Lifetime extension of HMX under demanding time-temperature conditions

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It will not be possible to discuss some details of this presentation since they relate to USML listed materials

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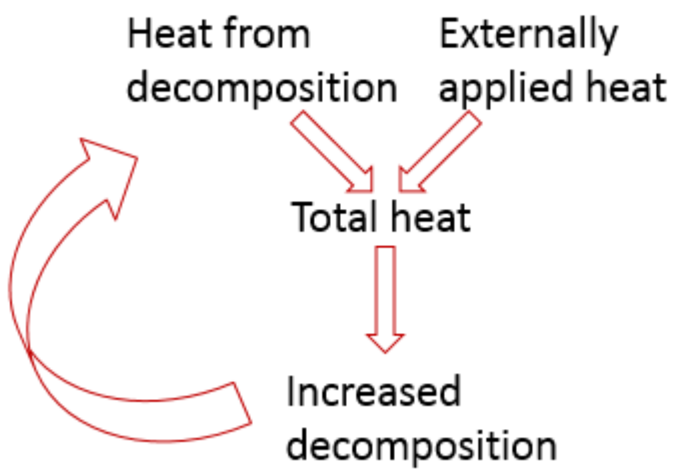
Lifetime Extension of HMX

The Challenge

- Decomposition of an explosive material can cause its temperature to exceed the applied temperature, leading to runaway degradation and autodetonation/deflagration.
- There are two fundamental ways to address this:
  - Increase the rate at which heat is removed from the system (by increasing thermal conductivity, increasing object surface area, etc.).
  - Reduce the rate of heat generation per unit volume



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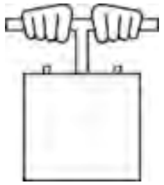
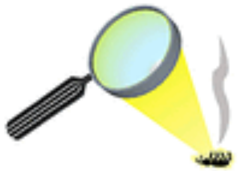
The Concept

- ❑ Reduce heat generation with energetic and non-energetic additives
- ❑ Potential issues facing an additive approach for HMX are
  - ❑ Explosive performance



  - ❑ Thermal decomposition
    - ❑ Offgassing/weight loss
    - ❑ Autodetonation/deflagration/burn



  - ❑ Impact sensitivity

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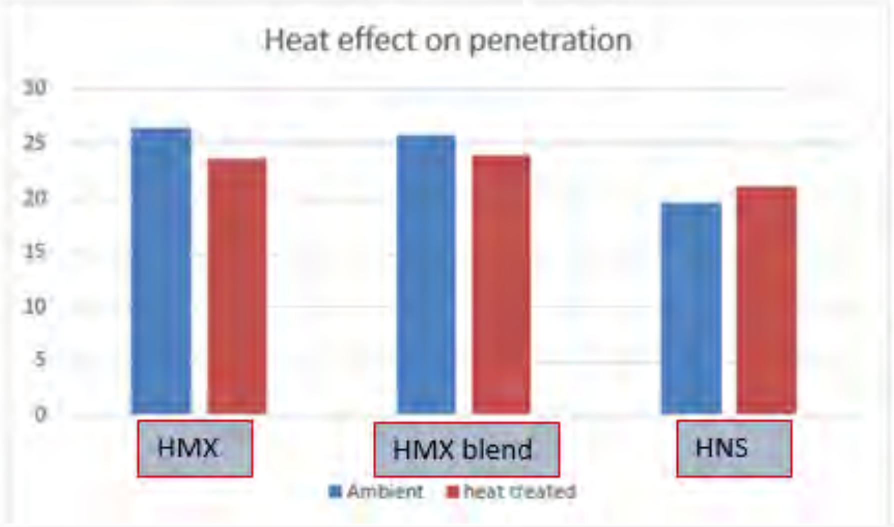
Performance

- Substantial nitramine can be replaced without substantial performance loss.
- In the example, approximately half of the HMX was replaced with lower-velocity explosive and inert content.
  - At ambient temperature, penetration is close to HMX.
  - After holding the charges for a day at 340°F (an aggressive condition) the test sample remained comparable to HMX.

