IS 12071 (1987): Guide for assembly of printed boards [LITD 5: Semiconductor and Other Electronic Components and Devices]

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Indian Standard

GUIDE FOR ASSEMBLY OF PRINTED BOARDS

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Indian Standard

GUIDE FOR ASSEMBLY OF PRINTED BOARDS

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Indian Standard

GUIDE FOR
ASSEMBLY OF PRINTED BOARDS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 24 March 1987, after the draft finalized by the Printed Circuits Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 Assistance has been derived in preparation of this standard from IEC Doc: 52 (United Kingdom) 169 'Guide for the Assembly of Printed Board' issued by the International Electrotechnical Commission (IEC).

1. SCOPE

1.1 This standard lays down guiding principles and practices to be applied to the assembly of components on printed wiring boards irrespective of their method of manufacture.

2. DEFINITIONS

2.1 For the purpose of this standard, the following definition in addition to those given in IS : 1885 (Part 6)-1978* shall apply.

2.1.1 *Taped Components* — Components attached to continuous tapes.

2.1.2 *Screen Printing* — A process for transferring an image on a surface by forcing a suitable media through a stencil screen with a squeegee.

3. HANDLING OF COMPONENTS PRIOR TO ASSEMBLY

3.1 Electrostatic Sensitive Components — It is necessary to safeguard certain types of components and devices against possible damage which may be caused by an electro-static discharge (static). General guidelines are given below but for details IS : 10087-1981† shall be referred.

3.1.1 The susceptibility of devices to static damage may vary considerably, but generally those devices constructed with thin oxide layers and extremely thin conducting paths only a few microns wide are most susceptible.

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*Electrotechnical vocabulary: Part 6 Printed circuits (*first revision*).

†Code of practice for handling of electrostatic sensitive devices.

Table 1 illustrates some typical values of electrostatic discharge to which devices are reported susceptible.

TABLE 1 SUSCEPTIBILITY TO ELECTROSTATIC DISCHARGE

DEVICE TYPE (1)	RANGE OF ESD VOLTS (2)
VMOS	30-1 800
MOSFET	100-200
GaAsFET	200-300
EPROM	100
JFET	140-17 000
SAW	150-500
OP-AMPS	190-2 500
CMOS	250-2 000
Schottky diodes	300-2 500
Film resistors	300-3 000
Bipolar transistors	380-7 000
ECL (Hybrid, PB level)	500-1 500
SCR	680-1 000
Schottky TTL	1 000-2 500

It is considered that, for practical purposes, if static potentials in the working environment may be held at less than 100 V, static problems shall be greatly reduced.

3.1.2 When considering the handling of static sensitive devices, the following two general rules shall be observed:

a) All work areas, manual or automated in which static sensitive devices are handled shall be static safeguarded areas.

b) Static sensitive devices/components or assemblies require the use of static protected containers during transport or storage.

3.1.3 In the assembly area, conductive items of equipment including tools, work stations, machinery and personnel may be grounded by a variety of methods obtainable from specialist suppliers. A resistance to ground of less than 1 GΩ is considered sufficient to discharge to a safe level in less than 1 GΩ. However, a minimum of 1 MΩ is necessary to limit current flow to a safe level.

Table 2 shows the maximum allowable resistances and discharge times for static safe operations involving personnel bearing in mind the capacitive effects of the human body.

TABLE 2 ALLOWABLE RESISTANCES AND DISCHARGE TIMES

(*Clause* 3.1.3)

MAXIMUM TOLERABLE RESISTANCE (1)	ACCEPTABLE DISCHARGE TIME (2)
From operator to ground via:	
Floor mat – 1 GΩ	1 s
Table mat – 1 GΩ	1 s
Wrist strap – 100 MΩ	0·1 s

3.1.4 Shielding of components sensitive to static shall be carried out from the receipt of component stage. The protection supplied by the device supplier shall be maintained as long as practicable. Where 'dual in-line' (DIL) packages are supplied in static shielded shipping tubes, these may interface directly to automatic insertion equipment and the devices need not be handled.

3.1.5 The likelihood of static damage is reduced but not eliminated once components are assembled to the printed board.

Assembled boards shall be transported or stored in conductive containers suitably grounded and boards with edge connectors shall be fitted with contact shunting shrouds to maintain board voltage levels constant.

3.1.6 Where boards are to be packaged in plastic bags or containers the materials of the bag or container shall be capable of preventing a static charge existing across the package.

Generally metalized film materials are more satisfactory as they provide true electrostatic shielding.

3.2 Edge Connectors

3.2.1 Edge connectors formed as part of a printed board (integral) or provided as a wired on (discrete) plug end are generally plated with a precious metal on the contact area.

It is important that the surface of the contact area is protected from damage or contamination during assembly processes.

3.2.2 Where the edge connector is integral with the board, it shall be necessary to protect the contact area with a heat resistant tape or shield during the mass soldering process.

Typically, a stainless steel shield may be employed to surround the edge contacts and prevent solder wetting, however, this shall be combined with a tape or heat resistant plastic shroud which protects the contact area from flux creepage. Any tape used for this purpose must have a non-transferable adhesive. Specialist tapes are available but shall be checked for adhesive transfer before use.

3.2.3 After processing any tape, etc, shall be removed from the contacts before the board is cleaned.

3.2.4 Subsequent to cleaning operations the edge connector shall be protected preferably with a slip-on moulded plastic shroud which combines protection with easy availability for test, etc.

The shroud shall be of a shape which clips on the board beyond the eontact zone. To prevent the scratching of the contact zone by gift which may have contaminated the shroud, the shroud should be pushed onto the board from the side.

NOTE — Only plastics with stable plasticizers shall be used to prevent transfer of plasticizers onto edge contacts.

3.2.5 Discrete edge conductors, not subject to mass soldering, shall be protected either as in **3.2.4** above or by a tape having adhesive edges and a clear centre section to be positioned over the contacts.

4. PREPARATION OF PRINTED WIRING BOARDS FOR COMPONENT ASSEMBLY

4.1 Stoving — Boards shall be so placed that there is free circulation of air round each board, and stoved at 120 ± 5°C for a minimum of 2 h. Increasing the time of stoving is not normally detrimental and it may be convenient to stove overnight.

4.2 Stoving Double Sided PWBs — In order to minimize blow holes in joints of mass soldered through plated hole printed boards, it is advisable to stove before assembly and within one week of the soldering operation.

