Research paper

Study on controlled detonation chamber system of chemical weapons (I)

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Abstract

As a destruction method of chemical weapons, the controlled detonation system named DA VINCH was developed. The main characteristics of it are 1) A cylindrical chamber, 2) Double walled structure, 3) Detonation in vacuum as well as 4) easy decontamination and maintenance. Model DV45 with maximum capacity of 45 kg TNTeq had been used to destroy about 600 chemical weapons by 280 shots and was examined after the operation. No harmful cracks were observed on the inner surface of the outer chamber.

Keywords: Controlled detonation, Chemical weapons, Chemical warfare materials, Detonation chamber, Multi-layered vessel

1. Introduction

By the Chemical Weapons Convention, coming into force in 1997, the development, production, stockpiling and use of chemical weapons are prohibited. Japan has no facilities of development, production and "Stockpile" of chemical weapons at all.

But as are known, there are some places where old chemical weapons were found and recovered in Japan, like Lake Kussharo, Samukawa Town in Kanagawa Prefecture, and Kanda Port in Fukuoka Prefecture. Moreover, there are many places in China where chemical weapons were abandoned by the Imperial Army of Japan after the World War II. Those Old or Abandoned Chemical Weapons are called "Non-Stockpile" and should be destroyed by the Government of Japan under the Convention.

Kobe Steel Ltd. (herein after called KSL), is the only company in Japan that is engaged in actual chemical weapons destruction, having destroyed more than 1,000 chemical bombs and 800 bottles with chemical agent, all of which were recovered from the sea or from the ground. Table 1 shows typical bombs destroyed by KSL. Yellow or red is an identifying symbol color of chemical weapons.

The authors have been engaged in all of the three big projects, through development, design and operation of the facilities. Through these experiences, the authors made a decision to develop a controlled detonation chamber system which can destroy any kind of "Non-Stockpile chemical weapons", which can be (1) heavily corroded, possibly with leakage, (2) deformed, (3) with fuse, armed, and/or (4) not fully identified.

Table 1 Munitions destroyed.

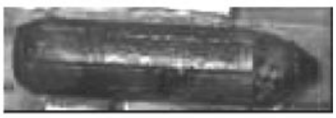
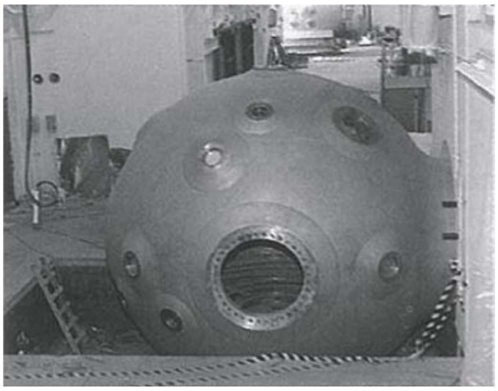
50 kg Yellow bomb	15 kg Red bomb
Mustard and lewisite mixture	Diphenylcyanoarsine, diphenylchloroarsine
	

Fig. 1 View of DA VINCH [6].



Spherical chamber
(By courtesy of Lawrence Livermore National Laboratory)

DV60 for Kanda Project

Fig. 2 Examples of spherical chamber and cylindrical ones [6].

The most common methods for destruction of chemical weapons are: (1) chemical neutralization and (2) incineration after separation of chemical warfare materials (herein after called CWM) from the explosive charge. At Lake Kussharo [1), 2)] CWM were neutralized followed by oxidization and explosive was separately destroyed by detonation. At Samukawa [3), 4)] CWM in the bottles were destroyed by neutralization followed by oxidization. The contaminated soil was cleaned up by a rotary kiln.

When the munitions are "stockpile", CWM and the explosive can easily be separated by reverse assembly or by water jet cutting. For non-stockpile munitions, however, complete separation of CWM from explosive is very difficult.

