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

Final report

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1 Executive Summary

On the basis of the Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment ("RoHS Directive") the European Commission has contracted Öko-Institut together with Fraunhofer IZM in order to evaluate and to assess both, existing exemptions listed in the Annex of the RoHS Directive based as well as five new requests. Basis for this evaluation are the criteria given in Article 5 (1) (b) of the directive.

In summary the following objectives were pursued:

1. Execute a clear assessment on whether five new requests for exemptions are justified in line with the criteria given in Article 5 (1) (b);
2. Perform a detailed review of existing exemptions listed in the Annex of the RoHS Directive based on the criteria for exemptions in Article 5 (1) (b);
3. Provide the involvement and consultation of stakeholders (inter alia producers of electrical and electronic materials, components and equipment, recyclers, treatment operators, environmental organisations, employee and consumer associations), including set up and continuous maintenance of an account / a website;
4. Provide recommendations for a clear and unambiguous wording of the reviewed and new exemptions

The following table gives an overview of the 29 existing exemptions subject to the review and the recommendations given by the contractor.

Table 1 Overview RoHS exemptions

<table>
<tr><th>No.</th><th>Current title</th><th>New No.</th><th>Recommendation</th><th>New Wording proposal</th></tr>
<tr><td rowspan="6">1</td><td rowspan="6">Mercury in compact fluorescent lamps not exceeding 5 mg per lamp</td><td rowspan="6">1</td><td rowspan="6">Continue with amended wording (expiry date 31 July 2014 except for general lighting purposes >150W)</td><td>Mercury in single capped fluorescent lamps not exceeding (per burner):</td></tr>
<tr><td>For general lighting purposes < 50W: 3,5 mg</td></tr>
<tr><td>For general lighting purposes ≥ 50W and < 150: 5 mg</td></tr>
<tr><td>For general lighting purposes > 150W: 15 mg (expiry date 31 December 2012)</td></tr>
<tr><td>For general lighting purposes with circular or square structural shape and tube diameter ≤ 17 mm: 7 mg</td></tr>
<tr><td>For special purposes: 5 mg</td></tr>
<tr><td rowspan="11">2</td><td rowspan="11">Mercury in straight fluorescent lamps for general purposes
– halophosphate 10 mg
– triphosphate with normal lifetime 5 mg
– triphosphate with long lifetime 8 mg</td><td rowspan="6">2a</td><td rowspan="11">Continue with amended wording, two exemptions (expiry date 31 July 2014)</td><td>Mercury in double-capped linear fluorescent lamps for general purposes not exceeding</td></tr>
<tr><td>Tri-band phosphor with normal lifetime T2: 4 mg</td></tr>
<tr><td>Tri-band phosphor with normal lifetime > T2 and ≤ T5: 3 mg</td></tr>
<tr><td>Tri-band phosphor with normal lifetime > T5 and ≤ T8 and < 183 cm: 3,5 mg</td></tr>
<tr><td>Tri-band phosphor with normal lifetime > T8 and ≤ T12: 3,5 mg</td></tr>
<tr><td>Tri-band phosphor with long lifetime: 5 mg</td></tr>
<tr><td rowspan="5">2b</td><td>Mercury in other fluorescent lamps not exceeding:</td></tr>
<tr><td>Halophosphates all shapes: 8 mg</td></tr>
<tr><td>T5 non-linear tri-band phosphor lamps: 8 mg</td></tr>
<tr><td>T9 non-linear tri-band phosphor lamps: 15 mg</td></tr>
<tr><td>Induction lamps: 15 mg</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">Mercury in straight fluorescent lamps for special purposes</td><td rowspan="4">3</td><td rowspan="4">Continue with amended wording but review the applicability by 31 December 2012</td><td>Mercury in cold cathode fluorescent lamps:</td></tr>
<tr><td>Mercury in short length (not over 500 mm) cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) not exceeding 3,5 mg per lamp until 31.12.2012</td></tr>
<tr><td>Mercury in medium length (over 500mm and not over 1500 mm) cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) not exceeding 5 mg per lamp until 31.12.2012;</td></tr>
<tr><td>Mercury in long length (over 1500 mm) cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) not exceeding 13 mg per lamp until 31.12.2012.</td></tr>
</table>

4	Mercury in other lamps not specifically mentioned in this Annex	4a-I	Continue with amended wording, two exemptions (expiry date 31 July 2014)	Mercury in **High Pressure Sodium** (vapour) lamps for general lighting purposes not exceeding in lamps with improved colour rendering index > 60
				P ≤ 155 W: 30 mg per burner
				155 < P ≤ 405 W: 40 mg per burner
				P > 405 W: 40 mg per burner
				Mercury in **High Pressure Sodium** (vapour) lamps for general lighting purposes not exceeding in other High Pressure Sodium (vapour) lamps
				P ≤ 155 W: 25 mg
				155 < P ≤ 405 W: 30 mg per burner
				P > 405 W: 40 mg per burner
				– P > 405 W: 25 mg
		4a-II		Mercury in **High Pressure Mercury** (Vapour) lamps except for general lighting (HPMV)
		4a-III		Mercury in **Metal halide lamps** (MH)
		4b		Mercury in **other discharge lamps** for special purpose not specifically mentioned in this Annex
5	Lead in glass of cathode ray tubes, electronic components and fluorescent tubes		Continue with amended wording (3 parts)	► Lead in glass of cathode ray tubes. Assuming that each exemption is required to have an expiry date, the consultants propose 31 July 2014 to give the stakeholders opportunities to submit evidence in the next review of the Annex for the further need of this exemption beyond 2014, if appropriate.
				► Lead in the glass of fluorescent tubes not exceeding 0,2% by weight. Expiry date: 31 July 2014.
				► Electrical and electronic components which contain lead in a glass or ceramic other than a dielectric ceramic, or in a glass or ceramic matrix compound (e.g. piezoelectronic devices) until 31 July 2014, and for the repair, and to the reuse, of equipment put on the market before 1 January 2015
6	Lead as an alloying element in steel containing up to 0,35% lead by weight, aluminium containing up to 0,4% lead by weight and as a copper alloy containing up to 4% lead by weight		Continue with amended wording (expiry date 31 July 2014)	(6a). Lead as an alloying element in steel for machining purposes and in galvanized steel containing up to 0,35% lead by weight
				(6b). Lead as an alloying element in aluminium containing up to 0,4% lead by weight
				(6c). Copper alloy containing up to 4% lead by weight

7a	Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead)		Continue with amended wording (expiry date30 June 2013)	Lead in high melting temperature type solders (i.e. lead-based alloys containing 85% by weight or more lead) until 30 June 2013, and lead in such solders for the repair and reuse of equipment put on the market before 1 July 2013.
7b	Lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signalling, transmission as well as network management for telecommunications.		Continue with amended wording (expiry date 31 July 2014)	Lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signalling, transmission as well as network management for telecommunications, until 31 July 2014, and for the repair or the reuse of such equipment put on the market before 1 August 2014.
7c	Lead in electronic ceramic parts (e.g. piezoelecronic devices)		Continue with amended wording (3 parts)	Electrical and electronic components which contain lead in a glass or ceramic other than a dielectric ceramic or in a glass or ceramic matrix compound, (e.g. piezoelectronic devices) until 31 July 2014, and for the repair, and to the reuse, of equipment put on the market before 1 August 2014.
				Electrical and electronic components for a voltage of 125 V AC or 250 V DC or higher which contain lead in a dielectric ceramic until 31 July 2014, and for the repair, and to the reuse, of equipment put on the market before 1 August 2014.
				Electrical and electronic components for a voltage of less than 125 V AC or 250 V DC which contain lead in a dielectric ceramic until 31 December 2012, and for the repair, and to the reuse, of equipment put on the market before 1 January 2013.
8	Cadmium and its compounds in electrical contacts and cadmium plating except for applications banned under Directive 91/338/EEC amending Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations.		Continue with amended wording (expiry date 31 December 2011 and 31 July 2014)	8a) Cadmium and its compounds in one shot pellet type thermal cut-offs until 31 December 2011 and in one shot pellet type thermal cut-offs used as spare parts for the reuse and repair of equipment put on the market before 1 January 2012. 8b) Cadmium and its compounds in electrical contacts until 31 July 2014, and in electrical contacts in spare parts used for the repair and reuse of equipment put on the market before 1 August 2014.

9	Hexavalent chromium as an anti-corrosion of the carbon steel cooling system in absorption refrigerators		Continue with amended wording (expiry date 31 July 2014)	Hexavalent chromium as an anti-corrosion agent of the carbon steel cooling system in absorption refrigerators up to 0,75 weight-% in the cooling solution except for applications where the use of other cooling technologies is practicable (i.e. available on the market for the specific area of application) and does not lead to negative environmental, health and/or consumer safety impacts.
9a	DecaBDE in polymeric applications		Recommendation obsolete	
9b	Lead in lead-bronze bearing shells and bushes		Continued with amended wording (expiry date 31 July 2014)	Lead in bearing shells and bushes for refrigerant-containing compressors for HVACR applications, with expiry date of 31 July 2014.
11	Lead used in compliant pin connector systems.		Continue with amended wording (expiry date 30 June 2010)	(11a) 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
				(11b) 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
12	Lead as a coating material for the thermal conduction module c-ring.		Continue with amended wording (expiry date 30. June 2010)	Lead as a coating material for the thermal conduction module C-ring 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.
13	Lead and cadmium in optical and filter glass		Continue with amended wording (expiry date 31 July 2014)	(13a) Lead in white glasses used for optical applications.
				(13b) Cadmium and lead in filter glasses and glasses used for reflectance standards.
14	Lead in solders consisting of more than two elements for the connection between the pins and the package of microprocessors with a lead content of more than 80% and less than 85% by weight.		Continue with amended wording (expiry date 31 December 2010)	Lead in solders consisting of more than two elements for the connection between the pins and the package of microprocessors with a lead content of more than 80% and less than 85% by weight until 31 December 2010, and for the repair and reuse of products that were put on the market before 1 January 2011.
15	Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit Flip Chip packages.		Continue with amended wording (expiry date 31 July 2014)	Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages until 31 July 2014, and for the repair, or to the reuse, of electrical and electronic equipment put on the market before 1 August 2014.

16	Lead in linear incandescent lamps with silicate coated tubes.		Not to be continued (transition period until mid 2011)	
17	Lead halide as radiant agent in High Intensity Discharge (HID) lamps used for professional reprography applications.		Continue exemption (expiry date 31 July 2014)	Lead halide as radiant agent in High Intensity Discharge (HID) lamps used for professional reprography applications.
18	Lead as activator in the fluorescent powder (1 % lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP (BaSi2O5:Pb) as well as when used as speciality lamps for diazo-printing reprography, lithography, insect traps, photochemical and curing processes containing phosphors such as SMS ((Sr,Ba)2MgSi2O7:Pb).		Not to be continued (transition period until mid 2011) except for sun tanning lamps (expiry date 31 July 2014)	Lead as activator in the fluorescent powder (1% lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP (BaSi2O5:Pb) - expiry date 31 July 2014.
19	Lead with PbBiSn-Hg and PbInSn-Hg in specific compositions as main amalgam and with PbSn-Hg as auxiliary amalgam in very compact Energy Saving Lamps (ESL).		Not to be continued (transition period until mid 2011)	Lead with PbBiSn-Hg and PbInSn-Hg in specific compositions as main amalgam and with PbSn-Hg as auxiliary amalgam in very compact Energy Saving Lamps (ESL).
20	Lead oxide in glass used for bonding front and rear substrates of flat fluorescent lamps used for Liquid Crystal Displays (LCD)		Not to be continued (transition period until mid 2011)	
21	Lead and cadmium in printing inks for the application of enamels on borosilicate glass.		Continue (expiry date 31 July 2014)	Lead and cadmium in printing inks for the application of enamels on borosilicate glass (expiry date 31 July 2014).
22	Lead as impurity in RIG (rare earth iron garnet) Faraday rotators used for fibre optic communications systems.		Continue (expiry date 31 December 2009)	Lead as impurity in RIG (rare earth iron garnet) Faraday rotators used for fibre optic communication systems until 31 December 2009.
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.		Continue with amended wording (expiry date 30 June 2010)	Lead in finishes of fine pitch components others than connectors with a pitch of 0.65 mm and less until 30 June 2010, and lead in the finishes of such fine pitch components used as spare parts for the repair and reuse of equipment put on the market before 1 July 2010.
24	Lead in solders for the soldering to machined through hole discoidal and planar array ceramic multilayer capacitors.		Continue (expiry date 31 July 2014)	Lead in solders for the soldering to machined through hole discoidal and planar array ceramic multilayer capacitors until 31 July 2014, and for repair and reuse of equipment put on the market before 1 August 2014.

25	Lead oxide in plasma display panels (PDP) and surface conduction electron emitter displays (SED) used in structural elements; notably in the front and rear glass dielectric layer, the bus electrode, the black stripe, the address electrode, the barrier ribs, the seal frit and frit ring as well as in print pastes.		Continue with amended wording (expiry date 31 July 2014)	Lead oxide in surface conduction electron emitter displays (SED) used in structural elements; notably in the seal frit and frit ring.
26	Lead oxide in the glass envelope of Black Light Blue (BLB) lamps.		Not to be continued (transition period until mid 2011)	
27	Lead alloys as solder for transducers used in high-powered (designated to operate for several hours at acoustic power levels of 125 dB SPL and above) loudspeakers.		Not to be continued (no transition period)	
28	Hexavalent chromium in corrosion preventive coatings of unpainted metal sheetings and fasteners used for corrosion protection and Electromagnetic Interference Shielding in equipment falling under category three of Directive 2002/96/EC (IT and telecommunications equipment). Exemption granted until 1 July 2007		Not to be continued (already expired)	
29	Lead bound in crystal glass as defined in Annex I (Categories 1, 2, 3 and 4) of Council Directive 69/493/EEC (*). (*) OJ L 326, 29.12.1969, p. 36		Continue (expiry date 31 July 2014)	Lead bound in crystal glass as defined in Annex I (Categories 1, 2, 3 and 4) of Council Directive 69/493/EEC.

The following table gives an overview of the 5 existing exemption requests subject to the review and the recommendations given by the contractor.

Table 2 Overview RoHS exemption requests

No.	Topic	Recommendation	Wording
1	Lead in Solders for the connection of very thin enamelled wires with a terminal	No clear recommendation possible	
2	Lead and Cadmium as components of the glazes and colour used to glaze or decorate lamp bases, lamp carriers or clocks	No clear recommendation possible	Lead and cadmium in glazes and colors used on ceramic lamp bases, lamp carriers and clocks until 31 July 2014.
3	Pb in solder of Cortex component	Refuse	
4	Cadmium within a color converting single crystal semiconductor film for use in solid state illumination or display systems	Grant (expiry date 31 July 2014)	Cadmium in colour converting II-VI LEDs (< 10 µg Cd per mm2 of light-emitting area) for use in solid state illumination or display systems
5	Lead in solders for the connection of very thin (<100 µm) enamelled copper wires and for the connection of enamelled clad aluminium wires (CCAWs) with a copper layer smaller than 20 µm.	No clear recommendation possible	

Beyond these specific recommendations some general considerations are given in Chapter 5 relating to transition periods, expiry dates and “Grandfathering” and whole product units as spare parts.

2 Background and Objectives

Article 4 (1) of Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment ("RoHS Directive") 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).

Article 5 (1) (b) of the Directive provides that materials and components of electrical and electronic equipment can be exempted from the substance restrictions contained in 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 outweigh the environmental, health and/or consumer safety benefits thereof.

On the basis of this provision, the Commission has received (and is still receiving) additional requests for applications to be exempted from the requirements of the Directive from industry. These requests need to be evaluated in order to assess whether they fulfil the above mentioned requirements of Article 5 (1) (b). Where the requirements are fulfilled the Commission may propose a Draft Decision amending the RoHS Directive and its Annex.

Furthermore, based on Article 5 (1) (c), the Commission shall carry out a review of each exemption listed in the Annex at least every four years or four years after an item is added to the list. Thus, also the deletion of materials and components of electrical and electronic equipment from the existing Annex has to be considered if their elimination or substitution is possible with regard to the criteria listed in Article 5 (1) (b) (see above).

As the RoHS Directive has entered into force on 1 July 2006 the first review of the Annex shall be done by 2010. Through assessment and evaluation of the existing exemptions and new exemption requests, a basis shall be provided for the forthcoming review of the Annex.

With regard to the above, the Commission has contracted Öko-Institut together with Fraunhofer IZM in order to fulfil the following objectives:

1. Execute a clear assessment on whether five new requests for exemptions are justified in line with the criteria given in Article 5 (1) (b);
2. Perform a detailed review of existing exemptions listed in the Annex of the RoHS Directive based on the criteria for exemptions in Article 5 (1) (b);
3. Provide the involvement and consultation of stakeholders (inter alia producers of electrical and electronic materials, components and equipment, recyclers, treatment operators, environmental organisations, employee and consumer associations), including set up and continuous maintenance of an account / a website;

4. Provide recommendations for a clear and unambiguous wording of the reviewed and new exemptions.

This final report gives an overview on all the results gathered during the assignment.

3 Scope

The scope of this study comprised both the evaluation of *i)* existing exemptions listed in the Annex to the RoHS Directive and *ii)* new exemption requests. Table 3 gives an overview on the thematic groups that have been set up in order to cluster the exemptions and new requests. Table 4 lists existing exemptions of the RoHS Directive's Annex that have been evaluated by Öko-Institut together with Fraunhofer IZM. The five new exemption requests received by the European Commission that were evaluated are listed there, too.

Table 3 Thematic groups

Group	Description
I	Hg + heavy metals in lamps
II	PB in solder / soldering technology
III	Pb in glass technology
IV	Pb in metals
V	Cd in electrical contacts
VI	CrVI applications
VII	Brominated flame retardants (BFR)

Table 4 Overview on exemptions listed in the RoHS Annex and new requests

No.	Topic	Group
Exemptions		
1	Mercury in compact fluorescent lamps not exceeding 5 mg per lamp	I
2	Mercury in straight fluorescent lamps for general purposes not exceeding: - halophosphate 10 mg - triphosphate with normal lifetime 5 mg - triphosphate with long lifetime 8 mg	I
3	Mercury in straight fluorescent lamps for special purposes	I
4	Mercury in other lamps not specifically mentioned in this Annex	I
5	Lead in glass of cathode ray tubes, electronic components and fluorescent tubes	III
6	Lead as an alloying element in steel containing up to 0,35% lead by weight, aluminium containing up to 0,4% lead by weight and as a copper alloy containing up to 4% lead by weight	IV

No.	Topic	Group
7	▪ Lead in high melting temperature type solders (i.e. lead-based alloys containing 85% by weight or more lead), ▪ lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signalling, transmission as well as network management for telecommunications, ▪ lead in electronic ceramic parts (e.g. piezoelectronic devices)[1]	II
8	Cadmium and its compounds in electrical contacts and cadmium plating except for applications banned under Directive 91/338/EEC (*) amending Directive 76/769/EEC (**) relating to restrictions on the marketing and use of certain dangerous substances and preparations. (*) OJ L 186, 12.7.1991, p. 59. (**) OJ L 262, 27.9.1976, p. 201.[2]	V
9	Hexavalent chromium as an anti-corrosion of the carbon steel cooling system in absorption refrigerators	VI
9a	DecaBDE in polymeric applications	VII
9b	Lead in lead-bronze bearing shells and bushes	IV
10	(Entry no. 10 of the Annex does not contain a wording for an exemption but rather a reference to an evaluation the Commission shall do according to Article 7 (2) and is therefore not cited here.)	
11	Lead used in compliant pin connector systems.	II
12	Lead as a coating material for the thermal conduction module c-ring.	IV
13	Lead and cadmium in optical and filter glass.	III
14	Lead in solders consisting of more than two elements for the connection between the pins and the package of microprocessors with a lead content of more than 80% and less than 85% by weight.	II
15	Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit Flip Chip packages.	II
16	Lead in linear incandescent lamps with silicate coated tubes.	I
17	Lead halide as radiant agent in High Intensity Discharge (HID) lamps used for professional reprography applications.	I
18	Lead as activator in the fluorescent powder (1% lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP (BaSi2O5:Pb) as well as when used as speciality lamps for diazo-printing reprography, lithography, insect traps, photochemical and curing processes containing phosphors such as SMS ((Sr,Ba)2MgSi2O7:Pb).	I
19	Lead with PbBiSn-Hg and PbInSn-Hg in specific compositions as main amalgam and with PbSn-Hg as auxiliary amalgam in very compact Energy Saving Lamps (ESL).	I
20	Lead oxide in glass used for bonding front and rear substrates of flat fluorescent lamps used for Liquid Crystal Displays (LCD).	III
21	Lead and cadmium in printing inks for the application of enamels on borosilicate glass.	III
22	Lead as impurity in RIG (rare earth iron garnet) Faraday rotators used for fibre optic communications systems.	III

[1] Original 27 Jan 2003:

- Lead in high melting temperature type solders (i.e. tin-lead solder alloys containing more than 85% lead),
- lead in solders for servers, storage and storage array systems (exemption granted until 2010),
- lead in solders for network infrastructure equipment for switching, signalling, transmission as well as network management for telecommunication,
- lead in electronic ceramic parts (e.g. piezoelectronic devices).

[2] Original 27 Jan 2003: Cadmium plating except for applications banned under Directive 91/338/EEC (*) amending Directive 76/769/EEC (**) (*) OJ L 186, 12.7.1991, p. 59. (**) OJ L 262, 27.9.1976, p. 201.

No.	Topic	Group
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.	II
24	Lead in solders for the soldering to machines through hole discoidal and planar array ceramic multilayer capacitors.	II
25	Lead oxide in plasma display panels (PDP) and surface conduction electron emitter displays (SED) used in structural elements; notably in the front and rear glass dielectric layer, the bus electrode, the black stripe, the address electrode, the barrier ribs, the seal frit and frit ring as well as in print pastes.	III
26	Lead oxide in the glass envelope of Black Light Blue (BLB) lamps.	III
27	Lead alloys as solder for transducers used in high-powered (designated to operate for several hours at acoustic power levels of 125 dB SPL and above) loudspeakers.	II
28	Hexavalent chromium in corrosion preventive coatings of unpainted metal sheetings and fasteners used for corrosion protection and Electromagnetic Interference Shielding in equipment falling under category three of Directive 2002/96/EC (IT and telecommunications equipment). Exemption granted until 1 July 2007.	VI
29	Lead bound in crystal glass as defined in Annex I (Categories 1, 2, 3 and 4) of Council Directive 69/493/EEC (*). (*) OJ L 326, 29.12.1969, p. 36.	III
Requests		
1	Lead in solders for the connection of very thin enamelled wires with a terminal	II
2	Lead and Cadmium as components of the glazes and colour used to glaze or decorate lamp bases, lamp carriers or clocks	I
3	Lead in solders in a third party component of Cortex family equipment	II
4	Cadmium for use in solid-state illumination & display systems	I
5	Lead in solders for the connection of very thin (<100 µm) enamelled copper wires and for the connection of enamelled clad aluminium wires (CCAWs) with a copper layer smaller than 20 µm	II

Exemption 28 has expired on 1 July 2007 and is thus automatically deleted from the Annex.

4 Recommendations

Within the duration of the contract between October 2007 and November 2008, three sets of public stakeholder consultation were evaluated.

On 28 January 2008 the first stakeholder consultation round was launched on the project website (http://rohs.exemptions.oeko.info/) and closed on 1 April 2008. This consultation covered 29 current exemptions to the RoHS Directive as well as the new exemption requests 1, 2 and 3 (see Table 4).

A second stakeholder consultation concerning exemption request 4 "Cadmium for use in solid-state illumination & display systems" was launched 29 May 2008 and ran until 31 July 2008.

A third stakeholder consultation concerning exemption request 5 "Lead in solders for the connection of very thin (<100 µm) enamelled copper wires and for the connection of enamelled clad aluminium wires (CCAWs) with a copper layer smaller than 20 µm" started the 13 August 2008 and was closed on 8 October 2008.

After a first evaluation process Öko-Institut and Fraunhofer IZM held several stakeholder meetings in June. During the preparation of these meeting sessions the technical stakeholder meeting on exemption 9(a) "DecaBDE in polymeric applications" which was originally scheduled for 13 June from 9:00–12:30 had to be cancelled. This was due to the fact that on 1 April 2008 the European Court of Justice (ECJ) had issued a judgement which rules that from 30 June 2008 onwards DecaBDE shall be banned in all applications falling under the scope of RoHS. The European Commission has accepted the ECJ ruling meaning that the exemption will be deleted from the Annex. A discussion on technical and scientific pros and cons of a possible exemption was thus not necessary.

Since this case had not been foreseen at the beginning of the contract on the evaluation of RoHS exemptions, the Commission first needed to decide on how to proceed with the information collected during the online stakeholder consultation in the light of these recent events. Afterwards the contractor was requested to prepare a summary on the already collected stakeholder information for the Commission (see section 4.15).

In the following sections the exemptions are described in-depth.

4.1 Exemption Nos. 1–4 General considerations on mercury in lamps

The 4 existing exemptions for the use of mercury in lamps are the first one listed in the RoHS Annex and thus among the ones having been valid for the longest time. Out of the 4, only the currently valid exemption 3 was subject to a public scientific and technical evaluation which has been reported by ERA [6].

The function of mercury in lamps lies within the light generating process to convert electricity into light. A detailed explanation is given by ELC:

“Electrons are emitted from a heated electrode colliding with mercury atoms and so transferring energy to the atoms which elevates them to an excited state. When these atoms fall back to their original status they emit photons (packages of energy), normally not in the range of visible light. Ultraviolet photons excite the fluorescent powders, which are coated on the inside of the tube, with a high degree of efficiency. As a result these emit visible radiation in a range of colours. Lamps based on these principles and operating at low internal gas pressure are called ‘fluorescent lamps’”.

In the context of the current contract, exemptions 1-4 have been subject to the first stakeholder consultation. A large number of stakeholder contributions have been received (cf. http://rohs.exemptions.oeko.info/index.php?id=61).

Following the consultation, stakeholders have been invited to participate in a technical stakeholder meeting on 10 June 2008. Further on, extensive exchange has taken place with stakeholders (mainly ELCF[3], environmental NGOs[4], JBCE[5], EICTA[6] and AeA[7]) before another meeting took place on 24 September with ELC, environmental NGOs, an independent Swedish expert representing the Swedish Consultant AF[8], Megaman[9], JBCE[10] and JELMA[11]. Prior to this latter meeting, the consultant had sent out a proposal for discussion to stakeholders including:

- Proposal on lamp type classification to be used as a basis for setting mercury content limits for certain groups of lamp types;

3 European Lamp Companies Federation

4 Representing the European Environmental Bureau (EEB), the Zero Mercury Campaign and the Green Purchasing Institute.

5 Japanese Business Council in Europe

6 European Information & Communications Technology Industry Association

7 AeA Europe: association of high tech companies of American parentage doing business of more than € 100 billion in Europe.

8 AF has compiled a report on the use of mercury in lamps in light of the RoHS Annex review [AF report]

9 Megaman is a European lamp manufacturer of compact fluorescent lamps.

10 Japanese Business Council in Europe

11 Japan Electric Lamp Manufacturers Association

- Proposal on new mercury limit values on the basis of the classification proposal;
- Open points for discussion (interpretation of Hg limit values, front runner vs. BAT vs. large market segments, lifetime, diameter-dependent limit values for linear fluorescent lamps, LED as a possible substitute, application-specific provisions, category 8&9 issues, substitution at application level, need for a “miscellaneous” exemption, transition period, expiry date and spare parts).

As an outcome of the meeting, the consultant sent out open questions that stakeholders would need to answer in order to allow for a final assessment with regard to a proposal for amended exemptions on the use of mercury in lamps. The consultant has received very extensive feedback from stakeholders which has been used for the formulation of recommendations. An overview on stakeholder involvement and progress made during the course of the project is given in the Annex.

However, despite extensive stakeholder involvement and fruitful discussions, there are three very opposing and different views remaining on how new mercury limits should be set ([1], [3], [4]). As far as possible the consultant has tried to make an independent technical and scientific assessment but in some cases this is not possible in the context of a pure evaluation of available information. As a general outcome, the consultant would like to state that in the case of mercury use in lamps a more in-depth study as well as further discussion with relevant stakeholders are needed in order to evaluate all necessary aspects (although the amount of external research has already been very large).

4.1.1 Lamp classification and current exemptions

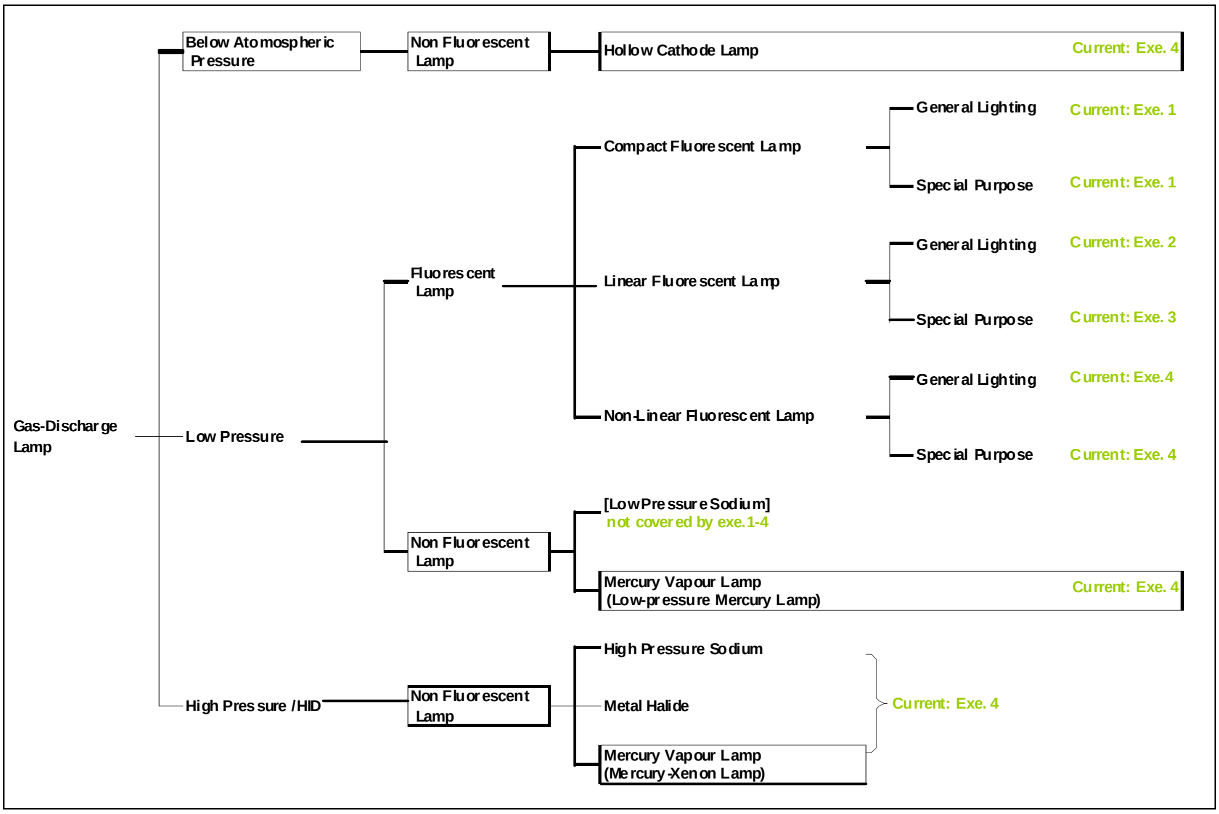

Figure 1 Overview on lamp type classification [4] + own modifications

Figure 1 shows the overall classification of gas discharge lamps to which mercury using lamps belong (as opposed to incandescent lamps). In general, the largest market shares of mercury-containing lamps include compact fluorescent lamps (CFLs) as well as linear and non-linear fluorescent lamps. High-intensity discharge lamps (HID) have until now not been given separate limit values but are an important lamp category that has been evaluated separately in this report. Fluorescent lamps can be divided into general lighting purpose and special purpose as well as compact (CFL), linear (LFL) and non-linear shapes.

Currently, the exemptions cover CFLs as one group, LFL for general purpose and LFL for special purposes as other groups and leaves all other lamps to be covered by exemption 4.

The exact wording being:

1. Mercury in compact fluorescent lamps not exceeding 5 mg per lamp.
2. Mercury in straight fluorescent lamps for general purposes not exceeding:
   a) halophosphate 10 mg;
   b) triphosphate with normal lifetime 5 mg;
   c) triphosphate with long lifetime 8 mg.

3. Mercury in straight fluorescent lamps for special purposes.
4. Mercury in other lamps not specifically mentioned in this Annex.

It should be noted that in the current wording “straight fluorescent lamp” does not correspond to the technically correct term but that “linear fluorescent lamp” should be used instead. Also, “triphosphate” is not the technically correct term and “tri-band phosphor” should be used instead [1].

4.1.2 Link to EuP

Under the EU regulatory instrument on eco-design of energy-using products (EuP), lighting has also been subject to preparatory studies and is subsequently followed by Commission Working Documents as well as Implementing Measures.

With regard to the use of mercury in lamps work on both tertiary sector lighting products (dealt with in Lot 8 and 9) as well as domestic lighting products (dealt with in Lot 19) includes recommendations that relate to the use of mercury in lamps. They have taken into account in the below discussion on mercury limits for the individual lamp types.

4.1.3 Category 8&9 aspects

Many stakeholders have given input on Category 8&9 specificities with regard to the use of mercury in lamps. The manufacturer Hamamatsu Photonics (represented within JBCE) has for instance introduced the use of mercury in special lamps using primary mercury line and continuous spectra [7]. These lamps are not fluorescent and not necessarily high pressure and can be marketed as Hollow Cathode Lamps and Electrodeless Discharge mercury lamps (e.g. used in atomic absorption spectroscopy), Low Pressure Mercury Lamp (e.g. used in absorption spectrometers) or Mercury-Xenon Lamps (e.g. used in water surface inspection systems and belonging to the category of high pressure lamps) – see Figure 1. Also, they can be used for UV Spot Light Source for UV Curing / disinfection. In general, they are used for very specific analytical / measurement applications in environmental, medical, control & measurement and industrial fields and contain very low amount of mercury (total of approximately 1 kg in the EU market) [7].

Until now such lamps were covered by exemption 4 and have thus not been reviewed within the ERA report on category 8&9 equipment [8]. No generally available substitutes exist for mercury in these applications since it is the specific spectral line that is required for those applications [7]. For some applications mercury-free alternatives exist (e.g. Excimer lamps which emit only within narrow wavelength ranges and are thus used only for certain medical applications) [9].

Category 8&9 equipment of course also uses mercury containing lamps as backlights for displays where inter alia colour accuracy is an important feature [9] [10]. Possible substitutes are discussed (e.g. Xenon lamps, LEDs and OLEDs) but all have disadvantages compared to mercury containing backlights even though there might be single applications for which substitution is feasible [9].

As a conclusion it can be stated that mercury containing lamps used in category 8&9 equipment have a wide range of applications and are represented over the whole spectrum of the lamp classification. Until now they were covered by exemption 3 and 4 and thus need to be covered by a new exemption. Concerning current exemption 3, the same argumentation applying to mercury used in display backlights for other type of equipment applies. With regard to current exemption 4, the ELC proposal [1] includes such a new exemption 5. The proposal by environmental NGOs [3] does not cover these kinds of applications.

In the section below, a new exemption 4b is recommended which would cover lamps for special purposes (cf. section 4.5.10) including those lamps belonging to category 8&9 which are not covered by the recommended exemptions 1-4a.

During the consultation process category 8&9 manufacturers represented by JBCE, COCIR, Test&Measurement Coalition have been involved. Their considerations as well as input by ERA have been taken into account. Nevertheless, it is not known to the consultant whether there are any other category 8&9 manufacturers that have particular considerations with regard to mercury content in lamps used in their equipment. Also, the consultant does not know which of these manufacturers considers the lamps used in its equipment as a component which would thus not be considered to fall under the current scope (cf. section 4.1.6).

When including category 8&9 equipment into the scope of RoHS new specific exemptions might thus become necessary. It is therefore recommended to foresee a sufficient transition period between inclusion into the scope and entry into force of the amended RoHS Annex allowing manufacturers to apply for an exemption if necessary.

4.1.4 General considerations on Hg limit values

In the course of discussions, questions arose what exactly is meant when setting a mercury limit in the RoHS Annex – would this refer to a nominal value, an average value or a maximum value including variances.

Environmental NGOs [3] state that the dosing accuracy of modern low-mercury dosing technologies allows for a dosing margin of 10% which is supported by a citation from a scientific journal. They have thus added this margin on market data found with regard to nominal values when putting together their proposal on new mercury limit values [3]: “We have further checked the status of the values indicated in different catalogues, and it seems that these are probably nominal. Nevertheless after recent communication with one major lamp manufacturer, they mentioned that there can be a small variation of +/- 0.3 mg in these nominal values.

This argument is further supported and in a stricter way, as with mercury capsule technology it is possible to achieve a high dosing accuracy and lamps with very low Hg content are produced; even amounts below 1.5 mg can be dosed with a variability lower than 10%. Our recommendations should be considered as maximum values since this margin is mostly built into our suggestions, and considering that there will be still enough time for industry to adapt to the new proposed values by utilising these new more accurate and safer dosing method."

The ELC explains the necessity to set higher limit values than those stated in product documentation as follows [1]:

"In practice, mercury from the discharge gets consumed over lamp life, meaning that it is not available anymore for the proper functioning of the lamp. The mercury gets mostly deposited and effectively bonded to the glass and the phosphor layer. This is reflected by the full curve (1) in Figure 2, which represents more or less a square root relationship with lamp life. The longer the burning time, the higher the amount of mercury needed. The variance in this mercury consumption, as depicted by the arrows, is considerable and depends on many factors (see below for counteracting measures). One could say that, in principle, a fluorescent lamp receives an overdosing of mercury, but that it is required to maintain lamp performance over time.

In order to maintain the properties over lamp life, one determines for a particular lamp design the amount of mercury needed (line 2 in Figure 2). The target mercury dosing (line 3) while taking its own variance into account, should be sufficient to allow for proper lamp life. Alternatively, this target value is called nominal or average value, and can be listed in catalogues.

The solid line 4 in Figure 2 is the line representing the RoHS limit (expressed as mg per lamp), the value of which has to take into account both variances of mercury consumption and of mercury dosing. On the one hand, we like to have this value as low as possible, but on the other hand, it should be safely chosen to (1) eliminate the customer risk of a non-performing product over the designed lamp life and (2) to be able to demonstrate in internal manufacturer's tests and in market surveillance tests, with the least effort, that products comply with the RoHS Directive. This leads to a built-in safety margin on top of the target mercury dose, finally leading to RoHS content limit."

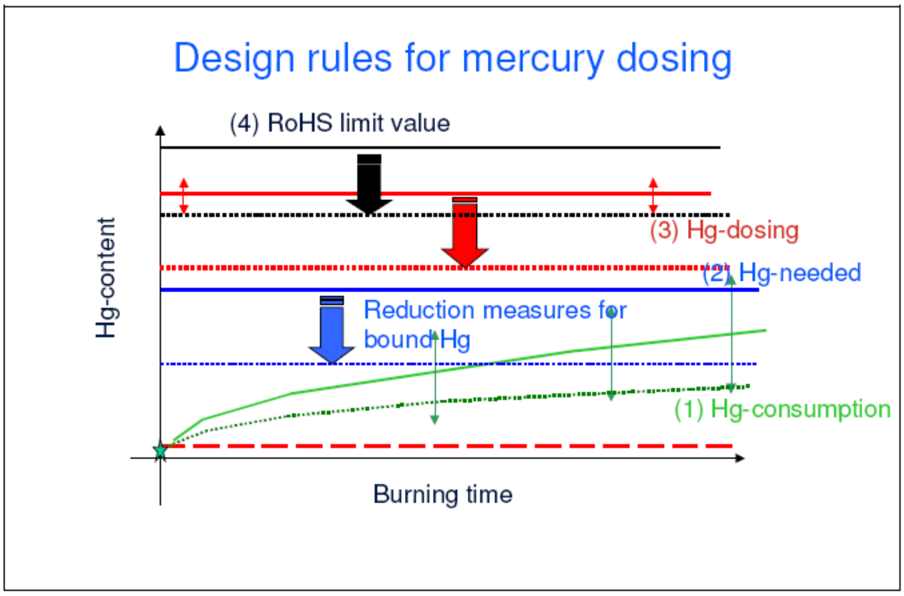

Figure 2 Explanation on how mercury is dosed [1]

Furthermore, ELC states that even with modern dosing technologies such as caps, pills and amalgams, “there is a certain distribution of the amount of mercury per single dose. The different dosing techniques have different variances. So for example the effective mercury content of lamps with a target or average value of 2.5 mg can vary between 1.5-3.5 mg. For manufacturers, an additional “safety margin” (as explained above) is essential to have legal certainty that a product is within the limit. So while in practice the average value may be 2.5 mg, the needed RoHS value in this example may be as high as 3.5 or higher.”

As last element influencing the setting of limit values, ELC mentions market surveillance. Currently, according to ELC, market surveillance regarding mercury content in lamps is not addressed in an appropriate way. Therefore, ELC has proposed a sampling procedure where a maximum of 10 lamps need to be tested [1] and concludes: “If the limit value is too close to the mean value, much higher numbers of lamps have to be tested in order to have statistical and legal certainty that a certain product is within the limit.”

The Swedish study [4] in this context has made the following proposal: “An alternative strategy is to relate the Hg content to efficacy and lifetime, i.e. amount Hg/lumenhour. The shorter lifetime and efficacy the lamps have, the lower amount of Hg content should be allowed. It might be cheaper and easier to improve the lifetime of the lamps than decreasing the Hg content. A fluorescent lamp with a lifetime of 20000 h compared with one of 100000 h and the same content of Hg and efficacy have a polluting relation of 1:5.”

Regarding market surveillance experts from lamp industry argue that currently there is no common standard on sampling Hg in lamps. Accordingly, reported data have to be assessed carefully to avoid misinterpretation.

Conclusion

The two main stakeholders involved in the process have no common position with regard to the interpretation of how a maximum limit value for mercury content should be set. While ELC states that dosing variances are of +/- 2 mg, environmental NGOs state they are of +/- 0,3 mg respectively +/- 10%.

The consultant is not in a position to judge which variances are “right”. ELC has not provided hard fact data supporting its request for a high variance compared to the NGO information which is at least supported by a scientific source. More time and resources as well as independent research and data on maximum mercury content and application specific variances are needed in order to judge whether the limit values proposed by each of the parties are realistic maximum values with regard to mercury consumption, dosing and margins needed for market surveillance.

4.1.5 Front runner vs. BAT vs. large market segments

The justification of the revised exemptions 1–4 as laid down in Article 5 (1) (b) of the RoHS Directive does not include the consideration of economic aspects. However, it can not be the goal of RoHS exemptions to harm industry without environmentally justified grounds. Nevertheless, it is the aim of the RoHS Directive to only allow exemptions in cases where substitution has more negative effects, or in cases where substitution is technically not practicable.

The latter is subject to very differing interpretations – what exactly is “technically practicable”? The following problems arise:

1. Lamp industry has objected proposals by experts (EEB and AF Consult) with the argument that the lowest Hg content only refers to certain front-runners, and that large parts of the EU lamp market would be harmed if such strict values were set as limit.
2. Here again, Article 5 (1) (b) does not contain any guidance on how to evaluate such an issue. However, in the past, evaluation has been done in the sense that if there is technology available on the market which can cover the demand and has lower hazardous substance content, then an exemption is not justified. Meaning, the goal of an exemption cannot be to protect all manufacturers from being kicked out of the market, but rather to allow the marketing of products for which no suitable alternative is available.
3. As a rule mercury dosing technologies is intellectual property of single manufactures and there is no common access to specific dosing technologies due to competition. Furthermore, changes in the dosing technology may cause the replacement of the whole production line. Against this background, achievements from one manufacturer can not be adopted easily by other manufacturers. Consequently, substitution may be technically practicable only under the provision of long transition periods.

4. Against the background of current discussions and due to lack of data, the consultant has not been able neither to identify what the best available technology (BAT) is for certain lamp types, nor to get an idea on where the lamp market is able to fulfil this BAT.
5. Information on mercury contents from both parties (ELC and environmental NGOs) leads to the question what market share would be covered if those limit values were to come into force.
6. Taking into account that it is an environmental policy goal to allow marketing of enough energy efficient lamps in order to cover the increasing demand, a detailed market research is needed in order to evaluate the consequences of the proposed limit values on the availability of energy efficient lamps. This however is out of the scope of this study.

Environmental NGOs [3] have stated that their recommendations on limit values have been based on extracts of findings from the US and EU market. "For high volume lamps we have in general chosen a maximum limit value which two or more of the main lamp manufacturers are meeting already today; for the smaller volume lamps we consider that the best/lowest level reached today by at least one main lamp manufacturer could be sufficient indicator to show what technology can allow for. For all cases it has to be considered however that new maximum limits will be required after a transition period, which will suffice for such a change."

Furthermore, their approach is that mercury limits "should be set to represent best in class for each lamp type based on a technological evaluation of what has and can be achieved, without undermining the energy efficiency criteria that will be set. Combining different types of technologies is likely to result in weaker standards designed to accommodate all models in a category."

ELC has the following position concerning front-runner approach [1]:

1. "The ELC believes that a frontrunner approach should not be taken as the leading principle in setting new mercury content limits. Instead, the ELC proposes reduction per lamp family based on collective assessment of technical process, while taking into account the practicability aspect and also other relevant aspects."
2. "A realistic mercury reduction limit can be achieved by judging its potential in relation to entire product families, based on manufacturers' collective understanding, instead of basing it on a product-by-product comparison."
3. "So far, it has not been fully taken into account that there is a huge variety within each product family, regarding purpose, technology, wattage, current density, size, life time, internal phosphor coating, production process etc. Mercury is intentionally added because it is necessary for fluorescent lamps. Mercury is "consumed" by different factors during lifetime, as explained before. It would be practically impossible to take the whole

product catalogue and do one-to-one comparisons of all lamp types, as proposed by other stakeholders."

4. "Lamp manufacturers fear that too severe reduction of limit values will lead to many cases of underperforming lamps." E.g. through reduced lifetimes.
5. "Product-by-product detailed data sharing and analysis (market volume, content details, manufacturing information etc.) might be seen as infringing on competition law)".

Conclusion

1. Mercury limits should not be based on a collective understanding by manufacturers but on hard fact data. If data sharing infringes competition law than manufacturers could provide data on a confidential basis.
2. Information should thus be made available by industry on market share of lamps below the proposed limit values in order to identify whether the increasing demand can be met.
3. BAT should be interpreted as "lamp containing lowest Hg content without reducing the lifetime and luminance efficacy". In principle this position is agreed on by both NGO's and manufacturers. However, there is no common standard to determine lifetime.
4. Also, lamp industry should be requested to submit data on maximum mercury content of lamps as well as exact dosing and consumption variances for each type of lamp put on the market in order to identify what sensible limit values are to be set.
5. Since there is no agreement on how market surveillance should take place in order to verify compliance with maximum mercury content it is not yet possible to identify a certain variance / safety margin that needs to be taken into account. Therefore, the Commission and Member States are urged to agree on a market surveillance procedure.
6. As for other exemptions and following Article 5 (1) (b) RoHS Directive, an exemption is not justified if substitution is scientifically and technically practicable. Thus, in cases where environmental NGOs have provided data on such substitutes the consultant has based his recommendation on these facts in those cases where no other data have been available.

4.1.6 Lamps under RoHS scope

In order to evaluate whether category 8&9 equipment falls under the scope of an amended RoHS Annex it first has to be clarified how the RoHS scope applies to lamps. Furthermore, the specificity of lamps as covered by RoHS has to be understood.

According to ELC [1], RoHS covers category 5 WEEE Directive ("lighting equipment") as well as electric light bulbs and luminaires in households. Annex IB WEEE Directive lists a number of examples for lighting equipment:

1. luminaires for fluorescent lamps with the exception of luminaires in households;
2. straight fluorescent lamps;
3. compact fluorescent lamps;
4. high intensity discharge lamps, including pressure sodium lamps and metal halide lamps;
5. low pressure sodium lamps;
6. other lighting or equipment for the purpose of spreading or controlling light with the exception of filament bulbs.

Against this background ELC concludes the following:

"From the above definitions, the ELC believes that nearly all lamps are within the scope of RoHS. However there is an important difference between Cat. 5 lighting equipment and other products under the scope of RoHS, and that is that lamps cannot be operated alone but need a fixture. These fixtures can be simple and cheap household luminaires but can also be expensive electrical and electronic equipment like medical or scientific devices. Lamps therefore also reveal the character of consumables.

Most of the lamps regarding market share put on the European market are used for general lighting purposes. But also lamps for special purposes are in most cases regarded to fall within the scope of RoHS. […]

Characteristics or usage scenarios which could lead to the conclusion that a lamp is not covered by RoHS are the following:

- Equipment concerned is part of another type of equipment that does not fall within the scope of WEEE Directive (according to the Art. 2 of WEEE), e.g. in vehicles.
- Purpose of the lamp is not "spreading or controlling light" and the lamp is part of an electrical or electronic equipment not falling within the scope (e.g. cat. 8&9 lamps), e.g. radiation sources for medical (therapeutic, diagnostic), scientific, industrial purposes.

Examples are:

- Automotive lamps;
- Lamps for skin treatment in medical equipment;
- Spectral lamps in scientific measuring equipment;

[…].

If a manufacturer comes to the conclusion, that a certain "lamp" does not fall in the scope of RoHS but is rather considered as a "component" of another type of equipment he has to be aware, that the equipment in which it is used might fall into the scope, in one of the Categories, and that then an extra exemption for the use of mercury in this equipment might be necessary."

Conclusion

With regard to category 8&9 it is concluded that lamps which are not considered by the manufacturer to be a component already fall under the scope of the RoHS Directive now. Hence, any amendment to the RoHS Annex will have an effect on lamps used in this equipment.

4.1.7 LED as a possible substitute

LEDs are electronic components that can be used to manufacture lamps. LED-based lamps are currently under strong technological development and are said to be able to replace current lighting applications in future [4]: "LEDs are today used in for example instrument panels, traffic signs, vehicle backlights, and coloured lights. Development is fast and white LED is more and more used in general lighting. Other areas available today are emergency lighting and decorative lighting. Among application areas to expect in the future are spotlights, torches and street lights. Time for developed products for most applications is estimated to around 2012." LED-based lamps are said to have the advantage of small size and higher energy efficiency as well as higher lifetime compared to current lighting applications. However, information on how far the technology is currently developed and for which applications LED are suited varies greatly.

When analysing the possibilities of using LED as a Hg-free substitute for current Hg-containing lamps, the following question needs to be answered: on a life-cycle based approach, what are the environmental impacts of LED-based lamps compared to current lighting applications (e.g. energy needed for production, efficacy, lifetime, …)? Since currently there seems to be no reliable data and information available in this respect, it is not possible to evaluate whether or not LED-based lamps can be considered as substitute with overall environmental benefit.

This statement may not be fully valid for some applications as stated by environmental NGOs [2]:

"LEDs are definitely applicable as replacements for exit signs and other applications for illuminating pathways. It can often replace low-wattage CFLs and linear fluorescents such as T2s used in exit signs. Increasingly, LEDs are replacing high-pressure sodium (HPS) lamps in street lights.[…]

As it has been mentioned above, in areas of low wattage applications where LEDs exist, last longer and are as or more efficient than fluorescent lamps, these should be preferred and no exemption should be granted for those applications."

This is supported by the Swedish study [4]: "There are different techniques to replace mercury in back lights in LCD screens but it appears though as the LED technology is the leading alternative in the question of quality issues and performance. Also for other imaging equipment such as scanners and projectors there are mercury free products on the market.

For several applications like for example exit signs, mobile phones, refrigerator lamps and commercial street signs there are already mercury free LED alternatives that are similar in capacity and quality."

It thus seems that LED-based lamps as from today are suited to be used in specific applications such as spot lights, decorative lighting, and displays to a certain extent[12]. Technological development for other areas of application is said to take about 5 years before sufficiently efficient and long-lasting lamps will be available on the market.

Conclusion

The consultant thus proposes not to consider LED as a possible substitute for lighting applications in general due to unknown environmental effects. Since overall environmental policy goal is to both reduce the amount of hazardous substances in EEE and at the same time to ensure high efficiency in order to reduce energy consumption, LED are considered as possible substitutes, only once they have reached higher or equal efficiency and lifetime. Therefore, this technology should be evaluated again during the next RoHS revision cycle in 4 years.

As LEDs are considered suitable substitutes for certain applications the next section will analyse whether a restriction of certain exemptions in this respect is feasible.

4.1.8 Substitution on application level

Some important questions that have arisen relate to substitution at application level, i.e. the questions whether e.g. halophosphate lamps could be replaced by tri-band phosphor lamps or whether LED-based lamps could replace mercury-containing lamps.

Should these substitutions at application level be considered as possible by stakeholders, there would be no justification for exempting these applications from the provisions of the RoHS Directive. From the information available so far, the consultant has concluded that halophosphates can be substituted by tri-band phosphor lamps as stated by the environmental NGOs [3]:

"Halophosphate fluorescents, which largely include older type fluorescent lamps such as linear and U-shaped T12s and circular T9s, are being phased out in the EU (and elsewhere) due to energy efficiency and light quality concerns. Many of these lamp types also have higher mercury content than equivalent tri-band phosphor models such as high-efficiency T8s and T5s. […] Often, low-mercury dosing technology is not used on older models because

[12] E.g. Dell Driving Transition to Energy-Efficient LED Displays - Announces 12-Month, 100 Percent Mercury-Free Target for New Laptops (cf. http://www.marketwatch.com/news/story/dell-driving-transition-energy-efficient-led/story.aspx?guid=%7BDC160909-8AC6-4C74-85B6-C5A694B76FF6%7D&dist=hppr)

manufacturers don't feel that it is economically beneficial to retool lamps that are less popular or in the process of being phased out.)"

This has been confirmed by ELC [1]:

"It is important to understand that the focus has been on the most innovative fluorescent products, like T5 or CFL, and not on the older, less energy efficient lamp categories. For example, no major steps have been taken for halophosphate lamps (application to be restricted in implementing measures of the EuP directive), or for T12 lamps (due to rapidly declining market relevance in the EU)."

According to ELC, substitution at application level can only be considered practicable if retrofit applications allowing substitution in existing luminaires exist. It claims that since this is not the case for halophosphates, other lamps cannot be considered as substitutes. However, if a provision on spare parts is introduced (cf. section 4.1.9), the existing exemption for halophosphates could be withdrawn since a substitution with less mercury containing lamps could take place for newly installed luminaires.

During the current evaluation process, information has been gathered on possibilities to restrict exemptions for certain specific applications where substitute technologies are available (e.g. use of LED in exit signs, use of Xenon lamps for certain applications etc.).

Since the lamps themselves are in the scope of the RoHS Directive, such a restriction would not lead to the effect that mentioned applications can only be used with a certain type of lamp, since in theory it would be possible to sell the corresponding luminaire without lamp, and the matching lamp separately without infringement to RoHS provisions.

The environmental NGOs [3] however mention the following: considering, that all these products/applications are electronic equipment and fall under the RoHS Directive, an exemption from the Hg-lamp exemption could be proposed in cases where certain applications can use mercury free and more energy efficient lamps. For example for exit signs, neon signs, laptop and LCD screens, the following text could be proposed: Exemptions 1-X of this annex shall not apply to *exit signs (containing housing, fixture and light source) and exit sign retrofit kits, neon signs, laptop and LCD screens.*

Conclusion

Unlike other exemptions, current exemptions for the use of mercury in lamps are not application-specific but refer to certain lamp types. Thus, even if there are substitute technologies for certain applications it is difficult to explicitly exclude these applications from existing exemptions while keeping the current exemption structure.

Nevertheless, following Article 5 (1) (b) the availability of substitutes needs to be taken into account. Hence, if applicable the consultant has decided to follow the environmental NGOs' proposal in this respect.

4.1.9 Transition period / expiry date / repaired as produced

ELC [1] has stated that for exemptions on the use of mercury in lamps no expiry date is feasible:

"There is no scientific or technical evidence to prove that there is a real alternative to the application of mercury in lamps. In the past much R&D has been devoted to finding a substitute for mercury. In most, if not all, cases this led to lamps with much lower energy-efficiency (at least 10% lower). Due to this appreciably[13] lower energy efficiency, mercury-free discharge lamps have only found niche applications in the field of general lighting. At this moment in time, product design changes, aimed at substitution of mercury, should be seen as scientifically and technically impracticable."

This statement does not take into account that substitution is not only considered as replacing mercury as a substance in lamps but can also be the substitution of mercury containing lamps with other mercury-free lamps if there are no negative environmental, health and consumer safety effects (cf. discussion under section 4.1.8).

Concerning the transition period ELC has proposed 1 July 2012 as timeline for entry into force of the new Hg limit values. Environmental NGOs propose a transition period until 2010 and an expiry date by 2014.

ELC [12] has commented that "as a matter of principle, the review date of RoHS exemptions must precede their date of expiry" since otherwise there is "legal uncertainty, ban of products leaving no alternatives if the exemption review was not done on time" and "de facto ban of products if no technical solution is available." ELC therefore proposed to "have the expiry date minimum two years after a review period is concluded".

With regard to the spare parts issues, the consultant considers that there is no need for such a provision for lamps since these are applications that are usually not maintained as such. This would rather apply to the luminaire, which, however, is not subject to the exemptions for mercury content.

<u>Conclusion</u>

Assuming a publication of an amended RoHS Annex in the Official Journal by the end of 2009, a transition period until 1 July 2012 would mean a little more than two years of transition period. Since not all stakeholders have been involved in the process and especially category 8&9 equipment manufacturers have not foreseen the current revision as necessary to request new exemptions in the light of upcoming amendments, a two year transition period is considered necessary.

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[13] "appreciably lower energy efficiency" appears to be a mistake

Even though industry does not consider an expiry date feasible, it is proposed to set the expiry date before the next revision cycle which would be approximately 2014. In principle the consultant agrees to the ELC request that the review should be finalised before the expiry date is reached.

It is considered useful to set an expiry date in order to give industry an incentive to deliver more data on mercury content in lamps put onto the EU market. As described above a lack of data availability made it difficult to evaluate what mercury limits were practicable (cf. section 4.1.5).

4.2 Exemption 1

“Mercury in compact fluorescent lamps not exceeding 5 mg per lamp”

4.2.1 Summary of contributions

ELC has provided a proposal on single capped fluorescent lamps depending on wattage, on general and special lighting purpose and on shape for smaller diameters (T4 and T5):

- General lighting purpose < 50 W: 3,5 mg;
- General lighting purpose ≥ 50 and < 150 W: 5 mg;
- General lighting with circular or square structural shape and tube diameter ≤ 17 mm (e.g. T4, T5): 7 mg;
- For special purpose: 5 mg.

In the Annex of their 15 October contribution [1] ELC has stated that single capped fluorescent lamp classification according to standard EN 60901 does not fit the current RoHS classification and that thus the wording “compact fluorescent lamp” (CFL) should not be used. Rather the CFL category should be referred to as “single capped fluorescent lamp”. The following picture has been added as illustration of a subdivision by topology and cap:

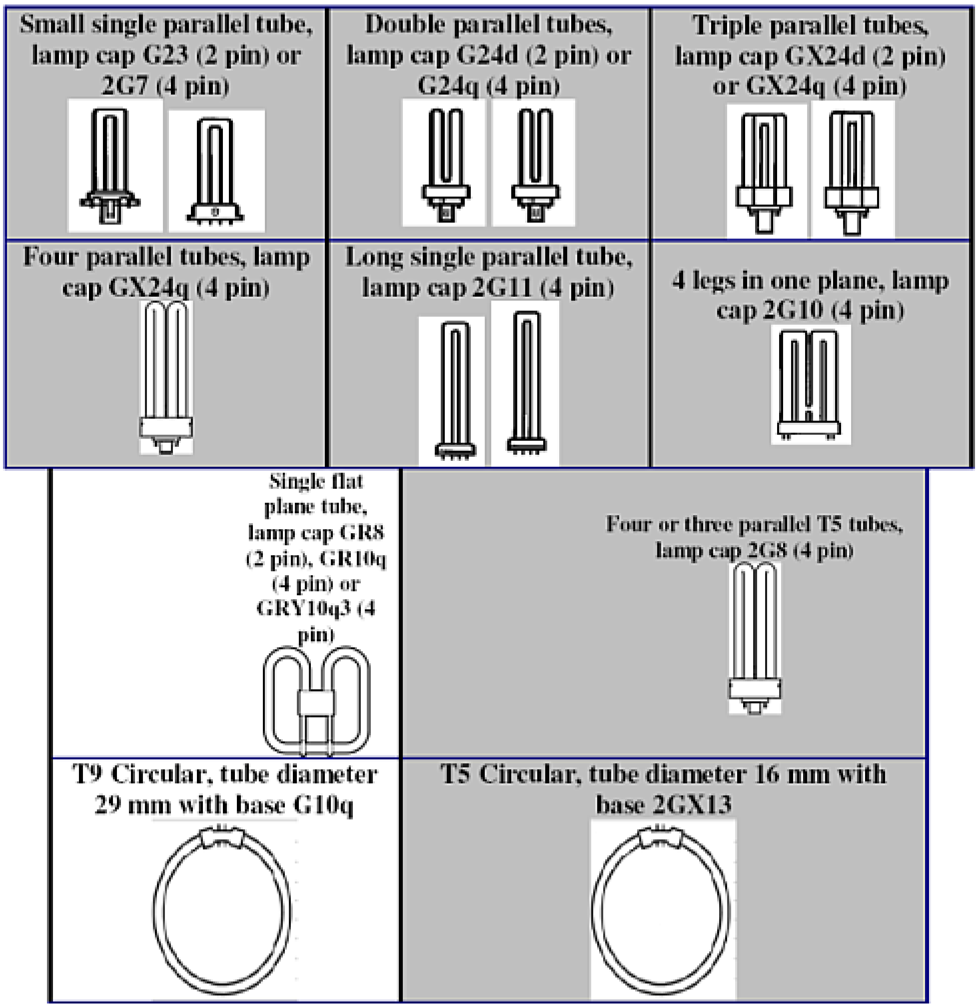

Figure 3 Overview on single capped fluorescent lamps [1]

Single capped fluorescent lamps with a wattage ≥ 150 W have not been included here since they are said to be newly entering the market without clear necessary mercury amount. ELC thus proposes to include them into another exemption with a limitation of 15 mg.

The lamp manufacturer Megaman (producing such high wattage single capped fluorescent lamps) has stated that their “Clusterlite” model cannot be considered as single-capped fluorescent lamp since they are not covered by the relevant standard (IEC 61199) and are thus currently covered by exemption 4 without any mercury limit [2].

Based on the extract of findings from the US and EU market, environmental NGOs have proposed the following limits for CFLs [3]:

- CFL for general purpose: 2 mg;
- CFL for special purpose: 3 mg.

These proposals are based on a different classification than the one provided by ELC and which is based on US technology analysis:

- CFL models that have an integrated ballast;
- CFL models that have a separate ballast.

Furthermore, environmental NGOs request their proposed values to enter into force by 2010 when the expected EU ban on incandescent lamps will take effect in order to ensure availability of low mercury CFLs. Also, they claim that ELC has not provided data to support the proposed limits.

The report on Mercury in lamps commissioned by the Swedish Chemical Agency (KEMI) [4] claims that "several source from the industry has expressed that technology is available to produce lamps with a mercury content of below 1 mg. […] A number of manufacturers declare it may be possible in the time perspective of 1-3 years to comply with a lower limit of 2 mg or even 1mg for many fluorescent and metal halide applications without significant reduction of lifetime and efficacy. For other manufacturers, which today have no access to the best technology, it may not be possible."

An additional comment sent by KEMI [5] states the following:

"The fluorescent tubes need very small amounts of mercury in the lamp to ignite and then sustain the discharge producing enough UV-photons for the light creating process. In the T5 25 W tube the specific needed amount is 0.01 to 0.05 mg mercury and it is comparatively about the same in the other tubes and CFLs. The tube also consumes mercury during life. It is mostly the glass envelope and the phosphors which absorbs mercury during the discharge. The light source companies have developed methods declining the absorptions of mercury. For example special sheltering layers have been attached on the glass and phosphors decreasing the mercury consumption. Also some problems is connected to the dosing of the mercury stuff but as we have been told the best methods here make it possible to limit the uncertainty to about 0.2 mg of mercury. Probably Philips and some other stakeholders already have the technology to delimit the necessary amount to 1 mg. Concerning the time for the new legacy 2012 it should be possible for the producers to meet the new proposals when they have three years extra from now[14]."

Under the corresponding EuP Lot 19 an indicative benchmark is given for non-directional household lamps: "the energy efficient compact fluorescent lamps with the lowest mercury content include not more than 1 mg mercury."[15] In this context the lamp mercury content is the mercury contained in the lamp and is measured according to the Annex of Commission Decision 2002/747/EC[16].

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14 I.e. until 2012

15 Working document on a possible commission regulation implementing directive 2005/32/ec with regard to non-directional household lamps.

16 In this regulation the mercury content is the average content of 8 lamps out of a 10 lamps sample and where the highest and lowest value have been deleted.

