

Air blast protection valve

FIELD OF THE INVENTION

This invention relates generally to air blast protection systems and particularly to air blast protection valves for use with systems.

BACKGROUND OF THE INVENTION

Protected spaces for people and/or equipment for group protection or military command posts and structures on the one hand have to be ventilated, while on the other hand they have to resist the impact of blast waves that could harm people, equipment and air filtration system components.

In order to protect against blasts, air entry and exit openings are fitted with blast protection valves that are able to protect against the most extreme situation. These provide effective protection for people and equipment against the impact of explosions caused during warfare or civil emergencies, including protection during repeated occurrences of both phases of the blast wave: the positive pressure phase and the negative suction phase. The valve has a closure element typically having the general shape of a convex plate that is designed to block the vast majority of the blast wave from entering the protected space and from drawing crucial amounts of air out of the protected space. To this end, the closure element is adapted to engage suitable valve seats within the housing on both sides, i.e. upstream and downstream, of the closure element.

The valve housing typically forms a channel for the air entering the protected space. During normal operation the moving air passes between the blast valve plate and the valve housing. During a blast, the high acceleration of the blast wave impacts the blast plate at high force and causes the closure of the air passage within milliseconds or fractions of milliseconds.

Often the gap allowing the air passage is symmetrical to a longitudinal axis of the valve. For example, the valve closure element may be designed as a flat plate, or as a structured plate for example spherical or semi-spherical or hybrids of such shapes, with an annular air gap surrounding the valve closure element and typically concentric therewith. The valve closure element has to be very strong to absorb the blast energy without deformation, while nevertheless having small mass in order to reduce inertia and allow short closing times.

The closure element is mounted for axial movement along the longitudinal axis of the valve so as to allow free passage of air at rated airflows with a minimum of air resistance, while closing the air passage extremely fast in case of a blast wave. This mounting is achieved by elastic elements that allow the closure element to reach the valve seats upstream and downstream and return to the initial position, so as to be ready to take the next blast, without damage or fatigue for all elements of the system. In most cases the elastic elements are springs, such as compressing springs or tension springs or a combination of both types of spring.

In the case of a strong blast wave, a fast positive pressure front accelerates the closure element, pushing it against the valve seat downstream which blocks the air flow and prevents the blast wave entering the protected space. The characteristic negative pressure segment of the blast wave, the suction phase, follows immediately and pulls the closure element back to the valve seat upstream and seals the protected space in the opposite direction from negative pressure impact. After the positive and negative pressure phases, the closure element is automatically returned to its original open position by means of the elastic elements.

The elastic elements are typically mounted upstream or downstream the closure element or around the periphery thereof. In such case, these elements are themselves subject to the direct or indirect impact of the blast wave. This is undesirable for two reasons. First, the air blast can damage or cause stress to the elastic elements; and secondly, the elastic elements obstruct the air stream and can increase the pressure loss.

FIG. 1 illustrates the general design of a shelter protected from blast waves and air contamination. At the air intake is one or many blast protection valves 1 installed through the wall. Incoming air into the shelter can come only through these valves. The air flow is drawn through piping 2 to air purification filters 3 that release filtered air through ducting 4 to a blower 5, which pressurizes the protected space within the

shelter. An air exit valve 6 regulates the air over-pressure in the protected space to a desired pressure; and it likewise is of the form of a wall-mounted device similar to the blast protection valves 1.

FIGS. 2 to 5 show a conventional blast protection valve. Air enters via an entry aperture 8 into a housing 9 having an exit aperture 10 and flows through an annular gap between the housing 9 and a valve plate 12 (constituting a closure element). Air flows inside the housing around the periphery of the blast valve plate 12 to the exit aperture 10. The valve plate 12 is resiliently displaceable within the air stream via tension springs 11 one end of which is attached to a periphery of the valve plate 12 and the opposite end of which is anchored to an internal side wall the housing 9. In such a configuration, the springs 11 partially obstruct air-flow, thus increasing the pressure drop across the valve and reducing its efficiency. Furthermore, the very high impact of the air blast acts directly on the side-wall of the springs 11, such that repeated operation of the valve causes damage to the valve, such as distortion and reduces its elasticity.

