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STAKEHOLDER CONSULTATION ON
ADAPTATION TO SCIENTIFIC AND TECHNICAL PROGRESS
UNDER DIRECTIVE 2002/95/EC ON THE
RESTRICTION OF THE USE OF CERTAIN HAZARDOUS
SUBSTANCES IN ELECTRICAL AND ELECTRONIC EQUIPMENT
FOR THE PURPOSE OF A POSSIBLE AMENDMENT OF THE ANNEX EXEMPTION 9b
(LEAD IN LEAD-BRONZE BEARING SHELLS AND BUSHES)

Company Background:

Emerson Electric, with sales exceeding $22.5 Billion, brings technology and engineering together to provide innovative solutions in industrial automation; process control; heating, ventilating and air conditioning; electronic and telecommunications; and appliance and tools. Emerson Climate Technologies, Inc. (Formerly Copeland Corporation) is a subsidiary Of Emerson Electric. Emerson Climate Technologies has divisions in the US, Europe and Asia, and is one of the largest manufacturer of commercial and residential air conditioning and refrigeration compressors. We have a global manufacturing capacity of over 8 million compressors yearly on three continents.

Emerson Climate Technologies, Inc. designs and manufacturers air conditioning and refrigeration compressors for the HVACR (Heating, Ventilation, Air Conditioning and Refrigeration, including Heat Pumps) industry. The compressors we manufacture are a "component" within the final HVACR system. The HVACR system is what is ultimately sold to the end user. The HVACR market sector that we service produces relatively large systems which are composed of a condensing unit outside of the building along with an evaporator sub-system located on the inside. Another primary application of our compressors is for Heat Pump Water Boilers. These systems are installed by professional electricians (that is, hard wired) and professional building contractors. Emerson Climate Technologies, Inc. does not produce compressors for small systems such as household food storage refrigerators or window air conditioners.

Executive Summary:

Emerson Climate Technologies, Inc. is committed to converting all its bearings to lead-free compositions. There are, however, major obstacles preventing us from satisfying the October 2009 deadline. The key reasons are the long qualification time required to assure reliability and durability and the absence of an adequate lead-free candidate for several applications.

Therefore, Emerson Climate Technologies, Inc. advocates the continuance of RoHS Annex Exemption 9b "Lead in lead-bronze bearing shells and bushes" as written. If, however, the broad nature of the current verbiage is not acceptable to the Commission, as a minimum, Emerson Climate Technologies strongly suggests more specific verbiage as follows: "Lead in

lead-bronze bearing shells and bushes for the Heating, Ventilation, Air Conditioning, Refrigeration and Heat Pump industry".

The following are answers to the questions of the consultation to help justify this position statement.

<u>Specific Questions for Exemption 9b</u>

1. In which applications / products falling under the scope of RoHS are lead-bronze bearing shells and bushes used? Please provide a comprehensive list also naming the corresponding WEEE (Directive 2002/96/EC) categories. Which applications fall under category 8 & 9 of the WEEE Directive?

It is important to note that since the inception of RoHS and still today, it is unclear within which precise WEEE category (if any) stationary HVACR equipment falls. Although Emerson Climate Technologies' compressors are components used in applications which normally would not be simply considered to be "household" appliance, Category 1 (Large Household Appliances) appears most appropriate so that is what is stated in the table.

Table I below shows the four major groups of products Emerson Climate Technology produces and the categories they fall within.

Table I

Products	**Number Of Bearing Designs Requiring Qualification**	**Applications**	**WEEE Annex 1B Categories**	**Category 8 and 9 Apply?**
Stationary Residential Air Conditioning and Commercial Refrigeration (1 1/2-6 H.P Models)	25 Variations	Drive and main bearings	1*	No
Stationary Commercial Air Conditioning (Models from 7 to 70 HP)	16 Variations	Drive and Main Bearings	1*	No
Stationary Small-Unit Refrigeration Models 0.5 - 5 H.P.	30 Variations	Main and connecting rod bearings	1*	No
Stationary Large-Unit Refrigeration (Models, 5 - 70 H.P.)	22 Variations	Main and connecting rod bearings	1*	No

Definitions:

Stationary Residential Air Conditioning and Commercial Refrigeration: Environmental cooling or heating systems for households (not window units) are composed of a condensing unit on the outside of the building and an evaporator inside the house. Heat pumps are included in this category.

