United States Patent

Jones, Sr.

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[45] **Sept. 12, 1972**

[54] PERSONNEL RESTRAINT SYSTEM FOR VEHICULAR OCCUPANTS

[72] Inventor: **John Leslie Jones, Sr.**, 1070 Glen Oaks Blvd., Pasadena, Calif. 91105

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[52] **U.S. Cl.** .....**280/150 AB**, 102/39, 222/5, 200/61.45

[51] **Int. Cl.**.....**B60r 21/06**

[58] **Field of Search**.....280/150 AB; 23/281; 222/3, 222/5; 9/316; 62/46–50; 102/39

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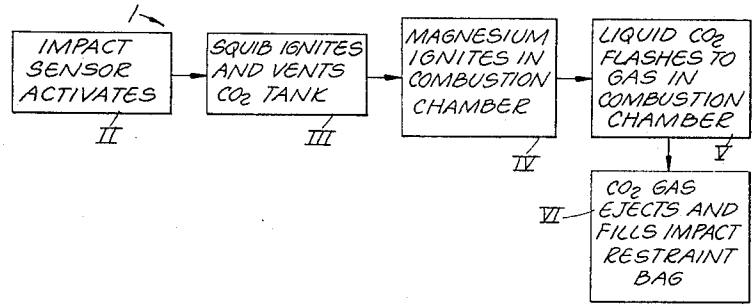
Primary Examiner—Kenneth H. Betts

Attorney—J. L. Jones, Sr.

[57] **ABSTRACT**

The personnel restraint system has an accordion pleated impact restraint bag, which is folded flat in a transverse U-bend and disposed in a case, which can be fixed under the vehicle instrument panel, adjacent to the front seat. In a quickly acting process an adjacently disposed tank of liquid carbon dioxide charge, is rapidly discharged through a ruptured tank sealing metal membrane on activating an impact sensor and firing a squib. Concurrently magnesium metal powder is blown into a metal combustion chamber duct and rapidly oxidized. The heat of combustion is utilized to vaporize the discharged liquid carbon dioxide to gas in the chamber duct. The heated carbon dioxide gas is ducted into the folded impact bag, rapidly expanding the bag into the vehicle compartment volume in front of the personnel seats. A second impact sensor can operate a second carbon dioxide tank which vents into the atmosphere adjacent to the gasoline tank, acting to flood the tank vicinity with carbon dioxide, to prevent or extinguish a gasoline fire.

15 Claims, 12 Drawing Figures



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3 Sheets-Sheet 1

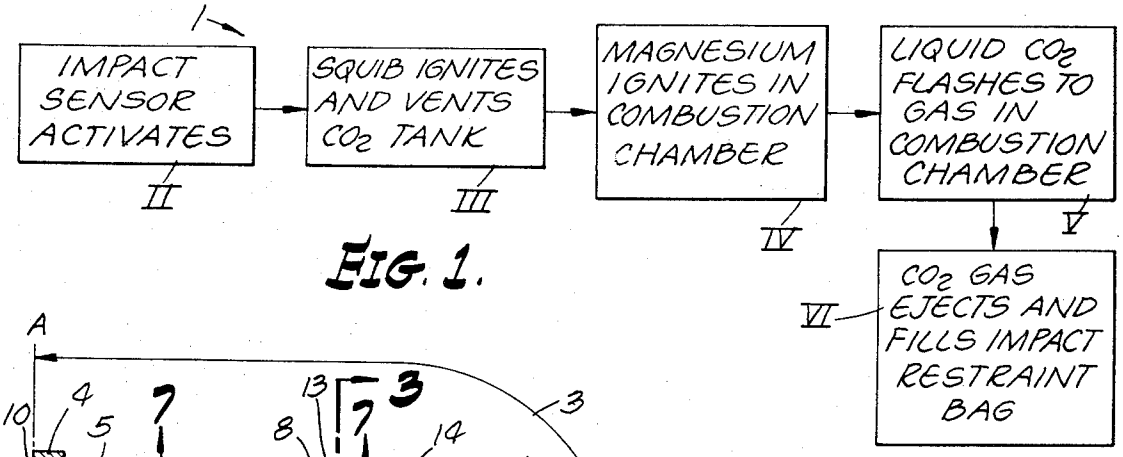


FIG. 1.

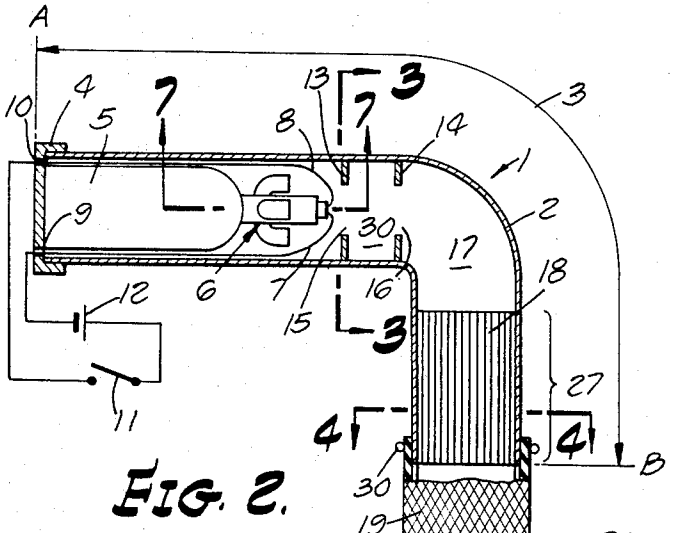


FIG. 2.

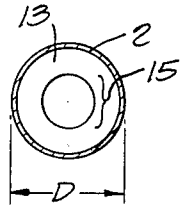


FIG. 3.

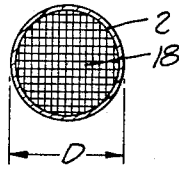
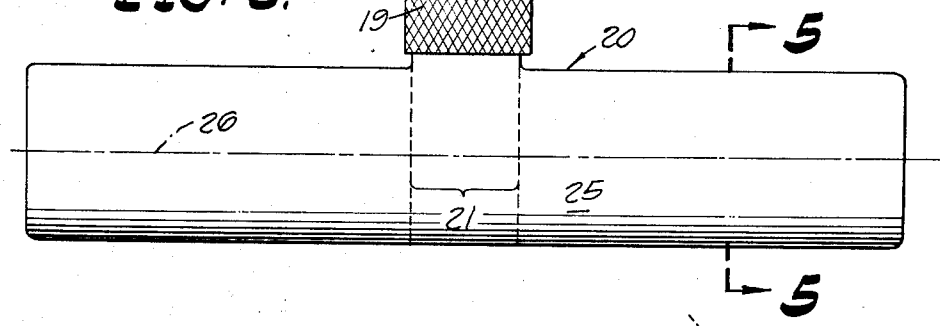


FIG. 4.



