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Adaptation to scientific and technical progress under Directive 2002/95/EC

EXCERPT
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E X C E R P T
of final report 2009

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4.17 Exemption No. 11

"Lead used in compliant pin connector systems"

This exemption was last evaluated in 2004 [1]. Producers of compliant pin connector systems had claimed tin-coatings as a viable substitute for the tin-lead coatings. The users of the pin connector systems opposed this view and asked for an exemption until 2010 [1].

The exemption was granted without an expiry date.

4.17.1 Description of exemption

Compliant pin connector or press-fit connectors systems provide a method of attachment and electrical contact between a connector and printed circuit board (PCB) which does not require a soldering operation. The pin contacts are inserted into plated through holes (PTH) in the PCB and the mechanical design of the pin provides reliable electrical contact.

The compliant pins must [1]

- be sufficiently flexible to deform as they are inserted into the holes without an excessively high force that might damage the plating in the holes
- be extractable for repair without damage to the board

The tin-lead plating on the pins contains only about 10% lead and is only about 1.5 microns thick. It is required to

- provide lubrication while the pins are inserted and withdrawn in order to reduce the insertion force [1]

- have an oxide on the surface that can be displaced during insertion [1]
- ensure good electrical contact once the pin has been inserted [1]
- prevent whisker growth [2]

Pin compliant connectors were developed to avoid the difficulties encountered in soldering such a large number of closely spaced pins. The total thermal mass would be so large that it was difficult to achieve the correct temperature throughout the connector for the solder to flow and wet the surfaces. The situation would be even more difficult with lead-free solders due to their slower wetting and higher assembly temperature. [1]

Pin compliant connectors can be extracted and reinserted several times to change PCBs (upgrade or repair). As solder is not used, smaller pads can be used around each pin, so that they can be placed closer together. [1]

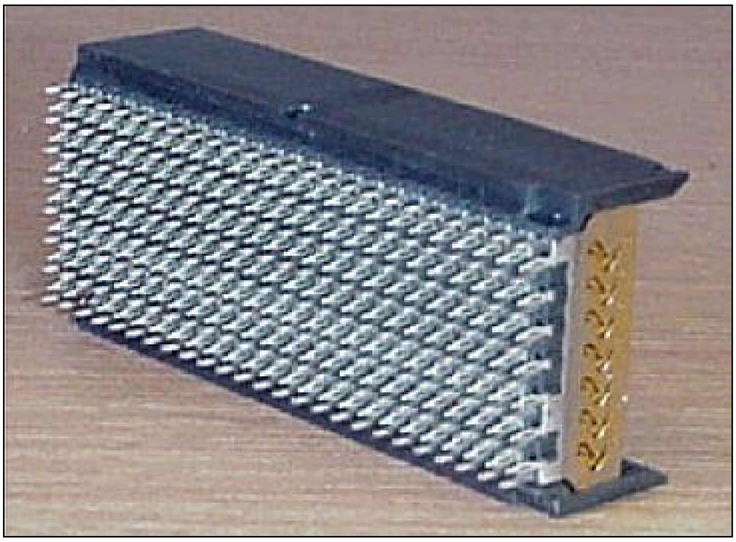
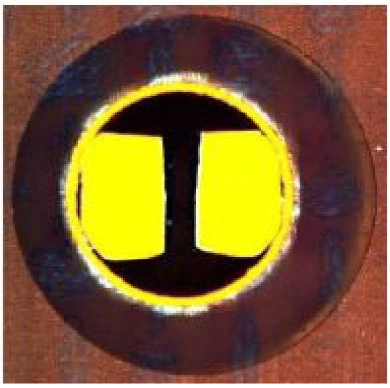


Figure 17 Example of a compliant pin connector system [1]

