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(54) **THERMAL EXPANSION VALVE FOR A RESIDENTIAL REFRIGERATION APPLICATION**

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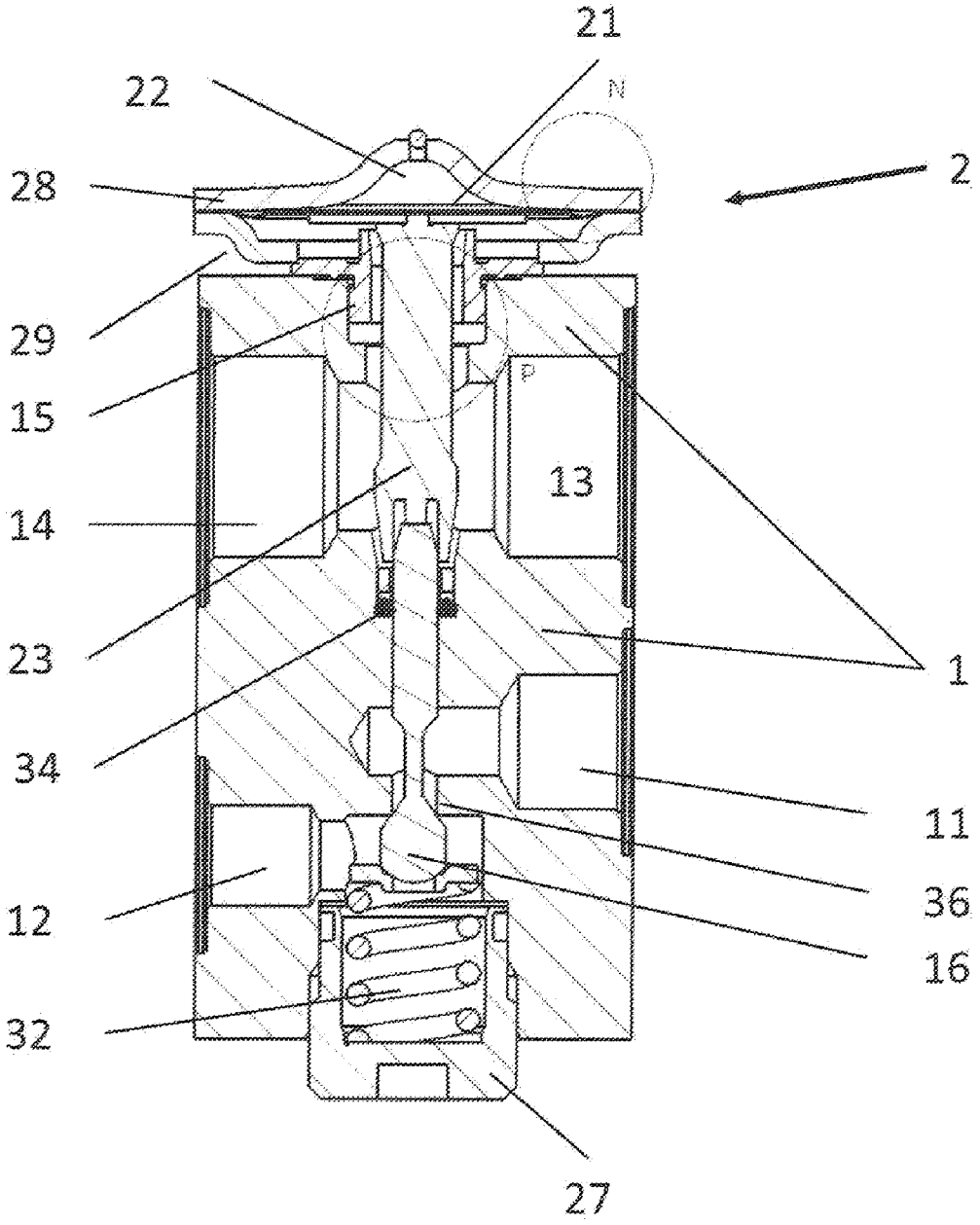
(57) **ABSTRACT**

The present invention is directed at a thermal expansion valve for a residential refrigeration application, including a valve body with a high pressure inlet, a low pressure outlet, a first suction gas port and a second suction gas port. The valve further includes a superheat defining mechanism with a diaphragm, a pushpin and a charge.



