March 14, 1961 R. C. ALLEN 2,974,596

PROPELLANT GRAIN IGNITER

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Fig. 1

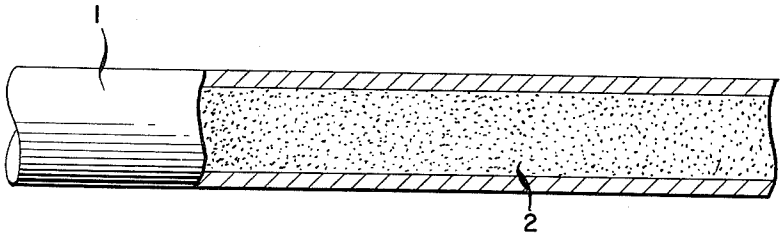
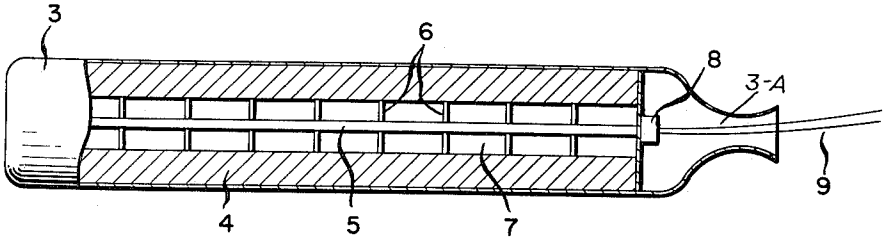


Fig. 2



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PROPELLANT GRAIN IGNITER

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1 Claim. (Cl. 102—70)

The present invention relates to a novel explosive device. More particularly, the present invention relates to an explosive cord by which an ignition stimulus is propagated at an extremely high velocity.

Heretofore, the transmission of ignition stimuli, which stimuli may be defined as those which will effect deflagration of an explosive, i.e. a flame, has been possible only at undesirably low velocities, that is, 130 seconds per meter in the case of safety fuse and 26 seconds per meter in the case of the more rapid Ignitacord. Although the transmission of initiation stimuli, or stimuli which effect the detonation of an explosive, i.e. a detonation wave, is possible at much higher velocities, that is velocities of the order of two or more thousand meters per second, e.g. 6000 meters per second in the case of "Primacord," these initiation stimuli cannot be used to bring about the deflagration of an explosive.

In some applications of explosives, a need exists for a device which will transmit ignition, or deflagration, stimuli at a very high, or detonation, velocity. For example, modern rockets generally have a solid propellent grain of a deflagrating composition as the energy source which will provide the thrust required to propel the rocket. In rocket terminology, grain refers to the entire mass of deflagrating composition and may, thus, constitute a mass weighing thousands of pounds. The entire mass, or grain, is actuated by an igniter which provides the flame required to effect the deflagration of the propellent composition.

In small rockets, the igniter may consist of an electric squib alone, whereas in larger rockets a squib in combination with a readily ignitable, highly exothermic material is used. These ignition systems have the main disadvantage of supplying heat to only the small portion of the propellent grain adjacent the ignition device. Since the full rocket thrust is not developed until the entire surface of the grain is reacting, a time lag exists between actuation of the igniter and actuation of the rocket. This time lag, which is dependent upon the length of the grain, the ignition temperature of the grain, the burning rate of the grain, etc., may be in the order of 50 or more milliseconds and, therefore, constitutes a serious problem. For example, when the rocket motor powers a missile directed against or by a high-speed aircraft traveling at a speed of 1000 miles per hour or approximately 1.5 feet per millisecond, a time lag of 50 milliseconds between igniter actuation and rocket actuation will permit travel of about 75 feet, more than enough to cause a miss.

