

Oct. 1, 1968

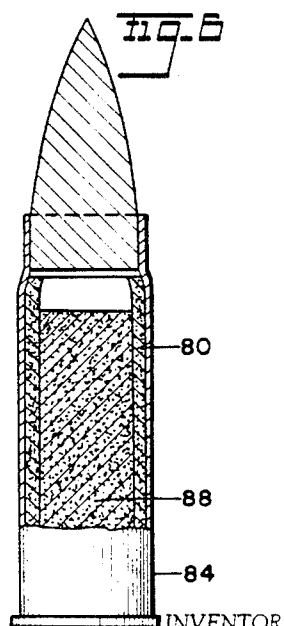
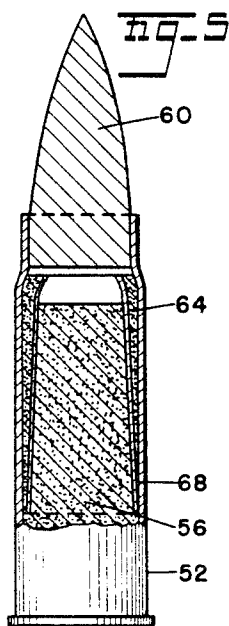
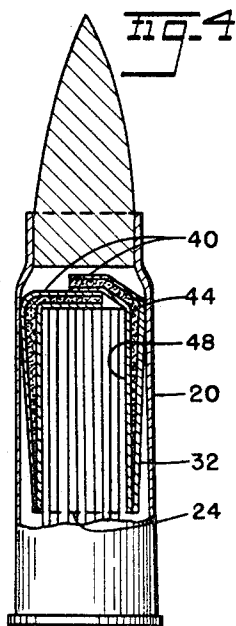
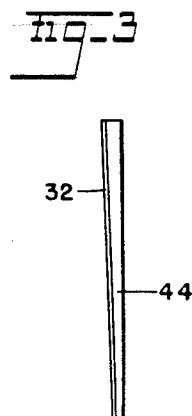
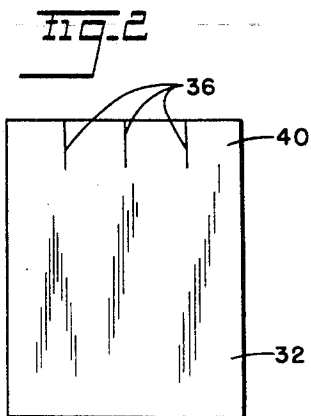
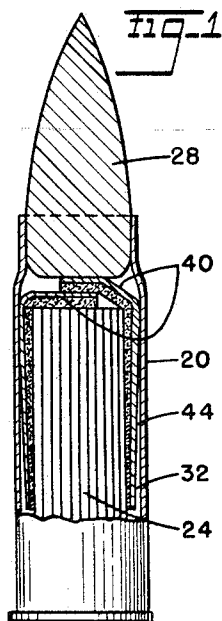
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3,403,625

WEAR REDUCTION ADDITIVES

Original Filed June 23, 1964

3 Sheets-Sheet 1



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WEAR REDUCTION ADDITIVES

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3 Sheets-Sheet 2

Fig. 7

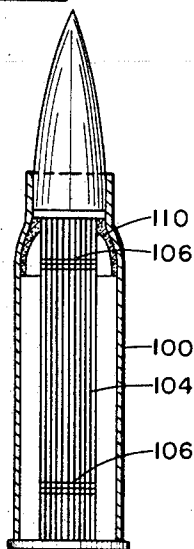


Fig. 8

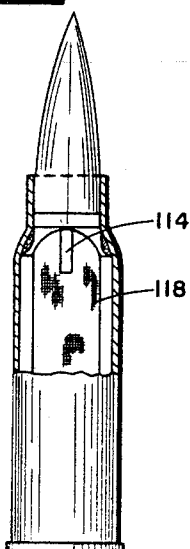


Fig. 9

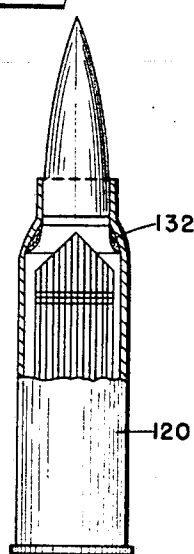


Fig. 10

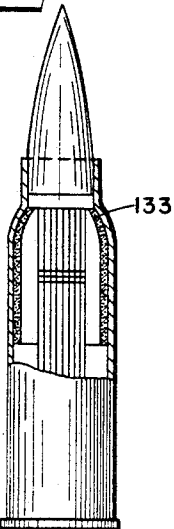


Fig. 11

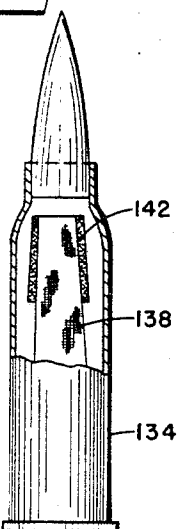
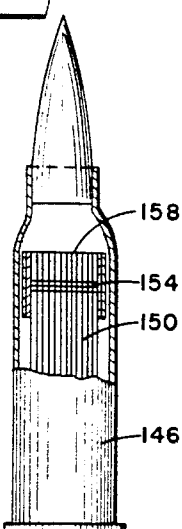


