Emerson Climate Technologies RoHS Exemption Request – Exemption 9b

Date of submission: 7 October 2014

1. Name and contact details

1) Name and contact details of applicant:

Company: Emerson Climate Technologies
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Name: Norbert Kaemmer
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Function: Vice President Engineering
Address: Pascalstr. 65
52076 Aachen-Oberforstbach
Germany

2) Name and contact details of responsible person for this application (if different from above):

Company: _____ Tel.: _____

Name: _____ E-Mail: _____

Function: _____ Address: _____

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2. Reason for application:

Please indicate where relevant:

☐ Request for new exemption in:

☒ Request for amendment of existing exemption in

☒ Request for extension of existing exemption in

☐ Request for deletion of existing exemption in:

☐ Provision of information referring to an existing specific exemption in:

☒ Annex III ☐ Annex IV

No. of exemption in Annex III or IV where applicable: 9b

Proposed or existing wording:

"Lead in bearing shells and bushes for refrigerant-containing compressors, with a stated electrical power input of only 9 kW or lower for the HVACR industry, with expiry date three years after the publication of the amended RoHS Annex"

Duration where applicable: 3 years

☐ Other: _____

3. Summary of the exemption request / revocation request

Emerson is requesting renewal for the exemption 9b for lead in bearing shells and bushes for refrigerant-containing compressors for heating, ventilation, air conditioning and refrigeration (HVACR) applications. This specific request, as mentioned in section 2, is precisely a request to extend the current exemption with a narrowed scope.

Emerson is in close interaction with the suppliers of journal bearings and is discussing options to replace lead. We have received samples from these suppliers of lead-free bearings which were subjected to the qualification process at Emerson. Bearing suppliers are not in the position to evaluate the behavior of lead-free bearings in the refrigeration compressor environment. Therefore it is in the responsibility of Emerson to verify that these bearings perform with equivalent reliability as compared to today's bearings.

Compressor testing for substitutes for which the exemption renewal is requested will not be completed until December 2015. While we have made significant progress on many of our product platforms (2014: 20% of total production volume is greater than 9 kW of electrical power input, representing 39% of lead) there remains a set of smaller compressor products that still pose many supply chain robustness and technical challenges.

Once suitable alternatives are proven, process changes in some cases may take up to 3 years. Process changes include:

- OEM testing; as these smaller compressors are typically used in residential and commercial air conditioning and refrigeration applications and as such, are subject to much a tremendous range and variety applications with many OEMs in many regions of the world.
- Qualification of suppliers; recent supply chain revelations, as well as technical challenges associated with the supply chain disclosure, has given us reason to make business decisions that have altered our initial plan of being compliant by June 2016.
- Production implementation; There are many different compressor models and derivatives which must be tested and approved in each OEM application before we can release our final design. Also, the smaller design format of these applications causes severe limitations on the design space within the compressor to support the new bearings. This combination of model families, application proliferation and smaller design window has caused the solutions for these smaller compressors to take longer.

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4. Technical description of the exemption request / revocation request

(A) Description of the concerned application:

1. To which EEE is the exemption request/information relevant?

   Name of applications or products:

   Refrigerant-containing compressors, with a stated electrical power input of only 9 kW or lower in size for the HVACR industry

a. List of relevant categories: (mark more than one where applicable)

☒ 1
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ 7
☐ 8
☐ 9
☐ 10
☐ 11

b. Please specify if application is in use in other categories to which the exemption request does not refer: _____

c. Please specify for equipment of category 8 and 9:
   1. The requested exemption will be applied in
   2. ☐ monitoring and control instruments in industry
   3. ☐ in-vitro diagnostics

   ☐ other medical devices or other monitoring and control instruments than those in industry