4.3 Stoving Multilayer and Flexible PWBs — It is recommended that multilayer and flexible circuits be stoved before being soldered. This action is necessary to drive out slowly the absorbed moisture and promote any gassification which may otherwise result in delamination or outgassing during mass soldering.

NOTE — Specifications for multilayer circuits and flexible circuits normally require specimens to be stoved at 125 ± 5°C for 1 h min before test of interleminal bond using a thermal shock.

5. MOUNTING OF COMPONENTS

5.1 Components shall be mounted on only one side of the board, generally opposite the major circuit pattern, unless otherwise dictated by design requirements, for example surface mounted chip capacitors.

The projection of the outline of the component on the board shall not extend over the edge of the board or interfere with board mounting and preferably shall be a minimum of 1·5 mm from the edge of the board and board guide or mounting hardware. The various factors that are important in mounting of components are discussed below.

5.1.1 *Orientations* — Horizontally mounted, non-polarized components should be oriented so that component marking and colour codes may be 'read' in the same direction. Non-polarized, vertically mounted components shall preferably be mounted so that the markings may be read from top to bottom. All polarized components shall be oriented so that their positive (+) or negative (—) symbols are visible.

5.1.2 *Accessibility* — The placement of any component on the board shall not prevent the insertion or removal of any hardware (total clearance included) used to mount the assembly, unless the assembly is considered disposable and is not intended for repair.

5.1.3 *Centering* — The body of the component shall be approximately centered between lead span, whenever possible and practical.

5.1.4 *Horizontal Placement of Axial-lead Components* — Axial-lead components shall be mounted so their axis is parallel to the mounting base. When not otherwise specified, components may have a portion of the body in direct contact with the printed wiring board.

5.1.5 *Components Mounted Over Conductors* — Components shall not be placed in contact with more than one conductor unless the board surface is suitably protected from moisture traps. This requirement applies to components with or without sleeving.

5.1.5.1 Care shall be taken when mounting metal cased components to ensure the casing does not come in contact with the conductive pattern. Sleeving may be used to insulate metal cased components. The sleeving shall be sufficiently transparent so that the identification markings remain visible and legible. Sleeved components shall not be mounted over or in contact with sharp solder connection points.

5.1.5.2 Adhesive pads of insulating material may also be placed under the component instead of sleeving but it is not good practice to rely on a solder resist film in this context.

5.1.5.3 Thermal degradation of components may result from contact with conductors on lands during mass soldering; adhesive pads may also be used as a thermal barrier.

5.1.6 *Vertical Component Mounting* — Axial-lead components mounted perpendicular to printed wiring boards should be installed with a minimum of 0·4 mm and a maximum of 3·0 mm clearance between the end of the component body and the surface of the circuit board to prevent entrapment problems. There should be no strain on the component lead when a spacer is used.

5.1.6.1 Radial-lead components when vertically-mounted should have their leads parallel to each other and perpendicular to the edge of the component-mounting base. Such components shall have their vertical axis within 5° of the plane that is perpendicular to the component-mounting base, unless otherwise restricted by design.

5.1.7 *Moulded or encapsulated ceramic or plastic components* — Moulded or encapsulated ceramic or plastic components shall be mounted so that the coating or sealing material does not enter the solder joint. Components installed in plated-through holes, shall maintain a minimum clearance of 1·5 mm between the surface of the board and the end of the lead coating. When holes are non-PTH the minimum clearance can be reduced to 0·75 mm.

5.2 Components-Lead Forming

5.2.1 *Preforming* — The purpose of preforming parts for retention to the board is to cobine the advantages of labour reduction achieved in straight through leads and the mechanical reliability of the clinched lead. Simple forms are used only to hold parts of the board prior to soldering; complex forms may be used for mechanical strength.

The forming of leads may be from a minimum of simple offset to a complex compound form. The major factors affecting the forming of leads are board thickness, lead diamater, lead material, hole size, and tooling required.

a) *Simple offset method* (*see Fig.* 1) — This gives the appearance of a straight through lead. The advantages are ease of forming and ease of insertion. The disadvantage is a minimum of retention force, and the resilency of small or soft component leads.

b) *The dimple* (*see Fig.* 2) — This method increases the retention to the board and gives better contact to the board. The main disadvantages are the die sets required to form the leads and the hole size to dimple height requirements. With the variation of lead sizes on the board this becomes the main concern.

