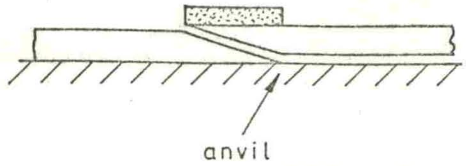
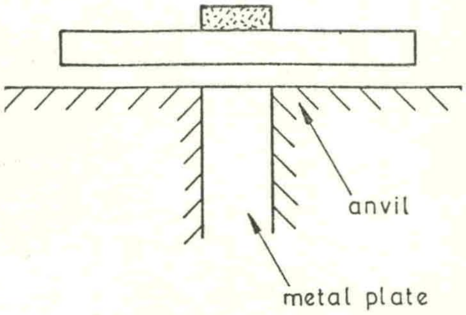
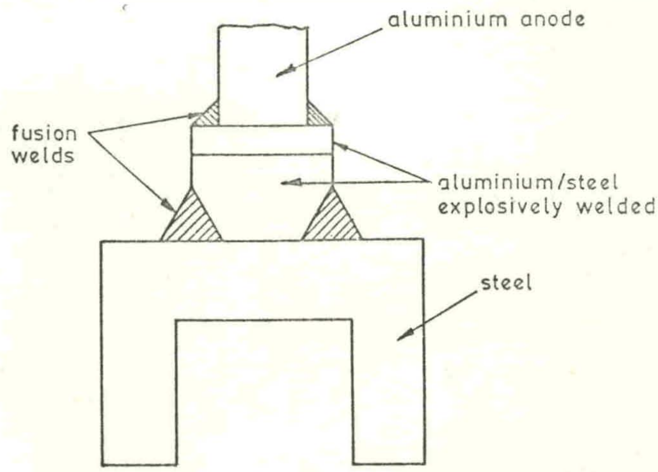


[Courtesy Weld Research Council.
46 Butt weld. (*Holtzman and Cowan.*[21])



47 Tee weld. (*Holtzman and Cowan.*[21]) [*Courtesy Weld. Research Council.*



[*Courtesy Welding Inst.*
48 Aluminium/steel transition joint. (*Stone.*[43])

claim they refer to an X-ray diffraction investigation on the same weld reported earlier by Davenport.[11] This investigation showed that the ordered α' phase was present at the interface, and Wright and Bayce point out that this would not be expected under the conditions of high cooling rate that any molten pocket would experience. The optical micrograph of the weld interface in question is wavy and considerable melting appears to have occurred.

Pietteur[73] has reported electron-probe traverses across the interface of a steel/copper weld in adjacent positions near the crest of a wave. These indicated that at the peak of the wave there was an abrupt change from steel to copper, while on a line slightly to the rear of the wave crest evidence of an intermediate phase consisting of Cu 80%–Fe 20% was visible. The optical micrograph again clearly showed that a layer of previously melted alloy extended forward from the vortex of the previous wave and, although present in both the above traverses, its thickness had decreased to below the resolution of the probe at the peak of the wave.

It can be concluded that the solid-phase bond obtained in an explosive weld is formed by the flowing together of grossly elongated surface grains, after the removal of the original surface contaminants by jetting. The differences between the observations of various workers is a consequence of the measuring techniques adopted, the differences between the explosives used, the ratio of mass of charge to that of the flyer plate, and the dimensions of the flyer plate. The temperatures reached at the interface and the cooling rate may well differ from one experiment to the next. It has been suggested[28] that the extremely high rates of strain in the weld zone could lead to a high concentration of point defects by the non-conservative motion of jogs. This could account for the increased diffusion rates referred to by Tylecote[74] and by Wright and Bayce.[20] The recovery and recrystallisation observed in thin foils[28] indicates that considerable dislocation and atomic rearrangement has occurred during and immediately after bonding, and it is not unreasonable to assume that detectable interfacial diffusion may take place in dissimilar metal welds.

3. Melting at the interface

There are three main sources of heating at the weld interface: the heat of detonation of the explosive, internal heating in the metal subjected to shock waves and high rates of deformation, and adiabatic heating of gases compressed between the plates.[28] Of these, the most important is the heating due to plastic deformation, particularly in the vortices of wavy interfaces where severe turbulence occurs, resulting in melting.

Molten layers observed in explosive welds are typically 5×10^{-3} cm thick and their structure and properties are governed by three main factors: alloying behaviour in dissimilar metal welds, extremely high cooling rates, and entrainment of atmospheric gases and surface contaminants.

In general, melting in explosive welding is not desirable because of the inherent weakness associated with cast structures. Figure 16 shows a continuous line where columnar grains meet[21,37] and typical gas porosity is illustrated in Fig. 53.[21]

Numerous reports have included evidence of alloy formation in the molten regions of dissimilar-metal welds. In the majority of cases the different electrochemical properties of the two metals allow only one metal to be etched, while the other metal and the alloy zone remain unetched. By careful polishing and etching, however, it has been shown that the alloy pockets may contain micron-sized crystals arranged in a swirled pattern, as seen in vortices of welds between similar metals.[37,68]

Metal combinations whose alloy systems normally contain intermetallic compounds may form such compounds in the melted zones when welded together explosively. These compounds are normally very hard and often cracking can be seen in these regions of high hardness, or cracks may originate from the indentation caused by a microhardness indenter. Numerous authors have published data regarding compounds and their effects on the properties of a weld. Rowden,[48] Bahrani and Crossland,[45] Lucas and Williams,[37] Carlson,[23] and Hollingum[75] have stated that compound formation occurs in titanium-to-mild steel welds. This phase has a reported hardness[45] of 1290 Hm, and tensile shear strengths of welds containing the compound are about one fifth of those with no compound.[23] Rowden[48] has shown that stress-relieving at 400°C (675 K) increases the thickness of the layer and causes more cracks to appear, though the shear strength differs little from the as-welded condition.

Welds between tantalum and mild steel have also been found to contain intermetallic compounds[20,60] with a measured hardness[21] of 1100 Hm. Holtzman and Cowan[21] concluded that a homogeneous compound Fe_2Ta was formed, and microhardness tests showed a uniform value across a layer. Wright and Bayce,[20] however, have observed various compositions of such layers by electron-probe analysis and therefore suggest that a transition or defect compound may have been formed. These workers also showed that the problem of brittle alloy formation in welding can be overcome either by proper control of the welding parameters to minimise melting, or by introducing a