Known explosive	Percent not nitramine	Detonation velocity (m/s)
Octol	25	8480
LX-11	20	8320
HTA-3	51	7893

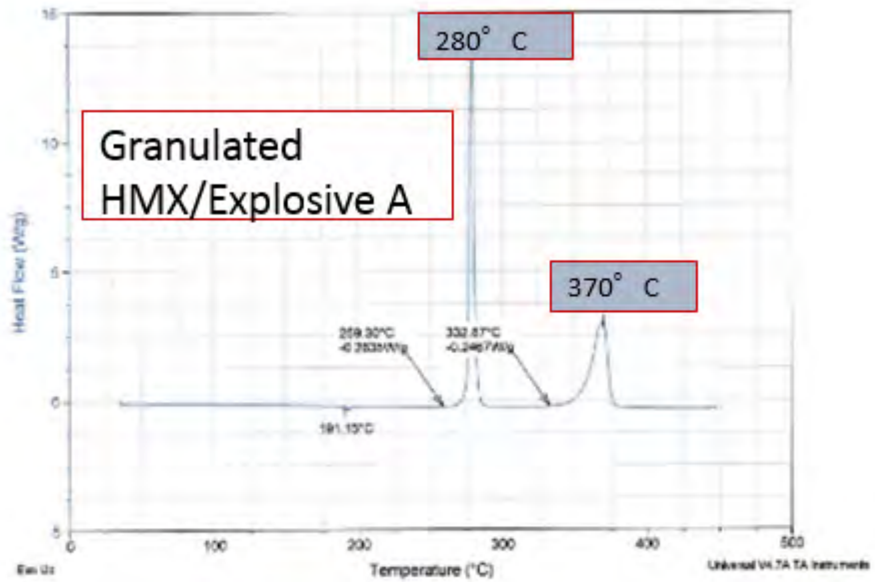


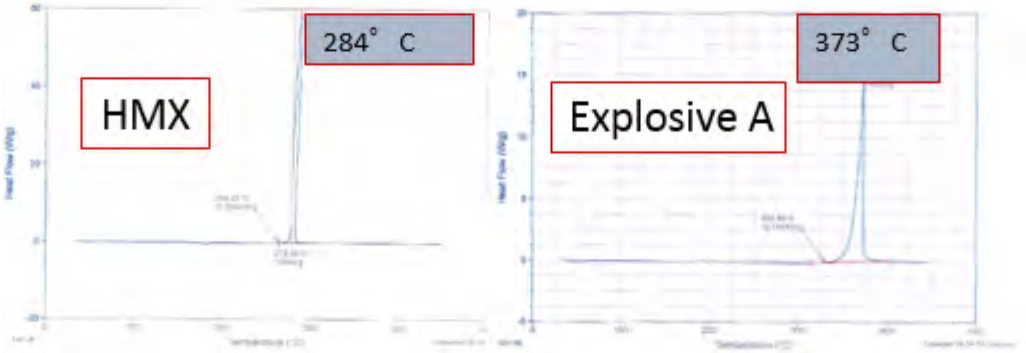
PJ2506 charges at ambient and after 1 day at 340°F

Detonation velocities from: Dobratz, B. Properties of chemical explosives and explosive simulants 1972 and Costain, T. The sensitivity, performance and material properties of some high explosive formulations TR4587 1973

Thermal Stability Testing – Differential Scanning Calorimetry (DSC)

- The DSC testing is useful for catching gross incompatibilities.
- The fast timescale, small sample size, and unrealistic configuration do not allow it to pick up subtle effects.
- For example, DSC results of HMX and a known cookoff-resistant explosive, separately and when granulated together, overlay perfectly.
- These ingredients can be declared compatible on this basis and might be expected to be a simple hybrid of the two decomposition behaviors.
- This is not the case in an actual component.





