July 16, 1968 J. P. PICARD 3,392,669

EROSION REDUCER

Filed Jan. 20, 1967

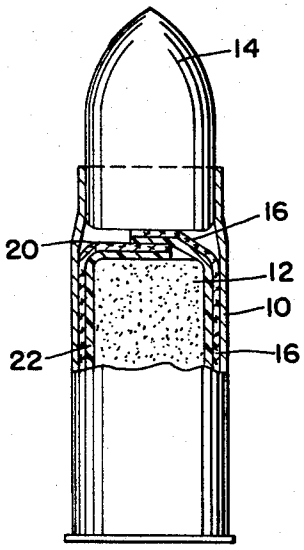


FIG. 1.

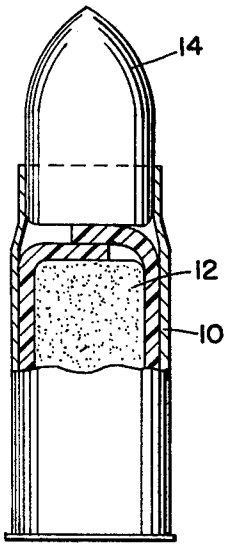


FIG. 3.

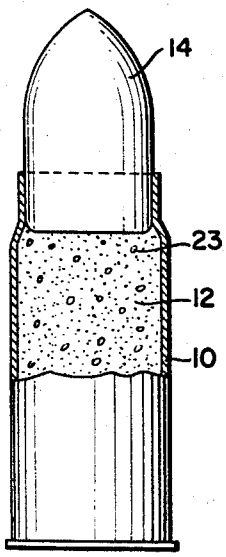


FIG. 4

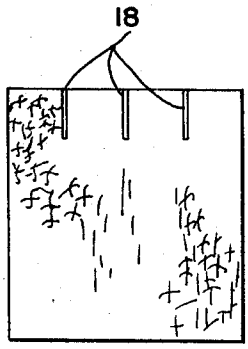


FIG. 2.

INVENTOR.
JEAN P. PICARD
BY Harry M. Saragovitz
Edward J. Kelly, Herbert Berl
& S. Dubroff
ATTORNEYS.

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EROSION REDUCER

Jean P. Picard, Morristown, N.J., assignor to the United States of America as represented by the Secretary of the Army

Continuation-in-part of application Ser. No. 522,796, Jan. 24, 1966. This application Jan. 20, 1967, Ser. No. 610,698

27 Claims. (Cl. 102—38)

ABSTRACT OF THE DISCLOSURE

Inexpensive chemical additives belonging to the silicates family have been discovered to have the inherent ability when added to propellant systems, to reduce wear or erosion of members coming in contact with hot gases resulting from the combustion of the propellants.

This invention is a continuation-in-part of my copending patent application, Ser. No. 522,796, filed Jan. 24, 1966, for "Erosion Reducer" and assigned to the same assignee hereof and which is now converted to streamlined application Ser. No. 676,681.

This invention relates broadly to ordnance items and more particularly concerns inexpensive and readily available chemical additives which are used with propellant systems for reducing wear or erosion in members, such as gun barrels, coming in contact with hot gases formed by ignition of the propellant.

The problem of excessive gun barrel wear has been a most vexing one because of economy and technical considerations. Jacobson et al., U.S. Patent No. 3,148,620, deals with the problem at length. However, the problem has not been adequately solved principally due to needed further gun barrel wear resistance and the generally high cost of additives employed. Etzkorn, German Patent 719,418 discusses the application of lubricating mechanisms to improve gun barrel wear by reducing friction when a bullet moves through a barrel. His device requires the use of cartridge bags having fibers of about 1 to 6 denier, the bag containing the lubricating medium or the lubricant is embodied in the fibers of the bag. Quite obviously, his lubricating device does not lend itself to modern production methods and is altogether too costly when considering the tremendous quantities of cartridges manufactured by or for the Government today.

It is therefore a broad object of this invention to economically reduce the wear or erosion in a member, such as weapon barrel, which is subjected to hot gases formed by ignition of propellant.

Another object of the invention is to provide cartridges with economically and readily available chemical additives which produce a laminar cooling layer on surfaces of members to be protected against wear, said additives being most efficient in reducing gun barrel wear, and smoke and flash upon ignition of propellant within the cartridge.

Further objects and advantages will become apparent to those skilled in this art from the appended claims and following description of the invention and exemplifications thereof, made in conjunction with the accompanying drawings showing exemplary embodiments and wherein:

FIG. 1 is a front elevation view, partly broken away, of a cartridge embodying an additive of the present invention;

FIG. 2 is a view of an unfolded sheet utilized in the cartridge of FIG. 1; and

FIGS. 3 and 4 are modified cartridges of FIG. 1.

Briefly, the present invention is based on my discovery that by incorporating certain inorganic additives (with cellulosic fibers if additional strength is desired, or synthetic polyester fibers of terephthalic acid sold under the trademark Dacron) into a propellant container, such as a cartridge case, for example, that gun barrel erosion can be greatly reduced.

