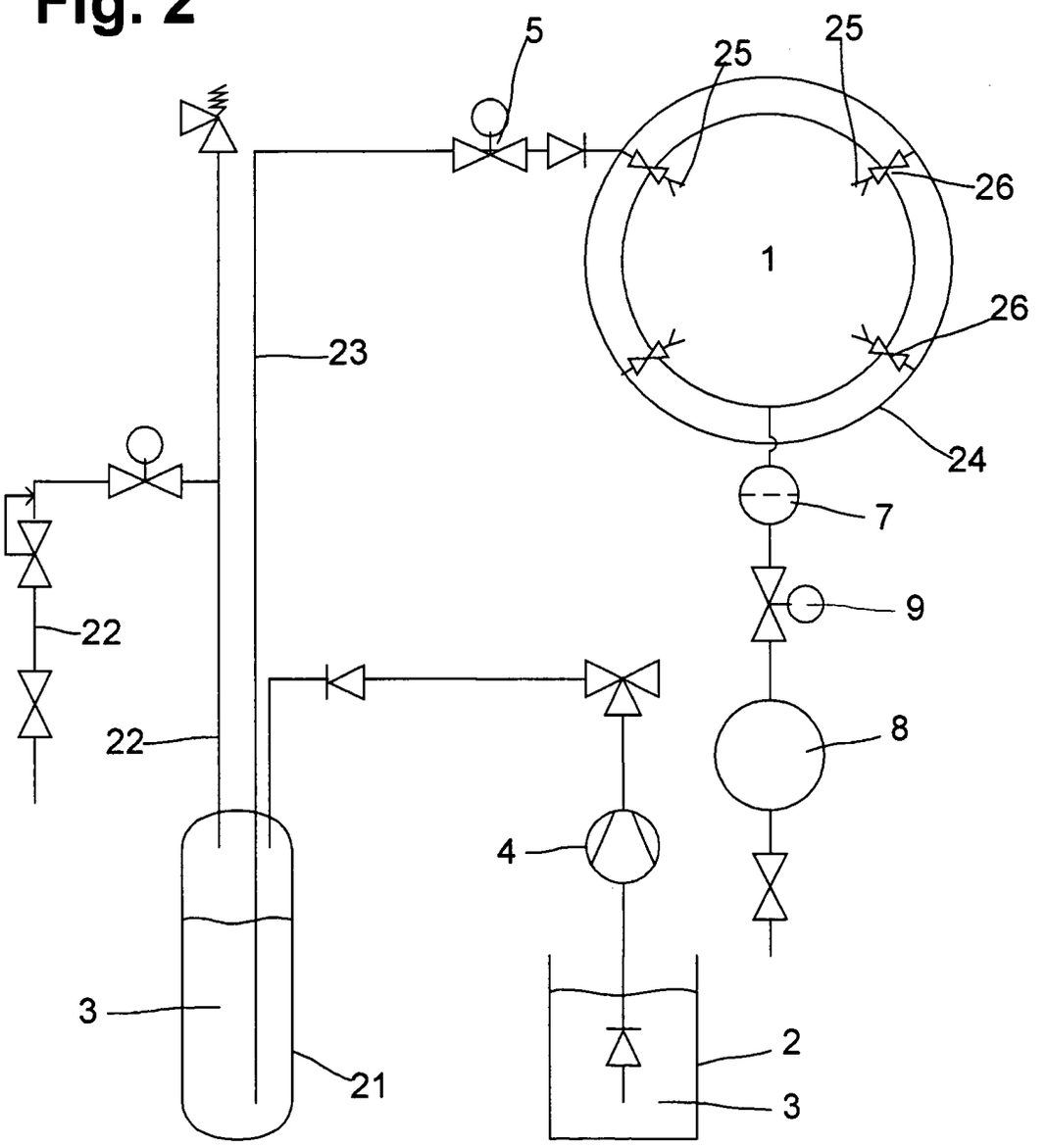


Fig. 3

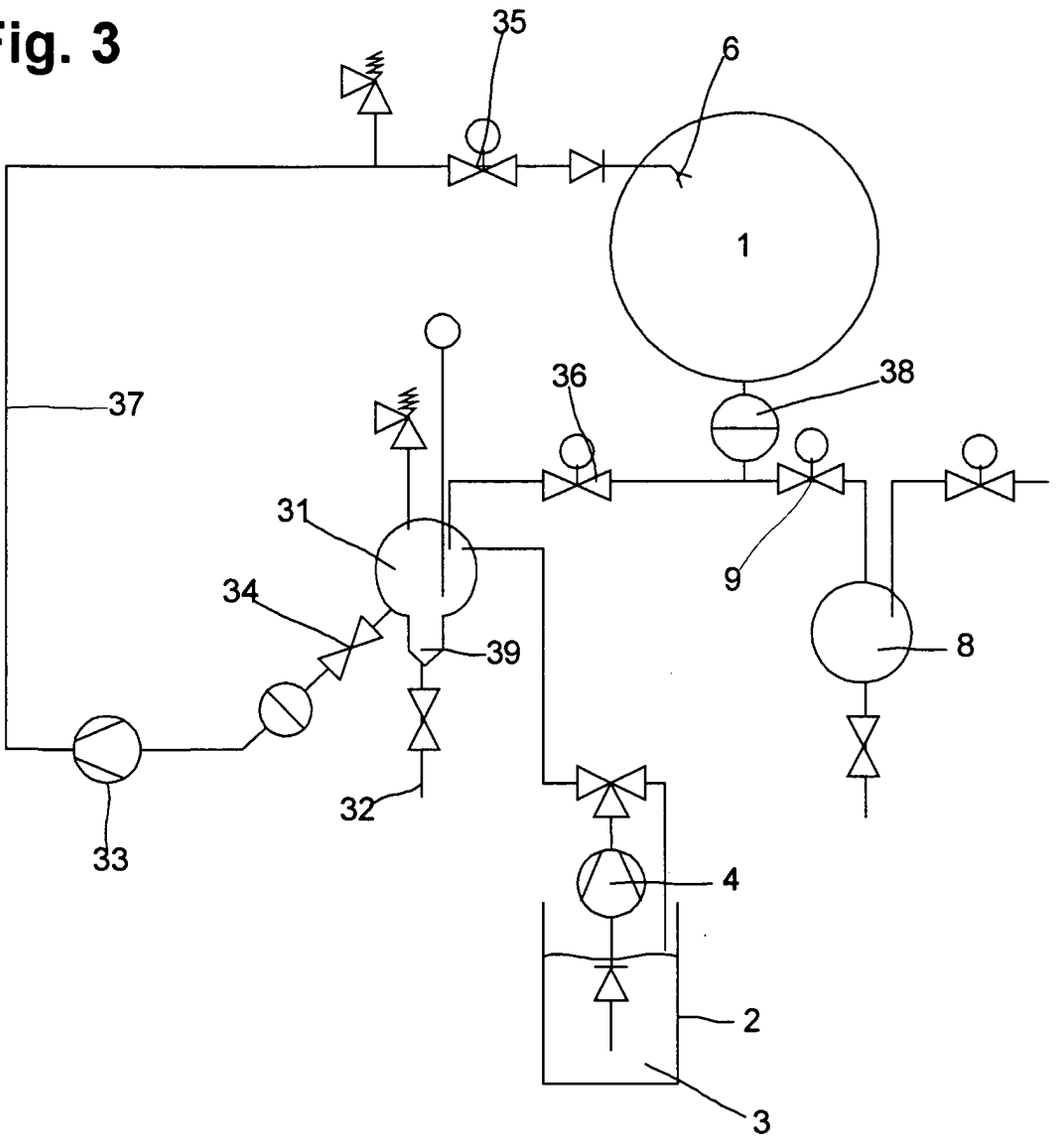


Fig. 4

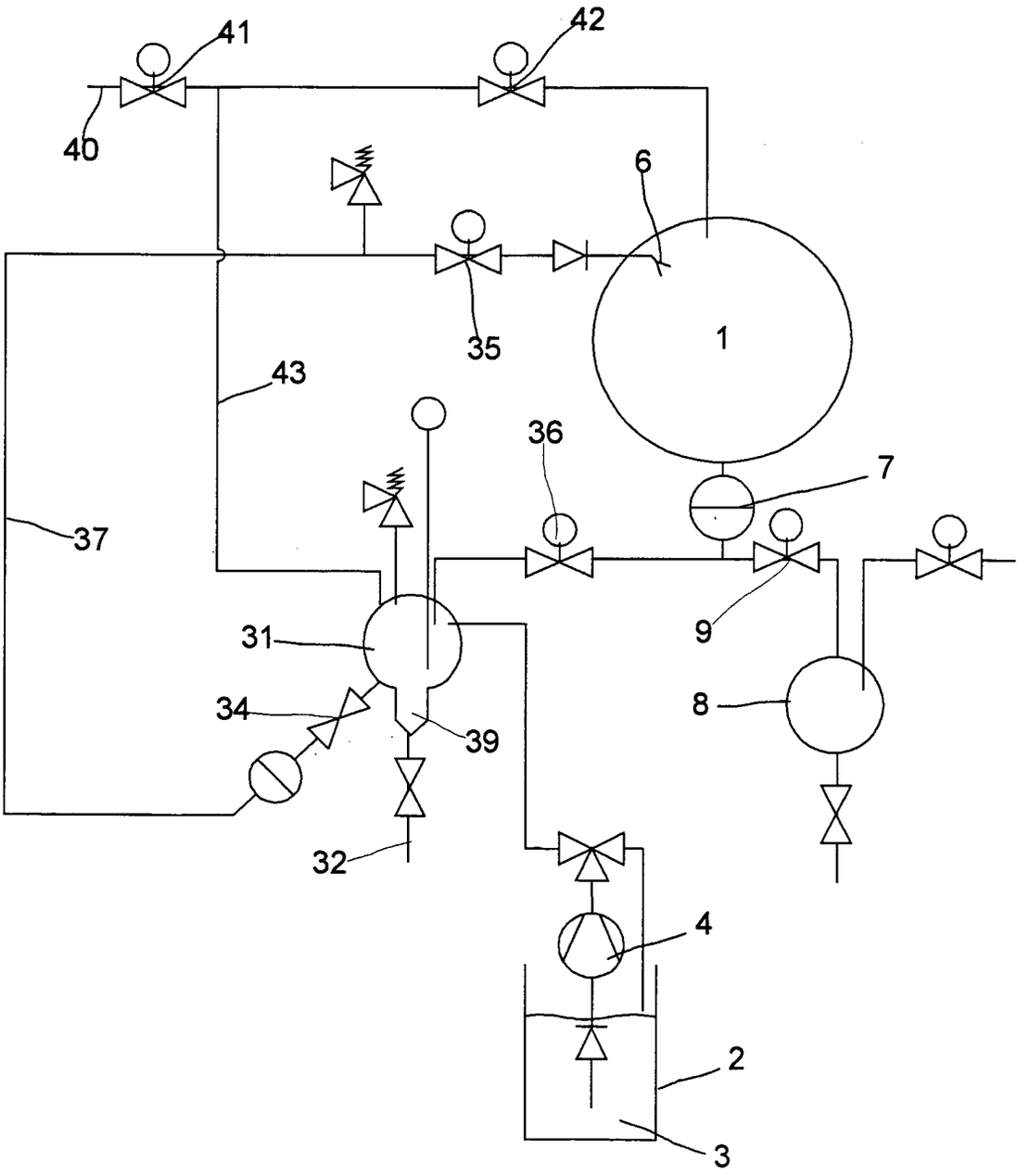