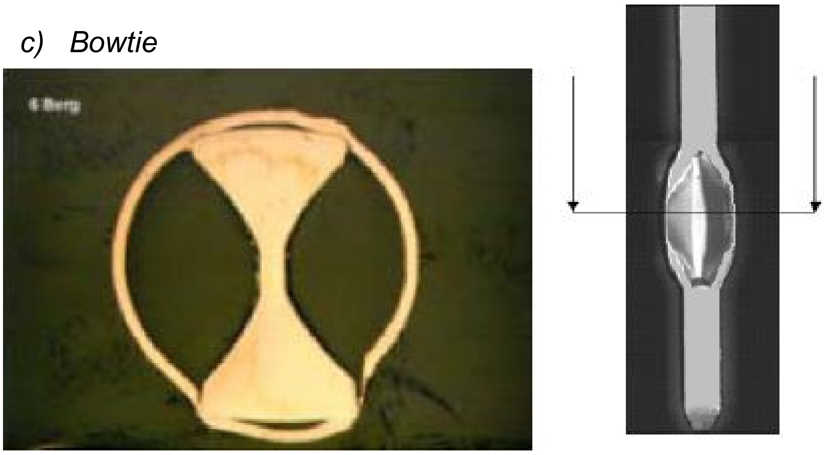
There are different types of compliant pin connector systems in use.

a) eye of needle



b) C-press

c) Bowtie



d) Action pin

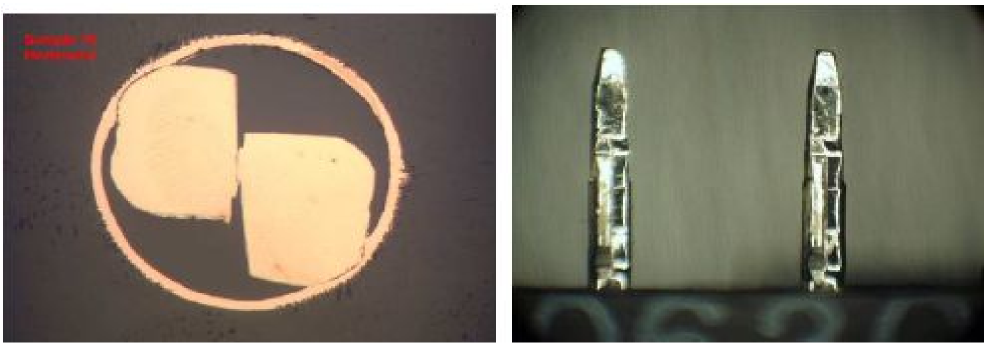


Figure 18 Types of compliant pin connector systems

Tin-lead plating covers only the termination portion of the contact, which includes the compliant section. The lead provides lubrication while the pin is inserted and withdrawn. The lead oxides on its surface are displaced during insertion enabling good electrical contact once the pin is inserted. Such connectors are used on printed circuit board assemblies contained in many types of computer and telecommunication equipment.

The amount of Pb in the SnPb plating ranges from 3–40%, but typically is in the 3–10% range. The plating thickness is thin, approximately 0.4–4.0 micrometer. Depending on the pin style and the number of pins on the connector, the total amount of Pb on a compliant pin connector may range from less than 1 mg to approximately 100 mg. [2]

A typical Server printed circuit board assembly (PCBA) might have 4 to 8 connectors per PCBA, up to as many as 20 connectors for a very complex PCBA. Based on these estimates, any PCBA should contain less than 2 gram of Pb from the compliant pin connectors. [2]

Based on estimates of the number of contacts per connector, connectors per PCBA, PCBAs per system and number of systems using compliant pin connectors shipped into the EU, the compliant pin connector exemption is estimated to account for 20-50 tonnes of lead shipped into the EU annually. The stakeholders say that the amount of lead shipped into the EU under this exemption will decrease as additional matte tin plated compliant pin part numbers are qualified for use in certain applications.

