than the various theoretical values derived by Fickett[4] using Kistiakowsky/Wilson and Lennard-Jones/Devonshire equations of state.


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Printed in Great Britain by Fisher, Knight & Co., Ltd., St. Albans.



(*Reprinted from Nature, Vol.* 202, *No.* 4934, *pp.* 758–759, *May* 23, 1964)


# DETONATION EMISSIVITIES AND TEMPERATURES IN SOME LIQUID EXPLOSIVES


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EXPERIMENTAL measurement of the spectral distribution of radiation from a detonation wave enables the detonation temperature and emissivity to be calculated using Planck's radiation equation, provided that the grey or black body nature of the wave is established. Several workers[1–4] since 1945 have used this method to determine detonation temperatures of condensed explosives, but although confirming the grey body nature of the detonation products no emissivities have been quoted. Gas emissivities are normally low, but under the conditions obtaining in the detonation of condensed explosives, where pressures and temperatures are greater than 100 kb and 3,000° K, statistical and quantum mechanical considerations suggest that the emissivities should be close to unity. This is substantiated by the experimental evidence adduced here for the liquid explosives nitromethane, diethylene glycol dinitrate (DEGDN) and ethyl nitrate.

A spectrophotometer was used to compare the intensity of radiation from the explosive with that from a temperature calibrated tungsten ribbon lamp at six selected narrow wave-bands in the visible region. Identical optics were used for each of the two light sources in each experiment, the radiation being focused by reflective optics on to the entrance slit of a Hilger medium quartz spectrograph which had been modified to enable the use of a photomultiplier detector at each selected wave-band. The output of each photomultiplier was fed through a cathode follower, displayed as a function of time on an oscilloscope and recorded photographically; the overall rise-time of the apparatus was 15 nanosec.

The explosive charge was contained in an aluminium tube, $2\frac{3}{4}$ in. inside diam., 3 in. outside diam., having at one end a 1-mm thick glass window and at the other a suitable initiator. It was immersed in water to help maintain the planarity of the detonation wave and to obviate the production of a highly luminous air shock at the end of the charge. The charge was viewed normal to the detonation front. Radiation reaching the spectrophotometer originated from only a small area 2 mm × 0·1 mm at the centre

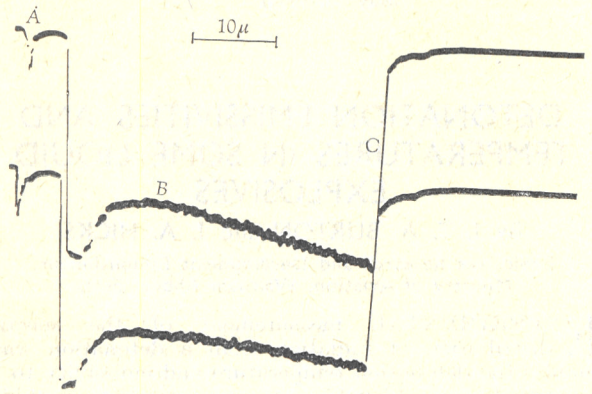


Fig. 1

of the detonation front, corresponding to a region of high confinement.

Fig. 1 is a typical record showing the time-resolved radiation intensity at two wave-bands for a nitromethane charge in which initiation phenomena of the type described by Campbell *et al.*[5] are observed between entry of the shock wave into the nitromethane (*A*) and the onset of steady-state detonation (*B*). As the detonation wave advances towards the window the apparent radiation intensity increases as a result of the decreasing optical absorption by the nitromethane. All intensity measurements were made at the end of the charge (*C*) to eliminate absorption effects.

