Consultation Questionnaire Exemption 7(a)

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

Bourns, Inc. comments are in red

Abbreviations and Definitions

BGA	Ball Grid Array
Bourns	Bourns Incorporated should read Bourns, Inc.
DA5	Die Attach 5, a consortium established to develop a Pb-free die-attach solution consisting of STMicroelectronics, NXP Semiconductors, Infineon Technologies, Bosch (Division Automotive Electronics), and Nexperia
EEE	Electrical and Electronic Equipment
ESD	Electro-Static Discharge
HMP	High melting point
HMPS	High melting point solders
LED	Light emitting diode
LHMPS	High melting point solders with a lead content of at least 85 %
Pb	Lead
RoHS	Directive 2011/65/EU on the Restriction of Hazardous Substances in Electrical and Electronic Equipment
Umbrella Project	A large number of company/business organizations/business associations that are participants in the RoHS Umbrella Industry Project

The Oeko-Institut has been appointed by the European Commission, within a framework contract[1], for the evaluation of applications for exemption from Directive 2011/65/EU (RoHS), to be listed in Annexes III and IV of the Directive.

Your organisations, Bourns Inc. and STMicroelectronics srl and Infineon Technologies AG on behalf of the Umbrella Project have submitted a request for the renewal of the above-mentioned exemption, which has been subject to an initial evaluation. A summary of the main argumentation for justifying the request is provided below (also including information from other applications submitted for the renewal of this exemption) as a first basis to be used in the stakeholder consultation planned as part of this assessment.

[1] The contract is implemented through Framework Contract No. ENV.B.3/FRA/2019/0017, led by Ramboll Deutschland GmbH.

Please review the summary of the argumentation provided to ensure that your line of argumentation has been understood correctly and provide answers to the questions that follow that are to address aspects requiring additional information and/or clarification.

1. Summary of argumentation of applicant on the justification of the exemption

1.1. Background

Two applications were made for the renewal of Ex. 7(a) for:

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

Both request the renewal of the exemption with its current wording for the maximum duration allowed by Article 5 of the Directive.

Bourns Inc. (hereinafter referred to as Bourns) requests the exemption explaining that lead enables soldering at higher temperatures, while maintaining the reliability of the connection. Lead-containing high melting point solders with a lead content of at least 85 % (LHMPS) are used in electronic components to maintain the integrity of the joints between the die and lead-frame at the board level assembly. Bourns argues that substitutes are currently not available, explaining that alternative solders must have properties to protect the solder from melting thereby creating a failure situation. (Bourns 2019)

STMicroelectronics srl and Infineon Technologies AG apply for the exemptions renewal on behalf of a large number of company/business organizations/business associations that are participants in the RoHS Umbrella Industry Project (Umbrella Project)[2]. The Umbrella Project specifies a wide range of applications where LHMPS are still needed (see Annex I), claiming that though research into possible substitutes has been underway for many years, suitable substitutes are yet to be identified. In essence, alternative technologies with similar ductility and strength as lead (Pb) alloys and that can survive a standard reflow process (or several) on printed circuit board with either leaded or unleaded solder are as yet unavailable. (Umbrella Project 2019)

1.2. The history of the exemption and a starting point for the current assessment

Exemption 7(a) for "*Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead)*" was initially listed in Directive 2002/95/EC (RoHS 1)[3], when it was published in 2003. The exemption was assessed twice to establish its continuous justification (Gensch et al. 2009; Gensch et al. 2016). In both assessments it was concluded that the exemption was still justified as substitutes were not available for the full range of relevant applications. However, it was also concluded that the exemption wording created a loophole, as its formulation did not restrict the application of the exemption only to areas where substitutes were not available. Evidence for this was provided already in the first assessment, where stakeholder information showed that in some cases, LHMPS are applied also in cases where solders with a lower lead content can be used.

An effort was made in the past (Gensch et al. 2016) to develop an exemption wording that would apply only to areas where the use of LHMPS could not be avoided, however this attempt did not

[2] See detail in application.

[3] Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, RoHS 1, European Union (13 February 2003)

culminate in a formulation that was suitable to eliminate the loophole while still exempting necessary uses of LHMPS. As part of this effort, the following areas were specified as applications where LHMPS were still needed:

1. For combining elements integral to an electrical or electronic component:
   a) a functional element with a functional element; or,
   b) a functional element with wire/terminal/heat sink/substrate, etc.;
2. For mounting electronic components onto sub-assembled modules or sub-circuit boards;
3. As a sealing material between a ceramic package or plug and a metal case; and
4. For high power transducers (both low and high frequency in professional sound applications.

The information provided at the time by applicants and involved stakeholders showed that in multiple areas substitutes were still not available, however it was only in relation to application areas in high power transducers and in die attach that detail was provided as to the effort and the partial success of developing alternatives (e.g., newer low frequency high power transducer designs and smaller die sizes respectively). An effort was made to develop an exemption wording that addressed all application areas:

> *"Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead) used:*
>
> *a) for internal interconnections in electrical and electronic components, i.e.*
>
> > *i) for die attach in power semiconductors with steady state or transient/impulse currents of 1 A or greater and/or blocking voltages beyond 200 V, or die edge sizes larger than 0.5 mm*
> >
> > *ii) in components with steady state currents of more than 1 A and/or blocking voltages beyond 200 V other than die attach*
> >
> > *iii) for other internal interconnections in electrical and electronic components excluding those in the scope of exemption 24*
> >
> > *iv) in HID lamps and oven lamps*
>
> *b) in solder balls for the attachment of ceramic BGA to the printed circuit board (second level interconnect)*
>
> *c) for the attachment of components to printed circuit boards (second level interconnect) in high temperature plastic overmouldings (> 220 °C)*
>
> *d) for mounting electronic components onto subassemblies (first level interconnect), i.e. modules or sub-circuit boards*
>
> *e) as a hermetic sealing material between a ceramic package or plug and a metal case*
>
> *f) other applications;" (Gensch et al. 2016)*

This proposal was discussed with involved stakeholders, who pointed out various limitations and provided a few counter proposals (see Annex II).