The EuP proposal for requirements on mercury content in CFLi lamps is included in the table below. It is the current value in the RoHS Directive for Tier 1 and on the value of the Community Decision (2002/747/EC) for Tier 2. For Tier 3, it is based on measurements made by VITO on CFLi's that are currently available on the market and confirmed by the statement of ELC at the stakeholder meeting in Brussels on 23rd November 2007 that 'a maximum of 1mg of mercury for CFLi's is possible'.[17]

Tier 1[18]	Tier 2	Tier 3	Benchmark
Hg ≤ 5,0 mg	Hg ≤ 4,0 mg	Hg ≤ 2,0 mg (or 3,0 mg if lamp life > 15000 h or 4,0 mg if lamp life > 20000 h)	Hg ≤ 1,0 mg

This is contradictory to what ELC has requested in [1]. ELC has been confronted with this contradiction and stated the following [13]:

"The wattage differentiation in the ELC contribution takes into account that high wattage CFL, which are normally not used for domestic lighting, need more mercury than those with lower wattages. […] Our ELC Working Group ET is not aware of this confirmation [referring to the above citation in the EuP report] and where the citation comes from. If this confirmation has been given, it was not correct from technical point of view. If there are really such lamps on the EU market this value addresses the average value per lamp (vs. a limit value) and does not take the variances within single mercury doses into account. Even if this value can be realized for some of the above mentioned lamp types/wattages this value can not be regarded as THE ONE general BAT regarding mercury amount […]."

4.2.2 Critical review

From the above it can be seen that many different stakeholders argue from many different point of views and that many different limit values are proposed. A comparison and the finding of a compromise are hindered due to the fact that hard fact data is lacking in most of the cases. Only environmental NGOs have done extensive data research, however not being able to trace back the specific technical requirements for the use of mercury in depth. Data provided in the context of the EuP preparatory study and forming the basis of the recommended limit values is not publicly available and can thus not be traced-back. Same accounts for the proposed limits by ELC which are not based on publicly available data. In [4] it is clearly stated that "an overall problem during this study has been to obtain unanimous

17 Vito 2008: Lot 19: Domestic lighting, Final Task Report, Task 8: scenario- policy- impact and sensitivity analysis, October 2008.

18 The working document includes the following dates: stage 1: 1st October 2009, Stage 2: 1st October 2011, Stage 3: 1st October 2013.

information about the situation of the mercury containing lamps on the EU market and what is reasonable to accomplish."

The overall environmental policy goal is to reduce energy consumption thus reducing GHG emissions from power generation. Energy efficient lamps can support this overall need. Even if mercury is contained in such lamps, mercury-related emissions through electricity generation are relatively higher. Scientific data has proven that mercury emissions are reduced more when the lamp itself consumes less electricity for the generation of light then when using mercury-free less efficient lamps[19].

From an overall environmental perspective it is more important to satisfy market demand and reduce mercury emissions due to electricity generation than to reduce the mercury content of the lamps themselves. It should thus be a goal of mercury limits set under RoHS not to hinder meeting the increasing market demand on energy-efficient lamps.

Concerning high wattages, long lifetime, CCFL, special purpose and non-linear CFLs (square and circular) different values have been brought forward (see above). Most of them are not supported by market data. Environmental NGOs have questioned ELC's statement that there is a correlation between lamp wattage and mercury content since their market data does not show such a correlation. However, it has to be stated that environmental NGOs have only looked at lamps up to 80 W. The correlation of long lifetime and mercury content as stated in the above EuP table is also not supported by market data.

Furthermore, ELC uses a different definition / classification than other stakeholders making a comparison between the different proposed values impossible. Also, the scope of the EuP values refers to domestic lighting only which is not necessarily equivalent to "general purpose" as used by ELC and environmental NGOs.

4.2.3 Recommendation

For general purpose CFLs a limit value of 2 mg – as proposed by environmental NGOs and by the EuP preparatory study on Lot 19 – is supported by market data. Environmental NGOs request this limit to be set by 2010, while EuP sets end 2013. However, the overall consequences on lamp market and its availability to meet increased demand are not known since currently only one lamp manufacturer is able to produce CFLs for general lighting purposes

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[19] This is described as follows in [5]: "Because mercury-containing lighting is more energy efficient than conventional incandescent lighting, less energy is needed to make the required electricity, thus translating to reduced mercury emissions from coal-burning power generating plants. The amount of mercury pollution that is offset using more efficient lighting depends on the type of lamps used and the fuel mix of the power plant generating the electricity. As analysed recently at the EEB conference, June 2008, by Peter Maxson, according to the US EPA, CFL is a "drop-in" substitute for incandescent, consumes up to 75% less electricity, causes the generation of substantially less CO_2, has up to 10 times longer lifetime, is a quick return-on investment, according to some USA estimates only 11% of Hg content would be released when a CFL is landfilled, and the total Hg release may be far lower when using a CFL than when using equivalent incandescent."

with a 2 mg Hg content. Additionally, CFLs for special purposes cover a very brought range of different lamps. These lamps with different range of performances can be classified by their wattage. Hence, the contractor recommends to follow the ELC proposals based on wattage classification in order to ensure the coverage of market demands.

For CFLs for general lighting purposes with a wattage higher than 150 W a mercury limit of 15 mg is recommended, following the ELC proposal and acknowledging that in this class development of CFLs is in an early stage. However, a revision of this limit in two years is strongly suggested as these lamps are newly entering the market.

For special shape CFLs smaller or equal to T5 a limit value of 7 mg as proposed by ELC is recommended. Market data cited by environmental NGOs supports a limit value of a maximum of 8 mg for any non-linear fluorescent lamp. The 7 mg limit value is thus considered to be feasible at least for those lamps smaller or equal to T5.

Concerning special purpose lamps environmental NGOs have proposed a 3 mg limit for those lamps that have been registered as being of special purpose. ELC requests a 5 mg limit and delivers a qualitative description of what is to be considered of special purpose (cf. section 4.5.10). For both limit values comprehensible market data is missing. It is recommended to request from manufacturers to clearly identify special purpose lamps together with a justification on why they cannot be covered by any of the existing limit values and to deliver according market data in order to allow setting an appropriate limit value.

Recommended wording exemption 1:

Mercury in single capped fluorescent lamps not exceeding (per burner[20])

- *For general lighting purposes < 50W: 3,5 mg*
  For general lighting purposes ≥ 50W and < 150: 5 mg
  For general lighting purposes > 150W: 15 mg
- *For general lighting purposes with circular or square structural shape and tube diameter ≤ 17 mm: 7 mg*
- *For special purposes: 5 mg*

As the development of the market and of the technology for CFLs for general lighting purposes >150W within the next years is especially difficult to assess, a revision of the Hg limit value two years after publication is recommended (31. December 2012).

For all other lamps covered by exemption 1 “Mercury in compact fluorescent lamps“ the 31 July 2014 is recommended as expiry date. Furthermore, the contractor recommends notifications for special purpose CFLs in order to collect data and information for future revisions of the Annex.

[20] This has been added by ELC in [12] and is explained as follows: “In case of one lamp containing more discharge vessels / burners (meaning the light giving unit, not yet assembled into a final product). […] E.g. so-called 3-way lamps, where 2 fluorescent discharge vessels are contained in one lamp.”

4.3 Exemption 2

The current wording of the exemption is:

"Mercury in straight fluorescent lamps for general purposes not exceeding: halophosphate 10 mg, triphosphate with normal lifetime 5 mg, triphosphate with long lifetime 8 mg".

The contractor recommends the subdivision into two parts of the current exemption:

2a covers double-capped linear fluorescent lamps for general purposes;

2b covers halophosphates, non-linear tri-band phosphor lamps and induction lamps.

4.3.1 Summary of contributions for new exemption 2a

In its 15 October contribution [1] ELC states that linear fluorescent lamps are referred to as "double capped" and sub-divided by diameter. The limits that ELC proposes are:

- Tri-band phosphor with normal lifetime and a tube diameter of < 9 mm (e.g. T2 lamps): 4 mg;
- Tri-band phosphor with normal lifetime and a tube diameter of > 9 and ≤ 17 mm (e.g. T5 lamps): 3 mg;
- Tri-band phosphor with normal lifetime and a tube diameter of > 17 mm and ≤ 28 mm (e.g. T8 lamps): 3,5 mg;
- Tri-band phosphor with normal lifetime and a tube diameter of > 28 mm (e.g. T10, T12 lamps): 5 mg;
- Tri-band phosphor with long lifetime[21]: 5 mg.

According to ELC double-capped lamps with a smaller diameter (e.g. T2 lamps) need slightly more mercury than T5 lamps. This correlation is explained by one lamp manufacturer as follows:

"The diameter of T2 lamps is much smaller than for T5, so that a different mercury dosing technology is necessary due to size restrictions. Mercury in T2 lamps is applied with dispensers, so called "flags" while T5 lamps have a "roof" construction mercury dispenser. The small distance between electrode and glass tube leads to impurities of the phosphor during operation originating from electrode material. These impurities lead to higher mercury "consumption" in our lamps. There is no room to "shield" the phosphor with construction elements like in T8 lamps."

[21] Long lifetime is defined as ≥ 25.000 where the installed luminous flux (lamp survival in % times lamp luminous flux in % or service life) is higher than 80% at 25.000 hours with an electronic ballast using the standardised 3 hour cycle.

Furthermore, ELC explains [1] that the Hg content of fluorescent lamps depends on the dosing technology used by the manufacturer. For T5 currently only one manufacturer is producing these lamps with 2 mg Hg content. It appears rather probable that a change-over within the production process which meets the market demands will take several years.

Environmental NGOs [3] state that instead of using diameter-defined classifications, usual denominations such as T5, T8 etc. should be used. In their data research they have looked at different kinds of linear fluorescent lamps but not at T2 lamp mercury content. The NGO proposal is as follows:

- Tri-band phosphor normal lifetime ≤ T5: 2 mg;
- Tri-band phosphor normal lifetime T8 < 6 foot[22]: 2 mg;
- Tri-band phosphor normal lifetime T8 > 6 foot: 8 mg;
- Tri-band phosphor normal lifetime > T8: 0 mg;
- Tri-band phosphor long lifetime[23]: 3 mg.

Environmental NGOs [3] claim that data they have found rather lies in the area of a 1,5 mg. Assuming a 10% tolerance, they conclude that a 2 mg should be able to be met for both T5 and T8. Also they argue that ELC has not provided any evidence on the fact that mercury is the limiting factor for long lifetime. However, the need for a higher mercury content in long life lamps can technically be explained: during the lifetime of the lamps mercury is consumed because it is deposited or bonded to the glass and the phosphor layer (detailed explanation see 4.1.4).

The Swedish study comes to the conclusion that “also for long lifetime lamps, low amounts of mercury is available […]. 1 mg should be reasonable limit in a proper time perspective” [4].

4.3.2 Critical review for exemption 2a

Here again, just as with the case of compact fluorescent lamps, a detailed market research would be needed in order to better compare the existing mercury limit proposals. This is especially valid for T2 and lamps bigger than T8.

However, as explained above, the mercury dosing technology for T2 differs and the argumentation can be followed. Therefore, the contractor recommends a 4 mg mercury limit for T2 lamps. For T5 lamps a 3 mg mercury limit is recommended since otherwise the market possibly can not be supplied as explained above.

For T8 lamps environmental NGOs propose two mercury limits according to the length of the lamp. Since lamps longer than 6 foot (>183 cm) do not exist on the European market no

[22] corresponds to approximately 245 cm

[23] > 25.000 h, 3 h starts

exemptions for those lamps is needed. For T8 ≤ 6 foot the NGO proposal is based on one manufacturer having developed a technology to produce these lamps with a 2 mg mercury content. Again, it is unsure whether this manufacturer alone can meet the market demands in case the NGO proposal would be followed. ELC proposes a 3,5 mg mercury content which allows more manufacturers to supply the market. Given the current situation, the contractor therefore recommends to follow the ELC proposal. Additionally, the contractor indicates that currently it is technically not advisable to replace T8 lamps with T5 lamp, as there are reasonable concerns regarding the safety of adapters being necessary to adopt T5 lamps in existing .installation [17].

For lamps bigger than T8 (T10 and T12) environmental NGOs have requested 0 mg limit and ELC has requested 5 mg. Both proposals are not based on specific technical arguments. These lamps are considered as phase-out models and the market is relatively small. Moreover, these lamps can be replaced by T8 lamps. Therefore, a mercury limit of 3,5 mg - as for T8 lamps - is recommended in order to accelerate the phase out of T10 and T12 lamps.

Concerning tri-band phosphor with long lifetime the contractor recommends to follow the proposal of ELC as for technical reasons long lifetime lamps need a higher mercury content. However, it is also recommended to define a European standard for long life (e.g. 25 000h or 30 000h lifetime) including a cycling standard.

4.3.3 Recommendation for exemption 2a

Taking available proposals into account and the support given by market data, the following wording is proposed:

Mercury in double-capped linear fluorescent lamps for general purposes not exceeding

- *Tri-band phosphor with normal lifetime T2: 4 mg*
- *Tri-band phosphor with normal lifetime > T2 and ≤ T5: 3 mg*
- *Tri-band phosphor with normal lifetime > T5 and ≤ T8 and < 183 cm: 3,5 mg*
- *Tri-band phosphor with normal lifetime > T8 and ≤ T12: 3,5 mg*
- *Tri-band phosphor with long lifetime: 5 mg*

The contractor recommends setting the 31 July 2014 as expiry date.

4.3.4 Halophosphates (exemption 2b)

Concerning halophosphates the corresponding EuP process comes to the following conclusion:

“It is recommended to set limits on the lamp mercury (Hg) content. According to information, provided by industry, it is not possible to produce halophosphate lamps with less than 10mg Hg. As a consequence, halophosphate fluorescent lamps could be excluded from the market by repealing in the RoHS-directive the exemption that was made on the mercury content of 10mg for certain fluorescent lamps. The maximum mercury content should be limited at an absolute maximum of 8 mg instead of 10 mg. Also imposing that the lamp lumen maintenance factor (LLMF) should meet at least the values listed in Table 100 would exclude halophosphate lamps from the market."[24]

Based on this, the environmental NGOs [3] have requested to adopt the proposed limit value for all halophosphate lamps (linear ones and also circular and u-bent ones). Environmental NGOs believe that halophosphates will be phased-out under EuP implementing measure on tertiary lighting for efficiency reasons and that the high mercury content should be a further reason to phase them out faster.

The Swedish study commissioned by KEMI [4] comes to the conclusion that "halophosphate lamps are generally exchangeable for triphosphor lamps."

In its October contribution [1] ELC proposes 10 mg mercury for Halophosphate phosphor lamps. However, some manufacturers can already produce these lamps with 8 mg mercury.

4.3.5 Other non-linear fluorescent lamps (exemption 2b)

Other non-linear fluorescent lamps (those not covered by exemption 1 and 2) have been requested the following values:

- ELC [1]: non-linear structural shape (e.g. circular (e.g. T9), U-bent, induction lamps): 15 mg;
- Environmental NGOs [3]: non-linear tri-band phosphor lamps: 8 mg;
- Environmental NGOs [3]: induction lamps: 7 mg.

4.3.6 Critical review for exemption 2b

Considering that halophosphates are low-efficiency and high-mercury containing lamps there is an agreement on environmental policy level that these should be phased-out. Taking into consideration that EuP addresses energy efficiency aspects and will regulate the phase-out under these considerations, RoHS needs to – in accordance with Article 5 (1) (b) – allow an exemption for the use of mercury in halophosphates only if there are no practicable substitutes. Since – as the Swedish study states – halophosphates can be retrofitted with tri-band phosphor lamps substitutes are available. There is no information whether this is valid for all shapes. Furthermore, since the EuP process came to the conclusion that a limit of 8 mg should be set for halophosphates which is supported by environmental NGOs, it is recommended to set such a limit for all halophosphate lamps which would lead to a phase-out just as the EuP lumen maintenance factor does. Additionally, as halophosphate lamps with 8 mg mercury content can already be produced in a way that the market demand is met, the lower mercury value seems feasible.

[24] Vito 2007: Final Report Lot 8: Office lighting; April 2007

For non-linear tri-band phosphor lamps the contractor recommends to distinguish between T5 and T9 lamps. Since T9 lamps can not be replaced by T5 lamps, which have a lower mercury content, and T9 lamps are still needed, the ELC proposal for these lamps is followed. For T5 lamps the environmental NGO proposal seems feasible.

“Induction lamps“ include a wide spectrum of different lamps. Since the NGO proposal of 7 mg is probably based on the BAT value of only one specific induction lamp type, the contractor recommends to follow the ELC proposal in order not hinder meeting the market demand.

4.3.7 Recommendation for exemption 2b

The recommended wording for exemption 3 would thus be:

Mercury in other fluorescent lamps not exceeding

- *Halophosphates all shapes: 8 mg*
- *T5 non-linear tri-band phosphor lamps: 8 mg*
- *T9 non-linear tri-band phosphor lamps: 15 mg*
- *Induction lamps: 15 mg*

As expiry date the contractor recommends 31 July 2014.

4.4 Exemption 3

The current wording of the exemption is

“Mercury in straight fluorescent lamps for special purposes”.

Taking into account that the contractor adjusted the lamp classification compared to the current RoHS Annex, this exemption therefore only covers **“Mercury in cold cathode fluorescent lamps (CCFLs)”**.

CCFLs are used as backlight lamps in displays as well as in scanners and projectors. Currently, for some applications, mercury-free alternatives using LED are available. Although there is no sound hard fact based scientific analysis available, environmental NGOs and the authors of the Swedish study claim that LED-based backlights are a valid substitute for CCFLs [3] [4].

ELC [1] and JELMA [14] have proposed the following limit values for CCFLs:

1. mercury in short length (not over 500 mm) cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) not exceeding 3.5 mg per lamp;

2. mercury in medium length (over 500 mm and not over 1500 mm) cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) not exceeding 5 mg per lamp;
3. mercury in long length (over 1500 mm) cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) not exceeding 13 mg per lamp;

It is important to note that JELMA requests the explicit mentioning of EEFLs (they are a type of CCFL) and that upon request of the consultant JELMA has proposed a limit value for CCFLs and EEFLs bigger than 1.500 mm (which was not taken into account by ELC in its proposal since the JELMA input was given after the last stakeholder meeting). Lamps of these dimensions are currently under development and a mercury threshold value was difficult to determine since the maximum length of the lamps is not yet known. Nevertheless, JELMA has proposed 13 mg as limit value.

AeA [16] and EICTA [15] have both requested a limit value of 5 mg – independently what length the lamps have.

Environmental NGOs request a limit value of 2 mg for CCFLs. They justify the 2 mg limit due to the fact that CCFLs should be considered as linear fluorescent lamps and should thus be given the same limit. NGOs further suggest that given the recent developments laptop computer and LCD screens should be mercury free by 2012.

The Swedish study comes to the conclusion that LED are "already been used some time in small displays but are successively introduced in larger displays. LCDs with LED are already available, especially for notebooks with small (13 inches) displays." Environmental NGOs confirm that "very recently Dell has announced that all new laptops will be 100 percent mercury-free by October 2009. […] Soon after Dell, HP announced that by 2010 their laptops will be mercury-free." They thus request that exemptions under RoHS should not be valid for these areas of application by 2012 at the latest.

For other areas of application (such as commercial signs / neon signs, exit signs and scanning devices), the Swedish study comes to the conclusion that there are also mercury-free alternatives existing.

4.4.1 Critical review

In the case of CCFLs no reliable market data is available. The industry proposal on limit values has been well justified on a qualitative level. Currently, no limit is set at all for these types of lamps. At this point of time it cannot be evaluated whether a 2 mg limit would be feasible for all CCFLs and no data has been provided either to support this request.

Penetration of LED as a substitute technology is taking place independently of RoHS exemptions. It is mercury-free but no evidence has been provided whether there are or not environmental drawbacks associated with this technology when used as a substitute.

Currently it is unclear whether the announced introduction of LED-based backlights in displays will be successful on the market. Furthermore, until now there seems to be no reliable data and information available on the environmental impacts of LED-based lamps compared to current lighting applications (e.g. energy needed for production, efficacy, lifetime, etc.) on a life-cycle based approach. Therefore, the consultant recommends to observe the further technological development and to review the applicability of this technology by 31.12.2012.

4.4.2 Recommendation

Concluding on the above the recommended wording would thus be:

- *Mercury in short length (not over 500 mm) cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) not exceeding 3,5 mg per lamp until 31.12.2012;*
- *Mercury in medium length (over 500mm and not over 1500 mm) cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) not exceeding 5 mg per lamp until 31.12.2012;*
- *Mercury in long length (over 1500 mm) cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) not exceeding 13 mg per lamp until 31.12.2012.*

Since for the application of CCFLs in the different areas of application substitute technology like LED-based backlights is already available, but without reliable data on the environmental impacts, it is recommended to restrict the exemption in time and to review the applicability of the new technologies by 31.12.2012.

Mercury in long length (over 1500 mm) cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) are not yet in development. In order to give industry legal guarantees for future developments, a limit value for this type of lamps is recommended by the consultant. The consultant, however, proposes a notification process for these lamps to collect data and information for future revisions of the Directive.

4.5 Exemption 4

The current wording of this exemption is:

"Mercury in other lamps not specifically mentioned in this Annex".

The contractor recommends the subdivision into two parts of the current exemption:

4a covers "Mercury in High Intensity Discharge Lamps"

4b covers "Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex".

ELC has stated in their 15 October contribution [1] that "mercury limits in High Intensity Discharge Lamps are only feasible and justified for the specific case of High Pressure Sodium Lamps."

4.5.1 High Pressure Sodium (Vapour) discharge Lamps (HPS) (4a-I)

Concerning mercury content in HPS lamps, ELC states the following in [1]:

"Mercury and sodium are usually overdosed in HPS lamps. […] In Europe, R&D efforts are devoted to an optimization of the efficacy. […] In order to realise this a certain dose of mercury is required. There is a risk that reduction of this dose leads to a shorter life of these products. […] Because of the higher operating temperature of low wattage and improved CRI lamps, they require relatively higher mercury contents."

Based on this argumentation the following values are proposed:

Mercury in High Pressure Sodium (vapour) lamps for general lighting purposes:

- not exceeding in lamps with improved colour rendering index > 60
  - P ≤ 155 W: 30 mg per burner;
  - 155 < P ≤ 405 W: 40 mg per burner;
  - P > 405 W: 40 mg per burner;
- not exceeding in other High Pressure Sodium (vapour) lamps
  - P ≤ 155 W: 25 mg per burner;
  - 155 < P ≤ 405 W: 30 mg per burner;
  - P > 405 W: 40 mg per burner.

ELC further on states that HPS lamps "cannot be exchanged by other technologies without having to change the fixture or to accept major changes like colour spectrum."

The proposed limit values are not supported by any data delivered by ELC.

Environmental NGOs on the other hand argue in [3] that setting such limits for HPS lamps is already an improvement compared to the current complete exemption but that mercury limits should be put on all HID lamps. Concerning HPS, they state the following:

"We understand that, as with other HIDs, the mercury content of HPS lamps tends to increase with wattage. We also understand that specialty HPS lamps – such as models that have a high colour rendering index, which enable them to deliver a white (rather than yellow) light – may require a higher mercury content and are justified because they offer safety improvements. […] According to data provided by the US lamp manufacturers Philips, Sylvania and GE, HPS lamps (with a typical CRI in the 20s) can meet much lower mercury levels than those proposed by the ELC […].The only models that we have seen with substantially higher mercury content are dual arc models (i.e., those with two burners). […] We understand that those types of HPS lamps […] need to have a higher mercury content." Nevertheless, environmental NGOs propose to set the ELC limits for low CRI models for these dual arc models since this is supported by their data research.

Furthermore, they state the following:

“Rather than watering down the single-burner HPS lamps for which substantial progress has been made to develop models with very low mercury content (which are offered by three major lamp manufacturers), this type of HPS lamp should be evaluated separately and given its own limits. Consequently we don’t support that low CRI single burner models should fall under the proposed ELC limits, and we propose lower separate limits for these latter models.

So for low CRI single burner models we would propose:

- P ≤ 155 W: 5 mg;
- 155 < P ≤ 405 W: 10 mg;
- P > 405 W: 25 mg”.

With regard to high CRI models, environmental NGOs state that “Our limited data on high-CRI HPS lamps shows that the mercury limits proposed by the ELC (30 mg for lamps <155 watts) may also be high. […] More data is needed on this lamp type to set a limit that reflects the upper end of the market.”

Limits proposed by NGOs are mainly based on data from the US market where HPS lamps can meet much lower mercury levels that those proposed by ELC. NGOs state that “the use of US HPS data seems applicable to this product category.” In contrast ELC argues that US “lamps have a lower efficacy than the latest generation of European lamps. In Europe, R&D efforts are devoted to an optimization of the efficacy. This is the reason why in the US one can find HPS lamps with a lower mercury dose. In Europe, HPS lamps with lower energy efficiency (“standard” types and mercury-free types) will be prohibited after 2012 (EuP IM). European HPS lamps are the most energy efficient in the world. In order to realize this efficacy a certain dose of mercury is required. There is risk that reduction of this dose leads to shorter life of these products. The amount of overdosing in European lamps is determined by the rate at which sodium is lost from the discharge. In modern processing and technology this rate can be limited. Therefore, the lamp industry is prepared to accept maximum limits for the amount of Hg in HPS lamps and proposes the values given above. Because of the higher operating temperature of low wattage and improved CRI lamps, they require relatively higher mercury contents”.

The following comparison of some EU and US lamps was provided by one European lamp manufacturer supporting their argument that EU lamps are more energy efficient by which higher Hg are justified:

Hg content	Phi	Lamp-type EU	PL	Lamp-type US	Phi	Hg content
[mg] max	[1000 lm]	NAV-	[W]	LU	[1000 lm]	[mg]
21.2 (average)	6.6	-T Super 4Y	70	LU Plus (non cycling	6.3	0.90
	10.7	-T Super 4Y	100	LU Plus (non cycling	9.8	0.90
20.4 (average)	17.5	-T Super 4Y	150	LU Plus (non cycling	16.0	1.81
	33.2	-T Super 4Y	250	LU Plus (non cycling	29.0	2.95
	56.4	-T Super 4Y	400	LU Plus (non cycling	50.0	2.95

The Swedish study [4] concludes that "due to colour rendering and mercury content this light source is no longer being further developed. […] adapters make it possible to change light source to metal halides which improves colour rendering."

4.5.2 Critical review (4a-I)

There is agreement among stakeholders that there are high and low CRI HPS lamps as well as single and double burner HPS lamps. Data on mercury content is only available for double-burner low CRI HPS lamps as well as single-burner low CRI HPS lamps. There is neither enough data on high CRI HPS lamps nor on the fact whether these are single or double-burner.

Data have been provided by one lamp manufacturer indicating that lower Hg levels in HPS lamps (as can be found in US lamps) result in efficacy losses of about 5-10%. This lower energy efficiency is not in line with the EuP Implementing Measures. According to EuP IM, HPS lamps with lower energy efficiency will be prohibited after 2012.

Substitution with other lamp technologies seems to be technically feasible but leads to changes in colour rendering and there is no information on whether this is beneficial in total.

4.5.3 Recommendation (4a-I)

Concluding from the above it is recommended to take over the limit values as proposed by ELC. The recommended wording is thus:

Mercury in High Pressure Sodium (vapour) lamps for general lighting purposes
not exceeding in lamps with improved colour rendering index > 60
– P ≤ 155 W: 30 mg per burner
– 155 < P ≤ 405 W: 40 mg per burner
– P > 405 W: 40 mg per burner
not exceeding in other High Pressure Sodium (vapour) lamps
– P ≤ 155 W: 25 mg per burner
– 155 < P ≤ 405 W: 30 mg per burner
– P > 405 W: 40 mg per burner

As expiry date the contractor recommends 31 July 2014.

4.5.4 High Pressure Mercury (Vapour) lamps (HPMV) (4a-II)

In HPMVs, the mercury in the discharge tube generates the light and provides the required electrical resistance. The mercury is completely evaporated under normal operating conditions. In its 15 contribution [1] ELC states that "reduction of the amount of mercury always leads to sub-optimal performance. The lamp dimensions and pressures are optimized for maximum efficacy at the existing gear. Hence if the discharge tube dimensions were to be changed to allow for a lower Hg content at the same voltage, then the luminous efficacy would be sub-optimal. For these reasons the position of the ELC is that a mercury limit for HPMV lamps is not possible."

Environmental NGOs state in their contribution [3] that HPMV lamps can be replaced by more efficient and less mercury containing HPS lamps and there is thus no justification to continue an exemption for these types of lamps. HPS lamps are available as retrofit kits as has been the result of NGOs' research. With regard to specialty lamps that might require higher mercury contents, environmental NGOs request that those lamps be labelled accordingly and granted an exemption under a separate heading for "lamps for special purposes".

The corresponding EuP activities came to the following conclusion:

"The proposed ecodesign requirement is to set minimum efficacy targets for street lighting lamps or for 'all' lighting applications so that HPM lamps are actually banned and HPS retrofits are used instead of them in installed luminaires. Even self ballasted (mixed light) HPM lamps could be excluded, because these can be replaced by CFL's with integrated ballast."[25]

[25] Vito 2007: Final Report Lot 9: Public street lighting, January 2007

With regard to retrofit HPS lamps, ELC states that "HPMVs can not generally be substituted by retrofit HPS lamps. This is only the case for certain applications, and only where colour rendering is not an essential requirement. Substitution is not at all possible for technical lamps like for example HBO lamps".

According to the lamp industry, recycling rates for HPMV lamps used in special applications are high as these speciality lamps are only applied by professional users. Data supporting the high recycling rates have, however, not been provided.

The Swedish study [4] comes to the conclusions that HPMV lamps have "low price, but a considerable higher amount of mercury and are now being replaced by metal halides and linear fluorescent lamps."

4.5.5 Critical review (4a-II)

Three different sources indicate that retrofit technologies are available for HPMV lamps used in general lighting. According to the criteria laid down in Article 5 (1) (b) this means that substitutes are available and that there is thus no justification for an exemption. There is no information available whether these substitutes have negative effects in the sense of Article 5 (1) (b).

For technical lamps that are used in special applications (e.g. in the production of semiconductors) a substitution of HPMV lamps by retrofit HPS lamps is not possible up to now.

4.5.6 Recommendation (4a-II)

Concluding on the above the following wording is recommended:

Mercury in High Pressure Mercury (Vapour) lamps except for general lighting (HPMV).

The consultant, however, proposes a notification process for those exempted special purpose HPMV lamps to collect data and information for future revisions of the Directive. As expiry date the contractor recommends 31 July 2014.

4.5.7 Metal halide lamps (MH) (4a-III)

In MH lamps, the mercury in the discharge tube generates only a minor part of the light. Its major role is to provide the required electrical resistance. The mercury is completely evaporated under normal operating conditions. MH lamps come in an enormous variety of shapes, caps, colour temperatures, colour rendering and wattages depending on the specific application. ELC states in its contribution [1]: "In all MH lamps, the amount of mercury dosed is such that the target lamp voltage is reached. Either over- or under dosing brings the lamp out of electrical specification. The only way to reduce the Hg content and still reach the required lamp voltage is a change in discharge tube dimensions. This however inevitably brings the lamp out of its photometric specification. For these reasons the position of the ELC is that imposing mercury limits for Metal Halide lamps is not feasible and not justified."

One lamp manufacturer provided the following overview on Hg levels in their MH lamps:

MH with ceramic burner: HCI lamps (max values)

Wattages	Mercury content
20 W	< 4 mg Hg
35 W	< 5.5 mg Hg
70 W	< 8.5 mg Hg
100 W	< 9.5 mg Hg
150 W	< 17.5 mg Hg
250 W	< 27.5 mg Hg

MH with quartz burner: HQI lamps

Wattages	Mercury content
70 W	< 19 mg Hg
150 W	< 26 mg Hg
250 W	< 33 mg Hg

Environmental NGOs in [3] state that "Metal halide (MH) lighting technology, like fluorescent lighting technology, has improved over time with respect to energy efficiency, rated life and mercury content. […] metal halide lamps can be divided into conventional standard MH models […] and more advanced metal halide pulse start technology (which includes ceramic metal halides). Standard metal halides not only have more mercury than pulse start metal halides, they also are less efficient and have a shorter lamp life. The Commission can help hasten the transition to more efficient, lower-mercury metal halides by establishing limits that this BAT can meet. It is important to note that all of the major manufacturers offer lines of these lower-mercury, energy-efficient metal halides; therefore, the availability of these technologies are widespread." Based on their data research they propose the following limit values:

Wattages	Proposed Mercury Limit
<25	2.5 mg
>25 <100	10 mg
>100 <200	15 mg
>200 <400	25 mg
>400	No limit

The Swedish study [4] comes to the conclusion that for "metal halide, which is a developing technology with many advantages, mercury content is decreasing. […] Regarding the metal halides there seems to be a good possibility to reduce the mercury content below 1 mg."

4.5.8 Critical review (4a-III)

Due to the fact that the function of mercury in the discharge tubes is to provide the required electrical resistance, it is only dosed in such concentrations that the target lamp voltage is reached. Either over- or under dosing brings the lamp out of electrical specification. Therefore, a misuse of mercury can be excluded.

A differentiation of limit values on basis of the wattages of MH lamps seems impracticable due to large variety of MH lamps: both MH lamps with quartz and ceramic burners are offered with different wattages, and each lamp type is produced with specific mercury contents.

4.5.9 Recommendation (4a-III)

Concluding on the above the recommended wording would thus be:

Mercury in Metal halide lamps (MH).

The consultant, however, proposes a notification process for those exempted special purpose HPMV lamps to collect data and information for future revisions of the Directive. As expiry date the contractor recommends 31 July 2014.

4.5.10 Exemption 4b "Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex"

Since there is a huge variety of lamps, probably not all lamps are covered by the above proposed exemptions. ELC requests an exemption for "mercury in other discharge lamps not specifically mentioned in this Annex" and justifies it as follows [1]: "The ELC believes that this exemption is absolutely necessary and justified due to the fact, that discharge lamps today need mercury for the generation of energy efficient light. Mercury limits in other than fluorescent and High Pressure Sodium (vapour) lamps would severely limit the development of new, better light sources in the future, if slightly more mercury would be necessary than allowed by an ambitious exemption.

Other discharge lamps include:

- Low or medium pressure mercury lamps for special purposes, like Hollow Cathode Lamps and pen-ray lamps
- High Pressure Sodium lamps for special purposes
- High Pressure Xenon lamps
- Projector lamps etc.

The ELC is also aware of the fact, that numerous very special lamps from other manufacturers, importers, equipment producers exist with small market shares for very special applications, that might be in the scope of RoHS. A narrow wording would exclude such lamps from the market making fixtures like measurement equipment unusable."

Environmental NGOs [3] are in favour of further exemptions for special purpose lamps if there is a justified need. They request individual identification of such special purposes lamps and a maximum limit of 10 mg. For any higher mercury content they propose prior approval.

ELC has in [1] provided a definition of special purpose lamps:

"Lamps for special purposes are needed where application specific characteristics are prescribed. They generally have the following characteristics:

- Special purpose lamps are manufactured basically in accordance with a general-purpose lamp making technology.
- The use of special design, materials and process steps provide their special features.

Fluorescent and other discharge lamps for special purposes include for instance:

- Where the non-visible radiation has highest importance, including:
  - Black light lamps;
  - Disinfection lamps;
  - Medical/Therapy lamps;
  - Lamps designed for UV emission like sun tanning lamps;
  - Pet care lamps i.e. aquaria lamps.
- Where different looking lamp designs are relevant for use, including:
  - Long length lamps (length ≥ 1800 mm);
  - Lamps with special components like integrated reflectors or with external ignition strip;
  - Lamps with special ignition features for example those designed for low temperatures.
- Where different applications require specific lamps, including:
  - Technical lamps for colour comparison;
  - Coloured lamps (incl. saturated colours);

– Lighting applications for food, such as bakeries etc.;
– Lamps used in horticultural lighting;
– Lamps designed for eye-sensitivity of birds and other animals".

Environmental NGOs argue that there is no justification why such lamps would need a blanket exemption.

The Swedish study [4] has come to the conclusion that lamps for special purpose are estimated to have a small market relevance in comparison to other lamps discussed above.

As stated in section 4.1.3 also lamps belonging to category 8&9 would fall under this heading.

4.5.11 Critical review exemption 4b

Since in the ELC examples of lamps that could fall under a potential "miscellaneous" exemption most are of special purpose it appears to be a good approach to provide a general exemption for such types of lamps (this would also include e.g. high-wattage CFLs that are not used for general purposes). Over-regulating these types of lamps may not lead to environmental benefits since their market relevance is considered to be low. However, as the proposed definition is a non-exhaustive list and since there is no data available on such lamps and their mercury content, manufacturers should be requested to clearly identify such lamps when put on the market as "for special purpose" and at the same time disclose the maximum mercury content in a notification process in order to collect data and information for future revisions of the Directive.

4.5.12 Recommendation exemption 4b

Concluding on the above it is recommended to grant an exemption for lamps for special purposes. The recommended wording is thus:

Mercury in other discharge lamps for special purpose not specifically mentioned in this Annex.

The consultant, however, recommends a notification process for those exempted special purpose lamps to collect data and information for future revisions of the Directive. As expiry date the contractor recommends 31 July 2014.

4.6 General recommendation

Environmental NGOs [3] as well as the Swedish study [4] have requested that manufacturers should disclose the maximum mercury content of all mercury-containing lamps and lighting equipment sold in the EU and mark their products accordingly. Environmental NGOs furthermore recommend to require information on the dosing method used as well as on the margins / accuracy of dosing.

This is not part of the RoHS exemption process as such but could be a valuable prerequisite for future evaluations and revisions.

4.7 References

[1] ELC contribution to Öko-Institut regarding RoHS exemptions 1-4 review (follow-up after the stakeholder meeting on 24 September 2008 in Brussels); 15.10.2008

[2] Megaman: Follow-up input stakeholder meeting 24 September 2008; 28/9/2008 ("Megaman_Clusterlite Classification_28.09.2008.ppt")

[3] Revised Environmental NGOs Response to Stakeholder consultation on mercury-containing lamps (EEB, Zero Mercury Campaign, Green Purchasing Institute); 10.11.2008

[4] AF-Consult AB: Mercury in lamps – reviewing the RoHS exemptions; report commissioned by the Swedish Chemicals Agency (KEMI); Stockholm, 3.10.2008 ("Final Mercury Report 081003.pdf")

[5] KEMI: Additional comment provided on 11/11/2008 ("Comments Kemi Hg in lamps_11.11.2008.doc")

[6] ERA-Report 2004; Dr. 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"

[7] JBCE / Hamamatsu; input as follow-up of stakeholder meeting on 10 June 2008; 4 July 2008 ("JBCE RoHS exemption No4_Follow-up_Document draft 3.pdf")

[8] Goodman, Paul: review of Directive 2002/95/EC (RoHS) Categories 8 and 9; final report, 19 September 2006

[9] ERA: stakeholder input concerning mercury in lamps used in the medical sectors; 16 June 2008 ("RoHS exemption 3 technical information final.pdf" and "RoHS exemption 4 technical information final.pdf")

[10] Test&Measurement Coalition: stakeholder input from 1 April 2008 ("Exemption-1_Test-Measurement-Coalition_31_March_2008.pdf")

[11] JBCE: Comments for RoHS " Exemption 1-4 "Mercury in lamp" – Proposal for discussion " for Stakeholder Meeting on 24 September, 2008. 23 September 2008 ("JBCE comments for exemprion1-4 Stakeholder Meeting_final.pdf")

[12] ELC comments to draft recommendation; 10.11.2008 ("Draft rec exemptions 1-4_8 including ELC comments 081106.doc")

[13] ELC reaction with regard to proposed 1 mg limit value for CFL; 18.11.2008 ("ELC reaction EuP 1mg.msg")

[14] Proposal on CCFL & EEFL from JELMA; 19 September 2008 ("Material for the stakeh meeting on 24th Sep.-JELMA.ppt" updated by "2008-10-15 JELMA Proposal for CCFLs.ppt")

[15] EICTA Position on Exemptions 1-4 "Mercury in lamps"; 23 September 2008 ("EICTA Position on Exemption 1-4 23rd September 2008.pdf")

[16] AeA position on exemptions 1-4; 23 September 2008 (e-mail from 23.09.2008 11:31)

[17] LIF Lighting Industry Federation; Technical statement No. 41 "T5 Lamp Adaptors for T8 Luminaires: Do they ensure energy saving and conformance with relevant standards and legislation?"(2007)

4.8 Exemption No. 5

"Lead in glass of cathode ray tubes, electronic components and fluorescent tubes"

4.8.1 General approach

The current exemption covers three fields of applications with quite different requirements. Therefore this exemption will be described in the following sections for each field of application separately.

Lead in glass of cathode ray tubes

Due to the basic functionality, in CRT displays electrons are accelerate toward a luminescent material deposited at the front panel. As the decelerating electrons produce radiation, lead as lead oxide is added to the glass matrix in CRTs to act as a shield against radiation. Thus lead as lead-oxide in the glass matrix is used due the ability to absorb gamma rays and other forms of harmful radiation. Furthermore lead oxide is used as sealing frit between funnel, panel and nec glass.

During stakeholder consultation and in the follow-up process, several contributions were received covering this field of application [5], [15], [16]. All of them agree that lead in the cone glass were the only effective method to shield x-rays emanated from the electron beam in CRTs. Only in the front glass barium could be used [5]. This position corresponds to descriptions available in literature.

Basically one could object that meanwhile other display technologies are available, notably LCD and PDP and that therefore substitution at a system level would be feasible. However, there are applications where the specific functionality of CRTs is superior to the new technologies, especially in the case of low and high ambient temperatures [17] as well when fast moving pictures are to be displayed. Therefore substitution at system level is currently not being feasible.

Against this background the consultant recommends to prolong the existing exemption. In this specific case lead is used due a functionality based on fundamental physical properties. It is not imaginable that another material could be found delivering the same function. Therefore there would not be advantages in defining an expiry date. [16]

Lead in glass of fluorescent tubes

The existing exemption was granted on request of ELC. ELC formerly claimed that lead containing glass was needed in flares and exhaust tubes for production process reasons.

ELC contributed to the current review as follows [5]: ELC members are in the process of phasing out lead of all lamp glass for most if not all lamps. Lead glass will be substituted by lead-free glass by changing the production process.

Against this background, the current exemption will not be needed further on.

However, Lamp glass producers use recycling glass for the production of new glass in order to save material resources and of course to save energy. According to ELC's contribution energy consumption for glass production is reduced up to 30% by the use of recycling glass [5]. As lamps (and other glasses) in the past did contain lead this substance is also contained in the recycling glass. Unfortunately every single batch of recycling glass is different regarding lead content. In order not to hamper the use of recycling glass a limit slightly higher than current limit of 0,1% wt is necessary, and it is necessary for all lamp glass, not only for fluorescent lamps. It is also necessary to have more legal certainty for manufacturers. From environmental point of view the use of recycling glass reduces energy use, reduces waste to be disposed of. As the use of lead in new glass is decreasing dramatically ELC do not expect to need this "exemption extension" for more than 1 period.

Lead in glass of electronic components

In contrast to the application fields of lead in glass mentioned above this field of application comprises a number of various electronic components. Typical examples are lead-based electrodes, resistors, capacitors, chip coils, chip inductors, resistance networks, capacitor networks, hybrid ICs, power semiconductors etc. Furthermore, this kind of electronic components are used for nearly all kind of applications, including the total range of WEEE categories. Therefore the current exemption covers lead-containing glass in different applications with quite different functions and different possibilities for substitution, accordingly.

Some stakeholders that produce rather specific products were able to provide specific data and to reflect the specific conditions of substitution. The specific arguments are summarised below.

4.8.2 Justification by stakeholders

During the review process several stakeholder contributions were provided:

Rosemount Inc. / Emerson Process Management submitted several documents related to three types of applications ([1], [2], [3] – by error, all documents were sent to the reviewers as submissions to exemption 25).

- Lead oxide containing glass in its high performance capacitive metal pressure sensors:
- The applicant points out that the high performance metal capacitive sensors are used as pressure, level and flow instrumentations in various process industries. The PbO-containing glass is used in a glass-to-metal seal within the sensors. Substitution problems are mainly due to safety issues as the replacement of the lead oxide (PbO)-containing glass carries the risk to reduce the reliability and therefore the control of the product. Substitutes would have to show the same or better temperature and pressure stability as PbO-containing glass. Furthermore a specific thermal expansion coefficient and specific flow and adhesion characteristics would have to be matched.
- Lead oxide containing glass in high performance electrochemical pH and ORP sensors:
- Similar to the previously mentioned application the pH and ORP sensors produced by Rosemount are also used in various process industries. The PbO-containing glass is used in a stem glass part which represents the basis of the sensor. According to the applicant the coefficient of thermal expansion, the high electrical resistivity, the high chemical resistance (even at elevated temperatures) as well as a good interference chemistry can currently only be met by PbO-containing glass. Again, the lack of substitutes is due to safety issues as a structural failure in the sensors may result in a loss of control and therefore represents a risk to the equipment, the environment and the personnel.
- Lead oxide containing glass seal frit to hermetically seal the reference chamber of sapphire based pressure sensors:
- According to Rosemount the PbO-containing glass is used in a hermetic seal part with sapphire based pressure sensors. These sensors are applied mainly in hazardous and remote industrial locations and substitution is currently technically and scientifically impracticable. In this type of application the thermal expansion coefficient does not represent a problem for substitutes. However, the vacuum, the firing temperature and the frit material itself, which may attack the metal conductors of the sensors, are the main reasons for a lack of substitutes. As for the previously depicted sensors a PbO-free alternative for sapphire based pressure sensors would at present represent a safety risk to the environment, the equipment and the personnel.

Despite several years of research and continuing efforts no technically feasible substitutes for the PbO-containing glass have been found yet and according to Rosemount no other company currently offers feasible substitutes. Furthermore the amount of lead per year (see data on 2006 and 2007) did not exceed 460 kg within the EU for all three types of sensors according to Rosemount.

Vishay provided information on PbO-containing glass in vitreous enamelled resistors for reliability applications as telecom-protection and on PbO-containing resistive paste in thick film resistors for power applications [4]. Although Vishay spent 1-2 man years on research for substitutes the mechanical and physical characteristics (e.g. dilatation coefficient and high temperature resistance for vitreous enamelled resistors and the ductility as well as the stability for thick film resistors) have not been met. However, Vishay noted that for their application several tonnes of PbO are consumed per year.

In their joint industry contribution **EICTA, AeA Europe, EECA ESIA and ZVEI** support the information provided by Rosemount and Vishay [5]. This contribution agrees with the previous statements that for Pb in glass for electronic components, in glass for protection-hermetic seals as well as in glass in glass frit substitutes are unavailable to date.

Sensata uses Pb-glass in thermal overload devices and therefore emphasizes once again on the safety issue of the material. As Pb-glass in these applications provides a low softening point and at the same time a hermetic sealing it is an essential safety issue for the end-application (e.g. refrigerators) [8].

The Japan Business Council in Europe (**JBCE**) in collaboration with a Japanese ICT Organization (**JEITA**) submitted sound information on the substitution difficulties for Pb-glass in glass frits thick film technology, showing that also climatic conditions pose a problem to the tested substitution materials [9].

In a submission document from **PerkinElmer** [10] the analytical application of Pb-glass in Channel Multipliers (CPM) is also explained as essential because PbO is used in solder-glass for this application. Additionally, **SCHOTT** – who uses solder-glasses for optoelectronic devices – explains the substitution of lead-containing solder-glasses is still unfeasible although several attempts of Pb-free solder glasses have been made [11].

4.8.3 Critical review

Environmental risks:

As the lead is bound within the glass there is no direct health or environmental risk of it in this application because the possibility of release to the environment is greatly reduced. According to some stakeholders there are several applications of Pb-glass in electronic components providing the function of security devices. A substitute of inferior quality might have disastrous consequences to personnel and to the environment in case of failure.

Research for substitution:

As described within several stakeholder contributions (e.g. Sensata [12], Joint industry contributions [5] & [9], SCHOTT [11]) research on substitution for lead in glass of electronic components has been investigated for years and is still to date. However, currently no substitutes are available and even promising substitution materials are missing. For future research it is also important to keep in mind that "alternative material" as bismuth, for example, may even increase the environmental impact and the energy consumption (e.g. as lead is a by-product of the bismuth production).

In summary a future substitute of lead in glass of electronic components would have to meet the following demands:

- match of the thermal expansion coefficient;
- affinity with material;
- electric stability;
- low softening point and low calcination temperature;
- weather, moisture and chemical resistance (e.g. acid resistance).

Wording:

Assuming that the current wording might be too widespread the contractor attempted to narrow the scope of the existing exemption. During the stakeholder meeting (11th June 2008) it was discussed to identify a new wording (for each kind of application) reflecting the different functionality of lead-containing glass. Another suggestion was to provide a component specific wording reflecting the specific functions (like hermetic seal etc.) for each single application, or at least for typical groups of application.

However, it became obvious that the changing of the current wording would be difficult. The challenge with a function specific list for these lead containing components is that first of all less obvious components (as photo multipliers) might be forgotten and second of all – as invention is an ongoing process – new inventions might be hampered by such a specific listing. Additionally, there are some cases where lead in glass provides more than one function. Furthermore a new wording with specific applications might create confusion in the supply chain. Additionally such a list would be quite complex which becomes obvious by regarding the JBCE list of electronic parts which use Pb-glass and which were obtained from a survey of 57 electronic component manufacturers [13][26]. A list of 18 products using Pb-glass components, submitted by the Test and Measurement Coalition [14], also supports this statement.

4.8.4 Recommendation

In order to reflect the different functions and applications and the developments described above we recommend to split up the existing exemption as follows:

- *Lead in glass of cathode ray tubes. (Assuming that each exemption is required to have an expiry date, the consultants propose 31 July 2014 to give the stakeholders opportunities to submit evidence in the next review of the Annex for the further need of this exemption beyond 2014, if appropriate.)*
- *Lead in the glass of fluorescent tubes not exceeding 0,2% by weight. Expiry date: 31 July 2014.*
- *Electrical and electronic components which contain lead in a glass or ceramic other than a dielectric ceramic, or in a glass or ceramic matrix compound (e.g. piezoelectronic devices) until 31 July 2014, and for the repair, and to the reuse, of equipment put on the market before 1 January 2015.* (see section 4.12 in this report)

4.8.5 References

[1] Rosemount submission to exe. 5 “Exemption_25_Emerson_I_26_March_2008.pdf”

[2] Rosemount submission to exe. 5 “Exemption_25_Emerson_II_26_March_2008.pdf”

[3] Rosemount submission to exe. 5 “Exemption_25_Emerson_III_26_March_2008.pdf”

[4] Vishay submission to exe. 5 “Exemption-5-6-7_VishaySA_31_March_2008.pdf”

[5] Joint industry contribution (EICTA, AeA Europe, EECA ESIA and ZVEI) to exe. 5 “Exemption_5_EICTA_and-others_1_April_2008.pdf”

[6] ELC submission to exe. 5 “Exemption-5_European-Lamp-Companies-Federation_31_March_2008.pdf”

[7] ELC submission to exe. 5 “Questions exemptions 5_ELC_2008-06-17 final.pdf”

[8] Sensata submission to exe. 5 “Exemption_5_Sensata_Technologies_31_ March_2008.pdf”

[26] This document has been considered as confidential until an e-mail exchange between Mr. Fasano (JBCE) and Öko-Institut (20.06.2008)

[9] JBCE partially confidential submission to exe. 5 "Exemption-5_JBCE_1_April_2008.pdf"

[10] PerkinElmer submission to exe. 5 " Exemption_5_PerkinElmer_1_April_2008.pdf"

[11] Schott submission to exe. 5 "Comparison of different solder glasses_22.08.2008.pdf"

[12] Sensata submission to exe. 5 "Sensata presentation for Stakeholder Meeting (2).ppt"

[13] JBCE submission to exe. 5 "JBCE_(File No,2)Summary of data Lead glass .pdf"

[14] T&M Coalition email to exe. 5 "TM coalition response to RoHS exe. 5 follow-up_7.08.08.msg"

[15] Pecht, Michael; Review of High-Lead Solder and Lead-Glass RoHS Exemptions. CALCE Electronic Products and Systems Center. University of Maryland. 25/03/2008

[16] HP Letter to the Öko-Institut. June 30, 2008

[17] Jäger, Ralph; Technical information on (1) Black and white CRT for viewfinder of professional-use camera, (2) Color CRT Monitor for professional-use

4.9 Exemption No. 6

"Lead as an alloying element in steel containing up to 0,35% lead by weight, aluminium containing up to 0,4% lead by weight and as a copper alloy containing up to 4% lead by weight"

4.9.1 Description of exemption

Lead is used as an alloying element in steels, aluminium and copper. The main effect of lead in these metals is an improved machinability. Lead acts as a lubricant and the addition of lead results in better chip fracturing and surface finish as well as in higher cutting speeds and a longer tool life.

In view of consistency in environmental legislation it should be noted that Annex II to the ELV Directive[27] also includes exemptions for the use of lead up to 0,35% in steel, (entry no. 1), up to 0,4% in aluminium, (entry no. 2) and up to 4% in copper (entry no. 3). Information and data provided in the context of the recent adaptation to scientific and technical progress of ELV Annex II [1] have been taken into account in the present adaptation of the RoHS Directive.

In the following sections the use of lead as an alloying element is discussed separately for each of the three metals steel, aluminium and copper.

[27] Directive 2000/53/EC on end-of-life vehicles (ELV Directive)

Lead as an alloying element in steel containing up to 0,35% lead by weight

In steel, lead is both used as an alloying element for machining purposes and for the production of galvanised steel.

Steel for machining purposes:

Lead is added to steel for an improved machinability: Through the lubrication effect of lead better chip fracturing, automation of the production process, high cutting speed and federates (low cycle times), longer tool life, better surface finish and more accurate dimension control can be achieved.

The main production countries of leaded steels are UK, Germany, France and Spain. The total production volume of leaded steel in the EU is estimated to be 1,3 Mt per year [2]. It is, however, not possible to accurately say how much of this material is used for applications covered by RoHS due to the length of supply chains and sales to stock-holders and intermediate processors selling steels to different applications. Within EEE, leaded steels are mainly used in larger equipment with smaller volumes. Therefore, yearly quantities are expected to be some tons at maximum [2].

Machining steels are used in a diverse range of final applications within electrical and electronic equipment. For example, leaded steels are used in bolts, screws, nuts, valve pins, bushings, housing, axles, shafts of electric motors, rotors etc.

Galvanised steel

Galvanisation is a metallurgical process that is used to coat steel with zinc. This is done to prevent corrosion (rusting) of steel.

The most common form of galvanisation is “hot dip galvanisation” where iron or steel articles are galvanised by dipping in a molten bath of zinc or zinc-alloy at a temperature of around 450°C. Hot dip galvanisation can be done in continuous or batch operation: Steel strip are usually hot dip galvanized in a continuous line by drawing the steel continuously through a bath with a liquid zinc alloy. Individual metal articles are hot dip galvanized by a process called batch galvanizing. The coatings of steel sheet/strip in continuous coating lines are typically thinner than the coatings obtained by general (batch) galvanizing.

Both the continuous and batch processes of hot-dip galvanizing result in a metallurgical bond between zinc and steel. The bonding region is an intermetallic compound, termed the “alloy layer”. However, continuously galvanized steel has a thinner alloy bonding zone which is usually only 1 to 2 µm thick with the total zinc coating being approximately 10–30 µm thick.

The batch galvanized steel has a thicker coating and the alloy layer comprises a higher proportion of the coating (approx. 40-60%). In some cases, the alloy layers comprise 100% of the coating. The zinc bath used in general (batch) galvanising can contain lead at levels up to 1,1%, dependent on the specific process type . The concentration of lead in the zinc bath used in continuous galvanizing is typically between 0,05 and 0,10% [3], [4]. The main function of lead in the zinc bath for general galvanizing is its influence on the viscosity of the molten zinc. Lead is beneficial to accommodate “free drainage” of excess zinc when the parts are removed from the zinc bath. Due to the lower viscosity of molten zinc, it is difficult to avoid small sags and ripples in the zinc coating in the absence of lead. The thicker the coating, the greater the tendency to form sags and ripples. The result is that the surface is not smooth and the coating is composed of locally thick and thin regions. Further beneficial effects of lead in the zinc bath can be summarised as:

- Ease of drossing – to aid recycling of the zinc bath;
- Avoidance of “floating dross” during galvanizing of complex geometries which may lead to adverse surface finish;
- Protect kettle from uneven heat distribution from burners – preventing dangerous “run-outs” of molten zinc.

Applications of galvanized steel in EEE include bolts, nuts, brackets and other small parts use in electrical assemblies that need to be prevented from corrosion.

EGGA (European General Galvanizers Association) has proposed to re-word exemption no. 6 in order to be consistent with the wording in the ELV Directive [17]:

“Lead as an alloying element in steel *for machining purposes and galvanized steel* containing up to 0,35% lead by weight, aluminium containing up to 0,4% lead by weight and as a copper alloy containing up to 4% lead by weight”.

EGGA further argues that the current wording is vague compared to the ELV entry and it is unclear that it includes the presence of lead in galvanised steel.

Lead as an alloying element in aluminium containing up to 0,4% lead by weight

With regard to the presence of lead in aluminium three different cases need to be distinguished:

- Aluminium alloys where lead is intentionally added for improved machinability.
- Aluminium alloys where lead is intentionally added for corrosion prevention.
- Aluminium alloys that contain lead unintentionally due to their production from scrap metal.

Aluminium alloys are typically far easier to machine than steel alloys and as a result additions to enhance machinability are not as widely used as for steel. Thus, the biggest share of aluminium alloys contains lead unintentionally due to the production from scrap metal. Leaded aluminium is used in bushing gears for motors, die-cast aluminium parts (e.g. RF filters, chassis) and in heat sinks.

In the EU currently ca. 2,7 million tons of aluminium casting alloys are annually produced from scrap. Majority of these is used in applications other than ICT[28] equipment. Within EEE, these are mainly used in larger equipment with smaller volumes. Yearly quantities are expected to be some tens of tons at maximum. In general, aluminium consumption of EEE industry is only 9% of the worldwide consumption.

Lead as a copper alloy containing up to 4% lead by weight

Lead is embedded as tiny nodules in the matrix of copper alloys and has the function of a chip breaker. The formation of short chips, which can be removed automatically, is facilitated by the lead nodules. Thus, lead acts mainly as a machinability enhancer.

Another characteristic of the lead is its function as a lubricant reducing the tool wear and the power consumption of machining processes. Furthermore, by reducing the friction between sliding surfaces, lead provides a better slide functionality for parts with closely fit sliding surfaces.

The typical lead content in copper alloys (brass) is 0,2 to 4,2% in accordance with CEN EN 12164 and 12165.

The average annual consumption of leaded brass in the EU is approximately 1 500 000 t. Figures on the share in the electronic sector have not been provided by the copper industry. However, it is estimated that yearly quantities in ICT[29] equipment are ten tonnes at maximum.

Typical applications of leaded copper in the electronic sector are antennas, connector contacts that are screw machined (e.g. most commercial RF[30] co-axial connectors), connector shells or other hardware that needs milling, valves, valve guides, battery terminals, temperature sensor housing, shafts actuators, pins and fittings.

4.9.2 Justification by stakeholders

Lead as an alloying element in steel containing up to 0,35% lead by weight

EICTA et al. [2], Eurofer [5] and ERA [6], [7] justify the continuation of the exemption as follows:

<u>*Steel for machining purposes:*</u>

Machining steel is used where individual components require machining as part of their production route. The specific function of lead in steel can be described in a number of ways. Fundamentally, lead is added to enable improved machinability. Machinability can be con-

28 Information Communications Technologies (ICT)

29 Information Communications Technologies (ICT)

30 RF: radio frequency

sidered as meaning any of the following; a reduced cutting force when machining steel, appropriate chip formation (length and form), facilitation of a smooth surface finish, facilitation of good dimensional achievement under commercial production conditions or reduced 'tool wear' during the machining operation. Machining encompasses a number of production operations, including; turning, grinding, rough forming, fine forming, drilling and parting. The specific function of lead in steel is to provide a lubrication effect from the material itself when that material is being machined into a component. Through this lubrication effect, the steel becomes more machinable.

The justification for the continued exemption can be summarised as follows: "All currently identified alternatives to lead as a machinability enhancer in steel have been formally assessed without identifying any addition that effectively replaces lead in all respects. Lead-free alternatives may show acceptable results in single machinability test, but the overall performance of the lead-free steels is worse than that of leaded steel. If a variety of machining operations is required or if deep drilling of material is required, lead is still considered the best machinability enhancer in an industrial production.

Customer demand supports the view that leaded steels are required rather than the alternatives which are currently offered by European steel manufacturers".

Reference is made by the steel industry to different reports investigating the machinability of lead-free steel alloys:

The University of Pittsburgh had developed a non-leaded low carbon free cutting steel (1215) containing 0,04-0,08% tin which they claimed can replace leaded free cutting steel (12L14). A range of machinability tests was undertaken with tin treated steel in order to investigate these claims [8]. The results of these tests indicated that tin treated free-cutting steels showed less favourable results with regard to the different aspects on machinability than leaded steels. It was concluded that tin cannot replace lead in free cutting steels.

The European steelmakers and component manufacturers formed a collaborative research project funded by the European Coal & Steel Research (ECSC) to evaluate potential alternatives to lead for low carbon free cutting and carbon/alloy grades.

The final report of this project summarises the results of machinability tests conducted with different lead-treated and lead-free steel alloys. These machinability tests included measurement of tool life, tool wear, surface finish, chip form, tool force and tool temperature. The steel grades selected for these tests were free-cutting steels (11SMn30), steels for hardening and tempering (C45) and case hardening steels (16MnCr5) with the following machinability enhancing additions:

Lead, bismuth, increased sulphur (with and without tellurium), tin (with low and high copper), phosphorus and calcium.

The general conclusion of these tests is that leaded steels showed the best performance in tests at lower cutting speeds with high speed steel tools and in deep hole drilling. Non-leaded alternative grades generally gave poorer chip form and surface finish. It was shown that of the alternatives bismuth is able to substitute for lead under certain conditions, although the cost of the addition may make it uneconomic, particularly for large scale application.

According to the steel industry, the hot workability of bismuth steels is reduced compared to leaded steels. Hot workability is a fundamental requirement for the steel production [1].

This parameter is of significance when the steel is being rolled to the required size for a customer from a piece with a larger (as-cast) cross sectional area. The reduced hot-workability of bismuth steels effectively means that it is significantly harder for a steel roller to produce a bar with the same machining properties and surface integrity if the steel obtains its machining properties through bismuth rather than lead.

It can be expected that there would be a higher energy cost associated with bismuth as well as potentially higher rejections (waste).

Although the machining properties of bismuth treated steels approach those of lead treated steels for certain machining operations, in the majority of machining operations lead remains the most effective machinability additive through its combination of machining characteristics.

It was further concluded in the report that calcium can substitute lead in C45 steels for use at higher cutting speeds. However, calcium treated steels have higher cutting forces, poorer chip form and have their best performance limited to a narrower range of machining speeds in comparison with the leaded product. It is highly likely that a variety of machining operations are required for many automotive components, such that the more limited benefits of calcium treated grades may not be able to match the benefits of leaded grades in many instances.

Steels containing tin generally did not show good performance in the machinability tests and thus, was not considered as a suitable replacement for lead in steel.

Eurofer states that negative environmental, health and/or consumer safety impacts caused by substitution of lead by alternative machinability enhancers are likely to manifest themselves as increased energy costs associated with a reduced effectiveness of that machinability enhancer in comparison with lead. There may also be influences of increased mining activity (through scarcity of supply) for elements that are less easy to recover and less abundant than lead, most notably bismuth [5].

Galvanised steel

With regard to the galvanisation of steel, the function of lead is not related to the improvement of the machinability or any other performance aspect of galvanised steel, but its influence on the viscosity of the molten zinc in the zinc bath during the galvanisation process itself.

The most common form of galvanisation is “hot dip galvanisation” that is performed in continuous or general (batch) operation depending on the form of steel to be galvanised: Steel strip are usually hot dip galvanized in a continuous line whereas individual metal articles are general (batch) galvanized.

Only the zinc bath used for general (batch) galvanizing contains lead in concentrations that give rise to a need for exemption. In contrast, the continuous galvanizing process does not require the addition of lead to the zinc bath. The main reason that lead was used in continuous galvanizing was that it causes the formation of the typical large spangled surface, which through the years was “the way to identify galvanized coatings”. Alternatively, antimony is mentioned as substitute to lead providing the same effect [4] and has allowed steel producers to largely eliminate lead from continuous galvanizing. In general (batch) galvanizing, the lead is beneficial to accommodate “free drainage” of excess zinc as the part is removed from the zinc bath. In some instances today, bismuth is being substituted for lead to achieve free drainage of the excess zinc. Alloys that contain bismuth for use by the general galvanizing industry are available today from a number of zinc suppliers. With regard to the substitution of lead to bismuth EGGA objects that bismuth is a co-product of lead production. There is currently no primary production of bismuth and its availability to meet the needs for all replacements for lead in industry is questionable [14].

A further galvanisation technique is electrogalvanizing (or electrolytic galvanizing or electroplating), which deposits the layer of zinc from an aqueous electrolyte by electroplating, forming a thinner less strong bond. Lead additions are not required in electrogalvanizing. Electroplating is in principle applicable both for individual steel articles and –with certain restrictions- for steel sheet/strip. According to information provided by stakeholders [6] continuous hot dip galvanized steel is used for large panels used as enclosures for equipment such as refrigerators and freezers. These all use large sheets of hot dip galvanised steel that are bent 90° to form the required shapes. Electroplating fairly small parts is straightforward but electroplating large sheets of steel would require very large equipment and is a more expensive process. Hot dipping can be added to the end of steel sheet production lines as the process is quick but it also used as a separate process. Hot dipping takes seconds whereas electroplating takes several minutes at least.

