Assistance to the Commission on Technological Socio-Economic and Cost-Benefit Assessment Related to Exemptions from the Substance Restrictions in Electrical and Electronic Equipment:

Study to assess renewal requests for 29 RoHS 2 Annex III exemptions [no. I(a to e -lighting purpose), no. I(f - special purpose), no. 2(a), no. 2(b)(3), no. 2(b)(4), no. 3, no. 4(a), no. 4(b), no. 4(c), no. 4(e), no. 4(f), no. 5(b), no. 6(a), no. 6(b), no. 6(c), no. 7(a), no. 7(c) - I, no. 7(c) - II, no. 7(c) - IV, no. 8(b), no. 9, no. 15, no. 18b, no. 21, no. 24, no. 29, no. 32, no. 34, no. 37]

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Report for The European Commission

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20.0 Exemption 6c: "Copper alloy containing up to 4% lead by weight"

Declaration

In the sections that precede the "Critical Review" the phrasings and wordings of stakeholders' explanations and arguments have been adopted from the documents provided by the stakeholders as far as required and reasonable in the context of the evaluation at hand. Formulations have been altered in cases where it was necessary to maintain the readability and comprehensibility of the text. These sections are based exclusively on information provided by applicants and stakeholders, unless otherwise stated.

Acronyms and Definitions

353 / C35300	Copper alloy with 1.5 to 2.5% Pb
360 / C36000	CuZn39Pb3, copper alloy with 3.3% Pb
CuZn21Si3P	Lead-free silicon-containing copper alloy
CuZn39Pb3	Copper alloy with 3.3% Pb
CuZn37Mn3Al2PbSi	Copper alloy with 0.2 to 0.8% Pb
CuZn42	Lead-free copper alloy with a higher zinc content
ECHA	European Chemicals Agency
EEE	Electrical and Electronic Equipment
ELV	End-of-Life Vehicle
HID	High intensity discharge lamps
JBCE	Japan Business Council in Europe
KEMI	Kemikalieinspektionen, Swedish Chemicals Agency
LEU	LightingEurope
Pb	Lead
TMC	Test & Measurement Coalition
Tpa	Tonnes per annuum
WEEE	Waste EEE

20.1 Background

Lead is embedded as tiny nodules in the matrix of copper alloys. It thereby acts as chip breaker and lubricant. This gives leaded copper alloys a favourable machinability, but also properties provided by lead in the finished component, such as e.g. electrical conductivity, slide functionality for parts with closely fit sliding surfaces and corrosion resistance.

The lead content in copper alloys (brass) can vary between 0.2 to 4.2% in accordance with European standards.[684] Among them, the alloy CuZn39Pb3 / C36000 is very commonly used as a standard alloy of copper and zinc containing 3.3% lead.

Six applications were made requesting a renewal of the exemption; they are presented here in alphabetical order of the applicants' names:

- **Bourns Inc.**,[685] an electronic component manufacturer, purchases different components manufactured from leaded copper alloys such as bushings, terminals, shafts, pins, backup strips, terminal strips, switch elements/ terminals, rivets. Bourns Inc.[686] explains that leaded copper alloys can be precisely processed in fast screw machines and provide corrosion resistance.
- **Dunkermotoren GmbH**[687] request the exemption for gear wheels and motor bushes for different motor applications. The leaded copper alloys allow a long lifetime of the machining tools and of the finished gear box application due to the slide functionality of lead. According to Dunkermotoren,[688] their applications could be manufactured with leaded copper alloys with a lead content of < 1%. Dunkermotoren[689] added that the lower threshold is only applicable to electrical drive technology and that their "*execution cannot be transferred to other industries*".

[684] CEN EN 12164 and 12165

[685] Bourns (2015a), Bourns, Inc. (2015a), Original Application for Exemption Renewal Request, submitted 19.01.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Bourns/6c_Exemption_extension_ap_6c.pdf

[686] Bourns (2015b), Bourns, Inc. (2015b), Answers to Clarification Questions, submitted 29.08.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Bourns/20150811_Bourns_Ex_6c_1st_round_of_Clarification-Questions.pdf

[687] Dunkermotoren (2014), Dunkermotoren GmbH (2014), Original Application for Exemption Renewal Request, submitted 15.12.2014, English version available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Dunkermotoren/151008_Anmerkungen_Ausnahmeantrag_Dunkermotoren_6c_Messing_english.pdf

[688] Op. cit. Dunkermotoren (2014)

[689] Dunkermotoren (2015), Dunkermotoren GmbH (2015), Additional Information to the Application, submitted 08.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Dunkermotoren/Additional_information_to_our_application_6c___Dunkermotoren.pdf

- **Framo Morat GmbH & Co. KG**[690] produces the "*soft partner of worm gears*" from leaded copper alloys for good machinability and because it supports the dry-running of the gear parts.[691] According to Framo Morat the copper alloy CuZn37Mn3Al2PbSi that has been tested within the company over a long time period for its mechanical properties. Especially the "*load-carrying capacity*", is an essential manufacturing parameter, experience with which is based on "*decades of internal testing and recording*". Framo Morat sells "*more than a million worm gears to more than 275 customers all around the world placed in all branches.*" Therefore Framo Morat cannot specify all the applications where the worm gears are used in.
- **LightingEurope (LEU)**[692] requests the exemption for contact-pins of various fluorescent lamps and starters for fluorescent lamps, GU10 (a type of lamp fixture) reflector lamps and high intensity discharge (HID) R-mini lamps. LEU states that the presence of lead results in a higher ductility of the copper-alloy pins.
- **PHOENIX Contact GmbH&Co. KG and HARTING KGaA,**[693] both component manufacturers of connectors, device connection technology and network components, switchgears, fieldbus components etc. requested the exemption on behalf of a number of organisations.[694] They do not apply for their own

[690] Framo Morat (2014), Framo Morat GmbH & Co. KG (2014), Original Application for Exemption Renewal Request, submitted 10.12.2014, English version available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Framo/Ex_6c_Framo_Morat_2015-08-13_RoHS_Exemption_Request_fkn_Public.pdf

[691] Framo Morat (2015), Framo Morat GmbH & Co. KG (2015), Answers to Clarification Questions, submitted 18.08.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Framo/20150818_Ex_6c_FramoMorat_1st_round_of_Clarification-Questions_fkn.pdf

[692] LEU (2015a), LightingEurope (2015a), Original Application for Exemption Renewal Request, submitted 16.01.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Lighting_Europe/6c_LE_RoHS_Exemption_Req_Final.pdf

[693] Phoenix Contact and Harting (2015a), PHOENIX Contact GmbH&Co. KG and HARTING KGaA (2015a), Original Application for Exemption Renewal Request, submitted 16.01.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Phoenix/6c_RoHS_Exemption_6c_Renewal_Dossier_16_JAN_2015.pdf

[694] The following 26 organizations supported the request (in alphabetical order): American Chamber of Commerce to the EU (AmChamEU), Avago Technologies Limited, Communications and Information network Association of Japan (CIAJ), DIGITALEUROPE, European Committee of Domestic Equipment Manufacturers (CECED), European Coordination Committee of the Radiological, Electromedical and Healthcare IT Industry (COCIR), European Copper Institute (ECI), European Garden Machinery Industry Federation (EGMF), European Partnership for Energy and the Environment (EPEE), European Passive Components Industry Association (EPCIA), European Power Tool Association (EPTA), European Semiconductor Industry Association (ESIA), Information Technology Industry Council (ITI), IPC-Association Connecting Electronics Industries, Japan Business Council in Europe (JBCE), Japan Business Machine and Information System Industries Association (JBMIA), Japan Electrical Manufacturers' Association (JEMA), Japan Electronics and Information Technology Industries Association (JEITA), Knowles, LIGHTINGEUROPE, Littelfuse, Orgalime, the European Engineering Industries Association, SPECTARIS, TechAmerica Europe

specific applications but rather provide a generic review of the uses of leaded copper alloys. It is not always comprehensible whether e.g. publically funded research or research conducted by the automotive industry is cited or whether own research is presented by Phoenix Contact and Harting. Phoenix Contact and Harting indicate contact spring legs, crimp contacts, gear pinions and bearings and bushings as applications of leaded copper alloys.

