United States Patent

Forsythe

[15] **3,640,645**

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[54] **METHOD AND APPARATUS FOR ASPIRATING FLUIDS**

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[21] Appl. No.: **853,647**

[52] **U.S. Cl.** **417/174,** 417/176, 417/177, 417/185, 417/191, 417/196

[51] **Int. Cl.** **F04f 5/50,** F04f 5/18

[58] **Field of Search**....417/191, 190, 177, 176, 196, 417/174, 185; 230/110, 103, 95; 103/266

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Primary Examiner—Carlton R. Croyle
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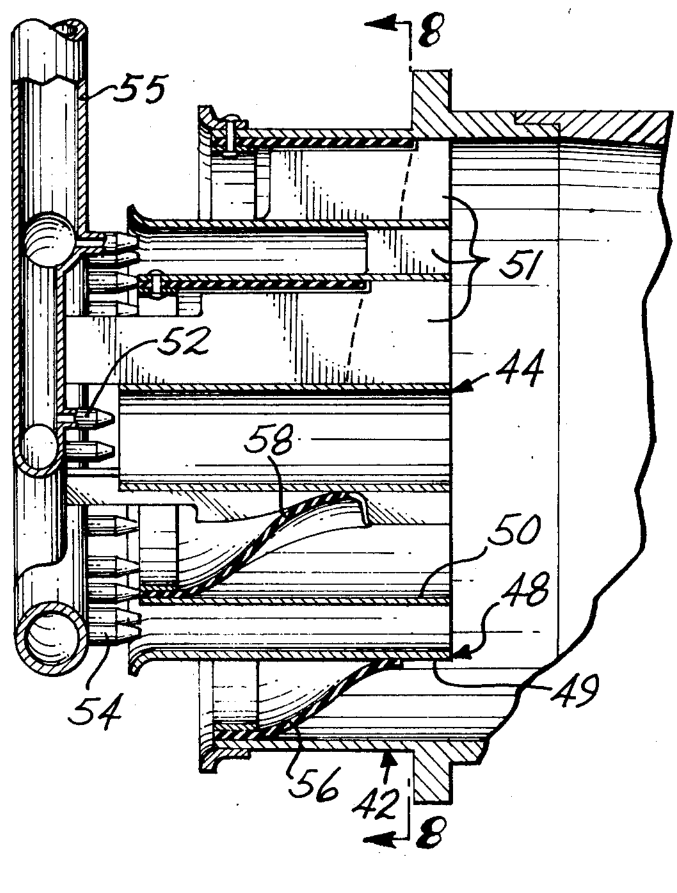
[57] **ABSTRACT**

An aspirator check valve in the form of a cylindrical sleeve which is restrained at its front end and along circumferentially spaced lines extending axially rearwardly from said front end, and is unrestrained in the remainder of its extent. The sleeve lies tight against an outer wall of the aspirator when open and when closed by back pressure buckles inwardly where unrestrained, to place rearward portions thereof tight against an inner wall. The upstream end restraining means includes a resilient band designed to flex radially inwardly in response to an over pressure, so that such sleeve also functions as an over pressure relief valve.

A shortened aspirator comprising a plurality of concentrically arranged primary and secondary flow passageways, and such an aspirator combined with the sleeve-type check valve.

20 Claims, 13 Drawing Figures



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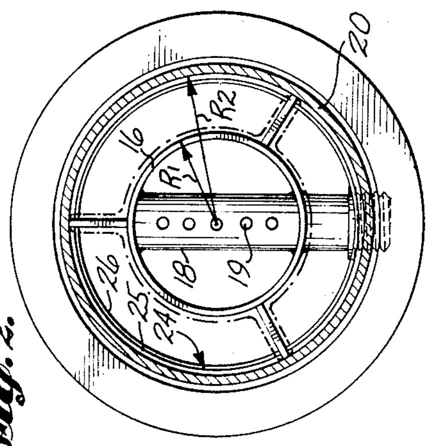


Fig. 2.

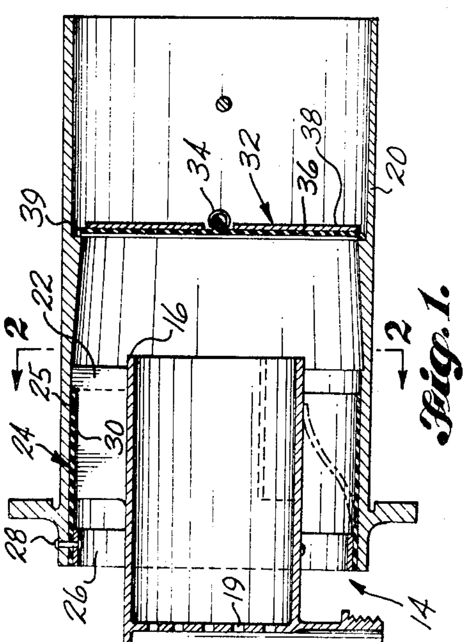


Fig. 1.

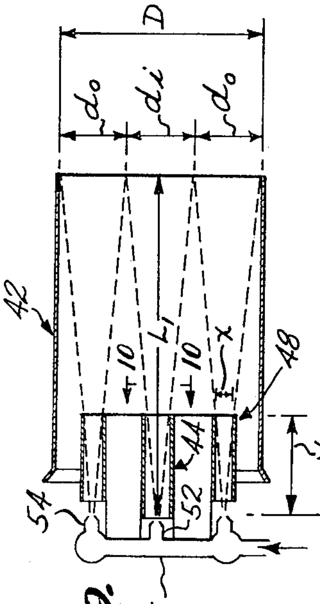
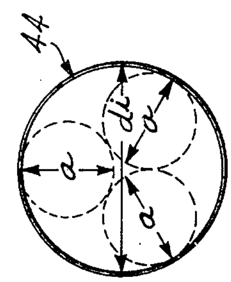


Fig. 9.



