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(54) **Cellulose based propellant.**

(57) The present invention provides a fibrous cellulose-based propellant for generating gas to inflate an air bag in a vehicle occupant restraint system. In one embodiment, the fibrous cellulose-based propellant includes cellulose, starch, an oxidizer, and a vitrifying agent. In another embodiment, a cellulose-based hybrid propellant includes cellulose, starch and potassium perchlorate for generating heat and gas to assist compressed gas in inflating an air bag in a hybrid restraint system. Also included in the present invention are methods for producing the cellulose-based propellant. In one method, fibrous cellulose and starch are suspended in a solution that includes an oxidizing agent and a vitrifying agent to produce a slurry, the slurry is then formed into a sheet of a desired density, the sheet is then at least partially dried, if required, and then formed into a desired shape for incorporation into a vehicle restraint system that employs an air bag. In another embodiment of the method, cellulose, starch and potassium perchlorate are used as the ingredients to form a hybrid propellant. In another method of the invention, cellulose and starch are mixed with an oxidizer and a vitrifying agent to form a mixture. The mixture is then extruded through a die to a desired shape and at least partially dried to form a porous

propellant.

EP 0 576 153 A1

Cross-Reference to Related Applications

The present application is a continuation-in-part application of U.S. Patent Application Serial No. 07/933,034 and U.S. Patent Application Serial No. 07/817,455.

Background of the Invention

1. Field of the Invention

The present invention generally relates to vehicle occupant restraint systems that employ air bags. More specifically, the present invention relates to a propellant for producing gas to inflate an air bag, a method for producing such a propellant, and an air bag vehicle occupant restraint system that utilizes the propellant.

2. Description of the Related Art

Generally, an air bag restraint system includes a reaction canister for containing a propellant that, when ignited, produces a gas that is used to inflate an air bag. To ignite the propellant, an igniter that is responsive to a signal provided by a collision sensor is disposed adjacent to the propellant. The air bag restraint system also includes an air bag that is located across an open end of the reaction canister. Located in the canister and between the air bag and the propellant is a filter for preventing the hot residues produced by combustion of the propellant from entering the air bag and possibly coming into contact with the occupant of the vehicle when the air bag is inflated. Briefly, operation of an air bag restraint system is initiated when the sensor detects an imminent collision or a collision and causes the igniter to ignite the propellant. Ignition of the propellant, in turn, produces gas to inflate the air bag and thereby prevent injuries to the occupant of the vehicle by restraining or inhibiting their movement. Shortly after inflation, the air bag deflates to permit the occupant to move and exit the vehicle if necessary.

Presently, the propellant most commonly used in air bag restraint systems includes sodium azide (NaN_3), which produces nitrogen gas for inflating the air bag when combusted. Propellants that incorporate sodium azide, upon combustion, produce a gaseous atmosphere of substantially 100% nitrogen gas for inflating the air bag. This is advantageous because nitrogen gas is substantially inert and can be inhaled by humans for short periods of time without harmful effects. The use of sodium azide does, however, present several drawbacks. Namely, sodium azide is a Class B poison and easily hydrolyzed into hydrazoic acid, which is also toxic and explosive. Moreover, sodium azide reacts

with heavy metals, like copper and lead, to produce a very sensitive primary explosive that can be easily detonated. Due to these factors, substantial precautions are necessary in the transportation of sodium azide, its incorporation into air bag systems, and in its eventual disposal when the air bag system in which it is incorporated is discarded that add to the overall expense of such systems. For example, special precautions must be taken during transportation of the sodium azide to prevent leakage of this toxic and reactive material into the environment. Additionally, the air bag restraint systems that incorporate a sodium azide-based propellant require containers for the propellant that are designed to prevent the sodium azide from contacting heavy metals, becoming hydrolyzed, and from leaking into the occupant environment of the vehicle. Moreover, during disposal of air bag restraint systems that employ sodium azide as a propellant, further precautions must be taken to prevent the sodium azide from coming into contact with heavy metals or becoming hydrolyzed. These drawbacks are further compounded by the increasing demand for passenger side air bags in automobiles that deploy air bags with volumes three to four times that of the driver's side air bags and therefore, require proportionately greater amounts of sodium azide propellant.

A further drawback associated with the use of sodium azide-based propellants in air bag restraint systems is that the process for producing such propellants is a relatively complicated process that involves blending the sodium azide with a refractory oxidizer, such as iron oxide or copper oxide, pressing the resulting mixture into pellets, and then establishing channels in the pellets for conducting gas and for controlling the burn rate of the propellant. The complexity of producing sodium azide-based propellants, in turn, increases the expense of the resulting air bag vehicle restraint systems that incorporate such propellants.

Yet a further disadvantage of sodium azide-based propellants is that it is difficult to design and manufacture the propellant with a desired burn rate. As previously mentioned, one proposed solution to controlling the burn rate of sodium azide-based propellants has been to establish channels in the pellets. The establishment of channels in the pellets adds to the complexity as well as the expense of manufacturing the propellant. Another proposed solution to controlling the burn rate of sodium azide-based propellants has been to incorporate graphite fibers into the propellant. This also requires additional manufacturing steps and increases the expense of the resulting propellant. Moreover, the degree to which the burn rate can be regulated by these solutions has, in many cases, proven to be subject to unacceptable variation.

Another disadvantage of sodium azide-based propellants is that combustion of the propellant produces a molten sodium oxide (Na_2O) residue that is in the form of relatively small globules with low viscosity. The relatively small size of the globules and their low viscosity necessitate the use of "slagging" agents to increase the viscosity of the residue and a relatively expensive filter to be interposed between the propellant and the air bag to prevent the residue from entering the air bag and possibly burning the occupant of a vehicle in which the restraint system is employed.

Alternatives to sodium azide-based propellants have been developed that are derived from hydroxamine acid and hydroxylamine derivatives. Further, propellants using polymeric binders, hydrocarbons, carbohydrates, and dialkali salts of bitetrazole and azobitetrazole have also been developed. Many of these alternatives to sodium azide-based propellants have many of the same disadvantages as the sodium azide propellants or other disadvantages that have not made it worthwhile to convert from the sodium azide-based propellants.

