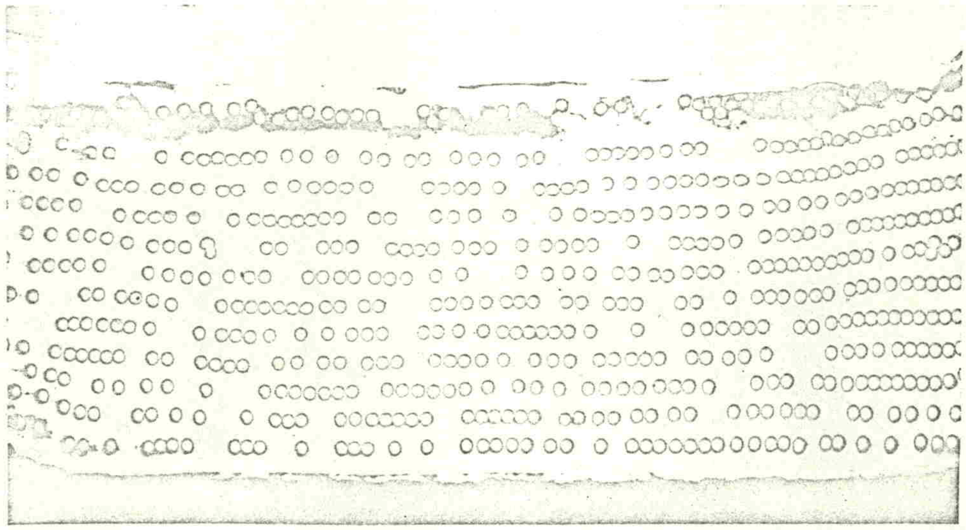
suitable third metal as a thin sheet between the weld plates. Boes[13] and Rosenstiel *et al.*[76] also referred to the use of a third-metal layer electroplated to one weld component as a means of avoiding the formation of brittle intermetallics between aluminium and stainless steel.

Deribas *et al.*[77] employed electron-probe and X-ray diffraction analysis to study alloy zones in explosive welds. They found that all metal couples examined could be placed in one of two classes according to their alloying behaviour. Class 'A' included the couples steel/copper, molybdenum/tungsten, and silver/steel, in which alloy compositions varied continuously between 0 and 100%. Class 'B' contained titanium/steel, iron/zirconium, and copper/lead for which definite stoichiometric compounds occurred. It was noted that these compositions were often not in agreement with normal phase equilibria for the couples examined, which suggested that these alloy zones are in a metastable condition.

Apart from the work of Deribas *et al.*[77] little definite evidence for the occurrence of non-equilibrium phases in welds has been reported. Buck and Hornbogen[64] noted the presence of an interfacial layer of uniform appearance and 10^{-4} cm thick in carbon replicas taken from a copper/mild steel weld. On heating to 250° C (525 K) this layer was seen to decompose into two stable phases. They concluded that the layer resulted from alloying in the molten state and that rapid cooling had caused a metastable phase to form. Several workers have found that the rear vortex of a wavy weld contains a higher fraction of the flyer plate, while the front vortex contains a higher fraction of the base plate.[37,45,48,75] Lucas and Williams[37] have pointed out that, since molten pockets have been seen to consist of sub-micron-sized grains, it is not correct to infer the existence of a compound on the basis of electron-microprobe analysis alone. Positive identification by a diffraction technique is essential.

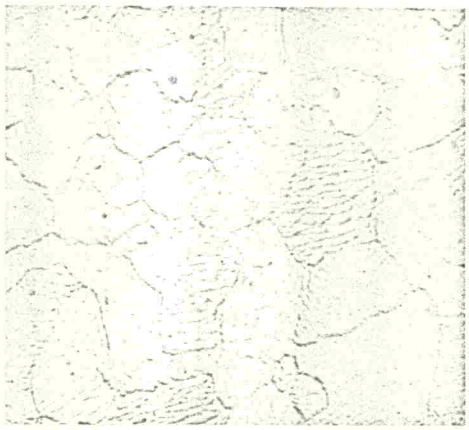
Thermal conductivities of solid metals are typically 0·5 cal/sec cm degC (209 W/m.K) and consequently small pockets of molten metal will experience extremely high quenching rates by conduction of heat into the adjacent colder regions. Cowan and Holtzman[19] have shown that in a time of 10^{-5}s, the typical time in which a weld is made, layers of liquid varying in thickness between 73 μm for copper and 31 μm for steel could solidify before the pressure was released. It is probable that such rapid solidification would not allow equilibrium phases to form.

Evidence of rapid cooling of melted pockets is seen in steel-to-steel welds. Lucas and Williams[37] have recorded a hardness of 450 Hm in the melted zone between low-carbon iron and mild steel, and examination of the carbon replica from this area showed it to be martensitic



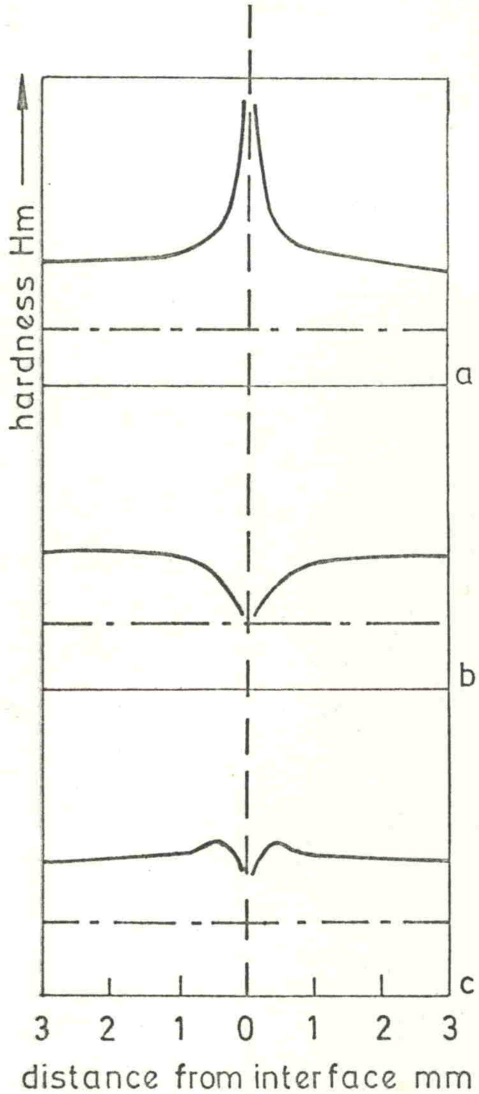
[Courtesy 'Nature'.

49 Composite of tungsten wires in copper matrix. × 8. (*Jarvis and Slate.*[63])



50 Carbon replica of vortex in Fig. 14. × 6 000.

51 Carbon replica of solid-phase bond in Fig. 14. × 1200.



52 Typical hardness profiles observed when two similar metals are welded under different welding conditions.
— — — — — weld interface
— - — - — hardness before welding
———— hardness after welding