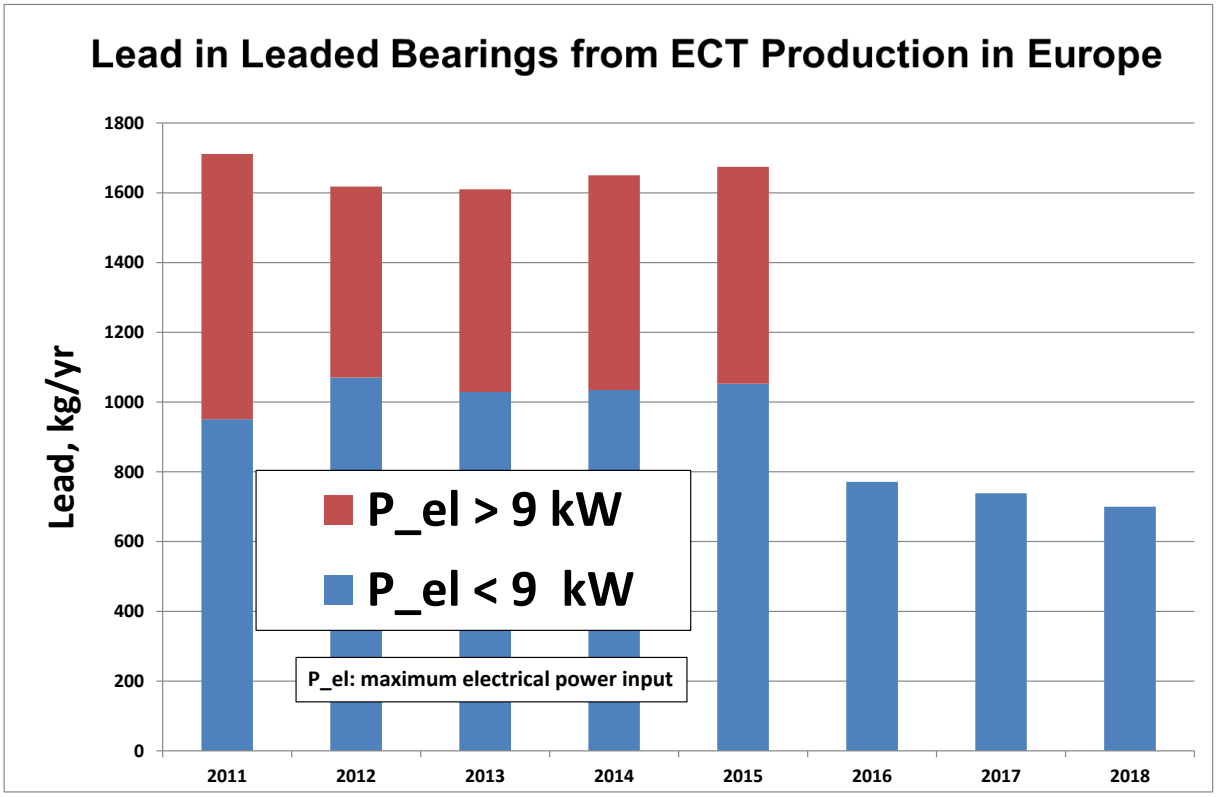
2. Which of the six substances is in use in the application/product?
   (Indicate more than one where applicable)
   ☒ Pb ☐ Cd ☐ Hg ☐ Cr-VI ☐ PBB ☐ PBDE

3. Function of the substance:

   Prevent premature failure during lubrication interruption

4. Content of substance in homogeneous material (%weight):
   0.1 – 3%

5. Amount of substance entering the EU market annually through application for which the exemption is requested: _____
Please supply information and calculations to support stated figure.



These Pb amounts are calculated from production volumes times lead content per compressor sold. Further details can be provided in a confidential communication.

6. Name of material/component: Lead / Bearing (bush)

7. Environmental Assessment: _____
   10. LCA: ☐ Yes
   11. ☒ No

(B) In which material and/or component is the RoHS-regulated substance used, for which you request the exemption or its revocation? What is the function of this material or component?

An important trait of air conditioning and refrigeration compressors is that they are hermetically sealed to prevent refrigerant leakage and ensure long reliable uninterrupted operation without service. Therefore, oil or bearings are not changed during the life of a compressor unlike in other non-hermetic applications or industries. Consequently, the demand in durability for those bearings is high and only sleeve lubricated bearings are capable of such life of continuous operation without overhaul. Rolling element bearings cannot withstand the design life required in these applications.

There are also inherent and unique lubrication problems with refrigeration and air conditioning compressor bearings. For reason of oil return to the compressor, the lubricant needs to be miscible to a large extent with the refrigerant being compressed and circulated through the closed system. This miscibility characteristic in turn means that the refrigerant will have a high degree of solvency for the lubricant, and lead to repeated "dry" start conditions during start-up after the system was off for some time. During such off-time the refrigerant may act as a "degreasing agent" that removes oil from critical bearing surfaces. Condensing and boiling repeatedly occurs on various internal surfaces of the compressor due to temperature equilibration between the indoors and outdoors part of such system.
Moreover, it is not uncommon during the life of a compressor for repetitive refrigerant flooding situations to occur, particularly during start-up, or system defrosting (in the case of Heat Pumps), leading to reducing the effective viscosity of the oil-refrigerant mixture to the point that it severely stresses the bearings. This event removes the vital lubrication necessary for proper bearing performance.