Another type of air bag restraint system is called a "hybrid" system. The name is derived from the fact that the air bag is filled with a combination of gas from a pressurized gas housing and gas from an ignited propellant. More specifically, when the hybrid system is activated, ambient temperature gas, typically argon, is released from a pressurized gas housing to partially inflate the bag. After a predetermined time delay, the hybrid propellant is ignited to supply more gas and to supply large quantities of heat to cause the ambient temperature gas from the pressurized gas housing to expand and further fill the air bag. In order to supply enough heat to expand the ambient temperature gas, the hybrid propellant typically burns about 1500°C hotter than the non-hybrid propellants described above. Typically, the propellant used in hybrid inflators have high burn rates. In order to maintain the burn rate at a manageable level, hybrid propellants typically must be extruded at nearly (e.g. approximately 98%) theoretical density. Hybrid propellants typically use polyvinylchloride as a fuel, which, because of its high chlorine content, must be neutralized with, for example, an alkali metal salt (e.g. carbonate), produces large amounts of smoke as a by-product when burned. These by-products could be dangerous to the occupant of the vehicle by virtue of their alarming obscurity (occupant of vehicle is disoriented by lack of visibility, and alarmed by the suggestion of a fire). In addition, polyvinylchloride based propellants are relatively expensive to manufacture.

Based on the foregoing, there is a need for a propellant for an air bag vehicle restraint system that reduces the use of sodium azide to, in turn,

reduce the problems associated with the transportation of sodium azide, the incorporation of sodium azide into air bag restraint systems, and the subsequent disposal of air bag restraint systems that employ sodium azide. There is the further need for a propellant for use in air bag restraint systems that can be easily and inexpensively manufactured. Moreover, a propellant for air bag systems is needed in which the burn rate of the propellant can be readily controlled or regulated. Moreover, a propellant for air bag restraint systems is needed that, upon combustion, produces a residue that reduces the need for a complicated or expensive filtering mechanism to prevent molten material or other residue produced by combustion of the propellant from entering the air bag and possibly injuring an occupant of the vehicle in which the air bag restraint system is installed. Furthermore, there is a need for a hybrid propellant that utilizes a less expensive process and produces less smoke as a by-product.

Summary of the Invention

The present invention provides a fibrous propellant for use in producing gas to inflate an air bag in a vehicle occupant restraint system that, in one embodiment, includes a fibrous fuel, such as fibrous cellulose, an oxidizing agent for reacting with the fibrous cellulose to produce a gas when the propellant is ignited, and a vitrifying agent for increasing the viscosity of the residue produced when the propellant is ignited. Among the suitable oxidizing agents are alkali metal nitrates, such as potassium nitrate, and alkali metal nitrites, which can be used alone or in combination with an alkaline earth metal nitrate or nitrite, such as strontium nitrate. The use of an alkaline earth metal nitrate or nitrite, in addition to serving as an oxidizing agent, supplements the vitrifying agent. Suitable vitrifying agents include alumina, silicon dioxide, boric oxide, and titanium oxide and various clays, e.g. Kaolinite (calcined or natural).

Another embodiment of the fibrous propellant includes a fuel, an oxidizing agent, and a fibrous vitrifying agent, such as a fibrous ceramic. Suitable oxidizing agents are the same as those for the embodiment that employs a fibrous fuel.

Yet a further embodiment of the fibrous propellant employs a fibrous fuel as well as a fibrous vitrifying agent. Appropriate oxidizers for this embodiment are the same as discussed with respect to the fibrous fuel and fibrous vitrifying agent embodiments.

The fibrous propellant has several advantages relative to many of the known propellants and especially sodium azide-based propellants that are used in air bag restraint systems. Namely, the

constituents of this propellant are relatively safe to transport, readily incorporated into an air bag restraint system, and, once incorporated into an air bag restraint system, reduce the need for special or precautionary disposal techniques when the vehicle within which the restraint system is installed is retired. Further, the residue that results upon combustion of the propellant is of a relatively large size and a high viscosity that permits a relatively simple and inexpensive filter to be employed in the air bag restraint system relative to the filters that, for example, are employed in air bag systems that use sodium azide-based propellants.

Another embodiment of the propellant of the present invention includes a fuel having cellulose and starch, an oxidizing agent, and a vitrifying agent. The use of starch as a portion of the fuel results in a propellant that burns cleaner than pure cellulose, that is, the starch burns more completely, thus giving off less carbon monoxide. In addition, the starch acts as a glue to increase the tensile and binding strengths of the propellant. Tensile and binding strengths are important for facilitating certain manufacturing processes, such as the sheet making process described herein where the propellant can be subjected to a variety of tensile and compressive stresses.

A further embodiment of the present invention includes the use of cellulose as the fuel for a hybrid propellant. A cellulose-based hybrid propellant is less expensive to process and produces less smoke as a by-product than the known fuels currently used for hybrid propellants. The fuel of the hybrid propellant can further include starch to provide a cleaner burning hybrid propellant. Starch further increases the binding strength, both laminar and tensile, of the hybrid propellant.

Other embodiments of the propellant of the present invention include agents for increasing the yield of nitrogen gas and altering the composition of the gases produced by combustion of the propellant. For example, 1-Nitroguanidine or Cyanoguanidine can be included in the propellant to increase the production of nitrogen gas and thereby increase the amount of nitrogen gas relative to CO_2 and H_2O , which are also produced by combustion of the propellant. Yet further embodiments include agents for affecting the burn rate or rate at which gas is produced by the propellant.

Also provided by the present invention is a method for producing a fibrous propellant that includes a fibrous fuel, such as fibrous cellulose and/or a fibrous vitrifying agent, such as a fibrous ceramic, and an oxidizing agent which is relatively simple and inexpensive. One embodiment of the process includes the steps of soaking the cellulose in a solution that contains the oxidizing agent to form a slurry; forming the slurry into a sheet in a

conventional mat making machine, such as a Fourdrinier or cylinder former, calendaring the sheet to a desired thickness; at least partially drying the sheet; and then forming the sheet into the desired shape for incorporation into the air bag restraint system. This method of producing the propellant also provides good control over the porosity of the resulting propellant and hence the burn rate of the propellant upon combustion.

Another embodiment of the above method includes the use of starch as a portion of the propellant fuel. Starch is useful for increasing the viscosity of the slurry, which ultimately affects the density and porosity of the final product. In addition, starch increases the laminar and tensile strength of the propellant. Also, as noted above, the addition of starch as part of the fuel results in a fuel that burns cleaner than pure cellulose, thus resulting in less carbon monoxide as a by-product.

Yet another embodiment of the present invention is the previously described sheet making method to make a hybrid propellant wherein the fuel includes cellulose and the oxidizer includes potassium perchlorate. As noted above, the use of cellulose as the fuel results in a less expensive fuel with less smoke as a by-product. In addition, starch can be added as a portion of the fuel to increase the laminar and tensile strength of the propellant and to provide a propellant that burns cleaner to produce less carbon monoxide as a by-product.

The present invention also provides a relatively simple and inexpensive method for producing a propellant that includes cellulose, starch, an oxidizer, and a vitrifying agent. One embodiment of the process includes the steps of mixing the cellulose and starch with a solution that contains the oxidizer and vitrifying agent to form a mixture; extruding the mixture under pressure through a die having a desired shape; and at least partially drying the resulting extrusion. The use of starch in the above process increases the extrudability of a cellulose-based propellant. In addition, starch provides a means for varying the viscosity of the mixture which affects the density and porosity of the final product. Also, as noted above, starch increases the binding strength of the propellant and burns cleaner than pure cellulose resulting in less carbon monoxide as a by-product.

