Sept. 19, 1972 F. E. SCHNEITER ET AL 3,692,495

GAS GENERATOR

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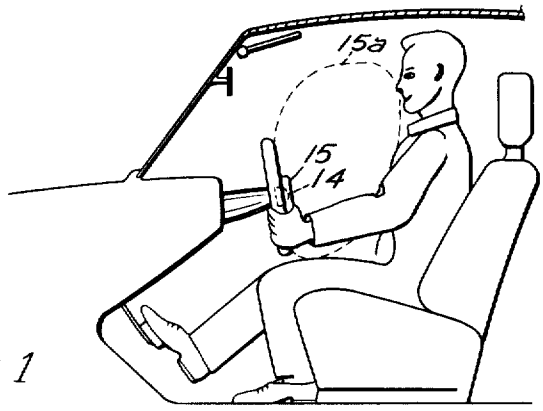


Fig. 1

Fig. 3

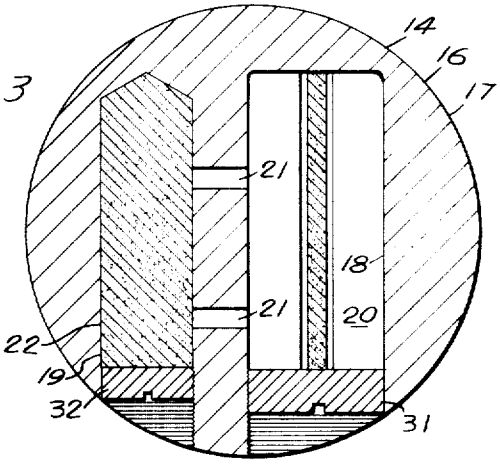
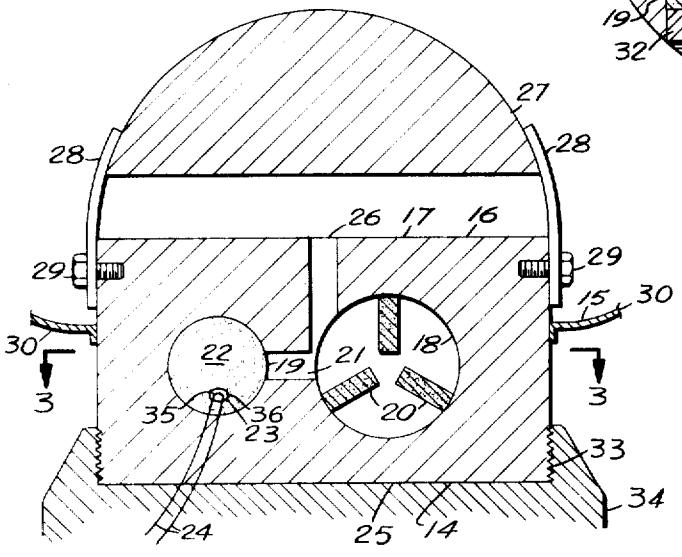


