2009 Insensitive Munitions and Energetic Materials Technology Symposium

Qualification Testing of the Insensitive TNT Replacement Explosive IMX-101

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Acknowledgments

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Introduction

- **PM CAS Program Objectives:**
  - Implementation of an EIDS* and IM Solution in 155mm Artillery Ammunition within 3 years
    - Reduce hazard classification from 1.1 to 1.6
    - Implement system IM solution while maintaining system performance
- **Explosive Technology Transition**
  - Provide an insensitive replacement for TNT
  - Provide a fully characterized, IM compliant, and ready for full qualification explosive
  - Provide an EIDS explosive solution

*Extremely Insensitive Detonating Substance

JIMTP Technology Objectives

- **System IM Objectives**
  - Demonstrate Type III response for Sympathetic Detonation (SD) without barriers at the 155mm diameter
  - Demonstrate Type V response for Fast Cookoff (FCO) of an artillery round
  - Demonstrate Type III/V response for Shaped Charge Jet (SCJ) at TNT energy
  - Maintain system performance (e.g., Fragmentation and blast overpressure)
  - Maintain acceptable production and life cycle costs (affordable and producible within industrial base)
  - Characterize Slow Cookoff (SCO), Bullet Impact (BI), and Fragment Impact (FI)

Explosive Formulations

	IMX-101	IMX-102	IMX-103
2,4-Dinitroanisole (DNAN)	40	--	--
* Proprietary *	40	--	45
3-Nitro-1,2,4-triazol-5-one (NTO)	20	50	--
Trinitrotoluene (TNT)	--	35	--
Wax	--	15	--
DEMN (Nitrate Salt Eutectic)	--	--	50
RDX	--	--	5

- Formulated from common and inexpensive ingredients
- Detonation Energy equivalent to TNT
- Low Hazard Sensitivity
- Melt pour processing similar to TNT

Engineering IM Tests

Fragment Impact

SCO

SCJI (50mm/81mm)

IM Test:	FCO	SCO	BI	FI	SD	SCJI	
Passing Criteria	V	V	V	V	III	III	
155mm Baseline (TNT)	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	
						50mm	81mm
IMX - 101	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IMX - 102	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IMX - 103	PASS	PASS	FAIL	PASS	PASS	FAIL	

- Past program to replace TNT for artillery projectiles produced IMX-101, IMX-102, and IMX-103
- Selected IMX-101

Explosive Producibility

- **Producibility**
  - Over 5,000 kg IMX-101 generated in production scale batches at BAE-Holston
    - One batch chosen for qualification (007)
  - Artillery round load studies at ARDEC
    - Optimized artillery round loading configuration and temperature profiles
    - Produced All Up Rounds for gun launch
    - Evaluated round QA procedures
      - Refine X-ray methods and data interpretation

Energetic Materials Qualification Process

- Purpose
  - Only qualified explosives will be used in munitions and devices for operational and training purposes
- Comprehensive assessment of the Energetic Material
  - Safe and Suitable for the intended use
- Assessment Includes
  - Small Scale Impact, Friction, ESD, Thermal properties
  - Ignition properties
  - Critical Temperature
  - Shock Sensitivity
  - Mechanical Properties
  - Sensitivity with age
  - Toxicity
  - Performance
  - Compatibility
  - System Sensitivity (e.g., Set Back From Gun Launch)

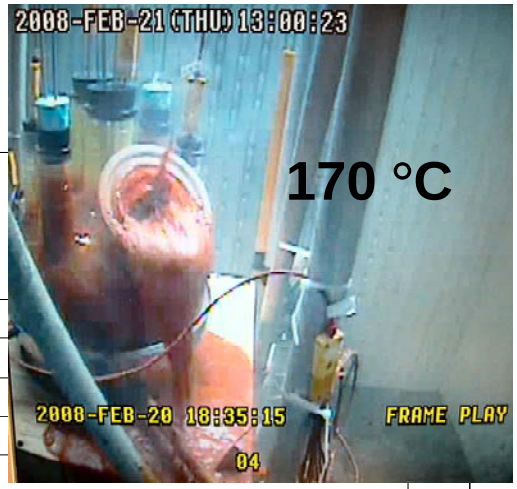
Small Scale Hazard Sensitivity

	ERL/ Bruceton Impact (cm)	BAM Friction (N)	ElectroStatic Discharge (ESD, J)	DSC (Exotherm peak; °C)	Vacuum Thermal Stability (ml/g, 100 °C/48 h)
TEST RANGE OR LIMIT	2.5 kg drop weight	80 N (Min.)	0.25 J	10 °C/min, 500 °C max	≤ 2 ml/g of gas evolved
IMX-101	> 100	240	No Go	223	0.34
TNT	88	216	No Go	300	0.10
RDX	27	168	Go	241	0.12

