Always a Step Ahead

ARDEC ARMAMENTS

Development of Environmentally Benign Pyrotechnic Delays

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OUTLINE OF TALK

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Outline

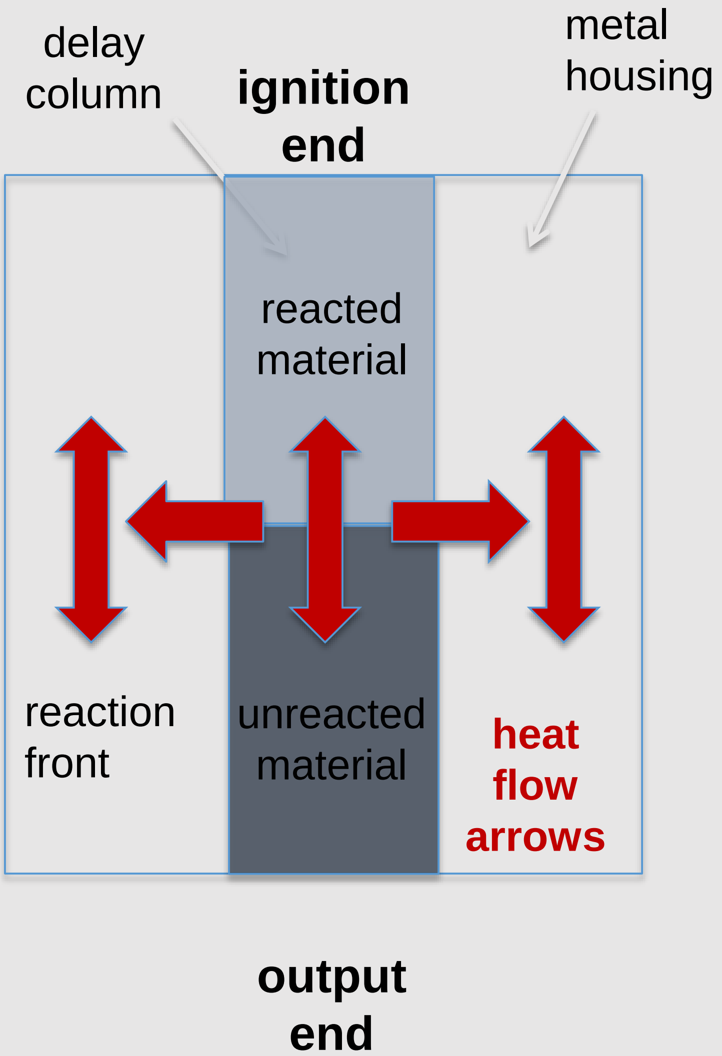
- Introduction to Pyrotechnic fuzes and delays
- Issues with current compositions used in pyrotechnic delays:
  - Hand held signals (M125A1, M126A1, M127A1, M158, M159, M195)
  - Smoke grenades (M201A1)
  - Fragmentation/Practice grenades (M213/M228)
- ARDEC's efforts to reengineer traditional pyrotechnic delays for fuzes
- Conclusions
- Acknowledgements

Pyrotechnic Delays

- Pyrotechnic delays are chemical timers that provide a delay between initiation and the intended event (*i.e.* fragmentation)
- Delay compositions can be either gas-producing or “gasless”
  - Gasless delays typically produce *less than* 10 mL gas per gram composition
  - Gasless delays are critical for sealed devices like most fuzes

Pyrotechnic Delays

- Pyrotechnic delays are composed of finely powdered metals, oxidizers, and additives pressed into metal tubes.
- Upon ignition a chemical reaction takes place between the constituents liberating a controlled amount of heat.
- The rate at which the reaction front moves from end to end can be controlled by varying the fuel/oxidizer ratio, constituent particle size, and loading pressure.
- Heat transfer within the column and ***into the housing*** also controls the burning rate.