Research is ongoing within the industry to develop new zinc-based alloys for general galvanizing. Principal research goals are *(i)* more zinc-efficient coatings (thinner coatings regardless of steel type) and *(ii)* coatings of more consistent appearance and surface finish. These goals are accompanied with a desire to reduce the presence of hazardous substances, including lead. Due to the fact that current lead prices are sometimes higher than those of zinc, there is no economic advantage to intentionally add lead to a galvanizing bath where it is not technically required. No feasible alternatives are yet available though for lead in general (batch) galvanizing for all types of component that may be used in electrical equipment within the scope of WEEE.

Lead as an alloying element in aluminium containing up to 0,4% lead by weight

EICTA et al. [2] and ERA [7] justify the continuation of the exemption as follows:

Aluminium alloys where lead is intentionally added for improved machinability:

By the addition of lead a better chip fracturing, automation of the production process, high cutting speed and federates (low cycle times), longer tool life, butter surface finish and more accurate dimension control can be achieved.

Aluminium alloys where lead is intentionally added for corrosion prevention:

The surfaces of aluminium parts are usually finished anodized for functional reasons since anodizing increases corrosion resistance and wear resistance. The function of lead is the higher resistivity of leaded aluminium alloys compared to tin or bismuth containing aluminium alloys against pitting corrosion in acidic systems e.g. brake systems. A certain lead content in aluminium alloys improves both layer adhesion and layer quality.

Aluminium alloys that contain lead unintentionally due to their production from scrap metal:

Aluminium produced from recycled scrap metal may unintentionally contain lead. The lead may have been added to the scrap stream over years through not accurately separated wheel rims, aluminium for machining purposes, lead from batteries, and other lead-containing applications. Thus, lead is included in the scrap flow as an impurity which cannot be separated during the scrap process phase.

There are two theoretical options to reduce the lead content in aluminium alloys in order to achieve the 0.1% limit:

1. Removal of lead from aluminium by metallurgical processes;
2. Dilution of scrap with primary aluminium.

Ad 1) Removal of lead from aluminium by metallurgical processes:

According to the European Aluminium Association (EAA) and the Organisation of European Aluminium Refiners and Remelters (OEA) the removal of lead from aluminium by a metallurgical process is technically not yet feasible on an industrial scale [1]. Research on the removal of lead from aluminium e.g. by melt purification is currently being conducted. The research activities are still in an early stage and have not yet produced practicable solutions for industrial applications.

Ad 2) Dilution of scrap with primary aluminium:

Theoretically, the lead content of scrap can be reduced by diluting the melt with primary aluminium. To reduce the lead content from 0,35% to 0,1%, it would be necessary to add 2,5 tonnes of primary aluminium to 1 tonne of recycled aluminium. Even with an average lead content of 0,2% in 55% of all aluminium casting alloys, in Europe an additional amount of ca. 1,1 million tonnes of primary metal would be necessary in order to reduce the lead content to 0,1% in aluminium casting alloys.

According to EAA/OEA the primary metal needed for diluting is not available, because the primary aluminium industry is already running at full capacity [1]. It would take years until additional capacities could deliver the material.

Currently, the global aluminium production is around 200 000 tonnes lower than the demand. New primary aluminium capacities, which are in the planning phase, are needed to supply the growing global demand for aluminium (average global increase annually 3,4%).

Diluting with primary aluminium is technically possible, but is restricted by the availability of primary aluminium. From an environmental point of view the dilution of scrap with primary aluminium is not considered to be a reasonable option because the quantity of energy needed to produce primary metal is 95% higher than the amount of energy needed to produce casting alloys from scrap.

From an environmental point of view the dilution of scrap with primary aluminium is not considered to be a reasonable option because the quantity of energy needed to produce primary metal is 95% higher than the amount of energy needed to produce casting alloys from scrap (EAA Energy figures primary recycling).

The recycling rate of aluminium is >95%. Due to the fact that lead is an unwanted tramp element with negative characteristics in the finished products if exceeding certain levels, the aluminium industry has an interest to keep the lead impurities in the secondary aluminium cycle as low as possible. In effect, the presence of lead in the recycling process is not so much an environmental problem but rather a question of product quality which will require compensation by dilution with primary aluminium at least to a certain grade.

EAA/OEA state that there is no risk to the environment and/or human health from aluminium with a lead content up to 0,4% by weight. It is argued that lead exists as an impurity in aluminium. Lead is present in 'solid solution' in the metallic crystal lattice or as dispersed constituents of a size smaller than 1µm. As aluminium does not corrode under normal conditions, the lead does not leach out when aluminium is exposed to atmosphere or neutral water during its use or in cases where it is littered in the nature after the end-of-life of a product.

Lead as a copper alloy containing up to 4% lead by weight

EICTA et al. [2], ERA [7] and Wieland-Werke AG [9] justify the continuation of the exemption as follows:

Lead is mainly added to copper alloys to enhance the machinability of these alloys. The formation of short chips, which can be removed automatically, is facilitated in the presence of lead. Under these circumstances wrought products can be processed around the clock on fully-automated fast-turning lathes. Another characteristic of the lead is its function as a lubricant. The self-lubricating effect of leaded copper alloys (brass) and the formation of short chips result in a reduced cutting force (Figure 4). A reduced cutting force in turn requires less energy during the machinability process leading to lower power consumption with increasing lead content (Figure 5). In addition, consumption of coolants and lubricants can be reduced during machining of leaded brass.

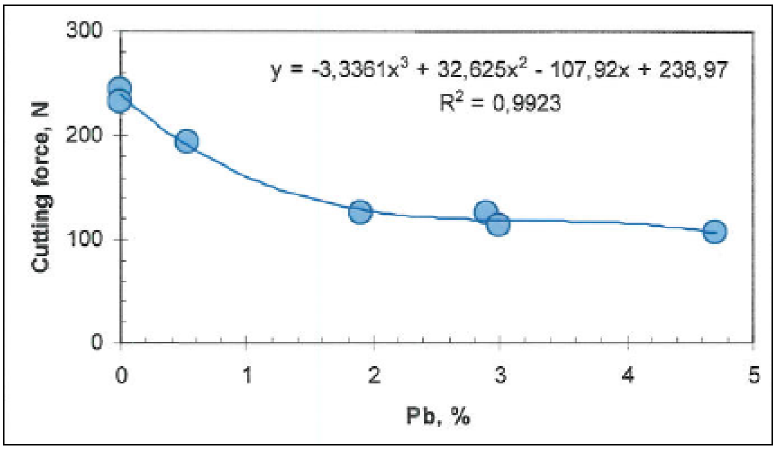

Figure 4 Cutting force depending on lead content [10] [11]

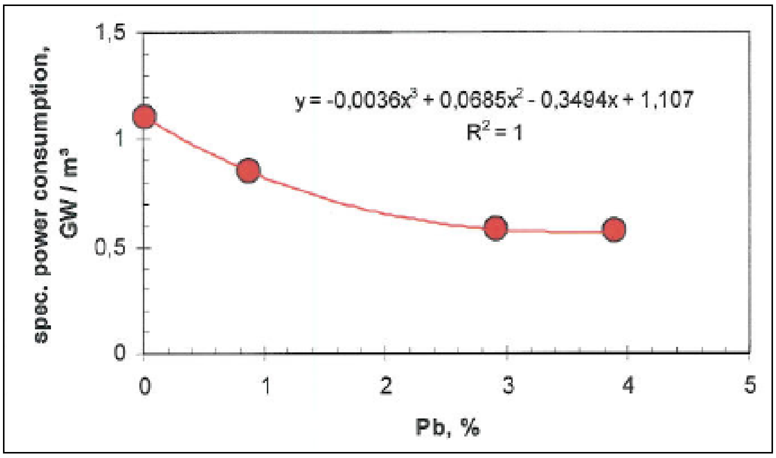

Figure 5 Power consumption per chipped volume depending on lead content [12]

By reducing the friction between sliding surfaces, lead provides furthermore a better slide functionality for parts with closely fit sliding surfaces. This is an important design criteria for valves, bearings, bushings and any parts which require “sliding” surfaces without galling or binding up.

In addition to its main function as machinability enhancer, lead in copper alloys shows further side effect:

Lead particles are able to pin grain boundaries during annealing and hot working. As a result wrought copper alloys containing lead have got a fine grained microstructure which is advantageous for many applications. Particularly a small grain size is necessary when miniaturised components have to be manufactured from copper alloys, for instance in EEE applications. Basically, grain refinement can also be achieved by alloying other elements which have a low solubility in the copper matrix, such as iron. However, iron would change the composition of the alloy and consequently its properties.

For certain copper alloys and certain mediums lead can slightly retard corrosion. The effect is most probably due to a surface film of corrosion resistant lead salts: During the machining and forming processes elemental lead that is present in the copper alloy is lubricated on the surface of the manufactured part forming a thin and more or less continuous coating. The surface layer of lead reacts with ambient mediums like saltwater to hardly soluble salts, which are for instance very stable in seawater. However, this mechanism is not as reliable as an targeted adding of alloying constituents such as aluminium, manganese, nickel etc. and is only considered as positive side-effect of leaded copper alloys.

Both the electrical and the thermal conductivity of copper alloys are not influenced by lead. However, copper alloys as a whole (i.e. regardless of the lead content) have better electrical and thermal conductivity than other materials, for example steel. For that reason they are frequently used for electrical components or thermal sensors.

According to the copper industry, there are no substitutes available having the same effectiveness in machining processes. Research on lead-free copper alloys has been carried out for many years without finding technical and economical equivalent alloys. Lead-free copper alloys exhibit different material characteristics and entail considerable cost increases due to higher copper contents. Users of those materials in the test period report on higher wear out of machines and tooling as well as on missing long time experience in production and usage of parts. Higher cycle times for semi-finished parts in lead-free alloys limit the production capacity which may lead to a bottleneck in supply.

CuZn-alloys (e.g. CuZn37, Cu-Zn-Si (EcoBrass®)) are being tested in some products as lead-free alternatives. Although silicon brasses like EcoBrass® have a high strength and moderately high corrosion resistance, their machinability (tool wear, energy consumption, chip size, surface properties of the work piece) is probably inferior to that of leaded free-cutting brass, and long-term experience (environment, reliability etc.) does not yet exist.

Among others bismuth has been considered as a potential substitute for lead in two-phase brass alloys. However, the use of bismuth significantly complicates the production of wrought alloys, i.e. rods, wires and profiles. Bismuth tends to wet the grain boundaries resulting in severe embrittlement, particularly at high temperatures. Although the embrittlement can be slightly reduced in alloys containing the elements Sn, In, P or Zn > 20%, nevertheless at elevated temperatures tensile strength and ductility (elongation) of bismuth-containing cast alloys are significantly lower than of wrought free-cutting brass containing lead. Furthermore, the internal stress in bismuth-containing alloys is increased caused by the expansion of bismuth during solidification. This is also the reason why these materials are far more susceptible to stress corrosion cracking. Bismuth containing alloys cannot match wrought leaded alloys in terms of machinability indicated by the machinability index of 85% at best. The hard bismuth inclusions are expected to cause higher tool wear. Thus, complex machining operations cannot be realised with bismuth containing brass.

During the stakeholder consultation one US manufacturer (Federal Metals Co.) was named who had developed lead-free copper alloys containing bismuth (Federalloys®). However, these alloys are for casting only and are not suitable for wrought alloys. Most of the applications for leaded copper alloys are as small parts some with complex shapes. These cannot be made by casting. The only uses of cast copper alloys in EEE would be as fittings to connect pipework in refrigerators, freezers and machines that require cooling systems. Connectors, clips, inserts, spindles, etc are made from wrought brass only.

Furthermore, Federalloys® are relatively new alloys which few manufacturers have evaluated and availability is only from one US supplier which would pose a risk if they could not meet demand or experience production difficulties.

The European copper industry summarises that bismuth-containing alloys are not able to substitute leaded copper alloys. The most important reasons are:

- Low ductility of bismuth-containing alloys at elevated temperatures.
- Machinability of bismuth-containing alloys is inferior to leaded copper alloys (only 66-85%).
- Hot shortness of wrought copper alloys due to bismuth-impurities. For that reason the choice of production processes for bismuth-containing alloys is limited.
- Contamination of scrap circuits.
- Poor availability of bismuth.

Recycling of scrap is important as machining creates large quantities of metals that should be re-melted, their composition adjusted and then re-used. However, certain combinations of different alloy types prevent recycling because segregation of alloy types is usually impossible in practice. Copper alloy scrap with both lead and bismuth cannot be used and has to be refined to produce the constituents in high purity forms. In addition to melting, this requires electro-refining of the copper and several complex furnace operations to separate bismuth from other metals. Most metals recyclers set very low upper limits for bismuth as this makes recovery of precious metals much more difficult. There will be a large environmental impact difference between recycling copper alloys without bismuth and copper alloys with bismuth, the former requiring energy only to re-melt it whereas the latter requires many energy intensive process steps.

With regard to the question whether the maximum concentration value of 4% lead by weight in copper alloys is still justified or whether it should it be adjusted e.g. to a maximum concentration value of 3% lead by weight, the copper industry emphasizes that the existing concentration value of 4% lead is still justified and necessary, in order to allow the use of adequate copper alloys in the different applications concerned.

The reason for the retention of the maximum concentration value of 4% lead by weight is as follows:

The machinability of copper alloys is parabolically enhanced with increasing lead content meaning that the benefit from lead diminishes at high lead levels (see Figure 6). A certain limit value of the lead content can be defined above that no pronounced improvement can be achieved. This limit value sensitively depends on the alloy system. For instance, in free cutting brass the value is between 3% and 4%. For that reason the maximum lead concentration of wrought copper-zinc-alloys specified by the standard DIN CEN/TS 13388 is 3,5 %, except for the alloy CuZn38Pb4 with a maximum lead content of 4,2%. On the other hand the specified maximum lead content in high-copper alloys (alloying content < 5 %) is 1,5 %. That is to say that the maximum limit of lead has to be defined for each family of copper alloys separately. To simplify matters the recommendation is to consider all wrought copper alloys listed in DIN CEN/TS 13388 and to take the highest standardised lead content as an over-all limit value, which is 4,5% in CuSn4Pb4Zn4. This is not far from a maximum concentration value of 4% when the rounding rule is applied. Therefore, the copper industry advise a maximum lead content of 4% for all copper alloys.

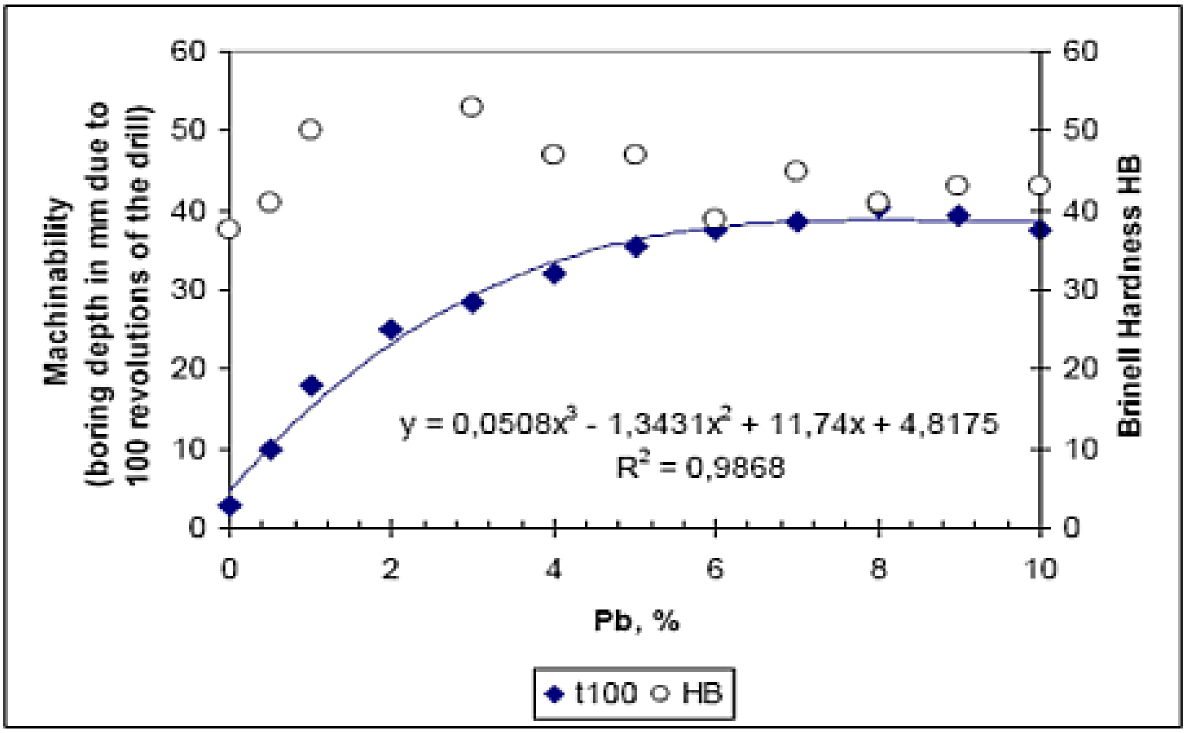

Figure 6 Machinability and hardness of CuZnPb-alloys [13].

4.9.3 Critical review

As already mentioned in section 4.9.1 there is an overlap between RoHS exemption no. 6 and ELV exemptions nos. 1 to 3. Annex II to the ELV Directive[31] includes exemptions for the use of lead up to 0,35% in steel, (entry no. 1), up to 0,4% in aluminium, (entry no. 2) and up to 4% in copper (entry no. 3).

In view of consistency in environmental legislation information and data provided in the context of the recent adaptation to scientific and technical progress of ELV Annex II [1] have been taken into account in the present adaptation of the RoHS Directive. In this context it should be kept in mind that the types of machining operations used for many automotive parts are similar to the processes used to make many parts used by the electronics industry,

[31] Directive 2000/53/EC on end-of-life vehicles (ELV Directive)

i.e. many drilling, cutting and turning steps to fabricate each part. Therefore, most of the conclusions drawn in the recent adaptation to scientific and technical progress of ELV Annex II can be transferred to the present evaluation.

Lead as an alloying element in steel containing up to 0,35% lead by weight

Steel for machining purposes:

With regard to steel for machining purposes, comprehensive tests indicate that lead-free alternatives are available providing comparable results to leaded steel in single machinability tests (e.g. bismuth or calcium treated steels). For example, the machining properties of bismuth treated steels approach those of leaded steels, but only for certain machining operations. In other operations like hot workability, the performance of bismuth treated steels was shown to be worse than for leaded steels. Due to the fact that steels usually go through a variety of successive machining operations, the overall performance of steels in the various machinability processes (chip form, tool life and wear, surface finish, tool force, hot workability, deep drilling etc.) is of a higher importance than the results of single machinability tests. This applies all the more because a good machinability of steel is not only economically relevant, but also important from an environmental point of view as a reduced machinability may lead to an increased energy demand during the production process. The provided test data indicate that lead-free alternatives do not yet show a comparable overall performance to leaded steels in a variety of machinability tests.

Calcium treated steels may substitute leaded steels in various applications, however a general substitution does not seem possible at the moment because calcium treated steels have their best performance limited to a narrower range of machining speeds in comparison with the leaded grades.

Bismuth is mainly produced as by-product of other metals among others bismuth sources are by-products associated with lead mining. There is currently no primary production of bismuth.

From the above it can thus be concluded that currently a general substitution of lead as alloying element in steel is not yet practicable.

Galvanized steel

Evaluating the above-mentioned arguments of the industry on galvanized steel the following can be concluded:

Lead is only used and required in general (batch) galvanizing of individual steel articles. In contrast, galvanisation of steel sheet/strip by hot-dip galvanisation in continuous line or electroplating of steel sheet or individual steel articles by electroplating does not require the use of lead. From a technical point of view, individual steel articles could be coated by electroplating instead of hot dip general batch galvanizing but the coatings have different performance characteristics. According to information provided by EGGA (personal communication) steel articles that are used for outdoor applications and are exposed to a more aggressive environment require a thicker coating for a better corrosion protection. This thicker, metallurgically bonded coating can only be realised by general (batch) galvanisation and not by electroplating.

During the stakeholder workshop the question came up whether the allowable level of lead in galvanized steel has to be related to the coating as homogeneous material or to the steel part in total as homogeneous material. As the definition of homogeneous material in RoHS applies to the application of the threshold limit of 0,1% lead but not to the requested exemptions within the Annex, this question was not considered as relevant for the further evaluation. It should be stressed that in the context of this exemption request "galvanized steel" is considered as the entity of steel plus zinc coating. The allowable level of lead in galvanized steel is therefore related to the full component i.e. steel plus zinc coating. However, due to the maximum solubility of lead in molten zinc, the amount of lead in the exempted components will be limited by metallurgy to a level significantly below the 0.35% allowed in the exemption.

Lead as an alloying element in aluminium containing up to 0,4% lead by weight

The biggest share of aluminium alloys contains lead unintentionally due to the production from scrap metal. There are two theoretical options to reduce the lead content in aluminium alloys to a level of 0,1% lead by weight in homogeneous material (i.e. the maximum concentration value up to which the presence of lead in aluminium would be tolerated without exemption):

1. Removal of lead from Aluminium by metallurgical processes;
2. Dilution of scrap with primary Aluminium.

With regard to option 1, publications are available confirming that in small scale experiments it is theoretically possible to remove lead from aluminium by the electrochemical addition of sodium or potassium [15], [16]. However, up-scaling this method form small scale laboratory experiments to industrial scale application was considered to be difficult, thus confirming the industry position that the research activities have not yet produced practicable solutions for industry applications.

Option 2 is technically possible, but is restricted by the availability of primary aluminium. From an environmental point of view the dilution of scrap with primary aluminium is not considered to be a reasonable option because the quantity of energy needed to produce primary metal is 95% higher than the amount of energy needed to produce casting alloys from scrap.

It can be summarised that removal of lead is technically not yet possible at industrial scale and dilution of aluminium by primary aluminium to a level < 0.1% is not meaningful from an environmental point of view.

Concerning the applications where lead is intentionally added to aluminium for improved machinability or for corrosion prevention lead-free alternatives containing e.g. tin or bismuth were shown to be less appropriate than aluminium alloys containing a certain amount of lead.

Overall, the stakeholders provided plausible information on the necessity of an extension of exemption 6 related to the presence of lead in aluminium.

Lead as a copper alloy containing up to 4% lead by weight

The copper industry has provided sound data indicating that intensive research on lead-free copper alloys has been carried out for many years without finding technical and economical equivalent alloys that provide all of the required characteristics of lead additions: Bismuth or silicon copper alloys are named as potential substitutes to leaded copper alloys but still show significant disadvantages.

Due to the fact that machining of copper alloys produces quite large quantities of scrap and swarf, recycling by re-melting and subsequent reuse is common practice. Mixtures of copper alloy with both lead and bismuth cannot be used together but must be separated because bismuth containing alloys are much more brittle particularly at elevated temperatures. Severe cracking has to be expected during hot working or use. Consequently, it would be imperative for the industry not to mix scrap / swarf of copper alloy with both lead and bismuth. But in a transitional period, when two strictly separated recycling loops would have to coexist the probability of scrap mixing would be quite high with possibly dangerous consequences. Therefore, a partial replacement of leaded copper alloys by bismuth copper alloys in selected applications is considered to be impracticable and needs to be considered with caution.

With regard to the maximum concentration value of lead in copper alloys the copper industry provided reliable data indicating that the beneficial effect of lead on the machinability of copper brass reaches is maximum at a lead concentration between 1,5–4% lead by weight depending on the alloy system. Industry, however, did not specify for which applications those alloy systems with the high lead contents of up to 4% are required.

Based on the provided data and information it can be concluded that the use of lead as copper alloy at the current state of the art is not avoidable in all applications. A partial replacement of leaded copper alloys by bismuth copper alloys in selected applications is considered to be impracticable.

Transition period and expiry date

Assuming that the amendment of the Annex in the RoHS Directive will be officially published end of 2009, new exemption 6 should come into force at the same time since no transition period is necessary due to the unchanged wording. The expiry date is proposed to be set at the time of the next revision because as of today no substitution seems technically feasible. Here again assuming an official publication of an amended RoHS Annex by end 2009, the expiry date would be four years later 31. July 2014.

Repair and upgrade

Furthermore, a clause should be added to the new exemption 6 explicitly mentioning that spare parts for what used to be applications covered by exemption 6 are exempted from substance use restrictions.

Inclusion of category 8 and 9

Since the use of lead as an alloying element in steel, copper and aluminium is the same for any electrical and electronic equipment – be it for the current scope or for categories 8&9 -, an inclusion of category 8&9 into the scope of the RoHS Directive would not lead to a need for change in the wording of exemption 6.

4.9.4 Recommendation

It is recommended to continue exemption no. 6 allowing the addition and/or presence of lead as alloying element in steel, aluminium and copper until the next review of the RoHS Directive.

Concerning the use of lead as an alloying element in steel, a change of the wording into "steel for machining purposes and galvanized steel" as proposed by EGGA is supported.

Due to the fact that exemption 6 comprises three quite different applications of lead as an alloying element in metals, it is proposed to split this exemption into three parts.

The new wording of exemption 6 would thus be:

(6a). Lead as an alloying element in steel for machining purposes and in galvanized steel containing up to 0,35% lead by weight
(6b). Lead as an alloying element in aluminium containing up to 0,4% lead by weight
(6c). Copper alloy containing up to 4% lead by weight

Alignment RoHS & ELV

In addition, it is recommended to align with exemption 1, 2 and 3, Annex II ELV Directive. Since the production lines of manufacturers are identical for RoHS applications and ELV applications related to exemption 6, a phase-out of lead will be either feasible for all areas at the same time or for none. Therefore, there should be a common exemption for both ELV and RoHS with the same expiry date, the same spare parts provision and the same review cycle. The above proposed wording for exemption 6 is therefore the same as in Annex II ELV Directive.

4.9.5 References

[1] Lohse et al. Adaptation to Scientific and Technical Progress of Annex II Directive 2000/53/EC, 2008

[2] EICTA et al. Stakeholder contribution, exe. 6 (Joint response from EICTA, AeA Europe, EECA ESIA and JCBE to the general and specific questionnaires relating to exemption “6. Lead as an alloying element in steel containing up to 0.35% lead by weight, aluminium containing up to 0.4% lead by weight and as a copper alloy containing up to 4% lead by weight), 31 March 2008

[3] GalvInfo Center Continuous hot-dip galvanizing versus general (batch) galvanizing; GalvInfoNote 2.3; Rev January 2007

[4] GalvInfo Center The spangle on hot-dip galvanized steel sheet; GalvInfoNote 2.6; Rev 1 June 2008

[5] Eurofer Stakeholder contribution, exe. 6; 1 April 2008

[6] ERA Stakeholder contribution, exe. 6; 28 July 2008

[7] ERA Stakeholder contribution, exe. 6; 16 June 2008

[8] Bateson, P.H. & Reynolds, P.E. Machinability evaluation of 1215 steel containing tin; British Steel Limited, Swinden Technology Centre, Moorgate, Rotherham, UK; Report No. SL/MA/R/S2916/16/99/D, 1999

[9] Wieland-Werke AG Stakeholder contribution, exe. 6; 28 July 2008

[10] Kuyucak, S. & Sahoo, M. A review of the machinability of copper-base alloys; Canadian Metallurgical Quarterly, 35; 1996

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[12] Stoddart, C.T.H. et al. Relationship between lead content of Cu-40Zn machinability, and swarf surface composition determined by Auger Electron Spectroscopy; Metals Technology, 1979

[13] Kessner, A. 'Die Prüfung der Bearbeitbarkeit der Metalle', Werkstatttechnik 24, 1924

[14] EGGA (European General Galvanizers Association) End of life vehicle Directive – Exemption for lead in galvanized steel; Papers submitted in response to the Öko-

Insitut e.V. request for technical guidance regarding the adaptation to scientific and technical progress of Annex II of the Directive 2000/53/EC (End of Life Vehicles), 2007

[15] Tailoka, F. & Fray, D. J. Selective removal of lead from aluminium, 1993

[16] Tailoka, F. et al. Electrochemical removal of lead from aluminium using fused salts. 1994

[17] EGGA (European General Galvanizers Association) Stakeholder contribution, exe. 6; 1 April 2008

4.10 Exemption No. 7a

“Lead in high melting temperature type solders (i.e. lead-based alloys containing 85% by weight or more lead”)

4.10.1 Description of exemption

The lead-containing high melting point solders with 85% of lead and more are addressed as HMP solders in the following. High melting point solders containing no lead will be abbreviated with lead-free HMP solders.

The compositions of HMP solders typically are in the range of 90–97% lead by weight. These alloys can be found in a wide range of products, encompassing WEEE categories 1 through 10.

EICTA [2] indicates several applications of HMP solders:

1. HMP solders are used to form high reliability electrical connections. Examples of applications include large BGA or solder column packages, as well as some discrete devices in high reliability electronics. The lead content facilitates solder joints with a high resistance to thermal fatigue and to electromigration failure.

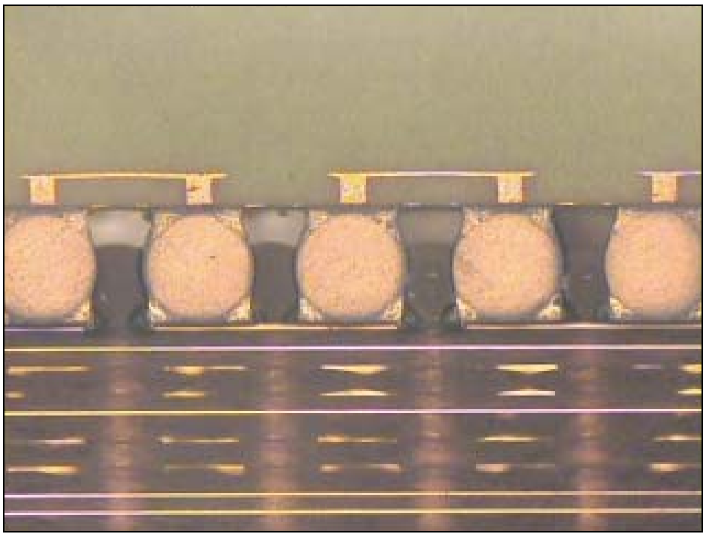

Figure 7 Ball Grid Array component with HMP balls [2]

2. HMP solders are also used to form a high conductivity thermal interface to the back of a semiconductor device, also known as die attach. The use of high melting temperature solders is required in power devices and discrete semiconductors. These typically are used in high reliability applications, such as server applications. The HMP solders enable high conductivity interfaces between the die and the lead frame/heat spreader. These are capable of meeting hierarchical reflow temperature requirements for components to be soldered to the board, while also having sufficient mechanical compliance required to prevent device damage during manufacture and operation.
   The melting point of these solders should be higher than the reflow temperature that is used for board assembly. The latter temperature has gone up to 260°C due to Pb-free assembly.
3. HMP solders are used as a sealing substance between tubular plugs and metal cases, e.g. in crystal resonators and crystal oscillators. These applications can be found in many products, including PCs, cellular phones, and other home appliances.

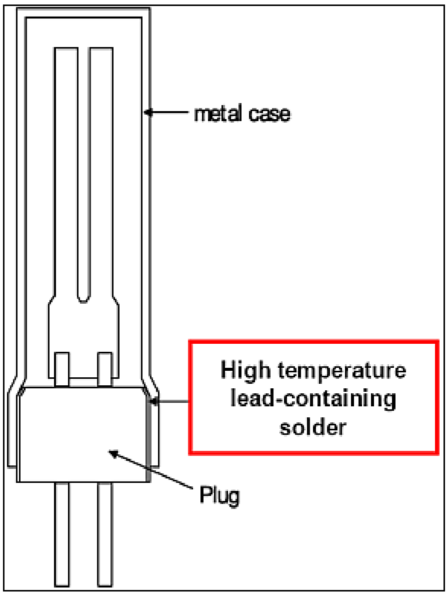

Figure 8 Schematic view of a crystal unit [4]

4. HMP solders are used for a reliable internal connection in passive components, to withstand soldering processes, especially those using lead-free solder. The varying lead content allows adjusting the melting point of the solder to the requirements of the manufacturing processes.

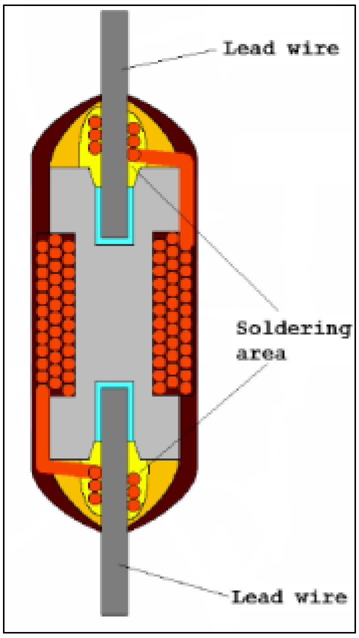

Figure 9 Passive component using HMP solders for internal solder joints [2]

High melting point solders containing lead are used in the following types of components that are commercially available and used by most electrical and electronics sectors [3]:

- Rectifiers
- Power semiconductor devices such as MOSFETs, power transistors etc.
- Voltage regulators
- Solder joints in equipment which operates at > 100°C
- Some types of fuses
- RF modules, attenuation modules and high frequency switches in telemetry medical devices
- Quartz crystal oscillators – some types
- Position sensor coils
- Inductor coils (some types)
- Surface mount transformers

JBCE [8] and EICTA [9] further complement the information on applications and technologies, in which they consider the use of HMP solders to be without alternative:

Intended Use	Reasons for Necessity	Related Products
Solders used for internally combining a functional element and a functional element, and a functional element with wire/terminal/heat sink/substrate etc. within an electronic component.	1. It is needed to achieve electrical characteristic and thermal characteristic during operation, due to electric conductivity, heat conductivity etc. 2. It is needed to gain high reliability for temperature cycles, power cycles etc. 3. When it is incorporated in products, it needs heatproof characteristics to temperatures higher than melting temperatures (250 to 260°C) of lead-free solders . 4. Stress relaxation characteristic with materials and metal materials at the time of assembly is needed.	Resistors, capacitors, chip coil, resistor networks, capacitor networks, power semiconductors, discrete semiconductors, microcomputers, ICs, LSIs, FCBGA, chip EMI, chip beads, chip inductors, chip transformers etc. (see Figure 10)

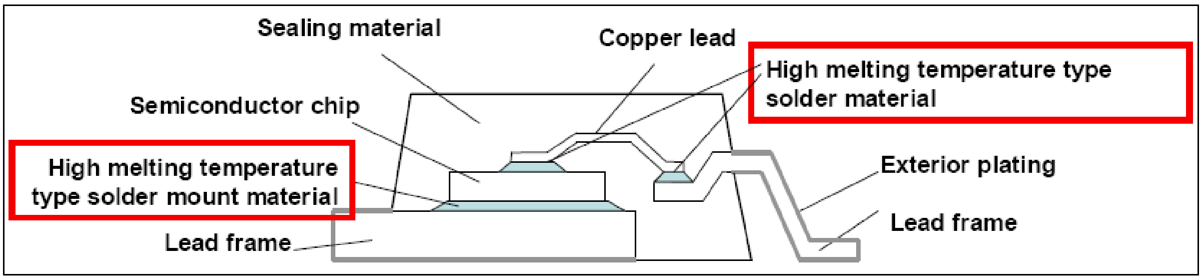

Figure 10 Schematic cross sectional view of internal semiconductor connection [8]

Intended Use	Reasons for Necessity	Related Products
Solders for mounting electronic components onto sub-assembled module or sub-circuit boards.	1. It is needed to achieve electrical characteristic and thermal characteristic during operation, due to electric conductivity, heat conductivity etc. 2. It is needed to gain high reliability for temperature cycles, power cycles etc. 3. When it is incorporated in products, it needs heatproof characteristics to temperatures higher than melting temperatures (250 to 260°C) of lead-free solders 4. Stress relaxation characteristic with materials and metal materials at the time of assembly is needed. 5. It is needed to prevent copper leaching that occurs when connecting it in the product using the copper wire.	Hybrid IC, modules, optical modules etc. (see Figure 11)

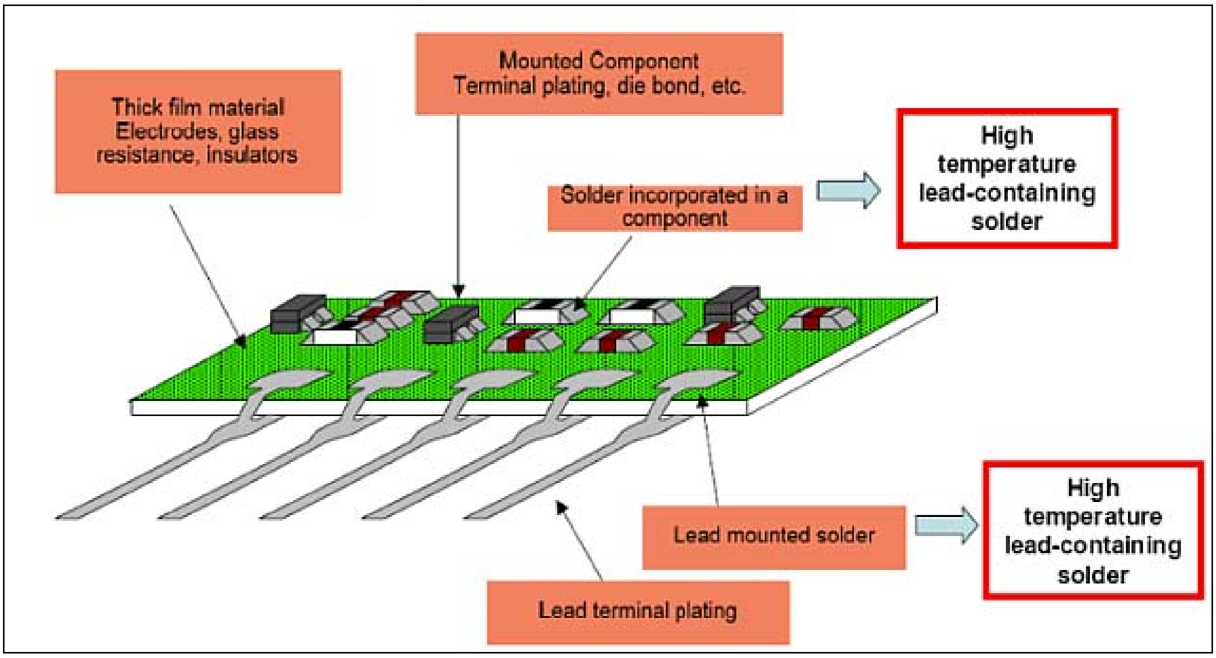

Figure 11 Schematic view of a circuit module component [8]

Intended Use	Reasons for Necessity	Related Products
Solders used as a sealing material between a ceramic package or plug and a metal case	1. Stress relaxation characteristic with materials and metal materials at the time of assembly is needed. 2. When it is incorporated in products, it needs heatproof characteristics to temperatures higher than melting temperatures (250 to 260°C) of lead-free solders. 3. It is needed to gain high reliability for temperature cycles, power cycles etc.	SAW (Surface Acoustic Wave) filter, crystal unit, crystal oscillators, crystal filters etc. (see Figure 8)

Annually, the production of such solders is estimated at around 10,000 t [1] containing about 9,000 t of lead. There is no information in this source neither on how this amount of solder relates to specific applications, nor how much of it is put on the market in electrical and electronics products in the European Union every year.

JBCE [7] estimates the amount of HMP solders put on the EU market with 3,600 t/year, corresponding to around 3,000 t of lead. This figure does not include the HMP solders contained in products imported into the EU market.

4.10.2 Justification by stakeholders

HMP solders are used because they are the only alloys that provide ALL of the following properties [3]:

- Melting temperature at ~280 – 320°C
- Ductility, as very hard materials induce strain onto adjacent materials if they have dissimilar coefficients of thermal expansion (TCE) when temperature changes occur and can cause fracture
- Good thermal and/or electrical conduction
- Good performance at high frequency (other die attach materials interfere with high frequency signals and so cannot be used)
- They do not form thick and brittle tin-copper intermetallic layers from interaction of tin (from solder) and copper substrates in equipment that operates at higher temperatures. These materials fracture under low strain if they are allowed to grow in thickness.

The stakeholders explain applications, in which the substitution of lead in HMP solders is scientifically and technically impracticable:

Electrical interconnects

EICTA [2] states that alternative alloys do not meet the reliability requirements. High lead solders contain a unique combination of ductility and reflow temperature hierarchy required for high reliability applications. At this moment there is no commercially available Pb-free material as a substitute that has the necessary electrical and / or thermal conductivity as well as the right material properties (such as coefficient of thermal expansion (CTE), ductility etc.) to maintain high reliability.

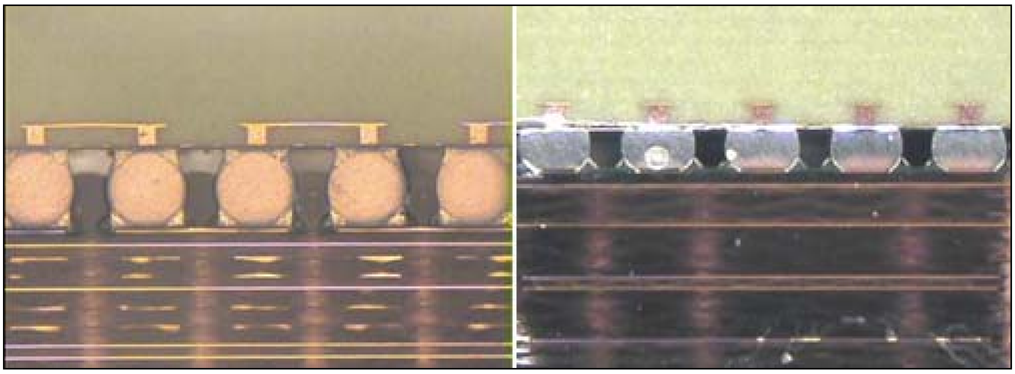

Figure 12 Ball Grid Array component with HMP balls (left) and lead-free solder balls [2]

Figure 12 shows a cross section of two versions of the same high-CTE ceramic package. One version uses HMP solder balls, while the other version used lead-free tin-silver-copper (Sn-Ag-Cu, or SAC) alloy balls. As can be seen, the distance between the package and the PCB is reduced considerably with the lead-free version. The lead-free solder balls melt during the assembly process, and collapses under the weight of the package. This reduced stand-off height significantly increases the solder joint strain for a given thermal cycle range. [2]

The replacement of high lead solder alloys in electrical interconnect will require a dramatic reduction in the solder joint stresses to enable the use of any of the known lead-free alloys. Lower solder joint stresses can only be achieved through the use of new electronic packaging materials. Selection of new packaging materials requires extensive electrical and mechanical characterization to assure long term reliability. An example of an alternative material that can reduce solder joint stress is replacement of ceramic ball grid array packages with organic laminate ball grid array packages. While these technologies have been shown suitable for many consumer applications, they have not yet been demonstrated to have adequate reliability for complex electronics interconnect, such as found in servers, networking equipment and high end gaming equipment. In addition, new Pb-free alloys will be needed to reduce electromigration (EM) failures to acceptable levels. Greater integration and higher power density of continually evolving electronic devices / systems will only exacerbate these factors. New Pb-free materials will need to handle future as well as existing conditions.

Thermal interface die attach

HMP die attach materials have a combination of good thermal performance, electrical performance and can deform in thermal cycling without cracking or causing joined components to crack. There are no known suitable Pb-free replacements. The high melting temperature alloys like AuSn are hard and brittle. Pb-free solutions perform poorly in thermal cycling reliability tests, typically cracking in either the solder or in the joints. Conductive adhesive materials do not yet have suitable thermal conductivity. These adhesives also have inconsistent results on joint quality. Development is underway, but could take many years to approach the capability of high Pb solder. [2]

The high lead solder has a high melting point as well as good thermal conductivity. The high melting point (> 260°C) is necessary because if the die attach material melts during board assembly there is a high chance of failures inside the package due to movement of the die (bond wire crossing). Although the die attach is high in Pb content the total volume is very limited due to the fact that this solder is only applied within the package in small amounts. [2]

Crystal oscillators

After the crystal resonator and crystal oscillator are delivered to the device manufacturer, the manufacturer solders them onto printed circuit boards. Recently, this solder is often Sn-Ag-Cu solder because of the lead-free trend. The temperature used for this soldering is 250° - 260°C. Sn-Ag-Cu solder melts at a temperature lower than 250°C (close to 217°C). However, crystal resonators and crystal oscillators that are joined by solder internally have to be able to withstand soldering temperatures of 250° - 260°C at the device manufacturer. For that reason, high temperature solder of more than 85% lead content is used to seal the interior of the crystal resonator or crystal oscillator to get the melting properties needed so the solder does not melt completely even at 250° - 260°C.

As a sealant, there are organic adhesives, but these cannot withstand vacuums because they are moisture-permeable. Therefore there are no substitute measures for high temperature solder. [2]

Lead-free alternatives

According to EICTA [2], lead-free alternatives have been developed for some uses, but are not a feasible replacement for all high-lead solder applications.

Current lead-free SnAgCu systems have melting points similar to the solders used in board assembly. If these solutions were used, then the die attach would become liquid, resulting in a reliability hazard. The same applies for the use of such solders in internal solder joints of passive components. SnCu alloys melt below 250–260°C as well, and thus create the same problems like the SngCu solder alloys.

SnAgSb as a further alternative suffers from the same low reflow temperature, as well as the uncertainty of the environmental impact of Sb (antimony).

SnAu80 is a commercially available Pb-free die attach with a high melting temperature, however, several concerns exist for this system. The interconnect is brittle, CTE mismatch between die and solder prevent the use on larger dies, and gold has a negative environmental impact according to EICTA [2].

AgCu alloys have a too high melting temperature at 700–900°C and thus are not a viable alternative either.

Table 5 gives an overview on different lead-free alternatives and their main properties.

Table 5 Overview on different lead-free HMP alternatives [3]

Material	Melting temperature	Ductility	Thermal and/or electrical conductivity
Lead, tin, silver alloy	300°C	Ductile	Good
Gold tin alloy (very expensive)	280°C	Hard and brittle	Good,
Tin- antimony alloy	232°C - too low	Fairly ductile	Good
BiSi and BiAg	~260°C moderately low	Hard and brittle	Good
Conducting epoxy resins (used as die attach for low power semiconductor devices)	Cured – do not melt, damaged by use at high temperature	Semi-hard varieties available	Poor (unsuitable for most power semiconductors)
Beryllium oxide (class 2 carcinogen)	Ceramic	Hard and brittle	Equal to copper

EICTA [2] claims that in all of the applications under discussion, the use of lead-free alloys would result in significant reduction in the reliability of a wide range of products. In the best case, decreased reliability would result in increased electronic waste due to premature device failure and reduced manufacturing yield. In the worst case, unexpected failures could cause consumer safety concerns. Many of the high performance / high reliability applications that use high-Pb solders require exacting performance characteristics because there is significant risk to human life / safety, including air traffic control, other transportation systems control and governmental security or defence systems. Low reliability substitutions in these systems would result in considerable human mortality / suffering. [2]

Invention of new Pb-free solders with appropriate melting ranges and with the necessary mechanical properties for sufficient reliability is still required. Since no candidates have yet been discovered, it is unlikely that such invention and subsequent reduction to practice can occur within the next four years. [2]

4.10.3 Critical review

<u>**Consequences of the material specificity of exemption 7a**</u>

Exemption 7a, contrary to other exemptions in the annex of the RoHS Directive, is not application, technology or use specific, but material specific. It generally allows the use of high melting point solders with 85% of lead (HMP solders) and more in electrical and electronic equipment wherever manufacturers want to use it.

In several applications, the substitution or elimination of the HMP solders at the current state of science and technology is impracticable. The exemption for such HMP solders therefore is fully justified for these cases according to the criteria of Art. 5. (1) (b) of the RoHS Directive. However, there are hints that HMP solders are used where alternative solutions reducing the amounts of lead are available.

1) The current general exemption for lead in HMP solders offers a loophole to bypass the use of lead-free solders or to avoid searching for other RoHS-compliant solutions that do not require the use of lead.
   Manufacturers use leaded HMP solders in applications, for which others offer lead-free solutions. The use of HMP solders in some quartz crystal oscillators where lead-free alternatives are available is an example (see [6], page 83). Although this use of lead is RoHS-compliant due to the material specific exemption for leaded HMP solders, its substitution in such applications is technically practicable. Despite of RoHS compliance due to the general character of this exemption, Art. 5 (1) (b) would not justify an exemption for such applications of leaded HMP solders. Such applications of leaded HMP solders contravene the objective of the RoHS Directive to reduce the use of lead in EEE.
2) The current general exemption unnecessarily increases the use of lead in applications, where lead-free solutions are technically impracticable and an exemption for the use of lower lead content solders would be possible or is already in place.
   "It has become more apparent that some of our customers are tending towards using higher lead alloys (typically 95% lead rather than 50% lead) ….". "…[we] have actively encouraged switching the lower lead content In/Pb solder alloys allowed by exemption 24." [5]
   Instead of using available or applying for a new exemption for the use of lead in low lead-content solders like e. g. the tin-lead solder with 37% lead (SnPb37), manufacturers may shift to HMP solders with high lead contents of 85% and more. Art. 5 (1) (b) would justify an exemption for the use of low lead content solders in these cases. Although the manufacturers achieve RoHS-compliance using the generally exempted leaded HMP solders, the use of this solder is not in line with Art. 5 1 (b).

Transition into application, technology or use specific exemptions

Considering the above-mentioned situation, and in line with the latest Commission decisions on exemptions which are application and technology oriented and thus are use specific, this exemption will be recommended to be changed into an application and technology specific one. The question for the review process hence was about the best way to achieve this transition.

Stakeholders described where the use of these HMP solders is still required. However, it cannot be assumed that these stakeholder comments cover all uses, in which the use of lead in HMP solders needs to be exempted in line with the criteria of Art. 5 (1) (b) of the RoHS Directive. Parts of the electronics industry thus might suddenly see themselves producing non-RoHS-compliant products if the general exemption would be changed into an application specific based on the available information from the stakeholder consultation for this review process. A new stakeholder consultation is required to give industry worldwide the opportunity to apply for the necessary application and technology specific exemptions.

Transition process and period

The reviewers propose leaving the exemption unchanged for now, but giving it an expiry date, which allows industry a reasonable time frame to apply for specific exemptions for the use of lead in HMP solders, where they are justifiable by the requirements set out in Art. 5 (1) (b).

The expiry date must allow for the application and technology specific exemptions to be in place before the material specific exemption ends.

Assuming the Annex will be amended until the end of 2009, the consultants propose 30 June 2013 as the expiry date for exemption 7a. This allows sufficient time to spread the information about the changes in the Annex of the RoHS Directive globally among the electrical and electronics industry. The remaining time is sufficient to reliably have the Annex of the RoHS Directive amended with the new exemptions for the high lead content HMP solders.

Necessity of exemptions for lead-containing high melting point solders

The stakeholders explained several applications and technologies, where the use of these solders is indispensable.

The consultants did not inquire whether the use of HMP solders actually is indispensable and without alternatives in each of the applications and technologies, which the stakeholders listed. Nevertheless, it is clear and common understanding, that there are several applications where the use of HMP solders with high lead content of 85% and more cannot be replaced at the current state of science and technology.

The general direction of the review in exemption 7a was the transformation process of the exemption towards an application and technology specific exemption.

After the official amendment of the Annex in the RoHS Directive, the stakeholders will have to apply for exemptions allowing the use of HMP solders in specific technologies and applications. The detailed assessment whether and how far the use of lead-containing high melting point solders is scientifically and technically impracticable in these applications or technologies will be conducted in these review processes.

To avoid misunderstandings, it must be clearly stated that exemption 7a is not recommended to expire because it is no longer needed, but just for the transformation from a material-specific to one or several application, technology and use specific exemptions.

Further on, it must be stated that the applications and uses of HMP solders, which the stakeholders submitted during this review process, are not exclusive. There may be other applications and technologies in which the use of HMP solders containing lead is justified in line with Art. 5 (1) (b), but which are not mentioned in this report. Stakeholders may apply for such exemptions once the RoHS Annex will have been amended officially.

4.10.4 Recommendation

Exemption 7a is a material specific exemption. It allows the use of high melting point solders containing 85% of lead and more (HMP solders) in all applications and technologies, even in those where lead-free alternatives are available, or where a specific exemption could be applied for or an existing one be used allowing the use of lead solders with lower lead contents. Such uses are not in line with Art. 5 (1) (b) and they contravene the spirit of the RoHS Directive to reduce the use of lead.

The stakeholders listed several applications and technologies where they state the use of HMP solders with 85% of lead and more to be without alternative. This list is not exclusive. It must be highlighted that there may be more applications and technologies requiring the use of HMP solders. The use of these HMP solders will be necessary further on in certain applications and technologies, and exemption 7a hence cannot be revoked. Lead-free alternative materials or alternative designs cannot substitute or eliminate HMP solders in all applications and technologies.

In line with the latest Commission decisions on exemptions which are application and technology oriented, the consultants propose transforming exemption 7a from its current material specific character into an application and technology specific exemption. To achieve this, the consultants recommend the continuation of exemption 7a in its current wording, but add an expiry date. Once the Annex of the RoHS Directive is amended officially, the stakeholders can start applying for application and technology specific exemptions following the example of the other exemptions in the Annex. The expiry date must reliably allow for application and technology specific exemptions to be in place once the general, material specific exemption 7a expires.

The RoHS Directive affects the electrical and electronics industry as well as their suppliers worldwide. It will take time to spread the change of exemption 7a and to organize the necessary exemption requests. The process from the submission of an exemption request until the official amendment of the Annex in the RoHS Directive may take more than one year. Assuming that the Annex of the RoHS Directive will be officially amended end of 2009, the expiry date 30 June 2013 is considered adequate to make sure the new exemptions are in place once the general exemption in its current wording expires.

For technical reasons, the repair and reuse of equipment, which was produced using HMP solders and was put on the market before the expiry of exemption 7a in its current character, must be made possible as well.

The future wording of exemption 7a is proposed as:

Lead in high melting temperature type solders (i.e. lead-based alloys containing 85% by weight or more lead) until 30 June 2013, and lead in such solders for the repair and reuse of equipment put on the market before 1 July 2013.

4.10.5 References

[1] Otmar Deubzer: Explorative Study into the Sustainable Use and Substitution of Soldering Metals in Electronics; PhD thesis TU Delft, January 2007, ISBN 978-90-5155-031-3

[2] EICTA online stakeholder consultation document “Exemption_7a_EICTA_and-others_1_April_2008.pdf”

[3] Paul Goodman, ERA; stakeholder document
“7 technical information final-Goodman.pdf”

[4] EICTA stakeholder document “EICTA position on Exemption 7a 28th July 2008.pdf”

[5] Stakeholder document “Exemption_7a_24_Syfer-Technology_31_March_2008.pdf”

[6] Ökoinstitut e.V., Fraunhofer IZM: Adaptation to Scientific and Technical Progress under Directive 2002/95/EC; final report July 2006; document “rohs_report.pdf”, http://ec.europa.eu/environment/waste/weee/pdf/rohs_report.pdf; last access 22 October 2008

[7] JBCE stakeholder document “Exemption-7a_JBCE_1_April_2008.pdf”

[8] JBCE stakeholder document
“JBCE Additional Input RoHS Exemption 7a-july2008.pdf”

[9] EICTA stakeholder document “EICTA position on Exemption 7a 28th July 2008.pdf”

4.11 Exemption No. 7b

"Lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signalling, transmission as well as network management for telecommunications"

4.11.1 Description of exemption

The equipment under exemption 7b,

- servers,
- storage and storage array systems,
- network infrastructure equipment for switching, signalling, transmission as well as network management for telecommunications,

has high reliability requirements and often is mission critical.

The function of lead in the solders is to make reliable mechanical and electrical connections between components and Printed Wiring Boards (PWB). In addition to these interconnections, leaded solder is also used in server applications for solder joints or interconnections within components such as flip chip modules (flip chips, capacitors, other devices), power modules, cooling technologies such as Small Gap Technology to solder pistons within a multi-chip module and vapour chamber heat sinks, as well as high performance board-terminated cable connectors.

The specific function of lead in this application is to provide a solder alloy having known, well characterized, and predictable fatigue life and shock performance characteristics when used to make electronic interconnections (electrical and mechanical interconnection between components).

The lead content in the tin-lead solders ranges between 35–45% lead by weight of a single solder joint. Related to the product, it may range from 0.5% to 5.0% by weight of the product. In total, the amount of lead used in such applications within the EU estimated with around 5,000 t per year. This estimation may not take into account the large number of lower complexity server components and PWBs that are already transitioning to lead-free solders as technically feasible.

4.11.2 Justification by stakeholders

The RoHS Directive has forced most electrical and electronic equipment to be produced with lead-free solders. Hence, there is experience available meanwhile with the processing of lead-free solders in a broad range of EEE. These products, however, have different operational conditions reliability requirements, and they are technically mostly less complex compared to the product groups for which exemption 7b still allows the use of leaded solders.

Table 6 Differences in technical complexity on PCB level between different IT products and server or network equipment

Characteristic of "typical" PCBs	Mobile phone PCB	Desktop computer PCB	Server or Network PCB
PCB thickness	0.5 mm	1 – 2 mm	Up to 10 mm, typically 2 – 4 mm
Number of layers in PCB	4 – 6	~12	>18 – 52
PCB size	30 cm^2	~900 cm^2	Various, up to 6200 cm^2
Types of components	Small low thermal mass	Mix of small and medium with a small number of large	Includes many larger high thermal mass components
Component density	High	Medium	High
SMT Reflow temperature required	235°C (used by Motorola)	~245 – 250°C (estimated)	260°C (sources: IBM, Lucent)

Source: ERA report [1]

Consequences of the thicker printed wiring boards and larger components

EICTA [4] explains that the thicker and denser PWBs cause additional stress placed on the solder joints as the product experiences temperature cycling due to power on/off cycles, or due to environmental conditions. Since board stiffness is a function of the cube of the board thickness, the thinner boards in consumer products will bend much more readily than a thicker board. A typical 3 mm thick server board will be 27 times stiffer than a typical desktop computer board with 1 mm thickness.

EICTA [4] further on says that the components applied are larger and more dense compared to consumer electronic products. The increased size of the component packages exacerbates the consequences of the stiffer thick PWBs resulting in larger CTE-mismatch strains at the corner solder joints of components like, e. g. flip chip packages. This strain increases roughly linearly with the distance from the centre of the component. These linear increases in strain accelerate thermal fatigue exponentially during server or component on/off cycles as they are accommodated by creep and cyclic damage within the solder joint.

Long-term reliability and life time prediction

The aging of tin-silver-copper (SAC) alloy can reduce the shock resistance and its fatigue performance. Without further understanding of the impact of the aging characteristics on solder joint reliability, this factor is still a concern for Pb-free solder long-term reliability for some applications. This has resulted in a proliferation of new lead-free solder alloys formulated to resolve these problems but still uncharacterized for long term reliability and assembly performance. [4]

According to EICTA [4], new failure mechanisms are associated with SAC solders. New failure modes / earlier failures than for SnPb solder have also been found for components such as Thin Small Outline Packages (TSOP), Quad Flat No leads Packages (QFN) and Ceramic Ball Grid Array (CBGA) packages through reliability testing

Efforts to develop accelerated life tests and predictive life time models have not yet resulted in validated methods. EICTA [4] says that it is necessary to have mathematical models to predict solder joint fatigue life from the results of accelerated stress testing. For tin lead solders, the most widely used equation to model fatigue life is the modified Coffin-Manson equation. This model was fully developed over a period of 20 years (1969-1989) and the industry has decades of experience in its use. [4]

EICTA [4] argues that to date, there are at least five different acceleration models that are under discussion. A wide range of industry associations have been working toward convergence of these models. Some of the models under discussion include the Solder Creep-Fatigue Equation, the Cyclic Damage Assessment, and modified versions of the Coffin-Manson model. These models are critical to design and component selection. Poor models could lead to poor choices that could lead to reliability degradation.

Reliability and operational requirements

EICTA [4] describes the network infrastructure equipment (NIE) in telecom networks is expected to operate with 99.999% of reliability or 5 minutes of downtime per year only. Failures of NIE can cause unscheduled downtime.

Similarly, according to EICTA [4], a typical server utilization capability is 24 hours per day, seven days a week, for a period of up to 10 years or more with a total downtime of 4 hours or less over the entire operational period. That equates to an operational percentage of 99.9985% over the 10 year field life of 87,600 hours typically expected of mainframe systems (or 30 years Mean Time Between Failures – MTBF). Servers also are expected to remain functional during most repair actions.

Soldering related issues

Most lead-free solders have higher melting points compared to tin-lead solders and therefore require higher temperatures in the soldering processes. Printed wiring board (PWB) robustness for 245°C reflow temperature compatibility has only been proven for PWBs with limited thickness (below 22 layers), which is well below that required for high end servers. As these qualifications have progressed, new failure modes have been discovered and must be thoroughly understood. The need for thicker cards, large arrays of fine pitch vias, low loss tangent materials, 2 oz copper and other complexities in construction increase the challenges in qualifying PWBs for server applications. In addition, thicker PWBs will likely increase the temperature exposure closer to 260C. For this higher temperature compatibility, no PWB suppliers have demonstrated the reliability required for server applications. [4]

Still today, some components and connectors cannot withstand Pb-free reflow profiles for complex and larger PWB assemblies without impact to electrical function or long term reliability. An industry standard like J-STD-075 is needed to identify, classify, and handle non-integrated circuit temperature sensitive components, but won't be released until mid-2008 at the earliest. [4]
Reflow equipment for higher complexity assemblies is not available at all suppliers. 10 or 12 zone ovens and vapour phase ovens for the complex assemblies used in mid-range and high-end Servers may be required. [4]

Limitations of lead-free soldering materials

The use of lead-free solders can cause excessive plated through hole copper dissolution, and inadequate hole fill can result in unreliable solder joints. [4]

Different lead-free finishes have been established in the market in the recent years. It is questionable whether organic solderability preservatives (OSP) can be extended to complex Pb-free applications. Technical issues with and manufacturing immaturity of new lead-free capable materials remain such as immersion silver (galvanic corrosion, poor resistant to corrosion in certain environments) and Pb-free Hot Air Solder Level (HASL) (consistent thickness and flatness of solder thickness) [4]

Component and capacitor joining for high reliability and to maintain a solder hierarchy is still dependent on high melting temperature, high Pb solders, which may have compatibility issues with SAC solders. [4]

Constraints of lead-free soldering for specific applications

Thermal applications like small gap technology and vapour chamber heat sinks have complex assembly and performance requirements and are only starting to be developed with Pb-free solders.
High performance board-terminated cable connectors – issues have been identified with light crimp and solder and soldering wires to cards for high performance cable assemblies. There is an impact on both reliability and performance with Pb-free solders.

Lead-free soldered equipment

EICTA [4] admits that over the past four years knowledge of, and experience with lead-free soldering technology has grown significantly enabling an increasing number of NIE (Network Infrastructure Equipment) and server products falling under exemption 7(b) to be delivered to customers with lead-free assembly. Schueller et al. [7] describe the conversion of a class A server to lead-free soldering in more details. A manufacturer of servers, NIE and storage equipment confirms to have lead-free soldered products in the market in which exemption 7 b would have allowed the use of lead.

In addition to these advances in PWB assembly technology, some cable assemblies have been qualified with Pb-free solder including [4]:

- soldering of wires directly to terminals;
- solder cup terminals;
- soldering of braid and drain wires for ground connections.

Also, feasibility work is in progress to find a substitute lead-free solder for the Small Gap Technology used to solder pistons in the cooling assemblies for complex high-end multi-chip modules. [4]

EICTA [9] points out that the availability of such components, submodules and equipment should not lead to the conclusion that lead-free technology is currently available, neither for all server class products nor for whole range of NIE products. The range of manufacturing complexity and product reliability demands represented across the various product portfolios is too broad for such a conclusion. Technology observations in certain product groups may not be readily extrapolated to other product groups.

Conclusion

EICTA [4] describes that overall, the industry continues to face two opposing forces. The first, driving towards completely lead-free soldered products, comes from a supply chain that is rapidly moving to provide only lead-free parts due to overwhelming demand from the largest segment of the electronics industry whose products are not included in the scope of the exemption.

The second, pushing to maintain the status quo, results from the need to have proven capability to forecast the long term reliability of lead-free server, storage and NIE products to meet the stringent requirements of telecom service providers and server / storage system customers.

EICTA [4] suggests applying the lead-free technology to all new models of entry level and mid-level complexity designs by 2012. Additional time will be required for redesign or phase-out of legacy low to mid-complexity products until 2014. For high-end servers, the exemption should be maintained through to 2016. EICTA also asks to maintain the spare parts supply chain for Pb-bearing products installed base (i.e. repair as produced).

4.11.3 Critical review

Technical complexity and high reliability requirements

The stakeholders plausibly explain that the equipment covered by exemption 7b can be more complex than other electrical and electronic equipment, which had been converted to lead-free soldering from 2006 on latest. The shift to lead-free solders and finishes for many 7b products can be technically more challenging and may introduce potential insecurities, the more as such equipment can be subject to very high reliability requirements over a life time over more than a decade, as the stakeholders explain. The equipment listed under exemption 7 b was allowed to further on use lead in solders, as failures can be mission critical affecting security and reliability of entire sectors like the telecommunications sector. The existing technical problems with components, lead-free solders and processing are well-known phenomena. Some of these problems or the possible consequences arising from them are not relevant for lower complexity equipment that was already transferred to lead-free soldering in 2006. Others were solved for most lower complexity products. The high reliability requirements and technical complexity of printed wiring boards in 7b-equipment aggravate such problems or their consequences, or they cannot yet be solved satisfactorily to allow a complete shift to lead-free soldering across the whole product range of equipment under exemption 7b. Lead-free soldering in high end equipment with the most complex PWBs and the toughest reliability requirements in particular is a challenge. It requires sufficient time to solve the remaining problems and to implement the full transition to lead-free soldering.

