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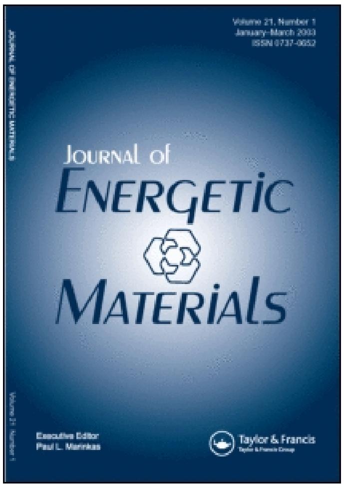

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EXAMINATION OF SOME PROPOSED RELATIONS AMONG HE SENSITIVITY DATA

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ABSTRACT

Recent data collected from the literature were used to test the general applicability of proposed empirical correlations of sensitivity data of high explosives (HE) and propellants. It was found that the relationships were not applicable to all explosives. In particular, insensitive high explosives and propellants did not conform to the empirical equations.

INTRODUCTION

At the Seventh Detonation Symposium, Weston et al.[1] proposed a number of empirical correlations among various sensitivity parameters of a restricted number of explosives. Table 1 lists the symbols and defines those parameters of interest to the present study. It is the objective of this study to compile available data for four of these variables in order to determine the range of applicability of some of the proposed

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relationships. It is particularly important to test the validity of the empirical relations for other explosives than the few considered in Ref. 1 in order to avoid their use in development fields for which they may not be appropriate. In particular, the question addressed here is whether these relations are generally applicable to the special fields of insensitive high explosives (IHE) and conventional composite propellants.

TABLE 1

HE PARAMETERS CONSIDERED

Symbol	Definition
a	Radius of Extex primer in Minimum Priming Test (MPT)[2]. a^3 = (mass Extex, mg)/3.20445
$x^*(8.3)$	Run distance to detonation in the wedge test[2] when the initial pressure is 8.3 GPa.
d_c	Critical diameter for propagation of steady-state detonation.
E	Critical flying plate kinetic energy fluence
L	50% gap thickness in the LANL large scale gap test (LSGT)[2]

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METHOD

Reference (1) used the critical flying plate kinetic energy fluence (E) to show an exponential relationship between E and L and linear relations between E and each of the group: a, $x^*(8.3)$, and d_c. By eliminating E from the analytical relations presented, the following equations are obtained.

$$x^*(8.3) = a \qquad (1)$$

$$d_c = 0.685\ [x^*(8.3) \text{ or } a], \quad \text{or} \qquad (2)$$

$$\log\ [x^*(8.3) \text{or } a] = 0.16435 + \log d_c \qquad (2')$$

$$\log d_c = 2.0316 - 0.03437\ L \qquad (3)$$

Eqs. (1) through (3), where all dimensions are in mm, can be used to study their ranges of applicability.

The relevant data that have been found in the literature are collected in Table 2; the reference for each datum is also shown. It is obvious that, for this study, a physically and chemically identical explosive and the identical charge preparation should be used for each set of four measurements. It is equally obvious that this is not always the case. However, some supplementary information is available, and will be considered in the next section.

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RESULTS AND DISCUSSION

The lines drawn in Fig. 1 (x^* vs a) are for Eq. 1; the points are for all relevant data available in Table 2. It is evident that Eq. 1 cannot hold for materials exhibiting a negative result in the minimum priming test (MPT). This is indicated in Fig. 1a. The parentheses about the HE name shows that the $x^*(8.3)$ value was