The magnitudes of wave-length and temperature in this work make $\exp(c_2/\lambda T)$ always much greater than unity, so that Planck's equation may be approximated by Wien's radiation law without loss of accuracy. The ratio of intensities of the detonation wave, *D*, and the standard lamp, *S*, is given by:

$$\log I_D/I_S = \log (\varepsilon_D/k\varepsilon_S) + (c_2/2{\cdot}303\lambda)(1/T_S - 1/T_D) \quad (1)$$

where $k$ is a transmission constant for the glass envelope of the standard lamp. Values for $k$ and $\varepsilon_S$ as a function of $\lambda$ and $T_S$ were obtained from the work of de Vos *et al.*[6,7]. Fig. 2 shows that a plot of the experimental values of log $I_D/I_S$ against $1/\lambda$ is very nearly linear. Since $\varepsilon_S$ is only a weak function of $\lambda$ and $T_S$ in this region it can be concluded that the detonation wave is a grey body emitter.

The determination of the detonation emissivity from the intercept (log $\varepsilon_D/k\varepsilon_S$) of the above plot is inaccurate because the required extrapolation to $1/\lambda = 0$ is non-linear. Equation (1) was solved by determining the value of the detonation emissivity for which the standard

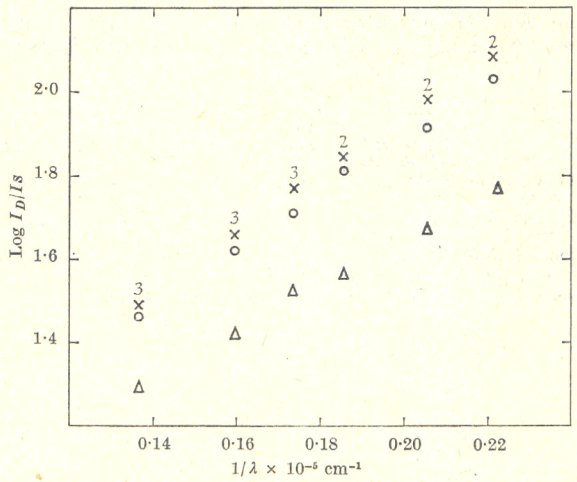


Fig. 2. ×, Nitromethane; ○, DEGDN; △, ethyl nitrate

Table 1

| $\varepsilon_D$ | $T_D$(°K) | Standard deviation (° K) | No. of determinations | Optimum values $\varepsilon_D$ | Optimum values $T_D$ |
|---|---|---|---|---|---|
| | | Nitromethane | | | |
| 0·9 | 3,495 | 21·1 | 15 | 1·15 | 3,380 |
| 1·0 | 3,445 | 14·7 | | | |
| 1·1 | 3,400 | 11·6 | | | |
| 1·2 | 3,362 | 11·8 | | | |
| 1·3 | 3,325 | 14·8 | | | |
| | | Diethylene glycol dinitrate | | | |
| 0·9 | 3,447 | 23·8 | 6 | 1·2 | 3,320 |
| 1·0 | 3,398 | 16·6 | | | |
| 1·1 | 3,355 | 12·0 | | | |
| 1·2 | 3,317 | 10·4 | | | |
| 1·3 | 3,274 | 14·7 | | | |
| | | Ethyl nitrate | | | |
| 0·9 | 3,226 | 18·5 | 6 | 1·15 | 3,130 |
| 1·0 | 3,184 | 12·4 | | | |
| 1·1 | 3,146 | 9·9 | | | |
| 1·2 | 3,112 | 10·7 | | | |
| 1·3 | 3,082 | 13·2 | | | |

deviation of the calculated detonation temperatures was a minimum (Table 1). It is apparent that the emissivities of the detonation products of the explosives examined are the same and are only slightly different from that of a true black body. Other condensed explosives will be examined to see if this conclusion is generally true.

We are not aware of any other published data for the detonation temperatures of diethylene glycol dinitrate or ethyl nitrate. The value for nitromethane of 3,380° ± 20° K is identical with that obtained in the unpublished work of Davis and Mader, cited by Fickett[4]. It is less than the experimental values of Gibson *et al.*[2] (3,800° K) and of Voskoboinikov and Apin[3] (3,700° K) but greater