THALES

Australian Government
Department of Defence
Defence Science and Technology Group

Energetic Material Qualification of Thales Australia Produced PBXN-111 (AX-2002)

Dr Caitlyn Neesam[1]
Energetic Materials Chemist

Nick Buggy[2]
Product Development Engineer

Pictures from Thales production files unless stated otherwise

Distribution Statement A: Approved for Public Release.

[1] Defence Science and Technology Group
[2] Thales Australia

Presentation Overview

- Purpose
- PBXN-111 & AX-2002
- Manufacturing Process
- Development Approach
- DSTG & Thales Australia
- EMQ Test Schedule
- Testing Considerations
  - Critical Diameter
  - Shock Sensitivity
- Future Work

Distribution Statement A: Approved for Public Release.
{OPEN}

Purpose

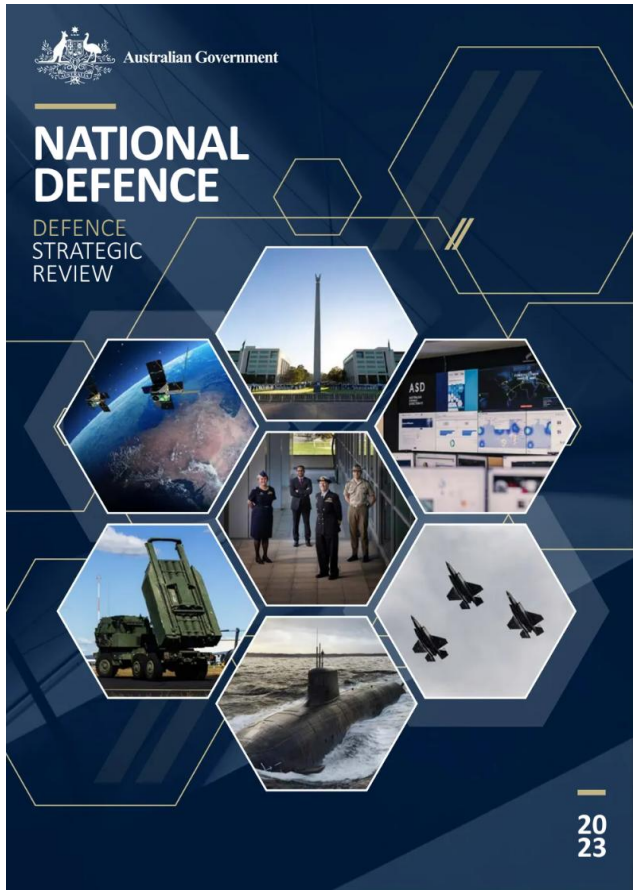
> Defence Strategic Review 2023

- Support undersea warfare requirements
- Expand sovereign manufacturing capability of specific GWEO subsystems and munitions

> Domestic supply chains

- Reduce dependence on strained & unpredictable foreign sources

> Industrial scale manufacture of PBXN-111 (AX-2002) in Australia



Source: Australian Government Defence (2023)

Distribution Statement A: Approved for Public Release.
{OPEN}

PBXN-111

> High Explosive used in underwater munitions

> Polymer bonded explosive (PBX) formulation

- Plasticised polyurethane matrix
- Cast cure process

> Active components

- RDX (20%) → secondary high explosive
- Al powder (25%) → heat generation
- Ammonium perchlorate (43%) → oxidation

> Rapid generation of large quantity of hot gas

→ High energy bubble ascends to surface



Source: Jennifer Parker (2026)

Distribution Statement A: Approved for Public Release.
{OPEN}

AX-2002

> Australianised variant of PBXN-111

> Domestically sourced ingredients

- Reduced Sensitivity RS RDX
  → Mulwala Defence Facility (Thales)
- Al powder

> Coated Explosive Materials (CXM)

- RDX phlegmatised with plasticiser
- Reduce sensitiveness → improved safety
- Produced at Mulwala by Thales

> Built-to-spec formulation

- Conforms with OEM specification



Distribution Statement A: Approved for Public Release.
{OPEN}

Manufacturing Equipment

> Baker Perkins dual planetary mixers

- Off-centre positioning of blades
- Minimal blade clearance from bowl
- Vacuum & temperature controlled
- Consistent and homogeneous mixing

> Carousel vacuum chamber

- Air entrainment in mixing & casting causes porosity
  → Casting under vacuum
- Designed for EMQ activities
- High capacity & flexibility



Source: Thales Australia (2026)

