The shock velocity can be calculated from an equation given by Cowan and Holtzman[19]

$$U_S = C_0 + \lambda U_P \qquad \ldots [11]$$

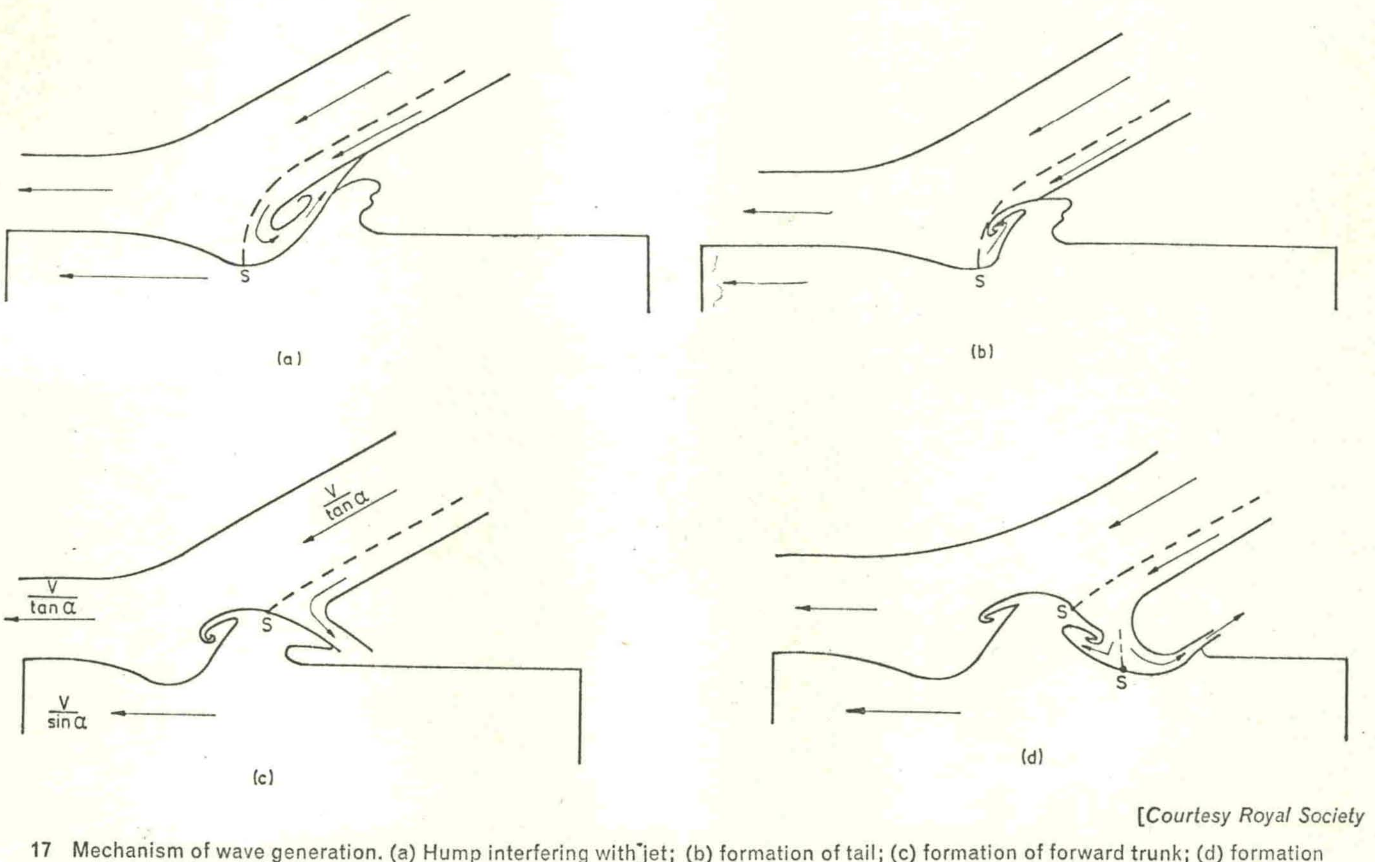
where C_0 = the bulk velocity of sound
λ = a constant which can be calculated from Walsh *et al.*[27]

