SAND2013-5352C

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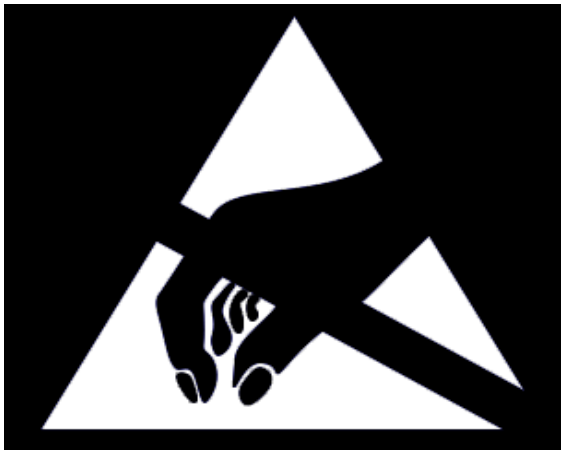

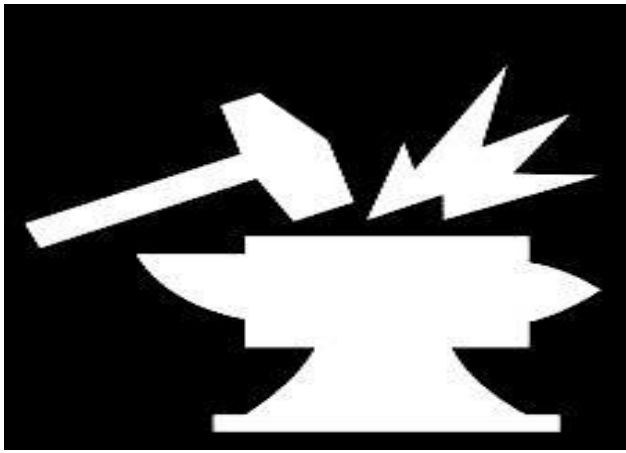

# Safety Testing of Ammonium Nitrate Based Mixtures

## Interpretation of Results, Reporting, and Method Development

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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# Component Materials of Interest

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| Material | Composition | State |
|---|---|---|
| Ammonium Nitrate (AN) | Fertilizer grade $NH_4NO_3$ | Ground, dried |
| CAN-27 fertilizer | 78% AN, 20% $CaMg(CO_3)_2$, ~2% $Mg(NO_3)_2$ | Ground, dried |
| Aluminum powder | 99.7% Al, Valimet H-2 → H-95 | Spherical (7-190µm) |

AN prills

CAN-27 prills

Al powder

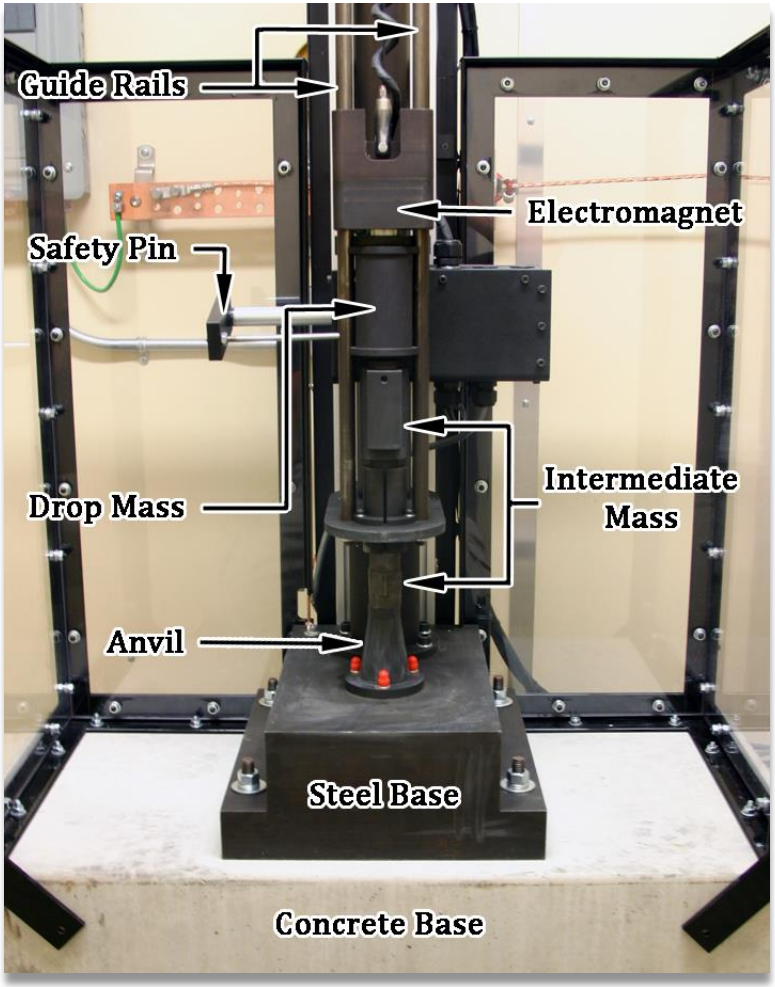
# Impact Testing

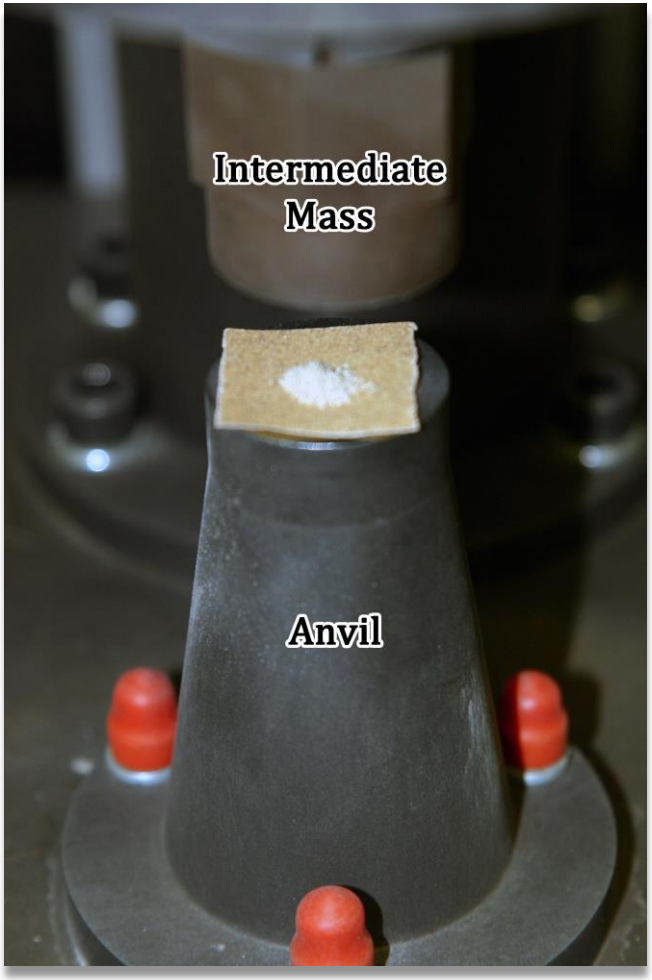
- Modified Bureau of Mines (MBOM) impactor design utilizing Type-12 tooling

- Test parameters:
  - 2.5kg drop mass and matching intermediate mass
  - 180 grit garnet sandpaper
  - 35±2mg sample mass

- Reaction detection is accomplished through operator observation during each shot and examination of the sandpaper post-shot.