Distribution Statement A: Approved for Public Release.
{OPEN}

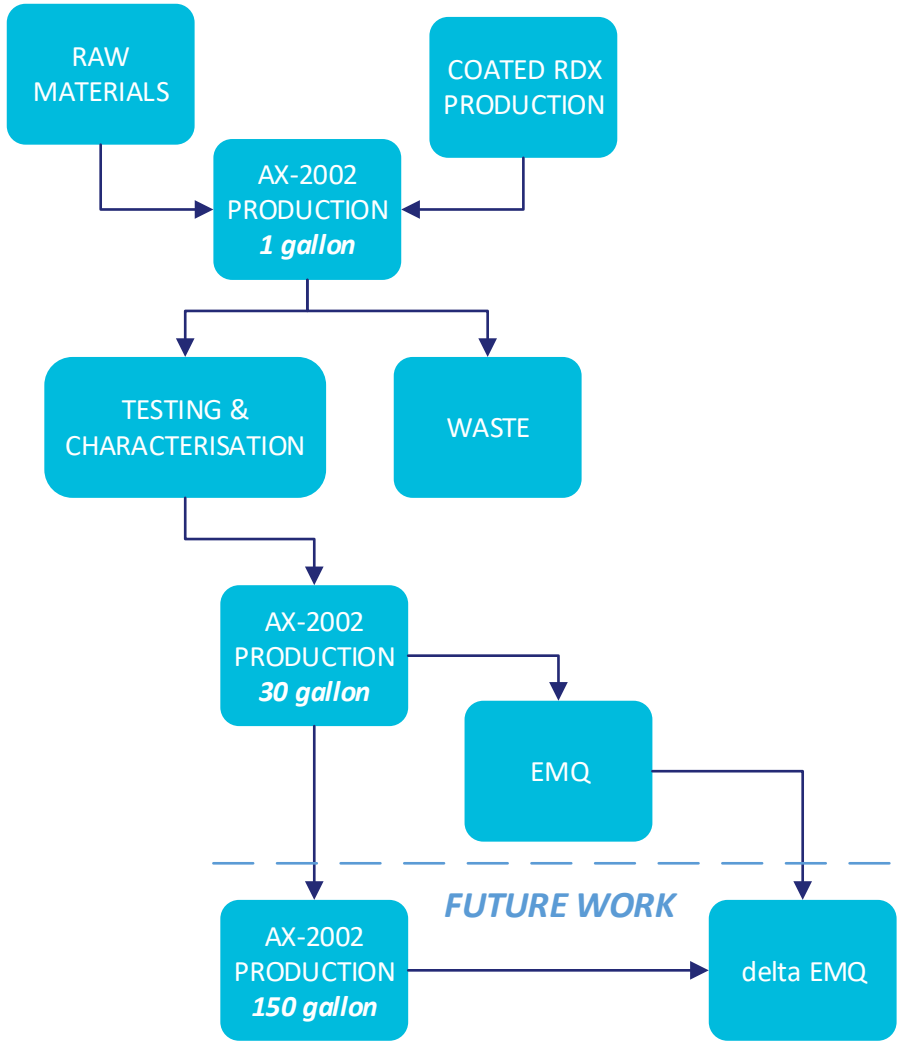
Safety Informs Development Approach

> Safety

- Material hazards
  - Explosives
  - Flammable powder
  - Potent oxidiser
- Production & Testing Life Cycle

> Approach

- Incremental scale up
  - 1-gallon → 30-gallon batches
  - Establish & validate manufacturing process
- Optimise formulation & process parameters



Distribution Statement A: Approved for Public Release.
{OPEN}

Testing and Characterisation

> Components

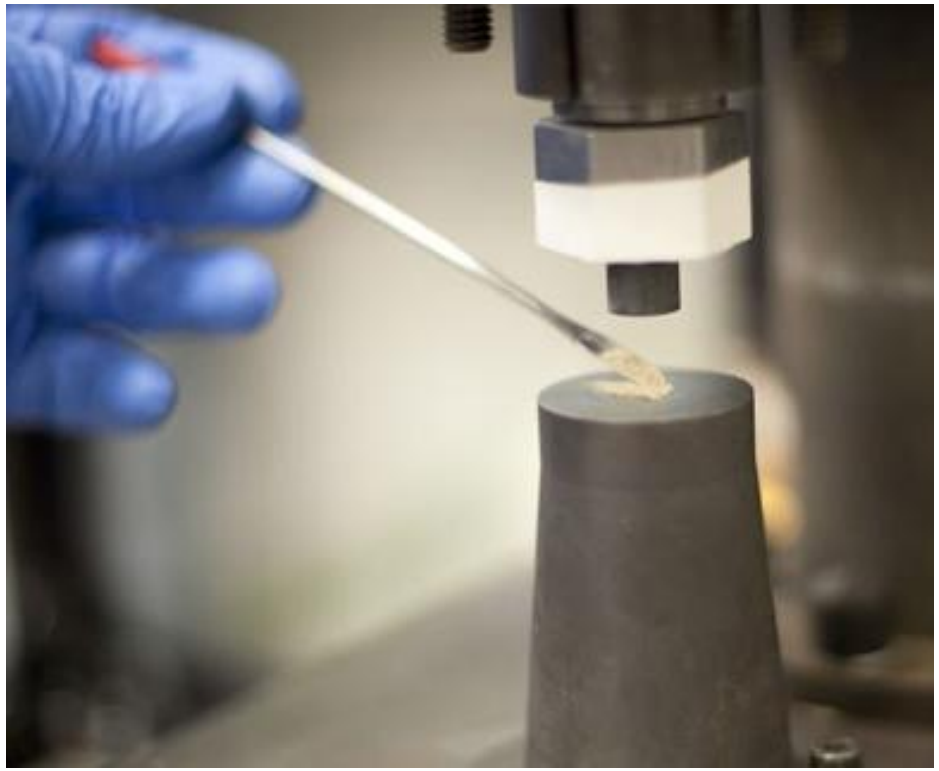
- Compatibility with energetics
- Lot acceptance
- Stability and storage (CXM)

> AX-2002

- Lot acceptance
- In-process testing
- Develop, validate & verify test methods

> Sensitiveness testing (FISH)

> Waste disposal



Source: Safety Management Services (2026)

Distribution Statement A: Approved for Public Release.
{OPEN}

Collaborative Approach

> Technical advisory

> Energetic Material Qualification of AX-2002 (DEOP 102)

- Test plan developed by DSTG
  - → Endorsed by Directorate of Ordnance Safety (DOS)
- DSTG consulted as SME
  - Test methods
  - Deliverables

> Testing

- DSTG Edinburgh: Performance & safety characterisation
- Thales Australia: Ageing study