Also provided by the present invention is an air bag restraint device that employs a fibrous propellant, which can use a fibrous cellulose-based propellant and/or a fibrous vitrifying agent, and a method for making the device.

Brief Description of the Drawings

Fig. 1 illustrates the process or method for producing a propellant that includes cellulose and

that is suitable for use in an air bag restraint system;

Fig. 2 is a cross-sectional view of a portion of an air bag restraint system that includes a cellulose-based propellant;

Fig. 3 illustrates one type of spirally shaped propellant unit that is suitable for placing in a tubular propellant housing of an air bag restraint system; and

Fig. 4 illustrates a second type of spirally shaped propellant unit that can be placed within a tubular propellant housing of an air bag restraint system.

Fig. 5 is a cross-sectional view showing the internal structure of a portion of a hybrid air bag restraint system that includes a cellulose-based propellant.

Detailed Description of an Embodiment of the Invention

The present invention provides a propellant for use in producing gas to inflate an air bag in a vehicle occupant restraint system. The composition of one embodiment of the propellant includes fibrous cellulose for, upon combustion, producing gas to inflate an air bag. A substantial portion of the fibers in the fibrous cellulose are at least 0.75mm in length. Presently, a plentiful and relatively inexpensive source of fibrous cellulose is pulp board or wood pulp. A substantial portion of the fibers in pulp board and wood pulp are on the order of 1mm in length. The propellant also includes an oxidizing agent for facilitating combustion of the cellulose material to produce the gas. Suitable oxidizing agents include alkali metal nitrates, such as potassium nitrate, and alkali metal nitrites, which can be used alone or combined with alkaline earth metal nitrates or alkaline earth metal nitrites, such as strontium nitrate or strontium nitrite. The alkaline earth metal nitrates and nitrites serve as oxidizers as well as supplement the function of the vitrifying agent. Presently, if an alkaline earth metal nitrate is used in the propellant, it is in an amount by weight of the propellant that is approximately equal to that of the alkali metal nitrate or nitrite. Also included in the propellant is a vitrifying agent for reducing filter requirements in the air bag restraint system by increasing the viscosity of the residue resulting from the reaction of the cellulose with the oxidizing agent. Among the known suitable vitrifying agents are aluminum oxide, boric oxide, silicon dioxide, titanium dioxide, and silicate clays, such as Kaolinite clay (calcined or natural), mullite, or mixtures thereof. A relatively inexpensive and readily available vitrifying agent that is presently being used in one embodiment of the propellant is calcined Kaolinite clay, which is a compound

of aluminum oxide and silicon dioxide.

Presently, the relative proportions of the components of one formulation of the propellant are as follows:

5 potassium nitrate - 66% by weight of the propellant;

cellulose - 22% by weight of the propellant; and

10 calcined Kaolinite clay - 12% by weight of the propellant.

Presently, the relative proportions of the components of another formulation of the propellant that includes an alkaline earth metal are as follows:

15 potassium nitrate - 33% by weight of the propellant;

strontium nitrate - 33% by weight of the propellant;

cellulose - 22% by weight of the propellant; and

20 calcined Kaolinite clay - 12% by weight of the propellant.

Another embodiment of the propellant includes a fuel, an oxidizing agent, and a fibrous vitrifying agent. Suitable fibrous vitrifying agents include fibrous ceramics in which a substantial portion of the fibers are at least 0.75mm in length. One such fibrous ceramic is the fibrous aluminosilicate sold under the trademark FIBER FRAX™ by Carborundum. The fuel can include fibrous fuels like fibrous cellulose and the oxidizing agent can, as in the prior embodiment, include an alkali metal alone or in combination with an alkaline earth metal.

Yet a further embodiment of the propellant employs both a fibrous fuel, such as fibrous cellulose, and a fibrous vitrifying agent, such as a fibrous ceramic. The oxidizing agent used in this embodiment can be the aforementioned alkali metal nitrate with or without an alkaline earth metal nitrate.

40 Another embodiment of the propellant utilizes starch as a portion of the fuel. It has been found that a fuel portion of the propellant comprising 70% to 90% cellulose and 10% to 30% starch provides a propellant with an increased binding strength. The increased binding strength provides a propellant that is less likely to crumble, tear or delaminate during and after the manufacturing process. For example, a propellant produced on a sheet making device, as described herein in more detail, is subjected to a variety of tensile and compressive forces that can cause failure in a propellant material. In addition, subsequent manufacturing steps of cutting and rolling the propellant further subject the propellant to forces that can damage the propellant. Furthermore, because starch is a shorter molecule than cellulose, it tends to burn more completely, resulting in less carbon monoxide than burning pure cellulose. Reduction of

carbon monoxide as a by-product is important because the contents of the air bag are expelled into the car after full inflation of the bag is obtained. Any by-products of the inflation process will likely be inhaled by the occupant of the vehicle. Thus, it is desirable to reduce any adverse impact on the human respiratory system. The starch embodiment also includes an oxidizer. Suitable oxidizing agents include alkali metal nitrates and alkali metal nitrites, which can be used alone or in combination with alkali earth metal nitrites and alkali earth metal nitrites, as previously mentioned.

The vitrifying agent of the starch embodiment should comprise enough of the weight percent of the propellant to increase the viscosity of the residue resulting from the reaction of the fuel with the oxidizing agent and to maintain the reaction rate below an explosive level. On the other hand, the vitrifying agent cannot comprise such a large percentage of the composition that it slows the reaction time to above 100 milliseconds, which is considered the maximum air bag fill-up time. It has been found that a vitrifying agent between 8% and 16% by weight of the propellant and preferably between 10% and 14% by weight of the propellant satisfies these requirements. Suitable vitrifying agents include those previously mentioned.

Turning now to Fig. 5, there is shown a cross-sectional view of a portion of a hybrid air bag restraint system 100 that includes a cellulose-based propellant of the present invention. The hybrid system 100 generally includes a stored gas housing 110 which contains pressurized gas. The stored gas housing 110 is appropriately attached to an orifice boss 112, and the orifice boss is appropriately connected to a manifold 114 which is ultimately connected to an air bag (not shown). An orifice disc 116 is positioned within the orifice boss 112 to initially retain the pressurized gas within the stored gas housing 110. A projectile 118 is positioned on the convex side of the orifice disc 116 and utilizes the propelling forces generated by the activation of a squib 120 to penetrate and pass through the orifice disc 116.

