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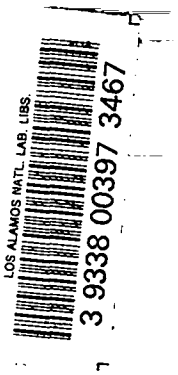

by

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ABSTRACT

The shock sensitivity of compacted PETN has been measured by the small-scale gap-test method with different gases in the pressing voids. Helium, argon, nitrogen, and carbon dioxide gases desensitized the pressings whereas oxygen sensitized the powder compacts. PETN pressings with mixtures of oxygen and nitrogen as the interstitial gas showed sensitivities intermediate to those observed with the pure gases. Effects were magnified with an increase in gas pressure. Sensitivity values of the pressings also depended upon the specific surface of the crystals, being less sensitive the greater the state of subdivision.

I. INTRODUCTION

Initiation of granular explosives pressings depends upon many factors. Experimental evidence exists which indicates that the gas type and pressure present in the crystal interstices have an important effect on the sensitivity to initiation by shock. For example, (1) the sensitivity of low-density granular PETN (pentaerythritol tetranitrate) decreases with an increase in the specific surface of the pressed explosive, with air at atmospheric pressure in the crystal interstices and decreases as the pressure of the interstitial air is increased,[1,2] (2) the substitution of nitrogen and argon gases for air, under pressure, in PETN pressings of both low and high specific surface material is accompanied by a decrease in explosive sensitivity,[2,3] and (3) the shock sensitivity of coarse- and fine-grained HMX (cyclotetramethylene tetranitramine) decreases with a variety of interstitial gases under pressure.[3]

The purpose of this report is to summarize and discuss sensitivity data obtained in past years that indicate the degree of importance and the role of interstitial gases in the explosion of low-density PETN pressings.

II. EXPERIMENTAL PROCEDURE

The small-scale gap-sensitivity test employed in this work was a modification of that of Cachia and Whitbread[4] where the PETN acceptor test charges were cylindrical, 1/2 in. long by 1/2 in. in diameter, and pressed to a loading density of 0.95 g/cm^3. Samples of PETN of two widely differing specific surface ranges (2500 to 3500 cm^2/g and 12,000 to 13,000 cm^2/g) were investigated, each with six gases--air, nitrogen, oxygen, argon, helium, and carbon dioxide--at pressures up to 2000 psig. Some shots also were fired with mixtures of oxygen and nitrogen gases in the pressing voids. The donor charges were 2/10-in.-long by 3/10-in.-diam plastic-bonded RDX pellets of 1.6 g/cm^3 density initiated by low-density PETN, which in turn was set off by an SE-1 detonator (electrically exploded bridgewire system). The attenuator or gap material was 1-in.-diam free-machining yellow brass in disks of various thicknesses. This donor-attenuator-acceptor combination was incorporated in a dural assembly in which the gas type and pressure permeating the PETN pressing could be varied by means of valves controlling the flow from external tanks. The assembly is shown in Fig. 1.

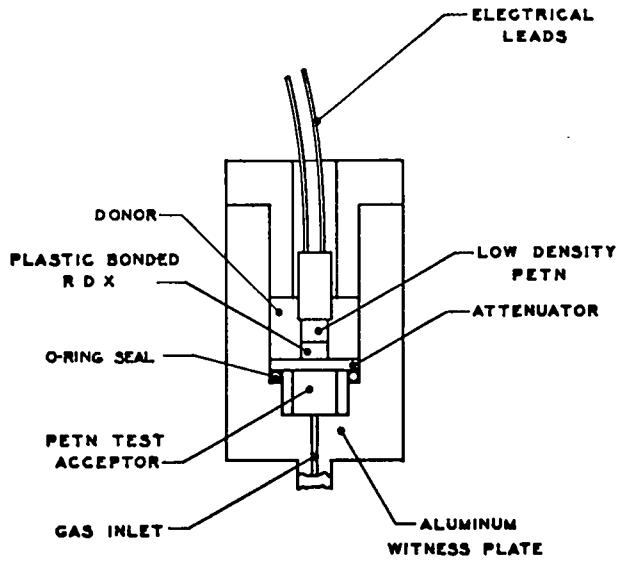

Fig. 1. Assembly for the shock initiation of PETN.

