Surrogate Test for M55 Nerve Agent Rocket Mortar by DAVINCH

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1. Introduction

DAVINCH^{TM}, the controlled detonation chamber system developed by Kobe Steel, Ltd., can destroy a whole chemical round containing a chemical agent and explosives without previous dismantling, but by a single detonation. Therefore, it can destroy safely the munitions with high risks in dismantling or any mechanical processing, including not only corroded and deformed non-stockpile munitions, which DAVINCH have been used to dispose of, but also any stockpiles which require special considerations for high risks of chemical or explosive hazards. Furthermore, DAVINCH can destroy any types of chemical agents by utilizing detonation energy, and one unit can be used for disposal of all types of chemical weapons or conventional munitions found at a site. Therefore, DAVINCH can be a safer solution for those munitions with high risks, and a versatile solution for the facilities where various types of chemical weapons and munitions should be disposed of.

As an example of the munitions which requires such a special consideration, M55 nerve agent rockets, containing GB or VX and propellant, are considered to be ones of the most difficult chemical munitions to safely store and destroy in U.S stockpiles. It is reported that some of them are leaking and some have the risk of accidental ignition. The conventional disposal process of these munitions including separation of the agents and explosives is thus considered to involve serious chemical and explosive risks, and the process should be separated from the process for other chemical weapons due to the special handling it requires.

In order to demonstrate the capability of DAVINCH to destroy M55 nerve agent rockets, a surrogate test was conducted using an actual size simulated munition.

2. M55 Rocket mortar[1), 2),]

M55 rockets were developed in the late 1950s and produced in 1960 to 1965, and currently stored in four sites in U.S. An M55 consists of a fin nozzle assembly, a rocket motor with solid double-base propellant, a chemical agent-filled warhead and fuze. The warhead contains 4.9 kg (10.7 pounds) of liquid GB or 4.5 kg (10 pounds) of liquid VX. These rockets are reported to have high risks of hazards in storage, because of the possibility of auto ignition of degraded propellant and because of leakage. GB rockets have particularly high risk of leaks because the acidic degradation products of GB corrode the thin wall of the warhead, which is made of thin aluminum. They have been disposed of by punching the rockets, draining the agent fill, shearing the emptied rockets, and finally incineration of the liquid agent and solid separately. Some incidents of fire, in which the propellant ignited in the shearing process, were reported.

3. DAVINCH

DAVINCH (Detonation of Ammunition in Vacuum Integrated CHamber) system consists of a detonation chamber (**Fig.1**), an off-gas system and auxiliary equipment. Chemical munitions with donor charge are detonated in the detonation chamber. The chemical agents are destroyed by the detonation.

Fig.1 DAVINCH (DV60)
Kanda, Japan

3.1 DAVINCH detonation chamber

The DAVINCH detonation chamber has distinctive features such as; the double-walled construction with the replaceable inner chamber protecting the outer chamber from fragments; the vacuuming previous to detonation and the sequential detonation to reduce the impulsive load, sound and vibration, and fatigue damage[3), 4),].

3.2 Off-gas treatment system

The off-gas is extracted from the detonation chamber and treated by the off-gas system before discharged, in order to meet the regulatory requirements. An oxidizer with cold plasma, the main component of the off-gas system, eliminates the carbon monoxide (CO) and the hydrogen (H_2), which are the main constituents of the off-gas. Although the oxidizer is not meant for the elimination of the residual chemical agents, because the off-gas from the DAVINCH chamber does not contain agents of a detectable level, it is confirmed to have the capability of agent destruction by the tests using actual agents and serves as a backup. The system has characteristics such as “hold, check and release” mode of operation that enables the off-gas to be analyzed before each batchwize release to ensure the gas does not contain chemical agents [5].

3.3 Record of actual Destruction

It has been used in Kanda, Japan, to destroy ocean-dumped chemical munitions from World War II, containing a mixture of mustard (HD) and lewsite (L) or diphenylcyanoarsine (DC) and diphenylchloroarsine (DA), and successfully destroyed more than 1,200 (as of November 2006) of those chemical munitions since 2004. It has been demonstrated that DAVINCH can destroy munitions containing other types of fills including phosgene (CG) and white phosphorous (WP) and high explosives (large conventional munitions) through detonation tests as reported previously [6]. The DAVINCH currently used in Kanda has a detonation capacity of 60kg-TNT.

4. Surrogate test for M55

4.1 Objectives

A surrogate test using an actual size simulated rocket was conducted to demonstrate the capability of DAVINCH system to destroy the M55 nerve agent rockets, after a series of preliminary tests which are not described here. In the test, the rockets with GB fill were chosen as the target munition.

The objectives were to demonstrate the destruction of the rocket with chemical fill and propellant by detonation without previous dismantling, evaluate the capability of the agent destruction and to evaluate the off-gas quality for safe discharge, with comparing it to the short-term exposure limit (STEL) of GB.

4.2 Procedures

The test was carried out using a DAVINCH DV60 (detonation capacity of 60kg-TNT) detonation chamber and a simulated munition for M55 with surrogate for GB and simulated propellant to demonstrate the destruction performance.

4.2.1 Simulated munition

The simulated M55 rocket is shown in **Fig.2**. and **Table 1**.

