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

Joint response from EICTA, AeA Europe and EECA ESIA to the general and specific questionnaires

relating to exemption 23

"Lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less with NiFe lead frames and lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less with copper lead frames"

31 March 2008

Content

General questionnaire

1. For which substance(s) or compound(s) should the requested exemption be valid?	Lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less with NiFe lead frames and lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less with copper lead frames.
2. What is the application in which the substance/compound is used for and what is its specific technical function?	Lead in the solderable finish on electrical terminations of components using a metal leadframe. The finish is required to provide a surface that can be soldered to create electrical and mechanical connection of the component to the printed circuit board.
3. What is the specific (technical) function of the substance/compound in this application?	Lead is present to prevent the formation of tin whiskers.
4. Please justify why this application falls under the scope of the RoHS Directive (e.g. is it a finished product?	Electronic components mentioned in 2 above do not fall directly under the scope of RoHS themselves, but become parts of products that are under RoHS. Those components, however, are used within EEE according to the scope of RoHS.
- Is it a fixed installation?	Typically No. Fine pitch parts can also be used in fixed installations.
- What category of the WEEE Directive does it belong to?).	EICTA products for this exemption fall under category 3 (IT and telecommunications equipment) and category 4 (consumer equipment). This could be used in other categories of products.
5. What is the amount (in absolute number and in percentage by weight) of the substance/compound in:	
i) the homogeneous material1	The concentration of lead (Pb) in the terminal plating alloy is typically below 20%, and is usually 3 – 15% by weight.
ii) the application, and	The thickness of the plating is only about 10 micrometers. Therefore, a typical electronic component using tin-lead electroplated terminations contains less than 0.1% Pb as a fraction of the mass of the component. Thus, the typical electronic component contains between 0.1 to 1 mg of Pb from the plating. This exemption request seeks to exempt Pb only in the platings for *fine pitch* components (0.65 mm or less), which are a small subset of all parts using tin-lead platings. Therefore, the total amount of Pb present from platings on fine-pitch components typically would be only from 1 mg to about 1 g per product.
iii) total EU annually for RoHS relevant applications?	Based on 2003 shipments of electronic goods to the EU, the annual amount of Pb used on fine-pitch components if this exemption were exercised would be approximately from 2,000 kg to 20,000 kg (2 – 20 metric tons). Amounts may be slightly higher than this estimate due to growth in consumption of electronics since 2003. It is important to recognize that the continuation of this exemption will have *essentially no impact on the shipment of lead-containing products into the EU* if widespread tin whisker failures do not occur. This is because virtually all fine pitch components are currently being shipped with lead-free platings. Only if widespread tin whisker problems occur would this exemption be exercised and the

	switch back to tin-lead platings be needed.
6. Please check and justify why the application you request an exemption for does not overlap with already existing exemptions respectively does not overlap with exemption requests covered by previous consultations.	Not applicable. Exemption currently exists.
7. Please provide an unambiguous wording for the (requested) exemption.	Same as current. "Lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less with NiFe lead frames and lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less with copper lead frames."
8. Please justify your contribution according to Article 5 (1) (b) RoHS Directive whereas:	
o Substitution of concerned hazardous substances via materials and components not containing these is technically or scientifically either practicable or impracticable;	The needs for this exemption are essentially unchanged since the original request was made (see the Annex for the original request). In summary, these include the following. 1. The main problem with these Pb-free, tin-based platings is that filaments of metal, known as "tin whiskers," may form and create electrical short circuits between closely spaced component terminals. These tin whiskers can cause functional failure of electronic products once they grow long enough to create short circuits between adjacent electrical terminations. Pb is the only alloying element of tin electroplatings that is known to eliminate the risk of tin whiskers. 2. The fundamental reasons why tin whiskers form and grow is still being researched and debated, even after several decades of investigation. There are many conflicting claims and much conflicting data in the industry, with no clear consensus emerging that provides a quantitative understanding. 3. The industry does not yet have sufficient understanding of how common tin whiskers may be on fine-pitch parts in service. Tin only based plating solutions have been in mainstream, Pb-free production for about 2 years. While no devastating tin whisker failures have been publicly reported, such a time period is less than would be expected for tin whisker problems to occur in most applications (PCs, servers, printers, etc.). Thus, while encouraging, the lack of problems to date does not guarantee success for mid- to long-life products (e.g. 5 – 10 years). 4. The necessary details of what plating process variables to control in order to prevent tin whiskers, and the precise process limits to impose, are not completely understood at this time. 5. There is currently no quantitative way to assess the risk of product failures due to tin whiskers based on "accelerated" laboratory data collected over a period of a few months. 6. The importance of this exemption will increase if and when the exemption 7.2 "*Lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signalling, transmission as well as network management for telecommunications*" is removed due to the length of life and mission critical nature of this equipment.
o Elimination or substitution of concerned hazardous substances via design	All materials used to form the electrical and mechanical terminations of ICs and other electronic components are unsolderable unless they are plated with a solderable finish. The only exceptions are "area array" components, which are practicable only for a subset of devices. For all other