The criterion of satisfactory initiation that led to detonation was either the production of a dent in an aluminum "witness plate" that formed the bottom of the pressure vessel or complete destruction of the pressure vessel; noninitiation produced neither of these, but only an equatorial bulge.

The sensitivity of the PETN pressings is reported in inches of brass attenuators where the greater the thickness of attenuator, the more sensitive the explosive assembly. The brass thickness at which there is a 50% chance of PETN detonation is designated as $T_{.5}$. These values were determined according to the method devised in 1943 at the Explosives Research Laboratory, Bruceton, Pennsylvania.[5] The attenuator thickness interval in the "up and down" method was 0.01 inch. The estimated standard deviation of the individual shots that make up each point is ± 0.01 in. of brass thickness.

Sensitivity can also be expressed as a function of the pressure behind the shock emerging from the attenuator,[4] and so an experiment was performed to characterize the output shocks of this particular gap-test. Pressure was calculated using the Hugoniot for free-machining brass[6] and measured free surface velocities of points on the attenuator surface after emergence of the shock wave. Because the shock emerging from the attenuator was nonplanar, it was necessary to observe the movement of the free surface in two dimensions as a function of time to measure the free surface velocity. This was accomplished by photographing tagged points on the brass surface with a rotating mirror smear camera through a stereoscopic system designed to give two orthogonal views of the attenuator surface in the camera film plane. Analyses of these records allowed the free surface velocity of these points to be calculated.

Measurements were made on five different thicknesses of brass from 0.025 in. to 0.315 in. with at least two shots fired at each thickness except for the thinnest attenuator. The pressure across the face of the attenuators was calculated at 1-mm increments, and typical pressure profiles for the various attenuator thicknesses are shown in Fig. 2. As might be expected, the pressure on the face of an attenuator is highest in the center and falls off rapidly at the edges of the donor charge. Figure 3 is a plot of the axial peak pressures against attenuator thickness. The curve fitted to the experimental points in this figure has the equation

$$P = 277\, e^{-4.46X},$$

where P is the pressure in kilobars, and X is the brass thickness in inches.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Results of experiments using individual gases and air are shown in Figs. 4 and 5. The data indicate several things: (1) all gases in the crystal

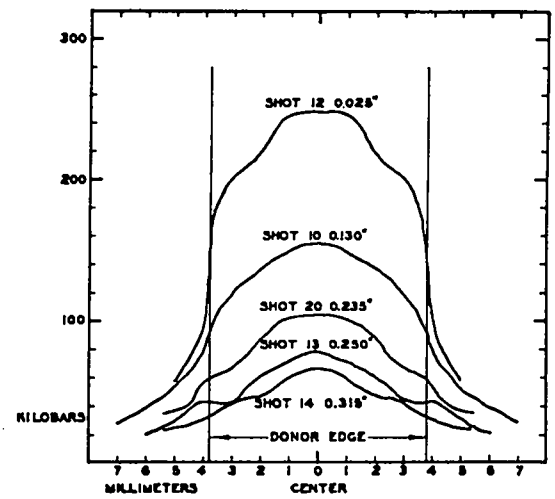

Fig. 2. Attenuator pressure profiles for indicated shots.

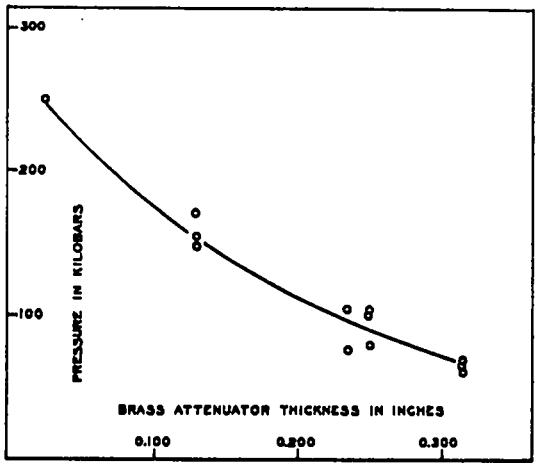

Fig. 3. Peak pressure generated at brass attenuator/PETN pressing interface vs thickness of brass attenuator.

