

Storage Life of an Aluminised HE Composition*

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ABSTRACT

Most high explosive compositions are organic in nature and they tend to undergo slow decomposition during storage under different environmental conditions. The decomposition degrades the molecular stability of the explosive, thereby resulting in reduced performance and service life. The knowledge of decomposition behaviour of the explosive mass determines the storage life of the composition. Hence, change in the chemical stability, sensitivity, mechanical strength and performance are of utmost importance in the prediction of storage life of explosive/munition systems.

This paper presents the results on the rate of gas evolution, change in sensitivity, and thermal stability and weight loss of high explosive compositions, viz., Dentex and TNT when exposed to elevated temperature. Based on the collected data, a tentative storage life for the aluminised (Dentex) composition has been computed to be 15 years. The data has been compared with TNT, a standard explosive for assessing the storage life.

1. INTRODUCTION

The storage life assessment of explosives and ammunitions is essential for their effective end use and safe handling. The explosive compositions filled in the munitions/warheads always have the tendency for slow decomposition during storage under different environmental conditions. The decomposition may accelerate due to direct contact with casing, elevated temperature, or direct exposure to environment. The decomposition of the explosive composition may increase the sensitivity which will be hazardous during handling and transportation. The gases evolved due to decomposition may increase the pressure which may lead to rupture/leakage of the casing. In addition to the above drawbacks, the performance of the system will also be reduced. The degree of decomposition of the explosive mass will determine the shelf life of the compound/composition. To reduce the experimental time, the experiments are conducted at accelerated condition. By applying suitable factors, the shelf life is estimated for the actual storage conditions.

The degradation phenomena of the compositions are determined with the help of several tests, including vacuum stability test (for measurement of volume of gas evolved), differential thermal analysis (DTA) (for knowing change in decomposition temperature) and gravimetric analysis and international heat test (for loss in weight and performance evaluation). In addition, theoretical calculations are also used for determination of decomposition and thereby assessment of the life of an explosive. Activation energies are also used to predict long-term storage life. The test assumptions are mostly based on Arrhenius type reaction rate equation¹.

Further, an assumption is made that the reaction rate increases by a factor between 2 and 3 for each 10 °C rise in temperature, which is in line with experimental results for many chemical reactions. This assumption indicates that the reaction time will double or triple with each 10 °C drop in temperature. These factors are given for a general case in which the reaction rates are unknown. The actual rates, when known, may

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be substituted in the equations used. Moses¹ has described various test conditions for assessing the shelf life of aerospace explosive components.

Normally, the extent of decomposition of a system is evaluated using the criteria²: (i) visual observation (for colour and cracks); (ii) amount of weight loss; (iii) detonation rate change; (iv) total gas evolved from a given quantity of sample; and (v) change in sensitivity, and mechanical properties.

Golopol *et al*³ have established an empirical relationship between service life and storage temperature for composition XTX-8003 as $147 e^{(-0.0268 \times T)}$; where T is the storage temperature in °C.

2. EXPERIMENTAL

2.1 Gas Volume Measurement

The standard vacuum stability apparatus has been used to measure the volume of gas generated at a particular temperature from a 5 g sample as a function of time. The temperature of the experiment has been set at 120 °C. Periodically, the volume of the evolved gas for the two samples has been measured. The relation between heating time in hours and the gas evolved in cc for the two samples is shown in Figs 1 and 2.

2.2 Loss in Weight

The sample (10 g) was transferred to a weighing bottle of 35 mm diameter and 50 mm height. The bottle

was then covered with a watch glass and weighed. The covered bottle and its contents were heated at 75 °C in a water-jacketted oven. It was later cooled in a desiccator and weighed. The loss in weight due to the volatility of the sample was calculated. The values calculated for different heating periods are given in Table 1.

2.3 Differential Thermal Analysis

Differential thermal analysis was carried out for the original and the aged samples heated at elevated temperature for prolonged time. The observed DTA curves are shown in Figs 3 and 4, for both original and the aged samples.

2.4 Sensitivity Tests

The impact and friction sensitivities of the original compound and aged samples were determined by standard methods. The values obtained are given in Table 2.