changes is technically or scientifically either practicable or impracticable;	components, a solderable finish based on tin or on the gold-based technology described in the original exemption request must be used in order to create a mechanical and electrical connection between the component and the printed circuit board.
o Negative environmental, health and/or consumer safety impacts caused by substitution are either likely or unlikely to outweigh environmental, health and/or consumer safety benefits thereof (If existing, please refer to relevant studies on negative or positive impacts caused by substitution).	These remain as described in the original exemption request (see the Annex). In summary: 1. We are not aware of any significant health or environmental risks posed by the substitutes for Sn-Pb platings on fine-pitch components. 2. This exemption is necessary as a "fall back" to ensure the reliability of products that use fine pitch electronic components. Such failures could result in safety risks for the public and failed products will become WEEE prematurely, placing an undue burden on both consumers, and the recovery and recycling infrastructure in the European Union.
9. Please provide sound data/evidence on why substitution / elimination is either practicable or impracticable (e.g. what research has been done, what was the outcome, is there a timeline for possible substitutes, why is the substance and its function in the application indispensable or not, is there available economic data on the possible substitutes, where relevant, etc.).	The technical literature on tin whiskers is vast. A summary of much of this literature is available in the most recent iNEMI User Group guideline published in December 2006. This document lists 85 references from the whisker literature, and can be downloaded at: http://thor.inemi.org/webdownload/projects/ese/tin_whiskers/Pb-Free_Finishes_v4.pdf The executive summary from this document states the following. 1. It is the consensus of the iNEMI User Group that pure tin electroplating presents a risk in high-reliability applications… 2. This document also acknowledges that, "… there are cost-effective alternatives available to *minimize* this risk." Note that these alternatives do not *eliminate* risk. 3. "… the tin whisker issue is **not solved** and continued emphasis on this topic remains important to the reliability of products."
10. Please also indicate if feasible substitutes currently exist in an industrial and/or commercial scale for similar use.	The use of substitutes for tin-lead platings is certainly feasible, and is in wide-spread use today. Substitutes include pure tin and high tin platings, as well as gold-based platings. Continuation of this exemption is requested to provide a "fall back" in case these solutions prove to be unreliable over the long term, **especially for long life and mission critical / high reliability products.**
11. Please indicate the possibilities and/or the status for the development of substitutes and indicate if these substitutes were available by 1 July 2006 or at a later stage.	The substitutes for tin-lead platings were available by 1 July 2006, and are in wide-spread use today.
12. Please indicate if any current restrictions apply to such substitutes. If yes, please quote the exact title of the appropriate legislation/regulation.	No legal restrictions apply to any of the potential substitutes.
13. Please indicate benefits / advantages and disadvantages of such substitutes.	These remain the same as described in the original exemption request (see the Annex). 1. In general, there are no significant advantages to the substitutes for tin-lead platings, either

	technically or economically. The disadvantage to the tin-based substitutes is that affected products may be prematurely discarded for recycling due to tin whisker failures. 2. The disadvantage to the gold-based platings is that their current unavailability would severely limit shipment of electronic equipment into Europe. Further, gold-based platings generally are not used on iron-nickel lead frame parts due to cracking of the finish during lead forming and subsequent corrosion concerns.
14. Please state whether there are overlapping issues with other relevant legislation such as e.g. the ELV Directive that should be taken into account.	The issues with potential whisker formation on tin-based platings and unavailability of components with gold-based platings for products in scope for RoHS are also present for electronics used in automotive applications. This issue was one reason for the lead in solder exemption in the ELV Directive.
15. If a transition period between the publication of an amended Annex is needed or seems appropriate, please state how long this period should be for the specific application concerned.	A transition period of 7 - 10 years from the original RoHS implementation date would be prudent.: 1 July 2013 to 1 July 2016. Since the vast majority of fine pitch components shipped into Europe are now lead free, such a transition period would not impact the amount of lead shipped to the EU (assuming all goes well) but would provide an important "safety net" in case tin whisker problems become widespread.
16. Additional comments	

Specific questions exemption 23

"Lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less with NiFe lead frames and lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less with copper lead frames"

The following specific questions should be answered in your stakeholder contribution if you support exemption 15 to be continued / amended / discontinued:

1. What has changed since the **last evaluation** in 2006? Are the above mentioned arguments still valid?	The industry has continued to research the tin whisker phenomenon, to establish standard testing methods, and to pursue risk mitigation steps. Despite these efforts, the risk of tin whiskers remains. The arguments described above and outlined in the original exemption request (see the Annex) are still valid. This is not a complete surprise since the scientific community has been struggling to understand the tin whisker phenomenon for over 40 years; it would be optimistic to expect the problem to be solved with just a few more years of work. Some of the specific work that has taken place since the last evaluation includes the following. iNEMI User Group guideline published in December 2006. This document lists 85 references from the whisker literature, and can be downloaded at: http://thor.inemi.org/webdownload/projects/ese/tin_whiskers/Pb-Free_Finishes_v4.pdf The executive summary from this document states the following. 1. It is the consensus of the iNEMI User Group that pure tin electroplating presents a risk in high-reliability applications… 2. This document also acknowledges that, "… there are cost-effective alternatives available to *minimize* this risk." Note that these alternatives do not *eliminate* risk. 3. "… the tin whisker issue is not solved and continued emphasis on this topic remains important to the reliability of products." iNEMI "DOE 5" Experiment. Results from this extensive set of experiments are available at: http://thor.inemi.org/webdownload/newsroom/Presentations/Accelerated_TW_Reynolds.pdf Objective: Attempt to correlate tin whisker growth with conditions of temperature and humidity. Possibly develop an acceleration model to describe how tin whisker growth under high temperature, high humidity conditions related to growth under more benign conditions (typically of most electronic equipment environments). Results: Tin whiskers form under conditions of high temperature and humidity, **even for platings subjected to the "post bake anneal" treatment.** A preliminary model to describe the temperature and humidity dependence of tin whisker growth was developed and remains to be validated. Testing and model development were performed only for tin over copper-based lead frames.

iNEMI Fundamentals and Test Development Team Activities

This team continues work to understand the fundamental mechanisms of tin whisker growth and to establish improved testing methods. Even though this team has met regularly since the previous evaluation of this exemption and has held several public workshops, many aspects of tin whisker growth remain without a sufficient understanding to provide predictive reliability models or fool-proof mitigation methods. Experiments are currently being planned to address fundamental aspects of tin whisker growth.

