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Supporting Munitions Safety

Large Caliber Projectile Fill Adherence

IMEMTS 2019

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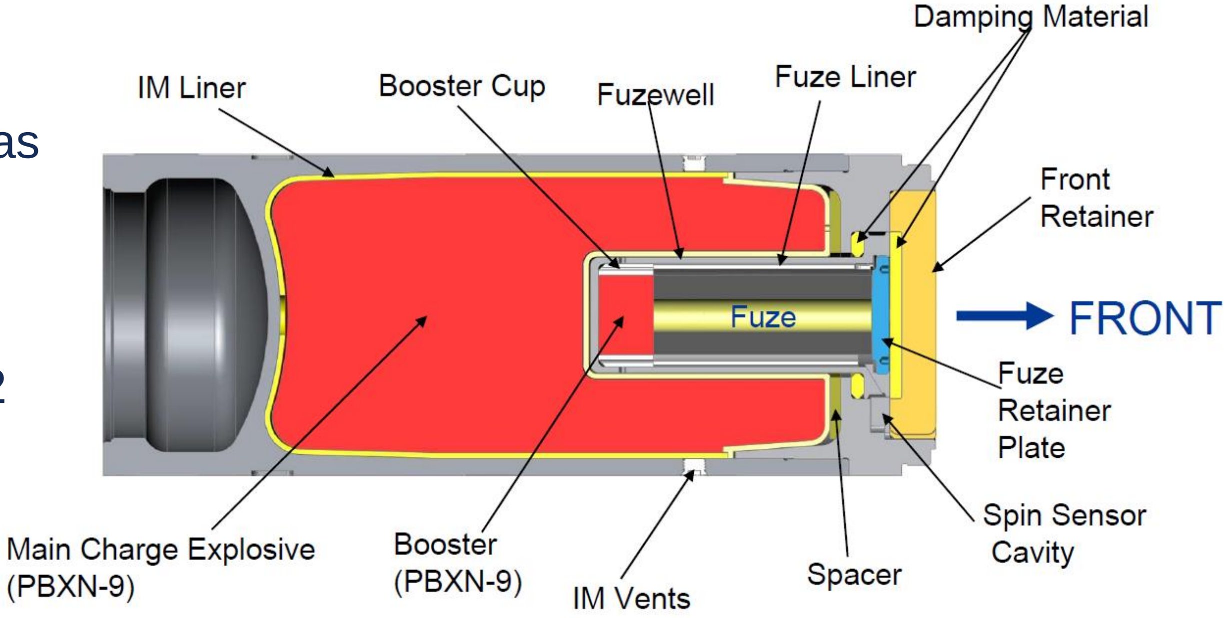
Explosive Loading

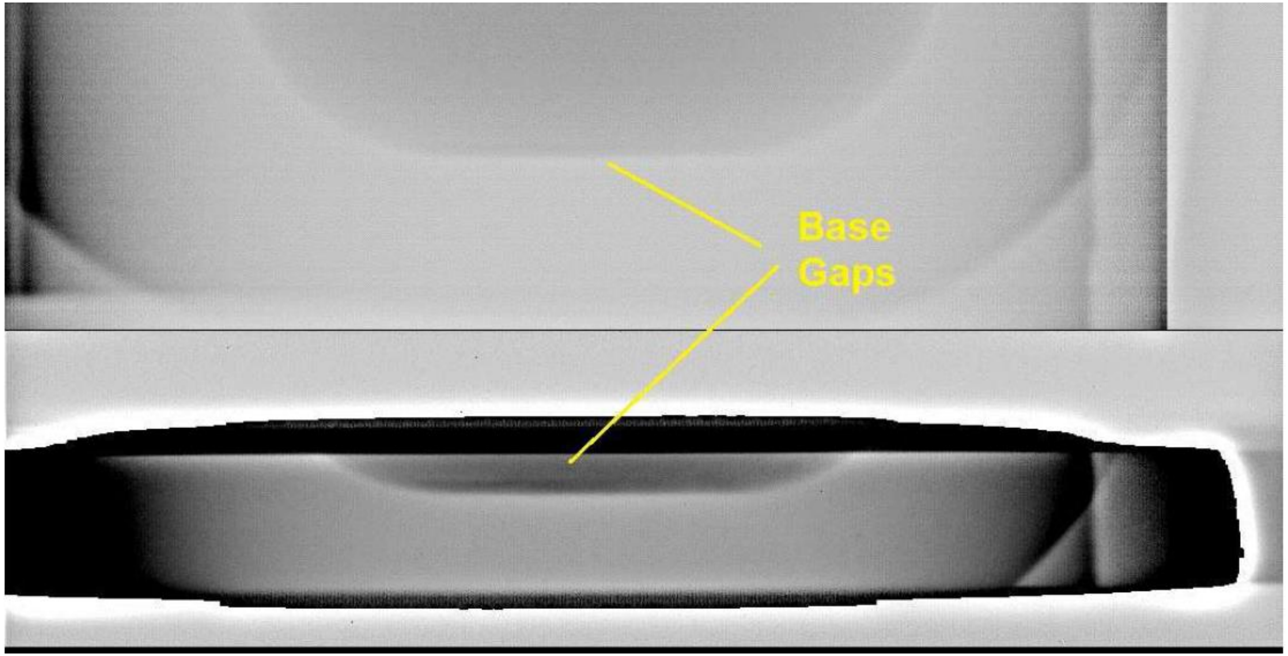
- Projectiles are filled using three primary methods: pressed, melt pour or cast cure.
- Pressed non-adhered fill: M982 Excalibur 155mm
  - Thick liner (appears to be several mm) with PBXN-9 billet
  - Not really what we would consider “non-adhered”