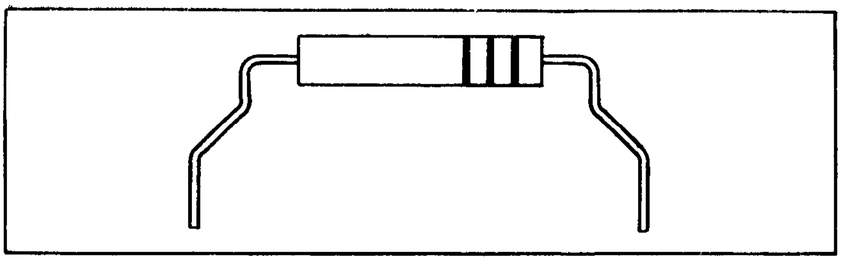

FIG. 1 SIMPLE OFFSET PREFORMED LEADS

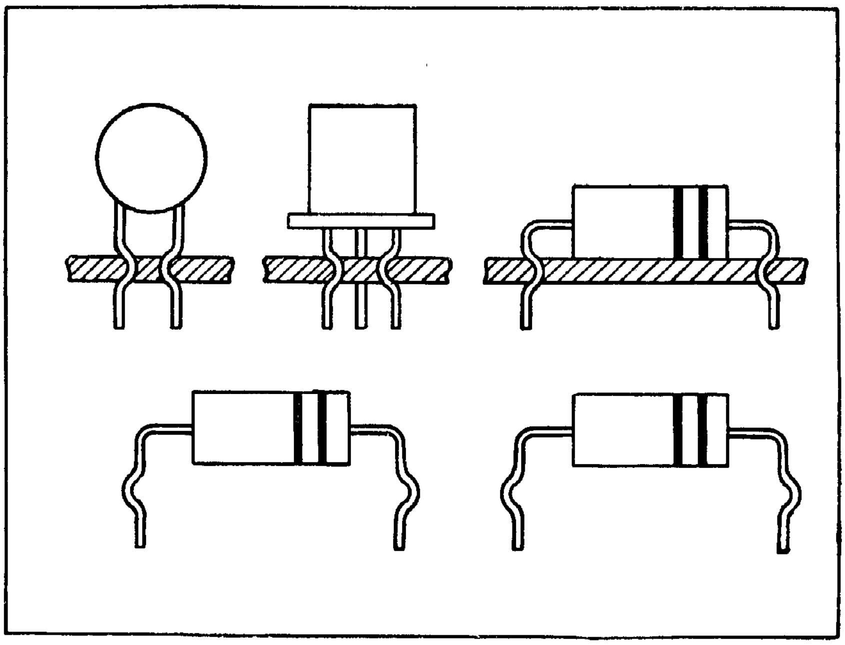

FIG. 2 DIMPLE PREFORMED LEALS

5.3 Lead Bend — The lead shall extend approximately straight out from the body of the component a minimum of 1·5 mm prior to the start of any bend except when the space is limited by high density packing the minimum may be 1·0 mm. The end of the body in this application is defined to include any coating meniscus, solder seal or weld bead, or any other extension.

It is essential that extreme care be taken when forming bends to prevent nicking or damage to the component leads and damage to the component body or seals; exposed base metal of component leads shall be retinned.

5.4 Mechanical Stress — The shock and vibration to which printed board assemblies are subjected during normal handling and testing can damage the lead terminations and lead-to-component body seals.

5.4.1 *Clips, Clamps and Brackets* — The following are the basic requirements which should be adhered to when components are mechanically secured by clips, clamps or brackets:

a) All clips, clamps or brackets shall be secured to prevent their rotation, such as by using two fasteners or onef astener and non-turn device;

b) Clamps and brackets which require their removal in order to replace the component shall be secured with a threaded fastener or other non-permanent fastener, unless the sub-assembly in which they are used is considered to be disposable or non-repairable;

c) The use of clips for glass envelope components shall be avoided.

5.5 Special Consideration

5.5.1 *Hermetically-Sealed Components* — Hermetically-sealed components, such as miniature relays, headers, glass eyelets, glass sealed capacitors, diodes and transformers, must be handled with caution to prevent damage to seals. The seals must not be chipped, cracked or crazed. Leads shall not be bent less than 1·5 mm from the seal. Hook and post type terminals sealed to headers shall not be bent closer than 1·5 mm to adjacent terminals.

5.5.2 *Heat Dissipation* — All parts dissipating 3 W or more (for epoxide woven glass base material) shall be mounted so that the body is not in contact with the board unless a clamp, heat sink, or other means is used to insure that the maximum allowable operating temperature of the board is not exceeded.

6. BOARD ASSEMBLY-METHODS

6.1 Manual

6.1.1 *Simple Layout Memorization* — If the board is of fairly simple design and of relatively low volumes, the operator may be advised to learn the board layout and, thereby get to know which components are placed and where.

6.1.1.1 Layout memorization is easier if the components to be mounted have easy distinguishing marks and are laid out on the board by the designer such that a sequence may be singled out. Reference points, such as silk screened legends, or positioning marks shall aid the operator.

6.1.1.2 With this method of assembly, it is preferable for components to be arranged in sequence in bins to suit any one operator. However this method has its disadvantages also. Although the technique requires a low investment, it involves a fairly high possible insertion error rate especially if operators have to memorize the layouts of several boards.

6.1.2 *Stage Assembly* — More complex boards may be assembled efficiently with a memorization technique if they are divided into two or more zones, each of which may be considered as small boards for an operator to memorize. The entire board may be assembled on an assembly line with each operator assembling different zones of the board.

6.1.2.1 It is generally accepted that in a line of this sort, the lost operator carries out a general inspection and that each assembly stage is worked out to take the same amount of time.

6.1.2.2 To assist operators when the same line is used for assembling several different types of board, a template may be provided to be placed over the board area in which the operator must not insert components. With each board type change, the operators template set must be changed.

6.1.2.3 The assembly line may be designed in such a way that each change of template provides for the corresponding components being offered from a gravity fed magazine or provide a visual indication against the relevant component bin.

6.1.3 *Sequence Assembly* — Where it is possible to identify a logical sequence which forms a serial path touching all the components on a board, a rapid method of accurate insertion may be applied.

6.1.3.1 A fixed board holder is used with as many bins as components, arranged in the same sequence as that identified on the board with the bins in a closed loop chain. The operator works through the board sequence taking sequentially from each bin (the bins may be stationary or presented to the operator by a drum, wheel system or linear transport system), until the entire board is completed.

6.1.3.2 Board changes may be accommodated by making the bin conveyor quickly interchangeable. Where a sequence is not readily obvious on a board an alternative sequence placing system may be applied.

6.1.3.3 A closed loop hopper chain is used to carry the boards and to present them one at a time to the operator. The boards shall be horizontal for this process and the mechanism is generally motor indexed but under the operators control.

Component bins may be either fixed or on an adjacent mobile arrangement.

6.1.3.4 The operator takes one component type at a time and loads the first board in all the appropriate positions, keeping to the same component type, the operator then indexes and loads every board. When all boards are loaded with that component, the operator selects a second type and repeats the operation.

6.1.3.5 There are two main advantages to this process.

a) Since the same component is inserted into the same position many times, learning the sequence requires minimal training.

b) The ability of operators to maintain a handful of components while inserting with the other hand reduces operator fatigue by reducing the number of pick-ups from separate bins.

6.1.4 *Visual Assembly Aids*

6.1.4.1 The simplest form of visual aid to assembly is the screen printing technique used to display component placement and orientation.

6.1.4.2 Where complex boards are to be normally assembled, an optical display may be used to provide guidance to the operator. A photographic slide projector using a closed loop of film projects an image directly onto the board assembled. The film has a slide for each component to be assembled on the board.

When an operator has assembled all the components of one type into the positions indicated by the projection, it is necessary to index the film to the next slide, which in the case of linked systems will also present a fresh bin of components, or provide an indicator lamp against the relevant bin.

Continuing indexing displays subsequent component positions and the relevant components.

6.1.4.3 *Lamp and optical fibre displays* — By arranging a set of small stranded lamps beneath the board assembly fixture and having them lit according to a specific sequence, a simple yet efficient assembly aid may be created. Assembly is performed in sequence with all components of the same type being inserted at each step of the sequence.

To begin with, the operator turns on the lamps for the first component type and completes insertion. Turning the lamps on for the second component type extinguishes the first set and displays in addition an indicator on the component bin for the second set. This process continues until the board is completed.

