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TITLE: HUGONIOT EQUATION OF STATE OF MYLAR

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MYLAR

Mylar has been used for a variety of applications in shock loading experiments. In particular it has been utilized as thin flyer plates in damage threshold and Hugoniot measurements performed using exploding foil facilities and thus its Hugoniot "equation of state" is basic to the interpretation of these experiments. ~~Recently~~ an experimental determination of the Hugoniot of Mylar in the stress range 3 to 30 kilobars has been performed, which is, to our knowledge, the first accurate data that has been ~~obtained for th~~is material.

In the experimental method employed, a shock was initiated by impacting a flat target with a flat-nosed projectile accelerated by a compressed gas gun. The experimental arrangement is shown in Figure 1. The technique makes use of stress gauges whose principle of operation is based on the piezo-electric properties of quartz and which have been discussed in detail by R. A. Graham.[1] The target, a quartz gauge, is mounted at the end of an evacuated gun barrel and impacted by a precisely aligned flat faced specimen of Mylar attached to a projectile. The velocity of the projectile is accurately measured. The gauge signals are transmitted by co-axial cable to oscilloscopes for recording. The pin mounted ahead of the gauge is used to trigger these oscilloscopes.

In order to obtain a sample that could be mounted on a projectile, the Mylar specimen was made up of a number of layers of 0.014" thick Mylar. The layers were bonded together using a thermo plastic adhesive, Schjel-Bond.

[1] R. A. Graham, F. W. Neilson, W. B. Benedick
Piezoelectric Current From Shock Loaded Quartz - A Submicrosecond Stress Gauge, J. App. Physics

Overall sample thickness was approximately 0.25". The gauge records indicate that a jump in stress is impressed upon a specimen at the impact surface. The magnitude of this jump is calculated directly from the gauge signal as described in Reference 1.

For a one-dimensional experiment as performed here, conservation of momentum requires that

$$U_q = \frac{\sigma}{P_q D}$$

where U_q is the particle velocity imparted to the gauge taken with respect to its unstressed portion, σ is the stress, D is the shock velocity, and P_q is the initial density of the quartz. Further, if continuity of mass across the impact surface is assumed then

$$U_m = U_o - U_q$$

where U_m is the particle velocity imparted to the Mylar and U_o is the impact velocity of the projectile.

Thus, since U_o is measured, it is possible to calculate the stress and particle velocity in the Mylar if the Hugoniot for quartz is known.

The following relationships between the shock and particle velocity for quartz derived by R. A. Graham[1] were used in the analysis of the data.

For $0 < \sigma < 25$ kbars

$D = 5.740 - 0.14\ U_q$ (mm/μSec)

and for $25 < \sigma < 50$ kbars

$D = 5.57 + 1.08\ U_q$ (mm/μSec)

Figure 2 shows a typical gauge record. The effects of the layering of the Mylar sample can clearly be seen on the top of the pulse. However, it should be noted that the initial stress jump is in no way modified by the layering and the derived

Hugoniot refers only to the Mylar. The sheets of Mylar used in the laminations were 0.014" thick thus providing the rise-time of the stress jump is less than 0.2 μSec the impact interface can have no knowledge of the first bond prior to the gauge signal attaining its true initial amplitude.

The data obtained is tabulated in Table 1 and plotted in Figures 3, 4 and 5. The shock velocity of Mylar at zero stress, i.e., sound velocity, was measured using a pulse technique and was found to be 2.23 mm/μSec with a standard deviation, S, of 0.037 mm/μSec.

The experimentally derived stress-particle velocity data was fitted to a quadratic form using the principle of least squares. The data points were weighted according to the reciprocal of the product of the errors, i.e., the area of the rectangle occupied by the data on a stress-particle velocity plot. The curve was forced to pass through the origin.

The data was found to be represented by

$$\sigma = 31.290 \ U_p + 20.786 \ U_p^2$$

where σ is in kilobars and U_p is in mm/μSec.

