evidence of a nonstructural phase transition at $42° \pm 1°$ K. Several attempts to measure all of the elastic moduli between 4° and 42° K have been unsuccessful because of very large acoustic attenuation for the majority of the ultrasonic wave modes; some data in the 4° to 42° K range are however, given in [3]).

In addition to a complete set of results covering the 78° to 298° K range, ref. [2]) contains the temperature dependence of the principal compressional moduli, c_{11}, c_{22} and c_{33}, up to 573° K. To complete the data between 298° and 935° K it was necessary to experiment with various coupling media and to develop techniques appropriate for the propagation of both longitudinal and transverse ultrasonic waves in small single crystals at temperatures considerable above ambient in vacuum.

The incentive to complete the studies in this temperature range arose from several areas of interest. First, the linear compressibility in the [100] direction has a negative temperature dependence in the range of 42° to 298° K. This anomaly together with some neutron diffraction results of Mueller *et al.* indicate that some type of magnetic order may exist in alpha uranium at temperatures above 298° K [4]). Secondly, at temperatures above 298° K there are several anomalies in other properties of alpha uranium, including a negative thermal expansion in the [010] direction [5]), the temperature dependence of the electrical resistance [6]) and specific heat [7]) and a severe temperature dependence of the critical resolved shear stress for (001) [100] slip as a plastic deformation mechanism [8]). Friedel [9]) has suggested that the thermal expansion and specific heat anomalies are the result of thermally excited changes in the electronic band structure which cause a rupture of the strong binding between the two nearest neighbor bonds and a corresponding increased attraction between third and fourth nearest neighbors, the latter leading to an increase with temperature of the vibrational frequency for certain thermal modes and a consequent negative curvature in electrical resistance versus temperature curve. In the cases of hcp titanium and zirconium such negative curvatures correspond closely to pronounced positive curvatures in certain shear modulus versus temperature curves [10]).

2. Experimental procedures

2.1. Sample preparation

Eight different single crystal plates and six different crystal orientations relative to the plate faces were used in this study. The preparation, physical dimensions and orientations of the plates are given in [1, 2]). The samples ranged in thickness from 2 to 3 mm with lateral dimensions of 4 to 6 mm.

2.2. Measuring technique

The measurement of the change in ultrasonic wave velocity with temperature for each of the three wave modes possible to propagate in each of six different crystal directions was carried out using the phase comparison technique described in [2]). The basic equation is as follows:

$$\frac{V}{V_0} = \frac{t}{t_0} \cdot \frac{f_n}{(f_n)_0} \left[\frac{n + \gamma_0/2\pi}{n + \gamma/2\pi} \right], \qquad (1)$$

where V is the wave velocity to be determined at any given temperature relative to a reference velocity V_0, which is that, measured at 298° K. The wave frequency $(f_n)_0$ corresponds to n integral wave lengths in a sample thickness of $2\,t_0$ for a velocity V_0 at 298° K. Disregarding the quantities in square brackets, V at any given temperature can be obtained from a measurement of f_n corresponding to the same number of wave lengths, n, as were present at 298° K and from a calculation of t, the specimen thickness at that temperature, using existing thermal expansion data. The quantity in square brackets arises from the change in the phase angle γ with temperature, $\gamma/2\pi$ being the correction to n necessary to account for the phase shift within the coupling material. The evaluation of γ has been described by McSkimin [11]). In the present measurements this correction was neglected in view of the very small $\gamma/2\pi$ values estimated from the relative intensities of the reflected wave trains.