

Selection and Final (Type) Qualification of PBXW-128 for the EFSS HE Round

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Abstract

The Expeditionary Fire Support System (EFSS) Program has selected and is Final (Type) Qualifying PBXW-128 as an IM compliant fill for its high explosive (HE) round. This paper presents a summary of the EFSS HE round explosive selection study along with PBXW-128 Explosive Qualification data and Final (Type) Qualification test plans. Criteria used to narrow the number of potential explosives are provided with the results of down-select testing. IM features incorporated into the round are discussed. On-going Qualification testing, with available IM results, will be summarized during the IMEMTS in April 2006.

System Description

The EFSS is a 120 mm rifled mortar-based system designed to provide mobile fire support for USMC expeditionary forces. The EFSS will supply the U.S. Marine Corps with an all weather, ground based, close supporting, accurate, immediate response, lethal indirect fire, weapon system. General Dynamics Ordnance and Tactical Systems (GD-OTS) is the prime contractor for the EFSS. The system is based on the 120 mm rifled-towed mortar developed by TDA Armaments, which has been fielded in 24 countries. The suite of EFSS ammunition provides four options: HE, practice, smoke, and illumination rounds. The HE warhead will be the primary ammunition. The system is being fielded expeditiously for the USMC in response to current world events.

Explosive Selection Process

The HE warhead body is ductile cast iron, designed and manufactured by TDA. The TDA round is filled with TNT, which reacts violently in IM tests and is not qualifiable by US Naval Sea System Command's Explosive Qualification standards. In late 2004, an explosive selection process was conducted to identify and rank candidate explosives for the Expeditionary Fire Support System (EFSS). This process involved establishing list of candidate explosives, developing ranking factors, and scoring each explosive

Potential candidate explosives for the EFSS were solicited from a number of sources. Some caveats were used to try to reduce the number of materials considered. Those were:



1. Material should be Navy Qualified or within 6 months of being qualified.
2. The only changes to the TDA HE warhead would be the explosive fill and the fuze.
3. Candidate explosive fill weight should be comparable to TNT fill weight.

Candidate Explosive Fills

The list of candidate explosives included pressed, melt-cast and cast explosives using RDX, HMX and DNAN (2,4-dinitroanisole) as the primary constituents. Many of the fills evaluated did not meet some or all of the program’s criteria but were still ranked to examine potential options. Limited data was available on some materials, which resulted in ranking penalties. TNT and Composition B were ranked as reference materials. Broad categories were established to assess the explosives, including: effectiveness, IM survivability, safety, reliability, and programmatic issues. Key data of the top ranked candidates, along with the reference fills, is provided in table 1.

Table 1: EFSS reference and candidate fill data

Explosive	Composition	Density (g/cc)	NOL LSGT (cards)	IM	Det Vel (mm/μsec)
PBXN-109	RDX /AI/HTPB	1.65	190	Burn ¹	7.6
PBXW-128	HMX/HTPB	1.48	124	Burn²	7.9
PBXW-114	HMX/AI/HTPB	1.71	156	Burn ^{2*}	8.15
PBXN-110	HMX/HTPB	1.75	178		8.33
PBXIH-137	RDX/binder	1.5			7.78
TNT	TNT	1.61	135		6.9
Comp B	RDX/TNT/Wax	1.72	201		8

BLU-110/111 Bombs ²Naturally fragmenting Test Units *BI test only

Final Selection Issues

The top candidate for the EFSS120mm HE round was PBXN-109 followed by PBXW-128 and PBXW-114. For these materials, two areas were considered high risk for meeting the program requirements: round effectiveness and IM. The trade study panel recommended that the compositions be evaluated in arena/lethality and IM screening tests. The lower density and energy were considered drawbacks for PBXW-128 and PBXW-114. Their lack of Final (Type) Qualification was considered also, but these explosives were both considered low risk for attaining full Qualification. PBXW-128 has very low shock sensitivity and good cook cookoff performance. It has been tested as a deformable explosive charge. While the PBXN-109 provides a higher output, the shock sensitivity presented risks for passing the fragment impact test. For all of the fill candidates, the slow cookoff test was considered a high-risk test because it can be particularly dependant on the hardware configuration. The program limited testing to lethality, slow cookoff, and fragment impact for two formulations, selecting PBXN-109 and PBXW-128.



Lethality Testing

Fragmentation Tests were conducted by GD-OTS, Rockhill Testing Facility, in Niceville, FL. Fragment sizes, numbers, velocities, and calculated lethal areas were compared with JMEM fragmentation data for TNT loaded 120mm warheads. Little difference was noted between computed lethal areas for the three explosive compositions.

IM Testing

National Technical Systems (NTS) in Camden, AR performed IM testing in accordance with MIL-STD- 2105C. Tests were conducted in the container as defined by the IM threat hazard assessment. The container provides little protection, but could confine and accelerate the munition response. The fragment impact test results showed a Type V, burning, reaction for PBXW-128 in the EFSS 120mm HE round and a Type IV, deflagration, reaction for PBXN-109. Slow cook-off tests were conducted in accordance with MIL-STD-2105C. Slow cook-off results were Type V, burning, reactions for both compositions in the EFSS 120mm HE round.

