

NON-RETURN CHECK VALVE AND CHECK VALVE APPARATUS FOR VACUUM SYSTEM

FIELD OF THE INVENTION

- 5 The field of the invention relates to non-return valves for use in vacuum systems. This application claims priority to GB2012603.3 filed on 13 August 2020, the entire contents of which is incorporated herein by reference.

BACKGROUND

- 10 Non-return valves are used in vacuum systems to allow fluid to be pumped in one direction and to resist the return of the fluid from a higher pressure region to the vacuum region. They are used for example as internal pressure relief valves such as blow-off valves, or as exhaust check valves in dry pumps, or as non-return valves in abatement systems. The pressure differences found within
15 vacuum systems can be high and these require effective seals.

- For applications with harsh thermal and chemical conditions, such as semiconductor applications, the processing chamber often contains strong acid/alkali gases, with solid and condensable by-products. The usage of check
20 valves containing elastomers, which materials are commonly used for sealing in such valves, becomes increasingly limited by the higher pump and pipe operation temperature requirements, especially within corrosive environments.

- It would be desirable to provide an improved non-return valve that has resistance
25 to corrosive and hot process gases and provides an effective seal.

SUMMARY

- An aspect provides a vacuum system non-return valve comprising: a baffle for extending across a flow path in said vacuum system, said baffle comprising an
30 aperture, a perimeter of said aperture comprising a valve seat; a valve member comprising a curved sealing surface configured to mate with said valve seat, said valve member and aperture being configured such that said valve member

obscures said aperture and seals with said valve seat to impede a flow of fluid from an outlet end to an inlet end in a closed position and is displaceable in use to move away from said valve seat and allow a fluid flow from said inlet end to said outlet end in an open position; at least a portion of said surface of said baffle surrounding
5 said aperture slopes inwardly towards said inlet end of said valve such that said aperture is smaller at said inlet end than it is at said outlet end; and wherein diametrically opposing portions of said sloped surfaces of said aperture subtend an angle of between 30° and 70°.

10 It has been found that a sloped surface around the aperture of the valve can provide an effective seal with the curved surface of the valve member and in particular angles of between 30° and 55°, in some embodiments between 30° and 45° have been found to receive the valve member securely, robustly and provide effective sealing. In other cases an angle of between 45° and 55° in some cases
15 45° and 100° has been found to be effective.

The inventors of the present invention recognised that where compressible elastomer type materials were not available for sealing it is particularly important that the sealing surfaces have a good contact if the seal is to be effective.
20 Furthermore, if the valve is to be displaced continually its orientation may change slightly each time it is displaced and thus, it is also advantageous if the available sealing surface is not localised to a particular orientation. A valve with a curved surface and a sloped valve seat provides an effective sealing surface and allows the valve member to seal effectively with the valve member in different
25 orientations. In this regard, although it might seem advantageous for the valve seat to have a curved cross section that corresponds to the curved cross section of the valve member, it has been found that for ease of manufacture and to limit the effect that deformation has on sealing properties a sloped, preferably conical valve seat is effective.

30 The angle of the slope, and relative sizes of the aperture and valve member are selected so that the slope of the surface at the valve seat is tangential to the

curved surface of the valve member at the desired mating position. In this regard where the valve seat and valve member are selected to have a similar diameter, then the valve member mates with the valve seat at a point closest to the widest part of the valve member where the slope of the valve member surface is steep, and in such a case the appropriate angle is a smaller angle. Having the valve member of a similar but slightly larger diameter than the valve seat has some advantages as it allows for a wider diameter valve seat and thus, improved conductance. However, it has been found that in a vacuum system a smaller angle means that initial displacement of the valve member provides a narrow opening that increases gradually due to the steep slope of the valve seat. This gradual opening regulates changes in the back pressure in the system, providing a gradual change in pressure and reduces any tendency of the ball to bounce in and out of the valve seat by reducing the initial leakage rate of gas through the valve. This allows for improved performance of the vacuum system and reduced wear on the valve when compared to a vacuum system with a check valve with a wider angled valve seat.

In some embodiments said valve member is made of metal and in other embodiments of a ceramic.

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In some embodiments, said valve member is made of stainless steel and in some embodiments said valve seat is made of stainless steel.

Stainless seal is robust, hard, resistant to high temperatures and provides an effective sealing surface.

