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[54] METHOD AND APPARATUS FOR GENERATING GASEOUS MIXTURES FOR INFLATABLE DEVICES

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[52] **U.S. Cl.** .... **141/4**, 9/11 A, 9/321, 23/281, 62/48, 222/3

[51] **Int. Cl.** **B65b 3/04**

[58] **Field of Search** .... 141/4; 9/11 A, 316, 319, 9/321, 325, 311; 222/3; 62/48; 23/281; 280/150 AB; 102/39

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[57] ABSTRACT

A pyrotechnically operated inflating apparatus is disclosed for generating gaseous inflation mixtures of carbon dioxide and combustion products of propellants. The apparatus includes a container for storing primary fluid inflation media. A control head is mounted on the container to govern the discharge of the primary fluid into an inflatable. The control head is provided with an internal space containing a pyrotechnic charge to generate, upon ignition, high temperature gases as secondary inflation media. A quantity of the secondary media is initially diffused throughout the container to elevate the pressure of the primary media to effect discharge from the container. The remainder of the secondary media is mixed with the discharging primary media at a downstream outlet orifice within the control head immediately prior to entry into the inflatable.

13 Claims, 5 Drawing Figures

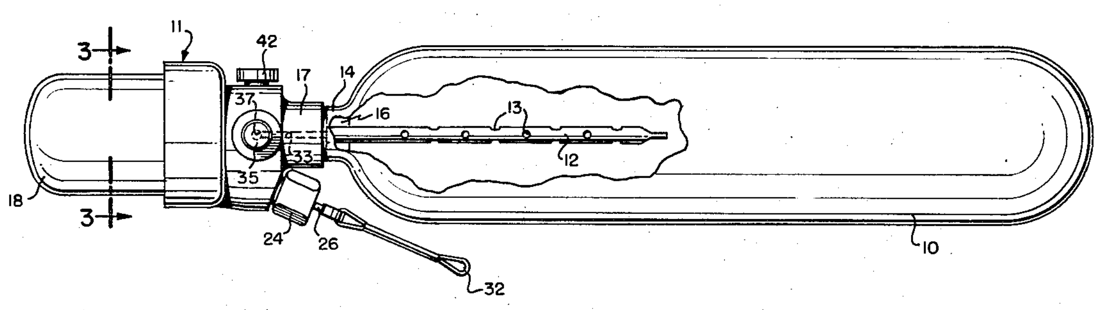

FIG. 1

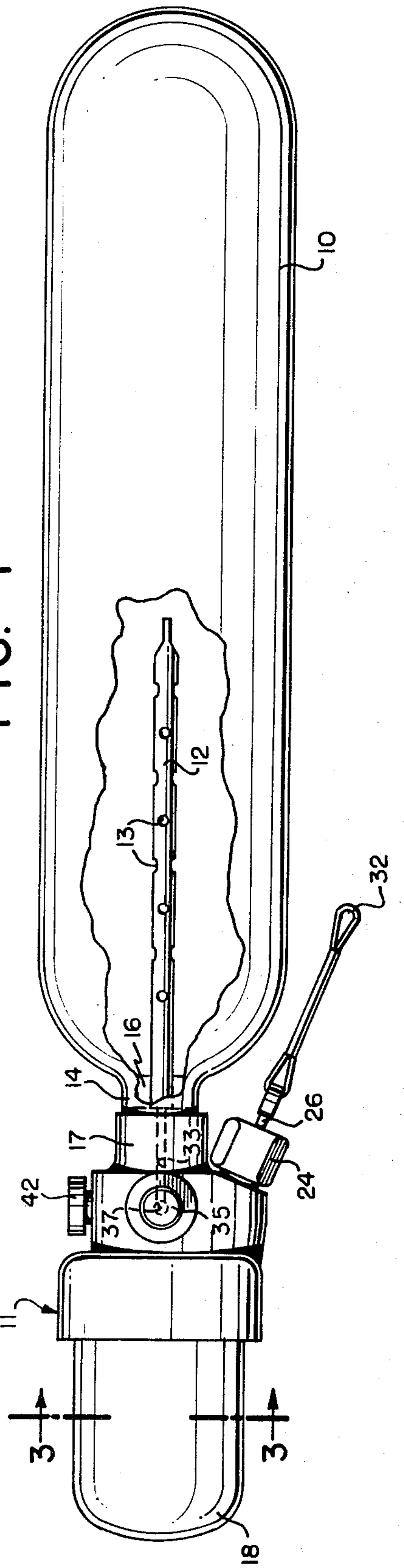
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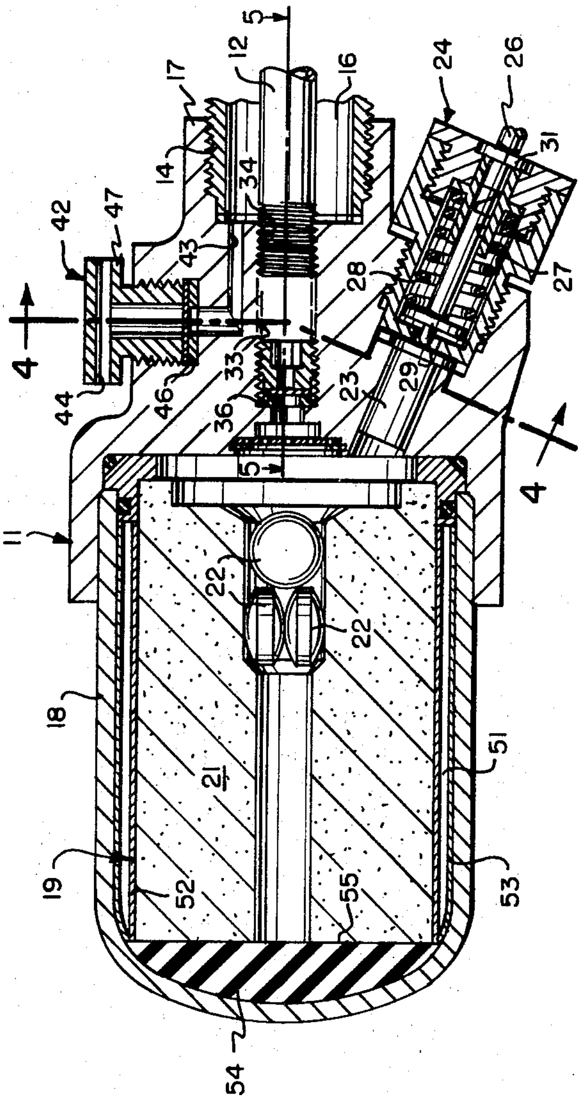
FIG. 2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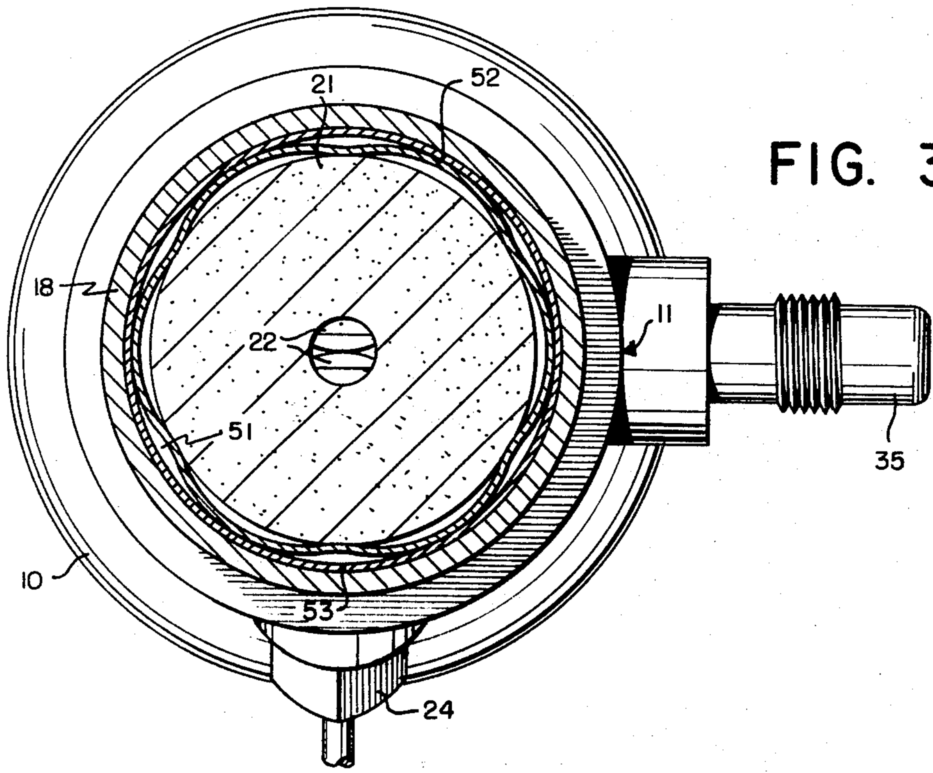
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FIG. 3