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TABLE 2. COMPILATION OF DATA IN THE LITERATURE

Material HE*	Density ρ_o g/cm^3	Critical Diameter d_c,mm	Ref.	LASL LSGT^2 L,mm	MPT Radius a,mm	Ref.	Run Distance x*(8.3),mm	Ref.	Extrapolated from**
Baratol-c 76/24 $Ba(NO_3)_2$/TNT	2.62-2.63	43.2	3	27.30	-		8.64	2	
Comp A-3	1.63	< 2.2	4	54.51	2.52^a	5	-		
91/9 RDX/Wax									
Comp B-c, (A)	1.70-1.74	4.28	3	43.2	5.79	5	5.63	2	
60/40/1 RDX/TNT/Wax							6.92	6	
Comp B-3-c	1.70-1.72	3.99±0.26	6	50.3	4.24	5	-		
60/40 RDX/TNT									
Cyclotol-c	1.74-1.76	6.0	3	44.3	6.26	5	-		
75/25-77/23 RDX/TNT		8.1	8						
DATB	1.78-1.80	5.3	8	41.68	2.61	5	< 3	8	
NQ-h	1.61	36.5	9	5.0^c	-		~(2970)	2	13.3^d
NQ-ℓ	1.61	13.2^b	9	5.0^c	-		~(1.87)	2	21.3^d
Octol-c 75/25 HMX/TNT	1.81-1.83	< 6.4	3	47.32	4.50	5	-		
Pentolite-c	1.70	6.7	7	64.74	2.89	5			
50/50 PETN/TNT									
TATB	1.71	7.94±1.6	10				2.61	2	5.6
	1.80-1.84	13	8				8.05	2	
	1.86-1.88	4	2	21.92	>11.4	2	(17.9)	2	11.4

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TABLE 2. COMPILATION OF DATA IN THE LITERATURE (CONT.)

Material HE*	Density ρ_0 g/cm^3	Critical Diameter d_c,mm	Ref.	LASL LSGT^2 L,mm	MPT Radius a,mm	Ref.	Run Distance x*(8.3),mm	Ref.	Extrapolated from**
TNT-c	1.62	26.9	7	28.30	-		(31.8)	2,6	9.2
creamed cast^e		23.7±1.7	11						
TNT-p	1.63	2.62	13,3	51.79	3.08	12	2.56	6	
		2.45	14						
PBX 9404, 94/3/3 HMX/NC/CEF	1.85-1.87	1.18	3	55.86	1.95	5	1.97	2	
PBX 9501, 95/2.5/2.5 HMX/Estane/(BDD/PA/BDNPF)	1.83-1.86	~1.52	2	55.52	-		2.28±0.02^f	2	7.2
PBX 9502 (X0290) 95/5 TATB/Kel F	1.90-1.94	9.0	3	22.33	>11.4	2	(28.5)	2	10
X0219 90/10 TATB/Kel F	1.92-1.95	15.0	3	-	>11.4	2	(52.2)	2,1	9.7
XTX 8003 (Extex)	1.53-1.56	0.36	3				0.328	2	
80/20 PETN/Sylgard							0.541	6	5.0

Table Notes:

*c,p mean cast and pressed, respectively
**End of range for reduced data. For extrapolation below lower limit of range, x* value is shown in parentheses.

a. Average of values for densities of 1.615 and 1.644.
b. A 2-point linear extrapolation.
c. Little or no difference in shock sensitivity between high and low bulk density NQ after pressing to 90% TMD.
d. Equation for reduced data for densities of 1.67-1.69 g/cm^3.
e. "Creamed cast" is used as at NSWC, i.e. the melt is stirred until it becomes milky because of the formation of small crystals; it is then poured.
f. Average of values at ρ_0 of 1.833 and 1.844 g/cm^3.