4.17.2 Justification by stakeholders

<u>Technical background</u>

Eliminating Pb from compliant pin connectors has two adverse effects:

- The lubricity of the plating on the compliant section decreases. The insertion force will increase as well, resulting in more damages to the plated through holes (PTH) in the printed circuit board (PCB) [2].
- Pb added to Sn in the connector finish significantly decreases the risk of tin whisker growth. Compliant pin connectors are particularly susceptible to the formation and growth of whiskers due to the compressive stress state imparted on the press fit component during service life. [2]

In the 2004 ERA study on this exemption [1], several of the larger compliant pin connector manufacturers had stated that tin can replace tin/lead coatings. The compliant pin system manufacturers and the users of these systems disagreed whether the higher insertion force could be overcome by a small increase in the hole diameter (not always feasible) and/or a decrease in pin size. [1] According to EICTA [2], such changes to the plated through hole ground rules may decrease the failure occurrences, but have not been proven 100% successful.

The main concern of users, however, was and still is tin whiskers. Tin whiskers may occur on electroplated tin coatings They can cause short circuits in electrical equipment leading to either complete failure or intermittent faults. Lead added to tin significantly reduces the susceptibility to whisker formation. Although tin/lead whiskers do occur, they are usually very short, so are not likely to cause a short circuit. [1]

It is the stress within electroplated tin coatings, which causes the tin whiskers. The exact mechanisms were not fully understood in 2004, and still today, in 2008, there are remaining questions despite of intensive research. For devices like compliant pin connectors, their way of use itself applies stress on the tin surfaces. In order to keep them in place and to reliably provide electrical contact, the pin surface must be pressed against the walls of the plated through hole ("pressfit connectors"!) with a certain force causing pressure on the tin or tin-lead platings once they are inserted. This pressure may cause compressive stress in the tin coating resulting in whiskers.

The compliant pin connector manufacturers said in 2004 that they can produce tin coatings that are not susceptible to tin whiskers and so the risk is small. The producers of high reliability products such as servers and networks in 2004 did not want to accept this risk, the more as the whisker phenomenon was not yet fully understood. [1]

During this 2008 exemption review process, there was no submission from compliant pin system manufacturers supporting the 2004 point of view that lead-free substitutes are available.

Testing of matte tin compliant pin connectors

EICTA [2] says that compliant pin connector systems are typically used in more complex printed wiring boards (PWBs) and not as often in consumer electronics. Server and storage applications require thicker printed wiring boards and do not accept any internal defects or damage to the PWB material surrounding the plated through hole (PTH). The complex printed circuit board assemblies of servers and storage applications require the capability to rework connector sites to maintain a high yield and reduce the amount of scrap hardware that must be disposed. [2]

Over several years, a significant number of compliant pin connectors with a 100% tin plating on the compliant section have been qualified for some server applications. This work involves several connector manufacturers and many compliant section designs. A significant number of qualifications, however, have not been successful. The success depends on the types of connectors used.

Positive results could be achieved in qualifying "C-press" pin connectors (see Figure 18 on page 142). While the stakeholders had limited the practicability of lead-free C-press connectors to specific conditions originally [9], further discussions on the exact conditions for exemptions allowed considering the use of lead-free C-press connectors as technically practicable in general. [11]

The results for the "eye of needle" designs vary based on supplier and connector specifics. Some "eye of needle" designs have positive qualification results, while others have failed due to plated through hole (PTH) damage. Failure mechanisms are not yet well understood.

Contributory factors to these failures may be the design of the compliant section, the interference fit between the compliant section and the PTH, and/or the material properties of the plating. [2]

When “eye-of-needle” (EON) designs have pins oriented in multiple directions within the same connector housing (---, |, /), the insertion & retention forces vary and as a result the wear mechanisms within the PCB via are no longer equal, resulting in failure to meet the minimum copper thickness remaining on the PTH. In some cases the tip of the connector pin is designed with a sharp edge instead of rounded blend and this contributes to failure to meet required specifications. [9]

EON pins oriented in a singular direction also have had a history of fails either in a single rework situation or double rework situation. The reasons are not clear, since there are multiple variables of terminal plating finish, plating thickness, pcb via finish, via plating thickness, via size, rework removal techniques and a host of manufacturer specifications that all vary. [10]

