2006 Insensitive Munitions & Energetic Materials Technology Symposium
Bristol, United Kingdom 24-28 April, 2006

Mine Clearance System — A Makeover We Can Live With

Marine Corps Systems Command

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The Mine Clearance System (MCS) in use by the United States Marine Corps today is essentially the same piece of ammunition that was successfully demonstrated in 1956 for deployment from the Landing Vehicle, Tracked (LVT) EX1, Beach Assault Vehicle. The Marine Corps needed a reliable demolition line charge for clearing a beach of mines and obstacles to allow the safe debarkation of personnel and armor. The system consisted of little more than a series of blocks of Composition C4 (approximately 1700 lbs) taped to a long piece of PETN Detonating Cord, fuzed and launched using the Mk 22 Rocket Motor. Many changes have been made to the system over the years to improve the system safety and reliability, but it continues to bear a unique resemblance to its aged forefathers. Landing Vehicle Tracked Engineer 1 (LVTE1) variants were firing the MCS in Vietnam in the mid 1960's, and it will be an integral part of the new Assault Breaching Vehicle, currently undergoing qualification.

While the system has undergone extensive product improvements, no effort has ever been made to improve its response to unplanned, external stimuli. The MCS has been identified as a priority item in the USMC IM Strategic Plan, and in an effort to comply with current requirements, the Program Manager for Ammunition, Marine Corps Systems Command, in conjunction with the Office of Naval Research (ONR), has initiated a program to transition this system into the 21st century. This paper will discuss the program plan and progress to date, on making sorely needed improvements to a system that is necessary to mission success, yet poses a potential threat to personnel and logistical systems.

Introduction

In 1950, the Naval Ordnance Test Station (NAWC, China Lake) was tasked to develop a demolition line charge capable of clearing beaches of mines and obstacles. Tactical maneuver capability during initial assault and subsequent operations ashore has always been a factor key to combat success for the United State Marine Corps (USMC). To sustain an offensive capacity, a system capable of defeating the enemy's counter-mobility efforts is a must. That system, the Model 301A Demolition Line Charge, eventually led to the development of the Picatinny T96 Linear Charge and ultimately the M58 linear demolition charge (LDC). The M58 LDC is, in essence, the Mine Clearance System (MCS) system we use today. Currently, the MCS rocket-towed linear demolition charge is the Marine Corps' premier system for this mission and is capable of providing a clear path for combat vehicles during minefield and barrier breaching operations. The system can clear a path up to 46-feet wide and 350-feet long through a minefield. Though the system has had periodic configuration changes incorporated to increase reliability, the main energetic materials used in the system have remained unchanged since its initial fielding. The MCS provides a "close-in" breaching capability for maneuver forces. The MCS system does not meet the current DoD requirements for resistance to insensitive munitions threats (unplanned stimuli). Novel technology is required to improve the employment of the MCS and support power projection for current and future Naval operations.

MCS is a joint U.S. Army/Marine Corps program procured through the Joint Munitions Command (JMC) Single Manager for Conventional Ammunition (SMCA), with life cycle management responsibilities having been assumed by the Marine Corps.

System Description

The MCS is a rocket-towed, linear demolition charge designed to provide a clear path for combat vehicles during minefield and barrier breaching operations. The system is comprised of a towing rocket motor, a remotely initiated fuze, and the LDC. There are two variants of the MCS. The MK1 and Mk2 MCS are similar, the only variance being the packaging configuration of the LDC deployed. The two systems utilize the Linear Demolition Charge M58A4/M59A1 (DODIC M913/ML25), respectively.

The total unpacked length of the linear demolition charge is 555 feet. The demolition section, containing the energetic materials, is 350-feet long and provides a standoff distance between the vehicle and the explosives of 205 feet.

The demolition section consists primarily of a 3/4-inch nylon core rope, 700 Composition C4 demolition blocks, and two strands of pentaerythritol tetranitrate (PETN) detonating cord. The total explosive weight of the demolition blocks is 1,750 pounds. The blocks are attached to the core rope similar in appearance to a linked sausage. The blocks are sheathed with an outer layer of nylon. The two strands of detonating cord pass through the entire length of the demolition section. The entire demolition section and arresting cable are then coiled inside the container. Most of the arresting cable is beneath the demolition section. The fuze, which is individually packaged, sits on top of the coiled demolition section in the MCS container.