interstices at atmospheric pressure influence the sensitivity of PETN to about the same extent--i.e., the $T_{.5}$ of a PETN pressing of a given specific surface is independent of the type of gas in the crystal interstices, (2) oxygen under pressure sensitizes PETN greatly, whereas air (with approximately 20% oxygen) does so slightly at pressures up to 4 to 500 psig, after which desensitization occurs, and (3) helium, argon, nitrogen, and carbon dioxide desensitize PETN at above-atmospheric pressures. In addition, the data show that the effect of gas type and gas pressure is qualitatively the same with both large and small specific surface PETN.

The gases chosen and the conditions of the experiment provided interstitial fluids that varied widely in physical properties. For example, (1) the densities of the gases at atmospheric pressure covered a tenfold range (Ar = 1.6×10^{-3} g/cm^3; He = 1.6×10^{-4} g/cm^3) while the elevated pressure ranges corresponded to increases of several hundred, except for carbon dioxide ($\sim$ 50) and oxygen ($\sim$ 10), (2) the room-temperature velocity of sound and the acoustical impedance varied by a factor as high as three, (3) the molecular complexity of the gases used included simple monatomic, diatomic, and triatomic structures, (4) the ratio of the specific heats varied from 1.3 (CO_2) to greater than 1.6 (Ar, He), (5) the viscosities ranged from 148 micropoises (CO_2) to 222 micropoises (Ar) at room temperature, and (6) the thermal conductivity varied by a factor of ten between carbon dioxide and helium.

No one of these properties has been found to correlate with all of the experimental results. However, the sensitivity results do indicate that the greater the molecular complexity of the gas, the greater its desensitizing effects. For example, for both samples of PETN, at constant gas pressure, the order of increasing effectiveness of desensitization is He, Ar, N_2, and CO_2. Our results thus seem to indicate that the suggestion made by Chick[3] that the gas acts as a deleterious heat sink is worthy of consideration.

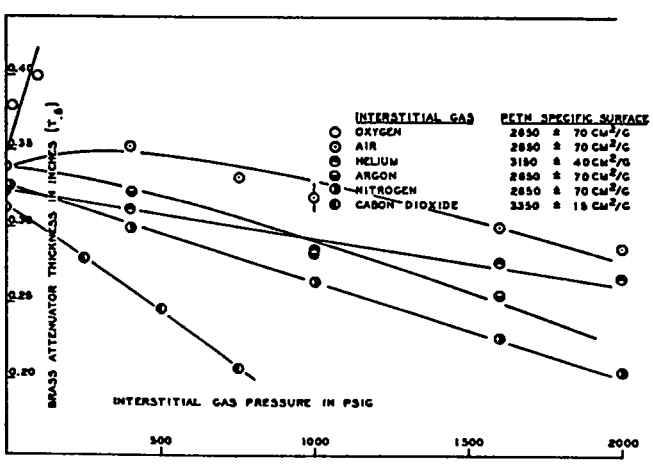

Fig. 4. Effect of interstitial gas pressure on the small-scale gap-test sensitivity of low specific surface PETN.

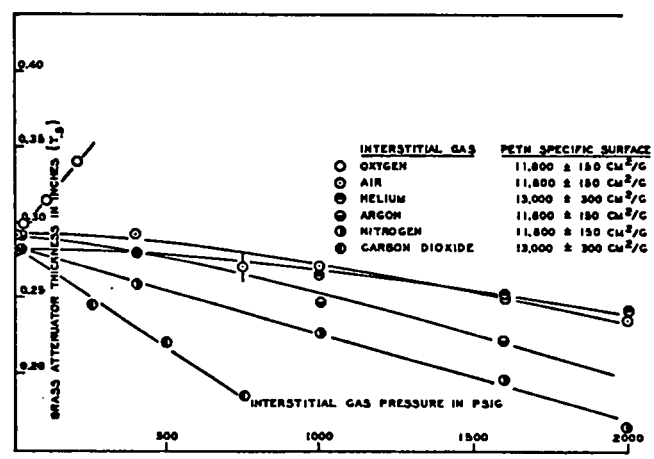

Fig. 5. Effect of interstitial gas pressure on the small-scale gap-test sensitivity of high specific surface PETN.