Table 1. HUGONIOT DATA FOR MYLAR

Shot	Measured Stress Kbars	Particle Velocity mm/μSec	Shock Velocity mm/μSec	Compression, V/V_o
187	3.55 ± 0.2	0.110 ± 0.001	2.339 ± 0.06	0.953 ± 0.001
188	8.74 ± 0.1	0.238 ± 0.003	2.661 ± 0.03	0.911 ± 0.001
189	14.71 ± 0.5	0.372 ± 0.003	2.865 ± 0.10	0.870 ± 0.004
190	19.95 ± 0.35	0.485 ± 0.008	2.980 ± 0.05	0.837 ± 0.003
191	21.7 ± 0.3	0.519 ± 0.006	3.030 ± 0.04	0.828 ± 0.002
196	27.5 ± 0.6	0.622 ± 0.004	3.204 ± 0.07	0.806 ± 0.004

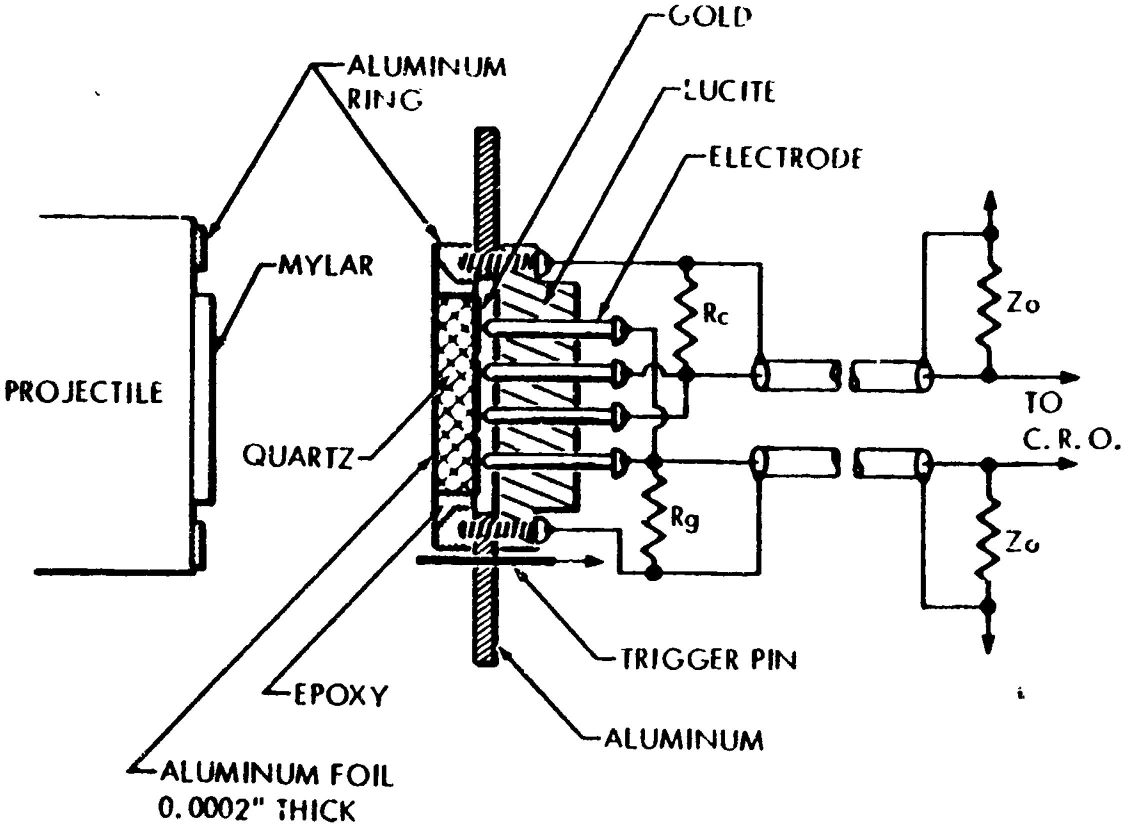