Fig. 2



INVENTORS:
FRED E. SCHNEITER
HOWARD E. JORGENSEN
LELAND E. DAVIS

BY: Edward E. McCullough
AGENT

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GAS GENERATOR

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Fig. 4

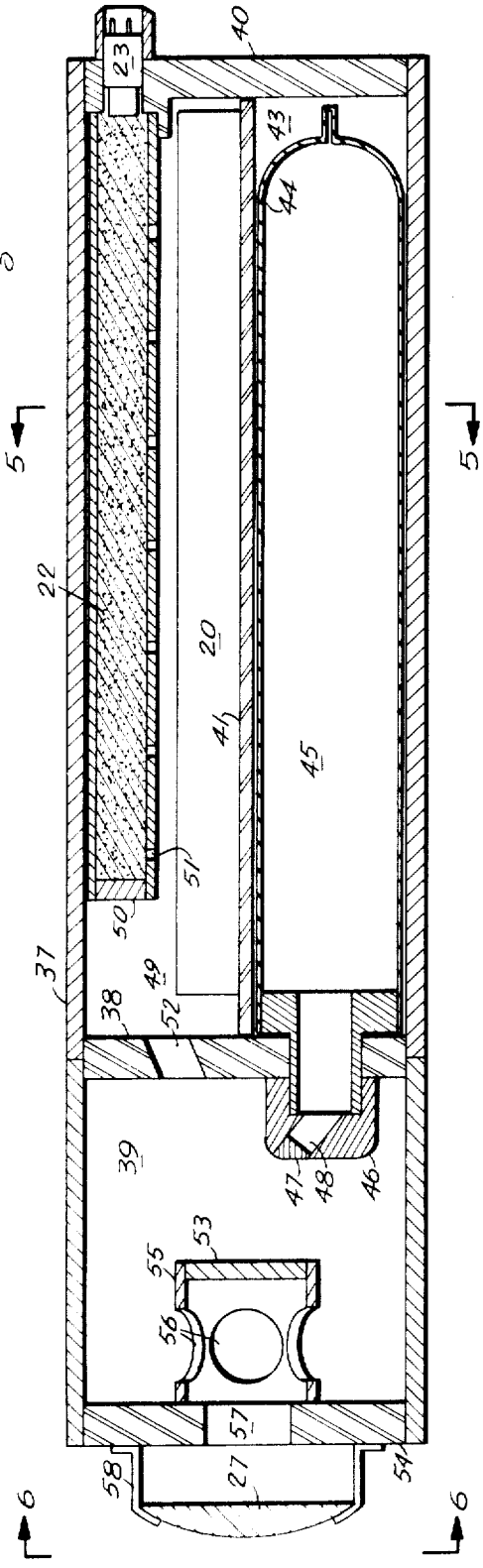


Fig. 6

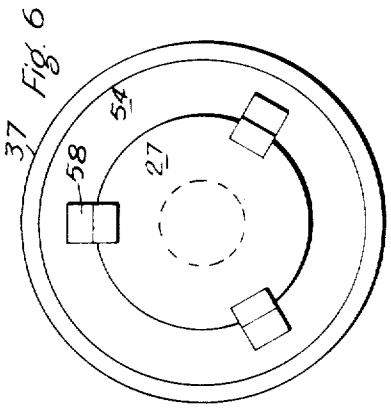
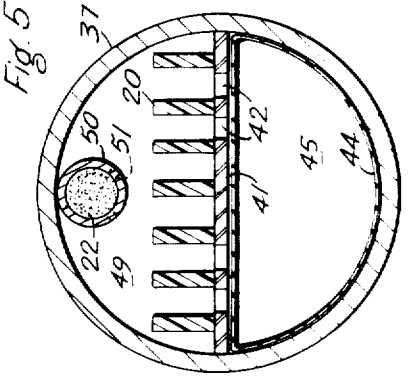


Fig. 5



INVENTORS:
FRED E. SCHNEITER
HOWARD E. JORGENSEN
LELAND E. DAVIS

BY: Edward E. McCullough
AGENT

Sept. 19, 1972 F. E. SCHNEITER ET AL 3,692,495

GAS GENERATOR

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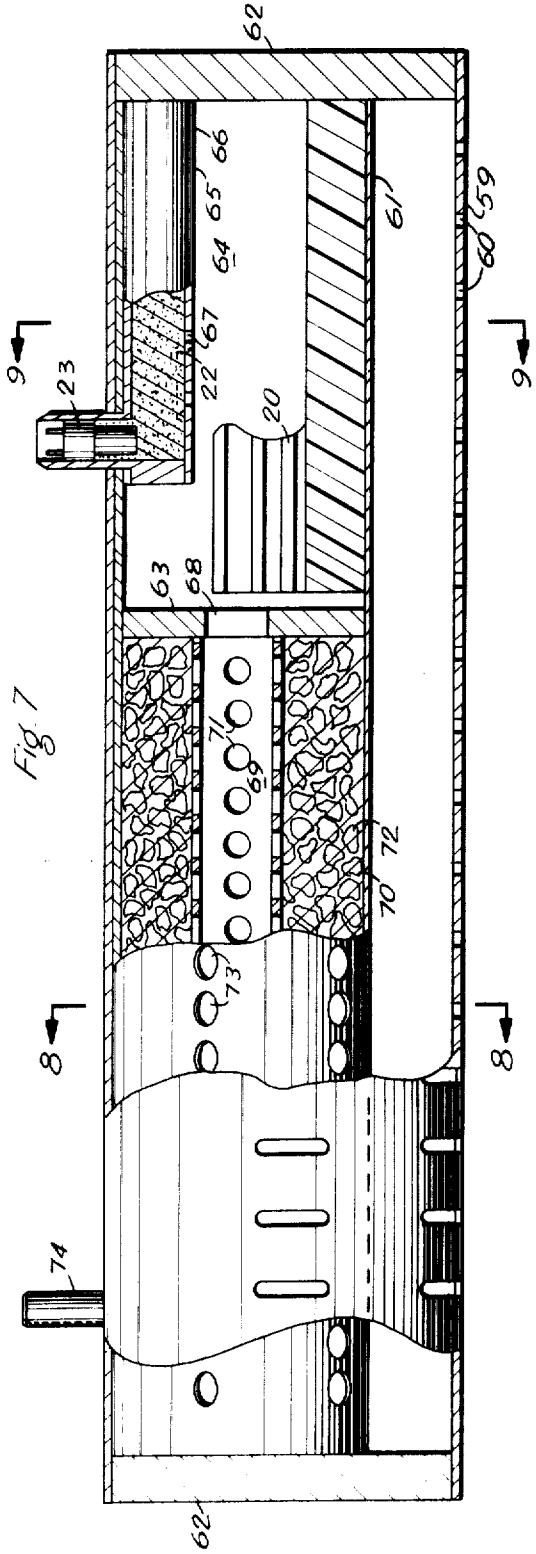