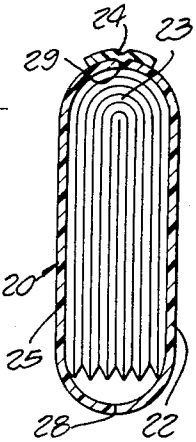


FIG. 5.

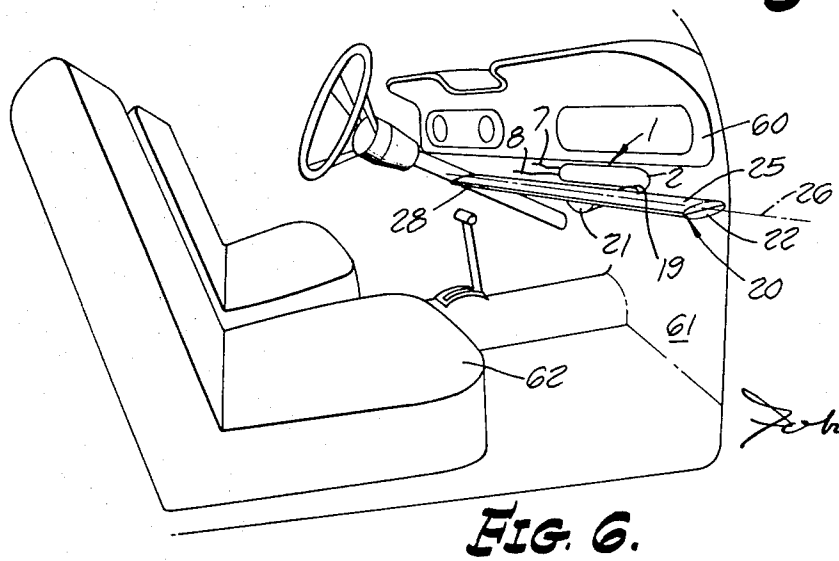


FIG. 6.

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FIG. 7.

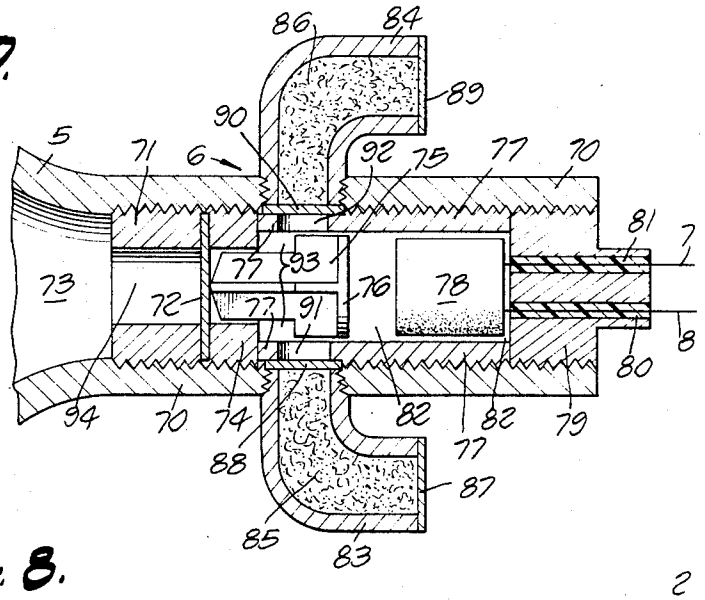
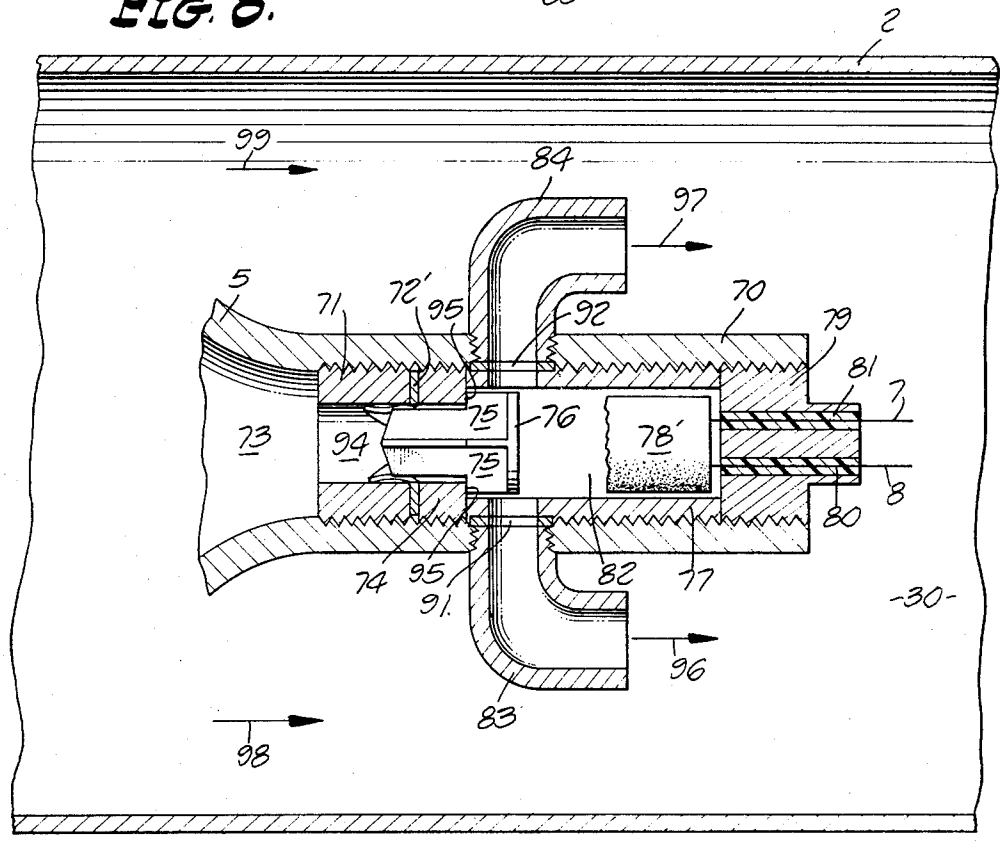


FIG. 8.