Stationary Commercial Air Conditioning: Same general configuration as above only applied to hospitals, businesses, factories, offices, etc.. The units are also typically larger than residential.

Stationary Small-Unit Refrigeration: Low temperature cooling or heating for commercial applications. Examples are: Dental air compressors, Commercial display cabinet freezers, ice machines, ultra-low temperature medical and research preservation (blood storage, etc.), body temperature control for medical applications, cooling for medical examination equipment such as MRI, computer cooling, semi-conductor production and in food preservation.

Stationary Large-Unit Refrigeration: Same as above only larger systems. Examples are reach-in or walk-in grocery store refrigerated boxes for food preservation and medical blood storage.

2. A similar exemption under the ELV Directive (200/53/EC) has recently been evaluated (entry 4 Annex II). Results are available at http://circa.europa.eu/Public/irc/env/elv/library?l=/stakeholder_consultation/evaluation_procedure/reports/final_report&vm=detailed&sb=Title. Which of the statements made for the use of such applications in automotive industry are also valid for RoHS relevant applications?

The rationale described in the Öko-Institute's report relating to the ELV also applies to RoHS, particularly in the case of the HVACR industry. The same general class of leaded bearings used in the automotive industry is used in the HVACR industry. The conclusion of Sander et al. made in 2000 also applies in the case of HVACR products, in which they state that "when substitution of lead by other alloying elements is considered, the main criteria are functional requirements during the use of the product (emergency lubrication) rather than costs". In fact, the newest ELV proposal actually requests the Commission to include an exemption for "A/C Compressors" along with engine and transmission parts. This underscores the unique needs of the HVACR bearing applications which are described further herein. In fact, in many ways bearing and bushing applications in the HVACR industry are more severe than in other industries because of the periodic presence of liquid refrigerant. Liquid refrigerant acts like a degreasing agent that has the ability to remove lubricating oil out of the bearings causing premature bearing failure (seizure). Lead is unique in that it helps prevent premature failure during lubrication interruption. 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.

As with the automotive industry, lead-free bearing material candidates have been proposed. However, the same general challenge articulated in the Öko-Institute's ELV report exists for the HVACR industry. That is, lead-free bearing alternatives are not available for all HVACR compressor applications. Existing bearing designs for refrigeration and air conditioning applications require several physical, chemical and mechanical properties to be met simultaneously. Many are highly loaded. This will be described in more detail later.

Another challenge identical to that of the automotive industry relates to the time required to adequately qualify a new bearing material. Given the critical nature and purpose of bearings in a compressor, the time it takes to qualify a new bearing material is nearly equivalent to the time it takes for a new compressor design. Several iterations of bearing bench testing; compressor testing and field studies are needed. This takes years to complete. In addition, there are over 1000 different models and sizes of compressors and the differences among them are significant enough to require separate non-transferable tests. This complicates the overall qualification process substantially.

Another aspect that mirrors the ELV study results is the question as to whether changing HVACR bearings could actually be environmentally counterproductive. Refrigerants that can cause global warming and ozone depletion are being changed to more environmentally safe refrigerants. This process has been taking place in stages over the years and will continue in the future. For instance, the EU is already converted to Hydrofluorocarbon refrigerants (HFC's) from Hydrochlorofluorocarbons

(HCFC's) and the U.S. will convert on 2010. A unique challenge exists to find a compatible oil to use with the new and greener refrigerant. Compressor lubricating oil needs to be appropriately miscible with its companion refrigerant. However, the HVACR industry has found that implementing new environmentally friendly refrigerants and oils requires design changes and long qualification times. Changing refrigerant and oil impact lubricity and subsequently, bearing design. This extra complication makes finding a lead-free bearing replacement especially difficult. The consequences of choosing the wrong lead-free bearing are: A higher field failure rate, a compromised range of system operation conditions and reduced compressor life. These will have overall negative effect on the environment. Moreover, unlike other bearing applications, bearing failures in the HVACR industry require the removal of the compressor in the field from the parent system. This procedure requires careful system shut-down, evacuation of the refrigerant and the un-brazing of connections. During this process, it is very likely that some refrigerant and oil will escape contributing negatively to the environment.