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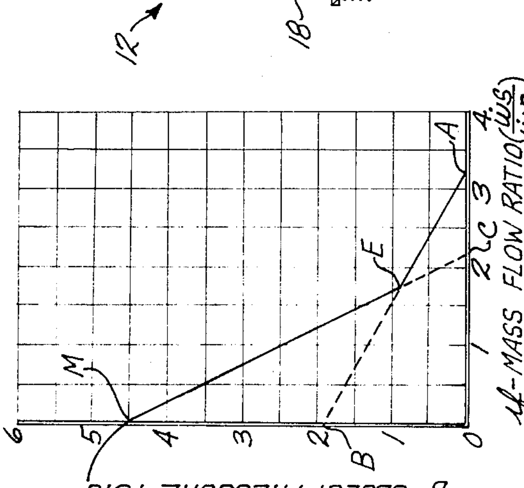

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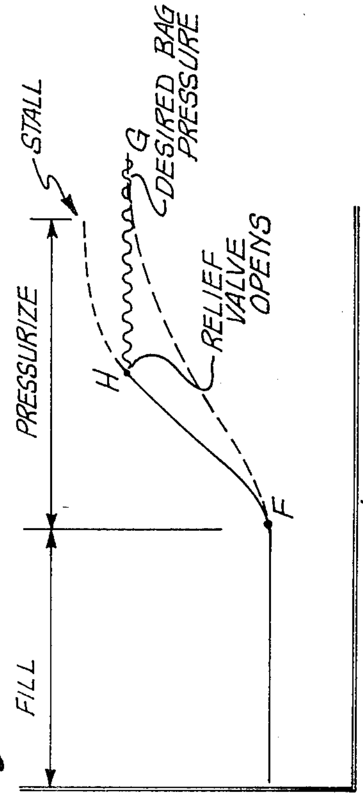

Fig. 4.

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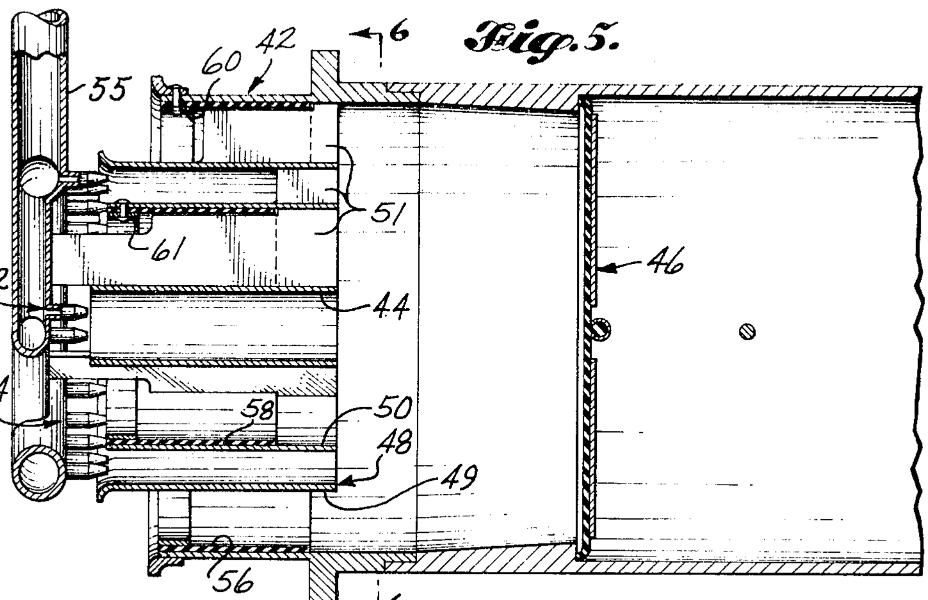
Fig. 5.



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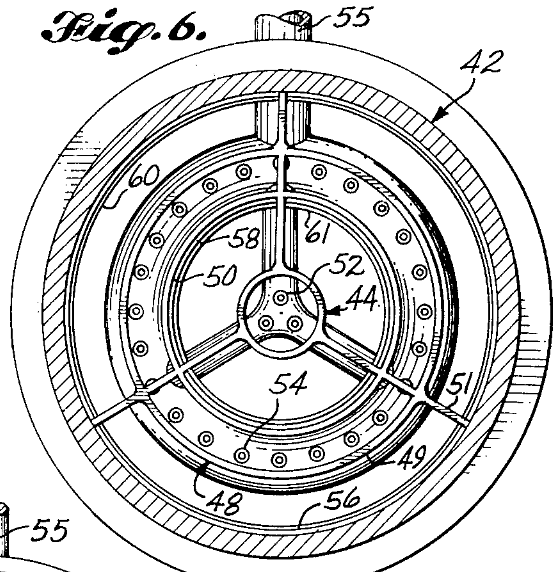