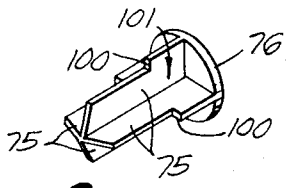
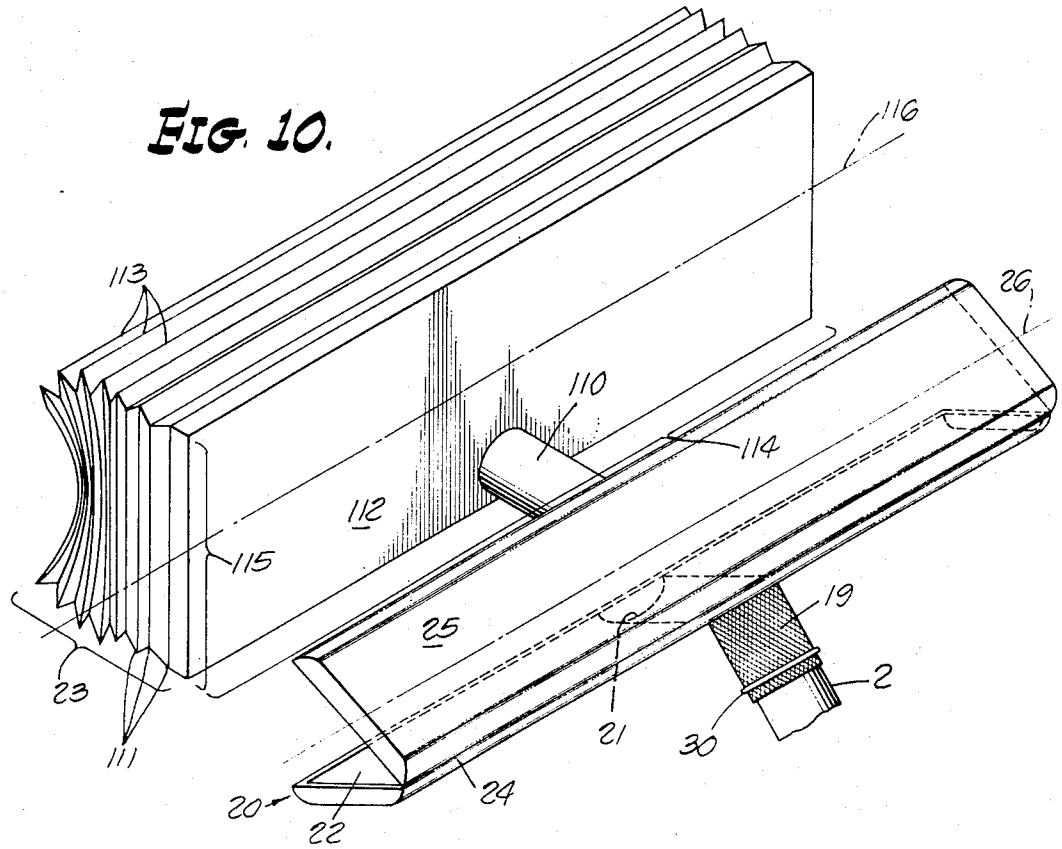


FIG. 9.

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FIG. 10.



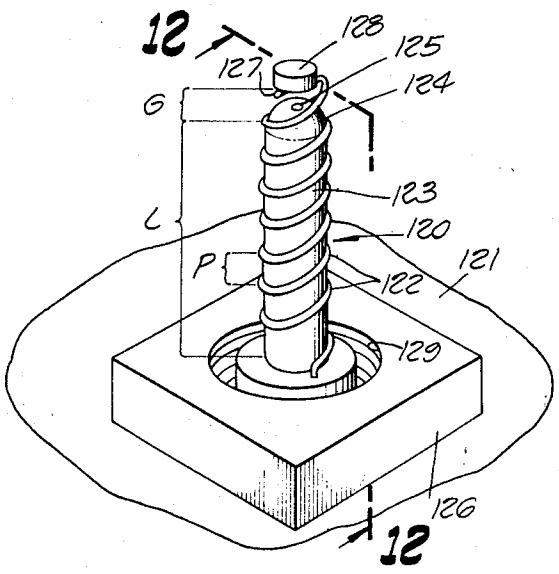


FIG. 11.

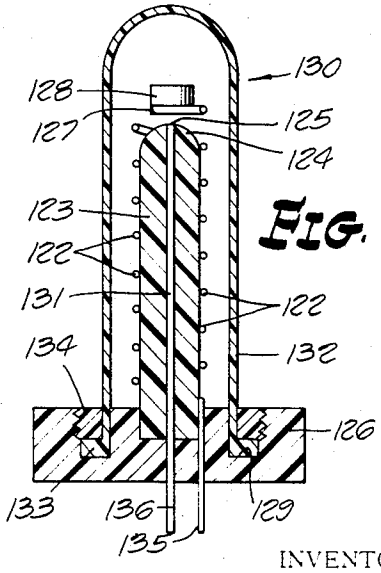


FIG. 12.

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PERSONNEL RESTRAINT SYSTEM FOR VEHICULAR OCCUPANTS

BACKGROUND OF THE INVENTION

There is a serious current need for a personnel restraint system for motor vehicles and the like, which can cushion and restrain the moving occupant of a passenger car, truck and an airplane when the vehicle suddenly impacts in an accident. Typically the personnel restraint system should guarantee protection against a head-on collision with a fixed barrier at 30 mph, without requiring voluntary participation by the vehicle's occupants, such as fastening seat belts, shoulder harnesses, or the like. The personnel should also be protected in lateral collisions at speeds up to 15 mph and from two complete vehicle rollovers at speeds up to 60 mph. The system should sense the varying crash situations and the impact bag should be triggered and deployed without harming the passengers, in less than 50 millisec.

One current personnel restraint system utilizes a 3,500 psi air tank source which empties into a woven nylon impact bag, once a thin metal tank diaphragm is punctured. An electronic omnidirectional sensor has redundant impact sensors. In another personnel restraint system compressed nitrogen gas is vented into an impact bag when the electrically fired dentonator opens the high pressure, tubular gas reservoir assembly. The high velocity gas flows through a controlled opening and is directed into the air bag through a diffuser system. A uni-directional sensor is employed in this personnel restraint system.

In still another system, a solid-state storage supply is proposed for the inflating gas. This inflation system requires a solid propellant charge which on combustion will not generate toxic gases and the propellant must burn at as low a temperature as possible, to decrease fire hazards. A suggested solid propellant generating gas suitable for the inflation of the impact bag has a solid coolant, ammonium oxalate, added to eliminate toxic gases such as hydrogen cyanide, hydrogen sulphide, carbon monoxide, and the like.

This invention eliminates the excessively high pressure gas storage requirement of the nitrogen tank, and the potential formation of toxic gases in the occupant compartment of the vehicle. It decreases the noise level of the operation of the personnel restraint system and increases the reliability of the automatic system activation by using an initiating squib or fuse. By rapidly flashing the liquid carbon dioxide with the heat of combustion of an ignitible magnesium composition, low cost and low storage pressure carbon dioxide is used.

