MSIAC
Munitions Safety Information Analysis Center

Supporting Munitions Safety

Magazine Loading Density Detonation Estimation

IMEMTS 2019

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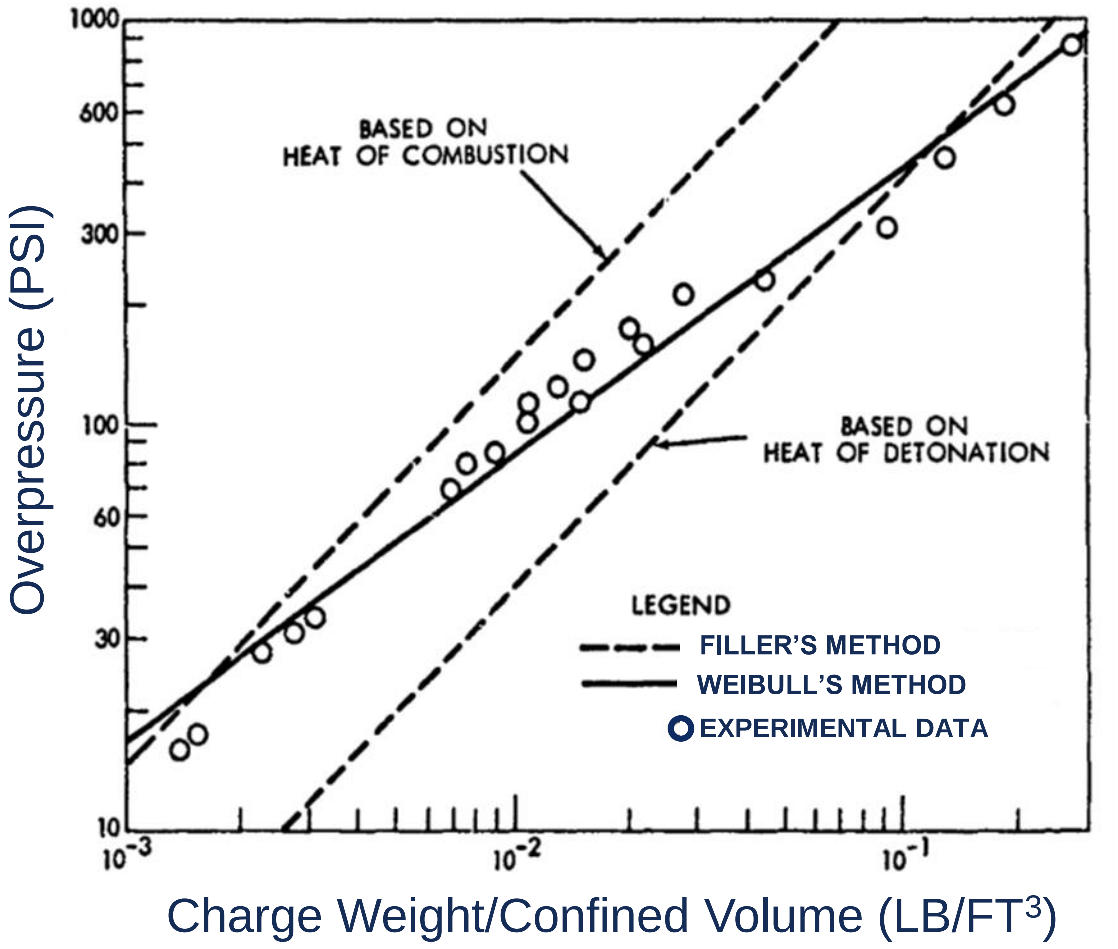
Outline

- Background
- Magazine Internal Pressure
- Explosive Burn Rates
- Critical Pressure to cause DDT
- Anti-armor Missile Example
- Summary

Background

- Many munitions now meet the IM fast cook-off (FCO) and slow cook-off (SCO) requirements.
  - Left under ambient unconfined conditions, it is doubtful that any of these munitions will undergo a deflagration to detonation transition.
  - However, if confined and ignited, most explosives and many propellants undergo DDT
  - In a magazine storage configuration, a potential source for munitions confinement pressure is induced magazine internal pressure
- In a magazine, above what loading density would we expect a deflagration to detonation (DDT) transition for a fire event?
- We have developed a simple method to estimate a DDT based on magazine quasi static pressure (QSP) and burn rate behavior