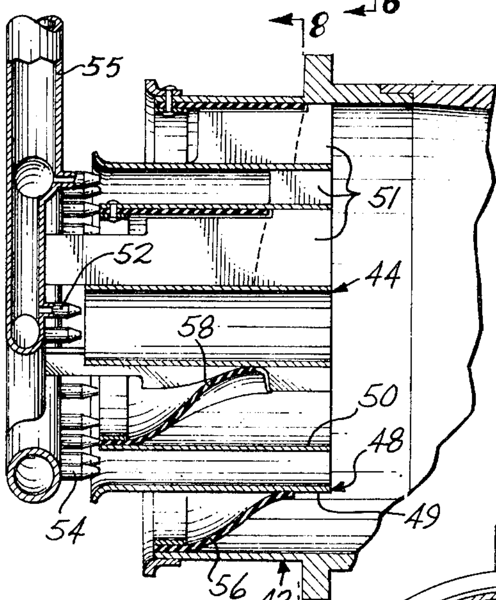
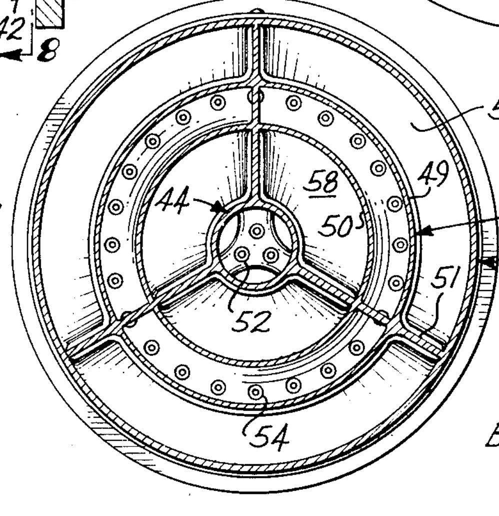


Fig. 7.

Fig. 8.



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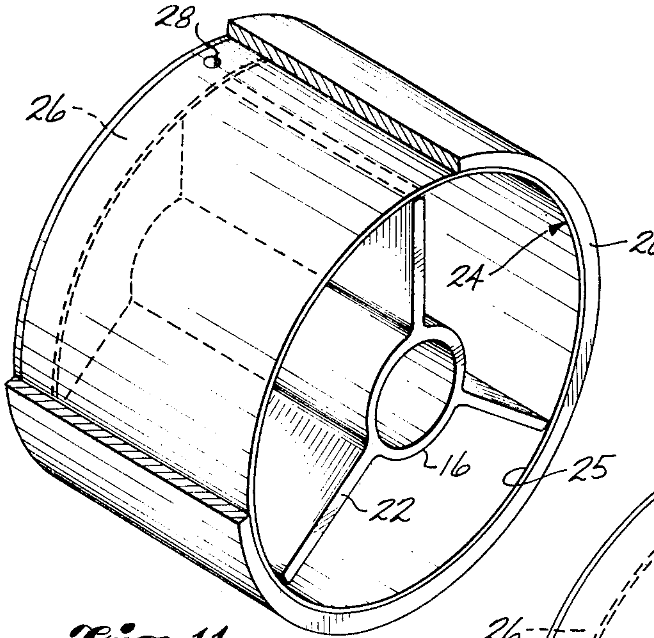

Fig. 11.

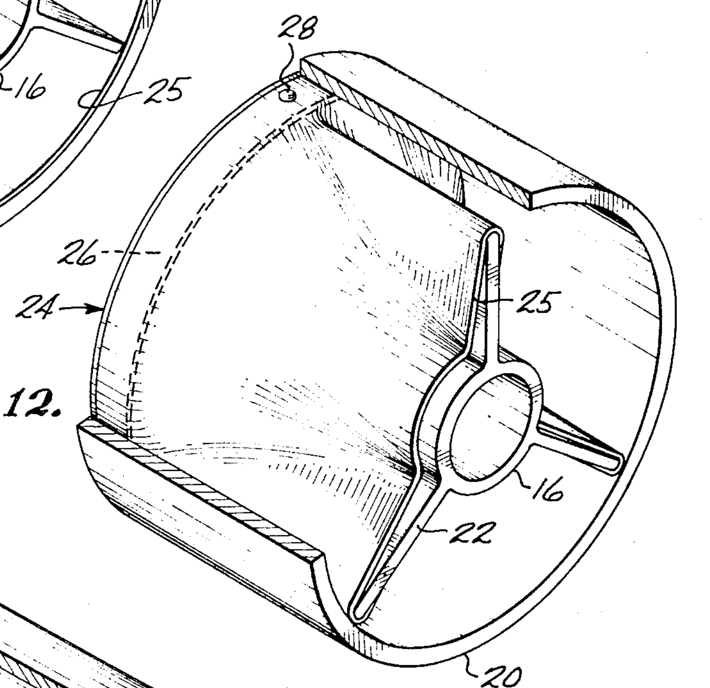

Fig. 12.

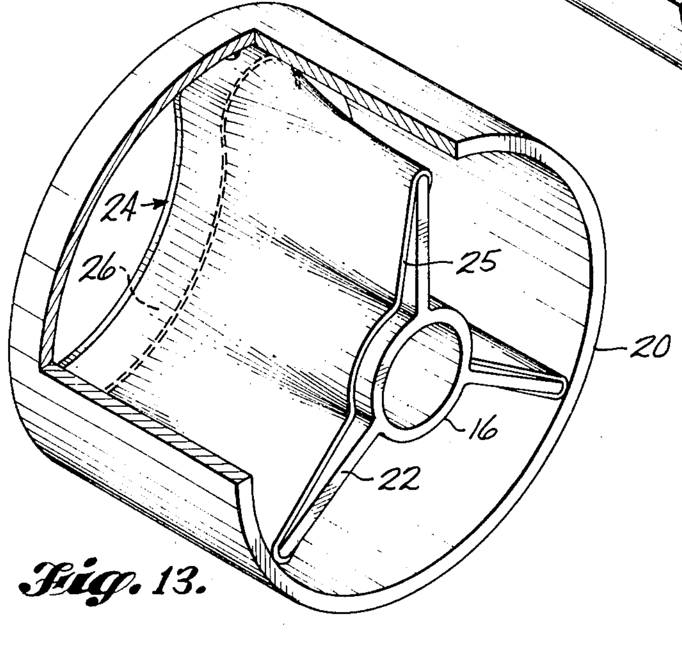

Fig. 13.

