WS No. 19 Mark III

PRINTED CIRCUIT REPAIR TECHNIQUES

Chapter 000 - List of Chapters

Note: This Issue 2, supersedes Issue 1, dated 18 Jul 69. The EMER has been completely revised and is now issued in Chaptered form.

INTRODUCTION

In order to facilitate up-dating and amendment of the information, this regulation has been separated into the following chapters:-

R/9008/Rad

END

PRINTED CIRCUIT REPAIR TECHNIQUES

CHAPTER 500 - Introduction, tools and materials

Errata

Note: This Page 0, Issue 2 supersedes Page 0, Issue 1, dated Mar 77, and is to be filed immediately in front of Page 1. The amendment marked ● is additional.

1. The following amendments are to be made to the chapter.

2. Page 2, Issue 1, para 4.a.

● a. Item (19), line 2.

(1) Amend designation to read: glass fibre tips, packs of 24

(2) Part number. Delete: 3439
Insert: 7920.

b. Under item (25) insert two new items:

(26) Pace Rework Centre type PRC 150 3439-99-116-6544
(27) Austin desoldering equipment F1/3439-99-137-7370.

R/95390

PRINTED CIRCUIT REPAIR TECHNIQUES

CHAPTER 500 - Introduction, tools and materials

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2. Page 2, Issue 1, under item (25)

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R/95390

PRINTED CIRCUIT REPAIR TECHNIQUES

CHAPTER 500 - Introduction, tools and materials

INTRODUCTION

1. The techniques described in this regulation apply to boards manufactured from the following materials.

Paper - Phenolic single and double sided.
Glass - Epoxy single, double sides and plated through holes.

2. Repairs to multilayer boards and repairs requiring welding techniques are considered to be outside the scope of this regulation and should not be attempted at any level other than base.

3. The repairs listed are in general suitable for printed wiring boards with track widths and spacings down to 0.5mm (0.020"). Some modifications or restrictions may be necessary for smaller widths and spacings. It must be borne in mind that the conductor pattern may be critical in some assemblies and this will need to be taken into account in assessing the feasibility of a repair, and choosing an appropriate method.

TOOLS AND MATERIALS

4. Assuming that a Telecommunications or Radar Technician tool kit is available the following additional items will be required.

a. Tool kits printed circuit board containing:-

(1)	Printed board holder and clamp (Microclamp 1100 - Metatool Ltd. Syston, Leics)	V5/4940-99-962-5392
(2)	Weller TCP2 soldering iron	F1/3439-99-~~122-2750~~ 133-9670
(3)	Weller PU2D power unit	F1/3439-99-~~122-2751~~ 133-9671
(4)	Weller DSTCP desoldering tool	F1/3439-99-122-6205
(5)	Light magnifier Terry 78 (H Terry & Sons, Redditch)	Z4/~~6625-99-193-3597~~ 6210-99-655-5742
(6)	Magnifier eyeglass	F1/6650-99-120-3960
(7)	Spring holder	F1/6650-99-122-7568

(8)	Vice pin No 1		F1/5120-99-910-6603
(9)	Broach instrument		F1/5110-99-910-4151
(10)	Pliers flat nosed 4.3/4"		F1/5120-99-120-6932
(11)	Nippers diagonal cutting 4"		F1/5110-99-120-6934
(12)	Nippers end cutting 4"		F1/5110-99-120-7263
(13)	Heat shunt tweezer		F1/5120-99-122-7570
(14)	Tweezers 4.1/4"		F1/5120-99-910-7984
(15)	Forceps dressing tweezer		F1/6520-99-210-9491
(16)	Mirror mouth examining		F1/6520-99-210-9103
(17)	Brush mop round No 1		F1/8020-99-943-0434
(18)	Brush water colour		F1/8020-99-943-0442
(19)	Brush contact cleaning		7920 F1/~~3439~~-99-122-2757
	glass fibre tips PACKS OF 24		F1/3439-99-122-5653
(20)	Brush watchmakers		F1/7920-99-943-2863
(21)	Handle scalpel No 4		H6/6515-99-210-4378
	Blades scalpel No 10A		H6/6515-99-210-3157
(22)	Drill miniature 12V DC		
	(PORTESCAP U.K. LIMITED) READING, BERKS		NIV
(23)	Brush circular white nylon A1		
	(THOMAS SUTTON LTD)		NIV
(24)	Tip Weller soldering iron		
	315°C/600°F	PTAA6	F1/3439-99-122-2756
	315°C/600°F	PTK6	F1/3439-99-122-2753
	315°C/600°F	PTCC6	F1/3439-99-122-2752
	430°C/800°F	PTJ8	F1/3439-99-127-8858
	315°C/600°F	PTL6	F1/3439-99-122-5654
	Multiple 700°F	SK 180-7TCP	NIV
	600°F	SK 137-6TCP	NIV
	700°F	SK 128-7TCP	NIV
(25)	Spring loaded removal tool		NIV
26	PACE REWORK CENTRE TYPE PRC 150		3439-99-116-6544

b. Materials

27	AUSTIN DESOLDERING EQUIPMENT	F1/3439-99-137-7370
(1)	Bags, envelope - pvc 10in x 5in	H4/HD 10075
(2)	Bags, envelope - pvc 10in x 8in	H4/HD 10077
(3)	Araldite	
(4)	Eyelets, copper	NIV
(5)	Eyelets, copper, single-tagged	NIV
(6)	Eyelets, copper, double-tagged	NIV
(7)	Tags, soldering, printed circuit, single	NIV
(8)	Tags, soldering, printed circuit, double	NIV
(9)	Insulation sleeving, pvc, electrical, 0.75mm i.d., white	Y3/5970-99-914-0387
(10)	"GENKLENE"	
(11)	Neoprene sheet	NIV
(12)	Solder multi-cored, 22swg	G2/3439-99-970-7724
(13)	Razor blade, single edged	NIV
(14)	Wire, electrical, copper, tinned 22SWG	Y3/6145-99-910-2376

(15) If Harwin pin type repairs are to be performed; then whichever are required of the following:- (see Chap 9)

(a)	Terminal post, (Harwin type H2081)	Y3/5940-99-100-5674
(b)	Terminal post, (Harwin type H2083)	Y3/5940-99-901-2186
(c)	Terminal post, (Harwin type H2085)	Z1/5940-99-915-0026
(d)	Terminal post, (Harwin type H2087)	NIV
(e)	Terminal post, (Harwin type H2088)	NIV
(f)	Terminal post, (Harwin type H2089)	NIV

(16) If VERO PINS (see Chap 9) are to be used whichever required of the following:-

	NAME	PART NO	HOLE DIA.	OVERALL LENGTH	
A	Shouldered half pin	TP/2145	0.025"	0.222"	
B	Terminal pin	TP/2144	0.040"	0.496"	
		TP/2140/3073	0.052"	0.469"	
C	Shouldered terminal pin	TP/11032	0.040"	0.380"	
		TP/2143	0.052"	0.470"	
		TP/2142	0.040"	0.380"	
D	Half pin	TP/11034	0.040"	0.286"	
		TP/2141	0.052"	0.286"	
E	Shorting pin	TP/11036	0.040"	0.125"	
		TP/11037	0.052"	0.125"	NIV
F	Miniature terminal	MT/11081	0.052"	0.360"	
		MT/11082	0.040"	0.360"	

All pins have a flow brightened tin finish.
A specially designed pin insertion tool is available.

Vero Electronics Ltd., Industrial Estate, Chandlersford, Hants. SOS 32R

(17) PIN INSERTION TOOL These tools are designed to aid the insertion of terminal pins.

PART NO	FOR USE WITH	
IT/2150	0.052" pins	
IT/2151	0.040" pins	
IT/11772/4	0.052" miniature terminals	NIV
IT/11772/5	0.040" miniature terminals	
(VERO ELECTRONICS LTD)		

(18) 3S-WICK CAPILLARY WICK SOLDER EXTRACTOR NIV
(J J Huber Ltd., Fourth Way, Wembley, Middlesex.

c. Locally manufactured tools

(1) Wire coiling tool (Fig 2)
(2) Eyelet funnelling tool (Fig 3)
(3) Anvil for Harwin pins (Fig 4)

Printed board holder

5. The printed board holder, mounted on a ball clamp, allows printed boards to be held in any required position whilst under repair. The maximum board width accommodated is 15in and the length of the vertical arms is 6.1/4in. Printed boards can be wired and soldered to within 1/16in of their edges.

Temperature controlled soldering iron

6. The soldering iron has a 24V, 38W heating element and an interchangeable range of temperature-controlled pencil-bits. Five bits are normally provided but a wide range is available for special purposes. Power supply is from a transformer, input 240V, 50Hz; output 24V, 60W. The transformer secondary is completely isolated and has a fusible link inside the case. If the iron is operated from some other power source the voltage must not exceed 26V rms or dc.

7. The advantages of using an iron of this type are:-

a. Leakage current to the bit from a 24V heating element is less than from one at mains voltage.

b. The soldering bit need not be earthed so there is less risk of damage if it is inadvertently used on a live circuit.

c. A high heat input controlled at a comparatively low temperature tends to maintain the correct temperature throughout soldering operations.

8. The soldering bits are of iron clad copper with a temperature sensitive element set into the base: each bit is marked with its working temperature. The range of bits available is shown in Fig 1. The tips of the bits are pre-tinned and should not be filed; they should be kept clean in use by wiping on the sponge fitted to the transformer case, this sponge should be kept wet.

9. Deterioration of bond between printed conductors and the board will occur if too much heat is applied during soldering so care is needed in the choice of bit temperature. The working temperature of the soldering bit should be at least 100°C above the melting point of the solder, but, for typical printed circuits, not higher than 315°C. The melting temperature of 60/40 solder is 188°C therefore the bits to be used for printed circuit work should be chosen from the 315°C (600°F) range, PT-A6 to L6. A higher temperature bit eg PT-C7 or PT-C8 will be found useful for general light soldering work. Lower temperature bits eg PT-C5, may be recommended in equipment EMERs, for use with the low temperature melting point solder, on particularly heat-sensitive assemblies. The diameter of the bit should be approximately the same as the width of a printed conductor. Only the five bits marked * in Fig 1 are normally supplied with the iron for printed circuit work.

10. The bit may be removed from the iron by unscrewing the knurled ring, sliding off the sleeve and pulling out the bit. The bit and the iron barrel of the iron should be cleaned with a brush before re-assembly.

Note: These pages 5, 5A, 5B and 6 Issue 2 supersede Pages 5 and 6 Issue 1 dated Jul 72. Paras 14-23 are additional.

11. The temperature control works magnetically; the iron must not therefore be placed on any ferrous object but rested in the spring holder when not in use.

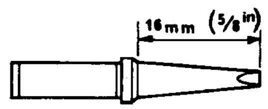
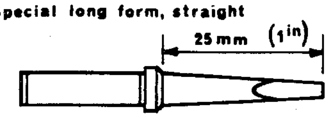
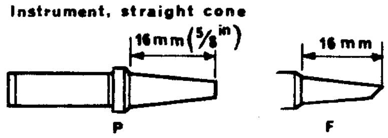
Wellertip	Width	MARKINGS & STANDARD TEMPERATURES 260°C/500°F	315°C/600°F	370°C/700°F	430°C/800°F
Standard screw-driver, straight 	1/32 in = 0.8mm	PT-H5	PT-H6	PT-H7	PT-H8
	1/16 in = 1.6mm	PT-A5	PT-A6	PT-A7	PT-A8
	3/32 in = 2.4mm	PT-B5	PT-B6	PT-B7	PT-B8
	1/8 in = 3.2mm	PT-C5	PT-C6★	PT-C7★	PT-C8
	3/16 in = 5.0mm	PT-D5	PT-D6★	PT-D7	PT-D8
Special long form, straight 	3/64 in = 1.2mm	PT-K5	PT-K6★	PT-K7	PT-K8
	5/64 in = 2.0mm	PT-L5	PT-L6★	PT-L7	PT-L8
Instrument, straight cone 	1/32 in = 0.8mm	PT-P5	PT-P6	PT-P7	PT-P8
	3/64 in = 1.2mm	PT-F5	PT-F6	PT-F7	PT-F8

Fig 1 – Table of soldering bits

Solder

12. The recommended solder is 22 swg 60/40 tin lead melting point 188°C with 5 cores of non-corrosive flux.

GENKLENE

13. Genklene is used as a solvent for dissolving flux residues and the general cleaning of printed circuit boards. It is non flammable and of relatively low toxicity. It should not be inhaled directly or ingested. It should be applied sparingly as it may affect certain paints used in component identification on early pattern boards.

PAGE PCB REWORK CENTRE (PRC 150)

14. This consists of a power source, which forms the main unit, and the following accessories:-

a. Solder Extractor Unit.

b. Soldering Iron.

c. Minichine System.

d. Thermopart Unit.

e. Lapflow Tool.

f. Provise.

g. Conform 1.

h. Hot Cubby.

Use of the Pace Rework Centre

15. Solder Extractor Unit

a. This is a soldering iron type tool equipped with removable hollow tips. An axial tube connected to the tip may be connected to either a vacuum or pressure outlet on the power source.

b. There are three modes of operation:-

(1) Vacuum Mode. The solder is first melted and then removed by the vacuum.

(2) Pressure Mode. The solder is first melted and then blown clear of the joint by air pressure. May also be used for the clearing of blocked or blind joints.

(3) Hot air jet Mode. Used for reflowing lap mounted components without touching the solder joint. Can also be used for softening some types of conformal coatings and other operations that require a hot air flow.

c. After one of the above modes has been selected the on/off action is controlled by means of a foot switch.

16. Soldering Iron

A conventional soldering iron whose heat can be varied by altering the ac supply fed to the iron. The control for this is located on the front panel of the power source. Note: the iron is not temperature-controlled.

17. Minichine System

a. This is a high torque low rpm flexible drive power tool providing facilities for most machining operations likely to be encountered in pcb repair work. A basic tool set for the minichine is also provided.

b. Some of the operations covered by the minichine are as follows:

(1) Removal of conformal coatings by abrasion.

(2) Repairs or modifications of tracks, pads etc using eyelets.

(3) Slitting, sawing and grinding small areas.

18. Thermopart Unit

This tool is used for softening and/or removal of conformal coatings between components, leads and boards. The unit uses quick change blades to which variable heat can be supplied on demand.

19. Lapflow Tool

A soldering tool similar to the thermoplating tool and used for reworking lap joints.

20. Provise

A set of various shaped cutting tools with a holder, used for the removal of soft conformal coatings.

21. Conform 1

Callipers for measuring hole spacing and forming axial lead components to fit desired spacing.

22. Hot Cubby

A detachable unit to hold the extractor unit and soldering iron. It includes a solder dump device and cleaning unit.