There are successful EON qualifications. It is critical to use the appropriate PCB and PTH design parameters to get the appropriate insertion / retention force. Industry is still refining the optimum parameters. Even with PTH vias / plating within the specifications that were established, there have been some production issues. EICTA [9] says that industry is still working through the requalification of the conversion of some of the EON connectors. [9]

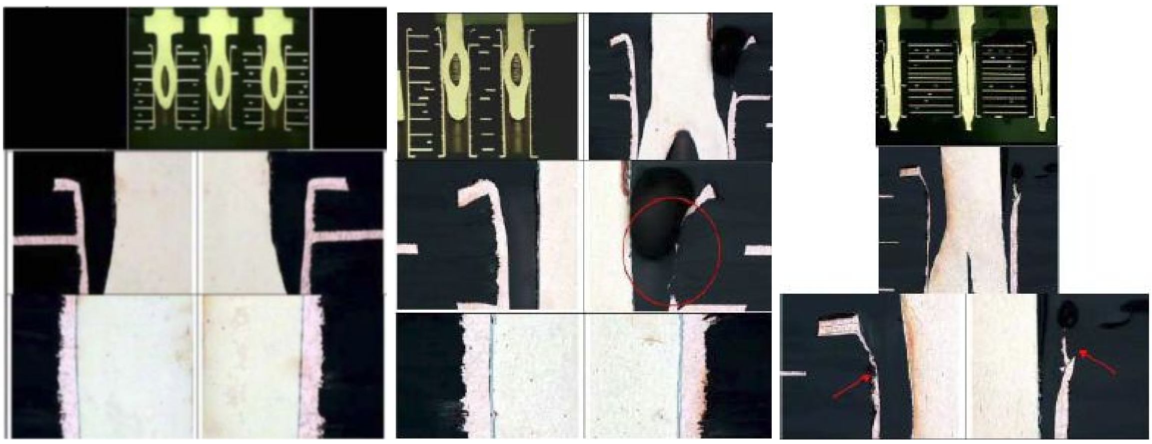


Figure 19 Cross sections of acceptable (left) and unacceptable insertion results after one (middle) and two (right) reworks

Testing of other than “eye of needle” and “C-press” compliant pin connectors, such as “bow-tie” and “action pin” designs, has uncovered unacceptable damage to plated through holes (PTH) in the printed circuit board (PCB), especially after rework, as a result of the significantly higher insertion/retention forces. [2]

Gold as alternative pin plating for whisker prevention

Gold coatings are resistant against whisker growth. The question therefore is whether and how far gold platings could be a viable option for compliant pin connectors.

EICTA [9] says that the insertion force of gold pressfits is greater that of SnPb pressfits, and it is even higher than for tin-plated pressfits. The type of Au plating also appears to affect the overall insertion forces. It's probably to say that Au may see insertion forces 10-20% higher than Sn. With tin compliant connectors, the insertion force partially decreases during the insertion process (relaxation), while this is not the case with gold compliant connectors. This lack of relaxation means that the pins will be more aggressive to the PTH than tin plated connectors.

EICTA states a minimum increase of about 30% in the insertion forces to as high as a 3X increase (worst case) comparing gold compliant pins to SnPb ones. The results depend on compliant pin type and hole sizes. The insertion force for tin compliant connectors typically does not increase for more than 20% compared to SnPb compliant connectors.

These higher insertion forces often result in unacceptable damage to the plated through holes (PTH), as Figure 20 shows.