Optical fibre displays operate in a similar manner to conventional lamp systems but only one main lamp is required for each sequence, the pattern being carried to the assembly fixture by an optical fibre array.

The demonstration panel for the fibres behind the board fixture is particular to each kind of board and may be produced using the holes of a base board of the type being assembled (enlarged holes where necessary). Component bins may be identified by an additional fibre from each array.

Where components with full length leads are to be assembled it becomes difficult to position fibre optics closely enough to the board underside for accurate siting but yet sufficiently far away to permit relatively long lead access.

In this instance the fibre optic display may be arranged to project down onto a half silvered mirror (dicroic mirror) through which the operator views the assembly fixture. The lights are then superimposed on the board which has sufficient clearance to permit long leaded components. These displays may also have the advantage of colour to identify component polarity.

6.2 Automatic Component Insertion (ACI)

6.2.1 Any general purpose automatic component insertion machine must include at least the following items:

a) An *xy* co-ordinate table with arrangements for holding one or more boards and driven through its co-ordinate dimensions in increments equal to the grid or sub-grid on which the board was originally designed,

b) An insertion head which may accept a variety of types of components and place them in the relative holes in the board,

c) A system by which the insertion head is fed with components in the correct sequence, and

d) A programmable numerical control unit which controls the whole system.

6.2.1.1 There are a number of basic problems facing assemblers using automatic insertion equipment. The main two are:

a) method of presenting components to the insertion heads, either sequenced components or a self-sequencing machine, and
b) accuracy of component placement, which depends on hole size, hole positioned tolerance, machine tolerances and laminate stability.

6.2.2 There are two basic methods for feading the head with components in the correct sequence. The machine may either select the components itself and thus have a magazine or reel for each component type or the machine may accept components ready sequenced and loaded in a form suitable for the insertion head to accept.

6.2.2.1 In the first method the machine will have to be provided with as many component stores as the board requires. This complicates the machine unless a minimum of component types are used. Where axial components tend to predominate, a pre-sequenced arrangement is preferable.

Usually dual in-line package (DIP) insertion machines operate by direct selection (*see* **6.2.5**).

6.2.3 *Sequencing* — Sequencing equipment is designed to prepare a set of axial (or other) components, arranged in the correct order such that when fed to an automatic insertion machine the sequence matches the placement programme of the machine. The system of carrying components to the machine is known as lead taping and a sequence is composed of a sequencer and a taping unit.

6.2.3.1 In automatic sequences the equipment is fed with reels of pre-taped components from the component supplier and under the control of a pre-set programme the machine will cut the component loose close to the tape and transfer it to a moving chain while other components are arranged in order as the chain moves step by step under the cutting heads. The chain with each component in the correct sequence carries them to the taping unit where the component leads are transferred from the chain to the tape. It must be remembered that axial lead components supplied on tape and subsequently arranged in position by a sequencer will have their leads cut twice (once from the supply reel and once during insertion).

6.2.3.2 As tape is commonly 6·35 mm wide, each lead is reduced by approximately 12·7 mm at each cut. As a consequence of this and the tolerance on the cutting operation the maximum insertion span is much narrower than it shall be with manual insertion.

Figure 3 illustrates this. The dimensions used are typical for popular axial lead devices but may vary in practice. Radial and other non-axial lead devices must be formed to approximate axial dimensions if auto inserted. Generally though these items are not taped from suppliers.

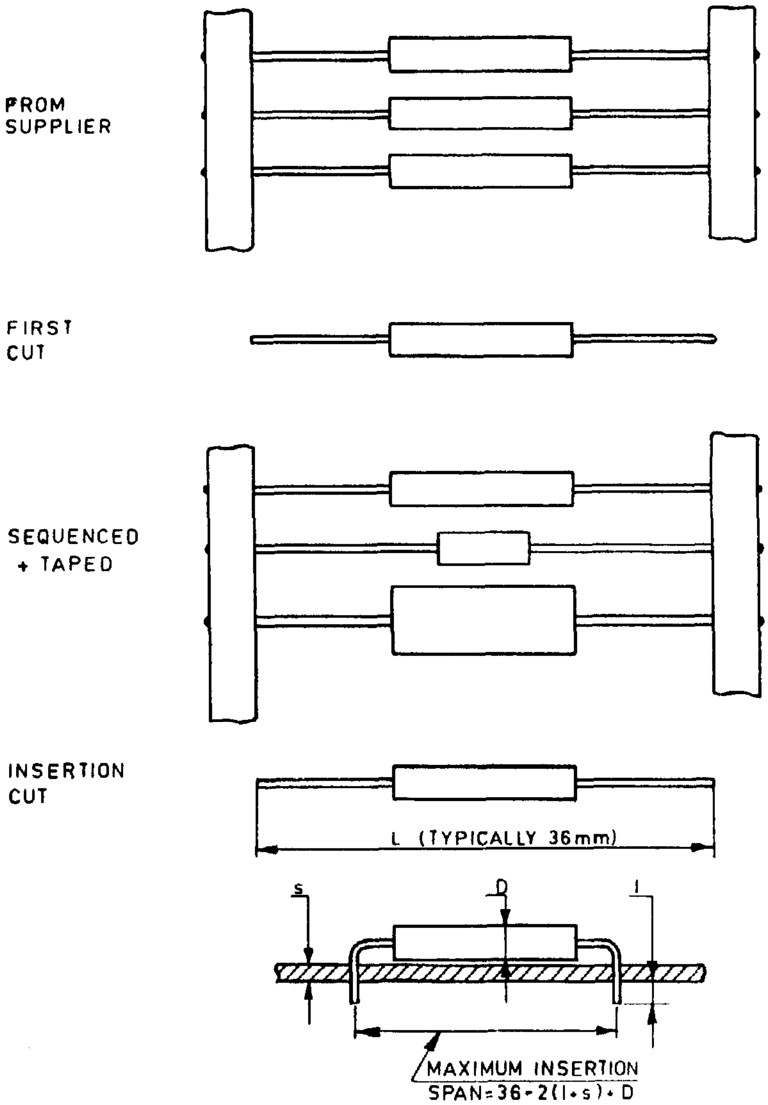

FIG. 3 COMPONENT SEQUENCING

The maximum insertion span (MIS) may be calculated from the sequenced component final cut length using the formula:

$$\text{MIS} = L - 2 (l + s) + D$$

where

L = final cut lengh,
l = length of protrusion of lead through board,
S = maximum board thickness, and
D = maximum component diameter.