# Impact Testing



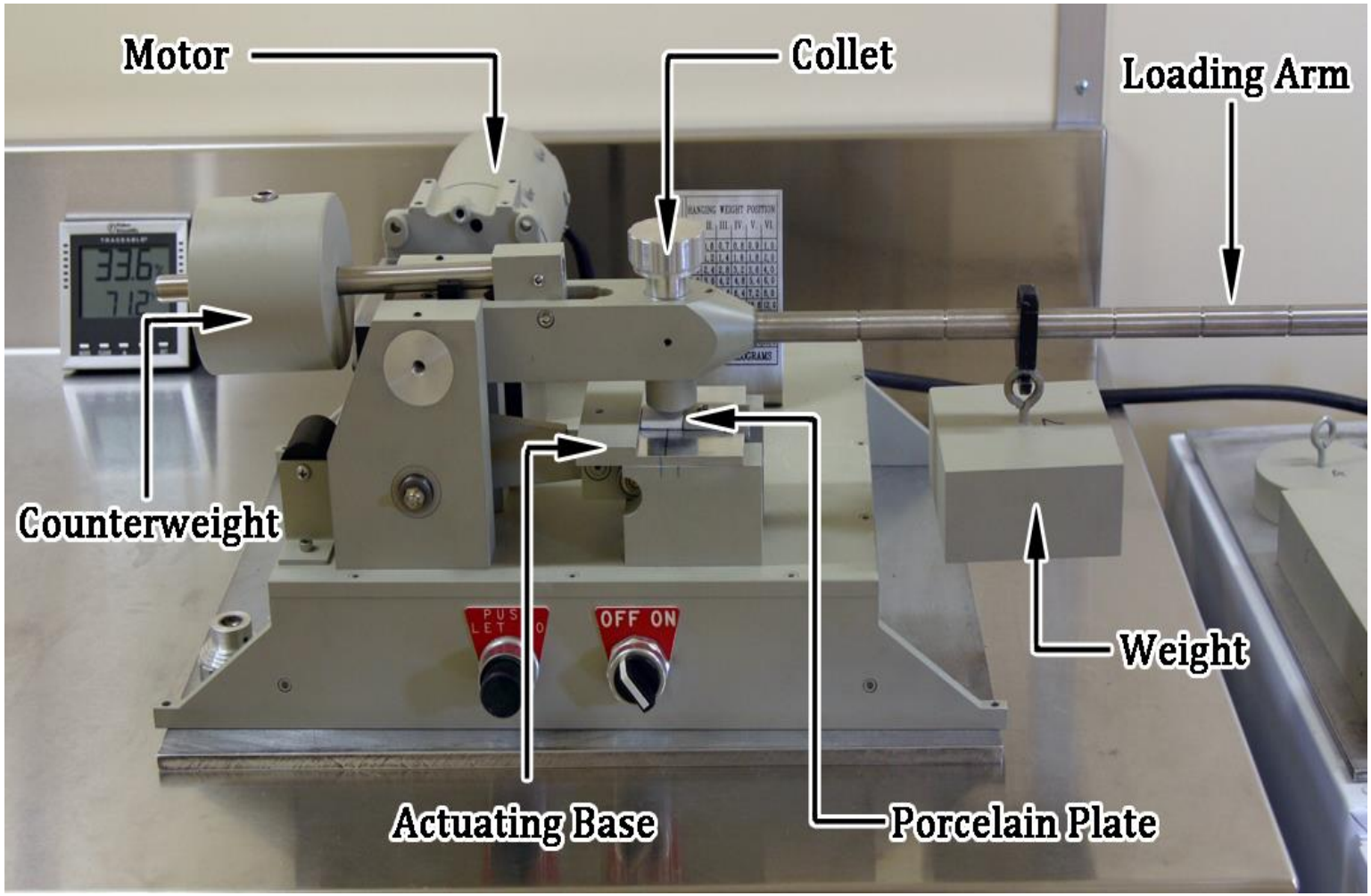
# Friction Testing

- Test parameters:
  - Porcelain pins/plates manufactured in Germany
  - Approximately 10mm$^3$ of material used per trial
  - Fresh sample/surface utilized for each trial

- Reaction detection is accomplished through operator observation (snaps/crackles, ejecta, flashes, odor) during each shot.

**Porcelain Pin** – useable twice (each end 1x)
**Porcelain Plate** – useable 5-10 times per side

# Friction Testing



# Electrostatic Discharge (ESD) Testing

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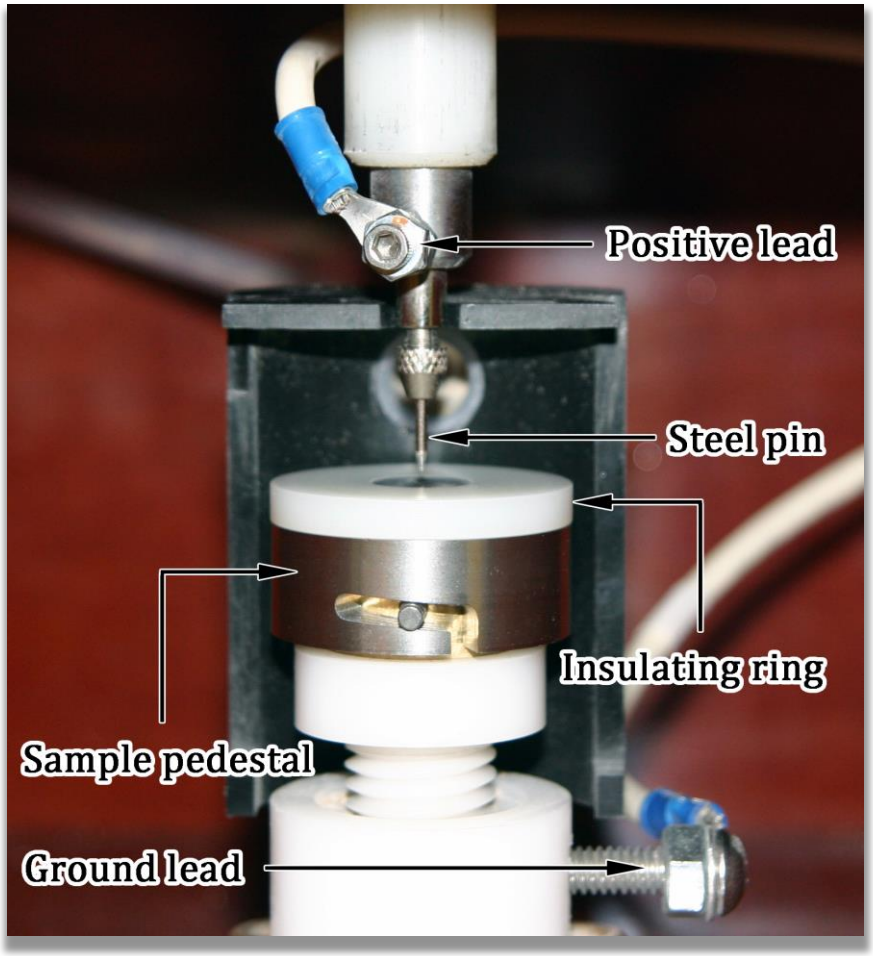
- Allegany Ballistics Laboratory (ABL) apparatus with an approaching needle design
- Usually conducted prior to impact or friction in order to determine grounding and bonding practices
- Multiple reaction detection methods are used, including gas detection ($CO/CO_2$), photography, and operator observation.
- Material results are typically compared to PETN