Adaptation to scientific and technical progress

Lead-free soldering is already implemented in some servers and NIE falling under exemption 7 b. This exemption review process targets the adaptation to the scientific and technical progress. Lead-free soldered product examples show that there is progress in the implementation of lead-free soldering in equipment under exemption 7 b, and the exemption must reflect this progress.

At the same time, the products under exemption 7 b cover a wide range of technical and technological complexity as well as reliability and safety requirements. On the Brussels stakeholder workshop in June 2008, it was discussed to exclude low- to mid-end servers from exemption 7b after an adequate transition period.

EICTA suggested the following re-wording of exemption 7b taking into account the scientific and technical progress in the server area:

Lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signalling, transmission as well as network management for telecommunications, except for low to mid-complexity server models newly introduced on the EU *market after 1 July 2012, where a low to mid-complexity server model is defined as a rack mount, pedestal or blade server having a single or dual processor capability.*

The consultants did not inquire any further, whether and how far the above wording actually would reflect the current status of lead-free soldering technology in the server area. EICTA's proposal excludes new models of low-/mid- end servers from the exemption, which will be put on the market after 1 July 2012.

Some lead-free soldered NIE and storage products, however, are also placed in the market already. This fact had not been properly taken into account at the Brussels workshop. A diligent adaptation of exemption 7b to the scientific and technical progress requires taking into account the current lead-free status of all equipment types where lead-free soldered versions are put on the market. This would demand a clear classification of products within each equipment type where lead-free product samples are available, but where different technical complexity or technical constraints prevent a thorough changeover to lead-free solders.

EICTA states: "While one can make logical arguments sufficient to defend the reliability of some lead-free NIE assemblies today, the case by case nature of these arguments makes it impossible at present to define in any practical manner classes of NIE products that can be produced lead-free and classes that cannot. Trying to limit the scope within NIE is today not possible or would require such a complex definition that it would create a large gray area and therefore be impractical." [4]

Finding clear technical categorizations for the products within each equipment type under exemption 7 b where lead-free soldering is already possible is either impossible, or would result in exemption wordings that are too complex to facilitate a clear understanding and interpretation by industry as well as for authorities monitoring RoHS compliance.

Instead of setting an expiry date for low- to mid-end servers in July 2012, it is therefore proposed to set a later expiry date, but then for all products under exemption 7b. This approach keeps exemption 7 b simple and clear.

Setting the expiry date

EICTA [4] pointed out that 2014 would be the earliest feasible date for the deletion of exemption 7b, and that more time would be required in case problems occur. The reviewer believes this expiry date to be reasonable for several reasons.

Hewlett Packard [12] explains that products under exemption 7 b in general have a much longer product life time and much longer redesign cycles, meaning the time until an existing product is redesigned in order to put a new model on the market. While consumer products, according to HP, have a one year design cycle with a 1-1.5 year product life, an enterprise server can have a 3 year design cycle and a 3-7 year product life. Because of a long product life cycle, many manufacturers have been forced into lifetime buy (LTB) situations for critical components. These are electronic components that are made specifically for normally just one customer. In the professional equipment area, like for example in the high-end server world, the number of units sold are small compared to consumer electronics. Users of such customer specific components therefore order small volumes of such components, which are too small for component manufacturers to maintain a permanent production of such components. They are hence produced once or a few times periodically, and the user maintains his production until he orders new ones or redesigns them to put a new model of his product on the market. Such LTB components on hand may not be suitable for lead-free soldering process temperatures, or themselves may not be RoHS-compliant unless they are redesigned.

The qualification period for lead-free soldered products is very long for complex systems. In many cases, the time to qualify a lead-free conversion is longer than the remaining product life. It is therefore not practical to redesign older products for lead-free soldering.

It is also important to consider that qualifications would need to be done at different levels, by the manufacturer, the system integrator, and the final customer. The re-design time and effort to bring a product with lead-free technology to the market thus requires a transition time of around 3 to 5 years. [12]

The 2014 expiry date would give equipment manufacturers 6 years time for adapting and redesigning their products including customer-specific last time buy components, in order to be ready for the 2014 deadline. This presumes that all the knowledge is available for the transition to lead-free soldering at the time when the redesign process starts. As this may be not the case for some high end products, they might have to start the redesign process towards lead-free soldered printed wiring boards later. The 2014 deadline thus may be ambitious or impossible to achieve for some high end equipment manufacturers due to the technical complexity and strict reliability requirements. They could use the next periodical review of the exemptions in 2012 to ask for an adaptation of the expiry date or an extension of the exemption for specific equipment types. Even after the 2012 review, there would be enough time to apply for specific exemptions before the expiry date in July 2014, in case they are necessary. The 2014 deadline thus would give industry every chance to have exemption 7 b adapted to the actual technical status of lead-free soldering in their products.

The ever more difficult supply situation with lead-finished components makes equipment manufacturers shift to lead-free as soon as possible any way. Even with the expiry in 2014, this is still a considerable motivation to shift to lead-free soldering before 2014 wherever possible, as far as the supply chain is ready to deliver RoHS-compliantly, and as far as customers are ready to move towards lead-free soldered products. A clear expiry date promotes this process, and makes it easier for manufacturers to convince their suppliers and to organize their supply chain, and to convince their customers to transition to lead-free soldered products, once the appropriate technical properties can be achieved. The manufacturers that already have lead-free soldered 7b-products in the market support the 2014 deadline [8], [11].

Repair of equipment

HP [12] states that "manufacturers are often under contractual obligation to customers to continue providing additional systems as the customers needs expand. The customers demand systems that are identical to the installed base to assure compatibility." HP proposes a grandfathering approach. The consultants think, however, that such an approach would not be in line with Art. 5 (1) (b). For details please refer to section 5.6.

4.11.4 Recommendation

It is recommended to continue the exemption, but to add the expiry date 31 July 2014. To facilitate technically sound repair, upgrade and capacity enhancement of products put on the market before the deadline, the use of spare parts using lead in solders must be allowed in products that were put on the market before the expiry date.

The consultants propose the new wording of exemption 7b as follows:

Lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signalling, transmission as well as network management for telecommunications, until 31 July 2014, and for the repair or the reuse of such equipment put on the market before 1 August 2014.

4.11.5 References

[1] Borgesen et al., "Pb-Free Solder: New Materials Considerations for Microelectronics Processing", MRS Bulletin, Vol.32, April 2007; document referenced in [2];

[2] EICTA stakeholder document
"EICTA Position on RoHS Exemption 7b, 20th August 2008.pdf"

[3] EICTA stakeholder document "EICTA position on Exemption 7B 28th July 2008.pdf"

[4] EICTA stakeholder document "Exemption_7b_EICTA_and-others_1_April_2008.pdf", submitted during the stakeholder consultation

[5] Goodman et al., Technical adaptation under Directive 2002/95/EC (RoHS) – Investigation of exemptions, ERA 2004, document "era_technology_study_12_2004.pdf"

[6] Kelly et al.; "Qualification of a Lead-Free Card Assembly & Test Process for a Server Complexity PCBA," Proceedings of SMTA-I, 10/07, Orlando

[7] Schueller et al., Dell Inc.: A Case Study for Developing Lead-Free Class A Server Products; Proceedings of the Electronics Goes Green 2008+ Joint International Congress and Exhibition, page 161 ff; 7-10 September 2008, Berlin, ISBN 978-3-8167-7668-0

[8] Markus Stutz, Dell Inc.; information sent to Dr. Otmar Deubzer, Fraunhofer IZM, via e-mail on 11 August 2008

[9] EICTA stakeholder document "EICTA Position on RoHS Exemption 7b 20th August 2008.pdf"

[10] Commission FAQ-Document Frequently Asked Questions on Directive 2002/95/EC on the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and Directive 2002/96/EC on Waste Electrical and Electronic Equipment

[11] Per Döfnäs, Ericsson; information sent to Dr. Otmar Deubzer, Fraunhofer IZM, via e-mail on 8 August 2008

[12] HP Hewlett Packard; Stakeholder document "HP Letter to the Oeko Institut – Rev3.1.pdf"

4.12 Exemption No. 7c

"Lead in electronic ceramic parts (e.g. piezoelectronic devices)"

4.12.1 Abbreviations and definitions

Curie temperature	Temperature at which piezoelectric ceramics loose their piezo-electric properties
Saturation polarization	Highest practically achievable magnetic polarization of a material when exposed to a sufficiently strong magnetic field
PTC	Positive Temperature Coefficient, materials increasing their electrical resistance with increasing temperature; as PTC ceramics used in PTC resistors or PTC thermistors
PZT ceramics	Ceramics consisting of a mixture of **P**b**Z**rO_3 and Pb**T**iO_3

4.12.2 Description of exemption

Lead and its compounds in components relevant to this exemption are used in thickfilm technology, in piezoelectric and dielectric ceramics and in PTC resistors. These applications are explained in further detail below.

Piezoelectric ceramics

Piezoelectric ceramics generate an electrical charge when mechanically loaded with pressure, tension, acceleration. This effect is the direct piezo effect. The polarity of the charge depends on the orientation of the crystals in the piezoceramic relative to the direction of the pressure. Conversely, the crystals in piezoceramics undergo a controlled deformation when exposed to an electrical field – a behaviour referred to as the inverse piezo effect.

Piezoelectric ceramics contain lead as high covalent compound in the ceramic matrix to achieve good ferroelectric properties in a wide temperature range. The best known performances can be reached with PZT ceramics, which are a mixture of $PbTiO_3$ and $PbZrO_3$. The lead content is between 50% and 70% by weight, depending on the proportion of zirconium (Zr) and titanium (Ti). [2]

EICTA [1] gives the following examples for products using PZT:

- Power transformers for PCs;
- Focus/zoom of mobile phone cameras;
- inkjet printers;
- hard disks;
- video recorders;
- video games;
- audio equipment;
- air conditioners;
- refrigerators and washing machines;
- smoke detectors;
- health measurement equipment.

PTC ceramics [1]

Materials increasing their electrical resistance with increasing temperature; as PTC ceramics (Positive Temperature Coefficient) used in PTC resistors or PTC thermistors. PTC ceramics is the description of an electrical material functionality which is used for overload protection in high voltage electric circuits. Usually PTC resistors are based on polycrystalline barium titanate which becomes semi-conductive by doping with further metallic oxides. The lead content within these materials is about 4% -14% by weight. PTC ceramics increase their electrical resistance with increasing temperature. Lead is also indispensable for these ceramics to achieve the required resistance-voltage characteristics and distribution of the resistance value.

PTC ceramics are mainly applied for overheat/overload protection in several products, for example in [1]:

- overheat protection in personal computers, in LCD and plasma display panel TVs, and in power supplies;
- current control in energy saving light systems and in compact fluorescent lamps;
- overcurrent protection in telephones and in measuring equipment.

Dielectric ceramics [1]

Dielectric ceramic is the basis for ceramic capacitors. Ceramic capacitors with high capacitance values for high voltage / high power applications need a lead based ceramic to achieve the necessary efficiency and to prevent self-heating. The lead content of these ceramics is about 50% by weight.

Dielectric ceramics are generally applied to prevent overheating of electrical and electronic devices or parts thereof [1]:

- Electrical and electronic control circuits;
- Ceramic capacitors for high power (exceeding DC 250 V and AC 125 V);
- HID (high intensity discharge) lamps.

Thickfilm technology

Thickfilm applications so far have been considered to be covered by exemption 5 (Lead in glass of electronic components) as well as exemption 7c (lead in electronic ceramic parts).

In thickfilm technology, thickfilm pastes are printed on a substrate, e.g. ceramics. The thickfilm paste is then sintered into the ceramic at high temperatures. This creates structures with the functionality of conductive paths, resistors, capacitors and resonators, which normally are verified using electronic components. The pastes contain lead to ensure the adhesion of the thickfilm layer on the substrate and/or to achieve conductive or other properties of the layer.

Figure 13 Thickfilm components [2]

Components based on thick film applications are very small, their lead content hence very low. [2]

Amount of lead used under exemption 7c

JBCE submitted information on the amounts of lead used under exemption 7c. Ceramics including lead is used in a large number of applications in a large number of final products making it impossible to actually survey the amounts of lead transported into the EU. [3]

JBCE estimates the amounts of lead based on electronic components for which production figures are relatively easy to grasp and adds that more ceramic components including lead may be of relevance which are not mentioned here. The figures should hence be understood as an estimate restricted to the information available to JEITA. They are not the ultimate figures on use of lead under exemption 7c. [3]

Table 7 Rough estimate of amount of lead per year used in ceramics [3]

Category	Component Name	Examples of Final Product	World Production Amount kpcs/Year *1	Amount of Lead Inclusion mg/pcs *2	Amount of Lead Used kg *3	Amount Transported into the EU kg *4
Piezoelectric Ceramics	Piezoelectric Transformer	Liquid Crystal for PCs, TV sets, etc.	78,000	900	70,200	
	Ceramic Filter	FM Radio, etc.	800,000	26	20,800	
	Ceramic Resonator (SMD	Digital Household Appliances, PCs, etc.	1,300,000	11	14,300	
	Ceramic Resonator (with lead wire)	Household Appliances, Remote Control, Mouse, etc.	1,800,000	5	9,000	
	Piezoelectric Buzzer	Air Conditioner, Washing Machine, etc.	500,000	53	26,500	
	Piezolectric Actuator (For OA Equipment)	OA Equipment	50,000	294	14,700	
Semiconductor Ceramics	PTC Thermistor	Compressor for refrigerators	150,000	390	58,500	
	PTC Heater	Drier, Household appliances, etc	360,000	1,600	576,000	
	PTC Thermistor	Power supplies, Communication equipment, Lighting, Household Appliances,	420,000	50	21,000	
Dielectric Ceramics	High-voltage capacitor	Power supplies of refrigerators, copiers, TV sets, etc	1,300,000	78	101,400	
				Total	912,400	271,895

*1 Japan Electronics and Information Technology Industries Association Estimat
*2 There are components with different shapes and masses, but we estimate the amount of lead for an average component item
*3 Estimate values calculated as explained in *1 and *2
*4 Calculated from the GDP of the EU (2006) (14.4 trillion dollars, 29.8% of World GDP

JBCE indicates the total amount of lead used in ceramics und exemption 7c with around 900 t per year [3]. The figures do not include the use of lead in thickfilm applications.

The amount of lead in ceramics in the European Union is estimated with around 270 t per year, excluding thickfilm applications.

As the estimates do not include all uses of lead under exemption 7c, the real amounts of lead are higher. More detailed figures are not available.

4.12.3 Justification by stakeholders

PZT ceramics

JBCE [3] claims the substitution or elimination of lead in PZT ceramics to be technically and scientifically impracticable.

For piezoelectric applications, the relationship between the Curie temperature and the constants of piezoelectric material is of crucial importance. In other words, it is essential that the piezoelectric ceramic performs according to minimum requirements at a given temperature. [3]

JBCE [3] explains crucial constants of piezoceramics.

Table 8 Essential characteristics of PZT ceramics [3]

Piezoelectric Strain Coefficient (d constant) (Piezoelectric material constant)	Indicates how efficient an electric field can generate strain of the piezoelectric material, or vice version how efficient a strain applied on the ceramic can generate an electrical field. Higher values indicate higher efficiency. d=strain **/** applied electrical field If the value is high, the piezoceramic can generate displacement efficiently from a low electric field. Also, the output is larger for sensors and it can be used as good sensor material with high sensitivity
Electro Mechanical Coupling Coefficient (k)	Coefficient to show the efficiency to transform and communicate electric alteration into the energy of mechanical alteration (or vice versa) due to the piezoelectric effect $k = \sqrt{\frac{\text{mechanical energy stored}}{\text{electrical energy applied}}}$ or $k = \sqrt{\frac{\text{electrical energy stored}}{\text{mechanical energy applied}}}$ [4] In order to gain filter characteristics, materials with high values in this category are essential.
Mechanical Quality Factor Coefficient	shows the extent of mechanical loss near frequencies where the piezoelectric substance resonates; in resonators and oscillators, as the value becomes higher, the oscillator becomes more efficient and the fluctuation in the resonance frequency decreases.

JBCE [3] admits that piezoelectric effects are also observed in lead-free ceramics like in barium titanate or bismuth/sodium titanate and others. However, lead-free ceramics can either not be produced in an industrial mass scale yet, or these materials fail to provide the necessary piezoelectric properties necessary for actuators, sensors, oscillators, filters, transformers etc. for comparison also see the final report on the review of Annex II of the ELV Directive [2].

The incorporation of lead into the crystal structure of ceramics is indispensable to obtain the required piezoelectric effects like high performance, the necessary Curie temperature etc.

Without the necessary minimum performance requirements in the respective applications, the piezoelectric ceramics cannot perform according to the standards and thus cannot be applied. Lowering the standards does not make sense, according to JBCE [3], as the proper function cannot be ensured. [3]

The material properties of lead-free piezoelectric ceramics, according to the stakeholders, extremely depend on the temperature and various mechanical parameters. A stable performance within typical ranges of temperature and mechanical impacts is necessary. [2]

The stakeholders also state that piezoelectric systems must be based on stable materials with marginal drift of properties and deterioration effects. The long-term performance of the mentioned material under continuous operation conditions is not known. [2]

The stakeholders conclude that the discussed lead-free piezoceramics do not show material properties to be suitable for a substitution of PZT ceramics. Additionally, these lead-free alternative piezoceramic materials cannot be manufactured in industrial scale with reproducible properties. The stakeholders do not see viable substitutes for piezoelectric ceramics at the present time. [1] [2] [3]

Exemption 11 in the Annex of the ELV Directive as well refers to the use of lead in ceramics. The exemptions from the technical point of view hence are identical. The information the stakeholders submitted is congruent with the information available on this topic from the review of Annex II of the ELV Directive.

During this review process, no opposing stakeholder views were submitted.

Dielectric ceramics

JBCE [3] states that most electronic components applying dielectric ceramics do not contain lead any more. Dielectric ceramics are used in different components, mainly in ceramic capacitors. JBCE [8] indicates that dielectric ceramics used in components with less than 125 V AC (alternating current) and 250 V DC (direct current) can be lead-free. Still, there are components currently used with electric voltage of less than the above stated parameters (for example 200 V DC) using lead, however substitution for lead-free alternatives is technically possible. [8]

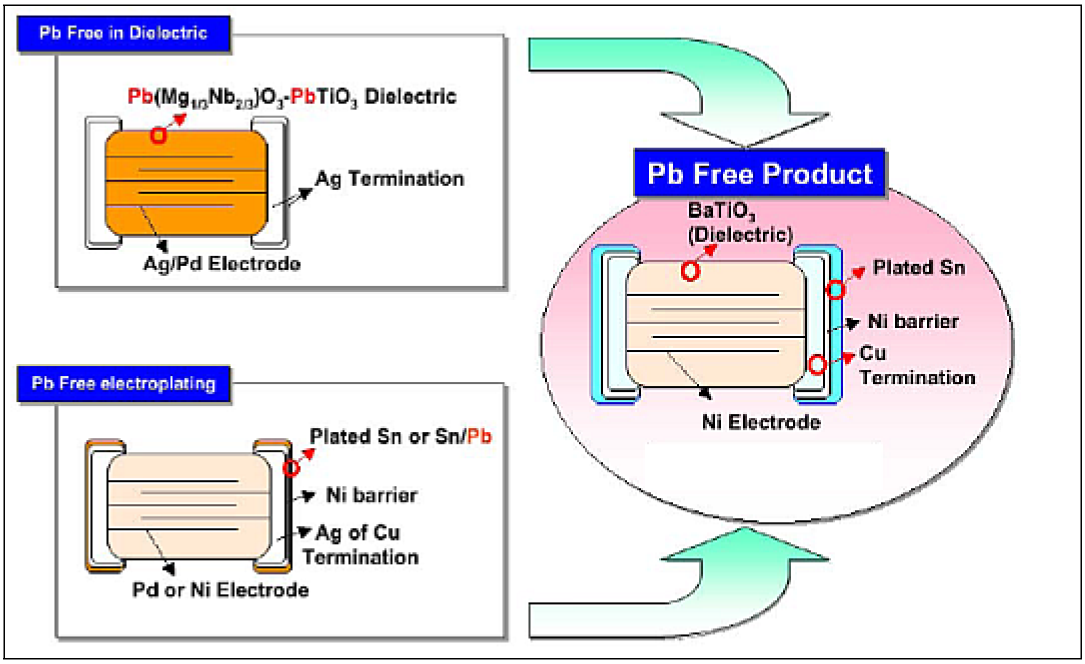

Figure 14 Substitution of lead in low voltage multilayer ceramic chip capacitors [8]

JBCE [8] states that for components still using lead-containing dielectric ceramics, but for which substitution perspective exists, a 5 to 10 year transition period would be required. Due to the wide usage and the large number of units used per device, it may generate confusion in the market unless an appropriate transition period is provided. JBCE [8] further points out that the exemption for the use of lead in ceramics was extended for the ELV Directive. If the applications for the use of lead in ceramics are restricted in the RoHS Directive, it will create confusion in the production and supply of products in the actual market. JBCE [8] would like to have a unification of the exemptions in the ELV Directive and the RoHS Directive. [8]

The substitution of lead is technically and scientifically impracticable in particular in high-voltage capacitors. No substitutes are available for high-voltage capacitors used with voltages exceeding 125 V AC or 250V DC. The use of Barium titanate has been proposed as a potential substitute material. However, it is likely to distort when voltage is imposed and the lack of strength is a concern in the application of electronic components which are used under high voltage. [1] [3] [8]

In order to obtain the function to withstand high voltage and to accumulate a large amount of electricity, a material which loses a small amount of accumulated electricity is required. Strontium titanate is appropriate for this. However, strontium titanate has a poor ability to accumulate electricity at room temperature. Thus, the ability to accumulate electricity is achieved only by adding lead as a shifter.

For high voltage capacitors using voltage exceeding 125 V AC or 250V DC, there is no prospect at present for lead substitution. Same degree of functionality cannot be assured for capacitors composed of dielectric materials other than ceramics either. The function of high voltage capacitors is regulated in safety standards, with which lead-free materials cannot comply.

PTC ceramics

JBCE [3] states that the solid-solution ceramics of Barium titanate and lead titanate is the only mass-produced material which can raise the Curie temperature of Barium titanate to the required level. Other than lead, there is no such material, which at the same time can be mass-producted and yields the necessary reliability.

If the Curie temperature can be 120 centigrade or below, it can be produced by adding strontium to Barium titanate. However, the product life and withstand voltage is poorer than using lead and there are problems to be solved before practical application. For a substitute material in case the Curie temperature of more than 130 centigrade is required as in overcurrent protectors, research and development of solid solution material of natrium and bismuth and Barium titanate is advocated. However, as the reliability and the mass-production technology is not ensured and there is no prospect of mass-produced supply of workable substitute material, the completion of substitution within several years is not in sight.

Exemption 11 in the Annex of the ELV Directive as well refers to the use of lead in ceramics. The exemptions from the technical point of view hence are identical. The information the stakeholders submitted is congruent with the information available on this topic from the review of Annex II of the ELV Directive.

No opposing stakeholder views were submitted during this review process.

Thickfilm technology

Lead is used in thickfilm technology. According to JEITA [2], alternatives with the properties equivalent to lead-containing glasses/thick film layers are not available on the market [2]. Lead-free alternatives to lead-containing thickfilm layers comprise borosilicate zinc glass and borosilicate bismuth glass; resistor alternatives include bismuth ruthenate, sodium ruthenate, strontium ruthenate and others. They can, however, not compete with the lead-containing thickfilm materials.

Technical properties, such as e.g. the high heat resistance in high operating temperature applications, make thickfilm applications indispensable. Conventional printed wiring board technologies hence cannot replace the thickfilm technology.

Roadmap towards phase-out of lead in ceramics

JBCE submitted the JEITA roadmap towards the substitution of lead in ceramics, as Figure 15 shows.

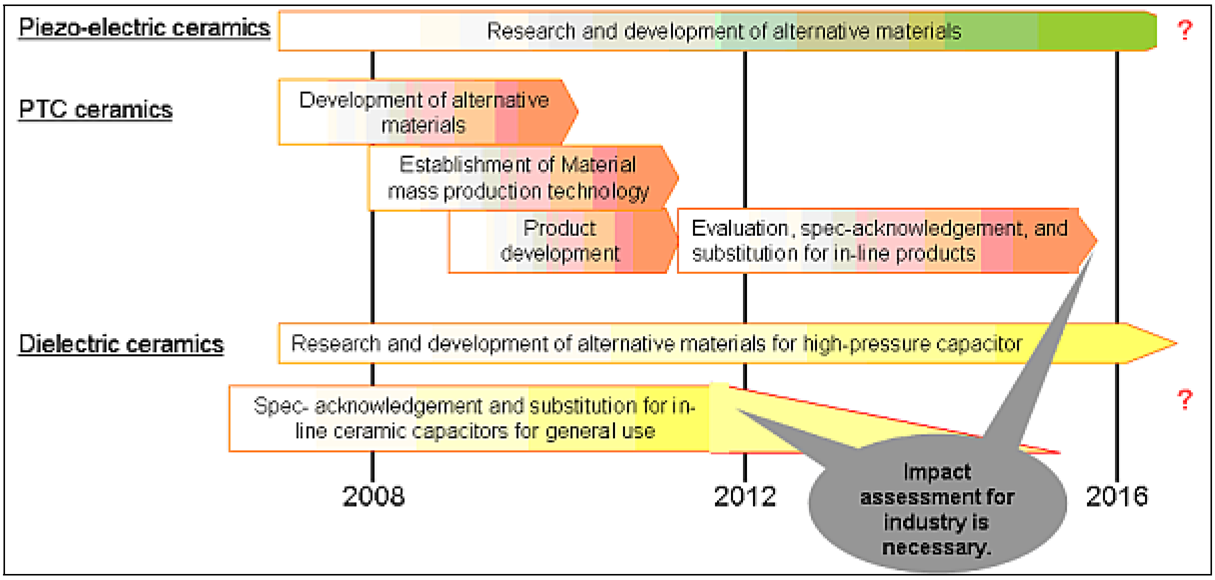

Figure 15 Roadmap to the substitution of lead in ceramics [3]

The above roadmap shows for the PTC ceramics that there are several steps to go from the pure availability of a substitute material to its applicability. This is plausible, as materials need to be tested and qualified for applications.

Lead-free substitutes for the ceramic materials discussed are not expected to be applicable before around 2015.

Opposing stakeholder views are not available.

4.12.4 Alignment of the RoHS and the ELV Directive

Developments in the review of exemption requests in the RoHS Directive

Lead in thickfilm applications has been considered to be present either as (part of) a glass or ceramic. Exemption no. 5 “Lead in glass of […] electronic components […]” and/or no. 7 “Lead in electronic ceramic parts (e.g. piezoelectronic devices)” were therefore believed to cover the use of lead in thickfilm applications.

In a previous stakeholder consultation round, a manufacturer of cermet-based trimmer potentiometers had requested a RoHS-exemption for the use of lead in thickfilms [5]. The manufacturer stated that he does not see his application either under the existing RoHS exemption no. 5 “Lead in glass of cathode ray tubes, electronic components and fluorescent tubes” or under no. 7 “Lead in electronic ceramic parts (e.g. piezoelectronic devices)”.

The thickfilm is used to generate the resistive layer on the ceramic base of the trimmer potentiometer. The manufacturer said that this resistive layer is a homogeneous material, as it can be mechanically separated from the ceramic base. This homogeneous material, the thickfilm layer containing the lead, for itself is neither a glass nor a ceramic material. Exemption 5 or 7 c therefore, according to the applicant, do not cover the use of lead in this thickfilm layer.

It is in the responsibility of the manufacturers to define the homogeneous material as well as to decide whether a specific exemption covers the specific use of a material, which is otherwise banned in the RoHS Directive. Neither the reviewers nor the Commission take such a decision. As the applicant's arguments were plausible, the consultants recommended the Commission to grant the exemption [6].

Review of Annex II of the ELV Directive

During the review of Annex II of the ELV Directive, given the above developments in the RoHS exemption review, it was discussed with the stakeholders whether exemption no. 11 of Annex II ELV Directive ("*Electrical components containing lead in a glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs"*) actually covers the thickfilm applications of lead-containing thickfilm layers in vehicles.

At the stakeholder meeting in Brussels on 10 October 2007, after consultation with the Commission, the contractor had proposed to amend the existing wording of exemption 11 in Annex II of the ELV Directive in order to increase the legal security for industry and to maintain the consistency between the RoHS and the ELV Directive:

Electrical components containing lead ***in a thickfilm layer (…)*** *or in a glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs.*

The stakeholders decided that the wording of the exemption in the ELV Directive "*Electrical components containing lead in a glass or ceramic matrix compound […]"* covers the use of lead in thickfilm applications. They stated that, assuming the thickfilm layers are homogeneous materials, the thickfilm layer contains the lead as a glass or ceramic matrix compound. The homogeneous material itself hence does not need to be a glass or a ceramic, in opposite to exemption 5 and 7c in the RoHS Directive. The stakeholders therefore claimed the wording of exemption 11 ELV Directive to cover thickfilm applications and asked not to change the wording [2]. The consultants followed the stakeholders request in their recommendation to the Commission.

Review of the Annex of the RoHS Directive

In this review process of the Annex of the RoHS Directive, it was discussed whether to adopt the wording of exemption 11 ELV Directive. As technically both exemptions cover the same issues, an alignment would be justified.

During the stakeholder workshop in Brussels on 10–12 June 2008, the stakeholders in principle supported the arguments raised during the review of Annex II of the ELV Directive. Nevertheless the wording was decided to be modified to further clarify the scope of this exemption:

*“Electrical **and electronic** components which contain lead in **a glass or ceramic** or a glass or ceramic matrix compound (e.g. piezoelectronic devices)”.*

This wording covers the following issues:

- Addition of “electronic components”
  Some legislation explicitly refers to “electrical and electronic” applications or equipment, like for example the WEEE Directive and the RoHS Directive. Exemption 5 and 7c in its current wording also refer to “electronic” components. This might raise concerns that 7 c might only apply to electrical, but not to electronic components. The stakeholders agreed to add the electronic components modification in order to avoid insecurities. [7]
- Lead in “a glass or ceramic”
  As discussed, the wording “lead in a glass or ceramic matrix compound” according to the stakeholders allows the use of lead in a homogeneous material, which itself is neither a glass nor a ceramic. The only precondition is that the lead is included in a glass or ceramic matrix compound, which, according to the stakeholders, is the case e. g. in thickfilm applications.
  The remaining question was whether this wording would also allow the use of lead in a homogeneous material, if this material itself actually is defined as a glass or a ceramic.

  To avoid insecurities, the wording was completed with the addition of “lead in glass or ceramic”.

The stakeholders agreed to this wording. They further on recommended the European Commission to provide a definition of a ‘matrix compound’ in a guidance document or FAQ. [7]

Consequences for the current exemption 5

If the Commission follows the proposal for the new wording of exemption 7 c, the "lead in glass […] of electronic components" part can be removed from exemption 5. This part of the exemption would then be integrated into exemption 7 c.

4.12.5 Critical review

Situation after review of information available until 31 October 2008

Under exemption 7c, lead is used in PZT ceramics, in PTC ceramics and in dielectric ceramics. The stakeholders explain that at the current state of technology, lead cannot be replaced in PZT ceramics and in PTC ceramics. The JEITA roadmap (Figure 15 on page 107) shows that for these uses of lead a substitution is not to be expected prior to 2016, hence not before the next general review of the exemptions.

For dielectric ceramics, the substitution of lead is technically practicable in components for a maximum voltage of 125 V AC or 250 V DC. For higher voltage applications, the substitution of lead is not yet possible, as the stakeholders explain. There is no substantiated stakeholder information available contradicting this information, neither on the feasibility of low voltage lead-free dielectric ceramics nor on the impossibility to replace lead in the higher voltage dielectric components.

Art. 5 (1) (b) requires the restriction of lead in dielectric ceramics to those areas where the substitution is technically impracticable. Exemption 7c therefore has to be repealed for lead in dielectric ceramics of electrical and electronic components for a maximum voltage of 125 V AC or 250 V DC. JBCE [8] asked for a transition period of at least five years. The dielectric components are widely used and in large numbers, and the components of some manufacturers still contain lead although the substitution is technically feasible. On request, the stakeholders could, however, not explain plausibly why and for which components or applications the long transition period of five years or more would be necessary.

Situation after 31 October 2008

The above review is based on the information available on 31 October 2008.

In December and afterwards, the reviewers received information that

1. the definition of "dielectric ceramics" might not be sharp enough in order to allow an unambiguous and clear understanding of the exemption wording [9].
2. the voltage limits of 125 V AC and 150 V DC may be too high for certain types of components containing dielectric ceramics in specific applications. The above proposed exemption wording would thus ban the use of lead in specific components, where viable alternatives are not yet available, or not yet long enough in order to allow a proper qualification of these components in all applications [10]. Other manufacturers of such components seem to experience similar problems.

Nevertheless, according to the information status after October 31, there seem to be remaining specific components in particular applications in the low-voltage area where lead-containing dielectric ceramics can not yet be replaced, or not within a few months. According to ZVEI [10], although most of these components using dielectric ceramics are available in lead-free ceramics, there is a remaining portion, where a replacement was not possible in particular applications. In consequence, manufacturers of ceramic capacitors still have to produce a limited number of low voltage capacitors using lead containing dielectric ceramic.

ZVEI [10] states that a manufacturer of components cannot identify all applications of the components, especially when considering the sales channels via resellers (distributors). Thus, a component manufacturer can only see, that still there is a small scale business with such "old" technology components, but cannot finally know, but does not know all the users and their specific applications.

Technically, drop in replacement with lead-free ceramic components using dielectric ceramics are not possible in all applications. The electrical properties of the ceramics are slightly different. In consequence, a user of the capacitors is forced to analyse all applications of those in all equipment, whether a re-design of the electronic circuit is necessary or not. [10]

This takes time, as such low voltage capacitors are widely used, and a typical customer may have to check hundreds of systems, test with new alternative components, and obtain the approvals from his customers, or authorities in case of applications in regulated areas. [10]

The remaining question vice versa is whether users of such components had not applied for exemptions, or reacted earlier. ZVEI [10] explains that a common and full material declaration system is not introduced to the whole electronic industry - thus most of component users, especially SME, do not have information on hand, whether ceramic capacitors contain lead or not. They only know, that the products they purchase are "RoHS-compliant", but not, whether this compliance is based on an exemption or not. The only chance for a component manufacturer to make the whole market aware of such a change to lead-free ceramics is, to publically announce the discontinuation of the delivery of such specific products, and to wait for the response from concerned customers, inform about alternative types and provide technical information and support for the conversion process. [10]

Obviously, manufacturers had informed their customers about the recommended changes of exemption 7c and the resulting consequences, and then only received feedback from customers and distributors.

This may at least in parts explain the difficult information flow.

As the information was available as late as in December 2008, it could not be clarified which components and which applications exactly would be affected in case of a ban of lead in dielectric ceramics. This cannot be decided on the spot, as the technical complexity requires an in-depth investigation and discussion with the different stakeholder sides. Given the above situation in industry, it must be doubted that this question could actually be clarified to a point that would allow drawing an exact line that would adequately address those specific cases where lead cannot yet be substituted in dielectric ceramics.

It is clear from the available information, that at least for most of the application spectrum, appropriate lead-free dielectric ceramics have been available for some time for low voltage uses. A long and general transition period of five and more years would hence not be justifiable by Art. 5 (1) (b). There are no hints that the cancellation of exemption 7c for these dielectric ceramic applications might have severe impacts on the availability of such components, or on the overall electrical and electronics industry sector.

A long transition period would not be justifiable with respect to single manufacturers that have shifted to components based on dielectric ceramics too late, where technically feasible. It is clearly stated in the RoHS Directive that all exemptions are reviewed at least every four years and therefore are temporary. Manufacturers hence can be expected to shift towards the use of lead-free ceramics once this is technically practical. The broad availability of lead-free components shows that his has been the case for some time already. Recommending a transition period to accommodate the needs of those manufacturers that have delayed the transition cannot be a reason for the continuation or a long transition period in line with Art. 5 (1) (b).

As it is not possible with respect to the end of the review process to further on investigate and discuss the issue sufficiently with the component manufacturers and those sectors applying such components, it is recommended to set the expiry of 31 December 2012 for lead in dielectric ceramics. Under the given circumstances, this expiry date would accommodate the requirements of Art. 5 (1) (b) as well as the complex technical and supply chain situation:

- An expiry date 31 December 2012 is close enough to appraise the fact that lead-free alternatives are available for most applications, and it is a clear signal to component manufacturers and users to shift to lead-free wherever possible as early as possible.
- The expiry date 31 December 2012 gives component manufacturers and component users time to shift and qualify more lead-free ceramic components in those particular cases where such alternatives so far have not been available or not yet long enough to qualify them for specific applications.
- The expiry date 31 December 2012 keeps the door open for industry to apply for specific exemptions in such specific cases where the substitution of lead in dielectric ceramics is not possible until end of 2012. Assuming the amendment of the RoHS Annex end of 2009, industry has a reliable time-frame to have specific exemptions installed before the expiry of the exemption.

Assuming that the Annex of the RoHS Directive will be amended until the end of 2009, it is recommended that exemption 7c expires on 31 December 2012 for lead in dielectric ceramics of electrical and electronic components for a voltage of less than 125 V AC or 250 V DC.

For all other uses of lead in ceramics under exemption 7c, viable lead-free substitutes currently are not available and are not expected to be available within the next years. Assuming that each exemption is required to have an expiry date, and in line with the COM requirements, the consultants propose 31 July 2014. This gives the stakeholders opportunities to submit evidence in the next review of the Annex for the further need of these parts of exemption 7c beyond 2014, if appropriate.

It could not be clarified why the definition of dielectric ceramics should not be sharp enough to allow a clear and unambiguous understanding of the exemption. The concern could not be substantiated to a degree that would allow a better and clearer wording and definition of “dieelectric ceramic”.

4.12.6 Recommendation

The consultants recommend setting an expiry date for lead in dielectric ceramics for low voltage components. Lead-free alternatives are broadly available and already are in use. However, there are clear hints that in specific components and applications, the substitution of lead in dielectric ceramics is not yet possible. Due to the complex technical and supply chain situation, it could not be further clarified which components in which applications would be affected.

Given the broad availability of lead-free ceramic components, the general continuation of the exemption until 2014 would not be in line with Art. 5 (1) (b). Assuming that the Annex of the RoHS Directive will be amended until the end of 2009, it is recommended that this part of the exemption expires on 31 December 2012 in order to adequately accommodate the different legal and technical requirements under the given circumstances.

For all other uses of lead in ceramics under exemption 7c, viable lead-free substitutes currently are not available, and are not expected to be available in the next years, according to the stakeholders. Assuming that each exemption is required to have an expiry date, the consultants propose 31 July 2014 to give the stakeholders opportunities to submit evidence in the next review of the Annex for the further need of these parts of exemption 7c beyond 2014, if appropriate.

The exemption must be split to reduce the complexity of the wording, which is proposed as:

- *Electrical and electronic components which contain lead in a glass or ceramic other than a dielectric ceramic or in a glass or ceramic matrix compound, (e.g. piezo-electronic devices) until 31 July 2014, and for the repair, and to the reuse, of equipment put on the market before 1 August 2014.*
- *Electrical and electronic components for a voltage of 125 V AC or 250 V DC or higher which contain lead in a dielectric ceramic until 31 July 2014, and for the repair, and to the reuse, of equipment put on the market before 1 August 2014.*
- *Electrical and electronic components for a voltage of less than 125 V AC or 250 V DC which contain lead in a dielectric ceramic until 31 December 2012, and for the repair, and to the reuse, of equipment put on the market before 1 January 2013.*

The above wording comprises the lead in “glass of electronic components” part from exemption 5, which is therefore deleted from exemption 5. At the same time, the wording, according to the stakeholders, covers the use of lead in thickfilm applications, which had been contentious with the previous wording of exemption 7c (and exemption 5).

4.12.7 References

[1] EICTA online stakeholder consultation document “Exemption_7c_EICTA_and-others_1_April_2008.pdf”

[2] Öko-Institut e.V./Fraunhofer IZM: Adaptation to Scientific and Technical Progress of Annex II Directive 2000/53/EC, final report January 2008, document “Final report ELV Annex II revision_rev.pdf”, download from http://circa.europa.eu/Public/irc/env/elv/library?l=/stakeholder_consultation/evaluation_procedure/reports/final_report/report_revision/_EN_1.0_&a=d; last access 20 October 2008

[3] JBCE online consultation stakeholder document “Exemption-7c_JBCE_1_April_2008.pdf”

[4] http://www.piezo.com/tech1terms.html#coupling, last access 20 October 2008

[5] Online stakeholder consultation for RoHS exemption requests, http://circa.europa.eu/Public/irc/env/rohs_6/library?l=/exemption_requests/trimmer_potentiometer/proposal_2pdf/_IT_1.0_&a=d, last access 20 October 2008

[6] Öko-Institut e.V., Fraunhofer IZM: Adaptation to Scientific and Technical Progress under Directive 2002/95/EC; final report; document “Final_Report_RoHS-Exemptions-October_2007.pdf”

[7] Information from Pascale Moreau, EPSON Europe, on behalf of EICTA; sent via e-mail to Dr. Otmar Deubzer, Fraunhofer IZM, on 24 July 2008

[8] JBCE stakeholder document “ROHS Exempted Application - Ceramic.doc”

[9] Stakeholder information via e-mail on 16 December 2008 and 9 January 2009 received from Lars Brückner, JBCE

[10] ZVEI stakeholder document “Concerns RoHS exemption 7c_01-2009_2.pdf” from January 2009

4.13 Exemption No. 8

“Cadmium and its compounds in electrical contacts and cadmium plating”

The complete wording of this exemption currently is:

Cadmium and its compounds in electrical contacts and cadmium plating except for applications banned under Directive 91/338/EEC amending Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations.

NEC/Schott [1] in the fourth stakeholder consultation in 2005 had submitted an exemption request to no longer allow the use of cadmium in “[…] applications of one-shot operation function such as thermal links […]”. NEC/Schott claimed to have cadmium-free solutions, and Öko-Institut recommended to remove the mechanical one-shot pellet type thermal cut-offs from the exemption in July 2007. The COM did not follow this recommendation, and exemption 8 is currently still in place without an expiry date.

In the current review process of the RoHS exemptions, several stakeholders ask for maintaining the exemption [2]-[10]. EACCM (European Association of Contact Material Manufacturers, [11]), KEMI Swedish Chemicals Agency [12], and a Chinese company [13] submitted stakeholder documents asking to restrict or to repeal exemption 8.

4.13.1 Description of exemption

Electrical contacts contain 10–12% of silver-cadmium-oxide (AgCdO). It prevents arcs when opening the contacts in case of high power / high current. Further on, it prevents the corrosion of electrical contacts which would reduce the durability and reliability. Corrosion can result in welding of the contacts, which would then destroy the functionality of the contact.

Cadmium-containing electrical contacts are used in manifold applications:

- switches, which again are used in many applications ranging from circuit breakers in information and telecommunication equipment, washing machines etc.;
- doorlocks in washing machines;
- thermal links for safety applications etc.

The stakeholders say they do not have information available on the absolute amounts of cadmium used under this exemption.

Thermal links

Thermal links are a specific application of cadmium under this exemption. Thermal links are non-resetting devices that function only once without refunctioning. They are used in thermal protection of equipment in which, under fault conditions, one or more parts may reach hazardous temperatures. [3] [16]

The following types of thermal links must be differentiated under the term "thermal links":

1. One shot pellet type thermal cut-offs;
2. One shot alloy type thermal cut-offs.

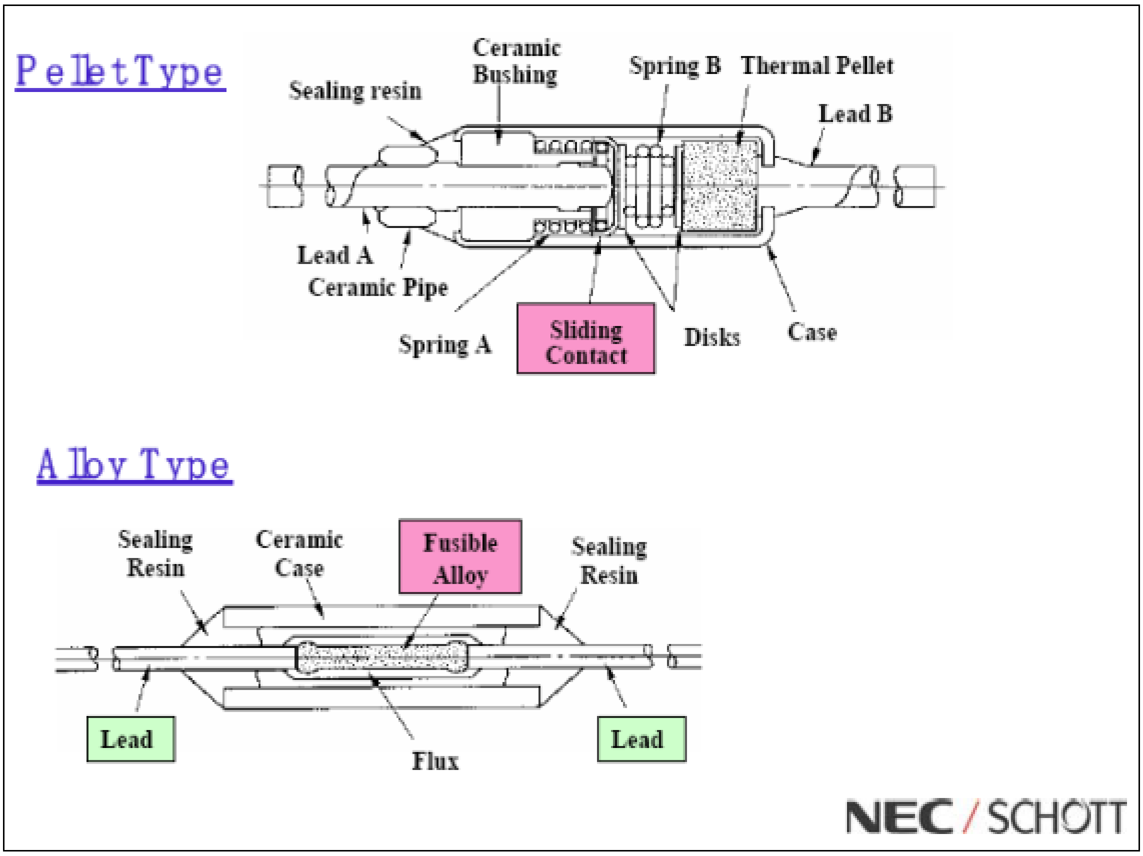

Figure 16 Types of thermal links: one shot pellet type thermal cut-off and one shot alloy type thermal cut-off

The one-shot pellet type thermal cut-off used to use cadmium on the sliding contact. Most alloy types contained lead, and some cadmium, too. Both types are available without cadmium and without lead.

NEC/Schott state that the "alloy type does not have an electrical contact" and hence this manufacturer does not see the alloy type thermal links to be covered by exemption 8. [15]

As no other stakeholders plead to include the alloy type thermal links into the exemption, or to withdraw the exemption for these devices, they are not taken into consideration in the following.

4.13.2 Justification by stakeholders

Silver-cadmium oxide is an ideal combination of materials for switching where arcing occurs. The cadmium oxide has two main functions [3]:

1. Prevention of welding of the contacts
   The arc melts the silver and the solid cadmium oxide matrix prevents welding when contacts close
2. Prevention of silver loss from the contact
   Cadmium oxide slowly vaporises at the high arc temperatures and this prevents it from building up at the surface which would increase the electrical contact resistance. This would in turn result in a rise in temperature from resistance heating and an increase in the erosion rate.

Some lower current contacts have been produced with silver-nickel. It is easier to use than silver tin oxide and does not increase in contact resistance. Silver nickel is not suitable for higher current switching. In fluorescent lighting equipment, contacts with silver nickel that switched higher currents failed by welding after only 18 months. [3]

The main alternatives to cadmium oxide in higher current switching are based on tin oxide and on zinc oxide, often with additional elements added, principally to modify the oxide particle size and shape. Both tin and zinc oxides have higher melting and boiling temperatures than cadmium oxide. They vaporize slower than cadmium oxide and so tend to build up on contact surfaces causing a gradual increase in contact resistance, as silver erodes. This increases the contact temperature which again may increase the wear rate and risk of welding. Many users of tin oxide and zinc oxide contacts complain that these materials are unsatisfactory substitutes for AgCdO because they wear faster and so have shorter lifes. Some manufacturers have found that silver tin oxide lasts for only half the time of silver cadmium oxide. [3]

Many, but far from all, off-the-shelf components now include cadmium-free contacts. However, they cannot be used as drop-in replacements. Design changes are required. It is necessary to make the contacts larger to compensate for the increased wear rate, and make other changes to switch and relay design. Thus, while silver cadmium oxide is suitable for a wide range of conditions, silver-tin oxide requires a more specific design, which then is suitable for a limited range of use conditions. [3]

Specific conditions in automotive electric contacts

The ban of cadmium in the ELV Directive forced the substitution of cadmium in contact surfaces. In automotive, silver tin oxide showed to be a suitable substitute. Lower current relays use silver nickel. Vehicles, however, use 12 or 24 volt DC (direct current) which gives very different arc behaviour to mains (240V) AC (alternate current) switching. Good performance in vehicles thus does not guarantee good performance for AC switching. [3]

Switching DC is different to AC. When a DC arc strikes on opening contacts, it will continue until the contact gap is sufficiently large for the plasma to be diluted by air and cooled. When AC contacts open, the arc will stop when the voltage reaches the null point (zero volts) as long as the gap is large enough to prevent it re-starting. AC voltage is a sign-wave where the voltage oscillates between positive and negative through zero. [3]

Automotive switching is also different to many electronic applications because many vehicle circuits have high inrush currents due to inductive loads. These result in brief high current surges that cause contact material vaporisation so that material transfers from one contact to the other. Silver tin oxide is particularly resistant to this as it is a material with high melting and boiling point, while at the same time the high inrush current vaporises sufficient material to prevent it from building up at the contact surface. Such a build-up would increase the contact resistance and spur the loss of silver and contact erosion as well as welding, as described before. The higher melting and vaporization point in this case is advantageous to maintain low contact resistance. [3]

Most applications in the scope of the RoHS directive and also in medical devices and monitoring and control instruments are AC applications without large inrush currents where silver tin-oxide is not universally suitable as a drop-in substitute unlike in automotive applications. [3]

Research, supply chain and qualification issues

The development of cadmium-free contact materials is by far more than simply changing the material only, but has to deal with many parameters, which even my vary depending on the application [3]:

- the gap between contacts when open;
- contact size (diameter and thickness);
- opening and closing speed;
- actuator design to minimise contact bounce; and also
- the choice of contact material composition and fabrication method.

The research and developments take a considerable amount of time.

One additional issue is that although silver cadmium oxide contacts from all suppliers behave similarly, the performance and behaviour of silver tin oxide depends on the essential minor additives that are used. Every supplier's product is significantly different in behaviour and performance. Testing of one type from one supplier may give good results whereas others will be found to perform badly. This is a significant disadvantage because if a suitable contact type is identified, this will have only one manufacturer and so there is a potential risk to supply if the manufacturer has production difficulties (e.g. a factory fire) or ceases trading. [3]

Most equipment manufacturers, except for the largest multinationals, do not carry out research into electric contact materials or switch and relay design and are only users of these products. The technical issues for choosing a suitable switch or relay design are complicated and are not understood by most equipment manufacturers who inevitably have to rely on their component suppliers for guidance. [3]

Research into substitutes and their qualification is being carried out at three levels [3]:

1. Manufacturers of the contacts are developing new materials which they test under simulated conditions although these may not represent all of those used by their customers.
2. Manufacturers of switches, relays etc. are also carrying out research to evaluate the new contacts, but are also having to re-design their components to achieve acceptably long reliable lives. Each type of switch or relay may be used in a wide range of conditions – with or without inrush current, switching frequency etc. and any contacts chosen must perform well under all conditions. This is possible with silver-cadmium oxide but more difficult with silver-tin oxide.
3. Finally, when the new switch and relay designs are available these have to be tested by equipment manufacturers using their own conditions for reliability assessment. Manufacturers need to obtain samples of a possible alternative, build equipment and carry out lengthy tests taking upwards of 6 months. The cost of these tests is at least several thousand Euros for each type of contact material and for each application. Frequently the first material evaluated is found to be unsuitable and so several types of contact need to be tested simultaneously which significantly increases the cost. This is particularly a problem for small and medium size manufacturers who cannot afford to do this. In addition medical equipment manufacturers will need to generate data for obtaining approvals under the medical devices directives which are required before the new components can be used. Some large multinationals have been investigating alternatives for several years, so far without success and so are still using silver-cadmium oxide in large quantities for at least some of their products.

Cadmium-free switches and relays are on the market for switching medium to moderately high currents, and they have been used. However, due to the above reasons, there are also many others that contain silver-cadmium oxide contacts and these are used by many European manufacturers. [3]

The removal of this exemption would particularly affect small and medium size manufacturers who do not have the resources to carry out the lengthy tests that are required. It appears that technically, substitutes should be available for all applications but some manufacturers have yet to identify suitable substitutes. In all cases, this will involve product re-design and lengthy and costly trials with no guarantee of success as simple drop-in replacements do not exist. [3]

For safety and durability/reliability reasons, AgCdO can not be replaced in most types of electrical switches and circuit breakers. [2] Despite of numerous tests over years, it has not been possible so far to replace all cadmium-containing electrical contacts [10].

Several other stakeholders support the continuation of exemption 8 in general or for specific applications [8, 9, 10, 11, 12, 13, 14, 15]. In principle, they put forward similar arguments like those described above.

Other stakeholders oppose the continuation of the exemption. The European Association of Contact Material Manufacturers claims that cadmium-free contact materials are available at this stage for all applications. It might, in certain cases, just need adaptations in the design of the electrical contact [16]. There are further stakeholder submissions claiming that alternatives are available for specific applications:

- for one-shot pellet-type thermal cut-offs [1] [15];
- for use in air conditioners [17];
- for electrical contacts, switches and relays [15].

Inclusion of cat. 8 and 9 equipment into the scope of the RoHS Directive

Documents were submitted pointing out the specific importance of exemption 8 for category 8 and 9 equipment (medical devices, monitoring and control instruments). They ask to extend exemption 8 [3], [13]. ERA states that any significant changes to medical equipment must be approved by a Notified Body as a requirement under the Medical Device Directives, which will require up to two years to complete including time for testing. When the new switch and relay designs are available to the medical equipment manufacturers, these have to be tested by equipment manufacturers using their own conditions for reliability assessment. In addition, medical equipment manufacturers will need to generate data for obtaining approvals under the medical devices directives which are required before the new components can be used. [3]

ERA says that category 8 and 9 manufacturers are now busy developing lead-free soldering technology and most, especially small and medium producers would have difficulty finding resources to also work on silver-cadmium oxide substitution due to a lack of suitably skilled manpower. [3]

4.13.3 Critical review

Cadmium platings

No supporting evidence was submitted during the stakeholder consultation that the further use of cadmium in platings, the second part of the current exemption 8, is required further on. During the stakeholder workshop in Brussels in June, there was no support for this part of the exemption either, but it was stated that the exemption probably is no longer needed for the products in the scope of the RoHS Directive. Further investigations at Amphenol in UK, a manufacturer using cadmium platings, confirmed that cadmium platings are no longer used for products in the scope of the RoHS Directive, but mostly for military and avionic applications.

In line with the requirements of Art. 5 (1) (b), the cadmium plating part of the exemption therefore can be revoked without any transition time.

One-shot pellet type thermal cut-offs (OPCOs)

NEC/Schott [1] in the fourth stakeholder consultation in 2005 had submitted an exemption request to no longer allow the use of cadmium in "[…] applications of one-shot operation function such as thermal links […]". NEC/Schott claimed to have cadmium-free solutions relying on AgCuO as contact material. Another manufacturer of one-shot pellet type thermal cut-offs states that "For pellet-type one shot thermal cut-offs, long-term reliability data can be reviewed and if acceptable, can entertain removal of the Exemption by 2010."[4]

For one-shot pellet type thermal links (=one-shot pellet type thermal cut-offs), meanwhile cadmium-free alternatives are available from more than one manufacturer. At least some manufacturers of end products already apply them or currently introduce them into their products. [14, 1, 15]

The substitution of cadmium in OPCOs thus is no longer technically impracticable, and the OPCOs must hence be removed from exemption 8 following the requirements of Art. 5 (1) (b). The OPCOs are, however, a safety-relevant component. Their proper function in products is indispensable and should not be put at risk. Failures may cause fire and other hazards. A proper expiry date for the OPCOs under exemption 8 therefore is crucial.

Viable cadmium-free OPCOs are available in the supply chain. Besides the supplier point of view, the users perspective, however, is important as well. A manufacturer of white goods [14] states that AgCuO is not a well known and well investigated contact-material in Europe. The introduction requires extensive investigation and testing. This manufacturer has started introducing cadmium-free OPCOs into its products. The required lifetime is 10 Years or 2000 washing or drying cycles. [14] For qualification, especially a lifetime-test in the machine, a thermal-shock-test and an electrical-overstress-test have to be carried out. In addition, the abnormal-operation-test for every type of application has to be repeated. The whole procedure takes about 1 year for each type of fuse. The white good manufacturer states that in the end it is the field experience that brings the final proof that the cadmium-free OPCOs are a viable alternative [14].

Further on, a simple drop-in exchange of the current cadmium-containing OPCOs by cadmium-free ones often is not possible. Different cut-off times and OPCO geometries, for example, can require different geometries of the OPCO environment in the equipment [14]. A simple and quick exchange thus is not possible, but needs a sound design or redesign of the equipment.

An appropriate transition time is therefore recommended allowing sufficient time for testing and evaluating the OPCOs and to adapt the design of the equipment to the cadmium-free OPCOs. Manufacturers should then be able to find the best cadmium-free option for their products.

Assuming the official amendment of the RoHS Annex by the end of 2009, it is recommended to set the expiry date for the OPCOs at 31 December 2011. This gives manufacturers 2 years time after the amendment of the Annex to select the most appropriate cadmium-free OPCOs and to adapt their products without compromising the safety of their customers.

In case category 8 and 9 equipment will be included into the scope of the RoHS Directive, the time line until end of 2011 is still long enough to apply for further specific exemptions accommodating the special conditions of these types of equipment.

Cadmium in other electrical contact materials

Cadmium-free materials like for electrical contacts have been available on the market for a while, as several stakeholders confirm [1, 2, 3, 11, 12]. Despite of some e-mail exchange, no further information could be obtained on the stakeholder comment from China [13] claiming that cadmium-free relays are available for use in air conditioners.

The main substitutes, which the suppliers offer are silver-nickel materials for lower current contacts and tin and zinc oxides for higher currents. They are used in electrical contacts already, in particular in lower current applications [3, 4].

However, the stakeholders' explain technically plausible that cadmium-free materials are not a drop-in replacement for the cadmium-containing contacts. On the equipment manufacturer side, it requires comprehensive testing and evaluation of the cadmium-free contacts and geometrical adaptations in the contacts and in the equipment to decide on a case-by-case base whether they are appropriate for the intended application. It is not clear, whether for every application appropriate cadmium-free materials are available. On request for more detailed information on cadmium-free alternatives for cadmium in electrical contacts, no further inputs were received from stakeholders that had pointed out to either have cadmium-free alternatives available or to know companies who offer them.

Cadmium-free contact materials are already used in electrical contacts, mainly in automotive application and in the lower voltage application range [3]. The stakeholders plausibly explain why the use of cadmium-free contact materials in automotive applications is technically different from other uses. This application thus is not a proof for the general viability of cadmium-free contact materials in other applications outside the automotive ones.

A limitation of exemption 8 to higher current applications is impossible or complicated. The stakeholders explain that for lower current applications, the different conditions in the specific application may not allow the use of cadmium-free contact materials in any case.

It might be possible to exclude a few specific cadmium contact applications from exemption 8. It would require defining the specific application conditions with possibly several parameters like current, inrush current, frequency of switching, life time, alternate or direct current, minimum available space in the product, operating temperature etc. This would not be manageable: it would require a complicated exemption wording, which would create confusion and insecurity in industry on the one hand. On the other hand, it would make monitoring difficult or even impossible for the authorities.

In order to nevertheless appraise and further promote the scientific and technical progress in this field, and to suffice the requirements of Art. 5 (1) (b), the exemption for cadmium in electrical contacts is proposed to expire on 31 July 2014. Assuming that the RoHS Annex is officially amended end of 2009, this expiry date accommodates four conditions:

1. As many electrical contacts are used in safety-critical applications, the transition to cadmium-free contacts must not compromise the safety of consumers. The testing and qualification procedures are comprehensive and lengthy, and additional design adaptations in products may be necessary. In particular in small and medium size enterprises, the manpower is limited, and it cannot be easily enhanced. Excessive pressure to replace cadmium-containing contacts might thus result in overhasty and not careful enough testing and qualification of the alternative solutions. This might endanger consumer safety. The expiry date in 2014 gives equipment manufacturers – including those of category 8 and 9 in case they are included into the RoHS Directive – enough time to carefully test and evaluate whether and how available or upcoming cadmium-free materials on the market are appropriate for their products.
2. Given the long and comprehensive qualification procedures, this expiry date should be early enough to spur manufacturers' efforts to implement cadmium-free contact materials in their products. This expiry date thus also appraises the fact that cadmium-free materials are available, should reward the suppliers offering such materials, and promote further research into cadmium-free alternatives.
3. As it is not clear whether cadmium can be replaced in each electrical contact application by the currently available contact materials, the expiry date must be far enough in

the future to allow industry applying for specific exemptions to maintain their products' safety. It must be made sure that such exemptions are in place before exemption 8 expires.

An earlier expiry date than 2014 might result in industry having to apply for many exemptions with unclear definitions and complex wordings similar to the situation now. Until 2014, there may be sufficient progress to avoid this situation. If industry can prove that the situation is technically as complex as it is now, the next general review for 2014 may accommodate this fact shifting the expiry date further into the future and maintaining the general exemption, or limit or completely cancel it otherwise.

4. In case category 8 and 9 equipment will be included into the scope of the RoHS Directive, the time line until July of 2014 is still long enough to apply for further specific exemptions accommodating the special conditions of these types of equipment.

4.13.4 Recommendation

Cadmium-free alternatives are available, although not always applicable. Maintaining exemption 8 in its broad and general character as it is now would not be in line with the requirements of Art. 5 (1) (b).

It is recommended to revoke the exemption for cadmium platings, as they are no longer used for equipment under the scope of the RoHS Directive.

The use of cadmium for electrical contacts in one-shot pellet type thermal cut-offs should be excluded from exemption 8 from 1 January 2011 on. Cadmium-free alternatives are available, but need time to be properly implemented in products, as such cut-offs are safety critical components.

Finally, the expiry date 31 July 2014 should be added to the use of cadmium in electrical contacts. Even though it is not clear whether they can be used in each application, cadmium-free alternative materials are available. A limitation of the cadmium use in electrical contacts to specific applications fails. The technical situation is complex, and a categorization of applications, in which the use of cadmium is allowed, would result in a complicated and unclear exemption wording. Additionally, end product manufacturers need time to test and evaluate whether and how the available or upcoming cadmium-free contact materials are appropriate for their products. Many contact materials are used in safety-critical applications, a careful transition hence is necessary not to compromise consumer safety. At the same time it must be made sure that equipment manufacturers can apply for specific exemptions in case cadmium-free alternatives do not work in some applications.

The proposed expiry date 31 July 2014 thus is a compromise between industrial feasibility, safety requirements and the requirements of Art. 5 (1) (b).

For a better understanding, exemption 8 is proposed to be split into two parts. The new wording of exemption 8 would thus be:

(8a) Cadmium and its compounds in one shot pellet type thermal cut-offs until 31 December 2011 and in one shot pellet type thermal cut-offs used as spare parts for the reuse and repair of equipment put on the market before 1 January 2012.
(8b) Cadmium and its compounds in electrical contacts until 31 July 2014[32]*, and in electrical contacts in spare parts used for the repair and reuse of equipment put on the market before 1 August 2014.*

4.13.5 References

[1] NEC/Schott Stakeholder consultation no. 4, http://circa.europa.eu/Public/irc/env/rohs_4/library?l=/requests_exemption/compounds_electrical&vm=detailed&sb=Title; last access July 2008

[2] EICTA et al. on ex. 8, Stakeholder consultation document "Exemption_8_EICTA_and- others_1_April_2008.pdf"

[3] ERA on ex. 8, Document "RoHS exemption 8 technical information final.pdf", submitted to Öko-Institut by Dr. Paul Goodman, ERA, in July 2008

[4] Stakeholder consultation documents "T-O-D RoHS Exempt 8 Response.pdf", "T-O-D Exemption 8 Input.pdf" and "ECTTOD Responses to stakeholders questions (0 1).pdf" from Emerson/Thermodisc

[5] Stakeholder consultation documents "Exemption-8_ITW-Metalflex_Specific-questions_31_March_2008I.pdf" and "Exemption-8_ITW-Metalflex_31_March_2008.pdf"

[6] Stakeholder consultation document "Exemption-8_Marquardt_31_March_2008.pdf"

[7] Stakeholder consultation document "Exemption 8-Ekowicki-Feb-08.pdf"

[8] Stakeholder consultation document "Exemption_8_Emerson_all_20_March_2008.pdf"

[9] Stakeholder consultation document "Exemption-8_Test-Measurement-Coalition_31_March_2008.pdf"

[10] Stakeholder consultation document "Exemption-8_Bleckmann_1_April_2008.pdf"

[11] Online stakeholder document „Exemption-8_EACMM_31_March_2008.pdf" from the European Association of Contact Materials Manufacturers

[32] The following addition was cancelled assuming that it referred to cadmium platings only, which were deleted from exemption 8: "except for applications banned under Directive 91/338/EEC amending Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations". In case the above addition is also necessary for the further specification of the exemption as it is worded here, it would have to be added again. This is subject to further clarification.

