TABLE II. Adiabatic second-order elastic constants of columbium obtained in the present and in previous investigations. The in-Tible 11. Adiabatic second-order clastic constants of columbian obtained in the present and in previous investigations. The intigators of Refs. 24 and 27 used ultrasonic methods and Refs. 25 and 28 used the resonance method. The values for the present amples listed without parentheses were determined directly from the measured ultrasonic wave velocities and the other values were alculated from them.  $C_S' = (C_{11} - C_{12})/2$ ,  $C_L' = (C_{11} + C_{12} + 2C_{44})/2$ ,  $K = (C_{11} + 2C_{12})/3$ , and  $A = C_{44}/C_S'$ .

stain the third oreoi Ref. 20. The to elastic constants ! mal elastic const....

Temp. density A  $C_L'$  a C44 B C12 8 (°K) (g/cm³) C11 B Present Tresent (1.7108)(0.5013)0.56592 2.1831 0.28368 (1.3335)(2.4653)298 8.578 -ample 1 (0.5022)(1.7098)0.56618 2.1828 0.28431 (1.3323)2.4645 298 8.578 sample 2 (0.5017)(1.7102)0.5661 2.1829  $0.2840 \pm 0.0006$  $(1.333 \pm 0.007)$  $(2.465 \pm 0.005)$ 8.578 Best" values 298 revious 1.718 0.51272.187 0.2873±0.0011 0.5604  $2.456 \pm 0.0098$  $1.345 \pm 0.014$ 8.578 300 Kef. 24 0.5482

 $1.387 \pm 0.46$ 

 $1.26 \pm 0.11$ 

1.21

\* Units of 1012 dyn/cm2.

Sef. 27

Ref. 25

Kef. 28

in the calculational equation

300

298

RT

$$m_n = [F(C_{ij})/\Delta p](2\Delta f/f_0). \tag{2}$$

 $2.456 \pm 0.015$ 

 $2.40 \pm 0.11$ 

2.34

This equation was used to calculate the value of the dope m for each of the runs. Uncertainty limits for the slopes were established based on the estimated

8.5605

8.578

Δf = +0,00404 at 5000 psi 15.856 fo = 15.85171 Mhz  $\frac{0.5661 \times 10^{12}}{3.4474 \times 10^{8}}$  (2  $\frac{\Delta f}{fo}$  +  $\frac{\Delta f^{2}}{fo^{2}}$ ) = + 0.837 \$15.854 15.853 15.852 Pressure - 103 psi

Fig. 1. Example of data for a hydrostatic pressure run. The pen circles are data before correcting for temperature changes during the run. The temperatures at the start, middle, and end of the run were about 25.5°, 26.0°, and 25.0°C, respectively. After each 500 psi pressure change, about 15 min was allowed for the tomperature to approach equilibrium before frequency readings

uncertainty in  $\Delta f$  and in the stress, p. Examples of a hydrostatic pressure and a uniaxial stress run are shown in Figs. 1 and 2.

2.215

2.11

0.2930±0.0018 0.5345

 $0.2821 \pm 0.0004$  0.571

0.2809±0.0007 0.57

1.743

1.59

1.64

0.495

0.493

Because of the redundancy in the number of relations available to determine the values of the single-crystal TOEC, and the wide range of uncertainties in the values of  $m_n$ , the data analysis from this point is highly subjective. Several procedures were tried with only slightly different results, so only one of these are described. The hydrostatic pressure data was considered the most reliable and was found to have the best internal consistency based on the relations  $m_2 = m_5$ , and  $m_1+m_2=m_3+m_4$ , which can readily be shown. The hydrostatic pressure equations were then solved

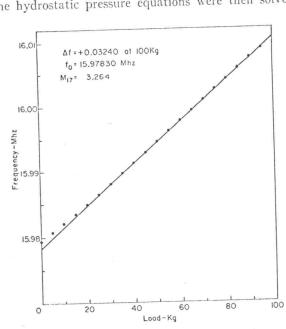


Fig. 2. Example of data for a uniaxial stress run. Some nonlinearity in the stress-frequency dependence at low stresses was often seen.

se samples caus aces in the threof the uniaxi. wave velocitiit no such differ tribution of the tency change

s for the TOE lations given l ables I-III i otropic medius here but will ! te single-crys' e given, and b ns. These eq. he second-ord ress in terms rd-order elast s are independ of the measure crimental sleps

 $\Delta f/f_0)^2 ]_n$ , 1

requency for - $\vdash F(C_{ij})$  is th nstants for the ion n in Table value observed nored resulting

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