- **Sensata Technologies**[695] purchases connectors, bushings, terminals, screws, hex nuts, washers, rivets for their following applications: thermal motor protectors, thermal circuit breakers, hydraulic magnetic circuit breakers.

Five out of six applicants[696] request a renewal of the exemption with the current wording:

"Copper alloy containing up to 4% lead by weight"

A further application submitted did not fulfil the minimum requirements of applications for exemptions stipulated in Annex V of the Directive and was not evaluated as such.

As for the history of the exemption, it has to be noted that since the RoHS 1 Directive was published in 2002, Ex. 6 has covered lead as an alloying element in steels, aluminium and copper.[697] Following the last revision on 2009[698], Ex. 6 was split into three exemptions 6a, 6b and 6c for each alloy respectively.

There is a corresponding exemption in the end-of-life vehicles Directive 2000/53/EC (ELV, listed in Annex II, as Exemption 3) with the same wording "*Copper alloy containing up to 4% lead by weight*". It was reviewed in 2015 by Oeko-Institut; the evaluation report has yet to be published. Where relevant within this chapter, it is referred to as the ELV revision.

(TAE), WirtschaftsVereinigung Metalle (WVM), Zentralverband Elektrotechnik-und Elektronikindustrie e. V. (ZVEI).

[695] Sensata (2015a), Sensata Technologies Holland B.V. (2015a), Original Application for Exemption Renewal Request, submitted 15.01.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_b_/Sensata/6a_6b_6c_RoHS-Exemptions_Application-Format_Ex_6a_b_c_Pb_in_St_Al_Cu.pdf
Sensata (2015b), Sensata Technologies Holland B.V. (2015b), Answers to Clarification Questions, submitted 20.08.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Sensata/Ex_6a6b6c_Sensata_Questions_response_20150820.pdf

[696] Dunkermotoren (2014) requested a lower threshold however stated later that this would be only applicable to their specific application (Dunkermotoren 2015)

[697] The wording of exemption 6 was as follows: "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"; http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002L0095&from=EN

[698] Gensch et al. (2009), Carl-Otto Gensch, Oeko-Institut e. V., et al. 20 February 2009, Adaptation to scientific and technical progress under Directive 2002/95/EC: Final Report. With the assistance of Stéphanie Zangl, Rita Groß, Anna Weber, Oeko-Institut e. V. and Otmar Deubzer, Fraunhofer IZM. http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf

20.1.1 Amount of Lead Used under the Exemption

Phoenix Contact and Harting[699] state that it is "*unfortunately not possible to identify exhaustively the components and EEE that use leaded copper alloys. As consequence the amount of lead per year cannot be calculated. An estimation based on the data of only two companies would not reflect the situation of the EEE industry.*" When asked to provide an estimation, Phoenix Contact and Harting stated the following:

> *"Ca. 2500 tpa lead based on a use amount of leaded alloys in EEE of 100,000 tpa with 2.5% lead threshold is assumed. Taken the recycling rate of more than 90% for these alloys 250 tpa new lead are needed for the market."*

The other applicants (in alphabetical order) provided the following amounts:

- Dunkermotoren[700] estimates that it places 1.7 t of lead per annum on the market.
- Framo Morat[701] estimates the amount of lead, which was placed on the market in 2014, at about 700kg.
- LightingEurope[702] calculates a total amount of approximately 38 ton of lead per year but stated that this amount will gradually decrease in the coming years because LED lamps have a longer life-time compared to conventional lamps.
- Sensata[703] estimates the amount of lead in lead-containing copper alloys used in Sensata products placed on the EU market at 500kg.

Bourns[704] provides a list that indicates the amount of Pb in its finished units. However, Bourns further states that it is not able to calculate the amount of lead because Bourns' parts are not finished parts. They are used in the assembly of other goods in the various EEE categories thus Bourns cannot determine the final use of their parts: "*Once our parts are sold either directly or through distribution, we do not have information on how all parts are used.*"

In the last revision of this exemption the following estimate was made: "*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 equipment are ten tonnes at*

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[699] Phoenix Contact and Harting (2015b), PHOENIX Contact GmbH&Co. KG and HARTING KGaA (2015b), Answers to Clarification Questions, submitted 14.09.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Ex_6c_Phoenix_Harting_Answers_1st_round_clarifying_questions_14.09.2015.pdf
[700] Op. cit. Dunkermotoren (2015a)
[701] Op. cit. Framo Morat (2015)
[702] Op. cit. LEU (2015a)
[703] Op. cit. Sensata (2015b)
[704] Op. cit. Bourns (2015b)

maximum." Taking into account the amounts of lead indicated by LEU, this can be understood to have been heavily underestimated.

20.2 Description of Requested Exemption

According to Phoenix Contact and Harting,[705] it is not possible to exhaustively identify the components and EEE that use leaded copper alloys. Phoenix Contact and Harting[706] explain that this is due to a complex structure of the supply chain where material specifications are not recorded and manufacturers of components/parts supply their products to different industries:

> *"In electrical and electronic industry there is no common database on the chemical composition of single parts. In addition the diversity of products is very high as RoHS covers diverse types of EEE and their components. These components are used in different industries with different requirements, organisations and structures. The consequence of this situation is that it is not possible to provide a list of components or equipment that contains leaded copper alloys."*

From the applications of single companies, gears as mechanically moving components can be differentiated from other applications: For the manufacturing of the gear parts, the applicants Dunkermotoren and Framo Morat mention that a leaded copper alloy (CuZn37Mn3Al2PbSi) is used (Framo Morat) or can exclusively be used (Dunkermotoren) that contains a lead of < 1% by weight.

Other components mentioned by the applicants are a variety of small parts that partly have electrical/conductive functions, such as the contact-pins LEU specified in its renewal request. Bourns[707] indicate the following applications containing the following components of leaded copper alloys: Brass pins, shafts, bushings, brass backup strips, terminals, terminal strip, switch element/terminal. Sensata[708] indicate very similar components to be made from leaded copper alloys: bushings, terminals, screws, hex nuts, washers, rivets. Phoenix Contact and Harting[709] mention some examples of components made from leaded copper alloys: spring contacts, crimp contacts and gears as an example of mechanical connecting parts.