More specifically, I have discovered that inexpensive and readily available additives, such as SiO_2, MgO, or Al_2O_3, individually, or mixed in any proportions, or as SiO_2/MgO and SiO_2/Al_2O_3 occurring in nature as talc, feldspar, and kaolin characterized by the mineral kaolinite, and further characterized by the generic name of silicates and having respectively the following empirical formula

$$3MgO{:}4SiO_2{\cdot}H_2O,\ K_2O{\cdot}Al_2O_3{\cdot}6SiO_2,\ \text{and}\ Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O$$

if contained within a cartridge case or propellant container, when incorporated within a suitable carrier as a hydrocarbon or plastic composition or within the propellants and placed inside the cartridge case or propellant container, that gun barrel erosion is remarkably reduced as well as smoke and flash when the cartridge case is fired. If a mixture of the oxides is used, I have found that excellent results are obtained when the oxides have the following ranges:

	Wt. percent
SiO_2	45–65
MgO	20–55
SiO_2	35–79
Al_2O_3	20–50

The oxides are preferably of fine particle size ranging between about 1 to 60 microns and it is not necessary that the oxides be free from ordinary impurities carried therewith. If the natural occurring minerals, talc, feldspar, kaolin or kaolinite are used, they may constitute the entire additive.

The oxides, individually or mixed, or talc, will be used in quantities varying between about 1 to 5 weight percent of the propellant charge, depending upon the operating pressure of the weapon involved and the type propellant being employed. The cellulose or Dacron fibers, when used, will constitute about 1 to 2% of the weight of the SiO_2, MgO, or Al_2O_3, or a mixture thereof, or talc, feldspar, kaolin and kaolinite.

My additives may be dispersed in a carbonaceous carrier material such as paraffin or microcrystalline waxes and other hydrocarbons melting between about 70 to 400° F., or the additives may be incorporated within a suitable matrix such as plastic foam synthetic fibers, and the like. Very satisfactory results have been obtained with polyurethane foams and paraffin waxes, the latter having a preferred melting point between about 120 to 250° F. Optionally, the additives of the invention may be used advantageously without any carrier material by blending with the propellants as will be described in detail hereinafter.

When a carrier is employed, my inventive sheet will comprise the chemical additive or additives dispersed in a carrier wax which will be impregnated in a textile adjacent the front part of the charge. Determination of minimum sheet thickness can be readily computed from the formula set forth in the patent to Jacobson et al. supra:

$$10\sqrt{C}\ \text{mg./cm./}^2$$

where C is the calibre of the firearm or weapon in cms.; and cm.^{2} refers to the area of the sheet. By sheet, I refer

to my additives, incorporated or dispersed, whether generally homogeneously or not within a wax carrier, including the textile or fabric upon which it is coated or impregnated. When polyurethane foams are employed as the "textile," my additive will be incorporated therewithin to comprise the sheet.

The formula given above may be expressed more generally so that it applies to all substances as follows:

$30\sqrt{U}$ gram calories per sq. cm. of sheet surface—that is the substance is such that in reacting with the propellant gases it absorbs $30\sqrt{U}$ gram calories per sq. cm. of the sheet surface.

One embodiment of my invention is illustrated in FIG. 1 wherein a cartridge is shown having a metal case **10**, propellant charge **12** comprised of a suitable propellant to be hereinafter described and a projectile **14**. Within case **10** and in contact with the inner surface thereof is a textile wrap **16** which may be of any suitable material such as rayon (preferred), cotton, silk, and the like. The upper section of wrap **16** has a plurality of vertical slits **18** (FIG. 2) through part of its length which form flaps **20** as shown in FIG. 1.

Textile **16** is coated, or coated and impregnated with an additive layer 22 composed of powdered SiO_2, powdered MgO, powdered Al_2O_3 or powdered mixtures thereof, or feldspar, kaolin and kaolinite. Flaps **20** and the additive layer coating **22** are adapted to be folded in overlapping manner over the upper surface of propellant charge **12**.

The additive coating is prepared by melting the wax and thereafter mixing with my powdered additive in proportions hereinafter described. Thereafter, the coating is applied to the fabric in the desired thickness and permitted to cool and thus forming my sheet.

When a cartridge is prepared without a carrier material in accordance with my invention, the SiO_2, MgO, or Al_2O_3, individually, or in combination, as talc, feldspar, kaolin or kaolinite, may be admixed or incorporated directly within propellant **12** or coated directly onto the outer surfaces thereof, the chemical additives in either case comprising about 1 to 5 percent by weight of the propellant charge. Optionally, my additives may be enclosed or contained in small plastic capsules **23**, as shown in FIGURE 4, of cellulose acetate, for example, and dispersed throughout the propellant or the additives may be simply dropped into a cartridge case or propellant container prior to its loading, the additives again comprising about 1 to 5 percent by weight of the propellant charge. Obviously, if no carrier is used, the necessity of employing a fabric or plastic foam is completely obviated.

