<u>Proposed RoHS Additional Substances Consultation – Beryllium and its compounds</u>

Submitted by:

John Wagner

Director of Materials Management

Association of Equipment Manufacturers

Email: jwagner@aem.org

Tel: 001 414 298 4164

<u>Background and issues caused by substitution</u>

AEM is a US trade association representing manufacturers of industrial equipment including products in the construction and agricultural sectors. Some of AEM members' products are in scope of the RoHS directive although many are excluded as types of professional Non-Road Mobile Machinery (as defined by RoHS) or as equipment that is specifically designed to be installed in excluded types of equipment. Products that are in scope are believed to be mainly in RoHS category 11 with some in categories 6 and 9.

Most AEM members' products are complex products designed for long lifetimes and high reliability. They must comply with other legislation apart from RoHS, such as the Non-Road Mobile Machinery (NRMM) Emissions Regulation that necessitates gaining approval in the EU from a Notified Body after any changes are made to product design such as would result from new RoHS restrictions. The NRMM Regulation requires engines to meet strict emissions limits, have proven reliability and long lifetimes and manufacturers must test engines to obtain this data before approval can be granted.

Another issue for AEM's members is that most of their products have niche uses and are not made in large numbers. However many of the component parts used are obtained from suppliers whose main markets are types of products that are excluded from RoHS, such as in heavy goods vehicles. AEM members may buy less than 1% of the total sales of a type of part from a component supplier and so have no influence over if or when the supplier develops an alternative RoHS-compliant version without the newly restricted substance. Suppliers will be reluctant to make changes if most of their customers do not want changes made as they will not want to have to gain re-approval for their products. As a result, it can take AEM's members many years to identify substitute parts, assess them, test them in engines, test in finished equipment and finally apply for EU approval before these can be sold. This can take 10 years or longer if sourcing substitute parts is especially difficult. The use of less reliable or lower performance parts is not an option as EU NRMM Emissions Regulation approval would not be granted. This 10 year timescale assumes that no new restrictions are adopted part way through, because if so, new components would need to identified and tested before finished equipment testing has to be re-started (this takes typically two years), which would extend the overall timescale required significantly.

Due to the considerable difficulties in achieving compliance, along with the uncertainties caused by the exemption request process (e.g. the time taken between submission and publication is now much longer than previously), some AEM members may consider withdrawing products from the EU market. If the next recast review results in the removal of some of the RoHS scope exclusions there could be more EU market withdrawal of products, especially if the list of RoHS restricted substances were to increase from the current 10. This would have a significant negative socio-economic impact on the EU.

The usage of RoHS substances in these products is limited to very small quantities comparing to the overall materials embedded in the finished product, which are nearly always collected for materials recycling or for refurbishment at end of life.

Supply chain RoHS data collection has been a significant challenge for our members due to the complexity of the impacted products and their supply chains. There can be up to 14 companies involved between raw material producer and AEM member manufacturer and this makes obtaining substance data difficult and time consuming. Some suppliers have been able to provide data on the proposed 7 additional RoHS substances, but most do not have this information and it will take some at least a year to obtain this information.

Some AEM members have identified needs for several RoHS exemptions for their products which have been requested in recent years via EUROMOT. Because of the safety, durability, and reliability requirement in our industry, alternative materials for restricted RoHS substances may not be available or feasible for machinery/equipment products that AEM members offer on the EU market The restriction of one or more of the proposed 7 new substances under RoHS is likely to result in need for additional exemption requests from our members. Due to the sophisticated material technologies embedded in the products our members offer, it is likely to take several years to just confirm the need for exemption requests.

AEM members have pointed out that it would be very beneficial across the industrial equipment industry, if any future restrictions were to be application specific, as is the approach used for REACH Annex XVII restrictions, or to exclude types of equipment that are unlikely to enter the EU waste stream due to manufacturers operating within the circular economy and so collect end of life equipment and ensure that it is safely recycled or refurbished for reuse, as is the case with most industrial equipment.

