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IM Explosive Replacement for Cratering Charge

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ABSTRACT

The M039 40 lb Cratering Charge is primarily used for cratering and ditching operations and the legacy item currently does not comply with Insensitive Munitions (IM) requirements, failing Fragment Impact, Sympathetic Detonation and Shaped Charge Jet Impact in logistical and tactical configurations. The goal is to replace the melt-castable explosive fill so performance is not compromised in the cratering charge while creating an IM-compliant demolition item.

The cratering charge is 39 lbs of Comp H6 explosive fill housed in tin plated steel. The Army version does not have a booster charge. The Marine Corps and Navy version of the cratering charge has a Comp A-5 booster. This explosive replacement effort focuses on the Army version, without a booster.

Low sensitivity explosives were explored in formulations with the objectives of maintaining the pressure and energy output of Comp H6, achieving melt-processing capability, and aiming for a 50% card gap value ≤ 100 cards. The performance of several formulations and the Comp H6 baseline were predicted by thermo-chemical equilibrium codes (Cheetah v.5). The candidates were subjected to safety and sensitivity, detonation velocity and dent tests to allow for down-selection for further evaluation. Larger failure diameter explosives may be considered due to the size of the M039 without causing foreseeable initiation problems since the M039 is dual primed with demolition charges. Program Manager – Close Combat Systems (PM-CCS) is funding the evaluation of the Comp H6 Replacement in the M039 end item and is committed to an Engineering Change Proposal (ECP) for the technology insertion in Fiscal Year 2011.

INTRODUCTION

The M039 40-lb Cratering Charge is a demolition charge primarily used for cratering and ditching operations. The legacy item does not currently comply with Insensitive Munitions (IM) requirements, failing Fragment Impact (FI), Sympathetic Detonation (SD) and Shaped Charge Jet Impact (SCJI) in logistical and tactical configurations.

The goal of the Armament Research, Development and Engineering Center (ARDEC) is to replace the melt-castable explosive fill with one that meets current Comp HBX Type H6 performance requirements and helps the cratering charge meet IM guidelines. The replacement explosive must use National Technology and Industrial Base (NTIB) ingredients for affordability and availability, and be melt-castable so existing load, assemble, and pack (LAP) procedures, equipment, and facilities can be used. Developing an insensitive replacement explosive will increase safety and likelihood of Soldier and platform survival.

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BACKGROUND

The cratering charge is a tin-plated steel housing loaded with 39 lbs of Comp H6 explosive. Baseline IM tests conducted on the charge showed vulnerabilities to FI, SD and SCJI threats.

Test	Result	Result Description
Fast Cook-off	**Pass**	Explosive vented/burned after 1 minute
Slow Cook-off	**Pass**	Explosive vented at 90 minutes & burned 1 hr 15 minutes after
Bullet Impact	**Pass**	Slow burn Note- Tested with a single 0.50cal AP bullet instead of a triple-round burst
Fragment Impact	**Fail**	High-order detonation
Sympathetic Detonation	**(Fail)**	Assessed to fail – not tested
Shaped Charge Jet Impact	**(Fail)**	Assessed to fail – not tested

Table 1. Baseline IM Test Results for legacy
M039 40-lb Cratering Charge loaded with Comp H6

The high content of RDX causes the cratering charge to be sensitive to unplanned stimuli. The NOL Large Scale Gap Test (LSGT) 50% card gap value for Comp H6 is listed as 166 cards[1] and is tested at ARDEC labs to be 183.5 cards. An objective is to lower the 50% card gap of the replacement explosive ≤ 100 cards.

The approaches to mitigating the vulnerabilities of the charge are to 1) lower the nitramine content in the formulation, 2) increase insensitive energetic ingredients, and 3) add an additive to aid in cook-off and processing. Lowering the nitramine content in the formulation makes the explosive less shock sensitive and adding insensitive energetic ingredients help the explosive candidates maintain the pressure and energy output of Comp H6 sensitivity explosives were explored in formulations with the objectives of maintaining the pressure and energy output of Comp H6, achieving melt-processing capability, and aiming for a NOL LSGT 50% card gap

[1] SW010-AG-ORD-010 REVISION 6, Technical Manual, List of Explosives for Navy Munitions

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value ≤ 100 cards. Meeting these parameters will give confidence to meeting Comp H6 performance and survival against some IM threats.

RESULTS

Different formulations were initially evaluated through a thermal-chemical computer code developed from Lawrence Livermore National Laboratory (LLNL) called Cheetah 5.0 that predicts the characteristics of detonation. The candidates whose energy and velocity of detonation (VoD) outputs were closest to Comp H6 were considered for further evaluation. The subsequent candidates were subjected to the following characterization and performance tests:

- Differential Scanning Calorimetry (DSC)
- Safety Tests (ERL Impact, BAM Friction, ESD)
- Vacuum Thermal Stability
- Small-Scale Burn
- NOL Large Scale Gap Test (LSGT)
- Velocity of Detonation (VoD)
- Plate dent

The final candidate formulations explored and arrived at using the technical approach detailed in the Background. The Cheetah predictions of the formulations and Comp H6 baseline are listed in the table below:

	DETAILS	DENSITY	PRESSURE	VoD	GURNEY
Formulation 1	TNT-based	1.85 g/cc	22.44 GPa	7.41 km/s	2.83
Formulation 2	DNAN-based	1.85 g/cc	25.11 GPa	7.69 km/s	2.86
Formulation 3	DNAN-based	1.79 g/cc	23.78 GPa	7.47 km/s	2.80
Comp H6	TNT-based	1.77 g/cc	19.49 GPa	6.83 km/s	2.78

Table 2. Candidate formulations & Cheetah predictions

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Differential Scanning Calorimetry (DSC)

The DSC was conduct in accordance with (IAW) STANAG 4515 "Explosives: Thermal Characterization by Differential Thermal Analysis, Differential Scanning Calorimetry and Thermogravimetric Analysis". The purpose is to determine the amount of heat required for the sample to undergo phase transition. The melting point and onset of decomposition may be read from the DSC results. The melting points for all three candidate formulations are between 75°C and 95°C.

