of the study one of the crystals was intentionally heated to $935^{\circ} \mathrm{K}$ to test the possibility that either the transformation temperature may be higher than $935^{\circ} \mathrm{K}$ with single crystals and/or that the transformation does not destroy the sample, as is the case for titanium and zirconium ${ }^{10}$ ). After cooling, this crystal was polycrystalline and physically deformed, indicating that neither of the above suppositions is correct.

### 2.4. Limitations caused by attenuation

A complete set of data for determining all nine elastic stiffness moduli and the available cross checks, or internal consistency tests, at all temperatures required that the velocities of 18 different wave modes be measured at intervals of $10^{\circ}$ to $20^{\circ}$ between $298^{\circ} \mathrm{K}$ and $923^{\circ} \mathrm{K}$. In fact, however, this schedule was not accomplished primarily because of acoustic energy losses within the uranium samples. These losses occurred for a majority of wave modes within
temperature regions which varied in range and limits and did not appear significantly affected by frequency changes within the range of $30 \mathrm{mc} / \mathrm{sec}$ to $50 \mathrm{mc} / \mathrm{sec}$. The losses were encountered in all samples, but only for certain wave modes and they occurred in reproducible temperature ranges during successive attempts to complete the measurements. In addition to these sample losses there occurred temperature and frequency dependent background losses caused by scattering of the acoustic waves within the buffer rods; consequently, it was not possible to measure the magnitude of the losses within the samples. The temperature ranges in which these losses prevented continuous measurements are given in table 1. The difficulties in measuring the shear mode velocities in crystal E above $300^{\circ} \mathrm{K}$ were apparently caused by a deformation kink produced during refacing the crystal after low temperature measurements were completed. The causes for the high attenuation above $325^{\circ} \mathrm{K}$ for both shear modes

Table 2
Equations used for evaluation of stiffness moduli

| Modulus | Equation | Temperature range ( ${ }^{\circ} \mathrm{K}$ ) |
| :---: | :---: | :---: |
| $c_{11}$ | Direct | 298-923 |
| $c_{22}$ | (1) Direct | 298-580, 650-850 |
|  | (2) $\frac{\varrho V^{2}{ }_{\mathrm{F}}+\varrho V^{2}{ }^{\text {FS }}-c_{11}{ }^{2} \cos ^{2} \theta_{\mathrm{F}}-c_{66}}{\sin ^{2} \theta_{\mathrm{D}}}$ | 298-740, 860-923 |
| $c_{33}$ | Direct | 298-923 |
| $c_{44}$ | (1) Direct, B | 298-375 |
|  | (2) Direct, C | 298-923 |
| $c_{55}$ | (1) Direct, A | 298-600, 825-923 |
|  | (2) Direct, C | 298-825 |
|  | (3) $\frac{\varrho V^{2} F-c_{44} \sin ^{2} \theta_{F}}{\cos ^{2} \theta_{F}}$ | 298-700, 823-923 |
|  | (4) $\varrho V^{2}{ }_{\mathrm{D}}+\varrho V^{2}{ }^{\mathrm{DS}}-c_{33} \cos ^{2} \theta_{\mathrm{D}}-c_{11} \sin ^{2} \theta_{\mathrm{D}}$ | 298-750 |
| $c_{66}$ | (1) Direct, B | 298-340 |
|  | (2) $\frac{\varrho V^{2}{ }^{2} S_{S}-c_{44} \cos ^{2} \theta_{\mathrm{D}}}{\sin ^{2} \theta_{\mathrm{D}}}$ | 298-923 |
|  | (3) $\varrho \varrho^{2}{ }^{\text {FL }}+\varrho \varrho^{V^{2}}{ }^{\text {FS }}-c_{11} \cos ^{2} \theta \mathrm{~F}-c_{22} \sin ^{2} \theta_{F}$ | $\begin{aligned} & 298-580,650-740 \text {, } \\ & 860-923, \text { from } \\ & \text { extrapolated } c_{22} \end{aligned}$ |
| $c_{12}$ | (1) $f\left(\varrho V^{2}{ }_{\mathrm{F}}, c_{11}, c_{22}, c_{66}\right)$ | 298-923 |
|  | (2) $f\left(\varrho V^{2}{ }_{\text {FS }}, c_{11}, c_{22}, c_{66}\right)$ | 298-740, 860-923 |
| $c_{13}$ | (1) $f\left(\varrho V^{2}{ }_{\mathrm{D}}, c_{11}, c_{33}, c_{55}\right)$ | 298-750 |
|  | (2) $f\left(\varrho \varrho^{2}{ }^{\text {DS }}, c_{11}, c_{33}, c_{55}\right)$ | 298-923 |
| $c_{23}$ | $f\left(\varrho V^{2}{ }_{\mathrm{E}}, c_{33}, c_{22}, c_{44}\right)$ | 298-923 |

