Performance Study of Civil War Vintage Black Powder

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ABSTRACT

A sample of Black Powder dating to the time of the US Civil War (ca. 1863) was harvested from cannon balls uncovered during an excavation on what had previously been the grounds of the Allegheny Arsenal near Pittsburgh, PA. A portion of this powder was eventually made available for an investigation of its properties. It was found to be in excellent condition, both physically and in its performance. Physically, it is essentially indistinguishable from high quality Black Powder of current production. Its performance under conditions replicating its normal use was only slightly less than that produced by a high quality powder of current production.

Keywords: Black Powder, US Civil War, Bormann fuse, quickness test, Eprouvette

Introduction

The stability and aging characteristics of Black Powder are occasional topics of discussion among pyrotechnists. A related question is, have the performance characteristics of Black Powder changed significantly over the years, possibly as the result of differences in raw materials or manufacturing methods? Having obtained a sample of Black Powder, dating to the time of the US Civil War (ca. 1863), the authors were able to investigate some of those interesting questions. This short article is the first in a series planned to report on those investigations.

Source of Powder Sample

Many of the exploding cannon shells produced by the North during the US Civil War were assembled at the Allegheny Arsenal, located in Pittsburgh, PA.[1] While some of the original site of the arsenal remains as a national historic site, much of it has been developed for other purposes, one of which is a gas (petrol) station. In 1972 there was an excavation at the gas station to install a new fuel storage tank. In the course of that excavation, approximately 1000 explosive cannon balls and rifled shells, dating to the Civil War (ca. 1863), were uncovered.[2] The shells were seized by the police for destruction by a bomb disposal unit. However, some of the shells in the best condition were saved from destruction. These shells were subsequently provided for analysis.

Since the shells were still potentially explosive, a remotely operated, barricaded, and water-cooled drill press was used to gain entry to the contents of the shells. For some of the shells, it was found that the seals on their fuses had failed. This allowed water to enter during the period of approximately a hundred years that the shells had been buried, thus ruining the powder they contained. However, the 32–pounder cannon balls were exceptions. These had a casing about 6 inches in diameter with a cast iron wall about an inch thick. Contained inside each shell were several pounds of Black Powder in apparently perfect condition, free flowing and showing no sign of deterioration. The lead-based "Bormann" time delay fuses,[3,4a] screwed into these cannon balls, provided sufficient integrity to protect the contents from intrusion of water over the preceding century of burial. It is the Black Powder from some of these 32 pounders that was provided for use in this study.

The organization of this article is such that the results of a series of physical and performance tests are presented, mostly without comment. This is then followed by a discussion of those results.

Physical Testing

A sieve analysis was performed on a sample of the recovered Black Powder, with the results listed in Table 1. Table 2 provides information on various granulations of Black Powder dating to about the time of the US Civil War and for recently produced powders. In comparing the granulations, it must be considered that current sieves have square holes produced by the interwoven wires forming screens, whereas the sieves of the Civil War era had round holes in thin sheet metal.[4b]

Table 1. Sieve Analysis of the Civil War Black Powder Sample.

Mesh(a)	Size (in.)[5]	Percent(b)
+12	> 0.066	0
–12 +16	0.047–0.066	15
–16 +20	0.033–0.047	45
–20 +30	0.023–0.033	30
–30	< 0.023	10
	Total Percent	100

Note that sieve sizes are US Standard. To convert inches to millimeters, multiply by 25.4.

(a) Minus (–) means the material passes through this mesh sieve. Plus (+) means the material is retained on this mesh sieve.

(b) Rounded to the nearest percent.