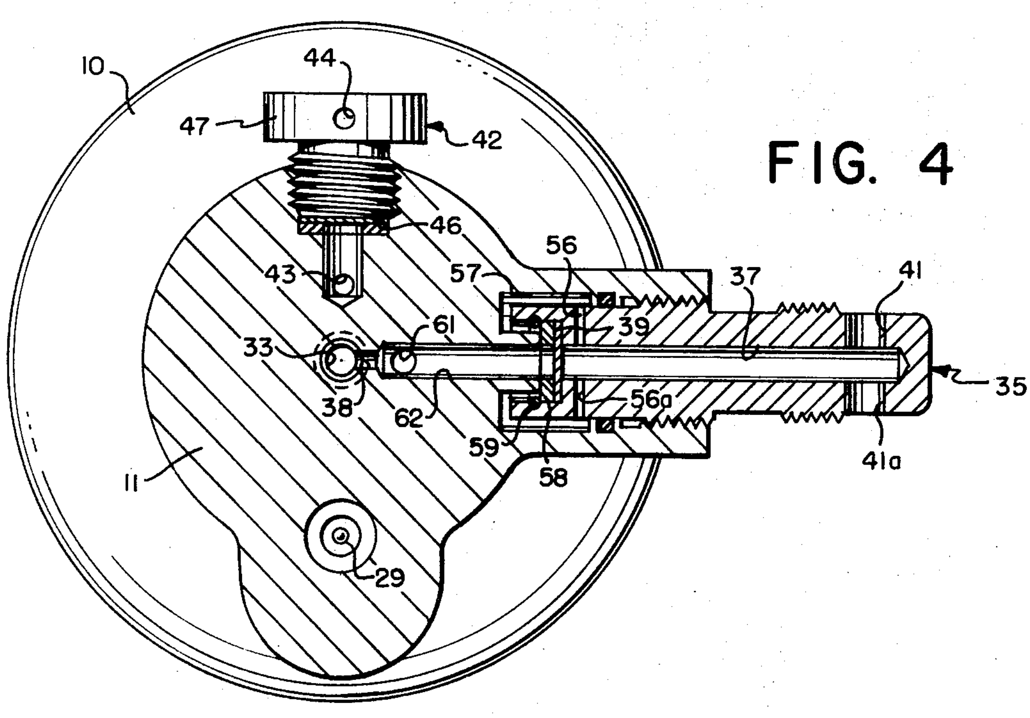
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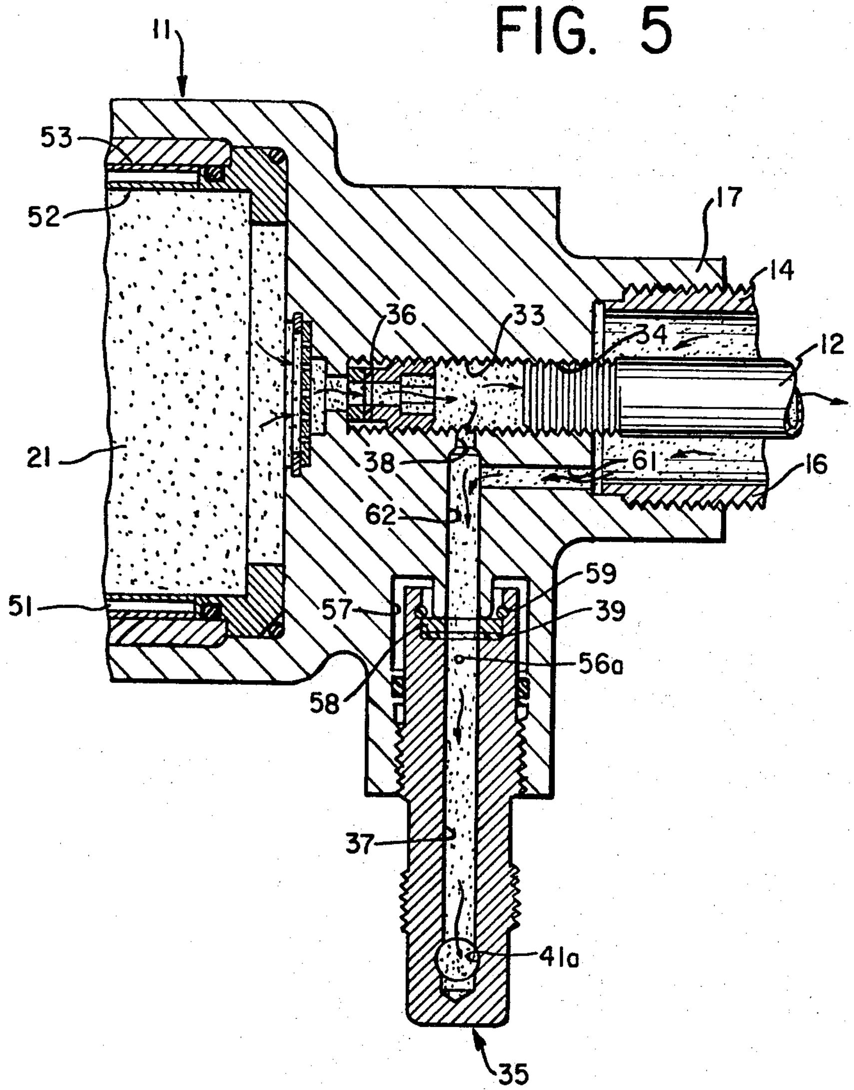
FIG. 4

FIG. 5



METHOD AND APPARATUS FOR GENERATING GASEOUS MIXTURES FOR INFLATABLE DEVICES

This invention relates to apparatus for charging or pressurizing an inflatable device such as a life raft, and in particular, to pyrotechnically operated inflating apparatus for generating gaseous mixtures of carbon dioxide and combustion products of propellants.

