Comparing Blast Pressure Variations of Lead Styphnate Based and Diazodinitrophenol Based Primers

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ABSTRACT

This article describes the blast pressure waves produced by detonation of both lead styphnate and diazodinitrophenol (DDNP) based firearms primers measured with a high-speed pressure transducer located at the muzzle of a rifle (without powder or bullet). These primer blast waves emerging from the muzzle have a pressure-time profile resembling free field blast pressure waves. The lead based primers in this study had peak blast pressure variations (standard deviations from the mean) of 5.0-11.3%. In contrast, lead-free DDNP-based primers had standard deviations of the peak blast pressure of 8.2-25.0%. Combined with smaller blast waves, these large variations in peak blast pressure led to delayed ignition and failure to fire in brief field tests.

INTRODUCTION

Over the past two decades, there has been a growing interest in removing lead from ammunition due to environmental and health concerns. For example, the US Army has issued the new M855A1 load with lead-free bullets to troops in Afghanistan. If lead-free bullets demonstrate field performance equal to their counterparts that include lead, the only lead needing to remain in duty ammunition would be lead based centerfire primers. Diazodinitrophenol (2-diazo 4,6 dinitrophenol, abbreviated as DDNP and also referred to as diazole and dinol) is regarded as a promising candidate to replace lead styphnate in centerfire priming compounds. An Air Force study showed that transitioning to training ammunition with lead-free bullets and primers can reduce instructor exposure to lead by 70% in indoor ranges and 41% in outdoor ranges.[1]

Testing of primer performance ultimately requires using ammunition fully loaded as it would be for a given application. However, it is also desirable to have a method to test and compare primer performance independently of a given cartridge and load to remove confounding effects of powders, bullets, neck tension, case capacity, bore friction, etc. so that performance of different primer designs can be compared more directly. The method employed here for directly comparing primer performance is to measure the blast pressure wave produced by impact detonation of a primer loaded in a cartridge case without any bullet or powder. In this study, measurements are presented for eight lead based primers (four large, 5.33 mm diameter, and four small, 4.45 mm diameter), and two DDNP-based primers (one large and one small).

Peter Griess is credited with discovering diazo compounds in 1858.[2] Over the next 50 years, the chemistry of diazo compounds and their applications were further investigated.[2] US patents for improved processes for manufacturing DDNP for explosive applications were awarded in 1922, 1935, and 1946.[3-5] In 1932, a patent for primer compounds including DDNP was awarded to agents of the Remington Arms Company.[6] In the 1980s, interest increased in using DDNP as a main component in non-toxic priming compounds, and since 1985 more than a dozen patents have been awarded for specific applications to small arms. Hoping to further reduce toxicity of gunshot residues, some of these formulations employ non-toxic oxidizers as well, such as zinc peroxide. Between 2000 and 2009, several American ammunition manufacturers offered at least one product line with lead-free primers, and DDNP-based primers were being manufactured on a commercial scale at Muron in Russia.[7]

METHOD

The measurement method was originally described in the Review of Scientific Instruments.[8] Blast pressures were measured using a high-speed pressure transducer (PCB 102B or PCB 102B15) placed coaxially with the 7.82mm diameter rifle barrel and directly facing the muzzle with no separation between the end of the barrel and pressure transducer. Only a primer is loaded in the brass cartridge case (no bullet or powder) and detonated by the impact of the firing pin.

A cable connects the pressure transducer to a signal conditioning unit (PCB 842C) that produces a calibrated voltage output, which is then digitized with a National Instruments PXI-5105 fast analog to digital converter operating at a rate of 1 million samples per second. The voltage waveform is converted to pressure using the calibration certificate provided by the manufacturer with each pressure sensor. Ten samples each of eight models of widely used lead based primers were tested along with two DDNP-based primers, a large rifle primer (model KVB-7E) and a small pistol primer (model KVB-9E) manufactured in Russia at Muron. Brief field tests were also conducted comparing two large rifle primers in loaded ammunition and noting muzzle velocities, accuracy, and ignition delays.

RESULTS

Figure 1 shows blast pressure waveforms of four primer types. The arrows in the figure denote the range of peak blast pressures for a sample size of 10. Compared with its average peak blast pressure, the DDNP-based KVB-7E has a much larger variation in peak blast pressure than other primers. (Waveforms for different models are offset in time to facilitate comparison.) Simple blast waves are usually characterized by peak overpressure, duration, and impulse (the area under the curve of pressure vs. time). Since the durations and basic shapes are similar, the impulse is nearly proportional to the peak pressure, and the peak pressure is the main distinguishing characteristic of these blast waves. Therefore, the results and discussion will focus on the average peak magnitude and the standard deviation of peak magnitudes for each primer type.