AUSTIN DESOLDERING SET

23. This equipment is purely a vacuum desoldering device, the vacuum being actuated by a handswitch.

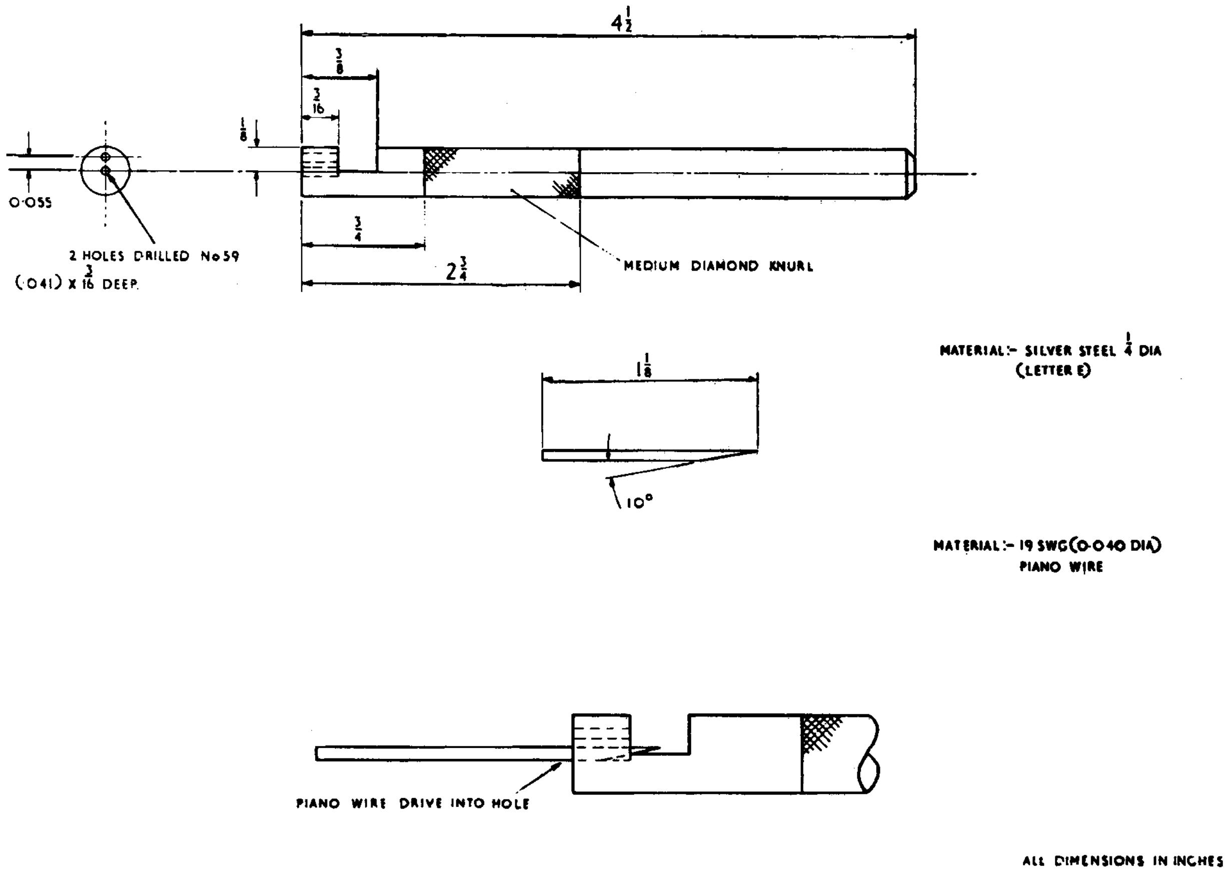


Fig 2 - Wire coiling tool

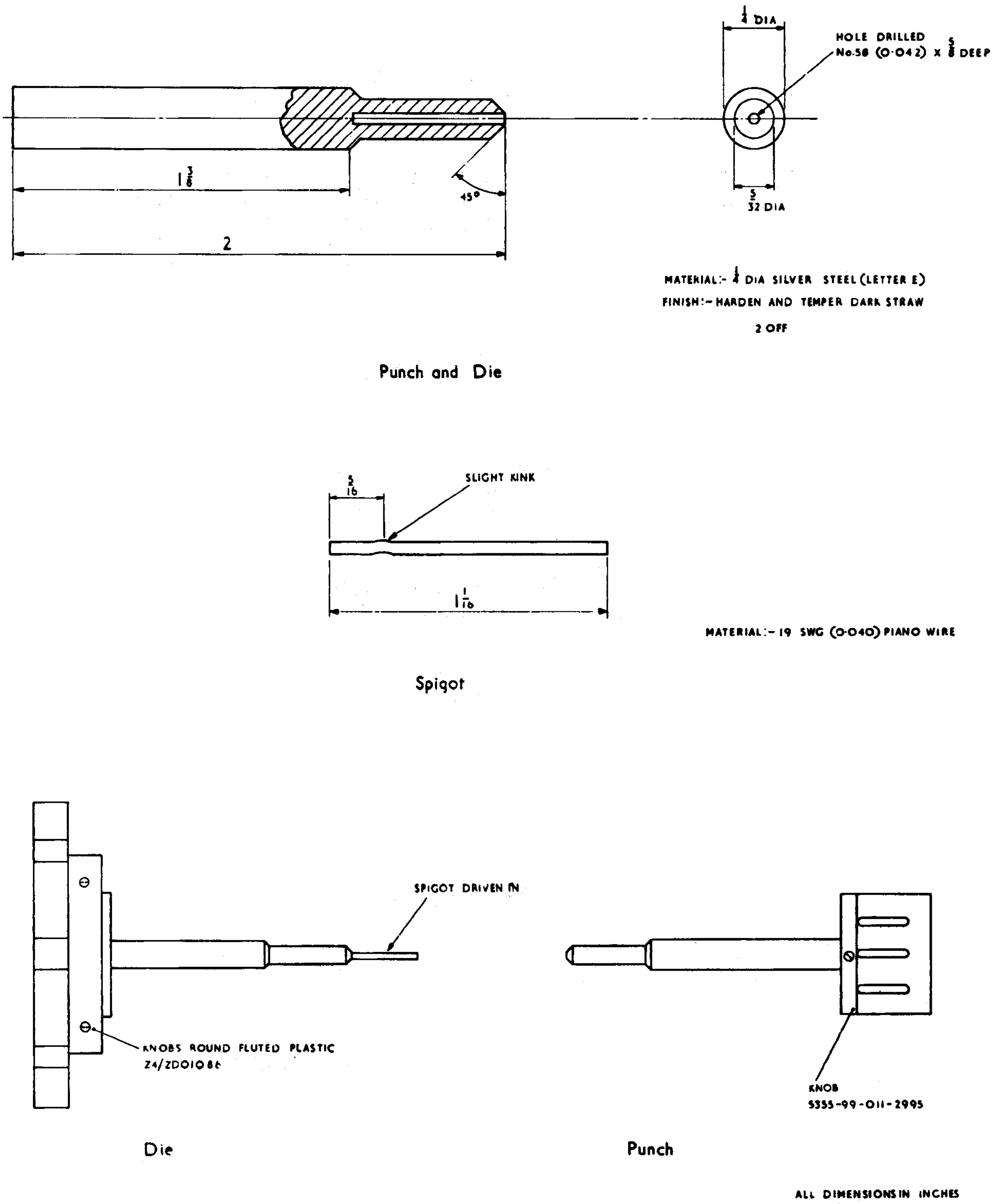
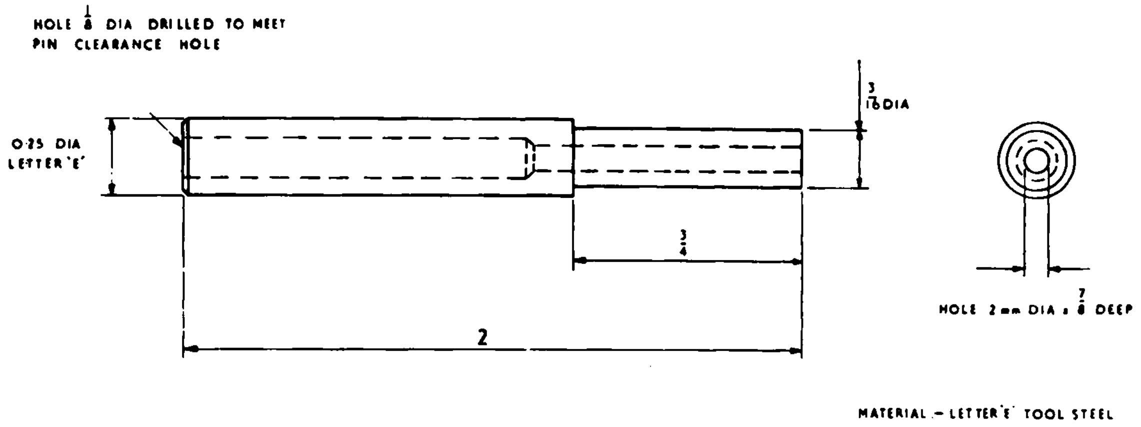
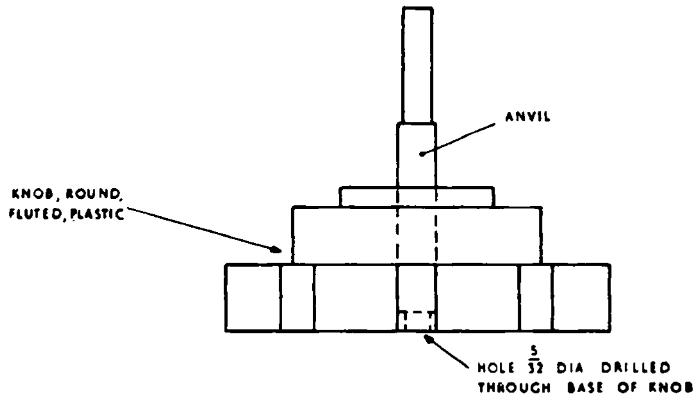


Fig 3 – Eyelet funnelling tool



HOLLOW ANVIL (FOR DOUBLE ENDED PINS)



TOLERANCES ± 1/64
ALL DIMENSIONS IN INCHES UNLESS
STATED OTHERWISE

Fig 4 - Anvil for harwin pins

END

PRINTED CIRCUIT REPAIR TECHNIQUES

CHAPTER 505 - REPAIR METHODS

General principles

1. Before attempting any repair the operator must be aware of the following principles:

a. It is recommended that the board be removed from equipment before repair.

b. Where a protective coating has been applied to both the component and the copper side of the board it may be found necessary to apply a sideways force to the component, after freeing the leads, in order to release it from the coating lacquer. Under these circumstances extreme care must be taken to avoid mechanical damage to the board.

c. Excessive heating of any joint should be avoided as this will reduce the strength of the bonding adhesive and damage more than the necessary minimum area of protective varnish.

d. Mechanical damage to the copper foil is most likely to occur when stress is applied to component leads in a direction that would force the copper from the board.

e. In techniques when the soldering iron is necessarily applied to the lands, the following should be noted.

(1) The application of the soldering iron should be for the minimum time compatible with melting the solder - particularly where transistors are involved.

(2) Where the board was originally finished with a protective coating, local repair to the damaged coating should be carried out immediately in order to prevent moisture absorption.

Work bench and tools

2. The work bench should be covered with a soft, easily cleaned material such as neoprene sheet and must be kept clean but not wax polished. All hand tools used for printed board repairs should be reserved for this use and kept clean and in good order. Cutting tools must be kept sharp.

Magnifiers should be mounted where direct sunlight cannot reach them otherwise severe damage and fire risk can be caused to any object at the focus. If the suggested illuminated magnifier is not obtainable a 60W adjustable bench lamp should be used.

Fault Finding

3. The following EMERs should be consulted for general fault finding information.

a. Tels A 108 – Semi-conductor devices

b. Tels A 339 – Semi-conductors circuits

c. Tels A 412 – Servicing semi-conductor equipments

4. Every application of heat to a printed circuit conductor causes some deterioration of the bond between conductor and board, so soldering operations should be performed only where necessary. Every effort should be made to identify correctly which components are faulty before removing them from the board and as much testing as possible should be done with components in situ. Test prods should as far as possible, be applied only to soldered joints because printed conductors are easily damaged by prods.

Handling of boards

5. Finger marks and dirt provide breeding grounds for fungi; printed boards should therefore be handled carefully by the edges and always held in the printed board holder for inspection or repair. Finger marks and grease should be removed with "Genklene". Boards not being worked on should be stored in pvc bags to protect them from dust and abrasion.

END

PRINTED CIRCUIT REPAIR TECHNIQUES

Chapter 510 - Removal of coatings

Insulating coatings (varnishes)

1. Before removing a component from a board it will normally be necessary to remove any insulating coating around the component land. Thick coatings may be carefully removed with a knife while thin varnish coatings on flat surfaces should be removed with the glass fibre brush. During the desoldering operation the desoldering tool will often burn through thin coatings, the charred residue is then cleaned off with the glass fibre brush after removal of the component.

Conformal coatings

2. Many boards now coming into service use will be found to have one of a variety of coatings generally described as conformal. In order for repairs to be effected this coating must be removed from the repair area.

Cleaning the repair area

3. After removal of any coating from the r epair area final cleaning should be made with a solvent cleaner applied with a camel hair brush. Suitable solvents are listed below. The following solvents are free from deleterious effects on paper-phenolic and glass-epoxide laminates:-

Methylated spirits
Iso-propyl alcohol
Trichloroethane
Genklene (ICI) - recommended due to lack of flammability and low toxicity.
Chloroethane NU (Dupont)
Arklone L (ICI)

PRECAUTIONS

4. a. Items 1 and 2 are highly inflammable.

b. In working with solvents care should be taken to minimise contact with the skin and the inhalation of v apour.

c. The solvent in use must be kept clean and is best dispensed into small bottles. It must be protected from being taken internally, or used as a clothes cleaner as this leads to contamination.

END

PRINTED CIRCUIT REPAIR TECHNIQUES

Chapter 515 - Removal of components

GENERAL

1. This section deals with the removal of components that require to be replaced. This includes components of the axial lead type and the multiple type with fixed leads.

Limitations

2. Extreme care is required to avoid damaging the circuitry, base laminate or other components. This could be caused by excessive heat application, improper tool usage or rough handling of the boards.

Removed components

3. All removed components are to be considered UNSERVICEABLE and reduced to scrap.

Removal of component with axial terminating wires

4. a. Using a pair of small side cutters cut the component wires and remove the component body.

b. Apply a temperature controlled desoldering iron to the joint and quickly remove the remaining component wire and solder.

c. Check that the hole is clear. If any solder remains it should be removed using a temperature controlled solder removal iron.

d. Inspect the land for signs of lifting. If the copper is found to be lifting the board must be rejected and a concession obtained to repair the defect by the method described later in this regulation.

e. Assemble a new replacement component in the normal way. Care should be taken to ensure that excessive heat is not applied to replacement components that are known to be heat sensitive.

f. Remove flux with a solvent cleaner.

g. Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

Removal of through mounted dual in line packages (Replacement using special tools)

5. a. When removing dual in line packages it is essential to melt the solder retaining both rows of terminals simultaneously and to remove the package quickly the moment the solder melts, this is best effected with the following special tools.

A temperature controlled multiple bit soldering iron and
A spring loaded removal tool.

b. If any of the leads were clinched over during assembly it becomes essential to melt the solder on these leads which should then be straightened before applying the following procedure.

c. Fit the removal tool over the dual in line package and apply the multiple bit simultaneously to both rows of terminals; the instant the solder retaining every terminal is sufficiently melted withdraw the package from the board. Using a temperature controlled solder removal iron remove excess solder from all holes.

d. Insert replacement component and resolder ensuring that each terminal is heated for only the minimum time required to effect a successful joint.

e. Remove flux with a solvent cleaner.

f. Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

Removal of through mounted dual in line package (Replacement when special tools are unobtainable)

6. a. Hold the board firmly in the clamp giving free access to either side of the faulty component. If the leads are sufficiently accessible using a small fine hack saw blade cut gently through each of the leads on both sides of the component and remove the body. If the leads are not accessible proceed as in para 8.

b. Using a temperature controlled soldering iron fitted with a 1/32in chisel, $600^{\circ}F/315^{\circ}C$ bit melt the solder around the first component lead and lift the lead from the hole using a pair of tweezers or snipenosed instrument pliers. Care should be taken to apply the iron for a sufficient time only to enable the lead to be freed. Repeat until all leads are free of the board.

c. Using a temperature controlled solder removal iron remove excess solder from all holes.

d. Insert replacement component and resolder ensuring that each terminal is heated for only the minimum time required to effect a successful joint.

e. Remove flux with a solvent cleaner.

f. Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

Removal of integrated circuit components mounted by the reflow solder method (to be replaced by hand)

7. a. Lay the board on a soft base (1" foam rubber) on the work bench, defective component uppermost.

b. Use a temperature controlled soldering iron fitted with a 3/64in chisel 600°F/315°C bit for flat packs and 3/32in for dual in line packages. Melt the solder around the first component lead and lift the lead from the board using a special probe. Care should be taken to apply the iron for sufficient time only to enable the lead to be freed.

c. Repeat until all leads are free of the board. Remove component.

d. Using a temperature controlled solder removal iron remove any excess solder from all lands.

e. Position replacement component and resolder ensuring that each terminal is heated for only the minimum time required to effect a successful joint. Use a small screwdriver or flat probe to hold lead in position until the solder has reflowed and solidified.

f. Remove flux with a solvent cleaner.

g. Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

Removal of integrated circuit components mounted by the reflow solder method (to be removed by use of special soldering bits).

8. a. Lay the board on a soft base (1in foam rubber) on the work bench. Defective component uppermost.

b. Select the correct special soldering bit and fit to a Weller TCP1 soldering iron. Allow the bit to become hot and tin with rosin cored solder.

c. Place the bit squarely on the component leads and push down for 2-5 seconds.

d. Using the appropriate forceps or a scalpel when component is stuck down, lift the component and soldering iron simultaneously.

Note: Do not attempt to lift the component if any resistance is felt, repeat procedure.

Removal of components with through mounted leads where the leads are inaccessible from the component side, eg TO5 and TO18 packages.

9. a. Hold the board firmly in the clamp giving free access to either side of the faulty component.

b. Using a temperature controlled desoldering iron remove the solder from one lead area.

c. Repeat for all other leads.

d. Using a soldering iron temperature controlled to 315°C/600°F remelt the solder around a lead and bend the lead vertical to the board with dental probe or penknife while the solder is still liquid.

e. Repeat for all other leads.

f. The component may now be free to separate from the board, but, if not, remelt the solder from around the first component lead and apply sideways pressure until the lead is free.

g. Repeat for all other leads.

h. Using a temperature controlled desoldering iron remove excess solder from all holes.

j. Insert replacement component and resolder ensuring that each terminal is heated for only the minimum time required to effect a successful joint.

k. Remove flux with a solvent cleaner.

l. Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

Removal of through mounted dual in line packages on unplated hole boards.
(Replacement using a soldering iron)

10. a. Using a temperature controlled desoldering iron, melt the solder at the joint. As the solder melts, remove the solder. Repeat for the remaining leads.

b. Using snipe nosed instrument pliers carefully straighten any bent leads.

c. Carefully remove the package from the board using fingers only or an approved removal tool.

d. Remove any surplus solder from the lands that might interfere with the replacement of the package. Take care to apply the iron for the minimum time required to remove the solder.

e. Examine the board for damage.

f. Insert the replacement package and resolder ensuring that each terminal is heated for only the minimum time required to effect a successful joint.

g. Remove flux with a solvent cleaner.

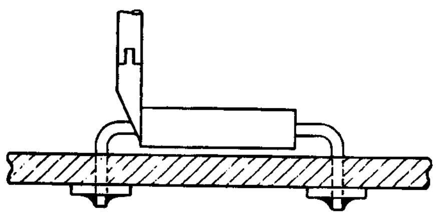
h. Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

Replacement on leads of previous component

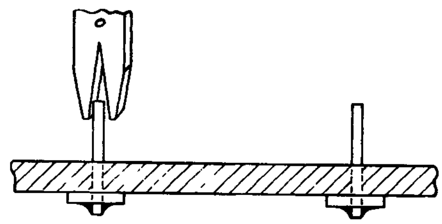
11. If the soldering land is inaccessible or, because the component has been replaced before, it is not thought advisable to subject the land to further heating, the ends of the old component leads may be left in position and the new component soldered to them. This method must be employed with discretion because the extra bulk of wire introduced could disturb the circuit function by altering the stray capacities and should only be used if all previous methods are not suitable.

12. Proceed as follows:-

a. Cut out the defective component close to its body (Fig 1); extra lead, if needed, can sometimes be gained by crushing the component with pliers.



(a) Cut out defective component close to body



(b) Straighten remaining leads and tin

Fig 1 – Removal of component from board

b. Straighten the remaining leads, clean them with the tongs, then, using a heat shunt to protect the soldered lands, tin the leads.

c. Clean and tin the leads of the new component, protecting the component with heat shunts.

d. Note the distance between the leads projecting from the board and mark the leads of the new component at the same spacing.

e. Insert the end of one lead of the new component into the wire coiling tool, bend the lead through 90° (Fig 2a), and rotate the tool to coil up the lead to the mark made at d., above (Fig 2b).

f. Remove the tool and r epeat d. and e. with the other component lead(s) (Fig 2c).

g. Check that the coils are the correct distance apart then cut off surplus coils leaving between one and two turns at each end. (Fig 3a).