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METHOD AND APPARATUS FOR ASPIRATING FLUIDS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to aspirating methods and apparatus and, more particularly, those especially adapted for use in rapidly pressurizing inflatable objects.

2. Description of the Prior Art

A rapid inflation rate is a requirement of many inflatable objects, particularly those used with emergency devices, such as escape chutes and rafts.

Prior art aspirating devices aiming towards rapid inflation of these devices have generally taken one of two forms. The first form is exemplified by the aspirator shown in the patent to Neigel U.S. Pat. No. 2,859,908. An aspirating gas is introduced as a high-velocity stream into a venturi nozzle adapted to discharge into the object being inflated. The upstream end of the nozzle is open to the surrounding air and the high-velocity gas stream creates a suction to draw or aspirate ambient air into the stream for the purpose of increasing its volume. When the object is sufficiently inflated, and delivery of the aspirating gas has ceased, a check valve in the nozzle is closed by back pressure to prevent deflation.

A second form of inflation aspirator is shown in the patent to Crawford et al. U.S. Pat. No. 2,772,829. It is adapted for use in installations wherein the combined stream of aspirating gas and aspirated air, although of a high volume, is of an insufficient pressure to fully inflate the object. A check valve is provided to be closed by back pressure when the pressure in the object being inflated reaches the pressure of the air and gas stream. Aspiration of ambient air is then stopped; however, the gas flow is continued and it, by itself being of a higher pressure than the gases in the object, continues to inflate the object.

Improved inflation techniques and apparatuses are disclosed in U.S. Pat. Nos. 3,460,746 and 3,460,747, owned by the assignee of the present invention. In the devices of these patents gases are aspirated through two stages. The first stage operates at a low pressure and high volume to rapidly fill the object to a low pressurization. When this low pressure is reached, the second stage is disabled by the action of back pressure acting against an annular flap-type check valve and further pressurization occurs at decreased volume but higher pressure by the first stage aspirator alone.

SUMMARY OF THE INVENTION

This invention is directed to the aspiration of fluids and particularly, although not necessarily limited to, the aspiration of fluids for the purpose of inflating an object. A feature of the invention is a sleeve-type check valve which prohibits backflow from the second stage of the aspirator. The sleeve is highly responsive and is self-sealing. It is also simple and inexpensive to manufacture and is virtually foolproof in operation.

Another feature is a combined secondary stage check valve and excessive pressure relief valve. The sleeve-type check valve lends itself to this dual use. The upstream end of the sleeve is secured to a resilient band. Relief of the excess pressure is accomplished by the excess pressure flexing the band radially inwardly to break the seal between the front end of the sleeve and the support wall therefor.

Still another feature is the concept of shortening the overall length of the aspirator by employing a plurality of injection nozzles as a substitute for a single nozzle. The nozzles are preferably also arranged at two locations, namely, centrally and in an annulus about the longitudinal axis of the duct. As the sleeve-type check valve is secured to the wall of the aspirator, it lends itself well to use in the combined multistage, multinozzle aspirator. By combining these concepts, the resulting aspirator is short, simple to operate and can produce high volume, high pressure, or both for any number of useful applications.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a longitudinal section of a two-stage aspirator employing a sleeve-type check valve;

FIG. 2 is a vertical section taken along line 2—2 of FIG. 1;

FIG. 3 is a graphical illustration showing the pressure-flow characteristics of the aspirator;

FIG. 4 is a graphical illustration showing the pressure-time characteristics of a two stage aspirator and comparing the time required to pressurize using the overpressurization relief valve versus customary pressurization without a relief valve;

FIG. 5 is a longitudinal section of a multistage aspirator employing a multinozzle injector;

FIG. 6 is a vertical section of the injector shown in FIG. 5 taken along the line 6—6 in FIG. 5;

FIG. 7 is a fragmentary longitudinal section of the aspirator shown in FIG. 5 with the sleeve-type check valve closed;

FIG. 8 is a vertical section of the aspirator shown in FIG. 7 taken along the line 8—8 of FIG. 7;

FIG. 9 is a schematic illustration of the spray cone pattern of the aspirator shown in FIGS. 5–8;

FIG. 10 is a schematic illustration of the inner tube as taken along the arrows 10—10 of FIG. 9; and

FIGS. 11, 12 and 13 are isometric operational views of a two-stage aspirator showing; in FIG. 11 fluid being aspirated in both stages; in FIG. 12 the second stage being closed by the radial inward movement of the downstream edge of the sleeve; and in FIG. 13 the excess pressure overcoming the elasticity of the resilient band to unseal the upstream edge of the sleeve.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The aspirator shown in FIGS. 1 and 2 comprises first and second stages 12 and 14, respectively. The first stage includes an inner duct 16 and an injector 18 having a plurality of orifices 19 for introducing the aspirating fluid. As in the aforementioned U.S. Pat. Nos. 3,460,746 and 3,460,747 the aspirating fluid is preferably a relatively high pressure, cool gaseous product caused by a mixture of hot gases, such as the products of combustion of ammonium nitrate type solid fuel grain, and a stream of a cold liquid refrigerant, such as a pressure liquefied fluorinated hydrocarbon. Other pressurized gases may be used; however, the advantage of using the foregoing aspirating fluid is that it exhibits a "no droop" characteristic which is highly advantageous for inflation applications. The inner duct 16 is positioned centrally inside an outer duct 20 forming the outer wall of the aspirator. Three evenly spaced radial support plates or struts 22 rigidly interconnect the inner and outer ducts. For second stage operation air is aspirated through the inner duct 16 and the annular opening between the inner and outer ducts. As is quite apparent the effective area of the second stage is considerably greater than for the first stage. In the preferred embodiment the area ratio is 3.85:1; however, this ratio is determined by the requirements of the aspirator and thus is not to be considered limitive.