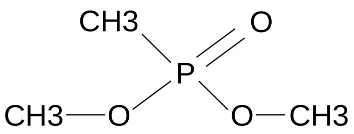
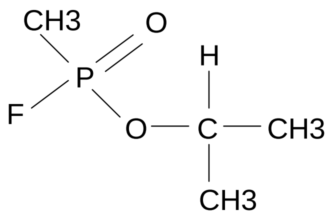
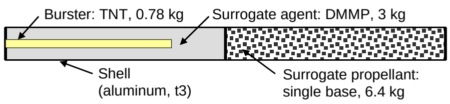
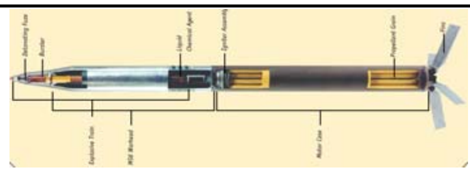
The size and the construction are simulated as truly as possible, although some features which are not important for the evaluation, such as the conical nose, fuse, fins and nozzle, were omitted. The burster and the propellant were simulated by industrial explosives which were available.

Fig.2 Simulated M55 rocket

Dimethyl methylphosphate (DMMP) was chosen as the surrogate for

GB.

Table 1 Comparison of simulated M55 rocket to actual M55 rocket

	Simulated M55	Actual M55
Size	Length: 1.62 m Diameter: 110 mm	Length: 1.98 m including conical nose, fuse, nozzle and fins Diameter: 115 mm
Weight	17.5 kg	25.5 kg including conical nose, fuse, nozzle and fins
Material	Aluminum, thickness 3 mm	Aluminum
Burster	TNT (flakes), 0.78 kg	Composition B or tetrytol, 1.45 kg
Propellant	Single-base smokeless powder (granule), 6.4 kg	Double-base propellant (solid), 8.8 kg
Agent	Dimethyl methylphosphate (DMMP) 3 kg **DMMP** 	Sarin (GB), 4.9 kg **GB** 
Structure		 http:/ / cma.army.mil/ include/ docrendition.asp?DocID=003675338

4.2.2 Detonation

The detonation was carried out according to the standard procedure of DAVINCH operation. The simulated M55 was surrounded with an emulsion explosive as the donor charge and installed in the detonation chamber. Then the chamber was vacuumed and minimum oxygen was injected. After that, all the valves were closed to make the chamber isolated and gas tight. Then the donor charge and the simulated munition were detonated. The conditions are shown in **Table 2**.

Table 2 Detonation conditions

Conditions		Remarks
Donor charge	22.2 kg	Emulsion explosive with booster* (plastic explosive containing PETN)
NEQ	28 kg-TNTeq.	Net Explosive Quantity, including both donor charge and inner explosives (burster and propellant*) *Exact TNT equivalence of the propellant is not known and assumed as 1kg/kg-TNT
HE/CA ratio	9.3	NEQ/(quantity of agent)

4.2.3 Sampling and analysis

The detonation product gas is sampled directly from the detonation chamber after the detonation before evacuating the chamber. The gas was then fed to the off-gas treatment system, and the gas treated by the oxidizer was sampled at a sampling point just after the oxidizer. The gas samples are analyzed by GC-MS.

The solid wastes generated by detonation, the fragments and the dust, were collected from the chamber and weighed and the samples were taken. The residual agent was extracted by a solvent and analyzed by GC-MS.

The deposit of residual agent on the inner surface of the chamber was sampled by wipe sampling. The residual agent was extracted by a solvent from the wipe cloth and analyzed by GC-MS.

4.3 Results and discussions

The simulated rocket, with the agent, the burster and the propellant was successfully destroyed in a single shot of detonation. The interior of the detonation chamber just after the detonation is shown in Fig.3. The fragments and dust are the only resulting wastes.

Fig. 3 Inside of DAVINCH detonation chamber after detonation

Table 3 Results

Results		Remarks
Agent in chamber off-gas	0.00138 mg/m^3	
Destruction Efficiency (DE) of DAVINCH chamber by detonation	99.999998%	gas
	99.99%	including solid wastes
Agent in Cold Plasma Oxidizer off-gas	0.00004 mg/m^3	< STEL of GB (0.0001 mg/m^3)
Destruction and Removal Efficiency (DRE) of DAVINCH chamber + Oxidizer	99.9999998%	gas

As shown in the **Table 3**, destruction efficiency of DAVINCH was very high and almost the entire agent was destroyed by detonation alone, with the residual agent level as low as 0.00138 mg/m^3 in the gas. The off-gas treatment by the Oxidizer further improved the off-gas quality, to achieve the level of 0.00004 mg/m^3 which is well below the STEL of GB, and that means the gas can be discharged to the atmosphere in most of the cases.

The solid wastes contained a trace of residual agent but it is considered to be reduced by a cleansing shot. A cleansing shot is a detonation of bulk explosive only, which follows to the detonation of munitions and off-gas extraction, when it is necessary. It further destroys the residual agent in the solid wastes and on the inner surface of the detonation chamber[6)].

Actually, a cleansing shot was carried out in this test, but a valid data was not obtained due to sampling failures.

According to the US regulation, the solid wastes should be kept in a gas-tight container and the head space monitoring should be carried out to confirm the agent vapor concentration is lower than the GPL level before the off-site disposal. In the case of DAVINCH, the solid wastes can be kept in the detonation chamber after a day's operation and the monitoring of the air in the detonation chamber in the morning of next operational day can replace the head space monitoring.

5. Summary

A simulated M55 rocket with the surrogate for GB, the burster and the propellant was successfully destroyed by a detonation by DAVINCH with a very high destruction efficiency of the agent and a concentration of the residual agent in the off-gas lower than the STEL for GB. The test demonstrated the capability of DAVINCH to safely destroy the M55 nerve agent rockets, which have high risks of chemical and explosive hazards, and demonstrated the versatility of DAVINCH, also taking account of the already proven capabilities to destroy the old Japanese non-stockpile HD, L, DC and DA munitions and the surrogate test with CG, WP and conventional munitions.

6. References

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