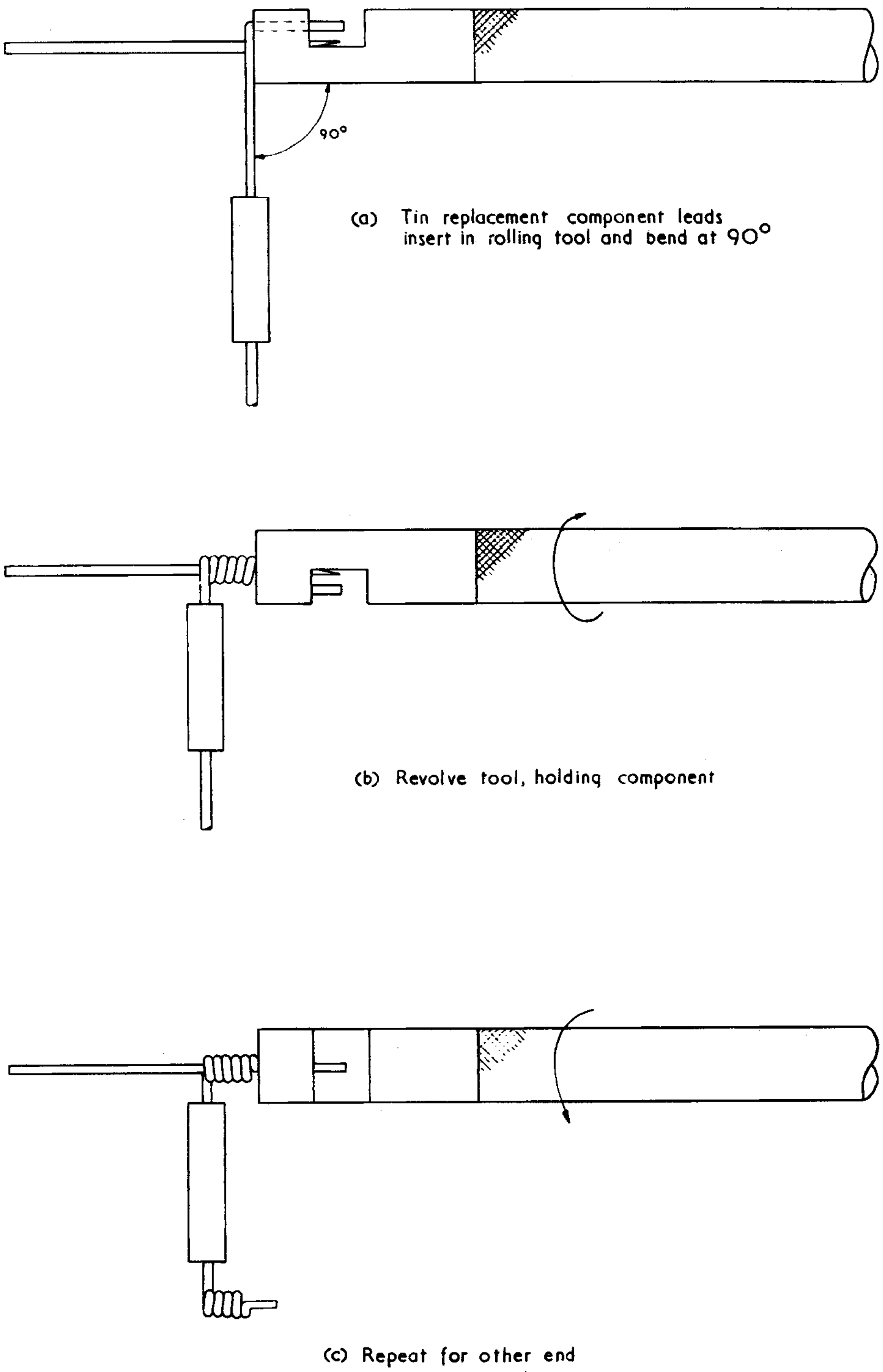


Fig 2 – Use of wire coiling tool

h. Fit coils onto the projecting wires on the board and cut off surplus wire above the coils. (Fig 3b).

j. Protect both component and soldered land with heat shunts and solder the joints. (Fig 3c).

k. Clean off flux residue with a suitable solvent cleaner and coat with the appropriate varnish.

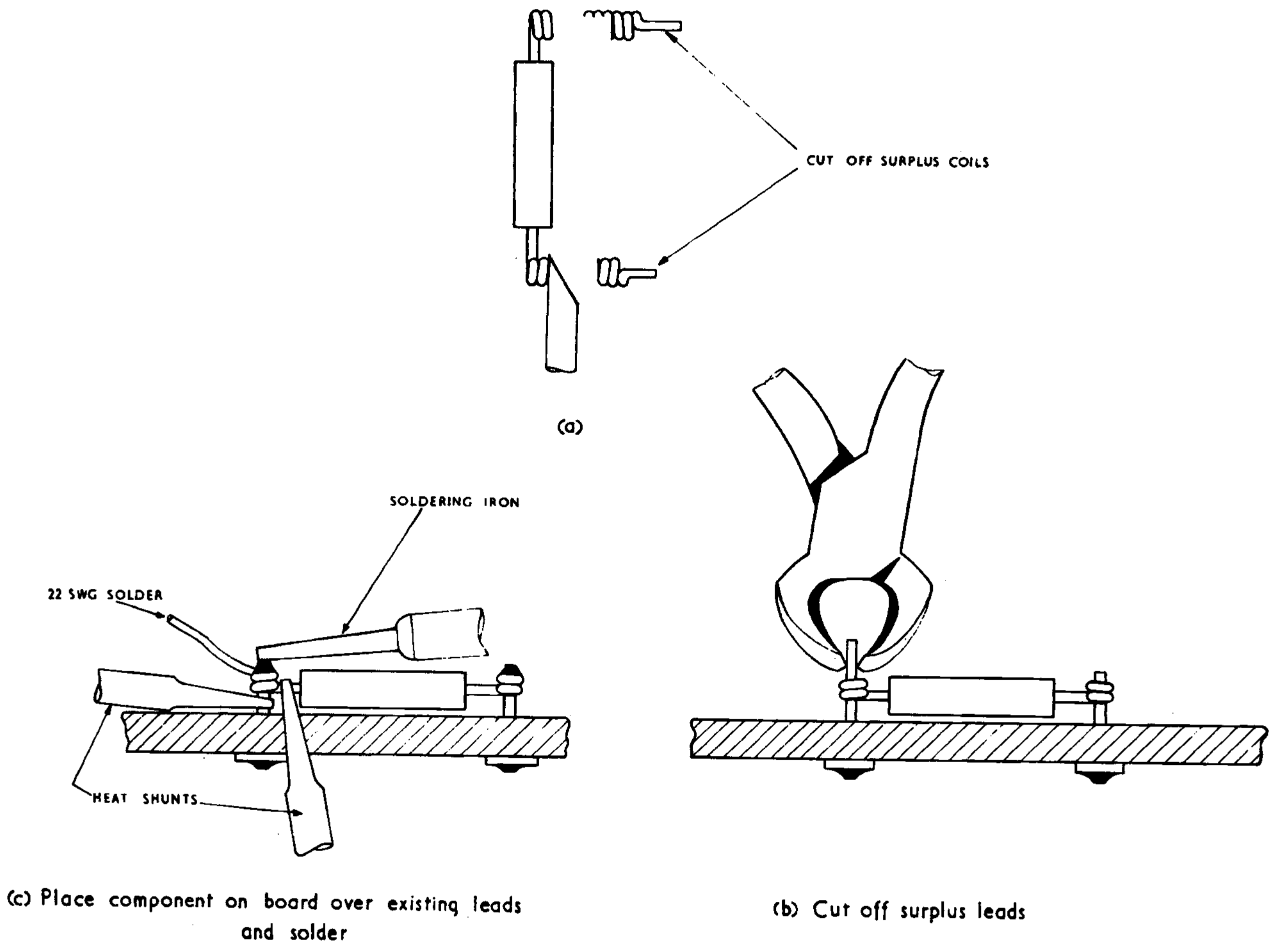


Fig 3 - Fitting component to existing leads

END

PRINTED CIRCUIT REPAIR TECHNIQUES

Chapter 520-Repairs using adhesives

SCOPE

1. The repairs to restore the bond between copper foil and paper/phenolic or glass/epoxide laminate, for which the use of adhesives is permitted, are detailed in chapter 325, para 15 et seq.

General

2. The standard required is that the adhesive bond shall withstand two soldering operations as described in BS 4025 Clause 9(e). The ideal adhesive would be a one-component rapid-curing compound which would comply with the above requirement. In practice it has been found that with those commercially available adhesives which have been tested, a hot cure is necessary for rapid results. If a cold curing system is used, the minimum time of cure is usually 24 hours. Even with cold curing adhesives, a more heat-resistant bond is usually obtained if some heating is applied during the curing cycle. One form of epoxide adhesive which has been tried is in solid-film form. This offers certain advantages in handling, but hot curing is necessary.

3. Before using any adhesive, proper cleaning of the surfaces to be bonded must be carried out. It is important that the repair procedure for a given adhesive should be strictly followed, otherwise poor bond strengths will result. Adhesives which have been found satisfactory are listed in para 9.

Preparation of the board

4. Remove excess solder from the joints involved with a suction iron or other suitable means. Clean the laminate and the copper foil with a suitable solvent using a small brush. It may be necessary in some cases to use a fine abrasive paper to clean the underside of the copper.

5. Mix equal parts of Araldite AY 105 and AY 953F. The pot life of this adhesive, once mixed is approximately 2.1/2 hours at room temperature. The adhesive should be applied with a disposable plastic spatula to both surfaces prior to them being pressed together. The two surfaces should then be pressed together and pressure maintained until the adhesive sets. Clamping may be necessary.

6. The curing time for the adhesive at room temperature is 24 hours; to speed the curing, where possible the board should be placed in an oven at 50°C for 3 hours. Where room temperature curing is employed, it should, if possible, be followed by 1 hour in an oven at 50°C.

7. After heating, the board should be allowed to cool for at least 1/2 hour before the resoldering of any component is attempted.

8. Alternatively the Araldite Twinpack epoxy resin repair kit may be used.

Suitable adhesives

9. a. Liquid Adhesives

GIBA Ltd	Araldite AY 105 with hardener AY 953F
Emerson & Cuming	Eccobond 104
Hysol Sterling	R8 2038 resin with H2 3475 hardener
W J Furse & Co., Traffic St, Nottingham	Epoxy Patch Kit 0151 (FILM)
Shell	Epikote 816

b. Solid adhesives

Johnson & Johnson	Permacel P 19

Apparatus for local hot curing of adhesives in the repair of printed wiring boards.

10. The soldering iron bit should be filed off flat, and shaped if necessary to suit the conductor to be handled. A piece of thin PTFE foil eliminates unwanted adhesion between the iron and the work. A suitable setting of the auto transformer should be found and noted prior to use of the tool on actual circuits.

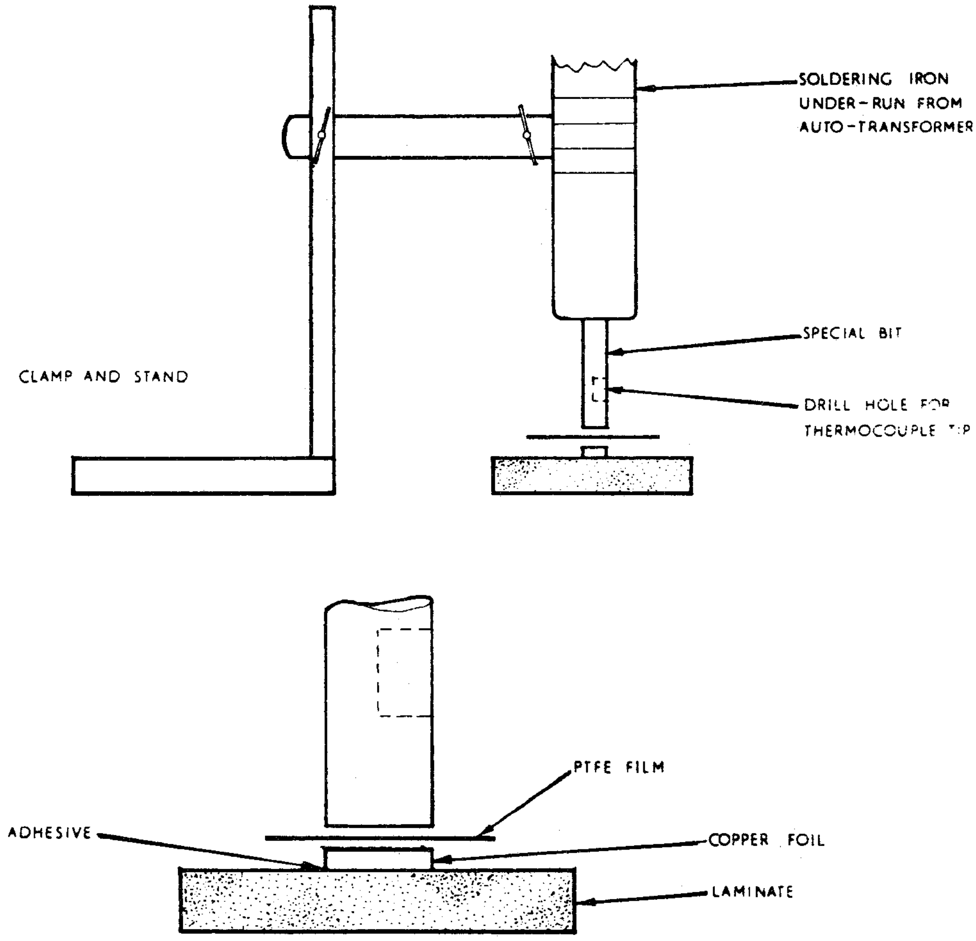


Fig 1 - Hot curing of adhesives

END

PRINTED CIRCUIT REPAIR TECHNIQUES

Chapter 525 - Repair by soldering

Cracked boards

1. Cracks in boards can often be seen by holding the board up to a 60W lamp. Any board which is cracked right through must be condemned. Surface cracks should be stopped at each end by drilling a hole with a No 60 (1mm) drill; if either hole needs to be nearer to a conductor than the minimum conductor spacing, the board should be condemned.

2. If a crack crosses any conductor it must be reinforced over the crack as follows:

a. With the glass fibre brush, very carefully clean the conductor for about 7mm on each side of the crack.

b. Cut a 5cm length of 22 swg tinned copper wire and 1cm from one end bend over at about 45°.

c. Tin the bent-over end of the wire and solder this along the conductor where it crosses the crack. Be careful that the leverage of the long end of the wire does not lift the conductor.

d. Cut off surplus wire, clean off flux residue with a solvent cleaner and varnish the area.