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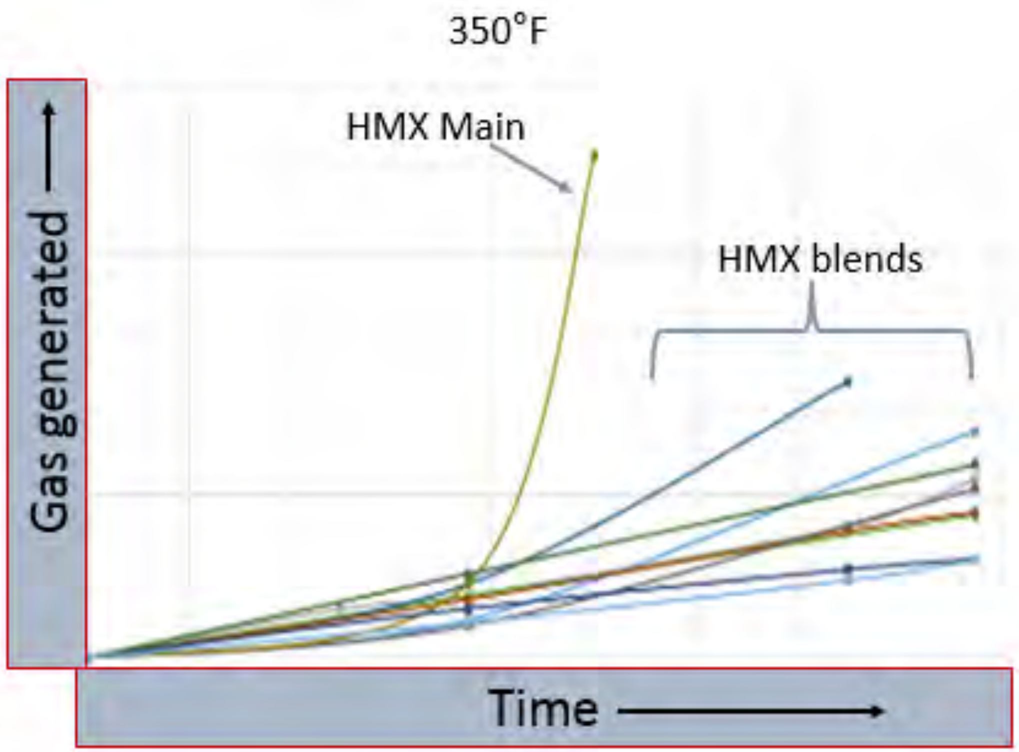
Thermal Stability Testing – Ampule Thermal Stability

- A significantly more realistic timescale is provided by ampule thermal stability testing.
- Degradation can be assessed over days/weeks.
- Larger sample sizes can be used, albeit only as a granular powder.
- A difference from HMX main can be seen in all of the samples.
- The change in slope in this test is of greater interest than the absolute value.



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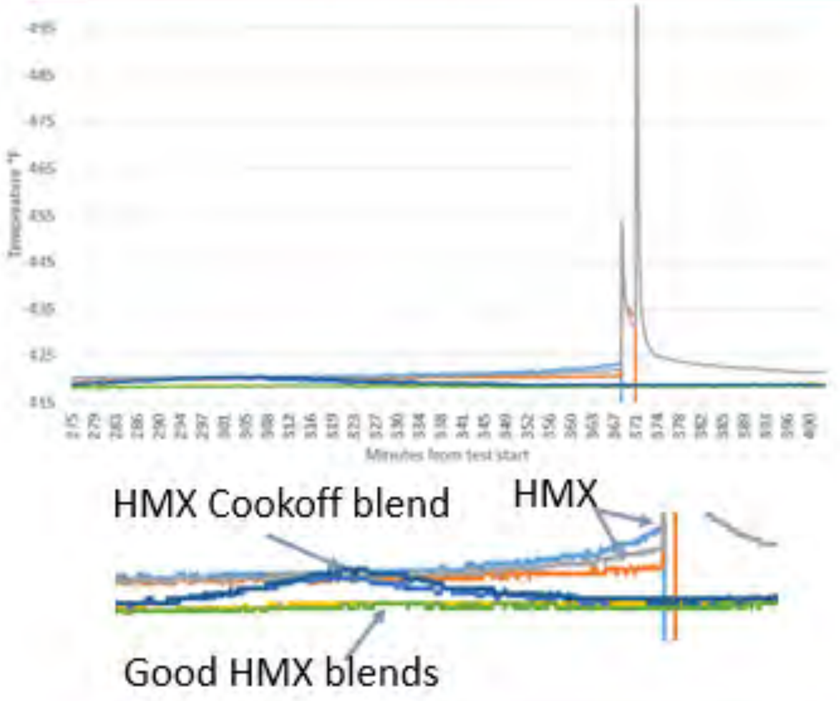
Thermal Stability Testing – Small Components