[12] Stakeholder consultation document "Exemption_1-2-3-4-6-8-9a-9b-25-29_Sweden_1_April_2008.pdf"

[13] E-mail from Mr. Echo Zheng, Xiamen Hualian Electronics Co. Ltd., China, to Öko-Institut on 23 April 2008

[14] e-mail communication between Mr. Bernt Peters, Bosch-Siemens Hausgeräte, and Otmar Deubzer, 11 August 2008

[15] NEC/Schott via e-mail, e-mail communication from Mr. Harald Schäfer and Mr. M. Gomi, NEC/Schott, with Otmar Deubzer, 10 August 2008

[16] IEC 691, International standard publication 691

[17] ERA-Report 2004, Dr. 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"

4.14 Exemption No. 9

"Hexavalent chromium as anti-corrosion of the carbon steel cooling system in absorption refrigerators"

4.14.1 Description of exemption

Chromate is currently used as a corrosion inhibitor in absorption refrigerators. These kinds of refrigerators are inter alia used in hospitals, hotels and small apartments (RoHS scope) as well as in caravans and motor homes (ELV scope). Absorption refrigerators are used in these areas of application due to the fact that they can work independently from electricity with a heat-driven technology using gas (propane / butane) or kerosene as energy source [1]. Furthermore, they have the advantage that they have no moving parts and are thus completely silent, making them further attractive for the above described uses. They mostly belong to category 1 "large household appliances" of the WEEE Directive. Some appliances like e.g. medical refrigerators and refrigerators for laboratory use belong to category 8&9 equipment [1].

Dometic – formerly Electrolux – states to be one of the main producers of absorption refrigerators in Europe[33]. Its absorption cooling units are constructed in carbon steel because of its strength as well as its good welding and cold-working properties. The refrigerant is an ammonia-water solution. The absorption cooling system is a completely closed system, which is pressurised with hydrogen gas. In order to prevent corrosion of the carbon steel cooling system sodium chromate is added to the refrigerant. This allows Dometic to produce absorption

[33] However, Dometic has less than 50% of the market of RoHS relevant applications. Several small actors from Italy, Turkey and China are present on the market.

refrigerators that can last 15 years or more: “Using chromate, a passive layer of chromium/iron oxide (Cr_2O_3 /Fe_2O_3) is formed at the steel surface and no precipitates that block the circulation are formed. Chromate is slowly consumed over lifetime.” [1]

The current exemption was already part of the original Annex to the RoHS Directive published in 2003. The use of CrVI for corrosion protection is also exempted from substance restrictions under the ELV Directive (entry no. 13 in latest amendment of Annex II ELV Directive published in Commission Decision 2008/689/EC of 1 August 2008).

According to Dometic, its annual production of absorption fridges in Europe amounts to 350.000 pieces out of which 200.000 are considered to fall under the RoHS Directive (the total RoHS relevant market is estimated at 400.000 – 500.000 units). With an average amount of 2 g CrVI per fridge, the total annual amount sums up to 400 kg of CrVI in RoHS relevant applications [2].

Dometic was the only stakeholder replying to the online stakeholder consultation34 and requests an extension of the current exemption since alternatives are said to give rise to difficult trade-offs in respect to product lifetime, product reliability and energy efficiency [1]. Its main competitor Thetford also provided some information upon request and basically supports Dometic’s position [3].

4.14.2 Justification by stakeholders

Dometic has provided supporting evidence for an extension of the exemption and justifies its request as follows:

Extensive research has been carried out at Electrolux between 1920 and 1999 as well as at Dometic between 2000 and now (Dometic claims to have about 300 test related cooling units that have been started since 2000): “Electrolux/Dometic has been conducting research into finding possible alternatives for the corrosion protection of absorption refrigerators. Not only has a significant in-house commitment been made but also Electrolux/Dometic has worked with a number of external research institutes and universities on this issue. Several long-term projects have been run with theoretical and practical studies on the corrosion process. Work has also been carried out with companies who are expert in corrosion protection where commercial inhibitors have been tested. The research has looked at alternative refrigerants, inhibitors, structural materials, surface treatment and combinations thereof.” Extensive and comprehensive documentation on these research activities has been provided as evidence [1].

The research activities of Dometic have looked at alternative refrigerants, inhibitors, structural materials, surface treatment and combinations thereof. So far only one inhibitor seems to be left over as a promising alternative [1].

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[34] Except for Emerson who did however not target exemption 9 in its contribution.

However, the following problems are still encountered with the alternative:

- Reduced life length of an alternative corrosion inhibitor

"The expected life length of an absorption refrigerator with hexavalent chromium as corrosion inhibitor is 15-20 years at continuous operation. For an absorption refrigerator with no inhibitor at all, the service life length is less then 1 year. […] The number of units using each alternative inhibitor does not yet provide sufficient statistical certainty to be able to foresee a firm service length. However, our tests of the most promising alternative inhibitor show an average indicative life length of 3-5 years. A shorter life length would result in a higher exchange frequency of products and consequently a more negative impact on the environment." [1]

- Reduced product safety

"Since the estimated life length of an absorption refrigerator with an alternative corrosion inhibitor is considerably less then one filled with hexavalent chromium, the risk that a leakage [releases of ammonia and hydrogen into the surroundings due to accelerated corrosion] would occur during active use of the absorption refrigerator is significantly higher." [1]

- Reduced product performance / lower energy efficiency

"When using an alternative corrosion inhibitor instead of hexavalent chromium, design changes in the hot areas / pump area need to be made to the cooling units of some models. This will most likely mean a loss in performance [i.e. temperature in the cooling compartment will increase by approximately 2-3°C]." The higher temperature does not allow to meet the standard requirements of EN ISO 7371 that foresee a temperature of 5°C in the fresh food compartment [2]. A performance loss could also mean an increased energy consumption by 10-15%. "However, this is not yet a statistically reliable basis for future projections and needs further validation in testing." [1]

Dometic has set up a list of technical characteristics that an absorption cooling unit inhibitor has to fulfil and their status quo with regard to research of alternatives [1]:

1. Must be compatible with the filling solution: still needs one year research to find solution.
2. Must be stable at high temperature and pH: fulfilled by alternatives.
3. Must withstand ageing and cold storage temperatures: fulfilled by alternatives.
4. Must create a protective layer to inhibit corrosion: more research with statistical relevance needed (life time issue).
5. Needs to maintain the protective layer: more research with statistical relevance needed (life time issue).

According to Dometic, accelerated life time tests are not representative since they need to be done with rising the temperature which changes other parameters leading to a possible distortion of the results [2].

Furthermore, Dometic states that the number of units that need to be tested in order to get statistical relevance are thousands and that one of the main problems is to achieve consistency of test results [2].

Dometic states that at least 10 years are needed in order to phase-out CrVI from their refrigerators and that an expiry date should be set earliest at that point of time. Furthermore it is stated that an acceptable maximum amount of CrVI would be 1.0 weight-% of CrVI based on the water part of the cooling solution [1].

With regard to substitution at application level, Dometic says that for some areas of use compressor-based alternatives are available. However, they are noisier than absorption refrigerators which may be a health concern for some consumers. On the other hand, large compressor-based refrigerators are more energy-efficient which may be an explanation why manufacturers do no investigate small-scale compressor-based refrigerators [2].

Dometic has set up a take-back scheme for commercial applications and runs a recycling scheme which assures the complete emptying of the cooling unit. Since chromate is consumed during use, nearly none is left over at point of take-back [2].

Thetford delivers arguments that go into the same direction, but did not provide any evidence or supporting documentation. Statements given are summarised as follows [3]:

Thetford is about to come to an agreement with a German researcher which has already done research on CrVI alternatives in the past. Also, its cooling unit supplier in the U.S. has done research in conjunction with a local university. However, Thetford says not to be at liberty to share results with the contractor.

Thetford feels it is currently impossible to deliver a roadmap or similar evidence showing the foreseen development of substitution efforts. It only states: “Limiting the environmental impact of our products is an important element of our philosophy, so obviously the research into possible alternatives for CrVI is important to us. We are aware of the regular revision of Annex II of the ELV, and we are also aware that the exemption for CrVI could end some time in the future. We intend to replace CrVI as a corrosion inhibitor as soon as an alternative can be found that has a significantly lower environmental impact than the current solution.”

As concerns the availability of substitutes, Thetford claims that “To-date, no other substance has been able to produce the same effect while keeping sufficient inhibitor in solution to insure long life of the refrigerator.”

4.14.3 Critical review

Evaluating the above-mentioned arguments the following can be concluded:

Comprehensive evidence was given on Dometic’s past and current commitment to investigate alternatives to CrVI. Many alternatives have been looked at such as oxidising and non-oxidising inhibitors as well as changes in material and design of the product itself. A roadmap has been provided showing that more time is needed for research. In its contribution, Thetford supports this statement.

Concerning possible disadvantages of using an alternative substance, the following can be concluded:

Reduction of lifetime: while it is true that a reduced lifetime generates negative environmental impacts (e.g. waste of resources, higher need of energy for production of more appliances, more impacts during recycling) it also has to be stated that most of the environmental impacts of an absorption refrigerator is generated through the energy consumption during use. Thus, a certain reduction in lifetime could be acceptable when using an alternative corrosion inhibitor. However, current lifetime is estimated at 15 years and lifetime with most promising inhibitor at 3-5 years, still being a rather large difference. As a conclusion it is recommended to review progress on life time issues with alternative inhibitors during the subsequent review.

Reduction of product safety: leakage is a general safety problem with absorption refrigerators. With CrVI it is less likely to occur during use phase since the chromium is consumed slowly and can last for more than 15 years. A reduction of product safety is regarded less critical if a certain reduction in lifetime is accepted and communicated to customers. Manufacturers should inform consumers that the product has a certain lifetime after which risk of leakage occurs. This aspect is however linked to an improved life length with an alternative inhibitor as stated above.

Reduction of product performance / energy efficiency: since cooling performance may decrease with an alternative inhibitor and this would lead to a higher energy need to achieve the same level of cooling down, it is indeed a negative environmental effect. Furthermore, existing standards would not be met which is clearly an argument in line with Article 5 (1) (b). However, the higher energy need has not been quantified by stakeholders and can therefore not be assessed.

From the above it can thus be concluded that currently substitution at substance-level is not practicable and that it would have negative environmental, health and safety effects.

With regard to substitution at application level it can be concluded that compressor-based refrigerators are more energy efficient than absorption refrigerators. According to Swiss studies ([4] and [5]), this difference is particularly significant for small-scale appliances. However, small-scale compressor-based refrigerators are only available for a small number of applications (starting with approximately 80 l and thus not suited as e.g. built-in minibars of approximately 40 l) and have the negative (health and environmental) effect of higher noise generation. Whether the effects due to higher noise generation outweigh the benefits of reducing energy consumption through the use of compressor-based refrigerators cannot be estimated since no reliable data is available. On the one hand the Swiss studies explicitly conclude that large energy saving potentials exist through substitution of absorption refrigerators with compressor-based ones. On the other hand this is apparently only applicable to refrigerators above minibar size. The only hindrance is noise which can be a negative effect when the refrigerator is used in small living spaces. Nevertheless, the Swiss studies state that even for compressor-based refrigerators technological improvement in this respect is feasible and also partly available on the market. Furthermore, one of the Swiss studies analysed that thermoelectric cooling (using the Peltier effect) is a viable energy-saving alternative to absorption refrigerators leading up to 30% savings [5].

As a conclusion it should be the goal to use compressor-based or thermoelectric refrigerators instead of absorption refrigerators wherever possible (e.g. through design changes in hotel rooms or similar areas of applications like putting the fridge in a small separated space). This is the case where electricity can be used as energy source for cooling (either through the electricity grid, batteries, solar energy or any other source of electricity).

In the framework of this contract it is however not possible to do a full market analysis on available low-noise energy efficient compressor-based refrigerators as well as on available low-noise and energy efficient thermoelectric refrigerators compared to absorption-based refrigerators. Furthermore, it should be noted that minimum energy efficiency requirements – applying also to absorption refrigerators – will be set under the EuP Directive thus possibly leading to a partial substitution of CrVI-using applications.

4.14.4 Recommendation

The argumentation of Dometic and Thetford in favour of an extension of the current exemption with regard to the use of CrVI in the cooling system of absorption refrigerators is well documented and sound with regard to the non-practicability of substitution at substance-level. However, substitution at application level is indeed possible in many cases and has been confirmed and recommended by independent Swiss studies. An exemption should thus only be granted for areas of application where the use of a compressor-based or thermoelectric refrigerator is not practicable and has negative impacts. Since in the framework of this study it is not possible to identify these areas of application as an exhaustive list of applications, the following new wording for exemption 9 is recommended:

Hexavalent chromium as an anti-corrosion agent of the carbon steel cooling system in absorption refrigerators up to 0,75 weight-% in the cooling solution except for applications where the use of other cooling technologies is practicable (i.e. available on the market for the specific area of application) and does not lead to negative environmental, health and/or consumer safety impacts.

Transition period and expiry date

Assuming that the amendment of the Annex in the RoHS Directive will be officially published end of 2009, new exemption 9 should come into force on 30 June 2011, allowing for a 1½ year transition period. Since research into alternatives is stated to last for 10 more years before being able to phase out CrVI, the expiry date is proposed to be set at the time of the next revision. Here again assuming an official publication of an amended RoHS Annex by end 2009, the expiry date would be four years later 31. July 2014.

Spare parts

Furthermore, a clause should be added to the new exemption 9 explicitly mentioning that spare parts for what used to be applications covered by exemption 9 are exempted from substance use restrictions.

Category 8&9

Since the technological principle and the production lines are the same, an inclusion of category 8&9 into the scope of the RoHS Directive would not have any effect on the manufacturers.

Alignment RoHS & ELV

In addition, it is recommended to align with exemption 13, Annex II ELV Directive. Since the production lines of manufacturers are identical for RoHS applications (be it category 1 or 8&9) and ELV applications, a phase-out of CrVI in the cooling unit will be either feasible for all areas at the same time or for none. Therefore, there should be a common exemption for both ELV and RoHS with the same expiry date, the same spare parts provision and the same review cycle. The above proposed new wording for exemption 9 will only have an impact on promotion of substitution if it is also taken over into Annex II ELV Directive.

4.14.5 References

[1] Dometic stakeholder contribution. exe. 9;” Exemption-9_Dometic_31_March_2008.pdf” 31 March 2008

[2] Discussion at stakeholder meeting between Dometic and Öko-Institut; Freiburg, 4 July 2008

[3] Thetford Stakeholder comment upon request by Öko-Institut; 25 July 2008

[4] Swiss federal Agency for economic activity: Kühlschränke für Hotelzimmer und Studios, 1992

[5] Swiss federal Agency for economic activity: Energieeffiziente Hotel-Minibar; 2004

4.15 Exemption No. 9a

“DecaBDE in polymeric applications”

The European Court of Justice (ECJ) has on 1 April 2008 issued a judgement which rules that from 30 June 2008 onwards DecaBDE shall be banned in all applications falling under the scope of RoHS. The European Commission has accepted the ECJ ruling meaning that the exemption will be deleted from the Annex.

A summary of the stakeholder contributions submitted for Exemption 9(a) before the Court's judgement is presented below:

Industry stakeholder argue that the EU risk assessment report on DecaBDE (EU RAR 2002, 2004) has concluded that there is no significant environmental, health or consumer safety risk and that no additional risk reduction measures are necessary beyond those already being applied[35].

As outlined in Chapter 3, the European Court of Justice (ECJ) had issued a judgement on 1 April 2008 which rules that from 30 June 2008 onwards DecaBDE shall be banned in all applications falling under the scope of RoHS. The European Commission has accepted the ECJ ruling meaning that the exemption is to be deleted from the Annex. A discussion on technical and scientific pros and cons of a possible exemption was thus not necessary.

Instead, the contractor was requested to prepare a summary on the collected stakeholder information for the Commission. This summary is presented in the following:

DecaBDE has intensively been investigated in more than 10 years of research so that for this substance more scientific data are available than for any other alternative flame retardant. In addition, industry claims that a Voluntary Emissions Control Action Program (VECAP) was initiated in 2004 to apply the best practices when handling DecaBDE both at manufacturing sites and on the supply chain. The aim of the program is to reduce emissions of DecaBDE. Overall, DecaBDE is one of the best investigated and controlled substances through the supply chain owing to the intensive risk assessment and ongoing monitoring and emission control programs.

Stakeholders further claim that with regard to its technical performance, DecaBDE enables a wide variety of materials to meet high fire safety standards and that it thus has a positive impact on consumer safety.

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[35] On 29 May 2008, the Commission published the results of the risk evaluation of bis(pentabromophenyl)ether (DecaBDE) in the Official Journal of the European Union (OJ C 131, 29.5.2008, p. 7–12). The conclusion of the assessment of the risks to workers, to humans exposed via the environment and to aquatic & terrestrial ecosystems is that there is a need for further information and/or testing.

Although industry admits that alternatives to DecaBDE exist, all stakeholders stress that none of the alternatives has gone through a risk assessment as extensive as that for DecaBDE. The main argument used against alternatives is that they do not have the same level of scientific data regarding their health and environmental impacts. Therefore, stakeholders conclude that it is not possible at this time to determine with any certainty if the negative environmental, health and/or consumer safety impacts caused by substitution are likely to outweigh the environmental, health and/or consumer benefits.

Table 9 gives an overview on the main stakeholder contributions concerning the retention of the exemption of DecaBDE in polymeric applications.

According to the RoHS Directive, the use of polybrominated diphenyl ethers (PBDE) is prohibited in electrical and electronic equipment. DecaBDE was exempted from the requirements of Article 4(1) of Directive 2002/95/EC until 30 June 2008. The justification of the exemption, published in Commission Decision 2005/717/EC (13 October 2007), reads as follows:

“(2) Certain materials and components containing lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) should be exempt from the prohibition, since the elimination or substitution of these hazardous substances in those specific materials and components is still impracticable.

(3) Since the risk assessment of DecaBDE, under Council Regulation (EEC) No 793/93 of 23 March 1993 on the evaluation and control of the risks of existing substances, has concluded that there is at present no need for measures to reduce the risks for consumers beyond those which are being applied already, but additional studies are required under the risk assessment, DecaBDE can be exempted until further notice from the requirements of Article 4(1) of Directive 2002/95/EC. Should new evidence lead to a different conclusion of the risk assessment, this decision would be re-examined and amended, if appropriate. In parallel industry is implementing a voluntary emissions reduction programme.”

The European Court of Justice (ECJ) annulled the DecaBDE exemption in its judgement dated 1 April 2008. According to the ECJ, the ban on the use of substances in electrical and electronic equipment covered by the RoHS Directive may only be lifted if no viable technical alternatives exists or would otherwise have an even more harmful impact on the environment and health than the substance whose use is banned. However, neither the possibility of substituting DecaBDE nor the possible effects of substitution had been considered by the EU Commission when adopting the exemption for DecaBDE.

ECJ concludes that "in adopting Decision 2005/717/EC as regards the exemption of DecaBDE, the Commission infringed Article 5(1) of Directive 2002/95. It follows that point 2 of the Annex to Decision 2005/717/EC must be annulled"[36].

The ban on the use of DecaBDE in new EEE became effective on 1 July 2008.

The Danish EPA performed a survey to identify and describe suitable alternatives to the brominated flame retardant DecaBDE and subsequently initiated a health and environmental assessment of selected alternatives to DecaBDE as proposed by the survey (EPA Denmark, 2007). The study did not develop a full evaluation of to what extent negative environmental or health impacts caused by substitution are likely to outweigh the human and environmental benefits of the substitution, but identified the existence of flame retarding alternatives to DecaBDE with less or equal environmental and health impacts.

JRC-IHCP-ECB prepared a report on "Alternatives to DecaBDE (deca bromodiphenyl ether) used in polymeric applications in electrical and electronic equipment" (EEE) commissioned by Directorate General Environment (DG ENV) (ECB, 2007). In this study, the JRC-IHCP-ECB has reviewed the production processes of DecaBDE and explored the availability of potential DecaBDE alternatives used in polymeric applications for EEE. The report concludes that substitutes do exist on the market for DecaBDE for the proposed applications and that many large electronic manufacturers claim to have moved to bromine-free alternatives. In addition literature data suggest that potential adverse environmental and human health effects of at least some substitutes may be minimal. However key data and information gaps in comprehensive risk assessments and hazard classification still exist, as well as uncertainties related to the potential impacts of degradation products of both DecaBDE and its substitutes.

[36] Point 2 to of the Annex to Decision 2005/717/EC: The following point 9a is added: '9a. DecaBDE in polymeric applications;'

Table 9 Stakeholder input on Exemption 9a: DecaBDE in polymeric applications

Arguments supporting continuation of exemption	Stakeholder
• EU RAR has concluded that there is no significant environmental, health or consumer safety risk and that no additional risk reduction measures are necessary beyond those already being applied. EBFRIP argues that on that basis there is not scientific justification for asking for an elimination of the use of DecaBDE • Industry is working with the EU authorities to monitor regularly DecaBDE levels in the environment and to control DecaBDE's industrial emissions in Europe via VECAP[37]: VECAP was initiated in 2004 to apply the best practices when handling DecaBDE both at manufacturing sites and on the supply chain. In the UK where the process has been operational since 2004, the effectiveness of VECAP can be demonstrated by year-on-year reductions in emissions. • DecaBDE has a positive impact on consumer safety as it enables a wide variety of materials to meet high fire safety standards • DecaBDE is believed to be the most effective flame retardant (FR) available in a wide range of different polymeric applications as it provides the right ignition resistance characteristics with changing the polymer quality and integrity • Alternatives to DecaBDE do not have the same level of scientific data regarding their health and environmental impacts: Alternatives exist, however, none of the alternatives has gone through a RA as extensive as that for DecaBDE. Some of the alternatives may pose unacceptable risks to the environment and human health by effects that are not yet known. For potential alternatives key data and information gaps in comprehensive risk assessments and hazard classification still exist and it is not possible at this time to determine with any certainty 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. • Effective flame active performance is only provided by halogen based FR normally in combination with antimony trioxide. Chlorinated or brominated FR are therefore the only other options which could potentially be considered as realistic substitutes for these applications. • Certain plastics with DecaBDE can be recycled because of their comparative stability in the recycling process. Plastics containing DecaBDE are superior to other plastics in terms of recyclability and be recycled five times. These plastics have also demonstrated in tests good energy recovery and are fully compatible with metal recycling. Summary: DecaBDE is a substance with no significant risk identified and is now one of the best controlled substances through the manufacturing supply chain than any other chemical used for EEE owing to its monitoring and emission control programs.	EBFRIP: European Brominated Flame Retardant Industry Panel
• Provides high fire safety standards (UL94) in a wide variety of products • Positive impact on consumer safety • Very good examined substances with a high level of scientific data on health and environmental behaviour available e.g. EU RAR; VECAP • Chemical and thermal stability of DecaBDE is not met by any other brominated flame retardants (BFR) • DecaBDE itself does not show any negative effects on health	Argus Additive Plastics GmbH

37 VECAP: Voluntary Emissions Control Action Program (emission reduction programme for DecaBDE through the supply chain)

Arguments supporting continuation of exemption	Stakeholder
• DecaBDE is used in custom cables which have a unique nature; removal of exemption would drive design changes both the individual components and to applications where the component is used • For alternative flame retardants less risk assessment data are available • Based on the outcome of EU RAR, DecaBDE does not meet criteria for restriction under RoHS	Test & Measurement Coalition
• EU RAR has concluded that there is no significant environmental, health or consumer safety risk	Electric Cable Compounds, Inc.
• EU RAR has concluded that there is no significant risk for the environment or human health and that therefore no additional risk reduction measures necessary. • Due to monitoring programs DecaBDE is far better controlled than any other alternative	State of Israel: Ministry of Industry, Trade & Labor
• EU RAR has concluded that there is no significant environmental, health or consumer safety risk • DecaBDE is FR with the most scientific data available showing it is safe while alternate FR are unproven • Industry is working with the EU authorities to monitor regularly DecaBDE levels in the environment an to control DecaBDE's industrial emissions in Europe via VECAP: • Positive impact on consumer safety as it enables a wide variety of polymeric materials to meet high fire safety standards • Alternatives are not as efficient and effective as FR and do not have the same level of scientific data regarding their health and environmental impact	RTP Company; INEOS NOVA; Campine NV Belgium

4.15.1 References

[1] EPA Denmark (Danish Environmental Protection Agency) (2007): Health and environmental assessment of alternatives to Deca-BDE in electrical and electronic equipment.
http://www.mst.dk/Udgivelser/Publications/2007/01/978-87-7052-351-6.htm

[2] ECB (European Chemicals Bureau) (2007): Review on production processes of decabromodiphenyl ether (DecaBDE) used in polymeric applications in electrical and electronic equipment, and assessment of the availability of potential alternatives to DecaBDE.
http://ecb.jrc.it/documents/Existing-Chemicals/Review_on_production_process_of_decaBDE.pdf

[3] EU RAR (2002): EU Risk Assessment Report bis(pentabromophenyl) ether, Volume 17; EUR 20402 EN; Final Report 2002

[4] EU RAR (2004): Update of the risk assessment of bis(pentabromophenyl) ether (decabromodiphenyl ether); Final Environmental Draft of May 2004

4.16 Exemption No. 9b

“Lead in lead-bronze bearing shells and bushes”

4.16.1 Description of exemption

Lead-bearing shells and bushes are currently exempted both, form the requirements of the RoHS as well as of the ELV Directive (entry no. 4 Annex II); however the wording differs slightly. Therefore during the last review of the Annex of the ELV Directive it was recommended to take care of a harmonisation of the wording reflecting similar or identical technical specifications [2].

Referring to automotive applications Sander et al. concluded in 2000, that applicability of lead-free solutions for bearing shells and similar anti-frictional parts could only be proven in some application fields. Furthermore, it was pointed out, that when substitution of lead by other alloying elements was considered, the main criteria were functional requirements during the use of the product (emergency lubrication) rather than costs [1].

As result of the review of the ELV Directive it was concluded that there is currently a dynamic phasing out of lead-containing bearing shells and bushes leading to the recommendation that only in very specific cases a prolongation would be necessary. The resulting proposal for a revised wording was as follows [2]: “Lead in Bearing Shells und Bushes for engines, transmissions and A/C compressors: 01.07.2011 [Review date: 07/2009]”

4.16.2 Justification by stakeholders

In the current review of the RoHS exemptions two contributions in relation to lead in lead-bronze bearing shells and bushes were received:

- In their joint industry contribution COCIR, Eucomed and EDMA argued for a continuation of the exemption with reference to the specific requirements to medical devices. The current exemption would be needed for table elevation mechanics in XRay, CT, MR and PET [3].
- Emerson Climate Technologies, Inc. applied for a continuation of the current exemption, too. While the company would be committed to converting all its bearings to lead-free compositions, there would be specific products where major obstacles from satisfying the October 2009 deadline occurred. Key reasons were the long qualification time required to assure reliability and durability and the absence of an adequate lead-free candidate for several applications [4]. The following products were specified concretely in this context:
  - “Stationary Residential Air Conditioning and Commercial Refrigeration: Environmental cooling or heating systems for households (not window units) are composed

of a condensing unit on the outside of the building and an evaporator inside the house. Heat pumps are included in this category.

– Stationary Commercial Air Conditioning: Same general configuration as above only applied to hospitals, businesses, factories, offices etc.. The units are also typically larger than residential.

– Stationary Small-Unit Refrigeration: Low temperature cooling or heating for commercial applications. Examples are: Dental air compressors, Commercial display cabinet freezers, ice machines, ultra-low temperature medical and research preservation (blood storage etc.), body temperature control for medical applications, cooling for medical examination equipment such as MRI, computer cooling, semiconductor production and in food preservation.

– Stationary Large-Unit Refrigeration: Same as above only larger systems. Examples are reach-in or walk-in grocery store refrigerated boxes for food preservation and medical blood storage."

- On request Emerson provided additional data describing the state of substitution process. The current state reflecting the requirements and the results of candidates for substitution is summarised as follows: [8]

	Candidates										
Requirement	A	B	C	D	E	F	G	H	I	J	K
Chemical Resistance	1	1	1	1	UE	2	2	UE	2	1	UE
Compatibility (scuffing resistance with steel)	1	1	1	1	1	2	2	UE	2	2	UE
Conformability	1	2	1	1	1	1	2	UE	2	2	UE
Embedability	1	2	1	1	1	1	2	UE	2	2	UE
Machinability	3	3	3	3	3	2	2	UE	2	1	UE
Friction Mitigation In Refrigerant Diluted Oil	1	UE	UE	UE	UE	UE	UE	UE	UE	UE	UE
Cavitation Resistance	2	1	2	UE	UE	1	1	UE	1	1	UE
Long-term wear resistance	2	1	2	UE	UE	1	1	UE	1	UE	UE
Contact Fatigue Resistance	2	1	2	UE	UE	2	1	UE	1	1	UE

UE: Under Examination
1: Acceptable Results
2: Marginal Results at high loading
3: Unacceptable Results

EMERSON

- In this contribution, the key technical reason to prolong the exemption is described as follows: liquid refrigerant is a strong solvent that can remove vital compressor oil from the bearings causing inadequate lubrication and increased friction. Yet, as friction increases, the efficiency diminishes and premature failure may ensue. In addition, field repairs due to bearing failures may result in refrigerant leakage. [8]
- This position is supported by another manufacturer of commercial compressors; in order to complete the qualification of RoHS compliant bearings in their compressors a 2 years prolongation of the exemption would be needed. [7]
- Another leading manufacturer claimed the RoHS conformity of comparable products already in 2006 [6]. However, although being requested several times this company could not provide more details on this issue.
- The Swedish Ministry of the Environment [5] indicates that according to a Swedish company there were lead-free alternatives to leaded copper alloys available on the market. The company stated that the alternative copper alloyed material would be both easy to machine and would not carry the brittleness normally associated with Bismuth or Bismuth-based bronze substitutes. Through the use of the alternative alloys it would be possible to replace lead in most copper alloys, not only in bronze alloys.

4.16.3 Critical review and Recommendation

Basically it has to be taken into account that in a lot of bearing applications lead could be substituted successfully. Therefore the question arises whether the specific requirements of the products mentioned in the contribution described above lead to the situation that in these cases substitution fails.

Considering the products appointed by Emerson it must be taken into account that there are specific conditions obviously leading to the situation, that substitution is still ongoing. Taking this into account the contractor recommends to continue the existing exemption, but to narrow the scope specifically to those applications, where refrigerants are used:

“Lead in bearing shells and bushes for refrigerant-containing compressors for HVACR applications, with expiry date of 31. July 2014.”

4.16.4 References

[1] Sander, J. et al.; Heavy Metals in Vehicles (Final Report); Ökopol – Institut für Ökologie und Politik GmbH, Hamburg, Germany; Report compiled for the Directorate General Environment, Nuclear Safety and Civil Protection of the Commission of the European Communities Contract No B4-3040/2000/300649/MAR/E.3. Hamburg 2000

[2] Lohse et al.; Adaptation to Scientific and Technical Progress of Annex II Directive 2000/53/EC. Contract N°07010401/2007/470145/ATA/G4. Freiburg 2008

[3] Joint Industry contribution to the ÖKO Institute's consultation on the Actual Exemptions from the RoHS Directive. Brussels, April 1, 2008

[4] Emerson Climate Technologies, Inc.; Stakeholder Consultation On Adaptation To Scientific And Technical Progress Under Directive 2002/95/Ec 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 Exemption 9b (Lead In Lead-Bronze Bearing Shells And Bushes). 20 March 2008

[5] Regeringskansliet, Ministry of the Environment; Memorandum to Stakeholder consultation on RoHS exemptions. 1st April 2008

[6] Mitsubishi Electric Europe B.V.; e-mail to Öko-Institut, 30/Oct/2008

[7] Danfoss Commercial Compressors; e-mail to Öko-Institut, 28/Nov/2008

[8] Emerson Climate Technologies, Inc.; e-mail to Öko-Institut, 27/Nov/2008

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]

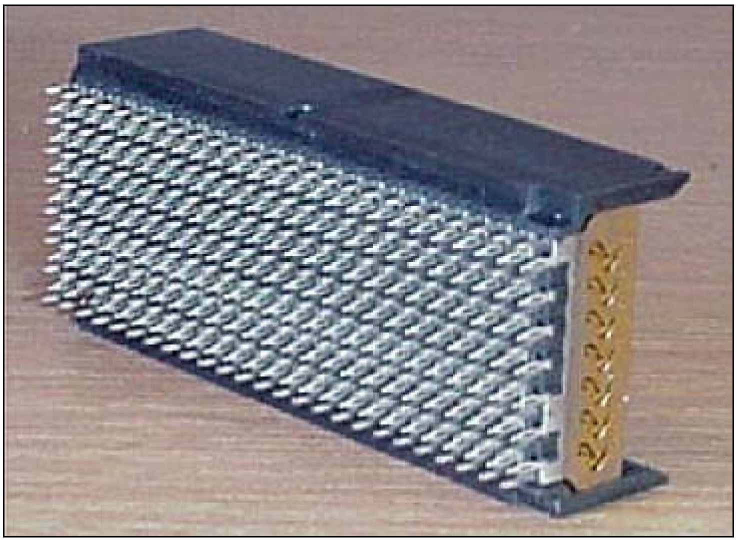


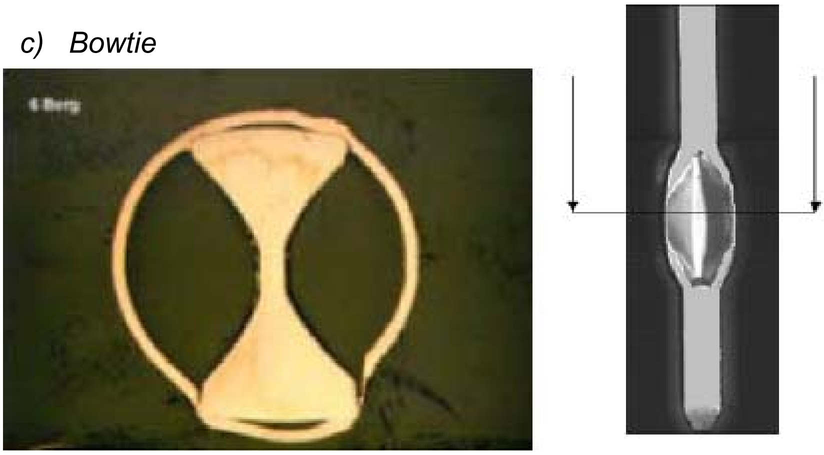
Figure 17 Example of a compliant pin connector system [1]

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

a) *eye of needle*

b) C-press

c) Bowtie



d) Action pin

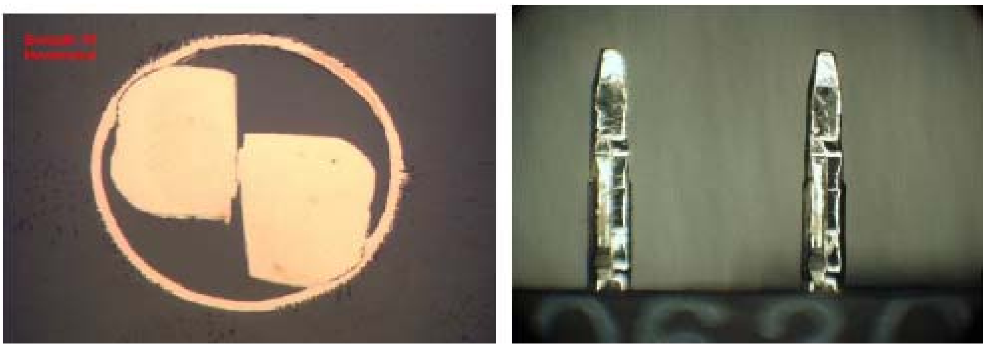


Figure 18 Types of compliant pin connector systems

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

Technical background

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 143). 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]

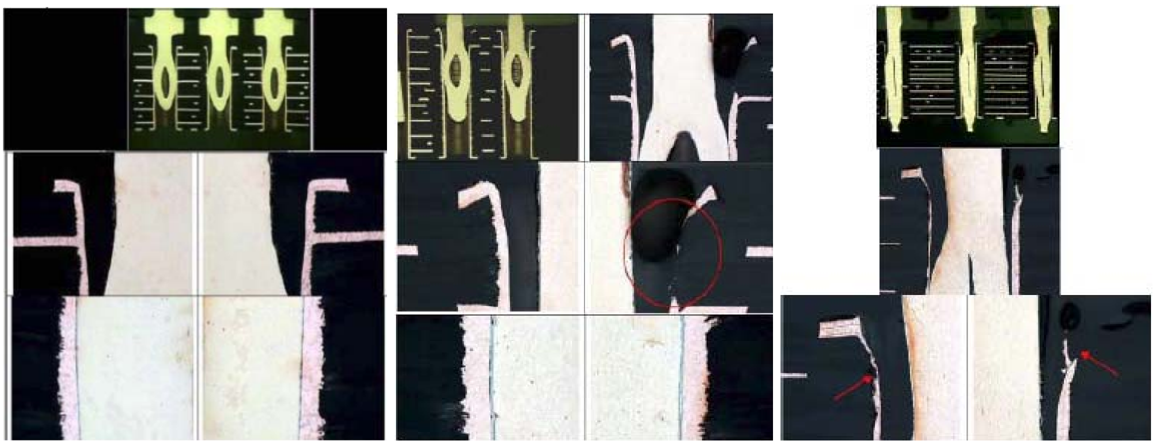


Figure 19 Cross sections of acceptable (left) and unacceptable insertion results after one (middle) and two (right) reworks

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.

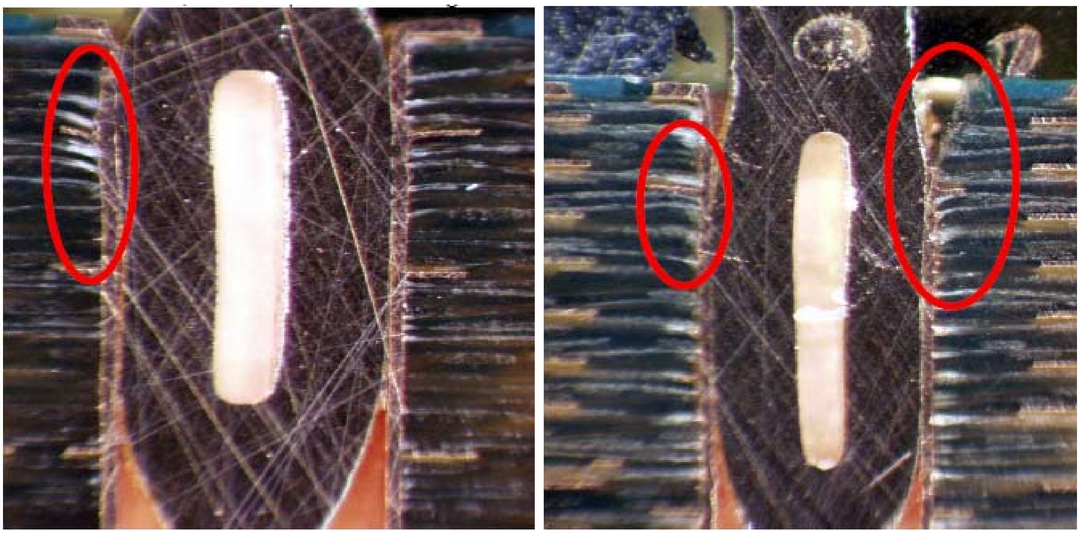


Figure 20 Cross sections of acceptable (left) and unacceptable insertion results with gold plated pins after initial insertion (left) and after two reworks (right)

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".

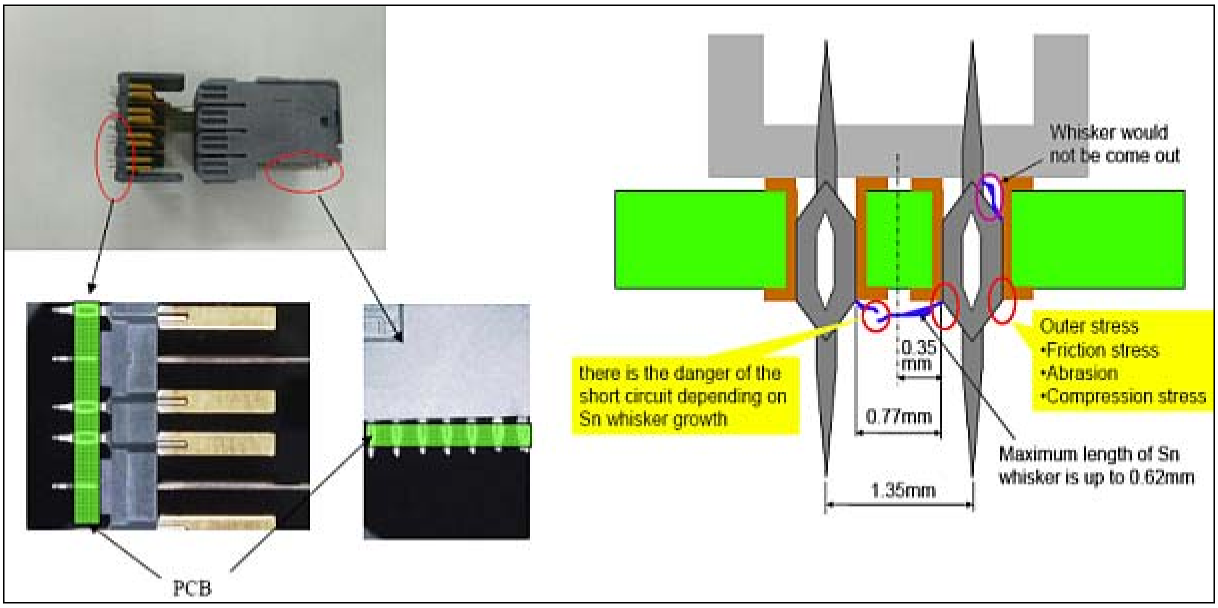


Figure 21 Dimensions of pin connector systems in high density applications [2]

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.

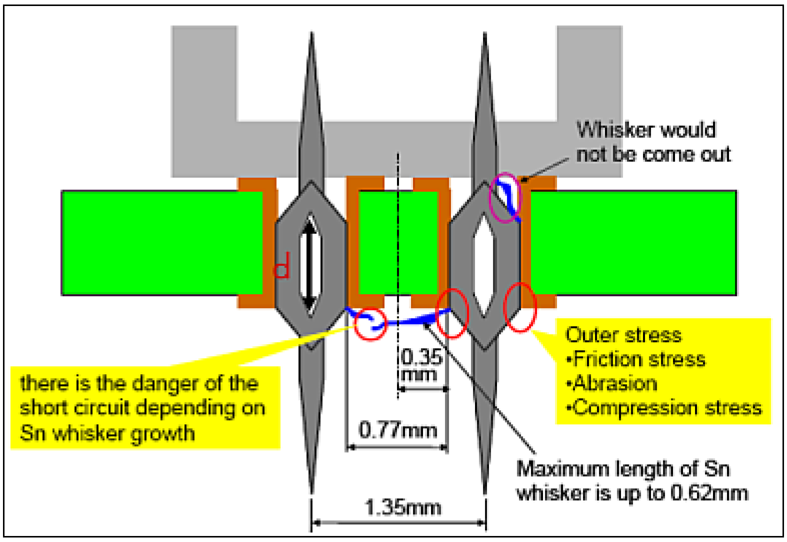


Figure 22 Consultants' proposal to change connector size preventing whisker short circuits

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
"Exemption_11_EICTA_and-others_1_April_2008.pdf"

[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

4.18 Exemption No. 12

“Lead as a coating material for the thermal conduction module c-ring”

This exemption was evaluated 2004 by ERA [1]. IBM, who uses this exemption in high end computers, had explained in 2004 that it wanted to replace those computers, which use the lead coated C-ring by new series computers without leaded C-ring some time in 2009. IBM therefore requested the exemption until 2010 [1]. The exemption was granted without an expiry date.

4.18.1 Description of exemption

The most important part of an IBM main-frame computer is an array of high performance microprocessor chips and memory chips which are mounted on a glass-ceramic substrate. To ensure the fastest signal transmission between the central processing units (CPU) and the associated memory, these devices are mounted as bare chips as close together as possible in an array with an area of 150 mm square.

The processor and memory chips generate a significant amount of heat, typically 1.4 kW, and therefore must be cooled efficiently. The computer otherwise cease to function if it overheated. The cooling is achieved by the Thermal Conduction Module (TCM). Cooling of the bare silicon chips is achieved by conduction of heat through a thermally conducting paste into a liquid cooled copper “hat”. As the silicon chips are not encapsulated, the module as a whole has to be hermetically sealed to protect the active surface of the chips, to ensure that the grease does not dry out and to prevent oxidation of the bumps, silicon and chip circuitry. This is achieved with a high vacuum, which is maintained by the lead coated C-ring seal.

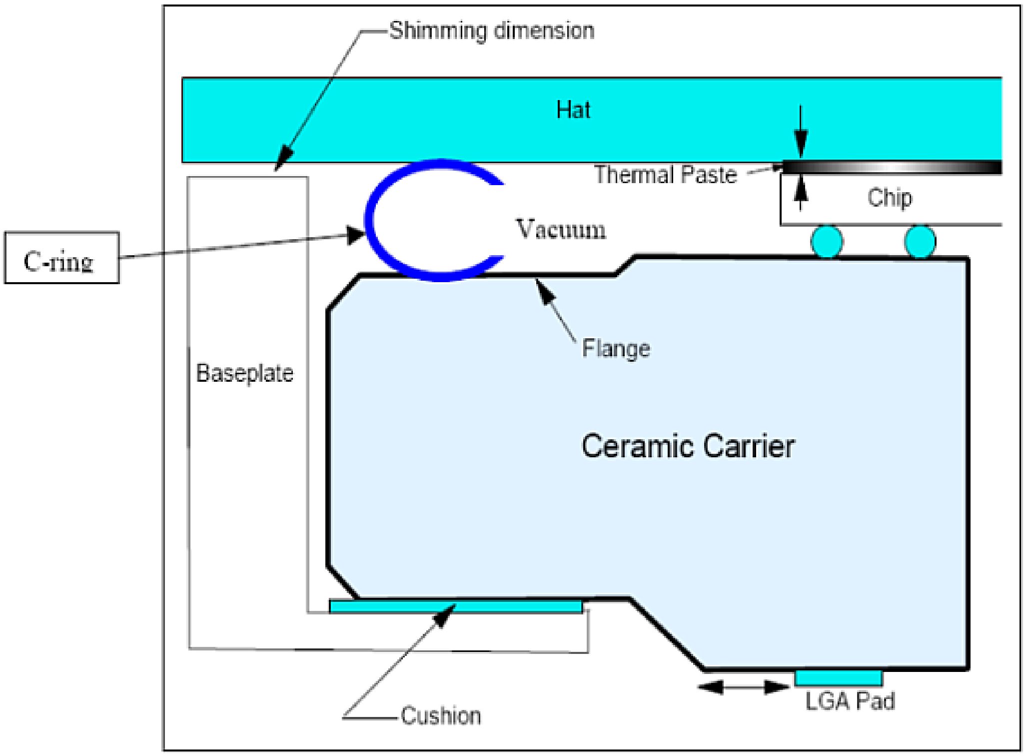


Figure 23 Cross section of a thermal conduction module with C-ring [1]

The very complex high performance chips cannot be adequately tested until they have been mounted in the module. On most of the assembled modules, a small number of defect chips need to be replaced. This means that the modules have to be dismantled, sometimes several times. The C-ring seal is inserted between the upper and lower plates of the modules to enable a demountable but sealed system. [1]

The lead coating on the C-ring provides a hermetic seal by filling small surface irregularities in the glass ceramic substrate, copper hat or C-ring body and facilitates movement during thermal excursions incident to TCM operation by lubricating the C-ring to hat and C-ring to ceramic substrate interfaces. [1]

The C-ring coating is 100% lead and comprises a maximum of 3 grams. Lead constitutes approximately 37% of the weight of the C-ring, and approximately 0.1% of the total TCM weight. It is currently estimated that less than 2.0 kilograms of Pb per annum will be shipped to EU countries as a C-ring constituent. [2]

4.18.2 Justification by stakeholders

EICTA [2] explains that, as mentioned in the 2004 evaluation [1], the IBM strategy in 2004 was to design future high end modules with fewer chips. This would result in fewer risk sites, that would obviate the need of rework. IBM's C-ring technology would thus have become dispensable in future applications.

The ever-growing demand for more intense computing power has mitigated that strategy. While fewer chips are indeed required, their size and complexity have resulted in more rather than fewer risk sites. The C-ring technology could thus not be phased out and is still required. [2] IBM hence had to change its strategy and had to stick to the C-ring technology. Instead of eliminating the C-ring technology, it had to be changed over to lead-free C-rings. After more than four years of research and development efforts, tin, as a Pb-free alternate material, has been developed for future applications. [2]

EICTA states that a lead-free substitute using tin was qualified and as of 26 February 2008 implemented in IBM's entire product line using the C-ring technology. For all server products going forward in time, Pb-free C-ring technology is "plan of record." No future offerings are planned with Pb-containing C-rings.

Nevertheless, EICTA [2] claims exemption 12 still to be necessary for existing products. The qualification of the lead-free C-ring technology in February 2008 was somewhat later than originally anticipated in 2004, so this innovation was not available in time for the products that are now in the market place. EICTA [3] says that there are server products that have been on the market for a number of years (legacy product) that still utilize SnPb C□rings.

The time needed to develop, qualify and implement Pb-free C-rings in these products had been projected not to be complete until 2012. As progress has been made, that projection is now revised to 31 Dec 2011, which EICTA [3] proposes as the expiry date for this exemption.

Because of markedly different performance requirements, each generation of high end computer equipment is a unique design. In order to qualify a Pb-free C-ring for a new application, it must undergo extensive reliability testing that takes years to complete. After the C-ring has been certified to be reliable in a particular TCM, then the manufacturing facilities for that TCM must be converted to the new component. Taking these factors together, an estimated transition period cannot be less than three years resulting in an expiry date for the exemption in the end of 2011. [2], [3]

EICTA [3] explains that a new product offering is not a direct replacement for a legacy product. The new product has different features and performance characteristics than are included in the legacy product. Therefore, each product fulfils a different need, and both products are sold concurrently for some period of time.

In addition, some sales contracts contain explicit obligations that specific products will continue to be marketed for a definite period of time to allow customers to increase the capacity of their server installations using the same equipment. EICTA [3] demands that those contractual obligations must be honoured. Due to the time constraints allowed for this response, EICTA [3] did not have the details of the contractual requirements for the system in question, but based on standard practice EICTA estimates that it may be necessary to offer this system at a minimum through the end of 2010. Present plans are to market legacy server products into 2012. [3]

EICTA [2] requests that repair and / or upgrade of TCM's high end servers manufactured under this exemption since 1 July 2006 are and will continue to be exempted from RoHS requirements for the useful life of the products. This is necessary because all repair / replacement TCM's have been or will have been manufactured before the product is declared "end of life," and the production facilities are / will be dismantled, rendering it impossible to retrofit existing repair / replacement TCM's with a Pb-free alternative. [2]

4.18.3 Critical review

In February 2008, IBM had qualified lead-free C-rings for thermal conduction modules. On the component level, the substitution of lead in thermal conduction C-rings hence is scientifically and technically practicable.

All of IBM's new generation servers using C-ring thermal conduction modules are equipped with this lead-free technology, and the exemption is no longer required for these products. The stakeholders, however, claim that a new product offering is not a direct replacement for a legacy product. As each product fulfils a different need, both products are sold concurrently for some time. In addition, according to the stakeholders, some sales contracts contain explicit obligations that specific products will continue to be marketed for a definite period of time to allow customers to increase the capacity of their server installations using the same equipment. The stakeholders demand that those contractual obligations must be honoured. They ask the exemption to be continued until 31 December 2011 at least.

The consultants assume a different point of view to maintain consistence with the requirements of Art. 5 (1) (b) and with the previous reviews of exemption requests. New models of products may be different in performance, but, as high end servers are designed to serve specific needs, the new models must be assumed to serve those needs as well as a minimum requirement. Otherwise, they would not be new models, but a completely new product that does not have a predecessor and serves a completely new and different market. The exemption was granted in 2006 for the use of lead in the C-rings of thermal conduction modules. The exemption therefore was and is restricted to the component level. If lead can be replaced on this component level and the component be qualified for use, the exemption is no longer justified, the more if at the same time products (not components only) are on the market that do not depend on this exemption.

The reviewers therefore do not see how the sales of older models using leaded C-rings could be justified in line with Art. 5 (1) (b) if at the same time new models with lead-containing C-rings are on the market proving that the substitution of lead in this application is technically practicable.

The stakeholders claim that sales contracts contain explicit obligations that specific products will continue to be marketed for a definite period of time to allow customers to increase the capacity of their server installations using the same equipment. EICTA [3] demands that those contractual obligations must be honoured.

Art. 5 (1) (b) would allow an exemption, if the negative health and/or consumer safety impacts caused by substitution are likely to outweigh the health and/or consumer safety benefits thereof. There is, however, no technical evidence that the sales of lead-containing C-ring servers is necessary in order not to jeopardize consumer health and safety to a degree that would outweigh the benefits of the lead-substitution. Legally, contractual obligations to deliver identical products for a period of time may be a serious issue for manufacturers, but an exemption based on such an argument would not be in line with Art. 5 (1) (b). Further on, manufacturers can be expected to take into account the temporary character of exemptions and thus not go into contractual obligations which are not sure to be accomplishable.

Given the overall situation, the consultants do not see the continuation of exemption 12 in line with the requirements of Art. 5 (1) (b). The substitution of lead in thermal conduction module C-rings is technically practicable.

4.18.4 Recommendation

The consultants recommend repealing exemption 12. The substitution of lead in thermal conduction module C-rings is technically practicable. The continuation of the exemption would therefore not be in line with Art. 5 (1) (b).

The exemption was originally recommended to expire in the end of 2009. It was granted without an expiry date. Assuming that the Annex of the RoHS Directive will be officially amended until the end of 2009, it is recommended that exemption 12 expires on 30 June 2010. This leaves time after the official amendment of the Annex in the RoHS Directive to notify customers of the official cancellation of the exemption and to prepare for it.

The repair of equipment put on the market with leaded C-rings prior to the expiry of the exemption should be allowed beyond this date, following the principle in Art. 2 (3) in the RoHS Directive.

The consultants therefore propose the following wording for the exemption:

Lead as a coating material for the thermal conduction module C-ring 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.

4.18.5 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] EICTA et al. online stakeholder document
"Exemption_12_EICTA_and-others_1_April_2008.pdf"

[3] EICTA stakeholder document "EICTA reply to questions on ex-12 21-10-08.pdf"

4.19 Exemption No. 13

“Lead and cadmium in optical and filter glass”

4.19.1 Description of exemption

In an earlier report on technical adaptation Goodman et al. came to the following conclusions [1]:

- “Most optical glass currently used in electrical equipment is now lead-free but there are certain specific applications where a combination of properties is required and these can be achieved only with lead.”
- However, “in a few specific applications, no alternative matches all of the characteristics. Some examples of applications for optical glass which contain lead include:
  - There are no alternatives to lead optical glass for projectors (described below)
  - Certain types of lenses such as those used in surveying equipment and certain professional;
  - camera lenses;
  - Some types of gradient index lens (e.g. Selfoc);
  - Micro-lithography equipment;
  - Certain types of high quality printers;
  - Other applications currently outside of the scope of the RoHS Directive, i.e. medical devices;
  - and Monitoring and control instruments.”

To clarify the scope, Goodman et al. proposed in this case a guideline as follows [1]: “Optical components used in electrical equipment such as glass lenses, optical filters and prisms where no lead-free alternative is suitable. Lead in the glass of electronic components is not included in this exemption as this is covered by item 5 of the Annex of the RoHS Directive.”

In relation to applications of categories 8 and 9 Goodman summarised the current use of lead in optical glass as follows [4]:

- Reason for the use of lead: “Most optical glass currently used in electrical equipment is now lead-free but there are certain specific applications where a combination of properties are required and these can be achieved only with lead.”
- Availability of substitutes for lead: “Most optical glass currently used in electrical equipment is now lead-free but there are certain specific applications where a combination of properties are required and these can be achieved only with lead.”

Based on data provided by Schott as the last optical lead glass producer outside China the annual amount of lead glass is presented as follows: [11]

Year	Lead glass produces by Schott [tons]	Lead equivalent [tons]
2005	440	270
2006	180	100
2007	240	140

Today, lead glass corresponds to 1,0–2,4% of total production; in contrast in 1996 the percentage had been more than 30%. The total amount of Cd-containing glass is estimated as 56 tons in 2007.

Concerning the substitution progress, Spectaris and Schott provided the following information:

- Consumer optics oriented companies replaced all their lead glass types by lead, arsenic-free glass types. New developed glass types since then are all lead, arsenic free.
- Schott replaced 66 glass types but maintained about 25 glass types due to inquiries from high end optics.

4.19.2 Justification by stakeholders

During this review, several contributions were provided:

- In their joint industry contribution COCIR, Eucomed and EDMA argued, that lead in glass would be essential for top optical performance, being especially important for devices that use very small lenses like endoscopes [2]. Furthermore medical imaging would require very good colour reproduction e.g. for identification of cancer tissues. Without cadmium in filter glass sensitive biological samples would not be protected from UV-radiation, thus enabling a sharp cut-off edge of certain spectral parts.
- Referring to a ceramic colour standard used to calibrate and check measurement performance of spectrophotometers and optical devices, CERAM Technology Ltd. explained that the steep reflectance slopes required cannot be achieved without Lead and Cadmium. In addition the alternatives often would have complex reflectance curves which make results from such standards hard to interpret in terms of instrument performance [3].
- In a letter for SPECTARIS Prof. Tünnermann points out that if a broad spectral transmission from the ultraviolet to the near infrared spectral region is needed, dense flint glasses with lead-doping as high-index material would be indispensable. Even in applications where no specific requirements concerning the uv-transmission are existing lead-free optical systems would require a larger number of optical elements compared to systems based on high-index flint glasses. Consequently lead-free optical systems would require more basis raw material. [5]

- In their joint contribution several European optical stakeholders provided a detailed overview about typical applications of lead containing optical glasses and cadmium containing filter glasses [6]. Furthermore the technical functionality of lead containing optical glasses (colour correction, transmission in the UV spectral region) as well as of cadmium containing glasses is described in depth.
- Further comprehensive contributions were received from the Test&Measurement Coalition [7], JBCE [8], EICTA and AeA [9], Schott [10] and Zeiss [11].

4.19.3 Critical review and recommendation

Data and information provided by various stakeholders give evidence that there are some applications where the use of lead and/or cadmium in optical glass will be necessary, as there are no viable substitutes. However, the wording of the current exemption was expected to be too wide, why a discussion was held with stakeholders how to narrow the scope. Both, a more precise wording based on specific applications as well as a wording reflecting the specific function of lead or cadmium respectively were discussed. Although stakeholder could provide an enumeration and list of application examples, this list would be by no means fully exhaustive, because applications which make use of these glasses would be possibly several hundreds in number.

Against this background we recommend to keep the material specific wording, but to re-word the existing exemption into two parts reflecting the fact, that cadmium is only in use in filter glasses:

- *(13a) Lead in white glasses used for optical applications.*
- *(13b) Cadmium and lead in filter glasses and glasses used for reflectance standards.*

For both parts, 31 July 2014 is proposed as expiry date.

4.19.4 References

[1] Goodman, P. et al.; Technical adaptation under Directive 2002/95/EC (RoHS) – Investigation of exemptions. Contract No. ENV.A.2/ETU/2004/0002. Leatherhead 2004

[2] Joint Industry contribution to the ÖKO Institute's consultation on the Actual Exemptions from the RoHS Directive. Brussels, 01 April 2008

[3] Sean Hillman, CERAM Technology Limited; Addition to Exemption No. 13 Lead and Cadmium in Optical and Filter Glass. Submitted 20 March 2008

[4] Goodman, P.; Review of Directive 2002/95/EC (RoHS) Categories 8 and 9. Final Report. Leatherhead 2006

[5] Tünnermann, A.; Letter to SPECTARIS. Jena, 17 March 2008

[6] SPECTARIS, Photoindustrieverband e.V., eurom, Photonics Cluster (UK), GIFO, EPIA, ESGA; Contribution Of The European Optical Stakeholders. Berlin, 26th march 2008

[7] Test & Measurement Coalition; RoHS Directive Scope Review. Contribution to Öko-Institut study on RoHS current exemptions. 01 April 2008

[8] Japan Business Council in Europe (JBCE); 13. Lead and cadmium in optical and filter glass. 01 April 2008

[9] Joint response from EICTA and AEA Europe to the general and specific questionnaires relating to exemption 13. 04 April 2008

[10] Dr. Peter Hartmann; Ecological Aspects / EC Directive RoHS, Hazardous Substances in Glasses. Presentation 05 June 2008

[11] Dr. H. Gross, Dr. U. Hamm; Prolongation of Exemption #13 “Lead and Cadmium in Optical and Filter Glass”. Presentation Version 1.2, 04 June 2008

4.20 Exemption No. 14

“Lead in solders consisting of more than two elements for the connection between the pins and the package of microprocessors with a lead content of more than 80% and less than 85% by weight”

The exemption was described and assessed in the 2004 ERA report [1]. The exemption is used in microprocessors of AMD. The competitor, Intel, claimed to have a lead-free solution available [2].

The exemption was granted without an explicit expiry date and now is subject to the general review of the RoHS Annex.

4.20.1 Description of exemption

Lead-solder is used in a microprocessor application with a high number of pins (i.e. microprocessors with a pin count of 630 pins and higher, e.g. a desktop microprocessor having more than 900 pins). The solder consists of 82% of lead, 10% of tin and 8% of antimony (Pb82Sn10Sb8).

This solder is specifically used to connect the pins to the package carrier providing both electrical connectivity and mechanical stability. The pins serve as interconnect between the microprocessor and the motherboard through a socket.

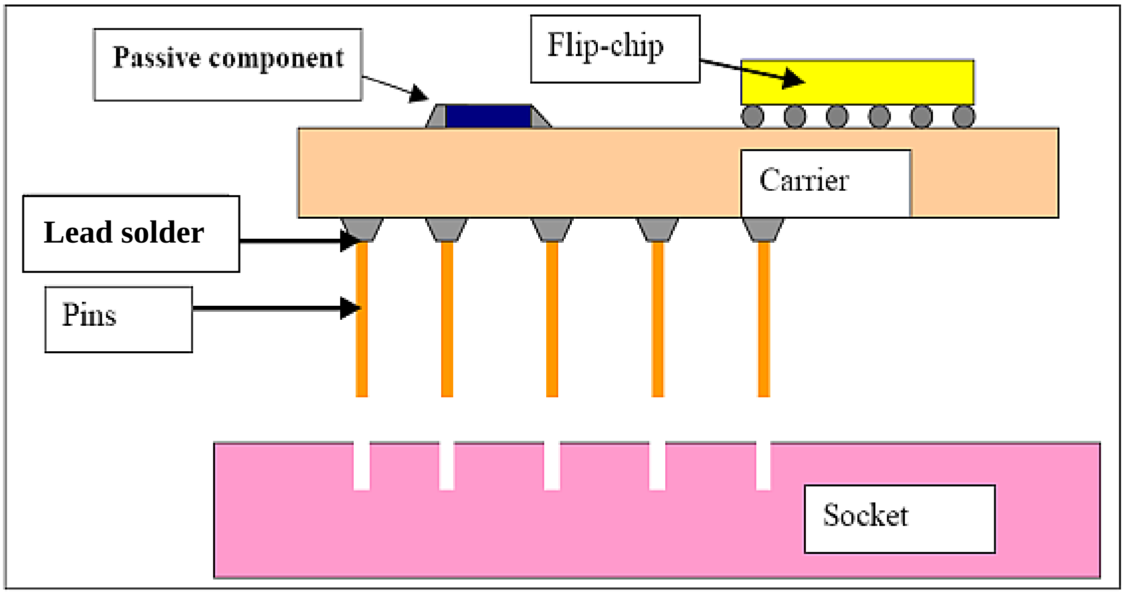


Figure 24 Schematic section of a pin grid array microprocessor package [1]

The large number of connections between the pin and the substrate requires very high reliability per individual connection, as the probability for package failure grows with the number of pins. As microprocessors will provide more functionalities, their packages will become larger and require an increased number of pins [4]. Lead-free solders, according to EICTA et al. [4], so far cannot provide the necessary product quality, yield and reliability in such high pin count applications.

Microprocessors are used in IT and communications equipment as well as in consumer equipment falling under the scope of the RoHS Directive: desktops, servers, embedded applications, mobile and handheld devices [4].

The lead content in the lead solder is more than 80% and less than 85%, or equal to around 0.5 g per microprocessor. The total amount of lead brought into the EU with applications using exemption No. 14 was nearly 6940 kg in 2007 [4].