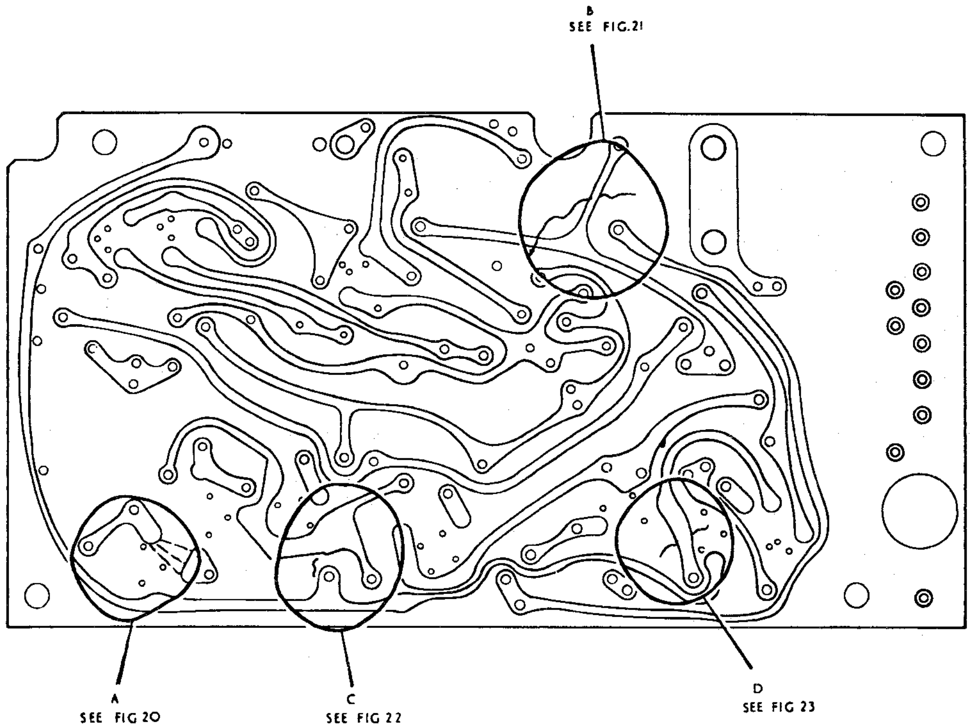


Fig 1 - Contamination and cracks - typical faults

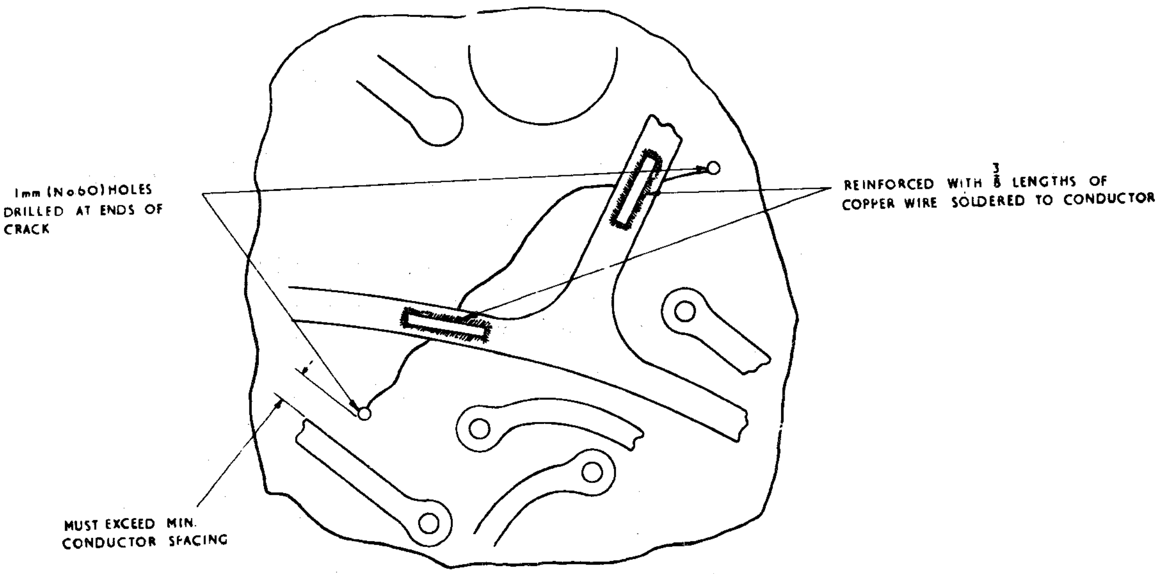


Fig 2 - Crack across common conductors

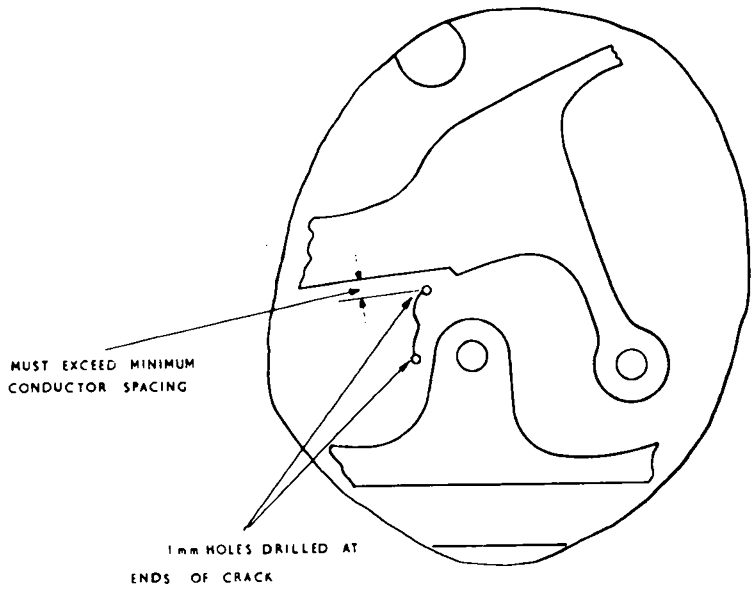


Fig 3 - Crack between separate conductors

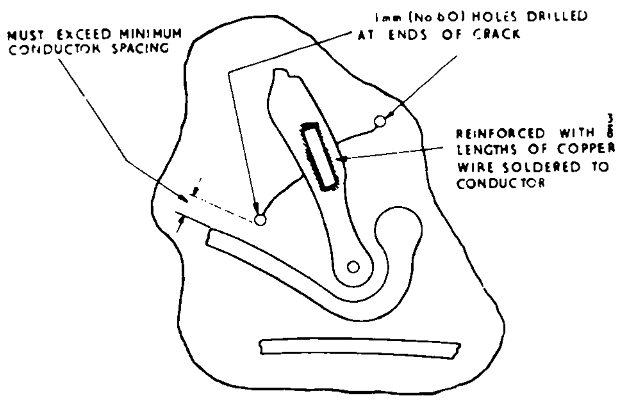


Fig 4 - Crack under single conductor

Contamination under protective coating

3. Low resistance paths caused by contamination in or under the protective varnish coating should be treated as follows:

a. Scrub the area with a glass fibre brush to remove varnish and contamination. Care must be taken when brushing near the conductors not to lift them from the board.

b. Brush off dust, and after any other necessary repairs have been completed, coat the area with the appropriate varnish for the equipment.

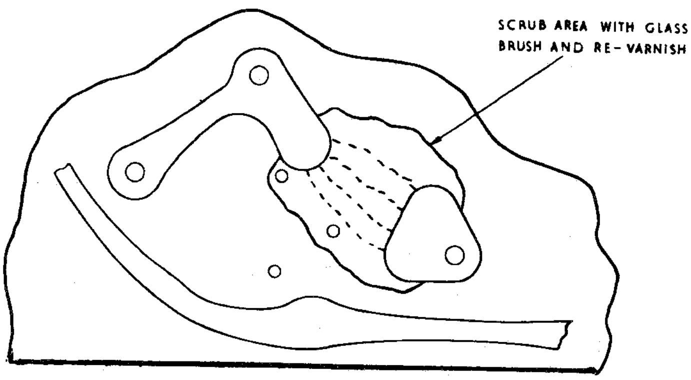


Fig 5 - Contamination under surface coating

c. If charring or scorching is present in a position which bridges, or significantly reduces, the gap between adjacent conductors the board should be condemned. Insulation checks may be carried out only if the components on the board can tolerate the applied test voltage.

Plated edge contacts and plated switch contacts

4. Repairs are not permitted other than at base levels.

Damaged and missing conductors

5. A conductor shown on the wiring diagram but found to be missing on the printed circuit or a damaged conductor giving evidence of:

a. a complete break

b. scratches

c. nicks

d. pinholes

which reduce the cross-sectional area of the conductor by more than the tolerance of the appropriate specification.

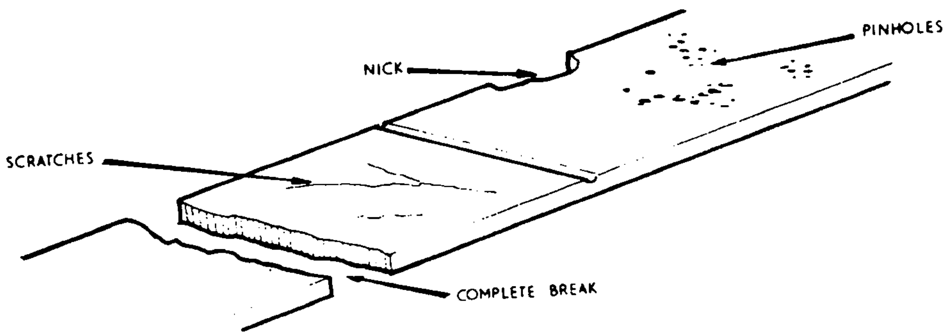


Fig 6 - Typical damage

Limitations

6. No repairs to unassembled single or double sided boards are permitted. Conductor widths and spacings must not be reduced below the allowable tolerance by any repair method. Repairs shall only be carried out when the cause of the failure is understood. The faults could be indicative of latent weaknesses elsewhere on the board or on the production film.

7. The repairs listed are in general suitable for printed wiring boards with track widths and spacings down to 0.5mm (0.020"). Some modifications or restrictions may be necessary for smaller widths and spacings. It must be borne in mind that the conductor pattern may be critical in some assemblies and this will need to be taken into account in assessing the feasibility of a repair, and choosing an appropriate method.

General

8. The techniques described can be satisfactorily applied to the outer layers of a multilayer board but great care must be taken to ensure that the method chosen does not include any operation liable to cause damage to an internal conductor. The choice of repair method depends to some extent on the separation between the points to be bridged. For the repair of scratches, para 15 (copper foil method) is the most suitable.

9. When the gap to be bridged is less than 20mm (0.8"), bare tinned-copper wire, soldered to the track, may be used, see para 18.

10. When the gap to be bridged is between 20 and 40mm (0.8-1.6"), insulated tinned-copper wire may be used, soldered to the conductor and run on the conductor side of the board, see para 19.

11. When the gap to be bridged is over 40mm (1.6"), insulated tinned-copper wire, run on the component side of the board and soldered to the conductors after passing through holes drilled at the side of the conductors, may be used, see para 21.

12. Insulated tinned-copper wire, run between relevant lands, may be used whatever the gap. When the g ap exceeds 40mm (1.6") it may be desirable to pass the wire through holes and run on the component side, see para 21.

13. Insulated wire run between component terminations may also be used whatever the gap, see para 21.

14. In subsequent paras repair methods are given in order of preference, however, the particular circumstance of damage will often dictate the repair method to be followed.

Repair of scratches, pinholes and nicks (damage less than 10mm)

15. A piece of pre-tinned-copper foil between 0.035mm and 0.070mm thick * should be soldered to the conductor, with a minimum overlap of 5mm (0.2") on each side. Where the gap to be bridged is greater than 3mm (0.12"), the foil should be bonded to the board with a suitable epoxide adhesive (see chap 5). The film adhesive is convenient for narrow gaps.

16. The length of foil to be bonded should not exceed 10mm (0.4"), in this case see para 18.

*NOTE This thickness is suitable for boards carrying 1 oz per sq ft copper (0.0014" or 0.035mm). For 2 oz or 3 oz copper, proportionately thicker foil should be used.

17. This method is preferred for the repair of scratches, but where the track widths are less than 0.5mm (0.020"), the foil strips become difficult to handle, and the repair may have to be carried out with suitable thickness tinned-copper wire as under, see para 18.

Broken or damage conductors - gap to be bridged less than 20mm

18. a. Insulated wire run to holes drilled through the damaged or broken conductor.

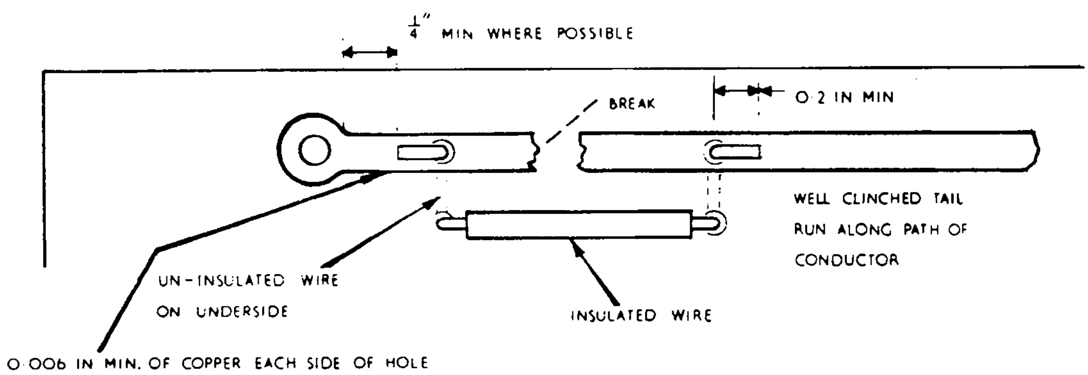


Fig 7

(1) Drill two holes (for preferred sizes see Fig 2) through the conductor either side of the break or damaged area. Drill from the conductor side - great care should be taken to ensure that the conductor is not lifted or that any damage is caused to components and conductors on the other side of the board. If the damaged conductor is on the component side of the board two additional holes will be required to enable the insulated length of wire to be run on the component side of the board.

(2) Cut to length a suitable piece of single strand copper wire. Pre-form the wire to run between the two conductors on the component side of the board. The route chosen should be the shortest permitted by the configuration of the components on the board. Strip the insulation from the ends of the wire or cut sleeving to length as appropriate.

(3) Clean both sides of the break in the conductor adjacent to the holes for at least 1/4in. with a glass fibre scratch brush. Ensure any coating is removed. Clean the areas with a solvent cleaner applied with a camel hair brush.

(4) Tin the newly cleaned area of conductor using a soldering iron temperature controlled to 600°F. Where gold plating is present care must be taken to remove gold contaminated solder. Re-tin with fresh solder.

(5) Insert the tails into the holes ensuring that the insulated length of wire is lying flat on the component side of the board. Clinch the tails onto the conductor in line away from the break or damaged area and solder in place. Remove flux with a solvent cleaner.

(6) If there is any danger of the insulated portion of wire lifting it should be held to the board with araldite applied at approximately 1in. spacings. Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

b. Short length of tinned copper wire to bridge the damage or missing conductor.

<u>NOTE:</u> This method should only be used when the damaged conductor is on the component side of the board, or where practical (ie dimensional) limitations preclude the use of para 18a.

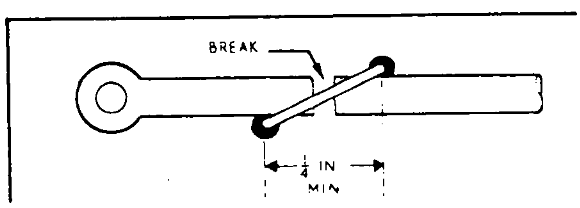


Fig 8

(1) Drill holes through the board, beside the conductor as shown in Fig 17. Clean the area to be soldered at least 1/4in. on each side using a glass fibre scratch brush. Ensure any coating is removed. Clean the area with solvent cleaner applied with a camel hair brush.

(2) Tin the newly cleaned area of the conductor using a soldering iron temperature controlled 315°C/600°F. Where gold plating is present care must be taken to remove gold contaminated solder. Re-tin with fresh solder.

(3) Take a piece of tinned copper wire and pass its ends through the holes. Secure the wire in position by twisting the ends together on the back of the board.

(4) Solder the wire in position. Remove the flux with a solvent cleaner.

(5) Fill the holes with araldite, allow to cure, then trim the wire ends off flush on the back of the board.

(6) Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

c. Bare tinned copper wire soldered directly to the tracks. (Only to be used as a last resort on gaps less than 20mm).

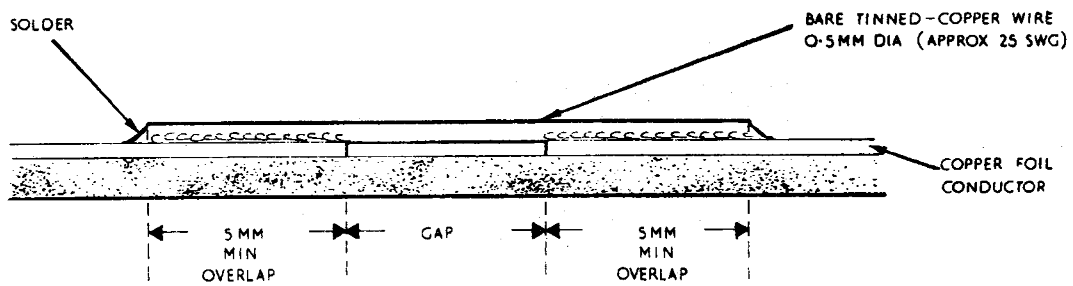


Fig 9

(1) The break may be bridged by means of bare tinned-copper wire soldered to the tracks as shown in Fig 7. The overlap should be at least 5mm (0.2") on each side and the wire should be in contact with the conductor along the whole length of the overlap.

(2) After soldering, the solder should show a good fillet between wire and conductor and be bright and smooth in appearance.

<u>NOTE:</u> For conductors wider than 1.5mm (0.06"), wire of 0.8mm dia (approximately 21 swg) should be used.

Gap to be bridged 20-40mm (0.8-1.6")

19. a. The methods described in para 18a. and 18b. should be considered and used if feasible.

b. Insulated wire soldered directly to the tracks.

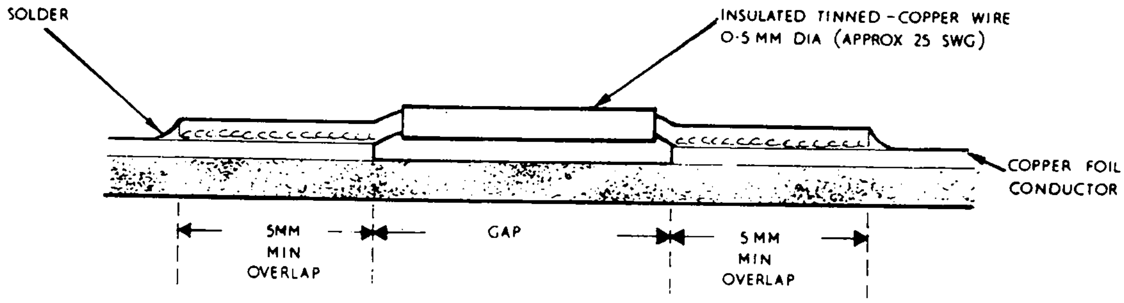


Fig 10

20. The repair is carried out as in para 18c. but using insulated wire. This method should only be used as a last resort and never on gaps exceeding 40mm. The new section of wire should be spot fixed to the board using adhesives as detailed in Chapter 5.

Gap exceeding 40mm (1.6").

21. a. The method described in para 18a. should be considered and used if feasible.

b. Insulated wire run between the relevant lands.

NOTE: This method is not considered suitable for use with Berg Griplet Terminals.

(1) Cut to length a suitable piece of single strand copper wire. Preform the wire to run between the two lands on the component side of the board. The route chosen should be the shortest permitted by the configuration of the components on the board.

(2) Strip the insulation from the ends of the wire, or cut sleeving to length as appropriate.

(3) Remove any coating present using a glass fibre scratch brush. Clean the lands with a solvent cleaner applied with a camel hair brush. Tin the lands using a soldering iron temperature controlled to 600°F/315°C.

(4) Insert the tails into the land holes ensuring that the insulated part of wire is lying flat on the component side of the board.

(5) Clinch the tails onto the lands and solder using a soldering iron temperature controlled to 600°F/315°C.

(6) Remove flux with a solvent cleaner.

(7) If there is any possibility of the insulated portion of wire lifting, it should be held to the board with araldite applied at approximately 1in. spacings.

(8) Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

(9) The circuit should then be checked to ensure that any critical conductor pattern has not been affected.

c. Insulated wire run between component terminals: Proceed as in para 18b. but note that this method is more likely to:-

(1) Damage components

(2) Create disturbance to critical conductor patterns.

