FINAL SCIENTIFIC AND TECHNICAL REPORT ON THE HIGH-PERFORMANCE HAND-HELD FOAMED NITROMETHANE SYSTEM

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1. EXECUTIVE SUMMARY

Field trials in Kosovo and Cambodia with the old Hand-Held Explosive Foam System confirmed the validity of the Foamed Nitromethane (NM) concept, but identified certain weaknesses in the hand-held system. A requirement emerged for a new foamed NM formulation, which retained the basic characteristics of the hand-held system and builds upon its strengths.

The new system and formulation that was developed, called NMX-foam (for NitroMethane eXplosive foam), offers more explosive power to successfully attack any blast mine, yet incorporates the modifications recommended from the old system in order to maximize its practicality.

Offering characteristics unavailable from conventional explosives, this new Hand-held NMX-foam System offers a versatile and effective alternative to conventional mine demolition techniques, and will be popular within the operational demining and EOD communities.

2. BACKGROUND

The disposable two-component Hand-Held Explosive Foam System was designed for the destruction of thin-walled Anti-Personnel landmines by Golden West under a contract with the U.S. Army Humanitarian Demining Directorate, Fort Belvoir.

Nitromethane-based foam explosives offer many advantages compared to conventional high explosives:

1. Classification as a flammable for transportation and storage, not as an explosive.
2. Ability to neutralize above ground and awkwardly placed mines and

booby-traps.
3. Increased Safety
4. Lower Costs.
5. Easy to train and use.
6. Disruption (blowing the battery or circuitry off an improvised device).

One of the main criteria used in the development of the Low-Cost Hand-Held NMX System was the utilization of commercially available components in the design and development of the system. All the system components (such as cans, valves, actuators and transfer adapters) were analyzed and selected from commercially available product lines of major industrial aerosol component manufacturers.

3. SYSTEM DESCRIPTION

The hand-held system (see photo below) consists of 500 grams of a nitromethane-based base solution in a disposable aerosol can (Unit A) and a second, smaller container (Unit B) with approximately 50 grams of blended liquid hydrocarbon propellants. In the field, just before use, the Unit B propellant is transferred into the Unit A base solution can. An explosive foam can be produced only after the two components are combined and dispensed from the Unit A aerosol can. When this mixture is exposed to the atmosphere, the liquid hydrocarbon propellant expands to a gas producing foam with a physical consistency of shaving cream. The foam produces a highly effective explosive. The foam makes intimate contact with uneven and rounded surfaces, where the use of solid high explosive blocks such as TNT and C4 are inefficient. It also simplifies the attack of above ground and awkwardly placed mines, improvised explosive devices (IED) and booby-traps. Mine neutralization occurs by spreading the foam from the Unit A aerosol can on the mine, then remotely detonating it with a number 8 equivalent blasting cap. The mine is destroyed by sympathetic detonation. Therefore, the foam should be applied directly to the part of the mine containing the explosive fill.

Hand-Held Aerosol NMX-foam System

4. TECHNICAL SUMMARY

a. Cold Temperature Operations:

Evaluations were made on the cold temperature operations of the kit. When both Units A & B are at the same temperature, transfer of the propellant can be made in less then 30 seconds down to temperatures of 38º ± 2ºF. The foam from Unit A at this temperature is light (0.30 ± 0.05 gms/cc) and tends to collapse rapidly. The foam begins to build to the normal height as it warms, but the foam is still less dense than at normal room temperature foam and with larger bubbles. When the pressurize Unit A is warmed back to 70º-75º the foam appears to be typical and the density is back to 0.50 ± 0.05 gms/cc. The spray rate is down to around 8-9 gms/sec. at this lower temperature, which would be expected since the pressure decreases to about 45 PSIG at temperatures below 50ºF. A safe operational temperature range would seem to be around 60º to 95ºF. This would be the temperature of the Units, not the ambient or surface temperature to which the foam is applied.

b. Mixing Procedure:

The procedure of adding the surfactant to the nitromethane (NM) was evaluated in the lab by three different methods. Because the surfactant first evaluated was a solid, a new spray powder form was available which dissolved much quicker than the solid chunks. The fumed silica is added slowly and folded into the mixture. The mixture does not seem stable and tends to separate; therefore constant agitation is required for several hours. Full stability is not realized for at least 24 hours at room temperature (75ºF). This procedure was used to mix the batch for the packaging. Agitation on the batch was intermittent during the filling of Unit A. The batch was checked and sample cans of Unit A were made in the laboratory of the mixture before any pre-production units were made. No separation was realized in the laboratory samples. The finished laboratory samples made from the production batch duplicated the specification of samples made by this procedure when the batch base solution was prepared in the laboratory. Six units were removed from the production units and tested and evaluated during production. All Units tested satisfactorily and met the anticipated specifications.