- The figure illustrates the thermocouple trace of boosters heated to 420°F in a sealed container.
- The gray line is an HMX booster.
  - Temperature is initially steady, and then begins to exponentially rise as it runs away.
- The green and yellow lines are HMX blends that are decomposing, but at a steady rate.
- The dark blue line is a HMX blend known to provide cookoff advantages.
- The temperature increase did not lead to detonation, but to a simmer. A mild early decomposition is useful in a fire, but not downhole.

Temperature trace of boosters heated to 420° F



Good HMX blend | HMX cookoff blend

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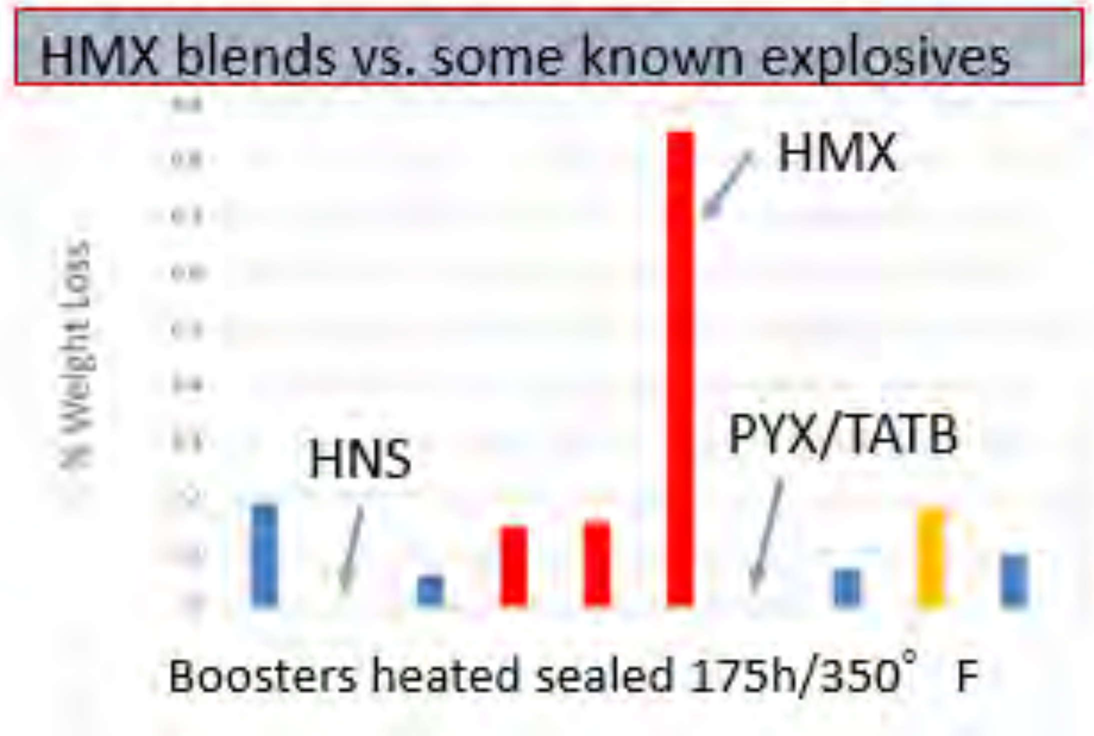
Thermal Stability Testing – Small Components

- A series of boosters was tested at 350°F to further narrow down the formulations.
- The boosters for some formulations appeared intact but fired poorly (yellow) or not at all (red).
- Formulations in blue all fired with reasonable power. One formulation from this group showed particularly low weight loss (~5%) and progressed into further testing.



