Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

IZM
Fraunhofer Institut Zuverlässigkeit und Mikrointegration

Adaptation to scientific and technical progress under Directive 2002/95/EC

Final report

Freiburg, 20 February 2009

Öko-Institut e.V.

Dipl.-Ing. Carl-Otto Gensch
Dipl.-Ing. Stéphanie Zangl
Dipl.-Geoök. Rita Groß
Dipl.-Biol. Anja K. Weber

Fraunhofer IZM

Dr.-Ing. Otmar Deubzer

Öko-Institut e.V.
Freiburg Head Office
P.O. Box 50 02 40
79028 Freiburg, Germany
Street Address
Merzhauser Str. 173
79100 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Deutschland
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Novalisstr. 10
10115 Berlin, Deutschland
Tel. +49 (0) 30 – 28 04 86-80
Fax +49 (0) 30 – 28 04 86-88

[12] Stakeholder consultation document "Exemption_1-2-3-4-6-8-9a-9b-25-29_Sweden_1_April_2008.pdf"

[13] E-mail from Mr. Echo Zheng, Xiamen Hualian Electronics Co. Ltd., China, to Öko-Institut on 23 April 2008

[14] e-mail communication between Mr. Bernt Peters, Bosch-Siemens Hausgeräte, and Otmar Deubzer, 11 August 2008

[15] NEC/Schott via e-mail, e-mail communication from Mr. Harald Schäfer and Mr. M. Gomi, NEC/Schott, with Otmar Deubzer, 10 August 2008

[16] IEC 691, International standard publication 691

[17] ERA-Report 2004, Dr. Paul Goodman et al.: Technical adaptation under Directive 2002/95/EC (RoHS) – Investigation of exemptions; final report Dec. 2004; Document "ERA Report 2004-0603.pdf"

4.14 Exemption No. 9

"Hexavalent chromium as anti-corrosion of the carbon steel cooling system in absorption refrigerators"

4.14.1 Description of exemption

Chromate is currently used as a corrosion inhibitor in absorption refrigerators. These kinds of refrigerators are inter alia used in hospitals, hotels and small apartments (RoHS scope) as well as in caravans and motor homes (ELV scope). Absorption refrigerators are used in these areas of application due to the fact that they can work independently from electricity with a heat-driven technology using gas (propane / butane) or kerosene as energy source [1]. Furthermore, they have the advantage that they have no moving parts and are thus completely silent, making them further attractive for the above described uses. They mostly belong to category 1 "large household appliances" of the WEEE Directive. Some appliances like e.g. medical refrigerators and refrigerators for laboratory use belong to category 8&9 equipment [1].

Dometic – formerly Electrolux – states to be one of the main producers of absorption refrigerators in Europe[33]. Its absorption cooling units are constructed in carbon steel because of its strength as well as its good welding and cold-working properties. The refrigerant is an ammonia-water solution. The absorption cooling system is a completely closed system, which is pressurised with hydrogen gas. In order to prevent corrosion of the carbon steel cooling system sodium chromate is added to the refrigerant. This allows Dometic to produce absorption

[33] However, Dometic has less than 50% of the market of RoHS relevant applications. Several small actors from Italy, Turkey and China are present on the market.

refrigerators that can last 15 years or more: “Using chromate, a passive layer of chromium/iron oxide (Cr_2O_3 /Fe_2O_3) is formed at the steel surface and no precipitates that block the circulation are formed. Chromate is slowly consumed over lifetime.” [1]

The current exemption was already part of the original Annex to the RoHS Directive published in 2003. The use of CrVI for corrosion protection is also exempted from substance restrictions under the ELV Directive (entry no. 13 in latest amendment of Annex II ELV Directive published in Commission Decision 2008/689/EC of 1 August 2008).

According to Dometic, its annual production of absorption fridges in Europe amounts to 350.000 pieces out of which 200.000 are considered to fall under the RoHS Directive (the total RoHS relevant market is estimated at 400.000 – 500.000 units). With an average amount of 2 g CrVI per fridge, the total annual amount sums up to 400 kg of CrVI in RoHS relevant applications [2].

Dometic was the only stakeholder replying to the online stakeholder consultation34 and requests an extension of the current exemption since alternatives are said to give rise to difficult trade-offs in respect to product lifetime, product reliability and energy efficiency [1]. Its main competitor Thetford also provided some information upon request and basically supports Dometic’s position [3].