Safety Tests

Safety Tests are necessary information for safe handling of the materials in processing, testing, and shipment.

The ERL, Type 12 Impact Sensitivity Test was conducted IAW STANAG 4489 Ed. 1 "Explosives, Impact Sensitivity Tests." The ERL, Type 12 Impact Tester uses a 2 ½ kg drop weight to determine the impact sensitivity of the samples. The drop height listed in the results table corresponds to the 50% probability of initiation. For comparison purposes, Class 3 PETN has a 50% impact height of 13.9 cm, Class 1 Type 2 RDX has a 50% impact height of 29.8 cm and TNT has a 50% impact height of 88.3 cm.

The Large BAM Friction Test was conducted IAW STANAG 4487 "Explosives, Friction Sensitivity Tests" and MIL-STD-1751A, Method 1024 "Bam Friction Test". A sample of material is weighed down by a desired load and a porcelain plate beneath the sample is reciprocated. For comparison purposes, Class 3 PETN reacts at 64N and does not react in 10 trials at 60N, Class 1 Type 2 RDX reacts at 192N and does not react in 10 trials at 168N.

The Electrostatic Static Discharge (ESD) test was conducted IAW AOP-7 "Manual of Data Requirements and Tests for the Qualification of Explosive Materials for Military Use".

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The results for the three formulations and Comp H6 are listed in Table 3.

	ERL Impact 50% impact height	BAM Friction	ESD
Formulation 1	77.9 cm	No reaction in 10 trials at 252N Reacted at 288N	No reaction in 20 trials at 0.25J
Formulation 2	108 cm	No reaction in 10 trials at 288N Reacted at 324N	No reaction in 20 trials at 0.25J
Formulation 3	60.7 cm	No reaction in 10 trials at 360N Did not react >360N	No reaction in 20 trials at 0.25J
Comp H6	37.6 cm	No reaction in 10 trials at 324N Reacted at 360N	No reaction in 20 trials at 0.25J

Table 3. Safety Test results

<u>Vacuum Thermal Stability</u>

The Vacuum Thermal Stability is conducted IAW STANAG 4556 Ed. 1 “Explosives, Vacuum Stability Test” and measures the stability of an explosive at an elevated temperature under vacuum. The sample is tested for 40 hours at 100°C and the gas evolved for a 5g sample shall not exceed 2mL. The information is necessary for safe handling of the materials in processing, testing and shipment. The test results are in Table 4.

<u>Small-Scale Burn</u>

The Small-Scale Burn test was conducted IAW TB700-2, Department of Defense Ammunition and Explosives Hazard Classification Procedures, UN Test 3(d) “Small-scale burning test”. The test determines the response of the test material to fire. The failure criterion is an explosion reaction. The information is necessary for safe handling of the materials in shipment. The results of the test are in Table 4.

	Vacuum Thermal Stability	Small-Scale Burn
Formulation 1	0.74 mL of gas generated for 5 g sample Pass	61 sec – Burn 63 sec – Burn Pass 70 sec – Burn
Formulation 2	0.51 mL of gas generated for 5 g sample Pass	50 sec – Burn 55 sec – Burn Pass 53 sec – Burn
Formulation 3	0.44 mL of gas generated for 5 g sample Pass	64 sec – Burn 61 sec – Burn Pass 67 sec – Burn

Table 4. Vacuum Thermal Stability and Small-Scale Burn results

<u>LSGT, VoD and Plate Dent</u>

Large Scale Gap Test (LSGT) measures the shock insensitivity of the explosive material. The explosive is loaded into steel cylinders, placed on top of a steel witness plate and initiated with different thicknesses of Poly(methyl methacrylate) (PMMA) between the booster and test charge. PMMA thickness is varied until the 50% probability of initiation is reached. The witness plate shows evidence that a detonation event had taken place.

VoD and plate dent tests are lab-scale tests for predicting performance output of the explosive material.

	NOL LSGT 50% card gap	VoD	Dent Depth	Estimated pressure output
Formulation 1	83.5 ± 5 cards	6.76 km/s 6.52 km/s	0.304 in. 0.309 in.	170.4 kbar
Formulation 2	100 ± 5 cards	7.30 km/s 7.27 km/s	0.362 in. 0.359 in.	226.7 kbar
Formulation 3	94.5 ± 5 cards	7.08 km/s 7.06 km/s	0.331 in. 0.318 in.	189.2 kbar
Comp H6	183.5 ± 5 cards	7.18 km/s 7.21 km/s	0.335 in. 0.337 in.	201.1 kbar

Table 5. LSGT, VoD and Plate Dent results

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CONCLUSION

The development of a replacement explosive for the 40-lb cratering charge yielded three good candidates which exhibit good performance and shock insensitivity characteristics. The candidates exhibited velocity of detonation and pressure output similar to Comp H6 while achieving shock sensitivities much lower than Comp H6. The new formulations are shown to be stable and safe to handle, process and transport. IM tests in the end item will be conducted at this point to further evaluate the candidates in the 40-lb cratering charge.