A check valve 24, in the form of a cylindrical flexible sleeve or wall section 25 of rubberized fabric or the like, is provided to close off the annular space between the inner and outer ducts when operation is confined to the first stage. The cylindrical sleeve is attached at its upstream ends to a flexible resilient band 26. The band functions as a relief valve if such is desired, and will be described in more detail below. Should the relief function not be desired the band may be eliminated and the upstream end of the sleeve 25 secured directly to the inside surface of the outer duct 20 or the band may be made sufficiently stiff to preclude flexing. In the preferred embodiment, the band, and thus the sleeve 25, is secured at spaced points adjacent the strut 22 by suitable fasteners, such as pins 28. The struts are cut away as at 30 in the region of the cylindrical sleeve so that the sleeve fits within the struts and is clamped at three equidistantly spaced points about the inside surface of the outer duct.

A main check valve 32 is positioned downstream of the inner duct 16 and includes a hinge 34 which supports a circular sheet of rubberized fabric 36 that is strengthened with reinforcing disks 38 of aluminum or the like 38. As described in the aforesaid U.S. Pat. Nos. 3,460,746 and 3,460,747, the main check valve 32 opens under the pressure of the incoming fluid and remains open until the pressure within the inflatable object is sufficient to close the valve into the position shown in FIG. 1. An annular ledge 39 is provided in the outer duct 20 to serve as a seat for the main check valve.

During second stage aspiration, the sleeve 25 is generally cylindrical in form and closely hugs the inner surface of the outer duct 20. When backflow commences, as a result of the pressure of the gases in the inflated object exceeding the pressure of the fluid aspirated in the second stage, the strongest backflow is generally along the inner surface of the outer duct 20. As a result the backflow of gases catches the loose downstream edge of the sleeve between the struts 22 and moves these edges radially inward. Pockets are thus formed circumferentially between the struts and radially against the inner duct 16 and the struts 22. The closed position of the sleeve is shown in phantom in FIG. 2 with the sleeve actually hugging the opposed surfaces of the struts and the outside surface of the inner duct 16.

An important feature of the invention is the fact that the perimeter drawn around the struts and the inner duct, the circumference of the sleeve, and the circumference of the inside surface of the outer duct 20 are related and this relationship may be varied to suit the application to which the aspirator is to be used. In the preferred form of the invention, it is desired that the circumference of the sleeve be approximately equal to the perimeter drawn around the struts and the inner duct so that it tightly hugs the struts and inner duct when closed. By the same reasoning, it is desirable that the circumference of the sleeve be approximately equal to the circumference of the outer duct so that it tightly hugs the outer duct when in the open position. There are many ways to obtain this substantial equality. One approach is merely to vary the circumference of the inner duct or the thickness of the struts. Another approach is to add appendages or the like from the inner duct to increase the perimeter. In the preferred form the substantial equality is obtained by using a preferred number of struts. In the preferred embodiment, three struts are employed to bring about the substantial equality. The equality results from the fact that the circumference of the inside surface of the outer duct is greater than the circumference of the outside surface of the inner duct by an amount equal to 2×3.1416 × the difference in their respective radii at these two points, R_2–R_1 in FIG. 2. In other words, the difference in circumference between the outer duct and the inner duct is approximately $6.28\times(R_2-R_1)$. If the circumference of the sleeve is equal to the circumference of the outer duct, the excess material must be distributed over the struts. The radial length of each strut is, of course, equal to (R_2-R_1). Since each strut has two opposed surfaces, three struts will use $6\times(R_2-R_1)$. It can thus be seen that only $0.28\times(R_2-R_1)$ remains to be distributed as surplus over the struts and inner ducts, that is, the perimeter of the struts plus the perimeter of the inner duct will equal 6 of the required $6.28\times(R_2-R_1)$. The $0.28\times(R_2-R_1)$ remaining is easily distributed about the struts and the inner duct resulting in a substantially tight fit between the sleeve and the struts and inner duct when in the closed position.

The principles of staging the aspiration of fluids into the inflatable object is best explained with reference to FIG. 3. The line drawn between 3.2 (point A) on the horizontal scale to the 2 (point B) on the vertical scale represents the flow rate of fluid into the inflatable object using the second stage of the aspirator alone. Actually the data is expressed in terms of a flow ratio of secondary fluid, i.e., aspirated fluid, divided by primary fluid, i.e., aspirating fluid; however, assuming a constant flow of primary fluid, the ratio represents the total flow into the inflatable object. The lines drawn between 2.2 (point C) on the horizontal scale and 4.5 (point M) on the vertical scale represents the flow rate using the first stage aspirator alone. It can readily be seen that the second stage aspirator, although producing a high volume of fluid out of the aspirator, can reach only a relatively low pressure whereas the first stage of the aspirator, although it has a low flow rate can produce a much higher pressure. The combination of the stages, that is, by stopping the second stage when the pressure in the inflatable reaches approximately 0.9 p.s.i.g. (point E) in the preferred embodiment, results in an initial high flow rate and a final lower flow rate but a relatively high pressure. The slope of this curve is best illustrated by the solid black line in FIG. 3.

The relief valve feature is shown in FIG. 1 and in the operational views in FIGS. 11–13. The upstream end of the sleeve 30 is bonded or otherwise secured to the resilient band 26. The band is of a circumference approximately equal to the inside surface of the outer duct 20 so that the sleeve is pressed into sealing engagement with the outer duct. In FIG. 12 the sleeve is shown formed into pockets to stop the backflow of gases when only the first stage is used. In FIG. 13 the backflow pressure exceeds the pressure required to deform the band such that the band moves inwardly relieving the pressure. In operation, the band is designed to flex when the desired pressure of the inflatable is reached and vibrates between the open and closed position to maintain such pressure.