# ESD Testing Reaction Detection

- Gas Analyzer ($CO/CO_2$)
  - Only useful when organic fuels are utilized (diesel, palm oil, sawdust, sugar, nitromethane, etc.)
  - Cannot be used for the most common fuel- aluminum powder.

- Camera System
  - 1 second exposure using 200mm macro lens and DSLR camera
  - Relatively new system, not in widespread use at this time
  - No standard for Go-No Go determination; still relies on operator judgment

# Small-scale Sensitivity Results

| Material | Fuel Wt. % | Impact (cm) $H_{50}$ | Friction (kg) TIL, 0 of 20 | ESD (J) TIL, 0 of 20 |
|---|---|---|---|---|
| PETN | - | 12.5 ± 0.8 | 3.3 | 0.125 |
| ANAl [Valimet H-2] | 10 | 84.1 ± 3.7 | 18.0 | 0.025 |
| | 15 | 101.9 ± 2.1 | 16.8 | 0.025 |
| | 20 | 102.6 ± 3.8 | 21.6 | 0.0125 |
| ANAl [Valimet H-5] | 10 | 95.0 ± 2.7 | 18.0 | 0.0125 |
| | 15 | > 115 | 18.0 | 0.0125 |
| | 20 | > 115 | 19.2 | 0.0125 |
| CANAl [Valimet H-5] | 14.4 | > 115 | 25.2 | 0.00625 |
| | 17.1 | > 115 | 25.2 | 0.00625 |
| CANAl [Valimet H-2] | 10 | 90.2 ± 0.8 | > 36.0 | 0.0125 |
| | 14.4 | > 115 | > 36.0 | 0.0125 |
| CANAl [Valimet H-95] | 14.4 | 112.7 ± 3.2 | 28.8 | 0.0125 |

**MAX stimulus levels:** Impact – 115cm, Friction – 36.0kg, ESD – 9.375J

# Reaction Detection - Easy

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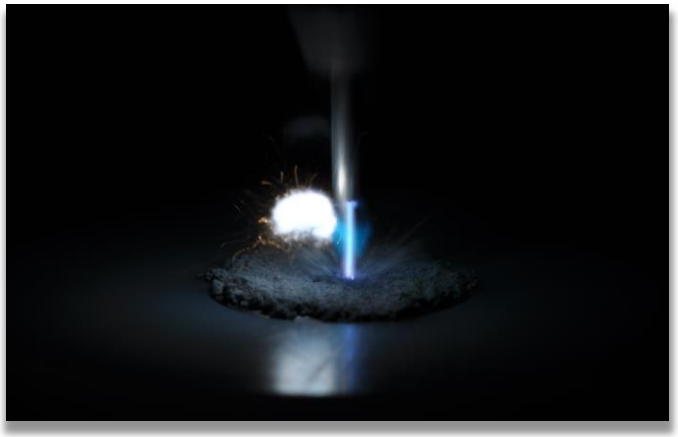
ANAl
20% H-2 Al



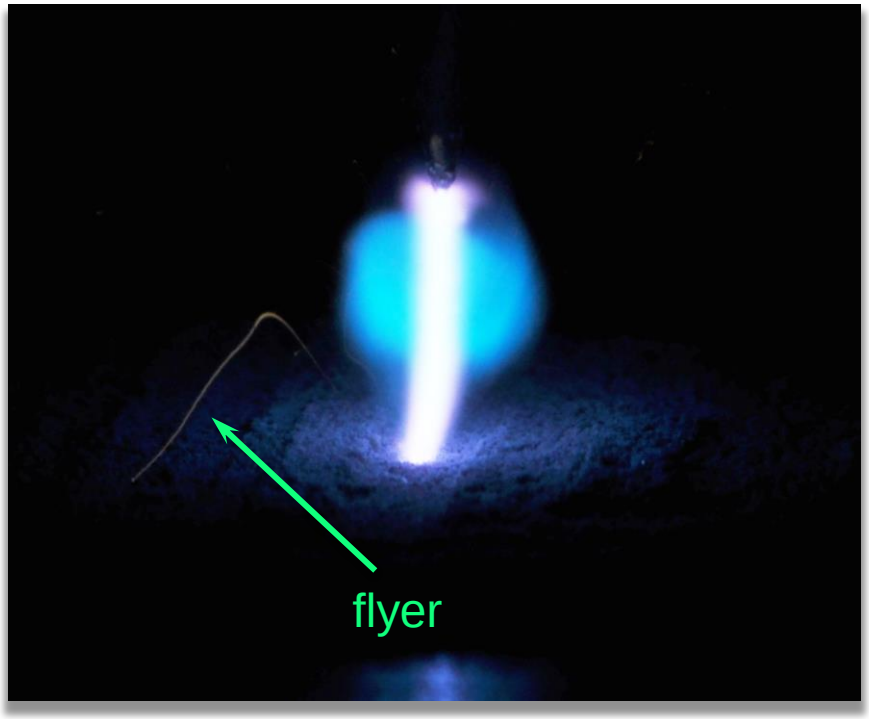
0.075 Joules
(TIL +2)

