

PCTWORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : C06B 31/56	A1	(11) International Publication Number: WO 96/27574 (43) International Publication Date: 12 September 1996 (12.09.96)									
(21) International Application Number: PCT/US96/02259 (22) International Filing Date: 20 February 1996 (20.02.96) (30) Priority Data: <table border="0"><tr><td>398,020</td><td>3 March 1995 (03.03.95)</td><td>US</td></tr><tr><td>517,564</td><td>21 August 1995 (21.08.95)</td><td>US</td></tr><tr><td>582,079</td><td>8 February 1996 (08.02.96)</td><td>US</td></tr></table> (71) Applicant: OLIN CORPORATION [US/US]; 350 Knotter Drive, P.O. Box 586, Cheshire, CT 06410-0586 (US). (72) Inventors: POOLE, Donald, R.; P.O. Box 4237, South Colby, WA 98384 (US). HOLLAND, Gary, F.; 20118 59th Avenue S.E., Snohomish, WA 98290 (US). WOLF, Nicholas, A.; 17410 S.E. Renton-Maple Valley Road #77, Renton, WA 98058 (US). WILSON, Michael, A.; 19212 27th Drive S.E., Bothell, WA 98012 (US). (74) Agents: ROSENBLATT, Gregory, S. et al.; Wiggin & Dana, One Century Tower, New Haven, CT 06508-1832 (US).		398,020	3 March 1995 (03.03.95)	US	517,564	21 August 1995 (21.08.95)	US	582,079	8 February 1996 (08.02.96)	US	(81) Designated States: AL, AM, AU, AZ, BB, BG, BR, BY, CA, CN, CZ, EE, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, RO, RU, SD, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, Eurasian patent (AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
398,020	3 March 1995 (03.03.95)	US									
517,564	21 August 1995 (21.08.95)	US									
582,079	8 February 1996 (08.02.96)	US									
(54) Title: THERMALLY STABLE GAS GENERATING COMPOSITION (57) Abstract There is provided a gas generating composition consisting essentially of a mixture of nitroguanidine and phase stabilized ammonium nitrate. Optionally, an elastomeric binder is also included. When the ammonium nitrate is phase stabilized with from about 7 % to about 20 %, by weight, of a potassium salt, the mixture is structurally and volumetrically stable over typical automotive operating temperatures and has a melting temperature in excess of 100 °C. The mixture generates large volumes of nitrogen and carbon dioxide when ignited with minimal generation of solids or toxic gases and is particularly useful as an inflating medium for automobile airbags.											

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgyzstan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic	KR	Republic of Korea	SE	Sweden
CG	Congo	KZ	Kazakhstan	SG	Singapore
CH	Switzerland	LI	Liechtenstein	SI	Slovenia
CI	Côte d'Ivoire	LK	Sri Lanka	SK	Slovakia
CM	Cameroon	LR	Liberia	SN	Senegal
CN	China	LT	Lithuania	SZ	Swaziland
CS	Czechoslovakia	LU	Luxembourg	TD	Chad
CZ	Czech Republic	LV	Latvia	TG	Togo
DE	Germany	MC	Monaco	TJ	Tajikistan
DK	Denmark	MD	Republic of Moldova	TT	Trinidad and Tobago
EE	Estonia	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	UG	Uganda
FI	Finland	MN	Mongolia	US	United States of America
FR	France	MR	Mauritania	UZ	Uzbekistan
GA	Gabon			VN	Viet Nam

THERMALLY STABLE GAS GENERATING COMPOSITION

This invention relates to chemical compositions for generating large volumes of gas. More particularly, a mixture of nitroguanidine, ammonium nitrate, potassium nitrate and an elastomeric binder is ignited and the gaseous combustion products used to inflate an automotive airbag.

Airbags, as a component of a passive automobile restraint system, are installed in the steering column and passenger side dashboard of passenger automobiles. The airbags inflate in a collision and, by restraining the passengers, minimize injury.

Typically, sensors mounted in the automobile detect a collision and send an electric signal igniting a chemical mixture that generates a large quantity of gas during deflagration. This gas is used to deploy the airbag.