Fig. 7

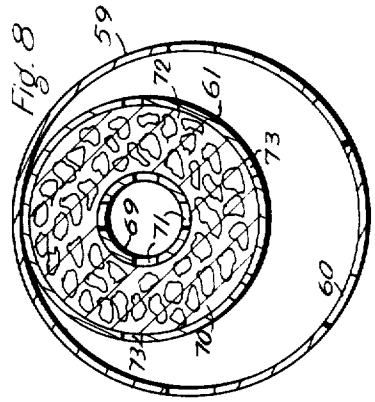


Fig. 8

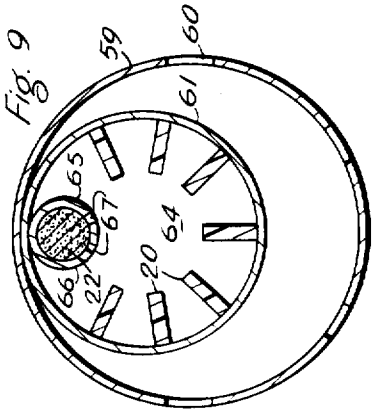


Fig. 9

INVENTORS:
FRED E. SCHNEITER
HOWARD E. JORGENSEN
LELAND E. DAVIS

BY: Edward E. McCullough
AGENT

Sept. 19, 1972 F. E. SCHNEITER ET AL 3,692,495

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Fig. 10

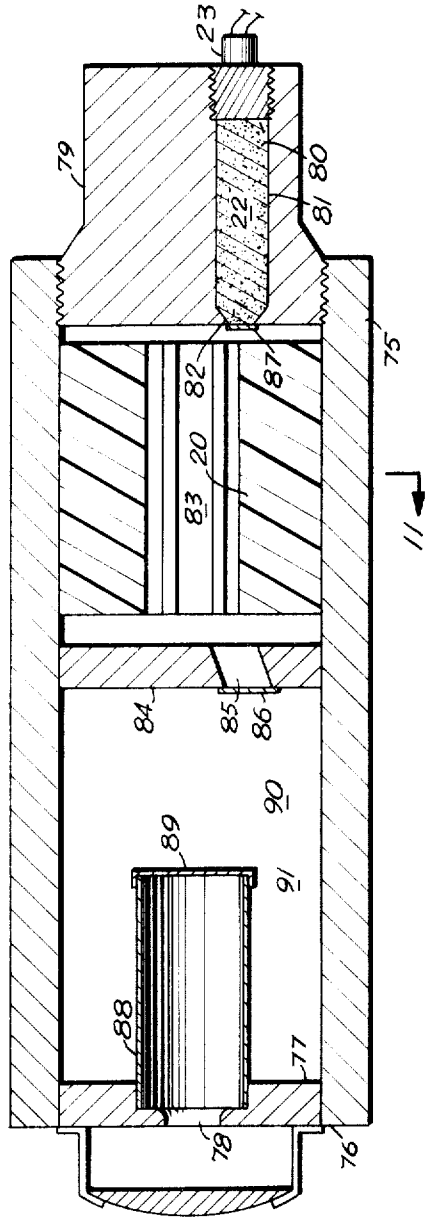
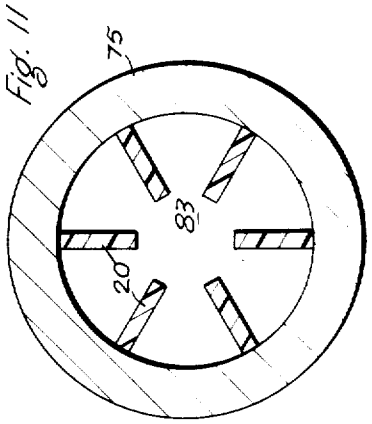


Fig. 11



INVENTORS:
FRED E SCHNEITER
HOWARD E JORGENSEN
LELAND E DAVIS

BY Edward E McCullough
AGENT

United States Patent Office 3,692,495 Patented Sept. 19, 1972

3,692,495

GAS GENERATOR

Fred E. Schneiter, Ogden, Howard E. Jorgensen, Hyrum, and Leland E. Davis, Brigham City, Utah, assignors to Thiokol Chemical Corporation, Bristol, Pa.

