

# INTERNATIONAL STANDARD



**Printed board assemblies –  
Part 1: Generic specification – Requirements for soldered electrical and  
electronic assemblies using surface mount and related assembly technologies**



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2018 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

#### IEC Catalogue - [webstore.iec.ch/catalogue](http://webstore.iec.ch/catalogue)

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

#### IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing 21 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

#### IEC Glossary - [std.iec.ch/glossary](http://std.iec.ch/glossary)

67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [sales@iec.ch](mailto:sales@iec.ch).



IEC 61191-1

Edition 3.0 2018-09  
REDLINE VERSION

# INTERNATIONAL STANDARD



---

**Printed board assemblies –  
Part 1: Generic specification – Requirements for soldered electrical and  
electronic assemblies using surface mount and related assembly technologies**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

ICS 31.190; 31.240

ISBN 978-2-8322-6051-7

**Warning! Make sure that you obtained this publication from an authorized distributor.**

## CONTENTS

|                                                   |               |
|---------------------------------------------------|---------------|
| FOREWORD.....                                     | 7             |
| 1 Scope.....                                      | 9             |
| 2 Normative references.....                       | 9             |
| 3 Terms and definitions .....                     | 10            |
| 4 General requirements .....                      | 11            |
| 4.1 Order of precedence .....                     | 11            |
| 4.1.1 General remark .....                        | 11            |
| 4.1.2 Conflict .....                              | 11            |
| 4.1.3 Conformance documentation .....             | 12            |
| 4.2 Interpretation of requirements.....           | 12            |
| 4.3 Classification .....                          | 12            |
| 4.4 Defects and process indicators .....          | 13            |
| 4.5 Process control requirements .....            | 13            |
| 4.6 Requirements flowdown .....                   | 13            |
| 4.7 Physical designs .....                        | 13            |
| <del>Design requirements .....</del>              | <del>13</del> |
| 4.7.1 New designs .....                           | 13            |
| 4.7.2 Existing designs.....                       | 13            |
| 4.8 Visual aids .....                             | 14            |
| 4.9 Proficiency of personnel .....                | 14            |
| 4.9.1 Design proficiency.....                     | 14            |
| 4.9.2 Manufacturing proficiency.....              | 14            |
| 4.10 Electrostatic discharge (ESD) .....          | 14            |
| 4.11 Facilities .....                             | 14            |
| 4.11.1 General .....                              | 14            |
| 4.11.2 Environmental controls.....                | 14            |
| 4.11.3 Temperature and humidity.....              | 15            |
| 4.11.4 Lighting .....                             | 15            |
| 4.11.5 Field conditions.....                      | 15            |
| 4.11.6 Clean rooms .....                          | 15            |
| 4.12 Assembly tools and equipment .....           | 15            |
| 4.12.1 General .....                              | 15            |
| 4.12.2 Process control .....                      | 15            |
| 5 Requirements of materials .....                 | 15            |
| 5.1 Overview.....                                 | 15            |
| 5.2 Solder.....                                   | 16            |
| 5.3 Flux .....                                    | 16            |
| 5.4 Solder paste .....                            | 16            |
| 5.5 Preform solder .....                          | 16            |
| 5.6 Adhesives .....                               | 16            |
| 5.7 Cleaning agents .....                         | 16            |
| 5.7.1 General .....                               | 16            |
| 5.7.2 Cleaning agents selection .....             | 17            |
| 5.8 Polymeric coatings .....                      | 17            |
| <del>General .....</del>                          | <del>17</del> |
| 5.8.1 Solder resists and localized maskants ..... | 17            |

|       |                                                                         |    |
|-------|-------------------------------------------------------------------------|----|
| 5.8.2 | Conformal coating and encapsulants .....                                | 17 |
| 5.8.3 | Spacers (permanent and temporary).....                                  | 17 |
| 5.9   | Chemical strippers .....                                                | 17 |
| 5.10  | Cleaning Agents.....                                                    | 17 |
| 5.11  | Heat shrinkable soldering devices .....                                 | 17 |
| 6     | Components and printed board requirements .....                         | 18 |
| 6.1   | General.....                                                            | 18 |
| 6.2   | Solderability .....                                                     | 18 |
| 6.2.1 | Parts solderability .....                                               | 18 |
| 6.2.2 | Reconditioning .....                                                    | 18 |
| 6.2.3 | Solderability testing of ceramic boards .....                           | 18 |
| 6.3   | Solderability maintenance .....                                         | 18 |
| 6.3.1 | General .....                                                           | 18 |
| 6.3.2 | Preconditioning .....                                                   | 18 |
| 6.3.3 | Gold embrittlement of solder joints .....                               | 19 |
| 6.3.4 | Tinning of non-solderable parts .....                                   | 19 |
| 6.4   | Solder purity maintenance .....                                         | 19 |
| 6.5   | Lead preparation.....                                                   | 20 |
| 6.5.1 | General .....                                                           | 20 |
| 6.5.2 | Lead forming.....                                                       | 20 |
| 6.5.3 | Lead-forming limits.....                                                | 21 |
| 7     | Assembly process requirements.....                                      | 21 |
| 7.1   | Overview.....                                                           | 21 |
| 7.2   | Cleanliness .....                                                       | 21 |
| 7.3   | Part markings and reference designations .....                          | 21 |
| 7.4   | Solder connection contours .....                                        | 21 |
| 7.5   | Moisture traps.....                                                     | 21 |
| 7.6   | Thermal dissipation .....                                               | 21 |
| 8     | Assembly soldering requirements.....                                    | 22 |
| 8.1   | General.....                                                            | 22 |
| 8.1.1 | Soldering process .....                                                 | 22 |
| 8.1.2 | Machine maintenance .....                                               | 22 |
| 8.1.3 | Handling of parts.....                                                  | 22 |
| 8.1.4 | Preheating .....                                                        | 22 |
| 8.1.5 | Carriers .....                                                          | 22 |
| 8.1.6 | Hold down of surface mount leads .....                                  | 22 |
| 8.1.7 | Heat application .....                                                  | 22 |
| 8.1.8 | Cooling .....                                                           | 23 |
| 8.2   | Reflow soldering .....                                                  | 23 |
| 8.2.1 | Requirements .....                                                      | 23 |
| 8.2.2 | Process development for reflow soldering.....                           | 23 |
| 8.2.3 | Flux application.....                                                   | 23 |
| 8.2.4 | Solder application .....                                                | 23 |
| 8.3   | Manual/hand soldering .....                                             | 24 |
| 8.3.1 | Non-reflow manual soldering .....                                       | 26 |
| 8.3.2 | Reflow manual soldering .....                                           | 26 |
|       | <del>Mechanized immersion soldering (non-reflow).....</del>             |    |
|       | <del>General .....</del>                                                |    |
|       | <del>Process development for mechanized immersion soldering .....</del> |    |

|        |                                                                        |                  |
|--------|------------------------------------------------------------------------|------------------|
|        | <del>Drying/degassing .....</del>                                      | <del>.....</del> |
|        | <del>Holding fixtures and materials .....</del>                        | <del>.....</del> |
|        | <del>Flux application .....</del>                                      | <del>.....</del> |
|        | <del>Solder bath .....</del>                                           | <del>.....</del> |
| 9      | Cleanliness and residue requirements .....                             | 27               |
| 9.1    | General .....                                                          | 27               |
|        | <del>Equipment and material compatibility .....</del>                  | <del>.....</del> |
|        | <del>Pre-soldering cleaning .....</del>                                | <del>.....</del> |
|        | <del>Post-soldering cleaning .....</del>                               | <del>.....</del> |
|        | <del>General .....</del>                                               | <del>.....</del> |
|        | <del>Ultrasonic cleaning .....</del>                                   | <del>.....</del> |
|        | <del>Cleanliness verification .....</del>                              | <del>.....</del> |
|        | <del>General .....</del>                                               | <del>.....</del> |
|        | <del>Visual inspection .....</del>                                     | <del>.....</del> |
|        | <del>Testing .....</del>                                               | <del>.....</del> |
|        | <del>Cleanliness criteria .....</del>                                  | <del>.....</del> |
|        | <del>General .....</del>                                               | <del>.....</del> |
|        | <del>Particulate matter .....</del>                                    | <del>.....</del> |
|        | <del>Flux residues and other ionic or organic contaminants .....</del> | <del>.....</del> |
|        | <del>Cleaning option .....</del>                                       | <del>.....</del> |
|        | <del>Test for cleanliness .....</del>                                  | <del>.....</del> |
|        | <del>Resin residues on cleaned board assemblies .....</del>            | <del>.....</del> |
|        | <del>Ionic residues (instrument method) .....</del>                    | <del>.....</del> |
|        | <del>Ionic residues (manual method) .....</del>                        | <del>.....</del> |
|        | <del>Surface insulation resistance (SIR) .....</del>                   | <del>.....</del> |
|        | <del>Other contamination .....</del>                                   | <del>.....</del> |
| 9.2    | Qualified cleaning/manufacturing process .....                         | 30               |
| 9.2.1  | General .....                                                          | 30               |
| 9.2.2  | Cleaning designator .....                                              | 31               |
| 9.2.3  | Upper specification limit .....                                        | 31               |
| 9.3    | Visual requirements .....                                              | 31               |
| 9.4    | Correlation of ionic testers .....                                     | 32               |
| 9.5    | Non-ionic residues .....                                               | 32               |
| 9.6    | SIR testing .....                                                      | 32               |
| 10     | Assembly requirements .....                                            | 27               |
| 10.1   | General .....                                                          | 32               |
| 10.2   | Acceptance requirements .....                                          | 32               |
| 10.2.1 | Process control .....                                                  | 32               |
| 10.2.2 | Corrective action limits .....                                         | 33               |
| 10.2.3 | Control limit determination .....                                      | 33               |
| 10.3   | General assembly requirements .....                                    | 33               |
| 10.3.1 | Assembly integrity .....                                               | 33               |
| 10.3.2 | Assembly damage .....                                                  | 33               |
| 10.3.3 | Markings .....                                                         | 34               |
| 10.3.4 | Flatness (bow and twist) .....                                         | 34               |
| 10.3.5 | Solder connection .....                                                | 34               |
| 10.3.6 | Interfacial connections .....                                          | 36               |
| 11     | Coating and encapsulation .....                                        | 36               |
| 11.1   | Conformal coating .....                                                | 36               |

