A New Gun Barrel Erosion Reducer

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EROSION of gun tubes by hot propellant gases has long been a problem. A significant reduction in erosion was achieved when titanium dioxide in a wax carrier was coated on a cloth and lined inside the top section of the cartridge case around the periphery of the propellant charge. This wear reducing additive method is basically a Swedish development and was patented in this country by Jacobson and Ek.[1]

We have been pursuing this problem from two aspects: the mechanism responsible for this reduction, and evaluation of materials other than TiO_2.

A silica-wax system was as good an erosion reducer as the TiO_2-wax combination. Its effectiveness was attributed to the large surface area of the silica particles and its high heat content. This finding led to the evaluation of commercially available metallic silicates. A magnesium silicate, talc, was significantly more effective than TiO_2. This note presents the data obtained to date with the various silicates, particularly talc.

Laboratory Studies

A standard 200-cm^3 closed bomb was modified by placing an erosion sleeve of gun metal in a barrel segment attached to the bomb's gage housing (Fig. 1).[2] Propellants with or without additives are burned in the bomb. A rubber stopper in lieu of a projectile is accelerated through the erosion sleeve and the barrel as the propellant burns. The propellants, with a single-perforated geometry, are fired at approximately 16,000 psi. The weight loss of the erosion sleeve for each series of firings is a measure of the extent of erosion. All pressures are measured with a strain gage and recorded with an oscillograph. A number of silicates were evaluated including kaolin, kaolinite, muscovite mica, feldspar, and talc. The latter is a magnesium silicate, whereas the others are aluminum silicates. The aluminum silicates were in no case superior to the talc.

An experiment was designed to study the effectiveness of talc vs TiO_2. Talcs that differed in particle size were obtained for this study. The TiO_2 had already been standardized as a wear-reducing agent. These additives were blended with four commercially available waxes ranging in melting point from 120° to 180°F. The additive/wax ratios, in turn, were $\frac{45}{55}$, $\frac{22}{78}$ and $\frac{11}{89}$. Five successive firings were made with each sample utilizing M2 Propellant (isochoric flame temperature, 3320°K) along with the waxes as controls. The results of this experiment are presented in Table 1. There were significant differences among the waxes as well as between the talcs and the TiO_2. Moreover, the 0.6-μ average particle size talc was significantly superior to the 2.6-μ talc. The more additive, and the less wax, used in the sample likewise resulted in a significant reduction in the wear of the erosion sleeve.

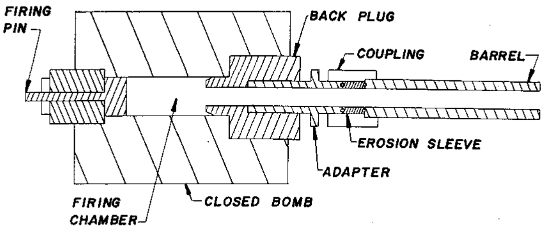

Fig. 1 Sketch of erosion apparatus.

Table 1 Erosion study of talcs vs TiO_2 in wax carrier[a]

	TiO_2, 0.6 μ				Talcs: Supreme, 2.3 μ			Talcs: Mistron vapor, 0.6 μ		
Additive, %	0	45	22	11	45	22	11	45	22	11
Wax carrier										
120[b]	10.2	5.3	8.6	12.1	1.5	6.7	9.0	3.4	4.9	6.0
140	5.7	4.5	7.6	9.4	5.3	7.2	9.0	4.0	4.8	6.7
160	9.3	4.8	7.5	10.3	5.1	6.5	8.7	3.5	4.7	5.7
180	8.4	5.0	7.6	11.0	3.3	5.3	6.9	1.5	3.2	4.0

[a] 30 g of propellant M2 (T_v = 3320°K) fired with 4 gm of blend of additive/wax carrier consisting of 45% additive/55% wax, 22% additive/78% wax, or 11% additive/89% wax. The erosion is expressed as milligrams wear for five successive shots.
[b] Melting point at 1 atm.