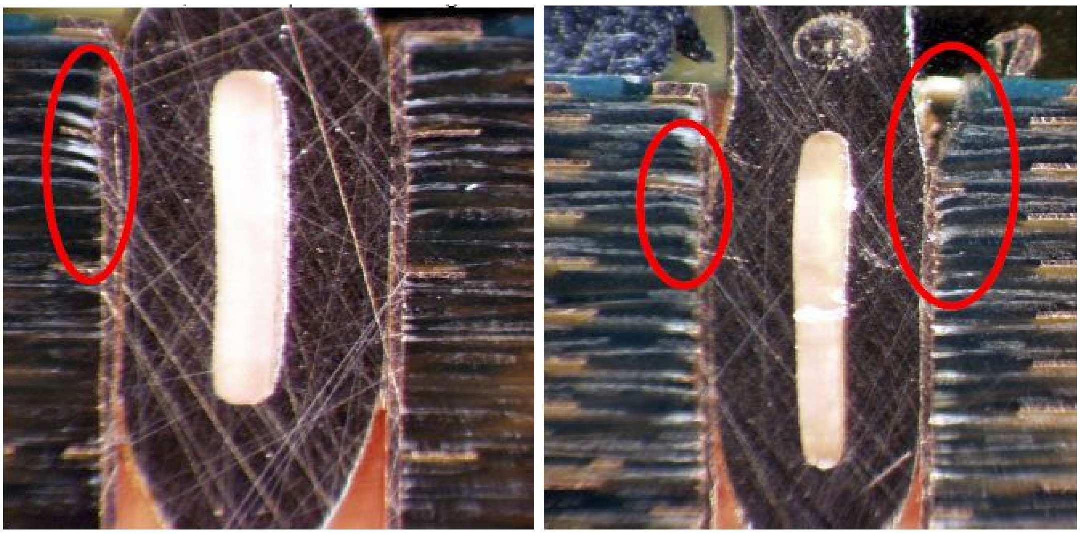


Figure 20 Cross sections of acceptable (left) and unacceptable insertion results with gold plated pins after initial insertion (left) and after two reworks (right)

In addition, the metallurgical properties of the gold plated compliant pins also pose concerns for rework. Gold and copper are 100% miscible and therefore interdiffuse quite readily. The high contact strains of pin insertion produce a substantial level of diffusion bonding at the contact points. Once local bonding occurs, the pin retraction results in an unacceptable PTH damage. [2]

Geometrical changes to decrease the insertion force

Increasing the PTH diameter or decreasing the pin thickness would reduce the insertion force of tin compliant connector systems.

EICTA [9] confirms that increasing the PTH hole reduces the insertion force, but for subsequent reinsertion & removal actions the via size increases causing the retention force requirements to be not met. Variations in the finished hole sizes by the PCB vendor may also result in missing the requirements for the pin connector systems.

EICTA [9] describes a case where the PTHs are within the necessary specifications, as are the pins, but the insertion forces are too low. This problem only occurred on a specific printed circuit board (PCB) and not another PCB design, which also uses the same connectors. It could not yet be found out why it is a problem on one but not the other. There could be issues with the material set (FR4) or it could be related to the PTH size.

According to EICTA [9] the normal forces between the compliant pin sections and the PTH walls are critical to reliability. Too little and they will not be gas tight and will ultimately be unreliable. Too tight and it will collapse the compliant section of the pin or damage the PTH walls, resulting in manufacturing defects or field reliability problems or both.

EICTA [9] negates that it is an option to change the hole or pin size without compromising the reliability of the connector.

Mitigation techniques for whisker prevention

Several whisker mitigation techniques are available for tin platings as a result of intensive research, mainly:

- postbake anneal treatment of components with tin finishes on copper after manufacturing, before application in products;
- nickel underlayer between the copper and tin finish;
- components that undergo a soldering process are less prone to whisker formation.

EICTA states that tin whisker mitigations such as a post-bake heat treatment and nickel underlayer may be effective for reducing whisker growth on other components than connectors, but have not been proven for compliant pin connector applications. In opposite to other components, the compressive stress causing whisker growth is – additionally – applied externally in connectors during their service life as permanent pressure is necessary to keep them in place. This additional external stress causes whiskers, while the above mitigation techniques focus on the reduction or prevention of stress generated from within the tin layer and the underlying metal layer. There is also evidence that the post bake anneal may simply slow the initiation of tin whiskers, rather than eliminate their formation [2].