(C) What are the particular characteristics and functions of the RoHS-regulated substance that require its use in this material or component?

It is critical to note that because of this special constraint (i.e., presence of liquid refrigerant), a highly performing bearing material is essential to the successful operation of an HVACR compressor. Stationary air conditioning and refrigeration compressors are also unique in that their design life is much greater than, say, automotive air conditioners. For example, stationary HVACR systems typically exhibit running times of greater than 50,000 hours for residential applications and in excess of 100,000 hours for commercial applications. In contrast, the typical runtime life for an automotive air conditioner compressor is 3,000 hours.
Lead has literally played an enabling role in allowing rotating high speed bearings to function successfully, even across many less demanding sectors of industry. Lead is one of the most effective metallic elements to create low friction between ferrous interfaces. In bearings, lead accomplishes this by transferring itself between the rotating members thereby preventing harsh metal-to-metal contact which would otherwise cause galling or seizure of the two surfaces. During times of inadequate lubrication (due to the presence of refrigerant), lead-free materials struggle to maintain comparable low friction relative to their lead-containing counterparts.
It follows that the "self-lubricating" properties of a bearing are critical to the high durability and reliability requirements of stationary refrigeration and air conditioning compressors and that the lubricious nature of lead is vital as a constituent of those sleeve bearings. No other commonly available metal other than lead has been found thus far to perform self-lubrication as well. Lead tends to smear between the bearing and the moving counter-face producing low friction during marginal lubricating conditions and when the bearing interface does get hot from lack of oil. Lead between the moving surfaces limits excessive friction and preventing seizure. Lead is unique in that it helps prevent premature failure during lubrication interruption.

5. Information on Possible preparation for reuse or recycling of waste from EEE and on provisions for appropriate treatment of waste

1) Please indicate if a closed loop system exist for EEE waste of application exists and provide information of its characteristics (method of collection to ensure closed loop, method of treatment, etc.)

The relevant components are partially used in equipment which falls under the WEEE directive for which a closed loop system exists. Another class of components is used in equipment not subjected to the WEEE regulation such as fixed installations. This equipment is entered into the general material waste and recycling stream as it presents a substantial material value, it is not entered into the normal household waste stream delivered to incineration plants or municipal waste dumps.

Please indicate where relevant:

☒ Article is collected and sent without dismantling for recycling

☐ Article is collected and completely refurbished for reuse

☐ Article is collected and dismantled:

- ☐ The following parts are refurbished for use as spare parts: none (to be confirmed by equipment producers)
- ☐ The following parts are subsequently recycled: _____

☐ Article cannot be recycled and is therefore:

- ☐ Sent for energy return
- ☐ Landfilled

2) Please provide information concerning the amount (weight) of RoHS substance present in EEE waste accumulates per annum:

☐ In articles which are refurbished to be answered by equipment manufacturers

☐ In articles which are recycled to be answered by equipment manufacturers

☐ In articles which are sent for energy return to be answered by equipment manufacturers

☐ In articles which are landfilled to be answered by equipment manufacturers

6. Analysis of possible alternative substances

(A) Please provide information if possible alternative applications or alternatives for use of RoHS substances in application exist. Please elaborate analysis on a life-cycle basis, including where available information about independent research, peer-review studies development activities undertaken

Emerson does have a fundamental understanding of the function and importance of lead in journal bearings and also has a general knowledge about alternative to lead in these devices. However, it is with the bearing manufacturer's competence, knowledge and manufacturing expertise to provide sample bearings which according to their expectations should be performing well in refrigeration compressors. It turned out that

this is an iterative process requiring the cooperation between the compressor manufacturer and the bearing supplier.