The insertion of a wear-reducing liner in the cartridge case for small arms ammunition would be impracticable because of the high-loading density of these rounds and the smallness of the cartridge cases. Consequently, the wear-reducing additive, talc, was incorporated in the propellant itself. The data presented in Table 2 shows that the incorporation of 2% talc in the propellant base grain was an effective wear-reducing agent for both 7.62 and 20-mm small arms ammunition.

Weapon Firings

In order to corroborate the favorable laboratory data for talc, this complex silicate has been evaluated in three systems to date. In the 105-mm gun, M68, the talc/wax mixture (2.3% ± 0.5% of the propellant charge weight) was coated on a rayon cloth and lined inside the top portion of the cartridge case around the periphery of the propellant charge. No wear occurred in the gun tube from firing 50 rounds, each, of the HEAT, M456 and APDS, M392 projectiles with M30 Propellant. Fifty, each, of these same two rounds with the standardized TiO_2/wax liner gave wear values of 3 and 4 mils, respectively.[3]

One hundred rounds were fired in the 175-mm gun M113, with the XM1 additive jacket slipped over the zone 3 bag of the M86E1 propelling charge. (This jacket weighed 2.9% ± 0.2% of the M6 Propellant charge weight.) The rate of wear was 40 mils/100 rounds using an additive jacket containing a talc/wax mixture.[4] Previous data showed that the average rate of wear was 49 mils/100 rounds when the additive jacket contained a titanium dioxide/wax blend.

Barrel erosion is a serious problem in the 40-mm M75 launcher. The life of the launcher was approximately 1500 rounds before the hot M2 propellant gases eroded away the

Table 2 Erosion from small arms propellants with and without talc added

	7.62-mm propellant IMR8138M[a]: Control	7.62-mm propellant IMR8138M[a]: 2.5% talc (0.6 μ)	20-mm propellant CR7814[b]: Control	20-mm propellant CR7814[b]: 2.1% talc (0.6 μ)
Web, in. SP	0.0139	0.0133	0.0208	0.0227
Measured heat of explosion, cal/g	896	898	879	808
Relative force at max pressure				
At 70°F	100.0	97.5	100.0	94.4
At −65°F	100.0	97.9	100.0	94.2
Erosion, mg[c]	4.8	0.5	5.0	1.2

[a] The calculated thermochemical properties of IMR8138M are: isochoric flame temperature, 2810°K; force, 324,800 ft-lb/lb.
[b] The calculated thermochemical properties of CR7814 are: isochoric flame temperature, 2590°K; force 308,800 ft-lb/lb.
[c] 30 g of propellant fired to give maximum pressure of 16,000 psi.

Presented as Paper 68-233 at the ICRPG/AIAA 3rd Solid Propulsion Conference, Atlantic City, N.J., June 4–6, 1968; submitted June 14, 1968; revision received August 12, 1968.

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forcing cone and the commencement of rifling. However, one launcher tube had over 5300 40-mm M385 rounds fired through it and still had not reached its condemnation limit when a polyethylene bag containing talc was placed on top of the propelling charge in the M169 case.[5]

Small Arms Program

An extensive program is now planned for the evaluation of 0.6- and 2.3-μ average particle size talcs in small arms ammunition. Four CR7814 propellant lots containing 1 and 2%, respectively, of both particle size talcs are being procured from the duPont Co. These four special propellant lots will be loaded at Lake City Army Ammunition Plant into cartridges, 20-mm T.P. M55A2, as well as a control lot of standard WC870 ball propellant. The ammunition plant will fire temperature coefficient and erosion tests with both the experimental and the control ammunition.