Australian Government
Department of Defence
Defence Science and Technology Group

THALES

Distribution Statement A: Approved for Public Release.
{OPEN}

Collaboration between DSTG and Thales Australia

> Technical advisory

> Energetic Material Qualification of AX-2002 (DEOP 102)

- Test plan endorsed by Directorate of Ordnance Safety (DOS)
- DSTG consulted as SME
  - Test methods
  - Deliverables
  - Capabilities

> Testing

- DSTG Edinburgh: Performance & safety characterisation
- Thales Australia: Ageing study

Distribution Statement A: Approved for Public Release.
{OPEN}

EMQ Schedule

Property	Test	Reference	Responsibility
Stability and Thermal Characterisation	Vacuum Thermal Stability Differential Scanning Calorimetry	STANAG 4556 STANAG 4515	DSTG
Ignition Temperature	Temperature of Ignition Ignition by Flash	STANAG 4491 EMTAP Test 4	DSTG
Explosive response when ignited	Train Test	EMTAP Test 5	DSTG
Electrostatic Discharge	Ignition by Electric Spark	STANAG 4490 EMTAP Test 6	DSTG
Impact Sensitiveness	Rotter Impact Rotter Impact with 1% Added Grit	STANAG 4489 EMTAP 1C	DSTG
Friction Sensitiveness	BAM Friction	STANAG 4487	DSTG
Shock Sensitiveness	Large Scale Gap Test Expended Large Scale Gap Test	DSTG Large Scale Gap Test	DSTG
Critical Diameter	Critical Diameter	DSTG Test Procedure	DSTG
Detonation Velocity	Detonation Velocity	DSTG Test Procedure	DSTG
Mechanical Properties	Uniaxial Tensile Test Shore A Hardness	STANAG 4506 Type A-2 Durometer	THALES
Variation of Properties With Age: Impact & Friction Sensitiveness Mechanical Properties Stability	Rotter Impact BAM Friction Uniaxial Tensile Test Shore A Hardness Differential Scanning Calorimetry Anti-oxidant Depletion Exudation Plasticiser Loss	STANAG 4489 STANAG 4487 STANAG 4506 Type A-2 Durometer STANAG 4515 Chemical Analysis Visual Evidence Chemical Analysis	DSTG DSTG THALES THALES DSTG DSTG/THALES DSTG DSTG/THALES

Distribution Statement A: Approved for Public Release.
{OPEN}

EMQ Schedule

Property	Test	Reference	Responsibility
Stability and Thermal Characterisation	Vacuum Thermal Stability Differential Scanning Calorimetry	STANAG 4556 STANAG 4515	DSTG
Ignition Temperature	Temperature of Ignition Ignition by Flash	STANAG 4491 EMTAP Test 4	DSTG
Explosive response when ignited	Train Test	EMTAP Test 5	DSTG
Electrostatic Discharge	Ignition by Electric Spark	STANAG 4490 EMTAP Test 6	DSTG
Impact Sensitiveness	Rotter Impact Rotter Impact with 1% Added Grit	STANAG 4489 EMTAP 1C	DSTG
Friction Sensitiveness	BAM Friction	STANAG 4487	DSTG
Shock Sensitiveness	Large Scale Gap Test Expended Large Scale Gap Test	DSTG Large Scale Gap Test	DSTG
Critical Diameter	Critical Diameter	DSTG Test Procedure	DSTG
Detonation Velocity	Detonation Velocity	DSTG Test Procedure	DSTG
Mechanical Properties	Uniaxial Tensile Test Shore A Hardness	STANAG 4506 Type A-2 Durometer	THALES
Variation of Properties With Age: Impact & Friction Sensitiveness Mechanical Properties Stability	Rotter Impact BAM Friction Uniaxial Tensile Test Shore A Hardness Differential Scanning Calorimetry Anti-oxidant Depletion Exudation Plasticiser Loss	STANAG 4489 STANAG 4487 STANAG 4506 Type A-2 Durometer STANAG 4515 Chemical Analysis Visual Evidence Chemical Analysis	DSTG DSTG THALES THALES DSTG DSTG/THALES DSTG DSTG/THALES

Distribution Statement A: Approved for Public Release.
{OPEN}

EMQ Schedule

Property	Test	Reference	Responsibility
Stability and Thermal Characterisation	Vacuum Thermal Stability Differential Scanning Calorimetry	STANAG 4556 STANAG 4515	DSTG
Ignition Temperature	Temperature of Ignition Ignition by Flash	STANAG 4491 EMTAP Test 4	DSTG
Explosive response when ignited	Train Test	EMTAP Test 5	DSTG
Electrostatic Discharge	Ignition by Electric Spark	STANAG 4490 EMTAP Test 6	DSTG
Impact Sensitiveness	Rotter Impact Rotter Impact with 1% Added Grit	STANAG 4489 EMTAP 1C	DSTG
Friction Sensitiveness	BAM Friction	STANAG 4487	DSTG
Shock Sensitiveness	Large Scale Gap Test Expended Large Scale Gap Test	DSTG Large Scale Gap Test	DSTG
Critical Diameter	Critical Diameter	DSTG Test Procedure	DSTG
Detonation Velocity	Detonation Velocity	DSTG Test Procedure	DSTG
Mechanical Properties	Uniaxial Tensile Test Shore A Hardness	STANAG 4506 Type A-2 Durometer	THALES
Variation of Properties With Age: Impact & Friction Sensitiveness Mechanical Properties Stability	Rotter Impact BAM Friction Uniaxial Tensile Test Shore A Hardness Differential Scanning Calorimetry Anti-oxidant Depletion Exudation Plasticiser Loss	STANAG 4489 STANAG 4487 STANAG 4506 Type A-2 Durometer STANAG 4515 Chemical Analysis Visual Evidence Chemical Analysis	DSTG DSTG THALES THALES DSTG DSTG/THALES DSTG DSTG/THALES