Critical Temperature

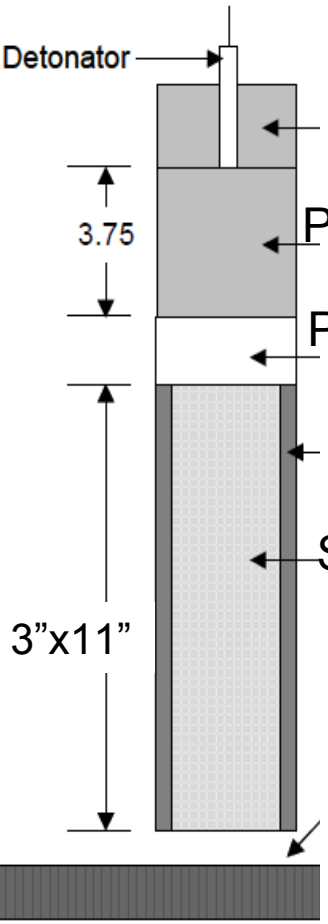
- Self Heating = Thermal decomposition of material produces heat faster than it can be dissipated to surroundings
- Critical Temperature = Lowest constant temperature at which a material can self heat catastrophically
  - No Scaling – same crit temp at 1-liter and 12-liter
  - Acceptable processing safety margin

Nonviolent Ejection



Shock Sensitivity

- Expanded Large Scale Gap Test (ELSGT)
  - 50% Gap Thickness

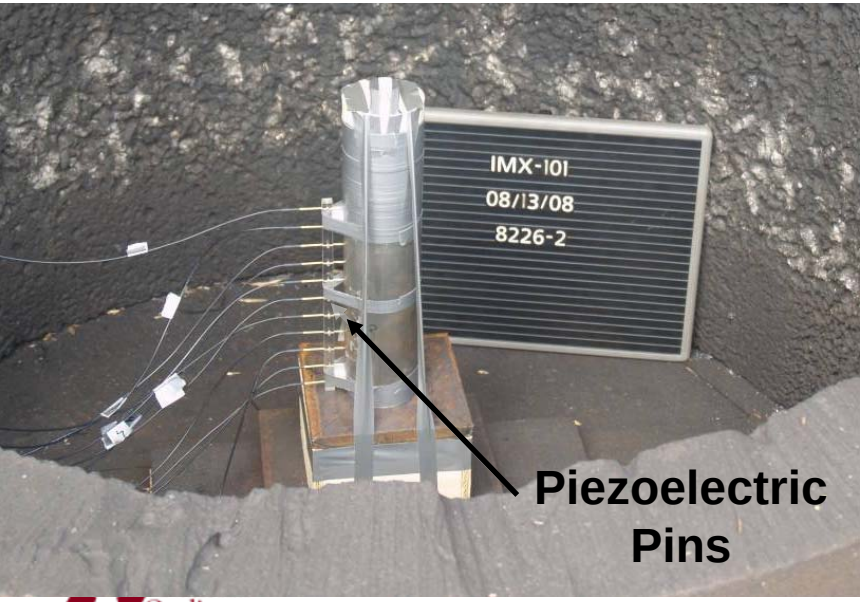


Test Number	Density (g/cc)	Gap (Cards)	Pressure (kbar)	Result
1	1.63	100	76	Go
2	1.64	200	51	No Go
3	1.64	149	61	Go
4	1.64	176	56	No Go
5	1.64	163	59	No Go
6	1.64	156	59	Go
7	1.64	159	59	Go
8	1.65	161	59	Go
9	1.64	162	59	No Go
10	1.64	157	59	No Go
11	1.64	152	60	Go
12	1.64	155	60	Go
TNT	1.59	438	14	
Comp B	1.69	489	10	

Detonation Velocity

- Detonation Velocity from ELSGT Samples

	Det Vel (km/s)	Density (g/cc)
▪ ***IMX-101***	6.9	1.64
▪ ***IMX-101***	6.9	1.64
▪ ***TNT***	6.9	1.64



Extremely Insensitive Detonating Substance (EIDS)

- Usual Hazard Classification for Explosives is 1.1 (Mass Explosion)
  - Large quantity-distance criteria imposed for bulk storage of ammunition
    - Separation distance for 4500 kg explosive was 381 m