This formula assumes approximate right angle lead bends (*see* **5** on component lead forming).

6.2.4 *Stability of Laminates* — If large boards are to be automatically inserted ($>200 \text{ mm}^2$), the stability of the laminate becomes important especially if paper based materials are used. Shrinking due to etching is often the only factor taken into account but subsequent operations involving heat (resist curing, etc) can also cause shrinkage.

6.2.4.1 No general guidance may be given on stability and this must be determined in conjunction with the laminate supplier. It is generally accepted however that glass epoxy materials do not suffer from significant dimensional changes.

6.2.5 *Dual in-line Package (DIP) Insertion* — The DIP was originally designed to be simple and economic, easily handled and able to be automatically inserted. Irrespective of the supplier of the device the package was intended to conform to limiting outline dimensions, however the range of dimensional differences in body packages are sufficiently wide to make reference to pin positions the only practical point for an automatic insertion tool.

6.2.5.1 Generally the devices are supplied with the pin rows spread at the base such that they are wider than the drilled pitch holes for mounting.

The ACI machine springs the pins towards the centre of the device to align them with the board holes and once entered the natural spring of the released pins retains the device.

6.2.5.2 Dual in-line packages are supplied in magazine tubes and these interface directly to the ACI machines. A sequencer is not needed for DIP's as the machine programme controls selection.

7. SOLDERABILITY — PROCESS CONSIDERATIONS

7.0 The solderability of a board is the most important characteristic which shall be maintained till it is fabricated. However, it easily gets effected by storage and calls for precautions during storage and special protective coatings of the metal surface.

7.0.1 During storage or ageing, whether natural or artificial, deterioration in solderability will occur. In the case of metallic coatings deterioration may be brought about by tarnishing/oxidation of the surface coating, by tarnishing/oxidation of the substrate through pores in the surface coating, or by inter-diffusion between substrate and coating(s). In the case of organic coatings applied to protect the metal surface to be soldered, deterioration may be consequent upon mechanical damage, porosity of the organic coatings, or diffusion of moisture and aggressive atmospheres through the coating.

7.0.2 The extent and rate of the deterioration of solderability with time vary greatly with the nature and thickness of the coating and the storage conditions encountered. It shall be noted however that after any period of storage exceeding three months solderability tests shall be carried out to ensure that the board is usable.

7.0.3 A brief description of various coatings which have good solderability as defined by the methods laid down in IS : 9000 (Part 18/Sec 3)-1981* is given in **7.1** to **7.5**.

7.1 Organic Coating — (Shelf life — four to eight months; Thickness — Varies with type).

These coatings are usually applied as lacquers. They are used to seal the reactive solderable surface of the copper which has been produced by the surface treatment, and are based on resins which do not interfere with the soldering process. They may assist in the fluxing or be dispersed by the flux and solder during the soldering process. Factors to be considered are that thin coatings are susceptible to damage and have a limited shelf life of a few months, and thick coatings may age or polymerize on prolonged storage and then may be difficult to disperse during the soldering operation, cheap but satisfactory if assembly is to be soldered in a short space of time.

7.2 Roller Solder Coating — (Shelf life — six to nine months; Thickness — 0·5 μm to 1·0 μm).

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*Basic environmental testing procedures for electronic and electrical items: Part 18 Solderability test.

Molten solder (usually conforming to S_n 60 of IS : 193-1982*) is coated onto the fluxed surface using a solder covered roller partially immersed in a solder bath. The coating is very thin and typically has a thickness of 0·5 mm. Such a coating has a shelf life of approximately six months but may not be applied in plated-through holes.

7.3 Tin and Tin-Lead Plating — (Shelf life — Plated six to twelve months. Fused twelve months minimum; Thickness — Plated 5 μm minimum, fused 7·62 μm before fusing).

Plated coatings of tin-lead alloy with 55 to 75 percent tin, normally 63 percent tin 37 percent tin are used. A minimum of 5 μm is required for good solderability, but when subsequent heat fusing operations are involved, a minimum of 10 μm is required to ensure that 5 μm remains over all significant surface afterwards. The heat fusing may be carried out using infra-red radiation or hot oil, and during these operations a redistribution of the molten tin or tin-lead alloy takes place. Under these conditions the final thickness of the solderable coating on the edges of pads and at the rims of plated-through holes may fall locally as low as 1 μm.

The melting point of a tin coating is approximately 50°C above the melting point of a solder coating.

Tin coatings are prone to whisker growth, and heat fusing of the tin lead plating will reduce the likelihood of whisker growth, as also will the co-deposition of small amounts of lead or copper.

7.4 Solder Dip and Hot Air Levelling — (Shelf life — Twleve months minimum; Thickness — 1 μm at rims of holes, 5 μm minimum elsewhere).

Printed boards are fluxed and dipped in molten solder (usually conforming to Sn 60 of IS : 193-1982*). On removal from the bath a hot air knife levels at the molten surface, and clears any plated-through holes if present, and provides a similar finish to that of a fused tinlead plating.

7.5 Gold Plating — (Shelf life — Six to twelve months; Thickness — 0·5 μm to 1·0 μm).

Gold finishes are not ideal for solder purposes because of the danger of brittle joints with thick gold deposits and porosity when thin coatings are used. Nevertheless, it is accepted that gold coatings do have to be soldered from time to time. For mass soldering it is preferable to pre-tin gold plated components leads in a 60/40 or 63/37 tin-lead alloy.

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*Specification for soft solder (*fourth revision*).

8. SOLDERING

8.1 For soldering of components to printed wiring boards, flux cored solder wire (60 percent tin) (*see* IS : 193-1982*) shall be used. Controlled temperature soldering irons are essential in establishing correct technique and avoidance of excessive heat transfer to the board and components.

8.2 It is permissible for solder resist to flow up to the edge of, or to cover via holes, or for a 'window' to be lift free to allow the via hole to fill with solder. Dry film solder resist may also be used to tent over via holes preventing the ingres of solder. This has the advantage of lengthening leakage paths over the surface of the board.

9. CLEANING OF BOARDS AND ASSEMBLIES

9.1 Solvents may be used to clean flux residue, etc, from printed boards but care shall be taken to ensure that the process used will not affect the term reliability of any component part of the assembly.

9.2 It shall also be borne in mind that cleaning with a solvent chemical will form a dilute mix of the contaminant and spread it over the board surface. Therefore, it is advisable to clean only when absolutely necessary and not as a matter of course.