|                                                                          |                                                                                |    |
|--------------------------------------------------------------------------|--------------------------------------------------------------------------------|----|
| 11.1.1                                                                   | Coating instructions .....                                                     | 36 |
| 11.1.2                                                                   | Application.....                                                               | 36 |
| 11.1.3                                                                   | Performance requirements .....                                                 | 37 |
| 11.1.4                                                                   | Rework of conformal coating .....                                              | 38 |
| 11.1.5                                                                   | Conformal coating inspection .....                                             | 38 |
| 11.2                                                                     | Encapsulation .....                                                            | 38 |
| 11.2.1                                                                   | Encapsulation instructions.....                                                | 38 |
| 11.2.2                                                                   | Application.....                                                               | 38 |
| 11.2.3                                                                   | Performance requirements .....                                                 | 39 |
| 11.2.4                                                                   | Rework of encapsulant material.....                                            | 39 |
| 11.2.5                                                                   | Encapsulant inspection .....                                                   | 39 |
| 12                                                                       | Rework and repair .....                                                        | 39 |
| <del>General.....</del>                                                  |                                                                                |    |
| 12.1                                                                     | Rework of unsatisfactorily soldered electrical and electronic assemblies ..... | 39 |
| 12.2                                                                     | Repair.....                                                                    | 40 |
| 12.3                                                                     | Post rework/repair cleaning .....                                              | 40 |
| 13                                                                       | Product quality assurance .....                                                | 41 |
| 13.1                                                                     | System requirements.....                                                       | 41 |
| 13.2                                                                     | Inspection methodology.....                                                    | 41 |
| 13.2.1                                                                   | Verification inspection .....                                                  | 41 |
| 13.2.2                                                                   | Visual inspection.....                                                         | 41 |
| 13.2.3                                                                   | Sampling inspection .....                                                      | 42 |
| 13.3                                                                     | Process control .....                                                          | 42 |
| 13.3.1                                                                   | System details .....                                                           | 42 |
| 13.3.2                                                                   | Defect reduction.....                                                          | 42 |
| 13.3.3                                                                   | Variance reduction .....                                                       | 43 |
| 14                                                                       | Other requirements.....                                                        | 43 |
| 14.1                                                                     | Health and safety .....                                                        | 43 |
| 14.2                                                                     | Special manufacturing requirements .....                                       | 43 |
| 14.2.1                                                                   | Manufacture of devices incorporating magnetic windings .....                   | 43 |
| 14.2.2                                                                   | High-frequency applications .....                                              | 43 |
| 14.2.3                                                                   | High-voltage or high-power applications .....                                  | 43 |
| 14.3                                                                     | Guidance on requirement flowdown .....                                         | 43 |
| 15                                                                       | Ordering data .....                                                            | 44 |
| Annex A (normative) Requirements for soldering tools and equipment ..... |                                                                                | 45 |
| A.1                                                                      | Requirements for tools and equipment.....                                      | 45 |
| A.2                                                                      | Abrasives.....                                                                 | 45 |
| A.3                                                                      | Benchtop and hand-soldering systems.....                                       | 45 |
| A.4                                                                      | Soldering iron holders .....                                                   | 46 |
| A.5                                                                      | Wiping pads .....                                                              | 46 |
| A.6                                                                      | Soldering guns .....                                                           | 46 |
| A.7                                                                      | Solder pots .....                                                              | 46 |
| A.8                                                                      | Process control .....                                                          | 46 |
| <del>Annex (normative) Qualification of fluxes.....</del>                |                                                                                |    |
| Annex B (normative) Quality assessment .....                             |                                                                                | 48 |
| B.1                                                                      | Process control (PC) .....                                                     | 48 |
| B.2                                                                      | Reduction of quality conformance testing.....                                  | 48 |
| B.3                                                                      | Audit plan .....                                                               | 48 |

|                                                                                               |    |
|-----------------------------------------------------------------------------------------------|----|
| Bibliography .....                                                                            | 50 |
| Figure 1 – Solder contact angle.....                                                          | 35 |
| Figure 2 – Solder wetting of plated through-holes without leads .....                         | 35 |
| Figure 3 – Coating conditions.....                                                            | 37 |
| Table 1 – Solder contamination limits; maximum contaminant limit (percentage by weight) ..... | 19 |
| Table 2 – Designation of surfaces to be cleaned.....                                          | 25 |
| Table 3 – Residue testing for process control .....                                           | 25 |
| Table 4 – Maximum acceptable rosin flux residues .....                                        | 26 |
| Table 5 – Electrical and electronic assembly defects .....                                    | 34 |
| Table 6 – Magnification requirements .....                                                    | 35 |

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## PRINTED BOARD ASSEMBLIES –

**Part 1: Generic specification –  
Requirements for soldered electrical and electronic assemblies  
using surface mount and related assembly technologies**

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

**This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.**

International Standard IEC 61191-1 has been prepared by IEC technical committee 91: Electronics assembly technology.

This third edition cancels and replaces the second edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) the requirements have been updated to be compliant with the acceptance criteria in IPC-A-610F;
- b) the term "assembly drawing" has been changed to "assembly documentation" throughout;
- c) references to IEC standards have been corrected;
- d) Clause 9 was completely rewritten;
- e) Annex B was removed because there are already procedures for circuit board assemblies.

The text of this International Standard is based on the following documents:

| CDV         | Report on voting |
|-------------|------------------|
| 91/1481/CDV | 91/1510/RVC      |

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 61191 series, published under the general title *Printed board assemblies*, can be found in the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

**IMPORTANT – The “colour inside” logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.**

## PRINTED BOARD ASSEMBLIES –

### Part 1: Generic specification – Requirements for soldered electrical and electronic assemblies using surface mount and related assembly technologies

#### 1 Scope

This part of IEC 61191 prescribes requirements for materials, methods and verification criteria for producing quality soldered interconnections and assemblies using surface mount and related assembly technologies. This part of IEC 61191 also includes recommendations for good manufacturing processes.

#### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-20, *Environmental testing – Part 2-20: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices with leads*

IEC 60068-2-58, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60194, *Printed board design, manufacture and assembly – Terms and definitions*

IEC 60721-3-1, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities* – ~~Section 1: Storage~~

~~IEC 61188-1-1, *Printed boards and printed board assemblies – Design and use – Part 1-1: Generic requirements – Flatness considerations for electronic assemblies*~~

IEC 61189-1, *Test methods for electrical materials, interconnection structures and assemblies – Part 1: General test methods and methodology*

IEC 61189-3, *Test methods for electrical materials, printed boards and other interconnection structures and assemblies – Part 3: Test methods for interconnection structures (printed boards)*

IEC 61190-1-1, *Attachment materials for electronic assembly – Part 1-1: Requirements for soldering fluxes for high-quality interconnections in electronics assembly*

~~IEC 61190-1-2, *Attachment materials for electronic assembly – Part 1-2: Requirements for soldering pastes for high-quality interconnects in electronics assembly*~~

IEC 61190-1-3, *Attachment materials for electronic assembly – Part 1-3: Requirements for electronic grade solder alloys and fluxed and non-fluxed solid solders for electronic soldering applications*

IEC 61191-2, *Printed board assemblies – Part 2: Sectional specification – Requirements for surface mount soldered assemblies*

IEC 61191-3, *Printed board assemblies – Part 3: Sectional specification – Requirements for through-hole mount soldered assemblies*

IEC 61191-4, *Printed board assemblies – Part 4: Sectional specification – Requirements for terminal soldered assemblies*

IEC 61249-8-8, *Materials for interconnection structures – Part 8: Sectional specification set for non-conductive films and coatings – Section 8: Temporary polymer coatings*

IEC 61340-5-1, *Electrostatics – Part 5-1: Protection of electronic devices from electrostatic phenomena – General requirements*

IEC/TR 61340-5-2, *Electrostatics – Part 5-2: Protection of electronic devices from electrostatic phenomena – User guide*

IEC 61760-2, *Surface mounting technology – Part 2: Transportation and storage conditions of surface mounting devices (SMD) – Application guide*

ISO 9001:2008, *Quality management systems – Requirements*

IPC-A-610E:2010, *Acceptability of Electronic Assemblies*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60194 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

#### 3.1

##### **bow**

deviation from flatness of a board characterized by a roughly cylindrical or spherical curvature so that, if the product is rectangular, its four corners are in the same plane

#### 3.2

##### **manufacturer assembler**

individual or company responsible for the procurement of materials and components, as well as all assembly process and verification operations necessary to ensure full compliance of assemblies with this document

#### 3.3

##### **objective evidence**

documentation agreed to between the user and the manufacturer

Note 1 to entry: The documentation can be in the form of a hard copy, computer data, computer algorithms, video or other media.

### 3.4

#### **process indicator**

detectable anomaly, other than a defect, that is reflective of material, equipment, personnel, process and/or workmanship variation

### 3.5

#### **proficiency**

capability to perform tasks in accordance with the requirements and verification procedures detailed in this document

### 3.6

#### **shadowing**

phenomenon where parts create a shadow of leads, lands, or other parts, which obstruct heating at reflow soldering or spreading solder at flow soldering

### 3.7

#### **supplier**

individual or company responsible for assuring, to the manufacturer (assembler), full compliance of components and base materials with the requirements and verification procedures of this document

Note 1 to entry: Components include electronic, electromechanical, mechanical components, printed boards, etc.

Note 2 to entry: Base materials include solder, flux, cleaning agents, etc.

### 3.8

#### **twist**

deviation of a rectangular sheet, panel or printed board that occurs parallel to a diagonal across its surface, so that one of the corners of the sheet is not in the plane that contains the other three corners

### 3.9

#### **user**

#### **procuring authority**

individual, company or agency responsible for the procurement of electrical/electronic hardware, and having the authority to define the class of equipment and any variation or restrictions to the requirements of this document

EXAMPLE The originator/custodian of the contract detailing these requirements.

## 4 General requirements

### 4.1 Order of precedence

#### 4.1.1 General remark

In the event of a conflict between the text of this standard and the applicable standard cited herein, the text of this document shall take precedence. However, nothing in this document supersedes applicable laws and regulations.

#### 4.1.2 Conflict

In the event of conflict between the requirements of this document and the applicable assembly—~~drawing(s)~~ **documentation**, the applicable user approved assembly—~~drawing(s)~~ **documentation** shall govern. In the event of conflict between the requirements of this document and assembly—~~drawing(s)~~ **documentation** that has not been approved, the differences shall be referred to the designated user activity for approval. Upon such approval, the provisions shall be documented (by official revision notice or equivalent) on the assembly ~~drawings~~ **documentation**, which shall then govern.

#### 4.1.3 Conformance documentation

Where this document requires documentary evidence to support conformance claims, each record shall be retained and be available for inspection for a minimum of two years from the date of the recorded occurrence (see ISO 9001).

#### 4.2 Interpretation of requirements

The introduction of product classification according to the levels and their end use (see 4.3) permits the user to differentiate the performance requirements. When the user elects to specify compliance with the mandatory requirements of this document, the following conditions apply:

- unless otherwise specified by the user, the word "shall" signifies that the requirements are mandatory,
- deviations from any "shall" requirement requires written acceptance by the user, for example via assembly ~~drawing~~ *documentation*, specification or contract provision. The word "should" is used to indicate a recommendation or guidance statement. The word "may" indicates an optional situation. Both "should" and "may" express non-mandatory situations. "Will" is used to express a declaration of purpose.

#### 4.3 Classification

This document recognizes that electrical and electronic assemblies are subject to classifications by intended end-item use. Three general end-product levels have been established to reflect differences in producibility, functional performance requirements, and verification (inspection/test) frequency.

It should be recognized that there may be overlaps of equipment between levels. The user (see 3.5) of the assemblies is responsible for determining the level to which the product belongs. The contract shall specify the level required and indicate any exceptions or additional requirements to the parameters, where appropriate.

##### *Level A: General electronics products*

Includes consumer products, some computer and computer peripherals, and hardware suitable for applications where the major requirement is function of the completed assembly.

##### *Level B: Dedicated service electronics products*

Includes communications equipment, sophisticated business machines, and instruments where high performance and extended life is required, and for which uninterrupted service is desired but not mandatory. Typically, the end-use environment would not cause failures.

##### *Level C: High-performance electronics products*

Includes all equipment where continued performance or performance-on-demand is mandatory. Equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment shall function when required, such as life support systems and other critical systems.

IPC-A-610 shall be used as workmanship standard.

NOTE Level A corresponds to class 1 in IPC-A-610

Level B corresponds to class 2 in IPC-A-610

Level C corresponds to class 3 in IPC-A-610

#### 4.4 Defects and process indicators

Table 5 lists the defects that are unacceptable and require attention (for example, rework, repair, ~~etc.~~). The manufacturer is responsible for identifying other areas of risk and treating those additional concerns as additions to Table 5. Such items should be documented on the assembly ~~drawing~~ documentation. Other than the unacceptable defects listed in Table 5, anomalies and variances from "shall" requirements are considered as process indicators, and shall be monitored when their occurrence is observed. The disposition of process indicators is not required.

Workmanship requirements shall ~~be consistent with IPC-A-610E, and~~ match the defined level of classification ~~identified in~~ according to 4.3.

IPC-A-610 shall be used as workmanship standard.

#### 4.5 Process control requirements

This document requires the use of process control methodologies in the planning implementation and evaluation of the manufacturing processes used to produce soldered electrical and electronic assemblies. The philosophy, implementation strategies, tools and techniques may be applied in different sequences depending on the specific company, operation, or variable under consideration, to relate process control and capability to end-product requirements. The manufacturer, subject to agreement by the user, may be exempt from performing specific quality conformance evaluations and inspections, detailed in this document, provided objective evidence of a comprehensive and current continuous improvement plan is available (see 13.3).

