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

(11) EP 2 397 794 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
21.12.2011 Bulletin 2011/51

(51) Int Cl.:
F25B 45/00 *(2006.01)*

(21) Application number: **11170208.0**

(22) Date of filing: **16.06.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **18.06.2010 GB 1010219**

(71) Applicants:
- **JTL Systems Limited**
  Newbury, Berks RG14 5SJ (GB)
- **Ernest West & Beynon Ltd**
  Paddock Wood
  Kent TN12 6BE (GB)
- **Gigiel, Andrew**
  Moorlynch
  Bridgewater
  Somerset TA7 9BV (GB)
- **Refrigeration Developments and Testing Ltd**
  Little Haseley
  Oxfordshire OX44 7LN (GB)

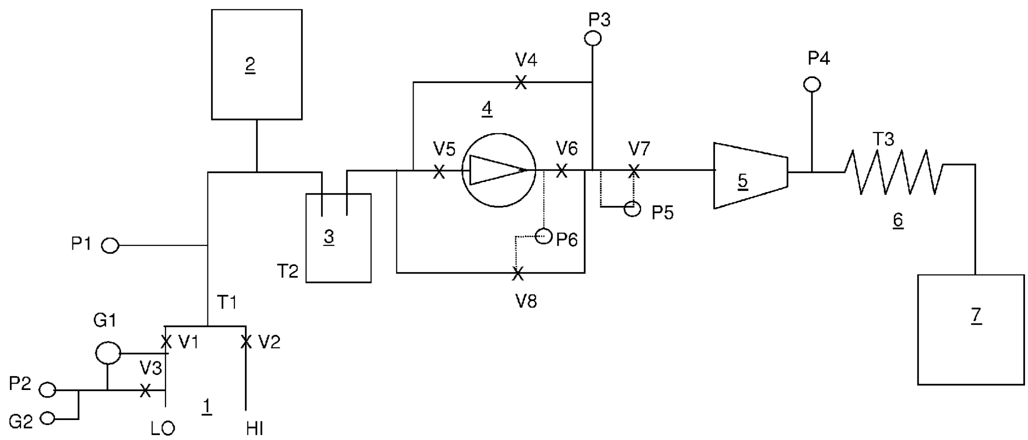
(72) Inventors:
- **Gigiel, Andrew**
  Bridgewater, Somerset TA7 9BY (GB)
- **Lawrence, John**
  Newbury, Berkshire RG14 5SJ (GB)
- **Evans, Judith**
  Little Haseley, Oxfordshire OX44 7LN (GB)

(74) Representative: **Cross, James Peter Archibald**
R.G.C. Jenkins & Co
26 Caxton Street
London SW1H 0RJ (GB)

(54) **Volatile Substance Recovery Method and Apparatus**

(57) Refrigerant or other volatile substance is extracted from a refrigeration system by applying a reduced pressure intermittently to it. The reduced pressure may be applied from a reservoir (2) that is evacuated substantially constantly by a vacuum pump (4), the reservoir being connected intermittently to the system. The reduced pressure may be pulsed on and off; this causes instantaneous boiling or flashing of the refrigerant or volatile substance within the system, such that it is extracted as a liquid and vapour mixture. As a result, much of the substance can be extracted largely as liquid, so that the latent heat of evaporation of the liquid is extracted outside the refrigeration system, thereby avoiding excessive cooling within the system.

Fig. 1



EP 2 397 794 A2

Description

Field of the Invention

[0001] The present invention relates to a method and apparatus for extracting volatile substances, such as refrigerants, from a system such as a refrigeration system or heat pump.

Background of the Invention

[0002] Refrigerant may need to be extracted from a refrigeration system for cleaning, recovery or destruction, prior to returning it to the system, recharging the system, or prior to disposal of the system. In all three cases, it is important to extract substantially all of the refrigerant from the system, and to be able to do so as quickly as possible.