Coated fabric **16** which is preferably one-half to five-sixths the length of the charge, may be wrapped around the propellant **12** or it may be held in position in the cartridge as the propellant material is poured in. If desired, fabric **16** may be secured to the inner wall of the case by glue or other suitable means so as to retain the coated fabric in position. Thereafter flaps **20** are folded over and projectile **14** is placed on top of the flaps as shown in FIG. 1. It will be understood that the invention is equally applicable to cartridges other than as illustrated. For example, artillery ammunition of the fixed, semifixed, separated, or separate-loading and high-pressure weapon types may be used advantageously with the additives described.

In the modified cartridge of FIG. 3, a sponge-like polyurethane foam **24**, impregnated with the additives of my invention, replaces the textile **16** and layer **22** of the cartridge of FIG. 1 and will similarly be provided with slits at its upper portion to facilitate its folding in an overlapping manner over the upper surface of propellant charge **12**. If desired, the impregnated polyurethane foam material may be glued, for example, to the inner wall of the case in a manner similar to the textile sheet.

In preliminary testing of the effectiveness of my inexpensive and readily available additives, laboratory apparatus was used which comprises a modified closed bomb simulating gun firing. The effectiveness of my additives was evaluated by measuring loss in weight of perforated steel cylinders employed to vent the combustion products produced by the burning propellant and around a selected portion of which was placed my sheet or impregnated polyurethane foam, or my additives were added or admixed into the propellant directly as aforedescribed. My additives work with equal effectiveness in cartridges and shells ranging from 22 calibre small arms ammunition to 205 ammunition. The amount and thickness of my additive sheet or impregnated polyurethane foam when a carrier is used, will depend on the size of the cartridge or shell as aforedescribed. For example, the textile **16** for a 105 mm. high explosive anti-tank shell was a piece of rayon woven from spun viscose rayon yarn containing a durable water repellant of melamine resin base and weighed between 2.80 and 3.20 ounces per square yard. The rayon was placed on a smooth surface and my additives poured thereon and spread evenly by scraping with a blade and resulted in a sheet slightly under $\frac{1}{16}$ inch in thickness. Determination of minimum sheet thickness can be readily computed for any calibre weapon from the formula aforementioned. In the case of impregnated polyurethane foams, the identical formula for calculating sheet thickness will be used.

The propellants used in determining the effectiveness of my additive are described in Table I below:

TABLE I.—PROPELLANT COMPOSITIONS AND PROPERTIES THEREOF

Propellant	M2	M9	M30
Composition:			
Nitrocellulose	77.45	57.75	28.00
(Percent N in nitrocellulose)	(13.25)	(13.25)	(12.6)
Nitroglycerine	19.50	40.00	22.50
Nitroguanidine			47.70
Potassium Nitrate	0.75	1.50	
Barium Nitrate	1.40		
Ethyl Centralite	0.60	0.75	1.50
Cryolite			0.30
Graphite	0.30		
Graphite (glaze)			0.10
Ethyl Alcohol (residual)	2.30	0.50	0.30
Water (residual)	0.70	0.00	0.00
Thermochemical Properties:			
Isochoric Flame Temp., ° K	3,319	3,799	3,040
Force, ft.-lbs./lb	360,000	382,000	364,000
Unoxidized Carbon, percent	Zero	Zero	3.2
Combustibles (H_2+CO), percent	47.2	32.8	41.0
Heat of Explosion, cal./gm	1,080	1,295	974
Gas Volume, moles/gm	0.03900	0.03618	0.4308

To show the superiority of my additives over other known additives, an erosion study was conducted using M2 propellant wherein the fabric material was a spun viscose rayon yarn covered with wax containing the additives as aforedescribed and the polyurethane foam had a density of 22 pounds per cubic foot although foams ranging between about 10 to 30 pounds per cubic foot have been found to work very satisfactorily.

TABLE II.—EROSION STUDY

Propellant type, M2.
Propellant charge, 35 grams.
Pressure range, 15,000 to 16,000 p.s.i.

Additive	Weight of Additive, grams	Erosion per shot expressed in mg. loss in weight per shot
Propellant (alone)		24.1
Paraffin wax (m.p., 180° F.)	2.2	2.8
Feldspar (alone)	2.0	0.8
Kaolin (alone)	2.0	0.6
Kaolinite (alone)	2.0	0.5
45 Pts. Feldspar/55 Pts. wax	4.0	0.7
45 Pts. Feldspar/55 Pts. of polyurethane foam	4.0	0.8
45 Pts. Al_2O_3/55 Pts. wax	4.0	0.8
45 Pts. SiO_2/55 Pts. wax	4.0	0.2
45 Pts. TiO_2/55 Pts. wax	4.0	0.8
45 Pts. 55/45 SiO_2/Al_2O_3/55 Pts. wax	4.0	0.7
22 Pts. 55/45 SiO_2/Al_2O_3/78 Pts. polyurethane foam	4.0	1.5
45 Pts. 75/25 SiO_2/Al_2O_3/55 Pts. of wax	4.0	1.2

In all cases, the oxides used were of a particle size of about 1 to 60 microns and the wax had a melting point of about 180° F., unless otherwise indicated.

The chemical compositions of the aforementioned feldspar, kaolin and kaolinite are presented in Table III, IV and V below:

TABLE III.—TYPICAL CHEMICAL COMPOSITIONS OF FELDSPAR USED

Ingredients	Samples (percent)		
	(1)	(2)	(3)
Silica, SiO_2	67.15	67.4	65.2
Aluminum Oxide, Al_2O_3	19.31	20.0	19.7
Ferric Oxide, Fe_2O_3	.05	0.27	0.15
Calcium Oxide, CaO	.80	0.5	0.30
Magnesium Oxide, MgO	Trace	Trace	Trace
Potash, K_2O	5.44	1.04	12.19
Soda, Na_2O	6.70	10.03	1.25
Loss on Ignition, H_2O	.34	0.50	1.18
Particle size in micron	1-60	1-60	1-60

TABLE IV.—TYPICAL CHEMICAL COMPOSITIONS OF KAOLIN USED

Ingredients	Samples (percent)		
	(1)	(2)	(3)
Silica, SiO_2	45.46	47.02	46.57
Aluminum Oxide, Al_2O_3	38.05	37.87	37.09
Ferric Oxide, Fe_2O_3	0.59	0.80	0.65
Calcium Oxide, CaO	0.17	0.08	0.25
Magnesium Oxide, MgO	0.20	0.16	0.24
Potash, K_2O	0.14	0.24	0.30
Soda, Na_2O	0.27	0.20	0.11
Titanium Oxide, TiO_2	1.32	0.21	1.29
Loss on Ignition, H_2O	13.82	13.49	13.54
Particle size in micron	1-60	1-60	1-60

TABLE V.—TYPICAL CHEMICAL COMPOSITIONS OF KAOLINITE USED

Ingredients	Samples (percent)		
	(1)	(2)	(3)
Silica, SiO_2	46.77	44.81	54.32
Aluminum Oxide, Al_2O_3	37.79	37.82	29.96
Ferric Oxide, Fe_2O_3	0.45	0.92	2.00
Ferrous Oxide, FeO	0.11	----	----
Magnesium Oxide, MgO	0.24	0.35	0.14
Calcium Oxide, CaO	0.13	0.43	0.32
Potash, K_2O	1.49	----	----
Soda, Na_2O	0.05	----	0.37
Titanium Oxide, TiO_2	----	0.37	----
Loss on Ignition, H_2O	12.95	14.27	11.80
Particle size in micron	1-60	1-60	1-60

When M9 propellant was used, the following results were obtained:

TABLE VI.—EROSION STUDY

Propellant Type, M9, Flake (3 mils).
Propellant Charge, 42 grams.
Pressure Range, 50,000 to 55,000 p.s.i.

Additive	Weight of Additive, grams	Erosion per shot expressed in mg loss in weight per shot
Propellant (alone)	----	150.0
Paraffin wax (M.P., 180° F.)	2.25	2.8
SiO_2 (alone)	2.25	49.1
Al_2O_3 (alone)	2.25	60.2
TiO_2 (alone)	2.25	72.0
45 Pts. SiO_2/55 Pts. wax	4.50	2.2
45 Pts. Al_2O_3/55 Pts. wax	4.50	5.2
45 Pts. TiO_2/55 Pts. wax	4.50	14.8
45 Pts. 55/45 SiO_2/Al_2O_3 Pts. of wax	4.50	4.7
22 Pts. 55/45 SiO_2/Al_2O_3/78 Pts. of polyurethane	4.50	6.2
45 Pts. 75/25 SiO_2/Al_2O_3/55 Pts. of wax	4.50	5.1
45 Pts. Feldspar/55 Pts. of polyurethane	4.50	6.2
45 Pts. of Kaolin/55 Pts. of wax	4.50	3.2
45 Pts. of Kaolinite/55 Pts. of wax	4.50	2.3
45 Pts. of Talc/55 Pts. of wax	4.50	1.2

In all cases above, the oxides or feldspar, kaolin, and kaolinite were of the order of about 1 to 60 microns particle size.

It is also within the embodiment of my invention to add the additives by admixture or blending within the propellant charge. To demonstrate the superiority of my additives over other known additives, comparative erosion tests were conducted using propellant compositions, fabricated by either extrusion or ball-powder technique and having a wide range of composition, flame temperature, force and heat of explosion. When the amount of additives used ranged between 1 to 5%, they were found to be equally effective when admixed with the propellants as when applied as a layer around the propellant as shown in Table VII. In all cases, the oxides used, such as talc, feldspar, kaolin and kaolinite were of particle size of about 1 to 60 microns.