BACKGROUND OF THE INVENTION

For many years, inflatable devices have been employed as flotation equipment, such as life rafts and the like. It has been customary to use liquefied carbon dioxide as a source of pressure media for inflating such devices. Carbon dioxide is particularly suitable because of its high storage density, relatively low storage pressure, non-flammability, low toxicity and its ability to be discharged at extremely low temperatures, for example, minus 65° Fahrenheit.

One difficulty with carbon dioxide is its tendency, upon expansion into an inflatable bag or envelope, to produce carbon dioxide snow or cold carbon dioxide gas, with the result that full inflation cannot be obtained within the short period of time required for emergency activation. Furthermore, carbon dioxide at low temperatures has been found to cause some damage to the material constituting the inflatable.

For this reason, it has been customary, heretofore, to mix the liquefied carbon dioxide with hot gaseous combustion products of propellants, such as burning powders, prior to escape of the carbon dioxide from the container in which it is stored under pressure. The hot combustion products heat the liquefied carbon dioxide to effect a change of state to the gas form, thereby to raise the pressure of the carbon dioxide to a predetermined level prior to release into the inflatable. In some cases, the carbon dioxide is retained in its storage container by a frangible disc until the pressure within the container rises to a predetermined level suitable for full inflation of the air bag. The disc ruptures upon attainment of the required pressure, and the carbon dioxide gas evacuates its container to fill the inflatable.

One difficulty with this prior type of inflation system is the inability adequately to control the build-up of thermal energy within the storage container upon ignition of the solid or liquid propellants. It has been found, for example, that these solid and liquid propellants release an excess of thermal energy to raise the temperature of the carbon dioxide beyond an acceptable level. This inability to restrain the build-up of thermal energy within the storage container has heretofore given rise to several important difficulties. One difficulty has been that an inflatable charged to the proper level with hot or warm carbon dioxide will become inadequately inflated upon subsequent cooling of the pressurizing gases. A prior solution to this problem has been to deliver the inflating gas at an excessively high pressure. This, in turn, has given rise to the possibility that damage to the inflatable fabric may occur as a result of such high initial pressures.

Accordingly, the primary object of the present invention is to provide a pyrotechnically operated inflating apparatus which effects a controlled mixing of the hot and cold properties of the pyrotechnic and carbon dioxide gases, so that the inflatable may be charged initially to an adequate and constant pressure with the inflation media at a temperature which will not damage the fabric.

In the preferred embodiment, this object is accomplished by providing inflating apparatus which consists of a container of fluid medium under pressure having an opening at one end, and a control head closing the opening and having an internal space which contains a pyrotechnic charge to generate high temperature gases upon ignition. Means are provided for diffusing throughout the fluid medium a quantity of the high temperature gases generated by the pyrotechnic charge. This raises the temperature and pressure of the fluid medium by a predetermined amount and causes the fluid medium to discharge through an outlet passage formed in the control head externally of the container. The remainder of the high temperature gases produced by the pyrotechnic charge is directed to the outlet passage to be mixed with the carbon dioxide fluid downstream from the storage container at an outlet orifice opening to the inflatable.

According to the invention, therefore, the temperature, pressure and volume of the stored fluid medium are raised initially within the storage container by mixture with a quantity of the pyrotechnic gases to cause the fluid medium to discharge through the outlet.

At the downstream outlet orifice, the remainder of the pyrotechnic gases is mixed with the discharging fluid medium to expand through the orifice and into the inflatable, thereby to supplement the pressure and temperature of the inflating fluid pressure media. Since a substantial portion of the pyrotechnic gases is mixed with the fluid medium at the downstream outlet orifice, its thermal energy is partially dissipated by the Joule-Thompson effect from expansion through the orifice into the inflatable. The temperature of the pressure media in the inflatable is therefore lower than that which has been attainable in the prior systems, in which all of the thermal energy of the pyrotechnic gases is utilized to heat the stored fluid medium prior to discharge. The chances of damage to the fabric as a result of unduly high thermal energy in the inflating fluid are therefore minimized. An additional advantage of the present invention is that a smaller initial volume of carbon dioxide may be stored in the storage container, thereby reducing the weight of the system.