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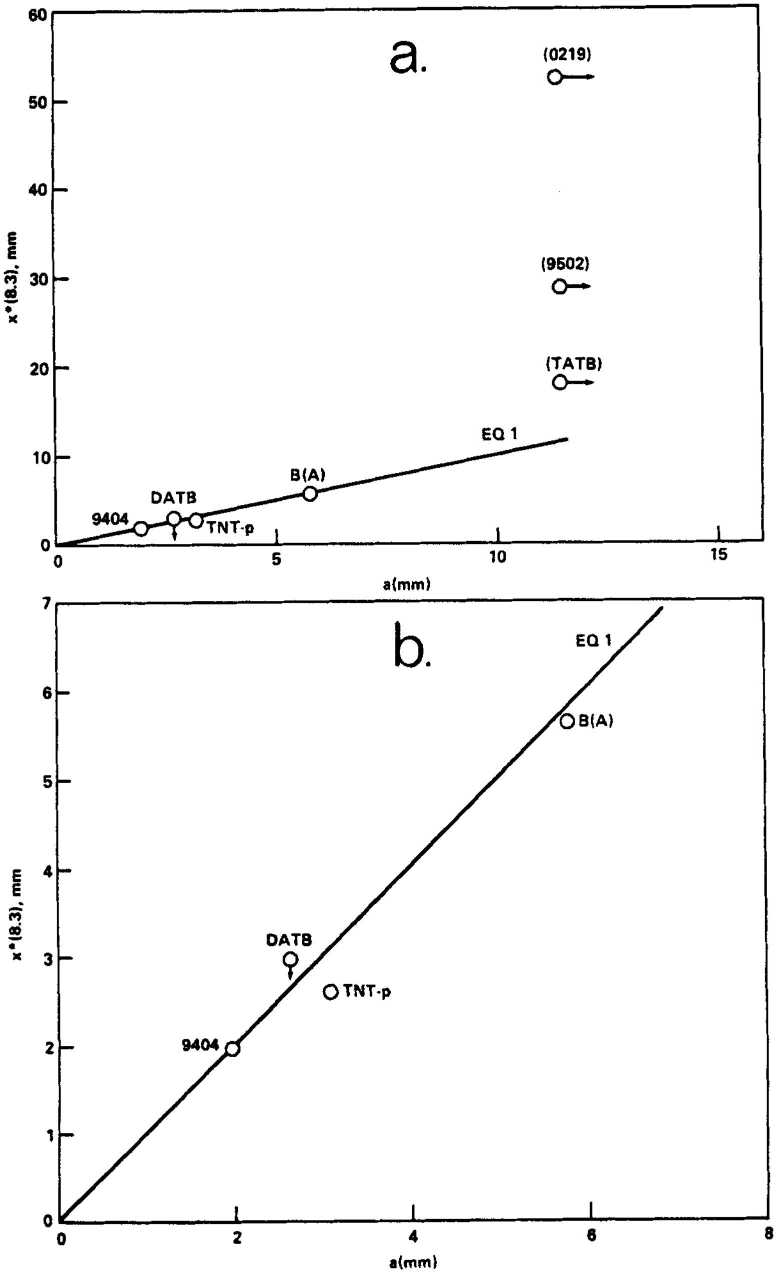

FIGURE 1. TEST OF EQUATION 1

obtained by extrapolating the reduced data equation[2] to a pressure below the range studied to derive the equation. Such an extrapolation is dubious because there is no assurance that the detonation will be initiated at the lower pressure of 8.3 GPa. The $x^*(8.3)$ values of X0219 of Table 1 and Ref. 1 seem to be the same; it is , therefore, assumed that the Ref. 1 value was also extrapolated down to 8.3 GPa. In any case, the arrows indicating $a > 11.44$ mm mean that TATB and its composites, PBX 9502 and X0219, produce negative results in the standard MPT, and hence cannot conform to Eq. 1.

Fig. 1b shows the data for the more sensitive HE on an expanded scale, one comparable to that of Fig. 3 in Ref. 1. For Comp B(A) and PBX 9404, the values of a, $x^*(8.3)$, and d_c in Ref. 1 and in Table 2 are the same. The values of a and d_c for TNT-p are also the same but x^*(TNT-p) of Table 2 is lower than that of Ref. 1 by about the amount TNT-p is below the Eq. 1 curve of Fig. 1b. Probably for identical charges and procedures, TNT-p would fall very close to the curve of Eq. 1. DATB might fall on the curve; a better value of $x^*(8.3)$ is required to determine its exact position. These few data appear to confirm Eq. 1 for these HE in this range, although even here much more data are needed to establish an empirical relation. However, as Fig. 1a illustrates, TATB and its 95% and 90% composites do not conform to Eq. 1. Since TATB is a relatively insensitive explosive and a major component of many IHEs, we are fortunate to have these data in considering applicability to IHEs.

