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Qualification Testing for PBXN-113 Containing Reclaimed HMX

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ABSTRACT

The use of insensitive explosive formulations in munitions reduces the risk of their accidental initiation due to external stimuli. Their use in Navy munitions has been a requirement for a number of years. Army and Air Force munitions continue to rely on TNT-based formulations due to their lower costs compared to IM explosive formulations that use RDX or HMX. Large quantities of scrap, obsolete, or aged HMX-based explosives are routinely disposed of through open burn / open detonation. A joint program between NSWC Indian Head Division, TPL Inc., Los Alamos National Laboratory, ATK Thiokol, and NSWC Crane Division is developing a method that recovers HMX from explosive formulations. The use of reclaimed re-qualified HMX in munitions offers the opportunity for substantial savings in loading costs compared to that of loading costs with virgin HMX. Prior to use in munitions reclaimed HMX should not only be characterized and tested for safety and sensitivity but the formulations using reclaimed HMX should also be tested for its ability to be processed into formulations and characterized in those formulations. Indian Head has performed qualification, Extremely Insensitive Detonating Substance (EIDS) and material property testing on PBXN-113. These tests will insure that PBXN-113 with reclaimed HMX complies with PBXN-113 specification as well as NAVSEAINST 8020.5C. Results of this testing has shown that PBXN-113 with reclaimed HMX has nearly identical test results as PBXN-113 with virgin HMX.

INTRODUCTION

The use of insensitive explosive formulations in munitions reduces the risk of their accidental initiation due to external stimuli. Their use in Navy munitions has been a requirement for a number of years. Many Army and Air Force munitions continue to rely on TNT-based formulations due to their lower costs compared to IM explosive formulations that use RDX or HMX. Large quantities of scrap, obsolete, or aged HMX-based explosives are routinely disposed of through open burn / open detonation. A joint program between NSWC Indian Head Division, TPL Inc., Los Alamos National Laboratory, ATK Thiokol, and NSWC Crane Division is developing a method that recovers HMX from explosive formulations. The use of reclaimed re-qualified HMX in munitions offers the opportunity for substantial savings in loading costs compared to that of loading costs with virgin HMX. Prior to use in munitions, Recycled HMX (R-HMX)

should not only be characterized and tested for safety and sensitivity but the formulations using reclaimed HMX should also be tested for its ability to be processed into formulations and characterized in those formulations.

BACKGROUND

Phase I of this program defined the technical and programmatic issues concerning the HMX recycling effort by TPL, Inc. TPL, Inc. has developed an acid digestion process in which a high purity HMX can be recovered with the by-products being utilized in commercial blasting agents. TPL, Inc. has designed a sub-scale plant for recovering HMX from the explosives LX-14, PBX-9501 and PBXN-110.

Phases II through IV focused on the chemical analysis of the HMX recovered from LX-14, PBX-9501 and PBXN-110. Both Naval Surface Warfare Center Indian Head Division (NSWC-IH) and Los Alamos National Laboratory have completed the characterization studies on the HMX recovered from LX-14, PBX-9501 and PBXN-110. The data from NSWC-IH shows that the recovered HMX met military specifications.

Phase V of this program included the formulating and processing of R-HMX in PBXN-113, formerly PBXIH-135, and characterization of the formulation. Qualification, Extremely Insensitive Detonating Substance (EIDS) and material property testing was performed. These tests will insure that PBXN-113 with reclaimed HMX complies with PBXN-113 specification as well as NAVSEAINST 8020.5C. The data from NSWC-IH will be reported here. The results of this testing has shown that PBXN-113 with reclaimed HMX has nearly identical test results as PBXN-113 with virgin HMX.

PBXN-113 with R-HMX COMPOSITION

PBXN-113 with R-HMX is a mixture of aluminum, R-HMX, and a hydroxyl-terminated polybutadiene (HTPB) binder system. The composition of PBXN-113 is summarized in Tables 1.