One object of the present invention, therefore, is to provide pyrotechnically-operated inflating apparatus which is capable of providing a full inflation response at temperatures low enough to avoid damage to the fabric of the inflatable.

Another object is to provide pyrotechnically-operated inflating apparatus which effects a full inflation response at pressures which remain substantially constant after the initial charging of the inflatable.

Still another object is to provide pyrotechnically-operated inflating apparatus which is capable of effecting a full inflation response in under ten seconds.

Yet another object is to provide inflating apparatus having a wide operating temperature range from approximately minus 65° Fahrenheit to plus 160° Fahrenheit.

A further object is to provide a closed inflation device which is operable in any attitude independent of external conditions.

A still further object is to provide a closed inflation device having relatively low weight and volume characteristics.

Yet another object is to provide a closed inflation device which employs the use of non-toxic gases having no harmful effects to the inflatable material.

A still further object is to provide a closed inflation device which is simple, reliable, and inexpensive to manufacture.

DESCRIPTION OF THE DRAWINGS

For a further understanding of the present invention, reference may be had to the accompanying drawings, in which:

FIG. 1 is an elevated top view, partially cut away, of a closed inflation device in accordance with the present invention;

FIG. 2 is a top sectional view of the control head portion of the apparatus of FIG. 1;

FIG. 3 is a view taken along the line 3—3 of FIG. 1;

FIG. 4 is a view taken along the line 4—4 of FIG. 2; and

FIG. 5 is a cross-section along lines 5—5 of FIG. 2.

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and in particular to FIG. 1, inflating apparatus is illustrated which generally consists of a container **10** for storing a fluid medium such as liquid carbon dioxide or the like under pressure, and a control head, generally indicated by reference numeral **11**, which is connected to one end of the container for governing the operation of the apparatus. The entire apparatus as shown in FIG. 1 is to be used in connection with an inflatable device (not shown) which may be a bag of any desired shape and size. The apparatus is particularly adapted for use in inflating boats, rafts, rescue devices, helicopter landing pads or the like.

As illustrated in FIG. 1, a portion of the container **10** is broken away to reveal the interior. In the preferred embodiment illustrated, an elongated diffuser tube **12** extends partway into the container substantially along the longitudinal axis of the container. The function of the diffuser tube will be explained in greater detail below. Illustratively, however, the diffuser tube extends inwardly of the container **10** from the control head **11**, and is preferably provided with a plurality of orifices **13** positioned around its circumference and at its free end to establish fluid flow communication between the interior of the tube and the contents of the container. It has been found that the present apparatus operates satisfactorily where the extent of penetration of the tube into the interior of the container is approximately 50%, as illustrated.

The container **10** is preferably provided with an elongated outwardly extending neck portion **14** which forms an outlet **16**. In the preferred embodiment, the outer surface area of the neck **14** is threaded for engagement with a correspondingly threaded receptacle formed as part of the control head **11**.

The control head is preferably substantially cylindrical in shape, and is provided with a cylindrical lower portion **17** which is internally threaded to receive the neck **14** of the container **10**. In this way, the control head **11** may be screwed down tightly to its operating position on the neck **14**.

The interior of the control head **11** is shown in cross section in FIG. 2. The control head is provided with a substantially cup-shaped formation **18** which is positioned so as to form an internal hot gas generating chamber, generally indicated by reference numeral **19**. A substantially cylindrical preferably solid propellant charge **21** is situated within the chamber **19**. Such a charge may be ignited by a plurality of ignition pellets **22** which generate initial heat sufficient to ignite the charge.

In the present embodiment, the pellets **22** are ignited by means of a percussion-actuated explosive, such as a cartridge **23**. A manually operated trigger mechanism, generally indicated by reference numeral **24**, is provided as part of the control head and consists of an impact plunger **26** slidably mounted within an appropriate guide channel **27** for striking the cartridge to effect ignition of the propellant charge.

It should be understood that an electrically actuated squib or a pressure-responsive ignition may also be employed, depending upon the particular use to which the inflating apparatus is to be put. The manually actuated ignition is preferred for use with inflation devices for life rafts and the like.

The impact plunger **26** is biased inwardly toward the cartridge **23**, illustratively by means of a coil spring **28**. The plunger is preferably of two-piece construction, consisting of an inner striker portion **29** and an outer shaft portion **31**. Upon a predetermined compression of the spring **28**, the striker portion separates from the shaft. Such compression of the spring is achieved, for example, by means of a pulling lanyard or cable **32** (FIG. 1) which is pulled so as to move the plunger outwardly to compress the spring **28**. Upon release, the striker portion **29** is driven inwardly under impetus from the spring **28** to fire the cartridge **23**.