- Hazard Classification of 1.6 (No Mass Explosion)
  - Separation distance for 4500 kg explosive is 52 m
    - Decrease logistics burden

    - System IM objectives become more achievable with less sensitive explosive

EIDS Characterization

UN Series 7 Tests

- EIDS Cap – Sensitivity to shock from standard detonator
- EIDS Gap – Sensitivity to a calibrated shock
- Susan Impact – Sensitivity to high velocity impact while confined
- EIDS Bullet Impact – 50 cal and two sample orientations
- EIDS External Fire – 30 minute bonfire
- EIDS Slow Cookoff – Increase temperature 3.3 °C/hr

EIDS Characterization

- EIDS Results - Cap

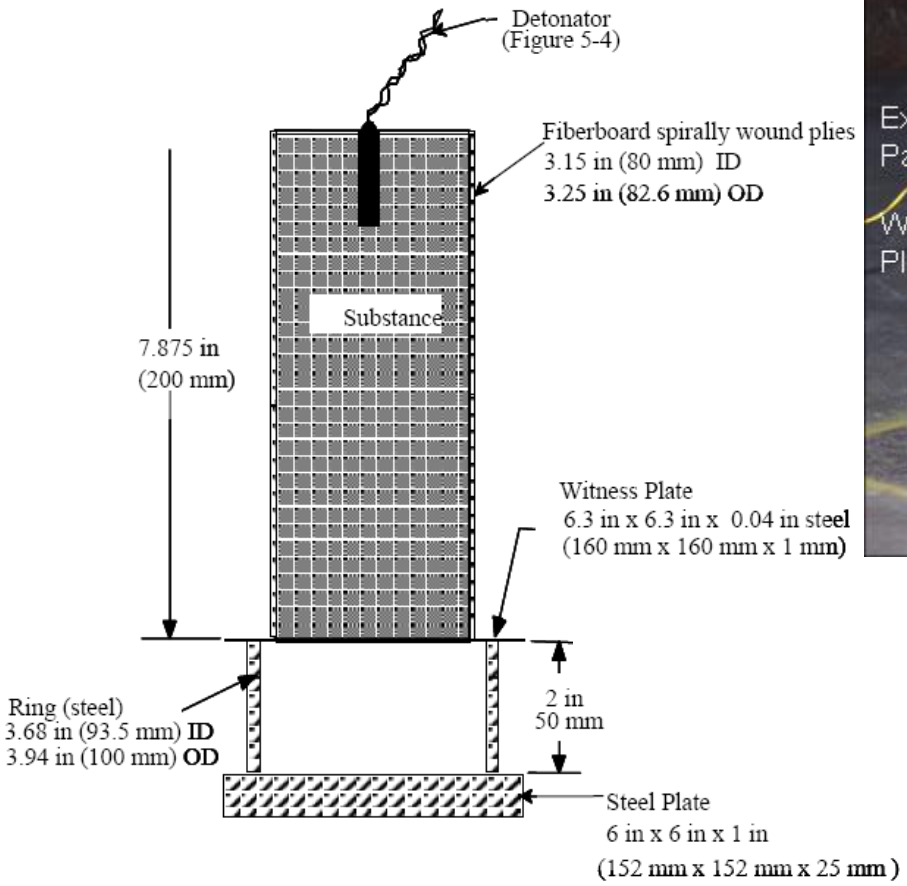
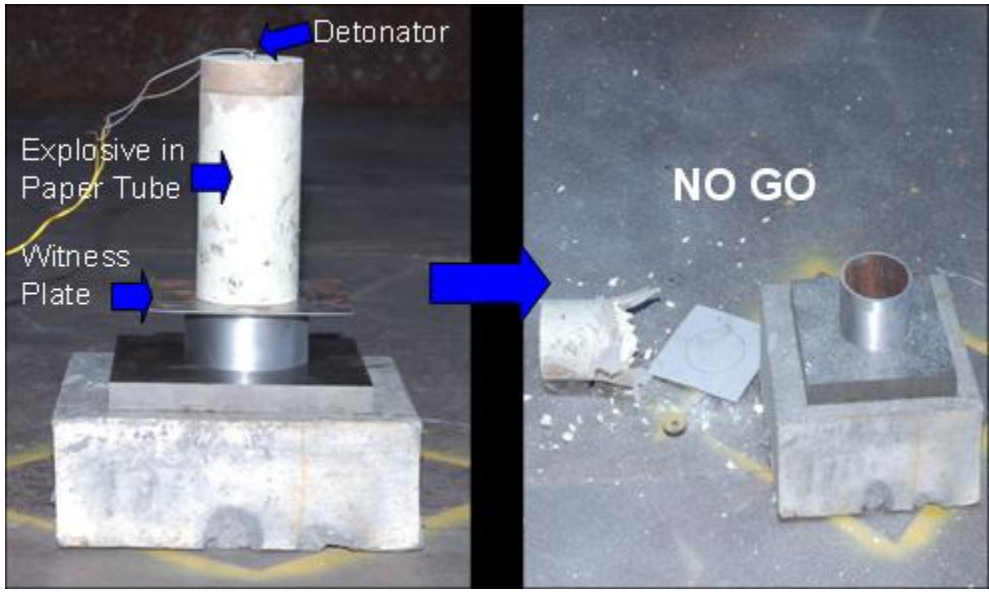