A gas generator housing 130 is contained within the stored gas housing 110 and is appropriately attached to an orifice sleeve 132 which is attached to the orifice boss 112. The gas generator housing 130 contains a hybrid propellant of the present invention 134, as well as an actuation piston 136, a percussion primer 138, and an ignition material 140 for igniting the hybrid propellant 134. A gas generator outlet 142 provides fluid communication between the gas generator housing 130 and the stored gas housing 110.

In operation, when a signal is received from a detector (not shown) indicating that the air bag should be deployed, the squib 120 is ignited, caus-

ing the projectile 118 to be propelled toward the disc 116 to penetrate and separate the disc 116 to allow gas to begin flowing from the stored gas housing 110, through the interior discharge ports 122, the orifice boss 112, the exterior discharge ports 124, and ultimately into an air bag. After the projectile 118 passes through the disc 116, the projectile 118 impacts the actuation piston 136 resulting in ignition of the primer 138 and the ignition material 140, and ultimately the hybrid propellant 134. The propellant gases generated by combustion of the propellant 134 exit the gas generator housing 130 through the gas generator outlet 142 to augment the flow of gases into the air bag.

The present invention is also embodied in a cellulose-based hybrid propellant 134 suitable for use in the hybrid structure described above. The hybrid propellant of the present invention typically contains approximately 73% potassium perchlorate and approximately 27% cellulose. The cellulose provides a hybrid fuel that is less expensive to process and produces less smoke as a by-product than other known hybrid fuels. In addition, the use of cellulose as the fuel facilitates the manufacture of the hybrid propellant on a mat making device, as described herein in more detail.

Another embodiment of the hybrid propellant employs starch as a portion of the fuel. As noted previously, hybrid propellants utilizing potassium perchlorate as an oxidizer must be formed at a high theoretical density, typically about 98%, in order to slow down the burn rate to the desired level. Because of this need for a high density, the hybrid propellant must have a high binding strength to maintain the propellant in a dense condition. Without a high binding strength, the fibrous hybrid propellant has a tendency to delaminate. It has been found that the substitution of starch for approximately 10% of the cellulose in a hybrid propellant increases the laminar and tensile strength of the propellant. In addition, as noted above, a fuel comprising 10% starch burns cleaner, and thus produces less carbon monoxide, than a pure cellulose-based hybrid fuel.

Combustion of the propellant produces the following gases: nitrogen, carbon dioxide, and H_2O . The relative proportions of these gases can be adjusted by altering the ratios of the cellulose, oxidizing agent, and vitrifying agent. Further, the relative composition of the gases produced by combustion of the propellant and the gas yield can be adjusted by including further ingredients in the propellant formulation. For example, the yield of nitrogen gas can be increased by the addition of 1-Nitroguanidine, Cyanoguanidine, or sodium azide to the formulation of the propellant. With respect to the inclusion of sodium azide in the propellant of the present invention, a small amount of sodium

azide, typically less than 15% of the propellant by weight, can yield a relatively large increase in the nitrogen gas produced by the propellant upon combustion. Sodium azide also increase the burning rate of the propellant. This amount of sodium azide is much less than the sodium azide-based propellants in which the sodium azide is primary producer of nitrogen gas. In these propellants, the sodium azide typically accounts for 60% or more of the weight of the propellant. Consequently, formulations of the cellulose-based propellant of the present invention that include sodium azide have proportionately reduced the disadvantages associated with propellants that rely upon sodium azide as a producer of most, if not all, of the nitrogen gas for inflating air bags in a vehicle occupant restraint system.

In addition to the production of gases, the vitrifying agent reacts with the combustion residue to form a glassy substance. For instance, with respect to formulations of the propellant that use potassium nitrate, the vitrifying agent unites with the potassium carbonate produced upon combustion to form potassium silicate or aluminate, and to aid in the release of CO₂ gas, among others.

The propellant can also include an agent for increasing the burn rate or rate at which the propellant produces gas. Typically, in passenger air bag restraint systems, the air bag must be inflated in 50 to 100 milliseconds to prevent injury to the occupant of the vehicle in the event of a collision. Consequently, the burn rate of the propellant employed in the air bag restraint system is of considerable concern. Agents for increasing the burn rate include sulfur and certain sulfur compounds. Other agents for increasing the reaction rate include alkali metal chlorates, such as potassium chlorate, which yield high burning rates at a relatively low combustion temperature.

The present invention also includes a method for producing a fibrous propellant, such as a fibrous cellulose-based propellant, for an air bag restraint system that is relatively simple, inexpensive, capable of continuous operation, adapts previously developed paper making equipment and provides good control over the porosity of the resulting propellant, which is an important factor in the burn rate of the resulting propellant. With reference to Fig. 1, the method of producing the propellant is now discussed. Initially, a fuel such as fibrous cellulose in the form of wood pulp 10 is input to a mixer 12 (i.e., hydropulper) that disperses the wood pulp 10 in a solution/suspension of an oxidizing agent. The oxidizing agent includes an alkali metal, such as potassium nitrate or nitrite, and can further include alkaline earth metals, such as strontium nitrate or nitrite, as previously discussed. The solution can also contain a residue vitrifying agent, an

agent for increasing the gas production of the resulting propellant, or an agent for increasing the burn rate of the resulting propellant. The vitrifying agent can be any of the fibrous or non-fibrous vitrifying agents discussed with respect to the composition of the propellant. As previously mentioned, the relative proportions of the constituents of the propellant can be adjusted to tailor the quantities of gas output by the propellant upon combustion. The mixer 12 combines the wood pulp 10 with the solution to produce a slurry 14 that is deposited onto a sheet making device 16 (e.g., a Fourdrinier paper making machine) at the desired mass per unit area. By soaking the individual cellulose fibers in a solution containing the oxidizer, the cellulose and the oxidizer become intimately mixed. This intimate mixing aids in producing a propellant that burns more thoroughly and produces less carbon monoxide than a propellant produced by not soaking the individual fibers before coalescing into a single mass.

The sheet making device 16 dewateres the slurry 14 to form a sheet 16 that is transported via a conveyor system 18 to a pressing section 20 that further consolidates and dewateres the sheet 16. After the pressing section 20, the sheet 16 is conveyed to a calendaring assembly 22 that forms the sheet 16 into a sheet 24 of a desired thickness and density. The ability to adjust the density of the sheet 24 is important because it is inversely related to the porosity of the propellant. Consequently, as the sheet 24 becomes more dense, the porosity of the sheet 24 decreases. The porosity of the propellant, in turn, affects the burn rate or rate at which the propellant produces gas after it is ignited. More specifically, the greater the porosity, the higher the burn rate of the propellant. Consequently, by controlling the density of the sheet 24, the burn rate of the propellant can be controlled or regulated. For example, if the sheet 24 produced by the roller assembly 20 is relatively dense, then the propellant will have a reduced burn rate relative to a less dense sheet of the propellant due to its reduced porosity.