The Civil War powder's bulk and grain density were determined and compared with a recently produced powder. A bulk density for the 16- to 20-mesh fraction of the Civil War powder was determined by placing 5.00 g of powder into a 10 cc graduated cylinder (10 mm ID), and vibrating to produce a minimum volume. The bulk volume occupied by the powder was then read to the nearest 0.1 cc. The results were reported in terms of mass per cubic centimeter, see Table 3. Following this, the interstitial sample volume was estimated by determining the volume (to the nearest 0.1 cc) of a light weight oil required to fill the air spaces between the powder grains. To limit possible migration of the oil into the powder grains, a minimum time was allowed to elapse during the measurement. Grain density was then determined after subtracting the interstitial volume from the bulk volume. Similarly, the bulk and grain densities were determined for a sample of Black Powder recently produced by Goex[8] and sieved to the same 16- to 20-mesh range.

Table 2. Size Ranges of Black Powder Granulations.

Civil War Era[4b] Black Powder	Passing(a) (in.)	Retained(a) (in.)
Musket	0.06	0.03
Mortar	0.10	0.06
Cannon	0.35	0.25
Current Black Powder[6]	**Passing Mesh(b)**	**Retained Mesh(c)**
2Fg (Sporting)	16 (3%)	30 (12%)
Class 4 (Military)[7]	16 (3%)	30 (5%)
Musket (Military)	14 (3%)	25 (5%)
Fg (Sporting)	12 (3%)	16 (12%)
4F (A Blasting)	12 (3%)	20 (12%)

Note that sieve sizes are US Standard. To convert inches to millimeters, multiply by 25.4.

(a) These are for sieves made with round holes.

(b) Maximum percent retained on this mesh sieve.

(c) Maximum percent passing through this mesh sieve.

Table 3. Density and Moisture Content of Black Powder Samples.

Powder Type (16–20 mesh)	Bulk Density (g/cc)	Grain Density (g/cc)	Moisture (%)
Civil War	0.98	1.67	0.67
Goex	1.03	1.75	0.53
Mil Spec 1962[7]	—	1.69–1.76	< 0.70
Mil Spec 1862[4]	—	≥1.75	—

Following the current military protocol for Black Powder moisture determination, samples of both the Civil War and Goex powders were weighed, placed in a 75 °C oven for 4 hours, allowed to cool briefly, then reweighed. The mass loss, expressed as a percentage, is the reported moisture content of the powder. These results are also reported in Table 3.

Performance Testing

An early instrument used to gauge the performance of Black Powder is an "Eprouvette", which is a pistol-like device, see Figure 1. The device has a small combustion chamber into which a charge of Black Powder is loaded. One end of the chamber is blocked with a spring-loaded pivoting baffle, with a ratchet to hold it in position against the closing force of a spring. When the powder is fired, using a standard percussion primer, the force of the explosion is determined by noting the extent to which the baffle has rotated. Five test shots were conducted using the 16- to 20-mesh samples of the Civil War powder and again using current production powder manufactured by Goex. The results, including the averages and their standard errors, are reported in Table 4. (Note that these results are dimensionless.)

Figure 1. Photo of Eprouvette,[9] an early Black Powder Tester.

A modern test of powder performance is the quickness test.[10] In this test, a small sample of powder is burned in a closed vessel, while recording internal pressure as a function of time. Typically, for this type of test, the level of confinement is sufficient to withstand the pressures produced without venting. However, the instrument used in this study had been assembled for use in studying fireworks lift and burst

Table 4. Eprouvette Test Results.

Trial	Civil War	Goex
1	4.0	3.5
2	3.5	3.5
3	2.5	2.5
4	2.5	3.5
5	2.5	3.5
Average	3.0	3.3
Std. Error	0.3	0.3

Note that the standard error is the standard deviation, using the *n*–1 method, divided by the square root of *n*, the number of measurements.

powders.[11] Accordingly, it was designed to operate in a relatively low pressure regime, typically using one of a series of rupture disks that limit the maximum pressure to a few hundred psi (a few MPa). The volume of this quickness tester is quite low (6.3 cc) to allow testing of very small powder samples. The standard procedure with this apparatus is to crush the powder sample using a mortar and pestle, then load 0.15 g of the 60- to 100-mesh fraction into the combustion chamber for test firing. In each case, ignition is accomplished using a tiny hot-wire igniter.[12]