3. DISCUSSION

From the data, it is observed that the evolution of gas is slow for TNT as compared to Dentex which indicates that the decomposition rate of Dentex is higher than that of TNT. Although the reaction mechanism and the composition of the gaseous products have not been determined, data on the volume of gas liberated

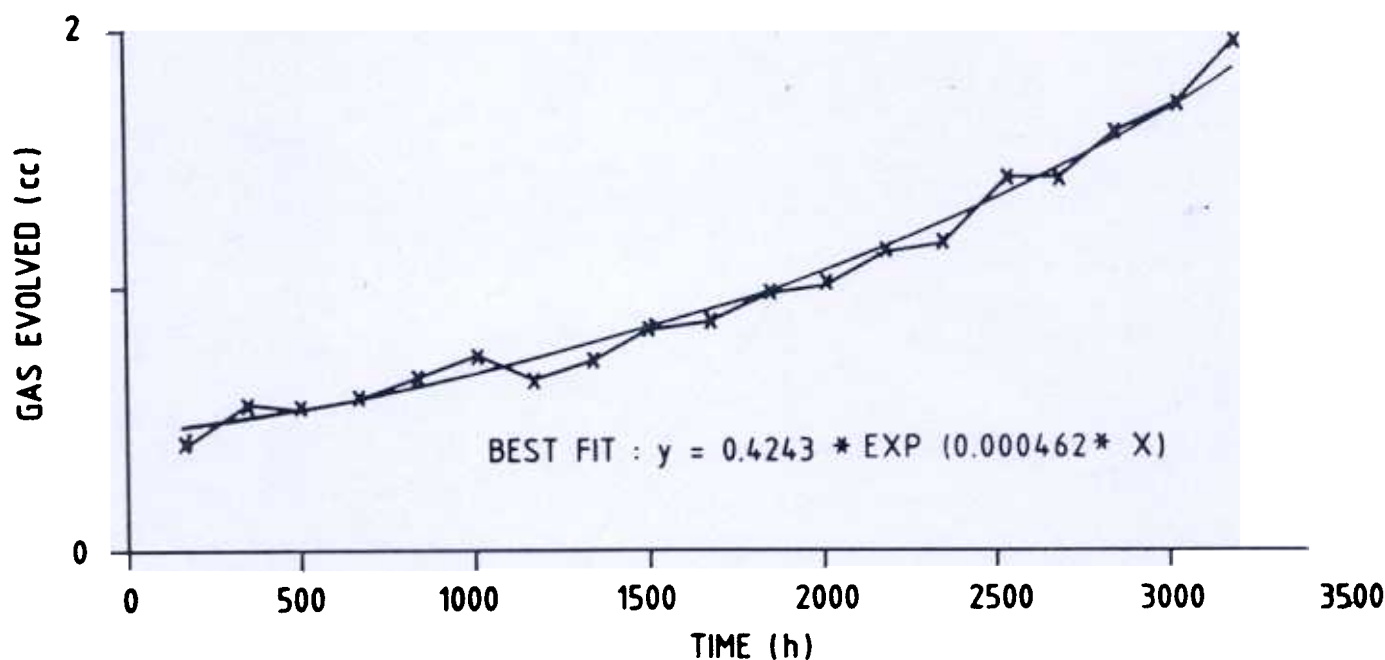


Figure 1. Gas evolved vs time curve for composition: TNT best fit: $Y=0.4243 e^{(0.000462 \times T)}$.

