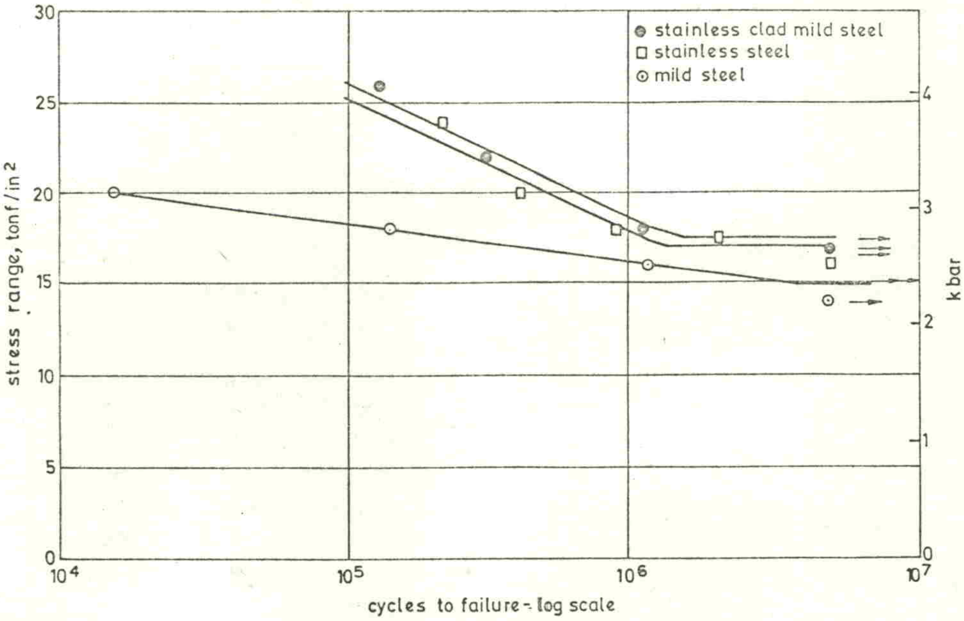
readily produced. The minimum hole diameter locates the tube so that the front portion is not in contact with the tube plate. As this is a parallel set-up a low-detonation-velocity explosive is required and *Trimonite No.* 3 powder explosive was used. Explosive packs as shown in Fig. 39 were made up for this work and a modified design of this kind would not be difficult to mass-produce. Table VI gives the various combinations that have been welded successfully.

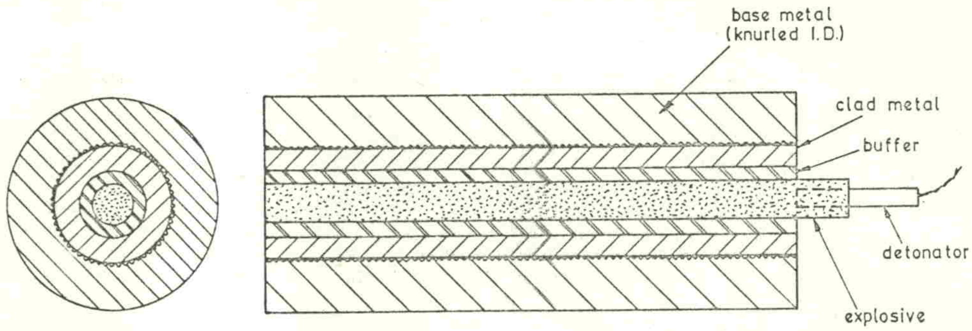
The explosive charge must not be placed too far back in the tube, as this could cause bulging or even splitting of the tube behind the tube plate. Metallurgical examination showed a long length of weld, though probably no bonding occurs close to the front surface of the tube plate. Williams and Crossland[57] discussed the welding of a nest of hard-drawn tubes into a naval brass tube plate (see Fig. 40).

Though exceptionally good surface finishes and cleanliness are not required, oil, grease, or water should be removed from the surfaces to be welded. If there is a thick oxide or paint film on the tube then these must be cleaned off before welding by means of a fine abrasive paper.

