DOE/NNSA Insensitive High Explosive (IHE) Qualification and Testing

International Explosives Safety Symposium and Exhibition
San Diego, CA

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9 August, 2018

LLNL-PRES-755265
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

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Outline

- Background of
  - DOE Insensitive High Explosive (IHE)
  - DoD Insensitive Munition (IM)
  - UN Extremely Insensitive Substance (EIS), formerly know as
  - Extremely Insensitive Detonating Substance (EIDS)

- Motivation to update the DOE IHE qualification

- Changes

- New Experiments

Reevaluating and improving the criteria for DOE IHE qualification enhances the safety of the nuclear stockpile.

Chapter IX of DOE-STD-1212-2012 prescribes a set of qualification tests for an Insensitive High Explosive

- A "senior group" of explosive scientists put the tests together in the early 1980s
  - Expected to be adaptable and constantly evolving based on expert judgement
- Addressed threats that weren't relevant to nuclear safety or they addressed ignition of the material without speaking to the hazard
  - worker safety and over-the-road transport covered by DOE/NNSA high-explosive handling protocols and DOT regulations
- E.g. #8 blasting cap test was directed towards *over the road transport* threats and loosely based upon DoD tests of that era
  - "super" insensitivity was when no commercial cap on the market would initiate the energetic at tap density
  - They did not anticipate that the definition of the #8 would evolve and become more powerful

IHE Qualification Tests
Drop-weight impact
Friction
Spark
Ignition and unconfined burn
Card gap
Detonation (#8 cap)
Cookoff
Spigot
Skid
Susan
Bullet impact

The Department of Defense (DoD) has protocols for qualification of Insensitive Munitions

Fast Cook-off (FCO)	Slow Cook-off (SCO)	Bullet Impact (BI)	Fragment Impact (FI)	Sympathetic Reaction (SR)	Shaped Charge Jet Impact (SCJ)
					
Fuel fire such as on a carrier flight deck	Fire in adjacent magazine, store or vehicle	Low velocity gunfire threats	High velocity fragments from high performance warheads	Propensity for mass detonation of adjacent rounds	Shaped charge weapon attack

IM Reaction Legend

I/II	III	IV	V	VI
Detonation/Partial Detonation	Explosion (Threshold for passing SR and SCJ)	Deflagration or propulsive reaction	Burning reaction (Threshold for passing FCO, SCO, BI, FI)	No reaction

- Engineering assessments (and calculations) can be used in lieu of testing
- Assessments should have similar confinement, energetic materials, and threat scenarios

IM requirements are for the munition system, they are related to (but can be independent of) the HE used in the warhead or rocket motor.

TB 700-2 (DOD Ammunition and Explosives Hazard Classification Procedures) calls for an Extremely Insensitive Substance (EIS) for HD 1.6 Assignment

- Ammunition and explosives (AE) hazard classification procedures for **transportation and storage** by the Department of Defense (DoD) Components (DoDC) and the Department of Energy (DOE)
- Assign the Class, Hazard Division (HD), and Compatibility Group for AE transportation and storage (e.g. HD 1.1D, 1.6N)
- TB 700-2 **excludes hazards during AE manufacture**

Tests address susceptibility to accidental initiation from a variety of hazards to arrive at a Hazard Division
This test is also subject to change

In 1999, DOE ESC permanently assigned HD 1.3 (later 1.3/1.6) for IHE Subassemblies and IHE Weapons, essentially equating 1.6 with DOE IHE

EMC
ENERGETIC MATERIALS CENTER

DOE IHE Qualification Tests:

- Drop-weight impact
- Friction
- Spark
- Ignition and unconfined burn
- Card gap
- Detonation (#8 Cap)
- Cookoff
- Spigot
- Skid
- Susan
- Bullet impact

UN Series 7 Tests for EIS:

- 7(a) EIS Cap*
- 7(b) EIS Gap*
- 7(c)(i) Susan*
- 7(c)(ii) Friability
- 7(d)(i) EIS Bullet Impact*
- 7(d)(ii) Friability
- 7(e) EIS External Fire*
- 7(f) EIS Slow Cook-off*

*Called out in TB 700-2 as same as DOE requirement

This analogy was made because the tests were "very similar"

The analogy between TB 700-2 1.6N and DOE IHE is convenient, but it doesn't acknowledge the unique hazard in nuclear weapons

- Nuclear weapons (especially those in assembly and disassembly) have unique and grave risks
- Electrical threats are not included
  - Lightning (worst case) does not initiate any stockpile maincharge - CHE (PBX 9501) or IHE
  - Electrostatic sensitivity is covered by handling regulations
- Worker safety is separate from the hazards of accidental detonation
- Machining safety has been, and will continue to be, tested separately

The unique hazard after accidental detonation of large, uncased, high explosive in production is the concern that drives an exclusive DOE/NNSA definition of IHE

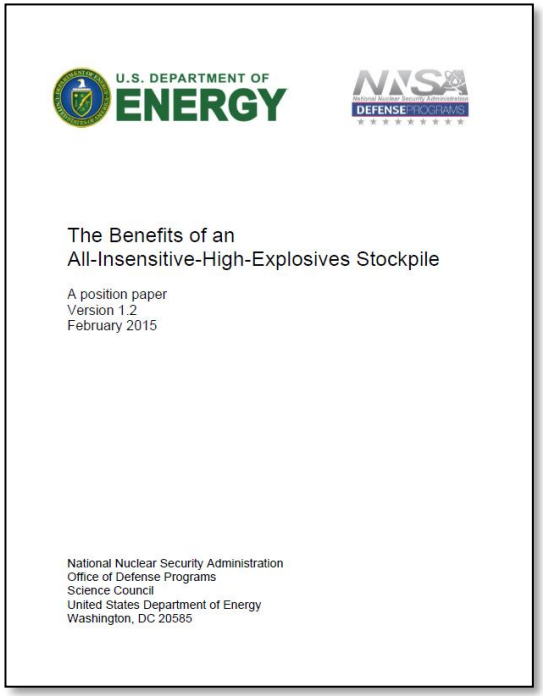
An NNSA paper recommends that all the PBX's used in nuclear weapons be Insensitive High Explosive (IHE)

IHE provides benefits to the stockpile including:

1. Improved safety
— Throughout the life cycle of the weapon
— In DOE and DoD custody

2. Improved Production efficiencies
— Production, surveillance, transportation, and dismantlement

DOE-STD-1212 calls out Deflagration to Detonation Transition (DDT) as a defining feature of IHE
— but there are no tests defined to quantify the behavior!
Only TATB and TATB formulations with Kel-F are qualified


U.S. DEPARTMENT OF ENERGY

NNSA DEFENSE PROGRAMS

The Benefits of an
All-Insensitive-High-Explosives Stockpile

A position paper
Version 1.2
February 2015

National Nuclear Security Administration
Office of Defense Programs
Science Council
United States Department of Energy
Washington, DC 20585

IHE is safer for a nuclear weapon because IHE won't initiate without a detonator (or booster), and burning IHE won't detonate; without detonation the hazards are greatly mitigated

In 2015, we proposed a change in the current qualification standard and Chapter IX of DOE-STD-1212-2012

- DOE IHE is differentiated from UN Extremely Insensitive Substance (EIS) and DoD TB 700-2 HD 1.6
  - DDESB conducted a thorough review in Nov. 2015 and concluded: “We have no objection to proceeding with this change”.
- Current standard is go / no-go and scenario specific
  - Basis in mechanism, generalization to other scenarios with quantification of margin is desired – with years of development this is now possible
- Material and Subassembly qualification paths are retained and improved

The proposed change looks significantly different from the current STD Ch IX, and it directly tests for the features of interest (Shock and DDT)

IHE shall be defined in the context of threats and material responses

- Mechanical
  - Shock stimulus
    - High-speed fragment from nearby explosion
  - Non-shock stimuli
    - Impact – weapon is dropped onto or crashed into something
    - Impact – something is dropped onto or crashed into weapon
    - Bullet
- Thermal
  - Fire / Cookoff

All possible insults cause *HEATING → THERMAL REACTION*
Shock is the only special case

New IHE material definition

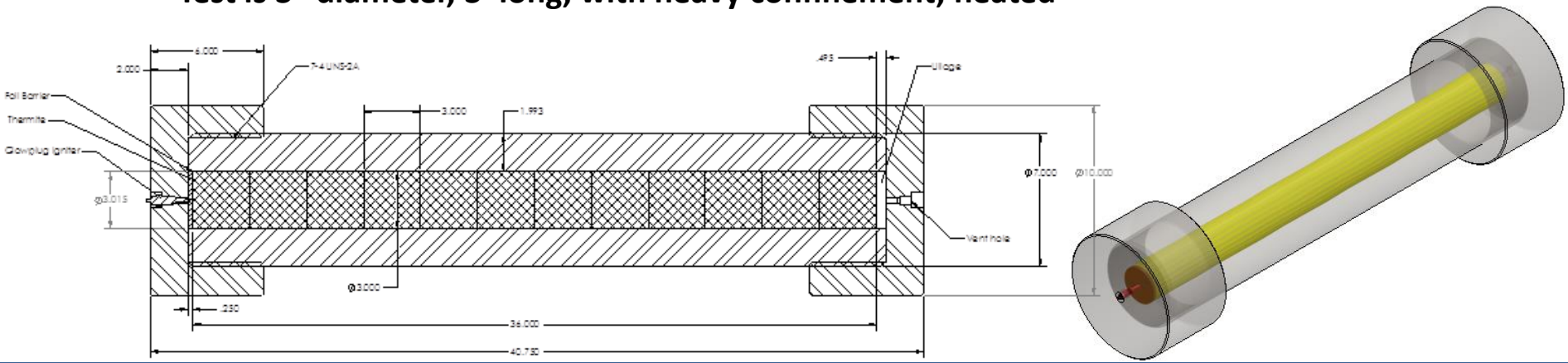
- **Insensitive High Explosive material is any mass-detonable explosive that, <u>in scales that are conservative and relevant to a nuclear weapon application</u>:**

1. **Does not transition from deflagration to detonation (DDT)**
2. **Does not transition from shock to detonation (SDT)**
   - Under 3.5 GPa, ≥3 μs 1-dimensional shock insult at 25°C (sustained)
   - Under 5.3 GPa, 0.5 μs 1-dimensional shock insult at 25°C (short pulse)
   - Under 1.5 GPa, ≥3 μs 1-dimensional shock insult at 10°C below the cookoff temperature of the explosive
3. Does not undergo violent deflagration in
   - Skid test
   - Bullet test

We cannot exclude shock (SDT) under all conditions - IHE must detonate to function as designed

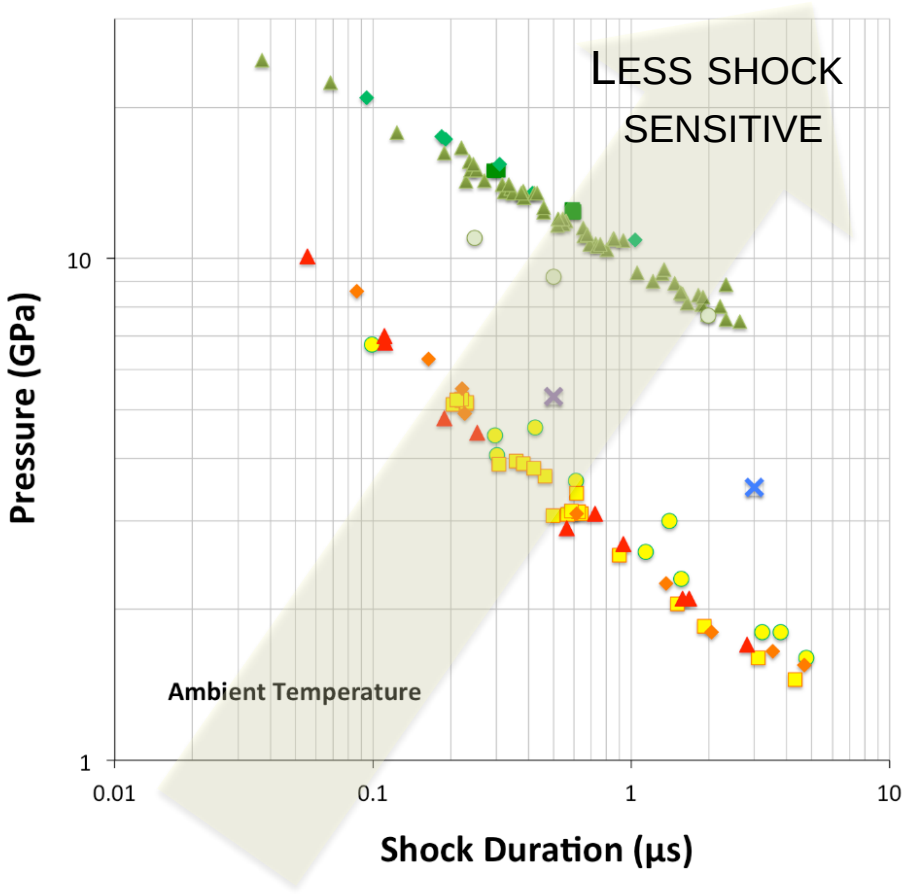
A material must not DDT (in weapon-relevant scale) to be considered an IHE