References

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Advanced Pressurization System for Liquid Rockets

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Nomenclature

c^* = characteristic exhaust velocity
g = acceleration of gravity, 32.174 ft/sec^2
I_s = specific impulse, lbf-sec/lbm
MR = mixture ratio = W_o/W_f
P = pressure
R = gas constant, ft-lb/lb°
t_b = burning time, sec
T = temperature, °R
V,v = velocity and volume, respectively
W = weight

Presented as Paper 68-628 at the AIAA 4th Propulsion Joint Specialist Conference, Cleveland, Ohio, June 10–14, 1968; submitted June 11, 1968; revision received September 11, 1968. This work was sponsored by NASA under Contract NAS8-19. The conclusions are the result of studies made at Rocketdyne in conjunction with the Propulsion Division of P&VE at Marshall Space Flight Center with several necessary inputs from previous studies made at Douglas[1,2] and additional information generously provided by R. J. Ceilnicky of Douglas. The important contributions of G. Baird of Rocketdyne are also acknowledged.

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Subscripts

BO,O = burnout and gross, respectively
c = chamber (injection end)
f,g,o = fuel, gas, and oxidizer, respectively
$NPSH$ = net positive suction head
p,PL = propellant and payload, respectively

Introduction

THIS Note describes advanced systems studies concerned with using the main propulsion system of a liquid rocket to provide some of the so-called auxiliary functions, thereby reducing pressurization system inert weights and resulting in system simplification. The engine would generate vaporized propellants for tank pressurizing. The engine can also burn most of the tank pressurizing gases and the liquid residuals presently unavailable. The net result is an increase in payload of 2250 lb (2%) for the Apollo mission (Table 1).

In the existing Saturn S-IVB stage, the tanks are initially pressurized by helium from a ground supply. During engine operation, the fuel tank is pressurized by gaseous hydrogen (GH_2) bled from the thrust chamber and the oxidizer tank is pressured by stored He, which is heated by an engine heat exchanger. For the Apollo mission, the first burn places the S-IVB in a 100-naut-mile earth orbit. During earth orbit coast, the fuel tank is vented continuously to 20 psia. The

Table 1 Potential payload gains for Apollo mission, S-IVB with J-2S

	Current design		Advanced system	
	W, lb	MR	W, lb	MR
Useful propellants	(225,300)	5.0	(226,591)	4.915
Main stage burn	225,300	5.0[a]	220,968	4.943[b]
J-2S tank repressurization prior to 2nd burn			4,277	4.0[c]
J-2S, end 2nd burn			1,346	4.0[c]
Boiloff in orbit	3,880	0	3,880	0
Tank pressurization gas				
Gaseous propellant	783	0.71	1,786	2.5
Helium (at burnout)	218	...	28	...
Liquid residuals	1,269	0.46	1,269	0.46
Propellant utilization reserve	136	0	136	...
Engine and ducts	1,133	0.55	1,133	0.55
Total unusable gases	1,001	0.94	454[d]	2.5
Total unusable liquids	1,269	0.46	206[d]	0
Performance reserve liquids[e]	3,200	5.0	1,969	4.0
Performance reserve gases[e]	0	...	1,360	2.5
Helium bottles	600	...	0	...
O_2/H_2 burner	50	...	0	...
Total inert (nominal flight)	6,120		3,989	
Total effect on payload				
Inert weight decrease			+2,131	
Increase in usable W_p			+ 97	
Decrease in engine MR			+ 161	
I_s during repressurization			− 61	
I_s (nominal flight)			− 40	
Gravity loss			− 30	
Net payload gain, ΔW_{PL}			+2,258	
Dry weight, including IU	29,257		28,607	
Stage inert weight	34,727		32,596	
W_O, at ignition	377,522		378,940	
W_{BO}, burnout weight	148,342		148,469	
W_{PL}, payload	113,615		115,873	

[a] I_S = 434.0, F = 240,000 lb.
[b] I_S = 434.34, F = 240,000 lb.
[c] I_S = 421.0, F = 50,000 lb.
[d] 25% of gases + 70 lb LH_2 trapped in tank + propellant utilization reserve LH_2.
[e] Total performance reserve = propellant for 0.75% of vehicle ideal ΔV = 302 fps.