Table 1. PBXN-113 with R-HMX Composition (Nominal)

Ingredient	Weight %	Function
R-HMX Class 5	45.00	High Explosive
Binder Material	20.00	Binder
Aluminum	35.00	Metal Fuel
Color: Gray		
Theoretical Maximum Density: 1.695g/cc		

FORMULATION AND PROCESSING

The HMX was recovered from the LX-14, PBX-9502 and PBXN-110 by digesting the binder with nitric acid. The HMX was mechanically separated via a centrifuge. The effluent was neutralized. The fractions of Class 1 and Class 5 materials were obtained

by sieving. Class 2 and 3 were eliminated because the average particle size of Class 3 was too large for recovery from LX-14 and the quantity of Class 2 was insufficient for testing. The formulation PBXN-113 uses class 5 HMX. NSWC-IH ground the TPL Class 1 recovered from the HMX using a fluid energy mill into a Class 5 granulation. NSWC-IH formulated two 5-gallon batches of PBXN-113 using the ground Class 5 HMX. The processing procedure for the mix was identical to the process for PBXN-113 with virgin HMX. The PBXN-113 was cast into test charges and allowed to cure. X-Ray of the charges revealed no anomalies. The following tests were performed.

QUALIFICATION TESTING

IMPACT SENSITIVITY

Samples of PBXN-113 with R-HMX were subjected to impact sensitivity testing. The tests were conducted in accordance with the procedures of MIL-STD-1751A, except that an in-house test apparatus was used in place of the Bureau of Explosives apparatus. Small cubes of approximately 35 mg mass were used as test specimens. The height of the 2.5 kg drop weight was varied in successive tests using a Bruceton procedure to estimate the height resulting in a 0.5 probability of reaction of the explosive (50% point). Based upon the test results the 50% height was determined to be 98cm.

CAP TEST

The cap sensitivity test is designed to determine the sensitivity of a substance to the shock from a standard detonator or blasting cap. NAVSEAINST 8020.8B, DEPARMENT OF DEFENSE AMMUNITION AND EXPLOSIVES HAZARD CLASSIFICATION PROCEDURES, UN Test 7(a) was performed in substitution for UN Test 5(a), no samples detonated. See Extremely Insensitive Detonating Substance Test section for details.

LARGE-SCALE GAP TEST

Several large-scale gap tubes (1.435” ID and 5.5” in length), which were loaded with PBXN-113 with R-HMX, were subjected to the Large-Scale Gap Test (LSGT). The PBXN-113 with R-HMX LSGT results is summarized in Table 2.

Table 2. Large-Scale Gap Test Results

Shot Number	Charge Density grams/cc	Card Gap (inches)	Go or No Go
1	1.810	1.25	NO GO
2	1.747	1.00	GO
3	1.810	1.12	GO
4	1.771	1.19	NO GO

5	1.803	1.15	NO GO
6	1.771	1.13	NO GO
7	1.806	1.12	NO GO
8	1.775	1.13	NO GO
9	1.779	1.11	GO
10	1.778	1.11	GO

Based upon these results the 50% Point for the shock initiation pressure for PBXN-113 with R-HMX is estimated to be approximately 52.7 kbars or 112 cards.

THERMAL STABILITY

A 50-gram sample of PBXN-113 with R-HMX was conditioned at 75°C for 48 hours. Testing was performed in accordance with NAVSEAINST 8020.8. Weights were taken both before and after testing. Pre-test weight was 50.03-grams while post-test weight was 49.33-grams, with a percent change of 0.30%. No explosion, ignition, change in configuration or significant loss in weight was experienced, thus PBXN-113 with R-HMX meets the thermal stability criteria.

SMALL-SCALE BURNING

A small-scale burning test is used to determine if small quantities of substances transition from deflagration to detonation when unconfined. A total of four tests were performed in which two 10gram samples and two 100gram samples of PBXN-113 with R-HMX charges were placed upon kerosene-soaked sawdust, which was then remotely ignited. Both charges exhibited burning reactions. This is a mandatory test for DOT hazard classification and was performed in accordance with NAVSEAINST 8020.8.

VACUUM THERMAL STABILITY

Two specimens were subjected to the vacuum thermal stability test in accordance with the procedures of MIL-STD-1751A. The average volume of gas evolved during each test was 0.09 ml/g/48hr. This is well below the maximum allowable limit of 2.0 ml/g/48hr.

FRICTION SENSITIVITY

Samples of PBXN-113 with R-HMX were subjected to friction sensitivity using the ABL friction tester at Indian Head Division, NSWC. The threshold initiation level (TIL) is the level at which 20 negatives are observed with at least one positive at the next higher level. Based on the results the friction sensitivity was determined to be greater then 980 psig.