Interstitial gases which were mixtures of oxygen and nitrogen gave PETN sensitivity values that were intermediate between those for pure oxygen and pure nitrogen. The 20% O_2/80% N_2 mixture (air) values were the same (to within the precision of the data) as those observed when ordinarily occurring atmospheric air was used. The 100% N_2 values fell in line with the data from the gas mixtures. The 100% O_2 values showed considerably higher PETN sensitivity than would be predicted from an extrapolation of the O_2/N_2 mixture data. It seems quite evident that oxygen by itself has a unique effect on the gap-test sensitivity of PETN. When mixed with N_2 its sensitizing effect is expressable in terms of its partial pressure and is less than if no other gas were present. Figures 6 and 7 show the data for both low and high specific-surface PETN with 500 and 1000 psig total pressure in the compact voids.

Although no detailed explanation of the pure oxygen effect can be given at the present time, two enlightening statements can be made: (1) no permanent supersensitive PETN-O_2 compound seems to be formed, and (2) the role of oxygen gas is to aid the development of a detonation.

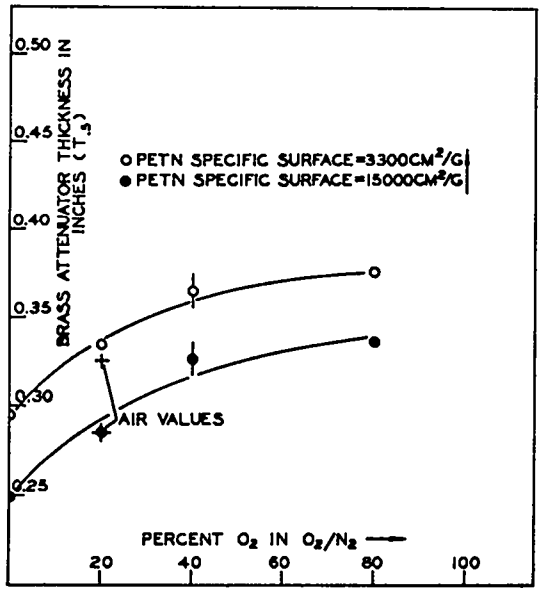

Fig. 6. Effect of oxygen content in O_2/N_2 gas mixtures on the small-scale gap-test sensitivity of PETN. Total gas pressure = 500 psig.

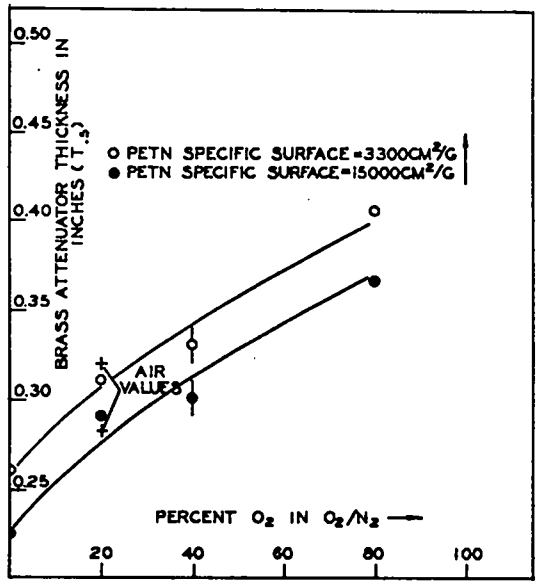

Fig. 7. Effect of oxygen content in O_2/N_2 gas mixtures on the small-scale gap-test sensitivity of PETN. Total gas pressure = 1000 psig.

The first of these is shown by the fact that no statistically significant difference can be observed between the $T_{.5}$'s of PETN samples that are held in contact with oxygen gas under pressure, but which had been replaced by air at atmospheric pressure just before firing and those obtained from similar PETN pressings that never have been in contact with oxygen gas.

