2009 Insensitive Munitions & Energetic Materials Technology Conference

Linear Demolition Charge

Insensitive Munition (IM) Program *(# 8238)*

May 11-14, 2009

Loews Ventana Canyon Resort, Tucson AZ

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Code E312F, Bldg 302-114

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and

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Joint Service Investment

- Technology Transition Agreement (TTA) established in 2005 as collaborative program between Office of Naval Research and PM-Ammo to improve the level of compliance for Mine Clearance System (MCS) to IM requirements and to improve the functional reliability of system
  - Jointly Funded 2005 And 2006
- Current Funding – PM-Ammo only

Program Leads for Tasking

- **Organization:** Program Manager for Ammunition
  Marine Corps Systems Command
  (MCSC)
- **Program Manager:** Mr. Jerry Mazza, MCSC
- **Assistant Program Manager:** Capt F. Matt Williams
- **IM Technical Support:** Mr. Scottie Allred
  Mr. Gregory DuChane

- **Organization:** PM Engineer System for ABV
  Marine Corps Systems
  Command (MCSC)
- **Program Manager:** Mr. Joseph Augustine
- **Project Officer:** Mr. Joseph Burns

- **Organization:** Naval Surface Warfare Center,
  Dahlgren Division
- **Project Manager:** Mr. Thomas Swierk
- **Shielding: Mr.** Greg Little

- **Organization:** Naval Surface Warfare Center,
  Indian Head Division
- **Project Manager:** Ms. Nancy Johnson
- **Energetic Materials:** Mr. Robert Hutcheson
- **Rocket Motor:** Mr. Leandro Garcia
- **Safety:** Ms. Vonderlear Fields
- **Configuration Manager:** Ms. Terrie Green

Current and Expected IM Response

M58 and M59 Linear Demolition Charge (LDC) IM Test Reactions						
SYSTEM	**FCO**	**SCO**	**BI**	**FI**	**SD**	**SCJ**
LDC						
M58A4/ M59A1 [1]	**V**	**V**	**I**	**I**	**I**	**(I)[2]**
M58A4E1/ XM651	**V**	**V**	**(V) [3]**	**V [3]**	**I**	**(I)[2]**
M1134A4 (Fuze)	**V**	**(V)**	**V**	**V**	**(Pass)**	**(Unknown)[2]**

() By analysis

1. M58 and M59 were evaluated by OHEB 22 May 2002 in accordance with "Hazard Assessment Tests for Non-Nuclear Munitions," MIL-STD-2105B. (NAWCWD TM 8380, Katsumoto K. T., *M913 and ML25 Linear Demolition Charge Insensitive Munitions Tests*, August 2002)
2. SCJ for M58/M59 is based on FI. The fuze is not likely to be hit by SCJ and therefore is likely to be a pass since it is not connected to anything else in the shipping container until launch
3. IMRB scored the test results for the all-up improved M58 as a NO Test due to not meeting the requirements of MIL-STD-2105C, but did score the sub-scale tests without detonating cord as Type V reaction. FI for M58 with the new detonating cord, relay cups and shield was a Type V reaction. (NSWCDD ltr 8010.1 Ser G702/005 of 13 Oct 2007, *IMRB Meeting on the M58 Linear Demolition Charge and Mk 22 Mod 4 rocket motor*)
4. Nomenclature for the IM version of the M59A1 has been receive as the XM651

ENERGETIC MATERIAL INFORMATION

New Energetic Materials IM Mine Clearance System (MCS)