ELECTROSTATIC SENSITIVITY

Test samples of PBXN-113 with R-HMX were subjected to electrostatic sensitivity testing in accordance with procedures of Appendix A of MIL-STD-1751A. The samples were tested on ABL Model 150 ESD tester with voltage equal to 5.785 KV DC. The threshold initiation level (TIL) is the level at which 20 negatives are observed with at least one positive at the next higher level. The result of the ESD test was 0.326 joules, since the pass requirement is 20/20 no fires at 0.25 joules, the ESD sensitivity of PBXN-113 with R-HMX is acceptable.

DETONATION VELOCITY

The detonation velocity of PBXN-113 with R-HMX was determined by performing two 2" diameter 12.5" long cylinder detonation velocity tests on the formulated samples. Detonation velocity was calculated from the time-of-arrival data obtained in each test using an electric pin circuit. The test data indicate that the steady-state detonation velocity of PBXN-113 with R-HMX is 6.98 mm/μs.

CRITICAL DIAMETER TEST

Several bare charges were prepared of PBXN-113 with R-HMX for critical diameter testing. Two test samples were prepared at each size, 0.75 ", 0.625", 0.5", 0.375", and 0.25", one from each of the two 5-gallon batches. Samples were tested for critical diameter by measuring the charge velocity. The test results showed that the critical diameter of PBXN-113 with R-HMX is less than 0.375 inches.

AGING STUDY

Several pan samples were aged at 70°C for 6 months. Pan samples were tested for mechanical properties, sensitivity test and composition analysis. Results for the aging study on PBXN-113 with R-HMX are shown in Table 3 and a graph showing the critical points in the aging study can be seen in Figure 1. Results show that there are no significant changes in mechanical properties after aging.

Table 3. Aging Study Data

Time	Sample	Shore "A" Hardness	Stress at Max Load (psi)	% Strain at Max Load
0	1	39	97.7	59.8
	2	39	97.9	63.2
	3	39	98.2	62.0
2 Months	1	47	119.0	63.7
	2	47	115.8	65.6
	3	48	116.7	65.0
4 Months	1	48	120.1	62.7
	2	48	118.1	65.1
	3	49	121.4	59.4

6 Months	1	52	133.2	60.9
	2	50	132.3	60.9
	3	51	136.2	56.0

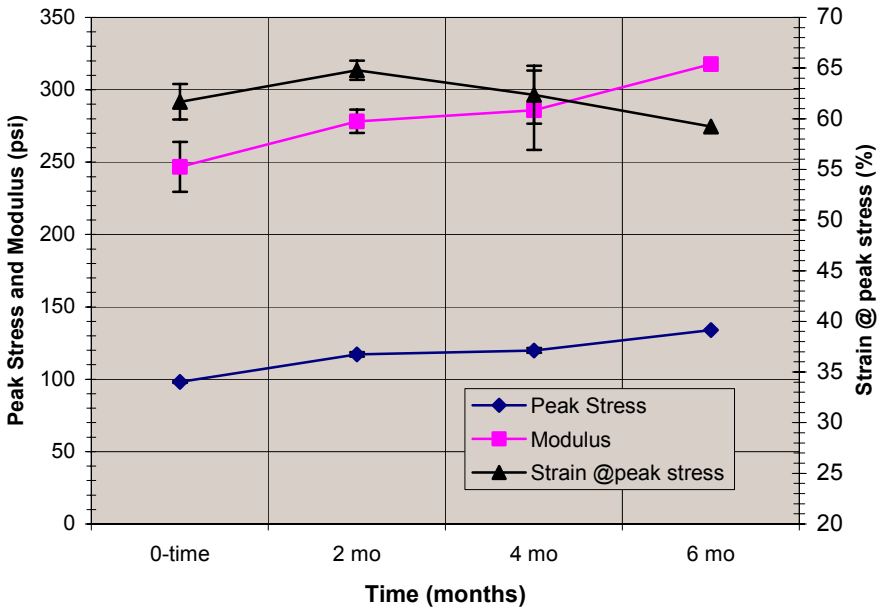

Figure 1. Aging Study – Critical Points in Time

COMPARISON

The results from the above tests on PBXN-113 with R-HMX are compared to the historical data for the same tests performed on PBXN-113 with virgin HMX are shown in Table 4.

Table 4. PBXN-113 with virgin HMX Compared to PBXN-113 with R-HMX

Test	PBXN-113 with R-HMX	PBXN-113 with virgin HMX	Units
Impact Sensitivity	83	98	cm
Friction Sensitivity	560	>980	psig
Electrostatic Discharge	0.853	0.326	joules
Vacuum Thermal Stability	0.146	.09	ml/g/48hr)
Gap Test (50% Point)	105/55.2	112/25.7	cards/kbars
Cap Test	No Detonation	No Detonation	
Small-Scale Burn	Burned	Burned	
Detonation Velocity	6.98	6.97	mm/□s
Critical Diameter	<0.375	<0.250	inches

Thermal Stability	No Reaction or Changes	No Reaction or Changes	
Aging Study	No Significant Changes	No Significant Changes	

EXTREMELY INSENSITIVE DETONATING SUBSTANCE TESTING

PBXN-113 with virgin HMX has been through the Test Series 7 substance test of gap, external fire, cap, friability, and slow cook-off. PBXN-113 with virgin HMX has been qualified as an extremely insensitive detonating substance (EIDS). In support of the qualification testing on PBXN-113 with R-HMX the formulation was also put through the EIDS testing.

EIDS GAP

The EIDS gap test is conducted to measure the sensitivity of an EIDS candidate to a specified shock level, i.e., specified donor charge and gap. Three Expanded Large Scale Gap Test (ELSGT) units were filled with PBXN-113 with R-HMX, prepared and tested in accordance with the procedures and criteria outlined in DoD Ammunition and Explosives Hazard Classification Procedures. Table 5 lists the items used and their weights, dimensions, and densities. All three units were tested and all three passed the gap test as evidenced by no detonations or explosions and recovery of most of the unreacted explosives. The results of the tests are shown in Figures 2, 3, and 4. Since all three tests results showed that there was no evidence of detonation, PBXN-113 with R-HMX passed the EIDS gap test.

Table 5. EIDS Gap Test Item Information

S/N	Type	NSN	Empty Wt. (lb)	Loaded Wt. (gm)	Exp. Wt. (gm)	Tube Diam. (in.)	Tube Length (in.)	Density (g/cc)
1	ELSGT	1376-LL-2140D02	14.14	8433	2019.1	2.875	11.00	1.725
2	ELSGT	1376-LL-2140D02	14.12	8424	2019.2	2.875	11.00	1.726
3	ELSGT	1376-LL-2140D02	14.10	8424	2028.2	2.875	11.00	1.733

Figure 2. Gap Test Shot 1

Figure 3. Gap Test Shot 2

Figure 4. Gap Test Shot 3

EIDS EXTERNAL FIRE

The EIDS external fire test is conducted to determine the reaction of an EIDS candidate explosive to external fire when it is confined. The test requires a minimum of five confined samples stacked horizontally and banded together. Three tests of five samples, banded together, for a total of 15 samples were testing in one external fire test, as shown in Figure 5. The test items consisted of 1.78”x7.875” steel pipes loaded with PBXN-113 with R-HMX in which both ends of the pipe bombs had steel end caps. The fuel for the fire was 150 gallons of jet fuel remotely initiated. Three witness screens were used and video, blast pressure, and radiant heat flux data was collected. Video footage of the test reveals 15 distinct reactions. The first reaction occurred approximately three minutes after the start of the fire. Within two minutes after the first reaction all 15 samples had reacted. Post-test inspection did not reveal any fragments weighing more then 1 gram beyond 15 meters. Fourteen of the 15 test units remained on the steel grating, as shown in Figure 6. One sample was found outside the burn pan, 8.5 feet away from the center of the steel grating. All samples were split down the side and all the ends caps remained on. Blast data revealed no overpressures for any of the fifteen reactions, there was no significant heat flux output above that of the fires, and there was no damage to any of the three witness screens. The 15 PBXN-113 with R-HMX loaded pipe bombs tested met the passing criteria for EIDS external fire test.