As disclosed in U.S. Patent No. 3,797,854 to Poole et al. one common chemical mixture contains an azide, such as sodium azide, and an inorganic oxidizer, such as potassium perchlorate.

Sodium azide is difficult to handle safely and it is toxic. Assembly of the airbags must be done in a controlled environment and disposal of undeployed airbag cylinders is difficult.

The search for a replacement for an azide/inorganic oxidizer composition to inflate airbags has lead to the identification of five targets for the ideal chemical mixture.

(1) The chemical mixture should generate a large volume of benign gases with minimal generation of noxious gases such as carbon monoxide (CO) and nitrogen oxides (NO_x). One problem with azide based compositions is a low gas output, typically less

-2-

than 1.5 moles of gas per 100 grams of the mixture. Azide alternatives can provide a significant increase in gas output, typically through the addition of CO₂ and H₂O to the exhaust. The
5 co-generation of CO and NO_x is limited by proper selection of propellant composition and proper combustion.

(2) The chemical mixture must be thermally stable at temperatures in excess of 100°C.
10 Automobiles may remain in service for many years and are subject to temperature extremes. The gas generating composition must have a working temperature in the range of from about -40°C to about 100°C. The chemical compounds when heated to
15 a temperature of 100°C should not exhibit a significant net weight loss nor any evidence of physical change.

(3) The generation of solids is detrimental. The solids do not assist in the inflation of the
20 airbag and must be filtered from the gas stream.

(4) The flame temperature or the combustion temperature of the chemical mixture should be as low as possible. At lower temperatures, decreased levels of CO are generated due to formation of more
25 carbon dioxide. Lower levels of NO_x are generated because of more favorable equilibrium and kinetic considerations.

(5) The chemical mixture should be deflagrating as opposed to detonating. On ignition,
30 the mixture should burn rapidly rather than explode.

One substitute for azide/inorganic oxidizer gas generating mixtures is a mixture of 5-aminotetrazole and strontium nitrate plus other additives as

-3-

disclosed in U.S. Patent No. 5,035,757 to Poole. These compositions typically have greater gas outputs than azide generating gas compositions and exhibit good thermal stability. However, the flame
5 temperature exceeds 2500K resulting in excessively high levels of CO and NO_x. Furthermore, although toxicity concerns are considerably reduced, as compared to azide propellants, gas output levels are limited by the high levels of solids in the exhaust
10 composition.

As disclosed in PCT International Publication WO95/25709 entitled "Gas Generating Propellant" that was published on September 28, 1995, one category of gas evolving compounds includes a guanidine salt.
15 Gas is generated by igniting a mixture consisting essentially of (by weight) 55%-75% guanidine nitrate, 25%-45% of an oxidizer selected from the group consisting of potassium perchlorate and ammonium perchlorate, 0.5%-5% of a flow enhancer and
20 up to 5% of a binder.

The mixture disclosed in PCT Publication WO95/25709 is for use an augmented airbag system. In augmented systems, the main use of the propellant is to heat a pressurized gas which is the primary
25 gas source for inflation of the bag. The amount of gas produced by the propellant is a small fraction of the total gas required to inflate the airbag.

An extrudable, non-azide based, propellant is disclosed in U.S. Patent No. 5,125,684 to
30 Cartwright. This propellant contains from about 45-80 wt. % of an oxidizer salt; an effective amount of a cellulose based binder; and from about 10-35 wt. % of at least one energetic component.

-4-

A nitrocellulose binder is not particularly favored for propellants intended for automobile airbag applications because of its poor chemical stability at the high temperatures experienced in the automobile environment. Additionally, the nitro (NO₂•) groups of the nitrocellulose contribute to the formation of higher levels of NO_x during combustion.

Ammonium nitrate (AN) based propellants offer the capability of meeting many of the targets for airbag inflation. Many AN-based propellants and explosives are known.

German Patentschrift 851,919, published October 1952 by Imperial Chemicals Industries Limited, discloses a gas generating compound containing ammonium nitrate, sodium nitrate, guanidine nitrate and nitroguanidine.