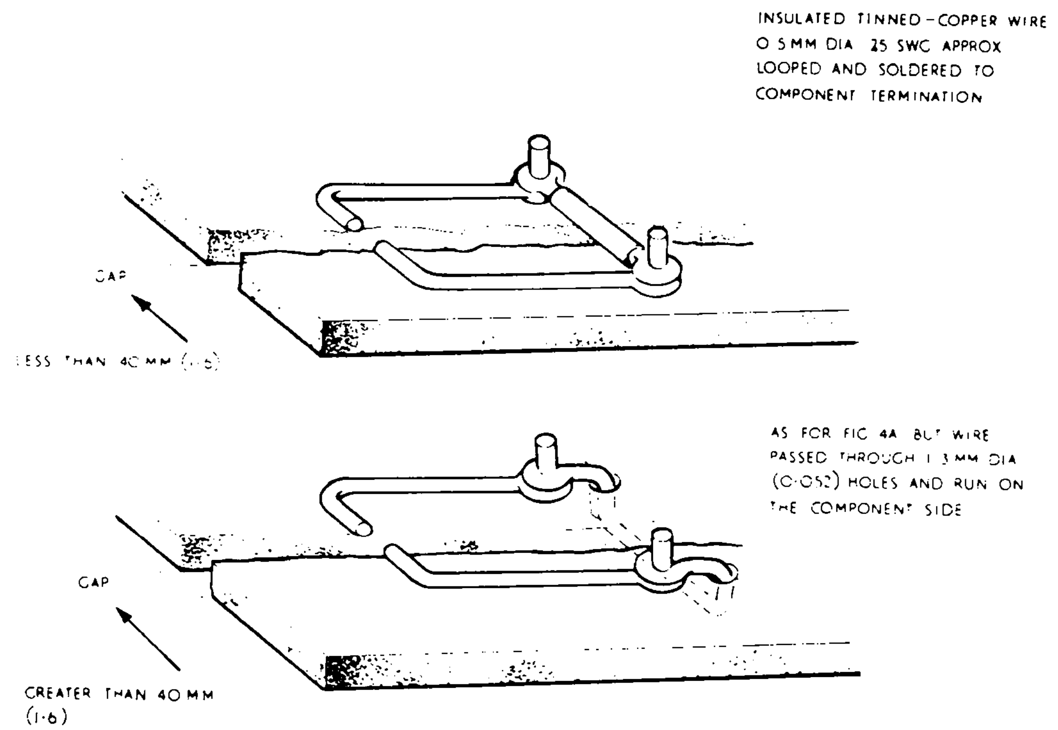


Fig 11

d. Insulated wire soldered directly to the tracks, run on the component side of the board and fixed to the board with adhesive at 10cm intervals.

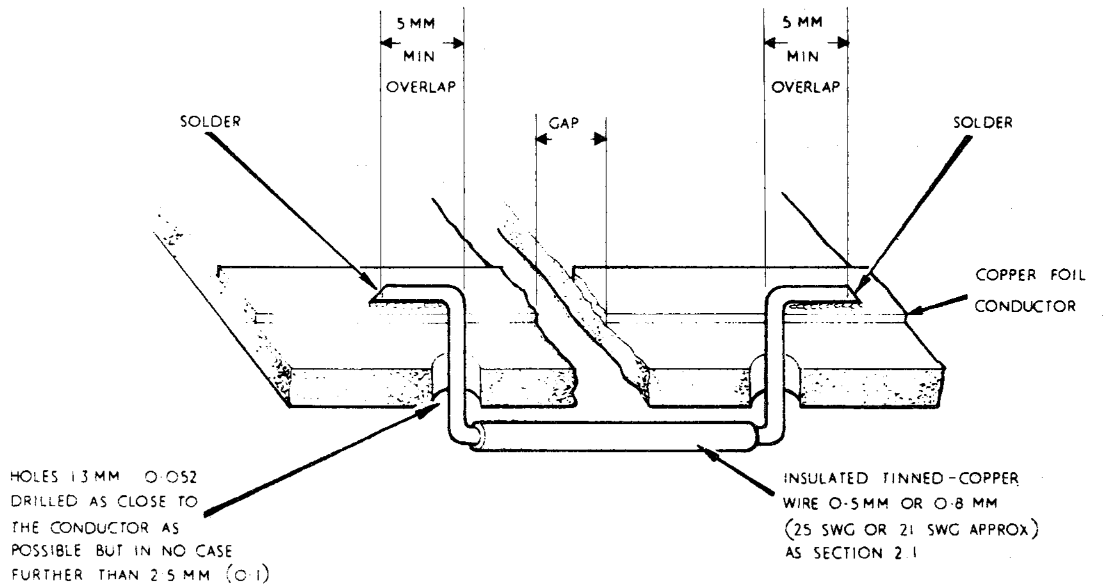


Fig 12

END

CONDITIONS OF RELEASE

(To be applied to documents which the recipient Government may not release to anyone outside its Defence Departments).

a. This information is released by the UK Government to the recipient Government for Defence purposes only.

b. This information must be accorded the same degree of security protection as that accorded thereto by the UK Government.

c. This information may be disclosed only within the Defence Departments of the recipient Government, except as otherwise authorized by Ministry of Defence (Army).

d. This information may be subject to privately owned rights.

PRINTED CIRCUIT REPAIR TECHNIQUES

Chapter 530 - Repairs using eyelets

Eyelet repair of damaged conductors (single sided boards only)

1. The use of eyelets as described in para 7b. and c. may offer a more appropriate repair method in certain cases.

2. If the missing length of conductor is less than the span of a double-tagged eyelet, then one of these may be fitted in the gap and soldered to the sound conductor on each side (Fig 1).

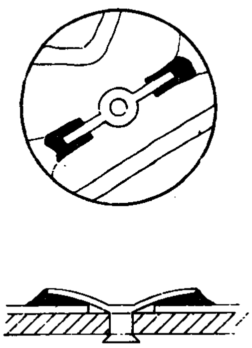


Fig 1 - Open circuit conductor - short section faulty

3. If the missing length of conductor is greater than the span of a double-tagged eyelet, then a single-tagged eyelet should be fitted at each end of the gap with its tag soldered to the sound conductor. The two eyelets are then connected together with 22 swg wire covered with insulating sleeving (Fig 2).

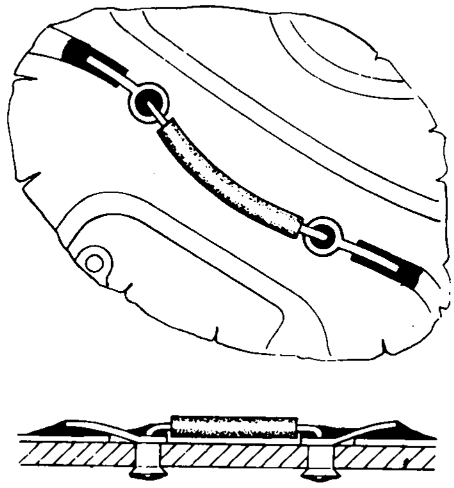


Fig 2 - Open circuit conductors - long section

4. If the missing portion of conductor involves a land this must be dealt with as described in paras 5 to 13.

Damaged or missing lands (not applicable to plated through hole boards).

5. Failure of a printed conductor may involve the lands to which components are attached and these must be repaired or replaced by suitable substitutes. Even if lands are not involved it is necessary to provide a firm anchorage to support the weight of new wiring and to prevent further lifting of the printed wiring.

6. The following methods are all feasible and are listed in order of preference.

a. A suitable tag or tagged eyelet may be inserted and soldered to the existing conductor (see para 7).

b. A suitable solderable pin may be inserted and the component lead soldered to it on the component side of the board. Tinned-copper wire is then used to connect the pin to the conductor (see para 8).

c. When the land is for mechanical attachment only, a loop of tinned-copper wire may be soldered to the component lead or pin (see para 9).

d. A damaged land may be overlaid with a similar land and a suitable length of attached conductor obtained from another board. This repair is applicable only when the damaged land is of adequate area to provide the required adhesion (see para 10).

e. Tinned-copper wire may be used to bridge the component lead and the conductor (see para 11).

f. In cases where circuit configuration is critical, a replacement land with a suitable length of attached conductor may be bonded to the laminate with an approved adhesive. The junction between the original and replacement conductors should be soldered (see para 12).

Lifted lands (repair by use of eyelets)

7. a. General. The commonest fault in printed wiring is lifting of a land, usually caused by application of excessive heat when soldering the associated component. The general repair method is to carefully cut away the lifted land, with a razor blade, and fit an eyelet in its place. Connections between the eyelet and the original wiring are made good with the tag(s) of the eyelet, No 22swg wire or soldering tags fitted under the flange of the eyelet, according to circumstances. The exact method needed depends upon the layout of the conductors and whether there is printed wiring on both surfaces or only on one surface of the board.

b. The preferred anchorages are eyelets of the types shown in Fig 3

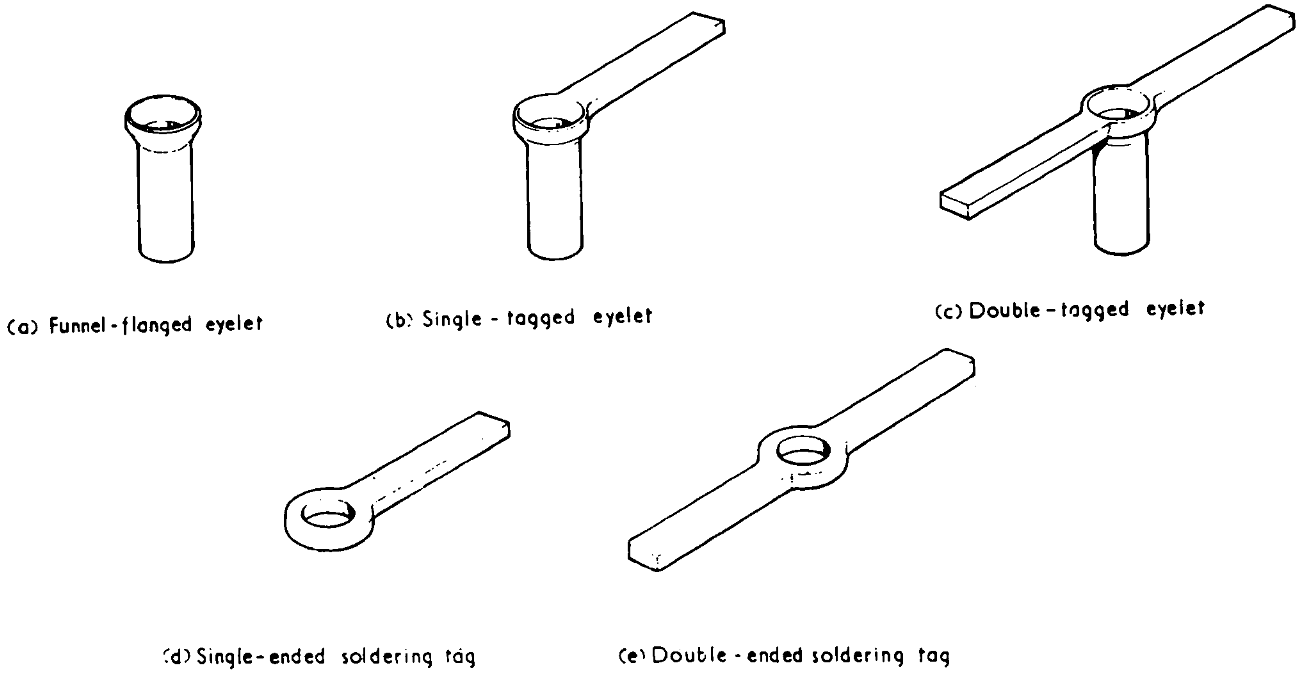


Fig 3

These eyelets may be used alone or in conjunction with special soldering tags.

c. Eyelets are fitted, using a locally manufactured funnelling tool (Fig 4) as follows:

(1) Drill a 1.7mm (No 51) hole through the board at the desired point.

(2) Select an eyelet and reduce its length by filing as necessary. The length of the eyelet shank must be: the thickness of the board, plus 1/32in, plus 1/64in for each soldering tag to be used with the eyelets. Simple holders for filing the eyelets may be made by drilling 1.77mm holes in pieces of plastic or metal of the requisite thickness.

(3) Shorten and bend the tags as necessary.

(4) Fit the eyelet into the hole from the conductor side of the board, together with any soldering tags to be used on this side. Insert the spigot of the funnelling die through the eyelet, from the same side.

(5) Stand the die on the bench so that the board is conductor side downward and fit any soldering tags needed on the 'reverse' side of the board. Slide the funnelling punch over the spigot (Fig 4).

(6) Press down the punch, by hand, to form the flange. With tagged eyelets or when soldering tags are used, a slight flange should first be formed by gentle pressure and the position of the tags adjusted before the flange is completed.

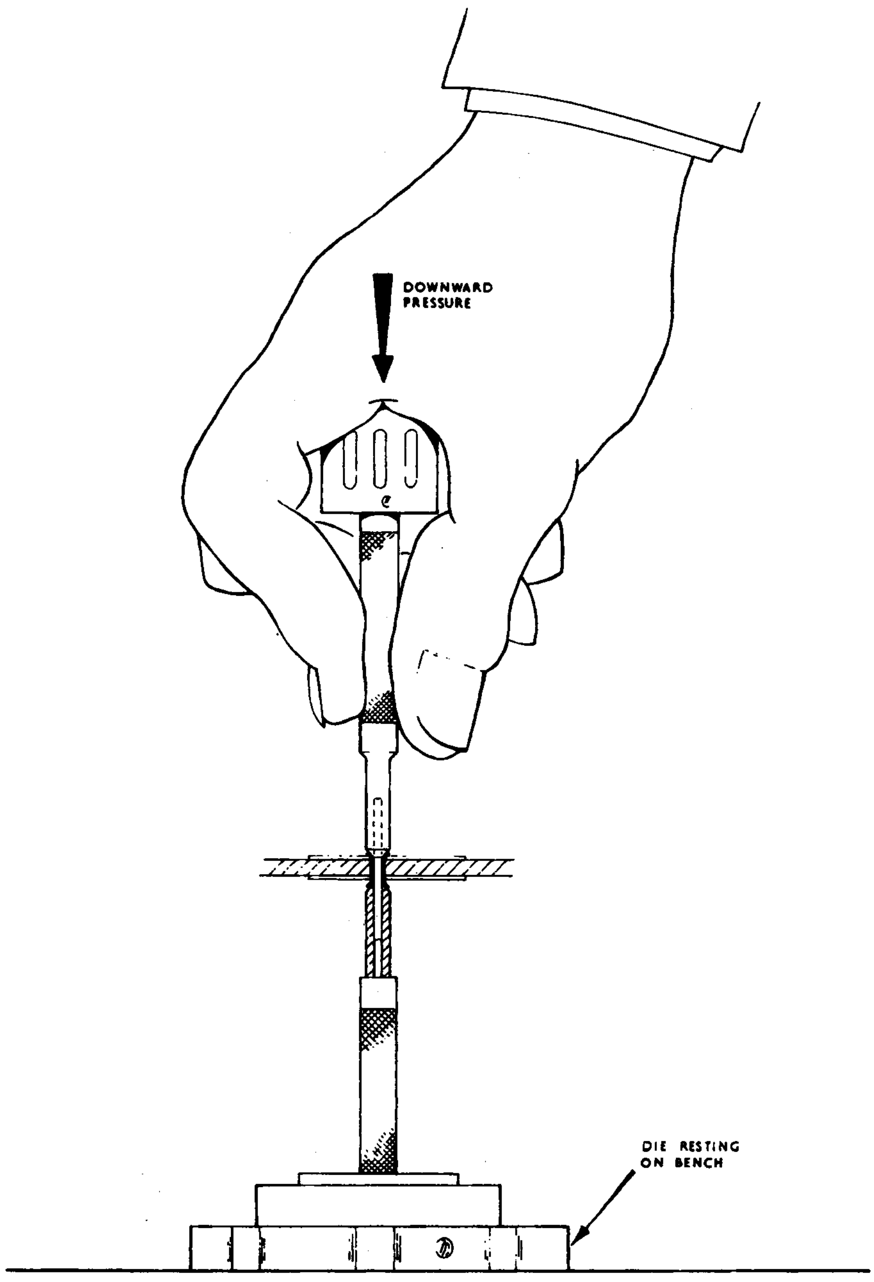


Fig 4 - Fitting of eyelets

d. Eyelet repair of single sided boards. Where an end land has lifted, a single-tagged eyelet may be fitted in its place and the tag soldered to the cut-off end of the original wiring (Fig 5). Where an intermediate land has lifted the choice of method depends upon the layout of conductors on each side of the land.

(1) If the conductor is straight, use a double tagged eyelet (Fig 6).

(2) If the conductor is slightly curved use a double tagged eyelet with one or both tags bent as required (Fig 7).

(3) If the conductor is sharply curved so that the land lies on a corner, too sharp to be matched by bending the tags, use a single tagged eyelet with a single ended soldering tag fitted under the flange (Fig 8). Care must be taken to solder the eyelet and tag together.

(4) If the land lies at a T-junction, use a double tagged eyelet and a single-ended soldering tag (Fig 9), or alternatively a single tagged eyelet and a double-ended soldering tag.

(5) Complicated junctions can usually be accommodated by a combination of tags and eyelets; choose the combination which gives the least number of soldered joints.