The control head **11** is further provided with an internal passage **33** which extends between the hot gas generating chamber **19** and the outlet **16** of the storage container **10**. In the present embodiment, the diffuser tube **12** is connected to the control head **11** so as to be in fluid flow communication with the passage **33**, whereby a quantity of the hot gases generated within the chamber **19** may be conducted through the passage **33** into the diffuser tube to be mixed with the fluid medium stored within the container **10**. The diffuser tube **12** is preferably threaded to the control head **11**, as indicated by reference numeral **34**.

In accordance with the present invention, there is provided a pressure-rupturable or frangible disc **36** to seal the passage **33** adjacent the opening to the hot gas chamber **19**, effectively to separate the fluid inflation media from the propellant mixture prior to actuation of the device. Upon ignition of the charge **21**, hot gases are generated which increase the pressure within the chamber **19**. When this pressure build-up reaches a predetermined value, the disc **36** ruptures to permit the hot gases to flow from the chamber **19** through the passage **33** and into the diffuser tube **12**. From there, the gases flow through the various orifices **13** of the diffuser tube and into the container **10** to mix with the carbon dioxide.

The outlet assembly of the control head **11** is depicted in FIGS. 4 and 5. In the preferred embodiment, the outlet assembly consists essentially of an outwardly protruding formation **35** having an outlet conduit **37** which extends from and is in fluid flow communication with the internal passage 33. A downstream propellant orifice, indicated by reference numeral 38, is provided at the juncture between the passage 33 and the outlet conduit. A second pressure-rupturable or frangible disc 39 is provided outwardly of the downstream propellant orifice 38, to seal the outlet conduit 37 thereby to prevent discharge through the outlet prior to the attainment of an inflation media pressure sufficient fully to charge the inflatable device.

A non-recoil configuration is preferably provided at the outlet end of the discharge conduit 37. A non-recoil mechanism for the present circumstances can take several forms, a preferred form including a pair of diametrically opposite side ports 41 and 41a, which serve to direct the discharging fluid in opposite directions substantially perpendicular to the outlet conduit. In this way, discharge reaction forces are minimized to prevent recoil of the apparatus upon actuation. Where desired, the non-recoil can also take the form of a separate cap member (not shown) having a pair of diametrically opposed side ports. Such a cap member may be constructed so as to fit over the discharge end of the outlet conduit.

As a precaution against the advent of intolerably high pressures being created within the container 10 should a malfunction occur somewhere in the system, an overboard safety relief system 42 is provided in the control head 11. A second internal passage 43 may be formed within the control head to extend between the outlet 16 of the container 10 and a safety relief vent 44. A pressure-rupturable disc 46 is provided to seal the passage 43 to prevent the inadvertent escape of the fluid inflation medium. Should the pressure within the container 10 rise to an unsafe level, the disc 46 will rupture to vent the fluid to the atmosphere through the passage 43 and the safety outlet 44. In the preferred embodiment, a non-recoil plug 47 is threaded into the control head both to secure the burst disc 46 in position across the passage 43, and to provide a pair of side ports, including the vent 44, to minimize the effect of discharge reaction forces arising upon the evacuation of fluid from the container, as described above.

In the prior type of inflation apparatus, a pyrotechnic charge is positioned within the storage container to facilitate the transfer of thermal energy to the inflation media. Under such circumstances, heat dissipation through the walls of the pyrotechnic chamber has not caused serious difficulties insofar as it was thought desirable to maximize the transfer of thermal energy to the carbon dioxide.

In the preferred embodiment of the present invention, the pyrotechnic charge and chamber are formed as part of the external control head. Under these circumstances, it is important to minimize heat loss through the walls of the pyrotechnic chamber.

In accordance with the invention, the outer diameter of the pyrotechnic chamber 19 is slightly less than the inner diameter of the chamber 18, so that a relatively thin substantially annular space 51 is left between the charge and the chamber walls. A substantially cylindrical corrugated shield member 52 may be provided in the space 51. The corrugations in the shield 52 are such that the shield is simultaneously in contact with both the outer surface area of the pyrotechnic charge and the inner surface area of the chamber wall. Prior to ignition of the charge, the shield 52 serves to stabilize the position of the charge within the chamber. By way of example, the corrugated shield 52 may be a thin skin having a thickness of approximately 0.005 inches.

Where desired, an outer substantially cylindrical thin metal shield or skin 53 may be provided within the annular space 51 as a further heat shield. The outer shield 53 is preferably positioned between the corrugated shield 52 and the chamber wall. By way of example, the outer shield 53 may consist of a relatively thin skin-like metal material approximately 0.001 inches in thickness.

One end of the ignition chamber 18 may be coated with a heat resistant resilient filler material 54, such as silicon rubber. In the preferred embodiment, the coating 54 is located at the distal or outer end of the chamber, and has a substantially planar inner face 55 which engages the corresponding ends of the pyrotechnic charge 19 and the heat shields 52 and 53. The rubber filling 54 serves to retain and to protect from damage the contents of the assembled pyrotechnic chamber in the event that the inflation unit is subjected to external vibrations or shocks. After ignition of the charge, the rubber filling also acts in an insulative capacity to minimize dissipation of heat generated by the burning charge, through the end wall of the chamber.