U.S. Patent No. 4,421,578 by Voreck, Jr., discloses an explosive mixture containing ammonium nitrate, potassium nitrate, nitroguanidine and ethylenediamine dinitrate. This composition was developed for explosive applications with an intent to replace TNT (2,4,6-trinitrotoluene). The eutectic formed when ammonium nitrate, ethylene diamine dinitrate and guanidine nitrate are mixed in the disclosed proportion has a melting temperature below 100°C. Propellant mixtures with such a low melting point are not suitable for applications such as automobile airbag inflators where temperature stability in excess of 107°C is frequently required.

Both ammonium nitrate and phase stabilized ammonium nitrate (PSAN) are thermally stable for extended periods of time at a temperature of 107°C. However, mixtures of AN and PSAN with a wide variety

-5-

of materials ranging from polymeric binders to high energy fuels to common burn rate catalysts do not exhibit acceptable thermal stability as measured by weight loss and/or melting. Table 1 illustrates this phenomenon.

TABLE 1

Oxidizer	Fuel	Additive	Weight Loss*
PSAN	None	None	≤0.1%
PSAN	Hydroxy-terminated polybutadiene (HTPB) /IPDI	Milori blue, carbon black	0.5%
PSAN	None	Milori blue	4%
PSAN	None	Carbon black	35%
PSAN	Hydroxy-terminated polycarbonate-IPDI	Milori blue	6%
PSAN	5-amino-tetrazole	None	Melts with loss of NH ₃
PSAN	ethylene diamine dinitrate, nitroguanidine	potassium nitrate	Melts<100°C ★★

Table 1 notes:

* = After thermal aging 400 hours at 107°C.

IPDI = isophorone di-isocyanate

Milori blue = an iron blue pigment.

★★ = composition of U.S. Patent No. 4,421,578.

A problem with the use of pure ammonium nitrate is that the compound undergoes a series of

-6-

structural phase transformations over the typical operating range of automobile airbag inflators. In pure AN, structural phase transitions are observed at -18°C, 32.3°C, 84.2°C and 125.2°C. The phase transition at 32.3°C is particularly problematic during temperature cycling because of a large change in the associated volume, on the order of 3.7%, by volume. Generally, any volumetric change is detrimental and it is desired to limit any volumetric change as much as possible.

Phase stabilization of ammonium nitrate by the inclusion of potassium salts, such as potassium nitrate and potassium perchlorate is known. PSAN containing 15% by weight potassium nitrate will successfully avoid the problematic phase changes and volume changes associated with pure AN.

There remains therefore a need for an azide-free chemical composition useful to inflate automotive airbags that generates large volumes of benign gases, has thermal stability at temperatures in excess of 100°C, generates a low volume of solids, has a low flame temperature and is not explosive.

Accordingly, it is an object of the invention to provide a chemical mixture that generates a volume of gas to inflate an automobile airbag. Other objects of the invention include that the chemical mixture is azide free, that the gas generated has a minimum amount of solids and noxious gases and that the propellant is physically and chemically stable through the range of temperatures required for automobile airbags.

-7-

One unique feature of the invention is that the chemical mixture resists thermal decomposition at temperatures in excess of 100°C. Mixtures of many chemical compounds with ammonium nitrate are not stable at temperatures in excess of 100°C, and these mixtures are not suitable for use in automobile airbags. Another feature of this invention is that the chemical mixture includes nitroguanidine and ammonium nitrate in a stoichiometric ratio that minimizes the generation of noxious gases such as CO and NO_x. Still another feature of the invention is that the combination of phase stabilized ammonium nitrate and an elastomeric binder increases the flexibility of the composition preventing physical degradation of the propellant during thermal cycling. Physical degradation of a compacted propellant is manifest by volumetric changes, fracture, reduction in resistance to fracture, an increase in the burn rate and combinations thereof.

