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THE ROLE OF AIR AND OTHER GASES IN FLYER-PLATE INITIATION OF EXPLOSIVES

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Flying-plate (slapper) devices find wide application as test vehicles for measurements of the shock sensitivity of explosives for a variety of detonation initiation requirements.[1] These devices consist of a flyer, barrel, and an acceptor explosive sample. Either chemical or electrical energy can be used to accelerate the flyer down the barrel to impact the acceptor. Such a slapper device[2] was used in the present studies. The characteristics of this device, in which electrical energy is used to drive the flyer, are given in the table.

Comparisons were made to relate initiation response due to the effect of air and other gases in the barrel of the device. Sensitivity tests in vacuum showed an initiation threshold about 5 to 10% lower in terms of flyer-plate velocity and impact pressure than for air. With one atmosphere of xenon in the device, the energy stored in the firing circuit had to be increased nearly a factor of three to cause initiation. These observations led to the present study of the effects of air and other gases in these devices.

As the Kapton flyer plate travels down the barrel of the device, some of the kinetic energy of the flyer is transferred to kinetic and internal energy of the gas trapped between the flyer and the solid explosive acceptor. The energy imparted to the gas can be transferred to the explosive prior to impact of the flyer in two ways: 1) The directed kinetic energy of the gas can cause

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compression of the explosive, and 2) a portion of the internal energy of the gas can be radiated and subsequently absorbed by the explosive. (Thermal conduction is too slow to be a mode of significant energy transfer in this device.)

Wave-motion computations were made using a one-dimensional code[3], Chart D, to simulate the flyer acceleration and gas compression in the test device. Shock pressure, temperature and density were computed for the gas as well as for the HNS acceptor. Since the shock in the gas precedes the flyer-plate, the shock impinges upon the acceptor before flyer impact. The shock reverberations in the gas that follow between the acceptor and the moving plate result in a rapid pressure increase in the gas prior to impact. For a flyer velocity of 2.57 km/s in this specific test device, the precompression pressure in air and acceptor achieve $\sim$ 0.12 GPa after the first reflection, followed by reverberation increases to $\sim$ 0.4 GPa and $\sim$ 0.9 GPa before impact. The temperature in air is calculated to reach 3 eV. The air is finally compressed to pressures comparable to the impact pressure between the flyer plate and the acceptor.

Compaction occurs in the porous HNS acceptor in a zone near the impact surface due to the early, relatively low-level shock. The compaction of the explosive acceptor surface appears to result in a desensitized layer. Because of the higher density in the acceptor as well as the flyer and the associated increases in shock impedance, the "impact" pressure is higher than would be expected for a given flyer velocity. Chart D wavecode results and VISAR[4] experimental data indicate slight flyer deceleration just prior to impact, apparently caused by precompression of the air in the barrel of the device.

In order to assess the extent to which optical radiation from the compressed gas might affect the performance of this device, we measured the intensity and spectral distribution of the emitted radiation. To perform these measurements, we replaced the HNS pellet with a sapphire window and masked the device so that only light passing through the window could reach the optical detectors. The optical diagnostics consisted of four absolutely-calibrated photodiodes, filtered for response in selected regions of the spectrum from the UV to the visible, and a gated, 500-channel optical multichannel analyzer (OMA). The signals from the photodiodes provided a time-resolved measurement of the emitted light intensity in particular wavelength bands while the OMA recorded the time-integrated emission spectra from 200 to 500 nm. Measurements of the emitted light were made with the device evacuated and with it filled with air, NO, Ar, Kr, or Xe at various pressures up to two atmospheres.

With the device evacuated, the time-integrated emission spectrum showed an onset at 450 nm, coincident with the transmission onset of Kapton. The time-resolved signals showed emission beginning approximately 100 ns before the peak of the dI/dt trace (bridge burst), rising to a maximum at burst, and remaining relatively constant until impact. These observations indicate that the emission from an evacuated device originates from the bursting foil plasma behind the flyer.

When gas is added to the barrel of the device, additional features are seen. The time-integrated spectra show UV emission down to 250 nm with a peak near 350 nm, and the time-resolved signals from the photodiodes show an intense emission spike prior to impact. The height and duration of this feature depend on the kind and pressure of the added gas. For air, this pulse of UV emission is approximately 20 ns long and corresponds to an optical flux at the sapphire window of approximately 2 x 10^4 W/cm^2. For xenon, the pulse broadens to nearly 100 ns and the peak flux increases by about a factor of 20. The results for NO, Ar, and Kr lie between these two extremes.

We determined the approximate optical depth of this UV emission in HNS to be about 10^{-2} mm by coating the inside of the sapphire window with a thin layer of HNS (which has an absorbence peak[5] near 300 nm) and then measuring the resultant attenuation of the detected UV emission. Combining the measurement of optical depth with the measurement of the UV flux for air indicates that an absorbed photon density of 2×10^{17} photons/cm^3 would occur at the surface of an HNS pellet. These photons are energetic enough (3 eV) to produce electronically excited states and radical species.

The Chart D computations indicate that the precompressed layer on HNS exceeds crystal density and is therefore probably rendered inert. Also, this inert zone thickness is calculated to be an order of magnitude greater than the optical depth of the UV emission from the radiating gas. Presumably initiation occurs when the shock energy from the flyer reaches undisturbed material beyond the precompressed region. Since the radiated energy does not reach this region, it probably has little effect on the initiation process. The primary effect of gases in these devices is to change the initiation sensitivity through compression of the acceptor prior to impact of the flying plate.

References

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2. N. O. Rhoton, Pantex Plant, to be published.
3. S. L. Thompson, "Improvements in the Chart D Energy Flow - Hydrodynamic Code V: 1972/1973 Modifications", Sandia Labs Report. SLA-73-0477, Oct., 1973.
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TABLE

Characteristics of the Flying-Plate Device

Bridge or Foil	-	Copper (0.0116 mm thick x 2.54 mm square)
Flyer	-	Kapton (0.0762 mm thick)
Barrel	-	Sapphire (2.286 mm i.d. x 1.27 mm long)
Acceptor	-	Hexanitrostilbene (HNS) (6.35 mm diameter x 5.08mm long; density 1.60 g/cc.
Firing Circuit	-	Capacitor Discharge Unit (CDU)
		$C = 11.1\ \mu F$
		$L = 39$ nH to 1.1 μH variable
		$R = 20$ mΩ to 40 Ω
		$V_c \leq 10$ kV