SUMMARY

The personnel restraint system is activated by one or more spring loaded impact sensors separately, permanently disposed in selected locations in a vehicle. On impact, one or more sensors electrically conduct at the sensor locations, firing a hot gas and flame generating squib. The hot gas operates a device which opens the metal diaphragm securing liquid carbon dioxide under pressure in a cylinder, and also ignites one or more magnesium power charges exteriorly disposed adjacent the cylinder exit orfice. The ignited magnesium is blown down the metal combustion chamber, which also confines the cylinder and the required air for metal powder ignition. The finely divided, hot reaction product, magnesium oxide, together with the heated residual air, and the radiating metal combustion chamber, rapidly and effectively exchange heat to raise the temperature of the liquid carbon dioxide being ejected from the tank, quickly flashing the carbon dioxide to a warm gas. The warm gas is quickly directed into one end of a flexible non-combustible membrane tube, coaxially secured to the end of metal heat exchanger duct. The membrane tube is permanently secured at its second tube end to a flat folded, accordion pleated, transverse axially U-folded, impact distortable, flexible membrane, restraint bag. Prior to filling the bag with warm gas, the flat, accordion pleated, U-folded bag is disposed in a protective, long, flat plastic case. The case is disposed under the lower forward edge of the typical car vehicle instrument panel, confronting the front seat. The long, flat, U-folded bag is protected by a pair of frangible hinged plastic covers of the case. A second integral hinge secures the cover when gas fills the bag, projecting the bag into the car volume adjacent the instrument panel and steering wheel, as the folded bag pleats are filled with gas to the required pressure. The same impact sensor or a second impact sensor can operate to open a second carbon dioxide tank disposed adjacent the gasoline tank, acting to flood the tank vicinity with carbon dioxide to prevent or extinguish a gasoline fire.

The chain of chemical and physical reaction times required to develop the restraint system to an operational safety condition are minimal. Typically, 1.14 lb. of liquid carbon dioxide at 928 psia and 77° F., flashes to occupy 10.1 cu. ft. at 77° F. and 1 atm. The liquid carbon dioxide can be rapidly vaporized by burning 2.47 gram of magnesium in 2.30 liters of oxygen in the air in the duct, using gas mixing orfice devices and a heat exchanger in the metal combustion chamber duct.

Included in the objects of this invention are:

First, to provide an integrated, rapidly acting, automated personnel restraint system for a vehicle carrying occupants.

Second, to provide a simple, low cost, reliable, rapidly acting, automatic carbon dioxide gas inflation means for a personnel restraint system in a personnel carrying vehicle.

Third, to provide a modular, secure, reliable, rapidly acting carbon dioxide gas inflation means for a personnel restraint system disposed in a motor vehicle.

Fourth, to provide a low cost, reliable, rapidly acting, heat exchange means for vaporizing liquid carbon dioxide in a gas inflation means of a personnel restraint system for passenger carrying vehicles.

Fifth, to provide a rapidly oxidizable, exothermic, heat exchange reactive means for rapidly flashing liquid carbon dioxide in a personnel restraint system disposed in a personnel carrying vehicle.

Sixth, to provide a rapidly acting, igniting and gas pressurizing means for a carbon dioxide gas inflating, personnel restraint system for a personnel carrying vehicle.

Seventh, to provide an accordion pleated, transversely axially U-folded, impact distortable, flexible membrane, impact restraint bag and a frangible protective case for a personnel restraint system for personnel carrying vehicles.

Eighth, to provide a rapidly acting, exothermic, heat exchange reactive process for rapidly vaporizing liquid carbon dioxide in a personnel restraint system disposed in a passenger carrying vehicle.

Ninth, to provide a rapidly acting, igniting and gas pressurizing process for a carbon dioxide powered personnel restraint system for a personnel carrying vehicle.

Further objects and advantages of this invention will become apparent in the following description, to be read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow sheet illustrating sequential steps in the operation of the personnel restraint system.

FIG. 2 is a partial sectional planar view of important components of the personnel restraint system.

FIG. 3 is a sectional view through 3—3 of FIG. 2.

FIG. 4 is a sectional view through 4—4 of FIG. 2.

FIG. 5 is a sectional view through 5—5 of FIG. 2.

FIG. 6 is a perspective view of the personnel restraint system confrontingly disposed to the front seat and under the instrument panel adjacent to the firewall of a motor vehicle.

FIG. 7 is a partial sectional view of the carbon dioxide and the system firing mechanism in 6, along the line 7—7 of FIG. 2.

FIG. 8 is a sectional view of the firing system mechanism of FIG. 7 disposed in the combustion chamber duct of FIG. 2, after ignition of the magnesium reactant, illustrating the carbon dioxide venting mechanism operation, as well as the ignition of the magnesium.

FIG. 9 is a perspective view of the typical structure of the carbon dioxide tank metal diaphragm knife cutter.

FIG. 10 is a perspective elevational view of the accordion pleated personnel impact bag, partially distended as it is being ejected from the bag carrying case, on filling with carbon dioxide gas.

FIG. 11 is a perspective elevational view of the impact sensor mechanism with the dirt protective cover removed.

FIG. 12 is a sectional view of the impact sensor of FIG. 11, illustrating further details of the construction of the sensor, enclosed in a permanently sealed dirt protective cover.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates in a flow sheet important steps required for the operation of the personnel restraint system 1. Illustrated first in box II, an impact sensor is activated, signalling that a personnel carrying vehicle is involved in an accident resulting in the rapid deceleration or acceleration of the vehicle or of the vehicle component to which the impact sensor has been permanently secured. The impact sensor, which is an electrical switch, closes the electrical circuit igniting a squib, which in turn vents a carbon dioxide tank as is indicated in the next step of box III. At a very short millisecond interval thereafter, a magnesium pyrotechnic composition is exothermically burned in a combustion chamber as illustrated in box IV. At a still later short millisecond interval, the liquid carbon dioxide is ejected from the carbon dioxide tank under pressure and flashes to a gas in the combustion chamber. The heat of vaporization of the liquid carbon dioxide is supplied by the exothermic heat of combustion of the magnesium as illustrated in box V. The warm carbon dioxide gas fills and ejects the impact restraint bag, as shown in box VI. The gas filled impact restraint bag then restrains and cushions any personnel thrown against the bag during an accident or the like.

Referring to FIG. 2 in detail, the personnel restraint system 1 is shown in planar, partial sectional view, having an L-shaped metal duct 2. The duct 2 typically extends from the A to B as shown by the arrow 3. At the cylindrical duct end A, a metal duct cover 4 is secured to the duct 2. A tank 5 containing liquid carbon dioxide is disposed inside the duct 2, adjacent to the duct cover 4 and is permanently secured in place in the duct 2 by known standard means. A system firing mechanism 6 is shown secured to the tank 5. A pair of ignition wires 7 and 8 extend from the firing mechanism 6 around the side of the tank and through the respective electrical insulator connectors 9 and 10 in the metal duct cover 4. The igniter wires 7 and 8 are then connected through an impact sensor switch 11 shown schematically as an equivalent electrical switch. The car battery 12 or an equivalent power source supplies power to actuate the system firing mechanism 6 when the impact sensor 11 is activated, as in an accident. A pair of combustion flame holders 13 and 14 also serve as mixing orfices for the combustion process which will be discussed later. The combustion flame holders 13 and 14 are secured to the interior wall of duct 2 and have a respective pair of mixing apertures 15 and 16. The duct elbow 17 continuously connects to and terminates at the heat exchanger 18. A flexible duct coupling means 19 is secured on the metal duct 2 by the retaining ring 30 and connected to the carrying case 20, which holds the impact restraint bag, not shown. The top half 25 of the carrying case 20 is shown in planar view, having a transverse axis 26 for the restraint bag which is enclosed in the case 20. A flexible membrane tube protective channel 21 of the case 20 is indicated in dotted lines, as being disposed on the under side of the case 20, connected to the flexible duct coupling 19.