c. Mixing of Base Solution:

The production batch was mixed in a stainless steel, jacketed closed tank with agitator. Hot water was circulated to the jacketed tank. The total time of heating and mixing required about 5 hours. The base solution stood for about 48 hours before filling. Filling was carried-out directly from the mixing tank by gravity feed to an air operated piston filler.

d. Unit A Filling:

The NMX-Foam base solution was screened during the can filling process with a stainless steel screen. This is a new procedure which seems to improve the consistency of the base solution by removing large air bubbles trapped in the thick base solution. Also, any foreign particles were moved that may present clogging of the valve.

The vacuum crimping procedure of the aerosol valve was also improved as the NM would boil with a vacuum above 20 inches of Hg. The vacuum crimping operation was held at 16 ± 2 inches of Hg during the closing of all the Unit A cans. Higher vacuums would pull material into the valve crimping tool causing can closure difficulties.

The units were marked for the proper spout orientation. The spout must be placed with care to avoid “losing” the vacuum, which is needed to help transfer the propellant rapidly from Unit B. The protecting cap for the spout is placed on the spout before the labeling is carried-out. After the labeling the unit is placed in a carton of 20 units each. The target for filling weight was 505 ± 5 gms/unit for all Unit A containers. Each case weighs 28.5 ± 0.5 pounds.

e. Unit B Filling:

The Unit B cans were vacuum crimped also in order to decrease the filling back pressure of the propellant. The same vacuum as Unit A was maintained. After the empty container was vacuum crimped with a valve, the unit was pressure filled with 49 ± 2 gms of propellant. Each unit was weighed and then the adaptor button was placed on the valve. A special pressurizing tool was used to press the adaptor transfer button firmly on to the valve. This procedure is required to properly seat the adapter onto the barb on the valve stem. The protective one-inch overcap was placed on the unit and then the unit was labeled. After the labeling, the unit was placed into a 20-unit case, which weighed 4.0 pounds (1,810 ± 15 gms).

f. Propellant Transfer:

The additional pressure (head) in Unit B helps the transfer of propellant into Unit A. When both units are the same temperature at the time of transfer, the vacuum in Unit A and the extra pressure in Unit B allows transfer at most all temperatures within about 25 seconds. If the vacuum or extra pressure is lost, shaking of Unit A may be required during the transfer to help dissolve the propellant into the NM, which reduces the pressure in Unit A. There is also a slight temperature change during the transfer that shaking will mitigate. Unit B refrigerates as the propellant leaves the can and the quick increase in pressure in Unit A creates a slight heating. This phenomena works against the rapid transfer and is somewhat overcome by shaking after about 15 or 20 seconds into the transfer procedure. At any rate, almost 40 grams of propellant transfers within 15 to 20 seconds. This amount of propellant is adequate to create the foam and empty Unit A. This amount is an increase in weight of about 8% of the system. The amount of propellant required was established in the laboratory. About 7½% is the maximum amount of propellant soluble in the system, and this concentration will consistently make a stable, dense foam with small bubbles. The present system is designed with approximately 20% over the minimum of propellant to satisfactorily deliver a successful foam. (See Appendix A “Instructions for Use” for Propellant Transfer Procedure).

Specifications:	**Unit A**	**Unit B**
Fill Weight	505 ± 0.5 gms	49. ± 2 gms
Pressure	16 inch Vacuum	95 ± PSIG @ 70ºF

5. KEY CHANGES AND IMPROVEMENTS

a. New Formulation:

There were several program objectives that required the compounding of a new foam Base Solution formulation. They were:

1) Density/Power Requirement: With the old formulation, various hydrocarbon mixtures were tested, but we were never able to achieve a foam density greater than 0.30 ± 0.05 gm/cc. One of the primary program objectives was to develop a system that dispensed foam that was powerful enough to deal with any conventional blast mine, no matter what the configuration or casing material.

This required additional power would also permit the new system to be used on medium-sized items of unexploded ordnance.

The old formulation was not capable of achieving this goal. A new formulation and propellant blend was required in order to increase the density and resultant power from the foam dispensed by the hand-held system. The result of the new formulation was a 67% increase in foam density to 0.50 ± 0.05 gm/cc, thus achieving this goal.

2) Performance Characteristics: Two other objectives of the program were to widen the temperature range of application to accommodate as many ambient conditions as possible, while dispensing the explosive smoothly and consistently, without clogging or the need for excessive shaking. It was determined that a new formulation and blending process, with proper screening of the mixture during filling, was required in order to meet these objectives. These objectives were achieved with the new formulation in the new NMX-foam System.