As for the applications related to the different components, the applicants explain the following:

[705] Op. cit. Phoenix Contact and Harting (2015b)
[706] Op. cit. Phoenix Contact and Harting (2015b)
[707] Op. cit. Bourns (2015a)
[708] Op. cit. Sensata (2015b)
[709] Op. cit. Phoenix Contact and Harting (2015a)

- **Bourns**[710] uses the above mentioned components in counting dials, encoders, panel controls, precision potentiometers, rotary sensors and trimming potentiometers.
  Bourns further state: "*With the wide use of applications for electronic components, subassemblies containing electronic components and finished products containing electronic components, it is not possible for Bourns to determine the final use in the various EEE categories. Some, such as EEE categories 1-9 are highly likely along with 11. Once our parts are sold either directly or through distribution, we do not have information on how all parts are used. Bourns' parts are not finished parts but used in the assembly of other goods such as cell phones and computers to name a few. Bourns cannot determine where the global parts that claim exemption 6c are used and the final destination of that finished product. Further, the end products that use these parts may not be under the RoHS scope. There may be other applications using this exemption that are out of the scope of Bourns customer base. There are just too many unknowns to provide accurate information."*
- According to **Dunkermotoren**,[711] the gear parts can be used in various EEE such as "slicers, retail scales, printers, woodworking machines, under water scooter, rehabilitation machines, dialysis machines, medial pumps, operating tables, magnetic resonance tomography, cash machines, automatic doors and automatic sun protection as well as in IT and telecommunication equipment, electrical and electronic toys, leisure and sports equipment, medical devices, automatic dispensers and other EEE not covered by any of the categories above."
- **Framo Morat**[712] explains that "*there are two possibilities to order a worm gear set. First there are catalogue sets which can be ordered right away and are in stock. The other opportunity is to order customized worm gears which are designed in a specific way for every customer himself. Considering the possibility of catalogue sets it is difficult to trace the final application, in which Framo worm gears can be found. One of the nameable examples is definitely the sector of geared motors and their affiliated surroundings.*"
- **Lighting Europe**[713] explains that the pins are used in various lamps and starters for lamps as already mentioned above.
- **Sensata**[714] describes that their sensor and control products are used in the following EEE: thermal motor protectors, thermal circuit breakers, hydraulic magnetic circuit breakers.

[710] Op. cit. Bourns (2015b)
[711] Op. cit. Dunkermotoren (2014)
[712] Op. cit. Framo Morat (2014)
[713] Op. cit. LEU (2015a)
[714] Op. cit. Sensata (2015b)

20.3 Applicant's Justification for Exemption

The justifications of the applicants for their specific components are summarized in the following Table 20-1. The applicants generally refer to a favourable machinability of leaded copper alloys, which is not substantiated further. In most cases the applicants also claim that the lead in the finished product has an additional function in the finished product. These functions are e.g. conductivity, corrosion resistance, dry-running performance or wear resistance.

Sensata[715] generally claims that "*because leaded copper alloys are not cheap, nor light, these materials will only be selected in product designs when needed under harsh mechanical and environmental conditions from the application and manufacturing point of view. Mostly in small parts that require smooth surfaces and narrow tolerances alike sliding elements, mechanical contacting elements and electrical applications.*"

[715] Op. cit. Sensata (2015b)

Table 20-1: Summary of the justification for exemption

Applicant	Part of Leaded Copper Alloy	Aspects of Machinability	Function of Lead in the Manufacturing of Product	Function of Lead in the Finished Product	Additional aspects
Framo Morat	Worm gear	Excellent mechanical properties	n.s.	Dry-running performance -> Increases of product lifetime and safety	Calculation of load-carrying capacity of leaded copper alloy are based on decades of internal testing and recording,* Economical characteristics
Dunker-motoren	Gear parts, Motor parts, typically bushes	Higher lifetime of tools, Lower process time.	n.s.	Reduction of sliding properties of gear parts in the gear box	n.s.
Bourns	Brass pins, shafts, bushings, Brass backup strips, Terminals, terminal strip, Switch element	Lubrication and chip control in order to run on automatic screw machines, Lead reduces heat generation during screw machine process, Less wear on tooling	n.s.	Brass forms a tin protective patina, Mechanical strength	Competitive cost, Availability of material in small bar sizes to reduce waste
LEU	Contact-pins in different forms	Reference made to Phoenix Contact and Harting	Ductility to provide a reliable connection of lead wire from the lamp to the contact-pin -> safety issue	Conductivity, Corrosion resistance, Ductility -> Integrity over lifetime Elasticity, Tensile strength	Ongoing changes in the lighting industry -> reluctance of suppliers to investments
Sensata	Connectors, bushings, terminals, screws, hex nuts, washers, rivets	n.s.	n.s.	n.s.	Restricted use of leaded copper alloy because material not cheap and not light

Applicant	Part of Leaded Copper Alloy	Aspects of Machinability	Function of Lead in the Manufacturing of Product	Function of Lead in the Finished Product	Additional aspects
Phoenix Contact and Harting	Spring contacts	Chip breaker, Internal lubricant	n.s.	Corrosion resistance, Low relaxation behaviour -> maintenance of contact forces	
	Crimp contacts		n.s.	Corrosion resistance, Ductility -> prevention of cracks.	
	Mechanical connecting parts such as e.g. gears		n.s.	Corrosion resistance, Wear resistance	

*: Framo Morat[716] explains on the load carrying capacity the following *"The calculation of load-carrying capacity is an essential part of the designing of a drive including worm gears. To ensure a realistic computation several material properties have to be known. These properties relating to CuZn37Mn3Al2PbSi cannot be found in common literature like "Niemann/Winter - Maschinenelemente 3" or "Dubbel -Taschenbuch für den Maschinenbau". Therefore the used properties are based on decades of internal testing and recording. Framo is not able to perform any realistic and scientific proved calculation of load -carrying capacity, if CuZn37Mn3Al2PbSi will not be available for use anymore."*

Source: Bourns (2015b), LEU (2015b)[717], Phoenix Contact and Harting (2015a), Sensata (2015b)

[716] Op. cit. Framo Morat (2014)

[717] Op. cit. LEU (2015b), LightingEurope (2015b), Answers to Clarification Questions, submitted 28.08.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Lighting_Europe/Ex_6c_LightingEurope1st_round_Clarification_LE_Answers_20150828.pdf

20.3.1 Possible Alternatives for Substituting RoHS Substances

Bourns and **Sensata** both purchase components from suppliers, however, the efforts to stimulate the supply chain towards the development of possible alternatives to lead-containing copper alloys differs. Sensata[718] mostly leaves the responsibility on the component manufacturer and does not specify the efforts taken with "*existing materials, none of which has proven to be a suitable replacement*". On the other hand, Bourns[719] indicates that they cooperate with their suppliers to explore possible solutions and they experiment with possible alternatives. Concerning alternatives tested and the respective problems, Bourns mentions the following alternatives (though not specifying the tests any further) that all "*have a higher raw material cost, a slower machining rate which reduces our capacity and shortens tool life*":

- "*Aluminium – slow machining;*
- *Zinc die cast – seal integrity issues;*
- *Nickel silver – required slowing screw machine by 50%; material finish not as good as brass.*"

Bourns[720] also mentions to have evaluated Ecobrass, but that it is not available in the required bar diameter size and was therefore not tested.

Dunkermotoren state that they have tested "*an alternative material. But the tests were negative. Now we restart the material search*."

Framo Morat[721] also indicates to have tested "*for example ECOBRASS or other lead-free (0.1%) materials, were not satisfying. The substitutes did not reach the mechanical properties of the used one*." Framo Morat does not further specify the tested lead-free material.

LightingEurope[722] state that there are basically contact-pins made of lead-free alloys already available on the market by one supplier, but that the lighting industry has no experience with lead-free contact material: "*There is no evidence that lead-free materials cannot be used, but given the long life -time of lamps in combination with the mass scale application it also cannot be proven that lead-free contacts have the same performance regarding safety and reliability under all application conditions (current density, temperature, humidity etc.).*" LEU also raises the concern that the current supply would not be able to satisfy the present demand of the market. LEU does not further specify the lead-free copper alloy.