The simplest method for destruction of chemical weapons is to detonate the entire munitions in a strong and massive chamber without separation. This paper describes on the development of such method, called the Detonation of Ammunition in Vacuum INtegrated CHamber (DA VINCH™). Figure 1 shows an out side view of DA VINCH, which is now practically used at Kanda [5)].

2. Items to be discussed to develop a controlled detonation chamber for chemical weapons

To develop a controlled detonation chamber, following items should be considered.

(1) Easy scaling up to have higher throughput
(2) Reduction of damage by fragments as well as by impulsive loading
(3) Reduction of sound and vibration for Public Acceptance
(4) Easy maintenance
(5) Easy inspection of crack initiation
(6) Less leakage of inner gas during operation
(7) Enough Destruction and Removal Efficiency (DRE) of CWM

3. Characteristics of DA VINCH

The outline of the characteristics of DA VINCH were explained on a separate paper [6)] of ASME.

3.1 Horizontal cylindrical chamber

The ideal shape of a detonation chamber is sphere when one source of explosive is installed at the center of the chamber, because the blast wave expands to all directions. The Non-Stockpile munitions to be destroyed, however, is not always placed at the center of the chamber, but with eccentricity, because of asymmetry of the munitions itself. Meanwhile, the diameter of spherical chamber is restricted by transportation limit and consequently, a spherical chamber has limitation in throughput.

A cylindrical shape, however, allows a larger throughput under the limitation of its diameter, when multiple munitions are installed at the different axial direction positions in the chamber. Figure 2 shows examples of a spherical chamber and horizontal cylindrical one.

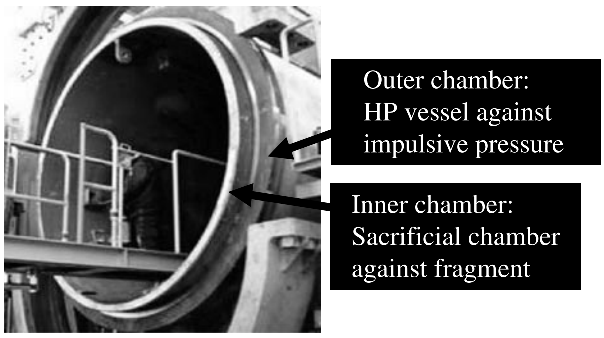


Fig. 3 The double walled structure of DA VINCH [6].

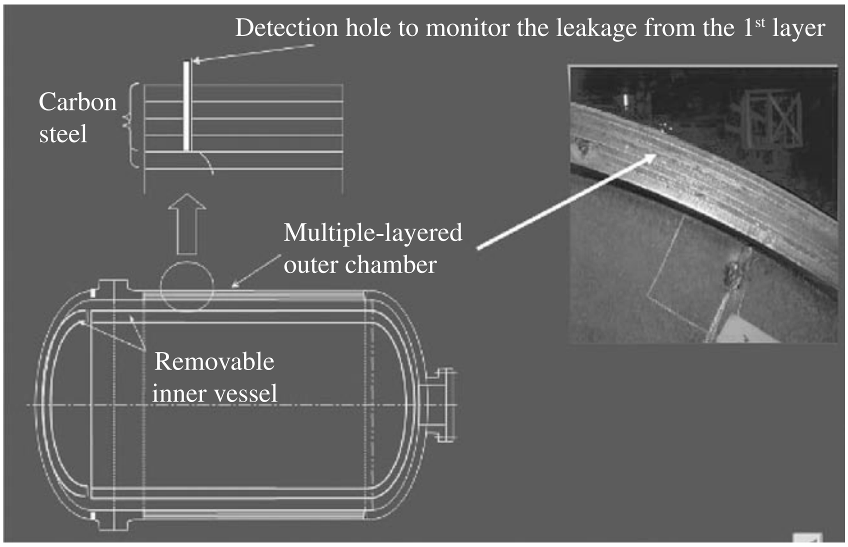


Fig. 4 Multiple-layered structure [6].