JEDEC Whisker Test Standards

The JEDEC standards organization formed a task group to develop three standards related to tin whiskers:

1) JESD22A121 – Test Method for Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes. This standard describes the technical methods of testing for tin whisker growth, and leverages the earlier work of iNEMI.

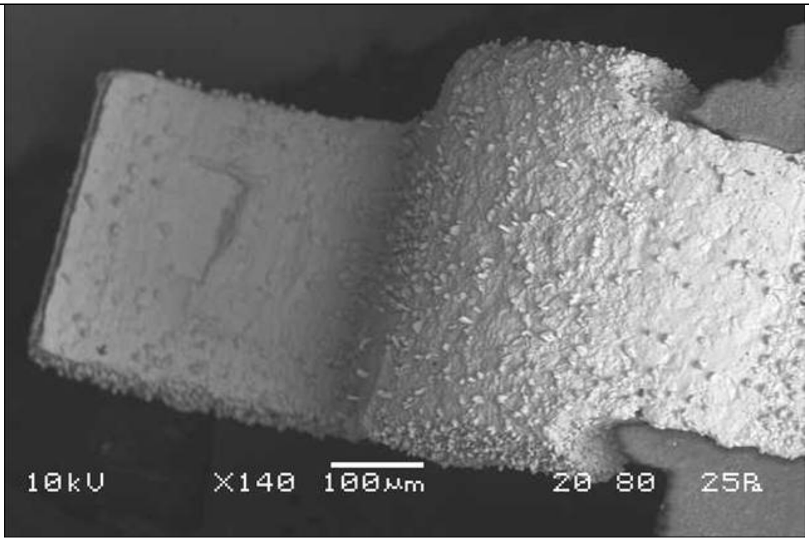
2) JESD201 – Environmental Acceptance Requirements for Tin Whisker Susceptibility of Tin and Tin Alloy Surface Finishes. This standard establishes a set of testing protocols, sample sizes, and failure criteria for various product classes. Together with JESD22A121, this standard is the main tool used by component suppliers and OEMs to establish acceptability of tin platings for use in products relevant to the standard (which do not include very high reliability products for aerospace, medical, or similar applications). **Passing of these tests is no guarantee that tin whiskers will not form over long time periods in service**.

3) JP002 – Current Tin Whiskers Theory and Mitigation Practices Guideline. This standard is a non-binding industry guideline on the tin whisker issue and risk mitigation methods commonly used in industry. The introduction of this document illustrates how Pb virtually eliminates tin whiskers and that pure tin, while adopted by the industry to meet the RoHS regulations, introduces risk. "In 1959, Pb additions of a few percent to Sn electroplate were found to greatly reduce the tendency to form whiskers [6] and interest in the subject waned. Legislation that will restrict the use of lead in electronic products sold in the European Union, due to be in effect on July 1, 2006, has led many electronic component suppliers to propose the removal of Pb from tin-lead plating, leaving essentially pure Sn. This approach is the most convenient and the least costly lead-elimination strategy for the majority of component manufacturers. However, for the high-reliability user community, the pure tin strategy presents reliability risks due to the whisker forming tendencies of pure tin and tin alloy plating."

In addition, tin whisker research continues to be reported in the scientific literature.

2. Has a **phase out** of the use of lead in finishes of fine pitch components others than connectors with a pitch of 0.65 mm or less with copper lead-frames taken place? If not, until when is it technically feasible?	Yes. The vast majority of suppliers have implemented pure tin platings, or platings with tin-bismuth or tin-copper alloys. Some suppliers have moved to Ni/Pd/Au finish, but these are only available for a minority of components from a minority of suppliers. Further, gold-based platings generally are not used on iron-nickel lead frame parts due to cracking of the finish during lead forming and subsequent corrosion concerns. Tin only based plating solutions have been in mainstream, Pb-free products for about 2 years. While no devastating tin whisker failures have been publicly reported, such a time period is less than would be expected for tin whisker problems to occur in most applications (PCs, servers, printers, etc.). Thus, while encouraging, the lack of problems to date does not guarantee success for mid- to long-life products (e.g. 5 – 10 years).
3. The exemption was recommended to expire in 2008 assuming that production capacities for gold-**based finishes** would be available as a safe alternative for fine pitch components with tin-based finishes. Please explain the status of availability for such components.	Gold-based finishes, such as Ni/Pd/Au have not found mainstream use within the industry. As stated above, the vast majority of components are plated with pure tin or tin-based alloys. Further, gold-based platings generally are not used on iron-nickel lead frame parts due to cracking of the finish during lead forming and subsequent corrosion concerns.
4. Please justify why the exemption should be **continued/withdrawn** with respect to the above mentioned arguments, or any other arguments and evidence supporting your statement.	The key reason to maintain this exemption until the next review is to provide industry the necessary time to determine whether or not tin whiskers will create significant product failures. As state above, the approximately 2 years of experience gained to date is insufficient to determine whether or not tin whiskers will form and create failures for most product environments. The current state of understanding regarding tin whisker initiation and growth is insufficient to make risk assessments with high confidence. Only product experience will ultimately answer the question regarding how large or small a problem tin whiskers in lead-free products will be. To safeguard **long life and mission critical products**, field experience of at least 7 to 10 years is needed. For products covered by the exemption for lead in solders for servers, storage, and telecommunications equipment (7b), tin-lead plating could be used on component terminations because it becomes part of the solder joints. However, this exemption does not cover all high reliability, long-life electronic equipment, such as commercial printers. Furthermore, if exemption 7b is phased out, then this avenue of addressing tin whisker problems would no longer be available.
5. What experiences exist with tin-based or other lead-free and **RoHS-compliant finishe**s on fine pitch or other components (with and/or without mitigation techniques applied)?	Gold-based finishes have been used for years and do not present a tin whisker problem. However, these finishes are subject to other technical problems (see the original request in the Annex) and gold-based finishes are not available for most components. Tin-based finishes have only been used for fine-pitch parts in lead-free products for about 2 years.