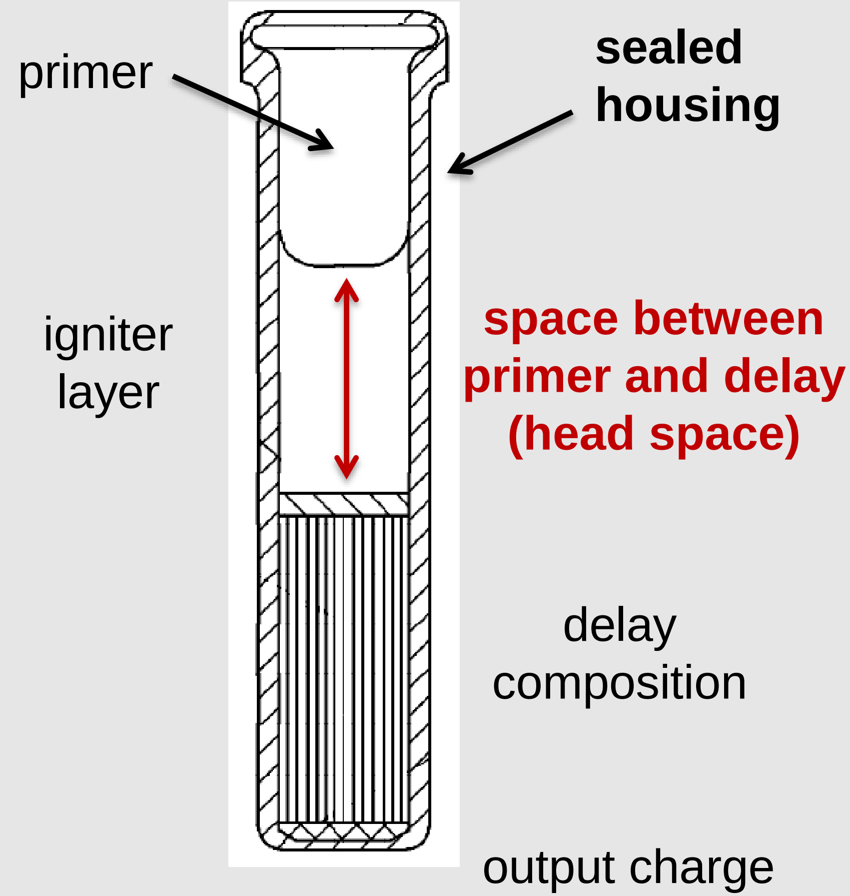


GASSLESS DELAYS

- Must design delay compositions to be nearly gasless for sealed fuzes

- If too much gas is produced by the delay it can lead to excessive pressure build-up in the sealed housing

- Excessive pressure can increase burning rate or cause *case rupture and failure*



M201A1 Fuze Delay Case Cross Section

Rational for Research

- Current military delays contain potassium perchlorate, barium chromate, and lead chromate which are environmentally hazardous compounds
- Reducing the use of hazardous materials in military munitions is critical for DoD since it will lead to safer manufacturing, eliminate risk of test range contamination, and potentially lead to cost savings.
  - The Under Secretary of Defense for Acquisition, Technology and Logistics issued a memorandum “Minimizing the Use of Hexavalent Chromium” in 2009 to reduce the use of Chromium (VI) whenever possible.
  - Massachusetts forced Camp Edwards to stop training with pyrotechnics in 1997 due to perchlorate ground water contamination from spent munitions.

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CURRENT MILITARY DELAY COMPOSITIONS

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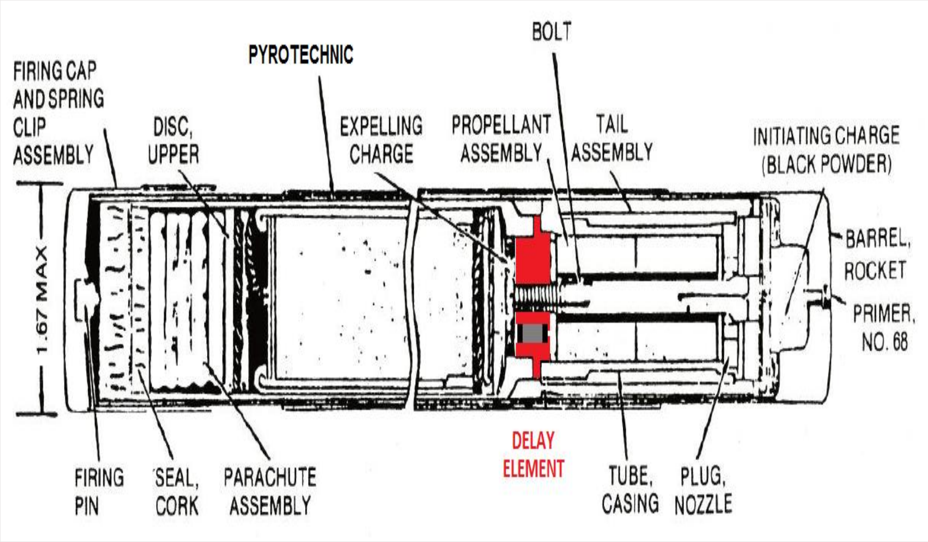
HHS and M208