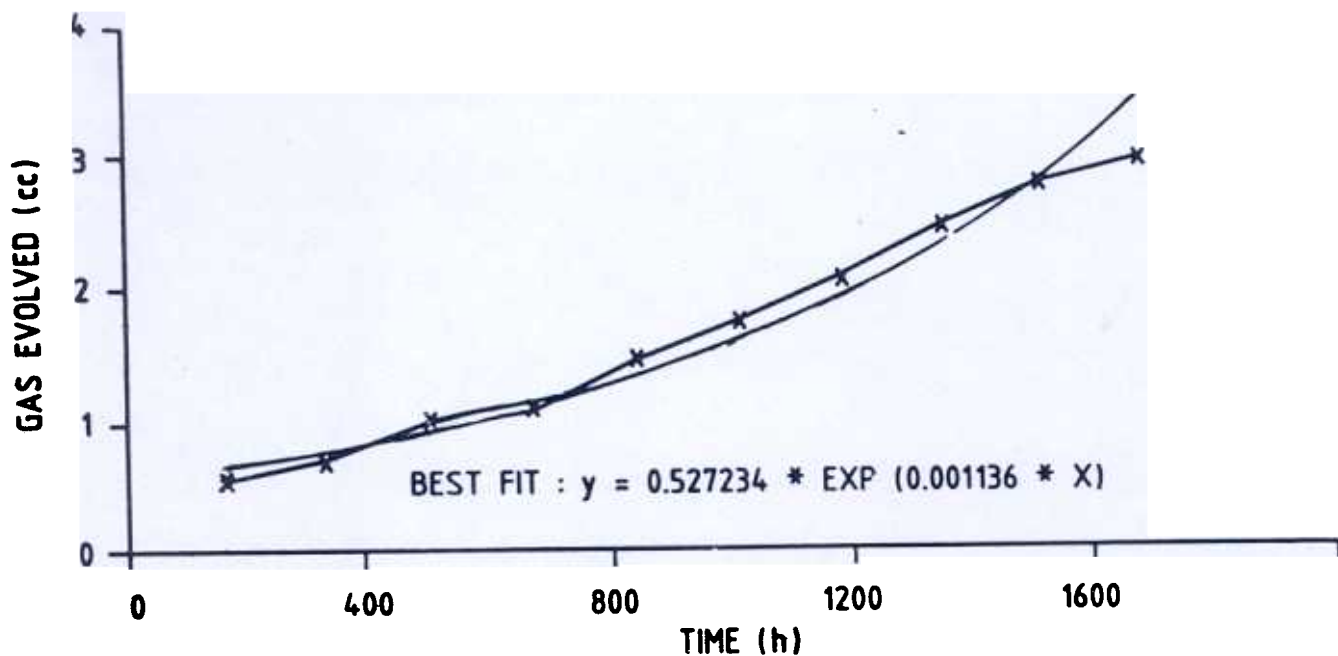


Figure 2. Gas evolve vs time curve for composition: Dentex: best fit: $Y=0.527234 e(0.001136 \times T)$.

Table 1. Weight loss of TNT and dentex

Composition	Percentage loss in weight			
	48 hr	96 hr	168 hr	288 hr
TNT	0.03	0.03	0.038	0.037
TNT	0.029	0.029	0.035	0.035
Dentex	1.35	1.39	1.42	2.013
Dentex	1.46	1.50	1.54	2.148

from 5 g sample confirms that the storage life of Dentex will be less than that of TNT. It is also evident from the data that on aging Dentex as well as TNT undergo changes in the explosive properties.

To assess the tentative storage life of the experimental composition, 2 cc volume has been taken as a maximum acceptable limit, which is conservative as compared to 3 to 5 cc limit for acceptance. A similar criteria has been adopted for TNT. With the help of

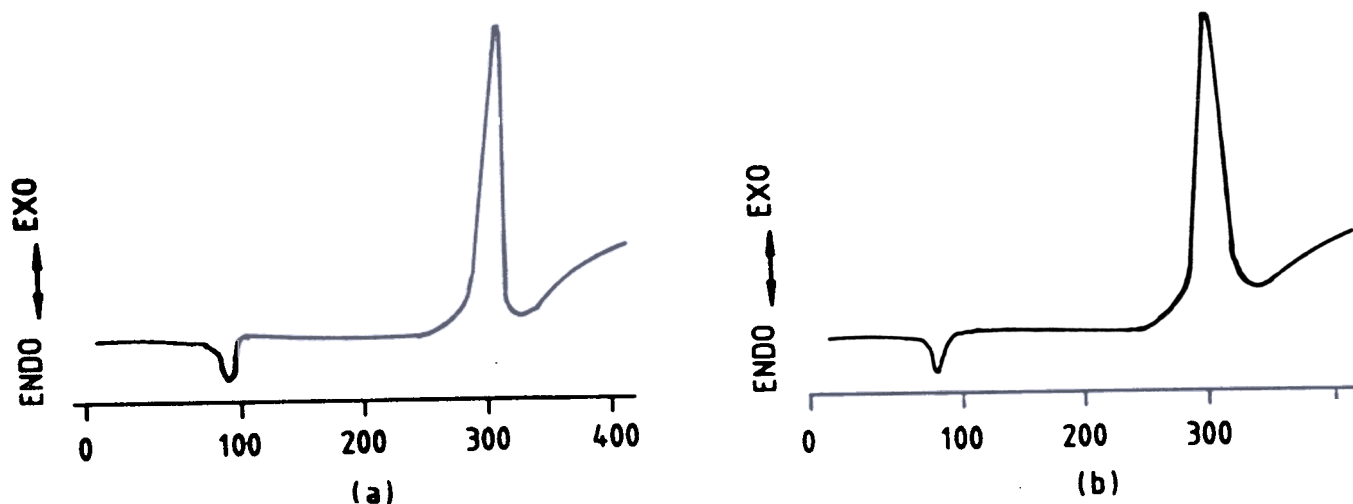


Figure 3. DTA thermogram of TNT (a) original, and (b) after heating at 120 °C for 1008 h.