Distribution Statement A: Approved for Public Release.
{OPEN}

EMQ Schedule

Property	Test	Reference	Responsibility
Stability and Thermal Characterisation	Vacuum Thermal Stability Differential Scanning Calorimetry	STANAG 4556 STANAG 4515	DSTG
Ignition Temperature	Temperature of Ignition Ignition by Flash	STANAG 4491 EMTAP Test 4	DSTG
Explosive response when ignited	Train Test	EMTAP Test 5	DSTG
Electrostatic Discharge	Ignition by Electric Spark	STANAG 4490 EMTAP Test 6	DSTG
Impact Sensitiveness	Rotter Impact Rotter Impact with 1% Added Grit	STANAG 4489 EMTAP 1C	DSTG
Friction Sensitiveness	BAM Friction	STANAG 4487	DSTG
Shock Sensitiveness	Large Scale Gap Test Expended Large Scale Gap Test	DSTG Large Scale Gap Test	DSTG
Critical Diameter	Critical Diameter	DSTG Test Procedure	DSTG
Detonation Velocity	Detonation Velocity	DSTG Test Procedure	DSTG
Mechanical Properties	Uniaxial Tensile Test Shore A Hardness	STANAG 4506 Type A-2 Durometer	THALES
Variation of Properties With Age: Impact & Friction Sensitiveness Mechanical Properties Stability	Rotter Impact BAM Friction Uniaxial Tensile Test Shore A Hardness Differential Scanning Calorimetry Anti-oxidant Depletion Exudation Plasticiser Loss	STANAG 4489 STANAG 4487 STANAG 4506 Type A-2 Durometer STANAG 4515 Chemical Analysis Visual Evidence Chemical Analysis	DSTG DSTG THALES THALES DSTG DSTG/THALES DSTG DSTG/THALES

Distribution Statement A: Approved for Public Release.
{OPEN}

EMQ Schedule

Property	Test	Reference	Responsibility
Stability and Thermal Characterisation	Vacuum Thermal Stability Differential Scanning Calorimetry	STANAG 4556 STANAG 4515	DSTG
Ignition Temperature	Temperature of Ignition Ignition by Flash	STANAG 4491 EMTAP Test 4	DSTG
Explosive response when ignited	Train Test	EMTAP Test 5	DSTG
Electrostatic Discharge	Ignition by Electric Spark	STANAG 4490 EMTAP Test 6	DSTG
Impact Sensitiveness	Rotter Impact Rotter Impact with 1% Added Grit	STANAG 4489 EMTAP 1C	DSTG
Friction Sensitiveness	BAM Friction	STANAG 4487	DSTG
Shock Sensitiveness	Large Scale Gap Test Expended Large Scale Gap Test	DSTG Large Scale Gap Test	DSTG
Critical Diameter	Critical Diameter	DSTG Test Procedure	DSTG
Detonation Velocity	Detonation Velocity	DSTG Test Procedure	DSTG
Mechanical Properties	Uniaxial Tensile Test Shore A Hardness	STANAG 4506 Type A-2 Durometer	THALES
Variation of Properties With Age: Impact & Friction Sensitiveness Mechanical Properties Stability	Rotter Impact BAM Friction Uniaxial Tensile Test Shore A Hardness Differential Scanning Calorimetry Anti-oxidant Depletion Exudation Plasticiser Loss	STANAG 4489 STANAG 4487 STANAG 4506 Type A-2 Durometer STANAG 4515 Chemical Analysis Visual Evidence Chemical Analysis	DSTG DSTG THALES THALES DSTG DSTG/THALES DSTG DSTG/THALES

Distribution Statement A: Approved for Public Release.
{OPEN}

EMQ Schedule

Property	Test	Reference	Responsibility
Stability and Thermal Characterisation	Vacuum Thermal Stability Differential Scanning Calorimetry	STANAG 4556 STANAG 4515	DSTG
Ignition Temperature	Temperature of Ignition Ignition by Flash	STANAG 4491 EMTAP Test 4	DSTG
Explosive response when ignited	Train Test	EMTAP Test 5	DSTG
Electrostatic Discharge	Ignition by Electric Spark	STANAG 4490 EMTAP Test 6	DSTG
Impact Sensitiveness	Rotter Impact Rotter Impact with 1% Added Grit	STANAG 4489 EMTAP 1C	DSTG
Friction Sensitiveness	BAM Friction	STANAG 4487	DSTG
Shock Sensitiveness	Large Scale Gap Test Expended Large Scale Gap Test	DSTG Large Scale Gap Test	DSTG
Critical Diameter	Critical Diameter	DSTG Test Procedure	DSTG
Detonation Velocity	Detonation Velocity	DSTG Test Procedure	DSTG
Mechanical Properties	Uniaxial Tensile Test Shore A Hardness	STANAG 4506 Type A-2 Durometer	THALES
Variation of Properties With Age: Impact & Friction Sensitiveness Mechanical Properties Stability	Rotter Impact BAM Friction Uniaxial Tensile Test Shore A Hardness Differential Scanning Calorimetry Anti-oxidant Depletion Exudation Plasticiser Loss	STANAG 4489 STANAG 4487 STANAG 4506 Type A-2 Durometer STANAG 4515 Chemical Analysis Visual Evidence Chemical Analysis	DSTG DSTG THALES THALES DSTG DSTG/THALES DSTG DSTG/THALES