4.20.2 Justification by stakeholders

According to EICTA et al. [4], alternative, lead-free solders and pin attach methodologies that exist today do not meet the necessary product quality, yield and reliability requirements for microprocessors with high pin counts and are therefore impracticable. AMD [3] uses higher pin counts of up to 940 pins for mass-produced PGA microprocessors compared to the maximum of 478 pins in Intel's mass production PGA microprocessors. The use of lead-free solders would translate to a double or even fourfold increase in pin movement and other associated quality and reliability issues in AMD products, as explained before already. Due to AMDs] significantly higher pin count, Intel's lead-free solution is not applicable to AMD's microprocessor technology [3]. Pin movement and other problems would lead to an increase in scrap, further burdening recycling and disposal systems in Europe. Also, pin positional tolerance is crucial to high manufacturing yields during board assembly. [3]

According to EICTA et al. [4], high pin counts result in increased tolerances and variations during pin mounting on the package and eventually lower the process margins in flip chip attach process. Pin counts have been increasing over time and will continue to do so. Microprocessors will provide more functionalities, their packages will become larger and require an increased number of pins.

The large number of connections between the pin and the substrate requires very high reliability per individual connection, as the probability for package failure grows with the number of pins. AMD states that it has shipped greater than 300 million microprocessor units using the Pb82Sn10Sb8 pin solder, without any quality or reliability failures related to the pin solder. [3]

<u>Experiences with use of lead-free solders</u>

EICTA et al. [4] state that AMD is actively pursuing development of lead-free solders as a substitute to the lead containing pin solder. However, studies have shown several constraints with the lead-free solders:

a) Pin movement

The pin moves from its desired, designed location. This compromises the socketing ability and thus affects the defect rate and mechanical reliability (see Figure 24). The applicant's product test involves multiple socket insertions (as many as 30x) to ensure product performance, quality and reliability before a part is shipped to customers. In case there is partial pin movement observe, which might even pass this internal test, there is still a high potential for pins detaching from the package in the customers' assembly process.

According to Master et el. [5], the probability of pin defects increases with the number of pins according to the formula

P = 1-(1-p)n	P: probability of a defective unit p: probability of a defective pin n: number of pins

With using lead-free solders, the probability p of a pin defect is higher compared to the use of the current PbSnSb solder, as explained above. To achieve the same level of reliability, the number of pins would have to be reduced. Vice versa, lead-free solders may yield sufficiently reliable products for pin grid arrays (PGA) with lower pin counts, but the probability of defects is too high for PGAs with higher pin counts in combination with lead-free solders. [5]

According to Master et al. [5], the socket may accommodate slight movement of a single pin, but is less forgiving with movement of multiple pins. Allowable movement of a single pin can be greater in magnitude than the allowable movement of multiple pins on a device. The threshold of allowable pin movement decreases when multiple pins move, because the movement is not constrained to the same direction. The effect of pin count on failing this tighter threshold can be calculated from the binomial distribution. In this calculation, it is assumed that a slight pin movement will not adversely affect socket insertion unless two or more pins move.

$$P = 1 - \sum_{r=0}^{1} \binom{n}{r} p^r (1-p)^{n-r}$$

Where r is the number of rejects (either 0 or 1 are allowed).
The device defective rate for the 940 package is approximately four times higher than the 478 pin package for the same pin defective rate. This ratio can be approximated by

$$\frac{P_{940}}{P_{478}} \sim \left(\frac{940}{478}\right) = 3.87$$

Under these circumstances, a 940 pin package would have nearly four times the reject rate as a 478 pin package. [5]
AMD [3] says that HP has found seemingly minor increases to the pin positional tolerance during the pin attach process resulting in significant increases in damaged pins during board assembly. This increases electronics scrap late in the manufacturing process, sometimes as high as 5%.

b) Solder climb
Lead-free solders climb up the pin (see Figure 24) and thus aggravate the insertion of the pins into the socket. Even if socketing is possible, the solder wears off and contaminates the contacts, as could be observed during the internal test with multiple socketing and desocketing actions. This may lead to arcing that consequently may damage the contacts or even the part itself.

c) Voiding
Increased tendency for voids in the lead-free pin solder joint affects pin strength and mechanical reliability.

d) Narrow soldering process window
The process window for the production of the pinned part is very small when using a lead-free solder. The melting points of the solder to attach the flip chip and that of the

pin solder must be sufficiently different. The pins and the flip chip are attached in subsequent solder processes to the carrier (see figure below). The pins must be attached first for logistical reasons. If the difference of the solder melting points is too small, the pin solder might melt when soldering the flip chip to the carrier. The pins may move away from their location, or even fall off.

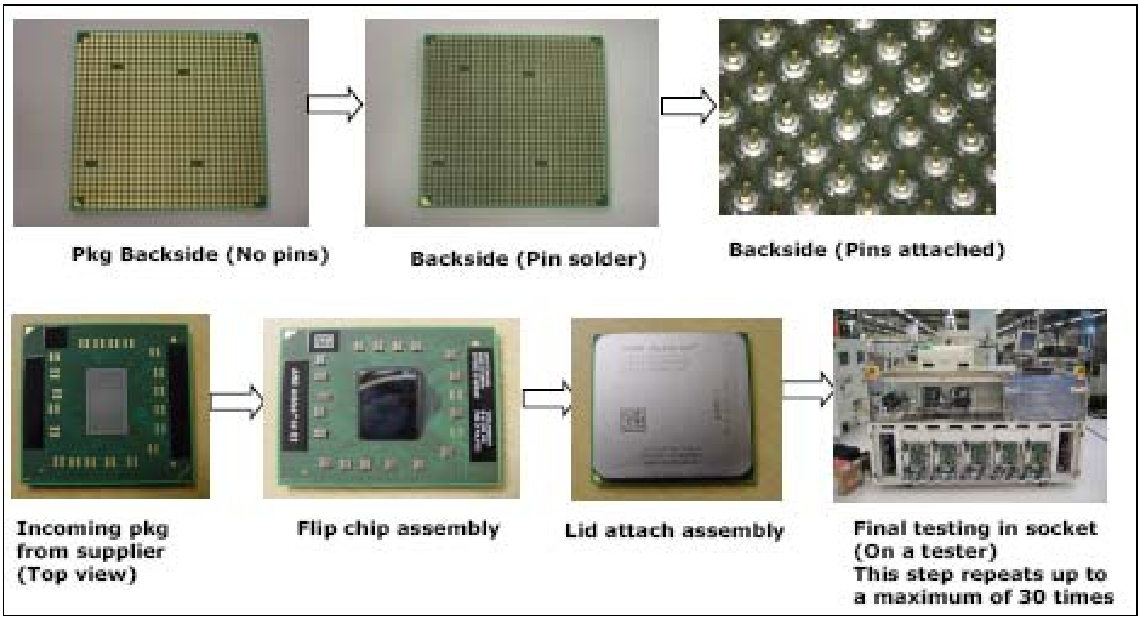


Figure 25 PGA assembly [3]

The applied lead-tin-antimony solder offers sufficient melting point difference to the flip chip solder in order to allow a proper flip chip attach without moving the pins from their correct position and alignment. Lead-free solders have a lower melting point compared to the PbSnSb solder. The process window to attach the flip chip to the package thus becomes smaller compared to the use of the PbSnSb solder. The end results of such issues are high yield loss in assembly and test, difficulty in scaling up to volume production and potential field failures at customers due to the loss of pin(s).

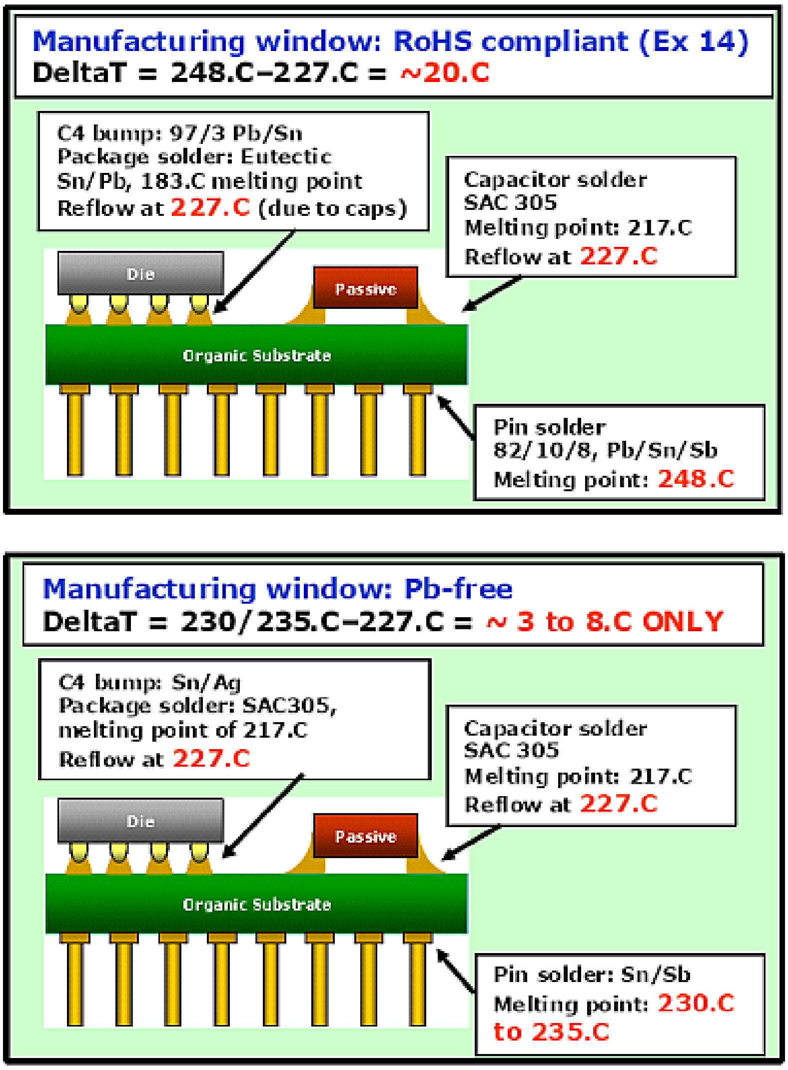


Figure 26 Narrowing of process windows with use of lead-free solders for pin attachment [8]

Manufacturing variations can induce temperature variations of about 10°C. Manufacturing variations include furnace-to-furnace variations, variations across the furnace belt, variations across the device when heated up in furnace (i.e. no uniform temperature from the C4 bumps to the pins when heated up in furnace) as well as other substrate and assembly variations.

Hence a manufacturing window of 3–8 deg C (as depicted above in the Pb-free scenario) leaves a minimal to negative margin to manufacture. In other words the use of Sn/Sb based pin solders is inconsistent with the assembly process window (229°C to 238°C) needed for the creation of proper SAC305 joints (capacitors and die). Pin movement would occur at the higher end of this temperature range, resulting in several quality and reliability issues [8].

e) Change of process order in pin and flip chip attachment

The pins are attached to the substrate before the flip chip is soldered on it. If the pins could be attached to substrate prior to the flip chip attach, the narrow process window with lead-free solder use could be overcome. The stakeholders explain, however, that the process in which pins are attached to the substrates MUST take place prior to flip chip attach.

The reasons for this are not just logistical, but also technical. The solder used to attach the pins to the substrates must have certain critical mechanical and thermal properties. The thermal property (melting point) has been discussed in detail. The mechanical properties (e.g. pin pull strength) are equally critical. The pin attachment needs to be sufficiently robust to withstand the various mechanical forces applied to it. These include the numerous insertions into various test sockets in AMD's test flow (at room, hot, cold temperatures), as well as multiple insertions/ removals of the package into motherboard sockets in OEM assembly or by the end-customer.

For the pin attach operation to be carried out on completion of AMD's assembly process, the pin solder would need to have a melting temperature in the 100°C to 125°C range. Anything higher than that would exceed the maximum temperature limit for epoxy degradation, and have severe negative consequences on the various epoxies used in the flip chip assembly process (underfill, thermal material, lid attach adhesive). Solders that melt in the 100°C to 125°C temperature range, and still provide the required mechanical robustness & chemical corrosion protection of the pin joints simply do not exist today, according to the stakeholders [8].

Further, the substrate manufacturer attaching the pins always 100% tests the organic PGA substrates prior to shipment to AMD. This is to screen out any as-manufactured defective substrates. This electrical test is a critical operation; not doing this test would result in additional yield loss after the die attach process in AMD's manufacturing flow. This is an unacceptable option because the microprocessor die would be lost by attaching it to a defective substrate, creating more waste. Thus, all the material and energy used to create the microprocessor would be wasted. The electrical test on organic PGA substrates is one of the last operations in the substrate manufacturer's process flow. It is always done after the pin attach process. The test setup contacts the PGA pins to carry out the electrical test.

If the pin attach operation were to be carried out by AMD on completion of the product assembly, the substrate manufacturer would need to carry out this electrical test (of bare substrates) by probing the sensitive pin attach land pads. Probing these pads would cause damage to the Ni/Au plating on the pads and potentially also some damage to the base Cu. This damage could have a serious negative impact on the integrity of the pin solder joint, since the mechanical robustness of the joint depends on the formation of a strong metallurgical bond at that interface with well defined intermetallics. Defects at that interface could also create solder voids and result in poor wetting of the exposed Nickel to the solder material. Hence electrical testing of the substrates is not practical before shipment to AMD [8].

For the reasons mentioned above, pin attachment on organic PGA packages is always done by the substrate manufacturer. It is one of their core engineering competencies when it comes to organic PGA substrate manufacturing. There are no semiconductor manufacturers (neither AMD nor anyone else) who attaches pins to organic PGA packages on completion of product assembly. [8]

f) Use of low-melting solders for flip chip attachment

In order to improve the manufacturing process window, different flip chip low melting solders were investigated. Solders containing Sn, Ag, Bi, In, Cu were studied and found to be non manufacturable for high volume package fabrication. Experiments were conducted to optimize the pin geometry, solder composition, solder volume and assembly process. Results continue to show pin movement and solder climb that do not meet product requirements. In certain situations such as to repair defects, the flip chip attach process goes through multiple reflows which exacerbates the above stated issues. [4]

The applicant continues to work internally and with his partners on non-traditional ideas, novel pin attach techniques and other potential changes to the pin material and geometry. No substantial improvements could be achieved. [4]

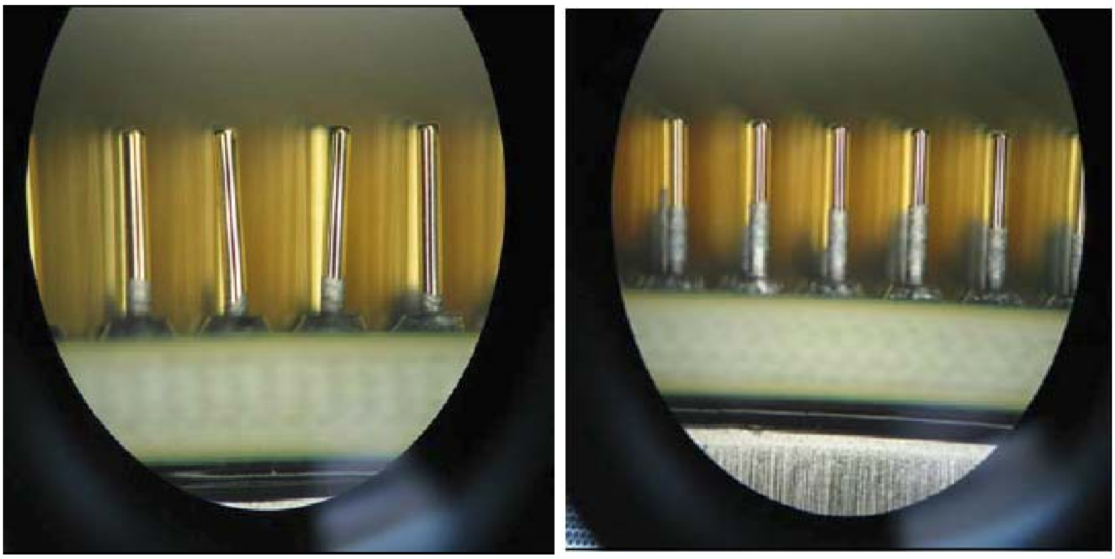


Figure 27 Moving pin (left) and solder climb under use of lead-free solders [4]

Alternative designs without pins

Ball grid arrays (BGA) and land grid arrays (LGA) in principle are alternative designs to the current pin grid array (PGA) design [4]. Currently, it is technically impracticable, especially for microprocessors with high pin counts, that consequently also require a high number of LGA interconnects. The high pin count PGA packages offer unmatched reliability advantages and flexibility compared to other packages at this high pin count. [8]

1. Land grid array (LGA) package microprocessors
   LGA is an interconnection technology that does not use pins any more and therefore does not need to use the pin solder for which this exemption is needed. However, based on customer feedback, transition to LGA is not possible for all products due to technical impracticability or lack of infrastructure in the customer application. Customers face significant challenges when they are forced to use products in LGA microprocessors. The motherboard sockets needed to house the LGA packages are more prone to damage and failure since they are inherently less robust than the sockets used to house PGA packages. LGA sockets are more complex in construction than the PGA sockets because they need to house the large number of spring-loaded pins needed to make proper electrical contacts with the LGA package pads. This complexity also results in a higher defect rate in the assembly of these LGA sockets onto the OEM motherboards.

   The stakeholders further on explain that a transition to LGA technically is not feasible for all products in the mobile product segment. For example, mobile applications require a lower profile for the socketed microprocessor on the motherboard. The LGA package form factor would require a socket that is significantly thicker than a PGA socket, due to the design of the interconnect required in the socket as well as the fact that a vertical clamping mechanism must be used to enable proper contact. PGA sockets do not need this vertical clamping mechanism. Hence an LGA processor in an LGA socket would have a significantly higher profile when compared to a PGA processor in a PGA socket. This higher profile is incompatible with typical mobile product (laptop etc.) case designs, where the overall profile height is a critical factor affecting the products ease-of-use and portability. [4], [8]

2. Ball grid array (BGA) microprocessors
   BGA microprocessor packages are another alternative, lead-free solution. Their use involves major infrastructure changes at the customer and also eliminates the flexibility of adding/removing the processor without affecting other components on the motherboard. BGA packages are not socketed onto the OEM motherboards. They are instead attached to the motherboard using a surface mount reflow operation. Once attached, it

> places major restrictions on the manufacturing flexibility at the original equipment manufacturer (OEM) factory, since defective parts could result in the entire motherboard getting scrapped. A defective microprocessor would need to be removed by a thermal operation where all the BGA solder balls are heated up to melting temperature, and this process could result in adjacent components being damaged, thus creating a reliability issue. Also, if the components adjacent to the microprocessor are defective, reworking them could have a negative impact on the reliability of the sensitive microprocessor device. Using a BGA package also completely eliminates the flexibility enjoyed by the end-customer today to easily replace and/or upgrade the microprocessor. Using a PGA package does not have the above technical limitations. Since it is socketed onto the motherboard, it can be easily removed and replaced during motherboard assembly or by the end customer. [4], [8]

The stakeholders conclude that an alternative package design is not feasible for all products segments due to technical impracticability or lack of infrastructure in the customer application. They therefore want to continue pursuing a lead-free pin solder solution and ask that the necessary transition time is taken into account in determining an appropriate expiration date.

Future activities

EICTA et al. [4] state that research for lead-free substitutes and for alternative designs has been ongoing since 2001, but no solutions have been found so far that meet the applicant's product quality and reliability requirements for microprocessors with high pin count. The large number of connections between the pin and the substrate requires very high reliability per individual connection as the probability for package failure grows with the number of pins.

The PGA technology, according to EICTA et al. [4], could not yet be fully replaced by alternative designs like BGA or LGA.

The applicant provided a roadmap showing his past and future activities to achieve a lead-free solution.

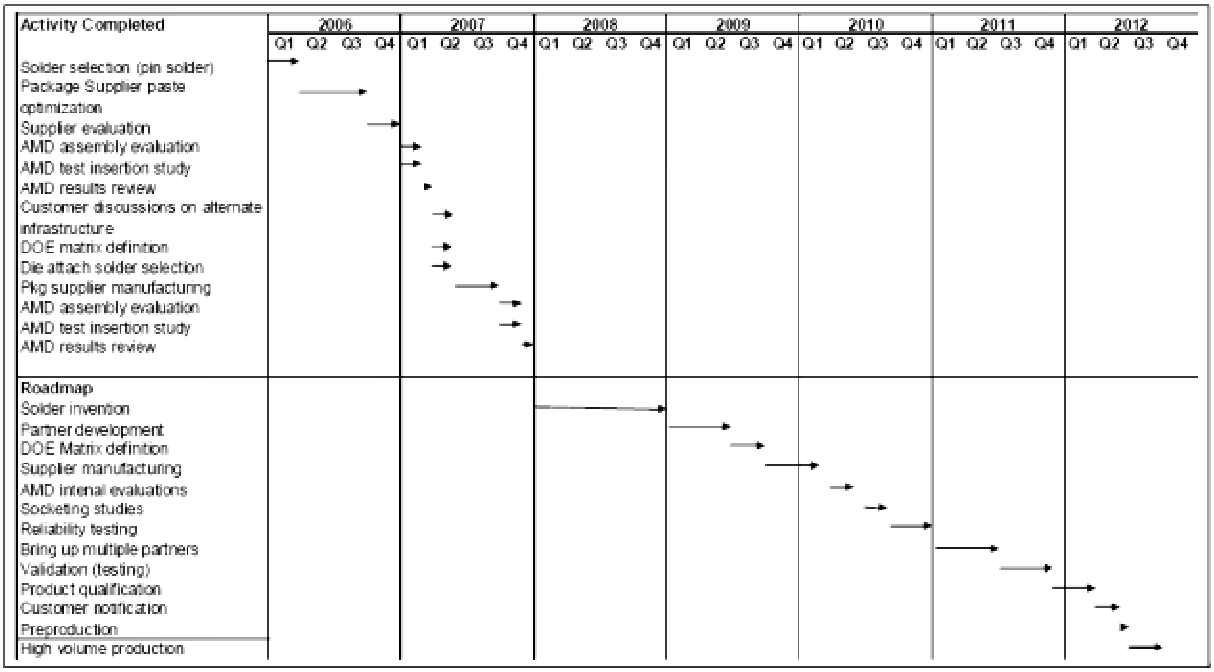


Figure 28 Roadmap towards the elimination of lead [4]

EICTA et al. [4] highlight that the roadmap relies on inventing a substitute solder in 2008. The roadmap is only valid if there is an invention done in 2008, which cannot be predicted with absolute certainty. If an invention could not be made within 2008, the roadmap will be subject to change.

Taking the optimistic view that an invention can be made in 2008 to eliminate lead in currently exempted pin solder, AMD asks that the pin solder exemption is extended until the end of 2012 or that at least an adequate transition time of 18–24 months is granted.

Support for continuation of exemption

EICTA, AeA Europe, EECA ESIA and ZVEI, support the continuation of the exemption [4]. They say that a manufacturable solution suitable for high volume production of microprocessors with high pin counts is not likely to be available by 2010. An expiration date for the exemption applicable to microprocessors with high pin counts is therefore not possible to name at this time.

Hewlett Packard [6] supports the continuation of the exemption stating that it is needed in order to continue shipping systems with certain processors from AMD. Without access to this exemption, HP would be forced to sell into the EU only systems using Intel processors.

Microprocessor architecture and high pin counts

AMD [3] states that there is no standard microprocessor that provides the "standard functionality" of a microprocessor. Significant differences exist in the architecture of microprocessors from different manufacturers. The effects of this are evident when looking at platform performance as well as platform energy efficiency or upgradability. The difference in pin counts reflects, among others, the different architecture. AMD has integrated more functionalities into the core microprocessor compared to other CPU manufacturers, which dictates a need to increase the electrical connections. Examples of functionalities additionally included in the core microprocessor are the integrated memory controller, which is an additional semiconductor part with Intel's technology, the Direct Connect Architecture, the size and arrangement of memory caches on the die, as well as number of power delivery planes to the different parts of the die of AMD processors as compared to Intel processors.

AMD [3] concludes that the overall withdrawal of exemption 14 could severely limit choice in an already monopolistic X86 microprocessor space as it might impact AMD's ability to supply reliable microprocessors.

Opposition of Intel to continuation of exemption 14

Intel opposes the continuation of the exemption stating that it uses tin-antimony (SnSb) lead-free pin attachment solder for pin grid array CPUs since 1999. [2] This solder, according to the stakeholder, proved to be the best solution. Intel says that this includes the 45 nm 100% lead-free CPU Penryn PGA and its earlier generation products that contained lead in first level interconnects. Currently, the Penryn PGA products with 478 pins are at ramp to high volume mass production [2], [7]. According to Intel [2], there is no high volume manufacturing issue.

Intel says it spent significant research and development efforts to enable lead-free PGA packaging, which comes together with Intel's lead-free die attachment process. Specific areas of work Intel achieved include advances in the solder metallurgy; optimization of geometries of the pin and solder; strengthening of interfaces and optimisation of all reflow parameters. Intel states to have PGA products in the market with up to 700 pins in lead-free pin attachment technology, and has announced lead-free soldered PGA microprocessors with close to 1.000 pins [7].

Summary of the case

AMD manufactures high pin count PGA microprocessors in mass production using a lead-containing solder for pin attachment. The competitor, Intel, has lead-free soldered PGA packages on the market. AMD [3], EICTA et al. [4] claim that lead-free solders might be a viable option to produce lower pin count PGA microprocessors like Intel's ones, but maintain lead-free solders not to yield reliable results in the pin attachment for high pin count PGA microprocessors manufactured in mass production [4], [10].

AMD, EICTA et al. say that AMD's and Intel's PGA microprocessors are different in architecture, and that Intel's PGA microprocessors therefore cannot replace the high pin count AMD PGA microprocessors. AMD additionally claims its high pin count microprocessor to be advantageous in energy efficiency, upgradability and performance without presenting further evidence for this claim.

BGA and LGA package microprocessors are an alternative to PGA ones. They do not use pins, and hence can be produced independently from exemption 14. They can partially replace the PGA microprocessors, but are more difficult to handle in manufacturing and are not a technically feasible alternative for all products, in particular not for mobile ones.

AMD, EICTA et al. therefore ask for the continuation of exemption 14 until 2012 stating that no adequate alternatives are available for the AMD high pin count PGA microprocessors using lead solder for the pin attachment.

Intel opposes these views and asks exemption 14 to be cancelled [2].

4.20.3 Critical review

As was already assessed in 2004 [1] and confirmed in the above stakeholder justification, there are lead-free soldered PGA microprocessors in the market. Additionally, BGA and LGA microprocessor packages are available, which do not have pins and thus do not depend on the use of solder with or without lead for pin attachment. The stakeholders explained that these BGA and LGA packages are not a full replacement of the PGA packages that offer unique advantages.

It must be clarified whether and how far the lead-free PGA microprocessors can replace the non-lead-free soldered PGA microprocessors. If they are a replacement, the avoidance of lead in this application is practicable.

<u>Architectural differences and alternative packages</u>

The AMD and the Intel PGA microprocessor architecture is different, as the stakeholders had explained. These architectural differences entail further differences, e. g. in the mother board sockets, to which the microprocessors need to be attached and the architecture of the motherboard that go beyond just adapting the number of pins.

The high pin-count and the lower pin count microprocessors cannot be simply exchanged, but require a redesign of the product, or parts thereof, into which they are installed, or even a change in the equipment manufacturing processes. The stakeholders claim that one microprocessor solution therefore cannot replace the other one and plead for the continuation of exemption 14.

According to Art. 5 (1) (b), an exemption is not possible if design changes – either on the supplier or the equipment manufacturer level or on both levels – eliminate the banned material. The users of microprocessors hence are expected to redesign their products to be able to apply lead-free soldered PGA microprocessors, or to shift to alternative packages like BGA or LGA microprocessors as far as technically viable. The architectural differences between the AMD and the Intel PGA microprocessors do not justify an exemption in line with Art. 5 (1) (b).

Functional equivalence

AMD claims that the high pin count solution has better platform performance as well as platform energy efficiency or upgradability. There is, however, no quantified information on this, and there is no evidence that this could outweigh the environmental advantages resulting from the substitution or elimination of lead, as Art. 5 (1) (b) would require to justify an exemption on energy efficiency or performance grounds.

Technologically, the AMD and the Intel microprocessors are different. Such differences are not relevant for this review process, however, as long as both microprocessor solutions have a certain level of functional equivalence. Even though there may be no standard microprocessor with a standard functionality, as AMD puts forward, it is still necessary to consider the functionality of a microprocessor under the specific aspects of Art. 5 (1) (b) in this review process. Despite of the architectural and technical differences the stakeholders put forward, the AMD as well as the Intel PGA microprocessor packages alone or with additional components technically can cover the functional requirements in all kinds of products in which microprocessors are used. This may require changes in product design and manufacturing processes to adapt the end product to the specific technical features, architectures and geometries of the respective microprocessor. Despite of the technical differences of the AMD and Intel microprocessor solutions, there is no proof that certain product groups could no longer be produced in case only one of the two PGA microprocessor solutions would be available on the market. No product groups would experience serious drawbacks for example in product performance, energy consumption or product features like weight and size of mobile products.

Lead-free soldered PGA microprocessors are on the market. Additionally, alternative packages like LGA and BGA microprocessors are available, although they cannot replace the PGA microprocessors in all applications, as the stakeholders had explained. The substitution of lead in the PGA packages of microprocessors or its elimination via design changes thus is technically practicable. The differences in technology and architecture between the AMD and Intel PGA microprocessors, and the limited applicability of alternative LGA and BGA microprocessor packages thus are no grounds to recommend an exemption in line with Art. 5 (1) (b).

Monopolistic market structures

AMD states that without exemption 14, choice in an already monopolistic microprocessor market will become smaller again, as AMD's ability to supply reliable microprocessors might be compromised [3]. Clearly, monopolies are of high concern in market economies whose proper function needs competition. In the context of this exemption review process, however, the reviewers cannot assess whether and how far the continuation or cancellation of an exemption weakens or strengthens monopolies. If the cancellation of exemption 14 results in monopolistic or more monopolistic market structures, it could have serious impacts, but the reviewers do not have the mandate to take this into account, as Art. 5 (1) (b) does not allow exemptions to prevent monopolies.

Conclusions

In the previous evaluation, the reviewer recommended exemption 14 to expire by 2010 [1]. In the stakeholder consultation, stakeholders applied to maintain the exemption beyond 2010 with mentioning 31 December 2012 as a potential date at which lead has been phased out in the currently exempted pin solder [10]. Given the situation as described above, the stakeholders' arguments do allow the continuation of exemption 14. The consultants hence recommend not to extend exemption 14 to suffice the requirements of Art. 5 (1) (b).

In the current version of the RoHS Annex, exemption 14 does not have an expiry date. Switching from one to another microprocessor with different architecture or a different package requires redesign and adaptations of the products in which these microprocessors are used, and changes in the production processes. Equipment manufacturers who so far applied the AMD PGA microprocessor packages need time to prepare their products and production processes for the use of microprocessors that are not produced using exemption 14. Assuming the official amendment of the RoHS Annex until end of 2009, exemption 14 is recommended to expire on 31 December 2010.

4.20.4 Recommendation

The substitution and elimination of lead for the attachment of pins in PGA microprocessor packages is technically practicable. The continuation of exemption 14 would therefore not be in line with Art. 5 (1) (b).

Exemption 14 is therefore recommended to expire on 31 December 2010 to enable equipment manufacturers preparing their products and their production for the use of microprocessors, which are not produced using exemption 14. It is further on recommended to facilitate the use of AMD PGA microprocessor packages with lead in the pin attachment solders for repair and reuse of equipment put on the market before the expiry date.

The new wording of exemption 14 is proposed as follows:

Lead in solders consisting of more than two elements for the connection between the pins and the package of microprocessors with a lead content of more than 80% and less than 85% by weight until 31 December 2010, and for the repair and reuse of products that were put on the market before 1 January 2011.

4.20.5 References

[1] Goodman et al. 2004, Technical adaptation under Directive 2002/95/EC (RoHS) – Investigation of exemptions, ERA 2004, document "era_technology_study_12_2004.pdf"

[2] Intel on ex. 14, Stakeholder document "Exemption-14_Intel_31_March_2008.pdf"

[3] AMD on ex. 14, Stakeholder document "Lead-free_Questions on Exemption 14_May21_2008_final.pdf"

[4] EICTA et al. on ex. 14, Stakeholder document "Exemption_14_EICTA_and-others_1_April_2008.pdf"

[5] Master et al., AMD, Stakeholder document "Effect of Pin Count on Device Defective Rate_May 21 08.pdf"

[6] Hewlett Packard; Stakeholder document "HP Letter to the Oeko Institut - Rev3.1.pdf"

[7] E-mails from Julian Lageard, Intel, received on 3 and on 10 October 2008 by Dr. Otmar Deubzer, Fraunhofer IZM

[8] EICTA stakeholder document "EICTA Position on Exemption 14 3rd Oct 2008.pdf"

[9] AMD stakeholder document "Letter to Dr Deubzer_IZM Oct 17 2008.pdf"

[10] EICTA stakeholder document "Letter to Dr Deubzer_IZM Oct 17 2008.pdf"

4.21 Exemption No. 15

"Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit Flip Chip packages"

This exemption was described and explained in details in the ERA report in 2004 [1].

4.21.1 Description of exemption

The exemption in its current wording allows the use of leaded solders for level 1 interconnects: the bumps and the solders used to attach the bumps to the chip carrier.

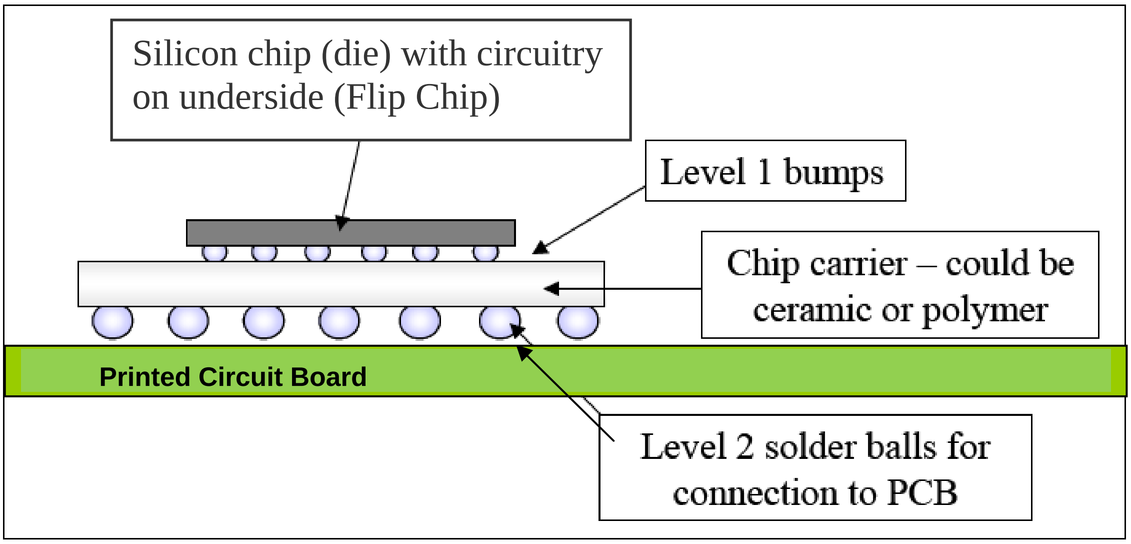


Figure 29 Flip chip package with ([1], modified)

The flip chip consists of the silicon chip, the underside circuitry and the bumps (balls on the underside). The bumps of the flip chip are connected to the contact areas of the chip carrier using a solder. Thus, a mechanical and electrical interconnect is formed between the flip chip and the chip carrier.

The flip chip and the chip carrier together form the flip chip package (FCP). These FCPs can be very complex, as the next figures show, with different die sizes and die thicknesses.

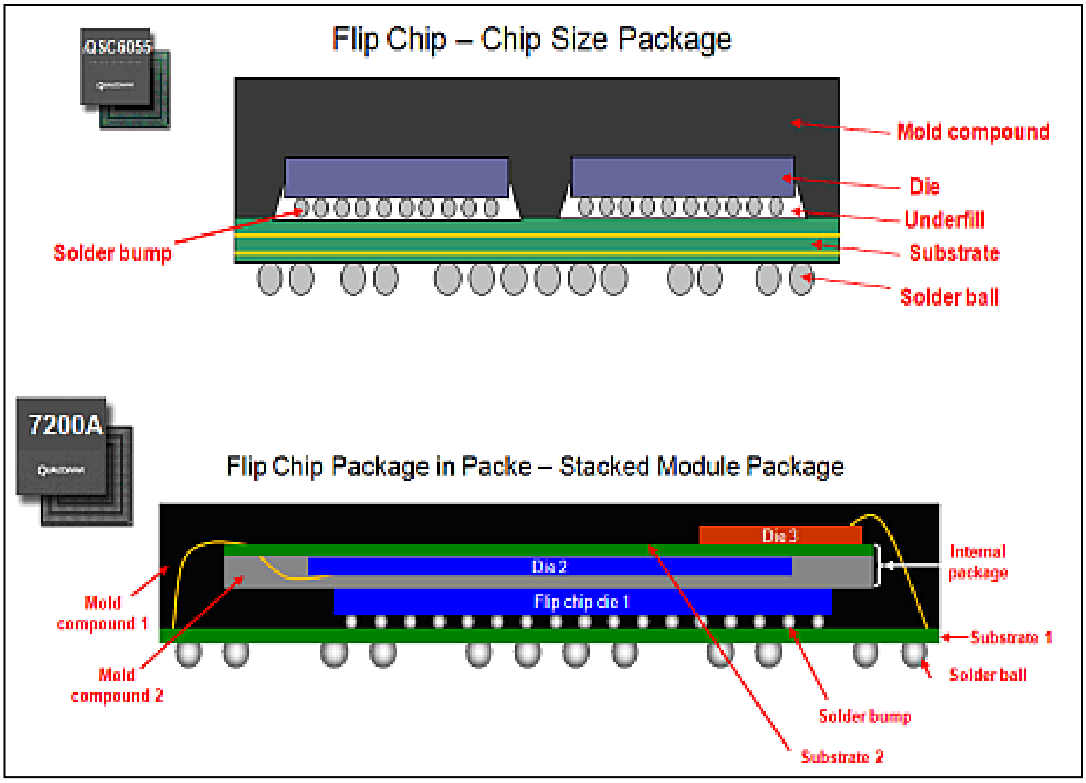


Figure 30 Schematic views of complex flip chip packages (small form factors, source: Qualcomm)

For the level 2 interconnects, lead-free solders can be used. For level 1 interconnects, different solders are applied [1]:

– High melting point solders with 85% and more of lead (e. g. 97%Pb3Sn, 90%Pb10%Sn)
– Lead-free solders, such as SnAg, Sn3.5%Ag0.7%Cu (SAC)
– gold, copper or gold tin
– eutectic solder (63%Sn37%Pb)

The solders used on level 1 in the flip chip connections must be [1]:

1. resistant to electromigration failure at the extremely high current densities required
2. able to create a solder hierarchy that allows staged assembly and rework of components in the manufacture process, and
3. have high ductility to reduce thermo-mechanical stress in under bump metallurgy (UBM) structures in particular in larger dies

Lead-free solders currently do not yet provide all these functionalities to a sufficient degree and hence are not appropriate to replace the leaded solders. Lead solders are in particular important for high reliability applications, large dies, and high performance applications with high current densities.

4.21.2 Justification by stakeholders

The stakeholders bring forward several arguments to justify the continuation of exemption 15. The arguments are summed up in the following sections.

Solder temperature hierarchy

Flip chip packages use high melting point solders with lead in order to achieve a solder hierarchy. They need a difference in the melting points of the solders applied on level 1 and level 2. Level 1 needs higher melting point solders in order to prevent the remelting of these solder joints during the soldering at level 2. The use of leaded solders with varying lead contents allows the adjustment of the melting points for the solders at level 1 depending on the requirements of the flip chip package or the production of the total device. [3]

Thermal mismatch

According to EICTA et al. [3], lead solders in the first level interconnects offer advantages that the current lead-free solders cannot provide. The core problem is the thermal mismatch between the die and the carrier due to the different coefficients of thermal expansion (TCE), and the resulting deformations as shown in the following figure.

Material	TCE ppm/°C
Silicon	~ 2.5
Ceramics	~ 7
Polymer carriers and PCBs	~ 14

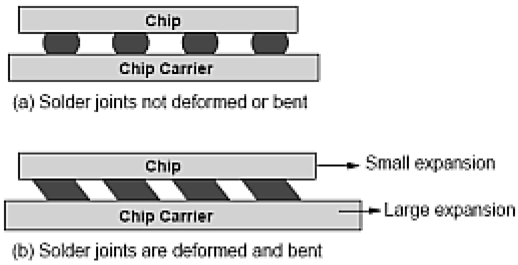


Figure 31 Coefficients of thermal expansion (TCE) and resulting deformation due to thermal mismatch [1]

The thermal mismatch problem increases with growing die diagonals. The differences in the thermal expansion coefficients become more effective in larger packages. The thermal stress increases with increasing distance of the bump to the centre of the die (distance to neutral point), and the most distant bumps thus contribute most to the mechanical stress on the die.

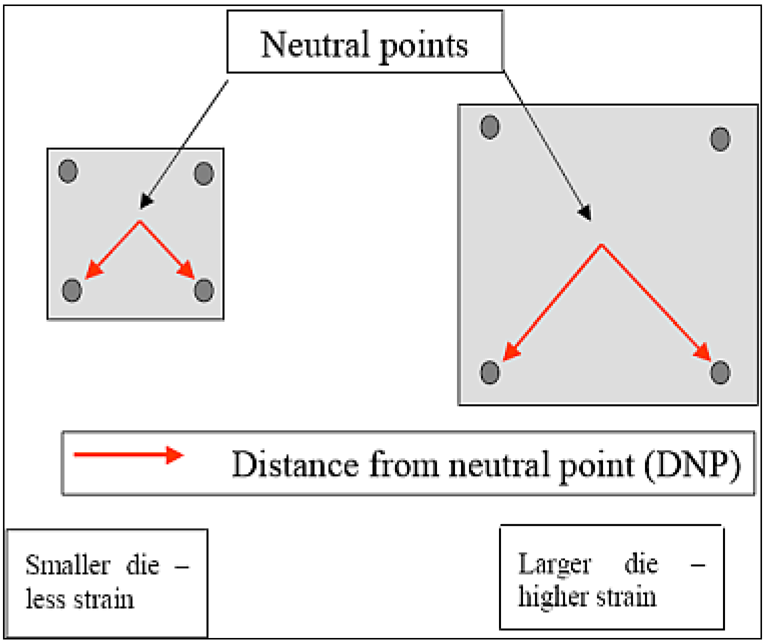


Figure 32 Increasing stress with increasing distance of the solder joint from the neutral point [4]

According to Xilinx [4] strain is imposed by several mechanisms including device fabrication. It is particularly severe however when the component's temperature changes as a result of differential thermal expansion. When temperature increases, the laminate expands more than the silicon and this applies a strain to the solder bump and to the materials to which these are attached. This strain can cause damage to:

- the dielectric material that is used as insulating layers on the silicon die surface, especially if low-k dielectric materials are used;
- the solder bonds to silicon die and to carrier circuit as a result of thermal fatigue;
- the silicon itself which may crack.

As the silicon die and carrier PCB are rigidly held by the solder bumps, the effect of differential thermal expansion is to apply an outward strain on the solder bump bonds. The applied force is partly relieved by distortion of the silicon and PCB which can "bow" outwards similarly to a "bimetallic strip" which bends when heated as a result of the different TCE values of the two metals. Therefore, as the expansion of the polymer laminate is constrained by the low TCE silicon, this results in warping of these two materials. Warping causes tension on joints which can cause cracking. Under-fill materials are injected between the die and carrier to reduce strain imposed on solder bumps by spreading out the forces induced by differential thermal expansion. [4]

Underfills are designed to put solder bumps into compressive strain which prevents fatigue failure but they also increase the overall stress to the package because they have larger TCE values than the carrier material and this causes warping. The distortion from warping causes cracking and delamination of low k dielectrics and detrimentally affects the planarity of the level 2 solder balls. If the level 2 balls do not lie in a flat plane, some (usually those in the middle) will not make contact with the PCB causing open circuits. [4]

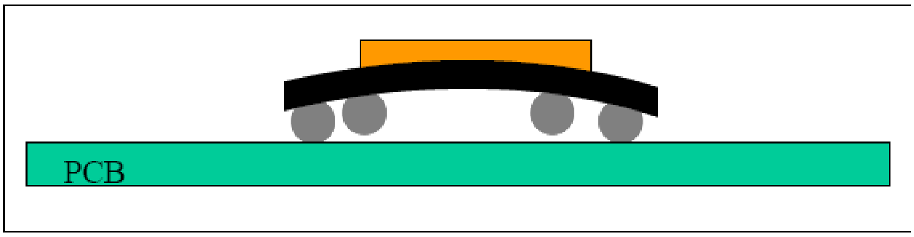


Figure 33 Warpage and effects on coplanarity of second level interconnects [4]

Research has shown that if the co-planarity of solder balls can be kept within 8 milli-inch (0.2 mm), good bonding to the printed wiring board is possible whereas worse co-planarity values indicate a high risk of open circuits. This value has been included in a standard published by JEDEC (Design Standard 95-1, section 14, June 2000). [4]

Lead-containing solders are ductile. Leaded solder joints absorb some of the tension between the silicon die and the ceramic or polymer carrier and hence protect the chip from fractures. Lead-free solders generally are stiffer and less ductile than lead-containing solders. The solder joint hence cannot compensate the thermo-mechanical stress. The tension from the thermal mismatch is directed into the chip, deforms the chip and can cause fractures. The thermal mismatch results in earlier failures of the lead-free flip chip package. In particular the low-k inner dielectrics in the die are prone to fractures, as they are brittle and are the weakest mechanical point in the die. [3]

Additionally, most lead-free solders have higher melting points. The elevated soldering temperatures require a strict control of the soldering profile, and even then it is not sure that the flip chip package will not be under residual stress after the soldering process: The materials expand to a different degree according to their thermal expansion coefficient, the solder melts and solidifies after the soldering process before all materials have returned into their normal expansion stage at room temperature. After the solidification of the solder joint, the materials (die, chip carrier) shrink, and the result is residual stress in the flip chip package after the soldering process. As lead-free solders solidify at higher temperatures, the die and the chip carrier are hotter at that time and hence change their thermal expansion more in returning to the original size compared to tin-lead solders. [3]

Electromigration

Most lead-free solders have a higher resistance than lead-containing solders. This may result in electromigration: material in the solder joint is dislocated from its original position due to the current passing through the solder joint. The result can be gaps and breaks in the solder joint, or voids, and in the end the failure of the solder joint. [3]

What is clear is that the electromigration effect increases with higher current densities. Smaller solder joints like the bumps in the flip chip in combination with the tendency towards higher performance devices exacerbate the electromigration problem for the flip chip packages. [1], [3]

Undercooling and reliability

Solidification of all tin (Sn) rich solder alloys, like the lead-free solders, requires the nucleation of Sn crystals from the melt. Sn crystals form in a low symmetry crystal structure with a very high activation barrier for nucleation. The further the melt temperature is lowered below the solidus temperature – the temperature at which the alloy is solid- the higher the thermodynamic driving force to overcome this activation barrier for the nucleation resulting in Sn grains in the solidified solder joint. [2]

Since homogenous nucleation in the melt is a stochastic process, it depends on the amount of Sn available. The probability of a nucleation event occurring therefore decreases with the volume of the melt. Thus, undercooling below the melting point is required for all Sn rich solder joints, but in small flip chip solder joints the level of undercooling required can be extreme. Undercooling as much as 60°C below the solidus temperature with tin-copper Pb-free alloys are documented. Problems with large undercooling of solder joints can occur when those joints arranged in large arrays as is the case for flip chip solder connections. The stochastic nature of significant undercooling to trigger Sn nucleation means that the solder joints in the array will be solidifying at widely varying times during the cool-down phase of the solder reflow operation. Packaging structures are not dimensionally stable during the temperature changes of reflow cool-down. Relative package distortions before final solidification of the array can create compromised solder joints at those few remaining solder joints that require the most extreme undercooling and are hence the very last to solidify. [2]

The undercooling effect and the resulting non-simultaneous solidification of solder joints hence is a problem increasing with the number of interconnects and with decreasing solder joint volumes in tin-rich solders, and is therefore a manufacturing-related reliability issue for flip chip packages. [2]

Impacts of SnAgCu microstructures on reliability and life time

After the soldering process, the “twinning” effect during cooling and solidification of high tin content solders, like most lead-free solders are, generates crystals in the solder joint with different steric orientation. The solidification and crystallization starts at a nucleation point and from there spreads into the solder joint. [3]

In flip chip bumps, the small volume makes it more probable that only one nucleation point exists. The result is that the solder joint is a single crystal. Crystals have a steric orientation, and the micromechanic properties in parts are dependent on the crystal orientation. This crystal orientation, however, may be different in each of the solder joints in a lead-free soldered flip chip. The result are bumps with more or less individual mechanical properties. Some of them, e. g., fail earlier than others under identical test conditions. The reliability and resulting life time of a lead-free soldered flip chip package hence are even more difficult or impossible to predict. The effect is in particular relevant for long life high reliability applications. [3]

Small solder volumes increase the “undercooling” effect during the soldering of lead-free solder joints, e. g. with tin-copper solders. Using silver containing lead-free alloys increases formation of large Ag_3Sn plates with complex effects on solder joint reliability. Such and other products of metallurgic reactions affect the mechanical properties of SAC solder joints as well as their reliability and life time. The formation of these products depends on the cooling rate after the soldering process, the solidification temperature, small deviations in the solder composition, annealing time and temperature, and the solder joint size. The complexity of the interference of all these factors result in solder joints whose properties cannot be fully predicted. Models to simulate the effects do not yet exist according to the stakeholders. Important material properties like the creep rate thus vary considerably between different solder joints. [3]

The SAC solder joint properties further on vary considerably and much more than SnPb joints during ageing and temperature cycling, and the effects are even stronger in small solder joints. The stakeholder say that in particular for high lead-free solder joints with their high tin contents, it is largely impossible yet to predict the reliability. [3]

The stakeholders conclude that the use of lead-free solders in flip chip bumps and solder joints thus is not yet possible in particular for high reliability applications.

Status and conditions for progress towards lead-free soldered flip chip packages

Table 10 gives an overview on the conversion towards lead-free level 1 interconnects.

Table 10 IBM Pb-free conversion roadmap estimate [source: IBM]

Pitch/Solder	Chip Size (mm)	Package	Current Density mA/khrs/°C	Node	Production
200µm Leaded	<21.5	Ceramic/NiP	250/100/100	65nm	2006
	<18.8	Organic/Eutectic	150/100/100	90nm	2007
150 Leaded	<14.7	Organic/Eutectic	100/100/100	65nm	2007
	<18.8	Organic/Eutectic	100/100/100	65nm	2008
200 Lead Free	<14.7	Organic/SAC	170/100/100	90nm	2006
	18.8	Organic/SAC	170/100/100	65nm	Tgt 2008
150 Lead Free	<14.7	Organic/SAC	170/100/100	45nm	2008
	<26	Organic/SAC	170/100/100	45nm	Tgt 2009
	<26	Organic/SAC	250/100/100	32nm	Tgt 2013
	<26	Ceramic/NiP	250/100/100	32nm	Tgt 2014

Note: this table has replaced the similar table from stakeholder document [3]. IBM had explained that the table in [3] is not correct and hence asked to replace it by the above version.
"Eutectic" indicates the use of SnPb37 solder containing 37% of lead per weight, "SAC" stands for lead-free tin-silver-copper solder.

The above roadmap, according to EICTA [3], is specific for IBM, but nevertheless representative of industry in general. The stakeholders abridge that the future "Pb-free Production" dates in the above table are estimates and targets. In many cases, invention is required for these dates to be achieved. Furthermore, these dates represent when Pb-free technology is estimated to be first commercially available. Additional transition time for qualification and implementation on specific products would be required.

The stakeholders [3] stated that the first small die organic packages were converted to lead-free solders in 2004, and the vast majority of components were released in preparation of the 1 July 2006 deadline in the RoHS Directive. In applications using small chips, it is advantageous to use organic chip carriers. All such packages have been converted to Pb-free solders, according to EICTA et al. [3]. On further inquiry into this statement, EICTA [6] confined it to refer to second level interconnects only. These solder joints, however, are not in the scope of this exemption and hence the above statement is obsolete.

The above table shows that smaller packages on organic carriers already use lead-free solders on first level are or will be converted to lead-free soldering in 2008 or 2009. Even several larger and more complex modules have been converted since then, but only around one year of experience is available, which according to [3] is short. Substitution of lead in the flip chip interconnect is currently underway for some other applications as well.

On the application side, previously promising alternatives have proven to be impractical in various high performance and / or high reliability applications. Some specific applications where lead solder is needed include those that require ceramic substrates and / or chips ≥ 14.7 mm on a side, ≥ 300 W, ≥ 100,000 POH (power-on hours), 100°C service temperature, and /or ≤ 65 nm pitch. [3]

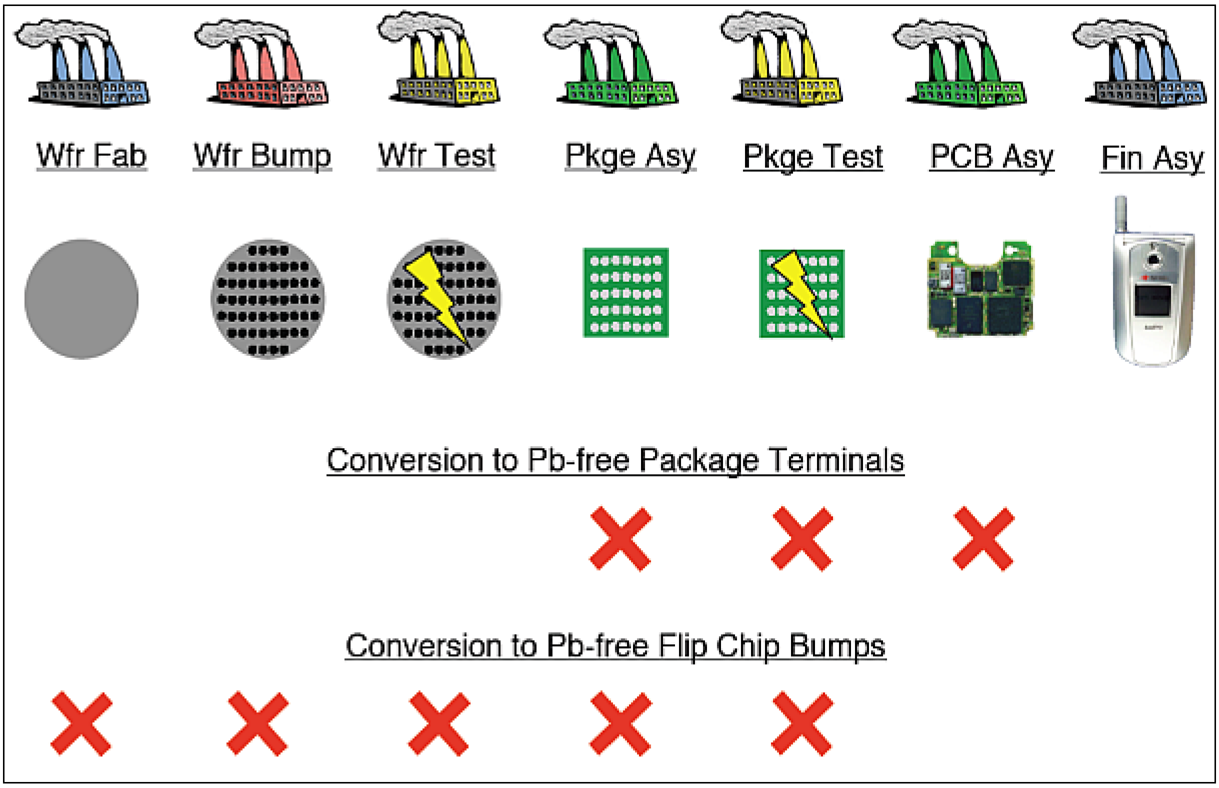
The stakeholders state that materials and design optimizations will be necessary which may require invention to overcome technical challenges such as electromigration, thermo-mechanical stress failure and to develop a solder melting temperature hierarchy. [3]

The stakeholder say that, as innovations are made in a particular application space (high reliability) or technology node (45 nm for example), they will be introduced to the market on an ongoing basis. These changes will preclude any back proliferation of these new lead-free flip chip technologies to older designs or technology nodes (65 nm, 90 nm etc). The stakeholders [3] state that some companies may be able to transition their products early (e. g. Xilinx [4]. Xilinx [4], a developer and manufacturer of reconfigurable chips known as field-programmable gate arrays (FPGAs), states that it will be possible by 2010 to produce flip chip devices with silicon die that are less than 17 mm along each side with lead-free solder bumps. For larger dies, this will not yet be possible by then.

According to EICTA [3], such individual company roadmaps do not represent the transition to Pb-free flip chip for the industry as a whole. They state that it is a complex technical issue, and because of the diversity of technologies and the time needed to validate reliability, it will take time for the entire industry to transition.

No single Pb-free bump solution is scalable across all flip chip technologies. There are many flip chip bump applications, including small thin packages and large high density packages. There are fine pitch and larger pitch bumps. Bumps are attached to many types of silicon die. Some products must survive routine high impact, while other products must survive constant minute vibrations. Flip chip package are used in high end servers, where they have to function reliably over long life of 10 years and more. They are also used in mobile phones, where they have to withstand shocks from dropping, vibrations and frequent temperature changes from switch on/off, but only over a short life time of a few years only. Each combination of density, package design, chip and substrate requires unique development as well as product and application specific qualification.

The shift from lead-containing towards FCPs using lead-free solders on the first level needs involvement and changes throughout the entire supply chain, as the figure below shows.



Note: Conversion ot Pb-free package terminals means the use of lead-free solders for second level interconnects; Pb-free flip chip bumps refer to the first level interconnects; Wfr: wafer; Asy: assembly

Figure 34 Involvement of the supply chain into conversion of FCPs to lead-free solders

The introduction of lead-free solders on the second level only needed the involvement of the supply chain starting with the package assembly, as the red crosses indicate in the above figure. Lead-free soldering on the first level is an interference requiring adaptations starting with the die up to the final assembly. Each wafer fab is working at specific technology nodes (45 nm, 60 nm, 90 nm, …) using specific production equipment and processing. Accommodating the various and partially conflicting requirements with lead-free solders in terms of thermo-mechanical stress, electromigration, manufacturability etc. needs new design rules in the wafer fab and in the following supply chain stages, the introduction of different dielectric materials, new material combinations on the die and carrier.

Additionally, each wafer fab has its own and very specific library of design rules and processing know how. This knowledge is competitive and will not be shared with others. As a consequence, each wafer fab requires an individual approach towards the conversion of lead-free soldering with the need of alignment with the other players in the supply chain. This is a further reason why it is not possible to draw a line where lead-free soldering is possible, and where it is not, besides the application aspects.

The stakeholders claim that for these reasons, the development of reliable lead-free FCPs for all the different applications takes time. Until the Pb-free flip chip process technology matures and is proven reliable in all applications through product qualifications, RoHS exemption 15 will remain crucial for flip chip products, according to EICTA [5].

The stakeholders claim that for these reasons, the development of FCPs for all the different applications takes time.

Until the Pb-free flip chip process technology matures and is proven reliable in all applications through product qualifications, RoHS exemption 15 will remain crucial for flip chip products, according to EICTA [5].

Necessity of a transition period

Once lead-free alternative systems have been identified and are being brought to commercialization, EICTA et al. [3] suggest 24 to 60 months implementation time is necessary for qualification by the semiconductor manufacturer and by the system integrator for final product qualification.

According to EICTA et al. [3], the specific time required depends primarily on the level of reliability testing needed to confirm robustness for the target application. Factors affecting implementation time include:

(1) new equipment design, manufacture, delivery, installation and qualification times;

(2) raw material and fabricated component procurement lead times;

(3) process debug and implementation with proven quality control periods. There is not a fixed transition time for Pb-free implementation, according to EICTA et al. [3].

4.21.3 Critical review

Confinement of stakeholders' arguments

The stakeholders plausibly explain the constraints related to the use of lead-free solders for level 1 interconnects in flip chip packages. The use of lead-free solders imposes additional problems in manufacturing of flip chip packages (FCP) as well as in their application, as the stakeholders describe.

Not all the stakeholders' arguments, however, actually are valid. In FCPs using underfills, the solder hierarchy issue is less severe or not an issue in case the underfilling is done carefully. The underfill keeps the first level solders in place and shape if they remelt during the reflow process for the attachment of the FCP to the printed wiring board. The use of underfills is common in FCPs.

On further inquiry, the statement could not be confirmed that the higher resistance of lead-free solders should be the root cause for stronger electromigration in lead-free solders. Electromigration, according to IBM, is a phenomenon mainly related to the interfaces of the solder joints and the underbump metallization/finishes. The selection and combination of materials forming the interfaces is crucial, not the resistance of the solder joint, or at best indirectly. Electromigration occurs with eutectic (SnPb37) solders as well, and it is not ultimately clear that lead-free solders perform worse in any case.

Restriction of exemption 15

Nevertheless, the stakeholders' arguments justifying exemption 15 make clear that the introduction of lead-free solders introduce new challenges difficult or currently even impossible to overcome. This applies to both the manufacturing as well as the application of lead-free FCPs. Lead-free FCPs cannot yet be manufactured neither for the whole of the FCP product range, nor for all applications where FCPs are integral and indispensable for the proper functioning and performance of state of the art products.

As lead-free FCPs nevertheless are available, the crucial question for this review process is whether and how far the use of lead on level 1 solder joints in flip chip packages can be limited to those applications where lead can not yet be substituted or eliminated.

EICTA [5] claims that the segmentation of FCPs or applications where lead-free solders can be used is not possible. The manufacturing and the use of lead-free soldered FCPs has to take into account many influencing and limiting aspects both on the manufacturing as well as on the application side, such as:

1. FCP-specifications
   a) Die size/edge length
   b) Die thickness
   c) Bump size
   d) Bump pitch
   e) Technology node
   f) Organic/ceramic carrier
   g) Dielectric material
   h) Materials, types and combinations of under bump metallization, finishes, solder
   i) With/without underfill
2. Application conditions
   a) Power/current density
   b) Hours on power
   c) Life time
   d) Reliability and operational requirements
   e) Application specific thermal and/or mechanical impacts

Nevertheless, Xilinx [4] claimed that by 2010 it should be possible to manufacture FCPs with less than 17 mm of die length with a reliability, which is lower than for the lead-containing FCPs, but sufficient. Xilinx was asked whether FCPs with less than 17 mm length dies could be excluded from exemption 15, and whether the die size actually would be a sufficient parameter to limit the exemption. No answer was received, and this stakeholder comment hence could not be taken into further account. Despite of this claim, Xilinx, however, supports the other stakeholders' arguments.

Based on the information submitted and confirmed by the stakeholders, a restriction of exemption 17 seems not to be possible in a way that would accommodate the technical situation as well as the need for a clear and manageable exemption wording. Opposing views of other stakeholders are not available.

Setting an expiry date

Simple and even more complex lead-free FCPs are available already, and their numbers will increase in the coming years. Art. 5 (1) (b) in this case requires the limitation of the exemption to those cases, where the use of lead in FCPs is technically impracticable. The stakeholders, however, explained that the restriction of exemption 15 to certain types and/or applications of FCPs is not possible due to the technical complexity.

To adapt exemption 15 to the technical and scientific progress, it is recommended to set an expiry date equivalently to other exemptions with a similar situation, like e. g. exemption 7b.

Time is required on one hand for the production start and qualification of the lead-free flip chip packages once the concept and design is available. The stakeholders [3] indicate a minimum of 24 months from this time on to prepare and start up full production and for a complete qualification along the whole supply chain into specific applications.
On the other hand, time is necessary to convert and further develop existing lead-containing FCPs into lead-free ones, or to develop completely new packages. Based on the information available, it is not yet clear when this can be achieved across the entire FCP product and application range. In any case, the time required for the qualification of these packages would add to the time when the lead-free FCP is available.

The reviewers hence recommend the expiry date 31 July 2014. According to the stakeholders, it is not yet be clear whether at this time in the future actually all FCPs will have been fully converted to lead-free solders. In this case, however, either the stakeholders can apply for the continuation of the exemption in its current wording, or the exemption can be adapted to the state of the art at that point in time. The situation might be different from now and allow such restrictions.

4.21.4 Recommendation

Based on the available information from stakeholders', and in the absence of opposing views, the overall situation justifies the continuation of the exemption in line with Art. 5 (1) (b).

Lead-free flip chip packages are on the market. Art. 5 (1) (b) in this case requires the limitation of the exemption to those cases, where the use of lead in FCPs is technically impracticable. The technical complexity, according to the stakeholders, makes it impossible to restrict the exemption.

Instead of restricting the exemption, the consultants therefore recommend the expiry of the exemption on 31 July 2014. Additionally, the new exemption wording should allow repair and reuse of equipment put on the market before the expiry of the exemption.

The new wording is proposed as follows:

Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages until 31 July2014, and for the repair, or to the reuse, of electrical and electronic equipment put on the market before 1 August 2014.

4.21.5 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] EICTA stakeholder document "EICTA Position on RoHS Exemption 15 8th August 2008.pdf"

[3] EICTA et al. on ex. 15; Stakeholder consultation document "Exemption_15_EICTA_and-others_1_April_2008.pdf"

[4] Xilinx stakeholder consultation document "Exemption15-Xilinx_Report_13_March_2008.pdf"

[5] EICTA stakeholder document "EICTA Position on Exemption 15 14th Oct 2008.pdf"

[6] Stakeholder document "RoHS v3.pdf", submitted by AMD, Freescale, IBM, Intel, Qualcomm and Texas Instruments

4.22 Exemption No. 16

“Lead in linear incandescent lamps with silicate coated tubes”

This exemption had originally been reviewed by ERA [1]. Incandescent lamps with silicate coated tubes are a special kind of incandescent lamp used mostly in bathroom lighting due to their good colour rending properties.

According to stakeholders substitutes exist for the use of lead in the coating and the exemption is thus not needed anymore. Incandescent lamps are foreseen to be phased-out from the EU market anyway and the market relevance is thus negligible.

4.22.1 Recommendation

Since substitutes exist and since these types of lamps have no further market relevance it is recommended to withdraw this exemption.

Transition period

Since supply chains need to adapt to the new situation a transition period of 18 months is recommended. Meaning that under the assumption that an amended RoHS Annex will be published in the Official Journal by the end of 2009, a transition period until mid 2011 is recommended.

Spare parts

A spare parts clause is not needed in this case since lamps as such are not repaired with lead-containing spare parts.

Category 8&9

As far as the contractor is aware there is no effect of the recommended withdrawal on category 8&9 equipment.

4.22.2 Reference

[1] ERA-Report 2004; Dr. 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”

4.23 Exemption No. 17

"Lead halide as radiant agent in High Intensity Discharge (HID) lamps used for professional reprography applications"

4.23.1 Description of exemption

Based on a request of the European Lamp Companies Federation (ELC), lead in the form of PbI_2 as component in filling of certain High Intensity Discharge (HID) lamps had been exempted from the requirements of the RoHS Directive. The function of PbI_2 consists in creating specific lines in the emission spectrum of the lamp, necessary for several professional UV applications: curing, reprography and label printing industry.

According to ELC's information at that time, the total annual amount of PbI_2 in this application had been about 10 kg (total EU market, 2004 figures) [1]; in its contribution to the stakeholder consultation carried out within this review, ELC numbers the annual amount of lead in this application less than 1 kg/yr, present as PbI_2. Furthermore, the number of lamps is assumed to be below 100.000/yr, according to a decrease compared to 2003 of about 50%. This decline would be in line with ELC's earlier projected decline of -10% per year [2].

4.23.2 Justification by stakeholders

ELC forwarded the only contributions within this review [2] [3]. ELC requested a continuation of this exemption, regarding efforts towards substitution of PbI_2 as component in filling of certain High Intensity Discharge (HID) lamps. ELC argued that no investigation had taken place to find substitutes, due to the low amount of lead per lamp, the overall relatively small and decreasing number of products, and the inability to substitute by another filling agent [2].

According to its earlier statement, ELC justified the request technically [1]: no substitutes were known that result in a comparable emission spectrum and efficacy. These lamps were mostly used for professional reprography applications (diazo-printing), whereas this technology was being gradually replaced by digital printing, leading to the decline in lamps being brought on the above-mentioned market. Therefore, no new systems were built with this type of lamps. For the same reason, no design changes were planned.

4.23.3 Critical review

Basically, the continuation of the current exemption should be granted, as viable substitutes obviously do not exist. Due to the technological changes to digital printing, substitution at system level would affect both reprography processes and equipment. Such efforts to redesign are definitively impracticable.

Against the background that the lamps could be expected mainly to be used for maintenance, the contractor took a rewording of the existing exemption[38] into consideration. ELC does not see a need to change the existing wording [3], as the term "mainly" would be misleading, as it would still allow the usage of the lamp either in old or (if applicable) in new equipment. As the use of this kind of lamps is very limited and therefore only very few lamps are affected, mainly (if not all used in old reprography equipment), the new wording would not reduce the use of lead.

4.23.4 Recommendation

Taking into account the above-mentioned situation, and especially the difficulty to narrow the scope of the exemption, the contractor recommends continuing the existing exemption. Due to the very low volume of lead (less than 1 kg/yr) and the declining usage of the specific type of lamps there is no need to add an expiry date to the wording of this exemption. Furthermore, it would be counterproductive not to continue the existing exemption and to set an expiry date due to the fact that these lamps will mainly be used as spare parts for existing equipment, thus enabling its further use. The consultants propose 31 July 2014 as expiry date, which is beyond the next RoHS Annex Revision, giving stakeholders the opportunity to submit evidence for the further need of this exemption in the next review of the Annex.

According to the stakeholders' contribution, it is not possible to appoint whether and to which extent applications attributable to WEEE categories 8 and 9 are affected by this specific exemption.

4.23.5 References

[1] Gensch et al. 2005; Adaptation to scientific and technical progress under Directive 2002/95/EC. Monthly report 2, final version. Freiburg, 28 October 2005

[2] ELC submission to RoHS exemption #17. Brussels, 31st March 2008

[3] Further ELC input to RoHS Exemptions 5, 7a, 16, 17, 18, 19, 20, 26. Brussels, 8th August 2008

[38] "Lead halide as radiant agent in High Intensity Discharge lamps used mainly for maintenance".

4.24 Exemption No. 18

"Lead as activator in the fluorescent powder (1% lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP (BaSi2O5:Pb) as well as when used as speciality lamps for diazo-printing reprography, lithography, insect traps, photochemical and curing processes containing phosphors such as SMS ((Sr,Ba)2MgSi2O7:Pb)"

4.24.1 Description of exemption

Following a request of the European Lamp Companies Federation (ELC), an exemption had been granted for lead activated UV emitting phosphors as used in low pressure Hg based fluorescent lamps. The functionality of this substance can be described as follows: the lead containing solid phosphor matrix determines both effective UV-C absorption (from the low pressure mercury discharge) and effective generation of (mainly) UV-A emission.

Applications for lamps containing lead as activator in the fluorescent powder are:

- sun tanning lamps, containing phosphors such as BSP (BaSi2O5:Pb) with an emission peak of 350 nm (ELC quoted in [1]).
- certain specialty lamps (applications: diazo-printing reprography, lithography, insect traps, photochemical and curing processes), containing phosphors such as SMS ((Sr,Ba)2MgSi2O7:Pb) and generating a broad emission peak centred at 360 nm (ELC quoted in [1]).
- pet care fluorescent lamps (e.g. for reptiles and birds) [2].

The specific energy demand of these kinds of lamps ranges from 4 to 200 W.

According to the current information brought forward by ELC, the total annual amount of lead put on the EU market is less than 1 ton. In the previous review of the request for this exemption, ELC had numbered the total annual amount of lead in these applications being approx. 600 kg (total EU market, 2004 figures) [1].

4.24.2 Justification by stakeholders

ELC forwarded the only contributions within this review [2] [3]: according to the information provided by ELC, a powder without lead is currently under development, however, proof of functionality and performance for different applications is needed. Possible substitutes could be rare earth phosphates, activated by rare earth ions[39]. However, ELC comments that a simple material substitution was not feasible, since a broad lamp product range and applica-

[39] YPO_4:Ce as an example for a lead-free UV emitting phosphor, La(PO_4):Ce as an example for a UV-B emitter.

tion range needed to be covered. A change to lead-free powder was not going to not change the energy efficiency.

The lamp industry (manufacturers and suppliers) searches for alternatives. Technical feasibility has not been demonstrated so far beyond development status. Especially in the case of sun tanning lamps there are specific requirements of safety standards which are explained by ELC as follows [2]:

"In accordance with EN standard 61228 Ed.2 (2008-01) sun tanning lamps need to be marked with indicators for the erythemally-weighed UV radiation, so-called X and Y marking. In order to satisfy the requirements for new lamps and for retrofit lamps for existing sun beds, sun tanning lamps usually contain a mixture of two fluorescent powders, one emitting primarily UV-A and one primary emitting UV-B. When properly mixed, desired output spectrum arises. The lead-free phosphor however emits both UVA and B. In practice not all required spectra can be created. The abovementioned EN standard forms the basis of lamp marking, and is required. It clearly limits room for substitution by lead-free phosphors. The regulatory demands come from the LVD ADCO group."[40]

Against this background, ELC calls for a continuation of the existing exemption for sun tanning lamps. For other applications a feasible expiring date of the existing exemption should be 18 months after publication.

4.24.3 Critical review

According to the information provided by the branch association, substitution of lead in UV emitting phosphors seems to be feasible from a scientific point of view. The time frame for implementation of 18 months after publication would be considered technically as challenging but practicable.

Unlike all other applications, sun tanning lamps need to fulfil specific safety requirements, and corresponding standards make substitution more difficult. This does not eliminate the possibility that consumer safety benefits are outweighed through substitution of lead activated UV emitting phosphors. Taking this situation into account and against the background that the amounts of lead are relatively small, a continuation of the current exemption seems appropriate.

4.24.4 Recommendation

Taking the above-mentioned implications into account, the existing exemption covering a broad range of applications should not be continued. A transition period of 18 months after publication (mid 2011) should be granted in order to ensure the technical implementation of

[40] http://ec.europa.eu/enterprise/electr_equipment/lv/guides/index.htm

substitutes. In order to ensure consumer safety in the case of sun tanning lamps, we recommend a revised wording of the current exemption as follows:

Lead as activator in the fluorescent powder (1% lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP ($BaSi_2O_5$:Pb).

The consultants propose 31 July 2014 as expiry date, which is beyond the next RoHS Annex Revision, giving stakeholders the opportunity to submit evidence for the further need of this exemption.

According to the stakeholder's contribution, it is not possible to appoint whether and to which extent applications being attributable to WEEE categories 8 and 9 are affected by this specific exemption.

4.24.5 References

[1] Gensch et al. 2005; Adaptation to scientific and technical progress under Directive 2002/95/EC. Monthly report 2, final version. Freiburg, 28 October 2005

[2] ELC submission to RoHS exemption #18. Brussels, 31st March 2008

[3] Further ELC input to RoHS Exemptions 5, 7a, 16, 17, 18, 19, 20, 26. Brussels, 8th August 2008

4.25 Exemption No. 19

"Lead with PbBiSn-Hg and PbInSn-Hg in specific compositions as main amalgam and with PbSn-Hg as auxiliary amalgam in very compact Energy Saving Lamps (ESL)"

4.25.1 Description of exemption

The current exemption was granted on request of the ELC for very compact Energy Saving Lamps (ESL) with PbBiSn-Hg and PbInSn-Hg in specific compositions as main amalgam and PbSn-Hg as auxiliary amalgam. According to the information provided by ELC to justify the exemption these substances control the Hg-vapour pressure inside small compact fluorescent lamps (especially the types with a closed cover) stabilizing the light output and lamp efficacy over a wide ambient temperature range, which would make it possible to replace incandescent lamps by energy saving lamps in a wide range of applications, both indoor and outdoor. Energy Saving Lamps would only be producible in GLS dimensions and shape when Pb-containing amalgam could be applied.

The current annual amount of lead is numbered by ELC as 200 kg/yr [2]; this value is corresponding to indication given in 2005 with about 300 kg (assuming that 15 Million out of 150 Million CFL-I lamps sold across Europe contain max. 20 mg Pb contained in amalgam (total EU market, 2004 figures, [1])).

4.25.2 Justification by stakeholders

ELC forwarded the only contributions within this review [2] [3]: According to the information provided by ELC, R&D had led to the identification of suitable lead-free alternatives. In the laboratory, amalgams without lead had been determined. Full scale implementation is planned for the upcoming 2 years.

4.25.3 Critical review and recommendation

Taking the above mentioned technical development into account, substitutes are available for which reason a continuation of the current exemption could not be justified further on. In order to ensure the technical implementation a transition period of 18 months after publication (mid 2011) is proposed. According to the stakeholders' contribution it is not possible to appoint, whether and to which extent applications being attributable to WEEE categories 8 and 9 are affected by this specific exemption.

4.25.4 References

[1] Gensch et al. 2005; Adaptation to scientific and technical progress under Directive 2002/95/EC. Monthly report 2, final version. Freiburg, 28 October 2005

[2] ELC submission to RoHS exemption #19. Brussels, 31st March 2008

[3] Further ELC input to RoHS Exemptions 5, 7a, 16, 17, 18, 19, 20, 26. Brussels, 8th August 2008

4.26 Exemption No. 20

"Lead oxide in glass used for bonding front and rear substrates of flat fluorescent lamps used for Liquid Crystal Displays (LCDs)"

4.26.1 Description of exemption

The exemption at hand was granted on a request of Samsung Corning Co. Ltd which was nearly in full accordance to the request of the European Lamp Companies Federation (ELC) on "mercury free flat panel lamp assembled by using lead containing glass solder" [1]. The request at that time was justified taking technical criteria as well as environmental/toxicological criteria into account [1]:

- "A number of possible substitutes for PbO as sinter material was evaluated (bismuth glass, zinc borate glass, tin phosphate glass). None of these potential substitutes met the required properties being softening temperature (adjustable between 350 to

600°C), adhesive strength, thermal expansion coefficient (similar to glass substrate) and chemical stability.

- Possible substitutes require higher calcination temperatures to improve the sintering characteristics leading to add ional energy consumption during production. Furthermore lead oxide-free glasses would require more energy due to the high softening temperature of these glasses.
- From a toxicological point of view all raw and basic materials used for possible substitutes are critical."

There is a direct interlinkage between the exemption at hand and exemption 31 "Lead in soldering materials in mercury free flat fluorescent lamps (which are e.g. used for liquid crystal displays, design or industrial lighting".

4.26.2 Justification by stakeholders

During this review, several contributions were provided:

- One stakeholder (who indicated its comment being not intended for publication) argued that the exemption would be further on needed for spare parts, because they are subject for reproduction. Otherwise there would be major redevelopments necessary for spare parts, but this would be from economic point of view no practicable.
- In their joint industry contribution COCIR, Eucomed and EDMA argued for a continuation of the exemption with reference to the specific requirements to medical devices. The current exemption would be needed by any modality employing a flat LCD monitor and the technology may impact the diagnostic sector [2].
- ELC pointed at the fact, that exemption 31 would not be covering exemption 20 completely as exemption 31 would be limited to mercury-free lamps, while exemption 20 would cover also mercury-containing lamps in one special application. As the affected lamps were not produced by ELC members, ELC informed stakeholder(s) in charge in order to give input to Öko-Institute, if the exemption 20 is needed in the future [3].
- In a further statement ELC stated that exemption 31 had a broader scope regarding application of the lamp but being limited to mercury-free lamps. ELC argues furthermore, there were no manufacturers known to ELC members, who would need exemption 20 any longer [4].

4.26.3 Critical review and recommendation

Within the scope of this review there were no contributions received by manufacturers of flat fluorescent lamps used for Liquid Crystal Displays (LCD), although this fact was well known by all relevant actors of the value chain. Against this background it is assumed that there are meanwhile viable substitutes for lead oxide available. Furthermore, there are no technically significant facts known that especially products relating to WEEE categories 8 and 9 require lead oxide in glass used for bonding front and rear substrates of flat fluorescent lamps used for Liquid Crystal Displays (LCD).

Taking this into account we recommend not continuing the existing exemption. In order to ensure the technical implementation a transition period of 18 months after publication (mid 2011) is proposed.

4.26.4 References

[1] Gensch et al. 2005; Adaptation to scientific and technical progress under Directive 2002/95/EC. Monthly report 4, final version. Freiburg, 20 December 2005

[2] Joint Industry contribution to the ÖKO Institute's consultation on the Actual Exemptions from the RoHS Directive. Brussels, 01 April 2008

[3] RoHS Revision: Exemption 20. E-mail Dr. Georg Niedermeier, June 11, 2008

[4] Further ELC input to RoHS Exemptions 5, 7a, 16, 17, 18, 19, 20, 26. Brussels, 08 August 2008

4.27 Exemption No. 21

"Lead and cadmium in printing inks for the application of enamels on borosilicate glass"

4.27.1 Description of exemption

The exemption came into force on 12 October 2006 based on the recommendation by Öko-Institut and Fraunhofer IZM to grant the exemption [1]. However, it was recommended to review this exemption including the following aspects:

- Do ESGA and ELCF represent all relevant stakeholders in this field of application or which other relevant stakeholders can be identified?
- Can all relevant stakeholders agree on the interpretation of glass marked with lead (and cadmium) containing inks as being a homogeneous material? Is this possibly valid only for lead or cadmium?
- Can cadmium-free printing inks also be used on borosilicate glass for applications ESGA initially requested an exemption for (e.g. coffee jugs)?

If an exemption appears to be further needed, it should be checked with stakeholders whether borosilicate and soda lime glass applications concerned – for which substitution is not feasible – can be listed exhaustively in order to narrow down the scope of the exemption.

Since the technological context of this application has not changed since, the general description is reproduced from [1] and updated with [2]:

The European Special Glass Association (ESGA) on behalf of the Duran Group had requested an exemption for the use of lead and cadmium in enamels on borosilicate glass. The substances are contained in inks printed on borosilicate glass in certain electrical and electronic equipment (for the major part on jugs for coffee makers and water kettles). The ink is used to print scales, warnings and logos on the glass.

The ink being considered a homogenous material contains between 37% and 48% PbO by weight and up to 11% CdO by weight. For the overall European market this leads to an annual consumption of 100 kg Pb and 2,6 kg Cd.

The lead in the ink is responsible for lowering the melting point, thus positively influencing the fusion with the glass matrix, and improving chemical resistance. As part of customer specification and consumer safety, the readability of markings in the case of coffee makers and water kettles has to be guaranteed for 400 dish-washer-cycles. Cadmium together with the lead gives the enamel a good resistance against temperature, acids and alkalis as they are used in domestic cleansers. Cadmium is thus also necessary to guarantee long-lasting markings.

4.27.2 Justification by stakeholders

The former applicant had argued that there is no substitute for lead and/or cadmium in the ink for printing markings on borosilicate glass and Duran has supported this with a new stakeholder comment in the context of the current evaluation [2]. There are lead-free alternatives available but these cannot guarantee the resistance to temperature, acids or alkalis. Since the relevant application is used for products that are regularly cleaned in dish-washers the applicant states that no lead-free alternative can be used. Concerning the low melting point function of lead the applicant states that there is no alternative lead-free ink that can be used on borosilicate glass.

In order to clarify potential substitutes the following questions were raised during the initial evaluation as described in [1]:

- Is it possible to mark the glass with etching/engraving instead of printing?
- Is it possible to use another kind of glass which does not need lead to lower the melting point of the ink?
- Is it possible to eliminate the marking on the glass completely?

The former applicant justifies the necessity of an exemption continuation as follows [1] [2]:

- It is technically possible to substitute marked glass by non-marked glass. However, marking is necessary for the functionality of the application and/or consumer safety.
- Marking the glass with etching/engraving does not seem to be technically feasible due to cracks and not sufficient resistance to acids and alkalis.
- Substituting the borosilicate glass by another kind of glass which would not require a low-melting point ink does not seem to be feasible since the glass has to meet specific

characteristics (e.g. resistance to heat, fast changes between hot and cold filling) which are not met by other glass types.

There is the theoretical possibility to use lead-free printing inks using other heavy metals such as bismuth. Trials carried out by the applicant did not lead to useful results: the lead containing ink passes more than 200 cycles in the dishwasher while the bismuth containing one passes only 50.

Duran itself is purchasing the inks in order to print them onto the glass. It claims that suppliers have no economic interest in developing lead and/or cadmium-free printing inks since the application on borosilicate glass is a niche market.

4.27.3 Critical review and recommendation

No stakeholder comments were received during the consultation period. Thus the questions which were identified formerly by Öko-Institut and Fraunhofer IZM [1] have not been addressed in depth as initially expected. Upon direct request the former applicant has sent a stakeholder comment. Furthermore ELC confirmed that their position recorded in the previous report [3] is still valid. According ELC, lead is used in printing inks on parts of the outer surface of lamps (e.g. fluorescent lamps). These markings are essential for product identification, as requested by safety standards. The marking has several functions, during entire life cycle:

- To identify the producer,
- to identify lamp type and wattage, which is relevant for safety, correct lamp replacement and recycling,
- CE, WEEE marking.

In this context it must be noted that the glass type being used for lamps are soda lime glasses, which are not covered by the existing wording of the exemption.

Independent of the situation that there is not much general interest with regard to this exemption it appears that substitutes fulfilling the criteria for durability of the marking do not seem to exist.

It is therefore recommended to continue the existing exemption as it is until the next review period, but to adjust the wording in order to ensure legal certainty (for details see [3]):

"“Lead and cadmium in printing inks for the application of enamel on glasses, such as borosilicate and soda lime glasses.”

Transition period and expiry date

Since the exemption is recommended to be continued no transition period is necessary. Assuming an official publication of an amended RoHS Annex by end 2009, the expiry date is recommended to be set four years later at 31 July 2014. Setting an expiry date will increase the incentive for research into lead and cadmium-free alternatives.

Spare parts

No spare parts clause is necessary at this stage since the exemption remains unchanged. However, once the exemption will have expired, a clause should be added that spare parts for what used to be applications covered by exemption 21 are exempted from substance use restrictions.

Category 8&9

There are no related category 8&9 applications known to the consultant. Since the exemption remains unchanged there are no effects onto products belonging to these categories.

4.27.4 References

[1] Gensch et al. 2005; Adaptation to scientific and technical progress under Directive 2002/95/EC. Monthly report 3, final version. Freiburg, 21 November 2005

[2] Stakeholder comment by Duran Group from 08 September 2008

[3] Öko-Institut e.V., Fraunhofer IZM: Adaptation to Scientific and Technical Progress under Directive 2002/95/EC; final report; document "Final_Report_RoHS-Exemptions-October_2007.pdf"

4.28 Exemption No. 22

"Lead as impurity in RIG (rare earth iron garnet) Faraday rotators used for fibre optic communication systems"

JEITA (Japan Electronics & Information Technology Industries Association) on behalf of NEC Corporation and Murata Manufacturing Co., Ltd and SUMITOMO METAL MINING CO.,LTD. requested this exemption for lead in optical isolators in the first stakeholder consultation on exemption requests in 2004/5 as exemption request no. 10 (http://ec.europa.eu/environment/waste/rohs_consult.htm). The exemption was recommended to be granted (Öko-Institut Report 2006; Annex 1 Monthly Report 3). After a stakeholder (Integrated Photonics) had submitted evidence that lead-free RIG Faraday rotators are available on the market, the originally positive recommendation was cancelled and it was then recommended not to grant this exemption (Öko-Institut Report 2006; Final Report). Unfortunately, by the time the 2006 final report was published, the initial positive recommendation given in monthly report 3 (Öko-Institut Report 2006; Annex 1 Monthly Report 3) had already been adopted by Member States and was then published in Commission Decision 2006/691/EC.

In 2006, in the 6th stakeholder consultation (http://ec.europa.eu/environment/waste/rohs_6_consult.htm, request no. 21), Integrated Photonics (IPI) challenged the exemption again and requested to withdraw it. IPI claimed to have a RoHS compliant solution.

Other stakeholders opposed the withdrawal of the exemption claiming that it will take time until lead-free rotators are qualified for use up the whole supply chain after the broad availability of such lead-free rotators.

It was recommended to revoke the exemption (Öko-Institut Report 2007; Annex 1 Monthly Report 6). Nevertheless, the exemption is still listed as exemption no. 22 in the Annex of the RoHS Directive and hence is subject to this general review of all existing exemptions.

4.28.1 Description of the requested exemption

The function of optical isolators consists in the reduction of reflection noise in several optic communication systems (transceiver, transmitter and receiver, optical amplifier). For this purpose rare earth iron garnet (RIG) are used because of their magneto-optical effect. The garnet crystal is grown by the so called LPE (liquid phase epitaxial) method which uses lead oxide as flux material. Lead is included into the crystal as an impurity.

The total quantity of lead used in RIG Faraday rotators worldwide is around 60 g per year according to JEITA (http://circa.europa.eu/Public/irc/env/rohs/library?l=/requests_exemptions/optical_isolators&vm=detailed&sb=Title).

4.28.2 Summary of justification for the exemption

Applicant's criteria for justification

The stakeholders supporting the exemption are aware that several RIG Faraday rotator manufacturers are on the market with lead-free products [1]. The supporting stakeholders argued that the RIG Faraday rotators, once they are available in lead-free, RoHS compliant versions, need to be handed through the supply chain with qualification necessary at each level of this supply chain. The following figure depicts the different stages of the qualification procedure.

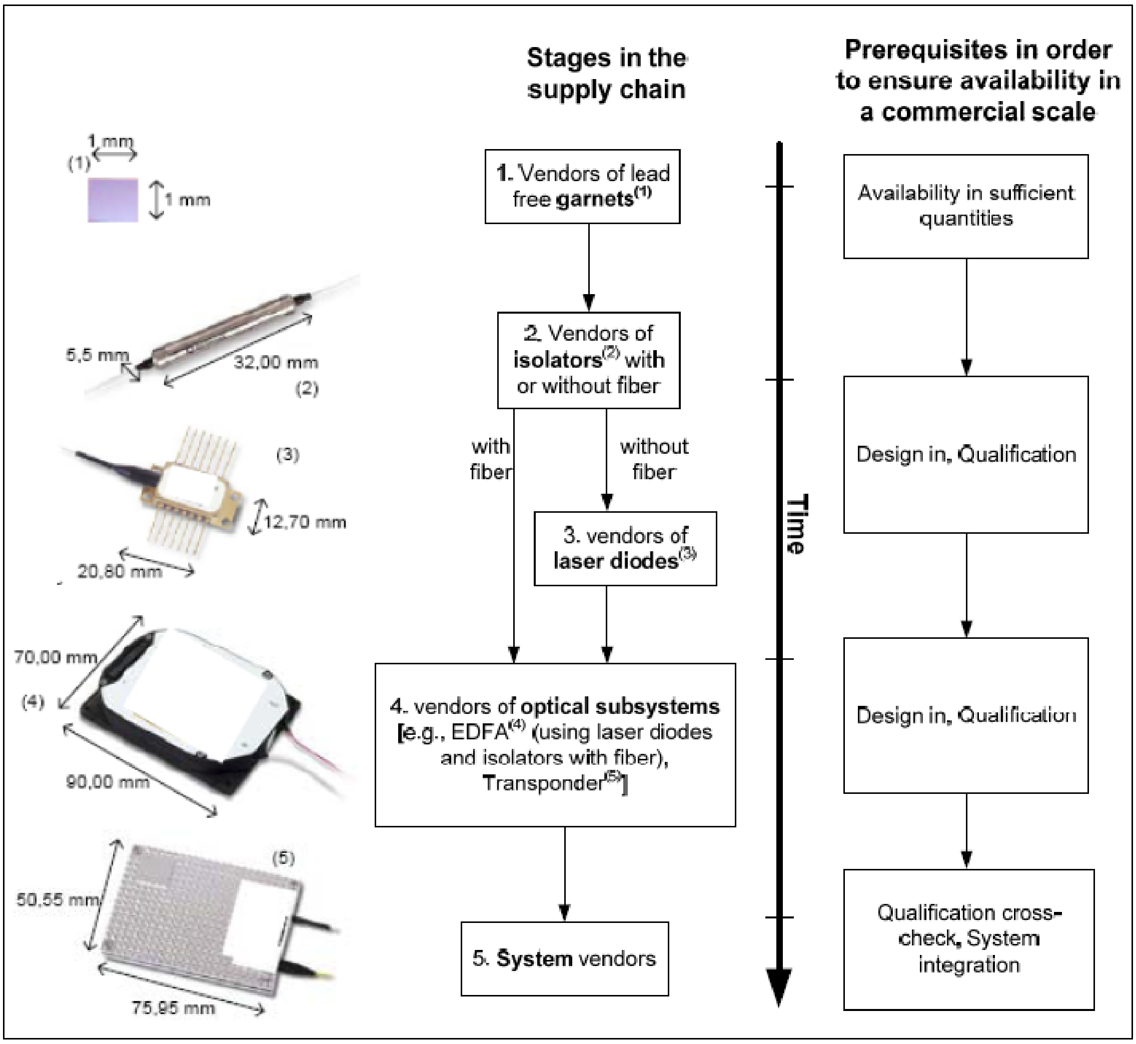


Figure 35 Overview of stages in the supply chain for fibre-optic communication networks [1]

The stakeholders supporting the exemption argued in January 2007 that the qualification procedure would require 36 months. These stakeholders hence request the exemption to be continued until January 2010. In this current exemption review round, they maintain this request.

IPI states that it had RoHS-compliant RIG Faraday rotators on the market since 2001, and that since IPI's submission to the stakeholder consultation in 2006 more than two years of time had been available for testing. IPI further on states that more RIG manufacturers announced RoHS compliant RIGs to be available since early 2007 and hence there was enough time for testing. IPI therefore wants the withdrawal of exemption 22. ([3], status March 2008]).

Qualification procedure along the supply chain

On further request, the stakeholders detailed the testing procedures and their durations. The following four standards are used in the testing at several stages in the supply chain [2].

1. Polarization independent isolators:
   Standard: Telcordia GR-1221 CORE
   Duration: 3 months minimum.
2. LD modules, transceivers:
   Standard: Telcordia GR-468 CORE
   Duration: 7.5 months (LD modules) with subsequent transceiver testing for another 3 months.
3. Fibre amplifiers:
   Standard: Telcordia GR-1312 CORE
   Duration: 6 months.
4. Network system equipments:
   Standard: Telcordia GR-63 CORE
   Duration: 3 months at systems manufacture, then at network lab tests another 3-6 months.

The total testing and qualification time sums up to 36 months, according to the stakeholders supporting the continuation of the exemption. They claim that it takes about 26 months from the identification of a qualified substitute at the isolator level until the final approval for installation in a network [2].

Qualification timeline for obtaining compliant devices with the new isolators includes development efforts, testing, and sourcing activities. For the development and testing activities, there are several layers with multiple tests required to be completed. Many of the tests at the TOSA (Transmit Optical Sub-Assembly) and transceiver level can be done in parallel reducing the total test time. For example, at the module transceiver level, qualification takes around 3 months then, comprising High Temperature Operating Life tests for 2000 hrs, Operational Damp Heat for 1000 hrs, Thermal Cycle testing for 500 cycles etc. [2].

Once a suitable isolator supplier has been identified with the 3 months of the above GR-1221 testing completed, the initial design and manufacturing processes for assembly with the new material would be less than 2 months of activity, building several alpha samples for the Design Verification Testing (DVT) to compare the performance level to the existing supply sources. These devices would then be used in the qualification of the TOSA assembly completing the Telcordia GR-468 testing in approximately 7.5 months for a given supplier of the isolator after the supplier's GR-1221 component level tests are complete [2].

Volume production of the isolator and TOSA is required to initiate the GR-468 testing as the test requires production level devices. With 13 months of development and qualification testing having passed since selecting the isolator components, the transceiver level development DVT activities commence. Approximately 2 months pass for full mechanical, electrical and optical DVT testing of alpha/beta transceiver devices [2].

Once this qualification stage is passed, it is started into production with GR-468 module level testing to be completed over a 3 month period as described earlier. For some suppliers this testing takes as long as 8 months due to resource limitations. Network systems providers then would conduct their respective DVT and qualification testing, consuming another 2 months for DVT and 3 months for qualification [2].

Over 23 months of development and testing time alone has passed before the first network lab testing commences, which will take approximately 3 more months and then the material would be ready for network testing. The total time sums up to around 26 months. No consideration is given for the sourcing and delivery issues between each part of the supply chain in the timetable provided here [2].

Importantly, much of the activity at the systems equipment manufacturing level depends on having a minimum two qualified sources for the isolator in the module level supply chain to ensure continuity of supply and order fulfilment before qualification and subsequent carrier qualification activities [2].

Actual GR-63 level testing would be delayed until two sources are available as the need is not for time to market, but for replacement of existing material. This process of qualifying a second source adds two months to the total testing time. Additionally, the ordering of qualified parts and shipping to the manufacturing location takes around two months and the manufacturing of final equipment and shipping to/placing on the market takes around six months [2].

The total time from the first availability of RoHS compliant Faraday rotators (garnets) to the sales start of the product along the supply chain adds up to 26 + 2 + 2 + 6 = 36 months [2].

IPI opposes this 36 months testing time stating that new compliant Faraday rotators are identical in form, fit, function, technical specifications and even composition (omitting the lead impurity of course) [3]. IPI says that the qualification thus is a relatively trivial matter which is only important at the first level of device manufacturing [3].

The stakeholders supporting the exemption explain that minor changes at the RIG physical properties (and their statistical distribution) may seem negligible to the manufacturer of these RIGs, but subsequent levels of integration may see unexpected issues. In addition, every step in the manufacturing process introduces additional stresses (mechanical, temperature,...) to the RIG. During the subsequent levels of integration the various sub-manufacturers must ensure that the statistical variations do not cause areas in the full range of functionality where a portion of the final modules would not meet their specification. The stakeholders therefore insist that testing and qualification of any new component like a lead-free RIG is necessary at all levels of the supply chain.

Reference time for 36 months moratorium

The supporting stakeholders say that information from suppliers to final equipment manufacturers in 2006 showed no awareness of new lead-free RIG technologies at the first level supply chain. In late 2006, final equipment manufacturers had become aware of the availability of the alternative RoHS-compliant RIG technology at the first level in the supply chain [2].

Final equipment manufacturers contacted their supply chain on updated timelines and qualification efforts again in January 2007 and in February 2008. In January 2007, less than 20% of the suppliers had done investigations and were in the process of evaluating alternatives [2].

EICTA states that switching suppliers requires much longer, extensive qualification processes with audits of facilities and test processes [2]. Qualification of the new suppliers manufacturing locations along with their reliability test facilities/labs would have to be completed prior to more extensive device level qualification testing can start. Validation of reliability failure modes for the new supplier devices along with comprehensive studies of their suppliers manufacturing/testing processes would be needed once the new supplier is approved for engagement. Witness programs for demonstrated reliability of additional at risk technology and parts used by the new supplier would also have to be completed – in series to the earlier timeline. Thus, while switching to a new supplier with an earlier transition time may buy time from a module availability perspective it would cost additional time from a supplier qualification perspective and a module characterisation perspective.

In addition, geometrical design changes may also be required. In other words a gain of one year in terms of module availability is easily neutralised or indeed turned into a loss of more than one year. Switching suppliers therefore is no solution for final equipment manufacturers. They therefore depend on their suppliers to have RoHS-compliant solutions available [2].

The supporting stakeholders claim January 2007 as a starting point in time to which to add the 36 months for the qualification procedure. The stakeholders agree to the expiry of exemption 22, but ask for a deadline until January 2010 [1] [2] [4].

Critical review of data and information given by the applicant or stakeholders

Lead-free RIG Faraday rotators are available on the market. The substitution or – in this case – avoidance of lead in these devices is scientifically and technically practicable. The continuation of the exemption under these conditions in principle is not in line with the requirements of Art. 5 (1) (b) in the RoHS Directive.

Final equipment manufacturers, however, have quality and reliability requirements for their products and have to assume the liability in case of failures in particular in safety and high reliability equipment. The final equipment manufacturers therefore must be given sufficient time to qualify RoHS compliant materials or components following the qualification procedures in place throughout the supply chain to ensure quality and reliability and to prove this to their customers, if necessary. Otherwise, beyond liability issues, it cannot be excluded that health and/or consumer safety impacts caused by substitution are likely to outweigh health and/or consumer safety benefits of the substitution, in particular in safety-relevant equipment.

Given this situation, exemption 22 must be repealed, but granting time for the appropriate qualification of the RoHS compliant RIG Faraday rotators would be justifiable with Art. 5 (1) (b).

The stakeholders supporting the continuation of the exemption explained that a qualification of the lead-free RIGs is necessary at all stages of the supply chain. They also detailed why it takes 36 months of qualification procedures from the first availability of the lead-free RIG Faraday rotators to end products that can be put on the market. The explanation is at least plausible. It is beyond the reviewers mandate to investigate into further details of the testing and qualification procedure.

It is yet another question when the suppliers should have started the qualification procedures. IPI states that it has had lead-free RIG Faraday rotators on the market since 2001, while the final equipment manufacturers claim that they had only become aware of such lead-free alternatives in 2006 [3]. EICTA claims that it is a requirement that two sources at least must be available for such a component as part of the qualification procedure [2]. IPI states that this has been the case since 2007 latest [3].

An evaluation of the above situation requires considering the following questions:

- The RoHS Directive puts the responsibility for RoHS compliance on the producers of final equipment, not on the suppliers. How far are final equipment manufacturers in a position to have all information available on RoHS-compliant materials and components in the first stage of a long supply chain? How far can they force the different stages in the supply chain to start implementing and qualifying RoHS-compliant solutions once they are available?

- Is a single source of a RoHS compliant material or component enough to force final equipment manufacturers into its use if the qualification procedure requires at least two sources, as EICTA claims [2] in this case?

Answers to these questions would require lengthy investigations into structure of the supply chain and of the supplier-customer relationship across the supply chain, and about who informed whom at what time. For the dual-source qualification requirement, it would have to be clarified whether and how far this requirement is justified technically or by health- and safety considerations – and hence is in line with Art. 5 (1) (b). Or whether it must be considered a logistical or otherwise non-technical argument, which would not be in line with Art. (5) (1) (b) with respect to an exemption request. Very probably, a clear answer would not be possible, and the investigation would be at the margin or beyond the reviewers' mandate.

With respect to the actual expiry of exemption 22, however, it is actually of little relevance. Accepting January 2007 as the starting time for the qualification procedure, as well as the 36 months of qualification time, exemption 22 would expire on 31 December 2009. As it will probably take some time until the official amendment of the Annex in the RoHS Directive, an earlier expiry date would actually hardly make any difference. It is hence recommended to grant the exemption with the expiry date of 31 December 2009.

4.28.3 Recommendation

It is recommended to grant the continuation of the exemption until 31 December 2009. The wording of the exemption is proposed as follows:

Lead as impurity in RIG (rare earth iron garnet) Faraday rotators used for fibre optic communication systems until 31 December 2009.

4.28.4 References

[1] Stakeholder consultation document "Exemption_22_EICTA_and-others_1_April_2008.pdf"

[2] Stakeholder consultation document "EICTA Position on RoHS Exemption 22 4th August 2008.pdf"

[3] IPI Stakeholder consultation document "Exemption_22_IPI_Statement_11_ March_2008.pdf"

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

4.29 Exemption No. 23

“Lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less”

The full wording of exemption 23 currently is:

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.

This exemption was recommended to be granted in the final report 2006 by Öko-Institut and IZM [1]. It was based on an exemption request by Hewlett Packard [2].

4.29.1 Description of exemption

Substance

Lead in tin-lead finishes with typically less than 20 mass-% of lead.

Function

Provide a solderable surface on the component pins, and prevent whisker growth resulting in short circuits between the pins and further reliability problems.

Specific application

Finishes on fine pitch components with a pitch of less than 0.65 mm.

Wording as requested by applicant EICTA et al. [3] and HP [4]:

“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 exemption would result in the use of around 2 to 2.000 metric tons of lead in the EU, based on the content of 0.1 to 1 mg of lead in a typical electronic component, around 1 mg to 1 g of lead per product and the shipment of EEE into the EU. [2] [3]

4.29.2 Justification by stakeholders

EICTA et al. [3] and HP [4] justify the continuation of the exemption as follows:

Fine pitch components are required for most computer & telecommunication equipment and in other product groups. Tin “whiskers” may form on Pb-free platings and create electrical short circuits between closely spaced component terminals. 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.

The stakeholders say that lead-free finished fine pitch components have just been in broader use for around two years. Tin whiskers are not expected to occur within just two years in most product environments. Thus, current experience with Pb-free platings is insufficient to determine whether or not tin whiskers will form and create failures. 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 with 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. The vast majority of fine pitch components shipped into Europe are now lead-free, so maintaining this exemption 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.

4.29.3 Critical review

State of science and technology

EICTA et al. [3] state that 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. EICTA et al. [3] and HP [4] request the continuation of this exemption 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.

The situation as the stakeholders describe it proves that the substitution of lead is no longer scientifically and/or technically impracticable in the finishes of such fine pitch components, and a general exemption hence would no longer be justifiable in line with Art. 5 (1) (b) of the RoHS Directive. It is not possible either to grant a general exemption *now* in order to maintain a fallback option for whisker incidents that might (!) occur in several years. Art. 5 (1) (b) in this case would allow a specific exemption in cases where such concerns can be proved in line with the criteria of Art. 5 (1) (b).

EICTA et al. [3] and HP [4] further on state that maintaining the exemption does not affect the shipment of lead into the EU, as virtually all fine pitch components are available with lead-free finishes, and hence want to continue the exemption as it currently is.

This argument, however, cannot be used as an argument for maintaining the exemption. The argument proves that there is no availability problem with lead-free finished fine pitch components. It further on proves that these fine pitch components are used in many applications throughout the electrical and electronics industry. Art. 5 (1) (b) does not allow an exemption if RoHS-compliant solutions are broadly available and even in use in the market place.

The official objective of the review process is the adaptation to scientific and technical progress of the RoHS Directive's Annex. The exemptions must reflect the state of science and technology, and the current exemption 23 therefore has to be adapted to the situation described above.

Appraisal of remaining risks and restriction to 7b-equipment

Whisker problems in fine pitch components in long life, high reliability, safety- and mission-critical applications at the current state of the art cannot be excluded. The potential for serious damages in case of failures could justify the use of leaded finishes on fine pitch components in such equipment until more field experience allows a better appraisal of the related risk.

The equipment under exemption 7b was originally exempted from the lead ban because it was acknowledged as the equipment of highest reliability requirements and of highest relevance for safety. EICTA et al. [3] explicitly mention long-life high reliability equipment as a main road block against the withdrawal of exemption 7b. It is therefore recommended to limit the use of fine pitch components with lead finishes to this equipment. Thus, the stakeholders' concerns about long-term reliability in safety-critical equipment could be met.

Integration into exemption 7b

Manufacturers of high reliability long life equipment as covered by exemption 7b will avoid the use of mixed technologies. Soldering fine pitch components bearing leaded finishes with lead-free solders is considered a reliability risk that should be avoided. It must hence be assumed that manufacturers of 7b-equipment will no longer use fine pitch components with lead-finishes once they shift – or have to shift - to lead-free soldering. Against this background it makes sense to align transition periods and expiry dates for these applications of fine pitch components with the deadlines for the use of lead in equipment covered by exemption 7b.

Exemption 7b allows the use of lead in solders in high-reliability and safety-critical equipment. Finishes on components are a special case of solders, as they melt in the soldering process and become part of the solder joint. The use of lead in finishes of fine pitch and other components in high reliability, safety-critical long-life equipment thus is allowed under exemption 7b. This part of exemption 23 thus can be considered to be integrated into exemption 7b. It must not be taken into account in the adaptation of exemption 23 to the scientific and technical progress.

Transition period for other than 7b-equipment under the scope of the RoHS Directive

Some stakeholders state that they are not aware of lead-free alternatives to fine pitch components with lead-free finishes, and that they have no experience due to the missing availability of lead-free finish fine pitch components [5]. This statement does not reflect the actual situation. EICTA et al. [3] state that lead-free finish fine pitch components are broadly available and used, as already mentioned before. Fine pitch components with tin or other lead-free finishes have been available on the market since early 2004 already [6]. Problems with whiskers so far have not been reported.

The availability and the broad and successful use of fine pitch components with tin or other lead-free finishes over several years therefore forces repealing exemption 23 for equipment not covered by exemption 7b. Article 5 (1) (b) would not justify the continuation of this exemption under these conditions.

A transition period would, however, be justifiable. There should be enough time after the official announcement of the amendment of the Annex in the RoHS Directive to spread the information about the change in the global electrical and electronics industry and its suppliers. In the face of the already broad use and common availability of lead-free fine pitch components, a transition period of half a year should be sufficient.

Assuming that the amendment of the Annex in the RoHS Directive will be officially published end of 2009, exemption 23 could expire on 30 June 2010.

Repair and upgrade

Reliability considerations require the continued use of fine pitch components with lead-finishes for repair and upgrade to avoid the use of mixed technologies. Repairing, e.g., equipment with lead-soldered printed wiring boards with lead-free finish fine pitch components is not acceptable. More generally, equipment should be upgraded and repaired as it was produced. The RoHS Directive acknowledges this fact in Art. 2 (3): *This Directive does not apply to spare parts for the repair, or to the reuse, of electrical and electronic equipment put on the market before 1 July 2006.*

Art. 2 (3) allows the use of non-RoHS compliant material in electrical and electronic equipment (EEE) products put on the market before 1 July 2006 for the purposes of capacity expansion and/or upgrade provided that the EEE is not put on the market as a new product. If after the capacity expansion and/or upgrade the EEE is put on the market as a new product, it should comply with the RoHS Directive. If after capacity expansion and/or upgrade the EEE is put on the market as a reused product, the RoHS Directive does not apply. [7]

The contractor recommends to apply the same principle for the use of lead in fine pitch components covered by exemption 23 after the expiry of the exemption. A clause should be added to exemption 23 explicitly mentioning that spare parts for what used to be applications covered by exemption 23 are exempted from substance use restrictions.

Inclusion of category 8 and 9

If the COM decides to include monitoring and control instruments and medical devices into the scope of the RoHS Directive, it might become necessary to allow the use of fine pitch components with lead finishes in at least some uses, applications or technologies. Like for other safety-critical and long-life equipment, an isolated shift to lead-free soldering maintaining lead-finishes on fine pitch components – or vice versa - is not to be expected due to reliability concerns.

In case category 8 and 9 equipment needs further exemptions for the use of fine pitch components, it should be discussed in the broader context with lead in solders. Devices of these categories that need to be exempted in line with Art. 5 (1) (b) could, for example, be included into a further on amended and amplified exemption 7b, which would then also allow the use of lead in finishes of fine pitch components.

[Ringhal AB] requests an exemption of monitoring and control instruments from the RoHS-Directive regarding lead in solder and soldering technology. Monitoring and control instruments currently are not in the scope of the RoHS Directive. It is beyond the contractor's mandate to recommend a general exemption (or its rejection) for product groups that are outside the scope of the RoHS Directive. Any recommendation about future exemptions for category 8 and 9 equipment requires an own in-depth analysis and evaluation on a case-by-case basis.

4.29.4 Recommendation

It is recommended to continue exemption 23 until 30 June 2010. Following the principle already established in Art. 2 (3) of the RoHS Directive, it is further on recommended to allow the use of fine pitch components with lead in finishes with a pitch of 0.65 mm and less as spare parts for the repair, or the reuse, of electrical and electronic equipment put on the market before 1 July 2010.

The split into copper lead-frame and nickel-iron lead-frame components in the current wording of exemption 23 does not add any additional information, but just makes the exemption more complicated.

Taking into account all arguments raised above, the future wording of exemption 23 is proposed as follows:

Lead in finishes of fine pitch components others than connectors with a pitch of 0.65 mm and less until 30 June 2010, and lead in the finishes of such fine pitch components used as spare parts for the repair and reuse of equipment put on the market before 1 July 2010.

4.29.5 References

[1] Öko-Institut / IZM Report 2006, Annex 1, Monthly Reports 4 and 9, downloadable from http://ec.europa.eu/environment/waste/weee/studies_rohs1_en.htm; last access July 2008

[2] Fine pitch HP; Stakeholder consultation no. 2, http://circa.europa.eu/Public/irc/env/rohs/library?l=/requests_exemptions/resistant_applications&vm=detailed&sb=Title; last access July 2008

[3] EICTA et al. on ex. 23 Stakeholder contribution exe 23; 1 April 2008

[4] HP Stakeholder contribution exe. 23; "HP Letter to the Oeko Institut – Rev3.1.pdf"

[5] ELCF Stakeholder contribution exe. 23; 31 March 2008

[6] NXP Pb-free Product/Process Change Notification, http://www.nxp.com/profile/corporate/environment/lead_free/cpcn/index.html, last access August 2008

[7] Commission FAQ-Document Frequently Asked Questions on Directive 2002/95/EC on the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE); http://ec.europa.eu/environment/waste/weee/pdf/faq_weee.pdf, last access July 2008

[8] Ringhal AB Stakeholder contribution exe.-7-11-12-14-15-23-24-27; 01 April 2008

4.30 Exemption No. 24

"Lead in solders for the soldering to machined through hole discoidal and planar array ceramic multilayer capacitors"

This exemption request was originally applied for by Syfer Technology in the first stakeholder consultation as exemption request no. 4. The evaluation of the request was published in the Öko-Institut Report 2006, Annex 1, Monthly Report 4 and in the Final Report [1]. The Commission followed the reviewers' positive recommendation and granted the exemption without an expiry date.

4.30.1 Description of the requested exemption

Multi Layer Ceramic (MLC) discoidal capacitors and planar arrays are the heart of modern EMC discrete filters, filter assemblies and filtered connectors. They are manufactured in a similar manner to MLC chip capacitors, building up layers of ceramic dielectric material interlaced with precious metal electrodes. A hole, or array of holes, are drilled in the ceramic, and the internal and external diameters metallised or plated. The capacitance is thus formed between the bore of each hole and the outer diameter of the ceramic material. Their relatively high complexity and high cost is vindicated by their high performance, but leads them to be used primarily in areas where this performance is essential, and high reliability is critical. They do not tend to be used in high volume commercial applications.

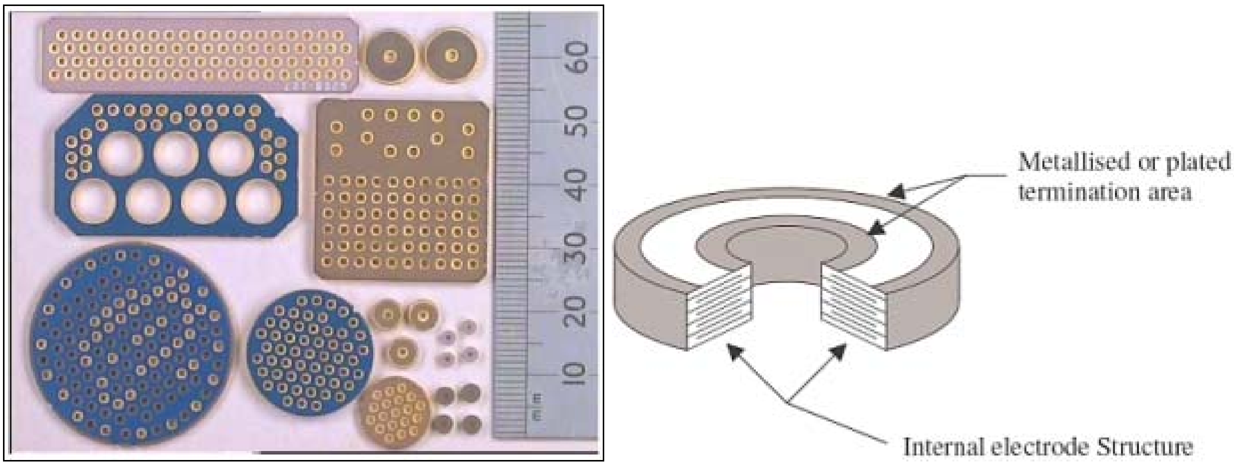


Figure 36 Examples of discoidal and planar array capacitors [2]

The machined through hole discoidal and planar array ceramic multi layer capacitors are contacted by soldering a copper pin into the central hole. The pin can then be contacted with wires as Figure 37 shows.

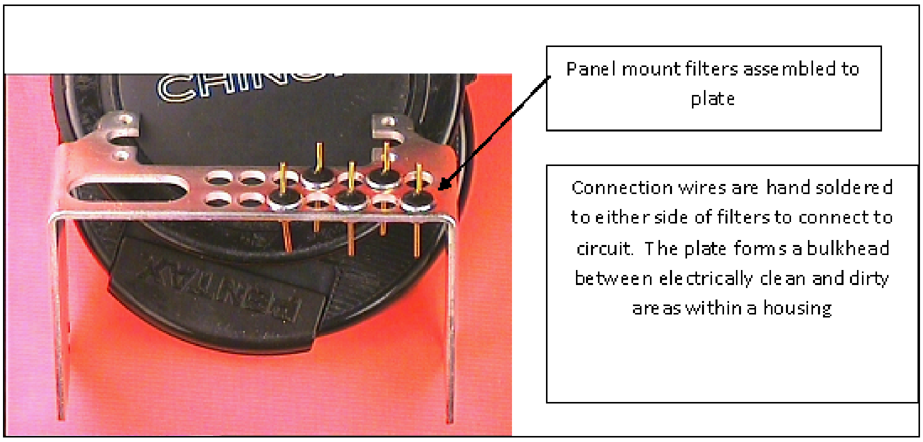


Figure 37 Partially populated complex filter plate [5]

Exemption 24 allows the use of lead solders for soldering the pin into the central hole. The lead-indium solders with 40% to 50% of lead content (PbIn60 or PbIn50) provide the combination of a suitable melting point and ductility. The ductility of this solder avoids cracking of the ceramic layer during and after soldering due to thermal mismatch between the ceramic capacitor and the copper pin.

The quantity of lead in the solder joints of each filter is estimated at around 5 mg per joint typically. Market growth has increased the total lead used in solder joints at Syfer to an estimated 5 kg in 2007 (previously estimated at 4kg in 2003).

The exemption affects a small number of manufacturers, and Syfer, the company that had originally applied for this exemption in 2005, claims to be the market leader. Therefore, it is estimated that the total amount of lead in such kind of components is in the same order of magnitude as the 5 kg.

4.30.2 Summary of justification for the exemption

Syfer states that the technological and scientific base for this exemption has not changed. The justification based on the 2005 and new information is summarized in short.

Lead-free solder alloys

According to the applicant, lead-free solders in connection with gold plated terminations cause cracking of the ceramic bodies after the soldering process due to thermal mismatch (CTE) with the copper pin.

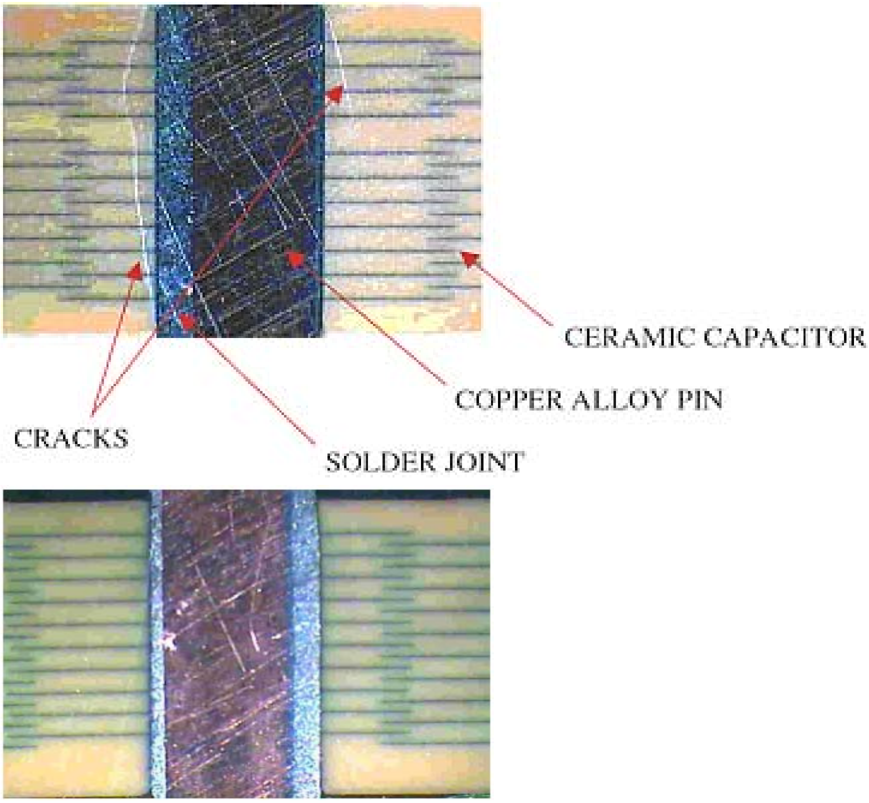


Figure 38 Defect capacitor soldered with SnPb36Ag2 lead-free solder (top) and correctly soldered with 50PbIn solder (bottom) [2]

The main reason for the CTE is the copper alloy pin. Alternative pin materials have been tested, but are not a viable substitute. The alternative materials do not provide suitable resistivity to allow sufficient current flow without excessive temperature rise.

Some companies may intend using PdAg terminations replacing gold together with lead-free solders. This avoids the cracking of the ceramic bodies. Tests, however, show that such devices show considerable deviations from the designed capacitance causing unacceptable losses of the filtering properties beyond the acceptable tolerances. The reason is the weaker – compared with gold terminations – adhesion between the ceramic and the AgPd plating causing lift-offs and/or the leaching of the PdAg layer in combination with lead-free solders. As state of the art, lead-free solders hence are not recommended to be used with AgPd platings neither. The problem does not exist with lead-containing solders. The loss of capacitance due to these failure modes affecting the filtering performance of the device may result in severe medium- and long-term reliability problems. [6]

Syfer says that some of its customers are tending towards using higher lead alloys (typically 95% lead rather than 50% lead) to overcome the limitations of the RoHS Directive. This was one option Syfer discussed in the original application, but considered to represent a negative environmental impact. High melting point lead solders (HMP, currently still exempted under exemption 7a) with Pb content > 90% also tend to have the ductility demanded, 92.5Pb/5In/2.5Ag or 95Pb/5In being the most likely solutions. These are deemed acceptable as the current directive annex exempts HMP alloys with >85% or more of Pb. However, alloys with this content of lead have much higher reflow temperatures - 92.5Pb/5In/2.5Ag has a liquidus temperature of 310ºC compared with 210ºC for 50Pb/50In. This will demand new equipment capable of reaching much higher temperatures. Trials have shown that an inert atmosphere will also be necessary to prevent oxidisation problems. The use of these HMP solders thus would increase the use of lead as well as the energy consumption due to the higher soldering temperatures and for the production of the inert gas. Syfer confines, however, that some applications require the use of HMP solders in such capacitors [2], [3].

Syfer says to have information that ductile lead-free solder alloys are being considered for development at Indium Corporation, one of Syfer's suppliers. [3]

Indium Corporation confirms that ductile high temperature alloys are needed and are therefore the subject of research. The solution cannot be easily achieved. "Classical" or simple alloy combinations are not likely to be effective and a more complex solution is most likely to succeed. This has the effect of widening the number of research avenues considerably. Several approaches have already been followed but have proved blind. The alloys either do not deliver their initial promise or are not capable of being transferred to production. In addition, as the result needs to be a novel material, a comprehensive test program will also be required. Research continues, but production is estimated to be several years off. [5]

Syfer concludes that it is presently confined to conventional, existing alloys. The ductility necessary for Syfer's application ultimately relies on the use of indium in high percentages, as indicated. Tin based alloys with high Indium content have very low melting points making them unsuitable. The use of lead is therefore necessary to both raise the melting point to an appropriate level and to maintain the ductility. [5]

Use of spring clips

Syfer [3] states an increased interest in the possibility of using spring clip contacts to replace the inner solder joints. The driver behind the use of spring clips is to reduce the assembly time and scrap costs relating to multi-way filter connectors & assemblies. Using spring clips allows the soldering operation of the assembly – in case of soldered-in clips – to take place away from the connector shell and pins. Working outside the connector shell makes the assembly easier, quicker and there is no risk of accidental contamination of mating surfaces with solder. After initial assembly, the individual capacitor elements can be tested and checked before installation into the housing. Testing of the connector after installation of the clipped array also allows any damage during insertion to be identified and reworked before the connector is finally sealed.

Fully soldered assemblies are harder to assemble and, in the case of a failure being identified, are generally not re-workable thus carrying a far greater scrap cost. On the other hand, the tooling cost (for solderless clips) and the cost of a soldered clip are higher compared to a solder solution without using pins. Syfer did not provide an overall cost calculation, as this would have to take the anticipated yield, cost of piece parts and potential cost of re-work into account.

There are two versions of spring clips. [5] [6]

- Soldered spring clips mounted into the capacitors using InPb solders as for standard solder joints, however, with smaller amounts of solder compared to the soldered clip-less version.
- Mechanical clips to make a solderless connection, this development is providing the main interest with regard to the exemption.

Syfer [5] confines that the use of spring clips has technical limits. Modern technology needs higher capacitances and working voltages to meet electromagnetic compatibility (EMC) requirements. At the same time, physical size is reduced to satisfy the push for lower weight and smaller equipment. The problem with spring clips is that they reduce the available capacitance and working voltage, and physically increase the size of the filters. [5] The conditions of their use thus may withstand the requirements in many applications.

Syfer [5] gives an example: A standard filtered connector with hole to hole pitch of 0.130" using a size 20 pin contact at 0.040" diameter will be soldered into a hole typically 0.045" diameter. A spring clip to suit the same application requires a hole diameter of 0.102" minimum and has a mounting flange of 0.126" diameter. The capacitance achievable is negligible and the clips will almost touch rendering them unsuitable. Spring clips would not be suitable for the majority of single line filters as space constraints would prevent their use. [5]

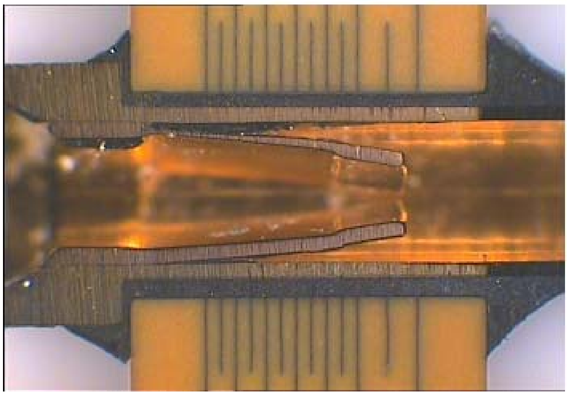


Figure 39 Cross section of a spring clip connection

The reduced capacitance and voltage rating of a part by imposing limitations on the hole dimensions has limited the use of spring clips to applications where this is not important. There are, however, more limitations to be taken into account.

Calculating the available capacitance requires a complex calculation with a number of variables to take into account. Syfer [5] explains that the available capacitance is a function of the area of electrode overlap in the capacitor and the dielectric thickness separating the electrodes (see Figure 36 on page 216). In a discoidal capacitor, the difference between the outer diameter and the hole diameters define the area of electrode overlap, bearing in mind that minimum insulation margins are required between the inner and outer diameters. The same rule applies to multi line planar arrays with more holes, but increasing the number of holes increases the complexity of the electrode design. [5] In most applications, the pin through the centre of the filter must have a defined size, based on physical strength and current carrying capacity. Using spring clips at a given pin size increases the hole diameter, which reduces the electrode overlap area and the available capacitance at a given total size of the capacitor, and it thus narrows the technical limits for the use of spring clips. [5]

In addition to the reduction in overlap area, there will also be a similar reduction on the creepage (transfer of electricity across a surface) and clearance (transfer of electricity in free air) across the surface of the capacitor. In many cases the spring clip will not physically fit in the spacing available. [5]

Syfer [6] explains that the spring clip itself has increased resistance and inductance over a standard solder joint, as a result of the contact area between the capacitor and the pin being reduced and the fact that the connection is purely mechanical. Typically, the joint resistance of a soldered line is less than 5 mOhm, compared to a similar design clip connection resistance of 20mOhm. If there is a risk of the contact moving due to vibration, or there is a risk of contamination getting between the clip fingers and the pin (such as epoxy encapsulation placed directly onto the capacitor) then the contact resistance can increase, adversely affecting performance.

Each connector manufacturer uses their own through pin dimensions, meaning each will demand different size clips to meet their own requirements. As the supplier of the ceramic Syfer [6] was in contact with a number of clip manufacturers to try and produce a standardised clip covering multiple pins diameters based on existing commercial designs. So far the manufacturers have told this is impractical. There are also issues with approvals - most of these types of component are being used in high reliability applications where a change of technology would require a full re-approval which is not always possible. [6]

Syfer concludes that spring clips offer a possibility to reduce the total lead usage, or to even avoid it. They are, however, not suitable for all applications and have technical constraints. Their applicability has to be assessed on a case by case base due to the multitude of production and application specific requirements to be taken into account.

Given the above constraints and limitations, Syfer [3] cannot see how the wording could be phrased to ensure that clips are used wherever possible. Each application has to be judged individually on merit and a decision made at the design stage. Solder is still the preferred method of joining the capacitor to the surrounding metalwork. [3]

Conductive epoxies

Syfer could not identify any conductive epoxy with the appropriate flow characteristics to flow into the space where the joint is to be made. [3]

Conclusion

Syfer states that the search for alternatives to lead based solders is continuing, but that solder currently is the only connection method that fulfils all the technical requirements. Until a new solder alloy can be developed offering the critical ductility, Syfer does not see any lead-free alternative for this application. [3] [5] Syfer therefore asks for the continuation of exemption 24.

No opposing stakeholder opinions were submitted during this review process.

4.30.3 Critical review

Syfer plausibly explains that viable lead-free substitutes for the lead-indium solders are not available, neither currently nor within the near future.

Spring clips soldered into the hole of the discoidal capacitor in principle are a way to reduce the use of lead solders. Solderless spring clips even could be a way towards RoHS-compliance without an exemption. Their usability, however, is limited to individual cases, which cannot be categorized. Several parameters affect the applicability of spring clips:

- The available space to build in the capacitor, as spring clip capacitors need more space to achieve the same capacitance.

- The maximum possible inner hole diameter, as spring clips require more space.
- The pin size in dependence of the current carrying capacity required.
- The capacitance required, as the achievable capacitance at a given capacitor size is limited.
- The tolerable resistance and inductance of the capacitor connection, as clipped capacitors have a higher resistance and inductance.
- Application-specific influences like e. g. vibration or contaminations that influence the resistance and of the clip connection and adversely affect the performance.
- The tolerable creepage and clearance of the capacitor, as this is different for clipped capacitors from soldered ones.
- Non-standardized pin and clip sizes requiring individual spring clip solutions for each manufacturer.
- Single line or multi-line applications, as the available spacing is smaller in multi-line applications so that a minimum distance between the clips might be fallen below.