It is a feature of the invention that the chemical mixture includes a mixture of nitroguanidine and ammonium nitrate in a ratio effective to produce deflagration rather than detonation on ignition. It is another feature of the invention that phase stabilized ammonium nitrate is used to prevent physical breakdown of the propellant on thermal cycling. In one embodiment, potassium nitrate is added to provide thermal stability up to 110°C. In addition, it is a feature of the invention that the flame temperature is less than 2450K.

-8-

It is an advantage of the invention that by using a mixture of nitroguanidine, ammonium nitrate and potassium nitrate in a specified ratio, a non-explosive chemical mixture generates a large volume
5 of benign gases on ignition. The flame temperature is below 2450K, minimizing generation of noxious gases such as CO and NO_x.

In accordance with one embodiment of the invention, there is provided a gas generating
10 composition consisting essentially of from about 35% to about 55% by weight nitroguanidine and from about 45% to about 65% by weight phase stabilized ammonium nitrate. The composition has a melting temperature in excess of 100°C and deflagrates when ignited.

15 In accordance with another embodiment of the invention, there is provided a gas generating composition consisting essentially of from about 5% to about 40% by weight nitroguanidine, from an amount effective to increase the flexibility of the
20 composition up to about 10%, by weight of an elastomeric binder, and from about 60% to about 85% by weight phase stabilized ammonium nitrate. The composition has a melting temperature in excess of 100°C and deflagrates when ignited.

25 The above stated objects, features and advantages will become more apparent from the specification and drawing that follows.

The combination of phase stabilized ammonium nitrate and nitroguanidine produces a series of
30 chemical compositions that, when ignited, generate high levels of a gas that has a low content of

-9-

noxious constituents such as CO and NO_x. The gas is characterized by a low level of residual solids and ballistics suitable for use as an inflator of automobile airbag units.

5 An unexpected benefit of these chemical compositions is thermal stability. Aging of the chemical composition at temperatures in excess of 100°C does not cause a significant weight loss or a change in ballistic properties. This thermal
10 stability in the ammonium nitrate - nitroguanidine combination was unexpected because of the typically high reactivity observed between ammonium nitrate and other materials at elevated temperatures.

 Another unexpected benefit of these
15 compositions is enhanced stability during thermal cycling. Thermal cycling of these compositions between -30°C and +80°C results in only very small changes in physical size and ballistic performance.

 Ammonium nitrate based propellants are
20 particularly useful in automobile airbag inflators because of the high gas outputs and the low levels of residual solids resulting from their combustion. The only solids produced by phase stabilized ammonium nitrate are derived from the additives used
25 to accomplish the phase stabilization.

 The chemical compositions of the invention include nitroguanidine (CH₄N₄O₂), a highly energetic fuel having a large negative oxygen balance (-30.7%). Nitroguanidine can be combined in a
30 stoichiometric ratio with phase stabilized ammonium nitrate to produce chemical mixtures that are relatively insensitive to impact (≥180 kg/cm),

-10-

friction (≥ 360 N) and electrostatic discharge (≥ 3 J).

The stoichiometric ratio of oxidizer to fuel is adjusted to provide a level of free hydrogen in the exhaust gases of between zero and about 3% by volume. More preferably, the level of free hydrogen is between zero and about 0.5% by volume. The stoichiometric ratio of oxidizer to fuel is also adjusted to provide a level of free oxygen in the exhaust gases of from zero to about 4% by volume. More preferably, the level of free oxygen is from zero to about 0.5% by volume.

Potassium salts, such as potassium nitrate, potassium perchlorate, potassium dichromate, potassium oxalate and mixtures thereof, are the preferred phase stabilizers with potassium nitrate being most preferred. Other compounds and modifiers that are effective to phase stabilize ammonium nitrate are also suitable. The stabilizing agent is present in an amount effective to minimize a volumetric and structural change associated with the Phase IV $\leftrightarrow$ Phase III structural phase transition that is inherent to pure ammonium nitrate.

The preferred phase stabilized ammonium nitrate contains from about 5% to about 25% by weight potassium nitrate and more preferably from about 10% to about 15% by weight potassium nitrate.

To maintain the desired chemical stability, effluent characteristics and ballistic properties of the chemical mix, the ratio of nitroguanidine to PSAN is, when substantially free of a binder, by weight, from about 1:1 to about 1:2 and more preferably from about 1:1.1 to about 1:1.5.