This time lag, of course, could be eliminated by means of an ignition device which would simultaneously ignite

the entire surface of the grain by transmission of the ignition stimulus at a very high velocity, thus combining the features of an ignition device with those of an initiation device. One such device is described in detail in copending application Serial No. 608,591 (C. O. Davis and G. A. Noddin, filed September 7, 1956, now abandoned, and assigned to the present assignee) and comprises a mass of a readily ignited pyrotechnic composition surrounding a length of explosive connecting cord having a core of 0.5 to 5 grains per foot of a high-velocity detonating explosive within a metal sheath. Although this assembly functions very satisfactorily and brings about the desired simultaneous ignition, the two-component nature of this assembly at times results in handling and storage problems. Therefore, a simplified ignition device which is capable of transmitting at detonation velocity the stimulus required to effect deflagration is highly desirable. Such a device would be of high utility especially in rockets and also for pyrotechnics and special effects applications.

Accordingly, an object of the present invention is to provide a simple and readily prepared high-velocity ignition-propagating device. Another object of the present invention is to provide an explosive cord which in itself detonates but effects the deflagration, rather than the detonation, of surrounding explosive materials. A further object of the present invention is to provide an improved ignition device especially suited for use with rocket propellent grains.

I have found that the following objects may be achieved when I provide an explosive cord comprising a mixture of a crystalline high-explosive compound, an oxidant, and a fuel confined within a metal sheath.

In accordance with the present invention, a mixture comprising 15–80% of a crystalline high-explosive compound, 10–82% of an oxidant, and 3–75% of a fuel is confined in a metal sheath such that the distribution of the mixture is 2–20 grains per foot of sheath length, the high-explosive compound being present in the amount of at least 1 grain per foot of sheath length.

In order to describe more fully the present invention, reference is made to the accompanying drawings, in which:

Figure 1 is a sectional view of the ignition-propagation cord of the present invention.

Figure 2 is a sectional view of a typical rocket motor assembly incorporating the ignition-propagation cord of the present invention, which view is given to illustrate one use of the cord.

In Figure 1, 1 represents a metal sheath, preferably of lead or a lead alloy, and 2 represents the mixture of high-explosive compound, oxidant, and fuel contained within the sheath.

In Figure 2, 3 represents the rocket motor casing which is tubular in configuration and has one end closed and the other forming a nozzle 3A. Within casing 3 is the propellent grain 4 having a central cavity throughout its entire length. These components of the rocket motor system are conventional. Disposed within the cavity of the grain 4 is the ignition-propagation cord 5 of the present invention, which is maintained within the cavity by positioning devices 6, which for example may be washers, so that an air space 7 is provided between the cord 5 and the grain 4. In initiating arrangement with one

end of the cord is an electric blasting cap 8, the lead wires of which are represented by 9.

In operation, actuation of the cord 5 by the electric blasing cap 6 causes ultrarapid transmission, about 2 to 5 thousand meters per second, of the ignition stimulus down the length of the grain 4 so that essentially simultaneous deflagration of the entire internal surface of the grain occurs. This simultaneously deflagration results in an immediate thrust or actuation of the rocket. Although I do not wish to be limited by a theoretical discussion of the functioning of the cord, apparently the detonation of the high-explosive particles present in slight quantity in the mixture 2 confined within the sheath 1 propagates at high velocity, causing detonation of the cord and a simultaneous deflagration of the entire exothermic oxidant-fuel mixture within the length of the sheath, which highly exothermic reaction produces a flame of sufficient intensity to ignite propellant compositions even though the quantities of reactants are very slight. Thereby, although the cord itself detonates to give the high-velocity propagation of the ignition stimulus, the cord brings about deflagration of the propellent grain.

The following examples serve to illustrate specific embodiments of the ignition-propagation cord of the present invention. However, they will be understood to be illustrative only and not as limiting the invention in any manner.