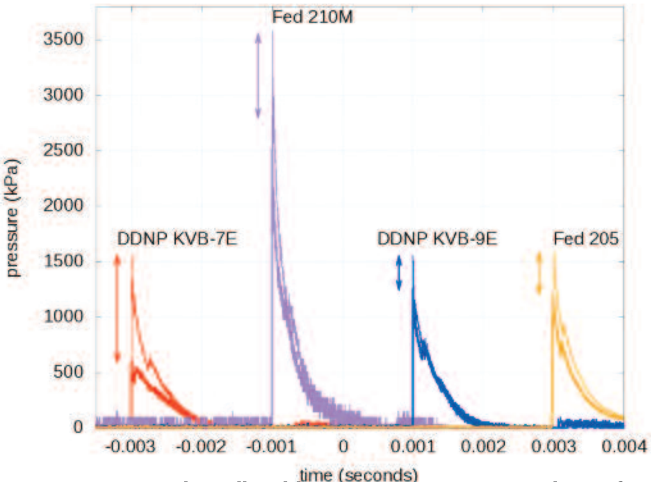

Figure 1. **Largest and smallest blast pressure waves are shown for two DDNP-based (KVB-7E and KVB 9E) and two lead based (Fed 210M and Fed 205) primers.**

Figure 2. **DDNP-based KVB-7E primer which produced a misfire in a 30-06 test load. The crater suggests the misfire was not due to a light primer strike. The other nine 30-06 test loads with this primer demonstrated a perceptible delay in ignition.**

Table 1. **Peak pressure averages and standard deviations from the mean (SD) with a sample size of 10.**

Primer	Diameter (mm)	Peak Pressure (kPa)	SD (kPa)	SD (%)
Fed 210M	5.33	2908	223	7.7%
Fed 215M	5.33	3811	192	5.0%
CCI 200	5.33	2561	270	10.7%
CCI 250	5.33	3587	404	11.3%
DDNP KVB-7E	**5.33**	**1186**	**296**	**25.0%**
Rem 7 ½	4.45	2303	186	8.1%
Fed 205	4.45	1469	103	7.1%
CCI 450	4.45	1602	104	6.5%
Fed 205M	4.45	1434	103	7.2%
DDNP KVB-9E	**4.45**	**1331**	**109**	**8.2%**

Table 1 shows average peak pressures along with standard deviations from the mean for the primers in this study. Primers of diameter 5.33 mm are labeled "large", and primers of diameter 4.45 mm are labeled "small" by manufacturers. Except for the DDNP-based large rifle primer, large rifle primers produce stronger blast waves than small primers, and "magnum" rifle primers (Fed 215M, CCI 250) produce stronger blast waves than non-magnum primers of the same size. There are significant differences in the standard deviations observed for different primer types, and it is notable that so-called "Match" primers are not always more consistent than non-match primers. Perhaps most notable is that in each group (large and small), the standard deviation of the DDNP-based primer is the largest percentage of its mean value. For the large rifle primers, the standard deviation of the DDNP-based primer (25%) is more than twice the standard deviation of any lead styphnate based primer that was tested.

Since it is of interest to know how much these blast pressure differences impact field performance, some brief field testing was conducted comparing 10 shots with the DDNP-based KVB-7E rifle primer with 10 shots of the lead styphnate based Fed 210M in each of two otherwise identical loads: 1) a 30-06 load using 51.0 grains of H414 (a ball powder) in Remington brass with a 220 grain Sierra MatchKing bullet and 2) a 7.62x51mm NATO load using 46.0 grains of Varget (an extruded powder) using Remington brass with a Berger 155.5 grain Fullbore boat tail bullet. Both tests were conducted with Remington 700 rifles in HS Precision stocks. The most obvious difference between the lead based and DDNP-based primers was a perceptible delay between firing pin strike and ignition in 15 of 19 shots with the DDNP-based primers (and one misfire); in contrast, there were no misfires or perceptible delays in ignition with the lead based primer. (In fact, in over one thousand rounds using lead based primers in these two rifles, the authors have never observed a perceptible delay in firing nor a misfire.) Figure 2 shows the primer which failed to ignite the powder charge and resulted in a misfire.