0.025 Joules
(TIL +1)

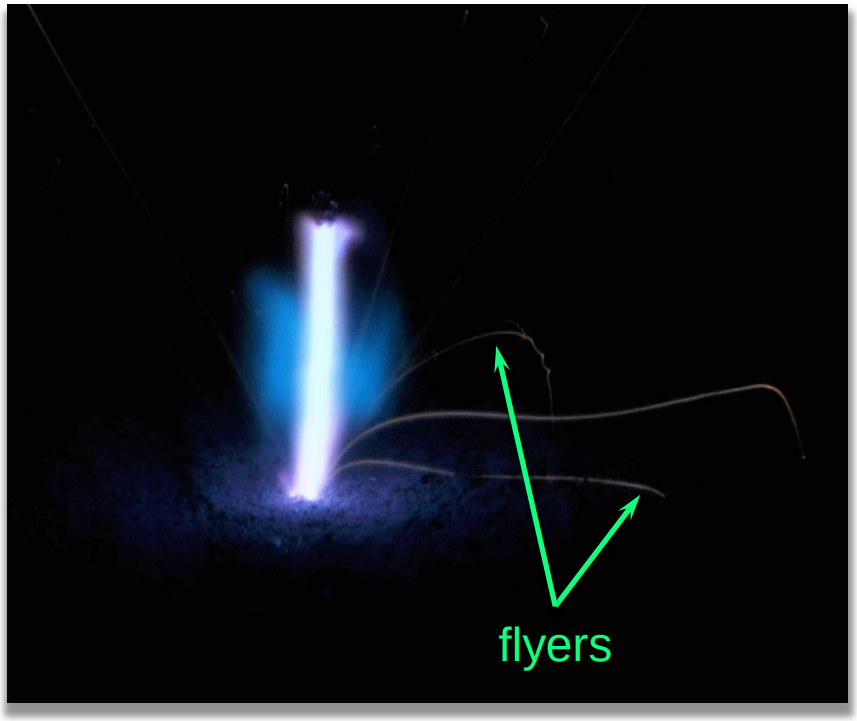
CANAl
10% H-2 Al

# Reaction Detection - Hard

CANAl - 17.1% H-5 Al




0.025 Joules
(TIL +2)




0.0125 Joules
(TIL +1)

# Possible False Indicators

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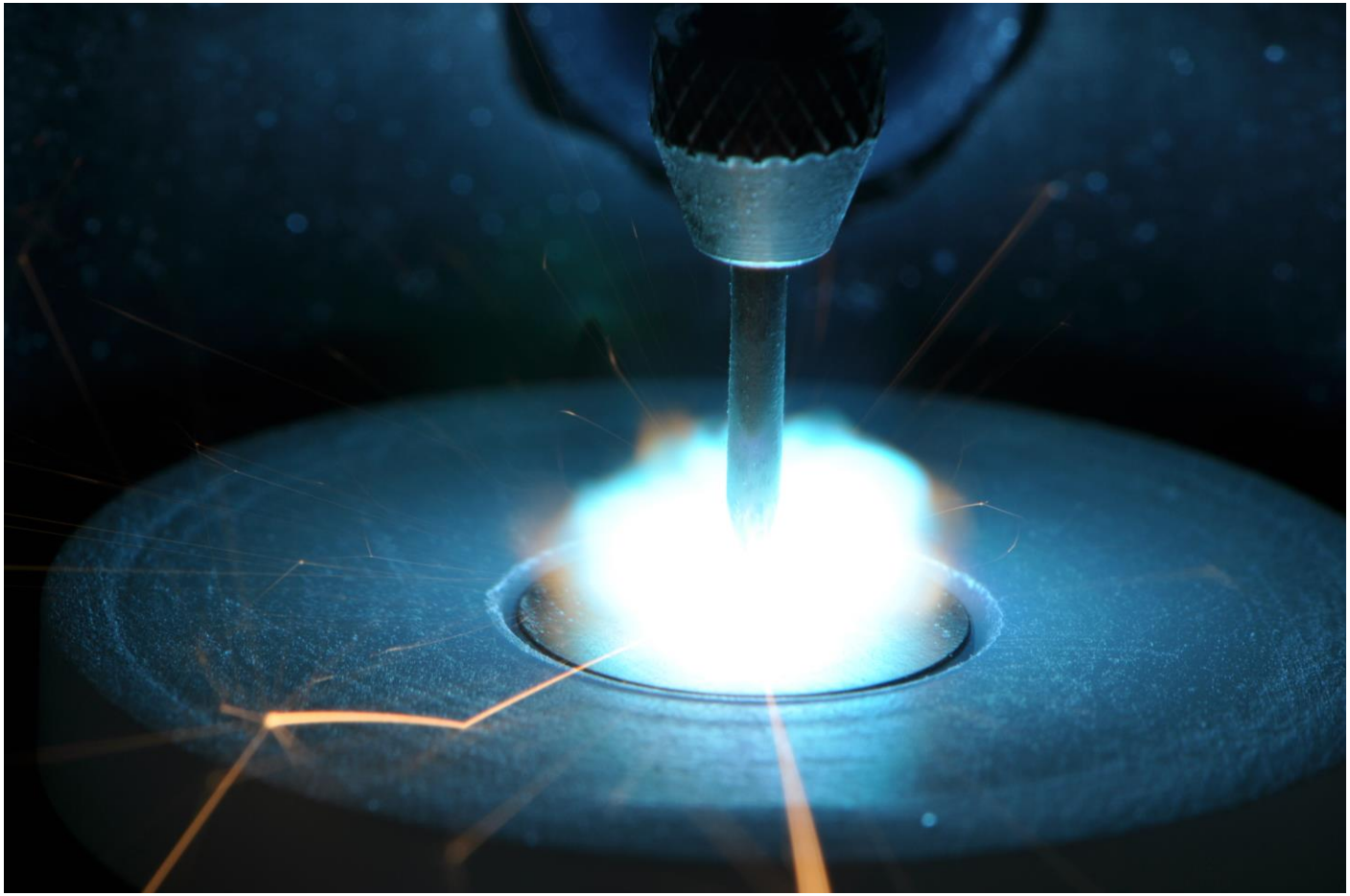
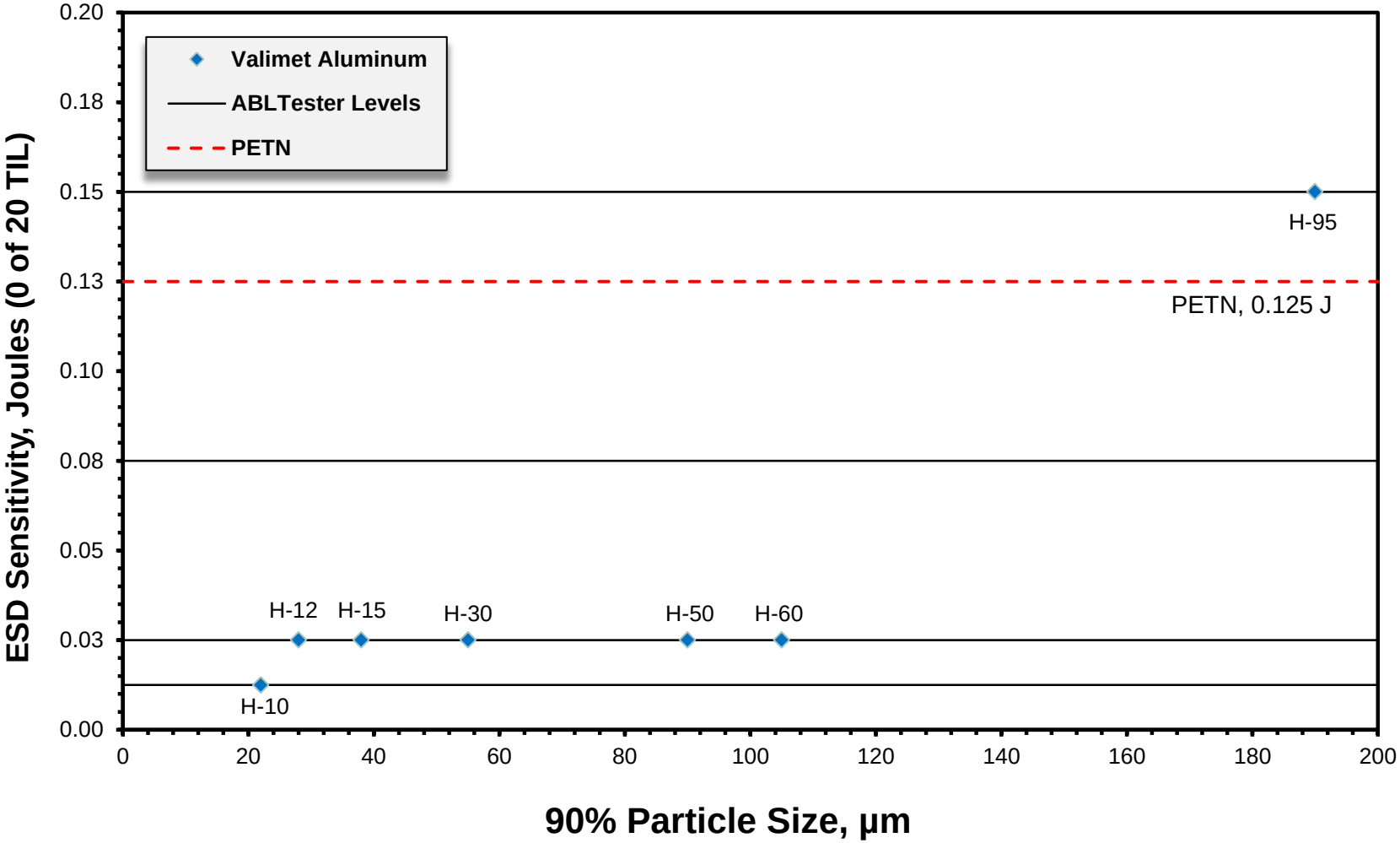