Anecdotal evidence according to EICTA [2] is available showing whisker growth that exceeds the JEDEC standard acceptance criteria when inserted connectors were subjected to the industry standard tin whisker test conditions. Furthermore, recent experiments by iNEMI show that tin whiskers form under conditions of high temperature and humidity, even for platings subjected to the "post bake anneal" treatment. The test itself (JESD 201 [5]) cannot for sure exclude whiskers, even if it is conducted successfully: "At the time of writing, the fundamental mechanisms of tin whisker growth are not fully understood and acceleration factors have not been established. Therefore, the testing described in this document does not guarantee that whiskers will or will not grow under field life conditions." (JESD201 [5])

One company reports that its requirements are for a valid mitigation practice plus successful testing to JEDEC JESD-201 Class 2 requirement. From the preferred suppliers, 80% have passed these requirements, 20% have not. In the total allowed supplier base, which is much larger, very few have passed these requirements. [9]

Connector manufacturers currently do not guarantee non-growth of whiskers. Regarding high density implementation and the use of Sn plating connectors, there is a risk of short circuits, as Figure 21 illustrates [2]:

- minimum space between compliant parts of connectors is "0.77 mm":
- maximum length of Sn whisker is "0.62 mm".

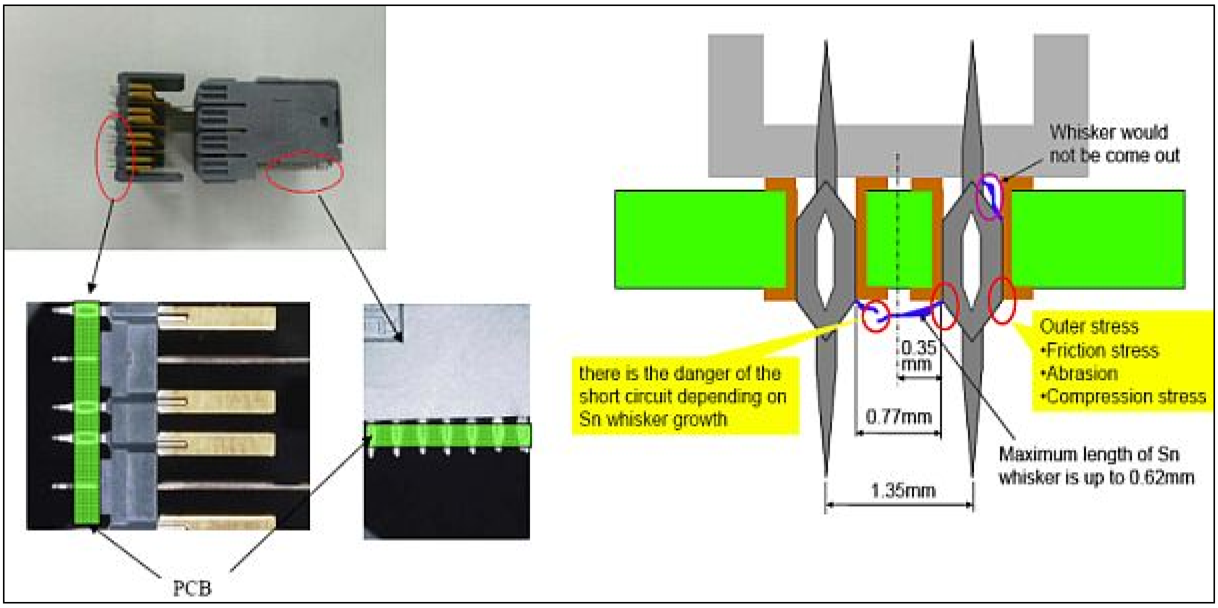


Figure 21 Dimensions of pin connector systems in high density applications [2]

The consultants proposed the stakeholders to shorten the length d of the spline (Figure 22 below) so that the line where the spline ends touching the PTH is not at the bottom edge of the PTH as in the drawing, but still inside the PTH. The whisker would then have to grow much longer and around the corner to be able to cause a short circuit. This change would at the same time reduce the insertion force, as the area where the PTH plating and the spline touch each other during insertion is much smaller.

