M115A2-M116A1 Simulator, Perchlorate Replacement Team

Excellence in Weapon System Acquisition, Team

SUMMARY

Approximately 500,000 M115A2 and M116A1 munitions (combined) are fired on Army training ranges every year. A 2001 study by the Army Environmental Command estimated that these munitions account for as much as 70 percent of all perchlorate released on Army ranges. This information prompted the Project Manager, Close Combat Systems (PM CCS), to develop a program to eliminate perchlorate in the training simulators. The Research, Development and Engineering Command (RDECOM) assembled the M115A2 and M116A1 Perchlorate Replacement Team with funding from PM CCS and the Deputy Assistant Secretary of the Army for Environment, Safety and Occupational Health. The U.S. Army Armaments Research, Development and Engineering Center (ARDEC) Pyrotechnics Branch and the Edgewood Chemical and Biological Center (ECBC) worked together to develop a perchlorate replacement for the training simulators. Together these organizations successfully developed and demonstrated a perchlorate replacement for the M115A2 and M116A1 training simulators.

"This program is part of an overall DoD-wide effort critical for demonstrating to the U.S. Congress and the public that DoD seriously considers potential risks to human health from perchlorate releases and is willing to act to reduce those risks quickly and efficiently."

- Shannon Cunniff, Director,
Emerging Contaminants Directorate,
Office of Deputy Under Secretary of Defense
(Installations & Environment)

Perchlorate Replacement Team Accomplishments:

- Developed a unique flash-bang replacement formulation for perchlorate without changing the function of the simulators. The switch to perchlorate-free simulators is transparent to the Soldier.
- Implemented a replacement formulation for perchlorate through an engineering change proposal in FY 2007, ensuring the production of the first perchlorate-free training simulators in FY 2008.
- Made an addition to the Engineering Change Proposal to modify the Technical Data Package which restricted the production of training simulators containing the pollutant perchlorate.
- Ensured the production of perchlorate-free simulators to begin in 2QFY 2008 and the contaminant simulators to be out of the supply system by the end of FY 2009.
- Reduced the amount of potassium perchlorate utilized on ranges and in Army ammunition plants by up to ten tons per year.
- Greatly reduced the potential for the release of perchlorate into the environment and drinking water.
- Made great strides in identifying other potential integration opportunities for perchlorate-free formulations; research may eventually replace perchlorate in M117/M118/M119 Family of Booby Trap simulators and the M274 Smoke Signature Practice Warhead for the Hydra 70mm rocket.

INTRODUCTION

The Department of Defense (DoD) uses many types of non-lethal training munitions on its installations and ranges. Two of the most widely used devices are the M116A1 Hand Grenade Simulators and M115A2 Ground Burst Projectile Simulators. The simulators create flash, bang and whistle (M115A2 only) effects that simulate battlefield conditions such as incoming projectiles, hand grenades and improvised explosive devices. These systems traditionally utilized a pyrotechnic composition that consists of potassium perchlorate and aluminum to produce the required effects. However, the Environmental Protection Agency (EPA) identified the perchlorate ion (ClO4-) as a contaminant of concern due to its high solubility, persistence in the environment and potential effects on human health.

The U.S. Army Environmental Quality Technology Ordnance Environmental Program. The M115A2 and M116A1 Perchlorate Elimination Program was the first project in this Program. Pictured from Left to Right: Dr. Brad Forch, ARL, Dr. Bill Anderson, ARL, Mr. Frank Novak, JMC, Dr. John Beatty, ARL, Ms. LaShanda Felton, AMRDEC, Mr. Mark Motyka, ARDEC, Ms. Sally Gaines, Corrpro/JMC, Dr. Gary Chen, ARDEC, Mr. Mike Hartley, ARDEC, Ms. Shawna Showalter, ARDEC, Mr. Christopher Fish, ARDEC, Ms. Gretel Raibeck, ARDEC, Dr. Ross Sausa, ARL, Dr. Mike McQuaid, ARL, Mr. Larry Warren, ARDEC, Mr. Noah Lieb, HAI/RDECOM, Dr. Mark Johnson, USACHPPM, Mr. Dave Redding, ECBC, Dr. Maggie Hurley, ARL, Mr. Joe Domanico, ECBC, Dr. Betsy Rice, ARL, Dr. Ed Byrd, ARL, Mr. Bill Ruppert, HAI/RDECOM.