3) Quality Control: Previous batches of the old formulation provided to us suffered badly from a quality control standpoint. Not only did component percentages differ, but analysis also showed that different types of surfactants were used in different batches. It was determined that the only way to provide a consistent formulation, that would achieve the power and performance characteristics stated above, was to compound the formulation ourselves to proper quality control standards.

4) Manufacturing: It was vital that the disposable low-cost hand-held system needed to be manufactured in a reliable, uniform and safe package that could be readily utilized and duplicated under the broadest environmental conditions anywhere in the world. Chemicals, component parts and equipment had to be commercially available materials that could be duplicated in such a manner that the performance of the NMX-foam System would not vary regardless of where or who manufactured the kits. Control of the base solution compounding process was vital to achieving this goal.

b. Density & Power:

The previous system produced foam with an average density of 0.30 ± 0.05 gm/cc. The new system produces a more stable foam, with smaller bubbles, and an average foam density of 0.50 ± 0.05 gm/cc. This increase in density has shown to significantly increase power over the old system, which was substantiated in field trials at an Army Test Site and the L.A. Sheriff's Bomb Squad Test Range. Dr. Patel, the Army's Technical Representative, is currently planning to arrange for determination of detonation velocity of the new system at the Army Test Laboratory.

c. Propellant Transfer:

Where the old system required a “venting” procedure in order to transfer all the propellant from Unit B into Unit A, the new system transfers approximately 40 grams in the first 15 to 20 seconds of application. It should be noted that this amount is enough to create an effective foam and empty the entire foam contents of Unit A. A simple second shaking of Unit A mixes the propellant with the base solution, and a re-application on Unit B quickly transfers the remaining propellant.

d. Flow Rate:

The previous system dispensed foam at a rate of 8.0 gm/sec. The new system dispenses foam at a lower velocity, but has increased the flow rate by 50% (12 ± 1.0 gm/sec).

e. Finger Pad Pressure:

The old system required approximately 68 seconds to empty an entire Unit A can of its foam. This sometimes resulted in “finger fatigue” for the operator. The new system requires only 45 seconds or less to empty all of the foam in the Unit A can. The design of the new valve results in easier actuation with less force.

f. Foam Dispersion:

The new system dispenses foam at a greater range of temperatures for the contents of the Unit A Base Solution Container (60º to 95ºF). In addition, as a result of screening of the base solution during the factory filling of the Unit A can, and an increase in diameter of Unit A’s valve orifices, the new system is more resistant to clogging during dispensing of the foam from Unit A.

g. Cold Temperature Operations:

Cold temperature operation and expansion of the foam for an effective application has been reduced by 10 to 15oF. the new suggested minimum temperature is now 50 ± 5oF.

6. FIELD TRIALS

On April 21 and 22, 2003 successful field trials with the new NMX-foam System were conducted at a U.S. Army installation. These trials were conducted under the supervision of Dr. D. Patel for proper application against a variety of Anti-Personnel (AP) and Anti-Tank (AT) mines. These trials confirmed the improved effectiveness of the new NMX-foam System against both thin-walled and thick-walled AP mines, as well as some types of AT mines (see Appendix B for complete Field Test Report).

7. CONCLUSION

Field trials were conducted at an Army Test Site on April 22-23, 2003. These trials were conducted under the supervision of Dr. D. Patel for proper application against a variety of Anti-Personnel (AP) and Anti-Tank (AT) mines as described below.

1. Results suggest that thin-walled AP mines of virtually any type can be destroyed by a single can or less of NMX-foam.
2. AT mines and thick-walled (fragmentation) AP mines generally require one to two cans to ensure complete detonation.
3. Operational tests are needed to optimize the use of NMX-foam regarding different combinations of charge size and placement.
4. Below is the conclusion from the observer from the Humanitarian Demining Training Center:

> "NMX Foam is another tool for the detonation of land mines in a Humanitarian Demining role as well as countermine. Since all mines may or may not have operational detonators, the quantity of NMX Foam may be questioned. Without knowledge or experience with the threat, one full can should be used on all A/P mines and two full cans for each A/T. Once the Section Commanders have the opportunity to test for the quantity required, then the amount of foam used maybe reduced."

The new NMX-foam System, with its higher density of 0.50 ± 0.05 gm/cc, offers increased power and effectiveness over the pervious hand-held system for the destruction of anti-personnel and anti-tank landmines. Along with other ergonomic improvements, this user-friendly system offers the operational demining and EOD community a safe and cost-effective alternative to conventional solid explosives.