	So far, the industry has not experienced wide-ranging problems with these finishes. As stated above, however, 2 years of experience is insufficient to guarantee success. One would not expect tin whiskers to be problematic in many product environments in just 2 years. Most pure-tin-plated components over copper leads use the “post-bake anneal” process to mitigate tin whisker formation. However, this practice may simply slow the initiation of tin whiskers, rather than eliminate their formation. Evidence of this was provided by Osenbach et al. (ref. 1) and iNEMI “DOE 5” experiment, where under various storage conditions tin whiskers formed on components subjected to the post-bake anneal (ref. 2)
6. Please explain the status of an internationally accepted **whisker test**.	The JEDEC tin whisker test standard, JESD22A121, was published in May of 2005. The JEDEC tin plating acceptance standard, JESD201, was published in March of 2006. The IEC published a tin whisker test standard in May 2007, IEC 60068-2-82 , “Whisker test methods for electronic and electric components.” While publication of testing and acceptance standards represents an important step forward for the industry, current tests have significant limitations in eliminating the risk of tin whiskers. Chief among these are: 1) The tests address platings made on a certain day (or a few days). They give a “snapshot” of performance. They do not address changes in whisker performance due to changes in the plating baths and processes that can occur over long periods of time. There is no way to assure ongoing plating quality from a tin whisker perspective. 2) There is no validated way to correlate the results of these tests to whisker performance in the field. 3) The tests do not address changes to the platings that take place during the process of soldering parts to a printed circuit board. 4) They do little to address the statistical nature of tin whisker initiation and growth, where response for thousands or millions of component terminations may not be well captured by testing of a small number of components.
7. Please explain the latest status of whisker research and tests on **NiFe leadframes** and the status of qualification of tin-based finishes for fine pitch applications.	The photograph below demonstrates the high density of tin whiskers than can form after a fairly small number of thermal cycles.

	 Figure 1. Tin whiskers grown on an Fe-Ni "Alloy 42" lead following 500 thermal cycles of -40°C to +85°C (photo courtesy of HP). While in this study Pb-free SAC solder appears to mitigate whisker growth during board assembly, our understanding of how board assembly generally affects whisker growth is still very unclear. This area of investigation has received almost no attention to date. Large OEMs have also received data from some suppliers that fail the JEDEC standard tests, while other suppliers provide data indicating JEDEC acceptable results. The reasons for such a disparity are not yet clear.
8. Please explain the latest status of whisker research and tests on copper lead-frames (whisker mitigation techniques etc.) and the status of qualification of tin-based finishes for fine pitch applications.	The research into tin whisker growth on copper lead-frames has continued since this exemption was first granted. One key outcome is that the often-cited mitigation method of the "post-bake anneal" at about 150°C for one hour within 24 hours of plating may simply slow the initiation of tin whiskers, rather than eliminate their formation. Evidence of this was provided by Osenbach et al. (ref. 1). Further evidence that this mitigation methodology is not "fool proof" is provided by the iNEMI "DOE 5" experiment, where under various storage conditions tin whiskers formed on components subjected to the post-bake anneal. <u>iNEMI "DOE 5" Experiment.</u> Results from this extensive set of experiments are available at:

	http://thor.inemi.org/webdownload/newsroom/Presentations/Accelerated_TW_Reynolds.pdf Objective: Attempt to correlate tin whisker growth with conditions of temperature and humidity. Possibly develop an acceleration model to describe how tin whisker growth under high temperature, high humidity conditions related to growth under more benign conditions (typically of most electronic equipment environments). Results: Tin whiskers form under conditions of high temperature and humidity, even for platings subjected to the "post bake anneal" treatment. A preliminary model to describe the temperature and humidity dependence of tin whisker growth was developed and remains to be validated. Testing and model development were performed only for tin over copper-based lead frames. Regarding qualification of components, this is certainly occurring based on the JEDEC standards. Sometimes components "pass" these tests and sometimes they "fail," and electronic product manufactures must manage this situation as best they can. The key point, however, is that this "qualification" strategy is used only because it is the best we have available at this time. As discussed in response to Specific Questions #1 and #6, passing these tests is no guarantee that tin whiskers will not form over long time periods in service. Results of these tests cannot be used to predict performance in service.
9. In case an exemption is still required, please provide a **roadmap** with activities, milestones and timelines towards the replacement of lead in these applications.	The key milestones that would trigger the safe elimination of this exemption are as follows. 1) Sufficiently long experience with tin platings in a wide variety of products to assure there will not be industry-wide problems due to tin whiskers. A period of 7 - 10 years from the RoHS implementation date would be prudent, which would be in the range 1 July 2013 to 1 July 2016. 2) A complete understanding of tin whisker growth mechanisms, validated quantitative models to extrapolate test data, and proven mitigation methods are in place. Since significant scientific progress is needed to achieve this state, a date is impossible to predict.

