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This response to the 5-August-2015 questionnaire from the Oeko-Institut and Fraunhofer IZM is submitted on behalf of NEMA and the participating industry associations and companies listed below.

American Chamber of Commerce to the European Union (AmCham EU) ID number: 5265780509-97	**European Partnership for Energy and the Environment (EPEE)** ID number: 22276738915-67	**Information Technology Industry Council (ITI)** ID number: 061601915428-87
DIGITALEUROPE ID number: 64270747023-20	**European Passive Components Industry Association (EPCIA)** ID number: 22092908193-23	

European Committee of Domestic Equipment Manufacturers (CECED) ID number: 04201463642-88	**European Power Tool Association (EPTA)** ID number: 85810161889-67	**ZVEI - German Electrical and Electronic Manufacturers´ Association** ID number: 94770746469-09
European Coordination Committee of the Radiological, Electromedical and Healthcare IT Industry (COCIR) ID number: 05366537746-69	**European Semiconductor Industry Association (ESIA)** ID number: 22092908193-23	**Fein**

Questions and Answers

Question 1:

The annex of the RoHS Directive 2002/95/EC (RoHS I) was reviewed in 2008/2009 including exemption 8, which resulted in the specification of the exemption into exemption 8a) and 8b)[1]. At that time, it was already clear that substitution and elimination of Cd in contacts in the new exemption 8b – which was taken over into Annex III of the recast RoHS Directive 2011/65/EU (RoHS II) - was viable, but required time as no drop in solution was possible. The properties of the Cd-free solutions which you put forward in your exemption request have been known at that time already. It was recommended in the review report to continue the exemption until July 2014 to give industry sufficient time to adapt available solutions and to search for new ones. With the shift from RoHS I to RoHS II this deadline was shifted to 2016, which adds another two years' time resulting in a total of around six years to enable Cd-free solutions.

Please explain why NEMA et al. ask for the continuation of the general exemption 8a (sic) given the above background, and taking into account that "In a number of applications no substitutes have been found yet which offer the same reliability as the exempted application," which implies that for most applications Cd-free substitutes are available. Please provide detailed information about the contacts where substitution or elimination of Cd was possible.

Response:

NEMA *et al.* have requested renewal of Exemption 8(b) because the conditions underlying the need for the exemption at the time the RoHS Recast Directive was promulgated remain present for many applications of electrical contacts. As noted in the Oeko-Institut's Feb. 2009 evaluation of this exemption: "*As many electrical contacts are used in safety-critical applications, the transition to cadmium-free contacts must not compromise the safety of consumers."* [6]

This consideration remains valid today and the reality is that ***viable*** substitutes for Cd-based electrical contacts do not yet exist for certain applications. A key element of viability is that the material be commercially available, which requires overcoming both economic and technological barriers. Testing and qualification of Cd-free materials continue but the procedures are comprehensive and lengthy. Moreover, design changes that may be necessary do not manifest quickly because electrical contacts are circuit components in relays, switches and breakers that in turn are part of larger end-products. Design changes can therefore have "cascading" effects on downstream users.

As the consultant has noted, reliable Cd-free substitutes are available for some applications. Several dozen different major categories of metal alloys have been developed for use in separable electrical contacts - one of which is AgCdO. Differing formulations within each major category result in literally hundreds of possible choices. Nevertheless, there remain applications for which no other material than AgCdO can perform to the necessary safety and performance standards. In NEMA motor control products (sizes 00-9), transfer switching products, motor hermetic overload relays, bypass contactors, and general-

[1] For details see Ref [6], page 115 sqq.

purpose power switches less than 30 amps AC or greater than 600 VDC at 600 amps, efforts to find a suitable replacement for AgCdO have been largely unsuccessful. [7]

So while research regarding Cd-free formulations has led to advances consistent with the goals of the RoHS Directive, this should not be viewed as evidence that viable substitutes for Cd contacts are – or will soon be - commercially available for electrical contacts in all circumstances. The suitability of alternative materials is affected by a range of factors such as voltage, current range, and required number of cycles associated with the application.

This multiplicity of factors leads to a substantial amount of trial-and-error by manufacturers and their suppliers during product development***. It also makes it highly impractical to specify with precision the conditions under which alternative formulations offered by material suppliers are suitable for a particular application.*** That being the case, Exemption 8(b) should be renewed in its current broadly stated form to allow manufacturers maximum flexibility in product design. Renewing the exemption as it stands will not impede the continued search for Cd-free substitutes, as described below.

Question 2:

Please explain in detail your efforts to introduce Cd-free electrical contacts, and provide tests and test results for those applications where the substitution or elimination was not successful.
Please take into account that the RoHS Directive considers substitution or elimination of restricted substances via design changes as a mean to achieve RoHS compliance. The fact that “the entire contactor will need major redesign in order to perform with the alternative substances”, as you mention in your exemption request, is therefore no viable justification for the continuation of an exemption. The same applies to the fact that “A drop-in replacement of Cadmium with other materials alone is therefore not feasible.”

Response:

There have been considerable resources invested in the search for cadmium-free silver metal oxide materials, dating from well before the period that Exemption 8(b) has been in place. Research by manufacturers such as AMI/Doduco, Brainin, Checon, Chugai, Danco, Deringer-Ney, Loxwood, Metalor, Naeco; academic institutions such as Carnegie-Mellon University, University of Virginia, the University of Technology - Vienna, University of Wales, Osaka University, University of Braunschweig, University of Southampton; manufacturers such as General Electric, Westinghouse, Siemens, Square-D, and Eaton Electrical; and private research firms such as the Electric Power Research Institute and the Battelle Institute, have conducted research into new contact materials. The number of material formulations, product applications, and test conditions is undoubtedly large. This work is also proprietary in most cases, with manufacturers reluctant to expose the results of their efforts to competitors. [2, 7]

Findings from test efforts can be seen in the proceedings of the IEEE Holm Conference on Electrical Contacts (53 editions), the Technical University of Lodz International Conference on Switching Arc Performance (10 editions), the RSIA International Relay and Switch Technology Conference (54 editions), and others. [7]

Question 3:

NEMA et al. mention silver metal oxide systems with silver tin indium alloys as a Cd-free alternative. Please explain where these alloys are scientifically/technically appropriate Cd-free solutions.

