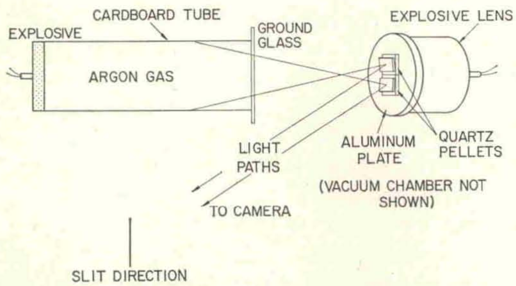

Fig. 3. Diagram showing relation of experimental assembly, light source, and camera.

manner is shown in Figure 4. The two specimens in this shot were Z-cut; the upper one was ⅛-inch thick and the lower one was ¼-inch thick. The final pressure was approximately 200 kb. At time T_0 the reflection from the rear (aluminized) face of the quartz extinguishes abruptly as the shock arrives at the quartz-aluminum interface. At time T_1 the first shock arrives at the quartz free surface. The traces are relatively smooth until the change in slope caused by the arrival of a second shock at time T_2; thereafter the traces are slightly irregular. A slight curvature to the trace of the first shock can be detected. This slowing up of the free surface is due to stress-relaxation effects, as was pointed out by *Wackerle* [1962].

The reason for the loss of reflectivity at the quartz-aluminum interface is not understood; however, it served as a distinct marker of the shock arrival time. That this trace does indeed occur at the proper time is shown by the experiments in which inclined mirrors were also placed on the aluminum surface. In those experiments the time of the first motion of the surface coincides with the traces due to loss of reflectivity.

The free-surface traces, as the free surfaces impact the lucite mirrors, are due in part to rotation of the mirrors resulting from the impact. This rotation changes the angle at which the mirrors view the light source. Note that between times T_1 and T_2 (Figure 4) the free-surface traces are evident because of brightening of the light intensity as the mirrors view the light source more nearly along its axis. The ground glass diffusing screen on the face of the light source is somewhat directional in its transmission. Distinct free-surface traces were obtained by adjusting the light source so that the line of sight from the free-surface mirrors initially intersected the side of the argon tube and did not intersect the shock in the argon (Figure 3). On rotation the free-surface mirrors directly view the argon shock, with consequent increase in intensity. The loss of reflected light as the second shock arrives at time T_2 is reproducible and, together with the change in smoothness of the trace, evidently signifies a change in character of the surface. These observations are consistent with the conclusion based on the data that the first shock causes

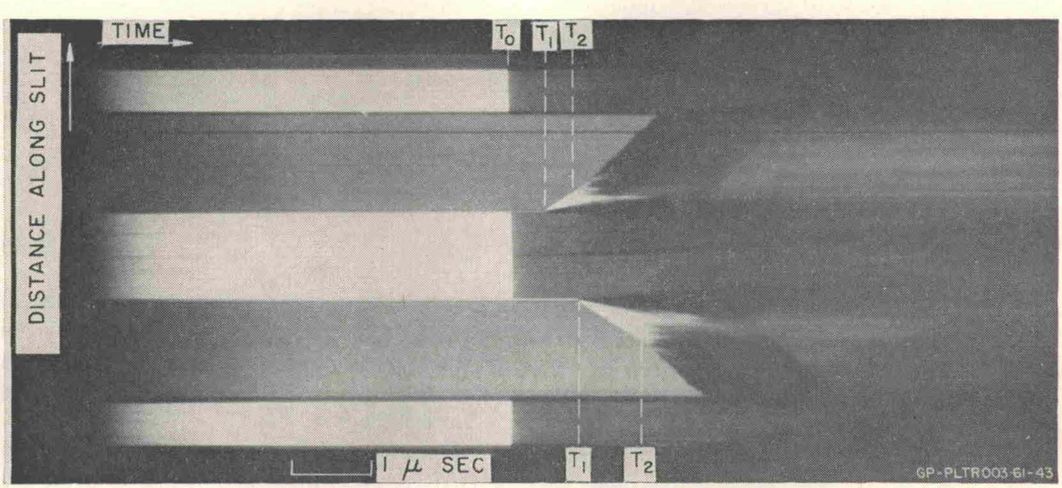

Fig. 4. Streak camera photograph showing shock arrival times and free-surface traces for shot 7394.

an irreversible change in the material—perhaps to a fractured state.

For reliable results the point of collision of the quartz free surface with the inside surface of the mirror must travel with supersonic velocity with respect to both quartz and lucite (non-jetting configuration). Consequently, the initial mirror angle must be less than approximately

$$\alpha_{max} = \sin^{-1} (u_f / U_s)$$

where u_f is the quartz free-surface velocity and U_s is the larger of the two shock wave velocities in quartz and lucite. This criterion restricted the usable mirror angles to less than about 8°.

Data reduction. The shock velocities were determined from distances measured on the film and the known writing speed of the camera. The velocity of the second shock requires corrections because of the motion of the free surface and because of the interaction of the second shock with the reflection of the first shock. The first of these corrections is straightforward, and a simple derivation gives

$$U_2 = \frac{d + u_{f1}(T_2 - T_1)}{T_2 - T_0} \qquad (1)$$

where d is the initial specimen thickness, u_{f1} is the free-surface velocity due to the first shock, and T_0, T_1, and T_2 are the arrival times of the shock fronts as shown in Figure 4.

The correction required by the interaction of the second shock with the reflection of the first requires knowledge of the state (and constitutive relation) of the quartz in the region between the two fronts and cannot be made unequivocally. The assumption that the material is stressed and relieved only elastically by the first wave leads, however, to a large correction and unreasonably high compression for the state behind the second shock in shot 7394 (Table 1). The results from that shot are the most sensitive to this correction because the second shock was relatively slow with respect to the first. For the other experiments the correction is smaller and does not appreciably affect the conclusions.

It should be emphasized, however, that the result for shot 7394 implies that an irreversible change in the material properties occurs between the two shock fronts. This conclusion is consistent with the observed relaxation of the state of the first shock and with the photographic observations just mentioned. It is not consistent with an assumption of elastic-plastic behavior as exhibited, for example, by aluminum [*Fowles,* 1961*b*].

Because of the arbitrariness of the interaction correction the data are here reported without such a correction. The correction used by *Wackerle* [1962] is plausible but does not significantly change the data of this paper.

The free-surface velocities were calculated from the measured slopes of the traces by means of the relation

$$u_f = \tan \alpha' / MF \tan \gamma' \qquad (2)$$

where α' is the effective angle of the inclined mirror with respect to the quartz surface, γ' is the angle of the trace on the film with respect to the space axis, M is the magnification or the ratio of the distance on the film to the corresponding distance on the shot, and F is the writing speed of the camera. The parameters α' and γ' of this relation are not identical to their nominal values α and γ because of tilt of the incident shock and slight departures from orthogonality of the slit and sweep directions. The corrections are given by

$$\tan \alpha' = \tan \alpha(1 + \theta'/\tan \gamma)$$

and

$$\tan \gamma' = \tan \gamma \sec \delta(1 - \tan \gamma \tan \delta)$$

where α is the angle of the inclined mirror with respect to the quartz surface, θ' is the angle of shock tilt as measured on the film, δ is the angle of the slit with respect to the normal to the sweep direction, and γ is the angle of the trace with respect to the slit direction (Figure 5).

The observed shock wave velocities and associated free-surface velocities are given in Table 1 with the initial conditions for each experiment and other quantities derived from the measured velocities.

The experimental precision based on assembly tolerances, camera resolution, and film reading errors is estimated to be ±1% in shock velocity and ±5% in free-surface velocity. Most of the