#### 4.6 Requirements flowdown

The applicable requirements of this document shall be imposed by each manufacturer or supplier on all applicable subcontracts and purchase orders. The manufacturer or supplier shall not impose or allow any variation from these requirements on subcontracts or purchase orders other than those that have been approved by the user.

Unless otherwise specified, the requirements of this document are not imposed on the procurement of off-the-shelf (catalogue) assemblies or subassemblies (see 14.3). However, the manufacturer of these items may comply as deemed appropriate.

#### 4.7 Physical designs

##### ~~4.7.1 Design requirements~~

~~Some structural and layout design requirements are given in the following subclauses.~~

##### 4.7.1 New designs

The printed board layout and mechanical and thermal structure of the electrical/electronic assembly should, where relevant, be based on an appropriate design standard (for example IEC 61188-5-1) or as approved by the user. When a manufacturer has objective evidence that a revised layout will produce good end product quality that fulfills the requirements of this document, the user and manufacturer should agree on the changes, and the layout **should** be modified appropriately.

##### 4.7.2 Existing designs

The requirements of this document should not constitute the sole cause for redesign of a currently approved design. However, when existing electronic or electrical designs undergo changes that have an impact on hardware configuration, the design of the latter shall be reviewed and user-approved changes made that allow for maximum practical compliance. Any manufacturer-proposed design changes shall be approved by the user; however, even though

the proposed changes result in compliance with this document and the manufacture of quality end products, the user is under no obligation to accept the proposed redesign.

#### **4.8 Visual aids**

Line drawings and illustrations are depicted herein to assist in the interpretation of the written requirements of this document. The written requirements take precedence.

#### **4.9 Proficiency of personnel**

##### **4.9.1 Design proficiency**

The design facility shall have documentation which demonstrates that formal design training for all technical workforce personnel has been accomplished. Training shall be given irrespective of whether such personnel have direct responsibility for product electronic/electrical design (see ISO 9001).

##### **4.9.2 Manufacturing proficiency**

Prior to commencing work, all instructors, operators and inspection personnel shall be proficient in the tasks to be performed. Objective evidence of that proficiency shall be maintained and be available for review. Objective evidence shall include records of training for the applicable job functions being performed, testing to the requirements of this document, and results of periodic reviews of proficiency (see ISO 9001 and IPC-A-610E).

#### **4.10 Electrostatic discharge (ESD)**

The ESD control programme shall be in accordance with IEC 61340-5-1 and IEC/TR 61340-5-2. Documented procedures, electrostatic discharge control for the protection of ESD sensitive electrical and electronic parts, components, assemblies and equipment shall be maintained during, but not limited to:

- a) receipt and test of incoming items;
- b) board, component and parts storage and kitting;
- c) manufacturing and rework;
- d) inspection and test cycles;
- e) storage and shipping of completed product;
- f) transport and installation.

Procedures for analysis of failures arising from ESD shall be documented and be available for review by an authorized inspectorate.

#### **4.11 Facilities**

##### **4.11.1 General**

Cleanliness and ambient environments in all work areas shall be maintained at levels that prevent contamination or deterioration of soldering tools, materials and surfaces to be soldered. Eating, drinking and use of tobacco products or illegal drugs shall be prohibited in the work area.

##### **4.11.2 Environmental controls**

The soldering facility should be enclosed, temperature and humidity controlled, and maintained at a positive pressure.

#### 4.11.3 Temperature and humidity

When relative humidity decreases to a level of 30 % or lower, the manufacturer shall verify that electrostatic discharge control is adequate, and that sufficient moisture is present for flux performance and solder paste applications. For operator comfort and solderability maintenance, the temperature should be maintained between 18 °C and 30 °C and the relative humidity should not exceed 70 %. For process control, the need for more restrictive temperature and humidity limits should be evaluated.

#### 4.11.4 Lighting

Illumination at the working surface of manual soldering and inspection stations shall be 1 000 lm/m<sup>2</sup> minimum.

#### 4.11.5 Field conditions

In field operations, where the controlled environment conditions required by this document cannot be achieved effectively, special precautions shall be taken to maximize the quality of solder connections and minimize the effects of the uncontrolled environment on the operation being performed on the hardware.

#### 4.11.6 Clean rooms

The assembly of electronics may necessitate the use of clean rooms to ensure compliance with the end production performance requirements of this document. If required, the class of clean room shall be agreed upon between the user and the manufacturer.

### 4.12 Assembly tools and equipment

#### 4.12.1 General

The manufacturer is responsible for the selection and maintenance of tools and equipment used in the preparation and soldering of components and/or conductors. Tools used shall be selected and maintained so that no damage results from their use. Tools and equipment should be clean prior to use and be kept clean and free of dirt, grease, flux, oil and other foreign matter during use. Soldering irons, equipment, and systems shall be chosen and employed to provide temperature control and isolation from electrical overstress EOS or ESD (see 4.10).

#### 4.12.2 Process control

If suitable process controls are not in place to ensure compliance with 4.12 and the intent of Annex A, the relevant detailed requirements of Annex A shall be mandatory. Assembly tools and equipment shall be used in accordance with a documented process that is available for user review. Assembly tools and equipment shall demonstrate process parameters as described in the process documentation.

## 5 Requirements of materials

### 5.1 Overview

Materials used in the soldering processes stipulated in this document shall be as specified hereinafter. Since the materials and processes specified ~~may~~ can be incompatible in some combinations, the manufacturer shall be responsible for selecting the combination of materials and processes that will produce acceptable products.

## 5.2 Solder

Solder alloys conforming to IEC 61190-1-3 shall be used. Any alloy that provides the service life, performance, reliability or regulatory requirements of the product may be used if all other conditions of this document are met and agreed upon by user and manufacturer.

## 5.3 Flux

Flux shall be tested and classified in accordance with IEC 61190-1-1 or equivalent, into one of the following three types:

- L = low or no flux/flux residue activity;
- M = moderate flux/flux residue activity;
- H = high flux/flux residue activity.

Types L or M flux shall be used for assembly soldering. For applications where the flux residue will not be removed (no-clean), the use of an L flux meeting the requirements of 9.6.9 without cleaning (C00) is recommended (see 9.6.3.2).

Inorganic acid fluxes and type H fluxes may be used for tinning of terminals, solid wire and sealed components. Inorganic acid fluxes may not be used for assembly soldering. Type H fluxes may be used for soldering of terminals, solid wire and sealed components when performed as part of an integrated fluxing, soldering, cleaning and cleanliness test system and either of the following conditions is met:

- a) usage is approved by the user;
- b) data demonstrating compliance with the testing requirements of Annex B is available for review.

When type H flux is used, cleaning is mandatory.

When liquid flux is used in conjunction with other fluxes, it shall be chemically compatible with the other fluxes and materials with which it will be used. The flux of cored solder shall be in accordance with this subclause. The percentage of flux in cored solder is optional.

## 5.4 Solder paste

Solder paste, solder powder and flux constituents shall meet the requirements of 5.2 and 5.3 and should be evaluated in accordance with IEC 61190-1-2 to meet the assembly process requirements.

## 5.5 Preform solder

Preform solder shall meet all applicable requirements in 5.2 and 5.3.

## 5.6 Adhesives

Adhesive materials used for attachment of ~~other than surface mounted~~ components shall be suitable for the application and compatible with the assembly.

## 5.7 Cleaning agents

### 5.7.1 General

Cleaning agents used for the removal of grease, oil, wax, dirt, flux and other debris shall be selected for their ability to remove flux residue, other residues and particulate contaminants. The cleaning agents should not have aggressive chemicals and shall not degrade the materials or the parts being cleaned. The cleaning process shall permit the assembly to meet the cleaning requirements of ~~9.6~~ 9.3.

### 5.7.2 Cleaning agents selection

Cleaning agents and mixtures of cleaning agents shall conform to all appropriate specifications and references. Mixtures of cleaning agents may be used provided they are suitably stabilized or inhibited.

The use of chlorinated solvents is not permitted. Water, water/alcohol or terpenes are to be considered as first choice for cleaning applications. Any cleaning solvent shall comply with applicable health, safety and environmental regulations.

## 5.8 Polymeric coatings

### ~~5.8.1 General~~

~~The detailed requirements for polymeric materials are defined in the following subclauses.~~

#### 5.8.1 Solder resists and localized maskants

Polymer solder resist coatings and temporary maskants in accordance with IEC 61249-8-8 shall be of a material that:

- a) does not degrade solderability or the substrate material or printed wiring;
- b) precludes solder flow to the masked area;
- c) is compatible, if left in place, with printed board base material, conductive material, the intended fluxes, adhesive and subsequently applied conformal coatings;
- d) can, if temporary, be readily removed without post-removal residual contamination harmful to the integrity of the printed board conformal coating, or assembly.

#### 5.8.2 Conformal coating and encapsulants

Conformal coating requirements for assemblies, including the type of coating (i.e. the material), shall be as specified on the approved assembly ~~drawing~~ documentation. If edge coating is specified on the assembly ~~drawing~~ documentation, it shall conform to 11.1.2.7. Encapsulants shall be suitable for the application and shall be compatible with the assembly.

#### 5.8.3 Spacers (permanent and temporary)

Materials used as mechanical stand-offs shall withstand soldering processes and should permit inspection of the solder joints (see 13.2.2.3). This requirement includes spacers that should withstand temperatures generated due to self-heating of components. Location, configuration and material shall be specified in the appropriate documentation.

## 5.9 Chemical strippers

Chemical solutions, pastes and creams used to strip solid wires shall not cause degradation to the wire.

## 5.10 Cleaning Agents

The cleaning agents should not have aggressive chemicals and shall not degrade the materials or the parts being cleaned. In addition, wires shall be neutralized and cleaned of contaminants in accordance with the suppliers' recommended instructions, and shall be solderable in accordance with 6.2.

#### 5.11 Heat shrinkable soldering devices

Heat shrinkable soldering devices shall be self-sealing and shall encapsulate the solder connection. Braided shield terminations shall be in accordance with detailed manufacturers' work instructions that have been prepared to reflect the requirements documented on an

approved assembly ~~drawing~~ documentation. ~~These self-sealing devices are exempt from the cleaning requirements of 9.4.~~

## 6 Components and printed board requirements

### 6.1 General

Electronic/mechanical components and printed boards shall conform to the requirements of the procurement document; ensuring conformance shall be the responsibility of the assembly manufacturer. Components and printed boards selected for assembly shall be compatible with all materials and processes used to manufacture the assembly.

NOTE For further information, see IEC 62326-1, IEC 62326-4, IEC 62326-4-1 and IEC/PAS 62326-7-1.

### 6.2 Solderability

#### 6.2.1 Parts solderability

Solderability of parts shall be the responsibility of the supplier and shall meet the requirements specified and agreed to by the manufacturer. Electronic/mechanical components and wires shall meet solderability requirements when tested in accordance with IEC 60068-2-20, IEC 60068-2-58 or equivalent; printed boards shall meet the requirements when tested in accordance with IEC 61189-3 or equivalent.

Prior to acceptance of parts for storage or use, the manufacturer shall ensure that the parts to be soldered have been solderability tested in accordance with a sampling plan and conform to the requirements of the applicable solderability specification. The user should specify the required solderability specification. Storage conditions shall comply with class 1K2 of IEC 60721-3-1 and IEC 61760-2.

#### 6.2.2 Reconditioning

When tinning and inspection is performed as part of the assembly process, that tinning operation can be used in lieu of solderability testing (see 6.3).

#### 6.2.3 Solderability testing of ceramic boards

Metallic elements of ceramic printed boards shall be tested for solderability as specified in IEC 61189-3, or by using an equivalent method.

### 6.3 Solderability maintenance

#### 6.3.1 General

The manufacturer shall ensure that all components, leads, wiring, terminals, and printed boards which have met the requirements of 6.2 are solderable at the start of hand and/or machine soldering operations. The manufacturer shall establish procedures to minimize solderability degradation.

#### 6.3.2 Preconditioning

Component leads, terminations, and terminals may be preconditioned (e.g. hot solder dipped) to provide solderability maintenance.