Distribution Statement A: Approved for Public Release.
{OPEN}

Testing Considerations

> **PBXN-111 (AX-2002) thermodynamically non-ideal explosive formulation.**

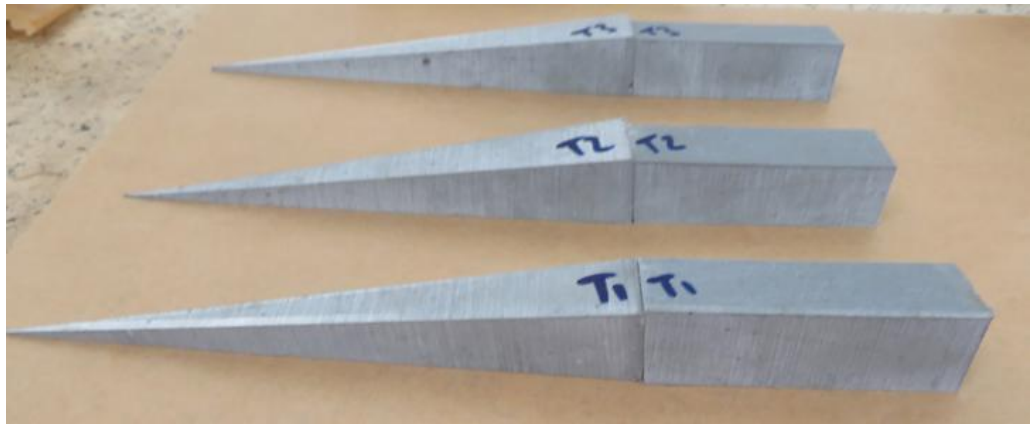
- Likes to burn, rather than explode in an aerobic environment

> **Difficult to determine critical diameter and shock sensitivity through traditional test methods.**

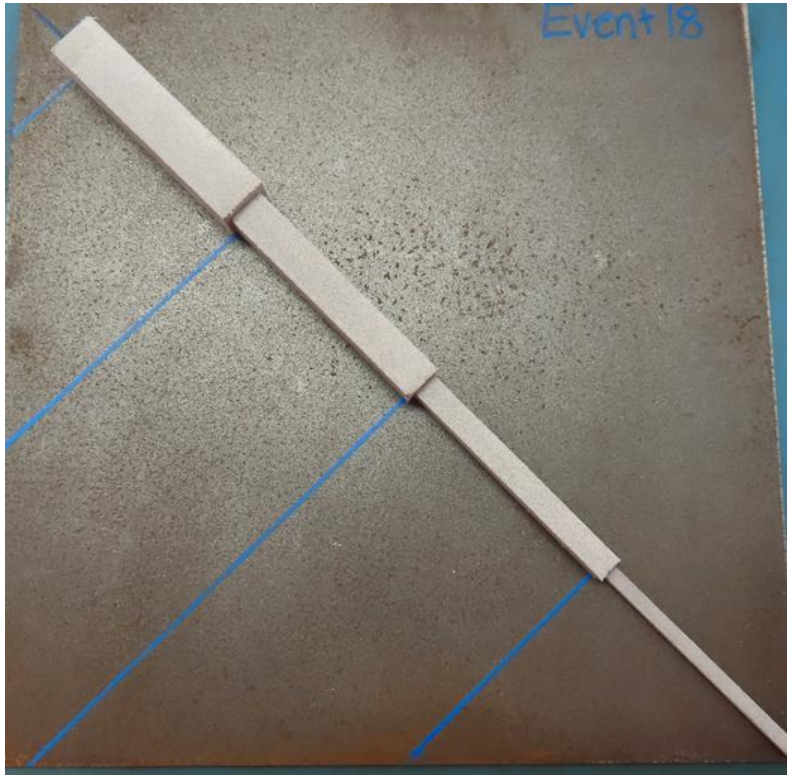
Distribution Statement A: Approved for Public Release.
{OPEN}

Critical Diameter (or 'Diameter of Failure')

- Minimum diameter at which a cylindrical charge of explosive sustains a high-order steady-state detonation
- More sensitive material = smaller critical diameter
- PBXN-111 is very insensitive = larger critical diameter.