The sheet 24 output by the calendar 22 is subsequently applied to a dryer 26 to remove a substantial portion of the moisture from the sheet 24. The semi-dry sheet 24 is then introduced to a shaper 28 that wraps or rolls the sheet into individual cylindrical or spirally shaped propellant units that are of a diameter which is suitable for insertion into a tubular-shaped propellant housing in an air bag restraint system. Fig. 3 illustrates one type of spirally shaped propellant unit in which the sheet 24 is rolled about the longitudinal axis of the unit. A different spirally shaped propellant unit is shown in Fig. 4. In this embodiment, layers of the propellant unit are established by helically winding the sheet

24 about the longitudinal axis of the unit. The shaper 28 can, however, be adapted to produce units of other shapes if required. The propellant units are subsequently applied to a perforator 30 that punches holes in the propellant units to reduce radial pressure gradients upon combustion of the propellant that may adversely affect the performance of the air bag restraint system. Much of the process described with reference to Fig. 1 can be implemented using paper processing technology, such as Fourdrinier paper processing machinery.

Another embodiment of the above-described sheet making method of producing a propellant involves the addition of starch to the slurry as a portion of the propellant fuel. The use of starch in the sheet making process described above provides a way of altering the viscosity of the slurry which ultimately affects the porosity and burn rate of the final product. In addition, the addition of starch as a portion of the fuel provides a cleaner burning propellant, thus producing less carbon monoxide as a by-product. Starch also acts as a binder in the sheet making process to increase the binding strength and decrease the likelihood of tearing or delamination of the propellant during and after the paper making process. Preferably, the fuel includes about 10% to 30% by weight of starch and, most preferably, approximately 20% by weight of starch.

Another embodiment of the above-described method involves its use in producing hybrid propellants. By utilizing cellulose as the fuel and potassium perchlorate as the oxidizer, the sheet making method described above can be used as a relatively simple, inexpensive, and continuous method of creating a high-density hybrid propellant. In addition, the sheet making process can include the step of adding starch to the slurry to replace approximately 10% of the fuel by weight. The addition of starch to the hybrid propellant is particularly useful in increasing the binding strength of the propellant, thus reducing delamination and tearing after the hybrid propellant has been compressed to about 85% to 95% theoretical density.

An alternative method for producing the propellant involves infusing the fuel, such as the fibrous pulp board, in a hot solution in which the oxidizing agent and any other desired agents, like a fibrous vitrifying agent, are dissolved or suspended. After a sufficient amount of the solution has been absorbed by the fuel, it is then cooled to crystallize the oxidizing agents and any other agents included in the solution in the fuel. The infused fuel, which is now a fibrous propellant, can then be subjected to a drying operation, a shaping operation and, if necessary, a perforating operation.

Another method for producing a propellant involves an extrusion process. The process involves

mixing cellulose, starch, an oxidizing agent, and a vitrifying agent into a slurry as previously described for the paper making process. The slurry is then compressed and extruded through a die of a desired cross-section to produce a continuous strip of wet extrusion. The wet extrusion can then be subjected to a drying operation, a shaping operation and, if necessary, a perforating operation. The addition of starch as a portion of the fuel in the extrusion process increases the extrudability of a cellulose-based propellant. In addition, starch provides a way to modify the viscosity of the slurry, which affects the density and porosity of the final product. In addition, the density and porosity of the final product is affected by the extrusion pressure used to extrude the slurry through the die.

Fig. 2 illustrates an air bag restraint device 34 that includes a propellant formed by combining a fibrous material, such as fibrous cellulose, with a suitable oxidizing agent. The fibrous material includes a fibrous fuel, a fibrous vitrifying agent, or a combination of both. Oxidizing agents include an alkali metal combined or not combined with an alkaline earth metal. The air bag restraint device includes a reaction canister 36 that has an open end 38 across which an air bag 40 is disposed and an interior 42 in which a cylindrically-shaped propellant 44 comprised of, for example, fibrous cellulose and potassium nitrate is housed. Positioned adjacent to the propellant 44 within the reaction canister 36 is an igniter or squib 46 that, in response to a signal from a sensor that detects a collision or imminent collision, ignites the propellant 44. The propellant 44, which can be the spirally shaped propellant unit shown in either Fig. 3 or Fig. 4, and the igniter 46 are disposed within a filter 52 that prevents residue from the combustion of the propellant 44 from coming into contact with the air bag 40 and possibly the occupant of the vehicle in which the air bag restraint device 34 is mounted. Due to the relatively high viscosity of the residue produced by the propellant 44, the filter 52 can be made from relatively inexpensive mineral felt material and the use of complicated and/or expensive filters reduced. The filter 52 can also include wire mesh and/or perforated and/or expanded metal mesh, but to a lesser extent than the filters used in known air bag restraint devices. The ability to use such a filter can be further enhanced by including a vitrifying agent, such as Kaolin clay or a fibrous ceramic, or an alkaline earth metal oxidizer like strontium nitrate in the propellant 44 as previously mentioned. A cylindrical housing 54 with a plurality of openings 56 for venting the gases produced by combustion of the propellant 44 houses the propellant 44, the igniter 46, and the filter 52. The air bag restraint device 34 is shown as being mounted to a dashboard 58. The reaction canister 36, the first

cylindrical housing 48, and/or the second cylindrical housing 54 are made of materials, such as steel (crimped or welded), that are capable of withstanding the heat and pressure produced during combustion of the propellant 44. If weight is a consideration, these components can also be made of lighter materials capable of withstanding the pressure stresses, like aluminum.

When the air bag restraint device 34 is in operation, a sensor (not shown) detects a collision or imminent collision of the vehicle with another object and generates a signal that is applied to the igniter 46. In response, the igniter 46 ignites the propellant 44, which then produces nitrogen, carbon dioxide, and H₂O gases. These gases flow through the filter 52, and then vent through the plurality of openings 56 in the second cylindrical housing 54 to then inflate the air bag 40. The filter 52 prevents the residue from the combustion of the propellant 44 from coming into contact with the air bag 40 and possibly the occupant of the vehicle. The air bag 40 has a porosity in the weave (not shown) that, after inflation of the air bag, permit the air bag 40 to absorb energy by deflating and the occupant of the vehicle to then move or exit the vehicle if necessary.