10. FLATNESS

10.1 Flatness of the printed board is important for the printed board assembly, that is the printed board with the components mounted and the soldering operation completed. Undue deviation from flatness may cause difficulties, for example:

a) reduction of clearance distances where the printed board is mounted parallel to another board or to shielding parts,

b) difficult or even impossible insertion into narrow guides, and

c) mechanical stressing of components and solder joints (with the danger of failure after some time).

10.2 If necessary, particulary with large printed boards, provision should be made to prevent undue deviation from flatness, for example by using appropriate reinforcement or stiffening means. Since the soldering operation influences the flatness, it is recommended that the stiffening needs be mounted prior to mounting and soldering the components.

10.3 The flatness of a printed board depends on several factors, for example the material used, the production processes used, the hole

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*Specification for soft solder (*fourth revision*).

pattern, the conductive pattern (even distribution of metal will normally give better flatness), and the size and type of the board. Hence there is not a direct correlation between the deviation from flatness of:

a) the metal-clad base material,
b) the printed board, and
c) the printed board assembly (components mounted and soldered).

10.4 The reliability and operation of surface mounted components are particularly dependent on board flatness (*see* **15.2**).

11. INSPECTION OF PRINTED BOARD ASSEMBLIES

11.1 The assembled boards shall always be checked by visual inspection with particular reference to the mounting of electronic components and damage to the board. An optical aid having a magnification of about X3 is usually adequate for visual inspection.

11.2 Defects may be divided into three categories, that is:

a) a defect which renders the item unsuitable for use, which if discovered during installation or when first put into use shall necessitate attention or corrective action;
b) one which is likely to cause failure or additional maintenance; and
c) one which is indicative of an unacceptable standard of workmanship or production.

11.3 Examples of common defects are as follows :

a) Damage to component wires. These shall be free from cracks, nicks and other mechanical damage which causes a reduction in the cross-sectional area which, in turn, reduces the current carrying capacity of the wire;
b) Damage to the encapsulation of components;
c) Incorrect mounting of components, for example,
    i) less than 1·5 mm of wire after the component encapsulation; (*see* **5.3**),
    ii) incorrect forming of component leads (*see* **5.3**),
    iii) incorrect seating of components (*see* **5.1.5** to **5.1.7**);
d) Damage to the base material, that is blisters, chips or scratches; and
e) Poor quality solder joints.

12. STORAGE CONDITIONS

12.1 Severe deterioration can occur if printed boards and components are stored in unsuitable conditions. Basically all boards and components shall be stored in covered, well ventilated containers. Enclosing in air-tight plastic bags or containers shall be avoided. Ambient temperature shall be between 15 and 30°C at a relative humidity of 25 percent to 60 percent. If the boards are to be used for automatic component insertion (ACI) than they should be stabilized at 20 ± 5°C at a R.H of 50 ± 10 percent. There must be no danger of corrosive atmospheres and the floor shall be non-dust generating. Cleaning shall be done by vacuum cleaner.

12.2 A 'first in first out' rotation must be strictly observed. The maximum storage time is normally six months, where this is unavoidably exceeded further solderability tests should be carried out as at the inward goods stage.

12.3 Printed wiring boards shall be stored flat and individually wrapped with a suitable low sulphur content tissue paper. When withdrawn from stores they shall be covered and protected from the weather if taken outside. Any time spent in sub or pre-selection stores, when added to other storage time, shall not exceed six months (*see* **7**). Handling of the tracks and other conductive surfaces shall be avoided.

13. TERMINALS AND CONNECTOR JACKS

13.1 Generally there is a broad range of devices used in or on a printed board. These devices are usually chosen for the following reasons:

a) To aid quick repair or replacement of components or devices,

b) For their ability to be automatically inserted,

c) To connect printed boards to each other,

d) To connect the board to other parts of the system external to the boards, and

e) To allow for test access.

13.2 These devices usually consist of pins or sockets which may be soldered into the board or alternatively, force-fitted.

14. CONFORMAL COATINGS

14.1 Assembled printed boards are frequently given a conformal coating to assist them in functioning under certain environmental conditions. Correctly chosen and carefully applied conformal coating will help to protect the assembly from the following hazards:

a) Humidity;

b) Dust and dirt;

c) Airborne-contaminants, for example, smoke, and hemical vapours;
d) Conducting particles, for example metal clips and filings;
e) Accidental short circuit by dropped tools, fasteners, etc;
f) Abrasion damage; and
g) Vibration and shock (to a certain extent).

14.1.1 Conformal coating is not a substitute for good design or the selection of adequate components and materials. It does, however, help to protect printed wiring boards which have to operate in hostile environments.

14.2 The conformal coating also help support the components so that the entire mass of the component is not carried by the solder joint.

14.2.1 Certain limitations are inherent in conformal coatings. These are as follows:

a) Conformal coating films, being permeable to water vapour and not being formulated with corrosion preventing fillers, such as chromates, will not prevent corrosion due to active electrolytic sites on the part being coated or salts trapped on the surface of the part under the coating.
b) Conformal coating films being permeable to water will undergo a reduction in insulation resistance as the thickness of a film increases. This is particularly the case in a fillet or resin around a component (such as, in integrated circuit).
c) Conformal coating resins, being organic and filling the voids between conductors, will cause a marked increase in interlead capacitance and consequent distortion of performance.
d) Conformal coating resins, being formulated for transparency and flexibility have high coefficients of thermal expansion so they may exert a lifting force in certain components causing faliure of solder joints.
e) Conformal coating resins, being formulated for electrical characteristics, are not formulated with adhesion promoting additives (such as phosphates), therefore they do not exhibit exceptional adhesion to metals, particulary solder.
f) Paraxylylene coatings excepted, most conformal coating resins, being similar to organic finishes, will exhibit pinholding and thin sport on sharp joints, edges of parts and conductor edges.
g) The emission of noxious fumes when repairing with solder iron.

14.2.2 The above, whilst limitations, may be overcome, and the situation optimized in the design of the assemblies, described in IS : 10424-1982* and by care in fabrication processes.