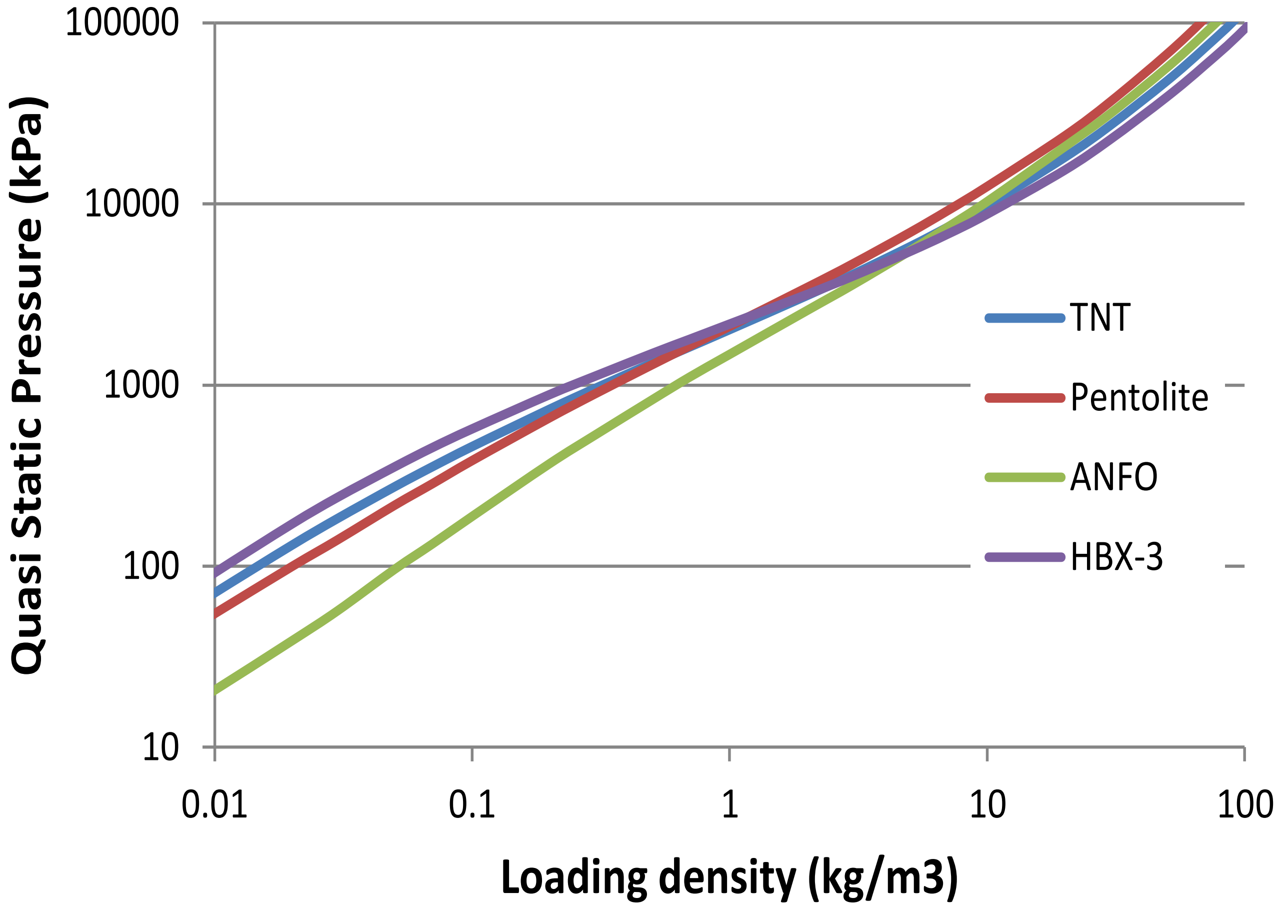
Magazine Internal Pressure



Calculated versus experimental internal pressure versus loading density for TNT

Proctor 1972

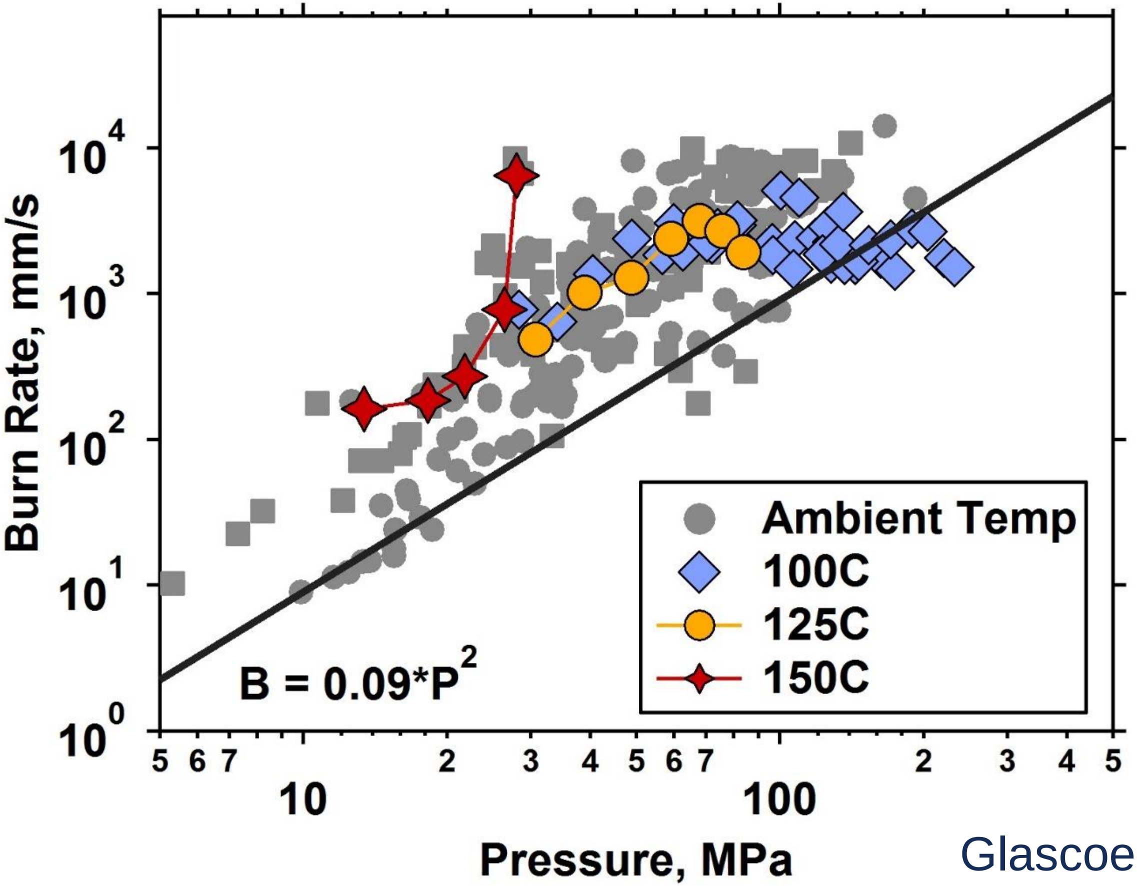
Magazine Internal Pressure



Calculated quasi static pressure (QSP) versus loading density for various explosives

van der Voort 2018

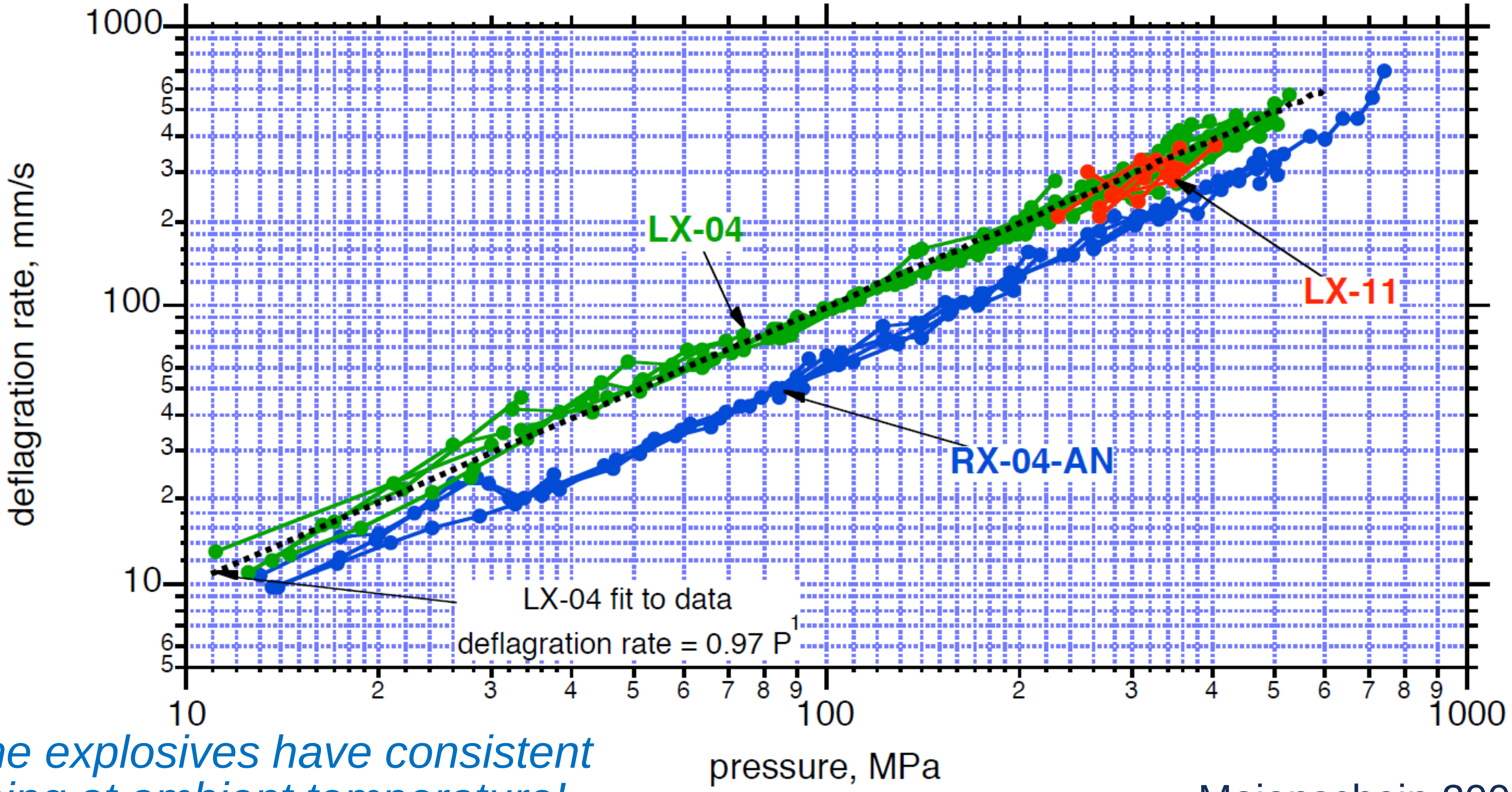
Comp B Burn Rates



- Erratic burning
- Very high pressure exponent
- Known for violent cook-off responses

Glascoe 2014

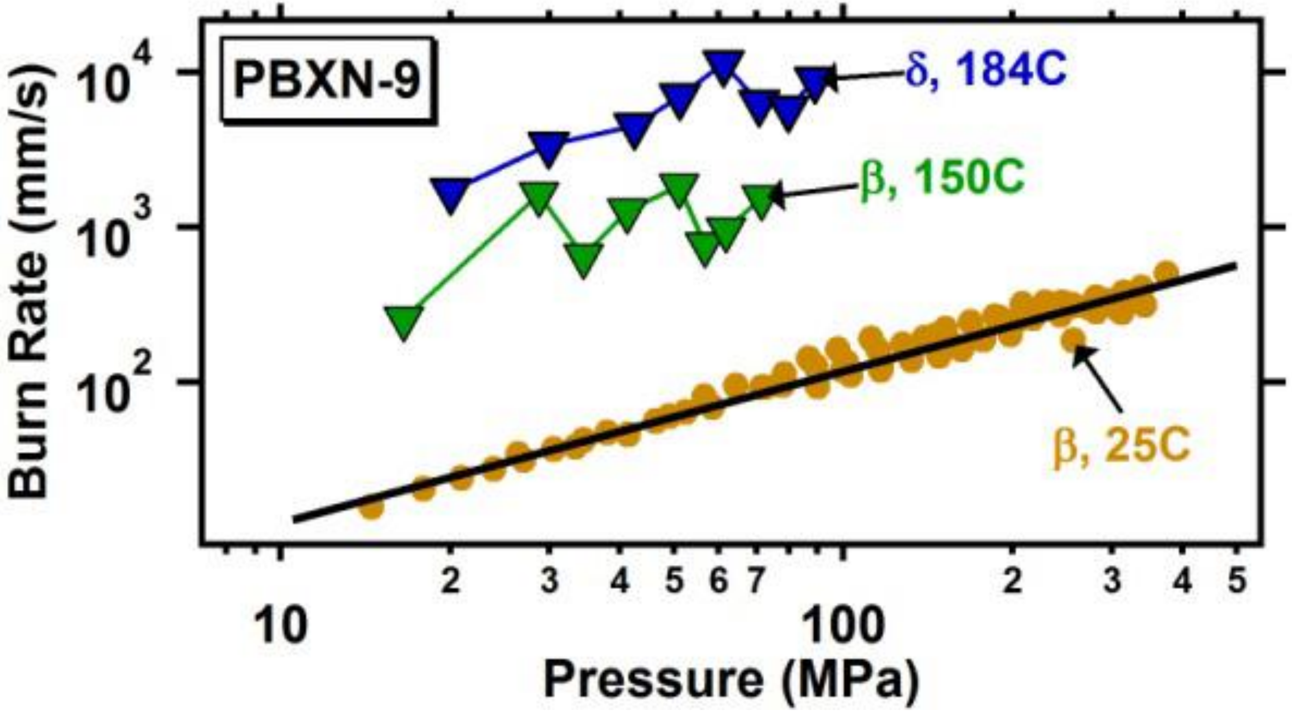
Plastic Bound Explosive Consistent Burning



Some explosives have consistent burning at ambient temperature!

Maienschein 2003

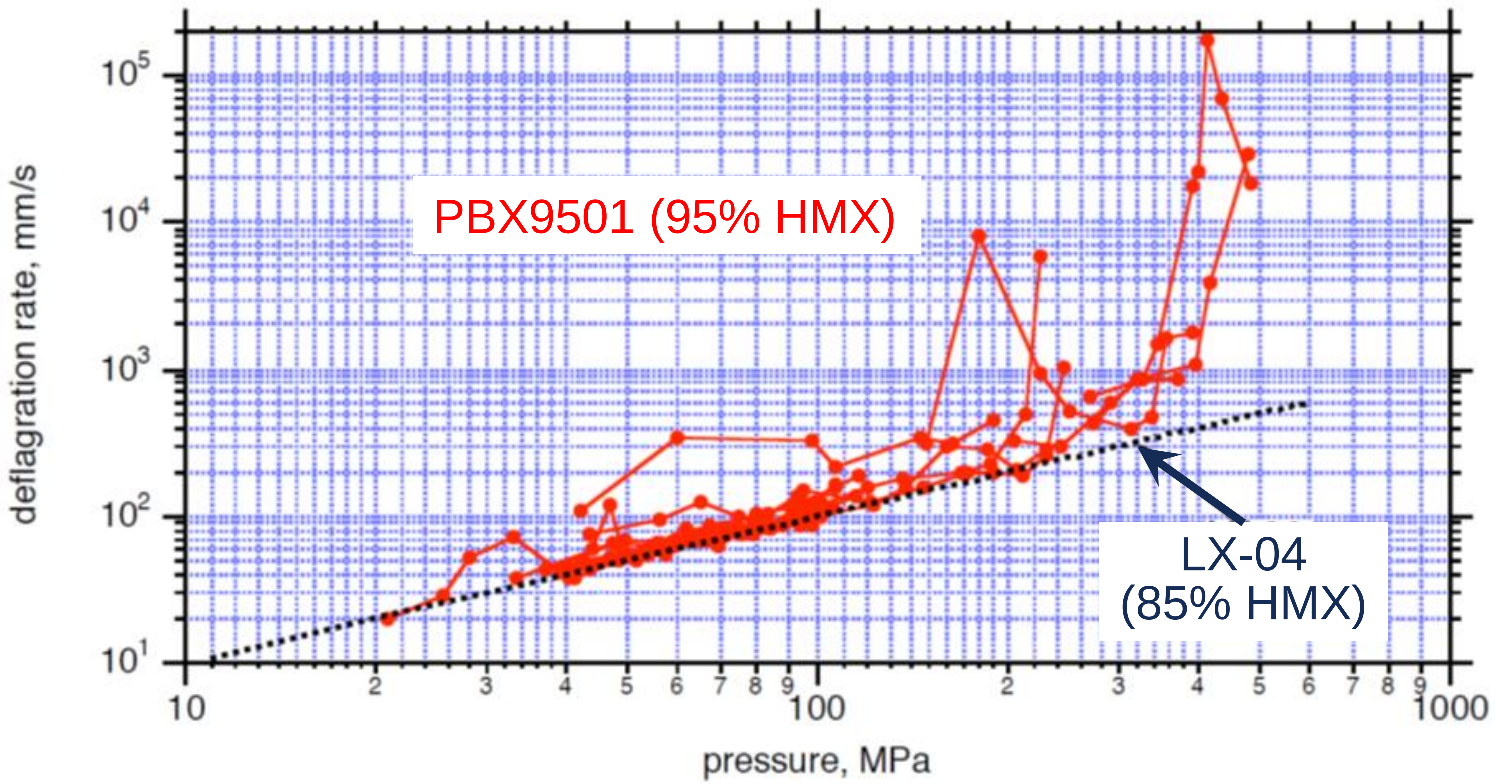
Explosive Burning at Elevated Temperatures



