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THE CHEMICAL AND BALLISTIC PROPERTIES
OF BLACK POWDER

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THE CHEMICAL AND BALLISTIC PROPERTIES OF BLACK POWDER

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16. Abstracts
The chemical and ballistic properties of black powder are described in terms of storage stability, hygroscopicity, ignition sensitivity, compatibility with other materials, and burning rate. Information is included on uses and users of black powder and sources of supply. Substitutes for black powder are briefly discussed. Extensive references are cited.

17. Key Words and Document Analysis. 17a. Descriptors

Pyrotechnics	Burning Rate
Explosives	Suppliers
	Compatibility
Pyrotechnic Igniters	Degradation
Primers (Explosives)	Hygroscopicity
Black Powder	Moisture Content
	Ignition
	Utilization

17b. Identifiers/Open-Ended Terms

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THE CHEMICAL AND BALLISTIC PROPERTIES OF BLACK POWDER

Black powder is not favored by most engineers for use in new designs. Still, there are instances where the unique ballistic properties of black powder are difficult or impractical to duplicate. This paper is a review of the availability, stability, and ballistic properties of black powder.

In the United States, sporting and military black powder is manufactured by E. I. duPont de Nemours & Co., Inc. Canadian Industries Limited, Montreal, also supplies black powder (Class 1 only) to the U. S. Army. Outside North America, the Nobel Division of Imperial Chemical Industries, Ardeer, Ayrshire, Scotland, manufactures black powder for world-wide distribution. According to DOT regulations, black powder is a class A explosive for purposes of shipping, handling, and storing.

Black powder is considered "stable"[1, 2, 3, 4]. According to Harrison[1], "There can be no question that in the absence of moisture black powder is extremely stable in normal conditions. I am informed that until World War I it was the practice of the French Army to preserve lots of black powder which had proved especially good, for use in time train fuzes and it was reported that some lots so preserved dated from Napoleonic times. During the Williamsburg reconstruction beginning in 1926, unexploded Civil War shell loaded with black powder were unearthed from time to time, and often were found with the black powder in them still in good condition."

Ellern[5] gives additional insight into the stability and uses of black powder. "The advantages of black powder are great sensitivity to ignition even at low temperature, economy, multiplicity of uses, and relative safety in handling. The disadvantages are hygroscopicity and limited stability, excessive flash and smoke, undesirable solid residue, difficulty in controlling burning rate, poor burning qualities under diminished pressure, and, finally, limited supply." According to Sheffield[2], "In the absence of moisture, black powder is of a high order of stability, its ingredients being essentially nonreactive with each other even at 120°C. However, the heating of black powder above 70°C (158°F) results in a change in composition or uniformity of composition due to the volatility of sulfur above 70°C."

Hygroscopicity and moisture content are vitally linked to the stability of black powder. Ellern [5] gives the equilibrium water content of black powder as follows (80°F): 0.2-0.6% at 20-60% relative humidity and 1.0-1.5% at 80-90% relative humidity. MIL-P-223B "Powder, Black" (for Class 7) allows 0.7% maximum moisture content. Sheffield [2] indicates acceptable stability at 0.7% moisture content. It is interesting to note that data in NOLR 1111 [6] suggest that the ignitability of black powder peaks at about 1% moisture content. Satisfactory ignition has been obtained in a specific application involving "threshold conditions" up to about 3% moisture content [7].

Numerous techniques may be employed to measure the moisture (or volatile) content of black powder. Typical procedures are "Volatiles (oven method)" and "Volatiles (vacuum method)" described in MIL-STD-1234 "Pyrotechnics: Sampling, Inspection and Testing" or the procedures specified in MIL-P-223 "Powder, Black." Development of an "NMR Transient Moisture Meter" for measurements over the range 0.1 to 1.3% moisture content was recently reported [13]. Black powder reacts with many materials, a condition aggravated by moisture. Consideration of compatibility with other materials is essential for any design incorporating black powder. Considerable compatibility data are available and can be found in the references cited with this paper, particularly Reference 12.

Sporting black powder is readily available. However, it is difficult to obtain developmental quantities of black powder certified to MIL-P-223. It appears that sporting black powder FFFFG is glazed while the MIL-P-223 counterpart, i.e. Class 7, is not. There may be other differences between commercially available black powder and black powder procured to the military specification.