Component	Explosive	Weight
Explosive Components Main Charge LDC (M58A4/ M59A1)		
Pellet	Composition C-4 Class III	1750 Nominal lbs
Detonating Cord	PETN	12.24 lbs
Relay Cups	PETN	6.24 g.
Explosive Components Main Charge LDC (M58A4E1/ XM561)		
Pellet	Composition C-4 Class III	1750 Nominal lbs
Detonating Cord	PBXN-8	16.35 lbs.
Relay Cups	Composition A-5	1.56 g
Explosive Components Rocket Motor (Mk 22 Mod 3/Mod 4 and EX 22 Mod 5)		
Propellant	N-5, Double Based	42.00 lbs.
Electrical Initiator	Bridgewire Composition	65 mg
	Initiator	220 mg
Igniter	Igniter Charge	48 g
Explosive Components Fuze (M1134A4)		
Bellows	Ignition Charge	120 mg
	Gas Producer	70 mg
Detonator	Ignition Charge	280 mg
	Intermediary Charge	15 mg
	Output Charge	15.2 mg
Lead (2)	Composition A-5	1284 mg

Distribution statement A: Public Release

Denotes changes from baseline materials

Linear Demolition Charge Background

- USMC requirement for a reliable, safe, and effective system for clearing mines.
- Provides a “close-in” breaching capability for maneuver forces.
- Utilizes 50^{+} year-old technology
- Since initial fielding there has been little done to form, fit or function.
- Procurement of Ammunition, Navy, and Marine Corps (PANMC) funds are provided to procure components which make up the Mine Clearance System.

Linear Demolition Charge Description

- Mine-clearing system used to clear path for tanks, vehicles and personnel. System clears a path 350 feet long by 46 feet wide path.
- Rocket Motor tows Line Charge from container over obstacles or minefields.
- Deployment platforms
  - Mk 1 Mod 0 – Up to three M59 line charges deployed from inside an Amphibious Assault Vehicle (AAV), uses the Mk 154 Hydraulic Launcher.
  - Mk 2 Mod 0 – Up to two M58 line charges deployed from the Assault Breaching Vehicle (ABV) or one M58 line charge deployed from Trailer, uses the Mk 155 Hydraulic Launcher.
- Effective against single-impulse, pressure-type, non-blast hardened anti-tank mines and mechanically actuated anti-personnel mines.

MK 1: AAV Launch of M59

MK 2: M58 Launched from trailer

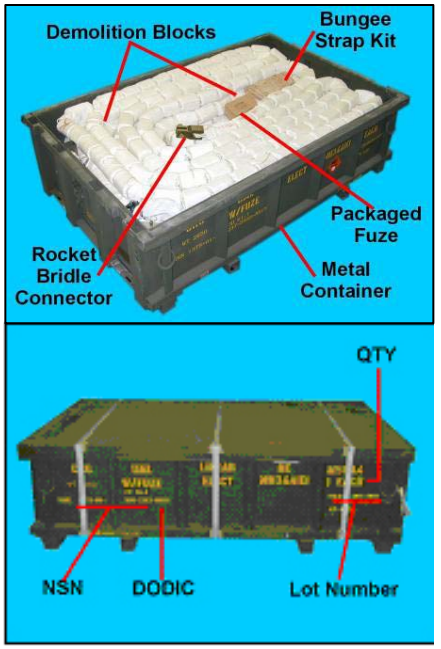
MK 2: ABV Launch of M58

Linear Demolition Charge Description

- Mk 1 Mod 0 MCS
  - M59 line charge in steel/aluminum shipping/storage container
    - Line charge unpacked length 555 ft
    - Explosive section 350 ft long
      - 700 Composition C-4 Blocks plus Detonating Cord
      - Total Explosive Weight 1750 lb
  - M1134A4 fuze
  - MK 22 Mod 4 rocket motor
- Mk 2 Mod 0 MCS
  - M58 line charge in steel shipping/storage container
  - M1134A4 fuze
  - MK 22 Mod 4 rocket motor

Note: M58 and M59 line charges are identical; containers and packing configuration are different

M59



M58

Linear Demolition Charge (LDC)