EXAMPLE 1

A mixture comprising 15% of very fine PETN, 43% barium peroxide, and 42% coarse aluminum powder was loaded into a 4-inch length of lead tubing 0.310 inch in outer diameter and about 0.16 inch in inner diameter. The tubing was drawn out by means of a series of dies into a tube 0.090 inch in outer diameter and 43 inches in length. The distribution of the mixture within the tube was 8.84 grains per foot. The ignition-propagation cord thus prepared was tested by positioning an 8-inch length of the cord longitudinally within polyethylene tubing and surrounding a portion of the cord with a double-base smokeless propellent powder. Upon initiation by an electric blasting cap, the cord detonated at a velocity of 2400 meters per second and ignited essentially simultaneously the entire surface of the propellent powder.

EXAMPLE 2

Another length of ignition-propagation cord was prepared in the manner described in Example 1. The cord was 0.065 inch in outer diameter and contained a mixture of 80% of cap-grade PETN, 10% of magnesium, and 10% of tellurium at a distribution of 3.08 grains per foot. Upon testing, the cord detonated at a velocity of 5800 meters per second and effectively ignited a deflagrating mixture comprising 63% potassium perchlorate and 37% aluminum.

EXAMPLE 3

The procedure of Example 1 was again followed in preparing an ignition-propagation cord having an outer diameter of 0.070 inch and containing a 50/40/10 mixture of PETN (very fine grade)/barium peroxide/atomized aluminum powder at a distribution of 3.8 grains per foot. This cord detonated at a velocity of 5500 meters per second. Its ignition capabilities were verified by its use to ignite a double-base smokeless propellent powder.

EXAMPLE 4

An ignition-propagation cord (0.138 inch in O.D.) and containing a 15/10/75 mixture of PETN (very fine grade)/barium peroxide/atomized aluminum at a distribution of 18.8 grains per foot was prepared and tested with a nitroguanidine-based propellant and with black powder. With both propellants, essentially simultaneous ignition of the entire surface was effected by means of the cord, which detonated at a velocity of 2100 meters per second.

EXAMPLE 5

An ignition-propagation cord having an outer diameter of 0.090 inch and containing 10.7 grains per foot of a mixture of 15/75/10 PETN (very fine grade)/barium peroxide/aluminum powder (admixed coarse and atomized) prepared by the exemplified method detonated at a velocity of 3000 meters per second and ignited an adjacent charge of black powder and of a nitroguanidine-type propellant, substantially simultaneous ignition occurring of the entire propellant surface.

EXAMPLE 6

When an ignition-propagation cord (0.090 inch in outer diameter) prepared by the method of Example 1 and containing a 15/82/3 mixture of PETN (very fine grade)/barium peroxide/atomized aluminum at a distribution of 10.96 grains per foot was tested with black powder (cord threaded through a 2-inch-long black powder pellet), the entire inner surface of the pellet was ignited essentially simultaneously. The cord detonated at a velocity of 2800 meters per second.

EXAMPLE 7

An 0.105 inch-outer diameter ignition-propagation cord was prepared in the afore-mentioned manner and contained a 30/35/35 mixture of PETN (very fine grade)/barium peroxide/aluminum powder (admixed coarse and atomized) at a distribution of 19 grains per foot. The cord detonated at a velocity of 4,150 meters per second and ignited essentially simultaneously the entire surface of 2-inch-long black powder pellet through which it was threaded.

EXAMPLE 8

An ignition-propagation cord containing a 50/25/25 mixture of PETN (very fine grade)/barium peroxide/aluminum powder (admixed atomized and coarse) at a distribution of 2.33 grains per foot also was prepared. The cord was 0.065 inch in outer diameter and detonated at a velocity of 4000 meters per second. When tested with a charge of black powder, this cord ignited the black powder satisfactorily.

EXAMPLE 9

An ignition-propagation cord, 0.090 inch in outer diameter, was prepared which contained a mixture of 30% nitromannite, 35% barium peroxide, and 35% aluminum powder (admixed coarse and atomized). The cord was tested with various propellants (smokeless powder, a nitroguanidine-based propellant, and black powder) and ignited all the propellent powders, essentially simultaneous ignition of the entire surface of each propellant occurring. Its velocity of detonation was 4000 meters per second.