The method of assembling the air bag restraint device illustrated in Fig. 2 includes providing a fibrous material, such as fibrous cellulose and/or a fibrous vitrifying agent, and combining the fibrous material with an oxidizing agent to form a propellant. In order to increase the strength of the propellant and to make the propellant burn cleaner, starch may be substituted for part of the cellulose. This step of combining the fibrous material with the oxidizing agent to form the propellant can be accomplished according to the sheet making method illustrated in Fig. 1, the extrusion method described above, or any other suitable method. The fibrous material and oxidizing agent can further be combined with an agent for increasing the gas yield, and/or an agent for increasing the burn rate of the resulting propellant, if desired. For incorporation into the air bag restraint device 34, the propellant is formed into a cylinder that can be contained within the first cylindrical housing 48 and that has a hollow interior within which the igniter 46 can be positioned. The resulting cylindrically shaped propellant 44 and the igniter 46 are then positioned within the first cylindrical housing. The first cylindrical housing 48 and the filter 52 are then positioned within the second cylindrical housing 54. The second cylindrical housing 54 is then attached to the interior surface of the reaction canister 36 and the air bag 40 is attached across the open end 38 of the reaction canister 36 to complete the assembly of the air bag restraint device 34. The air bag restraint device 34 can then be mounted in the

dashboard 58 of a vehicle or in any other suitable location.

The foregoing description of the invention has been presented for purposes of illustration and description. Further, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, and the skill or knowledge in the relevant art are within the scope of the present invention. The preferred embodiment described herein above is further intended to explain the best mode known of practicing the invention and to enable others skilled in the art to utilize the invention in various embodiments and with various modifications required by their particular applications or uses of the invention. It is intended that the appended claims be construed to include alternate embodiments to the extent permitted by the prior art.

Claims

1. A propellant for use in producing gas to inflate an air bag in a vehicle occupant restraint system comprising:
 - a fuel including cellulose;
 - an oxidizer for reacting with said cellulose to produce a gas; and
 - a vitrifying agent for increasing the viscosity of a residue produced by said cellulose reacting with said oxidizer.
2. A propellant, as claimed in Claim 1, wherein:
 - said fuel includes at least one of potassium perchlorate and a starch.
3. A propellant, as claimed in Claim 1, wherein:
 - said cellulose includes fibrous cellulose.
4. A propellant, as claimed in Claim 1, wherein:
 - said vitrifying agent includes a fibrous vitrifying agent and a substantial portion of the number of fibers comprising said fibrous vitrifying agent having a length greater than about 0.75 mm.
5. A propellant, as claimed in Claim 1, further comprising:
 - at least one of the following: an alkali metal chlorate, potassium chlorate and a sulfur compound for increasing a burn rate of said cellulose.
6. A propellant, as claimed in Claim 1, wherein:
 - said oxidizer includes at least one of the following: potassium nitrate, potassium nitrite, strontium nitrate, strontium nitrite, an alkali metal nitrate and an alkali metal nitrite.

7. A propellant, as claimed in Claim 1, wherein:
said cellulose is from about 70 percent to about 95 percent by weight of the fuel.
8. A propellant, as claimed in Claim 1, wherein:
said fuel is about 22 percent by weight of the propellant, said oxidizer is about 66 percent by weight of the propellant and said vitrifying agent is about 12 percent by weight of the propellant.
9. A propellant, as claimed in Claim 2, wherein:
said cellulose is from about 23 percent to about 31 percent by weight of the propellant and said potassium perchlorate is from about 69 percent to about 77 percent by weight of the propellant.
10. A propellant, as claimed in Claim 2, wherein:
said cellulose is from about 70 percent to about 95 percent by weight of the fuel and said starch is from about 5 percent to about 30 percent by weight of the fuel.
11. A propellant, as claimed in Claim 4, wherein:
said fibrous vitrifying agent includes one of a fibrous ceramic and a fibrous alumina silicate.
12. A method for producing a propellant for use in generating gas to inflate an air bag in a vehicle occupant restraint system comprising:
providing a fuel including cellulose; and
combining said cellulose with an oxidizer and a vitrifying agent to produce a propellant that, upon combustion, will produce gas and a residue of relatively high viscosity.
13. A method, as claimed in Claim 12, wherein:
said step of combining includes at least one of the following: soaking said cellulose in a solution that includes said oxidizer, forming said propellant into a desired shape for incorporation into a vehicle occupant restraint system that includes an air bag, and perforating said propellant.
14. A method, as claimed in Claim 12, wherein said step of combining includes:
soaking said cellulose in a solution that includes said oxidizer to form a slurry;
at least partially drying said slurry; and
forming said slurry into a desired shape for incorporation to a vehicle occupant restraint system that includes an air bag.
15. A method, as claimed in Claim 12, wherein:
said step of combining includes calender-
- ing said slurry into a sheet and rolling said sheet into a predetermined shape.
16. A method, as claimed in Claim 12, wherein:
said step of providing cellulose includes mixing said cellulose with potassium perchlorate.
17. A method, as claimed in Claim 12, wherein:
said step of providing cellulose includes providing fibrous cellulose.
18. A method, as claimed in Claim 12, wherein:
said step of combining includes using one of the following processes: infusion and Fourdrinier.
19. A method, as claimed in Claim 12, wherein:
said fuel is a fibrous fuel and said vitrifying agent is a fibrous vitrifying agent.
20. A method, as claimed in Claim 12, wherein:
said step of combining includes combining said fuel, said oxidizer and said vitrifying agent with at least one of the following: an agent for increasing gas production of said propellant upon combustion and an agent for increasing a burn rate of said propellant upon combustion.