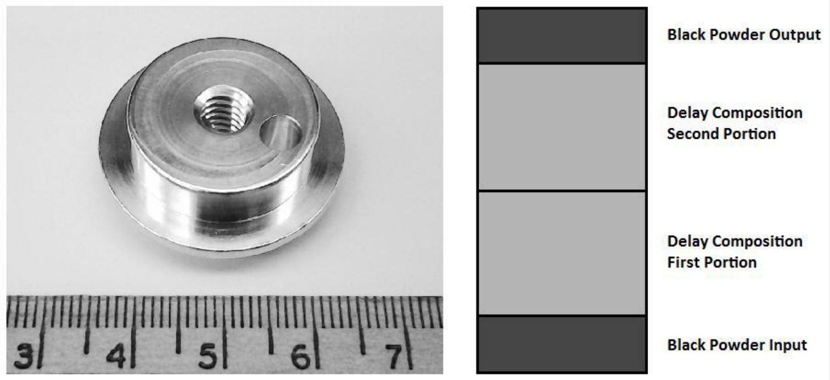
M201A1
M213, M228

Composition Name	Components	Inverse Burn Rate (s/in)	Inverse Burn Rate (s/cm)
tungsten delay	W, $BaCrO_4$, $KClO_4$, diatomaceous earth	0.15 – 38	0.06 – 15
manganese delay	Mn, $BaCrO_4$, $PbCrO_4$	2 – 14	0.8 – 5.5
zirconium-nickel delay	Zr-Ni alloy, $BaCrO_4$, $KClO_4$	2 – 12	0.8 – 4.7
T-10 delay	B (amorphous), $BaCrO_4$	0.35 – 3.5	0.14 – 1.4

Recent ARDEC Efforts at Redesigning Pyrotechnic Delays

- ARDEC researched alternatives to the tungsten delay used in the hand held signal family of rockets (2009-2012)
  - Funded by the US Army, RDECOM, Environmental Technology Acquisition Program
- These rockets all use the same tungsten delay housed in a massive aluminum disk (e.g. heat sink!) that serves as a structural component of the rocket
- Rocket motor burns for ~0.5 seconds and the delay vents into an empty chamber (or so we thought…more on this later!)





