PERSONNEL RESTRAINT SYSTEM
FOR VEHICULAR OCCUPANTS

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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 adjacent 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
FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

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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 milliseconds.

One current personnel restraint system utilizes a 3,500 psi air 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 electricity fired detonator 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 oxide, 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 ignitable 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 orifice. 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 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 orifice 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 confronting 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 cutting.

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 orifices 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 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 membranes 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 disposed 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 the combustion 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 the 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,

\[ 2 \text{Mg} + \text{O}_2 \rightarrow 2 \text{MgO} \quad \Delta H_1 = -143.8 \text{ kcal/mole} \]

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

\[ 2 \text{Mg} + \text{CO}_2 \rightarrow 2 \text{MgO} + \text{C} \quad \Delta H_2 = -96.8 \text{ kcal/mole} \]

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 is flashed to occupy 10.1 cu. ft. at 77 F. and 1 atmosphere. The heat required to vaporize the liquid carbon dioxide can be rapidly 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 orifices 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 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 slidable 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 coterminous 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, \( T = 2 \pi \sqrt{M/k} \).

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/131 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 fragile 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 said liquid 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 ignitable 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 insulative ly 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 orifice is coaxially disposed in said duct adjacent said metal cases containing magnesium composition, said at least one orifice 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 adjacent 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 ignitable 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 insulative ly 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 orifice is coaxially disposed in said duct adjacent said metal cases containing magnesium composition, said at least one orifice 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 folded flat 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:

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;

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.