esting to study the light transmission, over a large frequency range, of films prepared by the techniques of Appleyard and Misener[5] and of Shalnikov,[6] i.e., of films, deposited at sub-liquid air temperatures, for which there is no possibility of agglomeration.

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Viscosity of Glass as Affected by Dissolved Gases

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WHEN ordinary glasses of commercial types are melted and subjected to a vacuum, large quantities of dissolved gases are liberated causing considerable foaming of the molten glass. Although numerous investigations have been concerned with the composition of these gases, which consist of SO_2, O_2, H_2O, CO_2, and N_2 in amounts depending on the glass batch used, the effects of dissolved gases on the properties of the glasses have not been studied thoroughly.

We have made preliminary experiments dealing with the effect of dissolved gases on the viscosity of glass, the general method of attack being to melt the glass in vacuum in order to obtain gas-free glass and then to saturate different samples of this glass with various gases. The latter procedure consisted in melting the glass in a platinum crucible and bubbling the test gas through the melt by means of a platinum tube immersed in the molten glass.

Viscosity measurements by the fiber-elongation method indicate that the presence of CO_2 and H_2O decreased slightly the viscosity of a commercial soda-lime-silica glass at the annealing and strain points, as shown below. The precision of these measurements is ±2°F (Table I).

Table I.

	Softening pt. °F	Annealing pt. °F	Strain pt. °F
Glass melted in vacuum	1341	1018	960
Glass treated with CO_2	1344	1008	950
Glass treated with H_2O	1336	1004	949

The softening, annealing, and strain points correspond to viscosity of $\log \eta = 7.65$, 13.4, and 14.6, respectively.

Additional tests on viscosities of glasses made at temperatures up to 2500°F with a Bureau of Mines design of viscometer have not been conclusive. In these experiments the viscosity of a gas-free glass contained in a platinum cylindrical crucible was measured in an atmosphere of CO_2 or air containing water vapor. It was thought that the slow solution of the test gas in the glass would produce a change in viscosity.

Within experimental error no change in viscosity of the molten glass was noted, although the glass was held at these high temperatures for a period of two weeks. Whether the glass viscosity at high temperatures is unchanged by dissolved gases or whether the rate of solution of gas in glass under these conditions is insignificant has not been proven.

R-F Heating Cyclotron Filaments

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IN the construction and operation of radiofrequency generators as a source of power for the heating of the filaments of cyclotrons, it is customary to locate the radiofrequency oscillator itself at the control position to facilitate adjustment. This requires the use of a long transmission line between the oscillator and the cyclotron ion source and a consequent loss of energy due to the high currents flowing therein. It is suggested that the oscillator frequency be selected so that the transmission line may be made one quarter wave-length in length at the mean operating frequency of the oscillator. By this expedient the impedance looking into the transmission line from the oscillator will be very nearly a pure resistance of value equal to Z_0^2/Z_f where Z_f is the impedance of the cyclotron filament itself, and Z_0 is the characteristic or iterative impedance of the transmission line. By having a pure resistance load connected to the oscillator, the effects of slight changes in impedance of the ion source filament during operation will not affect the oscillator nearly as much as when it is operating into a random length of line and feeding a reactive load. The losses in such a system will be much less than those in present-day arrangements due to the elimination of wasteful reactive currents in the line. It will also be easier to couple efficiently from the oscillator to the line due to the use of the higher load impedance on the oscillator.

On the Possible Use of Brownian Motion for Low Temperature Thermometry

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THE thermodynamic scale of temperature below 1°K is at present based on a combination of calorimetric and magnetic measurements[1] which, although rigorous, requires elaborate time-consuming techniques. For this reason, it appears worth while to consider alternative possibilities of establishing a thermodynamic scale which may prove to be experimentally somewhat more adaptable.

In principle at least, one may use the Johnson noise developed by a resistor R at temperature T. Nyquist[2] has shown that the mean square fluctuation voltage developed by such a resistor is given by

$$\langle V^2 \rangle_{\text{Av}} = 4kTR\Delta f, \tag{1}$$

where k is Boltzmann's constant and Δf is the frequency range of the voltage fluctuations admitted to the detector. Unfortunately, a practical limit to the use of Eq. (1) is set by interference with the measurement, arising from shot noise in the grid and plate of the first amplifier tube. The shot noise arising from plate current is equivalent to the Johnson noise from a resistor of approximately $3r_p/\mu$ ohms at 300°K in the grid circuit. The shot noise from the grid current is given by

$$\langle V^2\rangle_{\text{Av}} = 2eI_gR_g{}^2\Delta f. \tag{2}$$

If we assume that Johnson noise must be at least as large as the extraneous shot noise, the lowest temperatures measurable with amplifiers employing ordinary commercial tubes are of the order of a few degrees Kelvin. However, if the first stage of the amplifier uses a Western Electric D-96475 electrometer tube, for which $r_p \leqq 25{,}000$ ohms, $\mu \leqq 3$, and $I_g \leqq 10^{-15}$ ampere, then by using a grid resistance of 10^9 ohms as a source of thermal noise, one may estimate that the lowest temperatures measurable are of the order of 0.01°K. With an input capacity of $30\mu\mu$f (probably a practical minimum), a grid resistance of 10^9 ohms yields a band width in the input circuit of about 5 cycles/sec. Thus, if the noise is integrated over 20 seconds, an accuracy of about 10 percent is attainable, using an amplifier with a pass band from about 2 to 3 cycles/sec. and a sensitivity of about 10^{-7} volt. Although such amplifiers have been built, they are rather expensive and require considerable care in adjustment and use. Furthermore, a grid resistance of 10^9 ohms implies the use of a semi-conductor such as carbon, and will therefore have an exponential temperature coefficient of resistance at the temperatures of interest. This circumstance introduces additional experimental difficulties which, although surmountable, lead one to consider alternative possibilities.

A comparatively simple thermometer based on the detection of Brownian motion appears to be provided by a quartz crystal bar. Consider one mode of mechanical vibration of such a bar, say, for simplicity, the fundamental mode of extensional vibrations parallel to the long dimension a, which we shall assume to be along the X axis of the crystal. By the equipartition law, the potential energy of vibration stored in this mode as a result of Brownian motion must equal $\frac{1}{2}kT$. Thus, denoting by s_{11} the elastic modulus and by b and c the other two dimensions of the crystal, we find for the mean square fluctuation in stress

$$\langle X_x{}^2\rangle_{\text{Av}} = (2kT/abc)(1/s_{11}). \tag{3}$$

Owing to the piezoelectric properties of quartz, a mean square fluctuation in voltage will be generated between the faces of the bar normal to the Y axis of the crystal, given by

$$\langle V^2\rangle_{\text{Av}} = \frac{32\pi^2}{ab}\frac{c}{\epsilon^2}\frac{d_{12}{}^2}{s_{11}}kT, \tag{4}$$

where d_{12} is the appropriate piezoelectric modulus and ϵ^2 is the dielectric constant. Equation (4) is based on the assumption that $h\nu \ll kT$. This condition, however, is not violated at 10^{-4} °K if ν is less than 10^7 cycles/sec. Taking $s_{11} = 1.3\times 10^{-12}$ cm²/dyne, $d_{12} = 6.9\times 10^{-8}$ e.s.u., $a = 5$ cm, $b = 0.1$ cm, $c = 1.0$ cm, and $\epsilon = 4.5$, one obtains

$$\langle V^2\rangle_{\text{Av}} = 1.4\times 10^{-12}T, \tag{5}$$

where V is in volts and T is in degrees Kelvin.

The operation of this device is based on the high Q (low damping capacity) of a quartz vibrator, since then all the energy in a particular mode will be concentrated in a very narrow range of frequency in the neighborhood of 50 kc. For instance, reasonable precautions ensure Q's of the order of 5×10^4 for such bars. With such a Q, the internal resistance of the quartz is only a few thousand ohms, so that an input resistance of 10^5 ohms is adequate. Thus, a sharply tuned amplifier with a band width of a few cycles and an input resistance of 10^5 ohms should, according to Eq. (1) and Eq. (2), permit the measurement in a few seconds of temperatures of the order of 0.001 °K with a precison better than one percent. With careful design of the input stage and selection of low noise input tubes, measurement of temperatures as low as 0.0001°K may be possible.

Several remarks should be added. Since both $\partial s_{11}/\partial T$ and $\partial d_{12}/\partial T$ must vanish at $T = 0$, a negligible error should be introduced by calibrating the thermometer at the boiling point of helium and then extrapolating. This procedure avoids the necessity of measuring s_{11} and d_{12} at each temperature which, though simple, is time consuming.

The principal experimental difficulty with the thermometer will be to insure good thermal contact without decreasing the Q of the oscillator. One feasible procedure would be to isolate the crystal mechanically (and thus thermally) for the short period necessary to measure $\langle V^2\rangle_{\text{Av}}$ after achieving equilibrium. There appears to be some possibility of preparing a crystal which is both paramagnetic and piezoelectric (e.g., $NiSO_4\cdot 7H_2O$, a poor example), and using the thermometer itself as a bath.

The values inserted in Eq. (4) were room temperature values. At lower temperatures these values will be somewhat different but should not change sufficiently to invalidate the main result.[3]

Unfortunately, the facilities required for an experimental test of the proposed device are not at present available to us. However, the preliminary considerations presented here seem sufficiently promising to warrant the consideration of active cryogenic investigators.

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[2] H. Nyquist, Phys. Rev. **32**, 110 (1928).

[3] Cf. W. G. Cady, *Piezoelectricity* (McGraw-Hill Book Company, Inc., New York, 1946), pp. 221–223.

The Power Spectrum of the Cosmic-Ray Cascade Component

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SEVERAL components of the cosmic radiation have been shown to follow at their point of origin a power law of the form $F(E) = \text{const. } E^{-1.8}$, where $F(E)$ is the number of the particles of energy greater than E.[1,2] If one