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Fig. 2 displays the data as d_c vs a or x^*. The lines are those for Eq. 2. Only a(TNT-p) has been used in accord with the observations from Fig. 1. Moreover, there are several cases in which LANL values were selected because d_c had also been determined at LANL. It was thought that there was a greater probability that the two determinations were made on samples of the same explosive prepared in the same way if both measurements were made at the same institution.

Fig. 2a shows the highest density TATB below the line of Eq. 2, and two lower density charges above it. At least one value of d_c for the latter is in doubt because the d_c vs ρ_0 trend of Table 2 data shows a maximum in d_c. No such maximum in a detonability curve has been reported although, in some cases, the existence of a minimum has been established. Fig. 2b has an expanded scale.

Finally the d_c vs a or x^* data have been plotted in Fig. 3 as log [a or x^*(8.3)] vs log d_c where the line drawn is for Eq. 2' although another line would give a better fit to the data for PBX-9404, Comp B(A), and cast TNT. There seems little doubt from Figs. 2 and 3 that, in general, d_c and a or x^*(8.3) are not directly proportional. Those explosives that do not conform to Eqs. 2 and 2' are: Baratol, DATB, TATB, and its composites PBX 9502, X0219, and cast pentolite. It is quite possible that HMX, RDX, TNT, and their mixtures will exhibit a linear relationship between d_c and x^* or a; such is frequently the case for a series of chemically related explosives. It is also possible that well designed experiments could establish the curve. However, Baratol,

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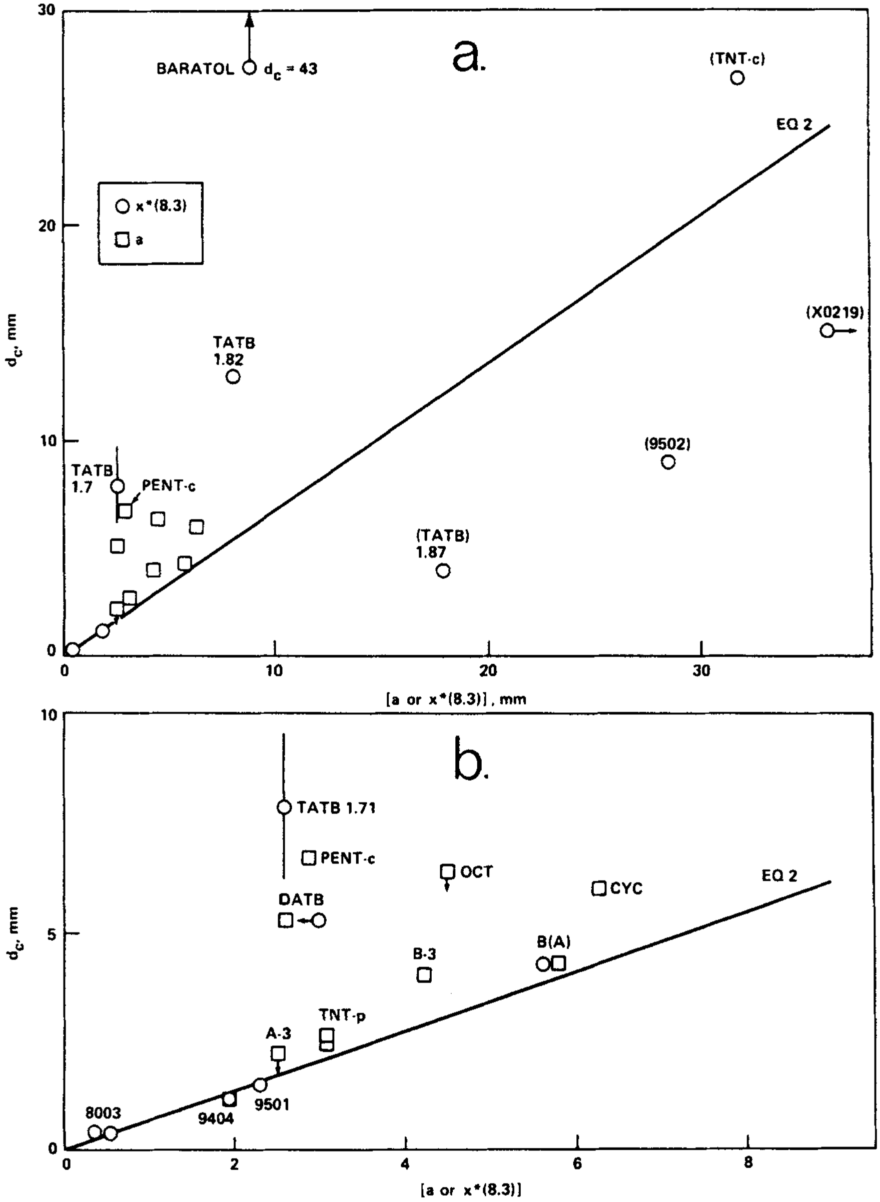