3.2 Double walled structure

To avoid difficulty of evaluating strength of an impulsively loaded vessel with dents and flaws by fragments, DA VINCH has double walled structure. Figure 3 shows the double walled structure.

The outer chamber is designed as a pressure boundary to withstand against detonation pressure, while the inner chamber is to resist impulsive detonation pressure and associated fragments. Because the inner vessel is easily removed and examined, it also can be thought as a sacrificial barrier.

The inner chamber is made of a special steel, expecting longer life.

3.3 Multi-layered outer chamber

The outer chamber is made of a multiple-layered cylindrical shell, the fabrication of which is an area of KSL expertise. The multiple layers act as crack arrestors, not permitting cracks in the innermost layer to propagate into the outer layers, due to the discontinuity of the structure.

As an additional precaution, any crack propagating through the innermost layer can be discovered by monitoring gas leaking through a detection hole. Figure 4 shows multiple-layered structure.

3.4 Detonation in vacuum

After installing munitions in the inner chamber, the atmosphere inside the chamber is evacuated, followed by a controlled detonation. The detonation in vacuum reduces the impulsive load to the inner chamber, as well as vibration and sound.

On the occasion of destruction of a 50 kg yellow bomb with donor charge of 17 kg, noise level was measured. Figure 5 shows the effect. The nearest residential area is 0.7 km distance from the detonation point, where the noise level is reduced from 52 dB to 46 dB when detonation is occurred in vacuum condition.

Detonation in vacuum offers another very important safety advantage. It is desirable to process toxic or radioactive materials in slightly vacuum condition. Negative pressure prevents them from being released out of their containments and let the air leak in, in case of the containments' flaw. Figure 6 shows the change of internal pressure. It is unavoidable that the internal pressure rapidly turns positive at the instant of detonation, but if the volume of the inner chamber is designed properly, the residual internal pressure becomes negative to the atmosphere after one minute following detonation.

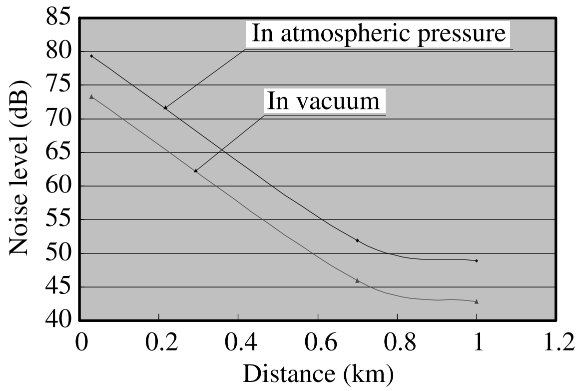


Fig. 5 Effect of vacuum [6].

Therefore, even if a sealing gasket has a flaw, potential puffing of detonation gas will stop naturally due to negative pressure in the chamber.

3.5 Easy decontamination

Decontamination of DA VINCH is also important for safe removal of fragments, inspection and maintenance.

Two different decontamination methods are applied for different surfaces of the structure, i.e.; a cleansing shot for the inner surface and an Electro-statically Charged Aerosol Decontamination (ECAD) for the gap between the inner and the outer chamber.

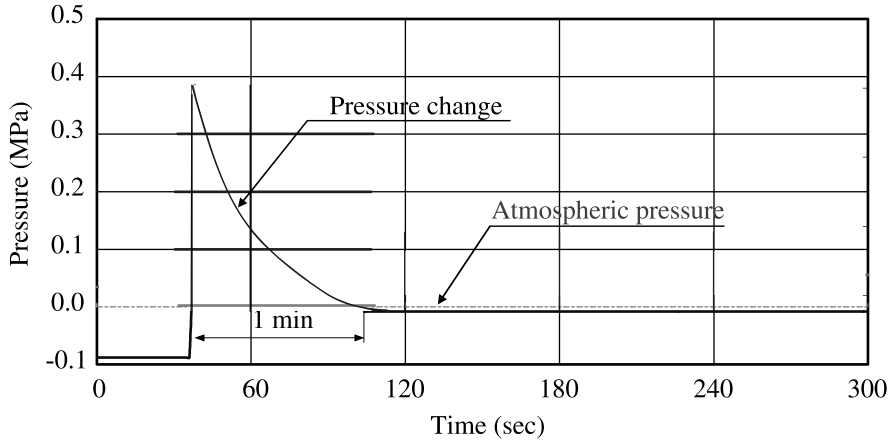


Fig. 6 Internal pressure after detonation.