APPENDIX A FIELD TRIAL RESULTS

April 22, 2003 – Anti-Personnel (AP) Mine Trials

Weather: Clear skies
Temperature: Approximately 60°F

Target Mine	**Application**	**Result** **(see attached photos)**
Small plastic-bodied AP blast mines • Two without fuze • One fuzed	1/3 can over top 1/3 can over top	Full detonation Full detonation
Italian VS-50 resilient plastic-cased AP blast mine • Two without fuze • One fuzed	2/3 can over top 2/3 can over top	Full detonation Full detonation
Russian PMD-6 wooden AP blast mine • One without fuze	1/2 can over top	Full detonation
Russian SPM mine • Two fuzed	1/2 can over top	Full detonation
Bounding fragmentation mines • Two without fuze • One fuzed	One can over top One can over top	Full detonation Full detonation

April 23, 2003 – Anti-Tank (AT) Mine Trials

Weather: Clear skies
Temperature: approximately 60°F

Target Mine	**Application**	**Result** **(see attached photos)**
Large round steel-cased AT blast mine • One fuzed	One can covering side next to main charge	Full detonation
Large round steel-cased AT blast mine • Two without fuze	One can covering side next to main charge	Partial detonation with unexploded components
Large square plastic-cased AT blast mine • One fuzed	One can covering side next to main charge	Full detonation
Large plastic-cased AT blast mine • One without fuze	One can covering side next to main charge	Partial detonation with unexploded components
Large plastic-cased AT blast mine • One without fuze	Two cans covering side next to main charge	Full detonation
Russian TMD-44 wooden AT blast mine • One without fuze	Two cans over top	Full detonation
Yugoslav TMA-5 plastic-cased AT blast mine • One without fuze	Two cans covering one side next to main charge	Partial detonation with unexploded components
Heavy AT mine with shaped-charge warhead (Misznay Schardin) • One fuzed	One can over top	Full detonation

Photo #1

Target: Small plastic-bodied AP blast mine, unfuzed

Application: 1/3 can over top of mine

Result: Full detonation

Photo #2

Target: Italian VS-50 resilient plastic-cased AP blast mine, unfuzed

Application: 2/3 can over top of mine

Result: Full detonation

Photo #3
Target: Russian PMD-6 wooden AP blast mine, unfuzed
Application: 1/2 can over top of mine
Result: Full detonation

Photo #4
Target: Russian SPM mine, fuzed
Application: 1/2 can over top of mine
Result: Full detonation

Photo #5
Target: Russian TMD-44 wooden AT blast mine, unfuzed
Application: Two cans over top
Result: Full detonation

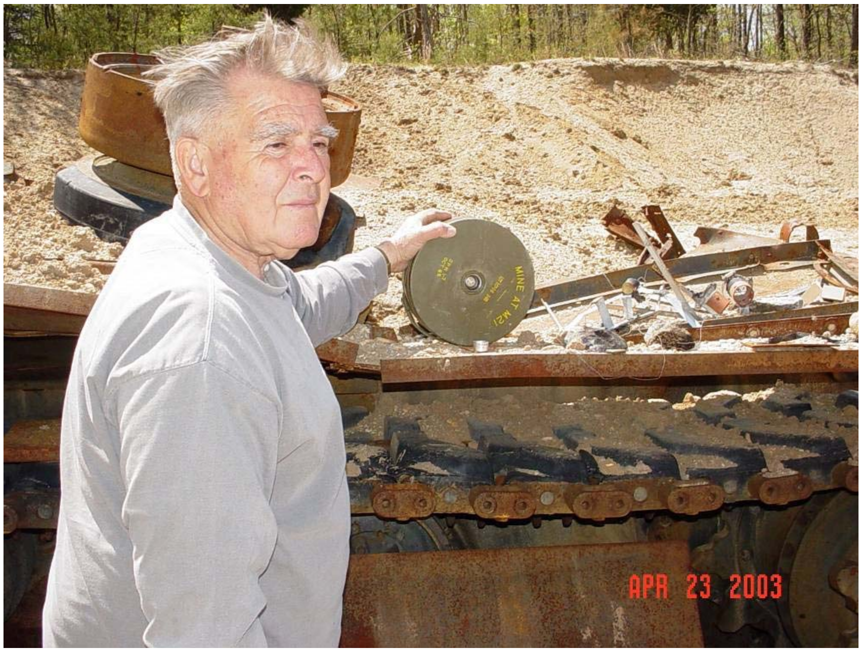

Photo #6
Target: Heavy AT mine with shaped-charge warhead (Misznay Schardin), fuzed
Application: One can over top
Result: Full detonation