- LDC Improvements
  - Completed DVT 26 Sept 07
    - 2 Full scale deployments
    - Multiple Partial Length Air Gun Deployments
    - BI and FI test of M58A4 modified w/Comp A-5 Relay Cup and PBXN-8 Detonation Cords
  - Completed CDR 17 April 08
  - Preparing TDP to procure qualification units
  - Received guidance from PM Ammo on 25 Sept 08 to incorporate a Line Cutter into the M58 LDC and container

Linear Demolition Charge (LDC)

- Accomplishments for M58/M59
  - Completed detonating cord testing December 2007
  - Down selected PBXN-8 to replace PETN loaded detonating cord
  - Down selected Comp A-5 to replace PETN loaded relay cups
  - Tested and down-selected shielding
  - Completed design for over-braid configuration for LDC
  - DVT M58 full system w/new detonating cord/relay cups/shielding
    - Shielding used Aluminum plate and ¾” ceramic balls
    - Shielding permitted C-4 to pass BI and FI in sub-scale tests
    - Shielding permitted M58 to pass FI and similar results for BI

DETONATING CORD
Testing Requirements

Test method	Objective	Results										References
		PETN (POMINS)		PBXN-8 (APOBS)		PETN (M58)		PBXN-8 (A1)		PBXN-8 (A2)		
		Amb	-65°F	Amb	-65°F	Amb	-65°F	Amb	-65°F	Amb	-65°F	
SCO	To Compare the reaction level to MIL-STD-2105C	N/A		Burn		Detonation		Burn		Burn		NSWC TR 90-170 For APOBS
FCO	To Compare the reaction level to MIL-STD-2105C	N/A		Burn		Burn		Burn		Burn		NSWC TR 90-170 For APOBS
Bullet Impact	To Compare the reaction level to MIL-STD-2105C	1/50 detonation		50/50 burns		1/1 detonation		5/5 Burn		5/5 Burn		NSWC TR 90-170 For APOBS
	To Compare Relay Cup reactions	1 det, 7 charred, 17 no reaction		no reaction		1/1 detonation		1/4 detonation of relay cup with no transfer to Detonating Cord		3/3 Burn		NSWC TR 90-170 For APOBS

Down Selected Detonating Cord

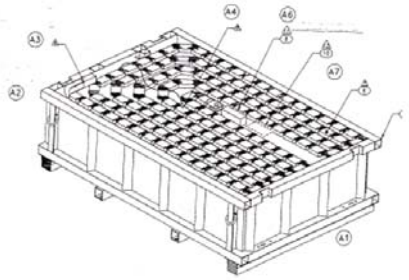
- Based on testing to date PBXN-8 has been down selected for the detonating cord with Composition A-5 Relay Cups
- WS 35291 generated to cover requirements

Main Charge for LDC

- Current M58/M59 System uses Composition C-4 for Main Charge
  - This material is suspected as the other major causes of System Failure
    - Looked at PBXN-9, PBXN-10, PBXIH-18 and other materials developed for IM improvements
    - Main Charge Program
      - Down Selected Main Charges
      - IM Response for these materials
        - FCO – Variable Confinement Cook-Off Test (VCCT) Test Results
        - SCO – VCCT Test Results
        - Fragment Impact Test Results
      - Transfer Testing
        - Results for the above reported at 2006 IM&EM Conference in a Poster Presentation
      - IM response in Hybrid Test
      - IM response in all-up system tests
      - All-up flight tests

HYBRID IM Testing

- Three IM Tests were performed
  - Hybrid Bullet Impact (BI)
    - 1 test without shielding – 250 lbs of C-4 and remainder inert = Hybrid System B
    - 1 test with shielding – 492.5 lbs of C-4 and remainder inert = Hybrid System A
  - Hybrid Fragment Impact (FI)
    - 1 test with shielding – 492.5 lbs of C-4 and remainder inert = Hybrid System A
- Perform Hybrid Tests without Detonating Cord on System
  - To determine if C-4 will survive if we replace the detonating Cord
  - 3 Modified M58A4 Line Charges
    - HE and Inert Pellets
    - 2 Hybrid System A
    - 1 Hybrid System B
    - All PETN Detonating cord & Relay Cups Removed
    - In Packing/Shipping Configuration
      - M58 (l x w x h) (82.15” x 53.75” x 24”)
    - HE & Inert Charges Identifiable By Color and Tape Indicator



Typical View of MICLIC HYBRID SYSTEM A & B M58 shipping container.