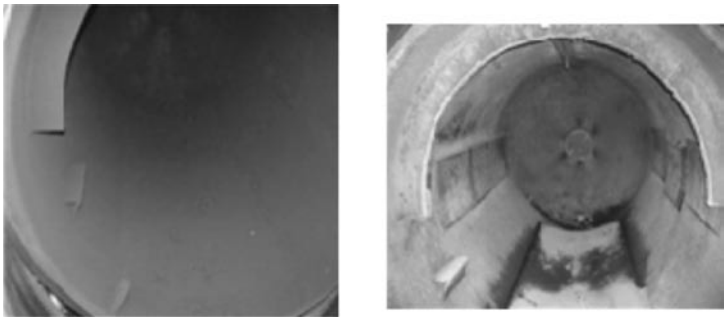


Fig. 7 Inside chamber before (left) and after (right) cleansing shot.

Table 2 Effect of cleansing shot.

Type	Conditions			DRE of surrogates**					
				Calculated for surrogate remaining in detonation product gas			Calculated for all**** remaining surrogate		
	Surro-gates (kg)	NEQ* (TNTeq. kg)	Ratio of NEQ/ surrogate	Oleic acid %	Dicyano-benzene %	CEES(2) %	Oleic acid %	Dicyano-benzene %	CEES*** %
Yellow-01	14.65	22.93	1.57	>99.9999	99.9999	>99.997	99.998	99.950	>99.992
Yellow-02	14.70	32.79	2.23	>99.9999	99.9999	>99.997	99.996	99.978	>99.985
Cleansing shot	0.10	11.33	-	>99.9999	>99.9999	>99.999	>99.999	>99.999	>99.995

* NEQ: Net Explosive Quantity
** DRE: Detonation and Removal Efficiency
*** CEES: chloroethlethylsulfide
**** Detonation product gas, fragments and dust

3.5.1 Cleansing shot

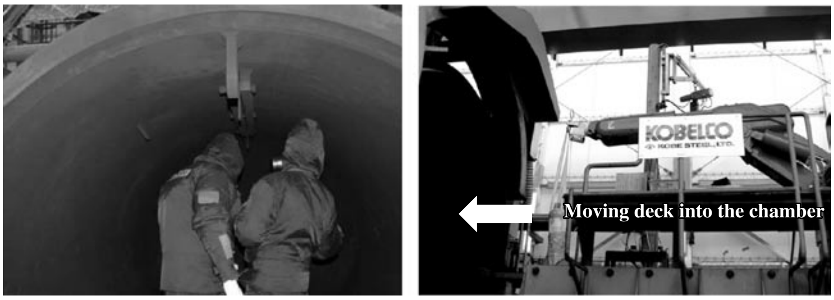
Cleansing shot is a new decontamination method to clean the inner surface. Appropriate amount of explosive is installed in the chamber for a cleansing shot. The effects are shown at Fig. 7. Table 2 shows the test results of the cleansing shot using surrogates. Surrogate is an alternative material to CWM for experimental work.

99.995 % or more of the surrogates on the surface of fragments, in the dust and in the detonation product gas were destroyed. Detail test conditions and results shall be reported in the separate paper of this series.

3.5.2 Electro-statically charged aerosol decontamination (ECAD)

Principle of ECAD is commonly used as electrostatic coating in automobile industries. Sodium hypochlorite is used as decontaminant.

Electro-statically charged aerosols spread all over the surfaces of the chamber even through the narrow gap. As the size of the aerosol is small, the amount of decontaminant can be remarkably decreased compared to water jet decontamination or rinsing.



