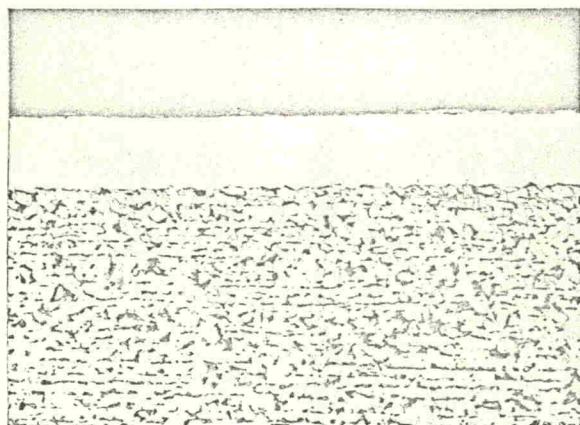
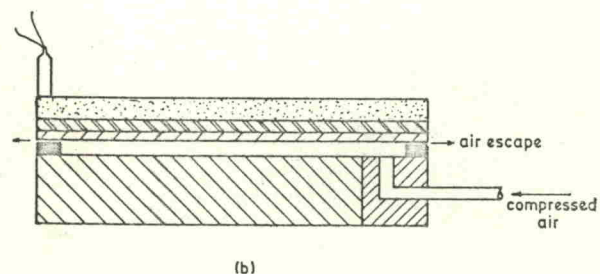
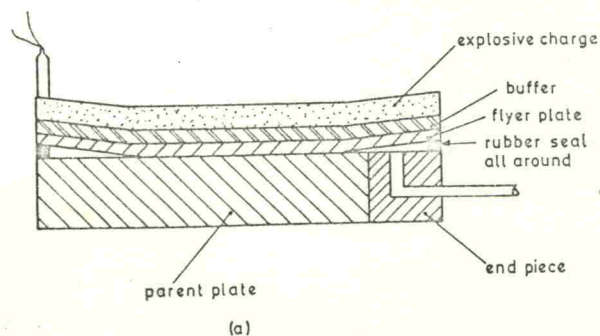


22 Welding of plates that are initially in contact.

24 Micrograph of mild steel clad with a 0.005 in. (0.127 mm) layer of brass.  $\times 70$ .

23 Air-supported flyer plate.

*Trimonite No. 3*, which is a lower-detonation-velocity explosive, they noted that welding could be achieved except for the first 1-2 in (25-50 mm), and they attributed this to the plates separating before the detonation wave arrived as a result of deformation in front of the detonation wave being possible, as demonstrated in Fig. 22. Crossland and Bahrani prevented this separation by means of mechanical constraint, and they then found that even with *Trimonite No. 3*, no welding was achieved. They concluded that separation between the parent and flyer plate is necessary to achieve welding.

Another arrangement proposed by Crossland *et al.*<sup>41</sup> has been provisionally patented by Crossland, Bahrani, and Shribman.<sup>42</sup> The method consists of supporting the flyer plate by gas pressure. Figure 23(a) shows the arrangement in the absence of gas pressure, as a consequence of which the plate is sagging. Figure 23(b) shows the pressure applied and the flyer plate lifting, rather like a flap valve, to relieve the gas pressure. There is some advantage in having a small angle of obliquity and this can be accommodated by the correct arrangement of the sealing strips. If necessary, an inert gas can be used as the pressurising medium. This method has been adopted successfully with *Trimonite* explosive.

Yet another arrangement has been proposed by Williams *et al.*<sup>32</sup> using polystyrene particles to separate the flyer and parent plate. They note that a slight initial angle of obliquity, with an explosive with a detonation velocity less than the sonic velocity, gives a better wave form and reduces the chance of forming a

continuous cast interlayer, particularly towards the end of the weld. A slight initial angle of obliquity can be achieved by selecting polystyrene particles of different sizes, small particles at one end increasing to large particles at the other end. In the case of *Trimonite No. 3*, no signs of voids have been observed at the weld interface, though very slight defects which may be associated with the particles have been noted.

For thick flyer plates it is adequate to support the flyer plate on blocks of polystyrene placed at its edges and a slight taper can be readily accommodated by introducing different heights of blocks.

To summarise, if a very thin flyer plate, such as the 0.005 in. (0.127 mm) thick brass flyer plate shown in Fig. 24, which was studied by Shribman,<sup>35</sup> is to be welded, then a contact method should be used even though a small area of no bonding will be found near the detonator. For plates of up to  $\frac{1}{8}$  in (1.6 mm) thickness the gas-supported principle appears to be satisfactory, and with even thicker plates, up to  $\frac{1}{4}$  in (6 mm), the polystyrene-particle technique can be adopted. With much thicker plates the edge-support technique is adequate.

Du Pont have clad areas up to 300 ft<sup>2</sup> (28 m<sup>2</sup>) and used flyer-plate thicknesses up to 1.3 in (33 mm), while thicknesses of 2 in (51 mm) have been used experimentally according to Stone.<sup>43</sup> At the Queen's University of Belfast, the largest plates clad have been 3 ft  $\times$  3 ft (900  $\times$  900 mm), with a mild-steel parent plate  $2\frac{1}{2}$  in (64 mm) thick clad with a  $\frac{1}{2}$  in (13 mm) thick flyer plate of aluminium bronze. The set-up is shown in Fig. 25 and the product in

Fig. 26. The problem with large plates is the weight of charge employed and the resulting noise and associated pressure pulse, which makes it necessary to have a site remote from human habitation. Stone<sup>43</sup> shows a photograph of the entrance to a tunnel used by Du Pont for carrying out explosive cladding. Apparently after a few blasts the tunnel roof became stabilised. Shribman<sup>35</sup> has reported tests using a vacuum tank which is claimed considerably to reduce the noise level, but whether this is a practical or economic proposition for large plates must be questioned. Another possibility is to bury the plates and explosive charge under a large heap of earth, but this requires earth-handling equipment as a very considerable thickness of soil would be required. For instance, from a private communication with Dr. Nemitz, a charge of 40-60 kg used in direct-contact forming operations required a mound of sand 3-4 m thick.

The strength of the bonds formed in explosive cladding has been extensively studied by Philipchuk,<sup>7</sup> Hayes and Pearson,<sup>17</sup> Boes,<sup>13</sup> Addison *et al.*,<sup>44</sup> Bahrani and Crossland,<sup>24,45</sup> De Maris,<sup>46</sup> Gelman *et al.*,<sup>47</sup> Rowden,<sup>48</sup> and Banerjee.<sup>49</sup> Static tests have included shear tests (Fig. 27), side shear tests (Fig. 28), tension tests (Fig. 29), and bend tests (Fig. 30), with the cladding on the top or bottom or side. Briefly, under ideal welding conditions and in the absence of unfavourable metallurgical conditions at the interface, such as a cast interlayer or brittle intermetallic compound, the strength of the bond is greater than the strength of the weaker of the two materials, and with the bend tests, even with the cladding on the side,