transducer and the sample crystal is critical. It must be completely free from gas bubbles as well as provide good acoustic coupling. If any gas bubbles are present at atmospheric pressure, at high pressure the sodium flows into the bubble space with accompanying distortion of the crystal. Early attempts, using paraffin as a cement, failed because there were reactive materials left in the paraffin to react with the sodium producing small bubbles in the bond. The procedure finally adopted was to maintain the crystal and transducer in a bath of the melted paraffin under a fore pump vacuum for several hours at a temperature of 70°C. After this time, the transducer was positioned on the crystal while both were in the bath. Then, both were removed from the hot paraffin bath and a small weight placed on the quartz to hold it in place while the crystal cooled and the paraffin seal froze. This treatment yielded consistently good bubble free bonds, and in addition annealed the sodium crystal before measurement. The paraffin seal will not transmit shear waves into stiff materials such as copper, but it apparently matches the acoustic impedance of sodium well enough to transmit both shear and longitudinal waves. The rf electrode was then painted directly onto the surface of the transducer with duPont 4817 silver paint. The sodium and/or paraffin deforms so easily that the quartz transducer does not break in spite of the large compressibility difference between quartz and sodium.

Measurements

For each crystal, appropriate longitudinal and transverse wave velocities, as well as the change of the velocities with pressure, were measured using the ultrasonic pulse echo method.[7-9] The details of technique for measuring the pressure derivatives are described in a recent article.[3] It will suffice to say here that the *change* of acoustic wave velocity as a function of pressure was measured as directly as possible, as the pressure was cycled up, then down several times. A typical raw data plot is shown in Fig. 2, giving the difference between time of arrival of a pulse echo of the C' wave,
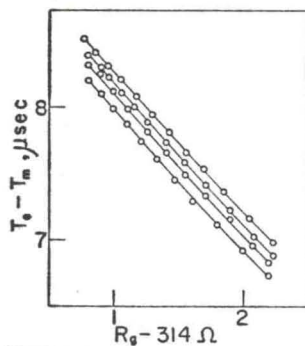

FIG. 2. Typical raw data plot showing difference between time of arrival of a pulse echo of the C' wave in a sodium crystal and a nearby time marker vs the pressure gage coil resistance. Four runs are shown; they have been separated slightly for clarity.

[7] H. B. Huntington, Phys. Rev. 72, 321 (1947).
[8] J. R. Neighbours and C. S. Smith, J. Appl. Phys. 21, 1338 (1950).
[9] J. R. Neighbours, F. W. Bratten, and C. S. Smith, J. Appl. Phys. 23, 389 (1952).

and a nearby calibration time marker, as a function of the change of the pressure gage coil resistance. The pressure range indicated is about 2000 bars.

We are interested in the initial slope of a curve such as Fig. 2. For the stiff materials copper, silver, gold,[3] aluminum and magnesium,[10] the curves plotted for change of transit time with pressure did not differ sensibly from a straight line, probably because the fractional change of volume of those materials was small over the 10 000 bar maximum pressure range used. The volume change of very compressible materials such as sodium is comparatively quite large over the same pressure range, so that appreciable changes in slope of such a plot may be expected. In practice the initial slope is difficult to obtain accurately from the data since the curve is not fitted well by a parabolic expression. In the interest of simplicity of data reduction and consistency of procedure from measurement to measurement, the data taken to obtain the initial or nearly initial slope of transit time with pressure,

TABLE I. Analysis and comparison of the values of the elastic constants of sodium. (Units are 10^{10} dyne cm^{-2}). The sample crystal orientation is listed after each value.

	$C = C_{44}$	$C' = (C_{11}-C_{12})/2$	C_{11}'[a]	$B_s = (C_{11}+2C_{12})/3$
Present	4.204[110]	0.587[110]	7.38[100]	6.62[110]
	4.190[100]	0.586[110]	11.01[110]	6.60[100]
	4.192[110]	0.586[110]		
		0.581[110]		
Average	4.19	0.585		6.61
Fuchs Theo. ($T=0°K$)	5.36	0.719		
Quimby and Siegel[b]	4.17	0.600		4.41
Bridgman[c]	...	...		6.65
Swenson[d]	...	...		7.25

[a] $C_{11}' = \rho v_{long}^2$, see reference (8).
[b] Extrapolated by us to 300°K from data taken over the range 80°K to 210°K.[11]
[c] B_T computed by us from isothermal dilatometric data and converted to B_s.[12]
[d] Computed from dilatometric data taken at 4.2°K.[13]

are restricted to a large number of points taken over the small pressure range 0–2000 bars. The procedure followed to estimate the initial slope was to make a least squares fit to a straight line covering data taken in the 0–2000 bar range. Thus the results obtained for the pressure derivatives are slightly lower than the true initial slopes. The systematic error is less than 5% in any case.

RESULTS

The room temperature values of the adiabatic elastic constants of sodium[11-13] are given in Table I. This table includes an analysis of the measurements made on each crystal in the present work, the elastic constants of sodium found by Quimby and Siegel[11] (which have been extrapolated by us to 300°K), and the value of the adiabatic bulk modulus derived from Bridgman's[12]

[10] R. E. Schmunk and C. S. Smith, J. Phys. Chem. Solids 9, 100 (1959).
[11] S. L. Quimby and S. Siegel, Phys. Rev. 54, 293 (1938).
[12] P. W. Bridgman, Proc. Natl. Acad. Sci. U. S. 21, 109 (1935).
[13] C. A. Swenson, Phys. Rev. 99, 423 (1955).