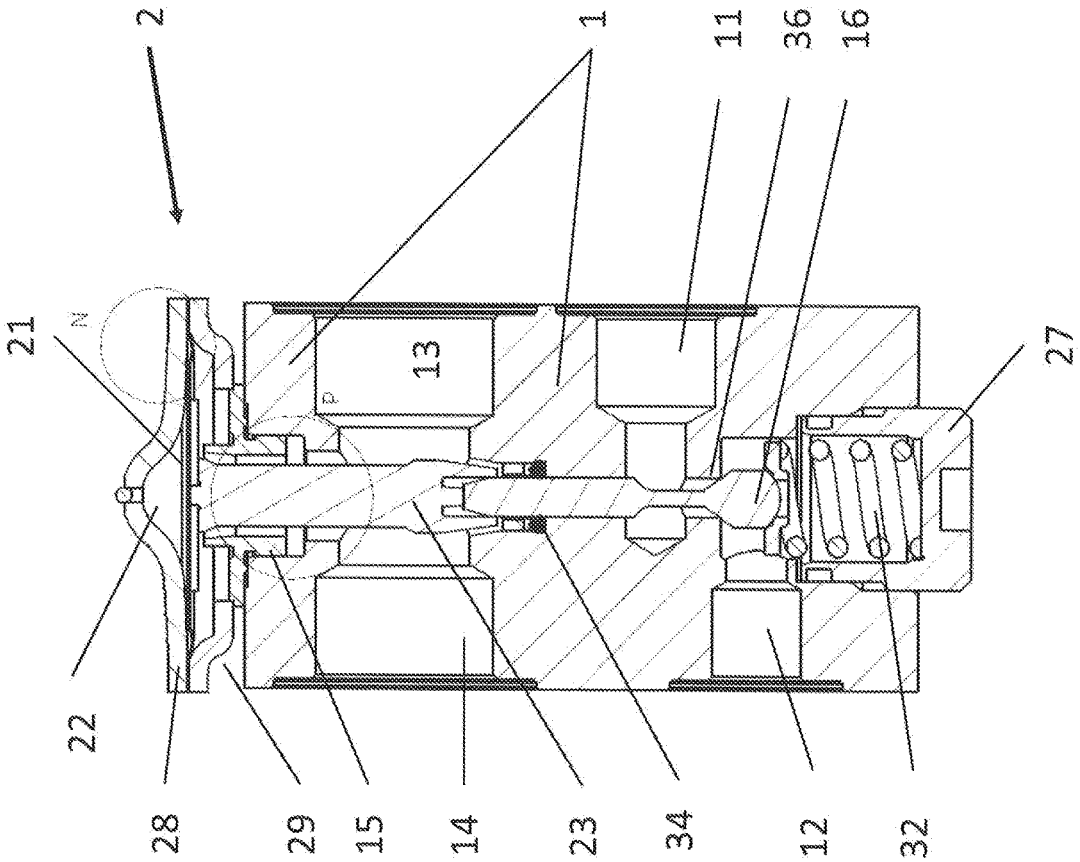


Fig. 1

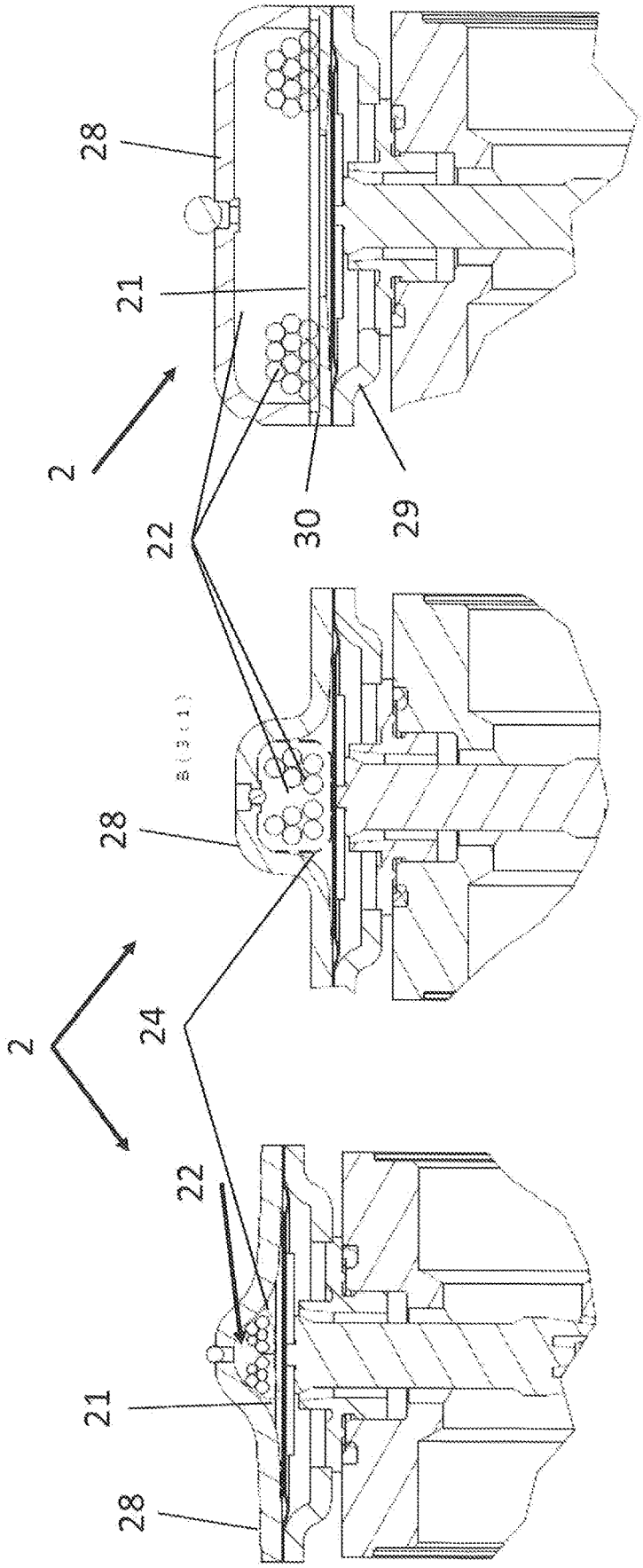


Fig. 2a
Fig. 2b
Fig. 2c
28
21
2
22
30
29
24

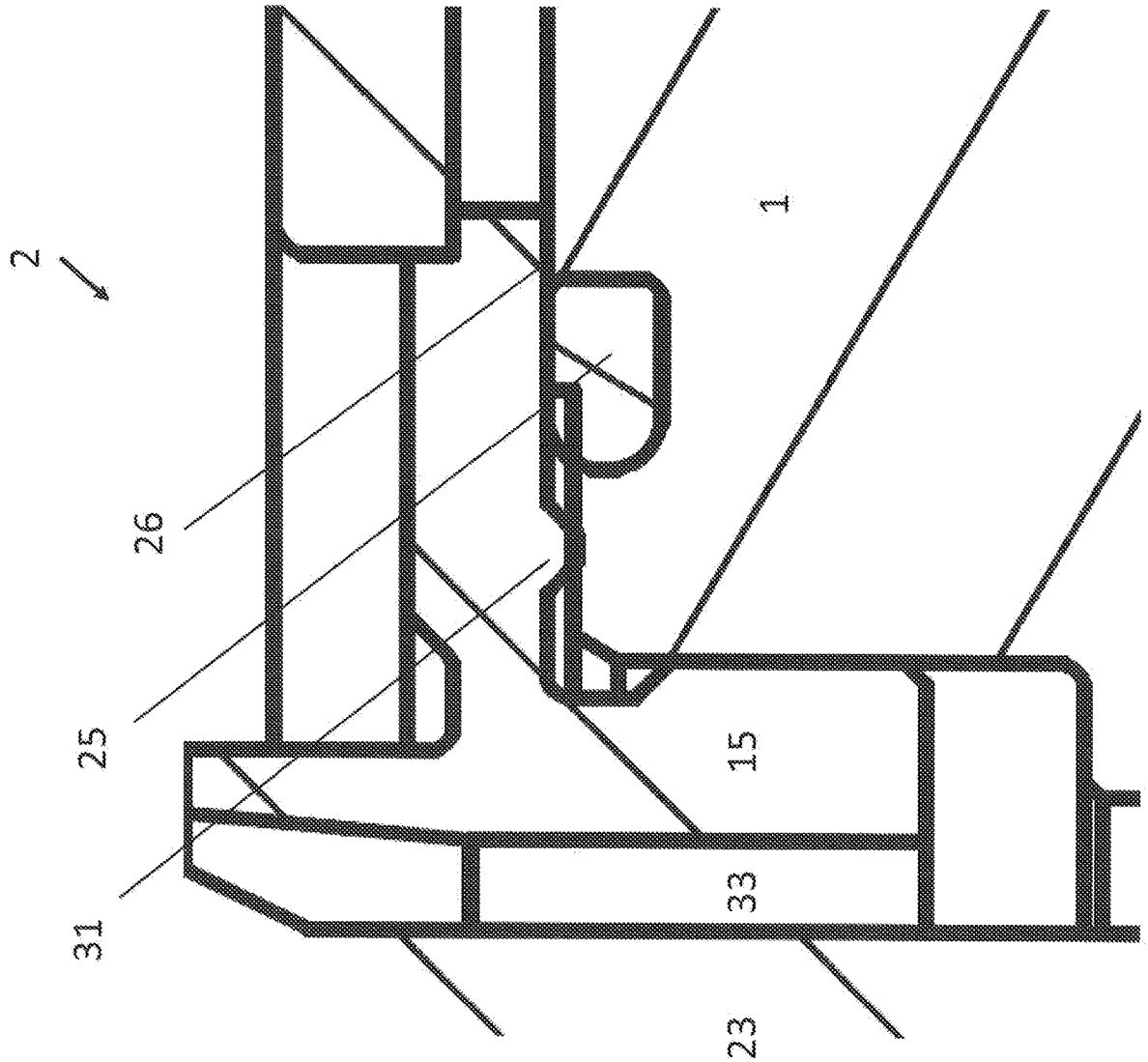


Fig. 3

Fig. 4b

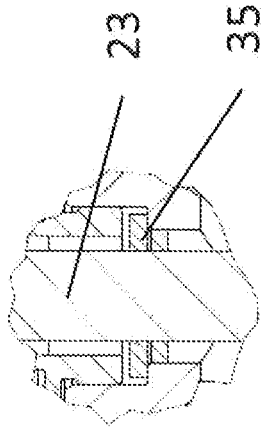
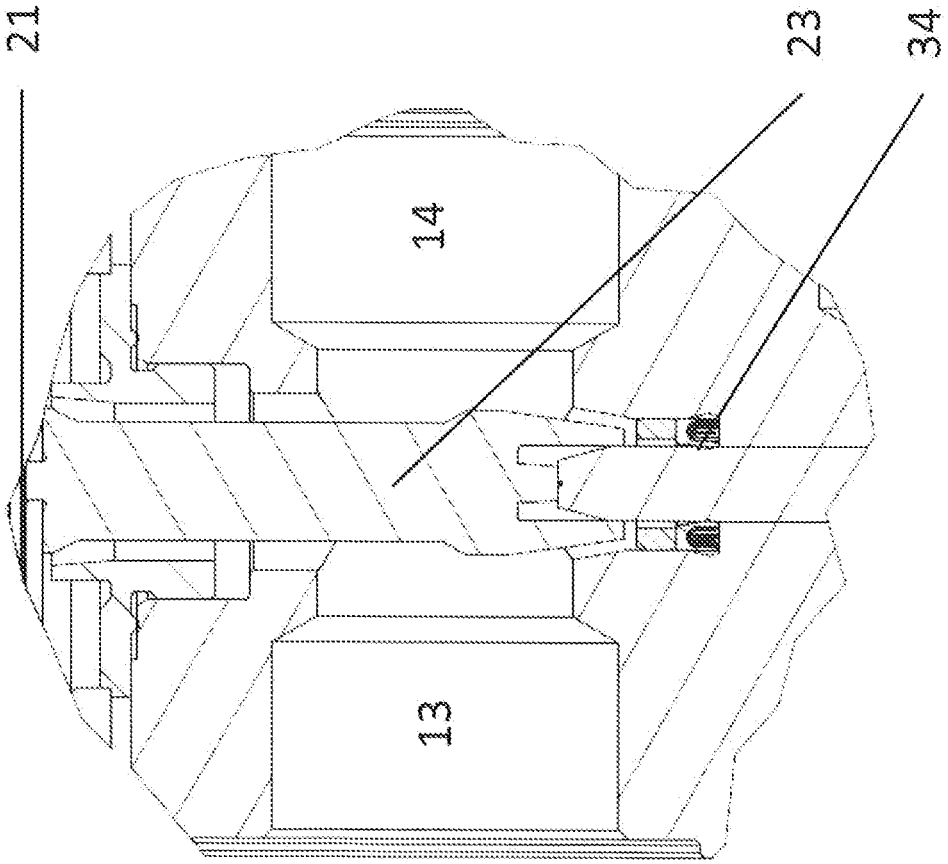


Fig. 4a



THERMAL EXPANSION VALVE FOR A RESIDENTIAL REFRIGERATION APPLICATION

TECHNICAL FIELD

[0001] The present invention is directed at a thermal expansion valve for a residential refrigeration application, comprising a valve body with a high pressure inlet, a low pressure outlet, a first suction gas port and a second suction gas port. The valve further comprises a superheat defining mechanism with a diaphragm, a pushpin and a charge.

BACKGROUND

[0002] The presently described thermal expansion valve (TXV) is a block type valve. However, the invention may also pertain to different types of valves.