By the use of this or a similar relief valve a method of inflation is permitted that uses a source of pressure higher than the desired final inflatable pressure. The method is best illustrated with reference to FIG. 4 in which the dotted line (between F and G) represents the customary practice of using a pressure source which at its maximum is approximately equal to the desired inflatable pressure. In the solid curve of the figure the use of the relief valve is shown. In this curve the second stage operates to point F to fill the object at a relatively constant low pressure and as the pressure begins to build up in the object and the second stage of the aspirator is closed, the curve proceeds at a much steeper slope to point H than in the dotted curve because the pressure source used for the solid curve is substantially greater than the desired object pressure. At point H where the relief valve, i.e., band 26, opens, the pressure is relieved and as the relief valve vibrates between the open and closed position the desired object pressure is maintained along the wavy line between points H and G. Thus the desired pressure is achieved sooner.

In the device shown in FIGS. 5–8 the aspirator is provided with an outer duct or conduit 42 and an inner duct or conduit 44. The aspirator also includes a check valve 46 identical to the check valve 32 of FIG. 1. In addition the aspirator shown in FIG. 5 includes an annular duct 48 having an outer surface 49 and an inner surface 50. The inner and annular ducts are mounted in the outer duct by suitable struts 51 similar to those of FIG. 1. A plurality of central nozzles 52 are provided for introducing aspirating fluid into the inner duct 44. A ring of nozzles 54, 24 in number in the preferred embodiment, are joined together and with the central nozzles 52 by a common pipe 55. The ring of nozzles injects aspirating fluid into the annular duct 48. An outer cylindrical sleeve-type check valve 56 is provided between the annular duct 48 and the outer duct 42. An inner sleeve-type check valve 58 is provided between the annular duct 48 and the inner duct 44. The valves 56 and 58 are identical to and operate in the same manner as the valve 24 shown in FIG. 1. The second stage is shown in operation in FIGS. 5 and 6 with the sleeves lying flat against the surface 50 of the annular duct 48 and the inside wall of the outer duct 42. When the pressure in the inflatable reaches a sufficient level to close the second stage, back pressure moves a stream of gases along the inner wall of the outer duct 42 and the inner surface 50 of the annular duct 48 to close the sleeves as shown in FIGS. 7 and 8. Aspiration from this point on takes place through the first stage alone with a reduction ratio in aspirating area of approximately 3.85 to 1. Further aspiration in the first stage is continued until the desired object pressure is reached at which time the gases back pressure deforms the resilient bands 60 and 61 to act as relief valves. When final pressurization is reached, that is the supply pressure diminishes to a level below the pressure in the object, the main check valve **46** is closed and the object remains fully inflated.

FIG. **10** illustrates in principle the technique for shortening the overall length of the aspirator without substantially affecting the aspirating efficiency of the device. In principle, a nozzle, such as those used in embodiment of FIGS. **5–8**, which are of diameters in the range of 0.1 inch, emits a spray in the form of a cone. It has been found that optimum mixing of the aspirating fluid emitted from the nozzle with the aspirated air surrounding the nozzle occurs along the boundary of this cone. The angle of divergence of the cone may be defined by the ratio of the length L of the spray cone at its point of intersection with the duct to the diameter D of the duct and preferably is between 6–9 to 1. This L/D ratio establishes the length of the aspirating duct when a duct of a predetermined diameter is desired. The diameter of the duct in the preferred embodiment of FIGS. **5–8** is, for example, 6 inches. To satisfy the L/D ratio it therefore is necessary that the length of the duct be 6–9×6 inches or a minimum of 36 inches. To utilize such a long duct in an aircraft slide inflation device is impractical.

The technique employed to shorten the effective length of the duct is to cluster a plurality of nozzles or preferably to cluster a ring of nozzles in an annulus around a central nozzle or cluster of nozzles, as shown for example in FIG. **6**. The theoretical shape of the spray cones emitted from these nozzles is best shown in longitudinal section in FIG. **9**. Thus assuming an L/D ratio of 6 and a duct diameter of 6 inches, it can be seen that the ring of nozzles **54** surrounding a central or nozzles **52** will provide in diametrical cross section a series of three spray cones, having diameters d_o and d_i respectively, filling the 6-inch diameter D of the duct. Each of the cones is equal to one-third of the diameter D of the duct at their points of contact. Consequently, the duct is substantially filled, but the lengths L, of the cones required to fill the duct has been decreased by a factor of 3 so that the approximate length of the duct using the plural nozzle configuration of FIG. **9** is only 12 inches. The optimum configuration of the sprays emitted from the annulus is an annular slit of approximately 10/1,000 of an inch in width. To manufacture such a device having a slit with such a dimension would be too expensive if at all possible. Thus the alternative is to approximate a slit by arranging a ring of nozzles, **24** in the preferred embodiment, each having an opening of approximately 0.07 inch. It is, of course, recognized that lesser numbers of larger nozzles or that additional rings of nozzles may also be used.