The two variants of the MCS system deploy the M58 and M59 LDCs. The only difference between the M58 and M59 is the packaging configuration, shown in Figure 1, and the launch platform. The M58 configuration is loaded on a Mk155 Launcher, Mine Clearance (LMC) Trailer and towed behind an armored vehicle, or fired from the Assault Breaching Vehicle (ABV). The M59 is a three shot system configuration loaded in the Amphibious Assault Vehicle (AAV) for transportation and employed from the Mk 154 LMC. The M69A2 and M69 are inert LDCs used for training.

Figure 1. M58 and M59, Linear Demolition Charges, Respectively

The Rocket Motor, 5-inch Mk22 Mod 4 (DODIC J143) is a solid-fuel rocket motor used for towing the M58, M59, M68A2, and M69 linear demolition charges over obstacles and minefields for breaching, training or test applications. See Figure 2.

The rocket motor is approximately 77-inches long, 5-inches in diameter, weighs 128 pounds, and contains 42 pounds of N-5 double based propellant. It has a tractor motor design which incorporates two forward mounted, rearward facing, exhaust nozzles which are threaded into the motor head-cap.

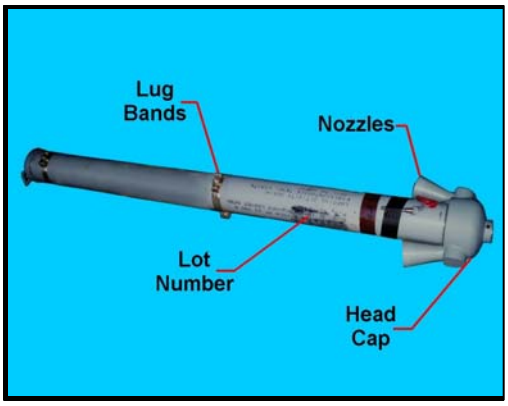

Figure 2. Mk 22 Mod 4, Rocket Motor 5”

The M1134A4 Fuze is designed to remotely detonate the M58 and M59 series linear demolition charges. The fuze is connected between the fuze connector front half on the charge and the fuze connector rear half on the arresting cable. The fuze is connected to the LDC and placed in the fuze holder on the launch platform prior to deployment. The rocket motor is initiated and pulls the charge out of the container and fuze from the fuze holder. When the LDC and arresting cable are fully extended the tension on the arming wire, which is woven into the arresting cable, provides the force necessary to break the fuze shear pin and extract the arming pin. Extracting the arming pin enables the fuze rotor to turn, opening two micro switches and completing an electrical circuit to the fuze circuit board.

After the charge has been deployed, the fuze is command initiated using a direct current power supply. Electrical current is applied at the selector switch/assembly control box, which is wired through the arresting cable to the fuze connector. The electrical charge will enter the fuze, passing through the closed micron switches, to the circuit board timer. The circuit board timer sends a controlled electrical pulse to the explosive bellows motors, which initiate and expand, turning the rotor and aligning the firing leads with the detonators. The circuit board timer electrical pulses then initiate the firing leads, initiating the fuze detonators, blowing through the base of the fuze, initiating relay cups crimped to the detonating cord, eventually initiating the C-4 blocks on the remainder of the charge.

The energetic materials used in the system, including the rocket motor and the linear demolition charge, are shown in Figure 3.

Explosive Components Main Charge		
Component	**Explosive**	**Weight**
Pellet	Composition C-4 Class III	1700 lbs. (nominal)
Detonating Cord	PETN	12.25 lbs.
Relay Cups	PETN	.014 lbs.
Explosive Components Rocket Motor		
Propellant	N-5, Double Based	42 lbs.
Igniter	Igniter Charge (MTV) Initiator ($BKNO_3$)	.11 lbs. .00049 lbs.
Explosive Components Fuze		
Bellows	Ignition Charge (ZPPV) Gas Producer (Single-base Smokeless Powder)	.00003 lbs. .00003 lbs.
Detonator	Ignition Charge (ZPPV) Intermediary Charge (Lead Azide, RD) Output Charge (PETN)	.00026 lbs. .00031 lbs. .00062 lbs.

