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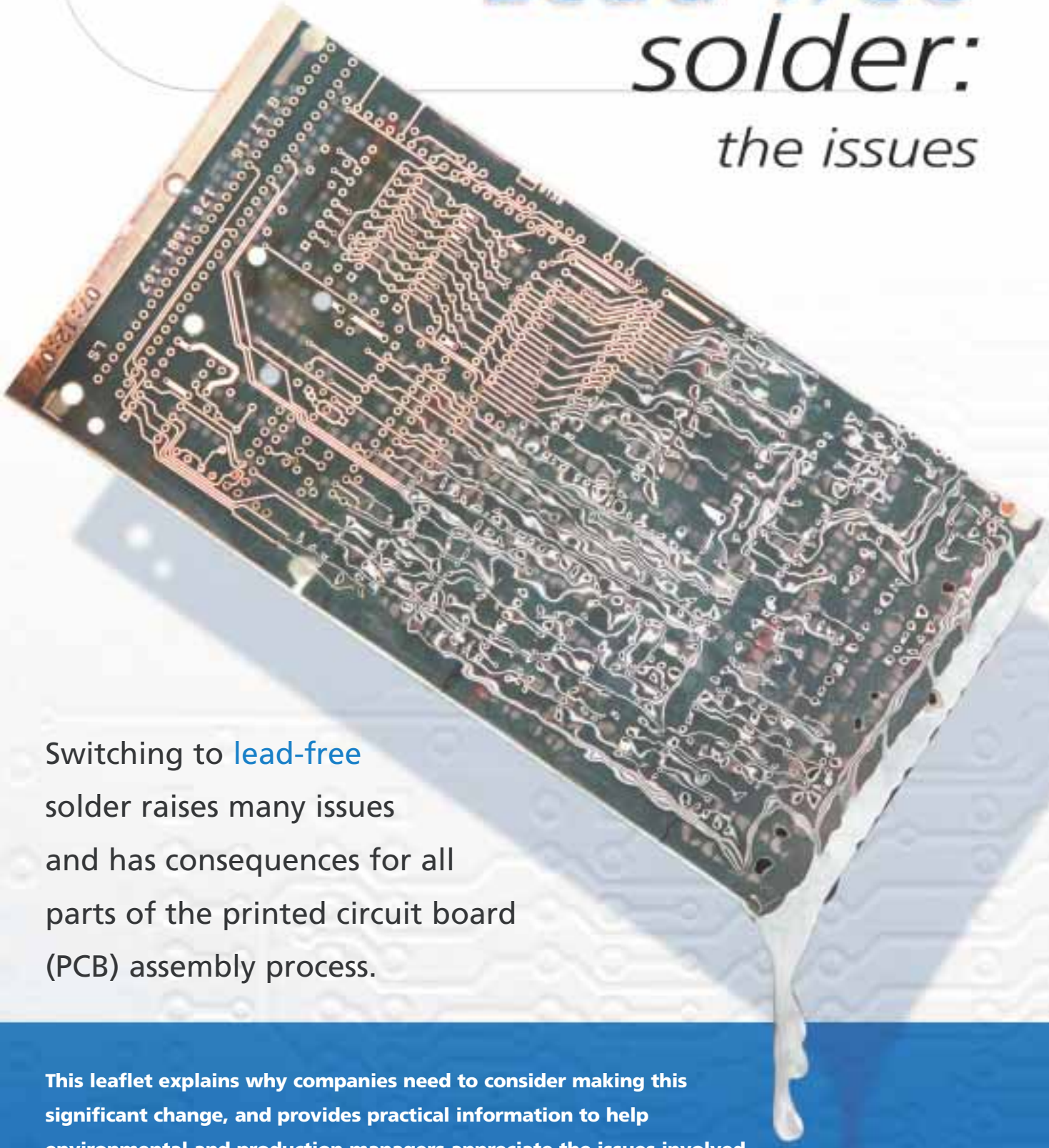
EN287

Lead-free solder:

the issues



Switching to lead-free solder raises many issues and has consequences for all parts of the printed circuit board (PCB) assembly process.

This leaflet explains why companies need to consider making this significant change, and provides practical information to help environmental and production managers appreciate the issues involved.

Sources of further information and advice are given on the back page.

Why go lead-free?