In FIG. 3 the metal circular duct cross section 2 is shown, having a combustion flame holder 13 coaxially disposed therein, with the mixing aperture 15 also coaxially disposed therein. The duct 2 has a typical diameter D. The function of the flame holder 13 is to hold the ignition flame of the pyrotechnic composition, as well as to produce mixing of the combustion products with the liquid carbon dioxide as it is ejected from the tank 5, as will be later described.

FIG. 4 also shows the circular duct 2 in cross sectional view with a diameter D and having a heat exchanger 18 filling the cross section for the length 27 along the duct 2, as shown in FIG. 2. The heat exchanger 18 typically fits closely into the duct diameter D and can be aluminum or copper wire screen of a suitable mesh size. Exchanger 18 also can be an extruded copper, aluminum honeycomb cross sectional or tubular structure, or other highly conductive metal composition, which can rapidly absorb heat and transfer heat to high velocity gases and liquids moving through the heat exchanger 18. The heat exchanger 18 can also be an expanded honeycomb type structure of sheet aluminum or the like, commonly used as a light

weight compression resistant member in aerodynamic surfaces such as airplane wings, or the like. The light weight aluminum honeycomb can be typically made by welding together a multiplicity of very thin aluminum sheets in linear patterns, and expanding the multiple sheet structure into an expanded honeycomb. Other metal compositions of high heat conductivity can likewise be used. The metal duct **2** and the heat exchanger **18** can also typically be mild carbon steel. In terms of the optimization of heat transfer rate vs the cost of the duct and its contained metal component raw material weight, if a sufficiently rapid heat transfer can be effected with steel, it can well be the most economical material and construction.

In the cross sectional view through 5—5 of FIG. **2** as shown in FIG. **5**, the plastic case **20** is shown to have a top case cover **25** and a bottom case cover **22** secured together by a frangible hinge structure **24**. The case **20** has the frangible hinge **24**, and a transversely linear front line lip **28** formed by the contact of the top case **25** with the bottom case **22**. The permanent integral hinge **29** secures top case **25** and bottom case **22** together. The impact restraint bag **23** is shown disposed inside the case **20**, folded in a transverse U-bend along the transverse axis **26** of the case **20**. The impact restraint bag **23** is shown to have accordion pleated multiple folds in the bag as will be later disclosed in detail.

The frangible plastic hinge **24** should be secured to the case **20** after the impact restraint bag **23** is folded and disposed in the case **20**. Suitably, the bag **23** is disposed in the bottom **22** of the case, then the top **25** of the case is placed in position at the front line lip **28** and the integral frangible plastic hinge **24** bonded in place on the case **20** securing the case components together. The frangible hinge **24**, which can be sealed completely along the length of the transverse axis **26** of the case can be a molded structure having a notch disposed therein which renders the hinge frangible at the notch cleavage. A plastic hinge composition having a particularly high notch impact sensitivity, such as polystyrene, or the like, is particularly suitable for the hinge structure. Other plastic compositions having suitable notch impact sensitivity may be utilized.

FIG. **6** illustrates the general configurational positioning of the personnel restraint system **1** disposed in a motor vehicle. In the illustration, the metal duct **2** enclosing the other typical components of FIG. **2** is shown disposed underneath the instrument panel **60** of the motor vehicle, with the duct **2** adjacent the firewall **61** of the car. The front seat **62** of the motor vehicle confronts the instrument panel **60** of the car in the usual configuration. The carrying case **20** for the impact restraint bag shown disposed underneath the instrument panel, with the case front line lip **28** generally disposed parallel to the instrument panel and adjacent to the panel **60**. The top **25** of the carrying case **20** is secured to the instrument panel by suitable well known means. The protective channel **21** for the flexible membrane tube in the case **20** is shown disposed on the underside of the bottom case **22**. Operationally, the carrying case **20** is shown disposed as close to the seat **62** as is comfortable and safe, in order to provide a minimum transit time for the impact restraint bag **23** disposed therein, when the personnel restraint system **1** is activated. The flexible coupling **19** is shown, providing a flexible means for permanently coupling the rigidly positioned carrying case and the other rigidly positioned components of the personnel restraint system **1**, enclosed in the metal duct **2**.

In FIG. **2** the duct **2** is shown disposed in a planar geometrical position, and it is likewise shown in the same planar position in the perspective view of FIG. **6**. However, the duct **2** can be rotated 90° to place the tank component **5**, or the like, in a vertical position, either with the duct cap **4**, or the like, down near the floor board of the car, or it may be placed vertically uppermost with the system firing mechanism **6** disposed directly below the raised tank **5**, or the like. When the tank **5** is placed vertically above the system firing mechanism **6**, liquid carbon dioxide will be ejected from tank **5** when the diaphragm **72** is ruptured. In the other placement positions of the tank **5**, more or or less liquid carbon dioxide will be directly ejected from the tank, depending on the angular position of the tank.

The details of the construction of the system firing mechanism **6** which are secured on the carbon dioxide tank **5** are shown in FIG. **7**. The internally threaded tank neck **70** of the carbon dioxide tank **5** is shown to have an internal collar **71** threaded into the neck **70**. A thin metal sealing diaphragm **72** seals the tank neck **70**, securing the internal tank volume **73** which contains liquid carbon dioxide. A threaded sealing collar **74** compressively seals the metal diaphragm **72** against the internal collar **71**. Thus a tank aperture **94** is provided through which the liquid carbon dioxide can be eventually ejected. Typically, a four edge cutter knife **75** is disposed in the tank neck **70** adjacent to the metal diaphragm **72**. A knife guide and spacer **77** is typically secured in the tank neck **70**, positioning the cutter knife **75**. A knife piston disc face **76** is integrally secured to the cutter knife **75** and slidably closes and fills the cylindrical diameter of the knife guide and spacer **77**. A firing squib **78** is disposed in the squib enclosure **82**. The squib sealing plug **79** seals the firing squib **78** in position. The plug **79** is typically threaded or secured immediately abutting the knife guide and spacer **77**, providing a loose enclosure for the firing squib **78** and preventing the squib **78** from being prematurely crushed or impacted into firing. The squib ignition wires **7** and **8** are conducted from the firing squib **78** through the pair of insulator connectors **80** and **81** to the remainder of the firing circuit. A pair of metal elbow cases **83** and **84** are shown oppositely disposed in the neck **70** of the tank **5**. Additional metal elbow cases may also be provided around the same radial plane of case **83** and **84**. The metal elbow cases **83** and **84** and the like are filled with the required amount of magnesium pyrotechnic compositions **85**, **86** and the like. The magnesium pyrotechnic composition can be simple magnesium powder, as is used in photography and the like. The metal elbow cases **83**, **84** and the like are sized to contain the required amount of magnesium composition. Each elbow case, typically **83**, has a pair of very thin metal foil sealing membrances **87** and **88** which are secured to the ends of the case and which secure the magnesium composition in the case until the system becomes operational. A similar pair of very thin metal sealing membranes **89** and **90** seal the elbow case **84**, or the like, containing the required magnesium