The concept of the annular ring of nozzles to shorten the length of the duct is, as shown in FIGS. **5–10**, also advantageously employed with the staging principles of the aspirator. In general the desired duct area of the aspirator for the second stage operation, that is, when check valves **56** and **58** are open, is based on a size limitation determined by the application for which the aspirator is to be used. In the preferred embodiment this second stage duct area is approximately 27 square inches. The first stage area (area of inner duct **44** and annular duct **48**) is based in part upon optimum pressure-pumping considerations rather than size. In other words, it is known that the nozzles must produce sufficient aspirating pressure to inflate the object to its desired pressure and this pressure is arrived at primarily as a function of cross-sectional area. In one preferred form shown in FIGS. **5–8** the desired pressure for the first stage at an aspirating fluid flow rate of 1.5 1b.m./sec. is 2.5 p.s.i.a. and requires a first stage area of 7 square inches. In the second stage about one-ninth of the cross-sectional area of the duct as shown in FIG. **9** is occupied by the central spray cone or cones and eight-ninths of the area is occupied by the ring of spray cones. This balance is desired to be maintained in the first stage. Thus two criteria are used to establish the configuration of the first stage of the aspirator. The first is the desired cross-sectional sectional area, for the preferred form 7 square inches, and the other is the maintenance of balance such that eight-ninths of the flow will occur through the annular duct **48** of the first stage and one-ninth will occur through the inner duct **44**. In other words, if the desired cross-sectional area of the first stage is to be 7 square inches, eight-ninths of this or 6.2 square inches must be the cross-sectional area of the annular duct **48** and 0.8 square inches must be the cross-sectional area of the inner tube **44**. Using this relationship, it can be seen then that the diameter of the inner tube, using

$$d=\sqrt{\frac{4}{\pi}A}$$

must be approximately equal to

$$d=\sqrt{\frac{4}{\pi}A}$$

or approximately 1 inch.

A further complication arises from the fact that at the downstream ends of the inner duct **44** and the annular duct **48** the diameter of the spray cones in the annular duct **48** are each approximately one-half inch as indicated by reference character x in FIG. **9**. Consequently at this point along the length of the aspirator the diameter of a single spray cone in the inner tube **44** would also be one-half inch. Since the required diameter of the inner cone, that is, the diameter necessary to satisfy the area requirement of 0.8 square inches, must be 1 inch, as derived above, it is necessary to expand the diameter of the cone by using a plurality of central nozzles in the same manner as described above to shorten the overall length of the aspirator. It of course should be noted that the L/D discussion pertinent to the second stage also applies to the first stage, that is, Y/X as shown in FIG. **9** must also be about 6–9 to 1. In the preferred form of the invention, three nozzles are used to arrive at an effective diameter at the downstream end of the first stage of the inner tube **44** which is equivalent to a 1-inch diameter. This of course will produce an overlap of the spray cones at the downstream end of the second stage but this overlap does not effect the operation of the aspirator to any substantial degree.

While several embodiments of the invention have been illustrated, these forms have been selected for the purpose of description only and are not to be considered as restrictive.

What is claimed is:

1. In an aspirator including a first passageway that is outwardly bounded by a first tubular wall, means for establishing a flow of fluid generally axially through said first passageway, and a second tubular wall spaced radially outwardly from said first tubular wall, said tubular walls together forming an aspirated fluid passageway radially between them, said passageway having an ambient air inlet and an outlet positioned to discharge the aspirated fluid into admixture with the fluid flowing through said first passageway, the improvement comprising:

a check valve comprising a flexible tubular sleeve having an upstream end, support means extending about said upstream end and normally supporting said upstream end tight against said second tubular wall, and additional support means normally holding said sleeve against said second tubular wall along a plurality of circumferentially spaced-apart lines extending generally axially rearwardly from said forward end, with said sleeve being sized to lie substantially tight against said second tubular wall when ambient air is flowing inwardly through said aspirated air passageway, and with said sleeve being substantially unrestrained rearwardly of said upstream end support means and between said additional support means, so that backflow through said aspirated air passageway will move the unrestrained portions of said sleeve radially inwardly and will hold downstream end parts thereof tightly against said first tubular wall.

2. The improvement of claim **1**, wherein said additional support means comprises radial support plates extending between said first and second tubular walls in axial planes.

3. The improvement of claim 2, wherein said support plates are three in number.

4. The improvement of claim 2, wherein said support plates are connected to said second tubular wall at locations rearwardly of said sleeve and are each recessed at their outer ends in the region of the sleeve, with the sleeve being clamped between the recessed portions of said support plates and the second tubular wall.

5. The improvement of claim 1, wherein the support means for the upstream end of said sleeve includes a resilient band, and means securing said band to said second tubular wall at points in common axial planes with said additional support means, said resilient band having sufficient elasticity to hold the entire upstream end of said sleeve outwardly against said second tubular wall during one level of back pressure within the aspirator but being deformable inwardly between said securement points to disengage the sleeve from said duct inner wall at a higher level of back pressure, so that said sleeve-type check valve also functions as an overpressure relief valve.

6. The improvement of claim 5, wherein said additional support means comprises radial support plates extending between said first and second tubular walls in axial planes.

7. The improvement of claim 6, wherein said struts are three in number and wherein said means for securing said band includes means for fastening said band to said struts.

8. A successive entrainment aspirator, comprising:

a first wall forming a first primary flow passageway having an inlet in communication with ambient air;

injector means arranged to introduce an aspirating fluid into said first inlet, with said aspirating fluid serving to aspirate ambient air into said first passageway;

a second wall circumscribing said first wall and being spaced radially therefrom to form an annular first wall secondary flow passageway therebetween having an inlet in communication with ambient air;

a third wall circumscribing said second wall and being spaced radially therefrom to form an annular second primary flow passageway therebetween having an inlet in communication with ambient air;

a fourth wall circumscribing said third wall and being spaced radially therefrom to form an annular second secondary flow passageway having an inlet in communication with ambient air, and with said fourth wall extending downstream a substantial distance downstream of the other walls, so as to form a large diameter total flow passageway downstream of the other said passageway;

second injector means arranged to introduce an aspirating fluid into said second primary flow passageway, with said aspirating fluid serving to aspirate ambient air into said second primary flow passageway, and with flow through said primary flow passageways serving to aspirate ambient air into said secondary flow passageways; and

check valve means in said annular first and second secondary flow passageways, for precluding backflow of fluids through such secondary flow passageways.