A combined 500,000 M115A2 and M116A1 munitions are fired on Army training ranges every year. A 2001 study by the U.S. Army Environmental Command (USAEC) estimated that these munitions account for as much as 70 percent of all perchlorate used on Army ranges. This information prompted the Project Manager, Close Combat Systems (PM CCS), to initiate a program to eliminate perchlorate in the training simulators. The Research, Development and Engineering Command (RDECOM) assembled the M115A2 and M116A1 Perchlorate Replacement Team with funding from PM CCS and the Deputy Assistant Secretary of the Army for Environment, Safety and Occupational Health. The technical leads for the program, the U.S. Army Armaments Research, Development and Engineering Center (ARDEC) Pyrotechnics Branch and the Edgewood Chemical and Biological Center (ECBC), worked together to develop a perchlorate replacement for the training simulators. Together these organizations successfully developed and demonstrated a perchlorate-free flash-bang formulation for the M115A2 and M116A1 training simulators. The formulation was implemented through an engineering change (ECP) proposal in FY 2007 and the first perchlorate-free training simulators will be produced in late FY 2008.

This was the first DoD program to eliminate perchlorate compounds from a munition based solely on environmental concerns. These efforts will eliminate perchlorate releases from training with the M115A2 and M116A1 simulators on every single Army infantry training site and at the Radford Army Ammunition Plant.

Perchlorate Background

Early concern about perchlorate came about after technology improvements enabled researchers to detect perchlorate in groundwater at significantly lower levels. EPA placed perchlorate on its Contaminant Candidate List for possible regulation in 1998 and required it to be monitored in drinking water under the Unregulated Contaminant Monitoring Rule in 1999. On February 18, 2005, the EPA established an official oral reference dose of 0.0007 mg/kg/day for the perchlorate ion, which translates to a drinking water equivalent level of 24.5 parts per billion (ppb). This level is consistent with the recommended reference dose included in the National Academy of Science's January 2005 report on perchlorate, which established a safe level for total daily perchlorate intake. This study found that perchlorate can inhibit thyroid functions by blocking the uptake of iodine by the thyroid gland. Pregnant

women, children and those with already low iodine levels are particularly at risk from perchlorate exposure.

To date, EPA has detected perchlorate in groundwater in at least 34 states. Several states have been proactive in regulating perchlorate by developing a maximum contaminant level (MCL). The MCL for California is 6 ppb and the MCL for Massachusetts is 2 ppb. These regulations are much lower than the recommended federal guidance of 24.5 ppb and could impact the use of perchlorate-containing munitions in these states. Although current federal regulations do not exist today, perchlorate may be regulated under the federal Clean Water Act in the future. The Office of the Secretary of Defense Emerging Contaminant Directorate placed perchlorate on the Action List because continued use of perchlorate has significant potential impacts to human health and the environment as well as the DoD mission.

The M116A1 (shown) is a 4" tall cylinder - roughly the size of a deck of cards.

Perchlorate compounds can potentially be released into the environment at any phase in the munitions life cycle: chemical manufacturing, cartridge loading and assembly, transportation, storage, use or demilitarization. However, one of the greatest areas of concern is the use of perchlorate-containing munitions on training ranges where releases can occur in two ways: if the munition does not function at all (i.e., a dud), or functions partially (i.e., a low-order round).

BACKGROUND

The Perchlorate Replacement Team's success is due to the contributions and capabilities of its members.

- Ms. Maryalice Miller – Director, Environmental Acquisition and Logistics Sustainment Program, Headquarters RDECOM / Acting Director, Environmental Support Office
- Mr. James Wejsa - Branch Chief, ARDEC Pyrotechnics
- Col. Raymond Nulk - Project Manager, PM CCS
- Mr. Frank Novak – Industrial Base Specialist, Joint Munitions Life Cycle Management Command (JMLCMC) Headquarters
- Mr. Joseph Domanico - Team Leader, ECBC Pyrotechnics
- Dr. Mark Johnson - Directorate of Toxicology, U.S. Army Center for Health Promotion and Preventative Medicine (USACHPPM)
- Ms. Kimberly Watts - Director, USAEC Sustainable Ranges Program
- Mr. William Ruppert - Assistant Program Director, Hughes Associates, Inc.
- Mr. Phil Grucci – President, Pyrotechnique by Grucci, Inc.
- Dr. Edward Bouwer - Professor, Department of Geography and Environmental Engineering, Johns Hopkins University