-11-

The gas generating composition of the invention generally consists essentially of, by weight, from about 35% to about 55% nitroguanidine and from about 45% to about 65% phase stabilized ammonium nitrate.

5 Additions such as flow enhancers or molding facilitators may be present provided the additions do not detract from the deflagratory characteristic of the composition.

10 In a preferred embodiment, the gas generating composition consists essentially of, by weight, from about 40% to about 46% nitroguanidine and from about 54% to about 60% phase stabilized ammonium nitrate.

15 In one most preferred embodiment, the composition consists essentially of, by weight, from about 43% to about 44% nitroguanidine and from about 56% to about 57% potassium perchlorate stabilized ammonium nitrate.

20 In a second most preferred embodiment, the composition consists essentially of, by weight, from about 42% to about 44% nitroguanidine and from about 56% to about 58% potassium nitrate stabilized ammonium nitrate.

25 Repeated thermal cycling, such as between -30°C and 80°C typically causes physical degradation of the compacted binder-less propellant. This physical degradation is in the form of an irreversible increase in volume that increases the surface area of the propellant and decreases the mechanical strength of the pill, both contributing to a change in ballistic performance. This physical degradation
30 may be inhibited by the inclusion of a binder to increase elasticity and by minimizing exposure to water.

-12-

The binder is present in an amount of from that effective to increase the elasticity of the propellant composition up to about 10%, by weight. More preferably, the propellant contains from about
5 0.5% to about 6%, by weight, of the binder. Lower amounts of the binder do not provide the necessary elasticity. Excessive amounts of the binder increase the amount of CO generated in combustion and generally have a negative effect on ballistic
10 performance.

The binder is generally classified as an elastomeric binder and is preferably selected from the group consisting of polyurethanes, polycarbonates, polyethers, polysuccinates,
15 thermoplastic rubbers and mixtures thereof. A most preferred binder is a polyurethane based on hexanediol/adipate/IPDI. Examples of binder based propellants and the associated properties are given in Table 2 below.

20 When the binder is present, the ratio of ammonium nitrate to nitroguanidine is altered because the hydrocarbon based binders require an increased amount of oxidizer for complete combustion. When the binder is present, the gas
25 generating composition contains from about 5% to about 40%, by weight, of nitroguanidine and from about 60% to about 85%, by weight, of phase stabilized ammonium nitrate. Preferably, the nitroguanidine is present in an amount of from about
30 10% to about 30%, by weight, and the ammonium nitrate in an amount of from 70% to about 80%, by weight.

-13-

A plasticizer such as hydroxy-terminated polybutadiene or dioctyladipate and a surface modifier such as an amino-silane (i.e. alkylamino-silane), an organotitanate or an organozirconate may be present, either singly or in combination, both in amounts of from about 0.1% to about 3%, by weight. Preferably, both are present in an amount of from 0.25% to 1.0%, by weight.

The function of the plasticizer is to enhance binder rheology through modification of the glass transition temperature. The function of the surface modifier is to improve the bond between the binder and the propellant solids.

A mixture of the phase stabilized ammonium nitrate and nitroguanidine powders of the desired chemical composition may be ground, commingled and compression molded into a tablet of a desired size using standard compression molding techniques. Typically, prior to burn rate measurement, the powders are pressed into pellets having a diameter of about 12.7 mm (0.5 inch), a length of about 12.7 mm and a mass of approximately 3 grams. The pellets are coated with a flame inhibitor, such as an epoxy/titanium dioxide mixture to prevent burning along the sides of the pellet.

The advantages of the chemical compositions of the invention will become more apparent from the examples that follow.

-14-

EXAMPLESExample 1

5 A quantity of 10% potassium nitrate in a phase stabilized ammonium nitrate mixture (10% KN-PSAN) was prepared by co-precipitating ammonium nitrate with 10 weight percent potassium nitrate from an aqueous solution. After drying, the solid was ball milled to reduce particle size producing a fine granular material.