TABLE VII.—COMPARATIVE EROSION STUDIES

Propellant Composition	Additive Added, Percent	Coating Added, Percent	Heat of Explosion, cal./gm.	Erosion (5 Shots), mg.	Relative			
					Force		Quickness	
					70° F.	−65° F.	70° F.	−65° F.
IMR 8138M (see Infra)	----	3.5	896	8.0	100	100	100	100
IMR 8138M TiO_2	2.1	2.8	908	1.7	98.6	97.5	112.7	112.3
IMR 8138M AlF_3	2.2	3.1	902	3.7	97.4	98.2	108.3	108.0
IMR 8138M Talc (Montana)	2.5	3.2	898	0.8	97.5	97.9	110.4	110.6
Ball Powder (see Infra)	----	1.0	871	6.3	100	100	100	100
Ball Powder Talc (New York)	2.0	1.0	867	0.8	97.5	97.9	98.2	99.0
CR 7814 (see Infra)	----	1.9	879	9.8	100	100	100	100
CR 7814 TiO_2	2.0	4.0	781	2.0	95.6	96.0	84.0	84.0
CR 7814 Talc (California)	2.1	3.7	808	1.2	94.4	94.2	89.5	84.5
CR 7814 Feldspar	3.5	3.5	800	3.0	92.4	91.2	88.1	85.0
CR 7814 Kaolinite	2.5	3.2	805	1.3	93.5	93.2	89.0	84.2
M2 (see Infra)	----	----	1,090	67.1	100	100	100	100
M2 TiO_2	3.6	----	1,042	8.8	91.9	94.7	84.0	84.0
M2 Talc (New York)	3.5	----	1,042	1.8	91.9	93.3	87.4	89.8
M2 Feldspar	3.5	----	1,042	3.2	91.9	93.4	36.2	88.9
M2 Kaolinite	3.0	----	1,050	2.1	92.0	94.1	85.9	87.8
M26E1 (see Infra)	----	----	977	12.4	100	100	100	100
M26E1 TiO_2	2.0	----	970	6.5	95.2	94.1	87.3	87.2
M26E1 Talc (California)	2.0	----	969	2.5	96.5	96.2	89.0	89.2
M26E1 Kaolin	4.0	----	955	6.8	87.1	86.1	85.3	84.1
M26E1 Feldspar	3.0	----	966	8.3	89.0	90.0	86.5	86.1
M26E1 Kaolinite	2.5	----	968	8.9	90.1	91.2	88.2	87.5
M30 (see Infra)	----	----	974	6.7	100	100	100	100
M30 TiO_2	2.0	----	970	5.3	97.1	96.7	96.8	87.2
M30 Talc (Montana)	2.0	----	970	2.9	97.3	96.1	97.0	94.1

Some of the propellant compositions used in determining the effectiveness of my additive are described below and/or in the examples hereinafter presented.

TABLE VIII.—PROPELLANT COMPOSITIONS AND PROPERTIES THEREOF

	Ball powder	IMR 8138M	CR 7814	M2	M26E1
Composition:					
Nitrocellulose (13.15% N), percent	83.8	100	100	77.45	68.7
Nitroglycerine	9.7			19.50	25.0
Potassium Nitrate (added)		1.0	2.0		
Barium Nitrate				1.40	
Potassium Nitrate				0.75	
Dibutylphthalate (added)			2.0		
Diphenylamine (added)		0.7	1.0		
Ethyl Centralite				0.60	6.0
Graphite				0.30	0.3
Methyl Centralite (coating)			4.0		
Ethylene Dimethacrylate (coating)		3.0			
Dibutylphthalate	5.5				
Diphenylamine	1.0				
Additive (added)		3.0	4.0	0.30	2.0
Graphite (glaze)				0.10	0.10
Thermochemical Properties:					
Isochloric Flame Temperature, ° K.	2,834	2,810	2,590	3,320	3,132
Force, ft.-lbs./lb.	335,800	324,800	308,800	360,000	362,000
Heat of Explosion, cal./gm.	871	866	781	1,080	977

Preparation of the products of this invention will be more clearly understood from a consideration of the following specific examples which are given for the purpose of illustration and are not intended to limit the scope of this invention in any way.

Example I

47 grams of kaolinite having a particle size ranging between 3 to 60 microns are stirred into 53 grams of melted paraffin wax having a melting point of 180° F. The resultant mixture was thoroughly mixed while maintaining the temperature at about 100° C. and then poured onto a piece of spun viscose rayon yarn of melamine resin base, the rayon yarn having been placed on a smooth surface. By means of a scraping blade, a uniform thickness of about 1/16 inch of additive wax was obtained. If desired, the melted additive wax mixture can readily be poured in molds of varying configurations.

Example II

22 parts of feldspar having a particle size ranging between about 5–40 microns are stirred into 82 parts of a resin prepolymer consisting of:

	Parts
Polyethylene glycol, low molecular wt.	10.5
Polyethylene glycol, high molecular wt.	6.5
Castor oil	36.48
Tolyl di-isocyanate	46.47
Acetyl chloride	0.05

After thorough mixing of the additive and prepolymer, 9.5 parts of a catalyst consisting of:

	Parts
Polyethylene glycol, low molecular wt.	17.2
Glycerol (2.5% H_2O)	34.5

and 8.5 parts of another catalyst consisting of:

	Parts
Polypropylene glycol nioxdiol	46.2
Dibutyl tin di-2-ethyl hexoate	1.0

are added thereinto and further thoroughly mixed, and then poured into a container, suitably of steel or aluminum, for example, and cured at 210° F. for at least 2 hours. The resultant mass or "bun" of impregnated polyurethane foam is then permitted to cool, removed from the container or mold and sliced into sheets of desired thickness with a band saw for use in cartridge case or, as described under Example I, may be poured into molds while yet in a pourable condition.