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[718] Op. cit. Sensata (2015b): "The Sensata supply chain for lead-containing copper alloys comprises companies whose expertise is in stamping and screw-machining. Neither Sensata nor the Sensata supply chain have the expertise or resources to develop alternatives to lead-containing copper alloys."
[719] Op. cit. Bourns (2015b)
[720] Op. cit. Bourns (2015b)
[721] Op. cit. Framo Morat (2014)
[722] Op. cit. LEU (2015b)

Phoenix Contact and Harting[723] show some machining examples with substitutes. It is not always comprehensible whether e.g. publically funded research by RWTH Aachen or research conducted by the automotive industry is cited or whether own research is presented by Phoenix Contact and Harting; therefore the information submitted by Phoenix and Harting is rather seen as a generic review of the current EU industry opinion:

- A drilling test with CuZn42, a lead-free copper alloy with a higher zinc content, and the silicon-containing CuZn21Si3P resulted in only 3% of the required life of the drill compared to the leaded copper alloy CuZn39Pb3; the lead-free alloys also needed significantly higher cutting forces in the case of the lead-free alloys.
- Crimp contact made from the alloy CuZn42 showed continuous cracks during the crimping process, which are not allowed for a mechanically resistant and permanently safe connection: A crack permits the penetration of any corrosive substances. As a consequence the resistance increases and the contact point is heated up. Thus the risk of fire or unreliability exists. Besides, if a crack reduces the required mechanical pressure exerted on the cable, the pull-out force is below the required value as given in standards. The pulled out cable can apply power to touchable parts and thus a hazard for people is the potential consequence. Also, due to the broken connection, equipment (for example a motor) would fail.
- A gear pinion made with the lead-free copper alloy CuZn31Mn2Si1Al1 mechanically connected to a gear pinion made from plastic as part of a gear box showed a higher wear, as compared to a gear wheel made from CuZn39Pb3; the corresponding plastic pinions showed a much greater wear with the lead-free copper alloys pinion, which could cause a premature failure.

Phoenix Contact and Harting[724] estimate that a connector pin as a simple component requires about 1000 labour hours for safety testing.

20.3.2 Possible Alternatives for Eliminating RoHS Substances

Two applicants mention the possibilities to use different materials:

- **Bourns**[725] generally mentions that a possible alternative would be stainless steel that has a higher cost of machining. Machinability ratings indicate that stainless steel is 40-50% as efficient as brass because stainless steel as a poor conductor of heat compared to brass results in elevated temperatures during machining operations reducing the life of tools. Besides, Bourns mentions

[723] Op. cit. Phoenix Contact and Harting (2015a)
[724] Op. cit. Phoenix Contact and Harting (2015a)
[725] Op. cit. Bourns (2015a)

that "*rod sizes for screw machines are readily available in 360 brass; not available in stainless without more scrap/waste.*"

- **Framo Morat**[726] mention that "*in the early 2010s*", it explored "*new and high developed coatings like DLC or a particular shaped chrome layer. The first attempts had shown that there is a chance of potential in this technology to substitute CuZn37Mn3Al2PbSi. The continuation of this research would involve the generating of a non -assessable amount of costs and human resources. Anyway there are still future projects planned, which are connected to this technology.*"

20.3.3 Environmental Arguments

Phoenix and Harting[727] state that "*leaded brass is to nearly 100% made from recycled material. Without exemption 6c copper alloys for electric and electronic equipment could not, as it is common today, easily be made from recycled copper alloys. Thus the urban stock which is one of the most important sources for copper in Europe could not* be used *as it is possible today.*"

Within this context, the following environmental arguments are also provided by the applicants:

- **Framo Morat**[728] explains that waste material from manufacturing is collected and stored in order for waste coolant to naturally drip from the material; then a specialized recycling company picks up the cuttings and centrifuges the last leftovers to remove remaining coolant. These dry cuttings are then sent to the material supplier who turns them back into new and usable work pieces. Framo Morat emphasises the certified and long -term reliable partnership with the material supplier.
- **LightingEurope**[729] mentions that the waste stream of fluorescent lamps, responsible for about 70% of the total amount of lead in contact pins of lamps, has a specified take back system (see Section 4.3.3.3 in Lamp general chapter); other lamps that are sold in the consumer channel (mainly GU10 lamps) will not be recycled and are handled as normal waste; LEU estimates that about 50% of the TL-and CFLni lamps have been recycled in 2014 which suggests that 13.5 tons out of the 38 tons of lead were recycled via WEEE (i.e. accounting the 50% recycling rate with the 70% fluorescent lamps for which take back systems exist).

[726] Op. cit. Framo Morat (2014)
[727] Op. cit. Phoenix and Harting (2015a)
[728] Op. cit. Framo Morat (2014)
[729] Op. cit. LEU (2015a)

20.3.4 Socio-economic Impact of Substitution

Some applicants mention possible costs related to substitution, but in a general way, without further substantiating and quantifying possible impacts:

- **Bourns**[730] claims an increase in direct production costs, however without providing further evidence.
- **Framo Morat**[731] mentions the profitability of the used copper alloy concerning the costs and lifetime of tools whereas the continuation of the research on substitutes "*would involve the generating of a non-assessable amount of costs and human resources.*"
- **LightingEurope**[732] claims an increase in direct production costs and in fixed costs related to substitution: "*Investments are necessary to switch-over from lead-containing to lead-free contact pins. Next to that the reject level (waste material) will be higher than with lead-containing copper alloy. There are no estimations on the total sum.*"

20.3.5 Road Map to Substitution

None of the applicants provide a road map for substitution.

20.4 Stakeholder Contributions

Twelve contributions to exemption 6c have been submitted during the stakeholder consultation. The contributions are presented in order of submission and are shortly summarized:

- **Mitsubishi Shindoh Co. Ltd.**[733] proposes Ecobrass as a lead-free copper alloy alternative, which has high strength, excellent machinability, exceptional wear resistance, good creep properties and superior corrosion resistance, as a replacement material for free-cutting brass rod CuZn38Pb3 suggesting that there is no difference in productivity from leaded brass. Mitsubishi Shindoh Co. Ltd.[734] lists as examples of Ecobrass applications electrical and electronic component gears, terminals, medical devices and valves for electrical water heaters. The input of Mitsubishi Shindoh Co. Ltd. is further presented in section 20.5.2.

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730 Op. cit. Bourns (2015a)
731 Op. cit. Framo Morat (2014)
732 Op. cit. LEU (2015a)
733 Mitsubishi (2015), Contribution by Mitsubishi Shindoh Co. Ltd., submitted 07.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Exemption_6c__2015-10-mitsubishi-shindoh-rohs.pdf
734 Mitsubishi (2015), Contribution by Mitsubishi Shindoh Co. Ltd., submitted 07.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Exemption_6c__2015-10-mitsubishi-shindoh-rohs.pdf

- **ODU GmbH & Co. KG**,[735] a leading international manufacturer of connection systems, supports the renewal request by Phoenix Contact and Harting. ODU GmbH & Co. KG[736] state that 95 % of their products would be affected if the exemption were not renewed and that they have made "*serious efforts in direct cooperation with our raw material suppliers, until now, no material could be found that would even rudimentarily be suitable and bearable as a substitute. Of course, we are continuing our efforts in this area, but desperately need the additional time the extension would bring.*"
- **GENBAND**[737] provides telecommunications equipment to many of the telecommunications companies in Europe and worldwide and supports the renewal of exemption 6c.
  GENBAND[738] points out that it purchases electrical components and products from other OEM manufacturers and therefore is not able comment directly on the technical aspects of material selection. GENBAND lists the following applications that need the use of leaded copper alloys: Connectors, power supplies, fans, heatsinks, electrical switches, potentiometers, EMI gaskets. GENBAND[739] also corrected the mistake in the consultation questionnaire, which correctly should say "*the lower relaxation behaviour achieved with leaded copper alloys maintains the contact forces in spring contacts*", and points out the relation to fire risk if the contact fails: "*The fire risk is created as the contact metal relaxes, causing the contact force to drop, increasing the contact resistance, increasing the heat in the connector, leading to melting and potentially fire.*"
- **The Robert Bosch GmbH**[740] generally supports the applicants without providing further information.
- **JBCE**[741] – Japan Business Council in Europe in a.i.b.l. states that they understand that EEE of category 8 and 9 are out of scope of this review. The JBCE