[0003] Typically, refrigerant is extracted from a refrigeration system using the compressor as a pump, or by means of an external vacuum pump or compressor. The latter is preferable because a harder vacuum may be needed to extract the refrigerant than the internal compressor is capable of producing. An example of such methods is disclosed in US-A-6427457.

[0004] However, reducing the pressure within the refrigeration system causes evaporation of the refrigerant, which therefore cools the system. This temperature reduction means that the saturated vapour pressure is also reduced. When the force due to vapour pressure of the refrigerant does not exceed the force due to surface tension of the refrigerant, change of state throughout the refrigerant cannot occur.

[0005] One way of overcoming this problem is to heat the refrigeration system during refrigerant extraction, but this is impractical in some types of system, which are arranged in such a way that heat cannot conveniently be supplied to some parts.

Statement of the Invention

[0006] According to one aspect of the present invention, there is provided a method of extracting refrigerant or other volatile substances from a refrigeration or other system, in which a reduced pressure is applied intermittently to the substance. Contrary to normal expectations, applying the reduced pressure only intermittently may lead to shorter extraction times than continuous application of the reduced pressure.

[0007] The reduced pressure may be applied from a low pressure reservoir that is evacuated substantially constantly by a vacuum pump or compressor, the reservoir being connected intermittently to the system. This allows the reservoir to be the subject of continuous suction and for any rise in the pressure within it during the times it is connected to the system to be overcome in the periods between connection.

[0008] The reduced pressure may be pulsed on and off. This causes instantaneous boiling or flashing of the refrigerant or volatile substance within the system, such that it is extracted as a mixture of liquid and vapour, such as for example foam. As a result, since most of the substance is extracted as liquid, the latent heat of evaporation of the liquid is extracted outside the system, thereby avoiding excessive cooling within the system.

[0009] In one preferred embodiment, the method comprises at least two stages. During an initial stage, the pressure applied to the substance is progressively reduced. The applied pressure is above the vapour pressure of the substance, so that instantaneous boiling occurs and the temperature of the remaining substance drops, as does the vapour pressure of the substance. The application of the reduced pressure is then switched off while the pressure is reduced, and the reduced pressure is then applied to the remaining substance once more. Hence, in the initial stage, instantaneous boiling of the substance occurs mainly due to the sensible heat of the substance itself.

[0010] During a final stage, the pressure applied to the substance is at or around a minimum pressure, and is applied intermittently to the substance at relatively long intervals compared to the initial stage. During the intervals between application of the reduced pressure, the remaining substance absorbs heat from the surrounding system, its temperature rises, and its vapour pressure is above the applied pressure so that instantaneous boiling occurs when the reduce pressure is applied once again.

[0011] The intermittent application of the reduced pressure may cause the remaining refrigerant in the system to move along through the system with each pulse, thereby encountering a part of the system that has not previously been cooled by evaporation of refrigerant, and avoiding excessive cooling of the refrigerant. The reduced pressure may be applied alternately to the low and high sides of the system, so that the remaining substance moves back and forth within the system, thus improving the heat exchange with the system.

[0012] Hence, the initial stage extracts the substance relatively quickly, using the sensible heat of the substance, while the final stage extracts the remaining substance efficiently, leaving as little substance remaining as possible.

[0013] The method may determine that substantially all of the substance has been extracted, by detecting that the pressure remains low and substantially constant during application of the reduced pressure, and between applications of the reduced pressure even if heat is applied to the system. Alternatively the method may determine that substantially all the refrigerant has been removed by the temperature of refrigerant removed in each pulse being substantially equal to the temperatures before and after the pulse. In a further alternative, the method may determine that substantially all refrigerant has been removed by a change of sound made as refrigerant is removed in each pulse.

[0014] Embodiments of the invention may advantageously extract substantially all of the volatile substance from a system more quickly than conventional methods. Embodiments of the invention may alternatively or additionally extract a greater proportion of the volatile substance than conventional methods. This advantage has significant environmental benefits, as it reduces emissions into the environment.

[0015] Other aspects of the invention include apparatus and/or a computer programme for performing the method.