Air ventilation or air filtration systems employing air blast protection valves are designed to provide a defined amount of airflow to a protected space according to a given standard. Total air throughput dictates the number of valves of given rating required. Larger valves are able to handle a higher air-flow and therefore allow the rated air-flow to be handled using fewer valves.

Financial considerations require that installation and running costs be optimized. Since installations may comprise up to hundreds of air blast protection valves, the required number of valves has a significant impact on investment costs. On this basis alone, it would appear to be desirable to minimize the number of blast protection valves in the system. This, in turn, suggests that valves of higher flow-rate be used and these are inevitably larger and more expensive.

As against this, a consideration of running costs requires that minimum energy be wasted owing to unnecessary pressure drop across the blast protection valves. This consideration leans toward increasing the number of valves so as to decrease the pressure drop across each valve.

It is thus apparent that the ideal solution is the optimum tradeoff between rated airflow and pressure drop. Clearly, for valves of a given rated air-flow, the required number of valves as well as their running costs may be reduced by increasing valve efficiency and this requires that pressure drop across each valve be reduced.

SUMMARY OF THE INVENTION

It is thus an object of the invention to provide an improved air blast valve having a higher efficiency than hitherto-proposed valves of comparable rating.

It is another object of the invention to reduce non-axial stress in the elastic elements of an air blast valve and to reduce axial movement thereof, preferably to less than the corresponding axial movement of the closure element.

The criteria that allowed reaching higher throughput without harming the elastic elements were a combination of at least some of the following:

- a) to significantly reduce non-axial stress to the elastic elements;
- b) to reduce axial displacement of the elastic elements to less than that of the blast valve closure element;
- c) to dispose the elastic elements outside of the air flow;
- d) to shape the elastic elements so that their moving parts have lower mass/length and elasticity and higher restoring forces.

These objects are realized in accordance with the invention by an air blast protection valve comprising:

a closure element resiliently supported within a housing;

a plurality of elastically deformable elements each having a respective first end that is anchored to a surface of the housing and each having a respective second end; and

a plurality of inelastic coupling elements each anchored at a respective first end to the second end of at least one elastically deformable element and anchored at a respective second end toward a periphery of the closure element;

the inelastic coupling element being adapted to convert axial movement of the closure element caused by an air stream acting on the closure element in either direction to a reduced axial movement of the respective elastically deformable element or elements anchored thereto.

In one embodiment of the invention that was reduced to practice, the closing time of the air blast protection valve was maintained within a range of less than two milliseconds and the valve was able to withstand at least three defined high impact blasts of up to 40 bars reflected in series without damage or change in airflow characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

FIG. 1 shows a pictorial view of a shelter system with a blast protection valve;

FIG. 2 is an isometric view of a prior art blast protection valve at the air entrance to the shelter;

FIG. 3 is a partial sectional view of FIG. 2;

FIG. 4 is a front elevation of FIG. 3 showing the springs and the blast plate;

FIG. 5 is a vertical cross-sectional view of the valve as seen through arrow **A-A** in FIG. 4;

FIG. 6 is a schematic cross-section of a detail of an air blast protection valve according to the invention showing operation of its closure element;

FIG. 7 is an isometric view of an air blast protection valve according to an embodiment of the invention with the plate in normal position;

FIG. 8 is a sectional view of FIG. 7 with the blast valve plate in its normal position;

FIG. 9 is an isometric view of the valve similar to FIG. 7 but showing the situation where a blast wave hits the blast valve plate;

FIG. 10 is a sectional view of FIG. 9 showing how the blast wave has moved the blast valve plate to an extreme position;

FIG. 11 an isometric view of the valve similar to FIG. 7, but showing the situation where a suction part of the blast wave pulls the blast valve plate to an extreme opposite position;

FIG. 12 is a sectional view of FIG. 11 showing how the suction part of the blast wave has moved the blast valve plate to the extreme position;

FIGS. 13A to 13D show details of a spring used in the valve illustrated in FIGS. 7 to 12 under the various operational conditions;

FIGS. 14A to 14C illustrate successive positions of the closure element of the valve as illustrated in FIGS. 5 to 11 under different operational conditions; and

FIGS. 15A to 15C show details of the closure mechanism in the respective operational conditions shown in FIGS. 14A to 14C.

DETAILED DESCRIPTION OF EMBODIMENTS

In the following description of some embodiments, identical components that appear in more than one figure or that share similar functionality will be referenced by identical reference symbols.