[735] ODU (2015), Contribution by ODU GmbH & Co. KG, submitted 12.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Stakeholder_Consultation_on_RoHS_Exemption_6c.pdf

[736] ODU (2015), Contribution by ODU GmbH & Co. KG, submitted 12.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Stakeholder_Consultation_on_RoHS_Exemption_6c.pdf

[737] GENBAND (2015), Contribution by GENBAND, submitted 14.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/EX_6c_GENBAND_STAKEHOLDER_CONTRIBUTION.pdf

[738] Op. cit. GENBAND (2015)

[739] Op. cit. GENBAND (2015)

[740] Robert Bosch GmbH (2015), Contribution by Robert Bosch GmbH, submitted 15.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Bosch-Stakeholder-contribution-Exemption-request-6c.pdf

[741] JBCE (2015), Contribution by JBCE – Japan Business Council in Europe in a.i.b.l, submitted 15.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Comment_on_public_cousulation_of_Exemption_request_2015-2_6_c__.pdf

understands that "*the exemption 6(c) in annex III can be applied to category 8&9 products for seven years from identified date when entry into force for each products, at the earliest July 2021.*"

- **CETEHOR**, the technical department of the Comite Franceclat (French Watch, Clock, Jewellery, Silverware & Tableware Centre)[742] explains that watch movements are 80 % made of leaded copper alloys (CuZn39Pb3). CETEHOR lists the following "*extremely small parts*" to be made of leaded copper alloys: plates, bridges, cogs, gears, screws, nuts, pins, pivots; their dimensional conformity have tolerances of 5 to 10 µm. CETEHOR[743] stated that these tight dimensional requirements are not met by lead-free copper alloys.
  CETEHOR[744] also claims that lead-free alternatives create a greater tool wear that needs a more frequent sharpening and higher consumption rates of tools and longer machining cycles required, which all cause financial problems.
  CETEHOR[745] estimated a quantity of lead of 120 kg per year based on the amount of 8 g of brass per watch for movement parts and the annual French production of quartz watches of 0.5 million.
- **ELTECNO**,[746] a producer of low-voltage switchgear and control gear assemblies, supports the renewal of the exemption with a content of lead in copper of 4%. ELTECNO uses leaded copper alloy for the terminals for the protective conductors and sometimes for the neutral conductors. ELTCNO[747] mentions the favourable machining properties but also corrosion resistance as performance requirement of leaded copper alloys.
  ELTECNO[748] indicates the following amounts of leaded copper alloys with a lead content of 3.3% used: 1.5 tpa, resulting in 47 kg lead per year.
- **HARTING KGaA**[749] discussed in its contribution the information provided by Dunkermotoren and Framo Morat that both indicate the use of a leaded copper alloy with a lead content of <1%. Harting KGgA stresses that both have used these alloys before and that their applications are very specific ones.

[742] CETEHOR (2015), Contribution by Comite Franceclat (French Watch, Clock, Jewellery, Silverware & Tableware Centre), CETEHOR, submitted 15.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Ex_6.c_Comite_Franceclat_Cetehor_20151012.pdf
[743] Op. cit. CETEHOR (2015)
[744] Op. cit. CETEHOR (2015)
[745] Op. cit. CETEHOR (2015)
[746] ELTECNO (2015), Contribution with picture by ELTECNO, submitted 19.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Ex_6c_ELTECNO_Answers_20151016.pdf
[747] Op. cit. ELTECNO (2015)
[748] Op. cit. ELTECNO (2015)
[749] HARTING al. (2015a), Contribution by HARTING KGaA et al., submitted 19.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Ex_6c_HARTING_KGaA__stakeholder_consultation_2015-10-16.pdf

As for properties of lead, HARTING KGgA et al.[750] adds the following: "*electrical conductivity, thermal conductivity, cold deforming behaviour, resistance welding, galvanizing ability, soldering at higher temperatures than 450 °C, relaxation behaviour, crimp ability, spring behaviour, high-speed stamping, physical properties (melting point, coefficient of thermal expansion, etc.), fabrication process properties (hot forming, brazing, etc.), etc.*" HARTING KGgA et al.[751] stresses that these properties as well as their interrelations "*cannot be seen as independent from the application*".

- **HARTING KGaA**[752] submitted a response to the contribution of Mitsubishi Shindoh; this input is discussed in section 20.5.2.
- **KEMI** Kemikalieinspektionen, the Swedish Chemicals Agency[753], interprets Article 5 in the RoHS Directive in the way that both the material or component and the specific applications need to be defined in the wording formulation of an exemption. Thus, "*it is no longer legally possible to decide on an exemption for lead in copper alloys whatever the use is.*"
  KEMI[754] therefore proposes the split into a number of more specific exemptions related to applications where it has been verified that feasible alternatives are currently not available. KEMI[755] extracted the specific applications that were mentioned by the different applicants, further discussed in section 20.5.5.
- **PennEngineering**,[756] a designer and manufacturer of specialty fasteners, supports the renewal request, however states that it agrees with a lower threshold of 2.5% than the current 4.0 % because they have found "*353 to be an acceptable alternative to 360*".
  PennEngineering[757] explains that leaded brass offers the advantages in their machining environment (multi-spindle automatic screw machines or single spindle CNC lathes) of significantly longer tool life leading to higher efficiency (less downtime), better surface finish, significantly higher surface speed and

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[750] Op. cit. HARTING et al. (2015a)
[751] Op. cit. HARTING et al. (2015a)
[752] HARTING et al. (2015b), Contribution by HARTING KGaA et al. as a response to the contribution of Mitsubishi Shindoh, submitted 19.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Ex_6c_HARTING_KGaA_response_Mitsubishi_Shindoh_2015-10-16.pdf
[753] KEMI (2015),Contribution by KEMI Kemikalieinspektionen, Swedish Chemicals Agency, submitted 19.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Ex_6c_KEMI_Answer_to_SC_RoHS_20151016_Lead_in_copper.pdf
[754] Op. cit. KEMI (2015)
[755] Op. cit. KEMI (2015)
[756] PennEngineering (2015), Contribution by PennEngineering, Danboro, PA, USA, submitted 19.10.2015; available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Ex_6c_PennEngineering_Consultation_Questionnaire_PE_AS_20151016.pdf
[757] Op. cit. PennEngineering (2015)

significantly higher feed rate. PennEngineering stated that they have experimented with lead-free Ecobrass and found it to machine significantly worse than 353 leaded brass, however do not provide further evidence. PennEngineering[758] states that they currently use 190.5 t ("*420,000 lb*") of the two different leaded copper alloys (353 and 360) per year globally; the amount of the contained lead is calculated at 3.86 tpa ("*8,500 lb*"). PennEngineering estimated that approximately 25% of its sales of leaded product go to EEE in the EU.

- The **Test & Measurement Coalition**[759] submitted a general contribution on Category 9 Industrial monitoring and control instruments, similar in nature to the contribution made by the JBCE.

20.5 Critical Review

20.5.1 REACH Compliance - Relation to the REACH Regulation

Appendix A.1.0 of this report lists Entry 30 in Annex XVII of the REACH Regulation, stipulating that lead and its compounds shall not be placed on the market, or used, as substances, constituents of other substances, or in mixtures for supply to the general public. A prerequisite to granting the requested exemption would therefore be to establish whether the intended use of lead in this exemption request might weaken the environmental and health protection afforded by the REACH regulation.

