We shall describe in some detail a new method of applying elastic uniaxial compression to single metal crystals. The method requires careful specimen preparation which will also be described.

The de Haas–van Alphen effect has been used, in a way similar to that of Shoenberg and Watts (1967), to measure the changes produced in the Fermi surfaces of zinc and cadmium when the uniaxial compression is applied parallel to the $\langle 0001 \rangle$ crystalline axis. Our results will be compared with other work on these metals, referred to above.

2. Experimental technique

2.1. General considerations

The de Haas–van Alphen effect is the oscillatory behaviour of the magnetic moment of metals which occurs when the applied magnetic field $\boldsymbol{B}$ is varied. Generally the oscillations which are periodic in $1/B$ contain several distinct frequencies F_i, each of which is proportional to an extreme cross sectional area A_i of the Fermi surface sectioned perpendicular to $\boldsymbol{B}$;

$$F_i = \alpha A_i$$

where α is a constant. Therefore the changes produced in F_i when stress σ is applied to a crystal give a measure of the changes produced in the Fermi surface, according to the following relations

$$\frac{\partial \ln A_i}{\partial \sigma} = \frac{\partial \ln F_i}{\partial \sigma} = \frac{\partial \ln \phi_i}{\partial \sigma} \tag{1}$$

where $\phi_i = 2\pi F_i/B$ is the phase of the oscillations.

In our experiments we were concerned to ensure that only elastic strain was produced. Therefore we did not exceed strains of order 10^{-4}, corresponding to stresses of order 10^7 N m^{-2}. Now, the larger sections of metal Fermi surfaces, comparable with a free electron sphere, have values of F sufficiently high that in fields of order 5 T, as used in practice, the phase would be $2\pi \times 10^4$. Therefore, if we assume that these larger sections scale approximately as would a free electron sphere, the strain applied would be capable of producing phase changes of order 2π. The phase change is usually of the same order for small sections of the Fermi surface because the fractional area change produced by a given stress is much greater.

In our experiments we measured the changes $\delta\phi_i$ produced by uniaxial compressional stress. Although there is some difficulty in measuring $\delta\phi_i$ with high precision, the most important technical problem is to ensure that when the stress is applied the measured $\delta\phi_i$ is due to the change produced in the size and shape of the Fermi surface and not due to rotational or translational motion of the specimen in the magnetic field. Careful specimen preparation and experimental design are needed and these will be described later. However, since we restricted our measurements to symmetry direction orbits (specifically $\boldsymbol{B}$ along $\langle 0001 \rangle$) the change of F with angle, and hence any spurious change of ϕ_i due to crystal rotation, was minimized. Furthermore we concerned ourselves only with the smaller orbits where frequencies have an inherently lower sensitivity to rotation or translation of the crystal. A further reason for ignoring the larger orbits was that their de Haas–van Alphen oscillations were often of very small amplitude; perhaps because of the inevitable cold working of the sample when it was initially stressed.

Although we have therefore ignored the larger parts of the Fermi surface, this is perhaps not too serious an omission because theoretical descriptions of the Fermi surface and its strain derivatives are most sensitively tested by the smaller pieces.

2.2. Mechanical

The apparatus used for applying uniaxial compression is shown in figure 1 and figure 2 (plate). An important feature of the design is that the pull rod does not pass through a vacuum seal to get inside the cryostat because the whole lever arm is enclosed in the vacuum tight box. It would seem that omitting the vacuum seal in this way is worthwhile in order to ensure that the stress applied to the specimen is accurately known (Gamble and Watts 1972). The lever arm had twenty equally spaced notches on to which a $\frac{1}{2}$ kg weight could be hung and we were thus able to increase the compressional force from approximately zero to 10 kg weight in $\frac{1}{2}$ kg weight steps. The weight was moved in a way very similar to that in which the rider is moved along the arm of a conventional sensitive weighing balance. The jaws, between which the specimen is compressed, are such that the upper one is machined accurately perpendicular to the suspension axis and the lower jaw is machined perpendicular to the axis of the bottom moving part of the suspension. There is a small residual play left in the pins which connect this lower part to the pull rod, in order to allow the jaws to be self aligning with the flat ends of the specimen when the compressional force is applied.

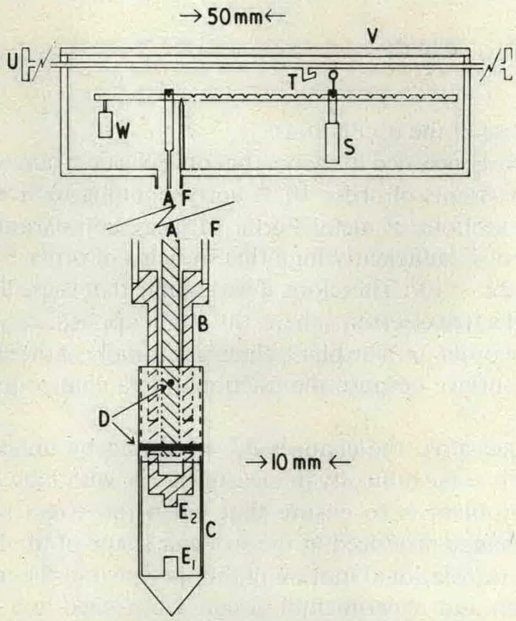

Figure 1. The stainless steel pull rod A is coupled directly to C by the pins D. The pins D pass through slots in B, enabling tension in A to produce compression between the moving jaw E_1 and the jaw E_2 which is held stationary (by the stainless steel tube F) with respect to the lever arm pivot. The weight S may be lifted by engaging T and rotating slightly the rod U. S is moved to different notches on the lever arm by sliding U along. The process is viewed through the perspex window V. W is a counter balance weight. The lever arm enclosure is vacuum tight. Various vacuum seals have not been shown. Note the scales are different for the two parts of the figure.