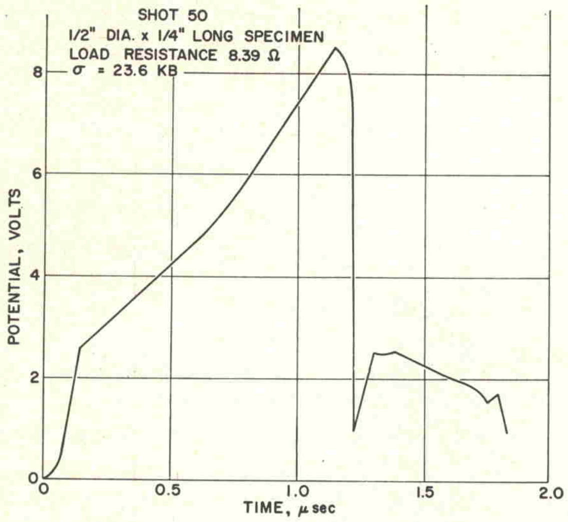

FIG. 4. Experimental current waveform for $D/l=2$.

quartz specimen is cemented to the impact face of the projectile so that an impact of quartz upon quartz is achieved. The dimensions of the quartz facing are chosen large enough to prevent the arrival of wave reflections at the specimen during the time of interest of the experiments. Figure 3 illustrates the impact end of the barrel showing projectile and specimen.

Since the impact occurs while the projectile is in the bore of the gun, it is necessary to measure the impact velocity in the bore of the gun. This is accomplished by three velocity stations 0.1000 ft apart with the last station 2 in. from the impact surface. The measurement is made by means of 0.010-in diam electrically charged pins which protrude through the side of the barrel. The projectile electrically grounds each pin during its passage, thereby discharging R–C circuits of short time constant characteristics. These signals are used to actuate two Hewlett–Packard 524C electronic counters with a least count of ± 0.1 μsec. By using three stations and two counters, the acceleration of the projectile can be measured and corrections made for the slight change in impact velocity from the last station to the impact surface. An error analysis of the system shows that the impact velocity obtained is accurate to a precision of at least 0.5%.

The quartz specimens used are short right circular cylinders of various diameters and lengths. The specimens used presently are x cut with the specimen oriented so that the x axis is aligned with the axis of the impacting projectile. With this arrangement, the stress wave produced by the impact travels along the x axis. The positive and negative electrical orientation of the x axis relative to the impact face is noted for all experiments. Polishing the specimen to a plate glass finish makes it possible to observe any visible flaws and to attain extremely flat surfaces.

The quartz specimen is placed upon an electrode of 7075 aluminum of the same diameter as the specimen and of a length long relative to the specimen. Aluminum was chosen to minimize acoustic mismatch and an epoxy potting was cast around the specimen and rear electrode for dielectric strength. This precaution is necessary due to the high electric fields developed as the stress wave propagates through the specimen. As shown in Fig. 3, the specimen and potting are placed in a Lucite specimen holder. This holder serves as a mold for the potting and as a means of attaching the specimen to the end of the barrel. The flat surface of the holder mates with a flat end surface of the barrel which is accurately perpendicular to the bore. The specimen holder is precisely machined after the specimen is assembled so that the flat mating surface is parallel to the impact face of the quartz within 0.0005 rad. With more elaborate care this can be held to 0.0002 rad.

Aluminum foil 0.001 in. thick was placed on the impact surface to serve as the front electrode. Both surfaces of the quartz used as the projectile facing were grounded with aluminum foil to prevent any of the charge developed on the projectile facing from being introduced into the circuit measuring the charge released from the quartz specimen.

When the specimen is attached to the end of the barrel, the bore of the gun is completely closed at both ends. To prevent air shock formation ahead of the projectile, pressure buildup as the projectile closes on the specimen, and the premature discharge of the various charged pins in the barrel, the barrel of the gun is evacuated to a pressure of approximately 10^{-2}mm Hg.

INSTRUMENTATION

The charge produced by a given impact is measured by means of a low resistance current-viewing resistor. The potential drop across this resistor as a function of time is observed on Tektronix 545 oscilloscopes using type L preamplifiers. The oscilloscopes and preamplifiers are calibrated frequently and precise time and voltage calibration traces are recorded on each record. Care is taken to position the traces on the same portion of the face of the oscilloscope with the pulse being recorded on the center 4 cm of the oscilloscope face. This is done to minimize errors caused by the nonlinearity of the oscilloscope face. The signal is transmitted through coaxial, low loss cable, RG-8/u. The traces are recorded on Polaroid type 47 film. The resistance of the current-viewing resistor is measured frequently to a precision of 0.2%.