Filed June 19, 1970, Ser. No. 47,788
Int. Cl. B01j 7/00
U.S. Cl. 23—281 3 Claims

ABSTRACT OF THE DISCLOSURE

A gas generator, suitable for filling inflatable structures in the presence of humans has a special, nontoxic, solid fuel in an orificed pressure vessel, ignition means therefor, and coolant means for cooling the gases produced on combustion of the fuel before they enter an inflatable structure.

CROSS REFERENCES TO RELATED APPLICATIONS

The present invention is related to and refers to, two other copending applications of the same assignee. They are designated: "Solid Fuel for Gas Generators" by Russell Reed, Jr., Roger R. Hendrickson, and Graham C. Shaw, Ser. No. 47,911 filed June 19, 1970; and "Coolants for Gas Generators" by Russell Reed, Jr. and Graham C. Shaw, Ser. No. 47,910 filed June 19, 1970.

BACKGROUND OF THE INVENTION

This invention relates to gas generators; and particularly to solid-fuel gas generators suitable for filling inflatable structures in the presence of humans.

The use of inflatable structures is becoming increasingly common. Although certain of these, such as various recreational equipment and inflatable furniture can be filled manually by an air pump, other inflatable equipment such as emergency life rafts must be quickly and automatically inflated. Conventional means of inflating such equipment has commonly included compressed gas in a pressure vessel, opened by mechanical or explosive means.

Of particular interest in the present invention is its use for inflating safety cushions for passenger-carrying vehicles. Such cushions are installed in a vehicle and are designed to be inflated rapidly and automatically to protect human occupants in event of a collision of the vehicle with some other object. Apparatus of this general nature are known in the prior art. For example, U.S. Pat. 3,336,045 to Y. Kobori describes a cushion device that is inflatable by a solid-fuel gas generator using an undesignated "explosive" material for the fuel. U.S. Pat. 3,450,414, to the same inventor, shows a similar device wherein the source of gas cited is dichlorodifluoromethane (Freon 12), liquid propane, and solid ethyl alcohol. Many other patents show inflatable cushions wherein the source of gas is a container of compressed gas that is opened in response to collision by some explosive means.

The compressed-gas type of inflation device has a number of disadvantages; (1) It is relatively bulky and difficult to package neatly in places such as steering columns; (2) Automobile manufacturers regard high-pressure containers of compressed gas, especially one equipped with explosive opening means, as a hazard on assembly lines; (3) They are also a hazard in shipping, storage, and handling; (4) They tend to be unreliable because of the ever-present possibility of leakage, especially after several years in an automobile; and (5) The pressure within the container can be dangerously increased by high ambient temperatures.

For these reasons, the solid-fuel gas generator is considered to be the superior source of gas for inflation of safety cushions: it can be contained in a much smaller package than compressed gas; it can remain reliable over long periods of time; and, if it is relatively insensitive to temperature and shock, it can be considerably safer than the compressed-gas type of inflation device.

However, the gases produced must also be nontoxic, because of the danger of rupture in the inflatable cushion; and it must produce gases that are cool enough to avoid burning the vehicle occupants. The source of gas must be capable of inflating the cushion within about 30 milliseconds after a collision signal is received. In a gas generator, this requirement for rapid inflation almost necessitates use of a fuel that is consumable at flame temperatures of the order of 2500° C. On the other hand, the violence of a typical collision forces the vehicle occupant deeply into the cushion and into intimate contact with the surface thereof. Hence, unless specific cooling means were provided to lower the temperature of the gases, the occupant would receive severe burns from the surface of the cushion. These two important problems, the toxicity and temperature of the inflating gases, have apparently received no consideration in the prior art.

SUMMARY OF THE INVENTION

The present invention, which is primarily directed toward overcoming these disadvantages of the prior art devices, provides a solid-fuel gas generator that produces nontoxic gas and that has specific, effective cooling means for lowering the gas temperature to a point that is safe for the vehicle occupant. The cooling means include the use of heat sinks to absorb heat from the inflating gases, mixing the gases with cooling fluids, and passing them through materials that react endothermically to produce cooling gases that mix therewith.

The principal objects of the invention are to provide a source of gas to fill inflatable structures, that is reliable over long periods of time, nonhazardous during prolonged storage, nontoxic, and free from excessively high temperatures. Important features of the invention are its compact size and easy replaceability.

These and other objects and advantages of the invention will be noted as the following detailed description is read with reference to the accompanying drawings. Any unmodified part will be designated by the same number throughout the disclosure.

DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a side view showing how the invention is installed in a typical automobile;

FIG. 2 is a central section in side elevation of a first embodiment of the gas generator;

FIG. 3 is a full cross section taken on line 3—3 of FIG. 2;

FIG. 4 is a longitudinal section of a second embodiment of the gas generator;

FIG. 5 is a cross section taken on line 5—5 of FIG. 4;

FIG. 6 is an end view of the invention shown in FIG. 4;

FIG. 7 is a view, principally in longitudinal section, of a third embodiment of the gas generator;

FIG. 8 is a cross section taken on line 8—8 of FIG. 7;

FIG. 9 is a second cross section taken on line 9—9 of FIG. 7;

FIG. 10 is a longitudinal section of a fourth embodiment of the gas generator; and

FIG. 11 a cross section taken on line 11—11 of FIG. 10.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIG. 1, the invention is typically installed in a steering column or in some other convenient place wherein it will be positioned to cushion the force of a collision for an occupant of the vehicle. The gas generator **14** is shown in broken lines, and an inflatable cushion **15** is shown by a solid line in its normal condition. The broken line **15***a* indicates the fully inflated condition of the cushion **15**. Devices for generating an electric signal in response to a collision are well known, and are not a part of the present invention. The most common instrument for this purpose is some kind of accelerometer that closes a switch in an electric circuit when unusual deceleration is experienced in the vehicle.

FIGS. 2 and 3 show a first embodiment of the novel gas generator **16**. It includes a housing **17** made of a solid, cylindrical piece of aluminum, and having two parallel bores **18** and **19** therein. A solid fuel **20** is bonded into the larger bore **18** (which is a pressure vessel, defining the combustion chamber) in the form of strips or bars as shown in FIG. 2. Small ducts **21** connect the two bores so that gases may flow from one to the other. An ignition composition **22** fills the smaller bore **19** which comprises the ignitor enclosure; and a small electric squib **23** in intimate contact with the ignition composition **22** has electrical conductors **24** extending through the base **25** of the housing **17**. A discharge orifice **26** leads from the larger bore **18** to the exterior of the housing **17**. A baffle **27** that acts both as a diffuser and heat sink to absorb heat from the inflating gas is positioned above the orifice **26** by brackets **28**, that are welded to the baffle **27** and are fastened to the housing **17** by screws **29**. Edges **30** of the cushion **15** may be welded to the sides of the housing **17**. The baffle **27** may be made of any material having a high rate of thermal conductivity, such as brass, bronze, copper, or aluminum. The outer ends of the bores **18** and **19** are threaded and are sealed by threaded plugs **31** and **32**. The housing **17** is externally threaded at its base for engagement in a threaded recess **33** in the steering column **34**.

On receipt of an electric signal, the squib **23** ignites the initiating composition **22** which, in turn, generates flaming gases that pass through the ducts **21** to ignite the solid fuel **20**. Gases from combustion of the fuel **20** then pass through the orifice **26** and impinge upon the baffle **27** which both diffuses the gases and cools them by absorption of heat therefrom. This cooling action is enhanced by the heat-sink nature of the housing **17**, also being preferably made of a solid block of aluminum. The diffusing action of the baffle **27** is primarily intended to avoid damage to the cushion **15**; but, by expanding the gases, it naturally cools them further. The summation of these cooling actions of the gases can lower the temperature thereof from about 2,372° F. to about 230° F.

The squib **23** is made of a small-diameter, resistance wire **35** surrounded by a small amount of an initiating composition **36** made of: 50 percent by weight of lead styphnate, 24 percent of potassium perchlorate, 24 percent of powdered zirconium, and 2 percent of an organic binder, such as VYLF, manufactured by Union Carbide.

A typical ignition composition **22** comprises, by weight:

	Percent
Boron powder	23.86
Potassium nitrate	71.17
Granular nylon (such as Du Pont Elvamide 8061)	3.96
Powdered graphite	0.99

The granular size of this material is controlled to range from 42 to 80 standard mesh.

The solid fuel **20** may be any one of a family of combustibles similar to solid propellants for rockets, having a binder that is a highly-oxygenated polymer containing only carbon, hydrogen, and oxygen; a curing agent containing the same elements; and either potassium chlorate or potassium perchlorate as the oxidizer. The binder to oxidizer ratio is adjusted to produce upon combustion a gas having less than 1.1% carbon monoxide, less than 1.0% methane, and only traces of hydrogen. No other toxic or flammable materials are present in the inflation gases. These compositions are described in greater detail and claimed in the copending application for patent titled "Solid Fuel for Gas Generators" by R. Reed et al., cited previously herein. A typical composition of this solid fuel is, in percentage by weight.