LDC IM IMPROVEMENT PROGRAM

Hybrid M58 Shipping Containers and Selected IM Performance Tests

***Bullet Impact Test on Hybrid System B Without Shielding Point of Impact* (AFT End Of Container)**

S/N: HB-001			
Temperature	50°F	**Relative Humidity**	55%
Barometric Pressure	29.86 inHg	**Wind Speed/Direction**	5.0 MPH / South
Bullet Type	Three (3) .50 caliber M-2 Armor Piercing		
Witness Plate Size	24"x60"x2" thick	**Witness Plate Damage**	Destroyed
Reaction Type	Type I	**Aim Point**	Center line of Test Unit

Probe Number	Distance	PSI	Delay Times	
1	40' 4.5"	No Data	1 to 2	94 ms
2	50' 7"	No Data	2 to 3	105 ms
3	50'	No Data		

Bullet Velocities (Ft/Sec)	
Gun 1	No Data
Gun 2	No Data
Gun 3	No Data

Test Results: Pressure lines cut and velocity screens destroyed. The system detonated on impact with the second round. The third round never left the barrel.

LDC IM IMPROVEMENT PROGRAM

Hybrid M58 Shipping Containers and Selected IM Performance Tests

***Bullet Impact Test on Hybrid System B Without Shielding Point of Impact* (AFT End Of Container)**

- **IMRB's score Type I** detonation **reaction**

LDC IM IMPROVEMENT PROGRAM

Hybrid M58 Shipping Containers and Selected IM Performance Tests

***Bullet Impact Test on Hybrid System B Without Shielding Point of Impact* (AFT End Of Container)**

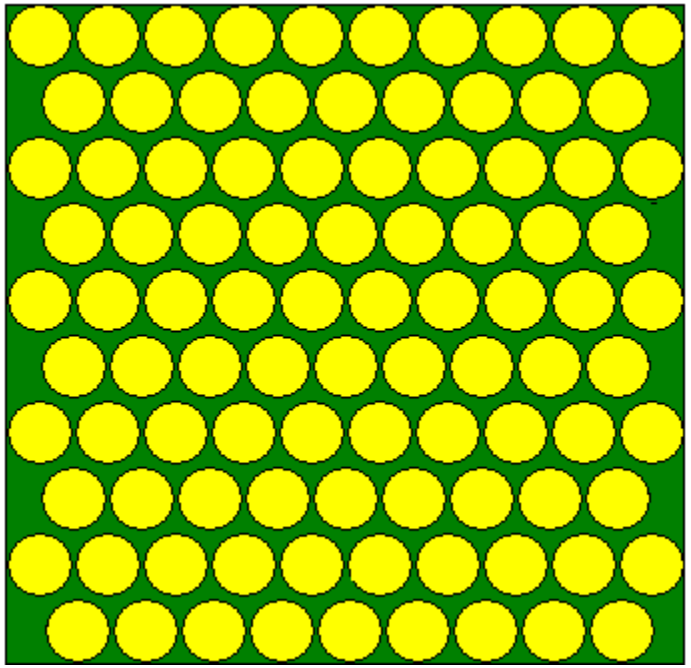
Shot #1 – Damaged Guns

Instantaneous Detonation after 2nd Round before 3rd Round could be fired

Shot #1 – Collection of some of the Debris

Shielding For BI and FI Hybrid Tests

- Shielding was used on the second BI test
- Shielding was used on the FI test.
- All shielding panels were 10” wide & 14” long.
- Description:
  - 5/8” Ceramic Spheres Bound In A Polyurea Coating
  - Backed By 0.202” High Hard Steel were attached onto LDC Container Test Target Area With Velcro
  - Applied To The Container On Day Of Test
  - All Shielding Material Provided By NSWCDD (Dr. Ray Gamache/Greg Little)
  - Previously discussed in IM & EM 2006 Poster # 3408