References:
1. J. Osenbach, et al., J. Mater. Sci: Mater Electron, Sept 2006.
2. H. L. Reynolds et al., "Accelerated Tin Whisker Test Committee Update: Phase 5 Evaluation," 2007. Available at: http://thor.inemi.org/webdownload/newsroom/Presentations/Accelerated_TW_Reynolds.pdf

Annex

Attached are the original exemption requests from HP & from EICTA. These give more technical background to justify the extension of exemption #23. (Additional documents attached).

Original HP Request

Original EICTA Request

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
ENVIRONMENT
ENV.G - Sustainable Development & Integration
ENV.G.4 - Sustainable Production & Consumption

DIRECTIVE 2002/95/EC ON THE RESTRICTION OF THE USE OF CERTAIN HAZARDOUS SUBSTANCES IN ELECTRICAL AND ELECTRONIC EQUIPMENT (ROHS).

CHECK LIST FOR REQUESTS FOR ADDITIONAL EXEMPTIONS

Industry has sent to the Commission's services a number of requests for exemptions from the requirements of the RoHS Directive that are additional to those currently covered by the study and the stakeholder consultation. In most cases these are not substantiated by scientific and technical evidence. The proposed check-list will enable the Technical Adaptation Committee (TAC) to carry out a first screening of the requests received. Proposals that successfully pass the screening process will then be considered for a possible exemption.

Article 4(1) of Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment[1] provides 'that from 1 July 2006, new electrical and electronic equipment put on the market does not contain lead, mercury, cadmium, hexavalent chromium, PBB or PBDE.' The Annex to the Directive lists a limited number of applications of lead, mercury, cadmium and hexavalent chromium, which are exempted from the requirements of Article 4(1).

Adaptation to scientific and technical progress is provided for under Article 5 of the Directive. Pursuant to Article 5(1): "Any amendments which are necessary in order to adapt the Annex to scientific and technical progress for the following purposes shall be adopted in accordance with the procedure referred to in Article 7(2):"

Article 5(1)(b) allows the exempting of materials and components of electrical and electronic equipment from Article 4(1) if their elimination or substitution via design changes or materials and components which do not require any of the materials or substances referred to therein is technically or scientifically impracticable, or where the negative environmental, health and/or consumer safety impacts caused by substitution are likely to outweigh the environmental, health and/or consumer safety benefits thereof;

In order to allow the TAC to consider submissions for additional exemptions, the information in Table I should be provided as a first step. The request for submissions should fulfil the criteria of Article 5(1)(b). The information provided should be supported, as far as possible, with relevant technical and scientific evidence.

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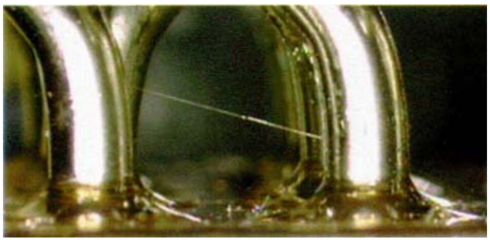
[1] OJ L 37, 13.2.2003, p. 19

TABLE I – CHECK LIST

PROPOSALS FOR FURTHER EXEMPTIONS FROM THE REQUIREMENTS OF ARTICLE 4(1) OF DIRECTIVE 2002/95/EC FOR SPECIFIC APPLICATIONS OF LEAD, MERCURY, CADMIUM, HEXAVALENT CHROMIUM.

Criteria	Information Please provide supporting technical and scientific evidence
1. Please describe the material / component of the electrical and electronic equipment that contains the hazardous substance. **Please indicate the type and quantity of the hazardous substance used in the homogenous material. Please indicate the quantity of the substance in absolute numbers and in percentage by weight in homogenous material.** **Please indicate the functionality of the substance in the material of the equipment.** **Please also provide an estimate of the annual quantities of the hazardous substance used in this particular application.**	The electrical terminations of virtually all electronic components (e.g. integrated circuits, memory “chips,” diodes, resistors, etc.) must be plated with a thin layer of metal to make them capable of being soldered to the printed circuit board. Today, these terminal platings are most commonly comprised of a tin-lead (Sn-Pb) alloy. One of the main reasons lead (Pb) is included in the plating is to mitigate the formation and growth of tin “whiskers” (see Criterion 2 information). The concentration of Pb in the terminal plating alloy is typically below 20%, and the thickness of the plating is only about 10 micrometers. In fact, a typical electronic component using tin-lead electroplated terminations contains less than 0.1% Pb as a fraction of the mass of the component. Thus, the typical electronic component contains between 0.1 to 1 mg of Pb from the plating. This exemption request seeks to exempt Pb only in the platings for *fine pitch* components, which are a small subset of all parts using tin-lead platings. [See definition of “fine pitch” under Criterion 2 information below.] Therefore, the total amount of Pb present from platings on fine-pitch components typically would be only from 1 mg to about 1 g per product. Based on 2003 shipments of electronic goods to the EU, the annual amount of Pb used on fine-pitch components during the limited time of this proposed exemption would be approximately from 2,000 kg to 20,000 kg (2 – 20

	metric tons).
2. Please explain why the elimination or substitution of the hazardous substance via design changes or materials and components is currently technically or scientifically impracticable.	Substitutes for Pb-bearing platings are usually pure tin or dilute alloys of tin with copper, silver, or bismuth. The main problem with these Pb-free, tin-based platings is that filaments of metal, known as “tin whiskers,” may form and create electrical short circuits between closely spaced component terminals (see Figure #1). Pb is the only alloying element of tin electroplatings that is known to eliminate the risk of tin whiskers.  Figure #1. Magnified photograph of a tin whisker growing from the electrical termination front right toward the termination front left. Taken from the NASA tin whisker web site: http://nepp.nasa.gov/whisker/. These tin whiskers can cause functional failure of electronic products once they grow long enough to create short circuits between adjacent electrical terminations. Fine-pitch parts are the most susceptible to such failures because the distance between the conductive leads is small. Modern electronic equipment requires the use of such fine-pitch parts to meet the computation speed and/or small size requirements of the market. For the purpose of this exemption, fine-pitch components are defined as those with electrical terminations spaced with centers 0.65 mm or less apart. In such parts, the distance between adjacent leads is considerably smaller than the center-to-center spacing, and is typically 125 to 300 micrometers. The 0.65-mm pitch was picked as a boundary for two reasons. The first is that 0.65 mm is a standard pitch for integrated circuits. The second is that

