Performance and Aging of Mn/MnO_2 as an Environmentally Friendly Energetic Time Delay Composition

Eric J. Miklaszewski[a], Anthony P. Shaw[b], Jay C. Poret[b], Steven F. Son[a], and Lori J. Groven[a,c]*

[a]Purdue University, School of Mechanical Engineering, West Lafayette, IN 47907, USA

[b]Pyrotechnics Technology and Prototyping Division, US Army RDECOM-ARDEC, Picatinny Arsenal, NJ 07806, USA

[c]South Dakota School of Mines and Technology, Department of Chemical and Biological Engineering, Rapid City, SD 57701, USA

* Email: lori.groven@sdsmt.edu

Supporting Information

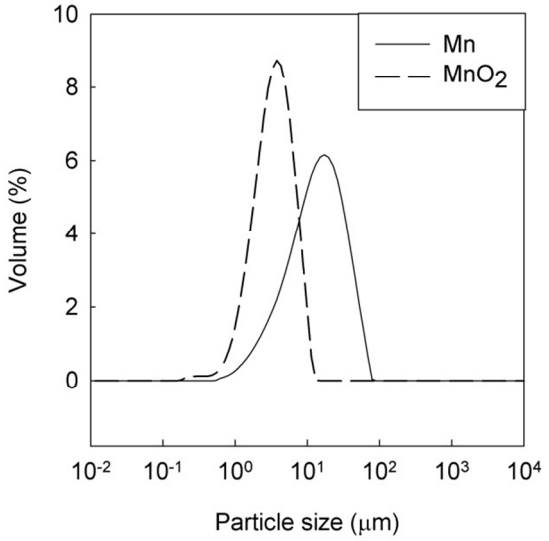
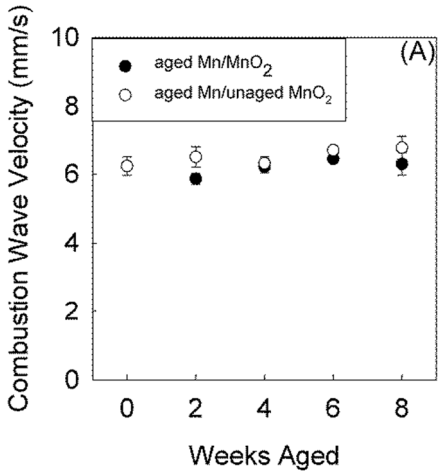


Figure S1. Particle size distribution of Mn and MnO_2 powder.



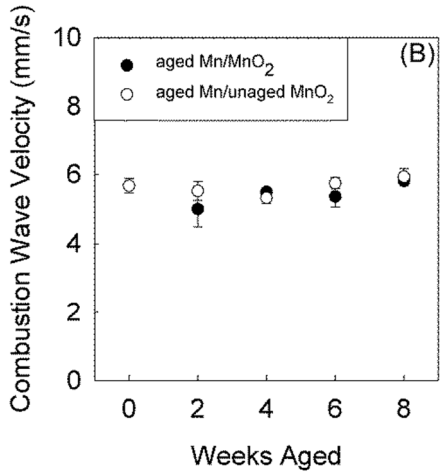


Figure S2. Combustion velocities of (A) Mn/MnO_2 (50/50) and (B) Mn/MnO_2 (60/40) as a function of aging duration. Open circles show data for aged Mn/unaged MnO_2 compositions and closed circles show data for aged Mn/MnO_2 compositions.

Si/Bi_2O_3 and $W/BaCrO_4/KClO_4$/Diatomaceous Earth Compositions Mixing Method.

Si/Bi_2O_3 and $W/BaCrO_4/KClO_4$/diatomaceous earth mixtures were dry mixed in 30mL HDPE bottles using the following procedure:

(1) Mix with Resodyn LabRAM mixer at 40% intensity for one minute
(2) Passed through a 50 mesh sieve
(3) Mix with Resodyn LabRAM mixer at 40% intensity for one minute
(4) Passed through a 50 mesh sieve
(5) Mix with Resodyn LabRAM mixer at 40% intensity for one minute

A1A Composition Mixing Method.