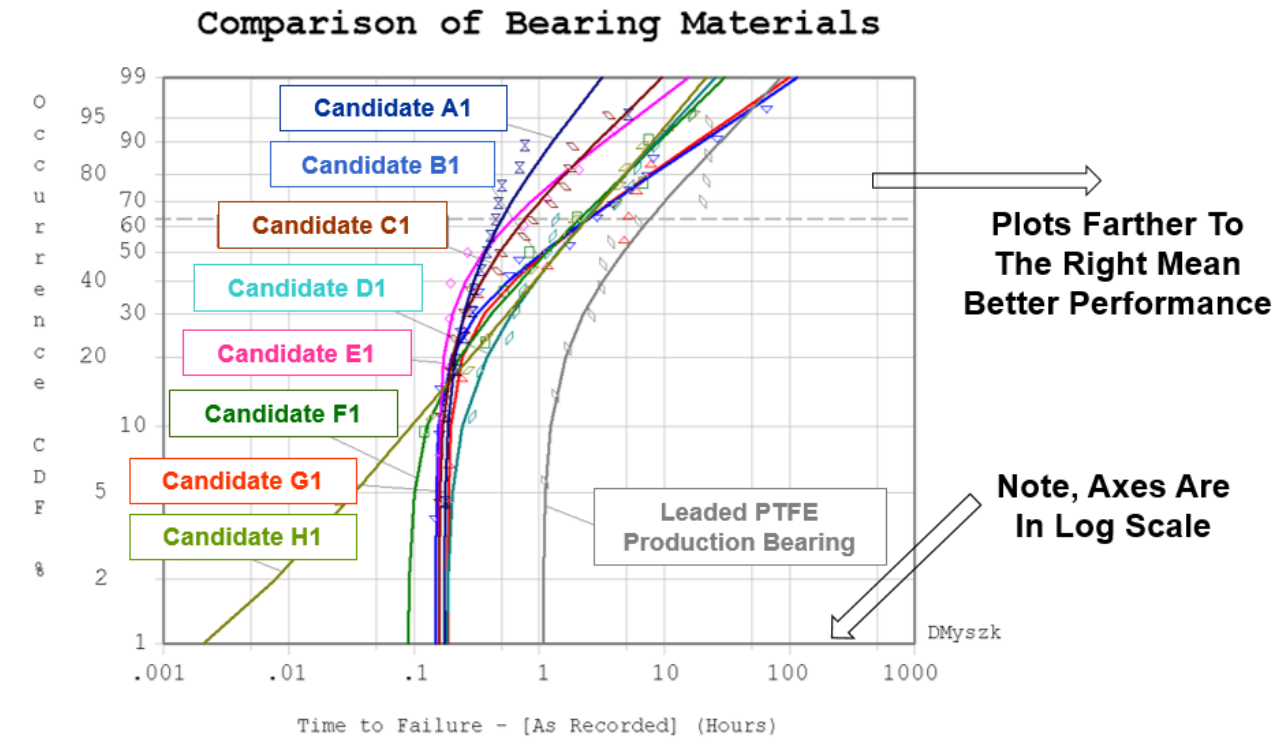
Metallic elements with equivalent performance to lead in HVAC&R polymer matrix composite bearings are very rare. Bismuth approaches the performance of Lead, but is not a common element and is, hence, expensive and only marginally available. Other metallic elements that are sometimes used for lubricity in HVAC&R bearing applications are: Tin, Cadmium and Indium. Tin does not supply adequate lubricity (low friction) relative to Lead. Cadmium is toxic and restricted by RoHS. Indium suffers from being rare and expensive, even more so than Bismuth. As far as replacements for lead other than metallic elements, there exists the following options: Molybdenum Disulfide, Graphite, Tungsten Disulfide, Hexagonal Boron Nitride, Carbon Fiber, Calcium Fluoride, Zinc Sulfide and PTFE. This is not an exhaustive list, but represent main ones. Not all these materials are individually equivalent to lead and sometimes it requires a combination of them to satisfy the tribologically-equivalent performance of Lead. Although it is possible to achieve performance parity with the aforementioned non-metallic options, most of these potential replacements for Lead are more expensive and less commonly available relative to Lead.

Emerson Climate Technologies, Inc. is committed to finding replacements for all its leaded bearing materials. Emerson Climate Technologies has spent significant resources (Global engineering, procurement, product planning and testing) and money on solutions for all products over the past six years. The amount we have spent, globally, is in excess of $5M and includes over 100,000 engineering hours thus far. Emerson has also worked with several bearing suppliers and multiple lead-free material candidates over the last decade, in an attempts to identify an acceptable bearing solution and these suppliers have also invested heavily in developing potential solutions for this unique engineering design challenge.

(B) Please provide information and data to establish reliability of possible substitutes of application and of RoHS materials in application

Testing procedures are outlined in 7b.