EXAMPLE 10

A number of cords were prepared which contained various mixtures of high explosive, oxidant, and fuel. The performance of these cords is summarized in the following table.

Table

Cord	O.D. (in.)	Composition (parts)			Distribution of Mixture (gr./ft.)	Velocity of Detonation (m./sec.)
		Explosive	Oxidant	Fuel		
A	0.065	PETN, 60	BaO_2, 20	{Mg, 10 / Te, 10}	3.8	5,200
B	0.080	PETN[1], 40	BaO_2, 30	Mg, 30	4.1	4,200
C	0.090	PETN[1], 40	$KclO_4$, 40	B, 20	5.0	3,700
D	0.080	PETN[1], 40	BaO_2, 45	B, 15	4.63	3,800
E	0.090	PETN[1], 30	BaO_2, 20	{Al[2], 10 / Ti, 40}	7.00	3,200
F	0.090	PETN[1], 30	BaO_2, 35	Zr, 35	9.96	4,500
G	0.090	PETN[1], 30	$LiClO_4$, 35	Al[3], 35	6.66	4,300
H	0.090	PETN[1], 30	BaO_2, 35	{Al[2], 10 / Fe, 25}	8.77	4,400
J	0.090	PETN[1], 30	BaO_2, 35	{Al[2], 10 / Zr, 25}	9.24	4,700
K	0.090	RDX[1], 30	BaO_2, 35	Al[3], 35	8.57	3,000
L	0.065	PETN, 75	Pb_3O_4, 22	B, 3	3.35	6,200
M	0.090	PETN[1], 30	$LiClO_4$, 35	Si, 35	6.54	4,200
N	0.090	PETN[1], 30	$LiClO_4$, 35	Zn, 35	7.77	4,700
O	0.090	PETN[1], 30	KNO_3, 30	Mg, 35	5.63	3,500

[1] Very fine.
[2] Atomized.
[3] Admixed coarse and atomized.

Upon testing, all the cords ignited propellent compositions satisfactorily. Cords A–E were tested with a double-base propellent powder, cords F–H with a single-base powder, cords J and K with a nitroguanidine-based propellant, and cords L–O with black powder.

As may be seen by reference to the foregoing examples, the ignition-propagation cord of the present invention gives excellent results with respect not only to its igniting ability but also to the velocity at which the ignition stimulus is transmitted. As has been illustrated, the desired velocity, i.e. 2000 or more meters per second, is obtained when the cord contains at least 1 grain of high explosive per foot of length. By varying the composition and distribution of the mixture of high explosive, oxidant, and fuel within the metal sheath not only the velocity of transmittal of the ignition stimulus but also its igniting ability can be controlled. When the cord contains at least one grain of high explosive per foot of length, the distribution of the mixture can be varied from 2 to 20 grains per foot without deleterious effects upon either the velocity or igniting ability of the cord. The use of less than 2 grains of the mixture per foot of the cord is not feasible because the energy of cords containing the mixture at such low distribution is insufficient, whereas the use of distributions greater than 20 grains per foot results in undesirable violence, i.e. shattering action and noise, of the cord.

The proportions of the components of the mixture also can be varied within wide ranges without deleterious effects. The high explosive component should comprise 15–80% of the mixture, the oxidant being present in the amount of 10–82% of the mixture and the fuel in the amount of 3–75%.

By proper selection of the proportions of these components, a wide variety of propellent powders can be ignited by the cord at various velocities. For example, when ignition at a high velocity of an easily ignited propellent is required, a cord containing a high percentage of high explosive and low percentages of fuel and oxidant is used. For more difficulty ignited propellants, a cord containing a higher proportion of oxidant and fuel and a correspondingly decreased amount of high explosive is used. Since at a given distribution of the mixture within the cord, the lower the high explosive content is, the lower the velocity of transmission of the ignition stimulus, cords containing the lower proportions of high explosive will transmit the ignition stimulus at lower velocities. Of course, by increasing the distribution of the mixture, or the total quantity of mixture per unit length, the velocity will be increased.