LDC IM IMPROVEMENT PROGRAM

Hybrid M58 Shipping Containers and Selected IM Performance Tests

Bullet Impact Test On Hybrid System A With Shielding Point Of Impact (Side Portion Of Container)

- Procedure
  - Bullet Impact Test was conducted in accordance with MIL-STD-2105C, paragraph 5.2.3
  - Purpose of the test is to evaluate the response of each test item to the bullet impact test specified in MIL-STD-2105C, Paragraph 5.2.3
- Unit Configuration
  - One containerized modified Hybrid A system
- Test
  - The System shall be impacted by three .50 caliber type M2 AP projectiles
    - Velocity of 850 ± 60 m/s (2800 ± 200 ft/s)
  - the center of the live pellet area to ensure live pellets are above, below, around and behind the bullet impact points.
  - This allows bullets to strike to the left and right of the aim point
  - The fixture will support the container and restrain it from any undesired motion due to the bullet impacts.
  - Pressure gauges were used to measure any resulting overpressure
  - Fragmentation distances and weights were recorded
- Criteria for Assessing Results
  - The criteria for assessing the results of this test are found in paragraph 5.2.3.4 of MIL-STD-2105C
  - The passing criterion of MIL-STD-2105C is no reaction more severe than Type V

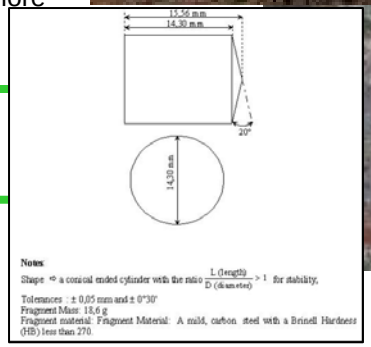
IMRB scored Type V Burning Reaction

LDC IM IMPROVEMENT PROGRAM

Hybrid M58 Shipping Containers and Selected IM Performance Tests
Fragment Impact Test on Hybrid System A With Shielding Point of Impact (Side Portion Of Container)

- Procedure
  - The purpose of the test is to evaluate the response of each test item to the Fragment Impact test specified in MIL-STD-2105C, Paragraph 5.2.4.
  - The tests are being conducted to evaluate the response of the System to impacts from three fragments moving at 8300±300 ft/sec.
- Unit Configuration
  - One containerized modified Hybrid A system
- Test
  - Each test item shall be impacted by 1 fragment size (conical ended cylinder weighing 18.6 grams)
  - Velocity of the fragment 8300 ± 300 ft/s
  - Fragments were aimed at the center of the live pellet area to ensure live pellets area above, below, around and behind the fragment impact point.
  - Pressure gauges were used to measure any resulting overpressure
  - Fragmentation distances and weights will also be recorded.
- Criteria for Assessing Results
  - The criteria for assessing the results of this test are found in paragraph 5.2.4.4 of MIL-STD-2105C
  - The passing criterion of MIL-STD-2105C is no reaction more severe than Type V.

IMRB scored Type V Burning Reaction



Demonstration Validation Tests (DVT)

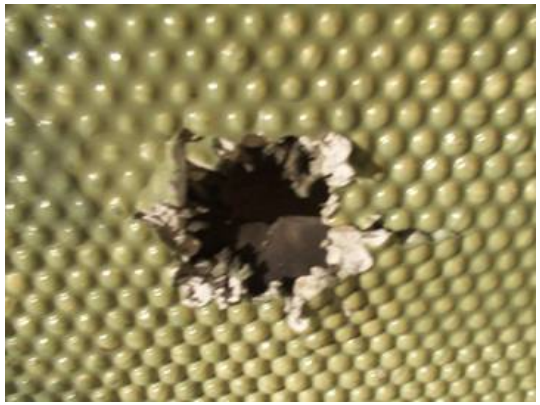
Optimizing Shielding Design

Ballistic testing recently completed to assess the response of various configurations to:

Minimize panel weight & evaluate low cost options

Typical Fragment Impact test results:

Panel front side (entry hole)



Panel backside (exit hole)

Recommended Shielding Configuration:

0.75 In. Ceramic Spheres

+

Polymer Adhesive Binder

+

0.25 in. Al Substrate Panel

Setup of the LDC for Bullet Impact

Camera view from Rocket Mountain of Bullet Impact

(1357) Smoke appears within minutes

(1400) Flames grow rapidly

(1403) Flames burst from the sides approx 27 ft on the right and 16 ft on the left

(1409) Flames begin to decrease through 1530

Post-test picture of the LDC Bullet Impact

IMRB scoring of NO TEST because test did not meet the test requirements. The IMRB did note that the reaction exhibited was consistent with Type V (Burning) standards.

Linear Demolition Charge Insensitive Munitions Fragment Impact Test Set-Up

Linear Demolition Charge Insensitive Munitions Fragment Impact Test Results

IMRB Scored FI Type V reaction

Summary of BI and FI

- Tasking was performed by NSWC Crane, Fallbrook Detachment
- The LDC Bullet Impact test was conducted on Dec. 13, 2006 at Hawthorne Army Depot (HWAD).
- The LDC FI test was conducted on 15 May 2007 at NAWS China Lake, Ca.
- For BI only 2 rounds were fired and they were 6 inches apart
- Fragment velocity was 8439 ft/sec
- Both the BI and FI tests of the M58 burned for 1 hr and 10 mins before flame out
- The LDC achieved the desired burning reaction from the BI and FI. The outcome had a type V like reaction (Burn).
- IMRB Scored All-up System BI No Test but Overall score a Burn
- IMRB Scored FI Type V reaction
- Confirmed IM performance objectives met
  - Improve BI from Detonation to Burning for M58
  - Improve FI from Detonation to Burning for M58

LDC IM IMPROVEMENT EFFORT

Full Scale Test Set-up for LDC

LDC IM IMPROVEMENT EFFORT

- Results
  - Testing culminated with deployment by a MK 22 Rocket and successful detonation train transfer on a full length hybrid Live-Inert LDC
  - Detonating cord management concepts Sinusoidal (Current Design) – Proved successful New connectors design for overbraid LDC system
    - Rocket Motor End Connector finalized and validated
    - Fuze-End Connector experienced a few modifications throughout the project
      - Minimized the weight and size of initial design

Summary of LDC

- Based on the Main Charge Testing
  - Down Selected to C-4
    - Risk that Shielding Works Satisfactorily with the XM651 packaging needs to be Proven
    - Minimal Risk that Shielding will weigh too much to allow the system to be moved
      - All indications are that all handling systems will be able to handle the additional weight
- LDC Design is Acceptable
  - Passes BI with Burning reaction
  - Passes FI with Burning reaction
  - SD and SCJ reaction will not change with design
  - Design Improves deployment method for LDC
  - Design maintains current capability for System Performance
  - Design maintains current system design margins
- Transition to Production

ACKNOWLEDGMENTS

- NSWCIHD Code R33 for their support in testing
- NTS for their support in the Hybrid BI and FI testing
- NSWCDD for their design of the Shielding used in the BI and FI tests
- NSWC Crane, Fallbrook Detachment for their support in Detail Development testing for all-up IM results in support of the TTA
- The support of the LDC Bullet Impact test by the Marine Corps Programs Division at Hawthorne Army Depot (HWAD).
- The support of LDC FI test at NAWS China Lake, Ca by the Ordnance Test and Evaluation Division.

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