As a comprehensive wording could not be agreed on, the following wording was recommended for the continuation of the exemption and also proposed as a starting point for the current assessment, seeing as progress could be expected in relation to the two latter application areas sooner than in other areas:

> *"Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead)*
> *I)in all applications not addressed in items II and III, but excluding applications in the scope of exemption 24*
>
> *II) for die attach*
>
> *III) for electrical connections on or near the voice coil in power transducers" (Gensch et al. 2016)*

It is noted that Delegated Directive (EU) 2018/742 of 1 March 2018, which presents the final decision regarding the prior evaluation of this exemption, constitutes the legal renewal of Ex. 7(a) with its initial wording. This document bases the decision on the final premises that "*no reliable alternatives are available on the market or are likely to be available on the market in the near future, a renewal of the exemption with a validity period until 21 July 2021 is justified, while nonessential splitting of the wording and a shorter period could generate unnecessary administrative burden for the industry*."

1.2.1. Volume of lead to be placed on the EU market through the exemption

Bourns (2019) specifies for its own application of Ex. 7(a) that approximately 117 million components containing a LHMPS were sold in 2014. Bourns estimates the total lead content of these parts to be approximately 77g per year. The average weight of the components is stated to be 0.37g.

The Umbrella Project (2019) explains that their estimated usage of lead in relation to Ex. 7(a) is based on interviews with a few member companies of the Umbrella working group. Answers ranged between few kg and 31 tons per year with minimum and maximum weights per unit ranging between 0.0005 mg to 226 mg (the need for modern semiconductors to be smaller in size has resulted in a decrease in the minimum lead quantity from 0.0013 mg to 0.0005 mg per device). The amount of Pb in HMP solders for EEE is estimated to be less than 0.2% of the total Pb placed on the market per year.

1.3. Technical description

Bourns (2019) specifies that LHMPS can be applied in various equipment and refers to the medical equipment, aerospace, automotive and military sectors as their customers. Semiconductor products use high-lead solder as a die attach material and/or as internal electrical interconnections within components including diodes, transistors, clip bonding of discrete devices and for surface mount and insertion components. Bourns refers to specific applications many of which are components that inherently protect EEE from irregularities in power supply such as Electro-Static Discharge (ESD), electricity surges, voltage level irregularities and overcurrent situations. Among the equipment and components that need to be protected from such impacts, Bourns mentions appliances in general, light emitting diode (LED) lighting and batteries in both vehicles and EEE such as mobile phones and medical equipment. In relation to fuses for protecting battery packs, it is mentioned that these are typically used in a harsh, extreme heat environment, where the solders must thus have properties to protect the solder from melting thereby creating a failure situation. It is not clear if these environmental operation conditions apply to all applications mentioned by Bourns.

The Umbrella Project (2019) explains that the exemption is needed for a wide range of electronic components as well as to manufacture equipment. It details a non-exhaustive list of application areas of LHMPS that are similar to the list specified in Section 1.2, specifying die and lamp socket as example applications for point 1(a) (combining a functional element with a functional element, which are integral to an electrical or electronic component), and specifying "*connecting magnet wire coil to flexible conductor*" which is understood to be an application description relevant to the high power transducers in point 4. Table 2 of the application provides specific examples for these four groups and additional reasons for the necessity of LHMP solders (see Annex I for examples).

LHMPS are said to have excellent wettability, reliability due to ductility and no re-melting during PCB reflow process. Components containing high lead solder are reflowed up to 260°C without melting the inner component solder which will soften at about 300C. Semiconductor-type devices require these high temperature solders to maintain the integrity of the joint between the die and lead-frame at board level assembly. (Bourns 2019; Umbrella Project 2019; DA5 2020)

Table 1 of the application specifies typical types and melting temperatures for solders currently used in applications falling under this exemption and refers to:

- Sn-85Pb with a melting point between 226 / 290 °C;
- Sn-90Pb with a melting point between 268 / 302 °C; and
- Sn-95Pb with a melting point between 300 / 314 °C.

The DA5 Project (DA5 2020), referred to in the Umbrella Project, specifies that the LHMPS PbSn5 and PbSn2Ag2.5 are used as chip-solders in packages for die attach applications specifying also the commercial competitiveness of LHMPS.

1.4. Applicant's justification for the requested exemption

Bourns (2019) explains that substitution has already occurred where SnPb solders could be substituted by a non-leaded solder, however does not provide examples of such applications. Nonetheless, together with a solder supplier Bourns is still researching and testing alternative solders or processes to eliminate LHMPS in applications where this has not yet been possible. Additional detail is not provided as such information is regarded as proprietary; however, this effort is explained to relate to a specific product line and Bourns states that it may not provide a solution for other product lines.

To clarify: Examples where SnPb solders (not high temp solders) have been substituted for lead-free options include parts such as trimming potentiometers, chip arrays, chip resistors, encoders, panel control, precision potentiometers. Some of these models prior to RoHS uses SnPb solder and solder dip plating (60/40, 90/10…) but not high temp solders. These parts have been updated to a lead free solder or plating. These are not the high temp solder parts which still use a lead >85% solder.

The Umbrella Project (2019) explains that substitution is currently not possible, mentioning the various properties required form substitutes. Alternative technologies are not yet available that have the combination of ductility and strength of Pb while retaining reliability during one or several reflow processes (melting of solder) which would otherwise weaken the bond.

1.4.1. **Availability of alternatives** *(Substitution or Elimination, roadmap to substitution, reliability of substitutes)*

Bourns (2019) refers to a few potential substitutes in its application including gold, zinc, bismuth or tin/ antimony-based solders. Potential substitutes are explained to have reliability issues including voiding/cracking/disruption after stress, growth of brittle intermetallics at high temperature and disruption during temperature cycling. For gold-based solders low ductility and a low melting point is explained to be a disadvantage in comparison to LHMPS. For the other mentioned candidates there is limited experience with alternatives regarding their reliability.