10 A mixture of 16.40 grams nitroguanidine and 23.60 grams of the 10% KN-PSAN was prepared by ball milling the powders to mix and reduce particle size. Pellets were formed by compression molding the powder to form grains of approximately 12.7 mm (0.5
15 inch) diameter by 12.7 mm length with a mass of 3 grams. The pellets were compression molded at approximately 296 MPa (43,000 psi) and then coated with an epoxy/titanium dioxide flame inhibitor.

The theoretical combustion temperature of the
20 mixture is 2409°C. The burning rate of the pellets was measured and found to be 8.6 mm (0.34 inch) per second at 6.9 MPa (1000 psi) with a pressure exponent of 0.47. The primary gas produced by combustion was, by volume, 53% water, 37% nitrogen,
25 9% carbon dioxide and 0.3% oxygen. The primary solid product produced by combustion was potassium carbonate.

Closed bomb aging of pellets at 107°C resulted in an average weight loss of 0.21 weight percent
30 after 400 hours aging. Drop weight test on this material indicates an impact sensitivity in excess of 180 kg•cm.

-15-

Example 2

A mixture of nitroguanidine and 15% KN-PSAN was prepared according to the process of Example 1 and pellets formed by compression molding. The composition, by weight, of this mixture was 42.3% nitroguanidine and 57.7% PSAN.

The theoretical combustion temperature of this mixture is 2399°C. The primary gas produced by combustion was, by volume, 52% water, 38% nitrogen, 9% carbon dioxide and 0.2% oxygen. The primary solid product produced by combustion was potassium carbonate.

The linear burn rate of these pellets was measured at 6.9 MPa (1000 psi) and found to be 8.1 mm (0.32 inch) per second. Differential scanning calorimetry (DSC) measurements revealed no endotherms characteristic of ammonium nitrate phase transitions over the temperature range of 0°C-115°C; confirming incorporation of potassium nitrate into ammonium nitrate to form PSAN. Endotherms corresponding to the ammonium nitrate Phase III-to-II and the Phase II-to-I structural phase transitions occurred at approximately 120°C and 130°C, respectively. The onset of AN melting occurred at approximately 165°C and the onset of an exotherm was approximately 245°C.

Example 3

A quantity of PSAN consisting of 13.7%, by weight, potassium perchlorate (KP) and 86.3% ammonium nitrate was prepared by co-precipitating the salts from an aqueous solution followed by

-16-

drying. The solid was then ball milled to reduce particle size.

A mixture consisting of 43.6% nitroguanidine and 56.4%, by weight, KP-PSAN was prepared by dry
5 blending using a ball mill with pellets then formed by compression molding.

Burn rate measurements at 6.9 MPa (1000 psi) indicated a burn rate of 8.6 mm (0.34 inch) per second and a pressure exponent of 0.67. The
10 combustion temperature is theoretically 2571 °K. The primary gas produced by combustion contains (by volume) 52% water, 37% nitrogen, 11% carbon dioxide and 0.1% hydrogen. The solid product produced by combustion is potassium chloride. Weight loss
15 measurements of propellant pellets at 100°C indicated 0.1% weight loss after 400 hours and 0.2% weight loss after 1000 hours.

Example 4

A 1.5 kg batch of 41.8% nitroguanidine and
20 58.2% of 10% KN-PSAN was prepared by ball milling 627 grams of nitroguanidine with 873 grams of a 10% KN-PSAN mix (prepared according to Example 1). After drying, the mixture was granulated to improve mixing and material flow. The pellets were
25 compression molded on a high speed tableting press and found to form pellets of acceptable quality.

The theoretical combustion temperature of this mixture is 2423°C. The primary gas produced by combustion, by volume, was 52% water, 37% nitrogen,
30 11% carbon dioxide and 0.1% hydrogen. The primary solid produced by combustion was potassium carbonate.

-17-

The pellets formed on the high speed tableting press were tested in a gas generator and found to inflate an airbag satisfactorily.

Cap sensitivity tests performed on the
5 aforementioned pellets (4.78 mm diameter, 2.03 mm thick) pursuant to United States Department of Transportation procedures indicated a negative sensitivity to initiation with a No. 8 blasting cap.