Figure 3. Mine Clearance Systems, Energetic Materials List

System IM Characteristics

To achieve total IM compliance, all system components must meet the minimum reactions to the external stimuli identified in STANAG 4139 (and MIL-STD-2105). Results of baseline IM tests conducted in 2002, summarized in Figure 4, indicate that the major deficiencies of the system are the ***detonation*** reactions of the M913/ML25 Linear Demolition Charge (LDC) when subjected to the bullet impact, fragment impact, and sympathetic detonation hazards, and the ***deflagration*** reaction of the MK 22 Rocket Motor when subjected to the slow cook-off hazard. The passing criterion for each hazard is a burning reaction with no detonation propagating as an SD hazard.

Mk1 and Mk2, Mine Clearance System (MCS) IM Test Reactions						
System	**FCO**	**SCO**	**BI**	**FI**	**SD**	**SCJ**
M58/M59*	Type V	Type V	Type I	Type I	Fail	N/A
Mk22**	Type V	Type III	Type IV	Type V	(Pass)**	N/A

*The M58 and M59 were evaluated in accordance to MIL-STD-2105C.

**Testing on the Mk22 Rocket met the requirements of the US Navy Bureau of Weapons WR-50 in 1983.

Figure 4. Baseline Insensitive Munitions Testing

The Makeover

MCS is a legacy system, which continues to be funded for procurement across the Future Years Defense Plan (FYDP). Developed many years before the implementation of insensitive munitions testing, the baseline level of IM compliance had never been established. In accordance with evolving US requirements, and the desire of the USMC to continually field safer, more reliable munitions systems, a series of IM test, in accordance with MIL-STD-2105B, was conducted at the Naval Air Weapons Center, China Lake, in 2002. The results of those tests are shown in Figure 4. Based upon those results, the program office implemented a Technology Transition Agreement (TTA) to address the system's shortfalls. This collaborative program between the Office of Naval Research (ONR) Program Manager, Sea Strike Future Naval Capability/Urban Asymmetric Expeditionary Operations and the Marine Corps Systems Command, Program Manager for Ammunition (PM Ammo) will develop and integrate Science and Technology (S&T) products to improve Insensitive Munitions (IM) characteristics of the MCS. ONR and NAVSEA have developed a plan of action and milestones to investigate and incorporate IM technologies as an improvement to the system. In a collaborative arrangement, the Naval Surface Warfare Center's Dahlgren and Indian Head Divisions are working as a team to complete this effort in support of the United Sates Marine Corps. This arrangement capitalizes on prior Navy investments and the individual laboratories established expertise. Their work, which is managed by ONR, is summarized in the following sections.

IM Improvement & Technology Transition Status

Rocket Motor Improvements. The MK 22 is a tractor rocket motor that uses a cartridge loaded, N-5, double-based propellant. In slow cook-off events, the entire propellant grain approaches the auto-ignition temperature, approximately 255°F, igniting nearly all of the propellant at once. The throat area of the existing safety thrust neutralization plug cannot relieve the resulting pressure rise, causing catastrophic failure. Performance requirements of the motor over the operational temperature range restrict potential propellant options to the double-base propellant types that are currently used. It was determined that pursuing a case venting option, as a solution to the SCO hazard, would provide the best potential for improvement.

The most promising venting design concept considered incorporates venting at both ends of the motor, while igniting the N-5 propellant on its intended burning surface prior to it reaching auto-ignition temperature. The technology involved with this venting concept uses a shape memory alloy called NiTiNOL (Nickel-Titanium Naval Ordnance Lab) that "remembers" a predetermined shape when exposed to a predetermined temperature. This concept has been demonstrated in the 2.75-inch rocket motor configuration. Upon actuation of this NiTiNOL mechanism, at a temperature below that of auto-ignition, both ends of the rocket motor are merely held in place by their o-rings. The Rocket Igniter Thermally Actuated (RITA) then initiates the intended burning surface of the rocket motor, also actuated using the NiTiNOL shape memory alloy. The exhaust gasses are then free to push out the ends of the motor and non-propulsively vent the excess pressure.

Linear Demolition Charge Improvements. Any potential changes to the LDC payload delivered by the MCS have elements that influence both IM and functional (performance related) characteristics. The areas to be addressed in this project must meet both of these elements and include energetic and manufacturing/assembly technologies.

Candidate explosive replacements for the Comp C-4 blocks and the PETN detonating cord and relay cups are being evaluated. Key parameters, such as qualification status, IM test history, performance, relative cost, and manufacturing process adaptability to the LDC are being considered in the selection process. More in depth information on this subject is being provided in an IMEMG poster session.