The Umbrella Project (2019) explains on the unsuitability of certain available substitutes that:

- Standard lead-free solders generally have lower melting points than LHMPS, though some are also used for reflow soldering of printed circuit boards. If used for sealing components and for making bonds inside components or in modules, such solders would melt during reflow and this would cause bond failure.
- Welding and brazing are mentioned as alternative bonding methods but require much higher temperatures. Brazing alloys typically melt at >400°C and welds are formed at >1000°C. The polymers used in electronic components and the silicon chip would be destroyed at these temperatures, making these techniques impractical.
- Crimp connections are often used in electrical equipment but suffer from many disadvantages. They cannot be used for sealing with their size also precluding use inside small electronic components. Their main limitation is reliability as repeated temperature cycles and vibration cause very small movements between crimp and terminal that cause the exposure of the underlying base metals that re-oxidise after their natural air-formed oxide is disrupted. As the amount of oxide increases, this can increase contact resistance to a level where the equipment no longer functions. In power circuits, the increased resistance will cause heating that can lead to fires

The following candidate substitutes are mentioned by the Umbrella Project (2019):

- Lead-free solders (with a solidus line above 250°C): Bi-2.5Ag; BiAgX®, Au-20Sn, Sn->43Sb, n-(4-6)Al(Ga,Ge,Mg), Sn+(Cu, Ni, etc.) (see also Annex IV for a list of alternatives and their melting temperatures);
- Adhesives are also named as a potential substitute.

Table 5 of the application provides a compilation of advantages and disadvantages of the various candidates. It is reproduced in Annex III.

Bourns and the Umbrella Project detail various properties of relevance to LHMPS, in some cases also defining the technical performance level necessary in alternative solders to substitute LHMPS. These are compiled in the table below. This information has been complemented in part with additional detail from (DA5 2020) which does not include a list of all properties, however some of these can be understood from the document

Table 1-1: Properties necessary in alternatives to LHMPS

Property	Specified by Bournes (2019)+ additional detail	Specified by Umbrella Project (2019) + additional detail	Specified in DA5 Project (2020)
High melting point	Yes: above 300°C;	Yes	Yes: Sn25Ag10Sb and Au20Sn are shown as

(i.e. the liquidus line)		For strain-gauged devices (extensometers) of Cat. 9 the need of LHMPS is also explained with their exposure to temperatures above 200°C	substitutes with suitable melting point, however their brittleness limits their reliability to only smallest die sizes with constraints on chip thickness, package geometry and surface materials
High softening temperature (i.e. the solidus line)	Yes: must be no lower than 260°C;		
Strong thermal conductivity	Yes	Yes	
Good thermal fatigue resistance	Yes		
Good wettability	Yes	Yes	Yes
Good ductility	Yes	Yes	
Corrosion-resistivity		Yes	
Appropriate oxidation nature		Yes	
Electrical conduction		Yes: for Section 1.2 points 1, 2 and 3.	
Properties relevant for assembly		Yes: for Section 1.2 points 1, 2 and 3. -Stress relief; - Heatproof to reflow temperatures;	Reflow 260°C (SMD)
Moisture sensitivity			Moisture sensitivity level MSL3 or better (SMD)
Sustaining of heat disipation		Yes: for Section 1.2 point 4 related to the high temperatures of the magnet wire and the proximity to the magnet wire coil	
Manufacturability	Yes		
High reliability	Yes: reliability factors in a harsh environment	Yes: high reliability to temperature and to power cycles due to stress relaxation from higher ductility materials	Yes
Cost effectiveness	Yes		

Source: Application requests of Bournes and the Umbrella Project for Ex. 7(a)

The Umbrella Project (2019) provides comparison of various elements with Pb in relation to some of the above properties in diagrams. This information was already available in the 2015-2016 evaluation and furthermore has neither a reference to specific applications nor to the comparison of specific solder alloy compositions and is not reproduced here again. It is explained that available substitutes do not provide the correct combination of properties that LHMPS do, however there is no clarification which combination of properties is needed in which application areas nor verification related to a certain substitute in a specific LHMP application, aside from a single case. In relation to a medical application (not specified which) it is said that a manufacturer is investigating substitutes. Additional detail is not provided nor detail for other applications aside from die attach as to the research into alternatives.

The Umbrella Project (2019) refers to two additional sources of information related to alternatives for die-attach applications: Vishay and the DA5 consortia.

Vishay is said to have evaluated lead-free materials for internal die-attach, including solder pastes and solder wires based on the BiAg, AuSn and SnAgCu systems as well as silver sinter pastes, sinter epoxy and silver epoxy from several suppliers. None of the evaluated materials have proved capable of replacing HMP lead (Pb) solder in terms of manufacturability, quality and reliability. Detail given in the Umbrella Project applications provides a summary of experience with some alloys. The SnSb solder material J-alloy (SnAg25Sb10) was used for internal die-attach of several Vishay diodes and thyristors for a couple of years, but this use was discontinued due to brittleness and reliability issues. Limitations of BiAg solders are also mentioned, where investigation is on-going, however the combination of poor electrical and thermal performance and the necessity to apply the material in solder-paste form is explained to mean that current candidates could only be used for limited and very niche products. (Umbrella Project 2019)

Information on efforts related to die attach is provided on the basis of the Die Attach 5 consortia (or DA5, a consortia to develop a Pb-free die-attach solution) which has been working with suppliers for several years to identify and evaluate alternatives to LHMPS. DA5 (2020) have evaluated a variety of new materials available from global suppliers of solders, high thermal conductive adhesives, silver (Ag) sintering and transient liquid phase sintering (TLPS) materials. DA5 recognize continuous improvement in the evaluated materials over the past 10 years, but these do not yet meet the DA5 requirements for quality, reliability and manufacturability. Over the years, DA5 is said to have examined more than 100 materials. In relation to the four types of alternatives, the DA5 (2020) provides the following data which from comparison with earlier contributions is understood to have been added after the 2015-2016 review of the exemption (detail is from (DA5 2020) unless otherwise noted):