Safety is also a concern for the HVACR industry in two respects. One is that many refrigeration applications involve supporting the medical industry. Some examples are: Body temperature control, chilling of examination equipment (such as MRI), blood preservation and dental air compression. Although compressor failure in these cases is an indirect safety hazard, it is important nevertheless. Secondly, HVACR compressors are essentially a pressurized vessel. Pressures can exceed 6800 KPa during operation with conventional refrigerants As such those compressors are pressure vessels and in the event of failure injuries could occur if proper safety precautions are not taken.

(Note in the following, questions 3 and 4 are addressed together)

3. Following the results of the evaluation of exemption 4 in Annex II ELV Directive, substitutes seem to be available. Please specify for which applications listed under point 1 substitutes are technically feasible or unfeasible. What is the current status of R&D efforts towards substitution of lead in the different applications? Which are the technical characteristics related to the use of lead that are essential for technical functionality of applications / products related to exemption 9b?

4. Which of the applications covered by exemption 9b are available as RoHS compliant products (i.e. without lead) on the EU market? Which applications are currently not available as RoHS compliant products?

A large scale effort has been underway since 2004 to develop lead-free bearings for HVACR compressors. The R&D status of the many compressor applications varies because, as mentioned earlier, qualification for each product is not directly transferable from one design to the other.
An earnest effort has been undertaken to test all available bearing materials. Although there appears to be feasible lead-free candidates in certain HVACR applications, there are no satisfactory replacements for certain other applications. The subsequent text will endeavor to explain this.

First, a brief summary explaining the special challenges encountered in an HVACR bearing system is in order:

Emerson Climate Technologies, Inc. produces several types of compressors for air conditioning and refrigeration and other niche applications. Two of the most common types of compressor designs are: Reciprocating (piston) and Scroll types.

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 can not withstand the design life required in these applications.

In addition, there are 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.

It should be apparent 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.

It is important to state at this point that lubricity of a bearing is only one of many requirements. The bearing must also possess compatibility (a measure of anti-welding properties), conformability (ability to compensate for misalignment), embeddability (absorb contamination), load handling capacity, have adequate fatigue resistance and have sufficient resistance to corrosion. Therefore, it should be evident that choosing a bearing even under normal compositional constraints is not trivial. Yet another complication is that several refrigerants and oils are used in HVACR. Each combination of oil, refrigerant and bearing type needs to be qualified independently before approval can be granted.

The R&D effort may be categorized into the following sequential phases: 1.) Identify Lead-free candidates, 2.) Perform comparative "bench" testing of the lead-free bearing materials, 3.) perform compressor qualification, 4.) Validate the associated manufacturing process and 5.) perform field testing.