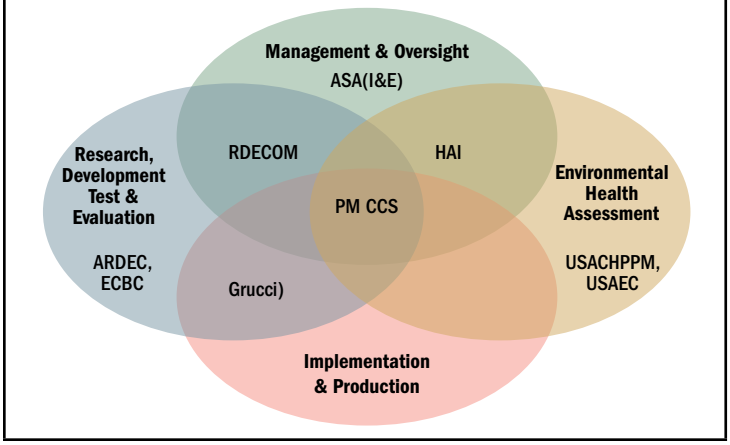
POSITION DESCRIPTION

Program Director Ms. Maryalice Miller at HQ RDECOM, and Assistant Program Director Mr. William Ruppert at Hughes Associates, Inc., managed the Perchlorate Replacement Team. They provided oversight to the program and facilitated interim progress reviews (IPRs). PM CCS manages the M115A2 and M116A1 programs for the Army and maintains munition availability and performance. PM CCS initiated this program to eliminate perchlorate from the munitions solely based on the potential environmental impacts of continuing to train with perchlorate-containing munitions. Mr. James Wejsa, ARDEC, and Mr. Joseph Domanico, ECBC, served as co-technical leads on this project. Each group competed to develop unique replacement materials that were tested side-by-side with the baseline perchlorate formulation. These efforts lead to a joint solution. Mr. Phil Grucci, President of Pyrotechnique by Grucci, used his facility at the

Four M116A1 Simulators Mimic an IED Attack on a convoy.

Radford Army Ammunition Plant to produce small-scale and limited production-scale runs of the replacement formulations for testing. Most major tests and demonstrations were also completed at the Grucci facility. Dr. Mark Johnson, USACHPPM, completed environmental health assessments (EHAs) for the replacement formulations to ensure that the replacement was more environmentally benign than the perchlorate formulation. Ms. Kimberly Watts, USAEC, helped develop the program by identifying the combined use of M115A2 and M116A1 simulators as one of the largest sources for perchlorate use on training ranges. The Johns Hopkins University conducted and published the most comprehensive study of its kind on perchlorate chemistry, occurrence and remediation. A representation of the Perchlorate Replacement Team's involvement is found in Figure 1.

Figure 1. Perchlorate Replacement Team



AWARDS AND SERVICES

- The Perchlorate Replacement Team was awarded the Secretary of the Army Award for Environmental Engineering in Weapon Systems Acquisition in January 2008.
- ARDEC received the 2007 Malcolm Baldrige National Quality Award.
- Dr. Gary Chen, ARDEC technical POC, received the 2006 Army Research and Development Achievement Award for the Reduced Optical Signature Emissions Solution program.
- Participants in the program are members of the National Defense Industrial Association and Association of United States Army.

ACCOMPLISHMENTS

Weapon System Acquisition Program Summary

The Perchlorate Replacement Team's goal was to develop a perchlorate-free flash-bang formulation to meet the specifications of MIL-S-10058 and MIL-S-10057 (Table 1). Another goal was to make the

Table 1: Performance Specifications

Requirement	M115A2 (MIL-S-10058)	M116A1 (MIL-S-10057)
Delay after Ignition	Whistle: 6-10 sec. Burst: 8-14 sec.	Burst: 6 to 12 sec. (Acceptance 8.5 sec. min.)
Burning Time	Photo Flash: Instantaneous Whistle: 2-4 sec	Photo Flash: Instantaneous
Sound Level	138 decibels at min. 75 ft. (Mil-S-10058H)	125 decibels at min. 75 ft. (Mil-S-10057H)

transition to a perchlorate-free simulator transparent to the Soldier. To do this, the team established a full set of end user requirements – sound, fragmentation, light, smoke, feel – with the objective of creating perchlorate-free simulators physically indistinguishable from the current M115A2 and M116A1 simulators.