### 6.3.3 Gold embrittlement of solder joints

#### 6.3.3.1 General

To minimize the impact of embrittlement of solder from gold-plated items (e.g. component leads, printed board lands), the total volume of gold in any solder joint shall not exceed 1,4 % of the volume (i.e., 3 % by weight) of solder present.

If there is documented objective evidence, available for review, that there are no gold-related solder embrittlement issues, or other metallic-surface finish solder-joint integrity problems associated with the soldering process being used, the following requirements may be eliminated.

#### 6.3.3.2 Gold on component ~~and piecepart~~ leads terminations

The manufacturer shall demonstrate compliance with the presoldering requirement:

- a) all gold-plated leads/terminations and terminals have either been pre-tinned or the gold has been otherwise removed from surfaces to be soldered, and/or
- b) the quantity of any residual gold present prior to soldering will not cause the limits given in 6.3.3 to be exceeded.

#### 6.3.3.3 Tinning of leads/terminations

Tinning of leads/terminations shall not adversely affect the components. A double-tinning process or dynamic solder wave should be used for effective gold removal.

The gold-removal process may be eliminated for components to be soldered using dip, wave, or drag soldering processes provided that:

- a) sufficient gold thickness exists to meet the solderability requirements in 6.2;
- b) sufficient time, temperature and solder volume exist during the soldering process to enable the requirements of 6.3.3 to be met.

#### 6.3.3.4 Gold on printed board lands

The volume of gold deposited on any printed board land intended for soldering components or terminals shall not cause the limits given in 6.3.3 to be violated.

### 6.3.4 Tinning of non-solderable parts

Component leads, terminations and printed boards not meeting the designated solderability requirements shall be reworked by hot solder dip tinning or other suitable methods prior to soldering. The reworked parts shall conform to the requirements of 6.2, except for steam ageing. Tinned areas of wires shall not conceal the wire strand(s) with solder. Wicking of solder under wire insulation shall be minimized. When required, heat sinks shall be applied to leads of heat-sensitive parts during the tinning operation.

## 6.4 Solder purity maintenance

Solder used for preconditioning gold removal, tinning of parts, and machine soldering shall be analyzed, replaced or replenished at a frequency to ensure compliance with the limits specified in Table 1. The frequency of analysis should be determined on the basis of historical data or monthly analyses. If contamination exceeds the limits of Table 1, intervals between the analyses, replacement or replenishment shall be shortened. Records containing the results of all analyses and solder bath usage (for example, total time in use, amount of replacement solder required, or area throughput) shall be maintained for each process system (see 4.1.3).

**Table 1 – Solder contamination limits; maximum contaminant limit (percentage by weight)**

| Contaminant                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <del>Preconditioning (lead/wire tinning)</del><br>Preconditioning maximum contaminant weight percentage limit SnPb alloys | <del>Assembly soldering (pot, wave, etc.)</del><br>Assembly Maximum Contaminant Weight Percentage Limit SnPb alloys | Preconditioning and assembly maximum contaminant weight percentage limit SACXXX lead-free alloys |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Copper                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 0,750 <sup>a</sup>                                                                                                        | 0,300                                                                                                               | Note <sup>b</sup>                                                                                |
| Gold                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0,500                                                                                                                     | 0,200                                                                                                               | 0,200                                                                                            |
| Cadmium                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 0,010                                                                                                                     | 0,005                                                                                                               | 0,005                                                                                            |
| Zinc                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0,008                                                                                                                     | 0,005                                                                                                               | 0,005                                                                                            |
| Aluminum                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0,008                                                                                                                     | 0,006                                                                                                               | 0,006                                                                                            |
| Antimony                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0,500                                                                                                                     | 0,500                                                                                                               | 0,200                                                                                            |
| Iron                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0,020                                                                                                                     | 0,020                                                                                                               | 0,020                                                                                            |
| Arsenic                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 0,030                                                                                                                     | 0,030                                                                                                               | 0,030                                                                                            |
| Bismuth <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0,250                                                                                                                     | 0,250                                                                                                               | 0,250                                                                                            |
| Silver <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 0,750                                                                                                                     | 0,100                                                                                                               | 4,000                                                                                            |
| Nickel                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 0,020                                                                                                                     | 0,010                                                                                                               | 0,050                                                                                            |
| Palladium                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 0,004                                                                                                                     | 0,004                                                                                                               | 0,004                                                                                            |
| Lead                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <del>0,100</del> N/A                                                                                                      | <del>0,100</del> N/A                                                                                                | 0,100                                                                                            |
| The tin content of the solder bath shall be within <del>±1,5</del> 1 % of nominal for the solder specified and tested at the same frequency as tested for copper/gold contamination. The balance of bath shall be lead or the items listed above.                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                           |                                                                                                                     |                                                                                                  |
| The total of copper, gold, cadmium, zinc and aluminum contaminants shall not exceed 0,4 % for assembly soldering.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                           |                                                                                                                     |                                                                                                  |
| NOTE When these metals are compositions of the solder alloy applied to the process, these are not considered to be contaminants.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                           |                                                                                                                     |                                                                                                  |
| <sup>a</sup> <del>Not applicable for Sn62Pb36Ag2; limits to be 1,75 % to 2,25 %.</del><br><sup>b</sup> <del>Not applicable for processes using Sn60Pb38Bi2 (alloy 19/ISO 9453) for attachment.</del><br><sup>ea</sup> When tinning fine-pitch leaded devices, the copper ratio should not exceed 0,300 %.<br><sup>b</sup> A maximum copper limit of 1,1 % may be specified as agreed between the user and the supplier. Printed circuit assemblies that are characterized as thick and thermally demanding may potentially have plated through-hole fill and/or solder joint defects due to the impact of copper on solder flow characteristics. |                                                                                                                           |                                                                                                                     |                                                                                                  |

## 6.5 Lead preparation

### 6.5.1 General

The detailed requirements for lead forming and preparation are described in the following subclauses.

### 6.5.2 Lead forming

The lead forming process shall not damage connections internal to components. The preferred methods of lead forming given in the manufacturer's specification shall be used. In addition, component bodies, leads and lead seals shall not be degraded below the basic component specification requirements.

### 6.5.3 Lead-forming limits

Whether leads are formed manually or by machine or die, components shall not be mounted if the component lead has unwanted nicks or deformation in diameter or width exceeding 10 % of the lead.

Exposed core metal is acceptable if the defect does not affect more than 5 % of the solderable surface area of the lead. Occurrence of exposed basis metal in the formed area of the lead shall be treated as a process indicator.

## 7 Assembly process requirements

### 7.1 Overview

Subclauses 7.2 to 7.6 deal with the requirements for the mounting of terminals, mechanical and electronic components, and wires to printed boards or other packaging and interconnecting structures. On assemblies using mixed component mounting technology, through-hole components should be mounted on one side of the printed board. Surface-mounted components may be mounted on either or both sides of the assembly.

When design restrictions mandate mounting components incapable of withstanding soldering temperatures incident to a particular process, such components shall be mounted and soldered to the assembly as a separate operation. In an assembly sequence where certain components are mounted and soldered followed by additional mounting and soldering, the appropriate steps shall be taken regarding cleaning of flux residues. If applicable, assemblies shall be cleaned after each soldering operation so that subsequent placement and soldering operations are not impaired by contamination (see Clause 9).

### 7.2 Cleanliness

The cleanliness of terminals, component leads, conductors, and printed wiring surfaces shall be sufficient to ensure solderability and compatibility with subsequent processes. Cleaning shall not damage the components, component leads, conductors or markings.

### 7.3 Part markings and reference designations

Part markings and reference designations shall be legible and components shall be mounted in such a manner that markings are visible.

### 7.4 Solder connection contours

Designs that utilize special solder connection contours as a part of a coefficient of thermal expansion (CTE) mismatch compensation system shall be identified on the approved assembly ~~drawing~~ **documentation**. The mounting technique shall be capable of performing with a solder connection that meets the requirements of 10.3.

### 7.5 Moisture traps

Within the constraints imposed by component and part design, parts and components shall be mounted to preclude the formation of moisture traps.

### 7.6 Thermal dissipation

When heat dissipation is required by the assembly, the material compatibility requirements of Clause 5 shall be followed.

## 8 Assembly soldering requirements

### 8.1 General

~~The detailed requirements for manual and machine soldering processes are defined in the following subclauses.~~

#### 8.1.1 Soldering process

Soldering processes, as specified herein, shall not result in damage to the components or assemblies.

#### 8.1.2 Machine maintenance

Machines used in the soldering process shall be maintained to assure capability and efficiency commensurate with design parameters established by the original equipment manufacturer.

Maintenance procedures and schedules shall be documented in order to provide reproducible processing.

#### 8.1.3 Handling of parts

Parts shall be handled in a manner to preclude damage to terminations and to avoid the need for subsequent lead straightening operations. Once parts are mounted on printed boards, the assembly prior to soldering shall be handled, transported (for example by hand or conveyor) and processed in a manner to preclude movement that would detrimentally affect the formation of acceptable solder connections. After soldering operations have been performed, the assembly shall be sufficiently cooled so that the solder is solidified prior to further handling to prevent hot cracking of the solder.

#### 8.1.4 Preheating

Assemblies should be preheated to minimize the presence of volatile solvents prior to soldering, to reduce the temperature differences across the board, to reduce thermal shock to boards and components, to improve solder flow, and to reduce the molten solder dwell time. The preheat temperature exposure shall not degrade printed boards, components, or soldering performance.

#### 8.1.5 Carriers

Carriers used for the transport of printed boards through the assembly line shall be of such material, design, and configuration that they will not impair solderability or cause board, part or component degradation or electrostatic damage (ESD) to components.

#### 8.1.6 Hold down of surface mount leads

Short, stiff or thick surface-mounted device leads shall not be held down under stress (for example by probes) during solder solidification so that the resulting initial stresses decrease reliability. The resistance reflow system (e.g. parallel gap, shorted bar, thermal transfer) should not deflect the leads more than twice the lead thickness. For short or thick leads, the deflection should be less than twice the lead thickness.

#### 8.1.7 Heat application

The elements to be soldered shall be sufficiently heated to cause complete melting of the solder and wetting of the surface being soldered.

### 8.1.8 Cooling

The connection shall not be subjected to detrimental movement or detrimental stress at any time during the solidification of the solder. Controlled cooling may be used with documented processes.

## 8.2 Reflow soldering

### 8.2.1 Requirements

The detailed requirements for reflow soldering operations are defined subclauses 8.2.2 to 8.2.4. Methods for reflowing solder for attachment of surface-mounted devices include, but are not limited to, infrared, vapour phase, convection (hot air/gas), laser, thermode (hot bar) or conduction. These should provide:

- a) the capability to apply controlled pre-heat to printed wiring assemblies;
- b) the thermal capacity to raise and maintain the soldering temperatures for the range of component thermal masses and solder joint sizes to within  $\pm 5^\circ\text{C}$  of their selected temperature profile, throughout the span of the required continuous soldering production run;
- c) within the constraints of thermal shock limitation requirements, to heat rapidly the surfaces to be joined and to cool them thereafter;
- d) to minimize the effects of shadowing and colour on individual component-heating rates.

### 8.2.2 Process development for reflow soldering

Manufacturers shall establish and maintain a reflow soldering process that is repeatable within limits defined for the process equipment. A reflow soldering process instruction shall also be developed and maintained. The manufacturer shall perform the reflow soldering operations in accordance with these process instructions. The process shall include, as a minimum, a reproducible time/temperature envelope including the drying/degassing operation (when required), preheating operation (when required), solder reflow operation, and a cooling operation. These steps may be part of an integral or in-line system or may be accomplished by a series of separate operations. If the temperature/time profile is adjusted for a different printed wiring assembly, or another assembly variation, the setting to be used shall be documented.

### 8.2.3 Flux application

Flux, when used, shall be applied prior to formation of the final solder connection. Flux may be a constituent of the solder paste or preform solder. Any flux meeting the requirements of 5.3 may be used provided that

- a) the flux or combination of fluxes does not damage parts,
- b) the subsequent cleaning processes (if required) shall be sufficient to comply with the cleanliness requirements in Clause 9 and not be detrimental to the product.