Fig. 12



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WEAR REDUCTION ADDITIVES

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3 Sheets-Sheet 3

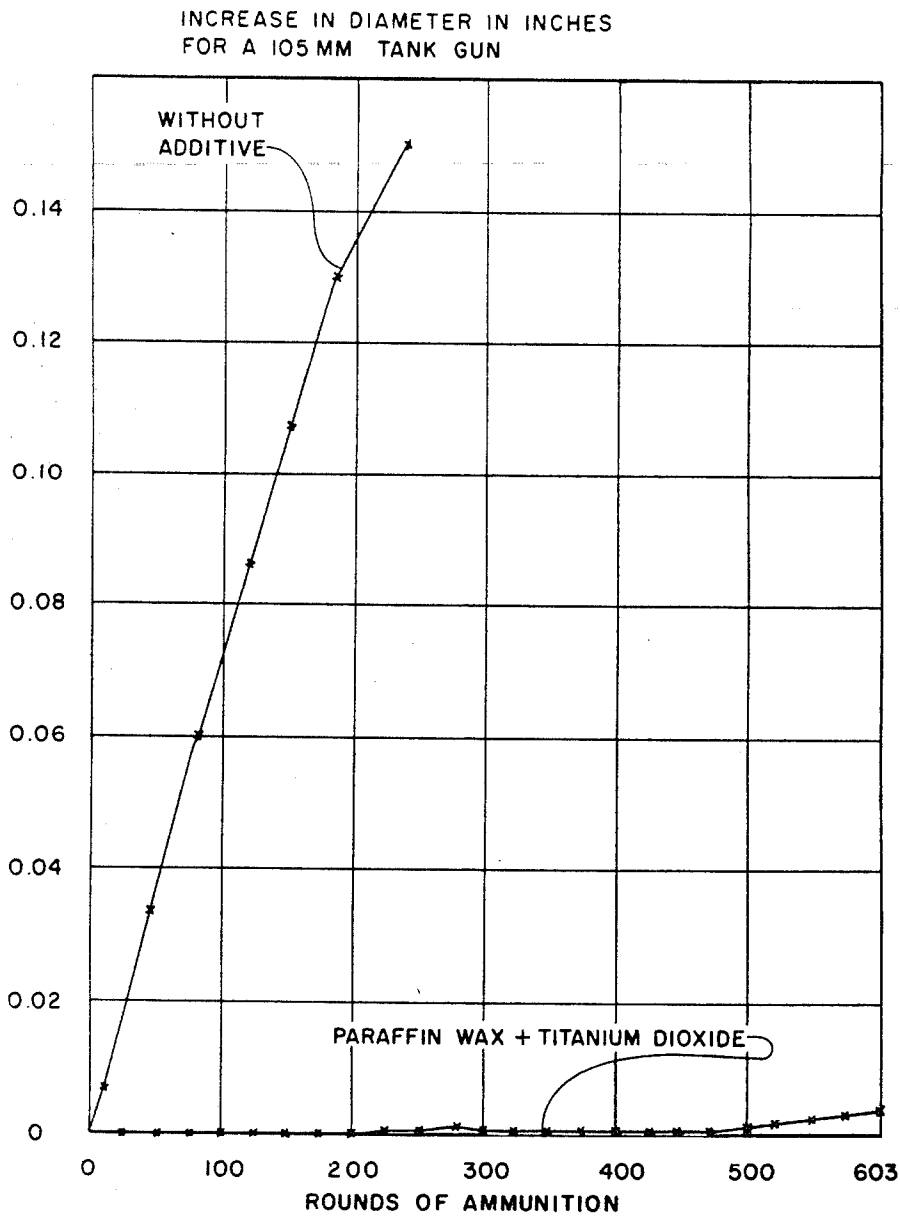


Fig. 13

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3,403,625

WEAR REDUCTION ADDITIVES

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Application Mar. 22, 1967, Ser. No. 625,269, which is a continuation of application Ser. No. 377,278, June 23, 1964. Divided and this application Jan. 18, 1968, Ser. No. 698,750

29 Claims. (Cl. 102—38)

ABSTRACT OF THE DISCLOSURE

The reduction of the erosion caused in gun barrels of relatively large caliber by associating an additive with the propellant charge. The additive is a finely divided, powdery, metal-containing inorganic substance capable of producing a temperature and erosion resistant layer on the inside of the gun barrel while the hot propellant gases flow therethrough without causing a material rise in the temperature of the gases. The additive is employed in an amount sufficient to produce the temperature and erosion resistant layer over the entire length of that portion of the gun barrel which is subject to erosion.

This application is a division of application No. 625,269 filed Mar. 22, 1967. Application No. 625,269 is a continuation of application No. 377,278 filed June 23, 1964 (now abandoned), which in turn is a continuation-in-part of application No. 153,299 filed Nov. 20, 1961 (now Patent No. 3,204,558). Application No. 153,299 is a continuation-in-part of application No. 126,747 (now Patent No. 3,148,620), and the latter application is a continuation-in-part of applications Nos. 46,008 and 46,009 filed July 28, 1960, both of which are now abandoned.

This invention relates to the use of substances, and methods of applying such substances, for reducing erosion in a member subjected to hot flowing gases. More particularly, the present invention provides compositions and methods of reducing wear normally attendant with the use of known propellant charges in firearm barrels, and the description of the invention is here made in connection with this function. By cartridge is meant a case, capsule, shell or bag holding a propellant charge for a firearm; in small arms and some guns the cartridge also includes the projectile.

The problem of excessive barrel wear has existed throughout the history of firearms; however, it is today particularly critical due to the more powerful propellant charges in modern cartridges. For example, the present life expectancy of a gun barrel may be 250 rounds, after which time it must be replaced. This has the obvious disadvantage of impairing accuracy of the gun after several firings and also necessitates removal of the gun from service for the period of barrel replacement. By using the additive compositions of the present invention it has been discovered that the life of a barrel in some instances can be extended to the entire service life of the gun and this can be done with good accuracy, e.g. instead of being limited to 250 rounds, the capacity of a gun barrel may be increased to accurately firing 2,000 or more rounds.

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The cause of barrel wear due to erosion is not fully understood, but it is thought to be due to melting, softening or chemical or physical deterioration of the barrel surface on firing, and a subsequent partial erosion of this weak layer by the outflowing combustion gases.