	0.65 mm represents a reasonable boundary for separating components at significant risk for whisker failures during product life from those components at lower risk. In tin-based plating evaluations following 6 months of isothermal storage, whisker lengths of about 50 micrometers have been commonly observed. If such growth continues, whisker growth rates in service could be 100 micrometers per year. For components with pitches of 0.4 mm to 0.65 mm, which correspond to terminal spacings of 125 to 300 micrometers, such growth rates could cause failures within 1.25 years. Given that two whiskers potentially could grow together, this failure time could be even shorter. Even if growth rates decay over time, failures are certainly possible within common electronic product lifetimes, which range from 3 to 20 years. The next largest standard terminal pitch is 0.8 mm, corresponding to terminal spacings of about 400 micrometers. Given the whisker growth rates described above, plus the decreasing likelihood of growing such a long whisker, the risk of whisker related failures is reduced. Tin whisker failures can be catastrophic. This risk of failure exists for all product applications, including mission critical ones. For example, NASA has reported the loss of satellites due to tin whisker failures (http://nepp.nasa.gov/whisker/failures/). It is difficult to say how many failures would be caused by introducing tin-based, Pb-free platings for fine pitch parts because such platings are not used today and there is no way to quantitatively predict whisker growth at this time. This inability to predict the risk level associated with tin whiskers lies at the heart of why this exemption is being requested, as described in more detail below. The industry does not have a reasonable

technical understanding of tin whiskers. First, the fundamental reasons why tin whiskers form and grow is still being researched and debated, even after several decades of investigation. There are many conflicting claims and much conflicting data in the industry, with no clear consensus emerging that provides a quantitative understanding, or a reliable technical alternative that is commercially feasible. For example, the National Electronics Manufacturing Initiative (NEMI) consortium has *three* separate groups currently working on the tin whisker problem, including one focused on the fundamentals of whisker formation and growth. While these groups have been operating for several years, the group comprised of companies expecting to use tin plating technology recently attempted to reach consensus on the best methods to mitigate tin whisker formation. As evidence of how far the industry is from a solution, no such consensus could be reached.

The industry does not yet have a good understanding of how common tin whiskers may be on fine-pitch parts in service, since up to now Sn-Pb platings have been used for the majority of such parts. However, recent testing by the NEMI consortium's Tin Whisker Test Development Group indicates that whiskering is common under test conditions. The most recent results of this group show that all of the most common tin-based, Pb-free platings form tin whiskers following only 8 months of exposure. The longest whiskers observed for the wide variety of platings studied ranged from 100 to 360 micrometers, in most cases longer than the spacing between leads on the finest pitch components. Tin whiskers were formed in both isothermal, humid environments and by thermal cycling – conditions expected during shipping and service for many electronic products. Furthermore, whiskers of this

	length were formed on ALL of the plating solutions examined, which included Sn-Bi, Sn-Cu and Sn-Ag alloys, annealed tin platings (promoted by some component suppliers as immune to significant whisker formation) and components subjected to a heat cycle simulating soldering of the component to the printed circuit board. The latter finding is consistent with a recent study in which subjecting components to soldering temperatures decreased the number of whiskers but increased the length of the longest (and most problematic) whiskers. Claims that whiskers do not form on components subjected to soldering temperatures have been made, but these findings involved statistically small sample sizes and may not be indicative of behavior for the large numbers of terminations found in many products or across the millions of products sold annually into Europe. Careful control of the electroplating process is one of the areas under investigation to reduce or eliminate tin whisker formation. Unfortunately, the necessary details of what variables to control and the precise process limits to impose are not known at this time. Thus, batch-to-batch variations in tin whisker response result, impairing the industry’s capability to ensure that tin whiskers will not form and cause product failures. No one has yet been able to show which process variables are actually at issue or how to control them. It is far from clear that the industry will gain the necessary process understanding any time soon. A critical impediment to finding a commercially viable technical solution is that it is difficult to obtain technical data from which to quantify tin whisker risk for particular plating solutions and particular products. Whiskers may form and grow rather slowly, even under laboratory conditions, necessitating

	long test times. There is currently no quantitative way to assess the risk of product failures due to tin whiskers based on “accelerated” laboratory data collected over a period of a few months or less. Just because whiskers do not form or grow to dangerous lengths in a two-month test does not validate that they will not grow and cause failures in a product intended to function for two years, five years, or longer. Furthermore, development of an accelerated test may never be possible because the conditions under which many electronic products operate are very similar to those that promote the most rapid tin whisker growth. In other words, the most accelerated test would still need to last nearly as long as the product is intended to function in order to validate that tin whiskering is under control. There are a number of non tin-based substitutes for Sn-Pb platings for the terminations of fine-pitch components. Reasons why these cannot fully replace Sn-Pb platings are described briefly for each class of substitute. See Table 1 at the end of this document for a summary. (1) Nickel-palladium (Ni/Pd) and nickel-palladium-gold (Ni/Pd/Au) layered platings. These platings have been used for a small fraction of fine-pitch parts for many years, and there are generally no significant technical reasons to make them impracticable. However, as described under “Criteria 4,” there are supply issues with these platings that make them unsuitable as a general replacement for Sn-Pb platings in time to meet the 1 July 2006 RoHS deadline. (2) Hot-dipped tin or tin alloy platings. This plating method cannot be used for fine-pitch components because the thickness of the plating cannot be controlled well enough. In fact, “bridging” of the tin-based metal between adjacent terminations occurs, which renders the component non functional. (3) Nickel-gold (Ni/Au)

