COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

Vol. 2 No. 3 Page Nos. 49–50 Date. 1 February 1963

Reprinted from: "*Applied Physics Letters*"

DOUBLE REFRACTION OF WATER AND SOME OTHER LIQUIDS IN STRONG SHOCK WAVES

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(Received 15 October 1962)

In the course of some investigations of the optical properties of liquids compressed by shock waves from explosions, we have observed that a number of pure liquids become anisotropic in the stressed region behind a shock front.

The method consisted, essentially, in photographing a shocked liquid between crossed polarizers, using uniform back illumination from a short-duration argon flash. Any region of optical anisotropy in the liquid appeared in the photograph as a bright area on a dark ground. In detail, the technique was an adaptation of one used earlier[2] to photograph shock waves by unpolarized light. The original arrangement was modified by inverting the explosive assembly (so that the shock wave moved into the liquid through the aluminum bottom of the cell) and by covering the two windows of the cell with pieces of Polaroid sheet cut in such a way that their directions of polarization were mutually at right angles and at 45° to the direction of travel of the shock front (see Fig. 1). Figure 2 shows a shock wave in water, photographed by this method. The double-refracting region appears as a bright area immediately above the advancing bottom of the cell. The diffuse appearance of the advancing front edge of the area is probably due to the curvature and unevenness of the shock front caused by the smallness of the driving charge and by inhomogeneities in the explosive (*cf.* ref 1). An independent measurement of the shock velocity, combined with Rice and Walsh's[3] equation of state for water, indicated that the conditions at the shock front at the time of the photograph were: pressure, 70 kbar; density,

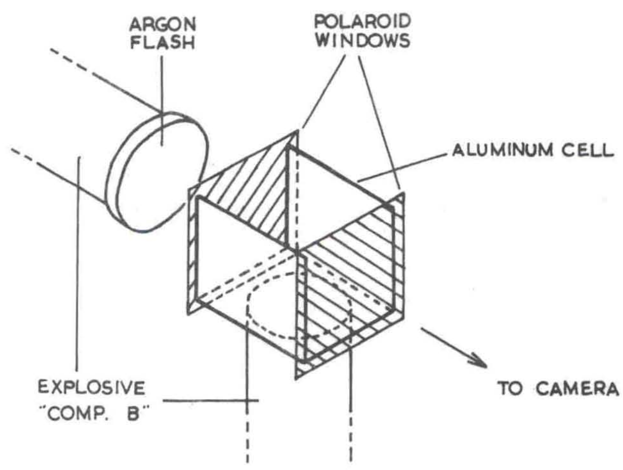

Fig. 1. A schematic diagram of the experimental arrangement. The hatching indicates the directions of polarization of the POLAROID windows. Light emitted by the products of explosion was shielded from the camera by steel masks (not shown).

INDEXING CATEGORIES

A. shock waves (in liquid)	
B. optical anisotropy	
C. crossed polarizers	
E	

1.56 g/cm^3; temperature, 370°C; flow velocity, 1.6 km/sec. A control experiment, in which the argon flash was fired in the absence of a shock wave in the water, proved that no light was transmitted under these conditions.

Fig. 2. Transmission of light through a shock wave in water viewed between crossed POLAROIDS. The back illumination was provided by a 0.2-μsec argon flash, fired about 1 μsec after the launching of the shock wave.

In addition to water, we have observed shock birefringence in methanol, acetone, n-heptane, 2,2,4-trimethylpentane and nitrobenzene. Attempts to detect the effect in carbon tetrachloride failed, presumably because this liquid becomes partially opaque in strong shock waves.[4]

It is very likely that the double refraction is caused by the presence of a large velocity gradient in the liquid behind the shock front. The phenomenon is basically similar to the Lucas effect,[5] in which anisotropy is induced in viscous oils by the action of ultrasonic compression waves. In our experimental arrangement the velocity gradient is associated with the Taylor wave of rarefaction which overtakes the shock front as the explosive pressure decays. Typically, the drop in flow velocity may be about 1 km/sec over a distance of 1 cm, corresponding to an average velocity gradient of 10^5 sec^{-1}. This is about a hundred times greater than the gradients that can be reached in ultrasonic waves, and the optical effects are correspondingly greater. None of the simple liquids which became double-refracting in our experiments had previously shown any detectable Lucas effect.

On the molecular scale, the anisotropy may arise either from partial orientation of the molecules in the direction of flow,[6] or from distortions produced in the molecules[7] and their distribution functions[8] by the velocity gradient. It should be possible to decide the relative importance of these factors by examining the behavior of liquids composed of effectively spherical polyatomic molecules (*e. g.*, methane) and of monatomic molecules (*e. g.*, argon).

We wish to thank H. G. David for his patient help in carrying out the experiments.

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