Blank test – 3.125 Joules

# Possible False Indicators

- While flyers can be a good indicator of a positive reaction, they can occur during blank tests (no material present) due to ablation of the steel base.
- Typically, this does not occur at lower energy levels (<0.1J).
- Flyers from this effect have a vivid orange color and straight trajectory compared to those caused by sample materials.
- Using current Go-No Go criteria, low-order ignitions of the Al powder fuel are causing high-ESD sensitivity results.

# Aluminum Powder ESD Sensitivity



# Propagating Explosion?

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- Are reactions (Go's) during small-scale testing indicative of a propagating explosive hazard when handling bulk quantities?

- Close inspection of photographs of reactions indicate that the reaction does not appear to begin at the site of electrical contact, but after the material is dispersed into the air.

- While material was always ejected from the sample pedestal during Go's, the majority of the material was never consumed.

# Propagating Explosion?

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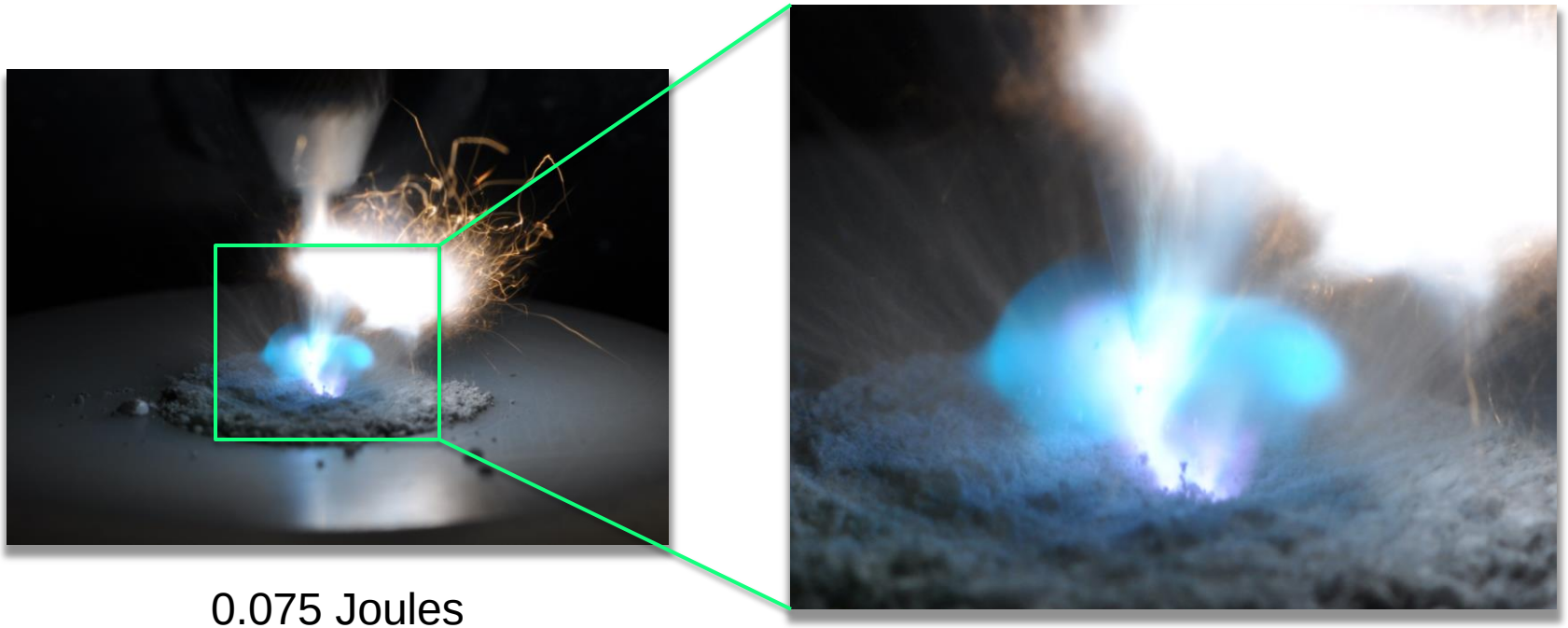
ANAl - 10% Valimet H-2