The use of PETN and "nitromannite," organic nitrates, and RDX, a nitramine, which are representative crystalline high-explosive compounds, as this component of the mixture has been exemplified. However, the specific high-explosive compound used is not critical to the present invention, and many other crystalline high explosives are suitable, for example, other nitramines such as cyclotetramethylenetetranitramine (HMX), ethylenedinitramine, and tetryl, other solid organic nitrates, azides such as lead azide, and nitro compounds such as TNT. Mixtures of these high explosives also are suitable. In certain cases, the use of high-explosive compounds of very fine granulation is advantageous, whereas in other cases the standard grades, for example cap-grade PETN, are suitable. The crystalline high explosives applicable to the present ignition-propagation cord are all cap-sensitive.

As the fuel component of the mixture, various metal powders including aluminum, magnesium, iron, zinc, boron, titanium, and zirconium, as well as non-metallic powders including tellurium and silicon, and mixtures thereof have been exemplified. These materials, of course, are merely representative of the numerous materials suitable for use as the fuel in the cord of the present invention. Other fuels which may be used include selenium, lead, manganese, nickel, and copper, among others, and also alloys such as ferrosilicon. A wide variety of oxidants also may be used in addition to the barium peroxide, red lead (Pb_3O_4), potassium perchlorate and nitrate, lithium perchlorate, and tellurium described in the examples, the last oxidant being capable of acting either as the oxidant or fuel depending upon the nature of the other components of the mixture. Additional oxidants which may be used are: sodium perchlorate, barium nitrate, ferric oxide, cupric oxide, potassium permanganate, lithium peroxide, etc. As in the case of the high-explosive component of the mixture, in certain instances the use of very finely powdered fuels, e.g. atomized aluminum, is preferable. By the terms "fuel" and "oxidant," as used in the specification and claim, is meant the reducing agent and oxidizing agent, respectively, involved in a redox reaction.

The easiest and simplest method of forming the ignition-propagation cords is the "drawing-out" method described in the first example, i.e. the loading of a relatively heavy-walled open-ended tube with a quantity of the mixture and the drawing out of the tube until substantially the desired distribution of the mixture is obtained. For ease of preparation of the cords, the metal sheath preferably is of a ductile metal, such as lead or a lead alloy, tin, copper, or aluminum, which metals facilitate the drawing-out step of the procedure. Of course, the

ductile metal selected should be nonreactive with the high explosive component.

The critical feature of the present invention is the provision of a continuous column of a mixture of high explosive, oxidant, and fuel confined within a metal sheath at a distribution of at least 1 grain of high explosive and 2–20 grains of the mixture per foot of length. By such arrangement, the cord itself is made to detonate, yet the entire quantity of explosive material adjacent the cord is made to deflagrate essentially simultaneously, which deflagration is impossible to achieve by means of conventional ignition devices.

Although the present invention has been described in detail in the foregoing, many variations are possible without departure from the scope of the invention. Therefore, I intend to be limited only by the following claim.

I claim:

A combination of an elongated propellant grain having a cavity extending substantially the length of said grain and disposed within and extending essentially the length of said cavity an igniter adapter to effect ignition of the entire exposed surface of said grain in said cavity with extreme rapidity, which igniter comprises a continuous column consisting essentially of a mixture of a crystalline high-explosive compound, an oxidant, and a fuel confined in a metal sheath at a distribution of 2 to 20 grains of said mixture per foot of length of said sheath, said high-explosive compound being present in an amount of about 1 to 16 grains per foot of length of said sheath and comprising 15–80% of said mixture.

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