Example III

17 pounds of kaolin having an average particle size of 3 microns was mixed with 0.2 pounds of Dacron fiber, 6 to 9 grams denier and about ½ inch long, and then thoroughly stirred into 22 pounds of molten paraffin wax having a melting point of 180° F. The resultant mixture was poured onto a spun viscose rayon cloth of melamine resin base as aforementioned to produce a uniform layer approximately 1/16 inch thick. When inserted in a 105 mm. cartridge in accordance with the invention, the cartridge being loaded with M30 propellant, the erosion on the gun barrel after firing 100 rounds therethrough was 0.004" on the barrel lands and 0.000" on the barrel grooves. When the same test was performed using identical amounts of TiO_2 or $CaSO_4$ and wax having identical particle sizes and melting points, the barrel lands were eroded 0.006" and 0.01" respectively and the barrel grooves 0.000" in both cases. Additionally, the TiO_2-wax additive produced substantially more smoke and flash than any kaolin-wax additive aforedescribed.

Example IV

Propellant formulation IMR 8138M aforedescribed containing various additives such as talc, feldspar, kaolin, kaolinite, mica, and related silicate materials varying from 1 to 5% of propellant composition weight were processed using the ingredients listed below in a manner hereafter described:

	Parts
Nitrocellulose (13.15% N)	100
Potassium sulfate (added)	1
Diphenylamine (added)	0.7
Solvent total	[1] 97

[1] Made of diethyl ether 65 parts and ethanol 35 parts.

To the dehydrated nitrocellulose (alcohol wet), screened through an 8-mesh screen and then placed in a mixer, such as a sigma blade type, for example, was added 2.5 percent by weight of talc and the required quantity of potassium sulfate and the whole mass dry blended for five minutes. Then the solvent containing diphenylamine was added while the mixer was still running. The mixing operation was carried out for one hour with cold water running through the mixer jacket. The propellant composition was then removed from the mixer and stored in a tight container until time for extrusion into desired web sizes. All screen sizes hereinabove and hereinafter referred to were U.S. Standard Sieve type.

Example V

Propellant formulation CR7814 aforedescribed containing various additives such as talc, feldspar, kaolin, kaolinite and related materials belonging to the silicates family in quantities varying from 1 to 5% of propellant

formulation weight were processed in accordance with the following:

	Parts
Nitrocellulose (13.15% N)	100
Potassium sulfate (added)	2
Dibutylphthalate (added)	2
Diphenylamine (added)	1
Solvent total	[1] 95

[1] Made of diethyl ether 65 parts and ethanol 35 parts.

The dehydrated nitrocellulose, alcohol wet, was passed through an 8-mesh screen and thereafter placed in a sigma-blade mixer, and 2.5 percent by weight of kaolinite added thereto and the required quantity of potassium sulfate. The resultant mass was blended for five minutes. To this mass was added very slowly the solvent ether/alcohol containing dibutylphthalate and the dissolved diphenylamine, the mixing being carried out for about one hour. During this time, the mixer was cooled by running cold water through the double-wall jacket. The mixer was then stopped and the propellant composition removed therefrom and stored in a tight container until used for extrusion into shapes and dimensions desired.

Example VI

Propellant formulation M2 aforedescribed containing various additives such as talc, feldspar, kaolin, kaolinite, and the materials in quantities varying from 1 to 5% of propellant weight were prepared by mixing the ingredients hereafter named:

	Parts
Nitrocellulose (13.15% N)	77.45
Nitroglycerine	19.50
Barium nitrate	1.40
Potassium nitrate	0.75
Ethyl centralite	0.60
Graphite	0.30
Total	100.00
Solvent total	[1] 26

[1] Made of 55 parts acetone and 45 parts ethanol.

To the dehydrated (alcohol wet) nitrocellulose, screened through an 8-mesh screen and placed in a sigma-blade mixer was added 3.5 percent by weight of feldspar, or any other like materials and the required quantities of barium and potassium nitrates, the whole mixture being blended for about five minutes. The solution of acetone containing nitroglycerine was then slowly added thereinto while the mixer ran for about five minutes. The graphite and ethyl centralite were added with the rest of the solvent and mixing was continued approximately for two hours at 112°±5° F. The mix was then allowed to cool, removed from the mixer and stored in a tight container to await extrusion into desired grain sizes.

Example VII

Propellant formulation M26E1 aforedescribed containing various additives such as talc, feldspar, kaolin and kaolinite and the like materials in quantities varying from 1 to 5% of the propellant weight were obtained by using the following ingredients and mixed in the manner hereafter described:

	Parts
Nitrocellulose (13.15% N)	68.7
Nitroglycerine	25.0
Ethyl centralite	6.0
Graphite	0.3
Total	100.0
Solvent total	[1] 26

[1] Made of 55 parts acetone and 45 parts ethanol.