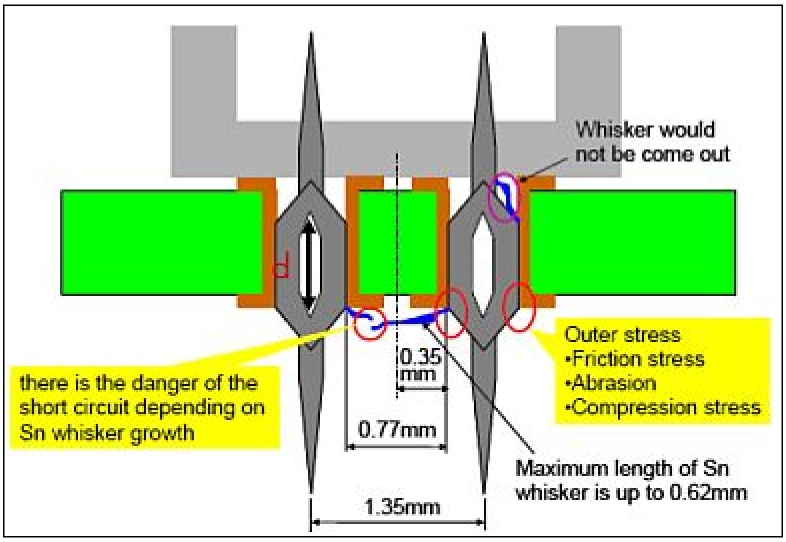


Figure 22 Consultants' proposal to change connector size preventing whisker short circuits

The stakeholders [9] commented that in addition to "whiskers," there is also the concern of fine "slivers" which are produced by skiving of the plating by the compliant pin during insertion of the connector into the PCB. If the slivers are dislodged from the PTH, they create the potential for metal-to-metal shorting like whiskers can. In qualification testing through shock and vibration, metal slivers were not dislodged, according to EICTA [9], and a shorter spline would yield smaller slivers, further reducing the risk of shorts. EICTA [9] states there is not enough experience, however, to validate this proposal. The greater concern would be the change in the contact force by changing the design.

Changing the board thickness and/or compliant pin length is not a practical option. The compliant pins are designed to achieve a proper contact normal force. They are typically made about as small as practical already so that they can work in as thin a board as possible. There is a minimum board thickness required for proper contact normal forces on compliant pin connectors. Board thicknesses are driven by other requirements, including layer counts, electrical considerations, material considerations, mechanical considerations, and reliability considerations.

Request for continuation of the exemption

EICTA anticipates solutions to replace 100% of the compliant pin connector systems with lead-free alternative coatings to take more than four years to complete. The stakeholder therefore asks to keep the exemption in place until 2012 at least. [2]

Hewlett Packard [6] and the Test and Measurement Coalition [8] support the EICTA arguments and plead for the continuation of the exemption without mentioning an expiry date.

Ringhal AB [7] asks to exempt monitoring and control instruments from the RoHS Directive. This category of equipment currently is not in the scope of the RoHS Directive. Further on, it would require an in-depth evaluation after an appropriate stakeholder involvement process in order to assess the justification of such an exemption in the light of the Art. 5 (1) (b) requirements. The evaluation of this request hence is outside the reviewers' mandate.

4.17.3 Critical review

Higher insertion forces causing damages to the plated through holes and whisker growth resulting in possible electrical short circuits are the key issues to be tackled in the replacement of tin-lead compliant pin connectors by lead-free ones. The substitution of lead is technically practicable in C-press compliant pin connectors. This type of pin connector could successfully be qualified. Art. 5 (1) (b) hence would not allow the continuation of the exemption for the C-press pin connectors. Assuming the Annex of the RoHS Directive is amended until the end of 2009, it is recommended to allow exemption 11 to expire for C-press pin connectors on 30 June 2010. This leaves the stakeholders some time after the official amendment of the new Annex to react on the new situation.