In the consultants' understanding, the restriction for substances under Entry 30 of Annex XVII does not apply to the use of lead in this application as lead is used as an alloying element. Copper alloys are used to produce various components and articles. In the consultants' point of view this is not a supply of a lead as a substance, mixture or constituent of other mixtures to the general public. Pb is part of an article and as such, Entry 30 of Annex XVII of the REACH Regulation would not apply.

Appendix A.1.0 of this report lists Entry 63 in Annex XVII of the REACH Regulation, stipulating that lead and its compounds shall not be placed on the market or used in articles supplied to the general public, if the concentration of lead (expressed as metal) in those articles or accessible parts thereof is equal to or greater than 0,05 % by weight, and those articles or accessible parts thereof may, during normal or reasonably foreseeable conditions of use, be placed in the mouth by children.[760] Entry 63 however further specifies this restriction not to be applicable for articles within the scope of the RoHS Directive 2011/65/EU.

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758 Op. cit. PennEngineering (2015)

759 Test & Measurement Coalition (2015), Contribution by Test & Measurement Coalition, submitted 19 October 2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/General_Contribution_Test___Measurement_Coalition_package_9_exemptions_20151016.pdf

760 Other restrictions of entry 63 cover e.g. jewellery and are thus not applicable here.

No other entries, relevant for the use of lead in the requested exemption could be identified in Annex XIV and Annex XVII (status January 2016).

Based on the current status of Annexes XIV and XVII of the REACH Regulation, the requested exemption would not weaken the environmental and health protection afforded by the REACH Regulation. An exemption could therefore be granted if other criteria of Art. 5(1)(a) apply.

20.5.2 Scientific and Technical Practicability of Substitution

Mitsubishi Shindoh Co. Ltd.[761] submitted a contribution to the consultation pointing out the lead-free copper alloy Ecobrass as a substitute material for many components, especially where high electrical conductivity is not critical although it is not possible for Ecobrass to replace all leaded copper alloys. According to Mitsubishi,[762] Ecobrass is used mostly as replacement material for free-cutting brass rod CuZn38Pb3 suggesting that there is no difference in productivity from leaded brass. Durability and corrosion resistance in various environments such as in soil or hot-humid conditions have also been validated.

As for examples of Ecobrass' applications for electrical and electronic components, Mitsubishi[763] list gears, terminals, medical devices, and valves for electrical water heaters.

Mitsubishi[764] also argue that Ecobrass has been adopted for the sliding component of vehicle air conditioner replacing C36000 and that the machining example of vehicle components is a model case for substituting small electrical and electronic components. Besides, Mitsubishi[765] argues that components used in large electrical home appliances are similar to valves and fittings used in drinking water fixtures and components.

For the suitability in electrical applications where the components require conductivity, which is understood to be the case for e.g. contact pins (applied for by LightingEurope), crimp contacts (mentioned by Phoenix Contact and Harting) or switch gears (mentioned by ELTECNO) or terminals (mentioned by Bourns), Mitsubishi states that "*Ecobrass can replace leaded-brass for high conductivity applications by plating with such materials as Ag or Sn, which is applicable for many components.*" E.g. Mitsubishi[766] mentions terminals to be manufactured from Ecobrass. Electrical conductivity is provided by silver plating that is applied after the machining process. According to Mitsubishi,[767] Ecobrass has been selected for terminals since 2005 and the total sales volume has reached 35

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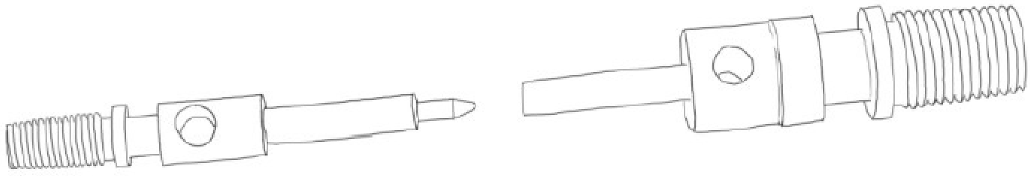
761 Op. cit. Mitsubishi (2015)
762 Op. cit. Mitsubishi (2015)
763 Op. cit. Mitsubishi (2015)
764 Op. cit. Mitsubishi (2015)
765 Op. cit. Mitsubishi (2015)
766 Mitsubishi (2016), Mitsubishi Shindoh Co. Ltd. (2016), Answers to Clarification Questions, submitted 15.01.2016.
767 Op. cit. Mitsubishi (2016)

tones. Mitsubishi[768] indicates that the sizes of material in use are ϕ5, 7 and 9 mm and continues to explain that "*assuming the size of material is φ7×40 mm, more than 2,500,000 products have been manufactured.*" The following figure shows a picture of the Ecobrass terminal.

Figure 20-1: Terminals made of ecobrass



Source: Mitsubishi (2016)

For applications where high conductivity is required, Mitsubishi recommends other lead-free copper alloys such as C18625, a high copper alloy that has a high electrical conductivity with strength equal to or exceeding leaded brass.

On Ecobrass, the applicants and the contributing stakeholder provided the following objections:

- Bourns[769] explains that in January 2001, Ecobrass was evaluated for machining capability and that the plant had difficulty in machining this material at that time. As a recent problem, Bourns stated that Ecobrass is not available in small diameter bars: "*Some trimming potentiometers require a diameter size of 0.075. Using a 0.250" would mean 91% waste if machined down to 0.075.*"
- GENBAND states "*The Mitsubishi –Shindoh in their contribution indicate that electrical and thermal conductivity are affected by the lead content. This makes their material not suitable for electrical conductors.*"
- Framo Morat[770] explains that "*first tests with possible substitutes, for example Ecobrass or other lead-free (<0.1%) materials, were not satisfying. The substitutes did not reach the mechanical properties of the used one.*"
- PennEngineering "*have experimented with lead-free Ecobrass and found it to machine significantly worse than 353 leaded brass.*"

From the objections above it is apparent that the machining processes cannot be equally run. This problem was also discussed during the ELV revision of the corresponding exemption, wherein the consultants could follow that Ecobrass may suffer technical drawbacks that still delay their implementation, e.g. in the case of Ecobrass, for

[768] Op. cit. Mitsubishi (2016)
[769] Op. cit. Bourns (2015a)
[770] Op. cit. Framo Morat (2014)

micromachining in automated series production. During the ELV revision Mitsubishi[771] submitted a drilling report that used a different drilling bit (carbide compared to high speed steel) that suggests how machining processes could be adapted to process Ecobrass. These adaptations are important in cases where machining knowledge on these alloys or usability of required equipment for these alloys is a key requirement for successful application. The automotive industry argued during the ELV revision that machining and processing of alternative alloys is in a very basic research stage because public funded research on fundamental parameters is still on-going in the field of machining. Welter[772] stated in a report compiled on behalf of the automotive industry that there is little know-how among the subcontractors specialized in micromachining and their tool suppliers and machining companies:

> *"The subcontractors specialised in the field of micro-machining are in general small or medium size companies. Usually they do not have the competences and resources to do the development needed for low cost, high volume production. They have to rely on external expertise and education. Apparently, until now, no activities were started aiming to define the machining parameters for lead-free copper alloys. For instance, in France, the Centre Technique de l'Industrie du Décolletage (CTDec) starts to be active when their members come up with specific demands for assistance. The CTDec has developed testing recommendation and sensors for evaluating new materials. The opinion is that the machining shops could rapidly gain their own experience by using these helps and try to deal with lead-free brasses. Besides the loss of productivity, the major problems will be the need to invest in more rigid equipment, to develop software for adjusting the rotation speeds of the machine e.g. to the different steps of the drilling process, as well as to find more convenient cutting tools. Unfortunately, tools have arrived nowadays at a mature level and there is little margin for innovation. In the USA and Germany first publications are coming up in specialised magazines giving some hints how to work with such alloys. Thus, in the USA a paper was published in 2009 discussing the problems occurring when machining lead-free and low-lead brass with 0.25 % of lead (the paper aimed at plants fabricating plumbing fittings and fixtures for the Californian market): the point was that these alloys should not be run like leaded brass, but rather like steel (Free 2009). The paper made some general recommendations, but without giving any detailed information. The same holds for the educational courses organised since 2013 by the German copper trade association (Deutsches Kupferinstitut). Furthermore, some brass mills start*

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[771] Mitsubishi (2015b), Mitsubishi Shindoh Co., Ltd., Micro-Drilling test report; submitted by Email 13 March 2015 during revision of the ELV exemption.