Briefly, barrel wear due to erosion is reduced in accordance with the present invention by incorporating in the cartridge a wear reduction additive. This additive may be located behind the projectile and in the forward portion of the propellant charge and be present in the form of a finely divided, powdery, inorganic substance having the physical and chemical properties of causing no material rise in temperature of the hot propellant gases at firing and of producing on firing a temperature and erosion resistant layer on the inside surface of the gun barrel by suspending a layer-forming substance in the hot, rapidly flowing gases emanating from the propellant charge to thereby form an erosion resistant layer on the barrel surface. It has been found that the additive may be applied in quantities such that wear due to erosion is greatly reduced, and in some instances wear has been reduced to a negligible value, without materially decreasing the muzzle velocity of the projectile or other performance factors of the gun and without causing undesirable effects on the gun barrel. Because of the reduced wear due to erosion and no material decrease in muzzle velocity resulting from use of the additive of the present invention, the accuracy of the gun is retained throughout the period during which a much larger number of rounds of ammunition are fired than would be possible when the additive of the present invention is not utilized.

The additive materials of the present invention may be utilized with conventional propellants that upon firing produce hot gases to reduce the normal wear effects caused thereby. The additive of the present invention may be mixed homogeneously with the propellant powder, or may be applied in a manner to surround the propellant charge, the additive being most effective when located near the forward portion of the propellant charge.

Prior attempts to offset the deleterious effects of propellant charges on firearm barrels have included the use of ammonium carbonate in a cartridge as disclosed in U.S. Patent No. 1,187,779 to Patten to produce relatively cool gases for surrounding the products of combustion of the main propellant charge and thereby protecting the barrel wall from the high temperature effects of such products. U.S. Patent No. 2,131,353 to Marsh discloses various additives for smokeless powder for forming a deposit in the gun bore to protect the latter against the rusting effects of humidity and the residual products of combustion of the powder remaining in the barrel, but not against the erosive effects caused during the few milliseconds when the hot propellant gases flow through the barrel. Therefore, while it has been proposed to form a rust resistant deposit and also to produce cool gaseous barrel insulation, the present invention provides protection against wear on metal members superior to prior art methods. Thus, this invention for the first time contemplates forming temperature and erosion resistant inhibitors to extend the life of firearm barrels and other metal members subjected to hot flowing gases. Moreover, this invention also provides gaseous insulation layers superior to such insulation disclosed by Patten by using more efficient materials, and in a much simpler and

more economical manner as will be described hereinafter. The method of Patten is impossible and inoperable because there is formed very corrosive NH_3 when decomposing ammonium carbonate.

Accordingly, it is an object of this invention to reduce the amount of wear in a gun barrel subjected to hot, rapidly flowing gases of the propellant charge.

It is another object of this invention to reduce the erosion in a metal member such as a firearm barrel by incorporating a novel erosion preventative material in the firearm cartridge.

It is still a further object of this invention to reduce wear on a metal member by incorporating material in a cartridge which will form a temperature and erosion resistant layer on the inside surface of a gun barrel by suspending a layer forming substance in the hot rapidly flowing gases emanating from the propellant charge, the layer forming substance being produced from a finely divided, powdery, inorganic substance introduced into the chamber of the firearm behind the projectile and at about or in front of the location of the propellant charge prior to firing the propellant charge.

Another object of this invention is to provide novel arrangements of an additive layer with respect to a propellant charge.

A further object of this invention is to provide novel additive materials for reducing wear in a gun barrel which are applied in a cartridge, around the propellant charge as by being secured to the inner wall of the cartridge case, to the textile or other like bag containing the propellant charge, directly to the charge, or by being incorporated within the material forming the wall of a consumable cartridge casing.

Still another object of this invention is to provide an additive layer for a cartridge which is simply and economically applied and which is retained in position by a suitable securing means.

A special advantage of the cartridge of the invention is the unchanged characteristics of the internal ballistics compared with the untreated charge. We have for instance found that the muzzle velocity and pressure are unchanged.

Further objects and advantages will become apparent to those skilled in this art from the appended claims, and from the following description as it proceeds in connection with the accompanying drawings wherein:

FIGURE 1 is a front elevation view, partly broken away, of a cartridge embodying the preferred additive of the present invention;

FIGURE 2 is a view of an unfolded sheet utilized in the cartridge of FIGURE 1;

FIGURE 3 is a side elevation view of the sheet shown in FIGURE 2;

FIGURE 4 is an elevation view of a cartridge, partly broken away, illustrating a modification of the present invention;

FIGURE 5 is a front elevation view of a cartridge, partly broken away, illustrating another embodiment of the present invention;

FIGURE 6 is a front elevation view of a cartridge, partly broken away, illustrating a further modification of the present invention;

FIGURES 7-12 are also elevation views of cartridges partly broken away, illustrating further modifications of the present invention as will be described. It will be appreciated that the drawings herein illustrate diagrammatically the use of additives in accord with the present invention and that the proportions are not necessarily to scale; and

FIGURE 13 is a graph showing the increase in the bore diameter of a 106 mm. tank gun as a function of the number of rounds of ammunition that are fired both without the additive of the present invention and with the additive, the particular measurements plotted here being taken at a point 25.25 inches from the rear face of the tube.

Referring now to the drawings, there is illustrated in

FIGURE 1 a cartridge having a metal case 20, a propellant charge 24 which may be comprised as is conventional, of propellant strips or grains, and a projectile 28. Surrounding the propellant charge 24 is a wrap 32 which may be of suitable combustible material such as rayon, cotton, silk or the like. The forward portion of the wrap that extends immediately behind projectile 28 and in front of the propellant charge 24 contains a plurality of vertical slits 36, shown best in FIGURE 2, which extend for part of the length of wrap 32 and which may be folded over to form flaps 40 as shown in FIGURE 1. In accordance with a preferred embodiment of the invention, flaps 40 are folded in overlapping manner over the surface of propellant charge 24 that faces the projectile 28.