For the "eye-of-needle" (EON) type compliant pin connectors, a qualification was possible in some cases, but not over the whole application range. The conditions of safe use of lead-free alternatives have not yet been clarified completely. The stakeholders could not specify a clearly defined application field where the use of EON type compliant pins was reliable. A restriction of EON type compliant pin connectors at the current state of technology is not practicable. For the other connector types (active pin and bowtie), the stakeholders did not indicate that viable lead-free compliant pin connectors could be qualified for use. The stakeholders proposed 2012 as the earliest possible expiry date for exemption 11. It is recommended to follow this request, but excluding the C-press pin connectors. This expiry date should be close enough to further on push manufacturers to seek qualification of lead-free compliant pin connectors wherever possible.

There were no opposing stakeholder views.

4.17.4 Recommendation

Based on the available information, and in the absence of opposing stakeholder views, the consultants propose the following further proceeding with exemption 11:

It is recommended to repeal exemption 11 for C-press compliant pin connector systems. The substitution of lead is technically practicable in these pin connector types. Assuming the new Annex will be officially published until the end of 2009, it is recommended to give the globally organized electrical and electronics industry time until 30 June 2010 to be informed and to react on the cancellation of this part of the exemption in the EU.

For other types of pin connectors, lead-free solutions are partially available. The underlying root causes for successful qualification or failure are, however, not yet fully understood. This situation should justify the continuation until 2012 as proposed by the stakeholders. It leaves time for further research, and for the proper qualification of pin compliant connectors towards the full substitution of lead.

The consultants propose splitting the exemption and recommend the following new wording:

11 a) Lead used in C-press compliant pin connector systems until 30 June 2010, and for the repair, or to the reuse, of electrical and electronic equipment put on the market before 1 July 2010.

11 b) Lead used in other than C-press compliant pin connector systems until 31 December 2012, and for the repair, or to the reuse, of electrical and electronic equipment put on the market before 1 January 2013.

4.17.5 References

[1] Paul Goodman et al.: Technical adaptation under Directive 2002/95/EC (RoHS) – Investigation of exemptions; final report Dec. 2004;
Document "ERA Report 2004-0603.pdf"

[2] Stakeholder consultation document
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[3] Öko-Institut e.V. in cooperation with Fraunhofer IZM: Adaptation to scientific and technical progress under Directive 2002/95/EC, Monthly Report 3, in the Annex I of Final report July 2005,
http://ec.europa.eu/environment/waste/weee/studies_rohs1_en.htm; last access 10/Oct/2008

[4] Stakeholder requests group 1, second stakeholder consultation on applications for RoHS exemptions,
http://circa.europa.eu/Public/irc/env/rohs/library?l=/requests_exemptions/resistant_applications&vm=detailed&sb=Title; last access on 10 October 2008

[5] Industry standard JESD201 "Environmental Acceptance Requirements for Tin Whisker Susceptibility of Tin and Tin Alloy Surface Finishes",
http://www.jedec.org/DOWNLOAD/search/JESD201.pdf; last access 10/Oct/2008

[6] Hewlett Packard stakeholder consultation document
"HP Letter to the Oeko Institut – Rev3.1.pdf"

[7] Ringhal AB online stakeholder consultation document “Exemptions-7-11-12-14-15-23-24-27_Ringhal_AB_1_April_2008.pdf”

[8] Test and Measurement Coalition online stakeholder document “Exemption-5-6-7-11-14-15-23-24_Test-Measurement-Coalition_31_March_2008.pdf”

[9] EICTA stakeholder document “EICTA reply to questions on ex-11 21-10-08.pdf”

[10] Information from EICTA, sent by e-mail to Otmar Deubzer, Fraunhofer IZM, on 28/Oct/2008

[11] Stakeholder information, sent by e-mail to Otmar Deubzer, Fraunhofer IZM, on 30/Oct/2008

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