Inflation systems of the present type may be initially charged with inflation media by utilizing several known techniques. In the present embodiment, the fluid medium is injected through the outlet conduit 37. Passages 56 and 56a are provided in the outlet formation or nozzle 35 to carry the charging fluid into a space 57 surrounding the inner end of the nozzle within the control head. During the charging or filling operation the nozzle 35 is only partially threaded into engagement with the control head. Accordingly, there is a continuous passage extending from one portion of the outlet conduit through the space 57 to an inwardly displaced portion of the conduit.

The burst disc 39 is preferably retained as part of the removable nozzle assembly by means of a gasket 58 and retainer ring 59. As the system is filled, the inflation fluid is diverted around the burst disc by means of the passages 56 and 56a and the space 57. In the preferred embodiment, the upper portion 62 of the outlet conduit 37 permits charging of the system by conducting the injected fluid medium through a passage 61 in the control head to the interior of the container 10. When filling is complete, the nozzle assembly is screwed down tight to seal the passage 57 from the outlet conduit inwardly of the burst disc 39.

In operation, an inflatable device is attached, in its deflated condition, to the nozzle assembly 35 of the control head 11. The inflation of the inflatable device is effected by pulling the cable or lanyard 32 to move the impact plunger 26 outwardly against the bias of the spring 28. At the appropriate point, the striker portion 29 separates from the shaft 31 and the action of the spring forces it inwardly to impact against the percussion-actuated explosive cartridge 23. The impact of the striker 29 against the end of the cartridge causes the cartridge to detonate and produce a flash which initially ignites the igniter pellets 22. The charge 21 then burns to produce hot gases which increase the pressure within the chamber 18 thereby applying pressure to the rupturable disc 36. When this pressure reaches a predetermined level, the disc 36 bursts and the hot gases flow through the passageway 33 and into the container 10 by means of the diffuser tube 12. Initial mixing, therefore, between the hot pyrotechnic gases and the stored fluid medium occurs within the container **10.** As the carbon dioxide is heated, it converts to a gaseous state thereby increasing the pressure within the container. As this pressure rises, the mixture of carbon dioxide and pyrotechnic gases is forced back through the passage **61** into the upper outlet opening **62** of outlet conduit **37.** It mixes there with hot gas supplied through the downstream propellant orifice **38** and into the upper outlet conduit **62,** thereby applying pressure to the outlet rupturable disc **39.** The pressure within the container **10** increases rapidly to a value which causes the disc **39** to rupture. The gaseous carbon dioxide and the pyrotechnic gases then flow through the outlet conduit **37** and through the side ports **41** and **41a** and from there into the inflatable device to effect the inflation thereof.

Since the pressure against the rupturable disc **39** rises very rapidly to the burst point, the entire supply of pyrotechnic gases generated within the chamber **18** of the control head **11** is not exhausted at the time that the outlet disc **39** ruptures. In accordance with the invention, further mixing between the pyrotechnic gases and the fluid inflation medium occurs at the downstream orifice **38** during discharge into the inflatable device.

This downstream mixing of pyrotechnic gases and carbon dioxide is an important feature of the present invention. As indicated above, one difficulty with the prior type of inflation system has been the inability of such systems adequately to control the build-up of thermal energy within the container. In part, this has been due to the fact that in the prior type of system all of the hot gases generated by the pyrotechnic charge have been evacuated directly into the container. Thus it has frequently occurred that in such systems, the temperature and pressure of the carbon dioxide is raised beyond an acceptable level.

According to the present invention, only that portion of the pyrotechnic gases required to elevate the pressure of the stored carbon dioxide to a level sufficient to burst the outlet disc **39** is actually mixed with the carbon dioxide within the container **10.** Upon rupture of the outlet disc, the majority of the remaining hot pyrotechnic gases mixes with the discharging fluid medium at the downstream orifice, giving rise to the predictable cooling effect of the Joule-Thompson principle upon entry into the inflatable device.

Furthermore, utilization of the pyrotechnic gases to augment the inflation charge may enable the use of a smaller quantity of carbon dioxide and consequently a smaller storage container, to effect a reduction in weight for the system.