Wrap 32 is shown to have a coating 44 on the surface facing propellant charge 24. In this embodiment, the additive of the present invention is coating 44 which may consist of titanium dioxide dispersed in a suitable paraffin wax having a melting point higher than any temperature normally encountered by ammunition during storage with the ratio of titanium dioxide to the paraffin wax being approximately about 1:1 by weight. The size of the particles of the titanium dioxide is not particularly critical, though small particles having a size and texture of talc have generally provided optimum results, e.g., pigment quality. In a 75 mm. gun where conventional triple base powder composed primarily of nitrocellulose, nitroguanidine and nitroglycerine (calorific value 850) was employed, optimum results were obtained utilizing an additive layer 44 that constituted about 3 percent by weight of the propellant charge.

The additive coating may be prepared by melting the wax and mixing it with powdered titanium dioxide. Thereafter, the coating is applied to the fabric in the desired thickness and permitted to cool. The thickness ratio of the top and bottom portions of layer 44 in the described embodiment is approximately 2:1 (see FIGURE 3). The thickness of layer 44 applied to flap sections 40 is substantially the same as the maximum thickness at the top side of the charge.

Coated fabric 32 which is preferably one-half to five-sixths the length of the charge, may be wrapped around the strips of charge 24; or it may be held in position in the cartridge as the propellant material, preferably in the form of grains, is poured in. Thereafter flaps 40 are folded over the projectile 28 placed on top of the flaps as shown in FIGURE 1.

As thus applied to the charge the additive coated fabric affords the following advantages:

(1) It positions the thicker portion of layer 40 around the upper part of charge 24 where it produces the greatest effect for guns of relatively large caliber;

(2) It has been found that with coated flaps 40, better results may be obtained than when no flaps are used. It is believed that this effect results from the flaps opening on combustion of the charge and extending forwardly to liberate the additive material into the forward portion of the case, and in some cases directly into the critical portion of the barrel next to the firing chamber where erosion is normally greatest thereby exposing the latter to additives in a more concentrated form than the additive material along the side of the charge which is delivered to the barrel; and

(3) The tapered cross section of layer 44 along the length of charge 24 locates the additive material so that it will be substantially uniformly consumed or liberated from the charge throughout the length of the latter.

The presence of the wax forming part of layer 44 is not essential to the present invention. Paraffin wax, however, provides not only a vehicle for holding the finely divided powdery substance such as titanium dioxide in its desired location, but is known to decompose when the propellant charge is fired and produce a cooling effect resulting from the chemical reaction of the carbon in the paraffin wax (1) with carbon dioxide in the combustion products to

form carbon monoxide and (2) with water in the combustion products to form carbon monoxide plus free hydrogen. As each of these reactions requires a considerable amount of heat, a cooling effect is produced which, as is known in the prior art, contributes somewhat to the reduction of the temperature on the inside surface of the barrel and thereby tends to reduce wear due to erosion by a very small factor. This means only the erosion to some extent at the commencement of the rifling but this effect is insignificant or absent in other places of the bore.

Thus, tests have shown that the use of a carbonaceous material such as paraffin wax is not as effective as an inorganic substance having the unique properties of the present invention.

Best results have been obtained where using wax that is a paraffin (approximately 85% carbon) having a melting point between 50° and 100° C. Microcrystalline wax e.g. Mobilwax 2305 currently produced by the Mobil Oil Co. or Ozokerite wax having the same or a higher melting point or mixtures thereof may be used. Examples of other materials found to be suitable are:

Alkyd resin paint (approximately 70% carbon), for example "China-Lack" currently produced by Dorch, Backsin and Co., of Gothenburg, Sweden.

Plastic (polyethylene, cellulose acetate, nylon, etc.).

Cellulose (approximately 40% carbon).

Nitrocellulose (approximately 30% carbon).

Grease—any lubricating grease such as petroleum jelly (e.g. petrolatum), a petroleum or synthetic lubricating oil thickened with a metal salt of a fatty acid such as aluminum palmitate, calcium palmitate or stearate, etc. or an oil thickened with a bentonitic clay and commonly used in lubricated ball valves. Other waxes such as ceresin and beeswax. Automobile undercoating compositions—e.g. "underseal" produced by the Minnesota Mining and Manufacturing Company.

When the wax is used, it has been found that in smaller caliber guns, the lower the melting point of the wax, the greater the effectiveness. However, from the standpoint of practicability, the wax should have a melting point above 50° C.

The additive of the present invention may consist of just the finely divided, powdery, inorganic substance, e.g. titanium dioxide, or it may be the combination of such a substance and an organic vehicle, e.g. wax. This inorganic substance must have the physical and chemical properties of (1) causing no material rise in temperature of the hot propellant gases at firing, and (2) producing a temperature and erosion resistant layer on the inside surface of the gun barrel by suspending a layer forming substance in the hot, rapidly flowing gases emanating from the propellant charge. Examples of inorganic materials which have been found to be operable in accordance with the present invention include: aluminum, boron, titanium, vanadium, silicon, chromium, zirconium, niobium, molybdenum, hafnium, tantalum, tungsten, uranium, zinc and thorium.

Although it may be possible to use the element by itself in the cartridge, it occurs in some instances that such element may be reacting with the combustion gases materially raise the temperature of the hot flowing gases and thus actually increase, rather than reduce, barrel wear. As a consequence, it is frequently necessary to use such element in the form of a compound such as oxide, fluoride or the like.

Additionally, many of these elements cannot be economically obtained in a finely divided powder form as a pure element, and hence, a compound such as an oxide is the convenient way of providing the inorganic element. The particular compound is not critical since the high temperatures involved cause most compounds to break down into their respective element. Since it is the presence of the inorganic element that provides the major effect toward reducing the barrel wear, the particular

compound by which the element is introduced is not critical, and there does not seem to be any property due to the chemistry of the compound that is significant toward reducing the wear due to erosion.