composition in it. The pair of apertures **91** and **92** each separately connect the cases **83** and **84** respectively to the knife cavity **93** in which the knife cutter **75** is disposed. The detailed structure of the firing mechanism **6** which is illustrated in FIG. **7** is that which exists in the configuration of the personnel restraint system **1** in FIG. **2**, prior to the initial operation of the system **1**. It is desirable that all of the components of the system **1** which lie between the lines A and B should be metallic, providing that the system can be well grounded except where electrical insulators are required.

Referring to FIG. **8** in detail, the system firing mechanism **6** is shown disposed in the partial sectional view within the metal duct **2**. The details of the firing mechanism **6** are shown in operative relationship after the firing squib **78** has been fired, converting it to the ruptured squib **78'**. The fired squib **78'** still occupies its essentially constant position within the squib enclosure **82**, but the knife cutter **75** is now shown driven through the thin metal membrane **72** which previously sealed the interior of the tank **73**. The ruptured diaphragm **72'** is shown bent in leaves at the side of the tank aperture **94**. The fired squib **78'** has evolved both high pressure gas and flame resulting from igniting the composition in the squib. The high pressure gas has pressed against the knife cutter piston face **76**, moving the piston to cut the ruptured diaphragm **72'**. The high pressure gas and the flame from the squib **78'** have blown the very thin foil metal membranes **87**, **88**, **89** and **90** of the cases **83** and **84** respectively, blowing out the magnesium pyrotechnic composition contained in the cases **83** and **84**. The magnesium pyrotechnic compositions are ignited by the flame of squib **78'**, and the magnesium composition burns in the oxygen of the air resident in duct **2**. For the purpose of insuring complete combustion of the magnesium composition, the sizing of the duct diameter D is that which provides sufficient oxygen in the resident air in the duct to burn all of the magnesium composition. The magnesium powder composition is blown in the direction of the arrows **96** and **97** by the high pressure gas from the squib **78'**. The arrows **98** and **99** indicate the average direction of flow of the reactants and combustion products in the chamber. For the purpose of clarity, the sections **30** and **17** of FIG. **2** are designated as the combustion chamber for the combustion of the magnesium. The combustion flame holders **13** and **14** have been suitably disposed to aid in the mixing of the reactants, as well as to provide flame holders for assistance in the completion of the combustion. The combustion process may also be completed in the absence of the flame holders **13** and **14**, but the flame holders can reduce the required length and volume of the sections **30** and **17**. The combustion process can take place not only in the sections **30** and **17**, but also in the heat exchanger **18**.

Typically, the magnesium burns in the well known reaction,

$$2\,Mg + O_2 \rightarrow 2\,MgO \qquad \Delta H_1 = -143.8 \text{ kcal/mole} \quad (1)$$

In addition, magnesium ignited in air can also react with carbon dioxide as illustrated in the equation (2) below,

$$2\,Mg + CO_2 \rightarrow 2\,MgO + C \qquad \Delta H_2 = -96.8 \text{ kcal/mole} \quad (2)$$

The fact that magnesium will react with carbon dioxide is important for the rapid vaporization of the liquid carbon dioxide as it is ejected under pressure from the tank **5**, or the like. Under the conditions of the operation of the personnel restraint system **1**, the carbon dioxide will not smother the oxidation of the magnesium which precedes it, for reaction (2) is also exothermic and will proceed with evolution of heat. Although the heat of reaction of equation (2) is smaller than (1), the reaction is sufficiently exothermic to provide energy for the vaporization process. Allowance can be made for reaction (2) by adding additional magnesium pyrotechnic composition, to the system firing mechanism **6**.

Typically, 1.14 pounds of liquid carbon dioxide (P vapor = 928 psia at 77° F.) flashes to occupy 10.1 cu. ft. at 77° F. and **1** atmosphere. The heat required to rapidly vaporize the liquid carbon dioxide can be quickly obtained by burning 2.47 grams of magnesium powder in 1.22 liters of oxygen in the air in the duct. In order to prevent undue temperature rises within the duct and to promote the efficiency of heat transfer in the vaporization process, a heat exchanger can be desirable. The combustion of the magnesium powder composition can be accelerated by utilizing finely divided magnesium powder and by providing mixing orfices to promote turbulence during the combustion process. The heat of vaporization of the liquid carbon dioxide at varying ambient tank temperatures can be compensated for by adding more than the theoretical amount of required magnesium. Additional magnesium over the theoretical will also compensate for combustion efficiency and heat transfer efficiency.

FIG. **9** is an elevational perspective view of the knife cutter **75** showing the four thin knife edges of the cutter. The cutter is shown to have the four knife shoulders **100** which can bear on the collar **74**, as at the area of contact **95** between the cutter **75** and the collar **74** in FIG. **8**. The cutter piston face **76** is shown to be circular, dimensioned to snugly fit into the cavity **82** without seizing or galling. Obviously other numbers of knife edges can be provided for the cutter **75** or the like. The shoulders **100**, or the like, are provided as stops to position the cutter **75** after actuation by the squib **78'**, so that the cutter apertures **101**, as outlined by the multiple blade edges, can allow passage of the carbon dioxide from within the tank volume **73**.

Referring to FIG. **10** in detail, after the combustion process takes place in the chamber **30**, **17**, and **18**, the flashed carbon dioxide gas flows through the flexible coupling **19** into the impact restraint bag **23**. The flexible membrane tube **110** which previously has been loosely lying in the protective channel **21** of the case **20** is now filled with carbon dioxide gas under pressure. The tube **110** now distends to its full length and snaps open the case **20**, by breaking the frangible hinge **24**. The distending tube **110** now ejects the accordion pleated impact restraint bag **23** which has been folded in a U-bend along the transverse line **26** of the case **20**. The ejected impact bag **23** is forced out of the case by the pressure of the carbon dioxide gas filling bag **23**. The accordion pleated folds typically **111** fill first at the face **112** of the bag adjacent to the duct **110**. The accordion pleated folds **113** furtherest from the bag face **112** tend to be filled last as is illustrated. Depending

upon the precise weight filling of the tank **5** with the required amount of liquid carbon dioxide, the bag **23** is fully distended with carbon dioxide under a slight pressure within milliseconds after activation of the switch **11**, as in FIG. **2**. By providing the required amount of magnesium pyrotechnic composition, the liquid carbon dioxide can be vaporized to carbon dioxide at a nominal ambient room temperature of **70°–90°** F. at a low pressure of 1–2 lbs. or the like. The accordion pleated impact restraint bag **23** has a length **114** when fully distended, which can be sufficient to act as a restraint bag for **1, 2** or **3** personnel occupying a motor vehicle seat, as required. The height **115** of the fully distended restraint bag **23** is that which is necessary to provide the impact restraint protection required for the personnel in the vehicle, and can be typically 12 to 24 inches or the like. For clarification, the transverse axis **116** of the bag **23** is shown, about which the bag is folded into a U-bend when disposed in the container **20**.