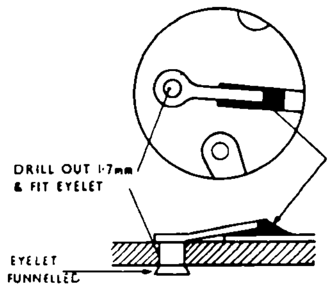


FIG 5 LIFTED END LAND (DETAIL 'E')

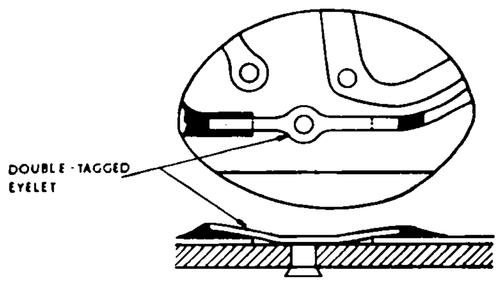


FIG 6 LIFTED LAND ON STRAIGHT CONDUCTOR (DETAIL 'F')

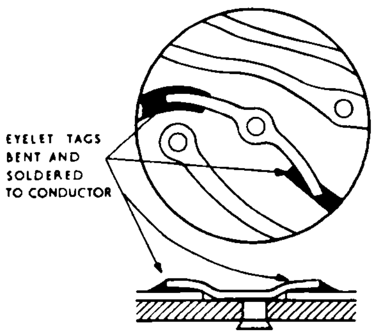


FIG 7 -LIFTED LAND ON CURVE (DETAIL 'G')

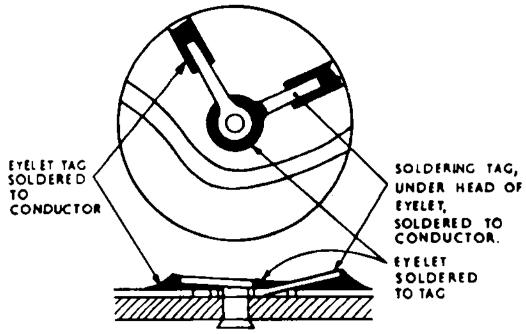


FIG. 8 LIFTED LAND ON CORNER (DETAIL 'H')

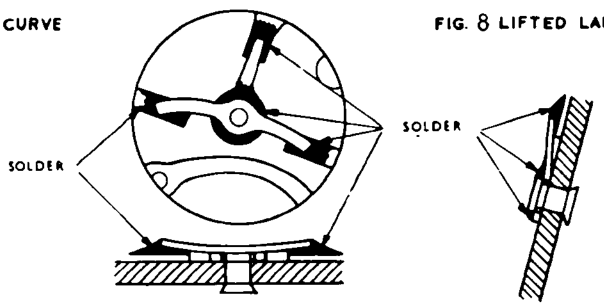


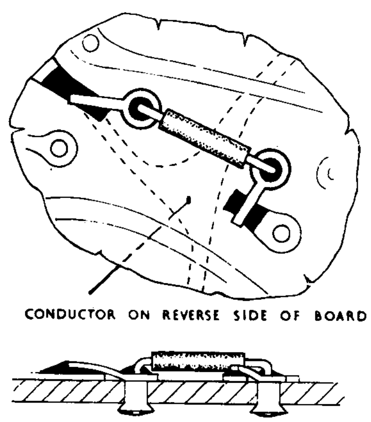
FIG 9 LIFTED LAND ON T-JUNCTION (DETAIL 'J')

Eyelet repair of double-sided boards (not plated through hole)

e. On double-sided boards it may not always be possible to fit eyelets in exactly the ideal place because of interference with conductors on the reverse side of the board. Occasionally this problem may be insoluble and the board must be condemned, but it should usually be possible to overcome it by:

(1) If spacing of adjacent conductors permits, positioning the eyelets to the side of the sound conductor, rather than in line with it, and soldering the tag across the conductor instead of along it (Fig 10).

(2) Removing more of the faulty conductor than is actually damaged, thus permitting the eyelets to be further apart. If necessary the conductor may be removed right back to the next land and an eyelet fitted in place of the land.



Lifted land repair using solderable pins

8. A suitable solderable pin may be inserted through the board, the component lead being looped round and soldered to one side. A piece of bare tinned-copper wire looped round the other side is soldered flat on to the conductor, the overlap being at least 10mm (0.4") (see also Chap 540).

Damaged land used for mechanical attachment only

9. When a land is for mechanical attachment only, a missing or damaged land may be replaced by a loop of tinned-copper wire or a suitable solderable washer soldered to the component termination. This is only suitable when the component beds firmly down onto the board.

Overlay of damaged land with a similar land

10. Where the adhesion of the land is satisfactory and the area has been reduced by not more than 25 per cent, the land may be overlaid with a second land obtained from another board. The underside of this land should be cleaned with fine abrasive paper and tinned with solder using a small iron. The land should be soldered over the existing land and conductor so that at least 5mm (0.2") of conductor is overlapped. A non-solderable pin inserted in the hole should be used to align the lands. When the component is soldered in, care should be taken to retain the second land in position. This type of repair is useful mainly when the damage occurs on the conductor side of the land, as illustrated above.

Use of tinned copper wire to bridge directly from the conductor to the component lead.

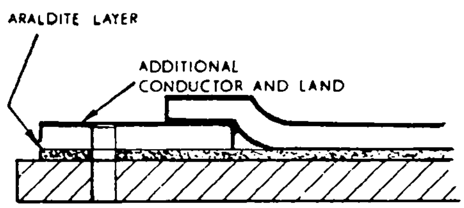
11. Damaged lands may be removed by cutting the conductor with a sharp instrument. The repair may be carried out by looping a length of bare tinned-copper wire round the component lead and soldering down to the conductor with at least 10mm (0.4") overlap. The gap between the end of the conductor and the component lead should be as small as possible, and in any event not greater than 5mm (0.2").

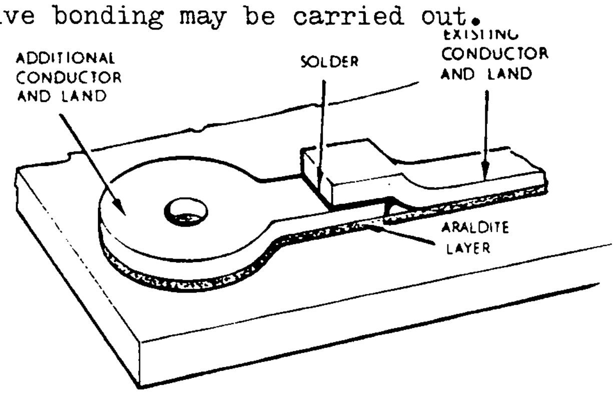
NOTE: This repair is restricted to cases where the mechanical support achieved is adequate for the particular component.

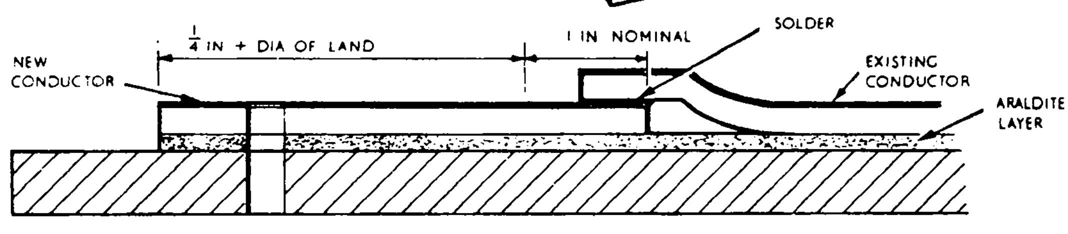
Use of a replacement land and length of conductor.

NOTE: This method restores the original circuit to its original configuration and is therefore electrically the most satisfactory. However it requires great care if mechanical and electrical restoration is to be fully achieved.

12. The repair may be effected by bonding a replacement land to the laminate by means of an approved adhesive. The replacement land should have sufficient conductor attached to it to enable an overlap of at least 5mm to be soldered to the existing conductor. The soldering operation should be carried out first, using a pin to locate the holes in the board and the replacement land. After removal of the pin, the adhesive bonding may be carried out.







13. In view of the care required a detailed sequence of operation which has been found to be satisfactory is described below.

(1) If a land lifts with part of the conductor (or where damage occurs to the land during its repair) the lifted portion should be cut off and discarded. Remove a similar sized land complete with tail from an unserviceable board.

(2) Clean and tin the affected conductor on the board and only the overlapping portion of the replacement conductor. The replacement land should then be positioned over the existing hole, using a non-solderable guide pin in order to maintain alignment of holes. Solder the tail of the replacement land to the conductor, ensuring that an overlap of at least 0.10in. is maintained.

NOTE: Do not tin underside of replacement land since adhesion to tinned surfaces is not as effective as that to copper.

NOTE: The distance between the end of the existing conductor and new land should not be less than 1/4in. as in Fig 11.

(3) The underside of the land and conductor and the topside of the board area to be repaired should be cleaned free of flux and dirt by application of a solvent cleaner applied with a camel hair brush. (Allow these areas to dry before proceeding with the next operation).

(4) The land and conductor should be lifted sufficiently to smear a small amount of araldite on the bottom of the land and conductor and the top of the board.

(5) The land should be pressed down with a blunt instrument such as a dental probe and any excess araldite removed.

(6) The repair should be allowed to cure.

(7) After the araldite is cured the component lead should then be resoldered.

(8) Remove flux with a solvent cleaner.

(9) Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

Repairs to double sided boards using plated through holes

General

14. Where there is printed wiring on both surfaces of the board, one side may be dealt with as a single sided board but if the land is plated-through to a corresponding land on the other surface of the board, this circuit must also be reinstated. If the other land is intact, the eyelet may simply be funnelled and soldered to the land (Fig 13) but if the other land is lifted as well it must be removed and a soldering tag fitted to the eyelet, before funnelling, to join up with the conductor (Fig 12).

Failure of plated-through holes

15. Where lands incorporating plated-through holes are repaired as in para 14, circuit continuity through the hole is restored by the eyelet used. If hole plating fails between intact lands it may be repaired as follows:

a. If the hole does not carry a component, a short link of 22 swg wire should be fitted through the hole, bent over and soldered to each land (Fig 14).

b. If the hole is to carry a component lead it should be drilled out, an untagged eyelet fitted, and soldered to the lands on each side (Fig 15).

A component lead should not be used to provide continuity through the hole because success would depend upon the lead being properly soldered on both sides of the board. If the component were subsequently replaced it might well be soldered on only one side and a fault would be caused.

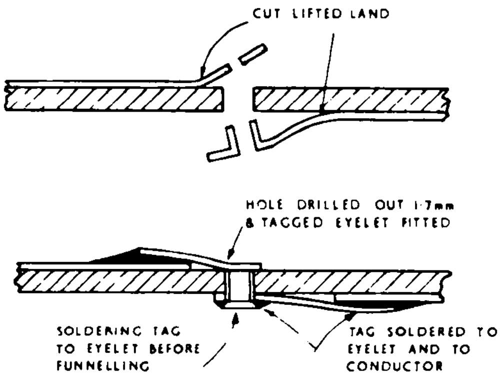


Fig 12 - Double sided board - Both lands lifted

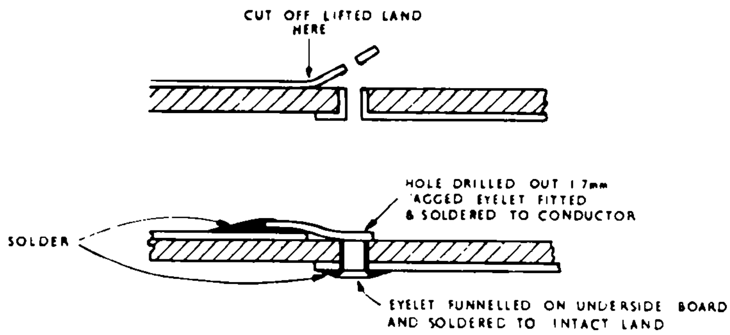


Fig 13 - Double-sided board - One land lifted

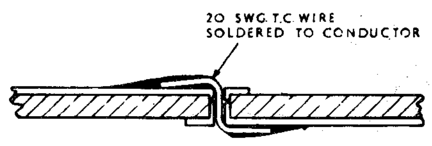


Fig 14 - Failure of plated - through hole, without component

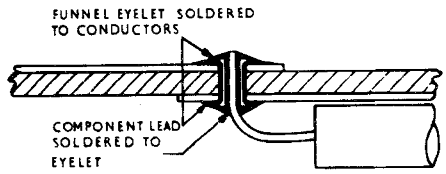


Fig 15 - Failure of plated - through hole, with component

16. Alternatively a tinned copper wire link may be passed through a suitably-sited hole and soldered along the conductors on each side for a minimum distance of 0.5mm (0.2").

If the configuration of the conductors allows it, and the width of the conductors is not less than 2.5mm (0.1"), the wire link may be in the form of a "C" connection (Fig 16).

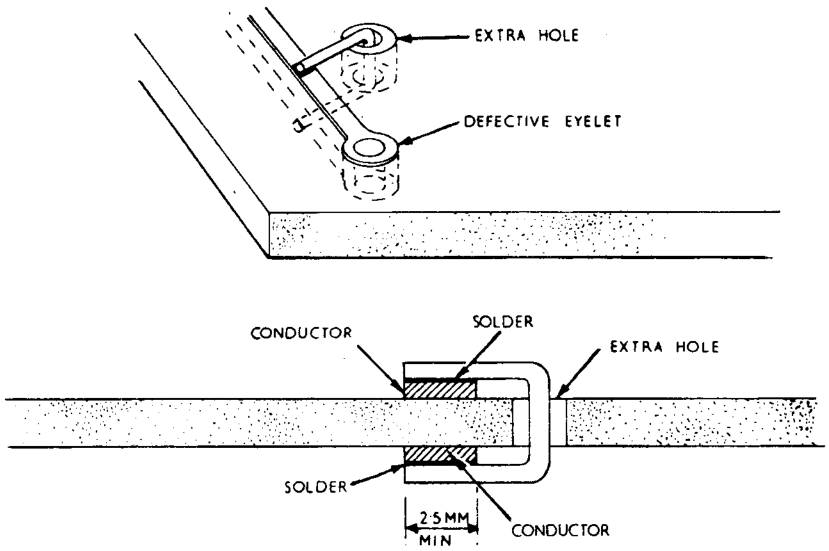

EXTRA HOLE
DEFECTIVE EYELET
CONDUCTOR
SOLDER
EXTRA HOLE
SOLDER
2·5 MM
MIN
CONDUCTOR

Fig 16

END

PRINTED CIRCUIT REPAIR TECHNIQUES

Chapter 535 - Repairs using Harwin or Vero Pins

INTRODUCTION

1. An alternative range of repairs is possible using Vero pins of the types listed in Fig 1 or Harwin pins as listed in Fig 2. These are tin-plated brass pins, partly fluted to be a force fit into a hole drilled in the board. The pins may be single or double-ended to project from one or both sides of the board, component leads or connecting wires being soldered to the projecting portion of the pin.

VERO PINS

2. Types of Vero pins are shown in Fig 1.

	Name	Part No	Hole dia.	Overall length
A	Shouldered half pin	TP/2145	0.025"	0.222"
B	Terminal pin	TP/2144	0.040"	0.496"
		TP/2140/3073	0.052"	0.469"
C	Shouldered terminal pin	TP/11032	0.040"	0.380"
		TP/2143	0.052"	0.470"
		TP/2142	0.040"	0.380"
D	Half pin	TP/11034	0.040"	0.286"
		TP/2141	0.052"	0.286"
E	Shorting pin	TP/11036	0.040"	0.125"
		TP/11037	0.052"	0.125"
F	Miniature terminal	MT/11081	0.052"	0.360"
		MT/11082	0.040"	0.360"

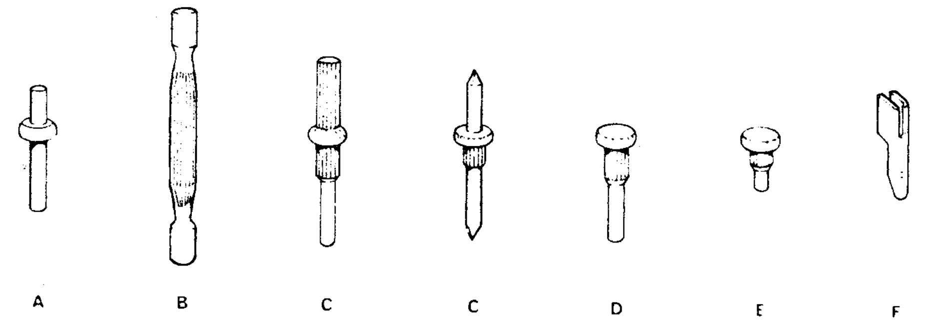


Fig 1 - Vero pins

HARWIN PINS

3. Types of Harwin pins are shown in Fig 2.

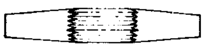
Pin type	Outline	Length (in)	Hole in Panel			Panel thickness	Part Number
			in	mm	No		
H2081		$\frac{3}{8}$	·062	1·6	52	$\frac{1}{8}$ TO $\frac{3}{16}$ -	Y3/5940-99-100-5674
H2085		$\frac{9}{32}$	·052	1·3	55	$\frac{3}{32}$ TO $\frac{5}{32}$	Z1/5940-99-915-0026
H2088		$\frac{9}{32}$	·039	1·0	61	$\frac{3}{32}$ TO $\frac{5}{32}$	NIV
H2083		$\frac{5}{8}$	·062	1·6	52	$\frac{1}{8}$ TO $\frac{1}{4}$	Y3/5940-99-901-2186
H2087		$\frac{15}{32}$	·052	1·3	55	$\frac{3}{32}$ TO $\frac{5}{32}$	NIV
H2089		$\frac{15}{32}$	·039	1·0	61	$\frac{3}{32}$ TO $\frac{5}{32}$	NIV

Fig 2 - Harwin Pins

4. Suitable drill sizes are indicated in Fig 3.

5. The general principles of repair using pins instead of eyelets are fairly obvious and no detailed instructions will be given. Examples of typical repairs are shown in Fig 4 to 6. Repairs with pins are, in general, not as neat as those with eyelets and do not usually permit the original wiring to be copied as closely. In some cases the projecting pin may be an embarrassment. This type of repair should therefore, as a general rule be employed only on boards which already use pins, in their normal wiring, or are too thick for eyelets to be fitted.

SIZE	USE FOR
0.5mm (0.020")	T018, T05 transistors and ICs, small diodes, microminiature components with leads.
0.6mm (0.024")	As above for more generous clearance; will require larger land.
0.7mm (0.028") 0.8mm (0.032")	DIL circuits, miniature components.
0.9mm (0.035") 1.0mm (0.030")	Standard components, resistors, small capacitors, small capacitors, wires etc
1.3mm (0.052") 1.4mm (0.055") 1.6mm (0.063")	Larger components, larger capacitors, etc.
2.0mm (0.079")	10 BA clearance
2.5mm (0.098")	8 BA clearance
3.0mm (0.118")	6 BA clearance
4.0mm (0.157")	4 BA clearance

Drill sizes may be indicated by land size, eg small lands 0.5mm, large lands 0.8mm. PWBs which have complex drilling requirements or those on which the same size lands are used for different size holes will require a drilling drawing.

Remember the land must be at least twice as big as the hole.