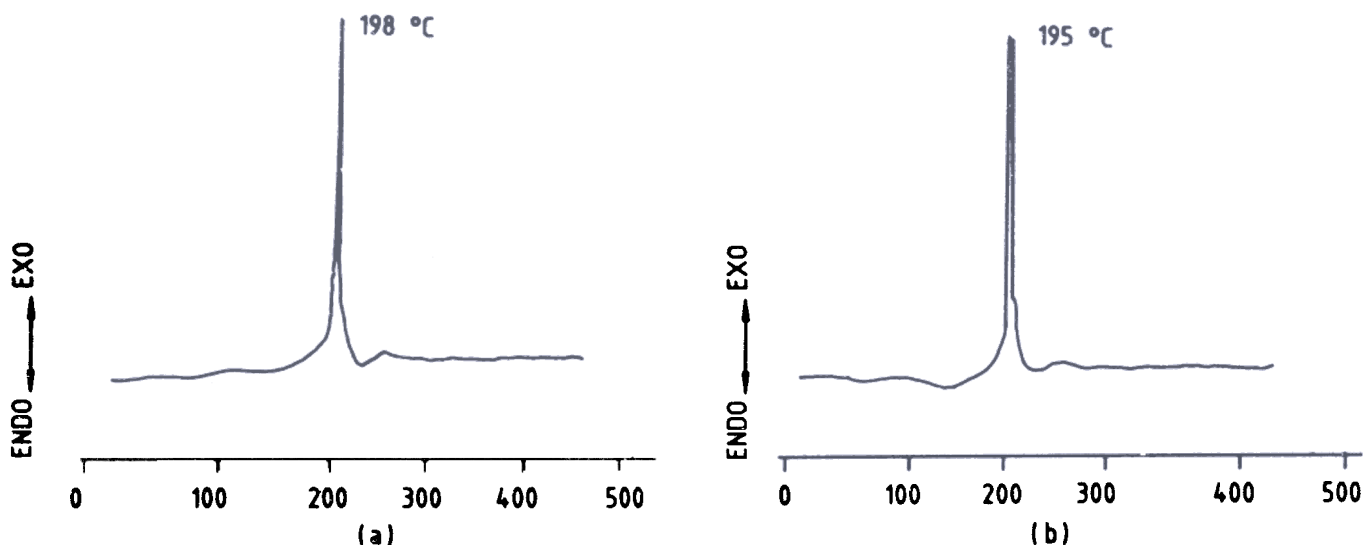


Figure 4. DTA thermogram of Dentex (a) original, and (b) after heating at 120 °C for 1008 h.

Table 2. Sensitivity test values

Composition	Impact and friction sensitivities							
	Original	Impact (50% explosion height) (cm)					Friction (kg)	
		168 hr	672 hr	Aged			Original	Aged
			840 hr	1176 hr	1512 hr			
TNT	> 130	130	130	130	122.5	115	36	36
Dentex	125.5	120	100	100	97	92.5	36	36

Fig. 1, the storage life of TNT has been determined using a conservative aspect and a factor of 2 has been adopted for the rate of change for 10 °C change in temperature. Based on the volume and decomposition factor, the life of TNT has been calculated at 55 °C which comes to 37 years. The useful life of TNT is known to be about 35 years. Using the same standards, a tentative life of 15 years has been given for Dentex. The relation between gaseous volume at 120 °C versus duration is shown in Figs 1 and 2.

Experiments have been conducted with bare explosive composition, but in actual conditions the compositions will always be filled in hermetically sealed casings. The sealing of the composition will reduce exposure of the composition to the environmental

conditions thereby increasing the storage life. In normal practice, the assessment of storage life is conducted with different intensified standard alternating trials (ISAT) with different environmental cycles at different conditions which have not been used for the present study. No experiments have been conducted so far to determine the efficiency of the explosive composition. Effort is continued to confirm the actual storage life of the composition in a given system. Further detailed studies will enable to forecast the actual storage life of the compositions under filled conditions.

From the DTA experiments, it has been observed that aged compounds start decomposing earlier than original compounds and the shift is approximately 3-4 °C which indicates that the stability of the

compounds is reduced. The sensitivity figures indicate that for TNT there is no appreciable change up to 840 h on heating at 120 °C. Sensitivity of Dentex changes immediately from 168 h which is indicative of its low stability.

4. CONCLUSION

The sensitivity of the compositions has increased, their thermal stability has been found to be lowered, and the gradual loss in weight is also noticed. The changes after the prolonged storage will make the composition unsafe and reduce the efficiency of the system. However, under the experimental period and determined tentative life, the changes can be considered negligible. From all these studies, the evolution of gas has been considered the governing factor for assessment of the life of the composition. Based on the data collected so far, the tentative storage life of Dentex

(bare composition) is computed to be 15 years which has to be confirmed by detailed studies.

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