FIG. 1

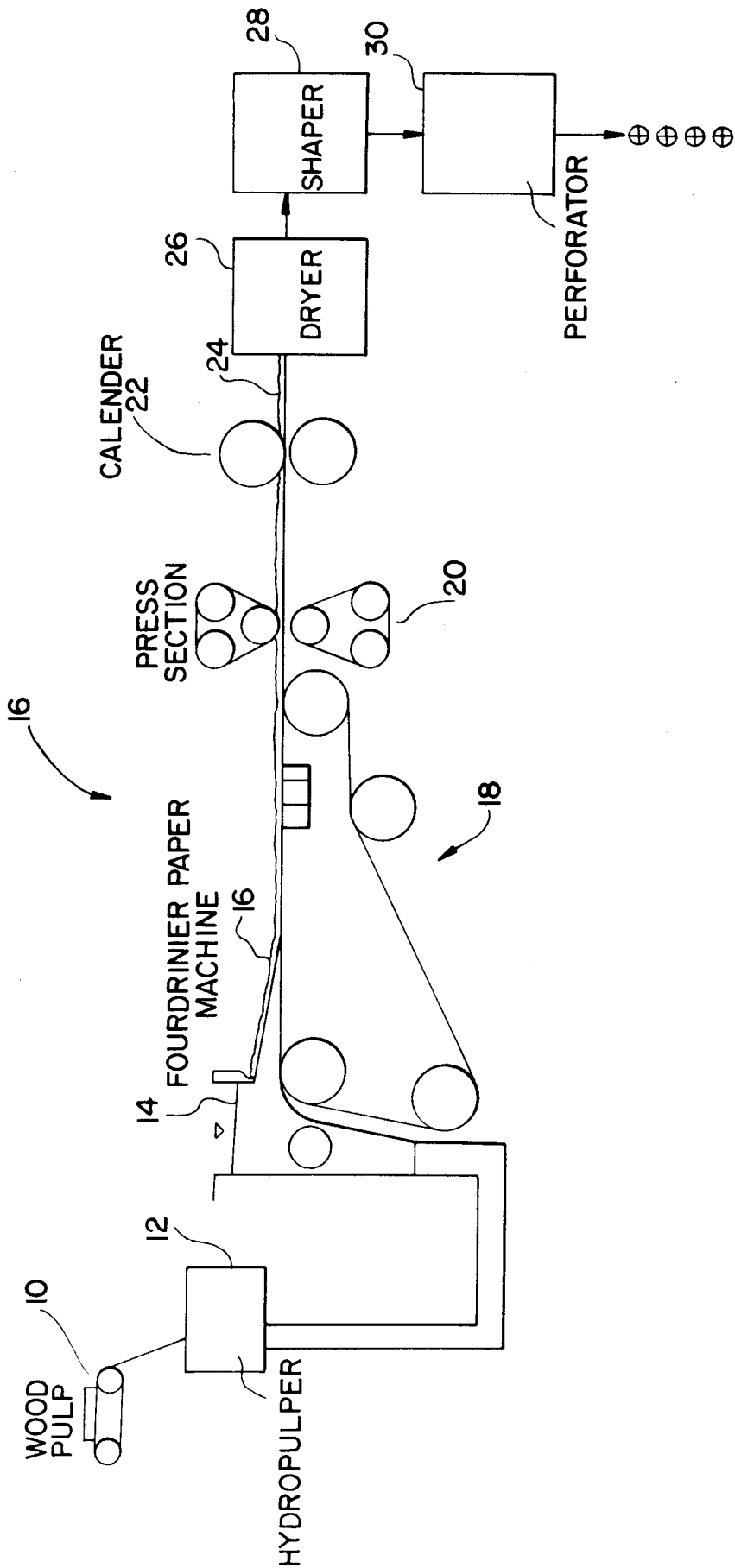


FIG. 2

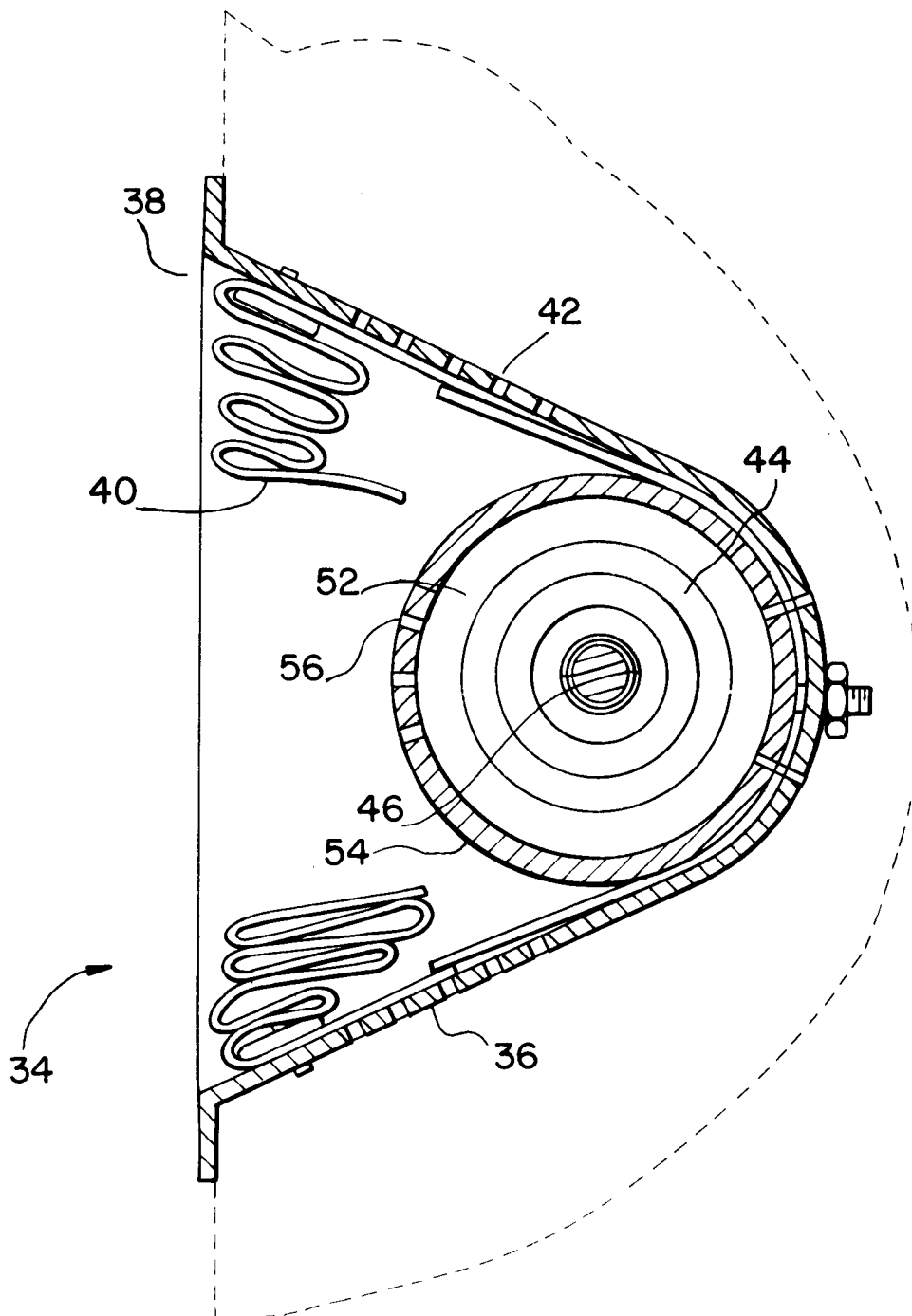


FIG. 4

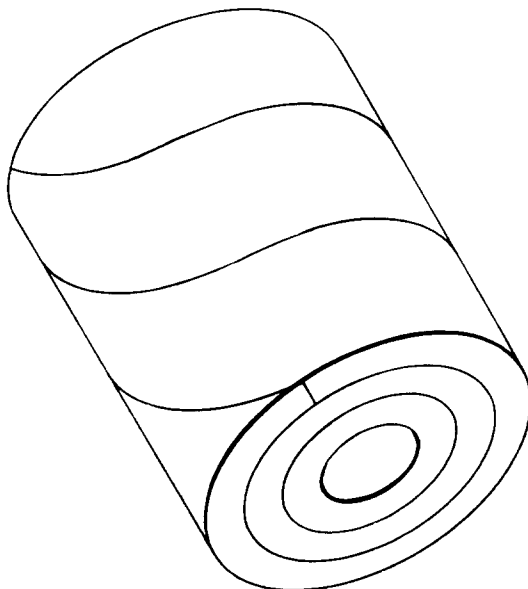


FIG. 3

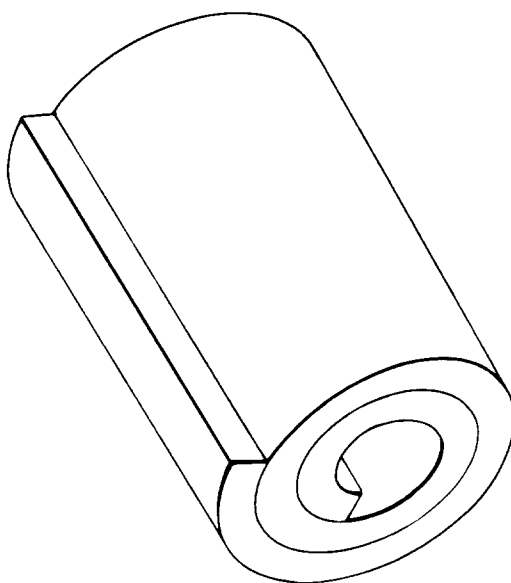
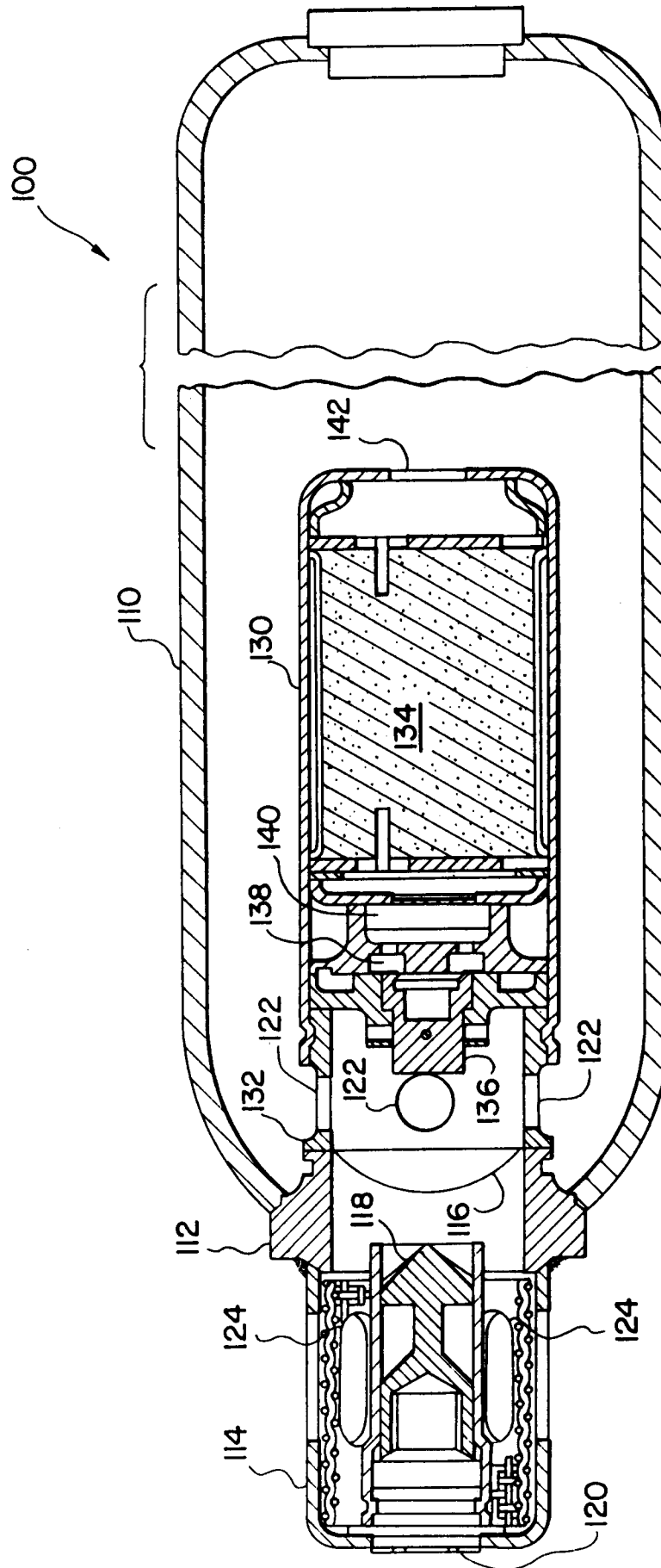


FIG. 5





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Application Number

EP 93 30 4107

Page 1

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-3 862 866 (H.G. TIMMERMAN ET AL.)	1,2, 5-10,12, 16 20	C06D5/06 C06B21/00 C06B31/02 C06B29/02
Y	* column 8, line 37 - line 48; claims * * column 9, line 13 - line 40 * * column 5, line 62 - line 63 * * column 4, line 64 - column 5, line 4 * ---		
Y	DE-A-2 351 401 (SOCIETE NATIONALE DES POUDRES ET EXPLOSIFS) * claims * ---	20	
A	US-A-3 213 793 (R.A. DRATZ) * column 2, line 4 - line 6; claims * ---	1,12-20	
A	WO-A-8 602 347 (E.F. KURTZ) * page 13, line 25 - page 14, line 32 * ---	12-14	
A	EP-A-0 482 852 (AUTOMOTIVE SYSTEMS LABORATORY INC.) * page 4, line 18 - line 33 * ---	1,12	
A	EP-A-0 438 851 (AUTOMOTIVE SYSTEMS LABORATORY INC.) * column 3, line 52 - column 4, line 17 * ---	1,12	
A	US-A-4 386 979 (C.H. JACKSON, JR.) * column 2, line 31 - column 4, line 47 * ---	1,12	
X	US-A-4 734 141 (R.V. CARTWRIGHT ET AL.) * column 2, line 30 - column 3, line 33 * ---	1,12,20	
X	US-A-1 831 760 (A. WIEBEN) * the whole document * ---	1-3,5,7, 12	
A	GB-A-535 971 (E. LORENZINI) * the whole document * ---	1-3,5-7, 10,12	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 08 OCTOBER 1993	Examiner SCHUT R.J.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	



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EUROPEAN SEARCH REPORT

Application Number

EP 93 30 4107

Page 2

DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
X	EP-A-0 474 115 (NIPPON KAYAKU KABUSHIKI KAISHA) * claims * -----	1, 12
		CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
		TECHNICAL FIELDS SEARCHED (Int. Cl.5)
The present search report has been drawn up for all claims		
Place of search THE HAGUE	Date of completion of the search 08 OCTOBER 1993	Examiner SCHUT R.J.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		