# COMPRESSIBILITIES OF SOLIDS AND THE INFLUENCE OF INERT ADDITIVES ON DETONATION VELOCITY IN SOLID EXPLOSIVES

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Experimental detonation velocity data are presented for 50/50 sodatol, 100/0, 95/5, 90/10, 85/15 and 80/20 RDX + water mixtures, 100/0 to 40/60 TNT + salt, 100/0 to 40/60 RDX + salt, 100/0 to 40/60 pentolite + salt, 100/0 to 40/60 TNT + glass and 100/0 to 40/60 RDX + glass mixtures. The thermohydrodynamic theory is applied together with a theory of compressibility outlined in this article in computing the velocities of the explosive-inert mixtures. The results are compared with the observed velocities and shown to be in good agreement. The theoretical parameters of the compressibility equations are shown also to be in good agreement with the experimental data of Bridgman. Moreover, the computed total compressions compare favourably with data measured by Walsh and Christian up to 300-400 kilobars. Finally the $\alpha(v)$ equation of state is examined for the above and some other mixtures and found to be of apparently general approximate validity. That is, the empirical curve discussed previously seems to apply within about 3 % in all of these mixtures.

The thermohydrodynamic theory provides, in solutions by the " inverse method ", valuable empirical equation of state data. In this application one employs the observed velocity-density or $D(\rho_1)$ data to solve for $\alpha(T, v)$ in the equation of state

$$pv = nRT + \alpha(T, v)p. \tag{1}$$

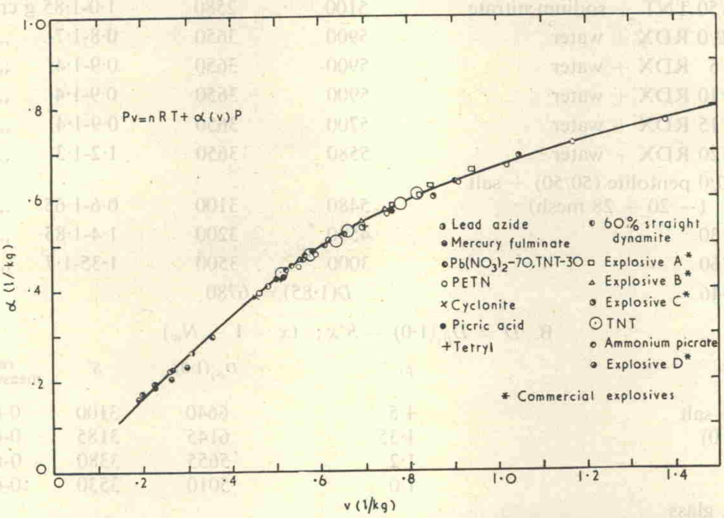


Fig. 1.—Correlation of explosives with " covolume " equation of state.

While it turns out that this method does not permit one to determine unambiguously the temperature dependent part of $\alpha$, results support the possibility that this component may be negligible and that $\alpha(T, v) \cong \alpha(v)$. Perhaps the most striking support of this approximation is to be found in the apparently general $\alpha(v)$ relation applicable in detonation illustrated in fig. 1.[1] Even more substantial evidence has recently been found in the influence of density on the rate of chemical reaction for TNT, ammonium nitrate and sodium nitrate.[2, 3, 4] One finds that the reaction rate increases with density at a rate corresponding to a temperature increase with density of about 500-1000° K $cm^3\ g^{-1}$. Since one may show that the increase in rate is almost entirely a normal temperature effect and not a pressure one, this result may be seen to support the $\alpha(v)$ approximation [2, 5, 6, 7] since this is approximately the density coefficient of temperature required by this approximation. Moreover, the most recent direct temperature measurements support this conclusion.[8]

In this article the validity of the $\alpha(v)$ curve of fig. 1 is examined for explosives containing sodium nitrate, water and various inert additives. A general theory of thermal expansion and compressibility of solids is then presented based on elementary fundamental considerations. This theory is then applied in computing the detonation velocities of explosives with inert additives ranging from zero to 60 % or more inert, and in further study of the covolume equation of state and the general $\alpha(v)$ curve.

## EXPERIMENTAL

The measured velocities summarized in table 1 were obtained by either the "pin-oscillograph" or "streak" camera method. Both of these methods have good reproducibility, but it is not always possible to control density as accurately, and the experimental error is therefore largely that associated with density fluctuations amounting to as much as about 3 % in loose-packed charges. Besides those examples of explosives containing sodium nitrate (SN) in fig. 1, SN was studied in 50/50 TNT + SN (cast and

TABLE 1.—EXPERIMENTAL DETONATION VELOCITY DATA ($msec^{-1}$)

A. $D = D_{1\cdot0} + S(\rho_1 - 1\cdot0)$

| mixture | $D_{1\cdot0}$ | $S$ | range of measurements |
|---|---|---|---|
| 50/50 TNT + sodium nitrate | 5100 | 2580 | 1·0-1·85 g $cm^{-3}$ |
| 100/0 RDX + water | 5900 | 3650 | 0·8-1·7 ,, |
| 95/5 RDX + water | 5900 | 3650 | 0·9-1·4 ,, |
| 90/10 RDX + water | 5900 | 3650 | 0·9-1·4 ,, |
| 85/15 RDX + water | 5700 | 3650 | 0·9-1·4 ,, |
| 80/20 RDX + water | 5580 | 3650 | 1·2-1·3 ,, |
| 100/0 pentolite (50/50) + salt (− 20 + 28 mesh) | 5480 | 3100 | 0·6-1·65 ,, |
| 70/30 | 4590 | 3200 | 1·4-1·85 ,, |
| 40/60 | 3000 | 3500 | 1·35-1·7 ,, |
| 54/46 | $D(1{\cdot}85) = 6780$ | | |

B. $D = D_{\rho_1}(1\cdot0) - S'x$; $(x = 1 - N_w)$

| | $\rho_1$ | $D_{\rho_1}(1\cdot0)$ | $S'$ | range of measurements |
|---|---|---|---|---|
| TNT + salt | 1·5 | 6640 | 3100 | 0-60 % |
| $(f(x) = 0)$ | 1·35 | 6145 | 3185 | 0-60 ,, |
| | 1·2 | 5655 | 3380 | 0-60 ,, |
| | 1·0 | 5010 | 3530 | 0-60 ,, |
| TNT + glass (beads − 20 + 28 mesh) | $[\rho_1 = 0{\cdot}82 + 0{\cdot}87x]$ | 4650 | 2170 | 0-60 ,, |
| RDX + salt (− 20 + 28 mesh) | $[\rho_1 = 1{\cdot}22 + 0{\cdot}3(x + x^2)]$ | 6765 | 2775 | 0-60 ,, |
| RDX + glass (beads − 20 + 28 mesh) | $[\rho_1 = 1{\cdot}20 + 0{\cdot}4x + 0{\cdot}8x^2]$ | 6630 | 2550 | 0-60 ,, |