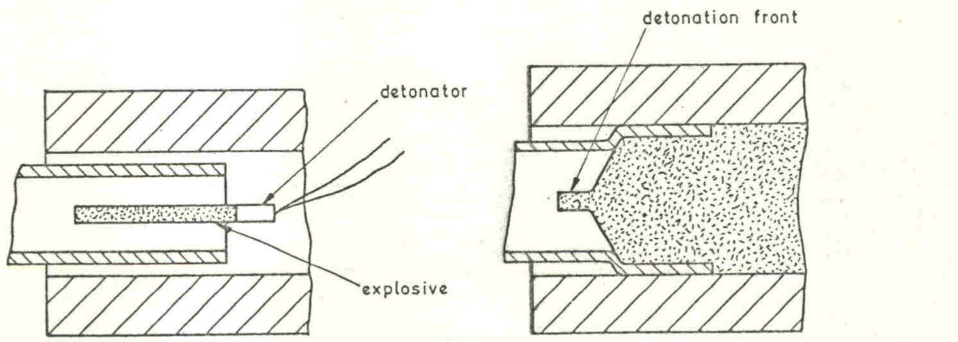
Hardie[56] welded mild-steel tubes to a mild-steel tube plate using a tube with a tapered O.D. This has the advantages of reducing the charge weight for a given impact velocity and keeping the ligament thickness to a minimum. He employed a high-detonating-velocity explosive and the weld interface showed regions of melting with solidification cavities. It was found that welds produced in an earlier explosion could be disrupted by nearby subsequent explosions and cracking of both tubes and tube-plate ligaments was experienced. The failure of the tubes may have been due to using too large a charge and an explosive with a high detonation velocity which would give a high-pressure pulse, together with inadequate material properties. Ligament cracking was more noticeable when charges in adjacent holes were detonated together, but again it seems probable that an excessive charge was used, and this could also explain the failure in welds adjacent to an explosion.



31 Fatigue test on mild steel clad with stainless steel. Mean stress + 14 tonf/in².



32 Cylindrical cladding. (*Philipchuk.*[1]) [Courtesy Amer. Soc. Tool Manuf. Eng.



33 Schematic illustration of the parallel-separation arrangement of components for explosively welding interfaces of tubular geometry.

Table VI Tube and tube-plate combinations that have been successfully welded

Materials		Tube plate						Tube				Explosive pack						
Tube	Tube plate	W		Do		Dc		Dt		t		Explosive	De		d		l	
		in	mm	in	mm	in	mm	in	mm	in	mm		in	mm	in	mm	in	mm
Cupro-nickel	Brass	$1\frac{1}{2}$	38·2	2	50·8	$\frac{17}{32}$	13·5	$\frac{1}{2}$	12·7	$\frac{1}{32}$	0·8	*Trimonite No.*3	$\frac{7}{16}$	11·1		0	$\frac{3}{4}$	19·1
Al brass	Brass	$1\frac{1}{2}$	38·2	2	50·8	$\frac{25}{32}$	19·8	$\frac{3}{4}$	19·1	$\frac{1}{32}$	0·8	"	$\frac{19}{32}$	15·1		0	$\frac{3}{4}$	19·1
Copper	Mild steel	3	76·2	3	76·2	$1\frac{1}{8}$	28·6	1	25·4	$\frac{1}{16}$	1·6	"	$\frac{13}{16}$	20·6		0	$1\frac{1}{4}$	31·8
Stainless steel	Mild steel	2	50·8	3	76·2	$1\frac{1}{32}$	26·2	1	25·4	$\frac{1}{16}$	1·6	"	$\frac{13}{16}$	20·6		0	1	25·4
Mild steel	Mild steel	2	50·8	3	76·2	$1\frac{1}{32}$	26·2	1	25·4	$\frac{3}{32}$	2·4	"	$\frac{3}{4}$	19·1		0	1	25·4
Mild steel	Mild steel	2	50·8	3	76·2	$1\frac{17}{32}$	38·9	$1\frac{1}{2}$	38·2	$\frac{1}{8}$	3·2	"	$1\frac{3}{16}$	30·2	$\frac{3}{8}$	9·5	$\frac{7}{8}$	22·2
Mild steel	Mild steel	3	76·2	4	101·6	$1\frac{29}{32}$	48·4	$2\frac{1}{4}$	57·1	$\frac{1}{8}$	3·2	"	$1\frac{5}{16}$	49·2	1	25·4	1	25·4

Note that the symbols in Table VI are explained in Fig. 39.