Response:

It is true that *Ag/SnO*$_2$ materials have been optimized for a range of applications by adding Indium (and other metal oxide additives) as well as modification in the manufacturing processes that result in different metallurgical, physical and electrical properties. Manufacturing of *Ag/SnO*$_2$ by internal oxidation is possible in principle, but during heat treatment of alloys containing > 5 wt% of tin in oxygen, dense oxide layers formed on the surface of the material to prohibit the further diffusion of oxygen into the bulk of the material.

By adding Indium to the alloy the internal oxidation is possible and results in materials that typically are rather hard and brittle and may show somewhat elevated contact resistance and thus be limited to applications in relays. [2]

Silver indium tin oxide (*AgInSnO*) is good for high inrush loads, like tungsten lamps, where the steady state current is low. Although more weld resistant, *AgInSnO* and *AgSn* contacts have a higher bulk resistance (less conductivity) than *Ag* and *AgCdO* contacts. [3]

As noted in the Oeko-Institut's technical evaluation of this exemption, while *AgCdO* contacts behave similarly regardless of the supplier, the behavior and performance of *AgSnO*$_2$ <u>depends</u> on the essential minor additives that are used. The fact that every supplier's product is significantly different means that testing a subject material from one supplier may lead to findings that differ from when the "same" material was tested from another supplier. That being true, it may be difficult to determine exactly the conditions under which silver tin indium alloys are "*scientifically/technically appropriate Cd-free solutions*." [6]

Finally, NEMA *et al.* reiterate that Indium has been determined to be a ***critical material*** by both US and the European authorities, thus presenting an ongoing risk of available supply to contact material manufacturers and their customers. China is the dominant producer of Indium, which does not occur in concentrations to justify dedicated mining and produced only as a co-product of zinc mining. Indium also is not easily substitutable and virtually none is produced through recycling scrap metal or other metal-bearing residues. [4, 5]

Question 4:

You state that “Replacement contacts built with alternative contact materials would be larger, requiring larger contactors which may not fit in the space of the original contactor, which can result in disposal and replacement of the entire end-product, also resulting in increased volume of products disposed into the waste stream.“
The RoHS Directive allows equipment to be repaired as produced. How can larger contacts then result in more waste due to the larger size of contactors?

Response:

NEMA *et al.* understand that manufacturers will not be required to retro-fit existing products with Cd-free replacement contacts, but can service them in their present configuration for the duration of their useful life. First, services may include contact kit replacements or complete contactor/starter/relay replacement. Second, larger contacts could not be used in the contact kit replacements, and contactors/starters/relays with larger contacts may not have the same footprint. In the first situation, more waste would be created by retiring early assets that could have instead been serviced. In the second situation, there is no way to predict the total impact, but the entire assembly/enclosure may have to be retired. Both scenarios create unnecessary waste.

As noted earlier, switches and relays containing electrical contacts are components in larger products. In general, products made with AgCdO contacts are smaller. They also last longer and thus require less frequent replacement. Changes in contact materials compelled by the RoHS restrictions could conceivably require design alterations (*i.e.,* size or shape changes) that will have a cascading effect on downstream product manufacturers and end-users. There is no way to predict this impact precisely, but the length and complexity of the design, testing, and manufacturing phases for electro-products ensures that it will be far-reaching and consequential. Imposing a strict time-line on this process by expiring the exemption will have the effect of “forcing” technology advancements before they are commercially viable. [7]

NEMA *et al.* acknowledge the inherent objectives of the RoHS Recast and are striving to “*adapt to scientific and technical progress*” as pertains to contact materials. But because they are principally product manufacturers and do not develop and supply the contact materials themselves, their control over the process is limited. Because their highest priority is safety, they must in every case use the contact formulation best suited to each product’s use conditions.

The basic properties required for an electrical contact material is low erosion loss, low temperature rise, good anti-welding properties, and high resistance to re-ignition of arc. Depending upon the operating conditions, a suitable material is selected from the array of materials available in the market. It is a “top-down” process, in other words, where the use conditions determine the necessary contact materials, as opposed to a “bottom-up” approach whereby preferred contact materials are allowed to define the characteristics and performance of the product. [1]

References:

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2. DODUCO "Wiki of Electrical Contacts" http://www.electrical-contacts-wiki.com/index.php?title=Silver_Based_Materials

3. "Contact Performance in Relays" – material reprinted, with permission, from the *Engineer's Relay Handbook*, 5th edition, published by the Relay and Switch Industry Association (RSIA) http://www.leachintl2.com/english/english2/vol6/properties/00050.html

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5. US Department of Energy – Critical Materials Strategy, December 2010 http://www.osti.gov/scitech/servlets/purl/1000846

6. (Carl-Otto Gensch, Öko-Institut e. V., et al. 19 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, Öko-Institut e. V. and Otmar Deubzer, Fraunhofer IZM. Freiburg: http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf; http://ec.europa.eu/environment/waste/weee/pdf/report_2009.pdf.

7. N. A. Czarnecki, "Cadmium in electrical contacts", NEMA white paper, revised May 18, 2012