- For **conductive adhesives**, these are said to have the same or better mechanical, thermal, and electrical properties compared to solder, and can be used in die bond equipment for dispensing, chip placement, and curing of the material (Drop-In Solution). As it is also specified that, depending on package type and die size, these can pass automotive environment stress test conditions (AEC-Q100, AEC-Q101), the consultants assume that at least in some cases, conductive adhesives provide sufficient reliability. In this respect, limitations are specified to possible applications with the following aspects that also have quantified thresholds (additional aspects can be viewed in source):
  - the maximum die size (~50 mm²), which is strongly dependant on package design, bill of materials and inclusion of a backside metal;
  - Use is currently only possible when the die thickness is >120 µm (though the Umbrella Project (2019) mentions that adhesives are the typical solution for very thin lead-frames (~200µm) due to unacceptable lead-frame bending after a high temperature soldering process);

- The moisture sensitivity level, which is greater than MSL3/260°C, is a limitation for high power devices. However, from past information application in low and medium power devices is understood to be possible.
- Information provided during the last assessment (Gensch et al. 2016) further clarifies that adhesives cannot be used for products with a high junction temperature (>175°C), as organic components of the glue tend to degrade at such temperatures.
- The Umbrella Project (2019) also indicates that adhesives can be a solution for packages which don't need to be exposed to the higher soldering temperature (~400°C soldering temperature versus ~150°C glue curing temperature). E.g. Ball Grid Array (BGA) packages with organic substrates use adhesives for die-attach. Furthermore, adhesives are explained to have a bigger process window as compared to solder and can be used also for non-metalized chip backsides.

- New information for **TLPS sintering** suggests that these could be used for smaller dies but have potential incompatibility for dies above 50 mm^2 due to high modulus and delamination risk. Potential reliability issues related to the formation of cracks are related to Kirkendall voids that form during IMC growth at 175°C during HTS. A risk of oxidation of copper is also mentioned if the oxygen concentration exceeds 300 ppm during sintering under nitrogen. In summary, though these materials are considered to have potential for use in SIP and clip packages, the maturity of the technology is still low and requires additional research to establish reliability, which appears to be dependent on the package / lead-frame material. Potential use for thin die (thickness <100µm) is also not yet clear.
- In relation to **alternative solders**, progress has been achieved for Zn-based alloys and for SnSb alloys.
  - For Zn-based alloys, the process temperature needs to be very high (above 410 °C), which presents a high risk for incompatibility with some chip technologies. In parallel, the formation of brittle intermetallics at high temperatures limits the reliability. However, new formulations demonstrate lower mechanical stress and reduced die cracking and improved reliability is expected for die<10mm^2 in combination with a new experimental lf[4] surface.
  - SnSb alloys are now offered as pre-form and not only in paste form. New formulations are available with improved melting point and the workability can be expected to improve in relation to voiding and die cracking in the future. Secondary reflow and reliability are not yet demonstrated.

Comparisons of the various technologies with LHMPS are provided by DA5 (2020) in a graphical form in relation to various key performance indicators and can be viewed in the document. All comparisons are in relation to dies with a thickness > 120 µm, suggesting that possible applications are currently limited to larger thickness dies. In all comparison, though improvement of performance can be shown in relation to the information available by the DA5 in 2015/2016, a level of comparability has not yet been reached and all types of alternatives still have lacking reliability. In this respect, the reliability of conductive adhesives and TLPS sintering are closer to that of LHMPS (ranked as good in comparison to very good) with silver sintering and alternative solders currently ranking significantly lower (poor).

[4] This is specified as it appears in the document.

1.4.2. **Environmental and health arguments** *(also LCA aspects)*

Bourns (2019) refers to the carcinogen properties of Pb and Pb soldering being considered an activity with a risk of exposure. However, hazardous properties are also mentioned for silver, copper and tin as comparison.

The Umbrella Project (2019) does not raise environmental arguments, explaining that as long as a suitable substitutes is not identified, assessment data cannot be provided. Nonetheless it is mentioned that a proposed alternative contains dibutyltin dilaurate (CAS# 77-58-7) which is a REACH SVHC, while other materials under current evaluation are also under assessment for possible hazardous properties like silver and antimony.

1.4.3. Socioeconomic impacts

Bourns (2019) states that alternatives for LHMPS with high gold content are typically high priced. For example, if a gold material was a potential substitute, it may drive the cost of the finished components up where it is difficult to be competitive. Equipment and/or process changes could be necessary in case that substitutes become available, currently however such substitutes do not exist.

The Umbrella Project (2019) does not raise socio-economic arguments, explaining that as long as a suitable substitute is not available, assessment data cannot be provided. It is however explained that a very large proportion of the electrical equipment currently used in the EU could not be sold in the EU should the exemption not be renewed, which would have adverse impacts on the EU's economy.

1.4.4. Roadmap towards substitution

The Umbrella Project (2019) states that various efforts are undertaken by the EEE industry to find substitutes for LHMPS, which currently have not concluded. The applicant explains the typical time scale from identification of a suitable substitute material to commercial use in electrical equipment as follows: Research and development of candidate materials last 4 years in average. If successful, an additional 6 years is considered necessary for the next phases up to mass production.

2. Clarification Questions

General

The Umbrella Project (UP) group has included Bourns in their discussions and communications. Bourns agrees with the UP group information provided below in questions 1 and 2. Please accept our reference to the UP group responses to the questions 1 and 2 in lieu of duplicating the information.