14.3 Coating Selection

14.3.1 The following coatings are typical of those that are acceptable for use with printed board assemblies (*see* **14.3.2**).

a) *Oleo resin varnish* (temperature range −55°C to +125°C) — A general purpose coating for non-demanding conditions. Easy to apply, may be removed by readily available solvents, xylene toluene. Easily repairable, good appearance.

b) *Acrylic varnishes* (temperature range −60°C to +135°C) — A general purpose coating for use where excellent electrical properties are required. May be removed with solvents; MEK, easily repairable, good shiny appearance.

c) *Epxoy coatings* (temperature range −60°C to +200°C) — A general purpose coating for use where the best electrical properties are required. This coating may be 'soldered through', otherwise coating must be mechanically removed. May be patched, has a good appearance, is more difficult to apply.

d) *Polyurethane varnish* (temperature range −55°C to +125°C) — A good coating where resistance to moisture and abrasion is required. Usually specified for military applications. Thin coatings can be 'soldered through' with a very hot iron (bit temperature approximately 420°C), otherwise coating must be mechanically removed. Can be patched, has a somewhat dull appearance, is more difficult to apply.

e) *Silicone varnish* (temperature range −55°C to +260°C) — A good coating where good dielectric and arc resistance properties are required. Also of value where higher temperature operation is necessary. May be patched, good appearance, easy to apply.

f) *Silicone rubber coatings* (temperature range −55°C to +260°C) — A good high temperature coating, with good abrasive properties. Primer required for optimum adhesion. Flexible, transparent, not easily repaired. Must be mechanically removed. Good appearance, not difficult to apply.

g) *Paraxylylene* (*parylene*) (temperature range −65° to +145°C) — Vacuum deposited polymers are available, which provide excellent protection against humidity and abrasion (*see* **14.3.2.6**). Being deposited from a vapour they are true conformal coatings,

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*Guide for design and use of printed boards.

penetrating all crevices, and coating all surfaces with al ayer of constant thickness. May be deposited in very thin films. Cannot be replaced using conventional techniques.

h) *Polystyrene and copolymers* — Suitable for use where optimum dielectric properties are required.

14.3.2 *Precautions*

14.3.2.1 Trichloroethylene and other chlorinated solvents should not be used on glass-silicone laminated material. Delamination and surface/component damage result with their use.

14.3.2.2 When applying epoxy, polyurethane varnish, or polystyrene coatings in thicknesses greater than 0·1 mm to boards containing glass diodes, the glass diodes shall be fitted with soft vinyl sleevings prior to application of the coatings. Glass envelope style diodes shall have stress relieving bends in their leads so that at least 6 mm of lead length lies between the body junction and the point of solder application.

14.3.2.3 Polyurethanes should have a minimum shelf life of three months: epoxies, silicones and polystyrene should have a minimum shelf life of six months when stored in original unopened containers in accordance with manufacturers recommendations. Date of manufacture shall be marked on the container.

14.3.2.4 Coatings may contain toxic solvents and shall be used with caution and in well ventilated areas. Supplier shall include a 'Warning' on the label of containers of material which may have a toxic effect on user personnel.

14.3.2.5 Core shall be exercised when coating assemblies with flat base components with leads projecting straight through the board (relays, crystal cans). These components shall be mounted sufficiently high off the surface of the board so prevent the coating from completely filling the area between the component base and board surface.

14.3.2.6 When thick layers of conformal coatings are used over brittle components, the differential expansion of coating, component and board, may cause cracking of the component or solder joint. For this reason, it is necessary to keep the coating thin. If there is any doubt as to the possibility of component damage, a buffer coating of pliant material may be used on the brittle components. A suitable material is heat shrinkable sleeving, polyethelene terephthalate.

14.4 Application

14.4.1 With the exception of paraxylylene, which is applied by vacuum deposition all of these coatings may be applied by dipping, brushing or spraying. Spraying or vacuum depositions are the preferred system, where thin coatings are required. With reasonable operator skill an even and thin coating may be obtained, without runs or drips. With spraying, masking is easy, and may be carried out by taping or sleeving the required components or areas. Masking for paraxylylene requires more care. If quantities make it economical, tooling may be made to protect whose parts of the assembly that are not required to be coated.

14.4.2 Brushing is a simple way of coating small numbers of boards. It is difficult to obtain thin coatings with this method, and coverage of densely packaged boards is not easy without getting blobs and runs. Care must be taken to see that no bare spots are left Masking is not usually required with this method of coatings, if the operator exercises care in applying the coating.

14.4.3 Dipping gives good coverage and ensures that all cracks and crevices are adequately coated. Masking with the dipping method is very difficult and not likely to be fully effective. If the appropriate viscosity of the coating material is chosen, dipping may produce good results, but very thin films are not obtainable, and some blobs and runs are inevitable.

14.4.4 Tapes, latex rubber, strippable polythylenes or vinyls may be used to mask required areas. If masking can be perfomed prior to cleaning (masks must be compatible with cleaning process) it is advisable, as handling of the cleaned part shall be minimized. Masking materials must be compatible with solvents in the coating resin and they must not inhibit or interfere with the cure.

14.5 Results

14.5.1 When curing is completed, the coating shall have the following characteristics:

A smooth homogeneous appearance, free from bubbles, pinholes, blistering, wrinkling, cracking and peeling. Unless the coating is deliberately made opaque, it shall not mask the colours or identification marks on components or the base laminate. The coating shall not discolour or damage any of the components, or other items coated.

14.5.2 When processed according to the vendor's specification the coating shall be fully cured with no signs of tackiness.

14.6 Other Considerations — Conformed coating requires complete cleanliness of the surface before application if it is to be effective. Following measures may also be taken when necessary.

14.6.1 *Solder Cracking* — Conformal coating under a flat component may contribute to solder cracking of the joints of that component by virtue of the expansion of the coating. For this reason, mount flat components off the board and avoid filling the gap with conformal coating.

14.6.2 *Compatibility* — Always check for compatibility between the components in the assembly, and the coating to be used. Also review the use of any cleaning liquids or solvents. It is also necessary to check that the cure cycle temperatures will not damage any components in the assembly.

14.6.3 *Measling* — Problems associated with conformal coatings are invariably caused by inadequate cleaning prior to coating. One example of this is 'measling', which shows as small white spots under the coating. The white spots are areas where the coating has failed to bend to the substrate. The cure is to strip and recoat after a thorough cleaning cycle.