The accordion pleated impact restraint bag **23** or the like can be typically formed of a non-combustible thin flexible membrane plastic material such as a polyvinyl chloride plasticized with a non-combustible plasticizer, or it can be formed of a non-woven fabric with a thermoplastic binder. It is possible to form the non-flammable plasticized polyvinyl chloride bag in a standard blow molding operation, utilizing well known commercial techniques. Likewise a non-woven, non-flammable thermoplastic fiber composition such as Dynel can be used to form a non-porous bag, which may be fabricated in a pattern cutting and bonding operation.

Referring to FIG. **11** in detail, the unidirectional reactive impact sensor components **120** are shown disposed on a structural component **121** of the personnel vehicle. The helical coil spring **122** is shown disposed snugly and loosely slidably coaxially fitted around the low friction coefficient electrical insulator post **123**, having a rounded terminal **124**. The post **123** can typically be polytetrafluoroethylene (Teflon) or other polyfluoropolymers, or the like, having very low coefficients of friction, and sufficient hardness to eliminate cold flow and distortion under the conditions of use in this sensor. A rigid metal electrically conductive rod end **125** is coterminus with the apex of the rounded post end **124** extending coaxially through the post **123** into the electrically insulating base **126**. The spring terminus **127** has an electrically conducting metal weight **128** permanently secured to the spring, and the weight **128** is disposed directly over the electrically conducting rod end **125**. The mass M of the metal weight **128**, the gap G between the weight **128** and the rod end **125**, and the length L of the electrically insulated post **123**, together with the pitch distance P between the turns of the helical coil spring **122** are configured in terms of the physical constant k of the spring **122** to provide electrical contact between the mass **128** and the rod end **125** at the required deceleration value to unidirectionally activate the sensor components **120**. An annular ring groove **129** is shown coaxially disposed around the post **123**, which is suitable for securing a protective dust and water tight cover over the active components **120**. The sensor behaves as a seismic pendulum, having a period, $T=2\pi\sqrt{M/kg}$.

FIG. **12** illustrates in sectional detail the components of the complete unidirectional impact sensor switch **130**. All of the active switch components of FIG. **11** are illustrated and the axially disposed electrical conducting metal rod **131** is shown coaxially disposed within the electrical insulator post **123**, the rod **131** terminating at the electrical contact end **125**. A water resistant and dust proof cover **132** is coaxially disposed around the active components **120** of the impact sensor **130**. The lip **133** of the cover **132** is shown disposed in the coaxial groove **129**. A threaded container ring **134** is shown threaded into the groove **129** locking the cover **132** into a permanent dust and water tight protective configuration in the base **126**. The pair of electrical terminals **135** and **136** are extensions of the coil spring **122** and the rod/**31** respectively. The terminals **135** and **136** may be formed and treated in conventional well known manner, to provide dirt and water resistant terminals which can be free of short circuiting and the like. The impact sensors can be permanently disposed behind bumpers, in door panels, and in other necessary positions on vehicles.

Further, a second carbon dioxide containing tank **5** or the like, together with the system firing mechanism **6''**, without the magnesium pyrotechnic composition, may be installed in the vicinity of the gasoline tank of the vehicle, as in the car trunk or the like. Typically, an impact sensor **130** or the like may be installed at the rear of the car, such as on or adjacent to the rear bumper. On signal from the sensor **130** that an impact has taken place in the rear of the vehicle, the firing mechanism **6''** can be operated, ejecting liquid carbon dioxide into the vicinity of the gasoline tank. The carbon dioxide will then vaporize and prevent or extinguish any fire generated by a ruptured gasoline tank.

The personnel restraint system taught in this invention is particularly suitable for automobiles, trucks, and other road driven motor vehicles subject to accidents. It can likewise have application to other personnel carrying vehicles such as speed boats, airplanes, and the like, by utilizing impact sensors particularly suited for the potential accident impact parameters.

In order to promote the safety and well being of the occupants of the motor vehicle, the personnel restraint system **1** should be essentially sold, installed and maintained as a single use disposable system. This mode of service requires that the system should be installed in the motor vehicle as a sealed unit, with a wire seal on the duct system cover **4** or the like, the seal to clearly indicate whether the duct system has been tampered with. After an accident it is proposed that the complete tank **5** and firing mechanism **6** be returned to a factory for rebuilding, and that a new unit be installed. Likewise the impact restraint bag **23**, or the like, should be disposable and thrown away with its carrying case after a single accident, for the frangible hinge will prevent the case from being easily re-used. In this manner it is possible to maintain safety standards. A new impact bag contained in a sealed carrying case would then be reinstalled in the vehicle. The personnel restraint system is tamper resistant in the sense that the system can be fabricated and installed with technique that will, on inspection, clearly indicate that the system has been tampered with.

Many modifications and variations of the improvement in the personnel restraint system may be made in the light of the teachings disclosed herein. It is therefore understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. In a process for rapidly operating a personnel restraint system suitable for protecting vehicular occupants, utilizing liquid carbon dioxide sealed in a tank, said carbon dioxide vaporizing on release from said tank and filling an impact restraint bag with carbon dioxide gas, the process improvement comprising:

a. propelling and igniting a magnesium pyrotechnic composition by an electrically ignited firing squib, said squib evolving gas at a flame temperature adapted to igniting said magnesium composition;

b. combusting said magnesium composition with the oxygen of the air resident in a combustion duct; and

c. heating and flashing all said released carbon dioxide to a gas, utilizing the turbulent heat transfer from the reaction products of the magnesium combustion process, said reaction products adapted to providing the required heat of vaporization for the liquid carbon dioxide.

2. In a process for rapidly operating a personnel restraint system suitable for protecting vehicular occupants, utilizing liquid carbon dioxide sealed in a tank by a thin metal diaphragm, said carbon dioxide vaporizing on puncturing said diaphragm and filling an impact restraint bag with carbon dioxide gas, the improved process comprising:

a. electrically igniting a squib, said squib evolving a required volume of high pressure gas at a flame temperature adapted to ignite a magnesium composition in air;

b. propelling a cutter knife to puncture said diaphragm, said knife propelled by said high pressure gas evolved by said squib;

c. concurrently with propelling said cutter knife, igniting and propelling said magnesium composition into a metal combustion duct, said magnesium composition rapidly combusting in and with the oxygen of the air resident in said duct and evolving heat; and

d. heating and rapidly vaporizing said released carbon dioxide to a gas, adaptively utilizing the evolving heat of combustion turbulently transferred from the products of combustion to flash all said carbon dioxide.