No need to touch the surface | Moving deck with a robotic arm

Fig. 8 Inspection of Belgium delegation at Kanda.

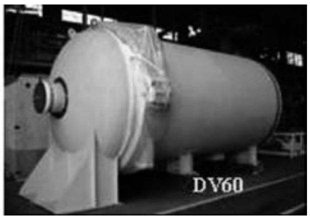
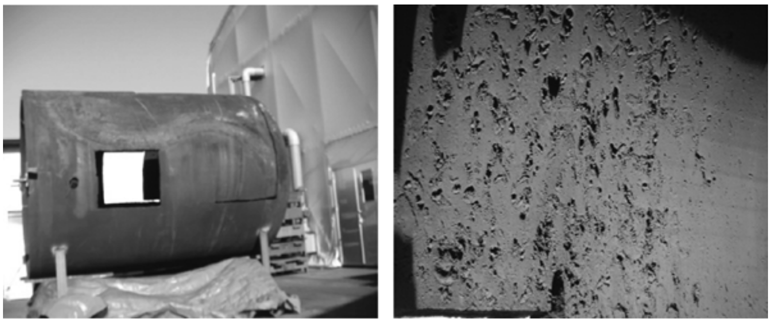
DV10	DV45	DV60
10 kg TNTeq 35 shots	45 kg TNTeq 280 shots	60 kg TNTeq 220 shots
		

Fig. 9 Series of DA VINCH.



Outer view of inner chamber | Dents by fragments

Fig. 10 Inner chamber of DV45 after 280 shots.

3.6 Easy inspection and maintenance

A moving operational deck allows access for inspection of the inner surface without contacting it. See Fig. 8. The sacrificial inner chamber can be readily replaced.

During the preparation or inspection, the chamber lid is opened for minimal period of time, while the continuous air flow should be kept from outside to the inside at a necessary flow rate to prevent particles and soot from diffusing.

4. Design, manufacturing and operation of DA VINCH

Through the consideration described at chapter 3, the authors engaged in design, manufacturing and operation of series of DA VINCHs, DV10, DV45 and DV60, the numeric of which designates for maximum capacity of kg TNTeq, respectively. Figure 9 shows the three systems. DV45 was replaced by DV60 only due to requirement of the higher throughput and not for its life.

After 280 shots by DV45, the inner chamber was removed to examine precisely. The results of examination are as summarized below.

4.1 The inner chamber

1) At the inner and outer surface of the chamber, no big damage was found. Figure 10 shows the inner chamber for examination.
2) The depth of the deepest dent caused by fragments is at most 3 cm.
3) Test plates were cut from the chamber and examined by electron probe micro analysis (EPMA).

No oxygen phase corresponds to the iron metal phase. Arsenic from CWM is located only in the iron oxide layer, and no penetration of arsenic into the iron metal phase. Figures 11 shows color mapping of the inner surface of the chamber.

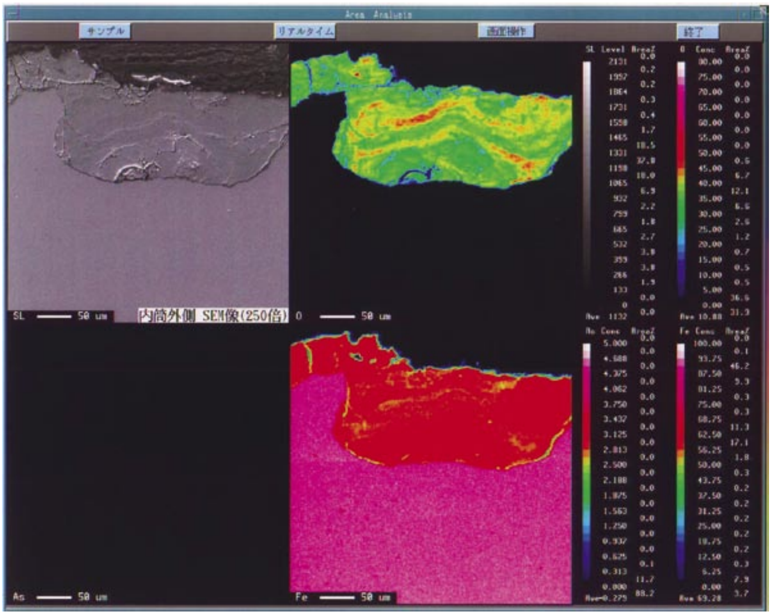


Fig. 11 Color mapping of the inner surface.