[772] Welter (2014) Jean-Marie Welter: Leaded copper alloys for automotive applications: a scrutiny; European Copper Institute, November 20, 2014; submitted as Annex 2 with the contribution of ACEA et al. (2014); http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2014_1/Ex_3/E3__02__Welter_2014_leaded_copper_alloys_for_automotive_applications-a_scrutiny.pdf

also to provide general information about machining (mainly macro-machining) the lead-free brasses. Nevertheless the overall perception is that presently machining shops can expect very little support from outside. Thus the forced modification of processing technologies will lead to a distortion of the market to the profit of large machining companies or of speciality machining shops. It is neither very clear whether the lath, tool and lubricant manufacturers have yet started to develop specific equipment and ancillaries for dealing with these new alloys in a productive way. It will still take many years until both the necessary know-how will be obtained and spread on a larger scale and the money will be available to invest into the production tools adapted to the new situation."

A German research project[773] on the improvement of the machinability of lead-free copper alloys developed concrete solutions and approaches that comprise adaptations of tool geometries, targeted supply of coolant lubricant in order to provide chip breaking and improve the process reliability. The use of adapted cutting materials (polycrystalline diamond) and tool coating (diamond coatings) provides significantly increased tool life and reduces the rate of metal removal. Productivity was additionally increased by the use of cutting plates with wiper geometry.[774]

To conclude, it is understood that there may currently still be some restrictions on putting lead-free copper alloys such as Ecobrass into successful applications. The process for adapting machining might take time but it is understood that it basically can be overcome in the future for at least some applications.

Generally, the assessment of scientific and technical practicability of substitution of lead in copper alloys is hampered by the fact that Phoenix Contact and Harting who applied for the renewal of the exemption on behalf of 26 EEE organisations and associations did not provide an exhaustive or even indicative overview on the different applications of leaded copper alloys in EEE. Asked for initiatives among the different industry associations and companies to set up an inventory for applications of leaded copper alloys that would allow in the future defining key requirements that are provided by leaded copper alloys, Phoenix Contact and Harting state:[775]

"There is no such inventory and it is also not planned to set up an inventory. The manufacturers that use leaded copper alloys belong to completely different industries. There is some collaboration between the manufacturers and the associations. But as RoHS is applicable to all EEE the associations have completely different members and the overlap is often quite small. It has to be noticed that such an inventory would contain many sensitive data and companies will not be

[773] Nobel & Klocke (2013), Nobel, C., Klocke, F. (2013), Zerspanen bleifreier Kupferwerkstoffe; IGF-Forschungsvorhaben 16867 N, available in German under: http://publications.rwth-aachen.de/record/230384/files/4856.pdf

[774] According to Nobel & Klocke (2013), wiper plates have a larger nose radius that allows high feed rates and results in a good surface quality.

[775] Op. cit. Phoenix Contact and Harting (2016)

able to give these data to others. Thus there will not be such an inventory where one could make an overview over all components or EEE with leaded copper alloys."

When asked to exhaustively specify the functionality of lead in EEE applications and to name performance indicators where possible which would allow assessing substitutes in the future, Phoenix Contact and Harting state:[776]

"As shown before the required properties of a material depend on the application and the environment the item will be used in. Thus it is not possible to give a general performance indicator for a material. Not all properties are relevant for all applications and every application will require different properties. Often these properties are not standardized values but it is the specific experience and expertise of the manufacturer. So there is no simple correlation that would allow defining performance indicators."

The consultants understand that there could be a large variety of different components in different surrounding conditions. However, the consultants are of the opinion that an inventory will help to define application groups to deduce the relevant properties. For example, during the ELV revision, the automotive industry[777] proposed as application groups for leaded copper alloys "sliding elements", "electric elements" and "mechanical connecting elements". The consultants expect that such an inventory would help to identify specific components in the future that could be evaluated as to the applicability of substitutes or of alloys with lower lead content.

20.5.3 Possible Alternatives for Eliminating or Reducing RoHS Substances

In this section there are two possibilities discussed, using different material in order to eliminate the use of lead or using leaded copper alloys with a lower lead content in order to reduce the use of lead.

The applicant Bourns[778] generally mentions that a possible alternative would be stainless steel, but claims that this has a higher cost of machining. Bourns does not specify the components where stainless steel could be used as a substitute. The consultants understand from the other alloy exemptions under RoHS that small connecting components, such as hex nuts or screws for example, are also manufactured by leaded steel and leaded aluminium alloys. Therefore in applications where the components have mechanically connecting functions and where the lead does not provide a function in the finished article, the use of different material should be explored.

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[776] Op. cit. Phoenix Contact and Harting (2016)

[777] ACEA et al. (2014), ACEA, JAMA, KAMA, CLEPA and EAA (2014a), Industry contribution of ACEA, JAMA, KAMA, CLEPA and EAA, submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2014_1/Ex_3/20141210_ACEA_AnnexII_3.pdf

[778] Op. cit. Bourns (2015a)

PennEngineering[779] claimed in its contribution that they achieved using a lower leaded copper alloy and therefore agree to lower the lead threshold of the exemption down to 2.5% from the current 4.0 %. However, from the information provided from the applicants and from the stakeholders submitting contributions a lower threshold of lead cannot be unambiguously defined for all applications. The consultants understand that it might generally be applicable for mechanically moving components. This assumption is based on the one hand on the information provided by Framo Morat and Dunkermotoren, which use leaded copper alloys with a lead content of < 1% for their gear parts. However, information provided by the automotive industry[780] during the ELV revision showed that applications with a low lead content in copper alloys are within the "sliding elements" and "mechanical connecting elements" application groups (close to 0.3% Pb within sliding elements and 0.2% Pb within mechanical connecting elements). It might, however not be the case for all mechanically moving components: CETEHOR[781] claims to use the alloy CuZn39Pb3 for their extremely small parts. Phoenix Contact and Harting[782] added information that for watch components the possibility for dry-machining provided by lead is an important performance requirement while for lead-free alloys lubricants are required. To conclude, the consultants propose that the use of lower leaded copper alloys should systematically be explored where the use of lead-free alloys is not practical.

20.5.4 Environmental Arguments

The environmental arguments mentioned by the applicants relate to particular aspects of e.g. the recycling of fluorescent lamps, or to very general ones, such as the importance of copper recycling. Such aspects are not further discussed here as they do not provide insight as to the comparison of leaded copper alloys with lead-free ones in relation to environmental impacts.

20.5.5 Stakeholder Contributions

Five contributions were submitted to the stakeholder consultation. The contributions of KEMI,[783] CETEHOR[784] and PennEngineering[785] are discussed in the sections above as well as below.

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[779] PennEngineering (2015), Contribution by PennEngineering, Danboro, PA, USA, submitted 19.10.2015; available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Ex_6c_PennEngineering_Consultation_Questionnaire_PE_AS_20151016.pdf
[780] Op. cit. ACEA et al. (2014)
[781] Op. cit. CETEHOR (2015)
[782] Op. cit. Phoenix Contact and Harting (2015a)
[783] Op. cit. KEMI (2015)
[784] Op. cit. CETEHOR (2015)
[785] Op. cit. PennEngineering (2015)

The contributions submitted by TMC[786] and JBCE[787] raise a legal question as to the availability of the current exemption to category 8 and 9 equipment. TMC and JBCE claim the availability of Annex III exemptions to category 8 and 9 for seven years starting in 22.7.2017.