Brief Description of the Drawings

[0016] There now follows, by way of example only, a detailed description of preferred embodiments of the present invention with reference to the Figures, as described below.

> Fig. 1 is a schematic diagram of a refrigerant extraction system in an embodiment of the invention.
> Figure 2 is a flowchart of the method of operation of the embodiment.

Detailed Description of the Embodiment

[0017] In the following description, functionally similar parts carry the same reference numerals between different embodiments. The drawings are intended to be schematic, and dimensions and angles may not be determined accurately from them.

Apparatus

[0018] As shown in Figure 1, the refrigerant extraction apparatus comprises, in series: an inlet 1 for connection to a refrigeration system; a low pressure reservoir 2; a liquid separator 3 for removing liquid entrained in the extracted refrigerant gas; a vacuum pump 4; a compressor 5 for compressing the extracted refrigerant gas, a condenser 6, and a refrigerant reservoir 7, such as a cylinder, for storing the extracted refrigerant liquid.

[0019] The inlet comprises one or more valve(s) that are intermittently opened to connect the low pressure from the vacuum pump 4 and low pressure reservoir 2 to the refrigeration system. In this case, the valves comprise a pair of valves V1, V2, connected respectively to the low side and high side inlets LO, HI of the refrigeration system. Each of the valves V1, V2 is a back-to-back valve, to hold pressure in either direction.

[0020] The low inlet LO pressure may be read directly by pressure gauges G1, G2 that operate respectively at higher and lower pressure ranges. Pressure transducers P1, P2 measure the pressure respectively downstream and upstream of the valves V1, V2. Valve V3 opens to connect the gauge G2 and pressure transducer P2 only when the pressure has fallen to the appropriate level, and is protected by a mechanical switch controlled by the gauge G1.

[0021] Temperature sensor T1 measures the temperature at the inlet 1; this sensor needs to have a very fast response time. Temperature sensor T2 measures the temperature at the liquid separator 3, and is connected to a heater control (not shown) that maintains the temperature of the liquid separator substantially constant, for example around 50°C with the refrigerant R245fa (pentafluoropropane).

[0022] Temperature sensor T3 measures the temperature, and pressure transducer P4 measures the pressure at the condenser 6. Temperature sensor T4 (not shown) measures ambient temperature.

[0023] Valves V4, V5 and V6 are switchable so as to bypass the vacuum pump 4, under the control of pressure transducer P3 which measures the intermediate pressure downstream of the vacuum pump 4. Stepper expansion valves V7 and V8 hold the intermediate pressure substantially constant, for example at 1 bara, under the control of pressure transducers P5 and P6 respectively.

Method

[0024] Figure 2 outlines the method of operation of the embodiment. The refrigerant extraction apparatus is first connected in a fluid-tight manner to the refrigeration circuit of the refrigeration system from which the refrigerant is to be extracted.

[0025] During an initial stage, the pressure P1 applied by the refrigerant extraction apparatus is progressively reduced, for example by varying the speed of the vacuum pump 4, or by throttling the line between the vacuum pump 4 and the low pressure reservoir 2, until a minimum applied pressure P1 is reached.

[0026] One example of the initial stage is shown in Figure 2. The initial value of P1 is set (S1), then the valves V1 and/or V2 are open (S2) so as to apply the pressure P1 to the refrigeration system. This causes instantaneous boiling or flashing of the refrigerant, which entrains liquid refrigerant in a mixture of vapour and liquid. The mixture is sucked out of the refrigeration system into the liquid separator 3, where the remaining liquid refrigerant boils and is prevented from reaching the vacuum pump 4 and/or the compressor 5, which may be damaged by liquid refrigerant.

[0027] In this way, the latent heat of evaporation is extracted mostly outside the system, which is therefore cooled to a much lesser extent. The vapour and liquid mixture is more dense than the refrigerant in the vapour phase. The mass that can be extracted by each pulse is therefore greater than it would be if the refrigerant were in the vapour phase.