Example 5

10 Propellant mixes having the compositions specified, in weight percent, in Table 2 were formed into pellets. Representative of the pellet forming process are:

A. The propellant mix having the composition
15 20.0% nitroguanidine, 75.0% of 15% KN-PSAN and 5.0% polycarbonate binder was prepared and pressed into pellets as follows.

A mixture of 200.0 grams of nitroguanidine and 750.0 grams of PSAN was prepared by dry blending
20 using a ball mill. 50.0 grams of polycarbonate dissolved in methylene chloride was added to the dry blend. The resulting slurry was mixed in 250 gram batches on a Baker-Perkins pint mixer and the solvent then removed under vacuum. The four 250
25 gram batches were then recombined and pellets were prepared by compression molding on a high-speed tableting press.

B. The propellant mix having the composition
10.5% nitroguanidine, 83.5% of 15% KN-PSAN and 4.0%
30 R45M-IPDI was prepared by dry blending 5.25 grams of

-18-

nitroguanidine and 41.75 grams of PSAN in a ball mill. A solution of 3.71 grams of R45M and 0.29 grams IPDI in 50 milliliters of methylene chloride was added to the dry mix.

5 The resulting slurry was mixed and the solvent evaporated by heating. The resulting powder was partially cured for 12 hours at 60°C and then pressed into pills at 26.69 k N (6000 lb-f). The partially cured pills were then fully cured for 3
10 days at 60°C.

 The densities of the pellets was determined and the pellets were then thermal cycled. After 100 cycles between -30°C and +80°C, the density was measured again. The density change (Δ density) is
15 recorded in Table 2.

-19-

Table 2

Binder	% Binder	% PSAN	% Fuel	B.R./ P.E.	Δ Density
None	-0-	56.9	43.1	0.36/ 0.44	-8.0
Kraton	1	62.2	36.8	0.36/ 0.42	-2.5
Kraton	3	73.0	24.0	0.30/ 0.55	-1.9
R45M- IPDI	4	83.5	10.5	0.21/ 0.84	-0.4
KM1733- N100	4	69.6	26.4	0.21/ 0.84	N.D.
Poly- carbo- nate	5	75.0	20.0	0.22/ 0.44	-3.7
Kraton	6.8	93.2 0	-0-	0.09/ 0.90	N.D.
HDO- AD/IPDI	7.50	84.3 0	8.20	N.D.	N.D.
R45M- IPDI	4.5	91.5	2 CB 2 MB	0.22/ 0.64	-0.9

Table 2 notes:

- Kraton is a polyethylene/butylene-polystyrene block copolymer manufactured by Shell Chemical Company.
- R45M is a hydroxyterminated polybutadiene manufactured by the Arco Chemical Company.
- IPDI is isophorone diisocyanate, manufactured by Huls America, Inc.
- KM1733 is a hydroxyterminated polycarbonate manufactured by Stahl USA.
- N100 is a biuret polymer based on 1, 6-hexamethylene diisocyanate manufactured by Desmodur.
- HDO-AD is a polyester diol adduct of hexanediol/adipic acid manufactured by Ruco Polymer Corp.
- CB is Carbon Black.
- MB is Milori Blue.
- P.E. is the pressure exponent.
- B.R. is the burn rate measured at 6.9 MPa (1000 psi).
- N.D. indicates values not determined.

It is apparent that there has been provided in accordance with this invention a gas evolving

-20-

chemical mixture that fully satisfies the objects,
features and advantages set forth hereinabove.

While the invention has been described in
combination with specific embodiments thereof, it is
5 evident that many alternatives, modifications and
variations will be apparent to those skilled in the
art in light of the foregoing description.

Accordingly, it is intended to embrace all such
alternatives, modifications and variations as fall
10 within the spirit and broad scope of the appended
claims.

-21-

IN THE CLAIMS:

1. A gas generating composition consisting essentially of:

from about 35% to about 55% by weight of nitroguanidine; and

from about 45% to about 65% by weight of phase stabilized ammonium nitrate, said gas generating composition having a melting point in excess of 100°C and capable of deflagration when ignited.