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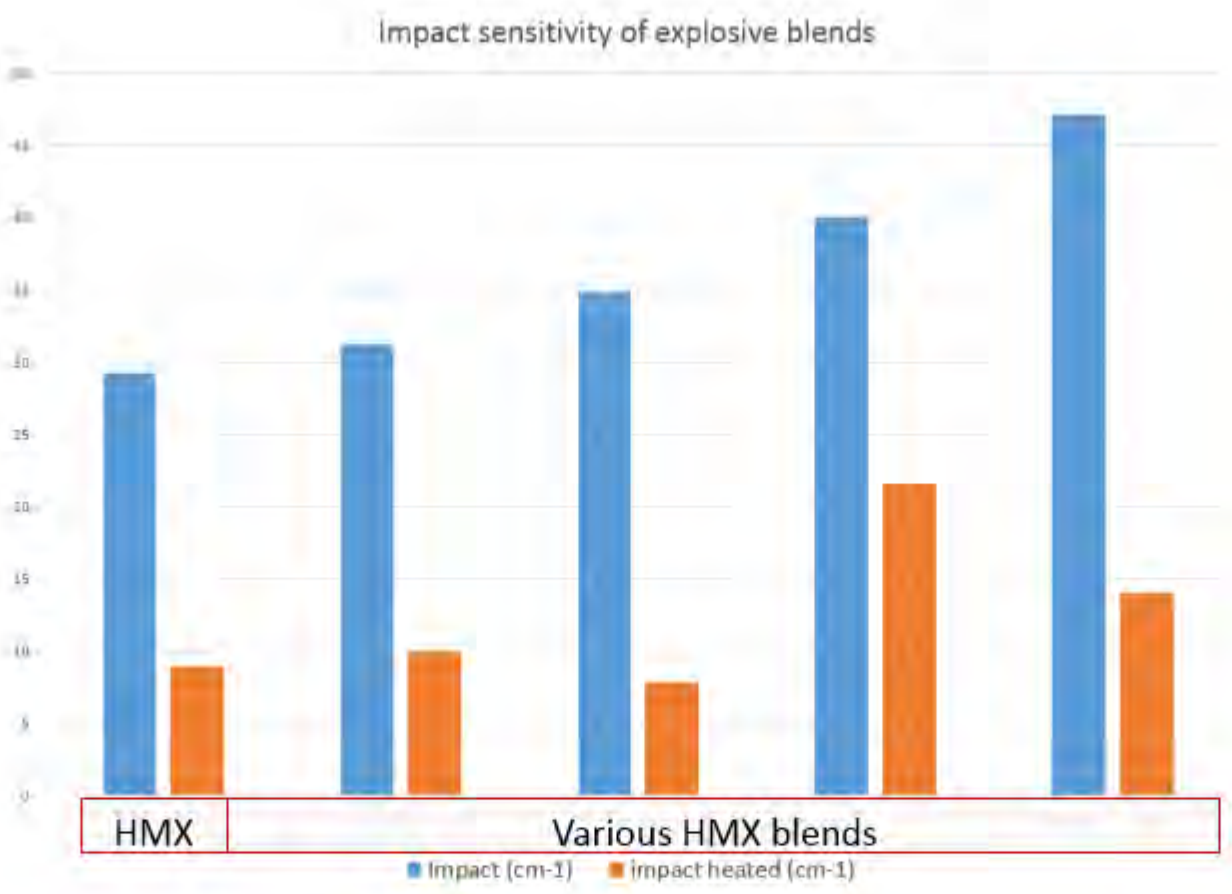
Impact Sensitivity

- The various HMX blends still possess increased impact sensitivity when the HMX converts to the delta crystal form.
- Some (including the preferred candidate) test as somewhat less sensitive, but typical HMX handling still seems appropriate.
- This did not prove to be a formulation selection criteria.