Bench Testing of Promising Bearing Candidates



Bearing Lubrication Test Expressed In Terms Of The Weibull Distribution. Each Line Represents The Statistical Distribution Of Bearing Life. Ordinate Is The Cumulative Probability Of Failure. Abscissa Is Bearing Run Time. Note, Leaded PTFE Bearing Is Approximately 5X's Better Than Nearest Competitor.

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7. Proposed actions to develop possible substitutes

(A) Please provide information if actions have been taken to develop further possible alternatives for the application or alternatives for RoHS substances in the application.

Further and ongoing work include both polymeric and solid bearing material options including impregnation, overlay, lining & backing material. Actions are currently underway to finalize testing, prepare for customer communication and reduction of leaded bearing inventory (supplier, Emerson Climate and OEM). Key materials and substances may include: PTFE, Molybdenum Disulfide, Calcium Fluoride, Aluminium Oxide, Carbon fibres, copper and iron.

(B) Please elaborate what stages are necessary for establishment of possible substitute and respective timeframe needed for completion of such stages.

Any new lead-free bearing must be equivalent to the legacy (leaded) bearings for the following attributes. All testing durations listed are absolute for one bearing material candidate.

- Chemical Resistance—the compatibility of the bearing material with the refrigerant and lubricant (Duration: 3 weeks)
- Scuffing Resistance—the ability to rotate against steel under high pressure and velocity without galling (and minimal friction) (Duration: 1 month)
- Conformability—the ability to physically conform to the shape of the counter-face it is rotating against maintain low unit loading (Duration: 4 months)
- Embeddability—the ability to embed debris and still function (4 months)
- Dry-running capability—the ability to perform well under marginal lubrication during liquid refrigerant conditions (4 months)
- Cavitation Resistance—the ability to resist implosive damage due to rapid gas pressure changes (Duration: 1 month)
- Long term wear—the ability to resist wear-out over 15+ years (Duration:1 year minimum for field test sites)
- Contact Fatigue—the ability to resist cyclic surface damage (Duration: 5 months)

Emerson Climate engineering qualification methodology includes:

1.) Design Review/FMEA

2.) Identify Lead-Free Candidates, Assess Chemical Resistance

3.) Perform Comparative Accelerated Lubricity "Bench" Testing

4.) Perform a Battery Of Compressor Reliability Testing (Performance / Durability

5.) Validate The Associated Manufacturing Process (Plant Pilots, Etc.)

6.) Notify OEM (Customer May Require Other Testing), Field Testing Option

8. Justification according to Article 5(1)(a):

(A) Links to REACH: (substance + substitute)

1) Do any of the following provisions apply to the application described under (A) and (C)? No

- ☐ Authorisation
- ☐ *SVHC*
- ☐ *Candidate list*
- ☐ Proposal inclusion Annex XIV
- ☐ Annex XIV

☐ Restriction

☐ Annex XVII

☐ Registry of intentions

☐ Registration

2) Provide REACH-relevant information received through the supply chain.
Name of document:
No REACH documents for bearings were provided to Emerson, specifically no notification about SVHC substances.

(B) Elimination/substitution:

1. Can the substance named under 4.(A)2 be eliminated?

12.☐ Yes. Consequences? _____

☒ No. Justification: It is the primary functional component of refrigeration systems for buildings, food and medical-products preservation.

2. Can the substance named under 4.(A)2 be substituted?

13.☐ Yes.

14. ☐ Design changes:
15. ☐ Other materials:
16. ☐ Other substance:

17.☒ No.

Justification: _____

While we are confident in our solution and supply chain decisions on compressors above 9 kW of electrical power input, approximately 80% of our production volume (compressors that are below 9 kW of electrical power input) will not have final testing completed until mid to late 2015. This may translate to a production implementation date of sometime after the deadline of June 2016. Production implementation may include all items listed in 7B above, but also supplier readiness, availability of material, environmental impact, and health impact. Process changes at the vendor(s) have given us not only technical challenges but timing challenges due to the large production volumes and the vast array of compressor models. The requested renewal time length of three years will allow us full implementation of all Emerson Climate Technologies products for exemption in question.

3. Give details on the reliability of substitutes (technical data + information):

The substitutes mentioned below (8.b.4) have passed our reliability testing in compressors above 9 kW of electrical power input across various compressor models. This includes all stages mentioned in 7b above. The testing for compressors below 9 kW of electrical power input continues with the same range of substitutes.