Glascoe 2014

- *At high temperatures, most explosives burn erratically*
- *In a fire event explosives in munitions normally don’t get that hot*
- *However, if they do …..it’s bad!*

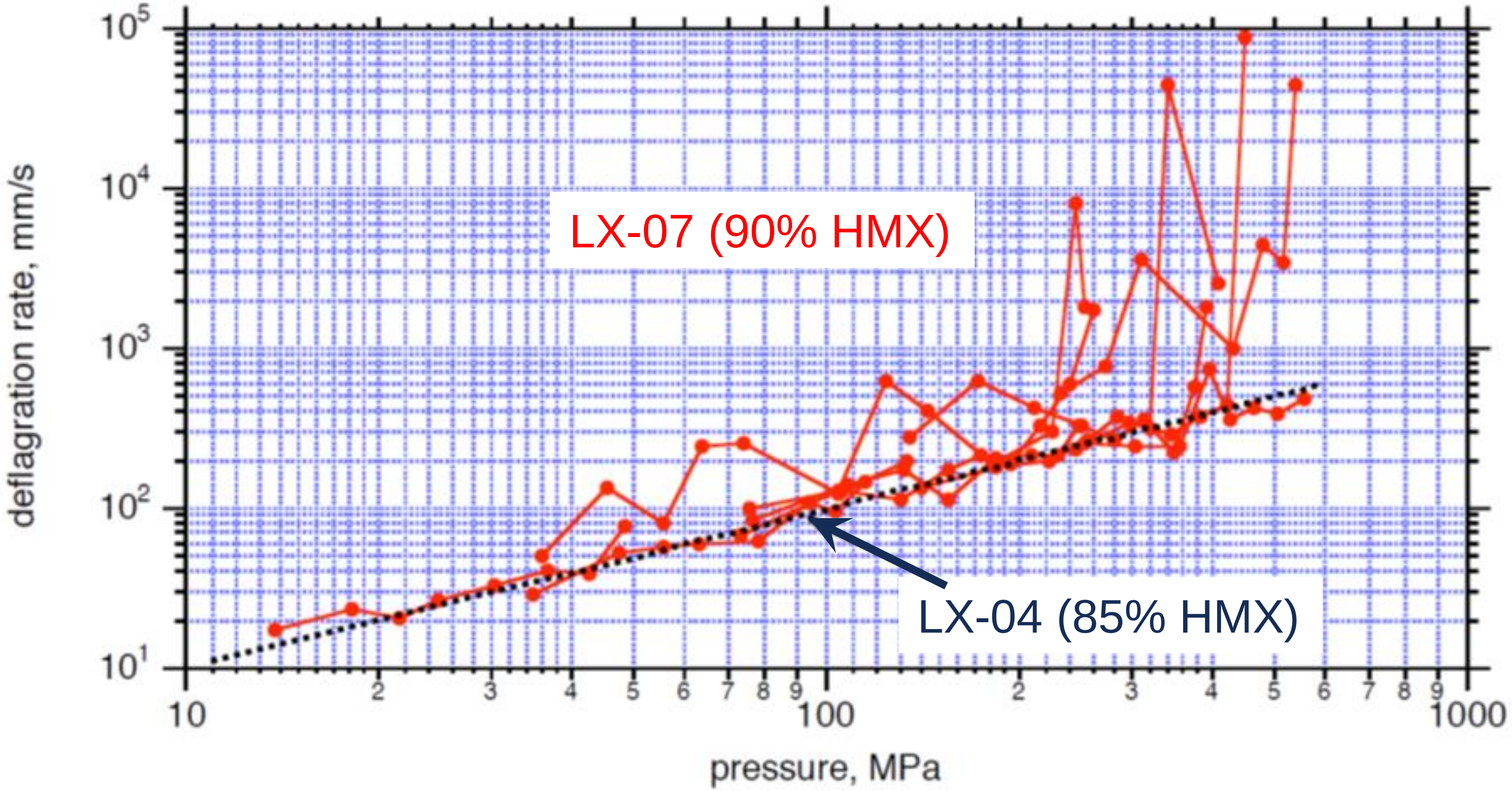
PBX9501 Burn Rate Data



Maienschein 2003

High nitramine content explosives can deconsolidate at high pressure

LX-07 Burn Rate Data



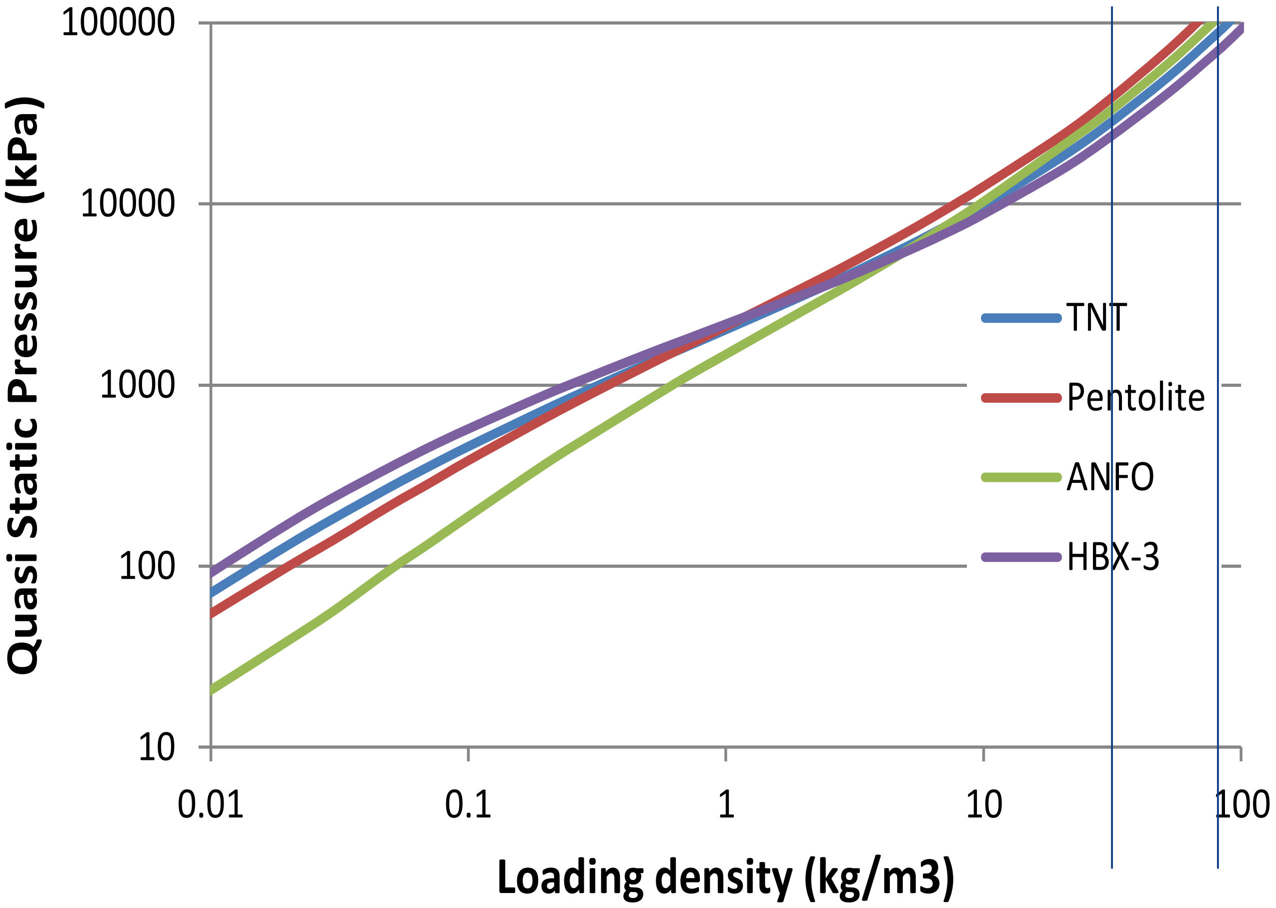
Erratic burning

- Very Conservative 40 Mpa
- Less conservative 100 MPa

Maienschein 2003

High nitramine content explosives can deconsolidate at high pressure

Magazine Internal Pressure



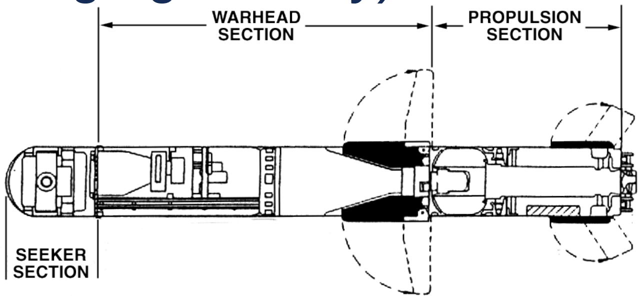
Erratic burning

- Very Conservative
  40 Mpa ≈ 40 kg/m³
- Less conservative
  100 MPa ≈ 80 kg/m³

Anti-armor missile example

How tight can you pack anti-armor missiles into a magazine and feel comfortable that they will not DDT if there is a fire event?

- Baseline assumption: the missile achieves a type IV or better response to FCO
  - If it has a type I or II response in FCO …it will detonate
- Anti-armor missiles typically use high nitramine explosives
  - LX-14, PBXN-9, …
- Use Javelin-like missile for the exercise
  - 127 mm diameter, 1.1 m length
  - Warheads explosive: ~3.6 kg (guess based on rough geometry)
  - Rocket motor: ~1.1 kg [Zhang 2012]
  - Using 1.4 TNT equivalency → 6.6 kg TNT
    - At high loading density, there is little afterburning



Anti-armor missile example

How tight can you pack anti-armor missiles into a magazine and feel comfortable that they will not DDT if there is a fire event?

- Very conservative (40 MPa QSP)
  - 6.6 kg / 40 kg/m^3 = 0.17 m^3
- Less conservative (100 MPa QSP)
  - 6.6 kg / 80 kg/m^3 = 0.08 m^3
- Minimum hexagonal space around the missile
  - 0.127 m x 0.127 m x 1.1 m = 0.15 m^3
- Missiles would need to be packed into the magazine nearly touching each other to exceed the very conservative estimate for magazine loading density to cause a DDT
  - IM packaging venting is vital for reducing response violence
  - LX-14 likely burn erratically above some pressure
  - PBXN-9 burns uniformly over the pressure range

Summary

- Method to estimate critical magazine loading density that will lead to DDT
  - Assumes that DDT occurs due to the increased rate of deflagration as a result of increasing internal magazine QSP
  - QSP is calculated using an estimated explosive equivalency, energetics mass and magazine volume
  - The burn rate behavior of the energetics contained in the magazine is then used as an indicator of whether a DDT would occur
- A test case was conducted using high performance anti-armor missiles
- These are conservative estimates, as they assume all of the energetic material is burnt to calculate QSP and they do not account for magazine venting
- This analysis is not applicable to munitions that have Type I or Type II responses from fast cook-off testing