[0003] Block type or similar TXV's without a separate sensor bulb are challenging to apply to systems requiring long valve time constants due to the nature of their design. The close vicinity of the charge (above the diaphragm) to the superheated suction gas causes very fast temperature and pressure changes of the charge. This can lead to unstable super heat control on larger refrigeration systems where the dynamics of the system causes the valve to "hunt" the superheat (SH), constantly opening and closing the valve in periods of seconds or minutes.

[0004] One way to avoid this "hunting" is to increase the time constant of the valve. The time constant defines the time it takes the valve to reach 63% of a new setpoint. E.g., if the SH increases by 4K, the time constant is defined by the time it takes for the valve to change the opening equivalent to 63% of a 4K SH increase.

[0005] The time constant can be affected in several ways, e.g. by changing the thermal resistance between the superheated gas and the charge and/or by changing other material properties and/or geometries of the valve or similar solutions.

[0006] However, when valve systems are designed for obtaining very high time constants, of e.g. 60-300 seconds or more, these solutions lead to systems, which are very sensitive to the tolerances of their components. In particular, the gaps between said components and the contact areas between the components influence conductive heat transfer significantly and are dependent on precise tolerances. Also, these solutions are strongly influenced by the effects of ambient temperature on the charge.

SUMMARY

[0007] The aim of the present invention is to overcome these problems by providing a cheaper and more robust valve. This aim is reached by a thermal expansion valve according to claim **1**. Preferable embodiments of the invention are subject of the dependent claims.

[0008] According to the invention, a thermal expansion valve for a residential refrigeration application is provided. The valve comprises a valve body with a high pressure inlet, a low pressure outlet, a first suction gas port and a second suction gas port. The suction gas ports may be bidirectional, i.e. they may function as an inlet or an outlet, depending on the direction of the fluid flow. The valve further comprises a superheat defining mechanism with a diaphragm, a pushpin and a charge. The superheat defining mechanism typically provides some mechanical feedback between the gas flowing through the valve and the position of the valve. The valve may be set by the superheat defining mechanism such that gas leaving the refrigeration application is maintained at or near superheat conditions.

[0009] According to the invention, the amount of charge is selected such that a part of the charge is in a liquid state at typical operation conditions of the refrigeration application. The charge may be selected such that at least some of the charge or rather the corresponding fluid is in liquid phase at all operation conditions of the refrigeration application. In other words, the charge is never fully in a gaseous state in normal operation conditions of the refrigeration application.

[0010] The typical operation conditions of the refrigeration application may correspond to internal temperature ranges of the refrigeration application, which the refrigeration application is designed for and/or external temperature ranges, in which the refrigeration application may typically be used.

[0011] The invention makes it possible to increase the heat transfer between the SH gas and the charge, and to control the time constant by adding ballast material to the charge, thereby achieving a robust, energy efficient design that is not significantly affected by production tolerances or ambient temperature. The charge may be understood to comprise only a fluid or a fluid and the corresponding ballast material.

[0012] Examples of designs for varying the heat transfer between the SH gas and the charge include the selections of the diameter and the material of the pushpin of the valve. Changing its diameter from 1.5 to 6 mm increases its cross-sectional area and thereby its heat transfer capacity by 16 times. Also, a material change from stainless steel to aluminum increases the thermal conductivity by 17 times. By combining these two factors, the thermal resistance of a 10 mm pushpin can be varied between 0.0015 and 0.4042K/W, i.e. by a factor of approximately 270

[0013] Alternatively or additionally, a passage or gap for the SH gas can be provided to the underside of the diaphragm, thereby increasing the effective heat transfer to the charge and reducing the time constant of the valve.

[0014] By variating the diameter of the pushpin and the size of the gap, the area of the passage can be variated significantly. For example, by variating the diameter of the pushpin from 1.5 to 6 mm and the size of the gap from 0.02 to 1 mm, the area of the gap varies from 0.1 to 18.8 mm^2, i.e. a factor of ca. 200

[0015] Alternatively or additionally, a guide element or flow restrictor can be placed between the pushpin and the valve body or valve house to guide the pushpin and optionally restrict the flow of gas along the pushpin and towards the diaphragm.

[0016] The internal structure of the valve may hence be designed in such a way that the heat transfer between the suction gas and the charge is very high. Accordingly, the time constant associated only with the immediate heat transfer between the suction gas and the charge will be very low. However, in the charge volume, an anti-hunt or ballast may be provided, increasing the time constant significantly. By having this design, the time constant is defined in the relationships between the charge volume, the amount/weight of charge (mg), the phase distribution of the charge or rather the fluid component of the charge, the distribution of the liquid phase of the fluid between a portion absorbed by the ballast material and a non-absorbed or free flowing portion, and/or the amount of ballast material.

[0017] These factors can be precisely controlled during the manufacturing of the valve. They will not be significantly affected by part tolerances. At the same time, due to the high heat transfer from the suction gas to the charge, the valve will be less sensitive to disturbances from ambient temperature. It can therefore provide better energy efficiency (i.e. operation at low SH conditions) and protect the compressor from e.g. flooding in all operation conditions.

[0018] In a preferred embodiment of the invention, the charge comprises ballast material and/or the charge comprises a refrigerant other than CO2 and/or the time constant of the valve is a function of at least the dimensions and materials of the superheat defining mechanism, wherein the superheat defining mechanism is designed for providing a time constant of greater than 30 seconds, in particular greater than 60 seconds, and wherein the charge is designed such that it determines the value of the time constant for the most part and/or that the superheat defining mechanism comprises a superheat setting screw. The time constant without consideration of the charge may be in the order of several seconds or less. However, the charge may increase the time constant to several tens or hundreds of seconds.

[0019] The ballast material or anti-hunt can consist of different materials and/or of a mixture of different materials. It may be provided in different shapes.

[0020] The charge may comprise or consist of different medias. Typical refrigerants such as HFC (R410A, R32, R134a), HCFC's (R22, R142b), HFO (R1234yf, R1234ze) or natural refrigerants (R290, R744), either with a single media or as a blend of multiple medias may be chosen. Additionally, the charge may be pressurized with an inert gas such as Nitrogen.

[0021] The amount of charge can vary depending on application, system type and amount of ballast used, but will typically range from 50-500 mg/cm^3 available volume. This is much higher than the typical charge for a block type valve, where the charge typically will be 5-20 mg/cm^3 available volume.

[0022] In another preferred embodiment of the invention, a protection member is provided between the diaphragm and the ballast material of the charge or the ballast material of the charge is in direct contact with the diaphragm and/or the charge density is 30 to 350 mg/cm^3, preferably 60 mg/cm^3 to 100 mg/cm^3 if ballast material is provided and 50-400 mg/cm^3 if no ballast material is provided.

[0023] Since the ballast material is in close vicinity to the diaphragm, a protection member may be required between the diaphragm and the ballast material, blocking the filter elements, or particles hereof, from damaging the diaphragm. This element can take many forms, like solid perforated, flat mesh, porous filter or like.

[0024] In another preferred embodiment of the invention, the superheat defining mechanism comprises a diaphragm top, a diaphragm bottom and/or a diaphragm support, wherein the diaphragm support comprises a perforated plate and/or a ring and/or a non-rotational-symmetric plate.

[0025] The diaphragm support may be used in particular in combination with a cylindrical or largely cylindrical diaphragm top. The diaphragm support may connect the diaphragm top to the diaphragm bottom and/or provide support for the diaphragm.

[0026] In another preferred embodiment of the invention, a connection element is provided for connecting the pushpin and/or the diaphragm bottom **29** to the valve body **1**.

[0027] In another preferred embodiment of the invention, the diaphragm top is shaped at least partially cylindrically. The cylindrical or partially cylindrical shape of the diaphragm top may advantageously increase the volume of the charge provided between the diaphragm top and the diaphragm.

[0028] In another preferred embodiment of the invention, ballast material of the charge comprises diatomite, a molecular sieve and/or marinite and/or is provided in cylindrical, cubic, conical, spherical and/or toroidal form.

[0029] In another preferred embodiment of the invention, the charge is pressurized with an inert gas such as nitrogen.

[0030] In another preferred embodiment of the invention, the high pressure inlet is provided between the low pressure outlet on the one side and the first suction gas port and/or second suction gas port on the other side with respect to an axial direction of the valve body.

[0031] In another preferred embodiment of the invention, the connection between the diaphragm and the valve body comprises a knife edge seal and/or an O-ring and/or a weld. The connection between the diaphragm and the valve body may include further components such that the valve body and the diaphragm are not necessarily in direct contact with each other.

[0032] In another preferred embodiment of the invention, the valve comprises a check valve. The check valve may simplify the use of the valve as a bidirectional valve.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] Further advantages and details of the invention are described with reference to the following figures, the figures showing:

[0034] FIG. **1**: section view of the thermal expansion valve;

[0035] FIGS. **2***a*-**2***c*: detailed section views of the top of the thermal expansion valve;

[0036] FIG. **3**: detailed section view of the connection between the diaphragm and the valve body; and

[0037] FIGS. **4***a*-**4***b*: detailed section views of the thermal expansion valve.

DETAILED DESCRIPTION

[0038] FIG. **1** shows a thermal expansion valve for a residential refrigeration application, which uses a refrigerant other than CO2. The thermal expansion valve comprises a valve body **1** with a high pressure inlet **11**, a low pressure outlet **12**, a first suction gas port **13** and a second suction gas port **14**. The valve further comprises a superheat defining mechanism **2** with a diaphragm **21**, a pushpin **23** and a charge **22**. The superheat defining mechanism **2** may comprise a valve element **16**, which can close, or open a valve orifice **36** provided on the valve body **1** and then controls the fluid flow between the high pressure inlet **11** and the low pressure outlet **12**. The pushpin **23** connects the diaphragm **21** mechanically to the valve element **16** and drives the valve element **16**. The diaphragm **21** is moved in dependence on the pressure gradient acting on it. This movement of the diaphragm **21** is transmitted to the valve element **16** via the pushpin **23** such that the amount of refrigerant passing from the high pressure inlet **11** to the low pressure outlet **12** and thus to the evaporator is controlled. A superheat setting screw **27** is provided at the bottom of the valve. The superheat setting screw **27** may be screwed with respect to

the valve body **1** for preloading the superheat defining mechanism **2** via a spring **32**. The spring **32** may be acting on the valve element **16** and may be pressing the pushpin **23** against the diaphragm **21**.

[0039] Inside a sealed portion of the superheat defining mechanism **2**, the amount of charge **22** is selected such that a part of the charge **22** is in a liquid state at typical operation conditions of the refrigeration application. The charge may comprise or consist of different medias. Typical refrigerants such as HFC (R410A, R32, R134a), HCFC's (R22, R142b), HFO (R1234yf, R1234ze) or natural refrigerants (R290, R744), either with a single media or as a blend of multiple medias may be chosen. Additionally, the charge may be pressurized with an inert gas such as nitrogen. The charge **22** may comprise a refrigerant other than CO2.

[0040] The superheat defining mechanism **2** comprises a diaphragm top **28**, a diaphragm bottom **29** and/or a diaphragm support **30**, wherein the diaphragm support **30** is shown in FIG. **2***c* and comprises a perforated plate and/or a ring and/or a non-rotational-symmetric plate. The diaphragm support **30** may be a component, which is separated from the diaphragm bottom **29** and the diaphragm top **28** prior to the assembly of the valve. During the assembly of the components of the valve, the diaphragm top **28**, the diaphragm bottom **29** and the diaphragm support **30** may be connected to each other, such that the diaphragm top **28** is connected to the diaphragm bottom **29** via the diaphragm support **30**. The diaphragm top **28** and the diaphragm **21** may enclose a volume, in which the charge **22** is contained. The diaphragm support **30** may be part of the enclosure of the charge **22**.