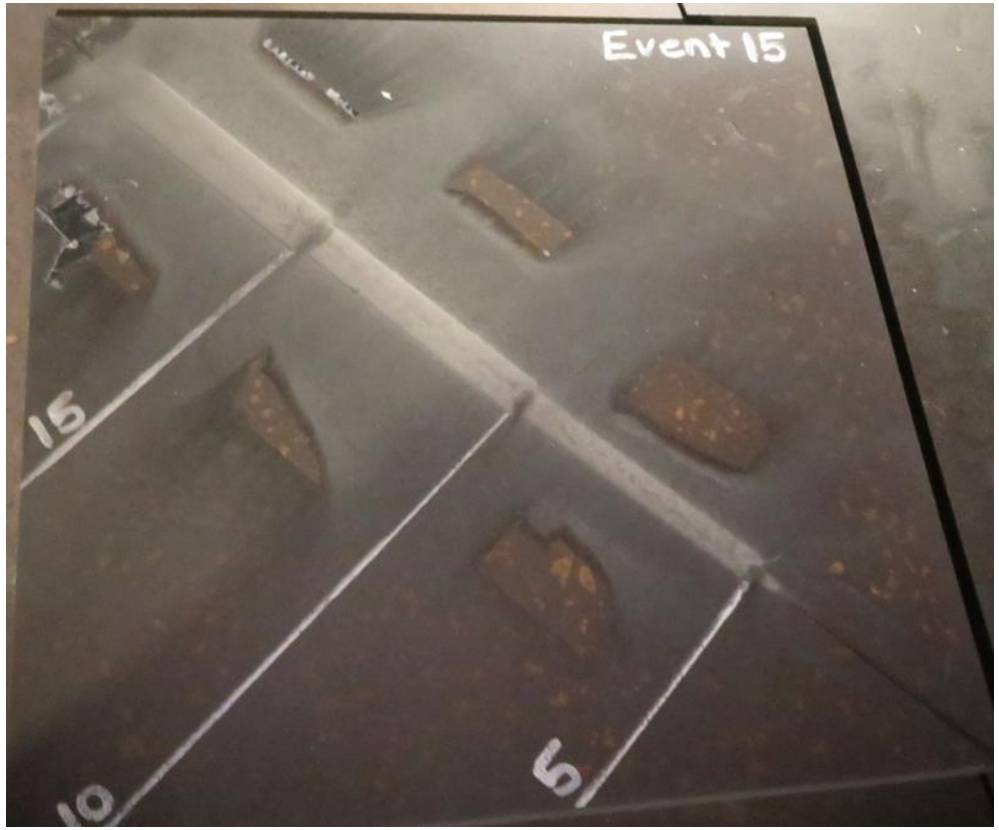


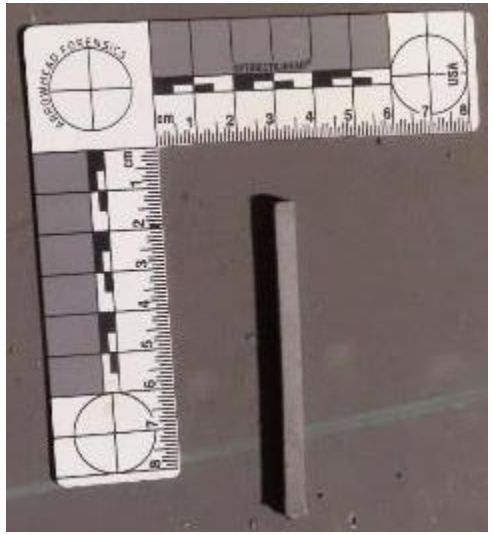


Distribution Statement A: Approved for Public Release.
{OPEN}

Critical Diameter (or ‘Diameter of Failure’)







Distribution Statement A: Approved for Public Release.
{OPEN}

Critical Diameter – ATTEMPT 1
Conical Charge Method





Distribution Statement A: Approved for Public Release.

Critical Diameter – ATTEMPT 2
Unconfined Diameter Method **

Charge	Height (mm)	**ID (mm)**	NEQ (g)	Average VoD (m/s)
1	490	**60**	2,508	5,400
2	442	**54**	1,832	Burning result only as evidenced by no VoD pin recordings and partial recovery of flexible circuit boards.
3	378	**46**	1,137	No reaction
4	338	**41**	808	Not tested – below critical diameter
5	298	**36**	549	Not tested– below critical diameter





** As recommended by Indian Head, US Navy

Distribution Statement A: Approved for Public Release.
{OPEN}

Critical Diameter – ATTEMPT 2
Unconfined Diameter Method

Charge	Height (mm)	**ID (mm)**	NEQ (g)	Average VoD (m/s)
1	490	**60**	2,508	5,400
2	442	**54**	1,832	Burning result only as evidenced by no VoD pin recordings and partial recovery of flexible circuit boards.
3	378	**46**	1,137	No reaction
4	338	**41**	808	Not tested – below critical diameter
5	298	**36**	549	Not tested– below critical diameter





Distribution Statement A: Approved for Public Release.
{OPEN}

Critical Diameter – ATTEMPT 2
Unconfined Diameter Method

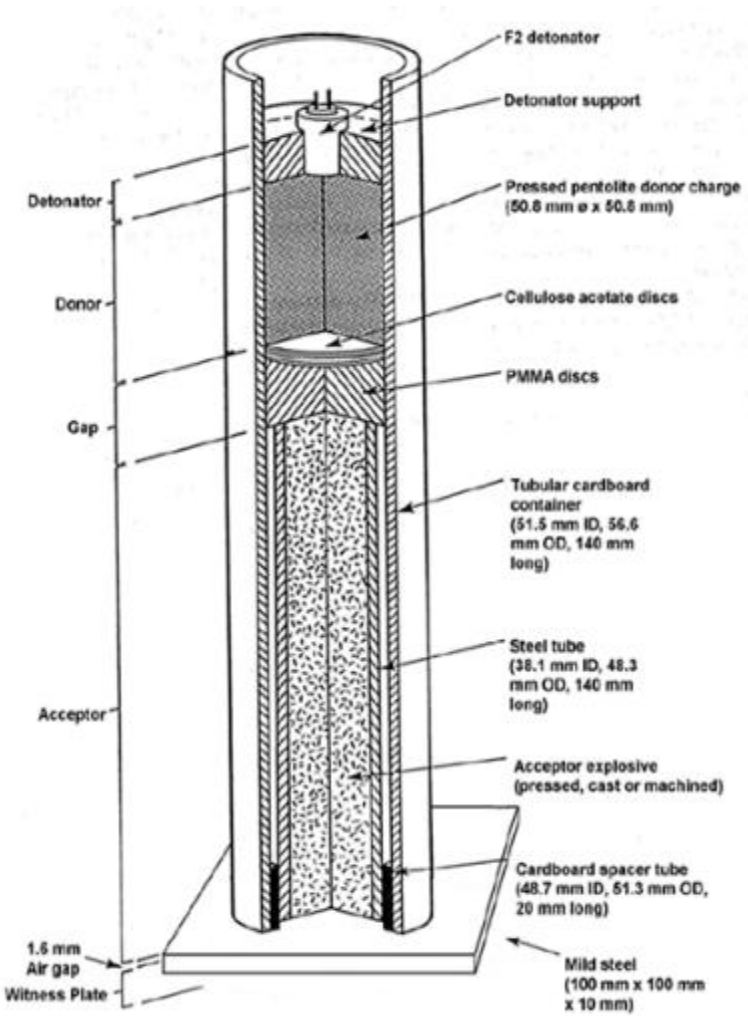
Charge	Height (mm)	**ID (mm)**	NEQ (g)	Average VoD (m/s)
1	490	**60**	2,508	5,400
2	442	**54**	1,832	Burning result only as evidenced by no VoD pin recordings and partial recovery of flexible circuit boards.
3	378	**46**	1,137	No reaction
4	338	**41**	808	Not tested – below critical diameter
5	298	**36**	549	Not tested– below critical diameter