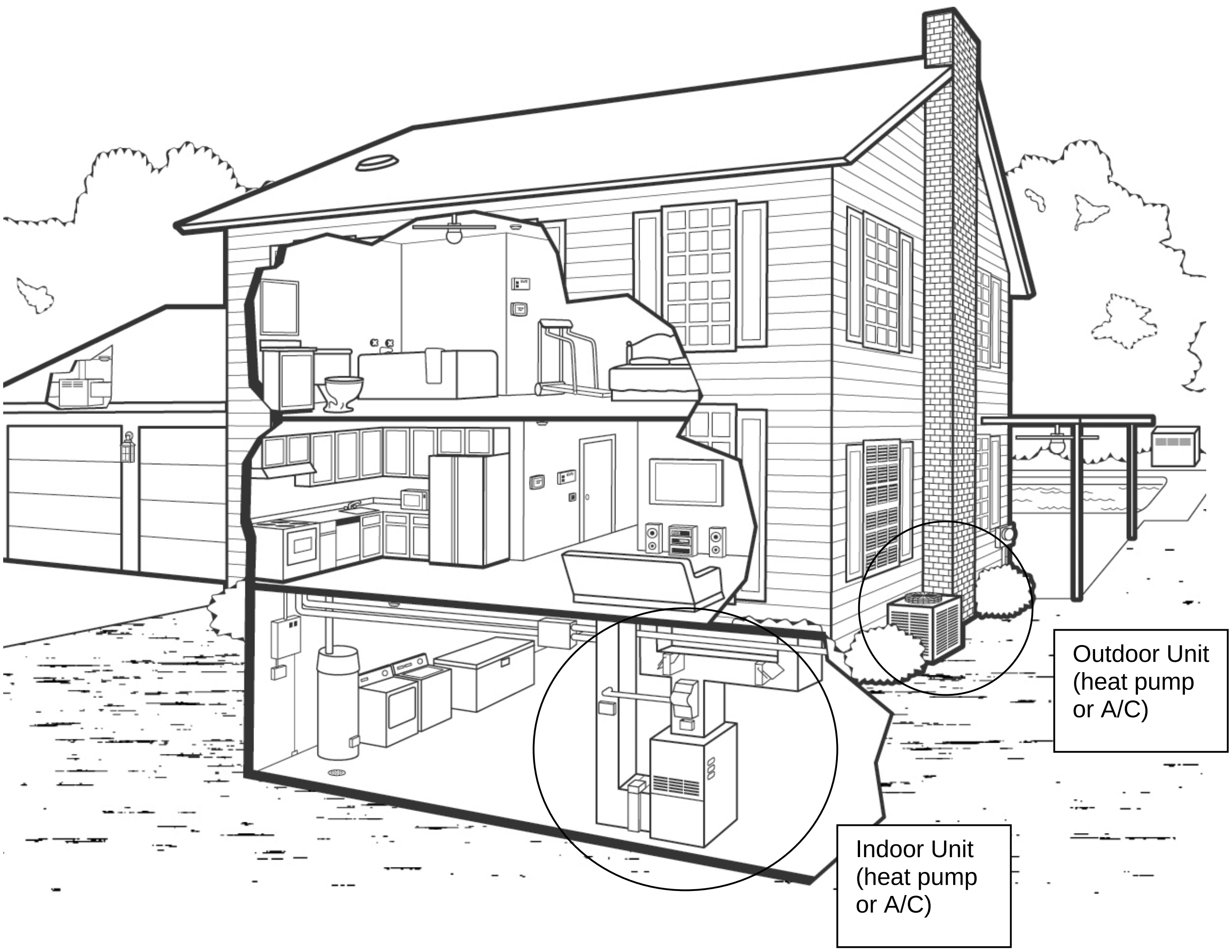
Table II in the Addendum describes the status of the R&D work to date.

Compressor Types 1 and 4 in the addendum table use the polymeric leaded bronze bearings shown below. There are feasible lead-free candidates available on the market for this kind of bearing, but to assure reliability and durability, Emerson Climate Technologies needs more time to complete its comprehensive assessment. This kind of bearing is used in the unmachined state.