Besides this multitude of influencing parameters, the single parameters partially interact. It is thus not possible to clearly define application fields allowing the use of spring clips, and if possible solderless ones, as otherwise the exemption would be needed further on.

High melting point solders with 85% or more of lead (HMP solders) currently are exempted from the RoHS Directive. Syfer [5] states that *“It has become more apparent that some of our customers are tending towards using higher lead alloys (typically 95% lead rather than 50% lead) ….”. “…[we] have actively encouraged switching the lower lead content In/Pb solder alloys allowed by exemption 24.”* As these solders technically are an alternative to the indium-lead solders with 40% or 50% of lead, a limitation of exemption 24 could be an additional incentive for manufacturers to use these HMP solders thus increasing the amount of lead in this application. This would not be in line with the spirit of the RoHS Directive and pose additional burdens on the environment from the use of additional lead and increased energy consumption for the processing of these HMP solders.

The overall situation, as Syfer describes it, and the absence of any opposing stakeholder views, would justify the continuation of exemption 24 in line with the requirements of Art. 5 (1) (b). It is therefore recommended to continue the exemption until the next review in 2014. Until then, in case the Commission follows the consultants’ recommendation, exemption 7 a allowing the general use of HMP solders will have been expired. The HMP solders would no longer be a general fallback option, but their use would be restricted to the cases where alternative solutions are not available. In the next review, it should be checked whether and how far new and more ductile lead-free alloys or progress in the spring clip technology allow restricting or repealing exemption 24.

4.30.4 Recommendation

The stakeholder's arguments and the overall situation justify the continuation of the exemption in line with Art. 5 (1) (b). The consultants therefore recommend continuing this exemption until the next review in 2014. Presuming that the Commission will require expiry dates to be set for each exemption, the reviewers propose 31 July 2014 for the expiry of this exemption.

The new wording of exemption 24 is proposed as follows:

Lead in solders for the soldering to machined through hole discoidal and planar array ceramic multilayer capacitors until 31 July 2014, and for repair and reuse of equipment put on the market before 1 August 2014.

4.30.5 References

[1] Öko-Institut e.V., Fraunhofer IZM; document "exemption-24_results_previous-evaluation.pdf"

[2] Syfer stakeholder document "Application for exemption for through hole ceramic devices.pdf"

[3] Syfer online stakeholder document "Exemption_7a_24_Syfer-Technology_31_March_2008.pdf"

[5] Steve Hopwood, Syfer; information sent via e-mail to Dr. Otmar Deubzer, Fraunhofer IZM, on 26 June 2008

[6] Syfer stakeholder document "Oct 2008 answers.doc"

4.31 Exemption No. 25

“Lead oxide in plasma display panels (PDP) and surface conduction electron emitter displays (SED) used in structural elements; notably in the front and rear glass dielectric layer, the bus electrode, the black stripe, the address electrode, the barrier ribs, the seal frit and frit ring as well as in print pastes”

4.31.1 Description of exemption

The exemption at hand was granted on a request of the Japan Business Council in Europe (JBCE), the Korea Electronics Association, LG Electronics and Samsung SDI. These stakeholders requested an exemption for lead in lead oxide glass used in plasma display panel (PDP) [1].

In February 2005, JBCE had stated that surface conduction electron emitter display (SED) was meant to refer to “other technology large-sized flat display panels”: due to the fact that the reasons have been almost similar for using lead oxide glass both for plasma display panels (PDP) and for surface conduction electron emitter display panels, and taking into account that there were overlapping issues to the use of lead oxide in seal frit, at that time, the requests were covered simultaneously, leading to the exemption titled above.

For both display technologies, lead oxide glass is used for the main structural elements of the panel, except the substrates. Although there are considerable differences between PDP and SED, both technologies are currently using lead oxide glass for sealing of casing (glass frit) and print pastes.

According to the assumption of the applicants at that time, the total amount of lead oxide in glass used for PDP accounted all together for about 400.000 kg p.a. (EU figures). Due to the fact that SED technology was still under development, annual quantities could not be estimated.

4.31.2 Justification by stakeholders

During this review, several contributions were provided[41]:

- In their joint industry contribution, COCIR, Eucomed and EDMA argued that the current exemption was needed by any modality employing glass plasma displays and the technology may impact the diagnostic capability [2].

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[41] Furthermore Rosemount Inc. / Emerson Process Management submitted several documents. However, these documents relate to other applications (lead oxide containing glass seal frit to hermetically seal the reference chamber of sapphire based pressure sensors, lead oxide containing glass in high performance electrochemical pH and ORP sensors, lead oxide containing glass in its high performance capacitive metal pressure sensors), but not to SED and/or PDP. The information provided by Rosemount Inc. / Emerson Process Management therefore is not applicable to the exemption at hand.

- Both the Swedish Ministry of the Environment [3] as well as Greenpeace [4] pointed out that, according to EuP preparatory study on TV, a lead-free PDP was on the market and Panasonic Corporation of North America had achieved the elimination of lead in PDPs. As a lead-free alternative was available and already in use, Greenpeace therefore called for removal of exemption 25: "At the very least, to allow other manufacturers to implement the developments that avoids the need for this exemption, retain exemption but include a challenging time after which the exemption will be removed (6 months)."[4]
- Japan Business Council in Europe (JBCE) provided a comprehensive update of the current situation of substitution of lead, covering lead oxide in SED.
- For the case of SED, the following information was submitted [5] [6] [7] [8]:
  - In the case of SED, an exemption for lead oxide remained necessary. The technical function of the substance as a seal frit is to ensure the vacuum seal in SED.
  - As SED was not shipped into the EU by now, the corresponding amount of lead oxide put into the EU annually could not be appointed. The amount of lead oxide was 37-44g in a 55-in. diagonal SED panel, and the lead content in lead oxide glass frit was about 60 to 70 wt%.
  - For some structural elements (notably: scanning wire, signal wire, inter-layer insulation membrane, black matrix, anode wire, insulation layer, resistance layer) substitution from lead oxide glass frit to Bi glass frit could meanwhile be transacted. As a result of this activity after 2005, the amount of lead could be reduced more than 60% by June 2008. Compared with a CRT, an SED contained lead by 1/100 or less.
  - In contrast, for vacuum seal substitution was still under development, because bismuth and tin-phosphate glass materials were not sufficient as a substitution of lead oxide glass. Substitutes would need high vacuum seal performance to assure vacuum level less than 1E-4Pa like CRTs.
  - Some possible materials and constructions were under continued evaluation, but due to long running reliability tests, substitution was not possible until the next review of Annex to RoHS Directive. From a current point of view it is intended to finish the substitution of lead around year of 2012.
  - Against this background, JBCE suggested a rewording of the existing exemption as follows: "Lead oxide in surface conduction electron emitter displays (SED) used in structural elements; notably in the seal frit and frit ring."
- For the case of PDP, the following information was submitted [9]:
  - PDP was filled with discharge gas larger than 1*E+4 Pa, which was higher than that of SED by 8 orders.

4.31.3 Critical review and recommendation

Basically, it must be taken into account that there are considerable differences between PDP and SED technology. In the case of PDP technology, lead-free technology is obviously available meanwhile, and there was no contribution from the level of manufactures in favour to prolong the existing exemption. Only from the level of users of the display technologies there are arguments to retain the current exemption. However, there is no information made available that there really are impacts on the diagnostic capability. Insofar, we recommend not to prolong this part of the current exemption.

The situation occurs differently for SED technology. Due to the specific conditions (vacuum seal) substitution of lead is still under development and currently not realisable. Therefore, we recommend continuing the exemption but taking a wording which narrows the scope considerably and setting the 31 July 2014 as expiry date.

Lead oxide in surface conduction electron emitter displays (SED) used in structural elements; notably in the seal frit and frit ring.

4.31.4 References

[1] Gensch et al. 2005; Adaptation to scientific and technical progress under Directive 2002/95/EC. Monthly report 4, final version. Freiburg, 20 December 2005

[2] Joint Industry contribution to the ÖKO Institute's consultation on the Actual Exemptions from the RoHS Directive. Brussels, April 1, 2008

[3] Regeringskansliet, Ministry of the Environment; Memorandum to Stakeholder consultation on RoHS exemptions. 1st April 2008

[4] Greenpeace European Unit asbl; Greenpeace response to "Stakeholder 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". Brussels, 01 April 2008

[5] Japan Business Council in Europe (JBCE); Answer for General questionnaire on Stakeholder consultation of RoHS exemptions 25 " PbO in SED". 24 June 2008

[6] Japan Business Council in Europe (JBCE); Answer for specific questions on Stakeholder consultation of RoHS exemptions 25 "PbO in SED". 24 June 2008

[7] Japan Business Council in Europe (JBCE); Explanation for Stakeholder consultation on RoHS exemptions 25 "PbO in SED". 11 June 2008

[8] Japan Business Council in Europe (JBCE); Additional data sheets for stakeholder consultation of RoHS exemptions 25 "PbO in SED". 24 June 2008

[9] Japan Business Council in Europe (JBCE); Answer for additional questions related to lead-free technology used in PDP on Stakeholder consultation of RoHS exemptions 25 "PbO in SED". 24 June 2008

4.32 Exemption No. 26

"Lead oxide in the glass envelope of Black Light Blue (BLB) lamps"

4.32.1 Description of exemption

The current exemption was granted on request of the ELC for PbO in the glass envelope of Black Light Blue (BLB) lamps. Typical applications of this kind of lamps are money checking, lamps for leak detectors, disco-lighting etc.

These lamps efficiently emit near ultraviolet rays at 315nm to 400nm which have strong photochemical and fluorescent effects. Through the usage of a special deep blue filter glass visible rays are absorbed and near ultraviolet rays can pass the glass.

According to the applicant, lead is essential for creating optimal optical properties: maximum transmission of UV light and minimum visible light transmission [1].

The total annual amount of lead in this application was numbered as about 50.000 kg p.a. (total EU market, 2004 figures) [1]; this information is in line with current assumptions provided by ELC [2]. Compared to the usage of Pb respectively PbO in other discharge lamp applications these figures are comparatively high.

4.32.2 Justification by stakeholders

ELC forwarded the only contributions within this review [2], [3]: According to the information provided by ELC, substantial progress has been made leading to elimination of lead oxide in the glass envelope by one of the ELC member companies. ELC therefore calls for an expiry date of the current exemption 18 months after publication.

4.32.3 Critical review and recommendation

Taking the above mentioned technical development into account, substitutes are available for which reason a continuation of the current exemption could not be justified further on. In order to ensure the technical implementation a transition period of 18 months after publication (mid 2011) is proposed. According to the stakeholders' contribution it is not possible to appoint, whether and to which extend applications being attributable to WEEE categories 8 and 9 are affected by this specific exemption.

4.32.4 References

[1] Gensch et al. 2005; Adaptation to scientific and technical progress under Directive 2002/95/EC. Monthly report 4, final version. Freiburg, 20 December 2005

[2] ELC submission to RoHS exemption #19. Brussels, 31st March 2008

[3] Further ELC input to RoHS Exemptions 5, 7a, 16, 17, 18, 19, 20, 26. Brussels, 08 August 2008

4.33 Exemption No. 27

"Lead alloys as solder for transducers used in high-powered (designated to operate for several hours at acoustic power levels of 125 dB SPL and above) loudspeakers"

During the stakeholder consultation, no substantiated stakeholder comments were submitted to support the continuation of this exemption.

The exemption originally was applied for by Meyer Sound (see third stakeholder consultation, http://circa.europa.eu/Public/irc/env/rohs_3/library?l=/requests_exemption/electricalmechanical/request_revhtm/_EN_1.0_&a=d).

4.33.1 Description of the exemption

A detailed description of the exemption as well as the justification and the critical review of the arguments can be found:

- in the final report from July 2006 of the RoHS exemption reviews
- and in Annex 1 (zip-file) to this final report under the following file name:
  Final Report_21.03.2006.pdf

Both documents can be downloaded from the Commission's website:
http://ec.europa.eu/environment/waste/weee/studies_rohs1_en.htm

4.33.2 Justification and critical review

Meyer Sound was informed twice via e-mail and via phone that the reviewers will recommend the removal of this exemption in case there is no supporting information. Neither did Meyer Sound react on this, nor did the reviewers receive any other additional information that this exemption is necessary further on.

4.33.3 Recommendation

There was no support for the continuation of this exemption during the review process. The reviewers hence assume that the original reasons that justified the exemption in line with article 5 (1) (b) have become obsolete. It is therefore recommended to repeal this exemption without a transition period.

4.34 Exemption No. 28

"Hexavalent chromium in corrosion preventive coatings of unpainted metal sheetings and fasteners used for corrosion protection and Electromagnetic Interference Shielding in equipment falling under category three of Directive 2002/96/EC (IT and telecommunications equipment). Exemption granted until 1 July 2007"

This exemption has expired on 1 July 2007 and was thus not subject to the current evaluation.

4.35 Exemption No. 29

"Lead bound in crystal glass as defined in Annex I (Categories 1, 2, 3 and 4) of Council Directive 69/493/EEC"

This exemption had originally been reviewed by the contractor in 2006 [1]. By that time the recommendation had been not to grant the exemption since there were no grounds that could be based on Article 5 (1) (b).

An add-on to this recommendation [2] made clear that the applicant and the contractor had opposing views:

"Upon request of the applicant, the consultant re-opened the dialogue on the recommendation given in monthly report n°3. It was agreed that the consultant would write an add-on to the existing text in report n°3 in order to better reflect the applicant's opposite view to the given recommendation.

In contrary to the consultant, the applicant argues that the functionality of a product (=electrical equipment) is NOT limited to the elementary technical function, e.g. the functionality of a chandelier is not only to spend light via the use of electricity but mainly to beautify and grace the room by the brilliancy of the crystals. Both aspects of functionality form an integral part of the product. Even if such an application could be realised with lead-, cadmium- and chromium-free alternatives, its whole functionality – according to the applicant – would not be given, since the quality of the application is directly linked to the optical and decorative properties of the crystal. The applicant states that substituting the crystals with RoHS-compliant ones would lead to a degradation in quality and thus not fulfil the needed requirements of a substitute.

A further example cited by the applicant is that a watch decorated with red crystals cannot be substituted with RoHS-compliant red crystals without crucial decrease in colour purity. This, he argues, does not fall under the term “substitution”. Substitution implies equivalency.

Article 5 (1) (b) leaves room for interpretation concerning the definition of what exactly can be understood by “technically/scientifically practicable”. The consultant and the applicant have diverging views on its interpretation.”

Since 2006 the situation has not changed. In the meantime the Commission has published exemption 29 on the use of lead in crystal glass justifying it the following way [3]:

“Crystal glass has been progressively used for decorative purposes on electrical and electronic equipment. Since Council Directive 69/493/EEC of 15 December 1969 on the approximation of the laws of the Member States relating to crystal glass (2) prescribes the amount of lead to be present in crystal glass and the substitution of lead in crystal glass is therefore technically impracticable, the use of this hazardous substance in specific materials and components covered by that Directive is unavoidable. Those materials and components should be therefore exempted from the prohibition."

4.35.1 Recommendation

In the stakeholder consultation no information related to this exemption was obtained. Since the justification given in [3] is assumed to be legally correct and thus still valid, it is recommended to further grant the exemption.

4.35.2 Expiry date

As it can currently not be foreseen when substitutes will be available respectively when the grounds for the justification of the exemption will not be valid anymore, it is recommended to set the expiry date at the time of the next revision – namely 31. July 2014.

4.35.3 References

[1] Gensch et al. 2005; Adaptation to scientific and technical progress under Directive 2002/95/EC. Monthly report 3, final version. Freiburg, 21 November 2005

[2] Gensch et al. 2005; Adaptation to scientific and technical progress under Directive 2002/95/EC. Final report. Freiburg, 28 July 2006

[3] Commission Decision of 12 October 2006 amending for the purpose of adapting to technical progress, the Annex to Directive 2002/95/EC of the European Parliament and of the Council as regards exemptions for applications of lead in crystal glass (2006/690/EC); OJ L 283/47

4.36 Exemption request No. 1

"Lead in solders for the connection of very thin enamelled wires with a terminal"

This is an application for a new exemption. Nevertheless, it was part of the stakeholder consultation for the review of the existing exemptions 1 through to 29 in the Annex of the RoHS Directive.

4.36.1 Description of the requested exemption

The tin lead solder with a lead share of 37% to 40% is used for the connection of enamelled copper wires with terminals by soldering for high-temperature applications in coils of low-voltage switch gear and control gear. The used wires have diameters between 0.03 and 2.5 mm. [1]

The solder makes two small solder points for the connection of the two ends of the enamelled copper wire of a coil to a terminal of an electrically conductive metal. The solder has to remove the enamel by thermal decomposition at a temperature above 450°C and to give an electrically conductive, mechanically strong connection. [1]

The enamel cannot be removed mechanically from wires with very small diameters. It has to be decomposed thermally by the hot solder at the connection area. The enamel has a high thermal stability (>180°C) for technical reasons of the application of the coil, so decomposition temperature has to be about 450°C. If lead-free solder is used the copper of the wire is totally solved in the solder and a very brittle connection which does not fulfil the requirements of the application is the result (switching operations with mechanical shocks). This does not happen in the case of solders containing 37 to 92% of lead because of the lower solubility of copper in the solder. For wires with diameters above 0.5 mm the mechanical strength of the connection is insufficient with a solder containing >85% of lead [1].

Each device contains 20-100 mg of solder with a lead share of 37 to 40%. The total mass of the device ranges from 100 g up to 1kg. [1] The applicant sells about 35 mio units a year with about 20–100 mg resulting in a total of 700 to 3.500 kg lead in his products. [2]

The applicant [1] indicates to have a global market share of about 20%. He, like all competitors of switch gear, mainly delivers into industry applications, which, according to the stakeholder, are outside the scope of the RoHS Directive. Around 3% of his production is supplied to the consumer industry, where it is used in contactors, overload relays, and current breakers. This share of products contains around 20 to 100 kg of lead. [1], [2]

The applicant therefore calculates that there is in total a global lead consumption of 20 to 100 kg multiplied by 5 (market share) in the consumer industry. The total amount of lead supplied into the consumer industry hence is around 100 to 500 kg per year. [1]

4.36.2 Summary of justification for the exemption

After further inquiry and information exchange, Siemens considered withdrawing the exemption request. The final decision required further internal clarifications at Siemens.

The final decision had been announced within the first week of November (November 3 to 7) 2008. The draft report was submitted to the Commission on 30 October 2008, and the request was agreed to be treated as withdrawn until Siemens' would take another decision in the first week of November.

Siemens [4] finally announced on November 20 to maintain the exemption request for the time being until a final internal clarification could be achieved until around December 2008. By that time, however, it was too late for the necessary further inquiries and to restart the evaluation of the exemption request. The final evaluation of the request was therefore not finished. In case Siemens finally still considers the exemption to be necessary, a new exemption request could be submitted to the Commission.

4.36.3 Recommendation

The exemption request could not be evaluated. The applicant informed the consultants too late that, contrary to a previous announcement, he does not withdraw the exemption request. A sound evaluation of the request was not possible any more.

4.36.4 References

[1] Siemens online stakeholder document "Request 1_Siemens_17_08_2007.pdf"

[2] Siemens stakeholder document "2008_05_27_RoHS_Ausnahmeantrag.doc" submitted to Otmar Deubzer, Fraunhofer IZM, on 30 May 2008

[3] Martin Birner, Siemens AG; information sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 29 October 2008

[4] Martin Birner, Siemens AG: information sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 20 November 2008

4.37 Exemption request No. 2

"Lead and cadmium as components of the glazes and colour used to glaze or decorate lamp bases, lamp carriers or clocks"

This is an application for a new exemption. It was part of the stakeholder consultation for the review of the existing exemptions 1 through to 29 in the annex of the RoHS Directive.

4.37.1 Description of the requested exemption

Ceramic bases are used for table lamps and also for clocks. Lead and cadmium are components of the glazes and colour used to glaze or decorate the lamp bases or carriers. While lead is used both in glazes and colours, cadmium is used as a pigment for certain colours, typically but not exclusively bright reds.

Figure 40 Examples for glazes and colours on lamp bases and carriers (source: Cerame-Unie).

The function of glaze is to seal the porous body surface and decoration making the item serviceable. It also greatly enhances the colours used for decoration, making them rich and vibrant. [2]

The ceramic base and components prove by far the highest insulating properties of any alternative lamp base. The ceramic insulators used for electrical transmission and switching are essential the same as the ceramic article under discussion. [1]

The glazes and colours are fired with or onto the ceramic base. Essentially the glaze forms a glassy phase on the exterior surface(s) of the ceramic base. Similarly, the firing process incorporates the decoration or colours into the glassy phase. The result is an extremely stable, resistant, insoluble and permanent cover or finish to the ceramic article. The applicant states that only severe abrasion or chemical attack can cause marginal releases of any of the components. The ceramic parts thus provide a stable and inert base for both lamps and clocks.

The applicant says that the glaze and decoration provide the ability to match or tone with environments in which they are placed. For lamp bases, the ceramic base and components have insulating properties. The ceramic insulators used for electrical transmission and switching are essential the same as these ceramic lamp bases.

The total quantity of lead used in the manufacturing of lamp bases and carriers for clocks is probably less than 5,000 t per year for the whole of Europe. Cadmium is only used as a pigment for certain colours typically but not exclusively bright reds and for yellow. [1], [2] The total amount of cadmium used for lamps and clocks in the EU is less than 25 tonnes/year [4].

4.37.2 Applicant's criteria for justification

The applicant was asked to clarify whether exemption 7(c) (lead in electronic ceramic parts) covers this use of lead in such ceramics. The applicant stated that exemption 7(c) does not apply since it covers a totally different application. A lamp base, lamp carrier or clock in the applicant's opinion does not fall under 'electronic ceramic part'. The applicant therefore decided to maintain the exemption request.

Lead is always used in certain glazes. Cadmium is rarely used in glaze and is used only for certain finishes. Lead, according to the applicant, is used in an insoluble form as lead bisilicate or encapsulated in a frit (a glassy compound). Cadmium is used only in an encapsulated form (with zirconium). [2] The ceramic lamp bases or clocks are produced in exactly the same ways as ceramic tableware to which the most stringent standards apply. Directive 84/500 EC, revised as 2005/31 EC sets the limits for lead and cadmium release for articles in contact with food where any human exposure would otherwise be an issue. [1]

Cerame Unie [4] claims that it is impossible to produce bright red and yellow colours without cadmium. These bright colours are typical and essential for ceramic wares, and a cadmium-free ceramic product without these colours hence would be a different product, according to the applicant.

The applicant [1] claims to have undertaken some unleaded glaze trials. Lead is essential to heal the pin-holes in the glaze during the firing stage. The pin holes are closed (healed) when the lead-containing glaze is fired. This characteristic is essential to ensure a smooth surface. Lead-free glazes have until now not proven to be able to substitute this essential function. [4]

Cerame Unie [2] says that any transition to unleaded systems glazes and colours is a massive undertaking. There are over 100 different colours in use at present (even within one company) to which there are infinite colour combinations. It will take time to trial all colour combinations and source alternatives. The glazes and colours have to be reformulated. They then have to be tested with respect to manufacturing processes as well as the end product. Some of the alternatives had to be rejected. The elements close to lead in the periodic table which potentially might give the same results could not be used. Some alternatives failed to provide satisfactory manufacturing tolerances e. g. insufficient coverage of the article to be glazed, recurrent faults in the firing process, or failure to provide sufficient durability in use. [2]

Finally, it does have to be recognised that it is difficult if not impossible to make leaded and unleaded products side by side. All the trials have to be essentially complete and satisfactory before a switch can be made.

There has been a considerable increase in the number of unleaded glazes and colours over the last 20 years. The numbers are likely to increase in the future. Commercially and aesthetically, the unleaded versions must match the previous version within a sufficient tolerance. Unleaded systems, according to the applicant, often result in less durability, potentially higher releases or exposures and if anything, higher risk. [1] Besides the unique properties described above, the applicant states that none of the lead- and cadmium-free alternatives would provide the same level of electrical insulation, water or moisture resistance, or durability. Ceramic bodies have differing water absorbencies: Porcelain and China < 0.3%, Stoneware <3.0% and earthenware normally less than 8% (by weight). In all cases, the test is carried out on the unglazed body which is boiled for 24 hours. A properly and fully glazed body would have a lesser absorbency. The glaze improves the water absorbency, the hygiene, the cleanliness and the aesthetics. There are no universal alternatives and in some case they are not as effective. [1] [2]

The applicant states that there are no universal alternatives to lead and cadmium. The alternatives are used where they exist. It has not been possible to find effective alternatives for all systems applications and colours. The applicant hence applies for this exemption.

Finally, Cerame Unie [4] points out that exemption 29 of the RoHS Directive exempts lead bound in crystal glass used for esthetical reasons in crystal luminaires, products with whom ceramic luminaires are in direct competition. In analogy, the use of cadmium and lead in these applications should be exempted as well.

Greenpeace [3] opposes the exemption request unless there is clearer and more detailed justifying evidence than is given in the applicant's exemption request.

4.37.3 Critical review of data and information given by the applicant or stakeholders

Consideration of risks

The applicant, Cerame Unie, asks for an exemption for lead and cadmium used in glazes and colours on ceramic lamp bases, lamp carriers and clocks. Cerame Unie explains that lead is used in an insoluble form as lead bisilicate or encapsulated in a frit (a glassy compound). Cadmium is used only in an encapsulated form (with zirconium). The applicant states that only severe abrasion or chemical attack can cause marginal releases of any of the components. The ceramic lamp bases or clocks are produced in exactly the same ways as ceramic tableware where legislation sets the limits for lead and cadmium release for articles in contact with food where any human exposure would otherwise be an issue.

The only viable base for an exemption is Art. 5 (1) (b). It allows an exemption for the use of banned substances 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;
- 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.

The RoHS Directive thus does not allow risk considerations as a criterion for an exemption. The stakeholder's argument indicating that there is no risk related to this use of lead and cadmium therefore is not in line with Art. 5 (1) (b) and does not justify an exemption.

Cerame Unie claims that unleaded systems, according to the applicant, often result in higher releases or exposures and higher risk. There is, however, no evidence what kind of releases or exposures these would be, how they could pose a higher risk and to what or to whom. In the absence of such evidence, the exemption would not be justified with respect to environmental, health or safety aspects in Art. 5 (1) (b).

Technical aspects of elimination or substitution of lead and cadmium

Technically, ceramic materials for lamp bases, lamp carriers or clocks are not without alternatives. There are other materials used for lamp bases, lamp carriers or clocks that do suffice all necessary safety and reliability requirements and do not require lead and cadmium in glazes and colours. The technical function of these ceramic clock and lamp bases can be provided using other materials than ceramics that do not depend on the use of lead or cadmium, like wood or glass. Technically, lead and cadmium can thus be eliminated by a design change and Art. 5 (1) (b) would not justify an exemption.

Lead- and cadmium-free materials are available, but, according to the applicant, they do not facilitate the full variety of colours to be achieved on ceramics, or not in the quality of the glazes and colours containing lead and cadmium. Not granting the exemption thus would impact the properties of future lamps and clocks. They would look different and might even disappear from the market. Customers might not appreciate the lead- and cadmium-free colours, or the more limited variety or even lack of colours compared to the current status, as in particular bright red and yellow colours would no longer be available.

Esthetical aspects of elimination or substitution of lead and cadmium

The question thus comes down to esthetical aspects. The fact that there has been a market for these products shows an appreciation by customers who buy these products, and not lamps or clocks with others than coloured ceramic parts. It is, however, not clear whether and how far customers would still buy such products if only the lead- and cadmium-free colours and colour spectrum was available.

The reviewers do not see themselves in a position to decide about esthetical aspects. Technically, the exemption is not required. Other than ceramic materials can provide the same technical function. Aesthetically, ceramic clock and lamp bases are different from other materials in this use that do not depend on the use of lead and cadmium. Lead and cadmium cannot be fully substituted in glazes and colours of these ceramic parts without compromising the quality and variety of colours to be achieved. The substitution using lead- and cadmium-free alternatives, or elimination – by using other than ceramic materials - of lead and cadmium in this application hence is possible, but the achievable results are not equivalent under esthetical aspects.

The reviewers recommend granting the exemption if the esthetical quality is considered as a function, which then cannot be achieved with lead- and cadmium-free glazes and colours. In this sense, the substitution of lead and cadmium in this application would be technically impracticable and Art. 5 (1) (b) would justify an exemption.

Focusing on the technical aspects only, the substitution or elimination of lead and cadmium in this application is technically practicable and the exemption would not be in line with Art. 5 (1) (b). The applicant's argument, however, that exemption 29 was granted, too, although it is based on esthetical aspects (decoration and more brilliant colour effects in leaded glass) should be taken into account.

Confinement of lead and cadmium use

A clear confinement of the exemption to certain glazes and colours would not be possible, as, according to the applicant, there is a multitude of tones and colours, and the glaze and colours must be seen as a system interacting to achieve the desired product properties. This unclear specification of the lead- and cadmium use in an exemption is of concern. The applicant says that lead-free glazes and colours will be used wherever possible, on the one hand. On the other hand, the applicant claims that leaded and unleaded systems cannot be used side by side in production. It must therefore be assumed that unleaded and maybe cadmium-free glazes and colours are not used even if they might be available.

On the other hand, the consultants do not see a possibility to confine the exemption in a way that would result in a clear and unambiguous exemption wording. "Colour" could be defined with wave lengths and light temperature etc. This would not be manageable in practice, neither in production nor in monitoring of the exemption, as the colour spectrum and appearance differences are too large. If the exemption is granted, it can thus not be limited to certain colours and glazes. The use is, however, restricted to ceramic parts for lamps and clocks, and as such would be different from a general exemption allowing, e. g. the use of cadmium in pigments in all electrical and electronic equipment.

4.37.4 Recommendation

The consultants cannot give a clear recommendation. Technically, the exemption is not required. Other materials than ceramic materials can provide the functionality of ceramic parts for lamp bases, lamp carriers and clocks. If ceramic parts are used in these applications, they could be used either without colours, or with lead-free glazes and colours. The substitution or elimination of lead and cadmium in this application thus is technically practicable. Aesthetically, the result of the elimination and substitution is not equivalent, as not all glazes and colours are producible in the same quality as with lead and cadmium. In case these esthetical aspects would be considered as a crucial aspect, Art. 5 (1) (b) could justify an exemption. The substitution or the elimination of lead and cadmium then would be technically impracticable with respect to the outcome.

In case the exemption is granted, it is recommended to add 31 July 2014 as expiry date. The current state of the art does not allow a clear confinement of the lead- and cadmium use in this application. This might change until 2014, and more appropriate lead-free glazes and colours might also be at hand by then.

Furthermore, it is not clear how the applicant has marketed his products falling under RoHS scope until now since an exemption would have been necessary from the beginning of the RoHS Directive's entry into force.

The wording of this exemption, in case it is granted, is proposed as:

Lead and cadmium in glazes and colours used on ceramic lamp bases, lamp carriers and clocks until 31 July 2014.

4.37.5 References

[1] Cerame Unie online stakeholder document "Request 2_Cerame-Unie_RoHS Check list.doc"

[2] Stakeholder document "Questions Cerame Unie.doc"

[3] Greenpeace online stakeholder consultation document "Exemption-25_Request_1-2-3_Greenpeace_1-April_2008.pdf"

[4] Cerame Unie stakeholder information sent via e-mail by Mrs. Astrid Volckaert to Otmar Deubzer, Fraunhofer IZM, on 31 October 2008

4.38 Exemption request No. 3

“Lead in solders in a third party component of Cortex family equipment”

This exemption request was one of five applications for new exemptions.

4.38.1 Description of request

The applicant manufactures and distributes systems for communication with Satellite Control Centre for telemetry, remote control, monitoring and control data. For his Cortex family products, the applicant uses an Intel motherboard as the central processor unit of the system, which is not available in a RoHS-compliant version.

4.38.2 Justification by stakeholders

According to the applicant, Intel does not intend to develop a RoHS compliant version of the above motherboard, declaring that this it is dedicated to servers and the use of lead in this component therefore is covered by exemption 7b of the RoHS Directive.

The applicant says that he has not found a similar RoHS compliant product on the market and that he cannot replace it without a complete re-design and re-qualification of the concerned equipment. In-Snec therefore asked for an exemption allowing the use of lead in this component. In-Snec otherwise has no solution to carry on manufacturing these Cortex products.

4.38.3 Critical review

During the online consultation, the applicant did not reply to the specific questionnaire. The applicant was asked to clarify whether he actually considers the products using the non-RoHS-compliant component to be in the scope of the RoHS Directive. They might be category 9 equipment (monitoring and control instruments) and thus be outside the scope of the RoHS Directive.

The applicant did not answer these questions. On May 20, he was sent the specific questionnaire by e-mail, but did not respond. The consultant made sure the contact data are correct, and sent the specific questionnaire again setting a deadline for reply. The applicant was asked to withdraw the exemption request officially in case he considers it to no longer be relevant.

The applicant did not respond. The further processing of this exemption request was hence stopped.

4.38.4 Recommendation

It is recommended not to grant the requested exemption. The applicant did not answer the consultant's questions on his exemption request.

4.39 Exemption request No. 4

"Cadmium within a colour converting single crystal semiconductor film for use in solid state illumination or display systems"

4.39.1 Description of request

Based on the exemption request by 3M (Minnesota Mining Manufacturing) submitted in April 2008 [1], II-VI colour-converted semiconductor light emitting diodes (II-VI LEDs) represent a revolutionary technology. This technology is currently not purchasable – even on the US market – but is planned to be put onto the European market by 3M in 2009.

As one specialty, the emission wavelength from the II-VI film can be tuned anywhere within the visible spectrum leading to an extremely good colour rendering. This is particularly important for the application in mobile projectors as the colour rendering is one of the main quality factors. At the present level of knowledge the II-VI material is therefore the only material system capable of light emission across the entire visible spectrum currently available.

3M submitted a request to the RoHS Directive because the II-VI-LEDs are intended to be used as replacements for Hg-containing lamps and conventional LEDs – especially in the mobile projector sector – and therefore fall under the scope of RoHS when used in lamps. The applicant also intends to increase the transition from gas discharge lighting to solid state lighting via this new LED technology. The main advantages of this technology compared to other light emitting sources are increased energy efficiency due to low power consumption [2] and increased lifetime (compared to all other conventional light sources apart LEDs).

3M expects the II-VI LEDs lifetime to be similar to those of conventional LEDs (35 000-50 000h). For mobile projector application the device lifetime is expected to be 20 000h. In comparison Hg-containing lamps for mobile projectors have an averaged lifetime expectancy of 8.620 h [3] [4].

Additionally II-VI LEDs provide sufficient colour saturation, instant-on, a small size as well as a high luminous efficacy (80 lm/W compared to 50 lm/W for commercial LEDs and fluorescent lamps) [3].

Concerning the amount of cadmium (Cd) used in these LEDs, the 0.3-9 µg Cd per II-VI LED (depending on the size of the LED) is a fairly small amount. In general, estimations of 3M predict less than 10 kg per year for all II-VI colour-converted LEDs distributed within the EU [1]. As the Cd is also tightly bound within this material, it represents no risk to human health and the environment initially. Furthermore, 3M points out that recycling is possible and that the company would work with the OEM who integrates the II-IV colour-converted LED-device into the final product in order to create a recycling program [3].

The applicant has requested an exemption with the following wording:

Cadmium within a colour converting single crystal semiconductor film for use in solid state illumination or display systems.

4.39.2 Justification by stakeholder

3M being the original applicant forwarded the only contributions within this review / stakeholder consultation process ([1],[2],[3] and [4]). Because of advantages regarding unique optical properties, energy efficiency, waste reduction and even the reduction of the use and the release of heavy metals to the environment in general (as will be explained below) 3M requests the grant of request 4.

The three main advantages of this special LED technology have been brought forward by 3M as summarised in the following:

Reduce the quantity of heavy metals released into the environment

According to 3M the new II-VI LEDs are foreseen to replace compact fluorescent lamps (CFLs). As CFLs contain mercury and additionally some other heavy metals in their lamp sockets, 3M points out that there is a higher necessity for heavy metals for CFLs than for II-VI LEDs. Nevertheless, the amount of Cd in the packaged II-VI LED will be very small (3M estimates a concentration of 8ppm). Because recycling for II-VI materials is possible the amount of Cd for the production of these devices can probably be even more reduced [3].

No other heavy metal than Cd is used to produce these II-VI LEDs, therefore the total impact of hazardous substances under the RoHS Directive appears to be relatively small.

Reduce the amount of energy needed via an improved energy efficiency

Beginning with the production process it is already important to note that with II-VI LED technology several improvements in manufacturing have been accomplished:

- During the device fabrication very little loss of material and therefore energy has been attained.
- Additionally, the waste of “bad LEDs” as for e.g. green-emitting LEDs can be reduced.
- Finally, the improvement of wafer-technology for II-VI LEDs also induces energy savings because of simultaneous fabrication of more than 10 wafers within one run [3].

Furthermore, the II-VI LEDS itself with its low power consumption and its extended lifetime compared to fluorescent lamps reduce the amount of energy needed throughout the whole II-VI LED lifetime.

Reduce the quantity of electronic waste (reduction of volume and number of electronic components)

The above mentioned energy savings via waste reduction (from the fabrication process up to the end-life recycling option) as well as the expected longer lifetime of these LEDs also contribute to a reduction of electronic waste in general.

4.39.3 Critical review

Comparison with other lamps (Fluorescent lamps & conventional LEDs):

As argued by 3M, in contrast to fluorescent lamps II-VI colour-converted LEDs do not contain other heavy metals than Cd since they do not contain lead as it is present in other lamp sockets. Additionally the amount of Cd is negligible compared to the mercury amount used for the production of fluorescent lamps [3]. However, the consultant is not in the position to balance or measure if the amount of heavy metals needed for CFL production represents a higher risk for the environment than the amount of Cd for the production of II-VI LEDs.

Compared to conventional / typical LEDs, II-IV colour-converted LEDs overcome the following limits as pointed out by 3M:

- "Limited range of wavelength commercially available [1]"– For II-VI LEDs it is unlimited within the visible spectrum for II-IV colour-converted LEDs.
- "Large variation in colour on individual wafers so that only a small fraction of LEDs emit light within an acceptable range for demanding applications. The rest are suitable only for low quality applications or are waste [1]." Undesirable characteristics and reduced performances caused by commercial LEDs or the combination of them are overcome by this technology which simply uses one LED for rendering different colours.
- "Power efficiency for green and yellow LEDs is lower than for blue and red [1]." As II-VI colour converted LEDs possess a 50% higher efficiency than conventional LEDs they also have a reduced power consumption.

Thus, II-IV colour-converted LEDs are considered suitable to replace current LED technology with an environmental benefit due to a higher energy efficiency at certain colours.

Environmental Risks:

As the amount of Cd contained within the II-VI colour-convertor material is covalently bound within the semiconductor lattice and additionally encapsulated within a glassy protective coating, it is stably bound and the possibility of release to the environment is greatly reduced. However, this is not an argument in line with Article 5 (1) (b) since only the impracticability of substitution or its negative effects can be taken into consideration.

Research for Substitution of Cd

According to the stakeholder contributions it is currently impossible to substitute or eliminate the cadmium in II-VI colour-converted LEDs without seriously deteriorating the performance. Because of the reduced colour range of Cd-free material the visual spectrum can not be covered completely in example (see [3] 5). However, 3M points out that research for Cd-free technology is in progress although a commercially available Cd-free technology will not be available within at least the next 4 to 5 years [2].

Since no sound data based LCA is currently available for this new technology a full assessment of the validity of the argumentation by 3M is not possible. Especially evaluation on whether a gain in efficiency compared to conventional LEDs and Hg-containing lamps outweighs the negative effects of heavy metal use can not be carried out. More scientific research is needed.

4.39.4 Recommendation

Against the background that solid-state lighting is intended to replace applications of fluorescent lamps, the described II-VI-colour-converted LEDs with their improved performances than typical LEDs (explained above) represent an exemption request which is justified according to Article 5 (1) (b). It is thus recommended to be granted temporarily until the next revision of the Annex of the RoHS Directive (expiry date 31 July 2014).

However, in order to avoid misuse based on a too general wording we recommend changing the wording of the current request into the following:

“Cadmium in colour converting II-VI LEDs (< 10 µg Cd per mm^2 of light-emitting area) for use in solid state illumination or display systems”.

4.39.5 References

[1] Original Request: “Cd in Colour-Converting Illumination or Display Systems.pdf”

[2] 3M E-Mail right after Meeting:
“3M's ROHS exemption Request Action items from discussion on 9-15-2008.msg”

[3] 3M submission to RoHS request no. 4:
“3M response to stakeholder consultation_2_23.September 2008.pdf”

[4] 3M submission to request no. 4, “3M additional info Cd in II-VI SSL_22Oct2008.pdf”

4.40 Exemption request No. 5

“Lead in solders for the connection of very thin (<100 μm) enamelled copper wires and for the connection of enamelled clad aluminium wires (CCAWs) with a copper layer smaller than 20 μm”

4.40.1 Description of request

Based on the exemption request by D&M PSS (Premium Sound Solutions) submitted in August 2008 [1], lead containing solders are used for the connection of different types of very thin wires explained in detail later on. The application of these wires is in light coils, when fast movement is required. It leads to the advantage of these thin and light wires that the power consumption during the life-cycle of the product is lowered.

The applicant has requested an exemption with the following wording:

Lead in solders for the connection of very thin (<100 μm) enamelled copper wires and for the connection of enamelled copper clad aluminium wires with a copper layer smaller than 20 μm.

4.40.2 Justification by stakeholders

The applicant uses these solders for high tone tweeters mainly on the automotive market, which fall under the ELV Directive. The applicant requests an exemption for product falling under the RoHS Directive. Supplementary, one other stakeholder [2] who produces 10.000-30.000 instruments concerned by soldering of enamelled copper wires diameters from 10 to 250 μm in France per year brought forward his plea to grant this request.

In the request document [1] it is pointed out that the focus lays on technical and scientific aspects in order to avoid parallel exemption initiatives to the RoHS Directive. If an application specific exemption would be preferred the applicant proposes the following wording [1]:

Lead in solders for the connection of the Cupper Clad Aluminium Wire of a tweeter voice coil to the tweeter frame.

According to the applicant, currently no alternative Pb free techniques are available. However, the applicant expects that at least one of the following alternative routes will be available by 2012-2014:

- RoHS compliant reliable solders or
- Solder-erosion-free Copper-clad-Aluminium Wires (NCCAWs) or alike with sufficiently low diameters.
- As it is mentioned by the applicant [1] “*The soldering problem could be partially overcome by replacing the CCAWs with copper wires*”. However, this replacement option strongly depends on the application. For applications which need thin copper wires

(thinner than 100 µm) such a replacement is technically unfeasible. For other special applications (e.g. tweeters) such a replacement would lead to a greatly increased power consumption because of the weight increase via copper wires. In tweeters the increase in power consumption would sum up to four times in order to "*compensate the loss in acoustical power*" caused by heavier copper moving parts [1]. However, no evidence on concrete testing was given. Only a rough estimation for the calculation was given by the applicant:

- "The loss in acoustical power upon the increase of weight of a moving part is governed by physical laws, resulting in the following formula:
- -20 log (moving mass with copper wire /moving mass with CCAW) = loss in acoustical power.
- With data from standard tweeters currently in mass production (tweeters for automotive falling under the ELV directive), we calculate the weight increase upon changing form CCAW to copper. The weight of the moving mass more than doubles. If the weight doubles, the loss in acoustical power is 6dB. To compensate a sensitivity of 6 dB in acoustical power, the electrical power of the speaker needs to be multiplied by a factor 4 to reach the same sound level (e.g. from 2W to 8W)."

Furthermore the applicant explains the two steps of his application, namely:

- Pre-tinning: Pb solder necessary
- During the pre-tinning of the CCAW, a thin layer of lead containing solder is placed upon the very thin wire.
- Solder the pre-tinned enamelled wire: Pb free solder step.

As the applicant points out, the Pb solder is only necessary for pre-tinning.

Advantages of the CCAW solders that have been brought forward by D&M PSS as summarised in the following:

These solders withstand 450°C and ensure an electrically conductive as well as a mechanically strong connection. Due to a lack of substitution material, as will be explained more detailed later on, these solders could currently only be replaced by HMP solders. As these contain even more lead in comparison (85% in HMP solders vs. 60% Pb) such a contra productive substitute will not be considered.

4.40.3 Critical review

As previously mentioned, the applicant's main argumentation for a grant towards his request is the reduced power consumption. However, an electrically conductive as well as a mechanically strong connection is also feasible with copper solders.

The contractor points out that it is scientifically not feasible to trade the lead consumption off against power consumption. A decision thus needs to be taken on other grounds. Whether or not an increase in power consumption justifies the request according to Article 5 (1) (b) can thus not be assessed by the contractor.

Furthermore the applicant indicates that there are no substitutes currently available. However, in a confidential submission the applicant indicates a promising breakthrough in the research for substitution. This leads to the fact that, with a high likelihood, substitution will be possible soon.

Research for substitution possibilities:

- RoHS compliant solder do not fulfil the requirements because they dissolve the copper too fast;
- Copper wires dissolve too fast in RoHS compliant solders;
- Remove lacquer with heat in a separate step: impossible, operating temperature window too small;
- Chemically stripping impossible and would also have higher negative environmental impact;
- Changeover to HMP solder as alternative does not make sense because of the even higher Pb content (>85%);
- NCCAWs (also called ”KCCAWs”): currently no option because diameter too big, (however in [2] the applicant informs the contractor on a confidential basis that good progress is currently being made in this direction.

Finally, the reviewer indicates that as an alternative connecting method welding was tested by the applicant. However, these tests have been abandoned in a very early stage because of the different melting temperatures of copper and aluminium.

4.40.4 Recommendation

Against this background the lead containing solders represent an exemption request which can not be evaluated with regard to the availability of substitutes and their possible negative effects.

Furthermore, it is not clear how the applicant has marketed his products falling under RoHS scope until now since an exemption would have been necessary from the beginning of the RoHS Directive’s entry into force.

4.40.5 References

[1] Original Request: “exemption_PSS_letter.doc”

[2] Mail from Chauvin Arnoux Group concerning request 5 (8 October 2008)

[3] D&M PSS submission to specific questions request #5: DMPSS_Reply_Specific Questions Request 5_08.10.2008.pdf (confidential)

5 Overall aspects and conclusions

This chapter includes overall conclusions on the evaluation process as well as general remarks that are valid for all exemptions and exemption requests.

5.1 General procedural observations

Three online stakeholder consultations have been carried out in the context of the current evaluation on 29 exemptions and 5 exemption requests. Even though the contractor has put a lot of effort into reaching a large number of stakeholders, not all exemptions and exemption requests have received the same level of attention.

Some exemptions and / or requests were not commented at all. This has lead to a need for further investigations in order to identify involved stakeholders and in order to search for data and information on substitutes.

Some exemptions have received a very high stakeholder attention leading to a very large effort with regard to organising an open and constructive discussion process.

In many cases extensive scientific and technical expertise and research was needed in order to assess whether or not an exemption is further justified. Also finding the correct wording and reaching a common understanding among stakeholders with regard to how an amendment of the Annex can be put into practice has not always been an easy task.

The contractor would therefore like to point out that further evaluations need different framework conditions.

5.2 Category 8&9

Since the evaluation of the current Annex did not take place within the general context of the RoHS review, it has its main focus on the current scope of the RoHS Directive, i.e. not including categories 8&9. Nevertheless DG ENV has expressed the wish to receive information on the consequences of the evaluation on categories 8&9 in case they would be included into the scope in the near future. However, it needs to be stressed that it was not possible to carry out a full in-depth evaluation in that sense due to several reasons:

Category 8&9 equipment is particularly complex and has different characteristics than most of the other EEE covered by the current scope. These include inter alia: long design cycles, custom-designed products, long lasting products, partly small production volumes, stronger requirements with regard to health & safety etc.

Thus, consequences of recommended amendments to the current Annex for category 8&9 equipment can only be identified through an in-depth analysis which has a specific focus on this type of equipment. This was not formally foreseen in the contract and would go beyond the mandate given to the contractor.

Category 8&9 industry was not aware of the fact that the current evaluation should also cover their type of equipment since if and when category 8&9 will be included into the RoHS scope is not yet decided. It was nevertheless involved in the evaluation process but could only deliver detailed technical information for some specific category 8&9 applications.

Transition to RoHS compliance for category 8&9 industry is taking place under the assumption that there are exemptions in force. Development and design changes needed to be started on that basis and did thus not take into consideration how an Annex could change when reviewed. Providing extensive information is thus time critical and relies on a not existing legal situation.

As a consequence of the above described points, the evaluation of the current Annex followed the following approach:

The consultations have been run with the information that possible consequences on categories 8&9 should be transmitted to the contractor.

In the next step, corresponding stakeholders were invited to take part in the further discussion process.

Information that has been provided either during the consultation or during the ongoing evaluation has been evaluated as far as possible with regard to consequences of proposed recommendations for category 8&9 equipment. However, this will be on a more qualitative and less technical level than for the current scope.

Due to the fact that two processes (review of the Annex and review of the whole Directive) are running in parallel that should have been running in one after the other, the contractor proposed the following approach with regard to enlarging the scope to categories 8&9:

When putting into force a new RoHS scope including categories 8&9, ERA's table 71[42] should be included as list of exemptions that enter into force at the same time.

Industry needs an appropriate transition period between publication of a reviewed Annex on the one hand and publication of a reviewed Directive on the other hand in order to apply for additional exemptions that are *i)* not covered by ERA's table 71 and *ii)* that were previously covered by the existing Annex but that are not anymore covered by an amended version.

Category 8&9 equipment related exemption requests then need to undergo an own specific evaluation.

[42] Cf. ERA-Report 2004 Dr. Paul Goodman et al.: Technical adaptation under Directive 2002/95/EC (RoHS) - Investigation of exemptions; final report Dec. 2004

5.3 Transition period

During the discussions with stakeholders issues around the necessity of a transition period between the publication of an amended Annex and its entry into force were addressed. In the past, stakeholders needed to comply with a new RoHS Annex from the day it was published in the Official Journal. This has often been criticised since industry did not know beforehand which applications would be exempted and if so with which kind of wording etc. During the current evaluation it was tried to identify realistic and reasonable transition periods. These have been proposed for every exemption assuming that an amended Annex would be published by the end of 2009.

5.4 Expiry dates

The contractor has integrated the aspect of setting expiry dates in the discussions with stakeholders. Where possible an expiry date has been proposed. However, there are applications for which an expiry date is not sensible since substitutes cannot exist from a technical point of view or can be foreseen not to exist within the next 5–10 years. In these cases, the contractor has recommended to set the expiry date at the time the next revision cycle starts. Most stakeholders, however, are not supporting this approach.

5.5 Adaptation of Art. 2 (3) to the scientific and technical progress

Art. 2 (3) of the RoHS Directive addresses the repair and reuse of EEE put on the market before 1 July 2006 with spare parts that are not RoHS compliant:

This Directive does not apply to spare parts for the repair, or to the reuse, of electrical and electronic equipment put on the market before 1 July 2006.

The Commission FAQ-Document [1] states that this article allows the use of non-RoHS compliant material in electrical and electronic equipment (EEE) put on the market before 1 July 2006 for the purposes of capacity expansion and/or upgrade provided that the EEE is not put on the market as a new product. If after the capacity expansion and/or upgrade the EEE is put on the market as a new product, it should comply with the RoHS Directive. If after capacity expansion and/or upgrade the EEE is put on the market as a reused product, the RoHS Directive does not apply.

The above article does not apply to EEE, which used an exemption with an expiry date after 1 July 2006. For instance, if the COM follows the recommendation to set the expiry date

31 December 2009 for the use of lead in finishes of fine pitch components with a pitch of 0.65 mm or less (exemption 23), such lead-containing fine pitch components would not be allowed for repairing or upgrading equipment put on the market between 30 June 2006 and 31 December 2009. Reliability and technical compatibility requirements, however, must allow the use of lead-finished fine pitch components further on for the repair and use of EEE, which was produced with such types of components. Simply switching to lead-free components in a system that was designed for and produced with lead-finished components might cause premature failures of the equipment and might have severe consequences for the manufacturers.

Following the principle implemented in Art. 2 (3), the consultants will add a clause to each individual exemption that expires allowing the use of the expired exemption in spare parts for the repair, and to the reuse of equipment put on the market before the expiry of the exemption.

An alternative approach would be to adapt Art. 2 (3) in a way that it allows the use of spare parts for the repair and to the reuse of any equipment that was designed applying an exemption and brought on the market before the expiry of the exemption.

A possible wording for such a revised Art 2 (3) reflecting the above considerations might be:

This Directive does not apply to spare parts for the repair, or to the reuse, of electrical and electronic equipment according to the "repair as produced" principle.

This wording would extend the use of spare parts containing banned materials for the repair, or to the reuse, of equipment that used an exemption before its expiry. Individual additions in each single exemption wording would then become obsolete. The wording of the exemptions would be simpler, and manufacturers would have more security for their planning. It would be clear that they can repair/reuse their equipment adequately without having to call for it in each exemption review. As the underlying principle is already implemented in Art. 2 (3), the proposed change in Art. 2 (3) would simply be an adaptation of Art. 2 (3) to the scientific and technical progress allowing the cancellation of exemptions after 2006. Additionally, the Commission's FAQ document [1] would have to be adapted accordingly.

As long as Art. 2 (3) is not adapted accordingly, each exemption in the annex with an expiry date will need an add-on allowing the use of non-RoHS-compliant spare parts for the repair and reuse of equipment put on the market before the respective expiry date.

5.6 "Grandfathering" and whole product units as spare parts

The stakeholders during the review process had raised the topic of grandfathering and legacy products. The consultants were asked to give their point of view on these issues based on the practices with the review of exemptions and the application of Art. 5 (1) (b) in the past.

<u>Grandfathering approach</u>

HP [2] has proposed to consider a grandfathering approach in the context with exemption 7b, which then might also be relevant for exemption 12. Once an exemption from the ban of a substance has expired, a grandfathering approach would still allow putting products on the market using that exemption. The condition however would be that this model of a product (legacy product) was put on the market before the expiry date of the exemption.

To give an example: Exemption7b is recommended to expire on 31 December 2014. All products of a model type X server contain lead in solders. The products of this model X were put on the market in November 2014 for the first time. A grandfathering approach would then allow putting products of model type X on the market further on after 31 December 2014. All new models of servers put on the market after 31 December 2014 for the first time would no longer be allowed to use lead in solders.

Based on the experience with the past reviews of exemptions and the application of Art. 5 (1) (b) in these reviews, and on the implementation practice of the RoHS Directive, the consultants think a grandfathering approach would not be in line with the provisions of Art. 5 (1) (b). The new models put on the market prove that the substitution or elimination of the banned substance is technically and scientifically practicable, while at the same time the old models further on are exempted. According to Art. 5 (1) (b), however, an exemption can only be granted if the substitution or elimination of the banned substance is technically or scientifically impracticable. Grandfathering approaches with reference to new models of products thus could be intrinsically in conflict with Art. 5 (1) (b). So far, the technical practicability of substitution or elimination of a substance throughout the past reviews of exemption requests was always referred to the respective components of a product, never to old/new models of products. Once a component of a product can be manufactured without using a banned substance that was exempted before, in some cases an appropriate qualification time may be required. This was then taken into consideration with an appropriate expiry date for the exemption. A grandfathering approach so far has not been applied.

The stakeholders claim that a new product offering is not a direct replacement for a legacy product. As each product fulfils a different needs, both old and new model products are sold concurrently for some time.

New models of products may be different in performance, but, as e. g. high end servers are designed to serve specific needs, the new models must be assumed to serve those needs as well as a minimum requirement. Otherwise, they would not be new models of a product, but a completely new product that does not have a predecessor and would serve a completely different market. The new model could not be a replacement at all for the older models, and the older models would have to be manufactured further on until customers changing needs would make them obsolete.

HP [2] argues that the spare parts article 2 (3) under the RoHS Directive would be one example for such a grandfather approach, as it allows producers to continue to place on the market non-RoHS spare parts for the repair of EEE placed on the market prior to 1 July 2006. The reviewers do not follow this argument. Art. 2 (3) of the RoHS Directive is not comparable to a grandfathering approach that would generally and independently from the use of the product allow the general sales of old models of products. The Commission's FAQ document clarifies that "[…] it is permissible to put on the market spare parts - containing the hazardous substances - for the repair of old equipment (put on the market before 1 July 2006), but not to repair new equipment (put on the market after 1 July 2006)." Art. 2 (3) thus allows putting on the market spare parts, but strictly limits the use of such spare parts to repair and reuse of equipment put on the market prior to a certain point in time, unlike a general grandfathering approach.

Additionally, spare parts are not exempted from the RoHS Directive, but they are out of scope, as the RoHS Directive does not apply to them. A grandfathering approach following the principle of Art. 2 (3) would require excluding older models of products from the scope of the RoHS Directive and to generally only apply it to new models put on the market after a certain deadline.

May "equipment" in the RoHS Directive refer to models of products, not to products, and may it hence be interpreted allowing a grandfathering approach? Article 4 of the RoHS Directive ("Prevention") uses the same "equipment" wording: "Member States shall ensure that, from 1 July 2006, new electrical and electronic equipment put on the market does not contain lead […]".The practical implementation of Article 4 in the RoHS Directive so far followed the product approach, not the model approach. Not a single piece of electrical and electronic equipment put on the market after 1 July 2006 was legally allowed to contain any of the banned substances, unless a respective exemption was in place, or the equipment was out of the scope of the RoHS Directive, like e. g. the spare parts. The legal practice so far therefore does not support a grandfathering approach either.

A grandfathering approach was applied in the End-of-Life of Vehicles (ELV) Directive. It exempts lead in solder in electronic circuit boards and other electrical applications […] used in vehicles type approved before 31 December 2010. The ban of lead refers to the new type approved models from 31 December 2010 on, but allows the use of lead after 30 December 2010 in vehicles that were type approved until 30 December latest. The question is how far the grandfathering approach used in the ELV Directive could be a justification to apply it in the RoHS Directive.

The ELV Directive does not set as concrete requirements for an exemption as does the RoHS Directive. Art. 4 (2) (b) (II) of the ELV Directive allows exemptions for banned materials if the use of these substances is unavoidable. There is no further specification of “unavoidable”. Further on, the technical background for exemptions and the conditions in vehicles may be different in the ELV and the RoHS Directive. Finally, the type approval of a vehicle is a clearly identifiable date. Would the same apply to new models of a product put on the market?

Whole product units as spare parts

Manufacturers see the need to sell legacy model products, like e. g. servers, into existing server networks, e. g. in telecommunication or data centres, for upgrade or capacity enhancement. Such networks can be highly complex systems, and changes, e. g. by replacing an older model server by a new model server, may adversely impact the network. The RoHS Directive acknowledges this principle in Art. 2 (3) taking out spare parts from the scope of the RoHS Directive. It allows the repair and even the upgrade and capacity enhancement of products that were produced using banned materials, according to the Commission’s FAQ document [4]: “The use of non-RoHS compliant material in electrical and electronic equipment (EEE) products […] for the purposes of capacity expansion and/or upgrade is allowed in principle provided that the EEE is not put on the market as a new product.”

Could Art. 2 (3) be interpreted to allow whole units of products to be considered as spare parts, which could then be put on the market for the repair, capacity expansion and upgrade of existing systems like server networks in telecommunication and data centres?

“In regards to spare parts, […] a "whole" unit, in this case the server would not be considered a spare part. During the initial phase of the original RoHS, industry debated this issue with the EU Commission asking for a FAQ to say that it was OK to do this. This was and still is important to the industry since we do whole unit exchange on certain products. For example your notebook computer may break and to quickly repair it, it would be exchanged with a working one. Your original notebook would be repaired and then it would be used to exchange with say mine when it broke. We do this on a worldwide bases. So a unit that broke in Pairs may go to Berlin. One that broke in New York City may also go to Berlin. The EU Commission saw this replacement product from New York City as being put on the market for the first time in the EU even though it was used for repair, meaning a spare part for original unit. At the time the EU Commission checked with legal services and they agreed with the EU Commission.” [3]

The above statement shows that there has been intensive discussion on this point before, and the result was that Art. 2 (3) would not allow the use of whole units for repair. The same would then apply for capacity enhancement and upgrades of server installations using whole legacy product units. Whole units so far thus have not been considered as “spare parts” in the sense of Art. 2 (3).

Considering the above statement, it is even more doubtful whether a grandfathering approach would be acceptable.

Summary and conclusions

In the consultants' point of view, a grandfathering approach would not be in line with Art. 5 (1) (b). If such grandfathering approaches should be allowed under the RoHS Directive, Art. 5 (1) (b) could either be changed, or an explicit article be inserted into the RoHS Directive defining the conditions under which such a grandfathering approach would be allowed explicitly.

Manufacturers claim that they may be contractually obliged to supply legacy products (products still containing a banned material after the expiry of the exemption) not only for the repair, but also for the upgrade and capacity enhancement of existing installations, like for example server networks in telecommunication or data centres. Manufacturers, however, can be expected taking into account the temporary character of exemptions and not to go into contractual obligations, which they may not be able to accomplish due to the temporary character of the exemptions.

In case consumer safety or health is at stake if such legacy products cannot be delivered into existing installations, manufacturers might be granted an exemption on a case by case base according to Art. 5 (1) (b) provided there is sufficient technical evidence.

For repair, non-RoHS-compliant components can be used following the principle manifested in Art. (2) (3) and in the Commission's FAQ document [1]. The consultants added a respective clause to all recommendations for exemptions including 7b and 12.

For manufacturers' business practice of repair as described above [3], it seems to be plausible to provide for the legality of such practices. Without further detailed inquiry, the consultants assume that the operational practice of such equipment does not allow longer operational time outs of such systems. The exchange of whole units in such installations thus may be an operational requirement intrinsic to the appropriate usability of such products. If industry can prove this and that it is necessary to use legacy products for this purpose, this interpretation of repair using whole units of products should be allowed. A possible solution might be adapting the Commission's FAQ document respectively or Art. 2 (3) of the RoHS Directive.

5.7 References

[1] Frequently Asked Questions on Directive 2002/95/EC on the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE); http://ec.europa.eu/environment/waste/weee/pdf/faq_weee.pdf, last access July 2008

[2] HP Hewlett Packard; Stakeholder document
"HP Letter to the Oeko Institut – Rev3.1.pdf"

[3] Ray Moskaluk, Hewlett Packard; information sent to Otmar Deubzer, Fraunhofer IZM, via e-mail on 24 October 2008

6 Annexes

6.1 Stakeholder documents

All stakeholder documents to each exemption and exemption request are provided on Data-CDs.

6.2 Overview on stakeholder involvement of current exemptions 1–4

Table 11 Overview on stakeholder involvement on Compact Fluorescent Lamps (CFLs)

CF lamp type	Specification	NGOs Proposal		EuP Proposal		ELC Proposal	
		Hg limit	Data	Hg limit	Data	Hg limit	Data
General purpose	< 50 W	2 mg	yes	1 mg[43]	no	3,5 mg	no
	≥ 50 W < 150 W					5 mg	no
	>150 W		no			15 mg	no
Square structural, circular		8 mg				7 mg	
Special purpose CCCFL		2 mg	yes			–	
Special purpose		3 mg	no			5 mg	no
Halophosphate	T12 + T9	8 mg		8 mg		10 mg	

Table 12 Overview on stakeholder involvement on Linear Fluorescent Lamps (LFLs) and non-LFLs as well as non-CFLs

LFL	Specification	EEB Proposal		ELC Proposal	
		Hg limit	Data	Hg limit	Data
General purpose (normal lifetime)	≤ T5	2 mg	yes	4 mg (T2), 3 mg (T5)	no
	T8	2 mg (< 6 foot)	yes	3,5 mg	no
		8 mg (> 6 foot)	yes		
	T10, T12	0 mg		5 mg	no

43 This 1 mg value is an indicative benchmark given for non-directional household lamps within the working document on a possible commission regulation implementing Directive 2005/32/EC for domestic lighting (Lot 19).

General purpose (long lifetime)		3 mg		5 mg	no
Non-LFL, Non-CFL	**Specification**	**EEB Proposal**		**ELC Proposal**	
		Hg limit	**Data**	**Hg limit**	**Data**
Tri-band phosphor U-bent, circular		8 mg	yes	15 mg	no
Induction		7 mg	yes	15 mg	no
CCFL/EEFL	≤ 500 mm	2 mg		3,5 mg	yes
	> 500 mm ≤ 1.500 mm			5 mg	yes
	>1.500 mm			13 mg	yes

Table 13 Overview on stakeholder involvement on High Pressure (HID) lamps

HID lamp type	**Specifications**	**EEB Proposal**		**ELC Proposal**	
		Hg limits	**Data**	**Hg limits**	**Data**
MV		drop-in repl.avail.	yes	no retrofit	
		0 mg		– (open limit)	
MH	< 25 W	2,5 mg	yes	– (open limit)	no data but technological argumentation
	> 25 W < 100 W	10 mg	yes		
	> 100 W < 200 W	15 mg	yes		
	> 200 W < 400 W	–			
HPS	CRI > 60	too high	not enough	30 mg (≤ 155 W)	
				40 mg (> 155 W ≤ 405 W)	
				40 mg (> 405 W)	
	CRI ≤ 60	5 mg		25 mg	
		10 mg		30 mg	
		25 mg		40 mg	