The additive of the present invention when incorporated in a cartridge in sufficient quantity produces on firing, a temperature and erosion resistant layer on the inner surface of a gun barrel by suspending a layer forming substance in the hot, rapidly flowing gases of the firearm which is capable of combining with the material of the inside surface of the gun barrel. This layer appears to be comprised of oxides, carbides, or nitrides; it protects the barrel from and is then partly removed by the hot combustion gases formed by the rear part of the charge. Some degree of protection and reduction of wear due to erosion results from the use of the additive in quantities less than that which produces a layer on the inner surface of the gun barrel that remains detectable after the firing is completed. Important protection can be obtained even though the layer including the inorganic material that forms, is totally removed by the combustion products of the propellant charge. After firing rounds with a due amount of additive, the protection lasts for the firing of a few rounds without the additive.

The inorganic substance that forms the important part of the additive layer may be applied in several ways, but in general it is preferred that this substance be dispersed in a continuous layer around the propellant charge. By placing the inorganic substance in a carbonaceous material such as wax, and disposing the additive layer around the charge, the inorganic substance will be readily and substantially uniformly carried into contact with the inner barrel surface by the combustion gases and there will also be some protection given by the cool gases formed by the carbonaceous substance.

Referring now to FIGURE 13, a chart is shown which has increase in diameter of the barrel as the ordinate and number of rounds of ammunition fired as the abscissa. Two curves are plotted, one marked "without additive" and the other marked "paraffin wax and titanium dioxide." The test results forming the basis for these curves were derived from the firing of a standard 105 mm. tank gun using the same APDS ammunition, except that the firing in one gun tube contained the additive. The specific manner by which the additive was applied for test data represented by FIGURE 13 is as follows:

A powder bag cloth was used as a backing for the impregnation or coating; the material was rayon, pure cellulose, the weight of which was approximately 30 grams per 2,000 cm.². A piece of cloth cut to a size of about 16" x 19" and weighing about 33 grams was used.

Titanium dioxide was dispersed in a paraffin. The titanium dioxide used was Kronos A, produced by Titangeellschaft M.b.H. of the German Federal Republic. This is a titanium dioxide of the anatase modification and classified as purity 99 percent.

The paraffin used had a solidification point between 156° and 163° F., with cleanliness requirements in the specification: Free acids consisting of maximum 0.1 ml., of potassium hydroxide (KOH/gram) and sulfate ash maximum 0.057%.

The paraffin was melted over boiling water and the titanium dioxide dispersed in the molten paraffin. The proportion of paraffin and titanium dioxide was 24 parts by weight of paraffin and 20 parts by weight of titanium dioxide. A small amount of a surface active agent, such as stearyl alcohol, can be added to the mixture to insure that the mixture would spread homogeneously on the cloth.

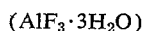
The molten mixture of paraffin and titanium oxide was then spread over the rayon cloth with a scraper to the proper thickness, i.e., a graduated thickness of approximately 1 mm. in the top of 0.5 mm. in the rear or lower part of the cloth or sleeve.

The cloth or sleeve was cut or serrated so as to form

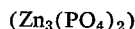
flaps; the sleeve was then partly folded so as to permit the sleeve to be inserted in the shell case. After the propellant had been placed into the shell case, the flaps or the cut tops of the cloth or sleeve were folded or pressed down on the top of the propellant so that the final round was similar to the embodiment illustrated in FIGURE 1.

A significant conclusion arrived at was that the bore wear after the firing of 601 rounds with the additive was so small that the life of the barrel or gun tube can be conservatively estimated to be more than 2,000 rounds, as compared with about 200 for ordinary rounds. It was observed that the accuracy of the gun tube was substantially as good at the end of firing 601 rounds as for the first few rounds when the additive was used; whereas accuracy fails with conventional ammunition as a result of wear causing an increase in the gun bore diameter.

The following inorganic compounds are effective: aluminum fluoride (AlF_3), hydrated aluminum fluoride



potassium titanium fluoride, chromium fluoride, vanadium pentoxide, titanium dioxide (TiO_2), niobium oxide (Nb_2O_5), tantalum oxide (Ta_2O_5), tungsten oxide (WO_3), zirconium oxychloride, borax, potassium titanium fluoride, sodium molybdenum oxide, sodium tungstate, chromium nitrate, molybdenum oxide, glass wool, the following zinc compounds: zinc oxide (ZnO), zinc sulfide (ZnS), zinc carbonate (ZnCO_3), zinc phosphate



zinc fluoride (ZnF_2), (zinc chromate (ZnCrO_4), zinc silicate (ZnSiO_3), zinc oxalate (ZnC_2O_4), and zinc arsenate ($\text{Zn}_3(\text{AsO}_4)_2$); hafnium oxide (HfO_2), uranium oxide (UO_2), thorium oxide (ThO_2), vanadium, tungsten, niobium, vanadates, tungstates, niobates, tantalates and titanates e.g. of alkali and earth alkali metals such as sodium and potassium, and carbides, nitrides, sulfides, oxides and silicides of V, W, Nb, Ta and Ti. Some materials such as MnO and CdO have been found not to give the desired effect. Manganese and cadmium apparently do not form a nitride, carbide or oxide which can provide the protective layer, possibly because they do not alloy or combine with iron in the necessary way.

Tests were conducted with a 20 mm. automatic cannon in which conventional cartridges and cartridges containing different forms of the inorganic substance mechanically mixed with and dispersed throughout the powder were used. The powder used was 7 hole N-C powder, and the total weight of the charge was 37 grams. The muzzle velocity was 840 meters/second and each test consisted of 2 series of firings each of 25 rounds. The cannon was fitted with a removable sleeve in the area between the chamber and the rifled portion of the barrel. After the firing the sleeve was removed and the wear was as ascertained by weighing the sleeve.