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In some embodiments said valve member is made of a different metal to said valve seat, in some embodiments said valve member comprises a nickel-chromium-molybdenum alloy, in some cases Hastelloy C276® (Nickel 57%, Mo 15 – 17%, Cr 14.5 – 16.5%, Fe 4 – 7%).

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Forming the valve seat and valve member from different metals, may help to inhibit bonding between the two at high temperatures. A nickel-chromium-molybdenum alloy such as Hastelloy C276® is a particularly good choice for the valve member being resistant to harsh environments and high temperatures.

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The configuration of the valve allows for effective sealing without the requirement for compressible elastomeric materials which may degrade at higher temperatures and in corrosive environments. This allows materials such as metals to be used, which materials are robust and resistant to many harsh environments.

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In some embodiments, said sloped portion of said surface surrounding said aperture extends from a surface facing said outlet end of said valve towards said surface facing said inlet end and becomes steeper for a portion extending to said surface facing said inlet end, said valve seat being at a location at or close to a change in said angle of slope.

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In some embodiments, the angle of the slope becomes steeper towards the inlet end and this allows the location of the valve seat to be close to the area where it becomes steeper and away from the edge of the aperture of the inlet side. This makes for a more robust valve seat where the valve seat portion that is supporting the valve member is not close to the edge of the aperture.

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In some embodiments, the material forming said valve seat has a roughness of between 0.1 and 1.0 Ra, preferably between 0.3 and 0.5 Ra.

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In some embodiments, the material forming said valve member has a roughness of between 0.01 to 0.5 Ra.

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The roughness of the valve member and valve seat have an effect on the quality of the seal and where the valve member and valve seat are made of metal rather than a more resilient material, this effect can be particularly important. It has

been found that roughness of between 0.1 and 1.0 Ra, preferably between 0.3 and 0.5 Ra provides an effective surface for the valve seat and an effective seal. Furthermore, such a surface can be produced in a cost effective manner. It may be advantageous if the valve member is formed to be smoother than the valve
5 seat.

An alternative embodiment provides an indent in the sloped surface of the aperture and this indent provides an area that does not contact the curved surface of the valve member such that the valve member contacts the valve seat
10 at two positions on either side of the indent. This can be particularly effective at sealing in effect providing two sealing locations.

In some embodiments, said valve member is solid, while in other embodiments said valve member is hollow. The valve member may be formed of a number of
15 materials and may be hollow or solid and is generally configured to have a certain mass, the mass being selected to provide appropriate protection against reverse flow of gasses while not being too large such that there it creates a significant back pressure on the vacuum system.

20 In some embodiments, the valve comprises a protrusion extending from said curved surface of said valve member, said protrusion extending through said aperture and comprising a retaining portion extending outwardly from said protrusion and configured to limit the travel of the valve member towards said outlet end when said valve is in said open position.

25 The valve member should be retained within the valve, and this may be done using a cage type mechanism for limiting the travel of the member towards the outlet, alternatively it may be done by a protrusion extending through the aperture and a retaining portion extending from the protrusion that is wider than the
30 aperture.

In some embodiments the baffle may extend across a pipe and where a cage type mechanism is used this may also extend across the pipe and in some embodiments be retained within the pipe as an interference fit.

- 5 A further aspect provides a vacuum system non-return valve apparatus comprising two vacuum system non-return valves according to an aspect arranged in series with respect to each other, such that fluid from an inlet end of said valve apparatus flows through a first of said non-return valves and then through a second of said non-return valves.

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- The non-return valves of embodiments may be used as a double check valve to provide additional protection against backflow. A check valve provides a possible leakage path for gas from the higher pressure outside of the vacuum system into the vacuum system. This can be particularly problematic for valves where
- 15 conventional elastomer sealing means are not used due to the harsh conditions experienced. The leakage rate depends on the pressure differential across the valve. A double check valve has an intermediate volume between two check valves and this volume is at an intermediate pressure when the valves are closed, such that the pressure drop across each valve is smaller than it would be
- 20 across a single valve. This results in a lower leakage rate for each of the check valves and thus, for the combined valve than would be the case were a single valve were used.

- In some embodiments, the system further comprises an intermediate volume
- 25 providing a flow path between said two valve seats, a length of said flow path being between 1.5 and 10 times a diameter of said valve seats, preferably between 1.5 and 6 times.

