have an inhibitive effect on the formation of the Bénard convection, as was recently demonstrated by Nakagawa². Chandrasekhar³ also points out that with motions at right angles to the magnetic field, the 'closing in' of the lines to produce the usual Bénard cell patterns becomes increasingly difficult. He also mentions that the lines around sunspots (photographed in hydrogen radiation) may be due to the inhibitive effect of their magnetic fields.

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² *Nature*, **175**, 118 (1955).

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Relation between the Initial Instantaneous Extension in Creep and the Yield Stress and Coefficient of Work-hardening in Polycrystalline Metals

IN the course of work on the creep of polycrystalline lead (99.99 per cent) under constant stress in the range 20–105°C., a full account of which is being prepared, it was found possible to measure the initial instantaneous extension with reasonable accuracy at the lower end of the temperature scale. At higher temperatures the period of low strain-rate, which intervened between the termination of the initial extension and the onset of the transient creep, diminished and the accuracy of measurement suffered in consequence. Nevertheless, as can be seen from Fig. 1, it was possible to establish that the tensile

of slightly deformed alpha-brass, but particularly the uniformity of the spacing between adjacent pile-ups, suggested that the hardening of the brass was of the interaction type, treated theoretically by Mott², which also leads to a parabolic strain-hardening law. An attempt was therefore made to apply this theory of interaction-hardening to the results obtained in the present work.

If, to conform with the method of testing, the shear stress is replaced by $\frac{1}{2}\sigma$, and the tensile strain is put equal to the shear strain, Mott's theory gives

$$\chi = G^2 b n / \pi^2 L$$

where $2L$ is the mean grain diameter, b the inter-atomic spacing in the slip direction, G the shear modulus and n the number of dislocation in the pile-up. According to Mott,

$$n \simeq (2\pi L / Gb) \tau_y$$

where τ_y is the yield stress in shear of the undeformed metal. Since, judging from Jacquet's results, n does not appear to be significantly dependent on L for grain-sizes as used by him, and also in the work here discussed, it follows that τ_y should be approximately inversely proportional to the grain-size. Further, from the above relations,

$$\chi \simeq (2/\pi) G \tau_y$$

which is independent of n . Now, very slow creep in polycrystalline lead is observed at tensile stresses³ of about 30 kgm./cm.², so that τ_y is less than 15 kgm./cm.² at 25°C., but must be greater than 3 kgm./cm.², which is the yield stress in shear for single crystals of high purity⁴. Therefore, taking $\tau_y = 10$ kgm./cm.² and $G = 5 \times 10^4$ kgm./cm.², the last equation yields $\chi = 3.2 \times 10^5$ kgm./cm.², which is in satisfactory agreement with the values obtained from the slopes of the lines in the left-hand figure: 2.8×10^5 kgm./cm.² for $2L = 0.11$ mm., and 1.7×10^5 kgm./cm.² for specimens with grain diameters $2L = 0.04$ and 0.06 mm. Owing to poor resolution of the experimental results in the last two cases, separate χ -values were not determined for these grain-sizes. It is apparent, however, that the ratio of grain sizes is close to the corresponding ratio of χ^{-1} -values. The value of n which is required to satisfy these results is of the order of 100 at 25°C., which is comparable with the mean value of the number of dislocations per pile-up as shown in Jacquet's micrographs. The comparatively high temperature-dependence of χ , indicated by the results in Fig. 1 (right), is of about the same magnitude as that of the yield stress in shear of lead single crystals in the same temperature-range⁴.

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² Mott, N. F., *Phil. Mag.*, **43**, 1115 (1952); **44**, 742 (1953).

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⁴ Neurath, P. W., and Koehler, J. S., *J. App. Phys.*, **18**, 79 (1951).

Fig. 1. Mean grain diameter: ●, 0.11 mm.; ▲, 0.06 mm.; ■, 0.04 mm.

stress σ was related to the initial tensile strain ϵ by the work-hardening law characteristic of polycrystalline metals of cubic symmetry:

$$\sigma^2/\epsilon = \chi(T)$$

where $\chi(T)$ is the temperature-dependent coefficient of work-hardening.

Jacquet's electron-micrographic evidence¹ of the formation of dislocation 'pile-ups' at grain boundaries