FIGURE 2. TEST OF EQUATION 2

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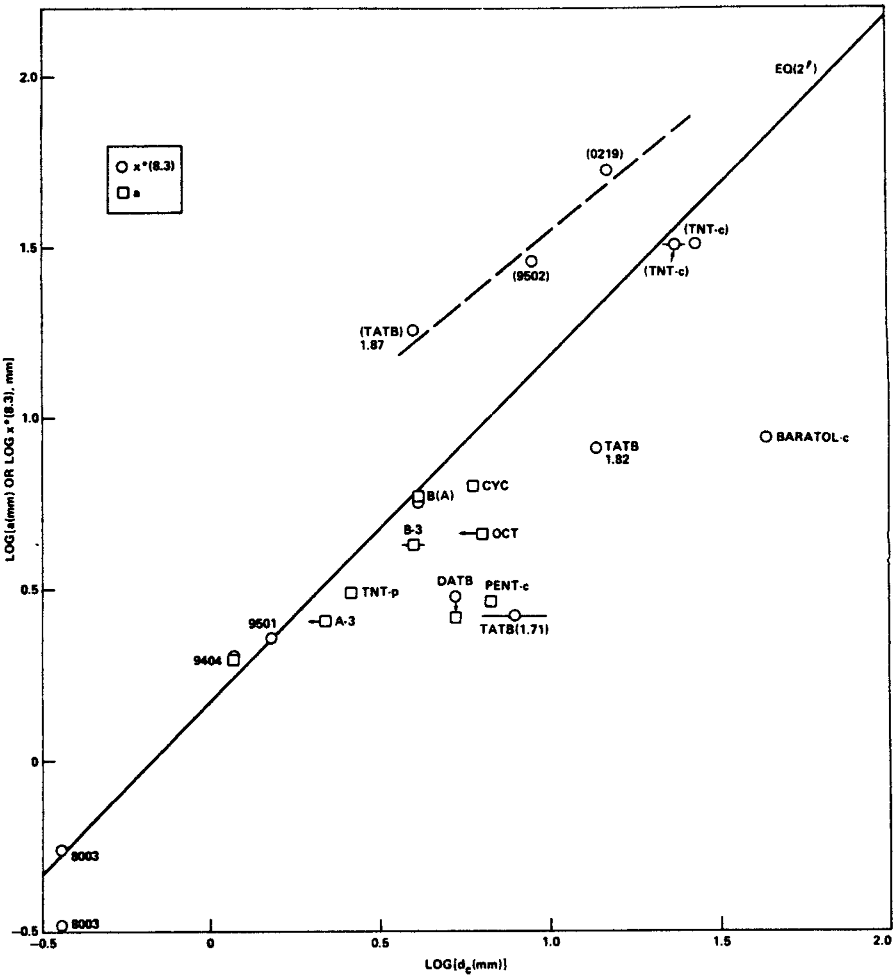

FIGURE 3. TEST OF EQUATION 2′

DATB, TATB and its composites would not lie on it.