Figure 5-20. EIDS Cap Sensitivity Test configuration (UN Test 7(a)) – Cardboard Tube



No Witness Plate Penetration in 3 Trials

PASS

EIDS Characterization

- EIDS Results - Gap

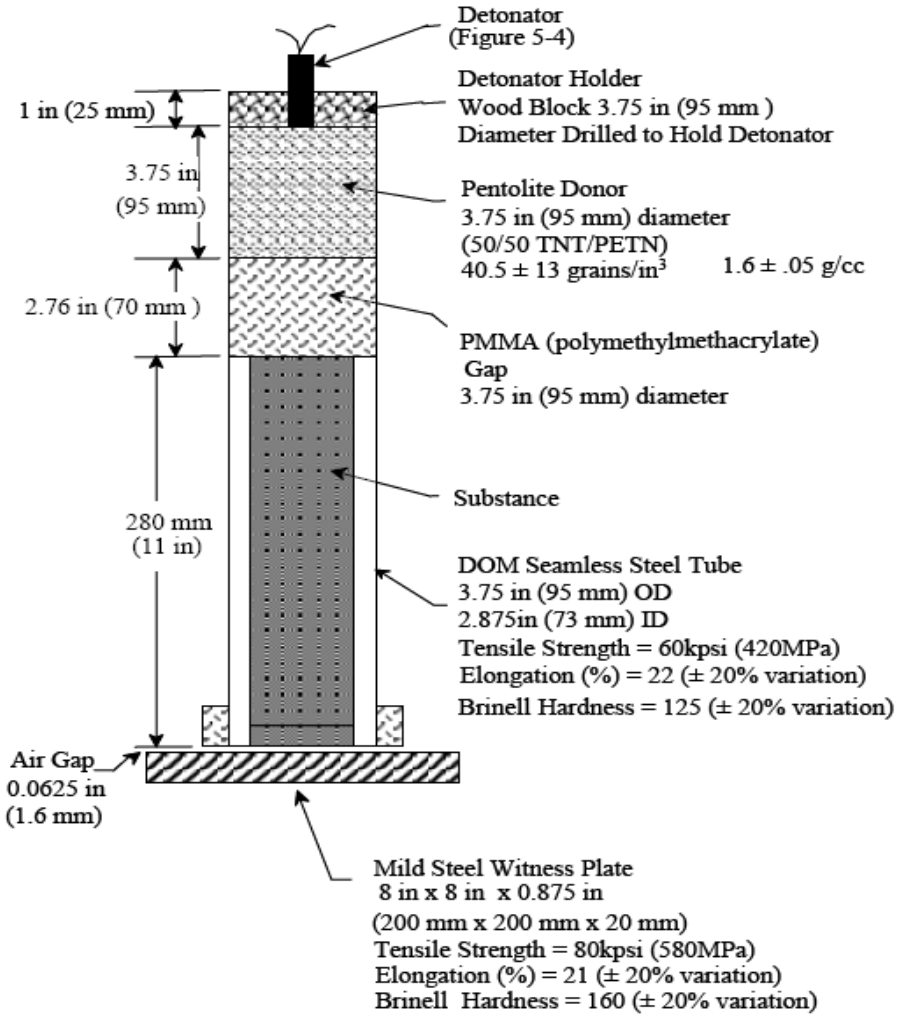


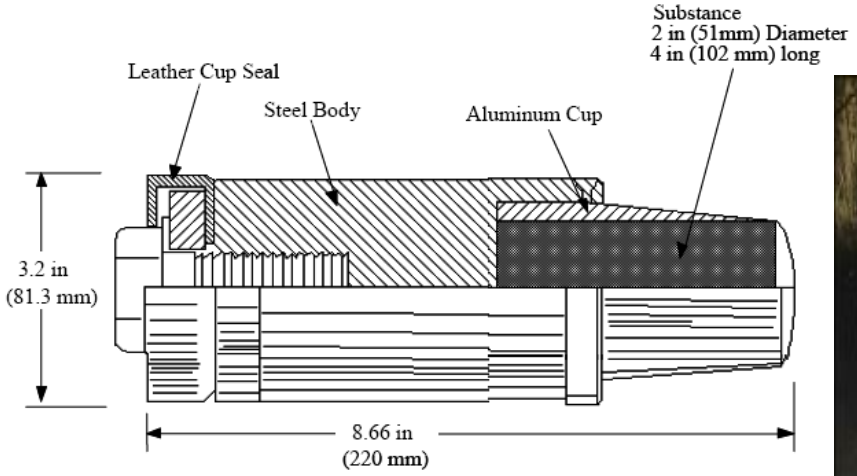
Figure 5-22. EIDS Gap Test configuration (UN Test 7(b))

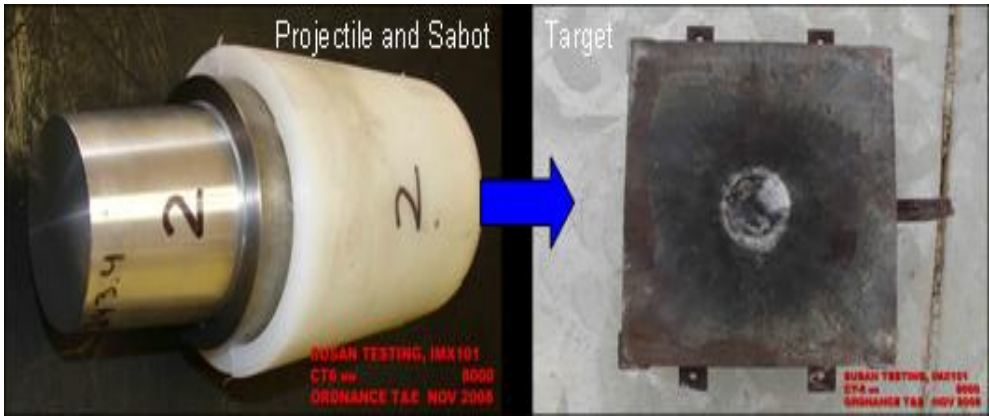
No Witness Plate Penetration in 3 Trials

PASS

EIDS Characterization