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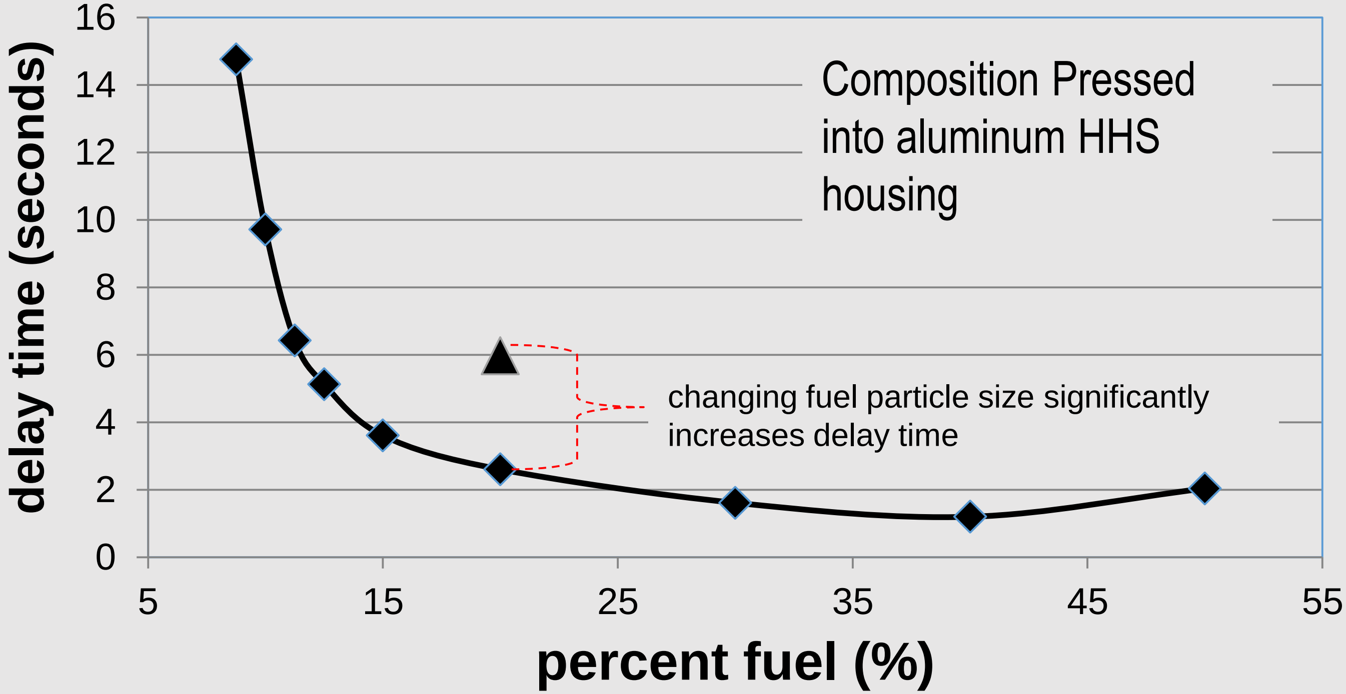
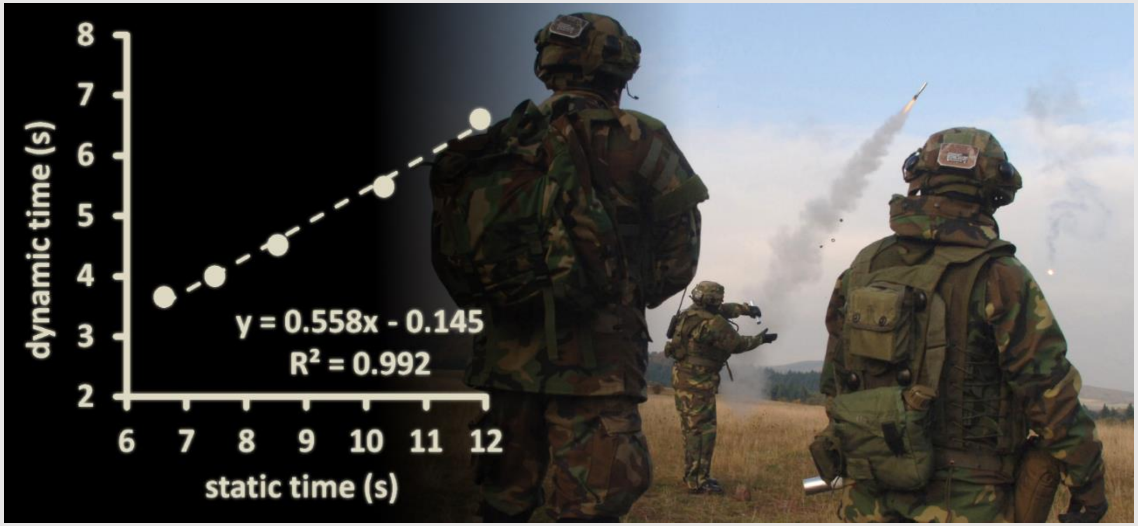
THE BORON CARBIDE DELAY

- The delay is based on boron carbide, sodium periodate, and polytetrafluoroethylene (PTFE)
- No more sensitive than the conventional tungsten delay
- Easy to tune the burn time by varying the fuel and oxidizer levels (while holding the PTFE constant at 10%)
    - Design time of 5 seconds