Answers to questions.

1. Applications in which beryllium metal and beryllium oxide are in use

Scope of possible restriction

Only beryllium metal, its alloys and beryllium oxide occur in electrical and electronic equipment (EEE). Other beryllium compounds such as the sulphate, chloride, nitrate, etc. have no known uses in EEE.

1.1 Products and applications

Some AEM members have surveyed their suppliers and have obtained data on beryllium in supplied parts. This is often difficult as supply chains can be very long. One example is that the end-product manufacturer is 14 levels away from the alloy manufacturer. As a result, data on uses is not yet complete. However some typical examples include:

- Sprung clips, contact springs, switch contacts and terminals in connectors
- Electric motor brushes
- Bearings and bushes of engines
- EMC seals used to ensure permanent electrical connections between enclosure parts that may need to be periodically separated for maintenance
- Integrated circuits
- High frequency high power integrated circuit packages (beryllium oxide). These are mainly used by the telecoms sector.

<u>1.2. Are these uses relevant to electrical and electronic equipment (EEE)?</u>

All of the above (in section 1.1) are used in types of EEE, although beryllium alloys also have uses in types of equipment that are out of scope of RoHS such as aircraft and other forms of transport. A study published by the European Commission shows the following[1]:

Use	In scope of RoHS?	Proportion of European consumption
Electronic equipment and domestic appliances	Yes	20%
Electronics and IT	Yes	20%
Road transport	No	15%
Aircraft, shipping and trains	No	10%
Others	No	35%

This study shows that only 40% of beryllium used in the EU is in equipment in scope of the RoHS Directive.

One manufacturer has found that beryllium (as alloys) occurs in 0.14% of the parts they use in types of high reliability, long lifetime industrial machinery.

<u>1.3 Is substitution possible?</u>

Beryllium is a rare and relatively expensive material and so electrical equipment manufacturers have already searched during the past decades for suitable substitutes and have already replaced beryllium where this has been technically possible. For example, high speed integrated circuits that contain beryllium oxide are only used if no alternative circuit designs or components are available and consumer products that have short lifetimes can usually use phosphor bronze instead of copper beryllium. As a result of cost reduction work, expensive beryllium parts have already been phased out where this is technically possible so that only those uses where no suitable substitutes exist remain.

Beryllium has been assessed[2] as for the REACH Regulation (by Germany). This concluded that:

"*Since substitution of Beryllium might be impossible in most cases (including the problematic cases), a general restriction does not seem to be the best option*".

Instead of a restriction, the study authors recommended that beryllium be a REACH SVHC and could also be included in Annex XIV as a way of regulating its use in the EU.

---

[1] Report on critical raw materials for the EU critical raw materials profiles. European Commission DG Enterprise and Industry, published 2014.

[2] https://echa.europa.eu/documents/10162/f76365ec-ce93-4422-bdf6-519517cc68be

Substitution in AEM members' products is not possible for the reasons explained in this document.

Alloys

Copper beryllium – A range of copper beryllium alloys are used by the electronics industry including AEM members. Each has specific physical and electrical properties that make them suitable for specific applications. Some have superior electrical conductivity to other alloys and are used if this is the most important parameter. However, each application will have a combination of requirements and so the best alloy overall would be selected. Important alloy properties are:

- Electrical conductivity.
- Tensile properties such as a yield strength, modulus of elasticity and a fatigue resistance are important for parts suitable as sprung contacts and other electrical components.
- Stress relaxation resistance or resistance to creep is important for long lifetime reliability as the contact force should not decrease with time, especially when used at elevated temperatures.
- Often it is the ratio of properties that are important, not the absolute values. For example, a large ratio of the modulus of elasticity versus the yield strength is important for high contact force

An illustrative example below compares the spring contact properties of copper beryllium with bronze alloys and also NKT322. This shows that copper beryllium with ca1.9%Be is superior overall, as it has superior electrical conductivity and the ratio of yield stress versus modulus of elasticity is higher than the other alloys.

Alloy	Yield stress N/mm2	Modulus of elasticity GPa	Ratio of Yield stress / Modulus of elasticity	Conductivity %IACS
Copper beryllium (1.8 – 2%Be)[3]	1120	127	8.82	25
NKT322[4]	800 to 1050	120	6.67 to 8.75	10 - 13
Bronze CuSn8	750	110	6.81	12
Phosphor bronze CuSn9P	800	108	7.4	12
Comments	Altered by heat treatment	Absolute value is less important than ratio	Highest values are best spring performance	Depends on heat treatment, but high conductivity is important to reduce oxidation caused by resistance heating

Nickel beryllium alloys are used where long lifetime spring properties is required at elevated temperatures such as in thermostats and connectors (plugs and sockets), which might be used, for example, in and next to engines. Although its electrical conductivity is inferior to copper alloys, it has a higher tensile modulus of elasticity and larger elasticity, so is used where these properties are essential. Nickel beryllium is however less common than copper beryllium alloys in electrical equipment and AEM members have so far only identified uses for copper beryllium alloys.

---

[3] Alloy B25 from http://www.ngk-alloys.com/NGK_Berylco_Design_Guide_En.pdf

[4] http://www.nmm.jx-group.co.jp/english/products/01_atsuen/02ticu.html

Aluminium beryllium – mainly used by the aerospace and space sectors whose products are outside of the scope of RoHS.

Beryllium oxide is used as an electrically insulating thermal conductor. Beryllium oxide has the highest thermal conductivity of any electrically insulating ceramic material.

Material	**Thermal conductivity**
Beryllium oxide	265 W/mK
Aluminium nitride	180 W/mK
Silicon carbide	70 W/mK
Boron nitride	60 W/mK
Aluminium oxide	25 W/mK

Another important property inside high speed integrated circuit packages is a low dielectric constant. Beryllium has a lower dielectric constant than other thermally conducting ceramic materials.

Is beryllium introduced from secondary sources?

When scrap electrical equipment (EEE waste) reaches end of life and is recycled, the metallic fraction that includes beryllium alloys and electrical circuits will be recycled using smelting processes. As beryllium is relatively expensive and so is only used when no alternatives are suitable, it is very uncommon in most types of electrical equipment and as a result, the concentration of beryllium in recovered secondary metals (mainly copper) is so low as to be undetectable. Secondary copper may therefore contain traces of beryllium but at such low concentrations that are not measurable.

2. Quantities and ranges in which beryllium and its compounds are in use

Quantity by application

Several copper beryllium alloys are used by the electronics industry, each having different physical and electrical properties. These alloys contain about 0.4% to about 2.0% beryllium. One AEM member has calculated that one of its products contains 2mg of beryllium metal, another has determined that an engine assembly contains 0.1g (100mg) and a third manufacturer has estimated that a product contains 5mg of beryllium metal. These types of end products can weigh many 100s of kilograms at least and so the beryllium concentration overall is very small.

Substitution trends

Due to the relatively high price and scarcity of beryllium, manufacturers have already replaced beryllium wherever possible. The only uses remaining are those where no suitable alternatives could be found.

3. Potential emissions in the waste stream
End of life management.

Beryllium alloys

Beryllium is recoverable from beryllium alloy production scrap, but the amounts present in most types of electrical equipment waste are too small to be recoverable or pose a risk of harm to workers, the public or the environment, any beryllium in EEE waste is lost because recovery when concentrations are extremely low is uneconomic.