EFSS IM Features

The EFSS program incorporated three key features into the HE round and its packaging to reduce the violence of the round's response to the IM threats. A Navy Qualified fuze, the M767 A1, was selected. This fuze is a standard US artillery fuze and has a proven safety and reliability record. The fuze booster is PBXN-5, which has a mild cookoff response. The fuze is integral to the round but is set into a liner that releases in fast and slow cookoff environments, reducing the confinement of the HE fill. To reduce the confinement of the packaging, the shipping container has blowout panels. These features were demonstrated during the NTS testing.

Selection of PBXW-128

The PBXW-128 was selected for the EFSS HE round based on the results of the lethality and IM testing and in conjunction with the previous ranking data. The lists below provide some of the factors considered in the final selection. The passing IM performance of PBXW-128 was the overriding factor in the decision while the limited production base was identified as a medium risk factor and the low density and lack of fielded systems were identified as low risk factors. The Explosive Selection Working Group concurred with this selection in June 2005.

PBXN-109 (64% RDX, 20% Al)

- Acceptable lethality
- Final Type Qualified as Navy's primary bomb fill
- Large production base
- Density close to TNT
- Potential for shortfall in IM performance (High risk)



PBXW-128 (77% HMX)

- Very low shock/setback sensitivity
- Acceptable lethality
- Potential for passing IM requirements
- Unproven production / limited production base (Medium risk)
- Lower density (Low risk)
- Unproven reliability/safety in deployed systems (Low risk)

The data in table 2 is provided from the energetic qualification of PBXW-128 in 1998 and recent EFSS testing.

Table 2: Qualification Data for PBXW-128

Parameter	Value	Reference
Composition	77% HMX / 11% HTPB / 11% IDP	
Advantages	Very insensitive: explosively deformable, high setback survivability	
Performance	Moderate	
Typical Density	1.48 g/cc	
TMD	1.51 g/cc	
No. 8 Cap	Detonation	
ERL Impact	38.6 cm	RDX: 7.4 cm
ABL Friction	>980 lb _f @ 8 ft/s	
ESD	4.2 joules (No Fire)	
NOL LSGT	124 cards/48.8 Kbar	Comp B: 201 cards
Det. Velocity	7.973 mm/s @ 1.48 g/cc	
Critical Diameter	<0.25 inches	
Coef. of Thermal Expan.	180 X 10 ⁻⁶ m/m-deg C [#] to 332 X 10 ⁻⁶ m/m-deg C [*]	
Fast Cookoff	Burn (NFTU)	
Slow Cookoff	Burn (NFTU/containerized 120 mm)	
Multiple Bullet Impact	Burn (NFTU)	
Multiple Fragment Impact	Burn (NFTU)	
Single Fragment Impact	Burn (containerized 120 mm)	

[#]full scale in EFSS HE round ^{*}lab scale

PBXW-128 Production

The production of the PBXW-128 loaded EFSS HE round has been transitioned from Indian Head Division, Naval Surface Warfare Center, Yorktown Detachment, to Ensign Bickford Aerospace and Defense Co. (EBA&D), Graham, Kentucky. The pre-selection test rounds were loaded at IHDNSWC, Yorktown. Since then, several batches have been produced at EBA&D and rounds have been successfully launched in ranging tests. Rounds have also been produced and delivered for Final (Type) Qualification. This experience reduces the previous “medium risk” concerns about the producibility of this explosive.



Thermal Expansion And Booster-To-Fill Gap Studies

To support the definition of production parameters and to define the acceptable gap between the booster and main charge, testing for thermal expansion properties was conducted. The historic data showing a large coefficient of thermal expansion indicated the booster gap could vary significantly over the operational temperature range. Recent thermal expansion studies indicate that the linear thermal expansion is dependent on the sample size. For the EFSS charge the thermal expansion was approximately one-half of that seen in earlier lab scale testing. Based on a lab-scale and a full-scale test series, concerns about expansion or contraction of the charge with thermal cycling were alleviated. In addition to the thermal expansion testing, it was demonstrated that this fuze could initiate the PBXW-128 over an air gap exceeding one inch. This allowed relief in the tolerances for the explosive load height.

Qualification Plans

Final (Type) Qualification testing will be conducted in 2006. The testing will be based on the requirements of NAVSEAINST 8020.8C, which requires the basic safety and IM testing of MIL-STD-2105C. A basic summary of the ordnance-specific testing to be performed for the EFSS is listed in table 3 below.

Table 3: Quick Look Qualification Testing Summary for EFSS Ordnance

Testing	Specification/Requirement
Hazard Assessment and Classification Testing / Basic Safety and IM Testing (excluding Spall Impact) -Combined 28-Day Temperature & Humidity and Thermal Stability -Combined Fast Cook-off/External Fire -Combined Sympathetic Reaction/Stack Test	NAVSEAINST 8020.8C /MIL-STD-2105C
Environmental/Durability Safety Tests	MIL-STD-810F
Unpackaged Drop	MIL-STD-331
Environmental Safety Tests	NAVSEAINST 8020.19 /MIL-STD-464A
Shipboard Shock	MIL-S-901D
Fuze Safety	MIL-STD-1316E /MIL-STD-331B
Fuze Arming Distance and Double Loading	MIL-STD-331C
Gun testing at proof pressure Acoustic assessment during firings Products of combustions toxicity analysis	Review by Naval Environmental Health Center (NEHC)
Hot gun testing	ITOP 4-2-504(3)
Performance Oriented Packaging (POP)	Title 49 CFR, Sections 178.603, 178.606 and 178,608
UN Replenishment/VERT Replenishment	MIL-STD-648C



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