STATIC VS. DYNAMIC BURN TIMES

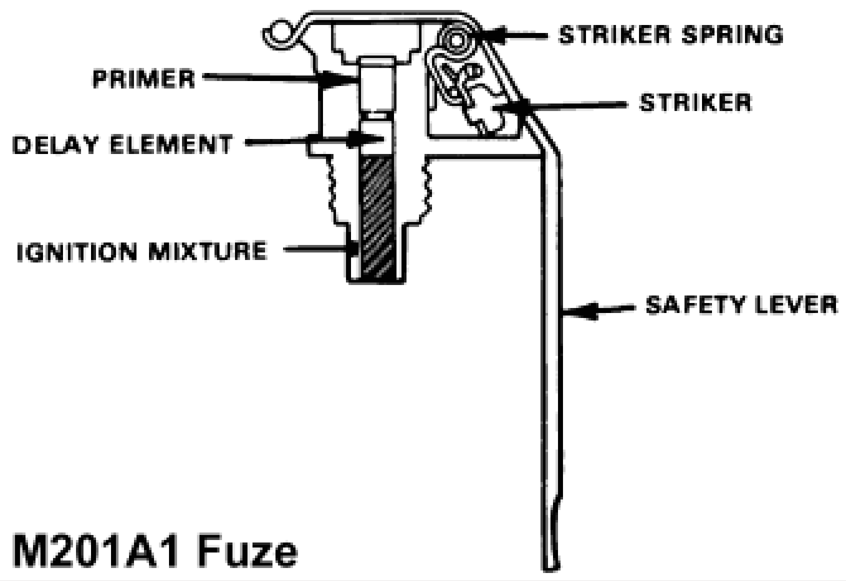


- In 2015 the boron carbide delay was functioned in hand held signal rockets and the dynamic delay times were measured
  - The short duration of rocket motor pressurization affected the delay burning time much more than we thought it would
  - Due to ambient pressure in the rocket motor chamber the dynamic burn time was approximately 50% of the static open air burn time!!!
  - Still meets the design requirement

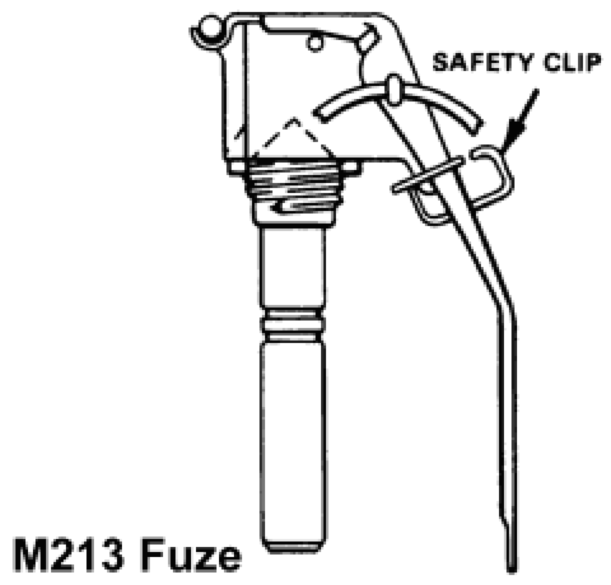
GASLESS DELAYS FOR FUZES

- For the past 2+ years ARDEC has been working on developing gasless delays for fuzes used in both smoke grenades and hand grenades
  - Three year effort funded by the Strategic Environmental Research and Development Program (SERDP)
- Goal is to develop environmentally benign delay compositions for both M201A1 and M213/M228
  - M201A1 fuze for smoke and incendiary grenades (M18, M83, AN-M14)
  - M213 fuze for M67 fragmentation grenade
  - M228 fuze for M69 practice grenade
- Focus is to develop simple binary or ternary delay systems that use readily available, low cost, non-toxic materials
  - Use extensive thermochemical modeling to aid in the design process and assist in understanding the thermodynamics of these reactions

M201A1 AND M213 FUZE



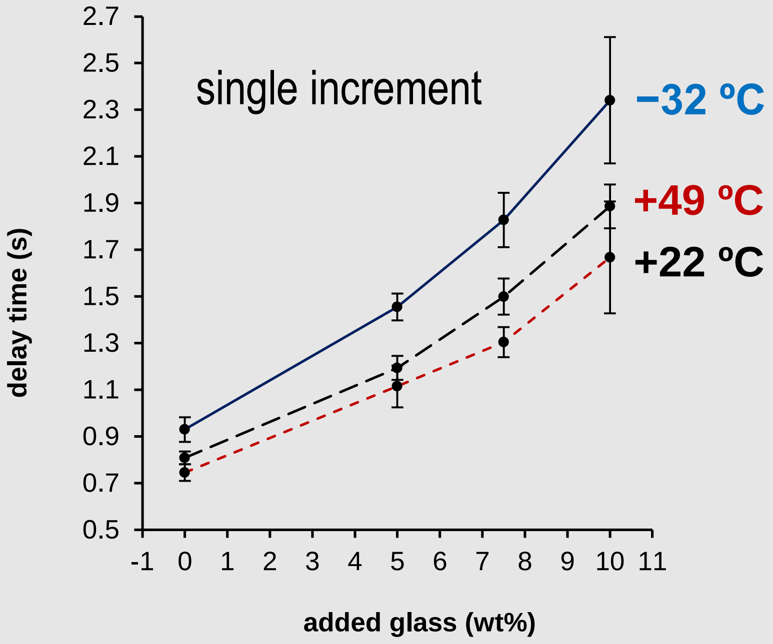
- Burn time from 1-2.3 seconds
- Delay pressed into an inner aluminum tube that is inserted into the fuze body