[0028] The detected pressure P2 within the system will rise initially as the refrigerant boils, but will then reduce down to the pressure P1 as the temperature of the refrigerant reduces to below boiling point, and become constant. In response to the pressure P1 and/or P2 becoming constant, the valves V1, V2 are closed (S4) and the pressure P1 is then reduced (S5). The step size of the pressure reduction may be predetermined, or may vary from one step to the next.

[0029] If the pressure P1 has reached a minimum value (S6), then the method progresses to the final stage; otherwise, the cycle of the initial stage repeats by opening the valves V1/V2 (S2). The interval between opening the valves V1/V2 in the initial stage is relatively short, such as 5-10 seconds, but is determined by the detected pressures P1, P2.

[0030] During the final stage, the valves V1, V2 are alternately held open for a short time t1 (S7, S9) so as to apply the reduced pressure P1 to the system. As in the initial stage, this lowers the boiling point of the refrigerant to a temperature significantly lower than that of the refrigerant within the system, causing instantaneous boiling or flashing of the refrigerant, which entrains liquid refrigerant in a mixture of vapour and liquid, which is sucked out of the refrigeration system into the liquid separator 3, where the remaining liquid refrigerant boils.

[0031] The valves V1, V2 are closed (S8, S10) for a time t2. During this time, the liquid in the system recovers some heat from its surroundings and the pressure is reduced in the low pressure reservoir 2. The refrigerant's temperature remains such that, when the low pressure is applied again, by operating valves V1 and/or V2, the refrigerant boils and a liquid and gas mixture results.

[0032] When the valves V1, V2 are opened once again, the remaining refrigerant is sucked towards the open inlet. Alternately opening the valves V1, V2 to the low and high inlets LO, HI causes the remaining refrigerant to move back and forth within the system, thus improving the heat exchange with the system.

[0033] The process of opening (S7, S9) and closing (S8, S10) the valves V1, V2 is repeated until it is determined (S11) that substantially all of the refrigerant has been extracted. This may be determined when the pressure within the refrigeration system, such as determined by pressure transducer P2, remains low and substantially constant when the valves V1, V2 are open, and stays at the same level when the valves V1, V2 are closed. This indicates that there is substantially no evaporation of refrigerant within the system, and therefore substantially no refrigerant.

[0034] Alternatively or additionally, the method may determine (S11) that substantially all the refrigerant has been removed, by the temperature (T1) of refrigerant removed in each pulse being substantially equal to the temperatures before and after the pulse. In a further alternative or additional step, the method may determine (S11) that substantially all refrigerant has been removed by a change in the sound made as refrigerant is removed in each pulse, for example by means of an acoustic sensor.

[0035] In response to the determination (S11) that all the refrigerant has been extracted, the process may be terminated, either immediately or after one or more further cycles of opening and closing the valves V1, V2 (S7-S10).

[0036] The timing of the valves V1, V2 during the final stage may be periodic, and may remain constant during extraction of the refrigerant, or may be varied to optimize the process, for example in response to measurements from the refrigeration system.

[0037] The opening and closing of the valves V1 and V2 and the control of the pressure P1 may be performed manually, or automatically by means of a suitable control, such as an electronic control. The electronic control may be programmable so as to implement the method of the embodiment, for example by means of a computer program. The computer program may be stored on a carrier or medium and loaded into the control.

Specific Example

[0038] In one example of an application of the embodiment, a refrigerant extraction apparatus was used to extract R245fa (pentafluoropropane) from the refrigeration system of an electronic system of an aircraft. R245fa has a boiling point of around 15°C at 1 atmosphere. Applying a continuous vacuum cools the refrigerant to around -80°C, at which point the force due to surface tension exceeds the force due to vapour pressure of the refrigerant so that change of state throughout the refrigerant cannot occur.

[0039] In the application of the embodiment to this example, the following values were used:

t1 = 4s
t2 = 56s

[0040] In other words, the valves V1 and V2 are opened periodically once per minute, with a duty cycle of 1:14 or 6.66%.