Inorganic substance	Weight reduction in mg.	Wear in percent
None.....	131.6	100
1% AlF_3	95.5	72.6
1% $\text{AlF}_3 \cdot 3\text{H}_2\text{O}$	14.9	11.3
1% ground glass wool.....	35.0	26.6
0.5% ground glass wool.....	57.4	41.8
1% K_2TiF_6	80.1	60.9

The inorganic substance may be arranged in the cartridges in other ways; for example, it may be contained in a thin sheet (or foil of propellant containing the inorganic substance; or it may be applied as a layer on celluloid or like foil.

The table below shows various arrangements of the inorganic and carbonaceous substances for use in a 37 mm.

cannon, and the reduction in wear in a removable sleeve achieved in tests similar to those described above:

	Inorganic substance	How arranged	Wear in Percent (Wear without either substance being regarded as 100%)
5			
10	$\text{AlF}_3 \cdot 3\text{H}_2\text{O}$	Contained in a propellant foil wrapped around the charge. Foil was 0.8 mm. thick and contained 25% by weight of $\text{AlF}_3 \cdot 3\text{H}_2\text{O}$.	20
	CrF_3	Contained in a foil wrapped around charge and composed of propellant. Foil was 0.8 mm. thick and contained 20% by weight of CrF_3 .	20
15	MoO_3	MoO_3 dispersed in varnish ("Ferbolack") applied to a 0.15 mm. thick celluloid foil wrapped around the charge.	35
	Na_2WO_4	The length of the layer was 10 cms., and 6 grams Na_2WO_4 was applied in a layer to 0.15 mm. thick celluloid foil wrapped around the charge. The length of the layer was 10 cms.	65
20	CrF_3	A cellulose enamel coating applied to the inner surface of the cartridge container and containing 25 gms./cm. ² (approximately 70%) of CrF_3 . The length of the coating was 5 cms.	40
25	$\text{Na}_2\text{B}_4\text{O}_7$	As a powder dispersed throughout the charge. Powder 2.5% by weight of the charge.	75
	$\text{Cr}(\text{NO}_3)_3$	As a powder dispersed throughout the charge. Powder 1.2% by weight of the charge.	50
	WO_3	Contained in a paraffin wax layer on the inside of the cartridge case. The layer was 50 mm. in length and 0.5 mm. in thickness and contained 50% by weight of WO_3 although 50-70% has been used successfully. Or instead of WO_3 , Nb_2O_5 was used with equally good results.	<5
30			
	ZnO	Contained in a paraffin wax layer on the inside of the cartridge case. The layer was 50 mm. in length and 0.5 mm. in thickness and contained 40% by weight of ZnO and 60% by weight of the wax.	<5
35	Zn	Contained in a paraffin wax layer according to the example with WO_3 and ZnO but with 67% by weight of Zn and 33% by weight of the wax.	<5
40	Ta_2O_5	Contained in a paraffin wax layer on the inside of the cartridge case. The layer was 50 mm. in length and 0.5 mm. thick, and contained 50% by weight of Ta_2O_5 .	<5
	TiO_2	Contained in a paraffin wax layer on the inside of the cartridge case. The layer was 50 mm. in length and 0.5 mm. thick, and contained 50% by weight of TiO_2 .	<5
45			

The following arrangement of the inorganic and carbonaceous substances in a cartridge for a 3-inch gun reduced the wear in a steel barrel to 10% of what it was previously; that is a reduction of 90%. A length of fabric coated with paraffin wax having a melting point of 70° C. was wound once around the front 3/4 of the tubes of conventional double base nitrocellulose powder containing nitroglycerine housed in a metal case. Powdered tungsten oxide was dispersed in the wax, and constituted 67.6% by weight of the mixture of wax and tungsten oxide and the weight of the coated textile length was 3% by weight of the charge. Similar tests with nearly equally good results, have been carried out with TiO_2 used in the place of WO_3 in the same amount.

Examples of other forms of the inorganic substance are zirconium oxide, ZrO_2 .

Similar tests with equally good results (less than 10% wear) have been carried out with a mixture of 40% by weight of ZnO and 60% by weight of wax and 67% by weight of Zn and 33% by weight of wax. Generally, the proportion of powdered zinc metal or the zinc compounds to the propellant charge is preferably 0.5-10 percent by weight for zinc, zinc oxide, or the zinc salt compounds listed above. It is also possible to use mixtures of zinc and zinc oxide or zinc and zinc compounds. The proportions of these mixtures may be 10-90 percent by weight of zinc and 90-10 percent by weight of zinc oxide, and preferably 40-60 percent of zinc and 60-40 percent by weight

of zinc oxide, zinc oxide being an example of a suitable zinc compound.

It has been found that a wear reduction effect also is obtained by using the inorganic substance according to the lower limit on the assumption that the substance is applied on a cartridge fabric, said fabric being placed within the case around the propellant charge. When directly coating the inside of the case with the inorganic substance in combination with the carbonaceous substance, the coating will hardly produce any effect, depending on the high thermal conductivity of the case preventing a sufficiently fast consumption of the coating in connection with the firing. If it is nevertheless for practical, economical and technical reasons desirable to place the coating directly on the inside of the case, the wear reduction effect can be obtained if the quantity of the coating on the upper part of the case is increased to at least 0.1% by weight of the charge and preferably to at least 1% by weight of the charge according to the dimensions of the gun, in order to obtain a reasonable effect. This can be explained from the fact that the lower part of the coating produces the necessary thermal insulation.

The part of the layer adjacent the front part of the charge is more effective than the part of the layer adjacent the rear end of the charge; in fact, if the layer extends the whole length of the charge, the rear half of the layer has little effect; and it is the front half, especially the front $\frac{1}{3}$, and particularly the front $\frac{1}{6}$, which has most effect in absorbing heat from that part of the propellant gases which cause the barrel wear. In heavier guns in which the time for the projectile to travel down the barrel is relatively long, for example $7\frac{1}{2}$ cms. guns, the part of the substance beyond the front $\frac{1}{3}$ of the charge is fairly effective, especially when using the first substance and in cartridges for such guns the substance should preferably surround at least the front half, and preferably the front $\frac{5}{6}$ of the charge.

The inorganic substance may be dispersed by mechanical mixing throughout the propellant charge. For example, good results have been obtained by dispersing $\text{AlF}_3 \cdot 3\text{H}_2\text{O}$ (about 1% of the charge weight) throughout the charge of a 37 mm. gun. However, even better results have been obtained by dispersing the inorganic substance in fine particles throughout the carbonaceous substance and applying the mixture in a continuous layer around the charge, either directly on the charge, on fabric covering the charge, or on the inner wall of the case. The primary reason for maintaining the additives and charge separate is that the gas flow in the barrel on combustion of the charge is to a certain extent laminar. Consequently, if the inorganic substance is uniformly dispersed through the charge a substantial part of the substance in the center of the charge is carried by the propellant gases past the part of the barrel where maximum wear normally occurs. Therefore, to obtain a greater effect, additive materials are advantageously arranged so that they surround the charge. Also, it is better to maintain the additives to be simply and cheaply adapted to existing cartridges so that they incorporate the invention. Still another reason is that there is no risk of any deleterious effect on the stability of the propellant.

In FIGURE 4 the arrangement of inorganic and carbonaceous substances to the charge is the same as that described in connection with FIGURE 1. However, layer 44 is covered with a layer 48 of combustible material such as paper for the purpose of further protecting the additive from the effects of heat or vibrations.

In FIGURE 5 is shown a cartridge having a case 52, charge 56, and projectile 60. An additive layer 64 embodying an inorganic substance and a carbonaceous substance dispersed therein, is positioned around the charge on the interior surface of casing 52. Adjacent the interior surface of the additive layer 64 is an optional sheet 68 of suitable combustible material, e.g. paper, celluloid,

nitratd cotton, wax paper, thin fabric, etc. Layer 64 extends along a substantial length of the case to a point closely adjacent the lower portion of projectile 60. The advantage of this arrangement is that the additive material will be made immediately available in highly concentrated form to protect the portion of the barrel usually eroded most severely.

Thus, in all embodiments of this invention, it will be understood that it is desirable to locate at least a portion of the additive as close to the forward end of the case as is feasible, or alternately to provide flaps which apparently accomplish this same purpose when the cartridge is discharged. The adhesiveness of the carbonaceous substance itself will generally be sufficient to hold the additive layer securely in place on the casing wall, particularly where the inorganic substance is dispersed in a layer of cellulose enamel or alkyd resin paint for example.

The material of which layer 68 is composed is selected to afford at least slight cooling effect (in the manner of a carbonaceous substance) when the round is fired, but more importantly it helps retain additive layer 64 in position and also protects it from deteriorating influences. It will be understood that layer 68 is not essential, but desirable where for example, the cartridges may be stored or used in hot climate or transported over rugged terrain.

It may be desirable to additionally protect and maintain the position of the additive material by enhancing the bond between the casing and additive layer 64. This may be accomplished by conditioning the case to receive and hold the additive layer more strongly. Thus, in accordance with the embodiment of the invention shown in FIGURE 5, the area of the inner casing surface to be contacted by layer 64 may be coated with a thin layer of glue or other suitable material to produce a rough surface before additive layer 64 is applied. Or, a thin coarse fabric such as gauze or the like may be applied to the casing inner surface by means of a suitable adhesive for receiving and holding the carbonaceous substance and dispersed inorganic substance in place.

Alternatively, the additive may be retained on the case wall by being impregnated into a layer of porous material having interstitially connected pores such as foam or sponge rubber or foam plastic. Also, since the rubber may serve as a coolant substance, the inorganic substance may be applied in a slurry to the porous material and dried.

FIGURE 6 illustrates a cartridge similar to that shown in FIGURE 5 with an additive layer 80 disposed on the inner surface of case 84 around charge 88 but without a thin intermediate textile or paper separating the charge and layer 80. Also, layer 80 is of uniform thickness throughout its length.

The following examples shown in FIGURES 7-12 illustrate different forms of fixed cartridges embodying the invention for use in a 37 mm. anti-tank gun whose barrel is made of chrome alloy steel and wherein the propellant charge is double base powder containing nitroglycerine and having a calorific value of 1150 calories. The charge weighs 220 grams, and it is arranged in strips each $225 \times 12 \times 0.65$ mm. The cartridge cases are, in all the figures 250 mm. long.

The cartridge shown in FIGURE 7 comprises a case 100, a charge 104 consisting of strips tied together by string 106, and a layer 110 of powdered vanadium pentoxide dispersed in an alkyd resin paint applied to the upper part of the inner wall of the cartridge case. The vanadium pentoxide constitutes 60% by weight of the layer. The thickness of the layer is 0.5 mm.; its length is 50 mm.; and its weight is 3 grams.

Instead of layer 110 being powdered vanadium pentoxide, ground glass wool may be used.

The cartridge shown in FIGURE 8 utilizes, for example aluminum fluoride or other inorganic substance contained in a bag 114 located within textile container 118. The wear reduction obtained with this cartridge is not as great as the wear reduction obtained in the cartridges

shown in FIGURE 7, probably because the additive does not surround the charge.