Distribution Statement A: Approved for Public Release.
{OPEN}

Shock Sensitivity – Large Scale Gap Test (LSGT)





Donor
(Pentolite*)

Gap
(PMMA discs)

Acceptor
(AX-2002 confined in mild steel tubing)



*Pentolite = 50% PETN, 50% TNT

Distribution Statement A: Approved for Public Release.
{OPEN}

Shock Sensitivity – Large Scale Gap Test (LSGT)

No-Go Go



Distribution Statement A: Approved for Public Release.
{OPEN}

Shock Sensitivity – Large Scale Gap Test (LSGT)

Go



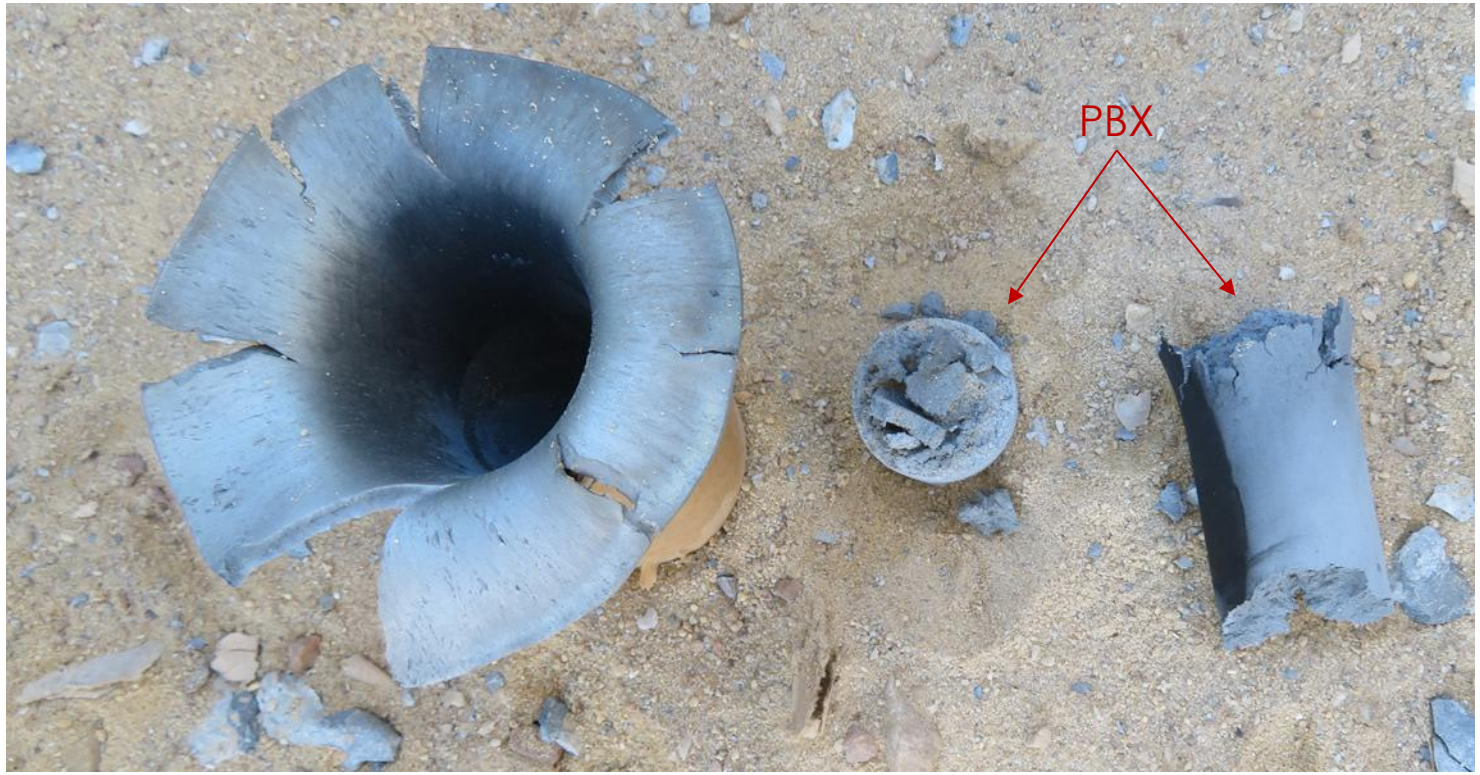


Distribution Statement A: Approved for Public Release.
{OPEN}

Shock Sensitivity – Large Scale Gap Test (LSGT)