In this study of Civil War Black Powder the standard method described above was used. Figure 2 is an example of the pressure versus time data from one quickness test. The figure also illustrates the simplified method used to deter-

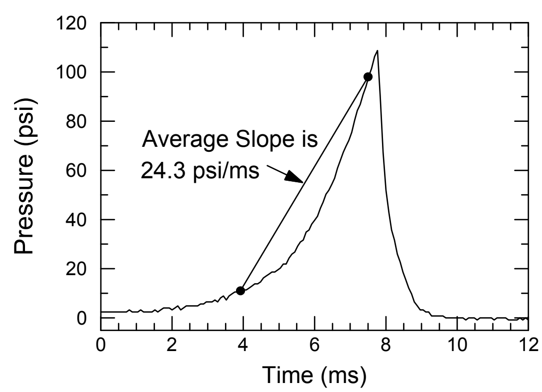

Figure 2. An example of a quickness determination for a sample of Civil War Black Powder.

mine its quickness value. The reported quickness values are the average slope of the pressure rise curve between the points equaling 10% and 90% of the peak pressure observed. A series of eight measurements were made, alternating between measurements for Goex and the Civil War powders. The results and averages are reported in Table 5.

Table 5. Results of Quickness Testing.

Trial	Goex (psi/ms)	Civil War (psi/ms)
1	35.5	24.0
2	36.1	24.2
3	33.3	19.4
4	35.8	22.8
Average	35.2	22.6
Std. Error	0.6	1.1

To convert psi per millisecond to kPa per millisecond, multiply by 6.89.

Note that the standard error is the standard deviation, using the n–1 method, divided by the square root of n, the number of measurements.

As a test of performance more nearly replicating the powder's use during the period of its production, test firings were made using a Black Powder rifle. Four test firings were made, using the 16- to 20-mesh fractions of samples of the Civil War and Goex powders. The rifle used was a Connecticut Valley Arms 50-caliber rifle with a 26-in. (0.66-m) barrel, firing a 360-grain (23-g) maxi ball using a powder charge of 50 grains (3.2 g). Projectile muzzle velocities were measured using a Prochrono Plus Chronometer (Model CEI–3200).[13] Test firing results are reported in Table 6, along with their averages and standard errors.

Table 6. Black Powder Rifle Results.

Trial	Civil War (ft/s)	Goex (ft/s)
1	1028	1078
2	1034	1068
3	981	1123
4	1019	1071
Average	1016	1085
Std. Error	12	13

To convert feet per second to meters per second, divide by 3.28.

Note that the standard error is the standard deviation, using the n–1 method, divided by the square root of n, the number of measurements.

Discussion

The physical appearance of the Civil War Black Powder retrieved from the cannon balls is consistent with its still being of high quality. The grains are hard and show absolutely no sign of physical deterioration. The powder is free flowing with minimal dust present. There is possibly a very subtle difference in color, as compared with current production powder (Goex), with the Civil War powder being ever so slightly lighter in color. Based on its general physical appearance, it would not be possible to detect that the Civil War powder was not of current production.

The granulation of the Civil War powder fits well with the range reported for Musket powder of that era, especially if it is recognized that, in 1860, the holes in military sieves were round and not square as they are today. Further, it would seem that the granulation is still consistent with today's US military specification for Musket powder. (See Tables 1 and 2.)

The grain density for the Civil War powder (1.67 g/cc) is close to that of current production powder and to the current US military specification. The grain density of the Civil War powder is a little lower than the reported standard of that time. It is uncertain whether there has been a slight change in the powder's density over time or if the powder had been manufactured to a somewhat different standard. The moisture content of the powder (0.67%) is still within current military specification. (See Table 3.)