3. In a carbon dioxide inflating gas, automated personnel restraint system for personnel carrying vehicles, having a liquid carbon dioxide gas supply disposed in a tank sealed by a thin rupturable metal diaphragm, the improvement comprising:

a. an electrically ignitible firing squib, adapted on igniting to evolving a required volume of high pressure gas at a flame temperature adapted to igniting a magnesium composition, and to rapidly propelling a cutter knife and rupturing said diaphragm, said squib being electrically insulatively disposed in a squib enclosure in said tank neck adapted to withstand said gas pressure;

b. at least one case cooperatively radially integrally connected to said tank neck and opening into said squib enclosure on propelling said knife to a predetermined tank neck stop;

c. a predetermined weight of magnesium pyrotechnic composition cooperatively disposed in said at least one case, said composition secured in said case by a pair of very thin foil membranes, said predetermined weight of said composition evolving a predetermined heat of combustion with the oxygen of the air;

d. a metal tubular duct cooperatively adaptively securely containing said carbon dioxide tank in a fixed position at one end of said duct, the duct volume containing sufficient oxygen in the contained air to combust said magnesium composition, the weight of said metal duct providing adequately safe strength and heat transfer characteristics for the magnesium combustion reaction;

e. a cover means for a first end of said duct disposed adjacent said carbon dioxide tank;

f. insulated electrically conductive wire means connecting said electric squib to an impact sensor means disposed exteriorly to said duct; and

g. a tubular coupling means, conductively tightly connecting the gas exit of the second duct end to a flexible membrane gas inlet tube of an impact restraint bag.

4. In the automated personnel restraint system improvement of claim 3, the further improvement wherein at least one mixing orfice is coaxially disposed in said duct adjacent said metal cases containing magnesium composition, said at least one orfice having a coaxially disposed mixing aperture.

5. In the automated personnel restraint system improvement of claim 3, the further improvement wherein a metal heat exchanger is coaxially disposed in said duct adjacent said second duct end.

6. In a carbon dioxide inflating gas, automated personnel restraint system for personnel carrying vehicles, having a liquid carbon dioxide gas supply disposed in a tank sealed by a thin rupturable metal diaphragm, the improvement comprising:

a. a cutter knife coaxially slidably disposed in the tank neck exteriorly disposed to rupturing said metal diaphragm, said knife having cutting edges adjacently disposed to said diaphragm and a piston face oppositely disposed to said cutting edges, said knife having positioning shoulders thereon, adapted to stop said knife in a cooperatively predetermined position on a tank neck stop on propelling said knife;

b. an electrically ignitible firing squib, adapted on igniting to evolving a required volume of high pressure gas at a flame temperature adapted to igniting a magnesium composition, and to rapidly propelling said cutter knife and rupturing said diaphragm, said squib being electrically insulatively and loosely disposed in a squib enclosure in said tank neck adapted to withstand said gas pressure;

c. at least one case cooperatively radially integrally connected to said tank neck and opening into said squib enclosure on propelling said knife to said predetermined tank neck stops;

d. a predetermined weight of magnesium pyrotechnic composition cooperatively disposed in said at least one case, said composition secured in said case by a pair of very thin foil membranes, said predetermined weight of said composition evolving a predetermined heat of combustion with the oxygen of the air;

e. a metal tubular duct cooperatively adaptively securely containing said carbon dioxide tank in a fixed position at a first end of said duct, the duct volume containing sufficient oxygen in the contained air to combust said magnesium composition, the weight of said metal duct providing adequately safe strength and heat transfer characteristics for the magnesium combustion reaction;

f. a cover means for said first end of said duct disposed adjacent said carbon dioxide tank;

g. insulated electrically conductive wire means connecting said electric squib to an impact sensor means disposed exteriorly to said duct; and

h. a tubular coupling means, conductively tightly connecting the gas exit of the second duct end to a flexible membrane gas inlet tube of an impact restraint bag.

7. In the automated personnel restraint system improvement of claim **6**, the further improvement wherein at least one mixing orfice is coaxially disposed in said duct adjacent said metal cases containing magnesium composition, said at least one orfice having a coaxially disposed mixing aperture.

8. In the automated personnel restraint system improvement of claim **6**, the further improvement wherein a metal heat exchanger is coaxially disposed in said duct adjacent said second duct end.

9. In the automated personnel restraint system improvement of claim **6**, the further improvement wherein

a. a multiple accordion pleated folds, flexible membrane, non-combustible, impact restraint bag, having a bag height, width and length of suitable dimensions, is folded flat in the plane of said multiple folds; and

b. a flexible membrane, non-combustible, distending gas inlet tube is permanently cooperatively affixed to a bag face aperture, at a first inlet tube terminus, and is secured to aid tubular coupling means at a second inlet tube terminus.

10. In the automated personnel restraint system improvement of claim **6**, the further improvement wherein, the multiple accordion pleated folded flat impact restraint bag has a transverse axial U-fold.

11. In the automated personnel restraint system improvement of claim **6**, the further improvement wherein, a long, flat protective case encloses said impact restraint bag and said gas inlet tube, said case having a shallow top case cover and a shallow bottom case cover, said top and bottom case covers having confronting case front lips, and having an integral frangible plastic hinge cooperatively securing the confronting case rear lips together, said integral frangible plastic hinge closely securing said top and bottom case cover prior to the breaking of said frangible hinge on expansion of said gas inlet tube and said restraint bag.

12. In the automated personnel restraint system improvement of claim **11** the further improvement wherein a flexible hinge also cooperatively secures said confronting case rear lips together.

13. In the automated personnel restraint system improvement of claim **6**, the further improvement wherein said tank neck adaptively points to said second duct terminus.

14. In a carbon dioxide inflating gas, automated personnel restraint system for personnel carrying vehicles, having a carbon dioxide liquid supply disposed in a sealed tank, the combination comprising:

a tubular duct;

a cover means sealing a first duct terminus, adjacent to a first duct end section;

a sealed tank containing liquid carbon dioxide, said tank secured in said first duct end section;

a tank venting means, providing rapid release of said liquid carbon dioxide from said tank on signal;

a combustible metal composition disposed adjacent said tank venting means, said composition providing heat energy on burning in the air resident in said duct;

an ignition means, on signal concurrently actuating said tank ventilation and metal combustion ignition;

whereby the heat of combustion of said metal composition provides the required energy for rapidly vaporizing said liquid carbon dioxide to gas, in said tubular duct.

15. In the automated personnel restraint system improvement of claim **14**, the further improvement wherein the metal composition is a magnesium pyrotechnic composition.

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