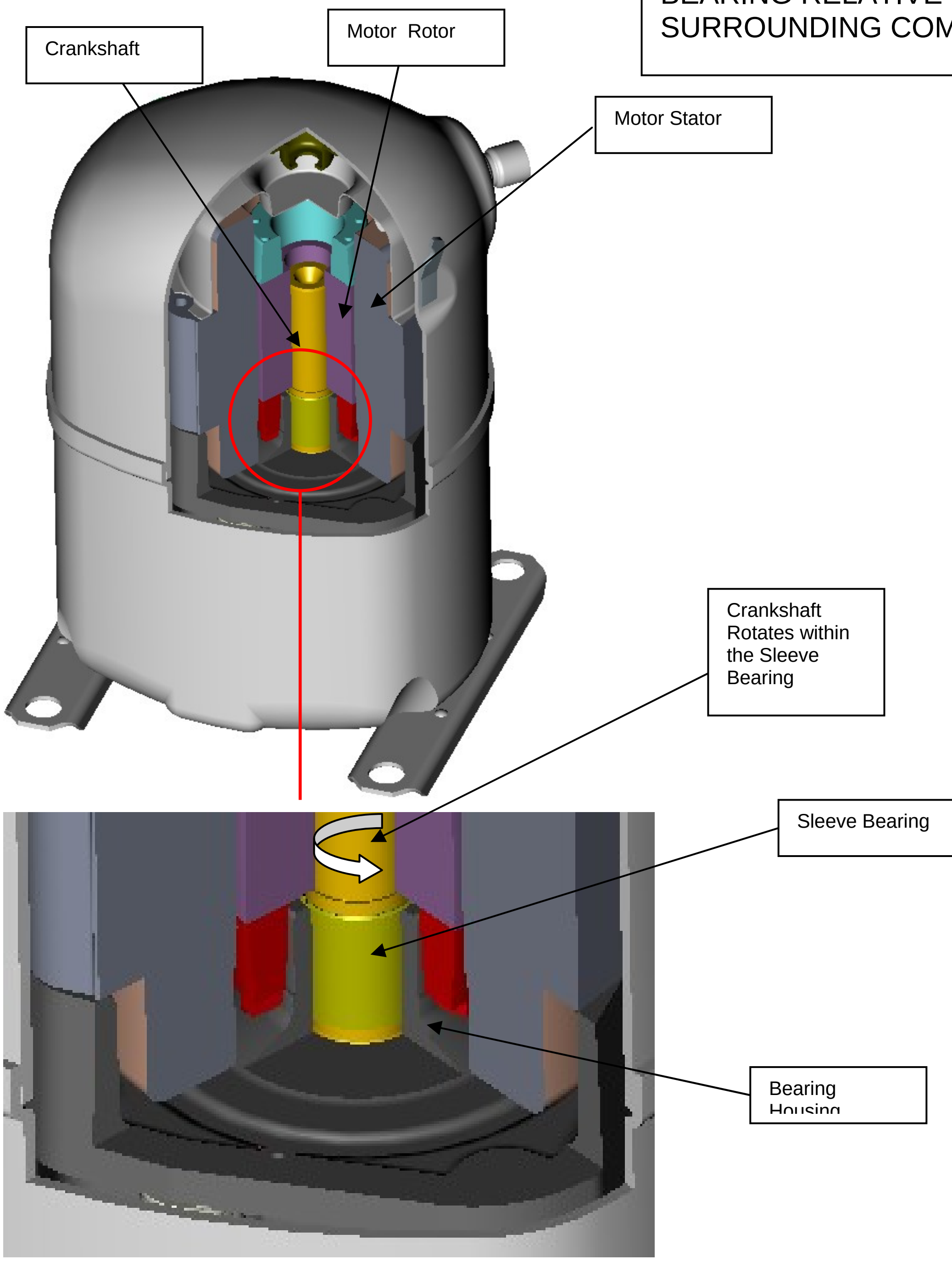
Compressor Types 2 and 3 in the addendum table are designed to require bearings that are used in the precision-machined state (requiring diametrical tolerances of 0.00635 mm). For compressor type 2, only one general type of lead-free precision-machinable sleeved bearing exists on the market today. This lack of selection represents a constraint to design and slows down the development process. Bearing type 3 has an extra constraint associated with it in that it is a non-sleeved "thick-walled" bearing (wall thickness of 6 mm). No feasible lead-free bearing material has been identified for this type of bearing yet. Dimensional tolerances are critical in the above discussion for bearing types 2 and 3 because the alignment of the crankshaft is dependent upon the bearing accuracy. Alignment of the crankshaft is important because it defines the gap between the stator and rotor of the electric motor that drives the compressor. The gap in electrical motors is critical. If the gap is too small or large the motor will not function and possibly overheat.