Use of black powder in new designs is not widespread. Aerojet-General Corp. designers used black powder in the CDU-12/B cluster. Recently, black powder was used in the BLU-48/B munition design [7]. Hamilton [3] states that "Black powder has been used as the intermediate charge in impulse cartridges such as the Navy MK9-0 and MK2-0 Impulse Cartridges. The black powder has been replaced with FA-878 primer mixture in the MK9 cartridge although the MK2-1 cartridge still uses black powder (Class 4) . . . Fine (Class 4) black powder is also used as a delay element for base detonating fuzes used in large-caliber Navy guns (5, 8 and 16-inch) where millisecond delays are required. Cannon (large grain) type black powder is also used in gun primers, that is, ignition systems for many Navy guns such as the 3, 5, 8, and 16-inch weapons.". The U. S. Army uses black powder in numerous applications such as igniters for propelling charges M3 and M4A1 for 155mm howitzers and propelling charge M86 series for 175mm gun cannon, the latter requiring nearly one pound for each round.

Perhaps the main reason that black powder is considered for new designs is its relatively high burning rate at low pressure and small pressure burn-rate exponent. Burn-rate data are given in References 9 and 11. A relation that has proven satisfactory for predicting performance with a Honeywell internal ballistics computer program is $r = 0.133\ p^{0.325}$ where r = rate (in/sec) and p = pressure (psia). Experimental data indicate that two expressions for burn rate are necessary for comprehensive calculations due to an observed transition in the region of 100 psia. Powders produced by different manufacturers exhibit different ballistic properties.

Available single and double base propellants, even porous "WC Blank," do not burn satisfactorily at low pressures compared with black powder. Alternatives to black powder, in such applications, have not proved superior. However, the pyrotechnic-propellant compositions that seem to approximate black powder are typically based on Zr/NH_4ClO_4 or $Zr/KClO_4$, both agglomerated with a binder such as nitrocellulose or double-base propellant in solvent, and then screened to produce granules. The addition of a small a ount of amorphous boron (MIL-B-51092) to fine flake double-base propellant (M5) also seemed to increase burning rate at low pressure to a level approximating black powder in one experiment.

Many others have investigated substitutes for black powder. Perhaps one of the most successful substitutions has been the use of compositions such as B/KNO_3 pellets for solid-propellant rocket igniters. Hamilton [3] reports that. . . . "black powder has been replaced with FA-878 primer mixture in the MK9 cartridge. . . . The FA-878 was in turn replaced with a zirconium-potassium perchlorate mixture (60% Zr + 40% $KClO_4$) with very satisfactory results." The delay compositions that have replaced black powder are well known.

The U. S. Army is the primary consumer of black powder in the U. S. Their procurement in 1967 and 1968 was over 4, 000, 000 pounds per year, about 1, 500, 000 pounds in 1969, and in 1970 is predicted to run 800, 000 pounds. Annual procurement by others, including the U. S. Navy, is estimated to be about 25 percent of the U. S. Army figures.

Some concern has been expressed over the availability, particularly the future availability, of black powder. As Carl L. Roberts reported [10], "The military requirements for black powder have not diminished nearly so fast in the past several years as the abandonment of production by private manufacturers. Annual military requirements may run to millions of pounds, and Ordnance desired to record as much as possible of the producer's art against the day when production by independent manufacturers may cease." And Hamilton [3] stated, "There has been a shortage of black powder the last year or two because of the Vietnam war but this no doubt has eased in recent months, since Navy warfare has been curtailed." The U. S. Army has not reported a shortage of black powder. Rather, concern has been expressed over a shortage of suppliers in the U. S. since the recent closing of the Austin Powder Company, Cleveland, Ohio, following an explosion.

It was previously noted in this paper that black powder appeared most readily ignitable at about 1% moisture content. Even more curious are the results of electrostatic sensitivity tests conducted at the Bureau of Mines [14]: "Moist black powder (up to 7% moisture) is more sensitive than dry black powder when tested under partial confinement. . ."

A discussion of black powder can not be complete without anecdotal reference to earlier times when the term gunpowder was synonymous with black powder. "The term proof spirit has its origin in an old method of testing whiskey by pouring it on some gunpowder and lighting. Ignition of the gunpowder after the alcohol burned away was considered proof that the whiskey did not contain too much water" [15].

Finally, the references with this paper would not be complete without including the excellent discussion of the chemistry, ballistics, and manufacture of black powder by Urbanski [16].

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