### 8.2.4 Solder application

#### 8.2.4.1 Workmanship

Enough solder shall be applied to components or boards or both to ensure that sufficient quantity is in place during reflow to meet the ~~end-point~~ workmanship requirements.

#### 8.2.4.2 Solder paste application

Methods for applying solder paste on surface-mount land pattern areas include, but are not limited to, screen or stencil printing, dispensing, or pin transfer. Solder paste shall be handled ~~by~~ in accordance with the material supplier's recommendation ~~for~~ to ensure proper

performance. Re-use or mixing of solder paste exposed for excessive periods (for example 1 h to 24 h depending on the material) with fresh paste should be avoided.

#### 8.2.4.3 Solid solder deposition (SSD)

Surface-mount land patterns can be coated with a defined amount of solder during the printed board's manufacturing process.

Different methods of solder application are permissible, for example:

- a) plating of SnPb; it shall not be applied to lead-free soldering;
- b) screen or stencil printing of solder paste followed by a reflow solder process. This process can be used with or without a flattening operation of the reflowed solder pads;
- c) application of molten solder;
- d) application of solder particles in an adherent flux (solid solder deposit technology).

The characteristics of the solid solder deposit on land patterns are the following:

- e) the applied solder has a plated or molten intermetallic bond to the surface mounting device (SMD) land pattern;
- f) the applied thickness of the solder is sufficient for a reliable reflow solder joint;
- g) the solder is applied with sufficient precision to the SMD land pattern;
- h) the flatness of deposited solder shall be suitable for the applicable component, for example fine-pitch devices require better flatness than most other components.

The amount of the solder shall be specified.

### ~~8.4 Mechanized immersion soldering (non-reflow)~~

#### ~~8.4.1 General~~

~~The detailed requirements for immersion non-reflow machine soldering are defined in the following subclauses. These soldering systems should provide:~~

- ~~a) the capability to apply flux to all points requiring flux;~~
- ~~b) the capability to apply controlled pre-heat to printed board assemblies;~~
- ~~c) the thermal capacity to maintain the soldering temperature at the assembly surface to within  $\pm 5^{\circ}\text{C}$  of the selected temperature, throughout the span of the required continuous soldering production run;~~
- ~~d) within the constraints of thermal shock limitation requirements, to heat the surfaces to be joined in a controlled manner, and to cool them thereafter;~~
- ~~e) sufficient mechanical energy to minimize shadowing effects and to assist wetting in the nooks and crannies between closely packed surface mount components.~~

#### ~~8.4.2 Process development for mechanized immersion soldering~~

~~The manufacturer shall maintain operating procedures describing the soldering process and the proper operation of the automatic soldering machine and associated equipment. For the soldering machine, these procedures, as a minimum, shall define the preheat temperature, solder temperature, rate of travel, frequency of temperature verification measurements, frequency and method of flux analysis (mandatory for low solids fluxes), and frequency of solder bath analysis. If any of the above mentioned characteristics are adjusted for a different printed wiring assembly, drawing number, or other positive identification element, the setting to be utilized shall be identified.~~

### **8.4.3 — ~~Drying/degassing~~**

~~Prior to soldering, the assembly may be baked to reduce detrimental moisture and other volatiles.~~

### **8.4.4 — ~~Holding fixtures and materials~~**

~~Devices, materials or techniques used to retain parts and components to the printed board through preheat, fluxing, soldering, and cooling stages shall not contaminate, damage or degrade printed boards or components. The devices, materials or techniques shall be adequate to maintain component positioning, and shall permit solder flow through plated through holes and/or on to terminal areas.~~

### **8.4.5 — ~~Flux application~~**

~~The flux used shall form a coating on the surface to be soldered. The flux or method of application should not damage or reduce reliability of components. The flux shall be thinned with material recommended by the flux supplier as necessary to meet the requirements of the flux application. The flux shall be dried sufficiently before soldering to prevent solder spatter.~~

### **8.4.6 — ~~Solder bath~~**

#### **8.4.6.1 — ~~Solder bath temperature~~**

~~The solder bath using the solder compositions defined in 5.2 should be maintained at a temperature recommended by the supplier of the solder. However, the temperature shall not exceed the resistance to soldering heat of the components mounted. For alloys other than those cited in 5.2, other temperature ranges may be required. For all alloys, the nominal temperature should have a tolerance of  $\pm 5^{\circ}\text{C}$ . This tolerance shall not put the bath temperature outside the established limits.~~

~~The temperature and time of contact between the assembly and the solder shall be dependent upon such factors as preheating, thickness of the board, number and size of contacts or conductors, and the type of parts. The period of exposure of any printed board to a solder bath shall be limited to a duration which will not cause damage to the board or components mounted thereon.~~

#### **8.4.6.2 — ~~Solder bath maintenance~~**

~~Solder bath purity in machine soldering of printed board assemblies shall be maintained in accordance with 6.4 and the following procedures:~~

- ~~a) dross shall be removed from the solder bath in a manner which assures that dross does not contact the items being soldered. Automatic or manual methods for dross removal are acceptable;~~
- ~~b) soldering oils may be intermixed with the molten solder and carried to the surface of the solder wave or applied to the surface of the solder wave or solder bath. The oil level should be controlled to preclude intermix of oil in solidified solder joints;~~
- ~~c) solder in soldering machines shall be analyzed on a regular basis in accordance with 6.4.~~

## 8.3 Manual/hand soldering

### ~~8.5.1 Requirements~~

~~The detailed requirements for manual/hand soldering are defined in the following subclauses.~~

#### 8.3.1 Non-reflow manual soldering

##### 8.3.1.1 Flux application

If used, liquid flux shall be applied to the surfaces to be joined, prior to the application of heat. The use of excess flux should be avoided. When cored solder is used, it shall be placed in a position that allows the flux to flow and cover the connection elements as the solder melts. When an external liquid flux is used in conjunction with flux cored solders, the fluxes shall be compatible.

##### 8.3.1.2 Solder application

A well-tinned tip (see 4.12) shall be applied to the joint and the solder introduced at the junction of the tip and the connection for maximum heat transfer. After applying heat and achieving heat transfer, the solder should be applied to the joint and not the soldering iron tip. Solder is supplied to a surface of the joint that ~~left from~~ is located to the left of the heating position. The method of application should be such that no solder ~~deposits~~ is deposited on the body of component. The solder and the soldering iron tip shall be quickly pulled apart from the joint metal. Solder shall only be applied to one side of a plated through-hole. The temperature of the soldering tip shall not exceed the specific working temperature. The application of heat should be within the restricted temperature and time specified. Heat may be applied to both sides of the plated through-hole. Some hand-soldering applications may require preheating to prevent damage to components.

##### 8.3.1.3 Heat sinks

When hand soldering is being carried out close to the body of heat-sensitive devices, a heat sink should be used between the soldering iron tip and the component body as necessary to restrict heat flow into the component.

##### 8.3.1.4 Solder wicking

Limited solder wicking during soldering of wire is permissible. Solder wicking shall not extend to a portion of the wire that is required to remain flexible.

#### 8.3.2 Reflow manual soldering

##### 8.3.2.1 Solder applications

Enough solder shall be applied to components, or boards, or both to ensure that sufficient quantity is in place during reflow to meet the end product requirements. Methods for solder application include dispensing or pin transfer of solder paste, or use of solder wire or preforms. Land patterns to which solder is applied shall be clean prior to solder application reflow methods.

##### 8.3.2.2 Reflow methods

Manufacturers shall establish a reflow soldering process that is repeatable within the limits defined for the hand soldering reflow equipment (for example hot air or gas, infrared). The reflow process instructions shall be developed and maintained and shall be performed in accordance with these process instructions.

The process shall include as a minimum a reproducible time/temperature envelope that includes the drying/degassing operation (when required). Reflow methods include hot air/gas guns, solder irons, or hot bar (thermode) or laser operations.

### 8.3.2.3 Shielding

When manual reflow soldering is performed, appropriate shielding should be provided so that adjacent components (next to the parts being joined) are not damaged or that the solder joints of adjacent components are not reflowed again.

## 9 Cleanliness and residue requirements

### 9.1 General

When the ~~post soldering~~ cleanliness designator (see 9.2.2) specifies cleaning option C-0 (no surface to be cleaned), the soldered assembly shall meet the visual inspection requirements of 9.3 except that evidence of flux residue is permitted.

If cleaning is required ~~(as in 9.6)~~ during and after processing, parts, subassemblies, and final assemblies shall be cleaned within a time frame that permits appropriate removal of contaminants, especially flux residue.

All items cleaned shall be cleaned in a manner that will prevent detrimental thermal shock and intrusion of cleaning media into components that are not totally sealed. The assembly cleaning shall be capable of meeting the cleanliness requirements as specified herein.

The cleaning media and equipment shall be selected for their ability to remove the contaminations and shall not degrade the materials, markings or parts being cleaned.

### ~~9.2 Equipment and material compatibility~~

~~The cleaning media and equipment shall be selected for their ability to remove both ionic and non-ionic contamination, and shall not degrade the materials, markings, or parts being cleaned. Analysis and documentation demonstrating compliance with these requirements shall be available for review.~~

### ~~9.3 Pre-soldering cleaning~~

~~The cleanliness of terminals, component leads, conductors, and printed wiring surfaces shall be sufficient to ensure solderability. Cleaning shall not damage or reduce the reliability of the components, component leads, or conductors. For post-soldering cleaning option C-0 (no surfaces to be cleaned), cleanliness shall be sufficient to ensure compliance with the final assembly cleanliness requirements.~~

### ~~9.4 Post-soldering cleaning~~

#### ~~9.4.1 General~~

~~When cleaning is required, flux residue shall be removed as soon as possible, preferably within 15 min, but no longer than 1 h after soldering. Some fluxes or processes may require more immediate action to facilitate adequate removal. Mechanical means such as agitation, spraying, brushing, etc., or vapour degreasing and other methods of application may be used in conjunction with the cleaning medium. The time between soldering and completion of cleaning may be extended for hand soldering operations provided interim cleaning is performed and complete cleaning is performed prior to the end of the production shift.~~

~~Terminations internal to self-sealing devices (e.g. heat shrinkable solder devices) shall be exempt from the cleaning requirements of this standard when the device encapsulates the solder connection.~~

#### ~~9.4.2 Ultrasonic cleaning~~

~~Ultrasonic cleaning is permissible~~

- a) ~~on bare boards or assemblies, provided only terminals or connectors without internal electronics are present, or~~
- b) ~~on electronic assemblies with electrical components, provided the contractor has documentation available for review showing that the use of ultrasonics does not damage the mechanical or electrical performance of the product or components being cleaned.~~

## **~~9.5 — Cleanliness verification~~**

### **~~9.5.1 — General~~**

~~Assemblies shall meet the requirements of 9.6 for cleanliness. The following methods are to be used to assess the amount of remaining particulate or foreign matter, as well as flux residues and other ionic organic contaminants.~~

### **~~9.5.2 — Visual inspection~~**

~~When made as part of a documented process control and product improvement system, visual inspection shall be based on a statistical sample (see 13.2.3). Otherwise, 100 % visual inspection shall be used to assess the presence of foreign particulate matter as required in 9.6.2, or flux and other ionic or inorganic residues as required in 9.6.3.~~

### **~~9.5.3 — Testing~~**

~~Periodic testing of cleanliness of the assembly after final cleaning (e.g. the cleaning prior to conformal coating, encapsulation, or incorporation into the next higher assembly) shall be conducted on a random sample basis (see 13.2.3) to ensure the adequacy of the cleaning process(es), as required in 9.6.5.~~

~~If any assembly fails, the entire lot shall be recleaned and a random sample of this lot, and each lot cleaned since performing the last acceptable cleanliness test, shall be tested. The frequency of testing shall be a minimum of once each 8 h shift, unless the process control system data supports a change in frequency.~~

## **~~9.6 — Cleanliness criteria~~**

### **~~9.6.1 — General~~**

~~Cleaning of assemblies shall be performed as necessary to remove~~

- a) ~~particulate foreign matter as required in 9.6.2, and~~
- b) ~~flux residues and other ionic or organic contaminants as required in 9.6.3.~~