The second--the role of oxygen gas in the build-up of shocks into detonations--was observed by Blackburn[7] in PETN pressings initiated by bursting bridgewires, not by shocks from donor explosive-metal disk assemblies. Smear camera records of the initiation of PETN pressings of 0.96 g/cm^3 density containing air at atmospheric pressure and oxygen at 300 psig are shown in the upper two pictures of Fig. 8. The ambient air-filled condition is shown in the top picture. Here the wire burst (top center) is followed by an acceleration to detonation (lines to lower left and right in the picture). The picture in the center of the figure is of an assembly in all ways similar to the first one except that the interstices are filled with oxygen at 300 psig. It is seen that this picture is like the former but the acceleration is faster. Oxygen has aided the development of the shock into a detonation. The bottom

picture of Fig. 8 involved an assembly like those used for air and oxygen except that the interstices were filled with 300 psig of argon. The explosives assembly failed to detonate. This suggests that

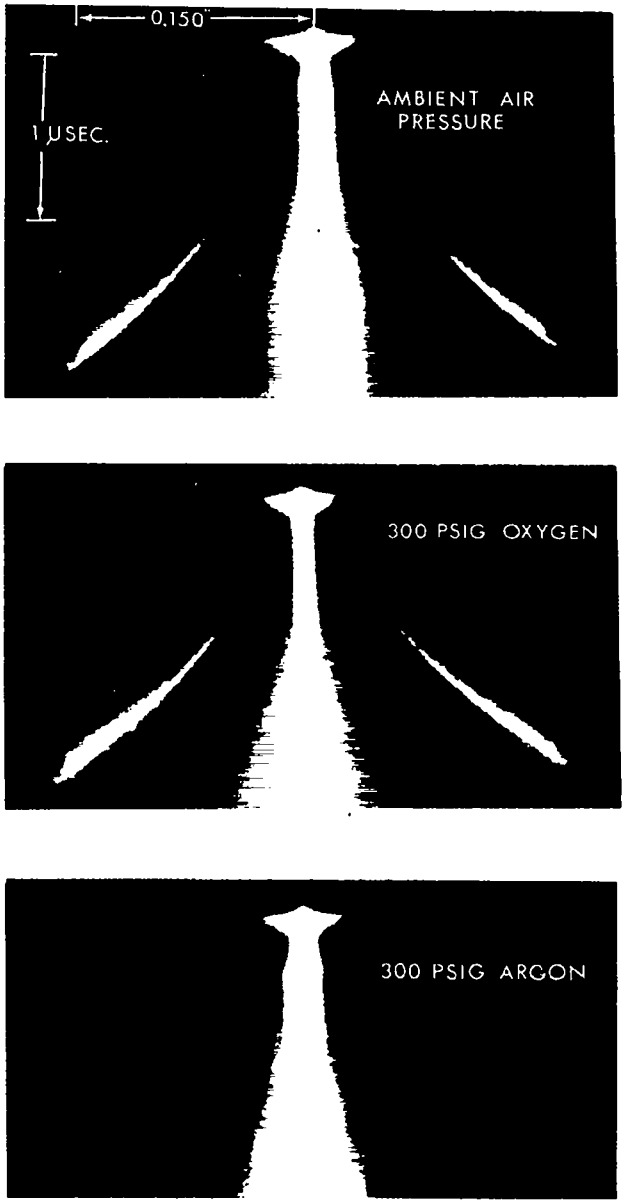

Fig. 8. Smear camera record: buildup to detonation in PETN pressings.

300 psig of argon has reduced the sensitivity of this assembly so that the initiation conditions are now in the "failure" area. We believe this action to be representative of the other PETN-desensitizing gases although we have not taken pictures of their initiation processes. Although there are differences between a system in which PETN is initiated by shocks generated in flat metal disks and a system in which the explosive is set off by a bursting bridgewire, it is hard to see how these differences could be great enough so that the role of oxygen and the inert gases would not be essentially the same in the two types of tests.

ACKNOWLEDGMENT

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