[0041] The time for total refrigerant removal varied with starting temperature:

48 mins starting at -30 °C
44 mins starting at - 19 °C
42 mins starting at - 16 °C

In each case, substantially all of the refrigerant was removed from the system.

Alternative embodiments

[0042] In alternative embodiments, one of the vacuum pump 4 and compressor 5 may be omitted. The initial or final stages may be performed separately; for example, the refrigerant may be extracted entirely by the process of the final stage, although this would be slower than performing both stages. Alternatively, in applications where it is not necessary to remove all of the refrigerant, then only the initial stage may be performed.

[0043] Aspects of the present invention may be applied to the removal of liquids other than refrigerants, such as water. The removal may be from refrigeration or other systems.

[0044] Alternative embodiments, which may be apparent to the skilled person after reading the above disclosure, may nevertheless fall within the scope of the present invention.

Claims

1. A method of extracting a volatile substance from a system, comprising:

   a. intermittently applying reduced pressure to the volatile substance in the system, such that the volatile substance forms a mixture of liquid and vapour; and
   b. extracting the mixture of liquid and vapour from the system.

2. The method of claim 1, wherein the reduced pressure is applied by means external to the system.

3. The method of claim 2, wherein said means for applying reduced pressure includes a vacuum pump and/or a compressor.

4. The method of any preceding claim, wherein the means for applying reduced pressure includes a reservoir that is connected intermittently to the system.

5. The method of claim 4, wherein the pressure within the reservoir is reduced when the reservoir is not connected to the system.

6. The method of any preceding claim, wherein the liquid and vapour mixture is extracted by applying said reduced pressure.

7. The method of any preceding claim, wherein liquid volatile substance within the liquid and vapour mixture is evaporated and collected externally of the system.

8. The method of any preceding claim, wherein the applied pressure is progressively reduced.

9. The method of claim 8, wherein the intermittent application of the reduced pressure is controlled according to a sensed pressure within the system.

10. The method of claim 8 or 9, wherein during an initial stage the applied pressure is progressively reduced, and during a final stage the applied pressure is substantially at a minimum pressure.

11. The method of claim 10, wherein the interval between application of the reduced pressure is substantially shorter during the initial stage than in the final stage.

12. The method of claim 10 or 11, wherein the reduced pressure is applied periodically during the final stage.

13. The method of any preceding claim, including terminating the process in response to a determination that substantially all of the volatile substance has been extracted.