1. Both applicants refer to various properties or functions that lead provides to LHMPS in its various application areas and for which alternatives must provide similar performance however in most cases, the minimum required performance is not specified. Please specify the range of performance required in relation to the properties in the table below or a threshold above or below which performance would be considered comparable. Furthermore, please indicate for which of the following application areas each of the

properties is relevant (please refer to the annotation of the application areas in this respect or add additional application areas):

a) For combining elements integral to an electrical or electronic component:

   i) a functional element with a functional element; or,

   ii) a functional element with wire/terminal/heat sink/substrate, etc.;

b) For mounting electronic components onto sub-assembled modules or sub-circuit boards;

c) As a sealing material between a ceramic package or plug and a metal case; and

d) For high power transducers (both low and high frequency in professional sound applications.

	Required performance (threshold/range)	Application areas
High melting point (liquidus line)		
High softening temperature (solidus line)		
Strong thermal conductivity		
Good thermal fatigue resistance		
Good wettability		
Good ductility		
Corrosion-resistivity		
Appropriate oxidation nature		
Electrical conduction		
Stress relief		
Heatproof to reflow temperatures		
Moisture sensitivity		
Sustaining of heat dissipation		
Manufacturability		
High reliability		
Other (please specify and explain principle)		

2. The current exemption wording is understood to be relatively general and to leave room for misuse. To eliminate this possible loophole, past assessment efforts have tried specifying the exemption wording into various application areas, an effort that was discussed controversly by stakeholders. Alternative approaches for specifying the exemption wording are:

- to specify application areas based on combinations of properties needed in the application and provided by lead; or
- to specify application areas where substitution was possible, excluding them from the exemption, for example: solder joints that can be exposed to temperatures below XX°C during assembly and/or operation.

Should these approaches show that the task is impractical in light of a wide range of differing application areas, provided information may support the justification of a wide range exemption. Please thus either provide a proposal as to possible application areas that can be excluded on the basis of function or properties or provide a proposal of property combinations for which the exemption is needed.

For Bourns:

3. In its application for exemption, your organisation specifies that in relation to its use of Ex. 7(a) approximately 117 million components containing a LHMPS were sold in 2014. Bourns estimates the total lead content of these parts to be approximately 77g per year. The average weight of the components is stated to be 0.37g. Please clarify this statement seeing as an average content of 0.37 gr in 117 million components does not add up to 77 g per annum.

   It does appear the calculation was not completed on the application. The 117M parts sold was a global figure and not necessarily just sold to Europe. It cannot be accurately determined since many of our parts are sold through distribution.

   Based on the 117M parts mentioned in the application, it has been determined the parts total weight is approximately 43,290K grams using an average component weight of 0.37g. The. solder weight per part range from 0.2 – 4.0 g with an average of 2.2g. The average lead content of the high temp solder is 88%. Using this information, the estimate of lead due to high temp solder used in components is 0.8381 metric tons globally. We do not have the data to provide an estimate just for the European market, but, it would obviously be less than 0.8 metric tons.

4. Bourns refers to automotive, aerospace, military, medical and industrial devices as relevant for the exemption but only the last two are assumed to be in scope of RoHS (automotive applications are subjected to the ELV Directive, at least some aerospace and military equipment benefits from exclusions in Article 2 of RoHS) . Please clarify this statement and explain whether it refers to applications that have “dual-use” in various sectors and thus are compliant with RoHS regardless of whether this is needed or not.

   Bourns does not manufacture equipment. Many of the components using exemption 7a can be used in various sectors. Since the end user and their application is not always known, it is difficult to separate RoHS and ELV, for example. ELV exemptions are similar to RoHS especially for high temp solders. The multiple-use in the various sectors are compliant with RoHS and also many ELV exemptions which is necessary to provide components to many potential customers. It is also unclear whether a component use is considered automotive or industrial. One example is a customer may use a Bourns component for a phone charging port in a vehicle. This port is used in a car but it does not needed to make the car run. It is an accessory. It is unclear whether this is an automotive use due to the use within a car but not a necessary to make the car run.

5. Bourns refers to a few of the requirements of alternative solders and provides links to solder suppliers but does not clearly state what the parameters are that need to be provided by an alternative – only the melting and softening temperatures are referred to quantitatively. Please specify what properties are relevant for Bourns equipment, also referring to information provided for the general question 1.

Bourns does not manufacture equipment. Bourns is a component manufacturer. Many components are custom parts manufactured according to customer specification. Some multi-use parts can be used for both industrial and automotive. The requirements for alternative solders are the same as the current Pb-containing high temp solders.

As mentioned in the application section 4C:

High temperature solders (>85% Pb) are used in electronic components to maintain the integrity of the joints between the die and leadframe at the board level assembly. The softening temperature must be no lower than 260C; there must be good thermal fatigue resistance; good wettability and ductility. Other factors include the manufacturability, reliability factors in a harsh environment and cost effectiveness. For lead-containing solders, the historical data of over 50 years of usage provides proven reliability.

Please also refer to the chart provided by the UP response for General Clarification Question 1 above on their response. This will also apply to Bourns manufacturing requirements.

For the Umbrella Project

6. The Umbrella Project provides an estimation as to the total amount of Pb placed on the market as ranging between a few kg and 31 tonnes per annum. Though it is argued that substitution was applied where possible, the broad range suggests that the exemption may be applied also in applications where it is no longer needed. Please clarify on what basis you assume that such misuse does not take place or propose how this could be guaranteed through a reformulation of the exemption, addressing only application areas where substitutes do not exist.
7. The Umbrella Project argues that available substitutes do not provide the correct combination of properties that LHMPS do. Please clarify which combination of properties is needed for applications in which LHMPS are needed, referring also to quantitative performance levels needed. If this combination differs between application areas, please provide specific combinations for the application areas specified in general question 1 above and refer as needed to additional application areas.

In case parts of your contribution are confidential, please provide your contribution in two versions (public /confidential). Please also note, however, that requested exemptions cannot be granted based on confidential information!

Finally, please do not forget to provide your contact details (Name, Organisation, e-mail and phone number) so that Oeko-Institut can contact you in case there are questions concerning your contribution.