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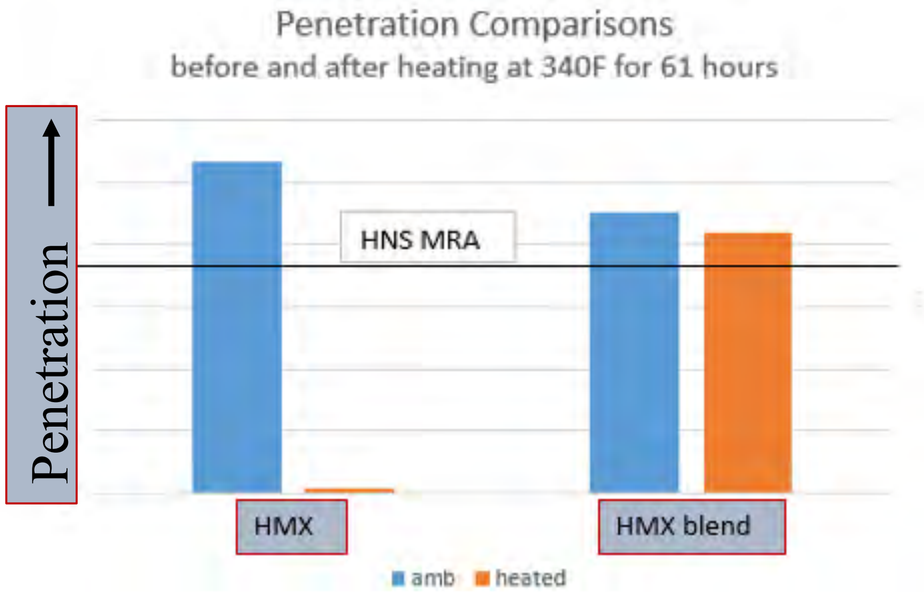
Performance Testing after Heating

- Initial heat testing of charges was performed with unoptimized loose charges heated in a sealed gun section and then cooled to ambient temperature before firing.
- After 61 hr, the charges were removed and inspected. The HMX charges had burnt up early (26 hr) and so could not be tested further.
- After 61 hr, the selected HMX blend charges were fired and showed a 7% performance loss, but still showed significantly greater penetration than HNS.