Figure 1 Experimental Arrangement

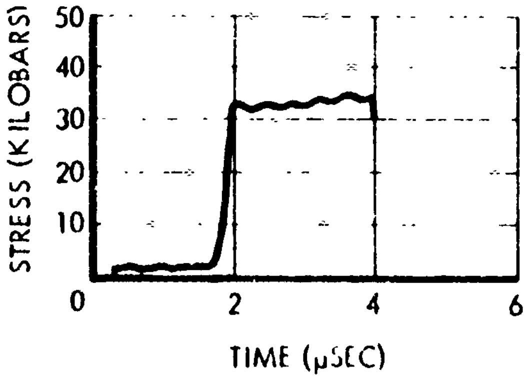

Figure 2. Typical Quartz Gauge Record

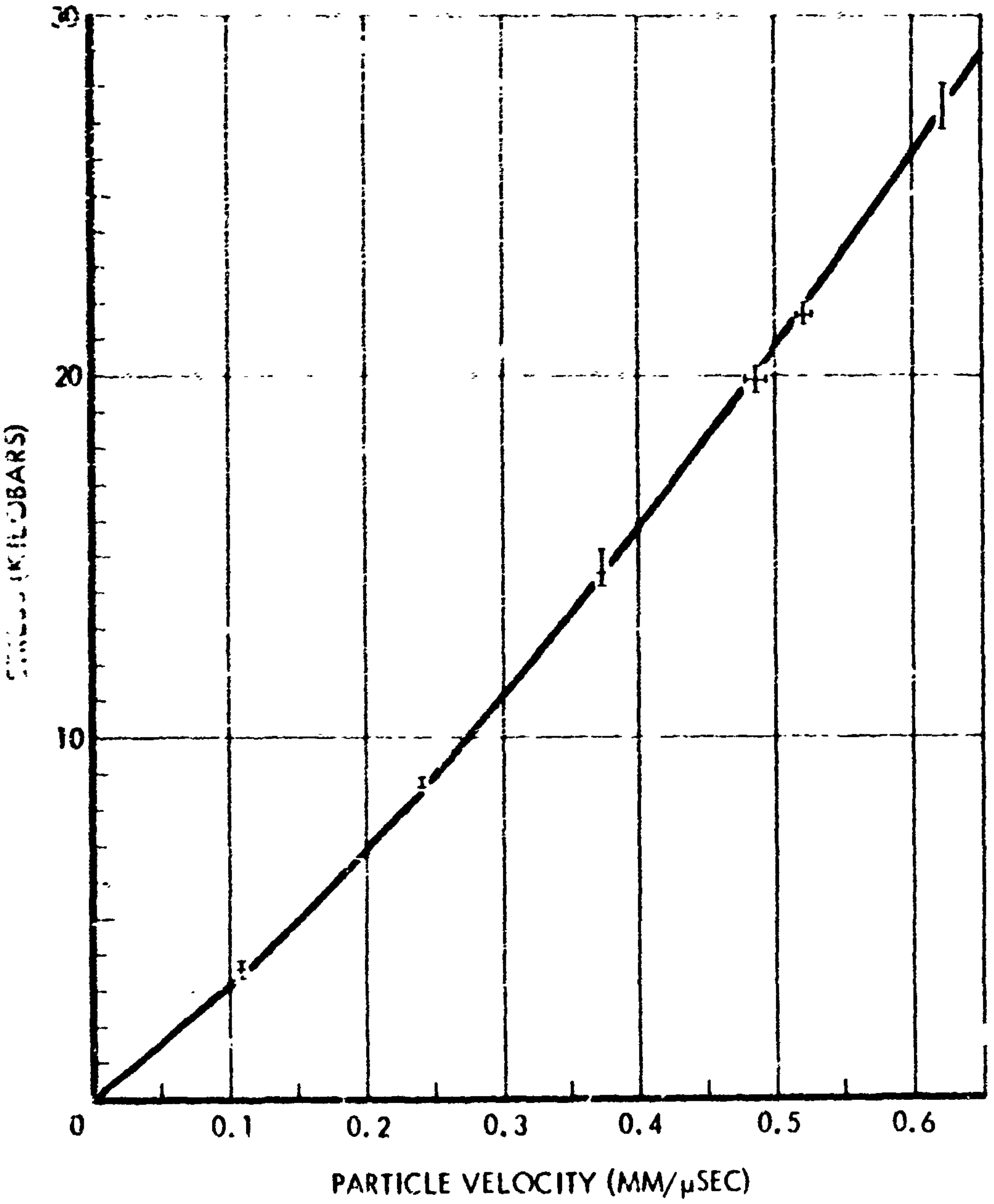

Figure 3. Stress as a Function of Particle Velocity for Mylar

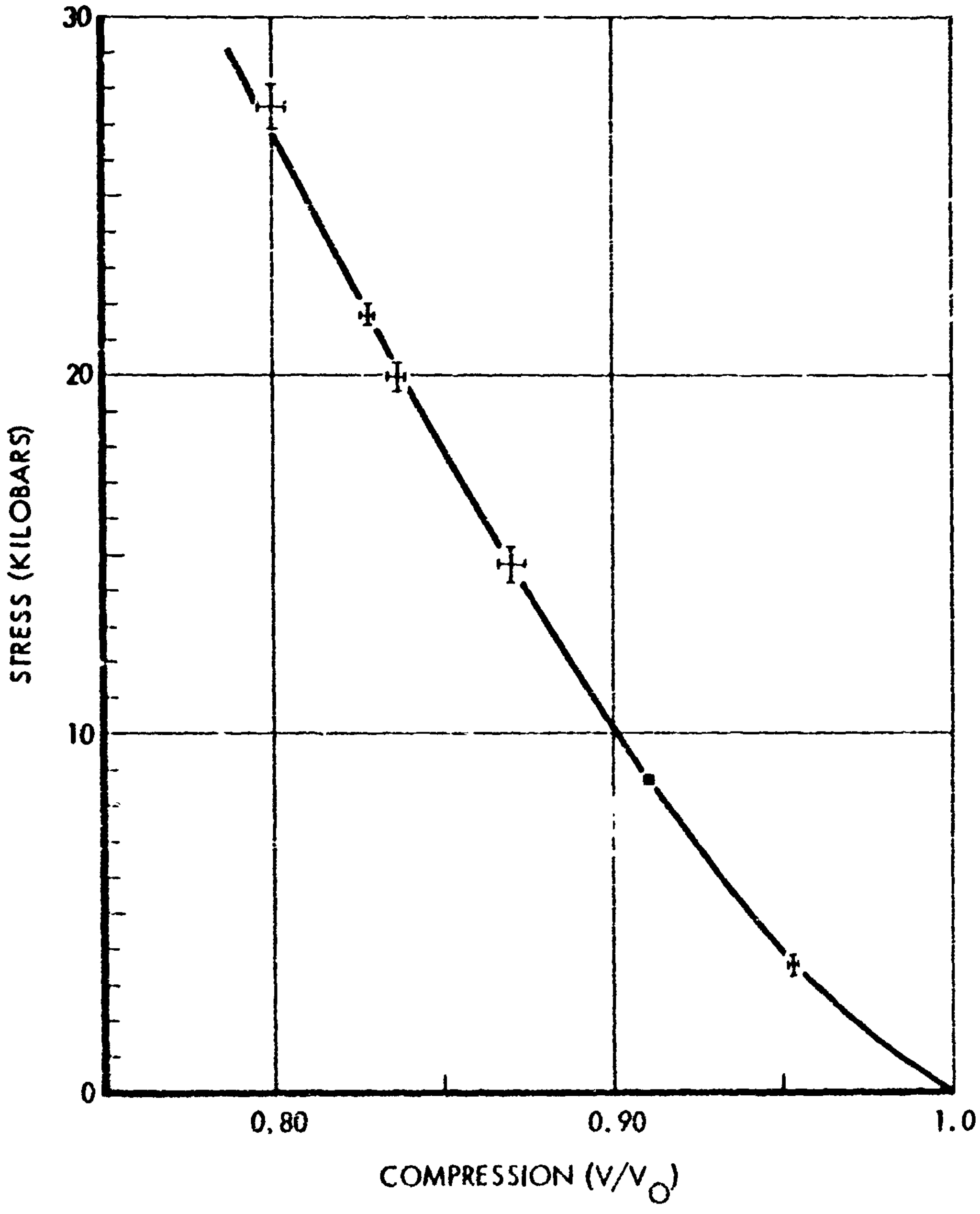