In terms of its performance under significant confinement, in the Eprouvette and Black Powder rifle tests, the Civil War powder produces results within 7 to 10% of that of current production Goex powder. (See Tables 4 and 6.) (Note that even though the powder samples had both been sieved to 16–20 mesh, it is possible that relatively small particle-size differences within this mesh range could have contributed to the difference observed in this study.) To help put this 7 to 10% performance difference into perspective, it should be noted that past examinations of other current production Black Powder (non-Goex) performed significantly poorer than the Civil War powder examined in the present study.[14]

At this time, it is not possible to say whether the small difference between the Goex and Civil War powders under confinement represents a degradation of its performance, as opposed to being the result of performing a limited number of tests, or the powder having been less effective originally. Such lesser performance could easily have been the result of less pure potassium nitrate and sulfur, or charcoal having not been processed optimally. It is also possible (likely?) that processing methods have improved somewhat over the intervening 135 years. (Another phase of this study is planned to look into some questions of the purity of the materials and differences in processing in comparison with current materials and methods.)

The only significant difference observed in this study are from the relatively low pressure quickness tests, where the average rate of pressure rise for the Civil War powder was about 35% slower than Goex Black Powder. (See Table 5.) At this time, the authors have no explanation for why this difference is so large, or why it is so much greater than differences observed in the other performance tests. It is possible that particle-size differences, within the 60–100 mesh range used, had an effect. Another possibility is that crushing the powder grains affected the samples differently, perhaps introducing microfractures in the particles. Of course, a third possibility is that it reveals a fundamental difference between the Civil War and Goex powders that is only significant in a relatively low pressure regime.

Additional Historical Background

The method of entry into the shells called "32 pounders" was not by the easier (and less hazardous) drilling through their relatively soft fuse (a 50:50 lead / tin alloy). Rather it was by drilling through the iron casing of the shell. This was done because the Bormann fuses have great historical value. Many deactivated shells from the war have been preserved and are available for study. However, in most cases, their fuses had previously been removed or destroyed.

The Bormann fuses were a type of time delay fuse wherein a compacted semi-circular ring of Black Powder meal was protected by a lead alloy covering. Access to the powder, for the purpose of its ignition, was gained by cutting a hole in the covering, thus exposing the powder to the burning gasses as the shell was fired from its cannon. Accordingly, various delay times could be selected on the battle field by selecting the point along the powder ring, where the lead was cut. Delays up to 5.5 seconds, in quarter-second increments, were possible. (See Figure 3.) Some of the fuses on the recovered shells had the delays marked in numbers, while others had them in Braille. (Most of the rifled shells had an inertia type of fuse designed to explode the shell on impact, and some of these still had their percussion caps in place.) It might be of interest to note that a variation of the Bormann fuse principle is still used on some military items today (e.g., some illuminating flare rounds[15]).

Figure 3. A photo of a Bormann fuse in place on a 6-pounder cannon ball.

At the end of the Civil War, many of the unused shells were returned to the Allegheny Arsenal for deactivation. Apparently this deactivation was accomplished by inserting a spanner wrench into holes in the fuses, and unscrewing them to remove the powder contained in the shells. In the case of the recovered shells, all the spanner wrench holes showed severe rounding indicating a failure of the attempt to remove the fuses. Apparently this inability to easily deactivate these shells was the reason for burying them.

The Allegheny Arsenal was a major supplier of munitions for the North during the US Civil War and was operational until 1901. However, it is most remembered as the site of a horrific explosion during the war that took the lives of 78 children employed for assembly work.[1] The children ranged in age from 12 to 14 and were mostly girls. Children were employed for economic reasons and because their small fingers aided in assembly of some munitions. The explosion occurred early in the morning hours of September 17, 1862. (This is the same date as the battle of Antietam, the single bloodiest date in the war.) The children were buried in a mass grave in the Allegheny Cemetery, just outside the grounds of the arsenal.

Acknowledgements

The authors wish to thank Clean Shot Technologies for performing the Black Powder rifle muzzle velocity testing, Martinez Specialties for supplying the thermal igniters used in the quickness tests, and L. Weinman and E. Brown for providing comments on a draft of this article.

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