The program was designed to mitigate technical risk from the start. ARDEC and ECBC competed to produce perchlorate-free prototypes. After exploring a large number of alternatives for a perchlorate-free oxidizer, ARDEC and ECBC selected different materials to develop two separate formulations for testing: one based on strontium nitrate (ECBC) and one based on potassium nitrate (ARDEC). During initial testing, the strontium nitrate formulation did not provide sufficient or consistent performance, so the potassium nitrate formulation was initially selected as the replacement. At the production scale, the potassium nitrate formulation did not perform as consistently as in the small-scale testing, so a third formulation of black powder and aluminum was investigated. The black powder formulation proved to be the most consistent at meeting all sound requirements and it was selected as the perchlorate replacement. All system requirements were met or exceeded, and the look, feel and performance of the perchlorate-free simulators will be exactly the same to the Soldier. In addition, this transition will require minimal changes to the current manufacturing line.

During qualification testing of the new formulation in the M115A2 and M116A1 simulators, active military trainers took part in a human factors assessment of the new design and reported that there were no significant differences noted between the new design and the older baseline design.

The new simulators formulation was approved and implemented through an Engineering Change Proposal (ECP) in April of 2007 to modify the Technical Data Package for the training simulators. This modification requires that the M115A2 and M116A1 training simulators are no longer produced using potassium perchlorate. Production of M115A2 and M116A1 simulators loaded with the perchlorate-free pyrotechnic formulation will begin in 2QFY2008, and the perchlorate-based versions will no longer be produced. The majority of perchlorate-based simulators will be out of the supply system by the end of FY2009. PM CCS invested additional funding to upgrade and expand the existing simulator production lines at Radford Army Ammunition Plant to take full advantage of the success of this program. This investment ensures full production capacity with the new formulations and will maintain munition availability, Soldier readiness and training capability.

Based on annual average usage numbers and the amount of perchlorate in the previous formulation, this project has reduced the amount of potassium perchlorate utilized on ranges and in Army ammunition plants by up to ten tons per year, benefiting Soldiers and surrounding communities by greatly reducing the potential for perchlorate exposure. In addition to reducing perchlorate used in the M115A2 and M116A1 simulators, the Perchlorate Replacement Team strives to identify other potential horizontal integration opportunities for these perchlorate-free formulations. RDECOM is directly leveraging this research to develop perchlorate replacements in other weapon systems including the M117/M118/M119 Family of Booby Trap simulators and the M274 Smoke Signature Practice Warhead for

Simulators create battlefield conditions during training.

the Hydra 70mm Rocket system as part of the U.S. Army Environmental Quality Technology Ordnance Environmental Program.

M116A1 used to simulate IED attack.

Team Communication and Coordination

Communication and coordination was a key factor in the Perchlorate Replacement Team's success. The Perchlorate Replacement Team combined environmental personnel with the technical energetics community to develop an environmentally preferable solution. This required communication between the groups to ensure that all goals were met. RDECOM managed the environmental aspects of the program, while USAEC sustainable range personnel and USACHPPM toxicologists played key roles in defining the impact of continuing to train with perchlorate-based munitions and ensuring that the replacement formulations would be environmentally preferable. RDECOM and USACHPPM analyzed environmental impacts of all candidate pyrotechnic ingredients and compositions, plus other simulator components such as fuses, coatings and adhesives, and provided expert recommendations in support of all key program decisions and down-selections. ARDEC and ECBC provided monthly reports to RDECOM to promote communication and ensure that all new formulations met environmental criteria as early in development as possible. The entire team met for regular IPRs to update the status of the program.

The manufacturer (Pyrotechnique by Grucci) played an integral role in assessing feasibility and producibility of the candidate materials. Grucci was involved from the start of the program and provided input into material development. The Grucci manufacturing facilities at Radford Army Ammunition Plant produced all limited scale production runs used in the testing and demonstration of the perchlorate-free simulators. In addition, Grucci hosted several IPRs, production plant tours and functional tests at their facility.