	Percent
WITCO Formrez F-17-80 ($C_{2.0}H_{2.50}O_{1.0}$ saturated, carboxyl-terminated, polyester liquid polymer)	14.32
Epoxy resin (diglycidyl ether of bis-phenol A)	3.58
Cure catalyst (e.g. iron linoleate)	0.10
Potassium perchlorate	81.83
Alon (Al_2O_3)	0.17

This formulation is the result of extensive laboratory mixing and testing for desired combusion products, processing properties and mechanical properties. The liquid ingredients are placed in a mixer, and the finely-divided potassium perchlorate is gradually added as they are being agitated. After the mixing has been completed, the fuel is pressed into forms and cured at 135° F. for 72 hours. Upon completion of the cure, the fuel is removed from the forms and cut into strips for use in the gas generator.

Measured combustion products typical for this fuel when burned in 4,000 p.s.i. pressure vessel are, in percentage by weight:

	Percent
Carbon dioxide (CO_2)	75.0
Carbon monoxide (CO)	1.1
Methane (CH_4)	0.2
Oxygen	16.7
Nitrogen	7.0
Hydrogen	Trace

Oxides of nitrogen—less than 90 p.p.m.

When the vehicle is subjected to collision, the cushion **15** will be inflated within about 30 milliseconds after impact. Experiments have indicated that this is sufficient time for the cushion **15** to perform its function of protecting the vehicle occupant from collision with the inside of the vehicle. Since the inflated cushion **15** would be a handicap to the occupant after it has served this purpose, provision is made for deflating it immediately. The primary mechanism for accomplishing this is porosity of the material from which the cushion is made. Alternatively, valve means, not shown, may be incorporated into the cushion **15**. The deflating effect of the escaping gas is enhanced by the fact that the gas will be cooling at the same time and, therefore, decreasing in volume.

The embodiment of the gas generator shown in FIGS. 4, 5, and 6 differs from that already described primarily in that cooling of the generated gases is not accomplished by heat absorption, but by mixing a cooling substance with the gases before they are expelled into the cushion **15**. A tubular housing **37**, closed at both ends, has a transverse partition **38** that forms an enclosure defining a small mixing chamber **39**. The space between the aft end **40** of the housing **37** and the partition **38** is further divided by a longitudinal partition **41**, that is filled with holes **42**. A coolant chamber **43** is defined by the coolant container formed by the partition **41** and the housing **37**, and is occupied by a flexible bladder **44** filled with a coolant **45**, such as water. The forward end of the bladder **44** is fixed into the transverse partition **38**, where it terminates in a nozzle **46** that is sealed by an easily-remova-

ble plug **47** in the orifice **48** and is canted toward the center of the mixing chamber **39**. The other chamber **49** formed by the longitudinal partition **41** is the combustion chamber and contains the solid fuel **20** in the form of long strips in parallel arrangement, each bonded at one edge to the partition **41**. A long tube **50** containing the ignition composition **22** and the electric squib **23** is closed at both ends and fixed to the wall of the combustion chamber **49** opposite the solid fuel **20**. This tube **50** has two parallel rows of small orifices **51** arranged to direct burning gases from the ignition tube onto the solid fuel **20** for ignition thereof. The electric conductors **24** of the squib **23** pass through the aft end **40** of the housing **37**, as shown in FIG. 4. The squib **23** and the ignition composition **22** are identical with those of FIGS. 1, 2, and 3, as is the solid fuel **20**. A first discharge orifice **52** in the portion of the transverse partition **38**, that helps to define the combustion chamber **49** is also canted toward the center of the mixing chamber **39** in opposition to the coolant orifice **48**. An internal baffle plate **53** is fixed on the inside of the forward end **54** of the housing **37** by a short tube **55** filled with holes **56**. The main discharge orifice **57**, whereby gases emerge from the gas generator to fill the inflatable cushion **15** is located in the center of the forward end **54** of the housing **37** in alignment with the internal baffle **53**. An external baffle **27** is also positioned in alignment with the orifice **57** and fixed to the forward end **54** of the housing **37** by brackets **58**.

Upon receipt of an electric signal, the squib **23** fires and ignites the ignition composition **22**, which, in turn, produces flaming gases that pass through the orifice **51** to ignite the solid fuel **20**. This fuel produces large quantities of gas, which simultaneously passes through the holes **42** in the longitudinal partition **41** to pressurize the bladder and through the canted orifice **52** into the mixing chamber **39**. This pressurization of the bladder **44** expels the plug **47** in the bladder nozzle **46** and causes coolant to impinge on the stream of gases emerging from the combustion chamber **49**. Further mixing of the combustion-chamber gases with the coolant is promoted by the internal baffle **53**, which creates considerable turbulence in the mixture before it passes through the main discharge orifice **57**. The emerging gases are further cooled and diffused by their impingement on the external baffle **27**, as described for the embodiment of FIGS. 1, 2, and 3. The wall of the cushion **15** may surround the forward end of the tubular housing **37** in sealed relationship therewith, as shown in FIG. 4, so that the gases emerging from the housing **37** will pass into the cushion **15**. The coolant **45** may also be any aqueous solution of a nontoxic salt, such as calcium chloride, or sodium carbonate.