Fig 3 - Suitable drill sizes

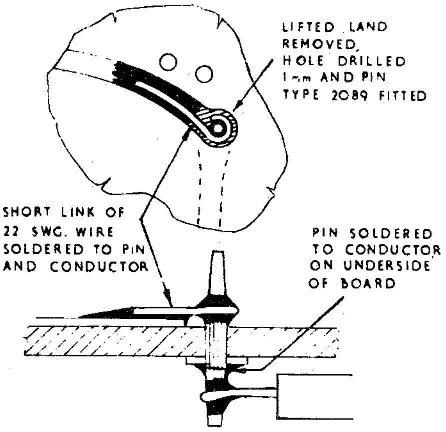


Fig 4 - Repair with pins - Lifted land

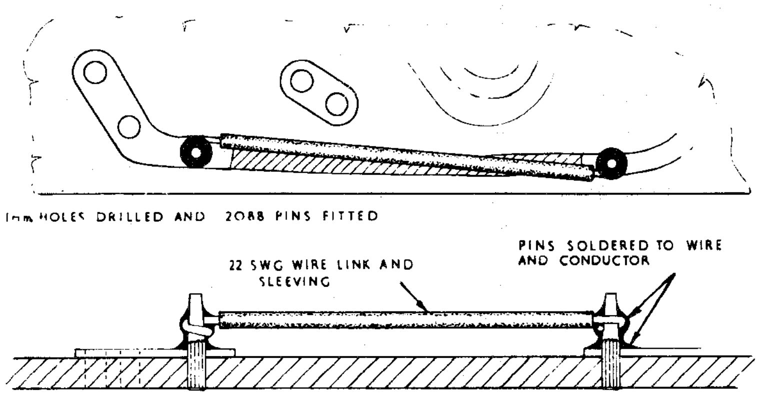


Fig 5 - Repair with pins - Open circuit conductor

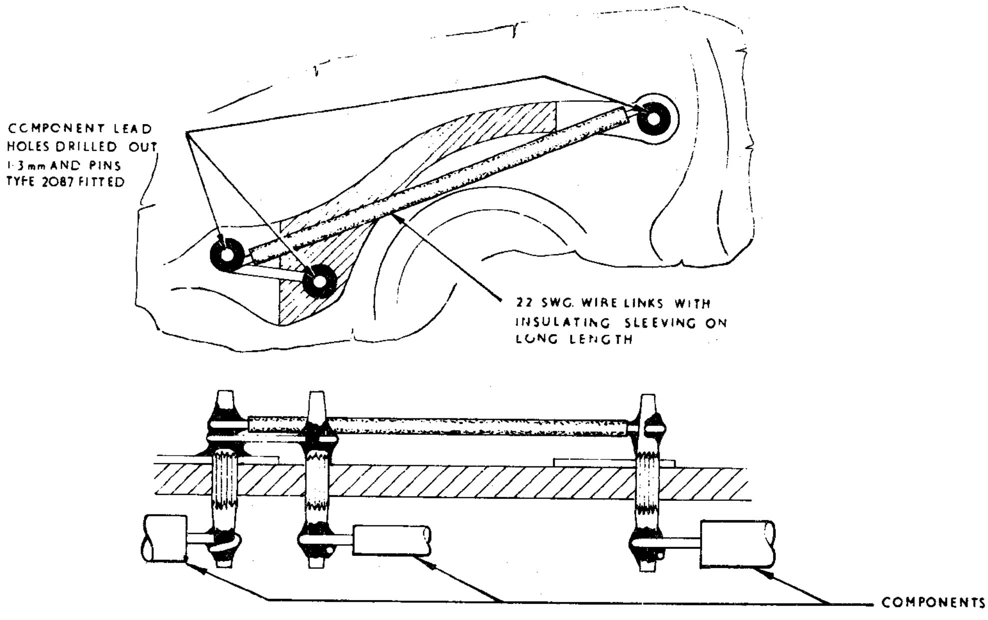


Fig 6 - Repair with pins - Large land and conductor lifted

6. Pins are fitted, using the appropriate insertion tools or locally manufactured anvils as follows:

a. Choose a pin appropriate to the thickness of the board and the number of wires to be accommodated.

b. Drill the correct sized hole in the board, taking care not to damage sound wiring or components on either side of the board.

c. Push the pin into the hole by hand as far as possible.

d. Using the appropriate insertion tool drive the pin to the correct depth.

e. When the pin is mounted through a printed conductor clean the conductor with the scratch brush and carefully solder the pin to the conductor. The soldering bit should be applied to the pin, not the conductor.

f. Attach connecting wires, as required, to the pin by wrapping them round it not more than 1.1/2 turns and soldering. All components must be protected by heat shunts.

g. NOTE: With the largest size pins it may be necessary to use a soldering bit at 370°C (PT-C7). Particular care must be taken not to overheat printed wiring and components.

h. Clean off flux residue.

7. To remove a pin:

a. Desolder the joint and unwrap and remove all wires from the pin, protecting components with heat shunts. Check that all solder has been removed.

b. Using the appropriate insertion tool or the hollow anvil and a punch remove the pin.

c. If a new pin is to be fitted, the hole must be drilled out to take the next larger size. If this is not possible the pin must be relocated ie a new hole must be drilled for a pin of the original size.

END

PRINTED CIRCUIT REPAIR TECHNIQUES

Chapter 540 - Alterations and additions to printed circuit boards.

ALTERATIONS

1. Should design changes necessitate the alteration of assembled boards full instructions will be given of how these changes should be effected. The instructions might include any of the repair techniques given in the various chapters of this regulation, it might also require that:

a. Additional conductors be fitted.

b. Existing conductors be disconnected.

c. Additional components be fitted.

Additional holes

2. Holes should be drilled to the instructions given. References given on drawings will always apply to the conductor side of the board.

3. A check should be made to ensure that the edge of holes drilled are always more than 1/64in. from any conductor and 1/16in. from any component. Care should be taken when drilling holes to avoid damage to components mounted on the board.

4. Drilling references will be given to fix the exact location of the holes. In order to establish the approximate location X and Y ordinates will be given as a drawing showing the adjacent pattern area and exact dimensions from easily identified lands.

ATTACHING ADDITIONAL CONDUCTORS TO THE BOARD

5. The additional wire should always be run on the component side of the board. Care should be taken to ensure that at no point does an uninsulated wire touch a component or that an insulated wire touches a component with a high running temperature.

6. Any of the methods outlined in Chaps 525-530 may be used subject to the limitations detailed. Alternatively terminal pin techniques can be used if considered suitable (see Chap 535), or addition of conductors by attachment to existing components (see Fig 1).

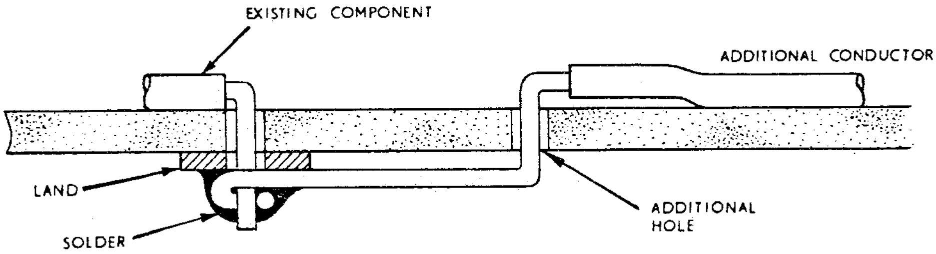


Fig 1

Removing existing conductors

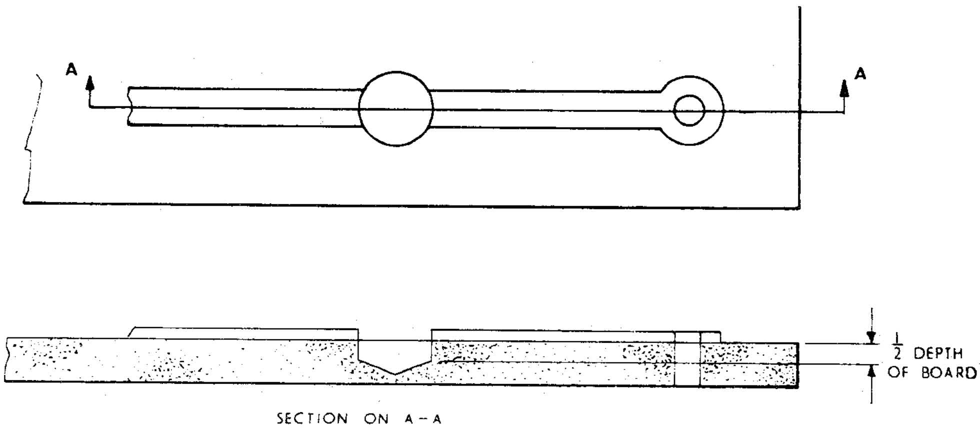


Fig 2

7. a. Drilling through.

(1) Drill a hole through the centre of the conductor to half the depth of the base material with a drill whose diameter is approximately twice the width of the conductor (Fig 2). (This method can only be used when no harm will be caused by the drilling to the other side of the board, ie the hole should always be more than 1/64in. from any other conductor and at least 1/16in. from any component).

(2) Clean edges of the hole and treat with two coats of polyurethane lacquer.

b. Cutting and peeling.

(1) With a scalpel carefully cut through the copper conductor in two places about 0.125in. apart, then gently peel away the portion of conductor between the two cuts, taking great care not to damage the base material. Seal the cut ends of the remaining conductors and the board using the original coating material or polyurethane lacquer.

Fitting additional components.

8. When design alterations make necessary the addition of components; sufficient space should exist on the board for the component and any necessary signwriting.

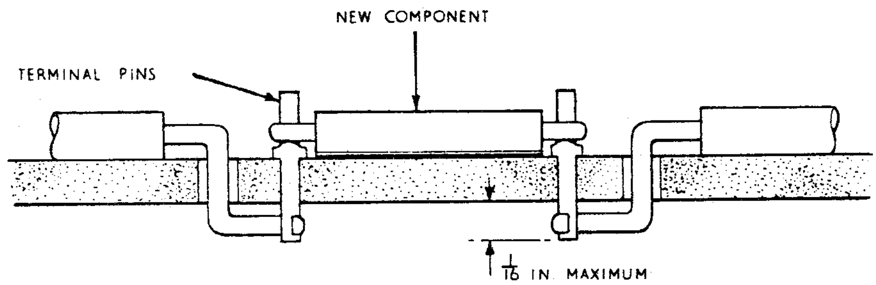


Fig 3

9. Follow carefully the instructions on alteration instructions. If the new component is to be wired between two existing components this will usually necessitate the addition of wire (para 53-70) and the connection of these wires to the component (Fig 3).

a. Drill four holes; size and position as specified on the alteration drawing.

b. Fit two terminal pins as recommended.

c. Pass additional wires through holes adjacent to the terminal pins and solder to the pins.

d. Solder additional component to terminal pins.

e. Remove flux with a solvent cleaner.

f. Restore the original coating where removed by the above procedure. If the original coating is unobtainable coat the affected area with polyurethane varnish.

10. The methods of repair so far described use eyelets as the principal anchorage.

END

PRINTED CIRCUIT REPAIR TECHNIQUES

CHAPTER 545

HANDLING PRECAUTIONS, ELECTROSTATIC SENSITIVE DEVICES

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Note...
These Pages 1 to 10 and Pages 1 to 4 Annex A Issue 4, supersede Pages 1 to 8 Issue 2 dated Aug 79 and Page 9 Issue 3 dated Jun 81.

CONTENTS

INTRODUCTION

1 Advances in the technology and fabrication of active devices have resulted in the introduction of more complex, physically smaller and electrically fragile devices into service equipments. These devices can easily be degraded by electrostatic discharge and are termed 'electrostatic sensitive devices' (ESSDs). Such devices include metal oxide semiconductors (MOS), field effect transistors (FET), some capacitors, thin film resistors, bi-polar transistors and small junction area semi-conductors. In some cases, these devices can be affected by potential as low as 20 V.

2 Damage to ESSDs is easy to induce, hard to detect and always costly and the handling precautions for them MUST be applied at every stage of manufacture, assembly, packaging, storage, transportation, repair and maintenance.

3 This regulation is consistent with BS 5783:87 and does not in any way replace that document.

THE NATURE OF STATIC ELECTRICITY

4 Static electricity is an excess or deficiency of electrons on a surface and can occur on both conductive and insulative materials. Static discharge is due to the transfer of electrons within a body or from one body to another. This transfer occurs due to the interaction of charged bodies or of charged and uncharged bodies and is called the Triboelectro Effect (see Annex A).

COMMON MISCONCEPTIONS

5 Several misconceptions are being aired about the handling of Electrostatic Sensitive Devices (ESSDs). Two of the most common are:

5.1 Once a device is mounted on a p.e.c. it is no longer susceptible to damage by static discharge. WRONG! A device so mounted can be even more vulnerable to this type of damage as tracks and leads on a p.e.c. can act as antennae and funnel the static discharge directly to the device.

5.2 The only devices that one needs to protect are CMOS-type devices. WRONG! Many other devices are even more sensitive than CMOS types and ALL semi-conductor devices are sensitive to some extent.

PREVENTING DAMAGE BY STATIC DISCHARGE

6 The basic concept in the prevention of damage to ESSDs is to prevent any build up of static and to remove, under controlled conditions, any existing charge. Damage to an ESSD is triggered by the existence of a potential difference across two points on the device. There are two basic rules for eliminating this potential difference and thus preventing static damage. These rules are:

6.1 Handle all ESSDs in Special Handling Areas (SHAs).

6.2 Pack all ESSDs, and all assemblies containing ESSDs, in either static dissipative or conductive containers at all times when not in use.

SPECIAL HANDLING AREAS

Definition

7 A Special Handling Area (SHA) is defined in BS 5783 as a working area where ESSDs may be handled without damaging them by discharge of static electricity.

Types

8 In MOD(Army) there are two basic types of SHA:

8.1 The static type, used in static workshops and some ERVs, a typical workshop layout being shown in Fig 1.

8.2 A Field Service Kit (FSK), for use where it would be impossible, or impractical, to install a static type, ie some ERVs, armoured vehicles, Land Rovers etc. Fig 2 shows the component parts of a typical FSK.

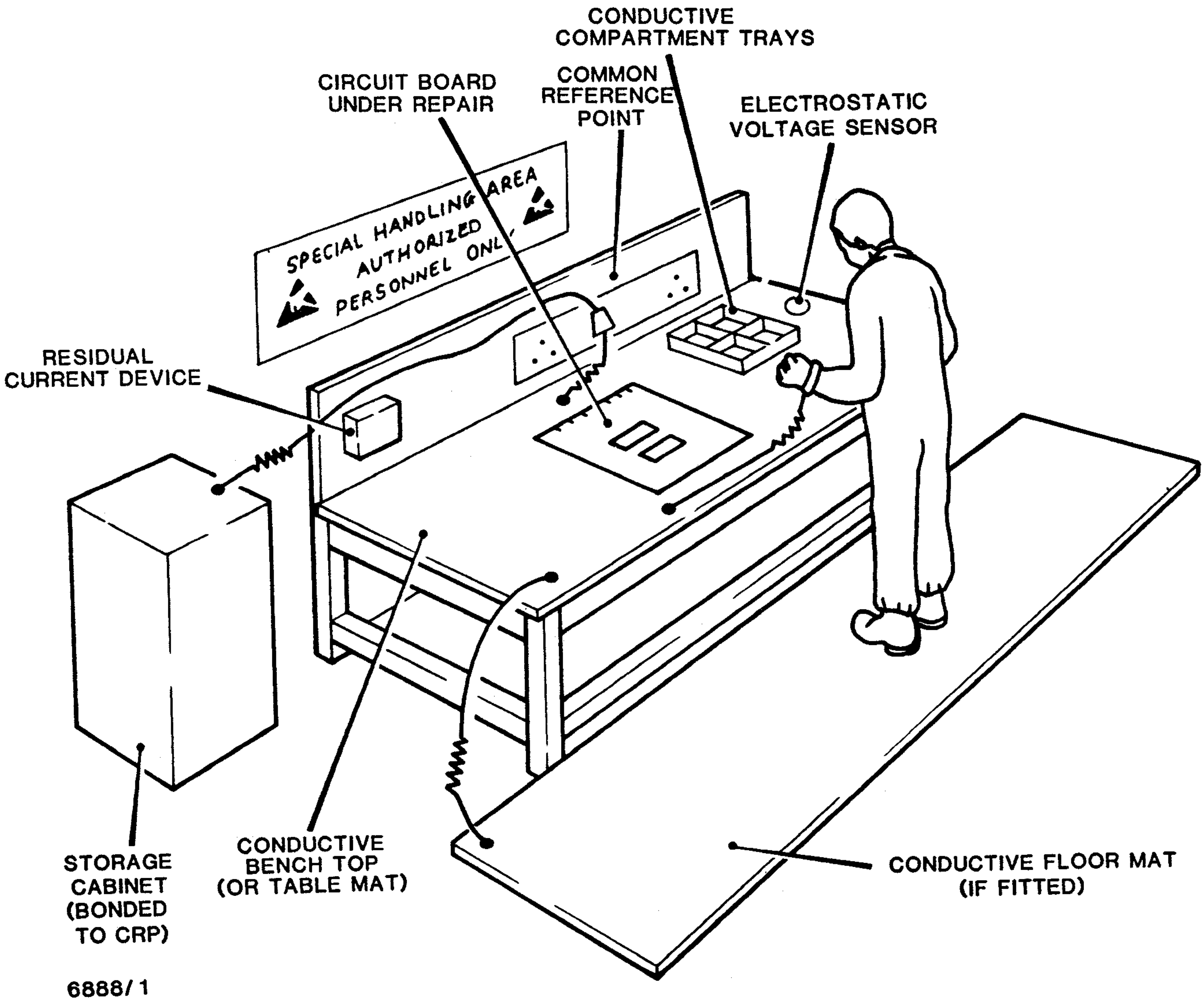
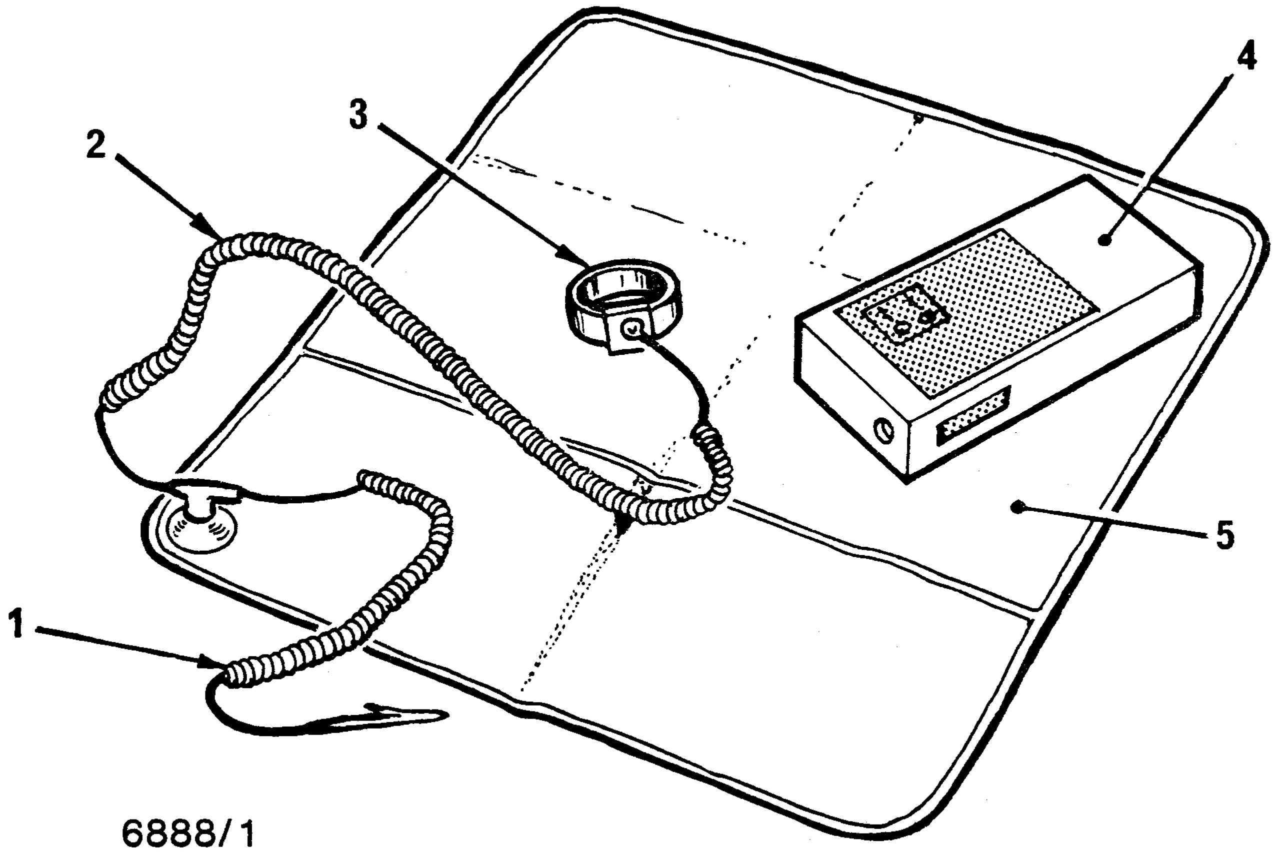