For mild steel-to-mild steel he claimed that with pressures of $0{\cdot}411 \times 10^6$ lbf/in² (28·4 kbar) or below there was no bonding, but at $0{\cdot}65 \times 10^6$ lbf/in² (45 kbar) up to $\nless 1{\cdot}93 \times 10^6$ lbf/in² (133 kbar) there was consistent bonding. For titanium-to-titanium, the respective figures were $0{\cdot}44 \times 10^6$ lbf/in² (30 kbar) and $0{\cdot}64 \times 10^6$ lbf/in² (44 kbar), and for copper-to-copper satisfactory bonds were achieved at $0{\cdot}77 \times 10^6$ lbf/in² (53 kbar) and above.

As yet the conditions for a satisfactory weld have not been fully described. In the meantime preliminary tests are required to determine the correct conditions; however, if the size of the test-piece is too small the results may not be representative. For instance, the dimensions in the plane of the flyer plate should be much greater than the thickness of the plate and the thickness of the charge, otherwise edge effects are of significance. One test-piece of great value is that suggested by Bahrani and Crossland[24] and shown in Fig. 12. It consists of a semi-cylindrical parent plate with the flyer plate suspended so as to be tangential to it, the detonation being initiated at the centre. As the flyer plate wraps itself around the parent plate the initial and final angles of obliquity vary, so that from one test-piece a range of angles is covered. The only criticism is that the clearance does not remain constant, but this is probably relatively unimportant as long as the minimum clearance is not too small to prevent the terminal velocity being achieved, or the largest clearance is not so great as to allow the terminal velocity to decay significantly.

In all these discussions the combinations of metals that can be welded have not been discussed. It is probably correct to say that no one has mentioned combinations that cannot be welded. Table V is a reproduction from Ref. 21 and lists the combinations that have given good bonds. Also, the form of the bond produced has not been discussed, but from Fig. 13–16 it will be apparent that many types of interface are possible. At large angles of obliquity the jet completely escapes and a straight interface with an indication of a shearing action on each side of the interface is obtained. At small angles interfacial waves are formed with the vortex areas in front of and behind the waves. These vortex areas contain a mixture of each surface and it appears that the jet has been partially or completely trapped. Lucas and Williams[37] have shown that the kinetic energy of the re-entrant jet in a typical welding situation far exceeds that required to cause melting when it impacts the parent plate. If the charge is too great and the angle is too small, then the wavy interface is seen to consist of molten pockets in the vortex area and solidification cavities are sometimes observed in the centre of these pockets. If the kinetic energy is sufficiently high, these areas of melting will join up to form a continuous cast interlayer in which the vortex areas can still be distinguished. At even smaller angles the interlayer appears to be of a much more nearly uniform thickness. The cast interlayer may be weakening, especially if brittle intermetallic compounds are formed.

The formation of waves at the interface has been studied by Abrahamson,[3] Cowan and Holtzman,[19] Otto,[14] Bahrani *et al.*,[25] and Hunt.[38] Otto has proposed two alternative explanations of welding. The first, which is applicable to two plates welded in contact, is a type of friction weld resulting from relative sliding between the plates. The second explanation relates to welding between obliquely colliding plates. By chance one plate moves ahead of the other and a tongue of metal from it penetrates the slower plate. This raises a tongue in the second plate, ahead of the collision point, and this penetrates the first plate.



[Courtesy Royal Society

17 Mechanism of wave generation. (a) Hump interfering with jet; (b) formation of tail; (c) formation of forward trunk; (d) formation of front vortex. (*After Bahrani et al.*[25])