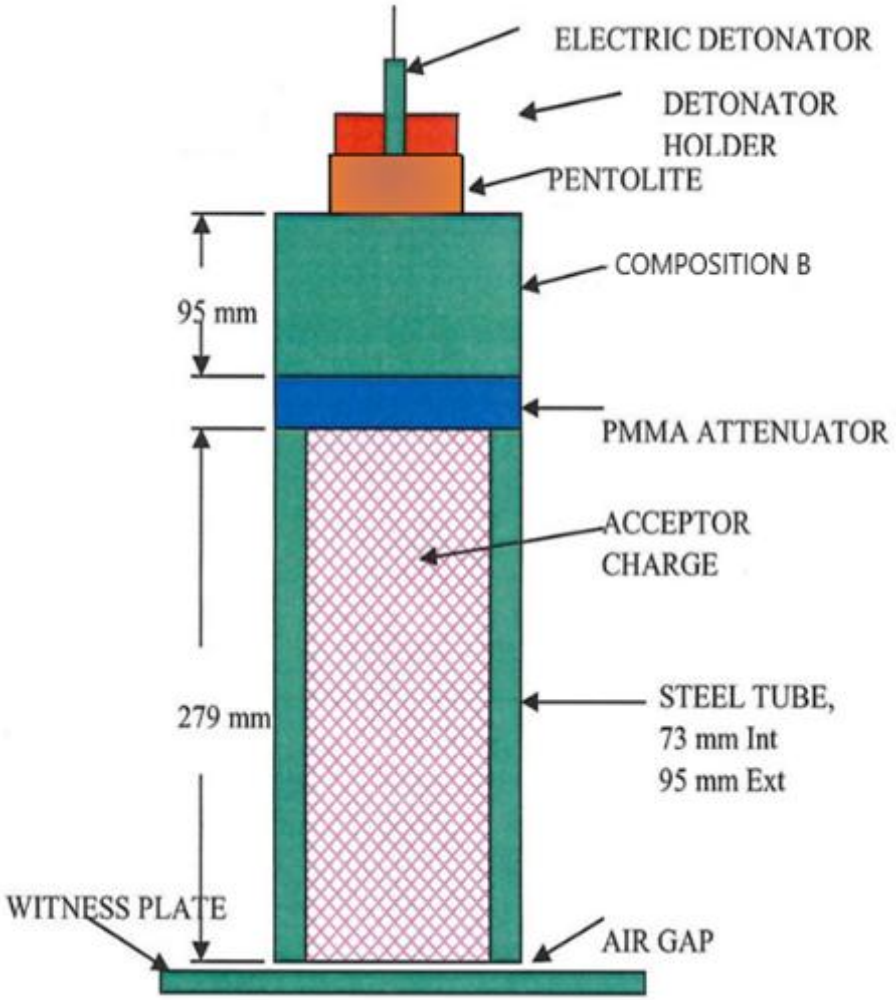
No-Go





Distribution Statement A: Approved for Public Release.
{OPEN}

Shock Sensitivity – EXPANDED Large Scale Gap Test (ELSGT)





Donor
(Pentolite and Comp B*)

Gap
(PMMA discs)

Acceptor
(AX-2002 confined in mild steel tubing)

NEQ of Acceptor charge
LSGT = 260 g
ELSGT = 2,200 g

*Comp B = 60% RDX, 40% TNT

Distribution Statement A: Approved for Public Release.
{OPEN}

Shock Sensitivity – EXPANDED Large Scale Gap Test (ELSGT)



60 L bin filled with water



Distribution Statement A: Approved for Public Release.
{OPEN}

Future Work

> Industrialise

- AX-2002
  - 150-gallon scale-up
- CXM production
- Validate material properties against baseline

> Delta EMQ of AX-2002 at production scale

- Physical & chemical properties
- Ageing study
- Further tests as agreed (DOS, DSTG, OEM)



Source: Thales Australia (2026)

Distribution Statement A: Approved for Public Release.
{OPEN}

Future Work

> Further industrial assessments to support scale-up

- Process parameters
- AX-2002 characteristics
  - Pot life & castability
  - Rheology
  - Curing profile
  - Thermal properties (cured & uncured)

> Underwater performance testing

- Further evaluation at DSTG's Underwater Explosive Testing Facility (UETF, Nagambie VIC)
  - Relative bubble energy (E_{RB})
  - Shock wave energy (E_{SW})



Source: The Slow Mo Guys (2016)

Distribution Statement A: Approved for Public Release.
{OPEN}

References

Australian Government Defence (2023). National Defence: Defence Strategic Review 2023. Retrieved from https://www.defence.gov.au/about/reviews-inquiries/defence-strategic-review

Jennifer Parker (2026). Sea mines: Australia's most dangerous blind spot Retrieved from https://www.jennifer-parker.com.au/post/sea-mines-australia-s-most-dangerous-blind-spot

Safety Management Services (2021). Sensitivity Testing. Retrieved from https://smsenergetics.com/testing/sensitivity-testing

Thales Australia (2026). Thales Australia Instagram, 30 April, 2026. Retrieved from https://www.instagram.com/p/DXvkkkCAFz6/

The Slow Mo Guys (2016). "Underwater Explosions at 120,000fps". Retrieved from https://www.youtube.com/watch?v=E5rGFZWQfzk

Distribution Statement A: Approved for Public Release.
{OPEN}



Source: Thales Australia (2026)

THALES
Building a future we can all trust

Australian Government
Department of Defence
Defence Science and Technology Group

Thank you

Questions?