A third embodiment of the gas generator **14** is shown in FIGS. 7, 8, and 9. In this embodiment, the gases generated by the solid fuel pass through solid particles that react endothermically to produce cooling gases that mix with those produced by the solid fuel. A tubular baffle **59**, closed at both ends, has a multiplicity of holes **60** in one side thereof. A smaller tube **61** serves as a housing for the gas generator proper. This tube **61** fits into the larger, baffle tube **59** so that its ends are closed by the end members **62** thereof, and the gas-generator-housing tube **61** is fixed at one side to the inside of the baffle tube **59** opposite the holes **60** therein. The housing tube **61** is divided into two chambers by a transverse partition **63**. One of these chambers is a combustion chamber **64**. The igniter **65** comprises a small tube **66** filled with the ignition composition **22** in the presence of an electric squib **23**, which has electric conductors **24** that are externally accessible. The igniter tube **66** is fixed to the inside of the wall of the combustion chamber **64**. Opposite the igniter **65**, strips of solid fuel **20** are radially positioned along the wall of the combustion chamber **64** and are bonded thereto. When the squib **23** is fired, flaming gases from combustion of the igniter composition **22** pass through two rows of holes **67**, that are directed toward the solid fuel **20** for ignition thereof. Gases from combustion of the solid fuel **20** then pass through an orifice **68** in the partition **63** into a diffuser tube **69**. The diffuser **69** is relatively small in diameter, is centrally positioned in the coolant chamber **70**, extends longitudinally thereof, and is filled with a multiplicity of holes **71** which allow gases from combustion of the solid fuel **20** to diffuse through particles of solid coolant **72** that fill the space in the coolant chamber **70** around the diffuser tube **69**. A multiplicity of holes **73** in that portion of the gas-generator housing **61** which forms the wall of the coolant chamber **70** permit the cooled gases to pass into the baffle tube **59**, where they are further diffused and cooled, and into the inflatable cushion **15**. A mounting stud **74** assists in installing the invention in a vehicle.

The particles of solid coolant **72** are made of dry chemicals that react endothermically to liberate gas in the presence of heat. Specific materials which are suitable for this purpose include sodium bicarbonate ($NaHCO_3$), ferrous oxalate ($FeC_2O_4 \cdot 2H_2O$), and oxalic acid

$$(C_2H_2O_4 \cdot 2H_2O)$$

These materials have fairly low decomposition temperature, are highly endothermic, and liberate gases without significant toxicity. The form of the coolant particles is critical to the function of achieving adequate cooling in the short period of time required for inflation of the cushion **15**.

A fourth embodiment of the invention is shown in FIGS. 10 and 11. A tubular housing **75** is closed at the discharge end **76** by an end plate **77** having a main discharge orifice **78** therein, and it is closed at the other end by threaded engagement with an igniter plug **79**. The igniter **80** is built into a bore **81** in the plug **79** which terminates in an orifice **82**. This orifice can direct flaming gases from the igniter **80** onto the solid fuel **20** that is positioned in the combustion chamber **83** in the manner that has been described for the previous embodiment of the invention. The combustion chamber **83** is formed adjacent the igniter plug **79** by a transverse partition **84** having an outwardly-canted first-discharge orifice **85** therein. The orifice **85** is sealed by adhesive tape **86**. The igniter **80** contains the same elements that have been described for previous embodiments of the invention, i.e., the electric squib **23** and the igniter composition **22**. The igniter orifice **82** is sealed with tape **86**, which is easily blown off by the hot gases when the igniter is fired.

A baffle **27**, identical to that shown in FIG. 4 is mounted externally over the discharge orifice **78** and spaced therefrom by brackets **58**, each fixed at one end to the baffle **27** and at the other end to the end plate **77**. It serves the same purpose as the baffle shown in FIG. 5. A short tube **88** is mounted internally on the end plate **77** in alignment with the main discharge orifice **78**. The inner end of this tube **88** is sealed with an easily-removable seal, such as adhesive tape **89**. A coolant chamber **90**, formed between the end plate **77** and the partition **84** is filled with a coolant material **91**. The coolant material **91** may be in liquid form, such as an aqueous solution of calcium chloride. Alternatively, solid coolant materials, such as those described for the embodiment shown in FIGS. 7, 8, and 9 may be used. If solid particles are used, some means of retaining them in the gas generator is desirable, such as a screen (not shown) that may cover the end of the tube **88** in addition to, or in place of, the tape **89**.