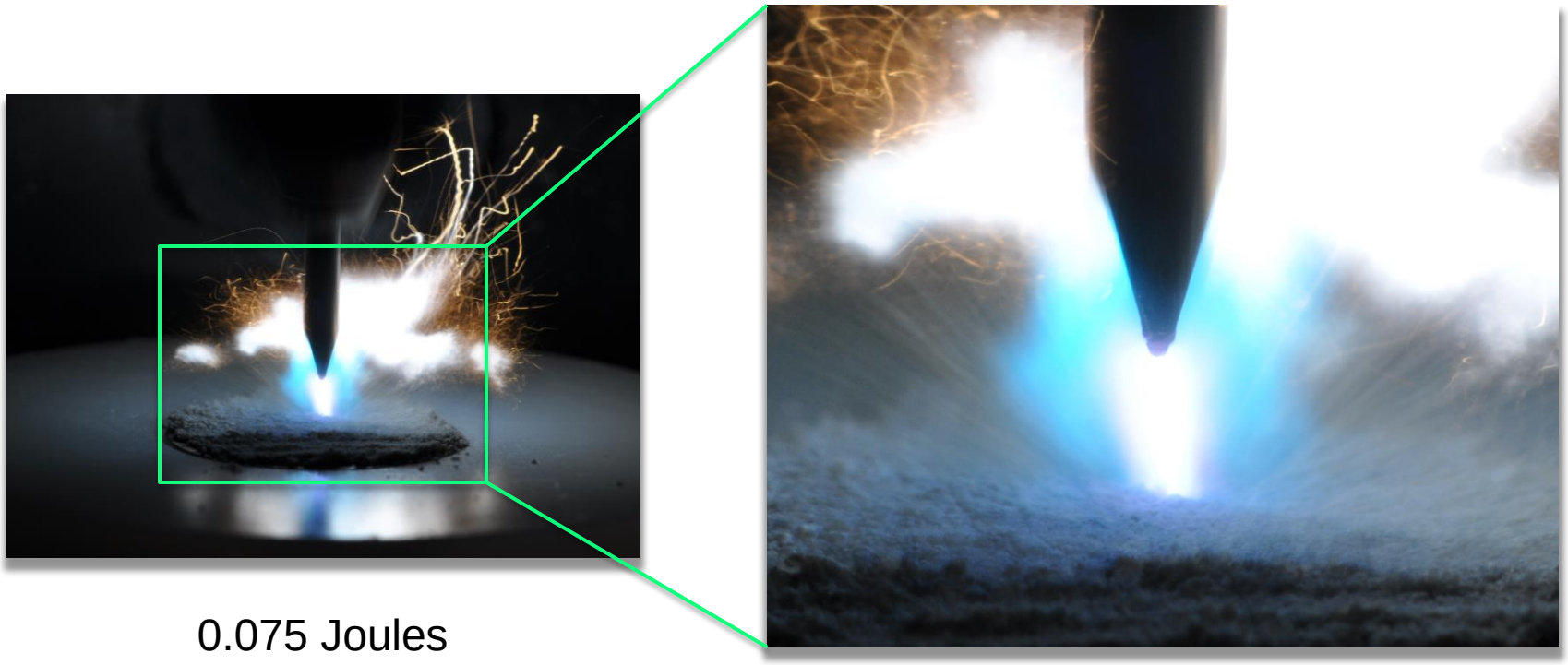


0.075 Joules
(TIL +1)

# Propagating Explosion?

Sandia National Laboratories

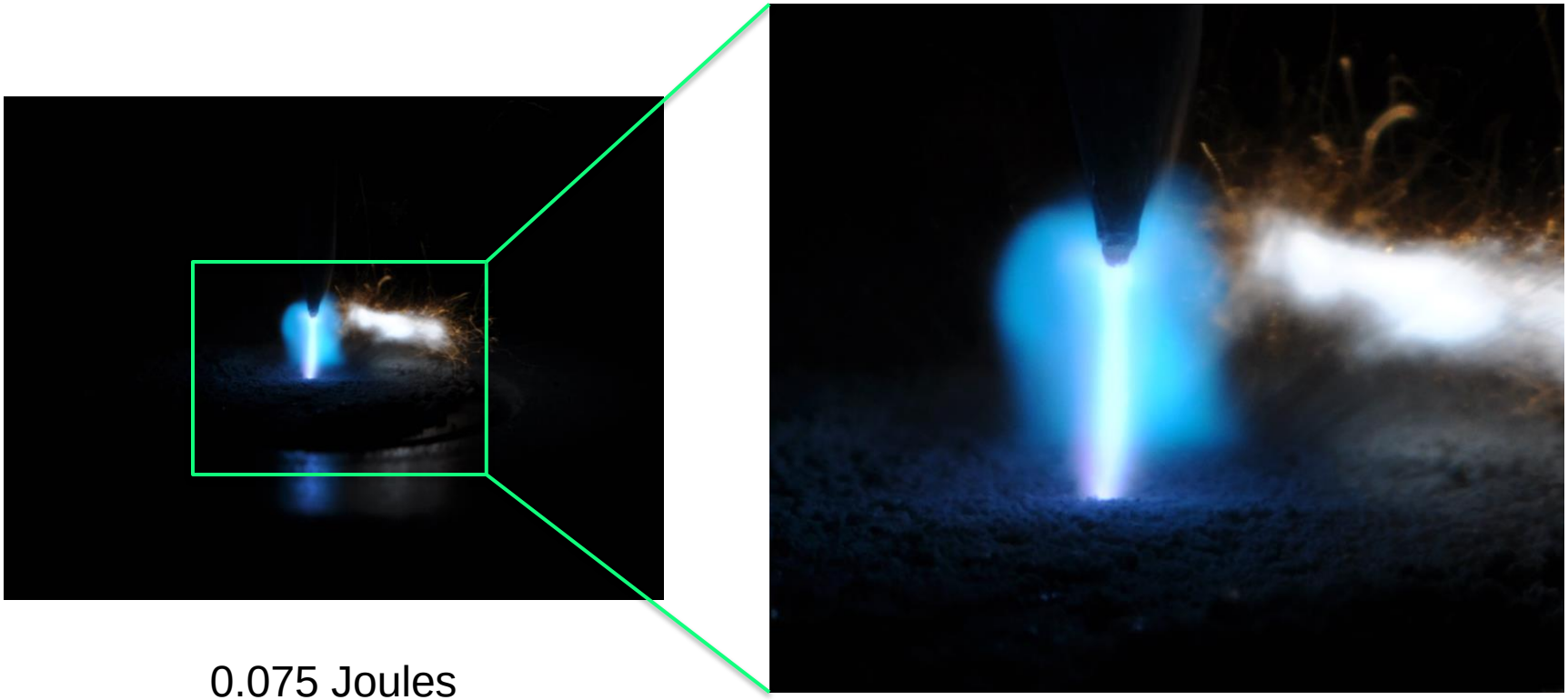
CANAl - 10% Valimet H-2



0.075 Joules
(TIL +2)

# Propagating Explosion?

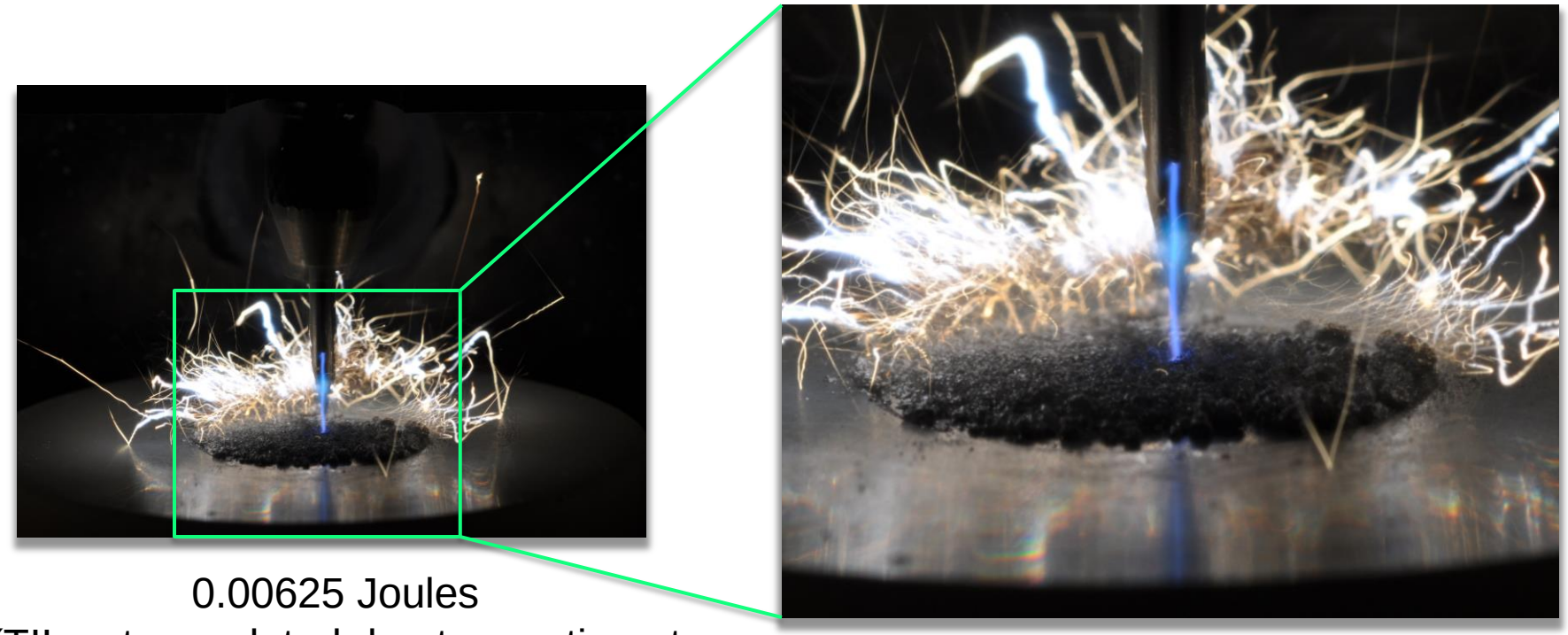
CANAl - 10% Valimet H-2



0.075 Joules
(TIL +1)

# Propagating Explosion?

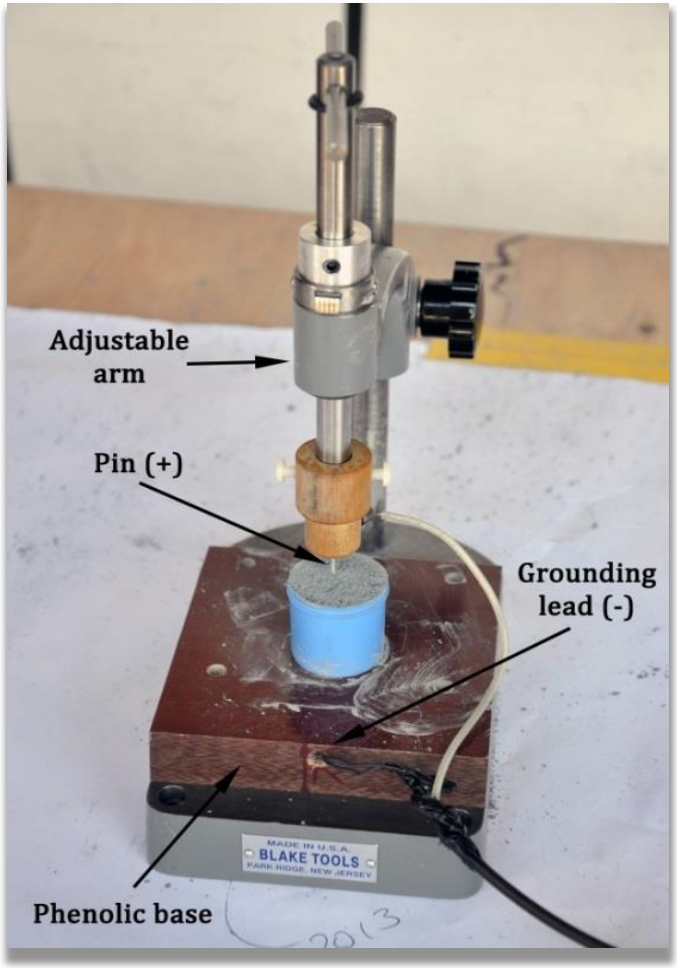
Enriched CANAl - 17.1% 870 flake
(wet method)



