

PREDICTION OF SAFE LIFE OF PROPELLANTS

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A mathematical formula has been derived to assess the safe life of propellants based on the rate of decomposition of nitric esters and action of stabilizers on the decomposition products of the nitric ester constituents of the propellants.

It is a characteristic property of almost all the solid propellants that the nitric ester constituents particularly nitrocellulose and nitroglycerine undergo slow but autocatalytic decomposition by their decomposed products even at ambient temperature. To suppress this autocatalytic decomposition of nitric esters, by converting the nitrogen oxides evolved to non-catalytic nitro-compounds¹, it is customary to include a stabilizer of some sort in propellant formulations. The rate of decomposition of nitric esters depends on the chemical structure of esters and action of stabilizers on the decomposed products^{2,3,4}. The stability of the propellants thus mostly depends on the action of the stabilizers.

Due to the gradual decomposition of nitric esters on storage, stability tests are necessary as a control for the safety of the propellants. Various methods have been mentioned in the literature to assess both the stability and the safe life of propellants. A standard formula has also been given in the literature to predict the safe life but its derivation was not found in the literature available which created interest to derive a similar formula and ultimately a formula was derived which gives almost the same results as obtained by the standard one.

It has been found by experience that a propellant becomes unstable when half the stabilizer has been used up. The period in which the concentration of the stabilizer falls half to its original value is termed half life period⁵ of propellant and the same period is adopted in service as safe life of the sample.

DERIVATION

A formula can be derived with certain assumptions² such as (i) a first order decomposition of nitric esters independent of the nature of the stabilizer, and (ii) a second order reaction between the stabilizer and the decomposed products of nitric esters. It is further assumed that the rate of decomposition of nitric esters are same throughout the storage as the whole amount of decomposition products are picked up by ideal stabilizers.

The reaction rate could then be formulated as the sum of the two terms as,

$$-\frac{d(C)}{dt} = K_1 + K_2(C)$$

Where K_1 and K_2 are rate constants, (C) is the concentration of the stabilizer at time 't', (---) indicates the fall in stabilizer content on storage.

As the concentration of NC-NG matrix in the propellant essentially does not change with time, the above equation is reduced to,

$$-\frac{d(C)}{dt} = K_2(C)$$

On integration,

$$-\int_A^{A-x} \frac{d(C)}{(C)} = K_2 \int_0^t dt$$

or $\log \left(\frac{A}{A-x} \right) = K_2 t$ (1)

If $x = A/2$, then $t = T$

Therefore equation (1) becomes,

$$\log \left(\frac{A}{A/2} \right) = K_2 T$$

or $K_2 = \left(\frac{1}{T} \right) \log 2.$

By substituting the value of K_2 in equation (1),

$$\log \left(\frac{A}{A-x} \right) = \frac{1}{T} \cdot t \cdot \log 2.$$

or $T^* = t \cdot \frac{\log 2}{\log \left(\frac{A}{A-x} \right)}$

Standard formula,

$$T^{**} = t \cdot \frac{\log (A + 2)}{\log \frac{A(1+x)}{A-x}}$$

Where T (in months) = time for stabilizer percentage to fall to half its initial concentration i.e. half life period of propellant.

t (in months) = time on storage.

A = initial stabilizer percentage.

$(A-x)$ = stabilizer percentage after storage for t months.

x = fall in stabilizer percentage after storage for ' t ' months.

K_2 is reaction rate constant for the reaction of stabilizer with decomposed products.

It should be noted that this equation is applicable only when there is sufficient stabilizer present to react with all the nitrogen oxides formed.

EXPERIMENTAL

Data have been collected by conducting that following two different experiments for several propellants and the results have been tabulated.

(i) Woolwich Test (Table 1)

(ii) Climatic Hut Trial (Table 2)

The details of these tests have been given in 'Service Text book of Explosives⁶'.

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TABLE I
WOOLWICH TEST

Propellant	Stabilizer	Percentage of Stabilizer		Half life period of propellant (in years)	
		Before the Woolwich test (A)	After the Woolwich test (A-x)	By the derived formula*	By the standard formula**
NRKN Lot No. NL 6899 for 7.62 mm (ICI)	DBA	1.13	0.78	22.71	20.65
Single base powder 152 for 7.62 mm (Bulgaria)	DPA	1.26	0.52	9.50	9.97
Single base powder 153 for 7.62 mm and 54 mm (Bulgaria)	DPA	0.96	0.29	7.03	7.89
Propellant for 7.62 mm PRB (Belgium)	DPA	1.06	0.56	13.19	11.36
NRN for 7.62 mm Lot No. NL 6747 (ICI)	DPA and methyl centralite	1.03 2.43	0.48 2.23	11.03	11.9
Prop. for 7.62 mm (Italy)	DPA	1.34	0.76	14.85	14.29
Cartg. QF 57 mm HEAT M 307A (Belgium)	DPA	0.93	0.49	13.14	13.00
Cartg. QF 76 mm HEAT M 50 Lot TVYU 7002	DPA	1.35	0.83	17.31	16.2

TABLE 2
CLIMATIC HUT TRIAL

Propellant	Duration in CHT (in years) at 120°F	Stabilizer	Percentage of Stabilizer		Half life period of propellant (in years)	
			Before CHT	After CHT	By the derived formula*	By the standard formula**
Ballistite B-16	2	Carbamite	0.6	0.22	8.05	8.41
CD/T-5/2	1	Carbamite	0.6	0.42	11.33	10.67
SPA—III	2	DPA	0.90	0.52	14.74	14.27

CONCLUSION

It can be seen from the results that the shelf-life obtained by both the formulae are almost same. Therefore derived formula can be used as a substitute at the place of the other one.

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