In operation, an electric signal responsive to collision will fire the squib **23** to ignite the ignition composition **22**, which in turn will ignite the solid fuel **20**. Hot gases from combustion of the fuel **20** are directed, in swirling motion, through the coolant material by the orifice **85** in the partition **84**. As pressure is built up in the coolant chamber **90**, the tape **89** on the tube **88** is quickly removed to allow escape of the gases into the inflatable cushion **15** via the diffusing baffle **27**. Tape seals **87** and **86** on

the igniter orifice **82** and partition **84**, respectively, are also very quickly removed by the hot gases from the igniter **80** and the solid fuel **20**. Reaction of the hot gases with the coolant materials described is highly endothermic and, although this cooling action would tend to diminish the volume of the gases generated by the solid fuel **20**, this volume may be even increased by particles and vapors added by the coolant materials. These coolant materials are more thoroughly described, and are claimed, in a copending application for patent titled "Coolants for Gas Generators" by Graham C. Shaw and Russell Reed, Jr.

An invention has been described that constitutes an advance in the art of gas generators for filling inflatable structures in the presence of humans. Although the foregoing description has been specific with regard to details, it should be noted that many such details may be replaced by equivalent means without departing from the scope of the invention, as it is defined in the appended claims.

The invention claimed is:

1. A gas generator for filling inflatable structures in the presence of humans comprising:

a tubular housing having closed ends with a main discharge orifice in one end;

a transverse partition in the tubular housing defining a mixing chamber adjacent the main discharge orifice;

a longitudinal partition in the housing extending from the transverse partition to the closed end opposite the main exhaust orifice, the longitudinal partition defining a combustion chamber on one side, and a coolant chamber on the other side thereof with an opening therein to allow pressure from the combustion chamber to enter the coolant chamber, a first discharge orifice being in the transverse partition between the combustion chamber and the mixing chamber and being canted toward the center of the mixing chamber;

a solid fuel in the combustion chamber;

ignition means in the combustion chamber for igniting the solid fuel;

a flexible bladder filled with liquid coolant in the coolant chamber;

a sealed nozzle on the bladder extending through the transverse partition and canted toward the center of the mixing chamber, so that, when the bladder is pressurized by combustion gases from the solid fuel, a stream of coolant therefrom may impinge on the stream of gas emerging from the first discharge orifice;

an internal baffle fixed in the tubular housing and spaced over the main exhaust orifice to promote thorough mixing of gas and coolant in the mixing chamber; and

an external baffle fixed to the tubular housing and spaced over the main exhaust orifice for further cooling and diffusing of gas emerging therethrough.

2. A gas generator for filling inflatable structures in the presence of humans comprising:

a tubular housing closed at both ends;

a transverse partition, having a discharge orifice therein, that divides the housing into a combustion chamber and a coolant chamber;

a solid fuel in the combustion chamber;

ignition means in the combustion chamber for igniting the solid fuel;

particles of solid coolant in the coolant chamber, that are capable of reacting endothermically with gas emerging from the discharge orifice when the solid fuel is burned;

a diffuser tube filled with holes and extending from the discharge orifice into the coolant chamber to promote rapid contact of the gas with the coolant particles, that are distributed between the diffuser tube and the housing wall, the housing also being filled with holes in that portion thereof which bounds the coolant chamber, whereby the cooled gases may emerge; and

a tubular baffle, closed at both ends, having holes therein, and enclosing at least the portion of the housing that forms the coolant chamber, whereby gases emerging from the coolant chamber may be baffled before entering a device to be inflated.

3. A gas generator for filling inflatable structures in the presence of humans comprising:

a tubular housing, closed at both ends, except for a main discharge orifice in one end;

a transverse partition in the housing dividing it into a combustion chamber and a coolant chamber adjacent the main discharge orifice, an outwardly-canted orifice being in the partition to direct gas from the combustion chamber against the wall of the coolant chamber to create a swirling motion to cause the gases to lose energy;

a solid fuel in the combustion chamber;

ignition means in communication with the combustion chamber for igniting the solid fuel;

a short tube fixed to the inside of the housing and surrounding the main discharge orifice, the tube extending into the coolant chamber so that it cooperates with the canted orifice in the partition by forming an annular space that tends to delay emergence of the gases from the coolant chamber and promotes the swirling motion thereof as initiated by the canted orifice;

rupturable sealing means over one end of the short tube, to be broken when gases are produced;

rupturable sealing means over the orifice in the partition to be broken when gases are produced; and

a baffle mounted externally on the tubular housing, spaced from the main discharge orifice in alignment therewith, to promote further cooling and diffusion of gas discharged therefrom.

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JAMES H. TAYMAN, JR., Primary Examiner

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