valuable in detecting the predicted phase change that exists between the second crystal echo and the buffer and first crystal echoes. (For aluminum and NaCl this phase inversion exists for all wave modes and crystal polarizations.) The double exposure photographs have also shown that a relative phase change sometimes occurs between two echoes and that this phase change increases or decreases as a function of position through the echo. This phase change was sometimes corrected by slightly altering the frequency of the pulse generator.

It is to be emphasized that the sample and seals were not disturbed during the transfer from liquid nitrogen to liquid helium. Furthermore, double exposure photographs (one exposure taken at 77·3°K and one at 4·2°K) showed that the wave shapes of the echoes did not change.

RESULTS

The quantity measured in this work was the transit time T of 10 Mc/s pulses in the crystals. From the transit time the velocity v of the wave is given by

$$v = \frac{2L}{T}, \tag{3}$$

where L is the length of the crystal. The elastic constant C_i is then given by

$$C_i = \rho v_i^2 = \rho \frac{4L^2}{T_i^2}, \tag{4}$$

where ρ is the density of the crystal. Since ρ and L change with temperature, these quantities had to be calculated at 77·3°K and 4·2°K and appear in Table 1 with other basic data used in calculating the results. The three elastic stiffnesses for cubic crystals of [110] orientation are $C'_{11}=\frac{1}{2}(C_{11}+C_{12}+2C_{44})$, $C'=\frac{1}{2}(C_{11}-C_{12})$ and C_{44}, corresponding to the three waves velocities, one longitudinal and two transverse. Although a [100] crystal was prepared, it was cleaved badly during a helium run and the data taken with this crystal is thought not to be reliable, except for the C_{11} mode at 77·3°K. Table 2 lists the velocities, elastic constants and adiabatic bulk moduli at 77·3°K and 4·2°K for the [110] crystal.

The length of the crystal at 295°K given in Table 1 is the average of 53 measurements made with a Starrett micrometer. The room temperature length of the crystal did not change during the sequence of runs to determine C'_{11}, C_{44} and C'. A back reflection Laue was taken to determine the crystal orientation ($\phi = 44° 56'$, $\theta = 90° 00'$); correction for this slight misorientation appear in the sixth place.

As explained above, the transit time measurements consisted of recording the helipot reading for several corresponding cycles in two successive echoes. This was done for the buffer–first crystal echoes and for the first–second crystal echoes. The precision of transit times measured in this way depends on several factors. The uncertainty due to the inability of the experimenter to set the helipot and due to the instability of the electronic equipment was not more than 0·05%. However, as mentioned above, the phase between two successive echoes sometimes changed slightly, creating different transit times between different parts of the echoes. These phase changes were not always

Table 1. *Basic data used in elastic constant calculations. The values at* 77·3°K *and* 4·2°K *are calculated from thermal expansion data*[6] *and the values at* 295°K. *An Avogadro's number of* $6{\cdot}02305\times10^{23}$ *was used in calculating the density*

		295°K	77·3°K	4·2°K
Molecular weight	58·448[4]			
Lattice constant (angstroms)		5·6393[7]	5·5983	5·5953
X-ray density (g cm^{-3})		2·1644	2·2123	2·2159
Linear coefficient of thermal expansion (10^{-6} deg^{-1})		39·9[6]	19·7	0·01
Length crystal A [110] (mm)		19·068	18·930	18·920
Isothermal bulk modulus (10^{11} dyne cm^{-2})		2·339[4]		

Table 2. Adiabatic elastic stiffnesses of NaCl *at* 77·3°K *and* 4·2°K. $C'_{11}=\frac{1}{2}(C_{11}+C_{12}+2C_{44})$; $C'=\frac{1}{2}(C_{11}-C_{12})$; *and* $B_s=\frac{1}{3}(C_{11}+2C_{12})$. C'_{11}, C' *and* C_{44} *are directly measured quantities on the* [110] *crystal*

	Mode	Longitudinal	Transverse	Transverse	
Polarization		110	1$\bar{1}$0	001	Adiabatic bulk modulus[2]
Elastic constant designation		C'_{11}	C'	C_{44}	B_s
77·3°K	Velocity[1]	4·661	3·205	2·457	2·715
	Elastic constant[2]	4·807	2·272	1·335	
4·2°K	Velocity[1]	4·678	3·236	2·457	2·739
	Elastic constant[2]	4·850	2·321	1·337	

[1] (10^5 cm/sec).
[2] (10^{11} dyne cm^{-2}).

present and never produced an uncertainty greater than 0·1%. The reproducibility of the transit time for any one given mode and polarization was found to be on the order of 0·2% or less. This result includes measurements made with different buffer rods (silica and other aluminum rods) and different seal materials (measurements involving different seal materials were made at 77·3°K only).

Even though there was good consistency between the buffer–first crystal time and between the first–second crystal time separately, the two transit times did not always agree. Where there was disagreement, the time between the two crystal echoes was greater by as much as 0·2% than the time between the buffer and first crystal echoes. This phenomenon has been observed previously in this laboratory and investigations to explain it are being planned. In this work only the transit time given by the buffer-first crystal echoes was used in calculating the elastic constants. The choice is based primarily on the fact that photographs of the leading edge of the second crystal echo showed a slight amount of signal mixing of the echo with spurious 10 Mc/s signal probably due to mode conversion and scattering off the side walls of the crystal and buffer rod. On occasions when the spurious signal appeared to be absent the two transit times were nearly in agreement. Considering the above factors plus the errors introduced in the thermal expansion calculations, it is thought that the absolute uncertainty of the elastic constants in Table 2 is no more than 0·5%. A measurement of C_{11} was obtained from the [100] crystal at 77·3°K prior to its cleaving, and it agrees with the value of C_{11} calculated from the [110] crystal data to better than 0·02%. Furthermore, even though the low temperature elastic constants determined from the [100] crystal are thought not to be reliable, they agree to within 0·3% of those elastic constants determined from the [110] crystal.

Table 3 shows a comparison of the 4·2°K elastic constants with other investigators. Comparison of these results with the recent work of LEWIS *et al.*[8] appears to be slightly outside the limits of uncertainty placed on the measurements, which suggests some sort of systematic effect. Measurements on the [110] crystal were made at room temperature using Salol as the seal material and the results agree with those of BARTELS and SCHUELE.[4] To compare various methods of measurement a series of materials have been measured in this laboratory using the buffer rod method and in the Olin Laboratory for Materials at Case using the pulse overlap method,[9] and agreement is found to be better than 0·1%.

LOW TEMPERATURE GRUNEISEN PARAMETER

WHITE[2] has measured the low temperature thermal expansivity of NaCl and at sufficiently low temperatures assumes the data can be fit to a