Phoenix Contact and Harting[788] state in this regard:

> *"We apply for renewal of this exemption for categories 1 to 7, 10 and 11 of Annex I for an additional validity period of 5 years. For these categories, the validity of this exemption may be required beyond this timeframe. Although applications in this exemption renewal request may be relevant to categories 8 & 9, this renewal request does not address these categories."*

As leaded copper alloys are understood to be relevant to all categories, it can be concluded that expiration dates should be specified for all categories.

20.5.6 The Scope of the Exemption

The scope of the current exemption is viewed as very wide. As mentioned above, the contribution of the Swedish Chemicals Agency KEMI makes reference to Article 5(1)(a) that stipulates an inclusion of materials and components of EEE for specific applications in the lists in Annexes III and IV. The specification of applications is understood not to be exhaustive for Ex. 6c. KEMI therefore proposes to split into a number of more specific exemptions, related to applications where it has been verified that feasible alternatives are currently not available. Though the consultants agree with the need to narrow the scope of the exemption, it is presently not possible to comprehensively conclude specific applications to narrow the scope of the exemption. Phoenix Contact and Harting[789] explain that *"in most cases the component manufacturer chooses the material due to the characteristics required for the specific component. The EEE manufacturer uses this component to build the EEE. As in the supply chain, often several stages between the component manufacturer and the EEE manufacturer exist the component manufacturer often does not know in which applications the component is used. On the other hand the EEE manufacturer normally does not know for which specific reasons the component manufacturer chose the material as this is the specific know-how of the component manufacturer."* This is similar to the situation of leaded steel alloys in Ex. 6a. Therefore a comparable approach will also be discussed for the leaded copper alloys, as follows below.

The consultants would expect that the scope could be narrowed based on application groups or based on critical properties and required performance in application groups. This could require a supply chain survey, in order to collect and compile relevant

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[786] Op. cit. TMC (2015)
[787] Op. cit. JBCE (2015)
[788] Op. cit. Phoenix Contact and Harting (2015a)
[789] Op. cit. Phoenix Contact and Harting (2015b)

information and to allow conclusions as to relevant properties and performance levels. Time may be needed in order to initiate such a survey along the supply chain to gain this information and screen all relevant applications relevant to arrive at an exhaustive list (of applications or of properties). However, this effort is presumed to be feasible as well as important for communicating to the customers where additional effort is needed in the applications of substitutes in the future.

As in the case of leaded steel alloys, in the case of leaded copper alloys the applicants Phoenix Contact and Harting[790] also point out the individual and specific situation of each machining company: "*For example the machinability is not one isolated property but it depends on material, tool, coolant, machining technology and of course of the part that is to be made. Thus the change of one parameter also causes changes in the other parameters.*"

Therefore it might be that an exhaustive list of properties also specifying the required performance level and the relevant performance indicators that are relevant for such properties might not be practicable to refine the scope of the exemption. To support this understanding, however, the complexity of the situation at hand needs to be presented and substantiated. The wide scope currently addressed in the exemption is open to misuse in cases where substitution might be possible. Therefore the consultants conclude that although a comprehensive list of applications may be long for refining the scope of the exemption, this is however of importance for establishing the potential of a change in scope. The consultants consider this to be the first step to further narrow the scope of the exemption, which the industry must be induced to undertake.

20.5.7 Exemption Wording Formulation

As with the other alloy exemptions, the need to narrow down the exemption is evident. However, at this time on the basis of the available information the consultants cannot conclude a list of exhaustive applications of leaded copper alloys, which would be a prerequisite for narrowing the exemption.

20.5.8 Conclusions

Article 5(1)(a) provides that an exemption can be justified if at least one of the following criteria is fulfilled:

- their **elimination or substitution** via design changes or materials and components which do not require any of the materials or substances listed in Annex II is scientifically or technically impracticable;
- the **reliability** of substitutes is not ensured;
- the total negative **environmental, health and consumer safety impacts** caused by substitution are likely to outweigh the total environmental, health and consumer safety benefits thereof.

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[790] Op. cit. Phoenix Contact and Harting (2015b)

The consultants understand from the information provided that there are substitutes available that could at least be used for some applications. However, the use of alternatives (e.g. Ecobrass) requires adaptations in the machining process. Consequently, substitution with Ecobrass is currently understood to have restrictions limiting its applicability to certain applications, and possibly requiring machining adaptations in others. There are results from publically funded research that suggest how to overcome machinability challenges. Therefore it can be assumed that at least for some applications, the machining problems can be overcome in the future. It can be understood that there are additional lead-free copper alloys; however information was not provided in relation to other specific alloys.

It is further noted that though the applicants and stakeholders provide some detail as to their efforts towards substitution, in most cases statements remain general in nature. Quantitative comparisons are not sufficiently available to allow comparing between leaded alloys and various lead-free candidates in relation to various application sub-groups.

The remaining applications have to be specified by performing an integrated survey of the supply chain in order to narrow the scope of the exemption to a comprehensive list of applications. This would need the engagement of EEE component manufacturers as different applicants mentioned the dependency of the supply chain. The consultants can follow that this would be time-consuming. However, the consultants think that the current scope is not justified and recommend a short-term exemption to allow performing such a survey.

The set-up of a comprehensive list of applications would also allow deciding, whether the lead content can be further reduced in a certain application range. It might be that for a specific application group a general lower lead threshold can possibly be achieved.

20.6 Recommendation

Based on the above considerations, it can currently not be concluded whether substitution of the use of copper alloys containing lead up to 4% by weight is scientifically or technically practicable. It appears that substitutes can be applied in some cases (lead-free or with lower lead content), however mutual factors that would allow conclusions for specific sub-groups cannot currently be identified. It can also be understood that at least in some cases, available substitutes cannot be applied.

The overall picture where substitution efforts are promising is not clear enough at present. The aim of a future review should therefore be an exhaustive inventory on the applications of leaded copper alloys together with their technical requirements in order to check the applicability of a more narrow scope for the exemption. This should also encourage machining process adaptation to be further investigated to process lead-free [and/or reduced lead] alloys. Various stakeholders explain that such a survey would not be practical; however it is the obligation of the applicants (and of stakeholders interested in the exemptions renewal) to provide sufficient information to justify exemptions and their renewal.

Thus, the consultants recommend the renewal of Exemption 6c with the current scope and wording. However to stress the need to set up such an inventory and to start an integrated approach and to initiate a comprehensive survey along the value chain with a view to, at least, identify lists of components or categories of applications for lead reduction or substitution, the consultants propose to set a short review period of three years. As it does not seem that most stakeholders have detailed plans as to how to promote substitution in the future, the consultants would further recommend cancelling the exemption, should industry fail to provide substantiated information in the future.

Exemption 6c	Duration*
Copper alloy containing up to 4% lead by weight	*For Cat. 1-7 and 10 and 11: 21 July 2019* *For Cat. 8 and 9: 21 July 2021* *For Sub-Cat. 8 in-vitro: 21 July 2023* *For Sub-Cat. 9 industrial: 21 July 2024*

Note: As it can be understood that the exemption duration may vary for various categories on the basis of Article 5(2), expiration dates have been specified here for all categories either on the basis of the requested duration in the exemption request which the consultants perceive to be justified, or on the basis of the validity periods specified in Article 5(2) for categories, which are newly in scope.

20.7 References Exemption 6c

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