[0041] A connection element **15** is provided for connecting superheat defining mechanism (**2**), particularly the diaphragm bottom **29**, to the valve body **1**. More details on the connection element **15** will be shown with reference to FIG. **3**.

[0042] The high pressure inlet **11** is provided between the low pressure outlet **12** on the one side and the first suction gas port **13** and/or second suction gas port **14** on the other side with respect to an axial direction of the valve body **1**. The axial direction of the valve body **1** corresponds to the vertical direction in FIG. **1** and to the linear movement direction of the pushpin **23**.

[0043] Usually, the expansion direction in block valves occur from a lower high pressure inlet to an upper low pressure outlet, i.e. in the opposite direction it occurs at the shown embodiments. One reason to do this is to avoid the need of a piston seal **34** on the pushpin **23** and/or cone. In the shown embodiments, a corresponding seal **34** is present and the expansion direction is from the upper high pressure inlet **11** to the lower low pressure outlet **12**. In other embodiments of the invention, the expansion direction could be inverted.

[0044] FIGS. **2***a* to **2***c* show detailed section views of the top portions of different embodiments of the thermal expansion valve. The top portions of the valve comprise major components of the superheat defining mechanism **2**.

[0045] The diaphragm assembly of FIG. **2***a* may typically comprise a charge **22** volume of e.g. 0.5-2 cm^3 and a charge mass of 25-1000 mg. FIG. **2***b* shows an intermediate solution with a diaphragm top **28** that both acts as an upper diaphragm **21** support and a partially cylindrical charge **22** enclosure. However, due to the shape and size of the part, it allows for a larger charge than the embodiment of FIG. **2***a*, e.g. 1-3 cm^3 charge **22** volume and a charge **22** mass of 50-1500 mg. FIG. **2***c* shows a diaphragm assembly that includes a diaphragm support **30** as well as the diaphragm top **28**, diaphragm bottom **29** and diaphragm **21**, thus allowing for a wide range of charge volumes, e.g. 2-10 cm^3 with a charge mass of 100 to 5000 mg. The diaphragm support **30** can be a ring, a perforated plate or a non-rotational-symmetric plate, such as a five-legged plate. The diaphragm **21** can be welded to the diaphragm support **30**, or to the diaphragm top **28** with the diaphragm support **30** fixed to the diaphragm top **28**.

[0046] In all embodiments, the charge **22** may comprise ballast material, which functions as a thermal-transfer-delay means. The ballast material is indicated by spherical objects between the diaphragm **21** and the diaphragm top **28**. The ballast material of the charge **22** may comprise diatomite, a molecular sieve and/or marinite and/or may be provided in cylindrical, cubic, conical, spherical and/or toroidal form.

[0047] The time constant of the valve is a function of the dimensions and materials of the superheat defining mechanism **2** as well as its charge **22**. The superheat defining mechanism **2** is designed for providing a time constant of greater than 30 seconds, in particular greater than 60 seconds. The charge **22** may be chosen such that it determines the value of the time constant for the most part.

[0048] The embodiments of FIGS. **2***a* and **2***b* show a protection member **24** provided between the diaphragm **21** and the ballast material of the charge **22**. The protection member **24** may also be provided with the embodiment of FIG. **2***c*. Alternatively, the ballast material of the charge **22** may be in direct contact with the diaphragm **21**. The charge **22** density may be chosen to be 30 to 350 mg/cm^3, preferably 60 mg/cm^3 to 100 mg/cm^3 if ballast material is provided and 50-400 mg/cm^3 if no ballast material is provided.

[0049] The embodiments of FIGS. **2***b* and **2***c* shown that the diaphragm top **28** may be shaped at least partially cylindrically. According to FIG. **2***b*, the cylindrical portion of the diaphragm top **28** may be of smaller diameter than the outer diameter of the diaphragm **21**. The diameter of the cylindrical portion may be half, a third or less of the diameter of the diaphragm **21**.

[0050] According to the embodiment of FIG. **2***c*, the cylindrical portion of the diaphragm top **28** may be of the same or nearly the same diameter as the outer diameter of the diaphragm **21**. The cylindrical portions of all embodiments may extend in an axial direction of the valve.

[0051] An additional diaphragm support **30** is shown in FIG. **2***c* between the diaphragm **21** and the diaphragm top **28**. The diaphragm support **30** makes it possible to connect the cylindrical and vertically oriented lowest portion of the diaphragm top **28** to the diaphragm bottom **29** and/or to the diaphragm **21**. The diaphragm **21** may be connected directly to the diaphragm support **30** at the bottom or the upper side of the diaphragm support **30**.