The data from the Polaroid pictures are enlarged by a factor of about 5 by using a Telereader, a commercial optical data projector, in conjunction with a Moseley X–Y plotter. The charge release is obtained by mechanical and electronic integration of the area under the current versus time record for the initial transit of the stress wave through the specimen. Using the precautions as given above, the estimate of the experimental precision of the reduced charge data is $\pm 3\%$.

TYPICAL RESULTS

Typical current versus time records are shown in Figs. 4 and 5 for two different specimen geometries. It is seen that the exit of the wave front from the specimen is marked by a definite drop in the current. Although the current does not drop completely to zero in all cases, the record is well defined if one considers only the time corresponding to the initial wave transit. Times after initial transit are not well defined since slight acoustic impedance mismatches at the aluminum electrode quartz interface cause wave reflections of unknown amplitude. The amplitude of this reflected wave is also dependent on the stress for stress greater than the dynamic yield point of the aluminum. Also complicating the later times are unloading waves from the boundary which are still present in the crystal after the exit of the initial wave front.

The charge released due to the initial transit of the wave is taken as the integral of the current versus time record during the indicated transit time.

The variation in waveform with specimen geometry is quite typical and behaves in a predictable fashion. This is explained by an added piezoelectric response from the unloading waves propagating inward from the lateral boundary. Electrical fringing effects would also be expected to be present for certain geometries. As shown by the $d/l=10$ waveform in Fig. 5, the waveforms approach the ideal square current pulse for the less bounded solids.

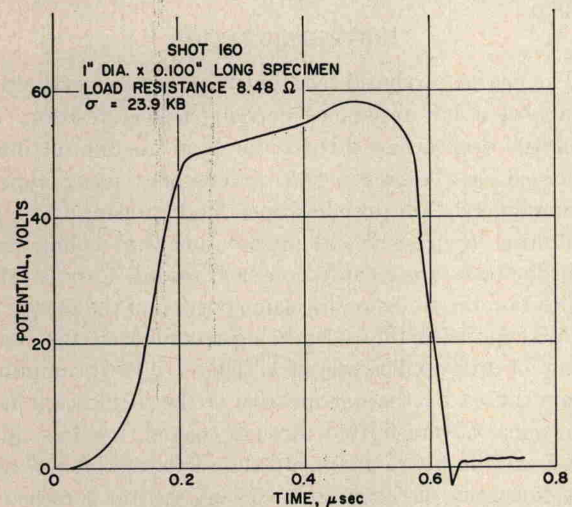

FIG. 5. Experimental current waveform for $D/l=10$.

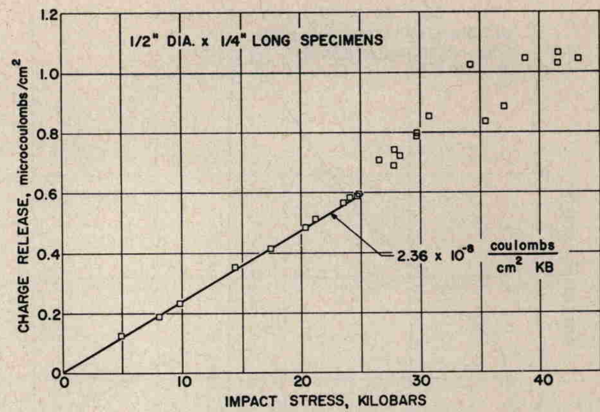

FIG. 6. Experimental piezoelectric relationship for $D/l=2$.

The piezoelectric behavior is illustrated in Fig. 6 by results published previously.[22,23] The experimental points shown in the linear range are all within $\pm 2\%$ of the linear least squares fit to the data. This is within the $\pm 3\%$ estimate of experimental precision for the charge data. A definite linear region is observed which extrapolates to zero within the experimental precision of the data. The slope of the line is an apparent piezoelectric constant which is found to be geometry dependent. The apparent constant approaches the low signal one-dimensional strain behavior for the large diameter-to-length specimens. Anomalies are also noticed in specimens oriented for negative electrical signal. A complete report on the results of the investigation is to be published later.

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