2. The gas generating composition of claim 1 characterized in that said phase stabilized ammonium nitrate is a mixture of ammonium nitrate and a stabilizing agent, said stabilizing agent present in an amount effective to minimize the volume and structural change associated with the phase change observed at approximately 32°C in pure ammonium nitrate.

3. The gas generating composition of claim 2 characterized in that said stabilizing agent represents from about 5% to about 25%, by weight, of said phase stabilized ammonium nitrate.

4. The gas generating composition of claim 3 characterized in that said stabilizing agent is a potassium containing salt selected from the group consisting of potassium nitrate, potassium perchlorate, potassium dichromate, potassium oxalate and mixtures thereof.

-22-

5. The gas generating composition of claim 4 characterized in that the ratio of nitroguanidine to phase stabilized ammonium nitrate, by weight, from about 1:1 to about 1:2.

6. The gas generating composition of claim 4 consisting essentially of from about 40% to about 46% nitroguanidine and from about 54% to about 60% phase stabilized ammonium nitrate.

7. The gas generating composition of claim 6 characterized in that said stabilizing agent is potassium perchlorate.

8. The gas generating composition of either any one of claims 1-5 characterized in that said stabilizing agent is potassium nitrate.

9. A gas generating composition consisting essentially of:

from about 5% to about 40%, by weight, of nitroguanidine;

from an amount effective to increase the elasticity of said composition up to about 10%, by weight, of an elastomeric binder; and

from about 60% to about 85%, by weight, of phase stabilized ammonium nitrate, said gas generating composition having a melting point in excess of 100°C and capable of deflagration when ignited.

-23-

10. The gas generating composition of claim 9 characterized in that said phase stabilized ammonium nitrate is a mixture of ammonium nitrate and a stabilizing agent, said stabilizing agent present in an amount effective to minimize the volume and structural change associated with the phase transition observed at approximately 32°C in pure ammonium nitrate.

11. The gas generating composition of claim 10 characterized in that said binder is selected from the group consisting of polyurethanes, polycarbonates, polyethers, polysuccinates, thermoplastic rubbers and mixtures thereof.

12. The gas generating composition of claim 11 characterized in that said binder is present in an amount of from about 0.5% to about 6%.

13. The gas generating composition of any one of claims 9-12 characterized in that said composition further includes from about 0.10% to about 3%, by weight, of a plasticizer.

14. The gas generating composition of claim 13 characterized in that said plasticizer is selected from the group consisting of dioctyladipate and hydroxy-terminated polybutadiene.

15. The gas generating composition of any one of claims 9-14 characterized in that said composition further includes from about 0.10% to about 3%, by weight, of a surface modifier.

-24-

16. The gas generating composition of claim 15 characterized in that said surface modifier is selected from the group consisting of organotitanates, organozirconates and amino-silanes.

17. The gas generating composition of any one of claims 9-16 characterized in that said nitroguanidine is present in amount of from about 10% to about 30%, by weight.

18. The gas generating composition of any one of claims 9-17 characterized in that said phase stabilized ammonium nitrate is present in an amount of from about 70% to about 80%, by weight.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/02259

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :C06B 31/56

US CL :149/48, 78, 109.6

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 149/48, 78, 109.6

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
APS TEXT

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

search terms: Gas Generant

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 3,912,562 (GARNER) 14 OCTOBER 1975.	1-18
A	US, A, 5,098,683 (MEHROTRA ET AL.) 24 MARCH 1992.	1-18
A	US, A, 5,125,684 (CARTWRIGHT) 30 JUNE 1992.	1-18

☐ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	*T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A document defining the general state of the art which is not considered to be of particular relevance	*X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*E earlier document published on or after the international filing date	*Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*G document member of the same patent family
*O document referring to an oral disclosure, use, exhibition or other means	
*P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

23 APRIL 1996

Date of mailing of the international search report

29 JUL 1996

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

ANTHONY R. CH

Telephone No. 703-306-4159