14. Apparatus arranged to perform the method of any preceding claim.

15. A computer program arranged to perform the method of any one of claims 1 to 13.

Fig. 1

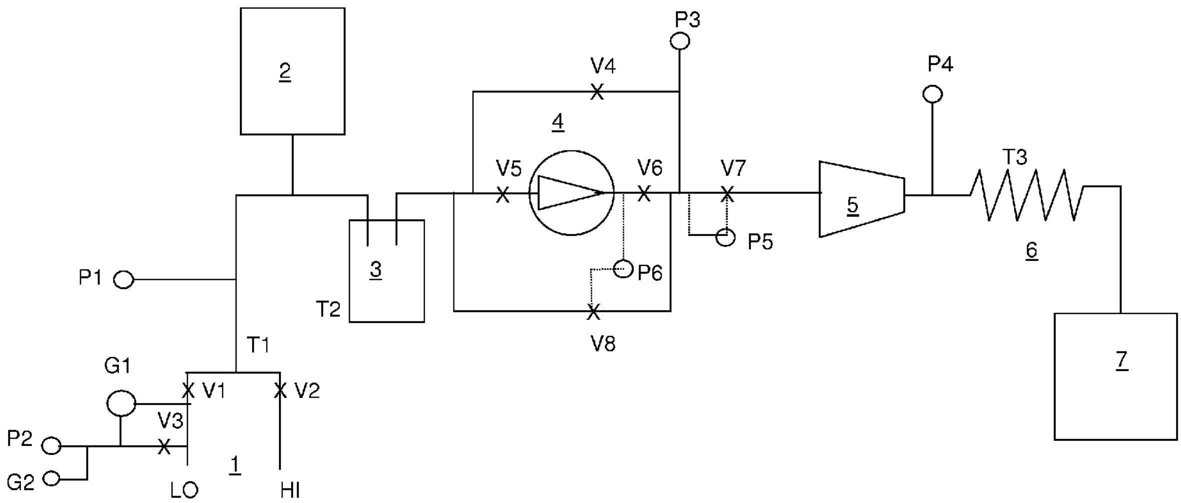
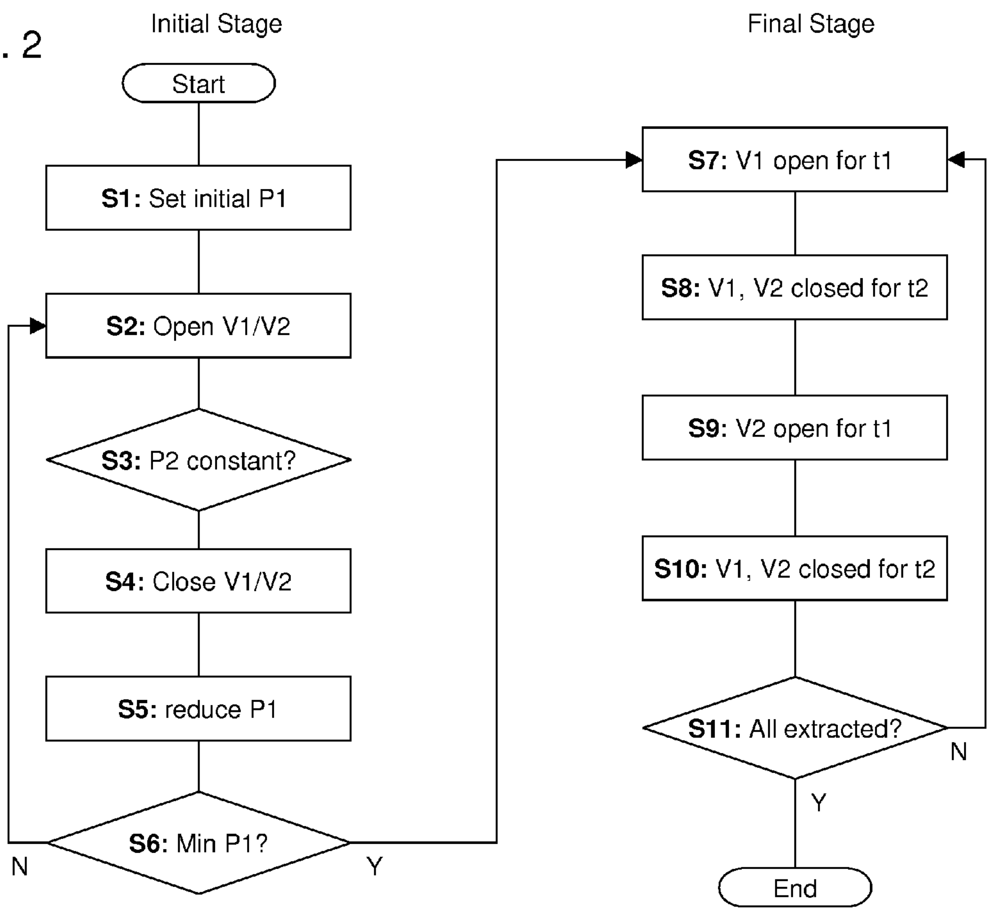


Fig. 2


Initial Stage
Final Stage
Start
S1: Set initial P1
S2: Open V1/V2
S3: P2 constant?
S4: Close V1/V2
S5: reduce P1
S6: Min P1?
N
Y
S7: V1 open for t1
S8: V1, V2 closed for t2
S9: V2 open for t1
S10: V1, V2 closed for t2
S11: All extracted?
N
Y
End

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 6427457 A **[0003]**