For safety, the A1A composition was wet mixed with a spatula in ethanol (~5 mL per gram of mixture) and then dried on a hot plate at 40 °C.

Additional Combustion Experiments in Aluminum Tubes and Hand-Held Signal Delay Housings.

Nominal sizing and vendor information for the powders used in experiments **in this section only** are summarized in Table S1. Particle size distributions for Mn and MnO_2 were obtained using a Microtrac S3500 laser diffraction particle size analyzer with water as the dispersant. Figure S2 shows the Mn and MnO_2 particle size data for the powders used.

Table S1. Vendor information of reactant powders used in supplemental experiments.

Powder	**Nominal Particle Size**	**Vendor**
Bi_2O_3	15.4 μm	Alfa Aesar
Black Powder	Class 7, 40-100 mesh	--
Mn	-10 micron	AEE
MnO_2	-325 mesh	Alfa Aesar
Si	MIL-S-230C, Grade 2, Class C	AEE

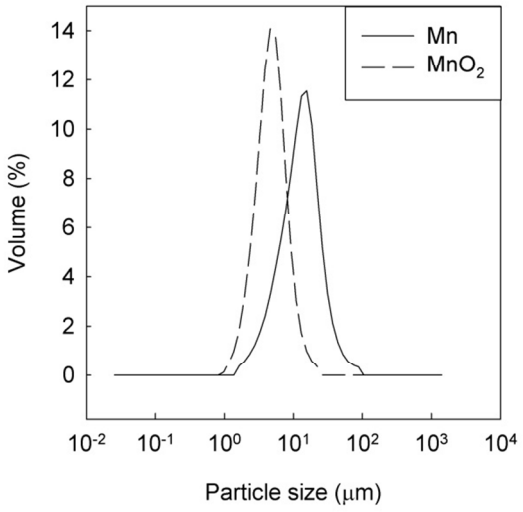


Figure S3. Particle size distribution of Mn and MnO_2 powder used for supplemental experiments.

Delay mixes were prepared by combining the components in conductive containers. Each was mixed on a vibrating shaker for 5 min, passed through a 30 mesh screen to remove any clumps, and then shaken again for another 10 min.

Aluminum tubes (15.24 mm long, 9.53 mm outer diameter, 4.74 mm inner diameter) and hand-held signal (HHS) delay housings[1] were loaded in two increments in the following order:

(1) 0.030 grams black powder (class 7)
(2) 0.050 grams 30/70 Si/Bi_2O_3 igniter
(3) first portion of delay mix
(4) press at 227 kg force (124.9 MPa)
(5) second portion of delay mix (same amount as in step 3)
(6) 0.030 grams black powder (class 7)
(7) press at 227 kg force (124.9 MPa)

The amount of delay composition was chosen such that the finished tubes and delay elements were nearly full. Column lengths for the tubes ranged from 11.84-12.12 mm. Column lengths for the HHS housings ranged from 8.76-10.01 mm. The finished items were ignited from the Si/Bi_2O_3 side with an electrically heated nichrome wire. Digital video recordings at 30 frames per second were used to determine functioning times. Linear column burning rates were calculated by dividing the column lengths by these times. For each composition and configuration, 5 items were prepared and tested and the results averaged.

Table S2. Combustion Experiment Data in Aluminum Tubes and HHS Delay Housings.

Mixture (Mn/MnO_2)	Configuration	Amount of Delay Composition (g)	Average Rate (mm/s)	Rate Standard Deviation
35/65	tube	0.57	6.12	0.21
45/55	tube	0.60	9.42	0.38
65/35	tube	0.63	6.27	0.10
35/65	HHS housing	0.46	6.19	0.22
45/55	HHS housing	0.47	8.73	0.32
65/35	HHS housing	0.48	5.86	0.07

References

1. Poret, J. C.; Shaw, A. P.; Csernica, C. M.; Oyler, K. D.; Estes, D. P., Development and Performance of the $W/Sb_2O_3/KIO_4$/Lubricant Pyrotechnic Delay in the US Army Hand-Held Signal. *Propellants, Explos., Pyrotech.* **2012,** *38*, 35-40.