To the dehydrated (alcohol wet) nitrocellulose, screened through an 8-mesh screen and placed in a sigma-blade mixer, was added 4% by weight of kaolin or any of the other desired additives and the mixture blended for five minutes. Then the nitroglycerine-acetone solution was added to the mixer while running for about five minutes. Then the graphite and some ethanol was added and mixed for twenty minutes. The ethyl centralite (alcohol wet) was then added and the whole mixing operation was carried out at 112°±5° F. for two hours. The propellant composition obtained was allowed to cool and then removed from the mixer and stored in a tight container awaiting extrusion into desired grain dimensions.

Example VIII

Propellant formulation M30 aforedescribed containing various additives such as talc, feldspar, kaolin, kaolinite, and like materials of the silicates family in quantities varying from 1 to 5% of the propellant weight, were manufactured according to the procedure hereafter described:

	Parts
Nitrocellulose (12.6% N)	28.0
Nitroglycerin	22.5
Nitroguanidine	47.7
Ethyl centralite	1.5
Cryolite	0.3
Total	100.0
Solvent total	[1] 20

[1] Made of 60 parts ethanol and 40 parts acetone.

To the dehydrated nitrocellulose screened through an 8-mesh screen placed in a sigma-blade blender was added 2% of talc by weight and one-half of the quantity of nitroguanidine. These ingredients were blended for five minutes. Then the nitroglycerine desensitized by solution acetone was added to the blender while runing and permitted to continue mixing for five minutes. The remainder of the nitroguanidine and the cryolite were added and mixed for twenty additional minutes. Finally, alcohol-wet ethyl centralite and the remainder of the solvent were added. The mixing operation was carried out between 105°–115° F. for a total of three hours. The propellant composition was then allowed to cool, removed from the mixer and stored in a tight container until extrusion time. The material was then extruded in the desired shapes and dimensions.

Example IX

The aforedescribed ball-powder containing additives such as talc, feldspar, kaolin and kaolinite in quantities from 1 to 5% were formulated according to the composition hereafter given:

	Parts
Nitrocellulose (13.15% N)	83.8
Nitroglycerin	9.7
Dibutylphthalate	5.5
Diphenylamine	1.0
Total	100.0

The nitrocellulose, either as ground reclaimed propellants or fibers, was slurried into 250 parts of water and heated with agitation at about 69° C. To this slurry under agitation was added 250 parts of ethyl acetate containing the diphenylamine. To this slurry was added, by dusting into the mixer, two parts of talc. To the talc slurry was added with continuous agitation 0.25 parts of dispersing agent, preferably collagen, gelatine-like animal glue although not limited thereto, previously dissolved in 250 parts of water. Then 350 parts of a 10% aqueous solution sodium sulfate was added thereto and agitation continued for one hour. The ethyl acetate was then removed by distillation and the resulting ball powder then screened, washed and reslurried in water. To this was added the nitroglycerine with continued agitation for five to six hours at 69° C.

The above operation was followed by the addition of the dibutylphthalate dispersed in 150 parts of water as

deterrent coating. The ball powder composition was then removed by decantation, cooled, rolled, dried, glazed and stored into adequate containers.

The cost of my additives, i.e., SiO_2, MgO, Al_2O_3 or feldspar, kaolin and kaolinite does not exceed about 5 cents a pound and is considerably more inexpensive than other prior art additives.

Although my impregnated polyurethane foam materials are not as effective as the kaolin-wax, feldspar-wax, and SiO_2/Al_2O_3-wax sheet, it is believed that the results obtained still indicate its high degree of satisfactoriness in reducing gun barrel erosion.

It is apparent from the foregoing description that I have provided additives for use in propellant systems wherein members coming in contact with hot gases produced by ignition of the propellant are protected against wear and erosion by the formation of cooler layers of gas adjacent the member. Plastic and fiberglass members as well as fiberglass-metal members also benefit from the additives of the invention. My additives are characterized by inexpensiveness and their high adsorptivity for hydrocarbons and certain organic compounds which lend themselves admirably for admixing into waxes and polyurethanes. My additives are further characterized by their complete compatibility with propellant ingredients and their ability to be admixed directly into the propellants in those instances where the size of the cartridge cases makes it impractical to use it in a wax layer around the propellants. Further, the stability and ballistic performance of weapons employing my additives are not at all adversely affected and they perform equally well when placed around the propellant charge or admixed within the propellant compositions.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

Reference is hereby made to patent application Ser. No. 523,015, of Daniel Katz, for "Wear Reduction Additives," filed Jan. 24, 1966, now Patent No. 3,362,328, assigned to the same assignee of this patent application.

I claim:

1. In a propellant system for providing thrust whereby hot gases are produced upon ignition of propellant and including means for containing said propellant, the combination therewith of the improvement for reducing erosion of members coming in contact with said hot gases, said improvement comprising an additive selected from the group consisting of feldspar, kaolin, and kaolinite incorporated within said containing means, said additive comprising 1 to 5 weight percent of said propellant.

2. The system of claim **1** further characterized by said additive being admixed with said propellant.

3. The system of claim **1** further characterized by said additive being coated on exterior surfaces of said propellant.

4. The system of claim **1** further characterized by said additive being disposed adjacent a base end portion of said containing means.

