attempt to construct the complete Fermi surface. Measurements of the temperature dependence of amplitude of the oscillations give an average effective mass for a cross section of the Fermi surface. Until fairly recently de Haas-van Alphen measurements had been done at low fields (15 kilogauss) and the effect was not seen in monovalent metals [18]. Lax has reviewed the information that these measurements have given for a number of metals, among them bismuth, arsenic, gallium, and zinc.[19]. More recently Shoenberg has used pulsed fields of 160 kilogauss to make de Haas-van Alphen studies on copper, silver, and gold [20]. The results on copper are of special interest, because they confirm the picture, proposed by Pippard on the basis of anomalous skin effect data, of a Fermi surface which touches the zone boundaries.

The most complete anomalous skin effect measurement is the determination of the Fermi surface in copper by Pippard [21] mentioned above. Maxwell's equations predict that the surface impedance of a metal, defined as the real part of

$$Z = \left(\frac{4\pi E_x}{H_y}\right)_{z=0} \qquad (I-1)$$

where E and H are the electric and magnetic fields respectively, is proportional to $\sigma^{-1/2}$, where σ is the dc conductivity. At sufficiently low temperatures, the surface resistance is anomalous in that it is independent of σ. In this anomalous region the surface resistance can be related to an integral containing the radius of curvature of a cross section of the Fermi surface. From measurements of the anomalous skin effect for surfaces of different orientations, one can attempt to reconstruct the Fermi surface. The method requires carefully polished surfaces and very pure materials, the latter to satisfy the requirement that the mean free path of an electron be much larger than the skin depth.

The attenuation of ultrasonic waves in metal single crystals subject to a dc magnetic field which is perpendicular to the direction of propagation has been used to investigate the Fermi surface of copper [22]. At low temperatures the main contribution to the acoustic attenuation is electronic; a magnetic field can cause electron orbits in real space to have the same diameter as wavelengths of sound. By measuring the location of the maxima and minima of attenuation as a function of magnetic field, an average radius of a cross section of the Fermi surface may be obtained. The detailed theory of this effect has been recently reviewed [23]. Further work on copper has confirmed many of the details of the Fermi surface proposed by Pippard on the basis of anomalous skin effect work and by Shoenberg on the basis of de Haas-van Alphen measurements [24].

Conventional cyclotron resonance techniques must be modified in order to study metals, since the radio frequency electric field cannot penetrate into the metal much further than the skin depth. Azbel and Kaner [25] have shown that a resonance effect can be obtained by using a dc. magnetic field parallel to the surface of the metal. Some of the electrons, which have circular orbits about an axis parallel to the field, come within a skin depth of the surface of the metal and can absorb rf. energy. If the frequency of the microwave energy is correct, a resonance can occur. This technique has been used to obtain effective masses in copper [26].

Magneto-resistance measurements on single crystals at low temperatures have been used to study the Fermi surface of copper [27]. The interpretation of the data requires an assumption that the scattering time is isotropic [i.e., $\tau(\vec{k}) = \tau(E)$]. The theory computes the dependence of the magneto-resistance coefficients upon parameters that express the warping or anisotropy of a spherical Fermi surface in terms of Kubic harmonics. The requirement that the scattering time be isotropic is important, since if it were not, the observed magneto-resistance could be attributed to a spherical Fermi surface with an anisotropic τ, or to a combination of anisotropic Fermi surfaces and scattering times. The amount of warping is obtained by fitting the theoretical expressions to the measured value of the coefficients. The results indicate that the Fermi surface actually touches the zone face in the 111 direction, in agreement with other work on copper; the fact that touching occurs indicates that the description of the Fermi surface as a warped sphere is not an entirely appropriate one and the warping parameters obtained may not be accurate.