- EIDS Results - Susan





Note: Projectile weight - 12 lb(5.4 kg). Contains approximately 1 lb (0.45 kg) of candidate EIDS

Figure 5-24. SUSAN Impact Test Projectile UN Test 7(c)(i)

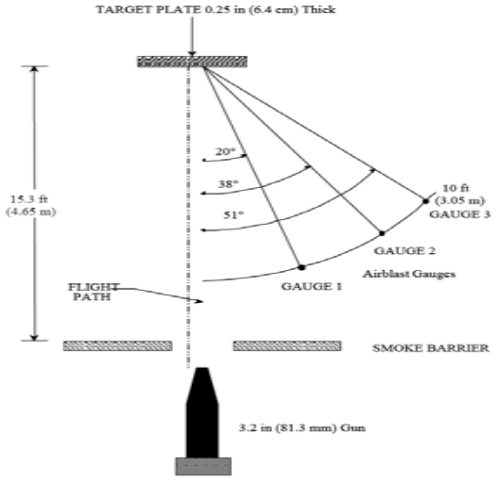


Figure 5-23. SUSAN Impact Test configuration (UN Test 7(c)(i))

-Launch Velocities were 340 to 365 m/s
-EIDS = < 3.9 psi blast overpressure in at least 5 trials
-The average overpressure for six IMX-101 tests was 0.4 psi