4.2 The Outer chamber

The inner surface of the outer chamber was examined by magnetic or dye penetrant examination and no single crack was found. Figure 12 shows the inner surface condition of the chamber. The red dots are caused by pitting corrosion of stainless steel, caused by the sea water brought with munitions.

4.3 Expected life

As discussed elsewhere [6], a fatigue damage evaluation system named DESTINY was developed and is used for daily operation. The name is abbreviation of <u>D</u>amage <u>E</u>valuation <u>S</u>ystem. a <u>TI</u>me? <u>N</u>ot <u>Y</u>et. DESTINY consists of two main systems, i.e., (1) strain-time history acquisition system of each shot and (2) cumulative fatigue damage evaluation system for all previous operations.

The results of this evaluation shows that 5,000 to 8,000 shots can be expected before crack initiation on the surface of the outer chamber, and 1,000 to 2,000 shots can be acceptable, depending upon the detonation condition.

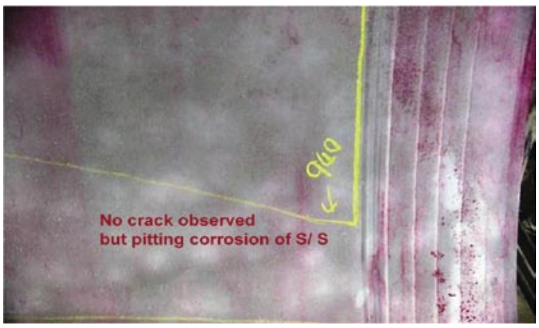


Fig. 12 Inner surface condition.

5. Conclusions

The authors developed DA VINCH and successfully put it into practical use. Through actual operation at Kanda, following items were confirmed.

1) A horizontal cylindrical chamber is suitable for higher throughput.
2) Doubled walled structure is proven to be effective.
3) Detonation in vacuum has advantages of noise and vibrant reduction.
4) After 280 shots to destroy 600 chemical bombs, no crack was found on the inner surface of the outer chamber.
5) The outer chamber is expected to endure 5,000 to 8,000 shots before crack initiation and the inner chamber bears 1,000 to 2,000 shots before replacement.
6) Cleansing shot and ECAD are demonstrated to be effective.

The authors wish to publish series of follow-up papers to describe:

1) Implosion and sequential detonation
2) Destruction mechanism and its destruction efficiency of CWM by detonation.

6. Acknowledgement

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化学兵器の制御爆破チャンバーシステム(第一報)

朝比奈潔[†]，玉井健司，竹田恭弘，黒瀬克夫

遺棄化学兵器など地中，海中から回収した化学兵器は，武器として保管・管理されている弾とは違って，経年による炸薬の鋭敏化，化学剤の漏洩，識別不能な場合など，処理に際し多くの困難を伴う。筆者らはその解決の一方法として，化学弾をそのまま爆破処理するシステムを研究，実用化した。その主な特徴は，①弾殻の飛散を防止する内筒と，爆轟時に発生する衝撃圧力を包蔵する外筒の二重構造爆破チャンバ，②多層巻外筒，③真空中爆破などである。真空中爆発は衝撃音や振動が少なく，爆破処理後内部が負圧になるため，特に化学兵器処理の安全性が高い。チャンバ内の除染法として静電気エアロゾル法の効果も確認した。280 ショット，約 600 の実化学弾処理後のチャンバは健全である。

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