[0052] FIG. **3** shows a detailed section view of the connection between the valve body **1** and parts of the superheat defining mechanism **2**. The connection between the superheat defining mechanism **2** and the valve body **1** may comprise a knife edge seal **31** and/or an O-ring **25** and/or a weld **26**. At least some of these features may be arranged in different radial order at the connection element **15** and/or at a connection interface between the diaphragm **21** and other components of the superheat defining mechanism **2**.

[0053] A known way of fixing and sealing the diaphragm assembly is by means of a thread and an O-ring **25**. The embodiment of FIG. **3** shows a knife edge seal **31** in combination with a rubber seal element, such as the shown O-ring **25**. The knife edge seal **31** is known for its near hermetic sealing properties, excellent temperature resistance and no chemical compatibility issues like rubber or polymers. The additional and optional rubber seal acts as an environmental protection and backup for the knife edge seal.

[0054] Alternatively or additionally, laser welding, soldering and/or laser brazing may be applied to the interfacing elements, such as the connection element **15** and the valve body **1**. An aluminium interface element or connection element **15** could be brazed to the stainless steel lower capsule, diaphragm bottom **29** and/or valve body prior to the laser welding.

[0055] A gap **33** is shown radially inwards of the connection element **15**. The gap **33** may be located between the connection element **15** and the pushpin **23** for providing a fluid passage between the first and second suction gas ports **13**, **14** and the diaphragm **21**. The diaphragm **21** is not shown in FIG. **3** but is situated above the components shown in said figure.

[0056] FIGS. **4***a*-**4***b* are detailed section views of the thermal expansion valve. FIG. **4***a* shows the positioning of the seal **34** on the pushpin **23**. FIG. **4***b* illustrates the positioning of a guide and/or flow restrictor **35** on the pushpin **23**. The guide and/or flow restrictor **35** may be provided between the first suction gas port **13** and second suction gas port **14** on the one side and the diaphragm **21** shown in FIG. **4***a* on the other side. The guide and/or flow restrictor **35** may limit the amount of fluid transfer between the gas ports **13**, **14** and the diaphragm **21** to a well defined amount.

[0057] Features not shown in the figures may include an additional check valve provided at the thermal expansion valve. The check valve may be an internal check valve, allowing the valve to be used in reversible systems, where the expansion function/orifice **36** shown in FIG. **1** is bypassed using said check valve.

[0058] While the present disclosure has been illustrated and described with respect to a particular embodiment thereof, it should be appreciated by those of ordinary skill in the art that various modifications to this disclosure may be made without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. A thermal expansion valve for a residential refrigeration application, comprising a valve body with a high pressure inlet, a low pressure outlet, a first suction gas port and a second suction gas port, the valve further comprising a superheat defining mechanism with a diaphragm, a pushpin and a charge, wherein the amount of charge is selected such that a part of the charge is in a liquid state at typical operation conditions of the refrigeration application.

2. The thermal expansion valve according to claim **1**, wherein the charge comprises ballast material and/or that the charge comprises a refrigerant other than CO2 and/or that the time constant of the valve is a function of at least the dimensions and materials of the superheat defining mechanism, wherein the superheat defining mechanism is designed for providing a time constant of greater than 30 seconds, in particular greater than 60 seconds, and wherein the charge is designed such that it determines the value of the time constant for the most part and/or that the superheat defining mechanism comprises a superheat setting screw.

3. The thermal expansion valve according to claim **2**, wherein a protection member is provided between the diaphragm and the ballast material of the charge or that the ballast material of the charge is in direct contact with the diaphragm and/or that the charge density is 30 to 350 mg/cm^3, preferably 60 mg/cm^3 to 100 mg/cm^3 if ballast material is provided and 50-400 mg/cm^3 if no ballast material is provided.

4. The thermal expansion valve according to claim **1**, wherein the superheat defining mechanism comprises a diaphragm top, a diaphragm bottom and/or a diaphragm support, wherein the diaphragm support comprises a perforated plate and/or a ring and/or a non-rotational-symmetric plate.

5. The thermal expansion valve according to claim **1**, wherein a connection element is provided for connecting the superheat defining mechanism to the valve body.

6. The thermal expansion valve according to claim **1**, wherein the diaphragm top is shaped at least partially cylindrically.

7. The thermal expansion valve according to claim **1**, wherein ballast material of the charge comprises diatomite, a molecular sieve and/or marinite and/or is provided in cylindrical, cubic, conical, spherical and/or toroidal form.

8. The thermal expansion valve according to claim **1**, wherein the charge is pressurized with an inert gas such as nitrogen.

9. The thermal expansion valve according to claim **1**, wherein the high pressure inlet is provided between the low pressure outlet on the one side and the first suction gas port and/or second suction gas port on the other side with respect to an axial direction of the valve body.

10. The thermal expansion valve according to claim **1**, wherein the connection between the diaphragm and the valve body comprises a knife edge seal and/or an O-ring and/or a weld.

11. The thermal expansion valve according to claim **1**, wherein it comprises a check valve.

* * * * *