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Ignitability of Nonhypergolic Propellants in Presence of Potassium Permanganate

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Many nonhypergolic fuels can be made hypergolic by introducing suitable additives.[1] In some cases, introduction of a hot surface brings about ignition, which presumably makes use of the fact that the temperature is increased in the zone of reaction. Since ignition is preceded by oxidative degradation processes, it seems that these would be accelerated by the use of stronger oxidizing agents. In this manner, many nonhypergolic fuels can be made hypergolic. The purpose of this note is to report the result of investigations undertaken from this angle.

An increasing amount of potassium permanganate was added to red fuming nitric acid, and the ignitability of various alcohols was tested with it. It was found that methyl alcohol, ethyl alcohol, propyl alcohol, isopropyl alcohol, butyl alcohol, secondary butyl alcohol and tertiary butyl alcohol all become hypergolic when 20% potassium permanganate is used. The ignition delay is below 0.3 sec in all cases. Studies were undertaken to elucidate the mechanism. The essential steps involved are the following:

$$\text{alcohol} \rightarrow \text{aldehyde or ketone} \rightarrow \text{acid} \rightarrow \text{degradation}$$

The intermediates in this reaction could be identified. As further confirmation of the mechanism, the ignitability of aldehydes and corresponding ketones was investigated. It was found that these ignite with red fuming nitric acid, which contains 10% potassium permanganate.

The role of potassium permanganate was investigated. It may be noted that only freshly dissolved potassium permanganate in red fuming nitric acid is effective. This gave us a strong suspicion that atomic oxygen is produced which acts as a much stronger oxidizing agent. This conclusion is supported by the fact that benzene also ignites with red fuming nitric acid containing potassium permanganate. Carbon disulfide also burns with a steel blue flame. However, the intriguing fact is that no reaction occurs with white fuming nitric acid. The role of NO_2 in the ignition reaction is not clear. Further studies are in progress.

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Normal Shock-Wave Properties in Imperfect Air and Nitrogen

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Because of the current interest in shock tube applications in the study of so-called real gas effects in gas dynamics, and since previous results did not include important imperfect gas‡ effects at high densities, recalculation and extension of previously published perfect gas calculations was necessary. The purpose of this note is to draw attention to the imperfect gas effects on the normal shock-wave properties especially at high shock strengths and quiescent gas pressures $p_1 \gtrsim 1$ atm.

Normal shock-wave properties have been computed for air[1] and nitrogen[2] in the range $M_S = 6(1)30$ into an ideal gas at a temperature of 300°K and pressures in the range from 10^{-4} to 10^3 cm Hg. The calculations were based on the recent thermodynamic data for imperfect air[3–5] and nitrogen.[3, 6, 7] Charts were presented[1, 2] for incident and reflected shock-wave conditions, stagnation conditions upstream and down-

Table 1 Imperfect and perfect gas normal shock-wave conditions in air

	Lewis and Burgess[1]	Feldman[8]
Air model	Imperfect	Perfect
M_S range	6–30	6–25
p_1 range (cm Hg)	10^{-4}–10^3	10^{-3}–76
Regions (see Fig. 2)	2, 2*s*, 20′, 20, 5	2, 2*s*, 20′, 5
Gasdynamic quantities	p, ρ, T, h, u, a, Z, S	p, ρ, T, h, u, Z^*

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‡ An ideal gas obeys $p = \rho RT$, $h = C_pT$, and $\gamma = C_p/C_v =$ const. A perfect gas will denote one obeying $p = Z^*\rho RT$ which includes dissociation and ionization neglecting intermolecular effects. An imperfect gas obeys $p = Z\rho RT$ which includes dissociation, ionization, and intermolecular forces. Local thermodynamic [i.e., thermal, mechanical (pressure), and chemical] equilibrium is assumed to exist for all conditions.