RETARDATION OF HIGH-VELOCITY STREAMS IN VARIOUS MEDIA

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Strong waves were generated in Plexiglas and in aluminum under a pressure of 2.9 and 7.1 mbars respectively. The retardation of high-velocity streams in air and in inert gases is analyzed.

With the aid of special detonation devices analogous to those in [1], strong shock waves were generated in Plexiglas and aluminum specimens. The velocity of these shock waves and the initial scatter velocity of the substance upon arrival of a shock wave at the free surface were measured with a photographic recorder; only the initial scatter velocity was measured in the case of aluminum.

The maximum velocity of a shock wave in Plexiglas reached 19.6 km/sec, the initial scatter velocity was 24.5 ± 2 km/sec. If the equation of the shock adiabatic for Plexiglas $D = 2.74 + 1.35U$, which has been proposed in [2] for pressures up to 2 mbars, is extrapolated into the higher pressure range, then for the shock wave velocity $D = 19.6$ km/sec we obtain a mass velocity $U = 12.5$ km/sec under a pressure $P = 29$ mbars and with a density of the material approximately 3.25 g/cm^3 behind the wave front.

Comparing the mass velocity to the initial scatter velocity, we find that the principle of velocity doubling within this pressure range applies here within the limits of test accuracy (10%). Calculations by the method shown in [3], with the assumption that approximately one third of the difference between total energy and elastic energy is spent on breaking down the chemical bonds, show that behind the shock wave front there has occurred a thorough decomposition of the Plexiglas material and that the projectiles comprise a mixture of solid carbon with molecules of water, hydrogen, and oxygen.

In the case of aluminum, the initial scatter velocity upon the arrival of a shock wave at the free surface was 24 ± 2 km/sec. Assuming this velocity to be equal to twice the mass velocity, and extrapolating the equation of the shock adiabatic for aluminum $D = 5.25 + 1.39U$ [4] into the higher pressure range, we obtain the shock wave velocity $D = 22$ km/sec at a pressure $P = 7.1$ mbars. Extrapolating the equation of state [5] into this pressure range will allow us to evaluate the thermal energy and the temperature of the compressed material: approximately $0.6 \cdot 10^{12}$ ergs/g and $4 \cdot 10^4$ °K.

It is well known that, during unloading of a material which has been compressed by a strong shock wave, there may occur complete or partial evaporation. Complete evaporation occurs when the entropy of the compressed material is higher than critical. For aluminum this critical entropy is $S_{cr} = 4.6 \cdot 10^7$ ergs /g·°C [6]. An evaluation of the entropy under our test conditions yielded $S = 4.8 \cdot 10^7$ ergs/g·°C, i.e., almost its critical value. Despite the approximate manner of our calculations, it appears certain that the state of the metal during unloading is nearly critical, i.e., the material is a mixture of vapor with fine liquid droplets.

We also studied, experimentally, the effect of the medium on the retardation of a high-velocity stream emerging upon the arrival of a shock wave at the free surface of specimens, with scatter into air under pressures of 0.1 or 1.0 atm and into an inert gas (helium, argon) under a 1.0 atm pressure. The test results for aluminum specimens have been plotted in U, l coordinates, i.e., in terms of the jet velocity U as a function of the distance l from the free surface (Fig. 1). According to the graphs, the retardation of an aluminum

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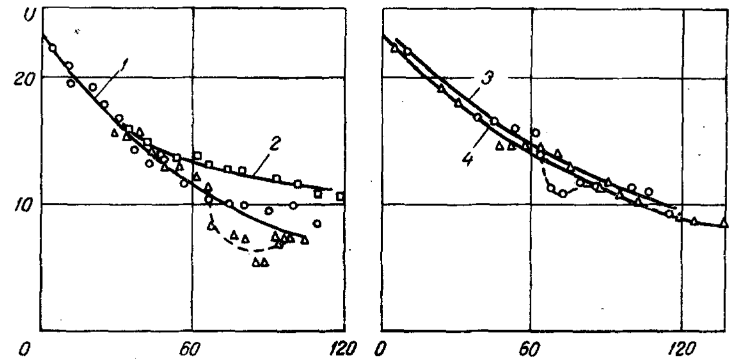

Fig. 1. Retardation of an aluminum jet: in air under 1 atm (1), in argon under 1 atm (2), in argon under 0.1 atm (3), in helium under 1 atm (4). Velocity U (km/sec), distance l (mm).

jet in argon and in air, both under 1 atm pressure, is almost the same along the initial segment (about 30-40 mm) from the free surface, but then becomes stronger in air than in argon (although the density of air is higher). One possible cause of this may be the occurrence of a chemical reaction between the incandescent aluminum vapor and air. This hypothesis is confirmed by the fact that the retardation curve for discharge into the air under a 0.1 atm pressure, when the oxygen content is lower and thus the oxidation reaction is slower, approaches the corresponding retardation curve for discharge into helium under a 1 atm pressure. The chemical reaction between aluminum and air oxygen along a shock wave has already been suggested in [8].

Tests pertaining to the scatter of fission products were performed in air under initial pressures of 0.1 and 1.0 atm. As was to be expected, both retardation curves are different here. While the 1 atm retardation curves for Plexiglas and aluminum fission products are similar, the 0.1 atm retardation curve for Plexiglas fission products lies above that for aluminum fission products and becomes similar to the retardation curve for aluminum in argon.

It is to be noted that in approximately 30% of all tests the retardation of a jet in air proceeded anomalously, namely the velocity dropped sharply a distance of about 60 mm from the free surface and then slightly rose (dashed lines on the diagram). This had possibly to do with the chemical reaction between the jet material and air. A definitive answer, however, will require a further thorough study of the problem.

The initial stream density during discharge into air under a 1 atm pressure was estimated by the method shown in [9], yielding approximately 0.18 g/cm^3 for aluminum and 0.38 g/cm^3 for Plexiglas.

Tests were also performed with a discharge of aluminum specimens into vacuum (10^{-3} mm Hg). On the basis of the recorded charts, one may conclude that during discharge into a very rarefied medium there appear not two but three incandescent streamers (as in [6]) which propagate at different velocities. The maximum velocity was about 40 km/sec (the darkest streamer), the velocity of the second streamer was 24 km/sec, and of the third streamer was 22 km/sec; meanwhile, only one streamer appeared under 0.1 atm and 1.0 atm pressures (as in [6, 7]). An explanation as to the causes and the nature of three streamers requires a further study.

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