5. The system of claim **1** further characterized by said additive being incorporated within said propellant.

6. In a system having a projectile associated with a cartridge having a propellant and means for containing said propellant, the combination therewith of the improvement for reducing erosion of members coming in contact with hot gases produced upon ignition of said propellant, said improvement comprising an additive within said containing means selected from the group consisting of feldspar, kaolin and kaolinite, and mixtures of the foregoing.

7. A cartridge as described in claim **6** wherein said additive comprises about 1 to 5 weight percent of the propellant, said additive being admixed with said propellant.

8. A cartridge as described in claim **6** wherein said additive comprises about 1 to 5 weight percent of the propellant, said additive being coated on exterior surfaces of said propellant.

9. A cartridge as described in claim **6** wherein said additive comprises about 1 to 5 weight percent of the propellant, said additive being disposed on a bottom portion of said cartridge case.

10. A cartridge as described in claim **6** wherein said additive comprises about 1 to 5 weight percent of the propellant, said additive being incorporated within the propellant.

11. In a system having a projectile associated with a cartridge having a propellant charge and means for containing said propellant charge, the combination therewith of the improvement for reducing erosion of members coming in contact with hot gases produced upon ignition of said propellant charge, said improvement comprising a sheet surrounding at least an upper half of said propellant, said sheet comprising a pervious material impregnated with a chemical additive selected from the group consisting of feldspar, kaolin and kaolinite, and mixtures of the foregoing.

12. In a system having a projectile associated with a cartridge having a propellant charge and means for containing said propellant charge, the combination therewith of the improvement for reducing erosion of members coming in contact with hot gases produced upon ignition of said propellant charge, said improvement comprising a sheet of a pervious textile fabric impregnated with a dispersion of a carrier and a material selected from the group consisting of feldspar, kaolin, and kaolinite, and mixtures of the foregoing.

13. The cartridge of claim **12** wherein said carrier is hydrocarbon.

14. The cartridge of claim **13** wherein said hydrocarbon is characterized by a melting point between about 70–400° F.

15. The cartridge of claim **12** where said carrier is paraffin wax.

16. The cartridge of claim **12** further characterized by said material consisting essentially of feldspar.

17. The cartridge of claim **12** further characterized by said material consisting of kaolin.

18. The cartridge of claim **12** further characterized by said material consisting essentially or kaolinite.

19. The cartridge of claim **12** further characterized by said material having a particle size range of about 1 to 60 microns.

20. In a system having a projectile associated with a cartridge having a propellant charge and means for containing said propellant charge, the combination therewith of the improvement for reducing erosion of members coming in contact with hot gases produced upon ignition of said propellant charge, said improvement comprising a sheet of a pervious textile fabric impregnated with a dispersion of a carrier and a material selected from the group consisting of Al_2O_3, a mixture of SiO_2 and Al_2O_3, feldspar, kaolin and kaolinite, and mixtures of the foregoing, wherein cellulose fibers are incorporated within said dispersion.

21. The cartridge of claim **20** further characterized by said cellulose fibers constituting about 1 to 2 weight percent of said material.

22. The cartridge of claim **20** further characterized by said cellulose fibers being about 6 to 9 grams denier and about ½ inch long.

23. In a system having a projectile associated with a cartridge having a propellent charge and means for containing said propellant charge, the combination therewith of the improvement for reducing erosion of members coming in contact with hot gases produced upon ignition of said propellant charge, said improvement comprising a sheet of a pervious textile fabric impregnated with a dispersion of a carrier and a material selected from the group consisting of Al_2O_3, a mixture of SiO_2 and Al_2O_3,

feldspar, kaolin and kaolinite, and mixtures of the foregoing, and wherein synthetic polyester fibers of terephthalic acid are incorporated within said dispersion.

24. The cartridge of claim **23** further characterized by said synthetic polyester fibers of terephthalic acid constituting about 1 to 2 weight percent of said material.

25. The cartridge of claim **23** further characterized by said synthetic polyester fibers of terephthalic acid being about 6 to 9 grams denier and about ½ inch long.

26. In a propellant system for providing thrust whereby hot gases are produced upon ignition of propellant and including means for containing said propellant, the combination therewith of the improvement for reducing erosion of members coming in contact with said hot gases, said improvement comprising an additive selected from the group consisting of Al_2O_3, a combination of SiO_2 and Al_2O_3, feldspar, kaolin, and kaolinite incorporated within said containing means, said additive comprising 1 to 5 weight percent of the weight of said propellant, said additive being encapsulated in plastic and dispersed throughout said propellant.

27. In a system having a projectile associated with a

cartridge having a propellant and means for containing said propellant, the combination therewith of the improvement for reducing erosion of members coming in contact with hot gases produced upon ignition of said propellant, said improvement comprising an additive within said containing means selected from the group consisting of Al_2O_3, a combination of SiO_2 and Al_2O_3, feldspar, kaolin and kaolinite, and mixtures of the foregoing, said additive comprising about 1 to 5 weight percent of the propellant, said additive being encapsulated in plastic and dispersed throughout said propellant.

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ROBERT F. STAHL, *Primary Examiner.*

BENJAMIN A, BORCHELT, *Examiner.*