### **~~9.6.2 — Particulate matter~~**

~~Assemblies shall be free of dirt, lint, solder splash, dross, etc. Solder balls shall be neither loose nor degrade electrical performance characteristics. Inspection for particulate matter shall be consistent with inspection methodology defined in 13.2.2.2.~~

~~Solder balls shall not reduce the minimum design electrical spacing by more than 50 %, and shall be fixed to the board surface. Additionally, not more than 5 solder balls per 600 mm<sup>2</sup> shall occur.~~

### **~~9.6.3 — Flux residues and other ionic or organic contaminants~~**

#### **~~9.6.3.1 — General~~**

~~The user and manufacturer shall agree to the cleaning requirements and the appropriate tests for cleanliness. In addition, the visual requirements for cleanliness shall be agreed to and specified.~~

~~It is the responsibility of the user to specify cleanliness. The user may wish to use the cleanliness designator that establishes the cleaning option and test for cleanliness in accordance with 9.6.3.2. In the absence of a specified cleanliness designator, the designator C-22 as described in the following subclauses should apply. In addition, the visual requirements for cleanliness (as in 9.6.3.3) shall be specified.~~

### **9.6.3.2 — Post-soldering cleanliness designator**

~~Where the user specifies a cleanliness designator, it shall be in the following form:~~

| Cleanliness designator | Cleaning option | Test for cleanliness |
|------------------------|-----------------|----------------------|
| C                      | 9.6.4           | 9.6.5                |

~~A two digit (minimum) code describes the cleanliness requirements for all assemblies covered under this standard. This code begins with the letter C then a dash followed by two or more digits. The first digit represents the cleaning option described in 9.6.4 and the second and following digits indicate the requirements for cleanliness testing described in 9.6.5. (If all five cleanliness tests are required, the cleanliness designator will have a total of six digits.)~~

### **9.6.3.3 — Visual requirements**

~~Surfaces cleaned should be inspected without magnification and shall be free of visual evidence of flux residue or other contaminants. Surfaces not cleaned may have evidence of flux residues.~~

### **9.6.4 — Cleaning option**

~~The first digit of the cleanliness designator defines the cleaning option. One of the following digits is used to define the surfaces of the assembly that are to be cleaned:~~

- ~~0 – No surfaces to be cleaned.~~
- ~~1 – One side (wave solder source side) of assembly to be cleaned.~~
- ~~2 – Both sides of assembly to be cleaned.~~

### **9.6.5 — Test for cleanliness**

~~The second and following digits of the cleanliness designator define the requirements for cleanliness testing. The following digits may be used in any combination (not including zero):~~

- ~~0 – No test for cleanliness required.~~
- ~~1 – Test for rosin residues required (see 9.6.6).~~
- ~~2 – Test for ionic residues required (see 9.6.7 and/or 9.6.8).~~
- ~~3 – Test for surface insulation resistance (see 9.6.9).~~
- ~~4 – Test for other surface organic contaminants (see 9.6.10).~~
- ~~5 – Other tests as deemed by user/manufacture agreement.~~

### **9.6.6 — Rosin residues on cleaned board assemblies**

~~If rosin based fluxes are used, assemblies shall be cleaned and tested in accordance with the following.~~

~~Assemblies that have been cleaned shall be tested in accordance with IEC 61189-1 and IEC 61189-3 (see Annex B), and shall comply with the following requirements for the maximum allowable level of rosin flux residues:~~

- ~~Level A: assemblies less than 200 µg /cm<sup>2</sup>~~
- ~~Level B: assemblies less than 100 µg /cm<sup>2</sup>~~

~~Level C: assemblies less than 40 µg/cm<sup>2</sup>~~

#### ~~9.6.7 Ionic residues (instrument method)~~

~~Assemblies shall be tested in accordance with IEC 61189-1 and IEC 61189-3 (ionizable detection of surface contaminants (dynamic method), or ionizable detection of surface contaminants (static method), see Annex B) and shall contain less than 1,56 µg/cm<sup>2</sup> NaCl equivalent ionic or ionizable flux residue. Other methods may be used when the sensitivity of the alternative method is shown to be equal to or better than the above methods with respect to detecting ionizable surface contamination.~~

~~In comparing the sensitivity between methods, the solvent used to extract the residue, the method used to present the solvent to the assembly, and the method of detecting the residue should all be considered.~~

#### ~~9.6.8 Ionic residues (manual method)~~

~~Assemblies shall be tested in accordance with IEC 61189-1 and IEC 61189-3 (resistivity of solvent extract, see Annex B). The surface contamination shall be less than 1,56 µg/cm<sup>2</sup> sodium chloride (NaCl) equivalent ionic or ionizable flux residue. Other acceptance values may be specified by the user for equivalent tests.~~

#### ~~9.6.9 Surface insulation resistance (SIR)~~

~~Test specimens processed in exactly the same manner as the assemblies being produced shall be tested for the effect of the contamination on the electrical insulation resistance of printed boards under high temperature and humidity in accordance with IEC 61189-1 and IEC 61189-3 (see Annex B) using the test conditions of IEC 61189-1. The test specimens shall have a minimum resistance of 100 MΩ after soldering and/or after soldering and cleaning, depending on the flux classification. The user and manufacturer may agree upon other test specimens, test conditions, and SIR requirements.~~

#### ~~9.6.10 Other contamination~~

~~Assemblies tested in accordance with IEC 61189-1 and IEC 61189-3 (see Annex B, surface organic contaminant detection test (in-house method)) shall not exceed the maximum acceptance level established by mutual agreement between user and manufacturer.~~

## 9.2 Qualified cleaning/manufacturing process

### 9.2.1 General

Unless otherwise specified by the user, the manufacturer shall qualify soldering and/or cleaning processes that result in acceptable levels of flux and other residues. Objective evidence shall be available for review. See J-STD-001 Appendix C for examples of objective evidence.

NOTE 1 Objective evidence can be provided by Surface-Insulation (SIR) testing of electronic assemblies following applicable standards or IPC-9202.

NOTE 2 Process ionic contamination test (PICT) data (or resistivity of solvent extract (ROSE) test data) can be used as a process control tool, but such test data alone cannot be used for prediction of assembly reliability under high-temperature/high-humidity environments.

Process ionic contamination test (PICT) data (or resistivity of solvent extract (ROSE) test data) using the historical acceptance value of 1,56 µg/cm<sup>2</sup> NaCl equivalence with no other objective evidence shall not be considered as acceptable objective evidence.

Unless otherwise specified by design, or by the user, the acceptability of the residue condition shall be determined at the point of the manufacturing process just prior to the application of conformal coating, or on the final assembly if conformal coating is not applied. Rework processes shall be included in the process qualification.

### 9.2.2 Cleaning designator

Unless otherwise specified by the user or the design authority, the manufacturer should specify a cleanliness designator that establishes the cleaning requirements and the process control tests for residues. The cleanliness designator is a 2-digit (minimum) code which describes the cleanliness requirements for all assemblies covered under this document. This code begins with letter C and then a dash followed by two or more digits.

The first digit represents the cleaning option in accordance with Table 2

**Table 2 – Designation of surfaces to be cleaned**

|   |                                                |
|---|------------------------------------------------|
| 0 | No surfaces are to be cleaned                  |
| 1 | One side (solder source side) is to be cleaned |
| 2 | Both sides of the assembly are to be cleaned   |

The second and following digits indicate the requirements for process control of residues in accordance with Table 3

**Table 3 – Residue testing for process control**

|   |                                                                                        |
|---|----------------------------------------------------------------------------------------|
| 0 | No test required                                                                       |
| 1 | Test for rosin residues required                                                       |
| 2 | Test for ionic residues required                                                       |
| 3 | Test for surface insulation resistance as agreed between the user and the manufacturer |
| 4 | Test for surface organic contaminants as agreed between the user and the manufacturer  |
| 5 | Other testing as agreed between the user and the manufacturer                          |

In the absence of a specific cleaning designator, the designator C-22 shall apply. A cleaning designator of C-00 defines a so-called "no clean" process with no testing of residues.

### 9.2.3 Upper specification limit

When a manufacturing process has been defined and qualified in accordance with 9.2 and when ionic residue testing is required, ionic process specification limits shall be determined as follows.

An upper specification limit (USL), based on test data or historical data for the process, shall be established. Any other USL shall be agreed between the user and the manufacturer.

If a USL based on test data is to be used, the manufacturer shall determine a statistically based sampling plan for measuring ionic residues using resistivity of solvent extract (ROSE) testing or other methods as agreed between the user and the manufacturer.

## 9.3 Visual requirements

Assemblies shall be free of dirt, lint, solder splash, dross, etc. Solder balls shall not reduce the minimum design electrical spacing and shall be fixed to the board surface. Solder balls shall not degrade electrical performance characteristics.

Surfaces cleaned should be inspected without magnification and shall be free of visual evidence of flux residues or other contaminants. Surfaces not cleaned may have evidence of flux residues.

#### 9.4 Correlation of ionic testers

If more than one ionic tester is used for judging product residue levels for the same product, a correlation study between the ionic testers shall be performed.

#### 9.5 Non-ionic residues

All other residue requirements shall be agreed between the user and the manufacturer. The agreement should include the test method, the test parameters and the pass-fail criteria.

When rosin flux residue testing is required, assemblies shall be tested in accordance with IEC 61189-1 and IEC 61189-3 (see Annex B of this document) and shall comply with the requirements in Table 4 for the maximum allowable level of rosin flux residues.

**Table 4 – Maximum acceptable rosin flux residues**

|         |                        |
|---------|------------------------|
| Level A | 200 µg/cm <sup>2</sup> |
| Level B | 100 µg/cm <sup>2</sup> |
| Level C | 40 µg/cm <sup>2</sup>  |

When surface organic contamination testing is required, the test shall be performed in accordance with applicable standards and IEC 61189-3 (see Annex B of this document) and shall not exceed the maximum acceptance level agreed between the user and the manufacturer.

#### 9.6 SIR testing

When surface insulation resistance testing (SIR) is required, test specimens processed in exactly the same manner as the assemblies being produced shall be tested for the effect of the contamination on the electrical insulation resistance of printed boards under high temperature and humidity in accordance with IEC 61189-5-502 and IEC 61189-3 (see Annex B) or another documented method agreed between user and manufacturer that determines test specimen, test conditions and pass-fail criteria and is available for review.

NOTE 1 IEC 61189-5-502 under preparation.

### 10 Assembly requirements

#### 10.1 General

Boards, components and processes described and specified in Clauses 4 to 9 provide for soldered interconnections that are better than the minimum acceptance requirements of this clause. Processes and their controls should be capable of producing a product meeting or exceeding the acceptance criteria for a level C product. However, soldered connections shall meet the product level (A, B or C) acceptance requirements specified by user.

#### 10.2 Acceptance requirements

##### 10.2.1 Process control

The manufacturer shall either:

- a) have a process control plan in accordance with 13.3; or

- b) perform 100 % **visual** inspection to the requirements of 10.3. If defects and process indicators exceed the corrective action limits specified in 10.2.2 for their respective level of opportunities (10.2.3), the manufacturer shall initiate corrective action to reduce their occurrence. For corrective action calculations, no more than one defect characteristic (see Table 2) or process indicator shall be attributed to a particular interconnection site (for example lead-to-land, via, lead-in-hole).

If the limits specified in this document are met, it is likely that the reliability of the joint has a high possibility of meeting the assembly expectations. However, the user has the responsibility for determining true reliability requirements based on design and end product usage.

### 10.2.2 Corrective action limits

Corrective action shall be initiated if

- a) defects listed in Table 2 exceed 0,3 % of the possibilities for their occurrence, and if
- b) process indicators (see 4.4) exceed 3,0 % of the total opportunities for their occurrence.
- c) As a minimum, the following general process indicator occurrences shall be monitored:
  - 1) markings (10.3.3);
  - 2) voids and blow holes (10.3.5);
  - 3) lead outline visibility (10.3.5);
  - 4) via interfacial connection wetting (10.3.6);
  - 5) other process indicators defined in the sectional specifications; and
  - 6) solder quantity.