The cartridge shown in FIGURE 9 comprises a case 120, strips 124 tied together by string 128, and an additive layer 132. The inorganic substance, for example, pulverulent aluminum fluoride ($\text{AlF}_3 \cdot 3\text{H}_2\text{O}$) is contained in a plastic ring such as polyethylene for example, located at the upper end of the cartridge case. In this embodiment of the invention the additive layer is relatively thick and short. The increased cross section of the layer enables the gas pressure to readily remove the material from the case into the barrel.

The cartridge of FIGURE 10 is substantially the same as the cartridge of FIGURE 7. The vanadium pentoxide 133 is, however, not dispersed in an alkyd resin paint but is fixed to the inside of the case as by a suitable adhesive.

The cartridge shown in FIGURE 11 comprises a case 134, a charge 138 contained in a textile bag, and a coating 42 on the upper part of the charge. The coating extends 10 cms. downwardly from the top of the container and consists of a cellulose enamel containing 70% of WO_3 . The weight of coating per sq. cm. is 50 mgs.

The cartridge shown in FIGURE 12 comprises a case 146, a charge 150 and a length of textile 154 wrapped around the upper part of the strips to form a layer containing the two substances. The textile length is coated with nitrocellulose paint 158 containing powdered aluminum fluoride in about 60% of the weight of the dried layer. The coated length 154 extends 10 cms. downwardly from the top of the propellant. The weight per sq. cm. of layer is 70 mgs.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respect as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by Letters Patent is:

1. For use in guns of relatively large caliber, a round comprising the combination of a projectile, a propellant charge adapted upon ignition to generate hot propellant gases capable of propelling the projectile through the gun barrel, whereby said barrel is subjected to erosion by the propellant gases as they flow therethrough, and an additive associated with said propellant charge for reducing the erosion of the gun barrel by the hot propellant gases, said additive being a finely divided, powdery, inorganic, metal-containing substance selected from the group consisting of the sulfides of titanium, tantalum, tungsten, vanadium, and niobium and mixtures thereof, said additive being present in an amount sufficient to produce a temperature and erosion resistant layer over at least substantially the entire length of that portion of the gun barrel which is subject to erosion.

2. The combination defined in claim 1 wherein said substance is a sulfide of vanadium.

3. The combination defined in claim 1 wherein said substance is a sulfide of tungsten.

4. The combination defined in claim 1 wherein said substance is a sulfide of titanium.

5. The combination defined in claim 1 wherein said substance is a sulfide of niobium.

6. The combination defined in claim 1 wherein said substance is a sulfide of tantalum.

7. The combination defined in claim 1 wherein the weight of the additive is in the range of from about 0.05 to about 30 percent of the weight of the propellant in the propellant charge.

8. The combination defined in claim 1 wherein said additive is dispersed throughout said propellant charge.

9. The combination defined in claim 1 wherein said additive is disposed around said propellant charge.

10. The combination defined in claim 1 together with a carbonaceous binder for said inorganic, metal-containing substance.

11. The combination defined in claim 10 wherein said carbonaceous binder is wax.

12. The combination defined in claim 10 wherein said carbonaceous binder is paraffin.

13. The combination defined in claim 1 wherein a layer of carrier material for said substance is coated on a textile base surrounding said charge.

14. The combination defined in claim 1 including a case having the propellant charge located therein, the additive being applied to the inside of said case.

15. The combination defined in claim 1 including a thin sheetlike carrier for the additive, said additive being applied to said carrier and said carrier having portions thereof folded over the front of the propellant charge and located between said charge and the projectile.

16. The combination defined in claim 1 including a layer containing a substantial amount of a carbonaceous material capable of producing a relatively cool gas upon firing of the propellant charge, said additive being in the form of finely divided particles and said particles being dispersed in said carbonaceous material containing layer.

17. The combination defined in claim 16 wherein the carbonaceous material containing layer in which the additive is dispersed is tapered in cross section and has a smaller thickness toward the rearward portion of the propellant charge than at the forward portion thereof.

18. The combination defined in claim 16 including a combustible protective cover overlying said carbonaceous material containing layer.

19. A method of reducing wear in gun barrels of relatively large caliber and of the type adapted to have a projectile propelled therethrough by the ignition of a propellant charge and therefore subject to corrosion by the hot propellant gases generated upon the ignition of said propellant charge and flowing through the barrel, said method comprising the steps of introducing a wear reduction additive into the gun before the projectile is propelled through the barrel thereof, said additive being a finely divided, powdery, inorganic, metal-containing substance selected from the group consisting of the sulfides of titanium, tantalum, tungsten, vanadium, and niobium and mixtures thereof, said additive being introduced into said gun in an amount sufficient to produce a temperature and erosion resistant layer over at least substantially the entire length of that portion of the gun barrel which is subject to erosion; and igniting said propellant charge to propel the projectile through the gun barrel and simultaneously dispersing said additive along the inner surface of the gun barrel to produce said temperature and erosion resistant layer.

20. The method defined in claim 19 wherein said substance is a sulfide of vanadium.

21. The method defined in claim 19 wherein said substance is a sulfide of tungsten.

22. The method defined in claim 19 wherein said substance is a sulfide of titanium.

23. The method defined in claim 19 wherein said substance is a sulfide of niobium.

24. The method defined in claim 19 wherein said substance is a sulfide of tantalum.

25. The method defined in claim 19 wherein the weight of the additive is in the range of from about 0.05 to about 30 percent of the weight of the propellant in the propellant charge.

26. The method defined in claim 19 together with the step of dispersing the additive throughout the propellant charge before the charge is introduced into the gun.

27. The method defined in claim 19 together with the step of disposing the additive around the propellant charge before the propellant charge is introduced into the gun.

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28. The method defined in claim 19 together with the step of mixing the additive with a carbonaceous binder before it is introduced into the gun.
29. The method defined in claim 19 together with the steps of applying the additive to a textile base and then surrounding the propellant charge with the textile before the propellant charge is introduced into the gun.

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