- In order for the double check valve to be particularly effective there should be a
- 30 volume between the two valves such that the pressure differential between the vacuum system and the outside is split across the two check valves. The smaller the intermediate volume the quicker the pressure in the intermediate volume

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reaches an equilibrium steady state value when the valves close. However, the volume should be sufficient to allow each valve to open and close without physically impacting the other valve.

- 5 In some embodiments, said intermediate volume is within a pipe connecting said first and second intermediate valves.

In some embodiments, the two check valves may be independent units and may be connected by a connecting pipe. The length of the connecting pipe is selected
10 to provide a suitable intermediate volume. In some cases, the diameter of the valve seat is between 1.5 and 10 times the lengths of the pipe between the two valve seats of the two valves.

In other embodiments, the apparatus comprises a combined outer housing for
15 housing both said first and second check valves.

It may be advantageous for the double check valve to be formed in a single housing which may be attached to the apparatus thereby requiring fewer sealing means. As has been noted before in corrosive and hot environments sealing
20 means deteriorate and thus, reducing the requirement for sealing means is advantageous.

In some embodiments, said combined outer housing is configured such that a flow path between said check valves comprises a portion running in an opposite
25 direction to a flow path in and out of said valve apparatus.

The combined housing may be configured such that the two check valves are arranged in effect side by side such that the flow path between them changes direction as it goes out of one valve and back down towards the second valve.
30 The direction of the gas flow in and gas flow out may be a single direction the direction of flow simply changing as it passes between the valves in the check valve.

Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with features of the independent claims as appropriate, and in
5 combinations other than those explicitly set out in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

- 10 Figure 1 schematically shows a non-return check valve according to a first embodiment;
Figure 2 schematically shows a non-return check valve with a wider angled slope;
Figure 3 schematically shows a non-return check valve according to a further embodiment;
15 Figure 4 shows a double check valve according to an embodiment; and
Figure 5 shows an alternative embodiment of a double check valve.

DESCRIPTION OF THE EMBODIMENTS

Before discussing the embodiments in any more detail, first an overview will be
20 provided.

For applications with harsh thermal and chemical challenges (e.g. semiconductor applications) a hot pump combined with a check valve that can be used at high temperatures with good corrosive resistance is desirable. Embodiments provide
25 a check valve that may be made completely of metal which shows good sealing performance. In some embodiments, stainless steel is used, the stainless steel of the valve seat being machined to have a surface roughness of between 0.1 and 1 Ra, preferably between 0.3 and 0.5 Ra. In some embodiments the valve member is machined to have a surface roughness of between 0.01 and 0.5 Ra.
30 In some embodiments the valve member is formed of a different metal to the valve seat in some embodiments it is formed of a nickel-chromium-molybdenum

alloy. In some embodiments sealing is further improved with the use of a double check valve.

Embodiments provide a check-valve with a valve member having a curved
5 surface abutting a sloped valve seat. The angle of the slope of the valve seat is selected in conjunction with the size of the valve member and aperture to provide effective sealing. In some embodiments, the valve member comprises a ball of diameter 30mm. The inner diameter for the valve seat is 26mm. The contact
10 between the ball and the seat is a single line contact. In some embodiments the valve is a metal valve while in others the valve body and seat may be formed of a ceramic. Metals and ceramic are suitable for high temperature and corrosive environment

In some embodiments the valve member and seat are formed of the same
15 material, while in others they are formed of different materials.

In some embodiments the valve is mounted within the pipes of the system, while in others a pipe connector is used.

20 Figure 1 shows a section through a check valve 5 according to an embodiment. Check valve 5 comprises a valve member 18 in the form of a ball and from which there extends a protrusion and retaining member 22. The retaining member being perforated to allow gas to pass through it. The valve member 18 mates with a valve seat 22 formed in a baffle 14 which extends across the pipe in which
25 the valve is mounted and which comprises an aperture having a sloped surface 25 of a first angle and a more steeply sloped surface. The valve seat 22 being located close to the change in angle of the slopes.

The check valve 5 is mounted via seals within a pipe and gas flows in the
30 direction of arrow 7 from a vacuum system towards an outlet. When the pressure in the vacuum system rises a force is exerted on valve member 18 which is pushed off valve seat 23 into an open position in which position gas can flow

through the aperture which is no longer obscured by valve member 18 and out through the top of the pipe. When the pressure within the system falls then the valve body 18 will return to the aperture under its weight and will seal with valve seat 23 such that gas at a higher pressure outside of the vacuum system may not enter the vacuum system.