### 10.2.3 Control limit determination

The total number of interconnection sites shall be used as the measure to which the percentage of defects or process indicators is applied. These calculations consider each surface mount termination, each through-hole termination, and each terminal termination as a single opportunity for determining the total number of opportunities for a given printed board assembly.

## 10.3 General assembly requirements

### 10.3.1 Assembly integrity

All products shall meet the requirements of the assembly ~~drawing~~ **documentation**. The electrical and mechanical integrity and the reliability of all components and assemblies shall be retained after exposure to all processes employed during manufacture and assembly (for example handling, fixing, soldering and cleaning).

### 10.3.2 Assembly damage

#### 10.3.2.1 Assembly requirements

Assembly damage to electronic and mechanical devices shall not exceed the requirements given in the present document and in IEC 61191-2, IEC 61191-3, IEC 61191-4.

Printed boards shall show no evidence of burning, blistering, or delamination as referenced in IEC 62326-1. Laminate scratches shall be treated as weave exposure.

#### 10.3.2.2 Unacceptable assembly defects

The following defects can be found in printed wiring assemblies: measles, crazing, blistering, delamination, weave exposure, haloing, edge delamination, and lifted lands or conductors.

The following conditions are causes for rejection:

- a) assemblies exhibiting measling or crazing defects affecting their functionality;
- b) blistering or delamination that make bridges between plated through-holes or between subsurface conductors, or which extend under surface conductors or over/under subsurface conductors.

### 10.3.3 Markings

Markings shall not be deliberately altered, obliterated or removed by the manufacturer unless required by the assembly ~~drawing~~ documentation. Additional markings (such as labels added during the manufacturing process) should not obscure the original supplier's markings. Where a loss of marking of the component part occurs, it shall be recorded as a process indicator to track and determine if a supplier has a potential marking problem, and determine the degree of corrective action (for example new materials, new processes, remarking, ~~etc.~~).

### 10.3.4 Flatness (bow and twist)

Bow and twist after soldering ~~shall~~ should not exceed ~~0,5 % or 1,5 mm for level C surface mount; 0,75 % or 2,0 mm for level B surface mount; 1,0 % or 2,5 mm for level A surface mount; 0,75 % for surface-mount and 1,5 % or 2,5 mm for through-hole (all levels) printed board applications. Mixed assemblies (SMT (surface mount technology), THT (through hole technology), etc.) shall meet the requirements for surface mount assemblies (see IEC 61191-2 and IEC 61189-3, IEC 61188-1-1).~~

### 10.3.5 Solder connection

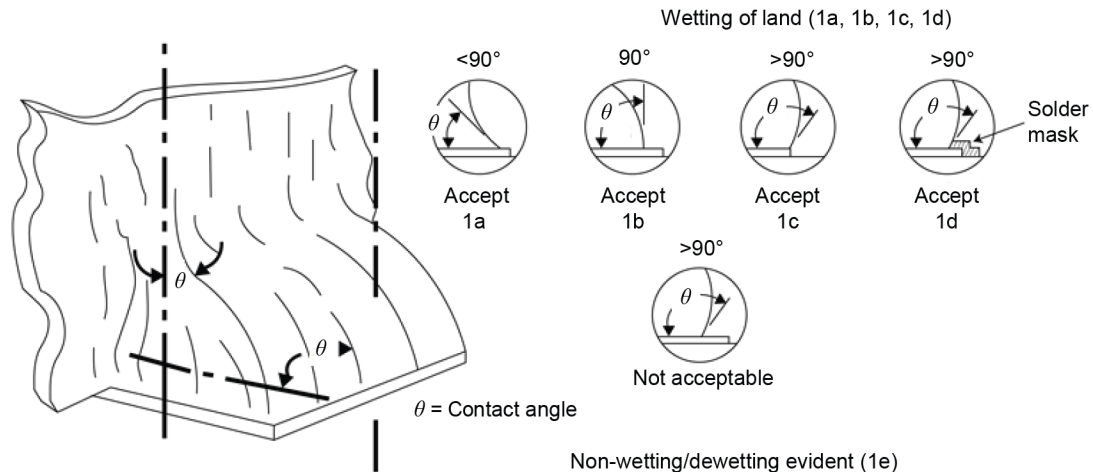
#### 10.3.5.1 Solder wetting angle

The acceptable solder connection shall indicate evidence of wetting and adherence when the solder blends with the soldered surface, forming a contact angle of 90° or less, except when the quantity of solder results in a contour that extends over the edge of the land (see Figure 1). The solder joints should have a generally smooth appearance.

~~A lead-free solder alloy composition will typically produce an appearance of surface roughness (grainy or dull) and greater wetting contact angles. These solder joints are acceptable.~~

If lead-free solder joints show a slightly rough (grainy or dull) appearance or greater wetting angles, these solder joints are still acceptable if all other criteria are fulfilled.

A smooth transition from land to connection surface or component lead shall be evident. A line of demarcation or transition zone where applied solder blends with solder coating, solder plate, or other surface material is acceptable, provided that wetting is evident. In the case of fused solder coatings, presence of the applied solder above the rim of the hole is not required if the hole wall and component lead exhibit good wetting (see Figure 2). Marks or scratches on the solder joint shall not degrade the integrity of the connection.



IEC

Figure 1 – Solder contact angle

### 10.3.5.2 Defects

The following conditions are unacceptable and shall be considered defects (see 12.1):

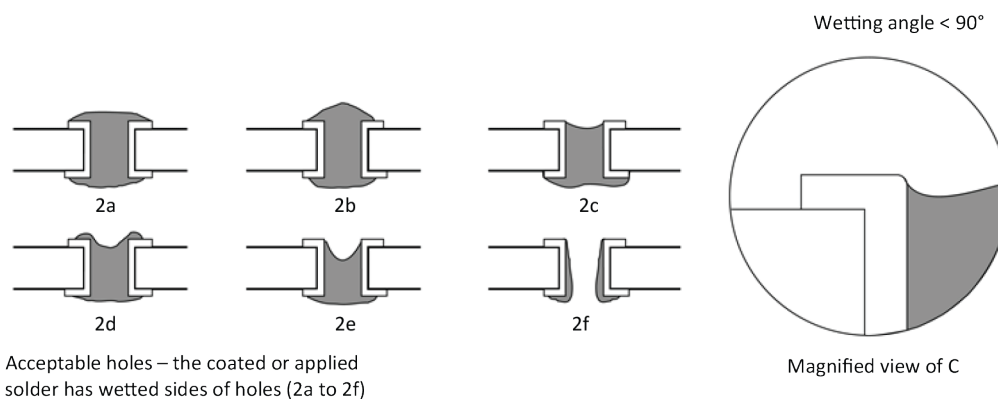
- a) fractured or disturbed solder connections;
- b) cold solder connection;
- c) greater than 5 % of the solder connection (except vias) exhibiting dewet or nonwet characteristics;
- d) excess solder that contacts the component body, **except SO and SOT packages**;
- e) gold embrittlement due to insufficient gold removal (see 6.3.3); and
- f) voiding by which the solder volume of the joint is decreased below the allowable minimum value.

**NOTE** SO and SOT packages are plastic small outline packages which can be wave soldered

### 10.3.5.3 Process indicators

The following conditions are acceptable, but shall be considered as process indicators and shall be documented and available for review:

- a) voids and the blow holes where wetting is evident, and which do not reduce solder volume below the allowable minimum;
- b) outline or lead not visible in solder joint because of excess solder.



IEC

Figure 2 – Solder wetting of plated through-holes without leads



### 10.3.6 Interfacial connections

Unsupported holes with leads or plated through-holes, not subjected to mass soldering and used for interfacial connections need not be filled with solder. Plated through-holes not exposed to solder because of permanent or temporary maskants and used for interfacial connections need not be filled with solder. Plated through-holes without leads, including vias, after exposure to wave, dip, or drag solder processing shall meet the acceptability requirements of Figure 2. Failure to meet this requirement shall be treated as a process indicator in accordance with Clause 13. Wetting of the top-side lands by applied solder is acceptable, but not required (see Figures 2c, 2e and 2f). Plated through-hole damage due to copper dissolution is a defect (see Table 2)

## 11 Coating and encapsulation

### ~~11.1 Detail requirements~~

~~The detail requirements for coating and encapsulation procedures are defined in the following subclauses.~~

### 11.1 Conformal coating

#### 11.1.1 Coating instructions

The material specification and supplier's instructions, as applicable, shall be followed. When curing conditions (temperature, time, IR intensity, etc.) vary from the supplier's recommended instructions, the alternate conditions shall be documented and available for review. The material shall be used within the time period specified (both shelf life and pot life), or used within the time period indicated by a documented system that the manufacturer (assembler) has established to mark and control age-dated material.

#### 11.1.2 Application

##### 11.1.2.1 Application details

A coating shall be continuous in all areas designated for coverage on the assembly ~~drawing~~ **documentation**. The coating fillets should be kept to a minimum. Conformal coating material shall not contain aggressive solvents. Conformal coating or method of application of conformal coating shall not damage or reduce the reliability of components. When used, masking materials shall have no harmful or degrading effect on the printed boards and shall be removable without leaving a contaminant residue. Dimensioning specified for masked areas shall not be decreased in length, width, or diameter by more than 0,8 mm by the application of conformal coating.

##### 11.1.2.2 Adjustable components

The adjustable portion of adjustable components, as well as electrical and mechanical mating surfaces such as probe points, screw threads, bearing surfaces (for example card guides) shall be left uncoated as specified on the assembly ~~drawing~~ **documentation**.

##### 11.1.2.3 Conformal coating on connectors

Mating connector surfaces of printed wiring assemblies shall not be conformal coated. The conformal coating specified on the assembly ~~drawing~~ **documentation** shall, however, provide a seal around the perimeter of all connector/board interface areas. Press-fit pins and connectors installed after conformal coating is applied shall be exempt from the seal requirement.

#### 11.1.2.4 Conformal coating on brackets

The mating (contact) surface of brackets or other mounting devices shall not be coated with conformal coating unless specifically required by the assembly ~~drawing~~ documentation. However, the perimeter of the junction between these devices and the board and all attaching hardware shall be coated.

#### 11.1.2.5 Conformal coating on flexible leads

Components that are electrically connected to the assembly by flexible leads (e.g. gull wing) shall as a minimum have the junction of the leads with the components and the assembly coated.

#### 11.1.2.6 Perimeter coating

Unless otherwise specified on the approved assembly ~~drawing~~ documentation, the outer perimeter of assemblies shall not be increased in total thickness by more than 1,0 mm as a result of conformal coating. The outer perimeter is defined as the area on each side of the board at a distance of not more than 6,0 mm inwards from the outer edge (see Figure 3).

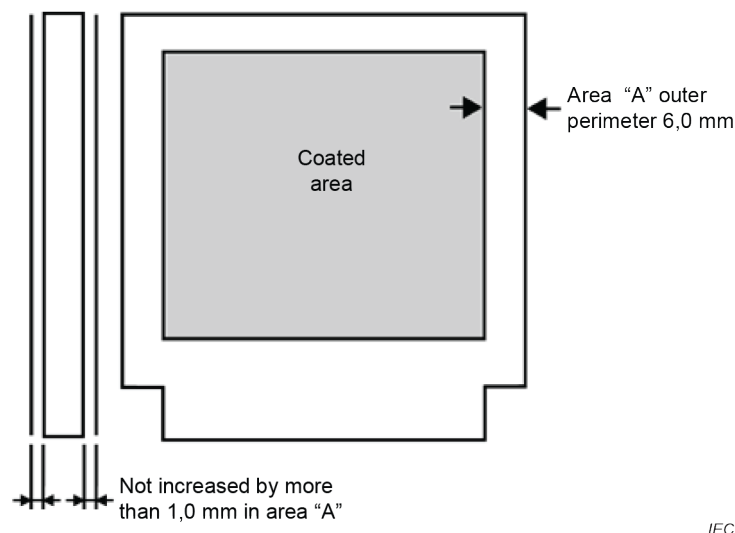


Figure 3 – Coating conditions

#### 11.1.2.7 Edge coating

Unless otherwise specified on the approved assembly ~~drawing~~ documentation, the dimensions of the assemblies shall not be increased in length or width by more than 0,8 mm on each edge, giving a total of 1,5 mm by application of conformal coating.