	layered platings. Immersion techniques cannot be used for reasons similar to those described for hot-dipped tin. Electroplating requires a thick gold deposit to ensure a non-porous plating, making this solution cost prohibitive. Electroplated Ni/Au fine-pitch parts are generally unavailable for this reason. (4) Silver (Ag) platings. Silver platings are not used on fine-pitch components because Ag forms "dendrites" or thin "tree-like" formations of metal that can bridge adjacent terminations and cause failure of the component. Furthermore, Ag platings are not very solderable, a problem that is exacerbated for fine-pitch parts.
3. Please indicate if the negative environmental, health and/or consumer safety impacts caused by substitution are likely to outweigh the environmental, health and/or consumer safety benefits. **If existing, please refer to relevant studies on negative impacts caused by substitution.**	We are not aware of any significant health or environmental risks posed by the substitutes for Sn-Pb platings on fine-pitch components, However, this exemption is necessary to ensure the reliability of products that use fine pitch electronic components. It would reduce product failure risk from tin whiskers for devices ranging from electronic cameras and mobile phones, to PCs and office equipment, to large servers and telecommunications equipment. For electronic products used in safety-critical applications, such failures could result in safety risks for the public. Furthermore, without this exemption, products will become WEEE prematurely, placing an undue burden on both consumers, and the recovery and recycling infrastructure in the European Union.
4. Please indicate if feasible substitutes currently exist in an industrial and/or commercial scale. **Please indicate the possibilities and/or the status for the development of substitutes and indicate if these substitutes will be available by 1 July 2006 or at a later stage.**	Leading electronics manufacturers have been working with their supply chain partners to find alternative solutions for Pb-free terminal platings that do not contain tin (and are therefore not at risk for tin whisker problems). One solution being examined is the use of layered nickel/palladium (Ni/Pd) and nickel/palladium/gold (Ni/Pd/Au) platings. From a technical standpoint, these platings are acceptable, and

	indeed have been used in certain applications for many years. Unfortunately, at present these platings are not widely available on fine-pitch electronic component terminations. Furthermore, there is currently no accepted technical solution for these platings on parts using iron-nickel alloy terminations (for example, memory devices). Although component suppliers have known for several years that RoHS legislation would restrict the use of Sn-Pb platings, few of them developed Ni/Pd or Ni/Pd/Au solutions. Instead, suppliers worked to develop tin-based Pb-free platings because it was believed that alloying and other strategies would solve the whisker problem. It did not. Now these suppliers are caught between the reality that whiskers form and the demands of their customers for Pb-free platings in order to meet RoHS requirements, so they must meet this demand with what solutions they have. Simply switching from tin-based to Ni/Pd or Ni/Pd/Au solutions is not simple and will take time and capital investment to accomplish. This is because the manufacturing methods involved are quite different for the two solutions, requiring significant development by suppliers to make this change. For tin-based platings, the electroplating is deposited after the metal leadframe is attached to the component and the terminations are bent into their final form. For Ni/Pd and Ni/Pd/Au platings, however, the electroplating is performed on the leadframe prior to attachment to the component and bending of the terminations. Therefore, considerable time and effort will be needed to convert a sufficient fraction of the world-wide fine-pitch component supply base to this solution in order to assure uninterrupted supply of electronic products into Europe.

	The need to exempt the use of Pb in platings for fine-pitch electronic components is proposed to expire on January 1, 2010. The period covered by this exemption would provide the electronics industry the time required either to find a solution to the tin whisker issues and/or to convert to palladium based (Ni/Pd and Ni/Pd/Au) platings.
5. Please indicate if any current restrictions apply to such substitutes. **If yes, please quote the exact title of the appropriate legislation/regulation.**	No legal restrictions currently would apply to Ni/Pd/Au platings on electrical component terminations, were these sufficiently available. No legal restrictions currently would apply to any of the other potential substitutes, though as described earlier, there are technical reasons why such substitutes are impracticable.
6. Please indicate the costs and benefits and advantages and disadvantages of such substitutes. **If existing, please refer to relevant studies on costs and benefits of such substitutes.**	In general, there are no significant advantages to the substitutes for Sn-Pb platings, either technically or economically. The disadvantage to the tin-based substitutes is that affected products are likely to be prematurely discarded for recycling due to tin whisker failures. This impact is potentially very significant because of the number and variety of products that contain fine-pitch components and, therefore, can be affected by tin whisker failures. Such equipment spans the entire spectrum of electronic products: from electronic cameras and mobile phones, to PCs and office equipment, to large servers and telecommunications equipment. Of course, such failures will cause customer dissatisfaction and increased costs, as well public safety risks for equipment used in safety critical applications. The disadvantage to the layered nickel/palladium (Ni/Pd) and nickel/palladium/gold (Ni/Pd/Au) platings is that their current unavailability would severely limit shipment of electronic equipment into Europe.

7. Please provide any other relevant information that would support your application for an additional exemption.	

Table 1. Summary of issues related to potential substitutes for Sn-Pb electroplating on fine-pitch electronic components prior to 1 January 2010.