9. The aspirator defined by claim 8, wherein said valve means each includes a flexible, cylindrical sleeve having its upstream peripheral edge substantially sealed against the outer wall of its respective passageway and its downstream edge secured at spaced points also to said respective outer walls.

10. The aspirator defined by claim 9, further including a resilient band secured at spaced points to the outer wall of said third annular passageway and secured to the entire upstream peripheral edge of said sleeve whereby said band presses said upstream peripheral edge of said sleeve against said outer wall to form said seal but is biased inwardly to break said seal when a desired predetermined pressure is obtained downstream of said sleeve.

11. In an inlet assembly for an inflatable including wall means defining an ambient air inlet passageway for the inflatable, and nozzle means for injecting an aspirating fluid into and through said passageway, for entraining ambient air into said inflatable, the improvement comprising:

said wall means including a radially movable wall section which initially occupies a flow bounding position in which the ambient air passageway is substantially completely open to ambient air and the flow rate of ambient air into the inflatable is relatively large, the said wall section having an outer surface in position to be subjected to back pressure within said inflatable so that when back pressure reaches a predetermined level it forces the movable wall section radially inwardly into a position reducing the size of the ambient air passageway, and means for limiting the extent of radially inward movement of said wall section so that when said wall section is in a radially inward position it blocks flow through an outer region of the ambient air passageway but a reduced size inner flow path remains which is sized to function effectively with said nozzle means for pumping ambient air into the inflatable at a decreased flow rate but at a higher pressure.

12. The improvement of claim 11, wherein the means for limiting the extent of radial inward movement of said wall section comprises a generally centrally positioned tubular duct.

13. An inlet member for an inflatable object comprising:

a cylindrical duct secured to said inflatable object and having an inner boundary;

central nozzle means arranged at the upstream end of said duct for injecting at least one generally central, generally conical jet along the longitudinal axis of said duct;

an annular array of additional nozzle means arranged equidistantly around said longitudinal axis between said duct inner boundary and said central nozzle means for injecting a plurality of outer, generally conical jets around said central jet, said additional nozzle means being positioned inwardly of said duct inner boundary about one-third of the radius of said duct and said central and outer jets generally intersecting one another at a location along said duct whereat the outer jets engage the inner boundary of the duct, said location of intersection being spaced longitudinally from said nozzles a distance equal to about 6 to 9 times the diameter of the duct divided by the number of diametrically arranged conical jets at said point of intersection; and

valve means for preventing unwanted backflow from the inflatable object through said inlet member when the inflatable object is inflated.

14. An inlet member for an inflatable object comprising:

a cylindrical duct secured to said inflatable object and having an inner boundary;

central nozzle means arranged at the upstream end of said duct for injecting at least one generally central, generally conical jet along the longitudinal axis of said duct;

an annular array of additional nozzle means arranged equidistantly around said longitudinal axis between said duct inner boundary and said central nozzle means for injecting a plurality of outer, generally conical jets around said central jet;

wall means forming an inner first-entrainment duct and an outer annular first-entrainment duct each aligned respectively with said central nozzle means and said additional nozzle means, said inner duct and said outer annular duct forming a first second-entrainment passageway therebetween and said outer annular duct and said cylindrical duct forming a second second-entrainment passageway therebetween, and means for sealing said passageways against a backflow; and

valve means for preventing unwanted backflow from the inflatable object through said inlet member when the inflatable object is inflated.

15. The aspirator defined by claim 14, wherein the cross-sectional area of said outer annular duct is about 8 times the cross-sectional area of said inner duct.

16. The aspirator defined by claim 14, wherein said central nozzle means includes at least three equidistantly spaced nozzles.

17. The aspirator defined by claim 14, wherein said means for sealing said first and second second-entrainment passageways includes inner and outer flexible, cylindrical sleeves.

18. The aspirator defined by claim 14, wherein said inner, first-entrainment duct wall means and said outer annular first-entrainment duct wall means are secured in place within said cylindrical duct by strut means having recessed portions therein, said means for sealing said first and second second-entrainment passageways including inner and outer flexible, cylindrical sleeves nested in said recessed portions of said struts and secured at their upstream peripheral edges to said annular first-entrainment duct wall means and said cylindrical duct, respectively.

19. The aspirator defined by claim 17, wherein said upstream peripheral edges of said sleeves are secured to resilient bands that are fastened at spaced points to said annular first-entrainment duct wall means and said cylindrical duct, whereby said bands press said upstream peripheral edges of said inner and outer sleeves against said annular first-entrainment duct wall means and the inner wall of said cylindrical duct, respectively, to seal but are biased inwardly to break the seal when a predetermined pressure is obtained downstream of said sleeves.

20. A successive entrainment inflation aspirator comprising an inlet tube for an inflatable, said tube having inlet and outlet ends;

valve means in said inlet tube for completely closing same and preventing outflow from the inflatable;

wall means in said inlet tube dividing the interior of the inlet portion of said inlet tube into at least one first-entrainment passageway and at least one second-entrainment passageway each of which is in communication with ambient air, said first-entrainment passageway surrounding said second-entrainment passageway;

nozzle means arranged to inject an aspirating fluid through said first-entrainment passageway, with said aspirating fluid and the ambient air entrained thereby serving as an aspirating fluid for said second-entrainment passageway said nozzle means comprising a circular array of nozzles directed to discharge axially of the first-entrainment passageway; and

valve means in said second-entrainment passageway for disabling it independently of said first-entrainment passageway.

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