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Linear Compressibility of Ice

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A novel technique of measuring the linear compressibility of ice at relatively low pressures (<0.5 kb) is described. A cathetometer was used in conjunction with a window-equipped pressure chamber to measure changes in the lengths of ice specimens compressed hydrostatically to 0.31 kb. A mean linear compressibility of 3.7 Mb^{-1} was obtained at −10°C, and the compressibilities perpendicular and parallel to the *c* axis of single crystals of ice were found to agree within 10%.

Few accurate data exist on the direct determination of the compressibility of ice in the low-pressure region (<0.5 kb). The most precise determination of the volume compressibility of ice in this low-pressure region would seem to be that measured by *Richards and Speyers* [1914], who obtained a value of 12 Mb^{-1} at 7.03°C in the pressure range 0.1–0.5 kb. This value was 2–3 times smaller than that indicated by the experimental data of *Bridgman* [1912] over the same pressure range. However, compressibilities computed from measurements of the elastic constants of single-crystal ice [e.g., *Jona and Scherrer*, 1952; *Bass et al.*, 1957; *Dantl*, 1969] all tend to confirm the experimental determination of Richards and Speyers.

In this study we have measured directly the linear compressibility of several types of air-free, crack-free chemically pure ice. The technique used eliminates the need for jacketed samples, permits measurements of compressibility as a function of crystallographic orientation of the specimens, and does not require knowledge of either the compressibility of the pressure medium or the volume changes occurring during compression. Our data are believed to be the first direct measurements of the linear compressibility of ice.

EXPERIMENTAL METHODS

Details of the experimental setup are illustrated in Figure 1. Major components of the test apparatus included a reservoir tank with an auxiliary pump, a manually operated 11-cm^3 displacement pump, an accurately calibrated Heise pressure gage, and the pressure chamber. Water-saturated kerosene was used as the pressure medium. The pressure chamber comprised a standard 12.7-cm ID pressure vessel, which could be securely bolted at one end and was fitted at the other end with a 7.6-cm-thick pressure sight glass. A Beck 1-meter-range cathetometer fitted with a 2.5-cm-range micrometer was mounted in front of the pressure window to measure directly the change in length ΔL of a specimen of ice of length L_0 compressed hydrostatically from zero gage pressure to 0.31 kb (ΔP). Accordingly, we can express the linear compressibility θ as

$$\theta = -(1/L_0)(\Delta L/\Delta P) \qquad (1)$$

Absolute accuracy of the pressure reading at 0.31 kb is estimated at 1.8 bars, i.e., 0.55%. All measurements were conducted in a temperature-controlled cold room maintained at a temperature setting of −10°C. However, temperatures in the chamber were monitored with a thermocouple to ensure that the total temperature difference during tests did not exceed 0.3°C. It was calculated that the correction for thermal expansion (or contraction) could be ignored if the temperature difference was held to <0.3°C.

Measuring technique. The technique used to measure linear compressibility is illustrated in Figure 2. Prisms of ice measuring 8.0 cm × 1.0 cm × 1.5 cm were frozen carefully to the base of a T-shaped aluminum support. Thin strips of moderately stiff photographic paper were laid carefully across the stem of the T