The aperture in baffle 14 has a sloped surface 25 adjacent to the outlet which subtends an angle of 60° with a sloped surface on the diametrically opposing side of the aperture and this provides a suitable slope for mating with the curved surface of the ball and providing a good seal. The slope becomes steeper towards the inlet of the valve such that the position of the valve seat is well defined and not towards one end of the sloping surface allowing the ball to be held securely and the valve seat not to be easily damaged.

Although the angle of 60° has been found to be effective for valve members where the diameter of the ball is close to the diameter of the valve seat. In some embodiments perhaps where the diameter of the ball is between 5 and 18% larger than the diameter of the aperture preferably between 5 and 10% larger a smaller angle of between 35° and 40° may be preferred. With this angle displacement of the ball from the valve seat provides an initially narrow channel and thus, a gradual more controlled change in pressure.

Figure 2 shows an alternative where the angle of the sloping surface 25 is a less steep angle and in this embodiment subtends an angle of 90° with the sloping surface on the diametrically opposed side of the aperture. As in the previous embodiment the slope gets steeper towards the inlet such that the valve seat is in a defined place on the surface. In this example, the diameter of the valve member and the diameter of the seat are more different such that the valve member is held at a position that is not close to the middle of the valve member and thus, the sloping angle of the curved surface is shallower and matches the slope of the valve seat. In this embodiment, the diameter of the ball is between 15 and 30% larger than the diameter of the valve seat. Here the displacement of

the valve member causes a greater initial change in fluid flow and may cause poorer performance in the pumping of the vacuum system when compared to a valve seat with a steeper angle.

- 5 Figure 3 shows an alternative embodiment where the profile of the surface of the aperture that forms the valve seat has an indent 27 within it such that two valve seats 22 are formed on either side of the indent. The inlet side of the aperture is smaller than the outlet side such that the valve member is held at both points and an effective seal is made at two points leading to better sealing.

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- Figure 4 shows an alternative embodiment where a double check valve 60 is provided using two check valves 5a and 5b of the previous embodiments. The two check valves form a double check valve and gas enters via inlet 32 and meets the first check valve 5a. If the pressure at inlet 32 rises to above the
15 pressure within the intermediate volume within pipe 50 the first valve 5a will open and gas will enter the intermediate volume in the pipe 50. An increase in pressure here will cause second valve 5b to open and gas will flow out of the system. When the pressure at the inlet falls below that of the pressure within the intermediate volume 50 then the check valve 5a will close. Similarly if the
20 pressure in the intermediate volume falls below that of the outside then the second valve 5b will close. In a vacuum system when the pump is started this will cause the pressure below 5a to increase and 5a will open. The pressure at the inlet of the pump is reduced (vacuum) but at the pump outlet the pressure increases due to the compression of the gas. The pressure in intermediate
25 volume 50 will increase and 5b will open. Whilst the pump is operating then usually there is enough gas flow to maintain the pressure differentials and keep 5a and 5b open.

- Stopping the pump will cause the pressure below 5a to drop and it will not sustain
30 the weight of 5a and it will close, similarly the pressure at 50 will drop and 5b will close.

The intermediate volume within pipe 50 is at an intermediate pressure when the two check valves are closed such that the pressure drop between the inlet 32 and outside is split across each of the different check valves which reduces the back leakage. In this regard the leakage across each valve depends upon the
5 pressure drop across the valve, thus, reducing the pressure drop by splitting it between two valves reduces the leakage. The intermediate volume should be selected to be sufficient for the two valves not to physically impact each other during operation, but preferably not significantly larger than this. A larger intermediate volume increases the time for the intermediate volume to reach an
10 equilibrium intermediate pressure when the double check valve closes and this impacts on the vacuum system that the check valve is attached to.

Figure 5 shows an alternative embodiment where double check valve 60 is mounted within a single housing 70. Having a single housing makes a valve
15 easier to mount to a system and also reduces the number of seals required to seal it to the system. As has been noted earlier, seals to high temperature corrosive systems can be problematic and reducing the number that is required can be advantageous.

20 This embodiment provides a particularly compact check valve that can fit into a small space. The two check valves are mounted side by side and this requires the gas flow to change direction as it travels through the valve.

Although the double check valve is shown with a valve member comprising a
25 protrusion and retaining member 22, it may be used with a curved valve member and some other retaining means such as a grid or cage between the valve member and the outlet.