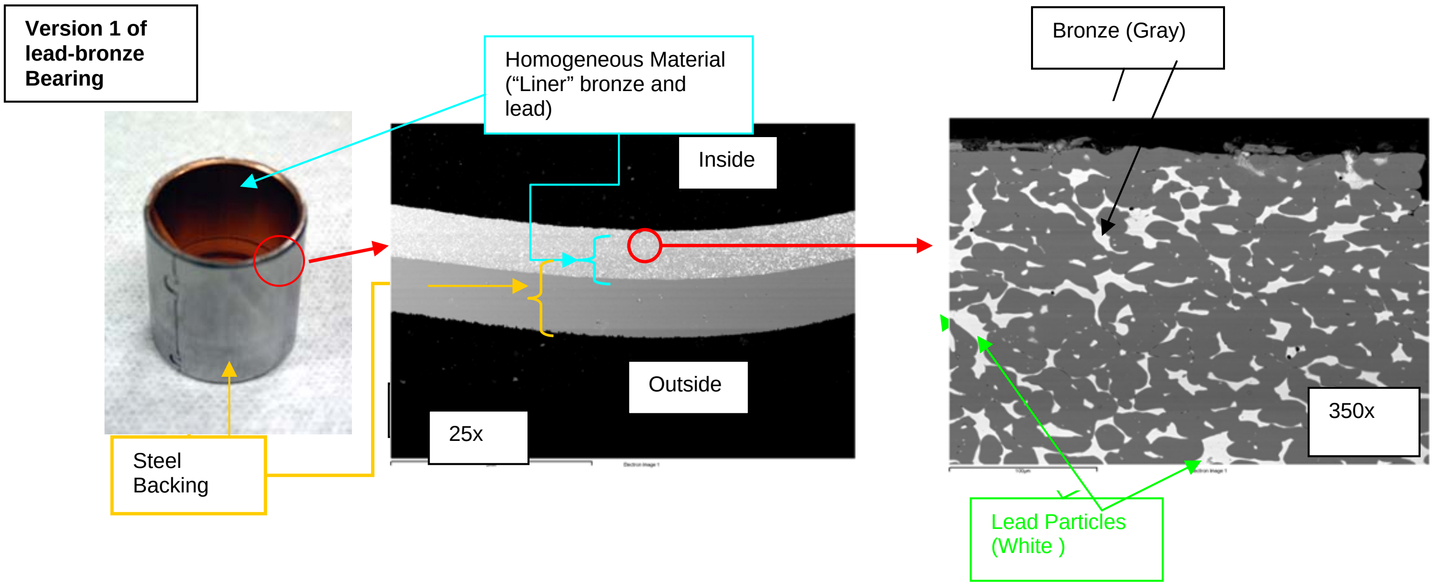
It is because of this very complex product design mix that the complete conversion to lead-free bearings is technically challenging and time consuming.