There are good reasons for switching to lead-free alternatives as soon as possible. The use of lead in electronics assembly within the European Union will be banned after January 2008 (and possibly as soon as 2006). This leaflet provides an overview of the key issues associated with a switch to lead-free solder for materials, assembly and reliability. It also highlights some of the questions relating to the various stages of the PCB assembly process, and points out some of the environmental, economic, technical and marketing benefits of moving to lead-free solder.

The toxicity of lead has prompted its replacement with more acceptable alternatives. In the UK, lead is no longer used in paints and leaded petrol has been effectively eliminated.

However, lead is still a key component of tin-lead solders used in electronics. The use of lead in electrical and electronic equipment increases costs associated with re-use, recycling and disposal. The European Commission's (EC) draft waste electrical and electronic equipment (WEEE) directive focused attention on the risk of lead in solder from discarded electronics in landfills being leached into watercourses. One of the aims of the draft WEEE directive was to ban hazardous materials such as lead in electronics. The latest draft of WEEE and the associated directive to restrict the use of certain hazardous substances (including lead) in electrical and electronic equipment were proposed by the EC in June 2000.

The forthcoming European Union ban on the use of lead has generated worldwide interest in the development and implementation of lead-free solders. Several alternatives have been identified and evaluated. For most mainstream applications, tin/silver/copper will probably be the first choice. Because of the higher melting point, there are implications for every stage of the PCB manufacturing, assembly and testing process. The simultaneous phasing out of brominated fire retardants means that the issue of flammability at the higher working temperatures will be critical. Compatibility of lead-free solders with existing components and coatings must also be considered. Then, the environmental impact of PCB assembly will be reduced, reliability may improve, market share may be increased and high value materials will be easier to recycle.

Companies in Japan and the Far East are already realising the commercial benefits of offering what their customers see as more environmentally friendly products. If you want to comply with forthcoming legislation and satisfy your customers' demands, think now about using lead-free solder in your products. This leaflet is intended to help you get started on your journey.

For information about the free help and advice available from Envirowise for the electronics industry, contact the

Environment and Energy Helpline on freephone 0800 585794

or visit the Envirowise web site at

www.envirowise.gov.uk

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Moving to lead-free solder:
considerations and consequences

Materials

Bare PCB

PCB

- Consider benefits of reduced use of brominated flame retardants
- Avoid use of low-grade laminate
- Change to pure tin as an etch resist
- Use thermally-stable solder masks

Alternative finishes

- Organic solderability preservatives
- Palladium, silver and tin alloys
- Lead-free hot air solder levelling
- Nickel-gold

Components

Thermal stability

- Consider component stability at soldering temperatures, eg 'popcorning effect'
- Consider component suitability at soldering temperatures, eg electrolytic capacitors
- Take into account the melting point hierarchy of solder in multichip modules (MCMs), etc

Alternative finishes

- Tin-copper, tin-bismuth, tin-silver
- Low-whisker tin
- Nickel-palladium (may not be cost-effective)
- Silver and silver-palladium (may not be cost-effective)

Solders

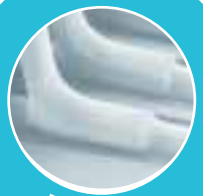
Fluxes

- Ensure flux compatibility with alloy used
- Use a resin or water-based flux
- Where possible, choose flux containing no volatile organic compounds (VOCs)
- Use 'no-clean' flux where possible

Solder alternatives

- Tin-silver-copper alloys for all techniques (215 - 220°C)
- Tin-copper possible for wave operations (227°C)
- Bismuth-based solders for low-temperature use
- Other alloys specific to the application
- Tin-bismuth-silver for reflow

Assembly



Reflow

Reflow profiles

- Optimise reflow profiles for selected alloy
- Allow for narrower process windows
- Optimise conditions according to the combination of assembly type, paste type, other materials and equipment for a particular application

Equipment

- Maintain good temperature control
- Consider energy consumption
- Use convection rather than infrared (IR) ovens
- Check temperature range of equipment
- Consider using inert gas atmosphere

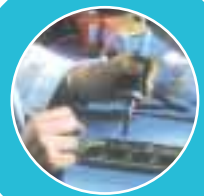
Wave

Soldering

- Take into account increasing copper levels when replenishing bath
- Consider using inert gas atmosphere
- Optimise wave design
- Watch for fillet lifting with lead components