Excalibur program reportedly decided not to use PBXW-114 as it “seriously failed a setback safety test and was discarded from further consideration”. PBXN-9 was therefore chosen over PBXW-114 and PBXN-112 [Rhinesmith 2003].



Explosive Loading

- Melt Pour: Typically meant to adhere to the projectile case
  - But it doesn't always adhere: bituminous or varnish interior coatings



Base gaps from melt pour explosive fillings x-ray inspection (images provided by ARDEC).

- Some UK melt pour fillings are meant to adhere.
- Other UK melt pour fillings are meant not to adhere
- Working group to discuss and investigate

Cast Cure Non-Adhered Fillings

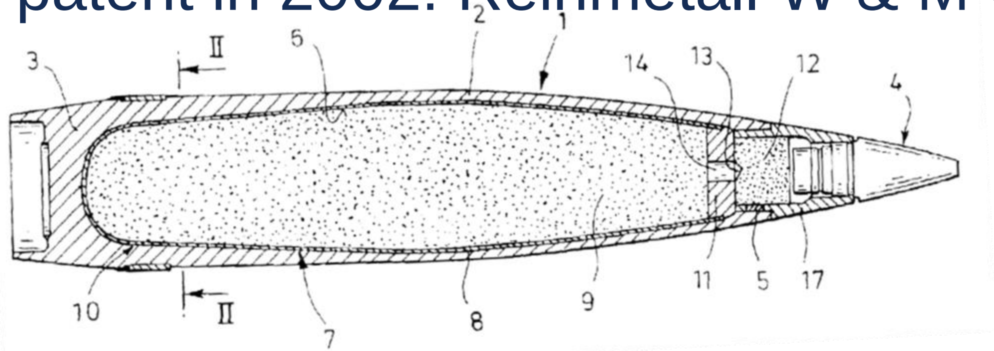
- Cast Cure: Significant number of purposely non-adhered fillings
  - BAE Systems Land UK loaded 105mm developmental L50: ROWANEX 1100 explosive

Was filled using a “flexible shell liner” [Morris 2005]

  - Eurenco (SME Explosive & Propellants Group SNPE at that time) sometimes fill with a thin liner with cast cure explosive in order to prevent explosive adherence to the case [Freche 2003, Freche 2006]
    - Noted that it is patented

Cast Cure Non-Adhered Fillings

- Earliest liner patent in 2002: Reinmetall W & M GmbH, Unterliss



A thin plastic liner (10 in figure) intended to help compensate for cast cure explosives high thermal expansion coefficient [Altenau 2005]

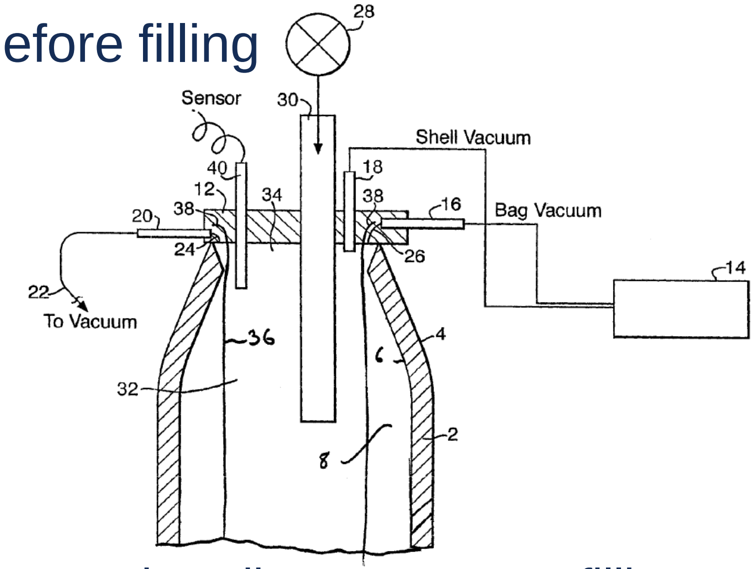
“The explosive charge is disposed in a plastic casing, comprised of an elastic material, inside the chamber of the high-explosive projectile.”