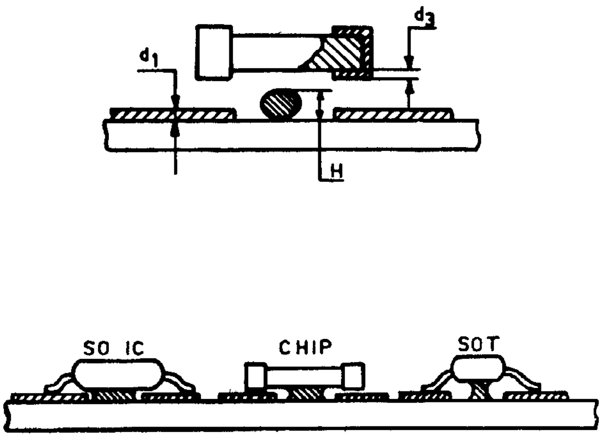
15. ASSEMBLY OF SURFACE MOUNTED COMPONENTS (SMC)

15.1 Adhesives

15.1.1 Surface mounted leadless or surface mounted leaded devices including chip components, cylindrical tubular leadless, active devices and particular type of transistors require adhesive attachment to their mounting board at the automatic assembly stage.

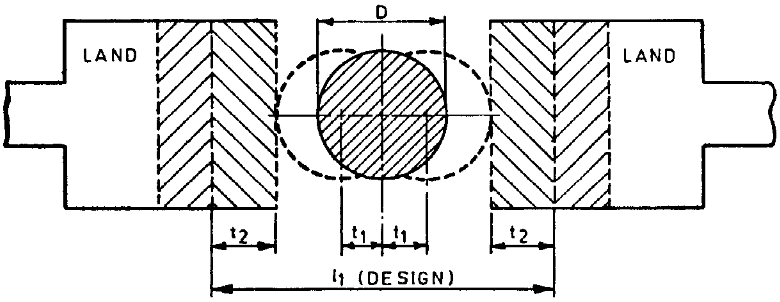
Ready mixed one part adhesives cured by ultra violet light and hot air (150°C) are typical of the automatically applied fixatives used in automatic component placement (ACP) equipment. Dispensing is set according to component weight and may be typically from 0·3 mg to 1·0 mg per component.

15.1.2 Different body shapes, such as chip capacitors require the adhesive dot to be able to reach the component body but not spill over onto the mounting lands when squashed by the component (*see* Fig. 4). The minimum diameter of the adhesive dot is therefore a function of the design space between lands (D_1), the tolerance on dot position around the ideal centreline between the lands (t_1) and the maximum positive tolerance (t_2) on land position (*see* Fig. 5).



Condition for adequate dot height $d_1 + d_3 < H$. This must be considered for all component types. 'SOT' devices have greater d_3 than chip components 'SO' mini 'IC' packages have base and leads co-planar.

FIG. 4 DOT HEIGHT



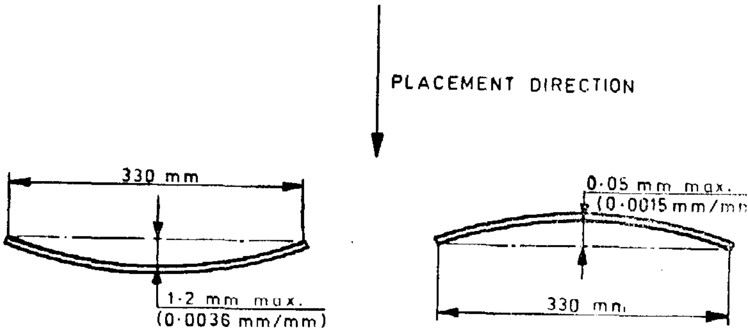
$D_{Max} = l_1 - 2t_1 - 2t_2$

FIG. 5 MAXIMUM DIAMETER OF DOT

15.1.3 Excess adhesive may be removed by alcohol and acetone solvents however if conventional components are mounted on the same board or plastic moulded devices, such as connectors, then suitability to these solvents should be checked.

15.2 Flatness

15.2.1 Due to the limitations of the leadless component in terms of mounting flexibility at the solder joint, the flatness of the printed board is very important. All types of components may be affected by bow and twist during equipment life but at the ACP stage the board flatness must be maintained between certain limits. Fig. 6 gives recommended flatness limits for unassembled boards for ACP.



6A 6B

NOTE — Where double-sided placement is planned the flatness figure must not exceed that shown in Fig. 6B for both directions of bow.

FIG. 6 BOARD FLATNESS REQUIREMENTS FOR ACP

15.3 Soldering

15.3.1 Soldering of leadless components will be either by vapour-phase (condensation) heating, conductive hot plate, hot gas or conventional wave soldering.

15.3.2 With the exception of wave soldering, all methods depend on adequte solder being present on the board at the joint interface.

15.3.3 It is difficult to provide sufficient solder via solder cream alone. Solder is best applied by electroplating the board surface using a solder mask confining the deposition of 0·15 mm to 0·2 mm of tin-lead (60/40) to the component footprint lands.

For increased stand off spacing, solder preforms may be used to provide a larger volume of solder.

15.4 Solder Pastes and Creams

15.4.1 Solder creams must be oxide-free to prevent the formation of solder balls. Defective solder creams will divide into discrete balls when melted on a non-solderable surface. Good creams will form a single sphere. For screening, 80 mesh is recommended for emulsion thicknesses ranging from 1 mm to 2 mm using 30 to 35 percent cream formulations.

15.5 Drying of Solder Pastes or Creams

15.5.1 It is important that all volatile solvents are driven out of the solder paste or cream prior to soldering. Rapid outgassing of solvents may move unattached components off the land pattern.

15.5.2 The preferred method is oven-bake out at 50 to 75°C. Solder manufacturers will advise on the recommended preparation of their product.

15.6 Reflow Soldering Methods

15.6.1 The preferred method for reflow soldering leadless components to boards is vapour-phase or 'condensation' heating. Vapour-phase machines are basically vapour degreasers which employ the condensation of per-fluorinated hydrocarbon vapour as a heat transfer medium.

15.6.2 The liquid is inert and typically may boil at 215°C which is a suitable temperature for common-tin lead solders. The heavy vapours help to exclude air and thus permit the use of mild fluxes.

15.6.3 Other soldering methods include hot plate heating, which works well for single sided ceramic boards, and belt transport systems using either radiant or convection heating.

15.7 Cleaning After Soldering

15.7.1 Vapour phase soldering greatly reduces polymerisation and charring of flux resins. Cleaning in a vapour degreaser using an active solvent (freon-alcohol azeotrope) with solvent-spray or agitation is usually satisfactory.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volts	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2