#### 11.1.3 Performance requirements

##### ~~11.2.3.1 Coating requirements~~

~~The detailed requirements for applied coatings are defined in the following subclauses.~~

##### 11.1.3.1 Thickness

The thickness of the conformal coating shall be as follows for the type specified:

- a) types ER (epoxy), UR (urethane) and AR (acrylic): 0,03 mm to 0,13 mm;
- b) type SR (silicone): 0,05 mm to 0,21 mm;
- c) type XY (paraxylene): 0,01 mm to 0,05 mm.

- d) type FC (fluoropolymer) ~ 0,01 µm

The thickness shall be measured on a flat, unencumbered, cured surface of the printed wiring assembly, or on a coupon which has been processed with the assembly. Coupons may be of the same type of material as the printed board or may be of a non-porous material such as metal or glass. As an alternative, a wet film thickness measurement may be used to establish the coating thickness, provided there is documentation that correlates the wet and dry film thicknesses.

#### 11.1.3.2 Coating coverage

Conformal coating shall be of the type specified on the assembly ~~-drawing~~ documentation, and shall:

- a) be completely cured and homogeneous,
- b) cover only those areas specified on the assembly ~~-drawing~~ documentation,
- c) be free of blisters or breaks which affect the assembly operations or sealing properties of the conformal coating,
- d) be free of voids, bubbles, or foreign material which expose component conductors, printed wiring conductors (including ground planes) or other conductors, and/or violate design electrical spacing; and
- e) contain no measling, peeling or wrinkle (non-adherent areas).

#### 11.1.4 Rework of conformal coating

Procedures that describe the removal and replacement of conformal coating shall be documented and available for review.

#### 11.1.5 Conformal coating inspection

Visual inspection of conformal coating may be performed without magnification. Inspection for conformal coating coverage may be performed under an ultraviolet (UV) light source when using conformal coating material containing a UV tracer. Magnification from 2× to 4× may be used for refereeing purposes.

### 11.2 Encapsulation

#### 11.2.1 Encapsulation instructions

The material specification and the supplier's instructions, as applicable, shall be followed. The material shall be used within the time period specified (both shelf life and pot life) or used within the time period indicated by a documented system the manufacturer has established to mark and control age-dated material.

#### 11.2.2 Application

##### 11.2.2.1 Quality details

The encapsulant materials shall be continuous in all areas designated for coverage on the assembly ~~-drawing~~ documentation. When used, masking material shall have no deleterious effect on the printed boards and shall be removable without contaminant residue.

##### 11.2.2.2 Encapsulant-free surfaces

All portions of the assembly not designated to receive encapsulant material shall be free of any encapsulant material.

### 11.2.3 Performance requirements

The applied encapsulant shall be completely cured, homogeneous, and cover only those areas specified on the assembly ~~drawing~~ documentation.

The encapsulant shall be free of bubbles, blisters or breaks that affect the printed wiring assembly operation or sealing properties of the encapsulant material. There shall be no visible cracks, crazes, mealing, peeling and/or wrinkles in the encapsulant material.

### 11.2.4 Rework of encapsulant material

Procedures that describe the removal and replacement of encapsulant material shall be documented and available for review (i.e., within the manufacturers' ISO 9001 documentation or equivalent written procedures).

### 11.2.5 Encapsulant inspection

Visual inspection of encapsulation may be performed with magnification.

## 12 Rework and repair

### ~~12.1 General~~

~~The detailed requirements for rework and repair are defined in the following subclauses.~~

### 12.1 Rework of unsatisfactorily soldered electrical and electronic assemblies

Rework of unsatisfactory electrical and electronic assemblies consists of addressing the defects listed in Table 5 and the non-conforming characteristics shown in the defect tables of the relevant sectional specification (i.e. IEC 61191-2, IEC 61191-3, IEC 61191-4) as appropriate.

Rework of unsatisfactory solder connections and other defects shall not be performed until the discrepancies have been documented. Documentation requirements shall be defined in the process control plan and may be on a sampling or audit basis. This data shall be used to provide an indication as to the possible causes and to determine if corrective action, in accordance with 10.2, ~~10.2.2 and 10.2.3~~, is required. When rework is performed, each reworked and/or reflowed connection shall be inspected to the requirements of 10.3.5 in accordance with 13.2.

**Table 5 – Electrical and electronic assembly defects**

| Defect No. | Defect description                                                                                                                                                                                                                                                                                                                   | Requirement subclause                                                                                                                            | Remarks |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| 01         | Violations of the assembly <del>drawing</del> documentation requirements<br>a) missing component<br>b) wrong component<br>c) reversed component                                                                                                                                                                                      | 4.1.2                                                                                                                                            |         |
| 02         | Damage to components beyond procurement specification or the relevant sectional specification allowance<br>a) component damage (cracks)<br>b) moisture cracking (pop-corning)                                                                                                                                                        | IEC 61191-2<br>IEC 61191-3<br>IEC 61191-4                                                                                                        |         |
| 03         | Damage to the assembly or printed board<br>a) measling or crazing that affects functionality<br>b) blisters/delamination that bridges between PTHs/conductors<br>c) excessive departure from flatness                                                                                                                                | 10.3.2<br><del>10.3.2.2</del><br>10.3.4                                                                                                          |         |
| 04         | Plated-through hole interconnections with and without leads<br>a) non-wetted hole or lead<br>b) unsatisfactory hole fill<br>c) fractured solder joint<br>d) cold or disturbed solder connection                                                                                                                                      | 10.3.5<br><del>10.3.5.2</del><br>10.3.6                                                                                                          |         |
| 05         | Violation of minimum design electrical spacing<br>a) conductive part body or wire movement/misalignment<br>b) solder balling<br>c) solder bridging<br>d) solder spikes<br>e) solder webs/skins                                                                                                                                       | <del>IEC 61191-2</del><br><del>9.6.2</del><br><del>IEC 61191-2</del><br><del>IEC 61191-2</del><br><del>IEC 61191-2</del><br>IEC 61191-2<br>6.3.1 |         |
| 06         | Improper solder connections (lead, termination or land)<br>a) dewetting or non-wetting<br>b) solder leaching<br>c) insufficient solder<br>d) solder wicking<br>e) insufficient reflow<br>f) incomplete joint (open circuit)<br>g) excessive solder<br>h) excessive solder voids<br>i) adhesive encroachment<br>j) gold embrittlement | 10.3.5.3<br>10.3.5.2                                                                                                                             |         |
| 07         | Damaged marking on the board<br>a) altered marking<br>b) obliterated marking                                                                                                                                                                                                                                                         | 10.3.3                                                                                                                                           |         |
| 08         | Failure to comply with stated cleaning or cleanliness testing                                                                                                                                                                                                                                                                        | <del>9.6</del><br><del>9.6.3.2</del><br>9.3.<br>9.5                                                                                              |         |
| 09         | Failure to comply with conformal coating requirements                                                                                                                                                                                                                                                                                | <del>11.2.3.3</del> 11.1.3.2                                                                                                                     |         |
| 10         | Copper dissolution                                                                                                                                                                                                                                                                                                                   | 10.3.6                                                                                                                                           |         |

## 12.2 Repair

Repairs are changes to an unacceptable end product to make it acceptable in accordance with the original functional requirements. The repair method shall be determined by agreement between the manufacturer and the user.

## 12.3 Post rework/repair cleaning

After rework or repair, assemblies shall be cleaned as necessary by a process meeting the requirements of subclauses 9.3 and 9.5.

## 13 Product quality assurance

### 13.1 System requirements

General requirements for the establishment and maintenance of an effective quality assurance programme incorporating process control systems (see 4.5) are given in the following subclauses.

### 13.2 Inspection methodology

#### 13.2.1 Verification inspection

Verification inspection shall consist of the following:

- a) surveillance of the operation to determine that practices, methods, procedures and a written inspection plan are being properly applied;
- b) inspection to measure the quality of the product.

#### 13.2.2 Visual inspection

##### 13.2.2.1 Visual sampling

Inspection prior to soldering (for example between component placement and soldering) or in between other process steps (for example solder paste application and component placement) should only take place on a sampling basis when analyzing the assembly process to identify solder joint defect causes. After soldering, the assembly shall be evaluated in accordance with the established process control plan (see 13.3) or by 100 % visual inspection (see 10.2).

##### 13.2.2.2 Magnification aids and lighting

The tolerance for magnification aid is 15 % of the selected magnification power (i.e. +15 % or a range of 30 % centred at the selected magnification power). Magnification aids and lighting (see 4.11.4) used for inspection shall be commensurate with the size of the item being processed. The magnification used to inspect solder connections shall be based on the minimum width of the land used for the device being inspected. Magnification aids should be in accordance with Table 6.

**Table 6 – Magnification requirements**

| Land widths and land diameters<br>mm | Inspection                  | Referee |
|--------------------------------------|-----------------------------|---------|
| >1,0                                 | <del>2×</del><br>1,5× to 3× | 4×      |
| >0,5 to ≤1,0                         | <del>4×</del><br>3× to 7,5× | 10×     |
| ≥0,25 to ≤0,5                        | 7,5× to 10×                 | 20×     |
| <0,25                                | 20×                         | 40×     |

Referee conditions shall only be used to verify a product rejected at the inspection magnification. For assemblies with mixed land widths, the greater magnification may be used for the entire assembly.

##### 13.2.2.3 Partially visible or hidden solder connections

Partially visible or hidden solder connections are acceptable provided that the following conditions are met:

- a) the visible portion, if any, of the connection on either side of the PTH solder connection (or the visible portion of the SMD connection) is acceptable;
- b) the design does not restrict solder flow to any connection element on the primary side (for example pin in hole component) of the assembly;
- c) process controls are maintained in a manner assuring repeatability of assembly techniques.

### 13.2.3 Sampling inspection

Use of sample-based inspection shall be predicated on meeting one of the following:

- a) when done as part of a documented process control system as in 13.3; or
- b) as part of the user-approved product assurance programme.

## 13.3 Process control

### 13.3.1 System details

Process control shall be a documented system, available for review, that meets the intent of ISO 9001, IEC 61193-3, or user-approved system. The primary goal of process control is to continually reduce variation in the processes, products, or services to provide product or processes meeting or exceeding customer requirements. The process control system shall include the following elements as a minimum:

- a) training shall be provided to personnel with assigned responsibilities in the development, implementation, and use of process control and statistical methods that are commensurate with their responsibilities;
- b) quantitative methodologies and evidence shall be maintained to demonstrate that the process is capable and in control;
- c) improvement strategies to define initial process control limits and methodologies leading to a reduction in the occurrence of process indicators in order to achieve continuous process improvement;
- d) criteria for switching to sample-based inspection shall be defined. When processes exceed control limits, or demonstrate an adverse trend or run, the criteria for reversion to higher levels of inspection (up to 100 %) shall also be defined;
- e) when defect(s) are identified in the lot sample, the entire lot shall be 100 % inspected for the occurrence(s) of the defect(s) observed;
- f) a system shall be put in place to initiate corrective action for the occurrence of process indicators, out-of-control process(es), and/or discrepant assemblies;
- g) a documented audit plan is defined to monitor process characteristics and/or output at a prescribed frequency.

Objective evidence of process control may be in the form of control charts or other tools and techniques of statistical process control derived from application of process parameter and/or product parameter data. This data can be acquired from sources such as inspection, non-destructive evaluation, machine operation data, or periodic testing of production samples. For attribute data, the key is understanding and controlling parameters in the process that influence the response in question and establishing controls at that point. Attribute data, measured in parts of  $10^{-6}$  nonconforming product, can generally be correlated to a process capability index (Cpk) generated using variable data (see Annex B).

Available resources (e.g. ISO 9001, IEC 61193-1, ~~etc.~~) should be used in establishing the process control plan and defining the characteristics and criteria.

### 13.3.2 Defect reduction

Continuous process improvement techniques shall be implemented to reduce the occurrence of defects and process indicators. When processes vary beyond established process control