“A drawback of plastic-bound explosive charges, however, is that they have a relatively large thermal-expansion coefficient, which may be eight to twelve times larger than that of a Steel projectile casing of a corresponding high-explosive projectile. In this type of explosive-filled projectile, tensions occur at positive temperatures, so the explosive body is held in the projectile casing, whereas the explosive body compresses at lower temperatures and rests loosely in the projectile casing.”

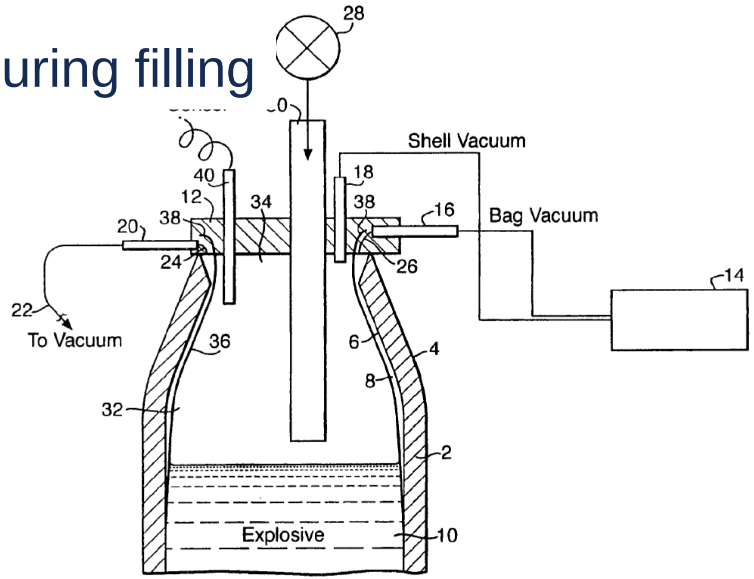
Cast Cure Non-Adhered Fillings

- 2008: BAE Systems plc

Before filling



During filling

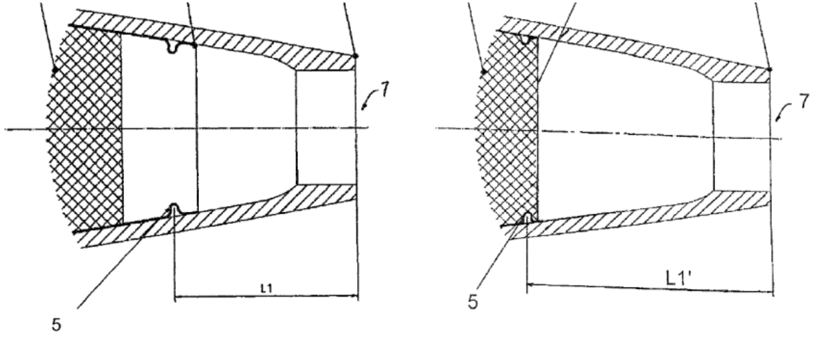


This patent describes a vacuum filling method in order to assure that the liner (an elastomeric bag, (36 in figure) makes contact with the projectile inner surface. [White 2008]

"The elastomeric bag is between 5% and 10% smaller than the shell cavity to ensure that the explosive material (filling) does not adhere to the inner wall of the ordnance shell. The bag also ensures that the filling 10 survives environmental changes without cracking."

Cast Cure Non-Adhered Fillings

- Patent in 2013: Reinmetall W & M GmbH, Unterliss

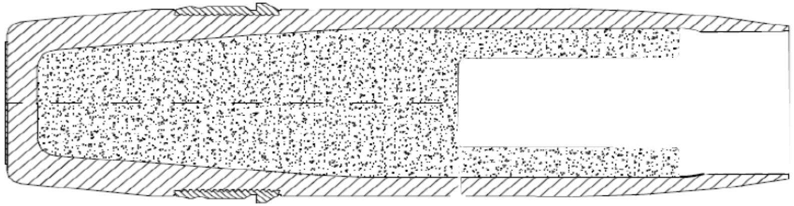


Invention intended to stop the liner from moving down the explosive billet and exposing the explosive billet directly to the projectile body interior [Schwenzer 2013]