Incorporating ESOH Integration into Systems Engineering

The program was managed through the complete lifecycle engineering concept. Environment, Safety and Occupational Health (ESOH), factors were considered in all aspects and decisions throughout the entire life-cycle of the munition. The program considered post-production and fielding issues including manufacturing, Department of Transportation (DOT) Transportation Hazard Classification, depot storage, Soldier usage and demilitarization as part of the complete life cycle. The new design will not add any unacceptable risks or liabilities in these post developmental areas.

ESOH Risk Management

First and foremost, the simulator perchlorate replacement effort was an environmentally-driven program. Therefore, the new materials had to be environmentally preferable when compared to perchlorate. USACHPPM was tasked to determine if the newly developed materials were more environmentally benign than the current formulations. USACHPPM developed the Environmental Health Assessment (EHA) program to support this effort by evaluating the ESOH impacts of replacement compositions and systems through a step-wise, phased approach to determining the environmental impacts of perchlorate replacements. USACHPPM worked with project leaders in parallel with their research to develop EHA reports for the perchlorate

replacements. This ensured that any potential environmental impacts of the new energetic formulation were known and that the alternatives had a significantly lower overall environmental impact than the current materials. This program made environmental performance as important as energetic performance. The EHA program has been implemented in the entire Environmental Quality Technology Ordnance Environmental Program and a similar program is being adopted by the Emerging Contaminants Directorate.

In order to assess and manage risks associated with environmental impacts, system safety and health hazards, PM CCS prepared and maintained a Programmatic Environment, Safety and Occupational Health Evaluation as required by DoD Instruction 5000.2, a Life Cycle Environmental Assessment per National Environmental Policy Act guidelines and a Health Hazard Assessment by USACHPPM on the perchlorate-free simulators.

The ARDEC Safety Office and the Army Safety Center issued Final Hazard Classifications (FHC) for both perchlorate-free simulators. The FHC for the perchlorate-free simulators will stay the same as for the previous formulation. There will be no additional hazards associated with implementing the perchlorate-free formulation.

Potential life cycle cost avoidances from implementing the perchlorate-free formulation include reducing range and ground water cleanup for perchlorate contamination, mitigating legal liability associated with perchlorate contamination and limiting training restrictions on key U.S. war fighter training ranges that would result in less than optimal training levels and Soldier readiness.

Hazardous Materials Management and Pollution Prevention

This program did not introduce any new hazardous materials or wastes. The Perchlorate Replacement Team took steps to select materials that posed the least risk throughout the life cycle of the system. Environmentally preferable products were identified and tracked for inclusion in technical manuals and authorized materials. This was assessed and confirmed by the USACHPPM, Army Developmental Test Center, Army Evaluation Center and the DOT. No new waste streams were generated that exceeded the risks or severity of the baseline design.

External Coordination

The Perchlorate Replacement Team coordinated with stakeholders throughout the entire process. The entire program was structured around meeting user requirements and requests. The Energetic Materials Qualification Board Integrated Project Team (IPT) influenced the team's activities. This board was responsible for assessing the necessary material characterization tests performed and the results that were acceptable before the Perchlorate Replacement Team could proceed with the perchlorate-free formulations. The Insensitive Munitions (IM) IPT assessed the new candidate munitions for the proper IM testing and the test results and the new formulation meets all requirements.

The Perchlorate Replacement Team provided input to Mr. Alex Beehler, Assistant Deputy Under Secretary of Defense (Environment, Safety & Occupational Health), before he testified before the House Committee on Energy and Commerce on April 25, 2007 to address the DoD's usage and approach to remediation of perchlorate ion activities. The team's efforts were highlighted to show that the DoD is actively pursuing perchlorate replacements where possible.

CONCLUSION

Through the hard work of the Perchlorate Replacement Team, the Army has greatly reduced the potential for the release of perchlorate into the environment. This project alone reduced the amount of potassium perchlorate utilized on ranges and in Army ammunition plants by up to ten tons per year. To put that in perspective, that amount of perchlorate is enough to contaminate 70 billion gallons of water at the 24.5 ppb threshold. This is roughly 200 times more water than the Tidal Basin in Washington, D.C. contains or nearly twice as much as the world-wide consumption of bottled water in 2004. This will greatly benefit Soldiers and their friends and families in the surrounding communities by eliminating a source of perchlorate used on training ranges. The team has eliminated the possibility that the military's future use of these simulators will contaminate drinking water with perchlorate.