Figure 1 - Typical layout for a Workshop Special Handling Area



1 Earth cord
2 Wrist stap cord
3 Wrist strap
4 Wrist strap tester
5 Static dissipative mat

Figure 2 - Typical Field Service Kit - component parts

Checking

9 SHAs must be checked at least once per month, by a duly appointed person, to ensure that all the component parts of the SHA are serviceable, all the connections are in good condition and that the proper procedures are being carried out. Records are to be kept of the results of all inspections, tests and any corrective action carried out or recommended.

Basic items for SHAs/FSKs

10 The basic items of equipment required to build a SHA or FSK are bench mats, common reference points, connecting straps, wrist straps and wrist strap testers.

10.1 Bench mat. The bench mat is manufactured of a partially conductive material, so that it cannot become charged and is capable of dissipating static charge from items placed upon it.

10.2 Common reference point (CRP). A CRP may be a piece of conductive material or a dummy 13 A plug with connections for wrist straps, bench mats, equipments etc. It also has a connection for the earth strap.

10.3 Connecting cords. Cords are required to interconnect the various items in the SHA. All cords should incorporate a minimum resistance of 1 Megohm.

10.4 Wrist straps. Wrist straps should be of an elasticated type of material, constructed such that they have a conductive element built into them, or of the metal expanding watch-strap type. They provide a path, from the operator, through the connecting cord and the common reference point, to ground. They must be tested daily using a wrist strap tester. If a wrist strap tester is not available a multimeter may be used. The wrist strap must be worn by the operator whilst it is being tested. The preferred method is to hold the wrist strap tester in the opposite hand to that on which the wrist strap is being worn and test from there to the loose end of the wrist strap connecting cord. This ensures that all the connections, through the wrist strap and connecting cord, are tested. If wrist straps and/or the connecting cords fail this test they must not be used. Records are to be kept of all the test results and of any corrective action taken.

10.5 Wrist strap testers. Testers are normally of a simple 'GO-NO GO' design, having a connection for the wrist strap connecting cord and a metal plate on one side, against which the hand is pressed. Use as described in Sub-para 10.4. When the tester is switched on an LED will light, indicating continuity through the system, (wrist strap, connecting cord and body), or a fail condition.

10.6 Floor mat. There may be a requirement to have a floor mat, (Fig 1), but normally only in static workshops. They are not seen as a requirement for vehicles at this time. Where they are used, the specifications are as for bench mats, (Sub-para 10.1).

Maximum Resistance

11 Table 1 shows the maximum acceptable resistance to ground for safe operating in SHAs, the minimum in all cases is 1 Megohm.

TABLE 1 MAXIMUM ACCEPTABLE RESISTANCE TO GROUND IN SHAs

Reading from operator through:	Maximum acceptable resistance to ground
Floor/Bench mat to Ground	1,000 Megohms
Wrist strap to Ground	10 Megohms

TRANSPORTATION OF ESSDs

12 The importance of protection for ESSDs is not limited to handling in SHAs. Whenever such devices leave the safety of controlled areas they must be packaged, or held in containers, offering the same degree of protection as found in a SHA. Any ESSD, or p.e.c. (panel electronic circuit) containing such a device, must at all times be correctly packaged and labelled.

13 If any such item is received in a workshop or store not packed and labelled correctly, it must be treated as suspect stock and returned to the supplying agency complete with the necessary Packaging Defect form.

IDENTIFICATION OF ESSDs

14 Equipments, assemblies, sub-assemblies etc, incorporating ESSDs are to be labelled as shown in Figure 3. These symbols are to be used on all circuit diagrams, parts lists, handbooks, general documentation etc, showing clearly the presence of ESSDs. The symbol or label must also be used to the innermost practical level of packaging, right on to the device itself, space permitting. The warning label, along with adequate instructions, must also appear on the exterior of the package.

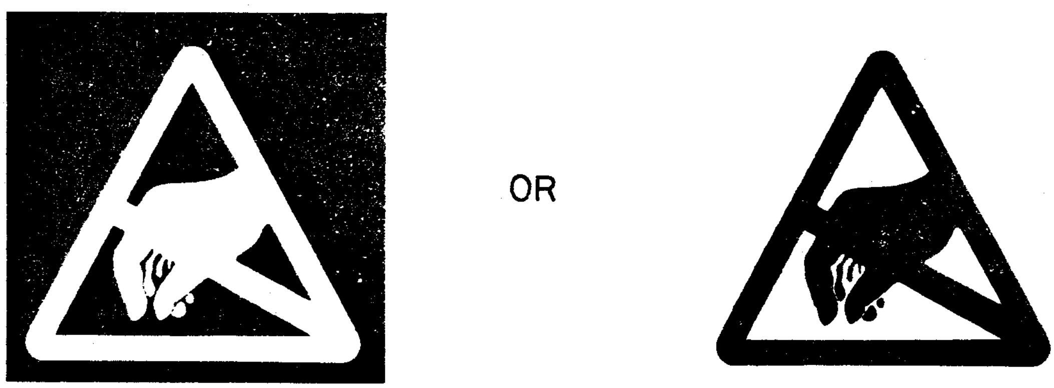


Fig 3 - Warning Labels/symbols

PRECAUTIONS

15 The following precautions must be taken when handling ESSDs, or p.e.c.s containing such devices:

15.1 Unprotected ESSDs must be handled only in properly equipped SHAs.

15.2 ESSDs must not be removed from their protective packing until required for use.

15.3 ESSDs must be properly packaged when being transported from one area to another.

15.4 All items coming into contact with ESSDs must be at the same potential as the ESSD.

15.5 ESSDs must not be inserted or removed from an equipment while power is being applied to the equipment.

15.6 All test equipment, (oscilloscopes, d.v.m.s etc), must be connected to the Common Reference Point (CRP) of the SHA.

15.7 Audible continuity testers must not be used on any equipment containing ESSDs.

15.8 Whenever possible, do not insert an ESSD until all other repairs have been completed.

15.9 Do not leave any pins of an ESSD open-circuited unless the equipment AESP/EMER specifically says to do so.

15.10 Only soldering/desoldering equipments having an auxiliary earth connection (eg the Soldering/Desoldering Equipment RE 800-4M, NSN W3/3439-99-215-0277) are to be used when fitting or removing ESSDs. The auxiliary earth connector must be attached to the CRP or bench mat prior to using the equipment.

15.11 If, for any reason, an ESSD, or p.e.c. containing such a device, is not returned to the equipment then it must be protected by being placed in a proper protective bag or box. Where possible the terminations should also be electrically short-circuited.

16 The following precautions should be taken by all personnel who are required to pack/unpack or otherwise handle ESSDs:

16.1 All packages recognised as containing ESSDs must be opened only in a SHA.

16.2 When ESSDs, or p.e.c.s containing such devices, are received correctly packaged, then any unnecessary unpacking/repacking must be avoided.

16.3 If procedures require that the contents of a package must be checked and/or identified then this must be done in a SHA. The use of transparent protective bags is recommended for this purpose.

16.4 If any ESSDs, or p.e.c.s containing such devices, are received incorrectly or inadequately packed, they must be returned to the supplier with the apropriate Package Defect Report form. Any ESSD or p.e.c. received in this manner must be treated as suspect and must not be used.

MAINTENANCE OF THE SHA/FSK

17 To ensure that the SHA is maintained in a serviceable condition the following checks shall be carried out:

17.1 Daily

17.1.1 Check the wrist straps, wrist strap connectors and all connectors associated with bench or floor mats for continuity and correct resistance readings, using a wrist strap tester or a multimeter.

17.1.2 Check the physical condition of wrist straps and all connectors.

17.1.3 Test the residual current device, if fitted, by pressing the test button and ensuring that the trip mechanism functions correctly.

17.2 Weekly

17.2.1 Check the physical condition of all bench and floor mats.

17.2.2 Check for static build up in the SHA using either a hand-held static meter or, if fitted, permanent monitoring equipment.

18 If any item in the SHA is found to be defective or in poor condition it must be replaced or repaired immediately. If the item concerned affects the overall efficiency of the SHA, ie the bench mat is found to have a short circuit to the CRP instead of a reading of 1 Megohm, the SHA must not be used until the defect has been rectified.

19 Records must be kept of all checks, repairs, replacements etc.

20 References to checks and records for SHAs, (Paras 17 to 19 inclusive), also apply to FSKs.

EQUIPMENT AVAILABILITY

21 The equipment necessary for general use in SHAs and FSKs is not yet available through RAOC sources although some items have been codified for use in specific projects, ie DIANA, GPTIRF, HDRS, PTARMIGAN. As equipment becomes available for general use this document will be up-dated.

RESEARCH AND DEVELOPMENT PROJECTS

22 All projects with equipments, assemblies, sub-assemblies etc which incorporate ESSDs must observe the following:

22.1 At the earliest possible stage, manufacturers must be made aware of the MOD(A) policy on the handling, packaging and storing etc of ESSDs.

22.2 All documentation, ie AESPs, parts lists, circuit diagrams etc, must indicate that ESSDs are being used in that equipment, and also identify specific components.

22.3 Repair charts must state that, where assemblies, sub-assemblies etc, contain ESSDs, special handling and packaging will be required.

22.4 Where p.e.c.s are to be backloaded for repair to Base Workshops, contract repair etc, all packaging and handling must be in strict conformity with this document.

ADVICE

23 Units requiring advice and/or assistance should contact:

Commanding Officer
Electronics Branch REME (31 MSG)
Leigh Sinton Road
MALVERN
Worcs WR14 1LL

Telephone (0684) 892781

Annex A

THE NATURE OF STATIC ELECTRICITY

1 The magnitude of the charge is primarily dependent on the size, shape, composition and electrical properties of the substances of which the body is made. Charges on insulators tend to remain in the area of the contact whilst charges on conductors are rapidly distributed over the entire surface of the conductor and also the surfaces of other contacted items.

2 The capacitance of a charged body relative to another body or to ground also has an effect on the electrostatic field. For example, when common polythene bags are rubbed, the charge potential while lying on a bench may only be in the order of a few hundred volts. However, when the bag is picked up by an operator, this can increase to several thousand volts. This is due to the decrease in capacitance and the conservation of the charge since:

$$Q1 = Q2 \text{ (conservation of charge)}$$

where Q1 is the charge on the first body,
and Q2 is the charge on the second.

By substituting CV for Q then:

$$C1V1 = C2V2$$

therefore, by transposition,

$$V2 = V1(C1/C2)$$

3 The human body acts as a capacitor which depends for the value of its capacitance on its proximity to other objects such as floor, work bench or even a large piece of equipment. This capacitance can change significantly during simple movements such as raising one or both feet, leaning toward an object, standing up etc. Typical percentage changes for some of these movements are shown in Table 1. In theory the voltage measured on a person is equal to the total charge on his body divided by his capacitance. Even when the measured voltage on a person is negligible, some induced net charge will exist on the body due to the charge on clothing, floor, bench etc. If the person is not grounded so that his net charge remains constant, then changes in his capacitance will cause measurable changes in his potential.

TABLE 1 : TYPICAL CAPACITANCE CHANGES IN A WORK AREA

Movement	% Change in Capacitance
Person seated, raising one foot	15 % decrease
Person seated, raising both feet and placing them on the foot rest	33 % decrease
Person seated, leaning forward in desk type chair with back	4 % decrease
Person standing, raising one foot	16 % decrease
Person seated, then standing up	13 % decrease

THE TRIBOELECTRIC EFFECT

4 The generation of static electricity caused by the rubbing together, or pulling apart, of two substances is called the 'triboelectric effect'. The list of substances in order of more positive charging to more negative charging as a result of this effect is called the 'triboelectic series'. (Table 2).

TABLE 2 : TRIBOELECTRIC SERIES

Air
Human hands
Asbestos
Rabbit fur
Glass
Mica
Human hair
Nylon
Wool
Fur
Lead
Silk
Aluminium
Paper
Cotton
Steel
Wood
Amber
Sealing wax
Hard rubber
Nickel and Copper
Brass and Silver
Gold and Platinum
Sulphur
Acetate and Rayon
Polyester
Celluloid

TABLE 2 : TRIBOELECTRIC SERIES (Continued)

Orion
Saran
Polyurethane
Polyethylene
Polypropylene
Polyvinyl chloride
Kelf
Silicon
Teflon

5 In Table 2 cotton is identified as a reference material. Materials listed above cotton tend to give up electrons when friction is produced thus becoming more positively charged whilst materials listed below it tend to absorb electrons, thus becoming more negatively charged.

THE EFFECTS OF STATIC DISCHARGE THROUGH ESSDs

6 Static discharges through all electrostatic sensitive devices are likely to cause failure symptoms similar to those described in the following paragraphs although reference is only made here to MOS devices.

7 A typical MOS device is composed of a number and variety of highly miniaturised 'conventional' electronic components manufactured in an integrated fashion, such that resistors, capacitors and other components are printed, or otherwise formed with their connecting tracks, by means of a metallisation process on to a substrate. The input gates of these devices are, in effect, small capacitors which couple through signals usually in the order of 0 V to 5 V. The dielectric of these capacitors is usually silicon dioxide with a thickness in the region of 0.1 microns. Thus, a MOS device may contain a number of very small capacitors, having a very high insulation resistance, very low capacitance and a very thin dielectric. Because of the thinness of the dielectric it can be easily ruptured when the voltage becomes too high.

8 A severe rupture will short circuit the gate and destroy the device. This is comparatively easy to find during testing. Minor ruptures of the dielectric, however, are virtually undetectable. Their immediate effect is to increase leakage current and/or alter the capacitance of the gate. These changes in the gate characteristics are by no means stable and, with normal usage, the range of switching levels and speeds at which the gate operates and controls other circuits, gradually alters. Depending on the severity of the rupture, the increased leakage can cause local molecular heating which, in turn, speeds up the final failure of the device. However, intermittent malfunction of the equipment is likely to occur some time before this final failure.

9 When a charged object comes into contact with a device the charge will be shared, current will flow and the voltage will divide between them. The rate of discharge is restricted by the capacitance of the object and the resistance of the path through which it flows. The voltage on the discharging object at time 't' is given by the formula:

$$V = V_o \exp(-t/RC)$$

where V = voltage at time t (volts)
V_o = initial voltage on the object (volts)
t = the elapsed time (seconds)
R = effective resistance to ground (ohms)
and C = capacitance of the object being discharged (farads).

RELATIVE HUMIDITY

10 The relative humidity of the atmosphere can have a significant effect on the amount of static electricity generated. Natural relative humidity can vary from 30 % to well over 90 %. In principle, the higher the humidity the less chance there is of static electricity being generated. In practice a level of not less than 60 % will be sufficient to keep an area safe from the build up of static electricity. It must be remembered, however, that in many cases this level of 60 % cannot be achieved as many work areas are air-conditioned or centrally heated and the humidity is kept artificially low.

END