Beryllium oxide

As with beryllium alloys, the amounts present in most types of electrical equipment waste are too small to be recoverable or pose a risk of harm to workers, the public or the environment. However there is a small risk to workers who analyse electrical waste if the sample that they take contains a component which contains beryllium oxide. The analysis process requires that the scrap is ground to a powder and this can result in the emission of very hazardous beryllium oxide dust. The analyst can take precautions if they are aware of beryllium oxide being present and manufacturers of components that contain beryllium oxide often use warning labels on these parts.

Potentials for emissions in the relevant treatment and mitigation measures

As the beryllium concentration of electrical equipment waste will usually be too low to be measureable, any emissions will also be undetectable. One US recycler claims that recycling of scrap that contains copper beryllium is safe and that beryllium is recoverable[5]. The Beryllium Science and Technology Association[6] has measured airborne emissions at a beryllium alloy factory and found that all analysed samples contained <0.2µg/m^3. The UK workplace exposure limit for airborne beryllium is 2.0 µg/m^3. All EU recyclers must comply with workplace exposure limits which are the same or similar to the UK limit.

4. Substitution

Applications where substitution are not practicable or reliable

Beryllium-free alloys are used for connectors, switch contacts, thermostats, etc. such as phosphor bronze and copper-titanium-iron alloys but each alloy has unique combinations of properties and so are not suitable as substitutes for those applications where beryllium alloys are currently used. Phosphor bronze, for example is much cheaper than beryllium alloys and so is often used in short-lifetime consumer products where it is suitable because its inferior resistance to spring force relaxation (i.e. lower Stress relaxation resistance) is not an issue. The US Geological Survey states[7]:

Copper alloys containing nickel and silicon, tin, titanium, or other alloying elements or phosphor bronze alloys (copper-tin-phosphorus) may be substituted for beryllium-copper alloys, but these substitutions can result in substantially reduced performance.

The EU REACH assessment of beryllium[2] came to the same conclusion stating: "*substitution of Beryllium might be impossible in most cases".*

Applications where substitution are underway

Where this has been possible, substitution has already taken place.

Constraints on substitution

[5] https://materion.com/-/media/files/corporate/faqs/faq101cubeandrecycling.pdf
[6] http://beryllium.eu/product-stewardship/recycling/
[7] https://minerals.usgs.gov/minerals/pubs/commodity/beryllium/mcs-2017-beryl.pdf

Properties of substitutes are different making them unsuitable in applications where beryllium is still used.

5. **Socio economic impact**

If a restriction were to be adopted, even though we believe that this is unnecessary, it will be important to allow manufacturers sufficient time to identify, test and gain approvals for substitutes. From past experience of AEM members with phthalate substitution, this can take up to 10 years or longer if some substitute parts are not available from component suppliers. Note that many components are made primarily for sectors outside of the scope of RoHS and so manufacturers have no incentive to develop substitutes. If research shows that no substitutes exist, AEM could apply for exemptions, but this would not be possible until the research had been completed with negative results available to justify the exemption.

In addition, past experience has shown that it can take more than 3 years (>4 years in recent years) from submission of an exemption request to the exemption being published in the EU Official Journal. Based on experience with phthalate substitution, a 10 year transition period appears reasonable, but as there are so many types of part that contain antimony oxide, the time needed is likely to considerably longer.

If beryllium were to be restricted before fully RoHS compliant equipment can be tested and gain NRMM Emissions Regulation approval from a Notified Body, many types of equipment could not be sold in the EU. For example, EU hospitals could not buy emergency generators, with potentially disastrous implications, construction equipment would not be available so that new buildings could not be constructed, and some farm machinery will not be available in the EU therefore affecting food production.

6. Further information and comments

There are many statements made by reputable organisations that substitution is not possible. Beryllium is relatively expensive and so manufacturers have already replaced it where this has been possible and so it is used only in applications where no alternatives exist. Therefore a restriction would be pointless as it would not reduce the quantity of beryllium used in electrical equipment but would necessitate both industry and the European Commission unnecessarily having to make considerable efforts to request, review and maintain exemptions, probably permanently.