Annex I: Intended Use and Examples for Related Products in which HMP lead (Pb) solders are utilized

Table 2 from the Umbrella Project application (reproduced as is):

<table>
<tr><th>Intended HMP solder use</th><th>Examples of related products</th><th>Reasons for necessity</th></tr>
<tr><td>– For combining elements integral to an electrical or electronic component:
- a functional element with a functional element; or,
- a functional element with wire/terminal/heat sink/substrate, etc.</td><td>– Resistors, capacitors, chip coil, resistor networks, capacitor networks, leaded inductors, power semiconductors, discrete semiconductors, microcomputers, ICs, LSIs, chip EMI, chip beads, chip inductors, chip transformers, power transformers, lamps, resistance temperature devices (RTD), electromechanical relays for automotive (just as reference) and industrial use, etc.
– [See Figure 1, Figure 2, Figure 3, Figure 4, Figure 5 & Figure 8]</td><td rowspan="3">– Stress relaxation characteristic with materials and metal materials at the time of assembly is needed
– When it is incorporated in products, it needs heatproof characteristics to temperatures higher than 250 to 260°C (this is the typical solder reflow temperature used for PCBs and wave soldering)
– It is needed to achieve electrical characteristics and thermal characteristics during operation, due to high electric conductivity, high heat conductivity/ thermal dissipation, etc.
– It is needed to gain high reliability for temperature cycles and power cycles due to stress relaxation from higher ductility material, etc.</td></tr>
<tr><td>– For mounting electronic components onto sub-assembled modules or sub-circuit boards</td><td>– Hybrid IC, modules, optical modules, etc.
– [See Figure 6]</td></tr>
<tr><td>– As a sealing material between a ceramic package or plug and a metal case</td><td>– SAW (Surface Acoustic Wave) filter, crystal resonators, crystal oscillators, crystal filters, etc.
– [See Figure 7]</td></tr>
<tr><td>– For connecting magnet wire coil to flexible conductor</td><td>– High power transducers (both low and high frequency) used for Professional Sound application [See Figure 9]</td><td>– Sustain the heat dissipation, the high temperatures of the magnet wire and the proximity to the magnet wire coil</td></tr>
</table>

***Table 2**: Intended Use and Examples for Related Products in which HMP lead (Pb) solders are utilized*

Annex II: Stakeholder views on the proposed exemption formulation

Excerpt from 2016 evaluation report, *(Gensch et al. 2016):*

Specification of Exemption 7(a)

According to the RoHS Directive[5] "Exemptions from the restriction for certain specific materials or components should be limited in their scope and duration, in order to achieve a gradual phase-out of hazardous substances in EEE, given that the use of those substances in such applications should become avoidable."

Exemption 7(a) in its current wording has a purely material-specific scope. It allows the use of lead in high melting point solders regardless of where and how these lead-containing high melting point solders (LHMPS) are used. It is thus a priority within RoHS that the scope of both exemptions should be reduced now, where possible, and further in future exemption review rounds through the promotion of research and development of lead-free solutions, as well as through improvements in exemption wording specifications.

Consultant's Proposed Rewording of Exemption 7(a)

Based on information provided by the applicants in this review and in previous exemption reviews, the consultants formulated a wording, targeting a scope, which is as narrow as possible to exclude the abuse of the exemption and promote specific research into lead-free solutions. In parallel, the same proposed wording is as wide as necessary to ensure all applications are covered where substitution and elimination of lead is still impracticable. Following two rounds of discussions with the stakeholders[6, 7, 8, 9], the consultants modified their original proposal to the below wording.

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

a) for internal interconnections in electrical and electronic components, i.e.

i. for die attach in power semiconductors with steady state or transient/impulse currents of 1 A or greater and/or blocking voltages beyond 200 V, or die edge sizes larger than 0.5 mm

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[5] Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast), RoHS 2, European Union (1 July 2011), recital clause (19)

[6] Freescale Semiconductors/NXP et al. 2016b "Answers to first questionnaire to all stakeholders, document "Exe_7(a)_Questionnaire-1_All-Applicants_2016-02-16_NXP-et-al.pdf", received via e-mail by Dr. Otmar Deubzer, Fraunhofer IZM, from Griffin Teggeman, NXP, on 25 February 2016" unpublished manuscript, Answers to first questionnaire to all stakeholders

[7] Knowles et al. 2016a "Answers to first questionnaire to all stakeholders, document "Exe_7(a)_Questionnaire-1_All-Applicants_Knowles-et-al_2016-02-16.pdf", received via e-mail by Dr. Otmar Deubzer, Fraunhofer IZM, from Stephen Hopwood, Knowles Capacitors, on 25 February 2016" unpublished manuscript, Answers to first questionnaire to all stakeholders

[8] IXYS Semiconductor GmbH 2016b "Answers to questionnaire 2, document "Exe-7(a)_Questionnaire-2_IXYS.docx", received via e-mail from Markus Bickel, IXYS, by Dr. Otmar Deubzer, Fraunhofer IZM, on 21 January 2016" unpublished manuscript,

[9] IXYS Semiconductor GmbH 2016a "Answers to the first questionnaire to all stakeholders, document "Exe_7(a)_Questionnaire-1-All-Stakeholders_Reply-Ixys_2016-02-26.pdf", received via e-mail by Dr. Otmar Deubzer, Fraunhofer IZM, from Markus Bickl, Ixys Semiconductor GmbH, on 26 February 2016" unpublished manuscript, Answers to first questionnaire to all stakeholders

> ii. *in components with steady state currents of more than 1 A and/or blocking voltages beyond 200 V other than die attach*
>
> iii. *for other internal interconnections in electrical and electronic components excluding those in the scope of exemption 24*
>
> iv. *in HID lamps and oven lamps*

b) *in solder balls for the attachment of ceramic BGA to the printed circuit board (second level interconnect)*

c) *for the attachment of components to printed circuit boards (second level interconnect) in high temperature plastic overmouldings (> 220 °C)*

d) *for mounting electronic components onto subassemblies (first level interconnect), i.e. modules or sub-circuit boards*

e) *as a hermetic sealing material between a ceramic package or plug and a metal case*

f) *other applications; expires on 1 January 2021 for EEE in cat. 1-7 and 10*

In a final round, this proposal was discussed with the stakeholders[10, 11, 12, 13] again. The following summarizes the applicants' comments.

The applicants[14] disagree with the proposed rewording of RoHS Exemption 7(a). Further, they disagree with the need to reword the existing RoHS-2 exemption 7(a) and they voiced concerns with splitting the exemption into multiple sub-sections. In order to maintain a simple exemption renewal process, they also object to the proposed inclusion of an expiry date for any application that is less than the 5 years allowed under RoHS 2. They further urge Oeko-Institut and Fraunhofer IZM to recommend to maintain consistent wording for RoHS exemption 7(a) and ELV exemption 8(e) based upon the wording included in the related European Commission's draft legislative proposal to amend ELV's Annex II currently under scrutiny by the European Parliament and the Council of the EU.[15]

Freescale/NXP et al. [16] are concerned about the technical complexity to determine, which sub-exemption applies to each homogeneous material, and the lack of incremental environmental, health and consumer benefits resulting from this delineation since alternative Pb-free solutions are not available on the market. Furthermore, they do not believe that any one company or group of

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[10] Freescale Semiconductors/NXP et al. 2016c "Answers to second questionnaire to all stakeholders, document "Exe_7(a) Questionnaire-2-All-Applicants_2016-02-16_NXP.pdf", received via e-mail by Dr. Otmar Deubzer, Fraunhofer IZM, from Griffin Teggeman, NXP, on 22 March 2016: NXP answers to questionnaire to all stakeholders" unpublished manuscript,

[11] Knowles et al. 2016b "Answers to second questionnaire to all stakeholders, document "Exe_7(a)_Questionnaire-1_All-Applicants_Knowles-et-al_2016-02-16.pdf", received via e-mail by Dr. Otmar Deubzer, Fraunhofer IZM, from Steve Hopwood, Knowles Capacitors, on 21 March 2016" unpublished manuscript,

[12] Knowles et al. 2016c "Answers to third questionnaire, document "Exe_7(a)_Questionnaire-2_Knowles_2016-03-29.pdf", received via e-mail from Steve Hopwood, Knowles, by Dr. Otmar Deubzer, Fraunhofer IZM, on 4 April 2016" unpublished manuscript,

[13] Bourns Inc. 2016a "Answers to first questionnaire to all stakeholders, document "Exe_7(a)_Questionnaire-1_All-Applicants_Bourns_2016-02-16.pdf", received via e-mail by Dr. Otmar Deubzer, Fraunhofer IZM, from Cathy Godfrey, Bourns Inc., on 7 March 2016" unpublished manuscript, Answers to first questionnaire to all stakeholders

[14] Op. cit. (Freescale Semiconductors/NXP et al. 2016c)

[15] Ibid.

[16] Ibid.

companies can currently adequately define the revised wording for a more detailed application and ensure that the new wording accounts for all required uses for LHMPS.

Applicants' Alternative Wording Proposals

Below, the applicants[17] attempt to enumerate the primary arguments related to the infeasibility of interpreting and applying the proposed exemption wording as given above:

- The 7(A)a)i structure is STATEMENT1 or STATEMENT2 and/or STATEMENT3 or STATEMENT4. The AND creates logic problems. [18]
- 7(A)a)i mentions "*transient/impulse currents"*. The inclusion of "*impulse"* improves the wording in comparison to the prior questionnaire, but still does not capture all the key criteria driving the LHMPS. Other criteria would include *'peak transient currents'*, *'resistance'* and the *'size'* of the power region within the die.[19]
- 7(A)a)i and 7(A)a)ii appear to exclude some products that required LHMPS. The immediately identified indicative examples include Zener diodes with die sizes < 0.5mm; clip bonded diodes and other products with currents ≤ 1 A & ≤ 200 V; SMD diodes or Axial diodes < 1 A and < 200 V; SMD or Axial diodes < 0.5 mm; some triacs or SCRs < 1 A; and transient suppressors.[20]
- 7(A)a)iii must cover LHMPS for all connections within a component, whether they are electrical or nonelectrical. The definition of internal connection does not provide this certainty. Some connections require LHMPS for electrical and / or electronic functions, others for thermal functions, and others for reliability under harsh conditions. As one example, it is not clear that this definition includes a heat shield that is attached to a component with LHMPS to allow subsequent Pb-free step soldering for mounting the component. This heat shield is part of the component when sold.[21]

Knowles et al.[22] add that from some points of view, an 'interconnect' is only an electrical connection so that the consultants' rewording proposal does not cover a non-electrical connection such as heat sink attachment. They would suggest that 'interconnect' is replaced with 'connection' or simply 'joint'. Knowles et al. ask, whether with regards to the definition of 'internal' – it is meant to include all connections within the space envelope of a single component, or if it only means connections that are hidden internally in the design. They also stress the example of the shielding cover and heatsink assembled onto the top of a ceramic substrate as part of an electronic filter. As the finished component will be surface mounted to a circuit board using Pb free alloys, the cover is soldered in place using LHMP solder alloy with the resulting joint being visible on the outside of the component. The connection to shield the device is made as part of the component manufacture and as such is part of the component and internal to its design, but as the joint is on the outside of the component the term 'internal' for a connection like this could be disputed. Knowles et al. in this case suggest that the reference to 'internal' could possibly be removed or changed to 'integral', covering all joints made as part of the component manufacture.

[17] Ibid.

[18] Ibid.

[19] Ibid.

[20] Ibid.

[21] Ibid.

[22] Op. cit. (Knowles et al. 2016b)

- 7(A)c) appears to exclude second level interconnections for lead frame products where molding occurs at temperatures ≥ 180°C but ≤ 220°C. [23]

Freescale et al. [24] state that also at the consultants' urging, they reluctantly considered and shared the below preliminary suggestions for a more detailed and functional wording. *None* of the proposals is acceptable to all members of the Freescale/NXP et al. working group. The differences between these proposals indicate a variety of subtle issues that arise when changing the exemption wording.