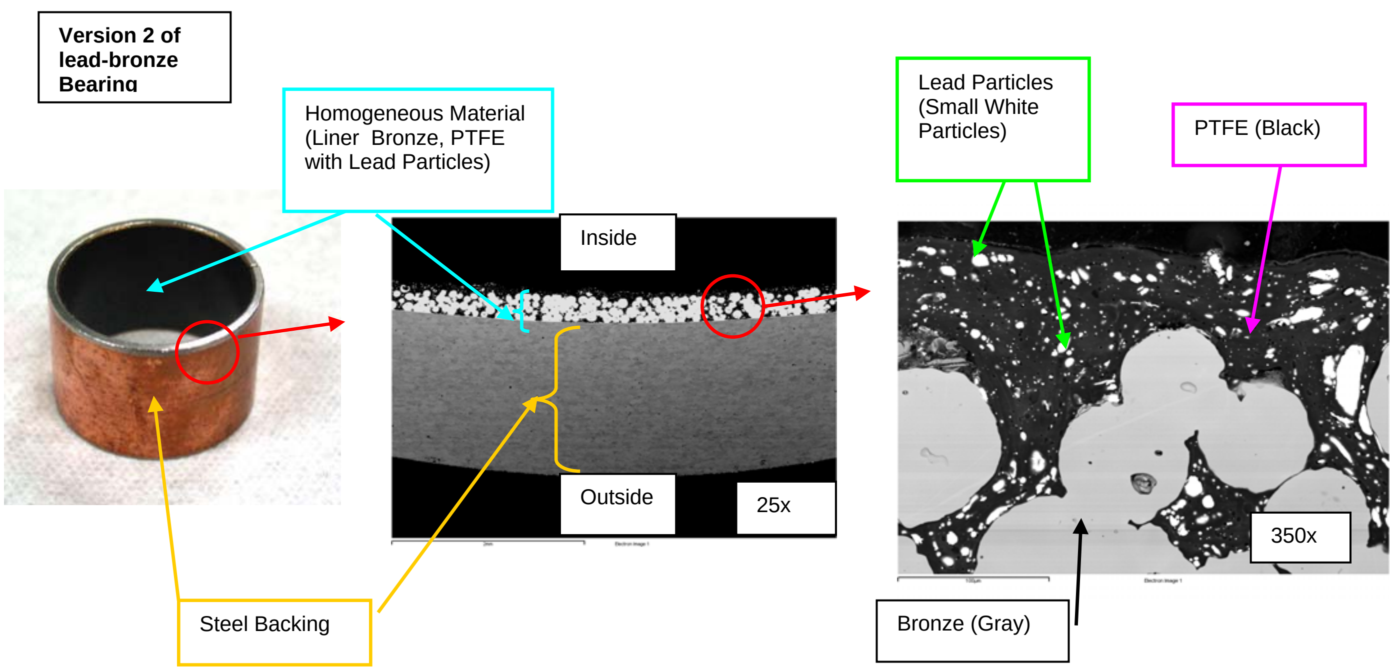
For reference, the following diagram shows the configuration of a typical stationary residential air conditioning/heat pump application. Also shown are a typical compressor and the location of its bearing and two types of leaded-bronze sleeve bearings showing their homogeneous materials.



COMPRESSOR CUT-AWAY SHOWING LOCATION OF SLEEVE BEARING RELATIVE TO SURROUNDING COMPONENTS.




Version 1 of lead-bronze Bearing
Homogeneous Material (“Liner” bronze and lead)
Bronze (Gray)
Inside
Outside
25x
350x
Steel Backing
Lead Particles (White)


Version 2 of lead-bronze Bearing
Homogeneous Material (Liner Bronze, PTFE with Lead Particles)
Lead Particles (Small White Particles)
PTFE (Black)
Inside
Outside
25x
350x
Steel Backing
Bronze (Gray)

5. Are manufacturers still investigating alternatives?
a. If yes, please provide a roadmap or similar evidence showing until when they intend to replace lead in bearings in the applications mentioned above.
b. If no, please explain and justify why no further research has been undertaken against the background that the RoHS Annex is subject to regular revisions.

Yes, bearing companies are still investigating new materials for lead-free alternatives. In particular, they are trying to develop more precisely toleranced bearings that are machinable without compromising lubricity and the other critical properties mentioned above. Our latest intelligence shows that bearing companies will have a wider spectrum of products to choose from within about four years. We have not found any information in the marketplace that a viable lead-free replacement for thick-walled sleeveless bearings will be available in the near future.

***6. Please state for applications name under point 1 the amount of lead used per application, the lead content in the homogeneous material, the annual production volume as well as the number of applications related to exemption 9b put on the EU* market annually.**

See Table III in the Addendum for this information.

7. Assuming the current exemption will be given an expiry date, what date do you think is technologically feasible for industry?

It is suggested that the review for the exemption be extended to October 2013. This will give the overall industry, and in particular the HVACR industry, enough time to convert products in a reliable manner to lead-free.

Yours sincerely,

Marc Scancarello
Director, Materials Engineering
Emerson Climate Technologies, Inc.