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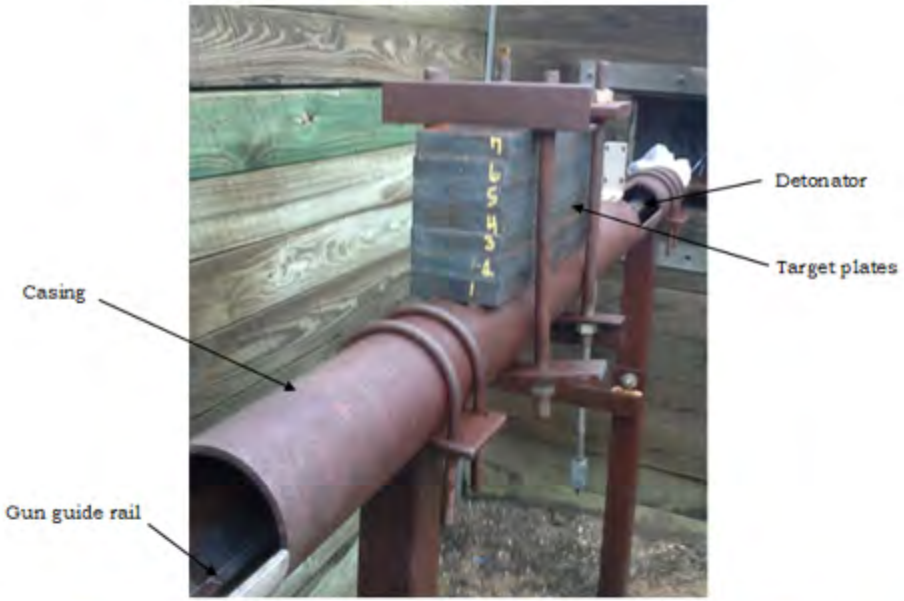
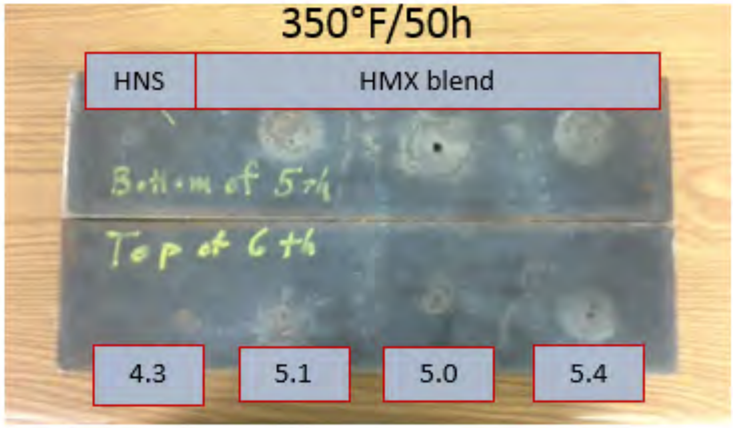
Performance Testing at Temperature

- Loose charge testing provides some insight into the level of performance degradation, but a more realistic picture is provided by firing the charges while at temperature.
- In these tests, the HMX blend charges were pulled out of the oven and immediately fired into steel plates.
- A 340°F/175-hr test was performed, followed by a 350°F/50-hr test.
- In both tests, the HMX blend outperformed the HNS baseline.





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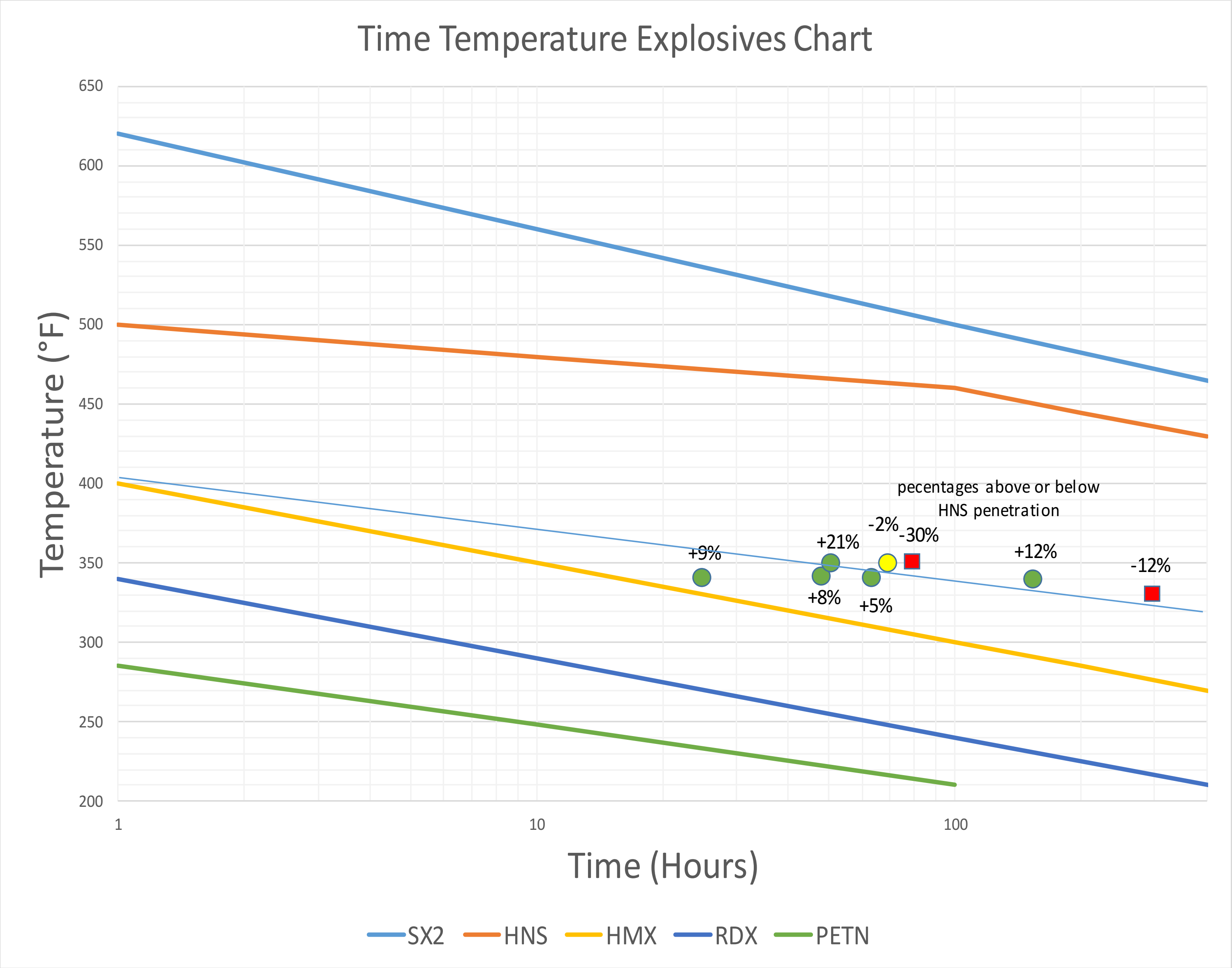
Summary of Heated Charge Tests