- 7(a) LHMPS used for internal or external interconnections in or to electrical and electronic components, HID lamps, oven lamps, hermetic sealing materials between a ceramic package or plug and a metal case, or other applications.
- 7(a) Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead) used:
  - for combining elements integral to an electrical and electronic component, including a functional element with a functional element; or, a functional element with wire/terminal/heat sink/substrate, etc.;
  - for mounting electronic components onto sub-assembled modules or sub-circuit boards;
  - as a sealing material between a ceramic package or plug and a metal case;
  - other applications.
- 7(a) Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead) used for:
  - internal interconnections within electrical and electronic components;
  - die attach;
  - plastic overmoulding;
  - ceramic BGA;
  - high power applications;
  - solders for mounting electrical and electronic components onto sub-assembled modules or sub-circuit boards;
  - solders used as a hermetic sealing material between a ceramic package or plug and a metal case;
  - HID lamps and oven lamps.
- 7(a) Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead) used:
  - for internal interconnections in electrical and electronic components;
  - in HID lamps and oven lamps;
  - in solder balls for the attachment of ceramic BGA to the printed circuit board;
  - for the attachment of components to printed circuit boards in high temperature plastic overmouldings;

[23] Op. cit. (Freescale Semiconductors/NXP et al. 2016c)

[24] Ibid.

- for mounting electrical and electronic components onto subassemblies;
- as a hermetic sealing material between a ceramic package or plug and a metal case; or
- in other applications.

Annex III: Advantages and Disadvantages of High Temperature Lead-free Solutions

Table 5 from the Umbrella Project application (reproduced as is):

Candidate for Substitution		Advantages	Disadvantages
	Bi system	· Solidus line is high · Joint operating temperature is comparable with conventional high temperature type solders. · Relatively low-cost	· Low ductility (very brittle) · Low strength · High electrical resistivity
	BiAgX®	· Easy drop in replacement for Pb-containing solder paste · Relatively low cost	· Brittle solder joints (solder cracks) · poor wetting, solder voids (can cause bond failure and other reliability issues) · thermal impedance increases (so unsuitable where heat conduction is required) · Melting temperature is 263°C
	Au-Sn	· Solidus line is high · Joint operating temperature is comparable with conventional high temperature type solders. · Strength is high	· Low ductility (too hard, so when used between parts with different CTE, this causes high strain leading to bond failure) · Lower melting point compared to HMP lead (Pb) solder
	Sn-high Sb	· Solidus line is high	· Low ductility · Concern of Sb toxicity (on REACH CoRAP list) · Temperature required to solder is ~50°C higher than Pb-based HMP solder and is too hot for some processes (as this will damage most polymers and possibly the silicon chip)
	Zn-Al system	· Solidus line is high	· Brittle and low ductility · Susceptible to corrosion and early failure · Temperature required to solder is significantly higher than Pb-based HMP solder and is too hot for some processes

Sn system + High melting temperature type metal	• It is still retentive even if it is remelted. The joint operating temperature is comparable with that of conventional high temperature type solder, depending on a combination of remelting. • Solidus line is high if all can be made inter-metal compounds	• For a resin mold, there is fear that a molten part may exude to outside of a component • Joint operating temperature is high, extending solder duration which might lead to high intermetallic growth which is often brittle and leads to a reliability issue • Fragile or low ductility because joint is mainly made of brittle inter-metallic compounds
Electrically conductive adhesive system	• No concern of remelting due to thermal hardening	• Poor heat conductivity • Poor electrical conductivity which can deteriorate with age • Susceptible to humidity • Difficult to repair • Insufficient reliability when qualifying for higher (Tjmax=175°C or above) junction temperature • Concern of some components' toxicity (classified as CMR)
Ag sintering systems	• No concern of remelting due to thermal hardening and/or pressure assisted sintering • High electrical and thermal performance	• Additional stress during processing (pressure assisted sintering) on the chip • Susceptible to humidity (porosity of Ag sponge) • High stress on chip due to stiff die-attach material • Concern of some components' toxicity (classified as CMR)

Table 5: Advantages and Disadvantages of High Temperature Lead-free Solutions

Annex IV: Composition and Melting Temperatures of Main Lead-free Solders

Table 4 from the Umbrella Project application (reproduced as is):

Category	Solder Type	Alloy Composition [wt %]	Melting Temperatures (Solidus Line / Liquidus Line)
Lead-free solders (Solidus Line 250°C or lower)	Sn-Zn(-Bi)	Sn-8.0Zn-3.0Bi	190 / 197°C
	Sn-Bi	Sn-58Bi	139°C
	Sn-Ag-Bi-In	Sn-3.5Ag-0.5Bi-8.0In	196 / 206°C
	Sn-Ag-Cu-Bi	Sn96Ag2.5Bi1Cu0.5	213 / 218°C
	Sn-Ag-Cu	Sn-3.0Ag-0.5Cu	217 / 220°C
		Sn-3.5Ag-0.7Cu	217 / 218°C
		Sn-4Ag-0.5Cu	217 / 229°C
	Sn-Cu	Sn-0.7Cu	227°C
	Sn65.0Ag25.0Sb10.0	Sn-Ag-Sb "J-alloy"	228 / 395°C
	Sn-low Sb	Sn-5.0Sb	235 / 240°C
Lead-free solders (Solidus Line more than 250°C)	Bi system	Bi-2.5Ag	263°C
	Bi system	BiAgX®	263 / 320°C
	Au-Sn system	Au-20Sn	280°C
	Sn-high Sb	Sn->43Sb	325 / >420°C
	Zn-Al system	Zn-(4-6)Al(Ga,Ge,Mg)	About 350 / 380°C
	Sn system & high melting temperature type metal	Sn+(Cu, Ni, etc.)	≧about 230 / >400°C

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