PASS

EIDS Characterization

- EIDS Results – Slow Cookoff

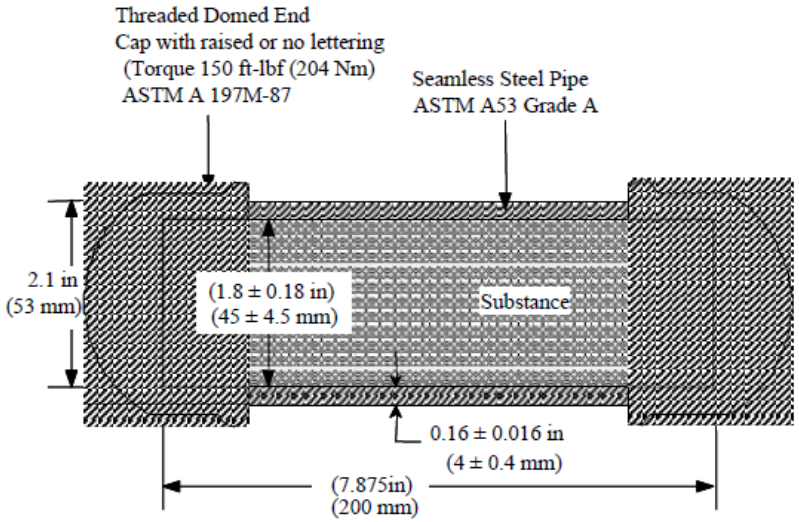


Figure 5-25. Standard Steel Pipe EIDS Test Item

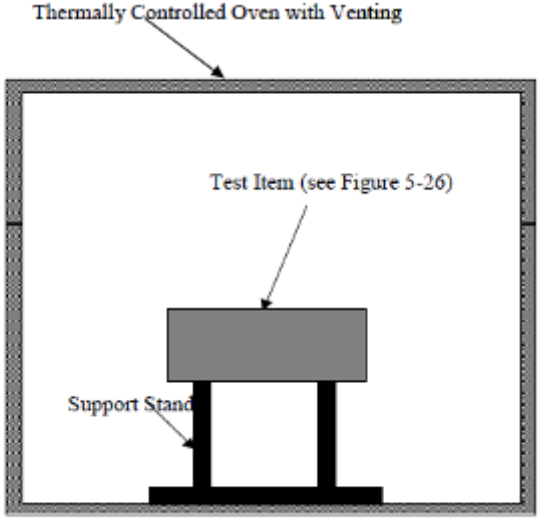
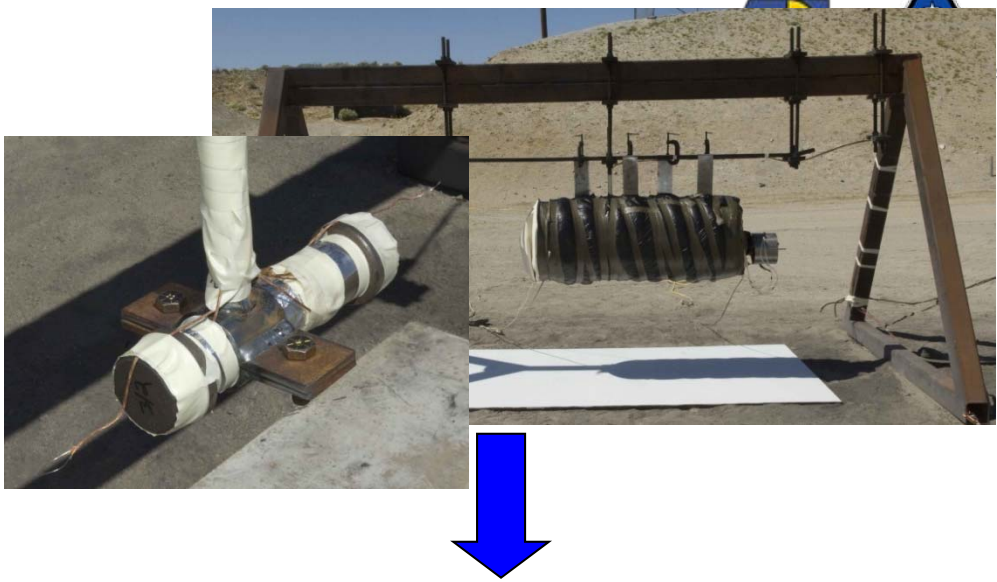


Figure 5-28. EIDS Slow Cookoff Test Configuration (UN Test 7(f))



Fail

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Summary

- IMX-101 was fully characterized for safety and suitability in its intended use
  - Hazard testing demonstrated that IMX-101 was less sensitive than TNT
  - Critical temperature assessment indicated that IMX-101 was safe to process under typical melt pour processing conditions
  - The shock sensitivity of IMX-101 was far less than TNT
  - The IMX-101 detonation velocity was identical to TNT
- EIDS testing indicated that IMX-101 is not a candidate for 1.6 Substance hazard classification due to a failing result from SCO testing

- The aging study will be completed this fall
- System IM testing is set to be conducted this summer