Although TATB does not conform to Eq. 2', there is a suggestion (dashed line of Fig. 3) that TATB and 90-95% TATB composites, at essentially voidless density, might exhibit another linear relationship analogous to that of the PBX 9404--Comp B line. If so, however, the lower density TATBs do not fall on that line; this raises the question of whether any porous charges conform to Eqs. 1-3.

Fig. 4 displays the data of Table 2 in a test of Eq. 3, the line shown in the figure. In this case, the HE that do not conform are nitroguanidine, (NQ) (high and low bulk density), Baratol, cast TNT, TATB, PBX 9502, cast cyclotol, Comp B-3, and pentolite. (Very probably X0219 would also be off the curve, but LSGT data for this material were not available.) Most of these explosives are relatively shock insensitive according to the LSGT; as in the case of Eq. 2, the sensitive HE, pentolite, is the extreme exception.

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In the case of simple composite propellants, we have very little data indeed. The best available are those for the SOPHY propellant and its variants containing 5-9.2% RDX, also quoted in Ref. 1. The propellant itself is an oxidizer/fuel mix consisting of AP/PBAN/Al and designated ANB-3226[15]. The relevant data are given in Table 3.

The critical diameter of this propellant, even when 9.2% RDX has replaced that amount of ammonium perchlorate (AP), is so large that the MPT would be negative and $x^*(8.3)$ could not be determined

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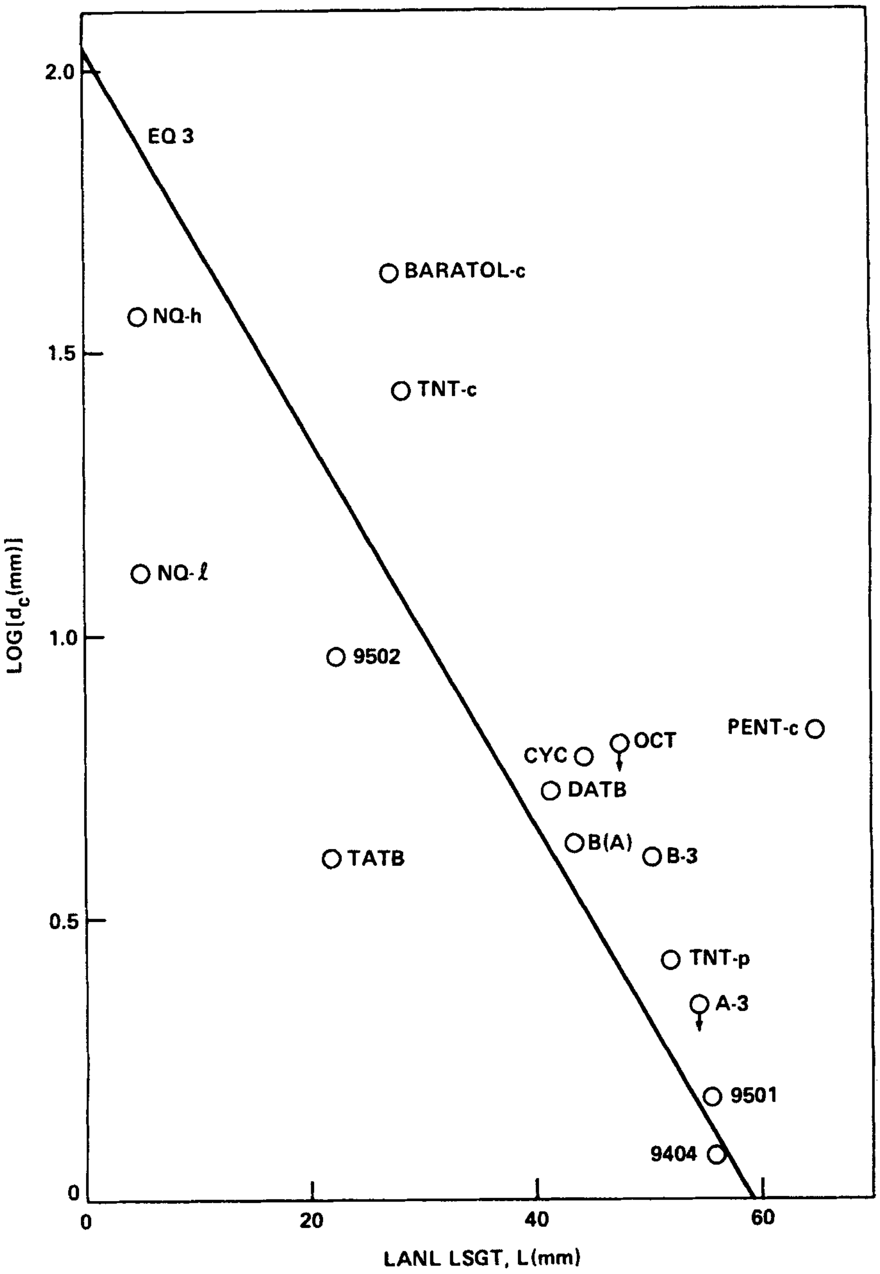