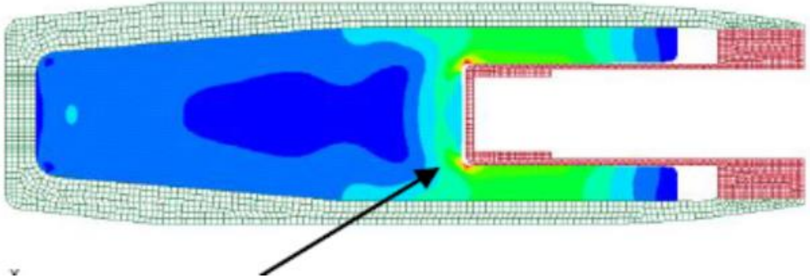
“In some cases, the liner is not stiff enough to be able to compensate its own thermal expansion in line with the expansion of the high-explosive charge. Due to its great thermal expansion, the high-explosive charge contracts and expands by several mm during cooling and heating, respectively. The liner contracts with the high-explosive charge but does not expand with it to the same extent. This causes a displacement of the liner on the high-explosive charge. Over many changes in temperature, the liner shifts to the rear relative to the high-explosive charge, so that the charge can become partially exposed.”

Cast Cure Partially Adhered Filling

Eurenco/OTO Melara Naval gun system 76 mm shell [Chabin 2012]



Explosive: B2263A (HBU 88B)



- “Anti adhesive liner is put on the internal parts of the structure except on a specific zone where the explosive loading bonds directly to the metal part.”.
- Stress/strain state calculated from axial/spin accelerations at high and low temperatures.
- Results compared to the mechanical properties (Split Hopkinson bar data).
  - Max stress at the corner bottom of the fuse well but below explosive capacity
  - No residual strain
  - Physical integrity of the explosive loading is ensured during the gun firing
  - No relative motion has been determined between the explosive loading and the structure that cancels risks of friction and so risks of initiation of the explosive

Cast Cure Non-Adhered Fillings

- Clearly the thin plastic liners are intended to overcome issues associated with thermal expansion of the explosive billet. Presumably this would be tearing or cracking of the explosive caused by thermal cycling and adherence to the projectile case.
- Verbal reports that cast cure explosives will sometimes partially detach or tear when thermally cycled due to adherence to the case.
- Interior case greasing is another possibility.
  - Collet [1983] greased interior Comp-B filled projectiles showed higher explosive base stresses (~40% increase) compared to non-greased Comp-B filled 155 mm projectiles

Thermal Expansions

Metals
- Aluminum: ~24 $x10^{-6}$/°C
- Steel: ~13 $x10^{-6}$/°C

Pressed Explosive
- Comp A-3: ~72 $x10^{-6}$/°C
- LX-04: ~71 $x10^{-6}$/°C
- PBX-9501: ~49 $x10^{-6}$/°C

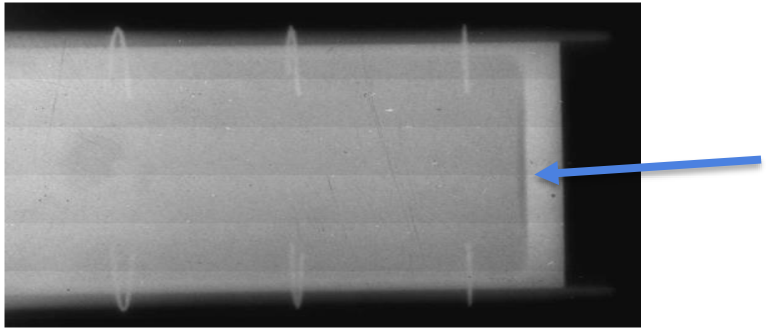
Between room temperature and 60°C

Melt Pour Explosive
- TNT: 52 to 57 $x10^{-6}$/°C
- Comp B: ~76 $x10^{-6}$/°C
- IMX-104: 62 to 101 $x10^{-6}$/°C [Patel 2015]

Cast Cure Explosive
- PBXN-106: 121 to 130 $x10^{-6}$/°C

Explosive Mechanical Response

- Lack of experimental data for the response of energetic materials during gun launch
- ARDEC Comp-B filled 155mm projectiles [Collet 1983]
  - Non lubricated cases: between 14% and 20% (15.4% average) of the theoretical pressure
  - Lubricated cases: between 9% and 32% (21.8% average) of the theoretical pressure
- BAE Land Systems UK cast cure simulant filled 105mm: close to theoretical pressure
- QinetiQ laboratory cast cure simulant filled 40mm (no case liner or lubrication): flash radiography [Church 2001, Huntington-Thresher 2006].



Gap shape indicates strong influence due to case adhesion

Summary

- Working Group currently investigating for melt pours
- Non-adhered filling appears to be often applied for cast cure explosives
  - Thin plastic liners or grease
  - Can be partial or complete case interior
  - Intended to overcome issues associated with the high thermal expansion of cast cure explosives.
- Very little data on dynamic fill response
  - Cast cure, melt pour, pressed fillings
  - Adhered versus non-adhered
- Limited results indicate that increased wall friction and increased explosive stiffness make considerable reductions to the explosive base stress profiles

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