The PETN detonating cord, which includes relay cups connected to the ends of each detonating cord section, is suspected of being the primary contributor to the detonation reactions observed in the baseline IM tests. The use of PETN detonating cords in a system of this type is forbidden in new development due to the DoD's restriction on the use of pure PETN past the fuze interrupter of a weapon system. This restriction is due to the extremely high sensitivity of PETN and its having contributed to a number of prior incidents. The Navy has evaluated several detonating cord and relay cup compositions during the development of other mine clearing systems, such as Anti-Personnel Obstacle Breaching System, Joint Amphibious Mine Countermeasure, and Distributed Explosive Technology. Key performance parameters in assessing candidate replacements for the PETN explosive include not only potential IM compliance, but also the ability to propagate shock along the length of the cord and across breaks or gaps in the cord that may occur during system storage or operation.

Since mass effects and confinement can significantly change the IM response characteristics, the Comp C-4 was isolated and its IM characteristics evaluated separately (in the absence of the PETN detonating cord and relay cups). Comp C-4 was found to be a contributing factor in the IM hazard test failures, so trade studies were initiated to evaluate potential alternatives. One primary objective was to quantify any advantages, such as cost, producibility, or improved blast output, that alternative materials would offer, in addition to the potential for improving the IM response to the hazard stimuli.

Trade studies were performed to evaluate potential detonating cord replacements. Prior subscale IM tests conducted by the Navy on various detonating cords show that Comp A-5, CH-6, and PBXN-8 can pass bullet impact tests. This information, along with a review of existing archival data for other mine clearing systems, provided the basis for a final selection of PBXN-8 as a potential detonating cord material. Additional information on this subject is also being provided in an IMEMG poster session.

The use of the Navy's patented structural overbraid technology for fabrication of the LDC is also being evaluated. Overbraid technology is currently in use in the production of APOBS and offers a lower cost alternative in the design and assembly of line charges. This fabrication method allows continuous processing of a single 350-foot line charge segment, which eliminates the need for the multiple, and highly sensitive, relay cups used in the current 4-segment line charge.

Container Shielding Upgrade. Many barrier and shielding concepts, including new materials and material combinations, have been investigated in recent years specifically aimed at reducing or mitigating the IM hazards associated with shock-induced threats. Replacing the energetic materials in the MCS may not be sufficient to ensure making significant improvement or reaching full IM compliance. The existing container, used for transport, storage and deployment of the MCS, must be considered as an opportunity to improve the level of ballistic protection available to the system. Important issues that must be considered here, in addition to the improved ballistic protection, are cost and weight (for logistic and deployment considerations). The most promising shielding concept that has been examined, as either an add-on or alternate design for this system, includes using hardened ceramic materials as a means of defeating (break apart to disperse the shock input) threat fragments or bullets. Ballistic testing is in-progress to evaluate ceramic ball armor panels for this application. More information on this subject was provided in another IMEMG presentation.

Future Application of the MCS

The Assault Breacher Vehicle (ABV), see figure 5, is a single platform that will provide deliberate and in-stride breaching capability to the assault force of the Marine Air Ground Task Force (MAGTF). It is based upon the Abrams Main Battle Tank chassis and incorporates a number of subsystems that provide the ABV with its specific mission capabilities. The integration of a new turret, full-width mine plow, dual MK 2 Mine Clearance Systems, lane marking system, remote control unit, and protective weapon system will make the ABV a survivable platform capable of accomplishing its mission while being capable of keeping up with the maneuver force. The ABV operates as part of a combined arms task force and is assigned to, and employed by, Combat Engineers as part of a synchronized operation to rapidly breach obstacles and create a lane for other vehicles to follow.

Figure 5. Assault Breaching Vehicle

Execution of the IM Improvement Program for the MCS is ongoing and a great deal of effort still needs to be completed. The potential for improvements, in the MCS' level of IM compliance, residual system safety, and ability to meet the user's performance requirements, will benefit the Marine Corps' user for years to come.

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Captain Michael (Mike) Marchand is an Ammunition Officer with 18 years of service to the Marine Corps. As the Assistant Program Manager for Linear and Demolition Charges in the office of the Program Manager for Ammunition, Marine Corps Systems Command, he has responsibility for total life cycle management of these systems. In that capacity, he is responsible for the procurement and IM efforts on the MCS and APOBS.

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