FIGURE 4. TEST OF EQUATION 3

from a standard wedge test. The LSGT result would be negative for the 5-7% RDX mixtures with d_c > 1.625 in., the diameter in the LSGT. The 9.2% RDX composition (d_c = 1.34 in.) might have a positive result when tested at ℓ/d of 2.46. However, this simple composite, even with the addition of 7.1% RDX, cannot conform to

TABLE 3

CRITICAL DIAMETER DATA FOR COMPOSITE PROPELLANT ANB-3226

Material*	AP %	d_c[15] mm
ANB	70	1615
ANB-I/RDX 95/5	65	146
ANB-II/RDX 92.9/7.1	62.9	66
ANB-III/RDX 90.8/9.2	60.8	34

*Binder and Al content kept constant at 15% each. RDX displaces equal amount of AP, the only component which is an explosive.

Eqs. 1-3. AP is the major component (70%) of this propellant and since most HE which do not conform to Eqs. 1-3 are the less sensitive explosives of relatively long reaction zones, neither AP nor ammonium nitrate (AN) would be expected to conform. Similarly, simple composites of high AP content would be expected not to conform. The behavior of ANB-3226 is consistent with this expectation.

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Weston et al[1] consider the large failure diameters of ANB-3226 containing 5-9.2% RDX anomalous. However, the large d_c for the unadulterated propellant is typical of simple composites, and addition of only 5% RDX reduces it over 10-fold. That reduction brings it within the range of d_c of the relatively insensitive HE. Thus, AP of 10µm at 80% TMD has d_c = 75 mm[16] and NQ-h at 90% TMD has d_c = 64 mm.[17] At voidless density the critical diameter would be much greater in both cases, but no one has attempted to measure it for either material.

CONCLUSIONS

Relationships described by Eqs. 1-3 are not applicable to all explosives and propellants. Most explosives which do not conform are those that are relatively insensitive and that have long reaction zones (e.g., TATB and its composites, NQ, and Baratol). On this basis, high density composites of AP and AN would also be expected to fail the fit as the simple composite ANB-3326 does. It follows that these empirical relations should not be used for prediction of explosive behavior of insensitive high explosives and propellants.

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