Excluding the misfire, the average velocity of the 30-06 load was lower (703 m/s) for the DDNP-based primer compared with the lead based primer (727 m/s). The standard deviation in muzzle velocities was comparable for the DDNP-based primers (4.8 m/s) and for the lead based primers (4.4 m/s) in the 30-06 load, and the average 5 shot group size (extreme spread measured at 200 m) was 2.5 minutes of angle (MOA) for the DDNP-based primers and 2.4 MOA for the lead based primers.

In the 7.62x51mm NATO load, both primers produced an average muzzle velocity of 823 m/s with the DDNP-based primer giving a smaller standard deviation (2.8 m/s) than the more powerful lead styphnate based primer (6.5 m/s). This agrees with the hypothesis that having a primer that is not more powerful than needed to reliably ignite the powder charge produces more consistent muzzle velocities than a more powerful primer.[9] The delay in ignition in 6 of the 10 shots with the DDNP-based primer suggests that this primer is at the low end of strength needed to reliably ignite 46 grains of an extruded powder. This ignition delay is the most likely cause of the larger average group size (2.5 MOA) of the DDNP-based primers in the 7.62x51mm NATO load compared with the lead styphnate based primers (1.8 MOA) at 200 m.

DISCUSSION

It is possible that DDNP-based primers from other suppliers might yield more consistent results. Unfortunately, Winchester, Remington, and ATK were all contacted but chose not to provide lead-free primers for testing. None of these companies offer lead-free primers as stand-alone components, and to our knowledge, DDNP-based primers are currently only available in training ammunition, with no major supplier offering service caliber or hunting ammunition for self-defense, law-enforcement, hunting, or military duty.

In the explosives literature, DDNP is reported to have a higher detonation velocity but a lower deflagration point and impact sensitivity than lead styphnate and lead azide.[10] The higher detonation velocity and pressures were reported to sometimes cause breech damage. In response, manufacturers of training ammunition have attempted to compensate by making various changes such as enlarging the flash hole, crimping the primer more tightly, and moving to a smaller primer diameter.[11][12] It is possible that the lower pressures and larger pressure variations reported here may be due to instability in shipping and storage rather than an inherent quality of newly manufactured DDNP based primers. The development of DDNP as a priming compound continues. Recent work suggests that improved manufacturing methods for a spherical DDNP may improve purity and decrease the impact sensitivity.[13]

While a main impetus for developing DDNP-based priming compounds was to reduce toxicity due to heavy metal compounds, it has been reported that there may be different health risks associated with exposure to their residues. Specifically, DDNP may activate an inappropriate immune system (allergic) response. Also, in enclosed rifle ranges, there are health risks associated with the use of compositions such as Sintox, which are mixtures of DDNP, tetrazine, zinc peroxide, and titanium. In part because of these risks, work is ongoing to develop non-toxic primers based on other compounds.[14] The assumption that lead-free ammunition is non-toxic has also been called into question by an Air Force study reporting a rise in health related complaints following the transition to lead-free ammunition, even though measured contaminant levels were all below occupational exposure levels.[15] Transitioning to lead-free ammunition does not reduce the ventilation requirements for ranges, as was believed at one time.

The history of primer technology is somewhat cyclical with several notable instances of new primer chemistry being introduced to better meet an environmental or gun maintenance concern with several decades passing before the new chemistry became reliable. In 2010, the Office of the Product Manager for Maneuver Ammunition Systems projected that green primer formulations for use in the US military will be evaluated and candidates selected in FY 2011, and that ammunition with green primers will be at full production by the end of FY 2012.[16] At the turn of the 20th century, primer development was driven by the need for a non-corrosive formulation. In the following years, changes in primers used by the military were necessary due to lack of shelf-stability, which led to misfires. This was a reason the US military moved from mercury fulminate-based primers prior to WWI to a formulation based on potassium chlorate, antimony trisulphide and sulphur. However, this formulation was associated with misfires and corrosion, forcing another change.[7]

The lesson of primer history is that care is needed to prevent another large scale move to new primer technology that will compromise field performance and produce unintended consequences. Since difficulty obtaining consistent field performance from lead-free rifle primers was observed in this study and has been noted by others [17][18], the authors recommend independent testing demonstrate the following characteristics before any DDNP-based primer is adopted for duty:

1. Peak blast wave magnitude and consistency comparable with lead based primers.
2. Misfire rates at or below those with lead based primers.
3. Shelf-life and long term stability comparable with lead based primers.
4. Muzzle velocity consistency and peak chamber pressure comparable with lead based primers.
5. Ignition delay times comparable with lead based primers.
6. Comparable accuracy with lead based primers in both machine rests and hand-held testing.

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