Although illustrative embodiments of the invention have been disclosed in detail
30 herein, with reference to the accompanying drawings, it is understood that the invention is not limited to the precise embodiment and that various changes and modifications can be effected therein by one skilled in the art without departing

from the scope of the invention as defined by the appended claims and their equivalents.

REFERENCE SIGNS

	5, 5a, 5b	check valve
	7	gas flow
	14	baffle
5	18	valve member
	22	retaining portion
	23	valve seat
	25	sloped aperture surface
	50	intermediate pipe
10	52	seals
	60	double check valve
	70	housing

CLAIMS

1. A vacuum system non-return valve comprising:
a baffle for extending across a flow path in said vacuum system, said baffle
5 comprising an aperture, a perimeter of said aperture comprising a valve seat;
a valve member comprising a curved sealing surface configured to mate
with said valve seat, said valve member and aperture being configured such that
said valve member obscures said aperture and seals with said valve seat to
impede a flow of fluid from an outlet end to an inlet end in a closed position and is
10 displaceable in use to move away from said valve seat and allow a fluid flow from
said inlet end to said outlet end in an open position;
at least a portion of said surface of said baffle surrounding said aperture
slopes inwardly towards said inlet end of said valve such that said aperture is
smaller at said inlet end than it is at said outlet end; and wherein
15 diametrically opposing portions of said sloped surfaces of said aperture
subtend an angle of between 30° and 70°.
2. A vacuum system non-return valve according to claim 1, wherein said
diametrically opposing portions of said sloped surfaces of said aperture subtend
20 an angle of between 30° and 55°.
3. A vacuum system non-return valve according to claim 1 or 2, wherein said
diametrically opposing portions of said sloped surfaces of said aperture subtend
an angle of between 30° and 45°.
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4. A vacuum system non-return valve according to any preceding claim,
wherein a material forming said valve member has a roughness of between 0.01
and 0.5 Ra.
- 30 5. A vacuum system non-return valve according to any preceding claim,
wherein a material forming said valve seat has a roughness of between 0.1 and
1.0 Ra, preferably between 0.3 and 0.5 Ra.

6. A vacuum system non-return valve according to any preceding claim, wherein said valve member and said valve seat are formed of stainless steel.
- 5 7. A vacuum system non-return valve according to any one of claims 1 to 5, wherein said valve member and said valve seat are formed of different metals.
8. A vacuum system non-return valve according to preceding claim, wherein said sloped portion of said surface surrounding said aperture extends from a
10 surface facing said outlet end of said valve towards said surface facing said inlet end and becomes steeper for a portion extending to said surface facing said inlet end, said valve seat being at a location at or close to a change in said angle of slope.
- 15 9. A vacuum system non-return valve according to claim 1, wherein said sloped surface of said baffle surrounding said aperture comprises an indent such that said valve member is configured to contact said sloped surface surrounding said aperture at two places at either end of said indent.
- 20 10. A vacuum system non-return valve according to any preceding claim, wherein said valve member is hollow.
11. A vacuum system non-return valve according to any preceding claim, comprising a protrusion extending from said curved surface of said valve member,
25 said protrusion extending through said aperture and comprising a retaining portion extending outwardly from said protrusion and configured to limit the travel of the valve member towards said outlet end when said valve is in said open position.
12. A vacuum system non-return valve apparatus comprising two vacuum,
30 system non-return valves according to any preceding claim, arranged in series with respect to each other, such that fluid from an inlet end of said valve apparatus flows

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through a first of said non-return valves and then through a second of said non-return valves.

13. A vacuum system non-return valve apparatus according to claim 12, further
5 comprising an intermediate volume providing a flow path between said valve seats
of said two valves, said flow path having a length of between 1.5 and 10 times a
length of a diameter of said valve seats.

14. A vacuum system non-return valve apparatus according to claim 13,
10 wherein said flow path has a length of between 1.5 and 6 times a diameter of said
valve seats.

15. A vacuum system non-return valve apparatus according to any one of
claims 12 to 14, said intermediate volume being within a pipe connecting said first
15 and second intermediate valves.

16. A vacuum system non-return valve apparatus according to any one of
claims 12 to 13, comprising a combined outer housing for housing both said first
and second check valves.

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17. A vacuum system non-return valve apparatus according to claim 16,
wherein said combined outer housing is configured such that a flow path between
said check valves comprises a portion running in an opposite direction to a flow
path in and out of said valve apparatus.

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