FIG. 6 is a schematic cross-section of a detail of an air blast protection valve 1 according to the invention having a closure element 15 that is vertically displaceable within a housing shown symbolically as 9. Springs 18 constituting a plurality of elastically deformable elements are anchored at a lower end to the housing and are coupled at an upper end to a periphery of the closure element 15 via inelastic coupling elements 16. The inelastic coupling elements 16 are adapted to convert axial movement of the closure element 15 caused by an air stream acting on the closure element in either direction to a reduced axial movement of the respective springs anchored thereto. In the figure, the inelastic coupling elements 16 are shown schematically as a mechanism that is fixed to the housing via an anchoring point 17 constituting a support means for slidably or pivotally supporting the inelastic elements 16 intermediate opposing first and second ends thereof. The inelastic elements 16 are coupled to the closure element 15 and to the spring 18 via flexible joints 21, whereby air pressure on the closure element 15 in either direction applies an axial force only to the springs 18.

FIGS. 7 and 8 show details of the air blast protection valve according to an embodiment of the invention. Air enters through an entry aperture 13 in the housing 9, passes axially around a valve plate 15 (constituting the closure element) and leaves the valve through an exit aperture remote from the entry aperture. The valve plate is resiliently maintained in its normal position by a lattice of thin cords 16 typically formed of steel wire, respective first ends of which are anchored to the valve plate 15 around a periphery thereof. The cords 16 constitute inelastic elements which pass through eyelets 17 (constituting support means) fixed to an interior surface of the housing 9 and are then anchored at a respective second end to one end of a tension spring 18 whose opposite end is anchored to the housing 9. In the embodiment shown in the figures, the spring 18 is anchored to an exterior wall of the housing toward the exit aperture and is covered by a protection plate 19. In such case, the cord 16, which is necessarily inside the housing, passes through a hole in the housing as best seen in FIGS. 14A – 14C.

As better seen in FIGS. 9 and 11, each spring 18 supports two cords 16, which pass over respective eyelets 17 and are then anchored to the valve plate 15, so that around a periphery of the valve plate 15 there is formed a symmetrical lattice of cords that are resiliently pulled by the springs toward the exit aperture of the valve. In such case, the eyelets 17 are preferably mounted symmetrically with respect to an axis of the spring 18 so that the cords 16 are anchored to the valve plate 15 at points on its periphery that are on opposite sides of the respective spring 18. This ensures that pressure on the valve plate 15 is distributed evenly to each pair of cords 16 and that each cord 16 applies the same force to the spring. However, other configurations are also possible. For example, only a single cord may be anchored to each spring and fixed to the valve plate 15 at a point thereon that is axially displaced from the axis of the spring 18. In either case, each cord passing through a respective eyelet 17 that is fixed to an internal surface of the housing 9 in axial alignment with the spring and that serves to slidably support the cord 16. Pressure on the closure element 15 in either direction thus applies an oblique force to the cord 16 and an axial force only to the spring 18.

Likewise, although the springs 18 are preferably anchored to an exterior wall of the housing 9 so as to be outside the air flow, they may also be mounted inside the housing. This is less satisfactory in that some force of the air blast is then directly applied to the springs, but it is nevertheless better than known designs in that the air passage is minimally obstructed, since the steel cords show a much reduced footprint to passing air than the much more massive springs.

FIGS. 9 and 10 show the impact of a blast wave to the elements of the valve shown in FIGS. 7 and 8 during the initial pressure phase. The valve plate 15 is pushed by the air blast to its utmost downstream position where it hits a seating 20. In doing so, the valve plate 15 pulls the cords 16 causing the springs 18 to stretch.

FIGS. 11 and 12 show the impact of the blast wave to the elements of the valve during the subsequent suction phase. The valve plate 15 is drawn to its utmost upstream position where it strikes the housing 9. In the process, the valve plate 15 pulls the cords 16 thereby stretching the springs 18.