	Tin-based electroplatings (including Sn, Sn-Bi, Sn-Ag, Sn-Cu)	Ni/Pd & Ni/Pd/Au electroplatings	Hot-dipped tin-based platings	Ag electroplatings	Ni/Au platings
Technical Issues	1. Growth of tin whiskers that can cause premature product failures. 2. Poor technical understanding, conflicting data, control processes not in place industry wide. 3. Reliability risk is unquantified and uncontrolled.	1. No accepted solution for Fe-Ni terminations. 2. For other components, no significant technical issues for the majority of applications. Has been used for more than a decade for a limited number of parts.	1. Not applicable to fine-pitch components due to "bridging" of material across closely spaced terminations. Such bridging renders the component non functional.	1. Not applicable due to growth of silver dendrites that create short circuits across closely spaced terminations, rendering the component non functional. 2. Poor solderability to the printed circuit board.	1. Immersion processes not applicable due to "bridging" of material across closely spaced leads. 2. Thick Au layers deposited electrolytically would be needed to avoid porosity problems.
Supply Issues	No anticipated issues.	1. Currently unavailable for Fe-Ni terminations. 2. For other terminations, only available from a small number of suppliers and for a small number of parts. Conversion to these platings industry wide would take significant time and effort.	Not available due to the technical incompatibility for fine-pitch parts.	Not available due to the technical incompatibility for fine-pitch parts.	Not available due to prohibitive cost, especially since thick electroplated layers of Au would be needed.

EICTA POSITION

1st February 2005

Stakeholders consultation on adaptation to scientific and technical progress under Directive 2002/95/EC of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the purpose of a possible amendment of the Annex. (Document sent out by the European Commission in December 2004).

1. Lead in tin whisker resistant coatings for fine pitch applications

The studies from iNEMI show the current status of experiments measuring whisker growth and the amazing range of tin whisker length that could result in product failure, depending on the spacing between adjacent terminations on components of various pitches. Neglecting the negative effects of whiskers in high frequency applications, the iNEMI document demonstrates that whiskers on adjacent terminations may grow towards each other, touch, and cause failure, thus creating the potential of product failure when whiskers grow to half the distance between terminations. This situation is demonstrated in figure 1 of the iNEMI paper. Combining this situation with the analysis of spacing between adjacent leads as a function of pitch, suggests the need to extend this exemption to all electrical component terminations, not just those of 0.65 mm or less (see Table 1 of the iNEMI document). This proposal is supported by the iNEMI data (figure 2 of the iNEMI document) showing that whiskers of critical lengths can grow in relatively short term experiments, which could cause failures of components of virtually any pitch (and thus the products in which they reside).

- Do feasible substitutes currently exist in an industrial and/or commercial scale?

No feasible substitutes currently exist in an industrial and/or commercial scale.

Leading electronics manufacturers have been working with their supply chain partners to find alternative solutions for Pb-free terminal platings that do not contain tin (and are therefore not at risk for tin whisker problems). One solution being examined is the use of layered nickel/palladium (Ni/Pd) and nickel/palladium/gold (Ni/Pd/Au) platings. From a technical standpoint, these platings are acceptable, and indeed have been used in certain applications for many years. Unfortunately, at present these platings are not widely available on fine-pitch electronic component terminations. Furthermore, there is currently no accepted technical solution for these platings on parts using iron-nickel alloy terminations (for example, memory devices).

Although component suppliers have known for several years that RoHS legislation would restrict the use of Sn-Pb platings, few of them developed Ni/Pd or Ni/Pd/Au solutions. Instead, suppliers worked to develop tin-based Pb-free platings because it was believed that alloying and other strategies would solve the whisker problem. It did not. Now these suppliers are caught between the reality that whiskers form and the demands of their customers for Pb-free platings in order to meet RoHS requirements, so they must meet this demand with what solutions they have. Simply switching from tin-based to Ni/Pd or Ni/Pd/Au solutions is not simple and will take time and capital investment to accomplish. This is because the manufacturing methods involved are quite different for the two solutions, requiring significant development by suppliers to make this change. For tin-based platings, the electroplating is deposited after the metal leadframe is attached to the component and the terminations are bent into their final form. For Ni/Pd and Ni/Pd/Au platings, however, the electroplating is performed on the leadframe prior to attachment to the component and bending of the terminations. Therefore, considerable time and effort will be needed to convert a sufficient fraction of the world-wide fine-pitch component supply base to this solution in order to assure uninterrupted supply of electronic products into Europe.

Please refer to exemption requests listed in the stakeholder consultation for further information on substitutes.

- Do any restrictions apply to such substitutes?

No legal restrictions currently would apply to Ni/Pd/Au platings on electrical component terminations, were these sufficiently available. No legal restrictions currently would apply to any of the other potential substitutes, though as described earlier, there are technical reasons why such substitutes are impracticable.

For gold plating the same rational would apply as given in exemption number 7.

- What are the costs and benefits and advantages and disadvantages of such substitutes?

The disadvantage to the tin-based substitutes is that affected products are likely to be prematurely discarded for recycling due to tin whisker failures. This impact is potentially very significant because of the number and variety of products that contain fine-pitch components and, therefore, can be affected by tin whisker failures. Such equipment spans the entire spectrum of electronic products: from electronic cameras and mobile phones, to PCs and office equipment, to large servers and telecommunications equipment. Of course, such failures will cause customer dissatisfaction and increased costs, as well public safety risks for equipment used in safety critical applications.

The disadvantage to the layered nickel/palladium (Ni/Pd) and nickel/palladium/gold (Ni/Pd/Au) platings is that their current unavailability would severely limit shipment of electronic equipment into Europe.