4. Describe environmental assessment of substance from 4.(A)2 and possible substitutes with regard to
    1) Environmental impacts:
    2) Health impacts:
    3) Consumer safety impacts:

As already mentioned, Emerson has a general knowledge about alternatives to lead in bearings. However, it is to the bearing manufacturers to provide sample bearings which according to their expectations should be performing well in refrigeration compressors. The bearing design, material composition and manufacturing is within the responsibility of the bearing manufacturers.

Substance	Environmental Impacts	Health Impacts	Consumer Safety Impacts	Additional Comments
PTFE, PFA, MFA	None in basic polymer state			Fluoropolymers that are widely used widely used for their high temperature performance and release properties.
PTFE, Molybdenum disulfide	None	None	None	This combination is commonly used as a dry film lubricant and is used in bearing and bushing applications.
Calcium Fluoride	None	None	None	Commonly used in aluminum-metallurgy, brake lining, glass manufacturing, enamel and glazing frits production, dental applications, and the production of welding agents.
Aluminum Oxide	None	None	None	Commonly used as a filler in polymers and some cosmetics
Iron Oxide	None	None	None	There are a number of iron oxides; the most common are iron(II) oxide (FeO), iron(III) oxide (Fe2O3), and iron(II,III) oxide (Fe3O4). Iron(II) oxide is used as a pigment. Iron(III) oxide is also used as a pigment and in magnetic recording tapes. Iron(II,III) oxide is used as a black pigment. Some of the iron oxide pigments are FDA approved for use in cosmetics, suggesting that there are no major health concerns.
Zinc Sulfide	None	None	None	Used as a pigment and as a window for visible optics and infrared optics. May form highly toxic and flammable hydrogen sulfide gas on exposure to acids.
Carbon Fibers	None	None	None	Carbon fibers are usually combined with other materials to form a composite. When combined with a polymer it forms a carbon fiber reinforced polymer with a high

				strength-to-weight ratio.
Copper, Iron, Aluminum	None	None	None	All are commonly used metals with wide application
Bismuth	None	None	None	No large commercial applications; primarily used to produce bismuth compounds which are used in pharmaceuticals, pigments, and cosmetics. Bismuth is also used in metal alloys and as a lead replacement. Most commercially produced bismuth is a byproduct of processing metals, particularly lead. It is generally accepted that bismuth and its compounds are less toxic compared to other heavy metals such as lead and antimony.
Silicon	None	None	None	Silicon's use as an alloying element in aluminum is the largest application. Another major application is chemical production, largely silicone. In recent years there has been growth in the use of silicon in solar panels, leading to increased demand; however, there appears to be no current availability issues.

⇨ Do impacts of substitution outweigh benefits thereof?
Please provide third-party verified assessment on this: Please see attachment below

Microsoft Word 97 - 2003 Document

(C) Availability of substitutes:

a) Describe supply sources for substitutes:

Emerson has identified supply sources for lead free bearings from our incumbent suppliers as well as several new suppliers that we consider and evaluate.

b) Have you encountered problems with the availability? Describe:

Repeating what was mentioned in 6a:

a. Bismuth approaches the performance of Lead, but is not a common element and is, hence, expensive and only marginally available.
b. Other metallic elements that are sometimes used for lubricity in HVAC&R bearing applications are:
    i. Tin does not supply adequate lubricity (low friction) relative to Lead.
    ii. Cadmium is toxic and restricted by RoHS.
    iii. Indium suffers from being rare and expensive, even more so than Bismuth.
c. As far as replacements for lead other than metallic elements, there exists the following options: Molybdenum Disulfide, Graphite, Tungsten Disulfide, Hexagonal Boron Nitride, Carbon Fiber, Calcium Fluoride, Zinc Sulfide and PTFE.

c) Do you consider the price of the substitute to be a problem for the availability?

☒ Yes In most cases yes, but not all cases.

☐ No

d) What conditions need to be fulfilled to ensure the availability?

a. All material specifications must be met
b. Supply chain group scrutiny of supply/demand of material and substance availability

(D) Socio-economic impact of substitution:

⇨ What kind of economic effects do you consider related to substitution?

☐ Increase in direct production costs

☒ Increase in fixed costs (depending on the substitute, region and product)

☐ Increase in overhead

☐ Possible social impacts within the EU

☐ Possible social impacts external to the EU

☐ Other:

⇨ Provide sufficient evidence (third-party verified) to support your statement: _____

9. Other relevant information

Please provide additional relevant information to further establish the necessity of your request:

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10. Information that should be regarded as proprietary

Please state clearly whether any of the above information should be regarded to as proprietary information. If so, please provide verifiable justification:
