Our results agree in some respects with the recently published measurements of millimeter wave absorption in tin,[10] in that we also find a decrease in the effective transition temperature below the dc value. The tin work shows the presence of superconductivity to energies of $1.95kT_c$ in agreement with our results which extend to $2.33kT_c$. However, the structure in the curves of Fig. 2 is not reported in the work on tin. The results of both the tin and aluminum measurements disagree with the prediction by Galkin and Bezuglii[11] that the difference in absorption between the superconducting and normal states disappears when $h\nu \gtrsim kT_c$. This prediction was based on an extrapolation of their measurements which covered the range $0.24kT_c < h\nu < 0.58kT_c$.

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[6] K. G. Ramanathan, Proc. Phys. Soc. (London) **A65**, 532 (1952).
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[8] Stainless steel has sufficiently low electrical conductivity so that the classical formula for absorption is applicable. Thus, the absorptivity of the stainless steel may be calculated from its measured dc resistivity.
[9] R_s and R_n, the surface resistances in the superconducting and normal states respectively, are defined as the ratios of powers absorbed to the square of the *rf* magnetic field at the surface.
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Mason's Dislocation Relaxation Mechanism

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IN a recent article Mason[1] has proposed a dislocation relaxation model which could possibly explain Bordoni's low-temperature internal friction peak. It is the purpose of this note to show that Mason's mechanism probably gives rise to an internal friction peak which occurs at a much lower temperature than those observed by Bordoni.

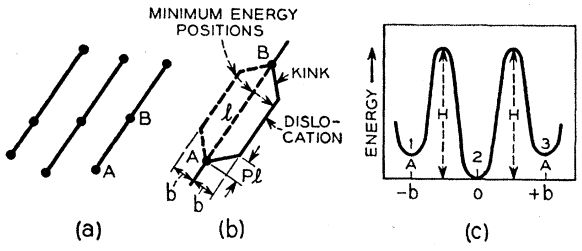

FIG. 1. Model proposed by Mason for dislocation relaxation.

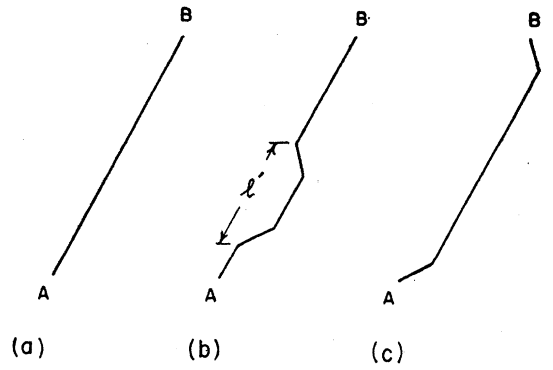

FIG. 2. Low-energy dislocation relaxation model.

Mason considered the situation pictured in Fig. 1. A dislocation segment is assumed to be pinned at two points. The lowest energy position is that in which the dislocation is perfectly straight. If there is a strong Peierls force, there are other equilibrium positions in which the dislocation is kinked [Fig. 1(b)]. The dislocation segments will thus be situated in potential wells [Fig. 1(c)]. An internal friction peak will occur when the jump time of a dislocation segment in moving from one equilibrium position to another is equal to the period, τ, of the applied cyclic stress. The temperature at which the peak occurs is thus given by

$$\tau = \nu^{-1} e^{H/kT}, \tag{1}$$

where ν is the natural frequency of vibration of a dislocation line in its potential trough, and H is the energy shown in Fig. 1(c). Mason calculated H by assuming that the whole dislocation segment between B and A (Fig. 1) moves together. He found that $H = \sigma_p b^2 l/\pi$, where σ_p is the maximum Peierls force, b is the length of the Burgers vector, and l is shown in Fig. 1.

Actually it is not necessary for the whole dislocation segment to move at once in going from one equilibrium position into another. Figure 2 shows another way in which this might be accomplished. Here a smaller kinked segment moves first over the potential hill and then expands into a longer segment. The energy involved in going from Fig. 2(a) to Fig. 2(c) is only $\sigma_p b^2 l'/\pi$, where l' is shown in Fig. 2. A lower limit on l' is reached when this length becomes comparable to the length of the kinks. Mason gives the approximate value $(\mu/\sigma_p)^{\frac{1}{2}}b$ for the length of a kink, where μ is the shear modulus. The lowest activation energy required to move a dislocation segment from one equilibrium position into another is thus of the order $2\sigma_p b^3(\mu/\sigma_p)^{\frac{1}{2}}/\pi$ instead of the value Mason calculated. Substituting this value into Eq. (1) gives for the temperature at the internal friction peak the expression

$$T = 2b^3(\mu\sigma_p)^{\frac{1}{2}}/\pi k \log \tau\nu. \tag{2}$$

Consider what T should be for copper. Using the values $\sigma_p = 1.9\times10^6$ dynes/cm^2 (Mason's estimate), $\mu = 3.2$

$\times 10^{11}$ dynes/cm^2, $b=2.55\times10^{-8}$ cm, $\tau=10^{-4}$ sec, $\nu=10^{10}$ sec^{-1} (Mason's estimate), one finds that the peak should occur at 4°K, a temperature twenty-four times smaller than the experimentally observed one. Agreement between theory and experiment could be had if σ_p were about 600 times larger than the value used above. Such a large value, however, would be in disagreement with a critical shear stress for copper found by Blewitt[2] (2×10^7 dynes/cm^2 at 4.2°K). It does not seem likely, therefore, that Mason's mechanism can account for Bordoni's peaks. It may, however, give rise to internal friction peaks in the liquid helium range.

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Comments on Weertman's Dislocation Relaxation Mechanism

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THE production of small loops at low temperatures by the combined thermal vibrations of all the normal modes of a dislocation considered as a stretched string probably occurs as suggested by Weertman.[1] However, it can be shown that these do not grow into larger loops at any temperatures of interest and contribute very little to the attenuation except at low temperatures. Furthermore, for lead they will contribute less than the least measurable internal friction $Q^{-1}=10^{-6}$ below 8°K. The least detectable friction in quartz of $Q^{-1}=10^{-7}$ does not occur below 6°K.

If we assume a small loop such as shown by Fig. 1 and consider that it maintains its form during the vibration, the potential well model resulting is the one shown on Fig. 1. The height A of the secondary wells and the difference between the potential maximum H and A are given by

$$A=2b^3[(T_{13})_0\mu/2\pi]^{\frac{1}{2}},\quad H-A=[(T_{13})_0b^2l_0/\pi]^{\frac{1}{2}},\quad (1)$$

where b is the Burgers vector, $(T_{13})_0$ the maximum value of the Peierls stress, μ the shear elastic constant along the glide plane, and l_0 the width of the flat part of the dislocation in the next minimum energy position. With this model it can be shown that the internal friction Q^{-1} is given by the equation

$$Q^{-1}=\frac{2e^{-A/RT}}{1+2e^{-A/RT}}\left[\frac{N_0(l_0+pl)^2b^4\mu}{kT}\right]\frac{\omega/\omega_0}{1+(\omega/\omega_0)^2},\quad (2)$$

where $\omega_0=\gamma\exp[-(H-A)/RT]$. The quantity pl is the length of one kink which for lead is about 1.8×10^{-5} cm. γ has been calculated to be 7.85×10^9 sec^{-1} and measured as 5.3×10^9 sec^{-1}. Figure 1 shows calculations for the longitudinal Q^{-1} [1/5.2 times the shear loss of Eq. (2)] at 26.5 Mc/sec. This corresponds with the measured results in a previous paper.[2] The Q^{-1} associated with various loop lengths l_0, from 2×10^{-5} to 3.2×10^{-4} cm, are shown. The number of loops assumed is 10^{10} per cubic cm, a typical value for pure lead. At low temperatures, for which only small thermal energies are available, small size loops will be generated. Since the larger sized loops will be associated with the highest internal friction, the peak of the internal friction curve will be associated with the lengths close to the full distance between pinning points. Theoretically second, third, and higher harmonic loops can be generated, but

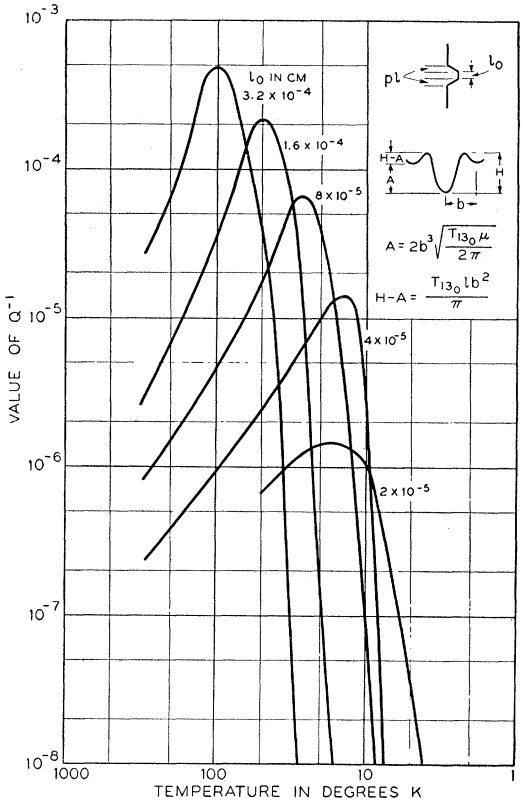

FIG. 1. Small dislocation loop, potential well model, and resulting attenuation curves for various values of l_0 for 10^{10} dislocation loops per cubic centimeter.

these will be associated with 2, 3, and more values of A and hence will have much higher temperature "cut-off" points and lower peak heights. Hence, as long as the loop shape remains unchanged, the only effect of including all of them in the calculation is to indicate more short loops than would occur in the material. In lead[2] the measurements show no dislocation loss of as much as $Q^{-1}=10^{-6}$ below 8°K, and in quartz[3] no dislocation loss as much as $Q^{-1}=10^{-7}$ below 6°K.

Weertman now assumes, without suggesting a mechanism, that a small loop will grow into a large loop due to the applied stress coupled with thermal