- The figure summarizes the charge tests performed with the selected HMX blend (both loose charges and hot well tests).
- Below the line constructed, the HMX blend provides a performance advantage over charges using high-temperature explosives.



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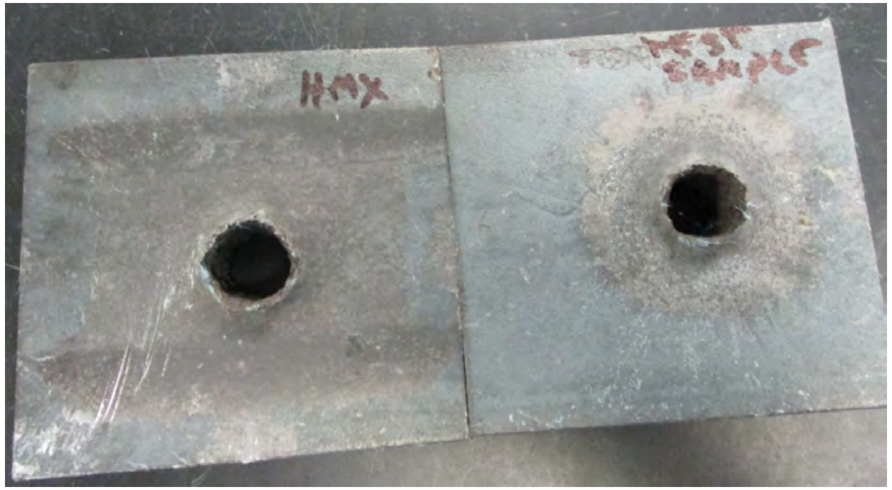
Conclusions

- Performance better than typical high temperature explosives can be maintained when significant quantities of HMX are substituted with low-/no- energy components. Without modification, many charges shot within 5% of fully developed HMX charges. With optimization, this would be expected to improve.
- This flexibility allows sufficient material to be added to a nitramine explosive to reduce the effect of self-heating.
- There is potential to achieve higher performance than high-temperature explosives can deliver in the range where typical nitramines cannot be safely used.



QUESTIONS? THANK YOU

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