FIGS. 13A to 13D show details of the spring 18 during different operational conditions of the valve. The springs have at least one end which is conical in shape, giving improved performance (smaller acceleration mass in the first moment of impact) and an increase in life time of the springs. FIG. 13A shows the spring prior to use

having a length of 61.6 mm. When mounted inside the valve, the spring is pre-stressed as shown in FIG. 13B where its length is 83.6 mm. FIG. 13C shows the spring during the pressure phase of the air blast, where its length is 93.6 mm and FIG. 13D shows the spring during the suction phase of the air blast, where its length is 123.6 mm. Thus during the blast cycle, the spring 18 increases in length by 10 mm during the positive pressure phase and by 40 mm during the negative suction phase.

FIGS. 14a to 14C show movement of the blast valve plate of a blast protection valve according to an embodiment of the invention. The blast valve plate can be flat or have at least at one side a convex shape, e.g. spherical. An important feature of the invention relates to the extent of linear movement of the blast valve plate as a multiple of the corresponding movement of the end of the spring. During the positive blast phase, the displacement of the valve plate was 50 mm compared to 10 mm for the spring, while during the negative suction phase the displacement of the valve plate was 118 mm compared to 40 mm for the end of the spring.

FIGS. 15A to 15C show details of the cords 16 in the respective operational conditions shown in FIGS. 14A to 14C. The eyelets 17 are anchored to the internal surface of the housing and facilitate sliding movement of the cords 16 during axial movement of the valve plate 15. To this end, the eyelets have a beveled channel that slidably supports the cord and which also serves to allow the cord to change direction without changing its angle of attachment to the springs. By such means, force applied obliquely to the cords is nevertheless translated to direct axial motion of the springs.

Although in the embodiments shown in FIGS. 7 to 15 the inelastic coupling element is constituted by a flexible cord, it will be appreciated that the principle of the invention as explained with reference to FIG. 6 may be realized using other approaches. For example, the inelastic coupling element could be constituted by rigid struts that are pivotably supported inside the housing in a manner similar to that shown in FIG. 6.

It should also be noted that the valve plate may have many different forms. Typically it is cylindrical in shape and is formed of material that is resistant to corrosion and temperature and has a thickness between 0.5 and 3 mm. By "cylindrical" is meant the surface formed by the volume of revolution about a line of points at a fixed distance from the line, forming an axis of the cylinder. In one embodiment, a downstream surface of the valve plate was generally spherical in shape and capable of withstanding a tensile stress in excess of 250 MPa.

CLAIMS:

1. Air blast protection valve (1) comprising:
 - a closure element (15) resiliently supported within a housing (9);
 - a plurality of elastically deformable elements (18) each having a respective first end that is anchored to a surface of the housing and each having a respective second end; and
 - a plurality of inelastic coupling elements (16) each anchored at a respective first end to the second end of at least one elastically deformable element and anchored at a respective second end toward a periphery of the closure element;
 - the inelastic coupling element being adapted to convert axial movement of the closure element caused by an air stream acting on the closure element in either direction to a reduced axial movement of the respective elastically deformable element or elements anchored thereto.
2. The air blast protection valve according to claim 1, wherein the inelastic coupling element comprises:
 - a flexible cord (9) having a first end anchored to the second end of the elastically deformable element and a second end anchored toward a periphery of the closure element; and
 - support means (17) anchored to an inside surface of the housing for slidably or pivotally supporting the inelastic flexible element intermediate the first end and the second end of the inelastic flexible element so that pressure on the closure element in either direction applies an oblique force to the inelastic flexible element and an axial force only to the elastically deformable element.
3. The air blast protection valve according to claims 1 or 2, wherein the elastic element is fixed to an external surface of the housing so as to be outside the air stream.
4. The air blast protection valve according to any one of claims 1 to 3, wherein each of the elastic elements is a spring.
5. The air blast protection valve according claim 4, wherein each spring has a reduced mass/length-ratio and an increased restoring force toward the second end of the spring compared to a remainder thereof.

6. The air blast protection valve according claim 5, wherein the spring at least the second end of each spring is conical in shape.
7. The air blast protection valve according to any one of claims 1 to 6, wherein the closure element is a valve plate of generally cylindrical shape formed of material that is resistant to corrosion and temperature and has a thickness between 0.5 and 3 mm.
8. The air blast protection valve according to any one of claims 1 to 6, wherein the closure element is a valve plate having a downstream surface of generally spherical shape and being capable of withstanding a tensile stress >250 MPa.
9. Use of the air blast protection valve according to any one of claims 1 to 8.