Figure 5. EIDS External Fire Test Setup **Figure 6. Fourteen Test Units Post-test**

EIDS CAP SENSITIVITY

The EIDS cap test is conducted to determine the sensitivity of an EIDS candidate to the shock from a detonator or blasting cap. Testing consisted of a 3”X6” sample of PBXN-113 with R-HMX weighing 5lbs placed on a lead cylinder, 1.5”diameter by 4.0” long and then placed on a witness plate. A RP-502 detonator was placed perpendicular to the sample and initiated. This procedure was done three times. The PBBXN-113 with R-HMX failed to detonate, leaving the lead cylinder in its initial length. Confirming that the explosive is not cap sensitive.

EIDS FRIABILITY

The friability test is conducted to establish the tendency of a compact EIDS candidate to deteriorate dangerously under the effect of an impact. Bare cylindrical shaped samples of 9 grams and 18mm in diameter of PBXN-113 with R-HMX were projected against a steel plate bolted inside a collection tank. Low pressure closed bomb was performed on the collected samples using 0.5 grams of black powder and a M100 electric match for initiation. The friability sample was inserted into a muslin bag with the initiation charge. The bomb volume was 106cc and the gauge was a Kistler model 601B1. The closed bomb pressure versus time data was used to determine the maximum closed bomb pressure and the dP/dt. The sample weights (pre and post impact), velocities, maximum pressure, maximum dP/dt, percent sample loss and the closed bomb loading density are shown in Table 6. The maximum dP/dt observed, 0.05 MPa/msec, was below the threshold value of 15 Mpa/msec. According to NAVSEAINST 8020.8B, PBXN-113 with R-HMX was deemed to have passed friability test.

Table 6. EIDS Friability Test Data

Recovered Sample Weight (g)	Velocity		DP/dt Max (Mpa/ms)	Pmax (MPa)	Beginning Weight (g)	Percent Loss	Loading Density (g/cc)
	ft/sec	m/s					
8.927	508	155	0.05	22.6	9.087	1.76	0.0842
8.901	492	150	0.02	22.8	9.052	1.67	0.0840
8.972	460	140	0.04	19.6	9.061	0.98	0.0846

SLOW COOK-OFF

EIDS slow cook-off test is conducted to determine reaction to a gradually increasing thermal environment and the temperature at which such reaction occurs. The EIDS slow cook-off units were prepared and tested according to NAVSEAINST 8020.8B. The test items consisted of steel pipes loaded with PBXN-113 with R-HMX in which both ends of the pipe bombs had steel end caps. An oven, containing the test item, provided a controlled thermal environment over a 40°C to 365°C temperature range and at the linear rate of 3.3°C per hour throughout the temperature operating

range. All three units passed with reaction temperatures at 187°C, 193°C, and 191°C. Since there were only pressure ruptures and the reactions were burning, PBXN-113 with R-HMX was deemed to have passed EIDS slow cook-off test.

SUMMARY AND CONCLUSIONS

The qualification test data obtained on PBXN-113 formulated with R-HMX indicates that its sensitivity characteristics are similar to those obtained on PBXN-113 with virgin HMX, as shown in Table 4. Both PBXN-113 formulated with virgin HMX and R-HMX passed all EIDS Testing. There were no significant changes in the aging study with the use of R-HMX in the formulation. The overall results indicate that the replacement of R-HMX for virgin HMX did not cause any significant changes in the explosive's sensitivity, performance, or aging characteristics.

FUTURE PLANS

Given the positive test results from the PBXN-113 with R-HMX qualification testing, the EFSS 120 mm rifled mortar has been identified as a potential customer. The mortar cartridge will hold 9 lbs of PBXW-128 containing 77% Class 5 HMX. The EFSS mortar cartridge is currently going through Hazard Assessment / Classification testing required to meet MIL-STD-2105C, Hazard Assessment Testing for Non-Nuclear Munitions and Final Type Qualification in accordance with NAVSEAINST 8020.8C using virgin HMX. If R-HMX can be used in the EFSS rifled mortar, the MARCORSYSCOM, Marine Corps Systems Command will be able to purchase more of the EFSS units.

The technical approach is to obtain R-HMX from TPL, verify the quality of the R-HMX through specification testing, formulate the R-HMX into PBXW-128, perform qualification testing on the formulation, and mirror several of the EFSS IM and environmental tests with the PBXW-128 with R-HMX. With successful results, an Engineering Change Proposal (ECP) will be pursued to provide a qualified source of R-HMX for acquisition and implementation in PBXW-128.

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