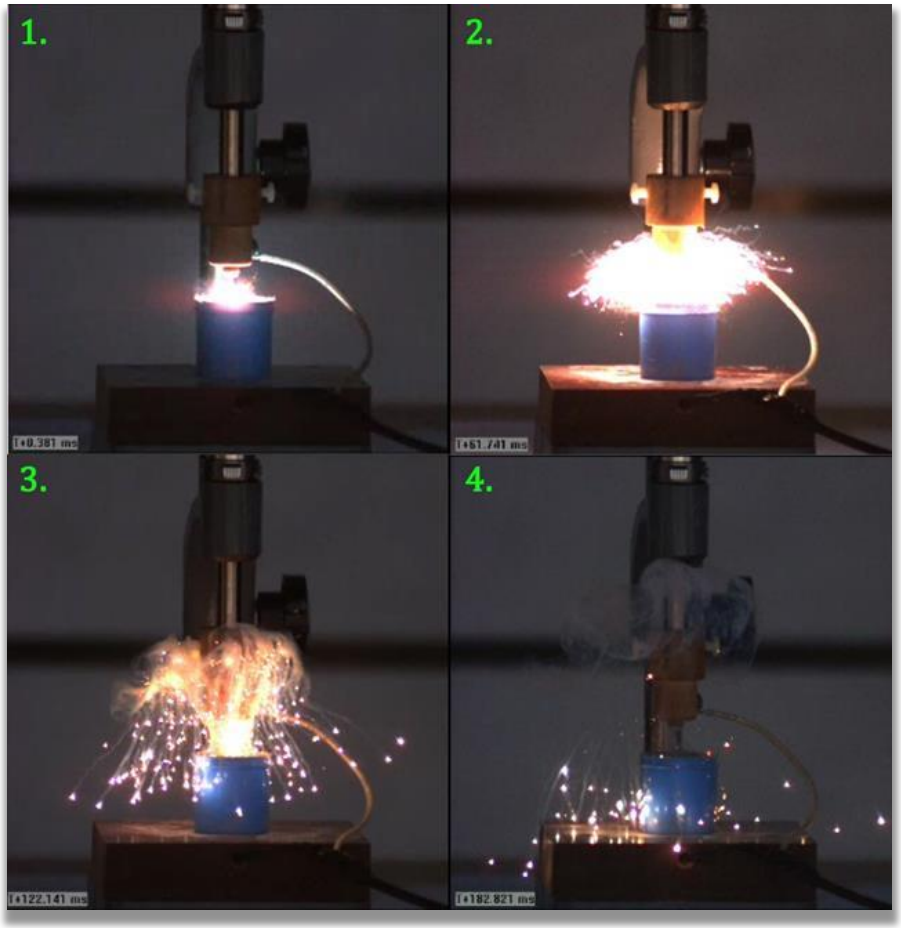
0.00625 Joules
(TIL not completed due to reaction at lowest stimulus level)

# Scaled-up ESD Testing

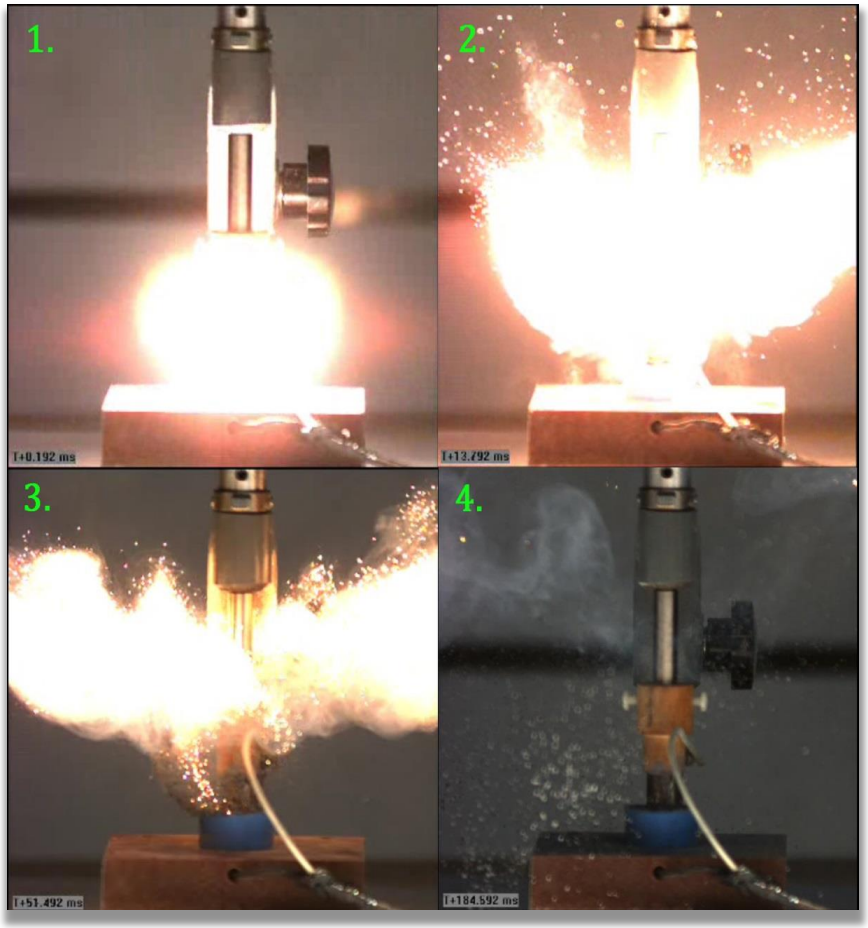
- Will stimulus levels that caused Go's in small-sale testing cause a violent, propagating reaction?
- Similar energy levels to the small-scale tester (Max:  18 Joules at 6kV)
- Larger sample masses (8-10g)
- Fixed gap needle (0.04in standoff from sample surface)



# Scaled-up ESD Testing




H-2 aluminum powder




ANAl (85:15)

# Scaled-up ESD Testing

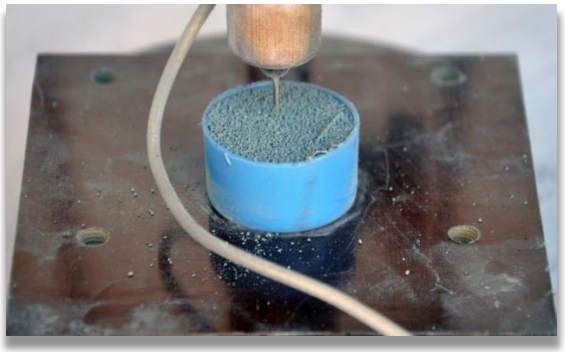
- Unreacted material is seen being ejected from the cup
- Majority of the material remained in the sample cup post-shot

**H-2 aluminum powder**

Pre-shot

Post-shot

**ANAl (85:15)**



Pre-shot

Post-shot

# Future Testing

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- Additional large-scale ESD testing at 30kV is planned to mimic “Standard Man” levels similar to NATO testing standard: STANAG4490.

- This method will deliver energy into the sample much more rapidly than previous methods.

- Mixture testing at various moisture levels is also underway as an alternative mitigation option.

# Conclusions

- Use of the “PETN line” for distinguishing primary from secondary materials is not always applicable for ESD testing of HME mixtures with metallic fuels.

- More detailed sensitivity data reporting/recording will reduce dependence on redundant testing in the future.

- This indicates that current interpretation of results and/or test methodologies may be inadequate, and may not represent realistic explosive hazards at larger quantities.

# References


1. Berry, Bruce R. SAND92-2416: Electrostatic Discharge Testing of Propellants and Primers, 1994.

2. Whinnery, L., Nissen, A., Keifer, P., and Tyson, A. SAND2013-3630: Imaging indicator for ESD Safety Testing.

3. STANAG 4490: Explosives, Electrostatic Discharge Sensitivity Test(s), 2001.

4. MIL-STD-1751A: Method 1031, 2001.


Questions?