Equipment

- Optimise existing equipment
- Modify equipment, as necessary, to avoid damage due to higher temperatures
- Consider possibility of corrosion when using standard stainless solder pots



Hand

Health and safety

- Avoid exposing operators to flux fumes (to prevent possibility of sensitisation)
- Implement working practices to take account of higher temperatures used
- Highlight improved working conditions from lower toxicity of lead-free solders
- Save money by eliminating need for lead blood tests for operators

Equipment

- Expect minimal problems with equipment, high power preferable
- Ensure correct selection of solder alloy
- Provide training to ensure operators are aware of issues associated with lead-free solder
- Avoid excessive soldering temperatures - they may cause damage

Reliability

Inspection

Optical

- Train and educate operators on different appearances of joints, eg they may be slightly duller and uneven
- Recalibrate automated optical inspection (AOI) equipment and software to account for reduced contrast

X-ray

- Discuss with equipment manufacturers (that they do not envisage any major problems)
- Note that lead-free solders have sufficient density to allow cracks and voids to be detected
- Set up equipment for the specific solder type

Service performance

Reliability

- When considering the performance of a particular joint, take account of factors such as:
  - shape and size
  - alloy
  - flux
  - substrate
  - interface intermetallics
  - processing conditions
  - wetting
  - ageing
  - service temperature and conditions

Materials selection

- Remember, reliability depends on correct material selection
- Note, fatigue performance of tin-silver-copper solders can be as good or better than tin-lead solders
- For service up to 90°C, tin-silver-bismuth solders provide good reliability
- Use tin-bismuth eutectic to provide reliable joints for low temperature service

Rework/repair

Practical issues

- Consider the need for higher temperatures and increased power to melt lead-free alloys
- Consider the need to preheat larger components
- With tin alloys, check soldering iron tips more frequently as the dissolution rate may increase

Materials compatibility

- Label board for alloy type
- When repairing boards, ensure solder type is correctly identified
- If solder type is not identified, use one compatible with most alloys, eg tin-copper
- Avoid contamination with lead

Benefits and concerns

Environmental

- Lead-free solders are less toxic
- Reduced risk of lead entering and polluting the environment
- Compliance with forthcoming legislation, including the draft waste electrical and electronic equipment (WEEE) directive and the draft reduction of hazardous substances (ROHS) directive

Economic

- Initial costs may be high
- Converting to lead-free assembly may involve other costs
- Recycling and disposal costs may fall
- Profit margins may be higher for 'green' product

Technical

- Improved reliability possible
- Lead-free board finishes exhibit better solderability and have a longer shelf-life
- Fewer defects with lead-free solder than with tin-lead solder in well-designed process

Marketing

- Continued access to European and world markets
- Consumer willingness to support products with less environmental impact
- Opportunity to demonstrate the company's commitment to the environment

For further information please contact the

Environment and Energy Helpline

0800 585794

Sources of further *information and advice*

Envirowise
Environment and Energy Helpline
Tel: 0800 585794 www.envirowise.gov.uk
E-mail: helpline@envirowise.gov.uk

Lead-free Soldering Technology Centre (SOLDERTEC)
Kay Nimmo Tel: 01895 272406 www.lead-free.org

National Physical Laboratory (NPL)
Chris Hunt Tel: 020 8943 7027 www.npl.co.uk/npl/ei/

Surface Mount and Related Technologies (SMART) Group
Tony Gordon Tel: 01494 465217 www.smtuk.demon.co.uk/leadfree.htm

ETMUEL Project at the Centre for Sustainable Design (CFSD), University of Surrey
Martin Charter Tel: 01252 892772 www.cfsd.org.uk/nepd/etmuel/index.html

Federation of Electronic Industries (FEI)
Dudley Ollis Tel: 020 7331 2054 www.fei.org.uk

Printed Circuit Interconnection Federation (PCIF)
Frank Coultard Tel: 020 7331 2035 www.pcif.org.uk

IPC - Association Connecting Electronic Industries
US organisation (formerly the Institute of Interconnecting and Packaging Electronic Circuits) www.leadfree.org

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Envirowise - Practical Environmental Advice for Business - is a Government programme managed by AEA Technology Environment and NPL Management Limited. This leaflet was prepared with assistance from SOLDERTEC at ITRI and Gary Wilkinson of Shipley Europe Ltd.

For further information please contact the

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0800 585794