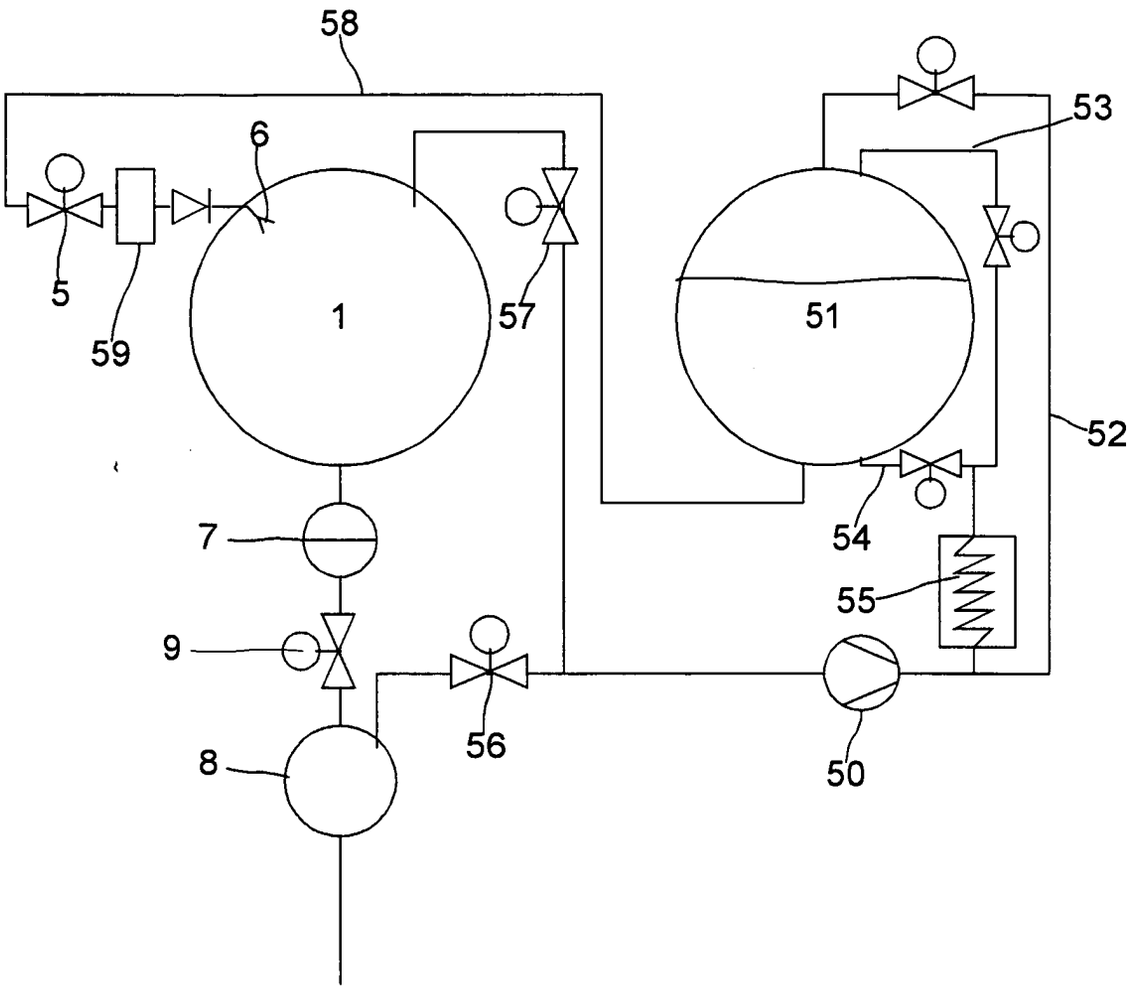


Fig. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 03 00 6420

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28 August 2003	van der Zee, W

CATEGORY OF CITED DOCUMENTS

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EUROPEAN SEARCH REPORT

Application Number
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 03 00 6420

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