- Ignition is a complex phenomenon governed by many competing processes
  - We cannot guarantee that ignition will never occur
  - Therefore we assume that ignition *DOES* occur
- Test is done in 3 varieties to include ignition mechanism and damaged material
  - Pressed material – cookoff, heated & ignited ; Molding prills, heated and ignited
- Test design incorporates large margins and replicates to account for the stochastic nature of DDT events
  - Test is 3” diameter, 3’ long, with heavy confinement; heated

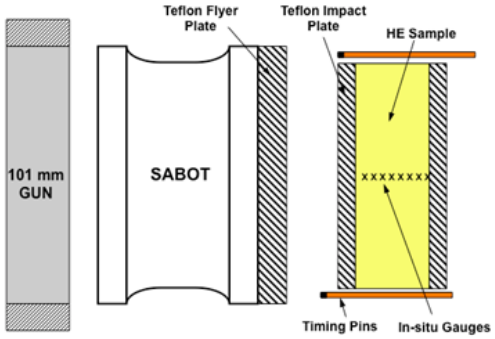


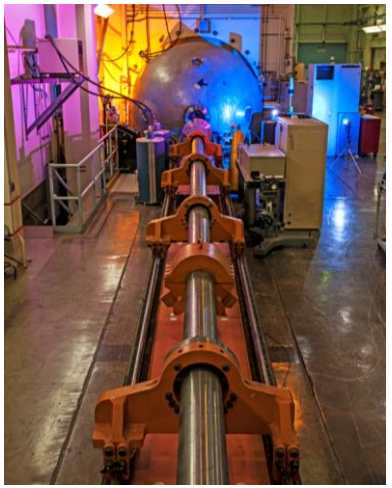
For an IHE: No development of a detonation wave within the tube length with three (3) replicates

An IHE must not react to a shock of ≥3.5 GPa for ≥3 μs (sustained) or ≥5.3 GPa for 0.5 μs (short pulse) at 25°C



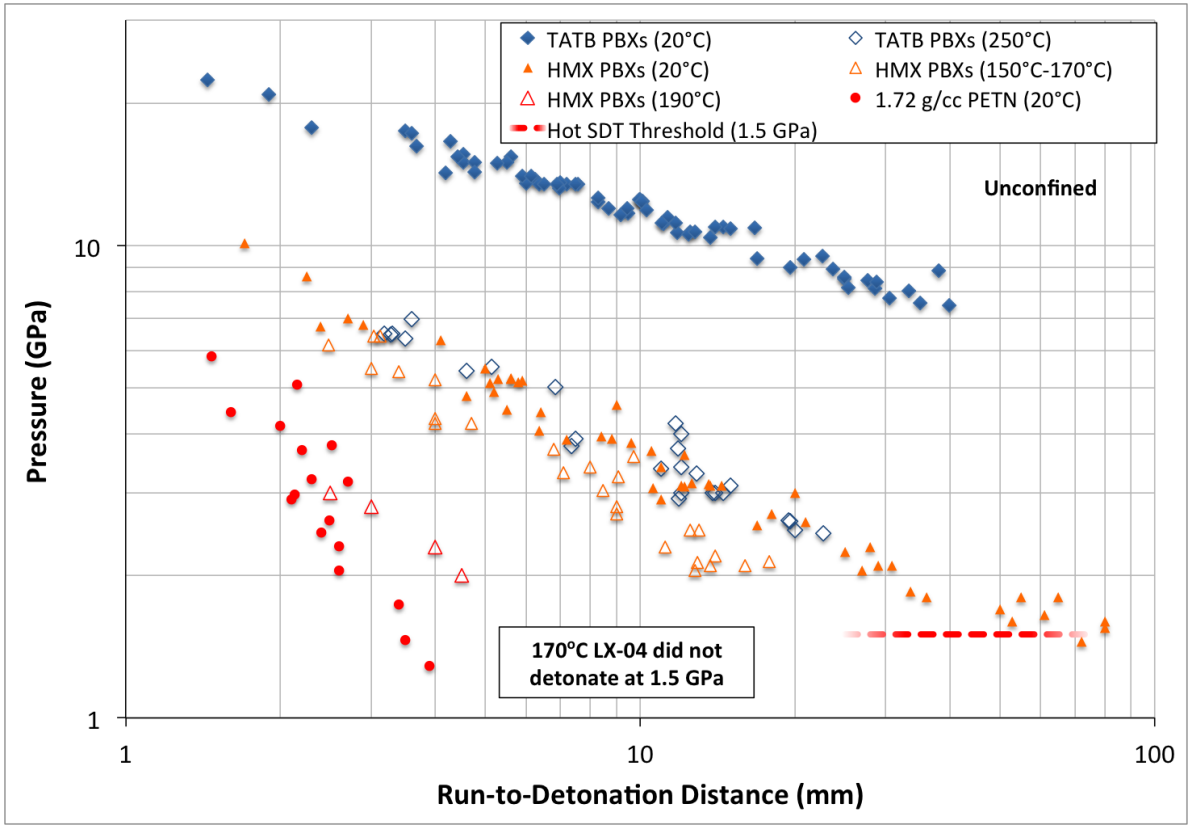
- LX-17-1
- LX-17-0
- PBX 9502
- UF-TATB
- LX-04
- PBX 9501
- LX-07-2
- LX-10
- 3.5 GPa, 3.0 μs
- 5.3 GPa, 0.5 μs





Sustained and short pulse loading account for a range of threats

An IHE must not react to a shock of ≥1.5 GPa for ≥3 μs (sustained) at 10°C below its cookoff temperature



5 DIE IN B-52 FIRE AT AIR BASE

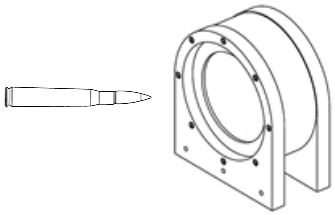
AP
Published: January 28, 1983

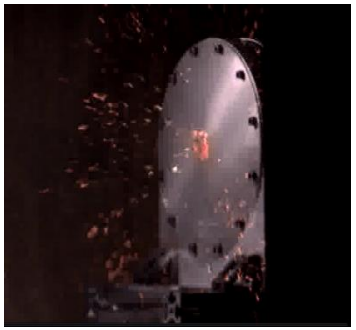
GRAND FORKS, N.D., Jan. 27— A B-52G bomber parked on a maintenance ramp exploded in a huge fireball today, killing five people and injuring eight others at Grand Forks Air Force Base, the authorities said.

This test ensures that no IHE becomes unacceptably sensitive at high temperature – the current standard has no high temperature requirement

Skid and bullet testing is retained from previous IHE definition

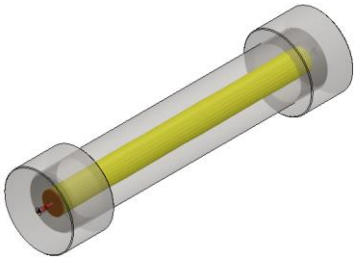
- Handling of large bare charges led to recent fatalities at Iowa Army Ammunition Plant
- The existing skid test was developed to address this risk, following 6 fatalities in 1959 at LANL and AWE
  - Skid test has been retained and modernized
- Bullet testing is a powerful demonstration
  - Bullet test has been retained and modernized

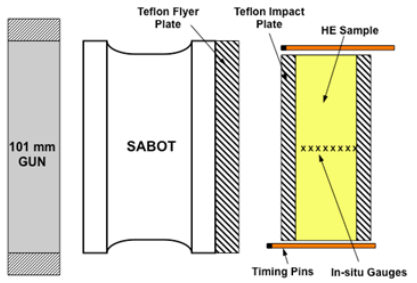




Insensitive High Explosive material is any mass-detonable explosive that, in scales relevant to a nuclear weapon:

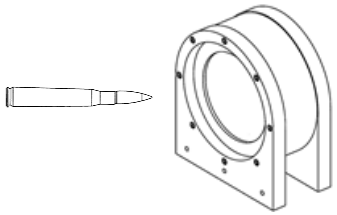
1. **Does not transition from deflagration to detonation (DDT)**
   - **Pristine, damaged, heated**
2. **Does not transition from shock to detonation (SDT)**
   - **Supported shock, short-pulse, heated**
3. **Does not undergo violent deflagration in skid test**
4. **Does not undergo violent deflagration in bullet test**





DDT SDT

SKID BULLET



These four (4) tests provide the basis for qualification of an IHE for DOE/NNSA

Acknowledgements

The effort to redefine an IHE was a multi-year endeavor with numerous colleagues from Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Sandia National Laboratories, and Pantex Plant, in addition to the respective DOE Field and Site Offices. The authors would like to acknowledge significant technical contributions to this effort were made by: Peter Dickson, Bill Andrews, Micha Gresshoff, George Overturf, H. Keo. Springer, Anthony Dutton, Laurence Fried, Barry Hill, John Taylor, Steve Malcom, Constantine Hrousis, Tommy Morris, Philip Rae, Chris Robbins, Craig Tarver, Daniel Trujillo, Leanna Minier, Michael Kaneshige, and Kevin Carr.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