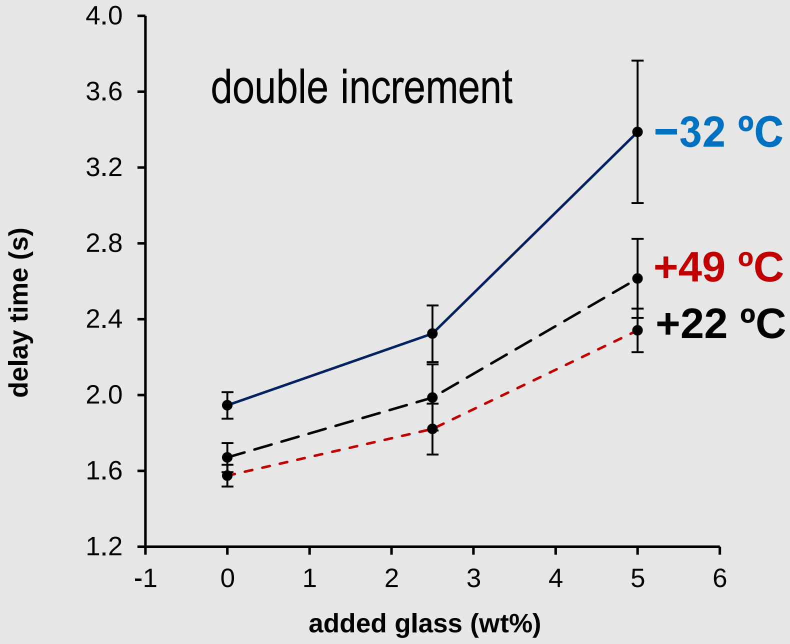


- Burn time from 4-5.5 seconds
- Delay is pressed *directly* into the zinc die cast fuze body
- Typically delay is pressed in 4 increments
- EVERY fuze is checked for defects to ensure safety

BINARY MN/MNO$_2$ DELAYS

- A very unique binary delay system that contains manganese in both the metal and metal oxide
- Chemical reaction produces manganese oxides that are more stable than MnO_2, thus the thermodynamic driving force for the reaction
- Below delay times are measured in the M201A1 fuze housing





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M213 FUZE

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- Since the M213 fuze has a longer delay time than the M201A1 we looked into delay systems that are slower then Mn/MnO_2
  - Evaluated a slower system composed of W/MnO_2
- Based on previous work performed with the W/MnO_2 in the M201A1 housing, we focused on 50/50 W/MnO_2 loaded into the M213
- Recent laboratory results show that the 50/50 W/MnO_2 works *really well* in the M213
  - Cold (-60F) 6.139 s (0.136)
  - Ambient (70F): 5.179 s (0.173)
  - Hot (145 F): 4.822 s (0.149)
- As part the SERDP program ARDEC developed a new igniter system that is used as both an igniter *and* expulsion charge!
  - Both the M201A1 and M213 use the ARDEC igniter on both the ignition and output charges
  - Contains **NO** hazardous materials (i.e. zirconium) and is safer to handle than existing ignition systems such as A1A!
  - Patent pending

CONCLUSIONS

- Over the past several years ARDEC has been working on developing new, environmentally benign delay compositions for a variety of munitions
- The use of thermodynamic modeling helps in the design process and reduces the amount of laboratory testing
- Smart selection of components aids in developing robust materials systems that are low cost, easy to obtain, and environmentally benign
- Testing in actual hardware (i.e. fuze) reduces the amount of laboratory testing and results in materials design that is better matched to end user requirements

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