What is claimed is:

1. Apparatus for inflating an inflatable device, comprising:

means having first and second interconnected zones for containing fluid inflation media under pressure;

a container for holding a charge of primary fluid inflation media under pressure within said first zone;

a control assembly for housing a pyrotechnic charge;

means forming part of said control assembly for igniting said pyrotechnic charge to generate high temperature secondary fluid inflation media;

means for introducing said secondary fluid media to both said first and second zones to form a first fluid mixture in said first zone having one proportion of secondary to primary fluid media, and a second fluid mixture in said second zone incuding the first fluid mixture having a greater proportion of secondary to primary fluid media, said introducing means including a diffuser tube having one end in communication with said control assembly for receiving the high temperature secondary fluid inflation media and also in communication with said second zone, the other end of said diffuser tube extending inwardly of said container and having a plurality of orifices positioned around its circumference to allow fluid within the tube to pass into said container; and

means for introducing said second fluid mixture to said inflatable device.

2. The apparatus of claim **1** wherein the interconnection between said zones comprises a conduit to conduct the passage of fluid from one zone to the other.

3. The apparatus of claim **2** wherein said diffuser tube is in fluid flow communication with said conduit, and a first pressure-sensitive element normally sealing said conduit and having a pressure surface in fluid flow communication with said second zone, said first element being adapted to burst when the pressure within said second zone reaches a first predetermined value to release the second fluid mixture.

4. The apparatus of claim **3** wherein said means for introducing said high temperature secondary fluid to said second zone includes an orifice former between said second zone and the pyrotechnic charge, said conduit having an outlet passage extending from said second zone to provide fluid flow communication with the inflatable device.

5. The apparatus of claim **4** further comprising means forming a second outlet passage from said first zone, a second pressure-sensitive element normally sealing said second outlet passage and having a pressure surface in fluid flow communication with the primary fluid of said first zone and, said second element being adapted to burst when the pressure within said first zone reaches a second predetermined value greater than said first value, and means communicating with said second outlet passage to enable the primary fluid to vent when said second element bursts.

6. Apparatus for inflating an inflatable device, comprising:

an enclosure having first and second interconnected but separately defined zones for containing fluid inflation media under pressure;

a charge of primary fluid inflation media within said first zone;

a control assembly mounted on said enclosure and having a chamber containing a pyrotechnic charge;

means forming part of said control assembly for igniting said pyrotechnic charge to generate high temperature secondary fluid inflation media;

means substantially enveloping said pyrotechnic charge for retaining within said chamber thermal energy generated by ignition of said charge;

means for introducing said secondary fluid media to said first and second zones to form a first fluid mixture in said first zone having one proportion of secondary to primary fluid media, and a second fluid mixture in said second zone having a greater proportion of secondary to primary fluid media; and

means for introducing said second fluid mixture to said inflatable device.

7. The apparatus of claim 6 wherein said enveloping means comprises at least a first substantially cylindrical heat shield within said chamber and surrounding a major portion of the surface area of said pyrotechnic charge.

8. The apparatus of claim 7 wherein said heat shield is corrugated.

9. The apparatus of claim 8 wherein said enveloping means further comprises a second substantially cylindrical heat shield member positioned between said corrugated shield and the internal walls of said chamber.

10. The apparatus of claim 6 wherein said enveloping means comprises a heat-resistant resilient material coating one end of said chamber, and having a substantially planar inner surface engaging the corresponding end of said pyrotechnic charge.

11. The apparatus of claim 10 wherein said resilient material comprises silicone rubber.

12. The method of inflating an inflatable device comprising:

generating a predetermined charge of hot gases under pressure in a confined volume;

mixing said gases with a predetermined charge of carbon dioxide under pressure in a first confined zone to increase the pressure of the carbon dioxide, said mixing being limited to maintain a greater pressure within said confined volume than within said first confined zone;

releasing the mixture of gases and carbon dioxide from said first zone;

passing said mixture from said first zone to a second confined zone;

mixing said gases with said mixture in said second zone to increase the pressure of said mixture, said mixing being limited to maintain a greater pressure within said confined volume than within said second zone;

expanding said mixture from said second zone to cool said mixture; and

introducing the expanded mixture into the inflatable device.

13. Apparatus for inflating an inflatable device, comprising:

means for containing a charge of primary fluid inflation media within a first zone;

means defining a second zone including means for interconnecting said first and second zones,

a control assembly containing a pyrotechnic charge; said control assembly including means for igniting said pyrotechnic charge to produce a high temperature secondary fluid inflation media;

an outlet conduit communicating with said second zone and including a rupturable pressure responsive device therein for normally blocking discharge of fluid from said outlet conduit, and

means for introducing said secondary fluid media to both said first and second zones at all times that said secondary fluid is being produced to form a first fluid mixture in said first zone having one proportion of secondary to primary fluid media, the first mixture being conveyed by said interconnecting means to form a second fluid mixture in said second zone having a greater proportion of secondary to primary fluid media, said pressure responsive means being ruptured in response to the fluid present in said second zone at a predetermined pressure to permit discharge of the second fluid mixture from said outlet conduit; and

means for introducing said second fluid mixture to said inflatable device.

* * * * *