Figure 4. Stress as a Function of Compression for Mylar

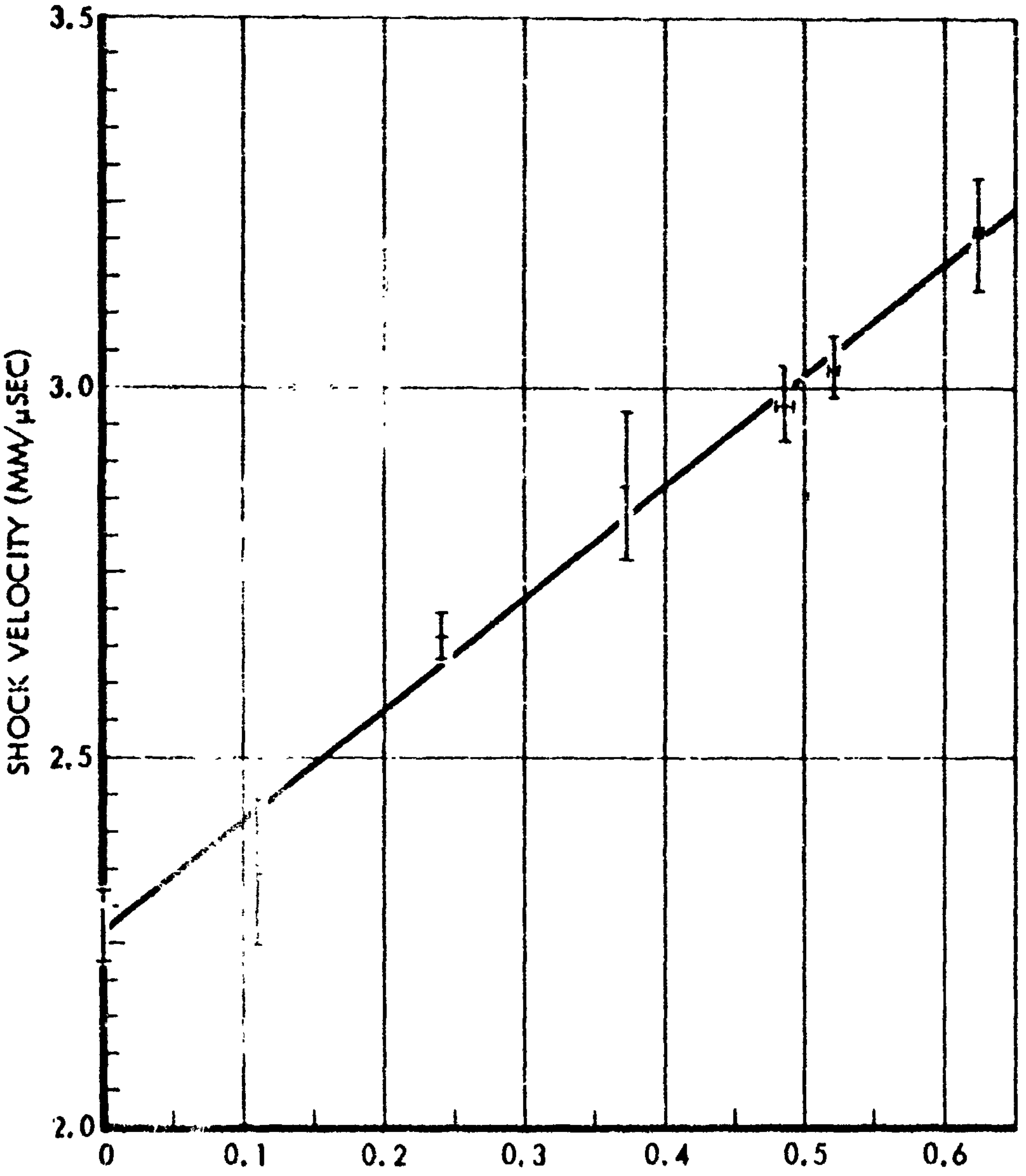

Figure [illegible]. Shock Velocity as a Function of Particle Velocity in Mylar

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