4.14.2 Justification by stakeholders

Dometic has provided supporting evidence for an extension of the exemption and justifies its request as follows:

Extensive research has been carried out at Electrolux between 1920 and 1999 as well as at Dometic between 2000 and now (Dometic claims to have about 300 test related cooling units that have been started since 2000): “Electrolux/Dometic has been conducting research into finding possible alternatives for the corrosion protection of absorption refrigerators. Not only has a significant in-house commitment been made but also Electrolux/Dometic has worked with a number of external research institutes and universities on this issue. Several long-term projects have been run with theoretical and practical studies on the corrosion process. Work has also been carried out with companies who are expert in corrosion protection where commercial inhibitors have been tested. The research has looked at alternative refrigerants, inhibitors, structural materials, surface treatment and combinations thereof.” Extensive and comprehensive documentation on these research activities has been provided as evidence [1].

The research activities of Dometic have looked at alternative refrigerants, inhibitors, structural materials, surface treatment and combinations thereof. So far only one inhibitor seems to be left over as a promising alternative [1].

[34] Except for Emerson who did however not target exemption 9 in its contribution.

However, the following problems are still encountered with the alternative:

- Reduced life length of an alternative corrosion inhibitor

"The expected life length of an absorption refrigerator with hexavalent chromium as corrosion inhibitor is 15-20 years at continuous operation. For an absorption refrigerator with no inhibitor at all, the service life length is less then 1 year. […] The number of units using each alternative inhibitor does not yet provide sufficient statistical certainty to be able to foresee a firm service length. However, our tests of the most promising alternative inhibitor show an average indicative life length of 3-5 years. A shorter life length would result in a higher exchange frequency of products and consequently a more negative impact on the environment." [1]

- Reduced product safety

"Since the estimated life length of an absorption refrigerator with an alternative corrosion inhibitor is considerably less then one filled with hexavalent chromium, the risk that a leakage [releases of ammonia and hydrogen into the surroundings due to accelerated corrosion] would occur during active use of the absorption refrigerator is significantly higher." [1]

- Reduced product performance / lower energy efficiency

"When using an alternative corrosion inhibitor instead of hexavalent chromium, design changes in the hot areas / pump area need to be made to the cooling units of some models. This will most likely mean a loss in performance [i.e. temperature in the cooling compartment will increase by approximately 2-3°C]." The higher temperature does not allow to meet the standard requirements of EN ISO 7371 that foresee a temperature of 5°C in the fresh food compartment [2]. A performance loss could also mean an increased energy consumption by 10-15%. "However, this is not yet a statistically reliable basis for future projections and needs further validation in testing." [1]

Dometic has set up a list of technical characteristics that an absorption cooling unit inhibitor has to fulfil and their status quo with regard to research of alternatives [1]:

1. Must be compatible with the filling solution: still needs one year research to find solution.
2. Must be stable at high temperature and pH: fulfilled by alternatives.
3. Must withstand ageing and cold storage temperatures: fulfilled by alternatives.
4. Must create a protective layer to inhibit corrosion: more research with statistical relevance needed (life time issue).
5. Needs to maintain the protective layer: more research with statistical relevance needed (life time issue).

According to Dometic, accelerated life time tests are not representative since they need to be done with rising the temperature which changes other parameters leading to a possible distortion of the results [2].

Furthermore, Dometic states that the number of units that need to be tested in order to get statistical relevance are thousands and that one of the main problems is to achieve consistency of test results [2].

Dometic states that at least 10 years are needed in order to phase-out CrVI from their refrigerators and that an expiry date should be set earliest at that point of time. Furthermore it is stated that an acceptable maximum amount of CrVI would be 1.0 weight-% of CrVI based on the water part of the cooling solution [1].

With regard to substitution at application level, Dometic says that for some areas of use compressor-based alternatives are available. However, they are noisier than absorption refrigerators which may be a health concern for some consumers. On the other hand, large compressor-based refrigerators are more energy-efficient which may be an explanation why manufacturers do no investigate small-scale compressor-based refrigerators [2].

Dometic has set up a take-back scheme for commercial applications and runs a recycling scheme which assures the complete emptying of the cooling unit. Since chromate is consumed during use, nearly none is left over at point of take-back [2].

Thetford delivers arguments that go into the same direction, but did not provide any evidence or supporting documentation. Statements given are summarised as follows [3]:

Thetford is about to come to an agreement with a German researcher which has already done research on CrVI alternatives in the past. Also, its cooling unit supplier in the U.S. has done research in conjunction with a local university. However, Thetford says not to be at liberty to share results with the contractor.

Thetford feels it is currently impossible to deliver a roadmap or similar evidence showing the foreseen development of substitution efforts. It only states: “Limiting the environmental impact of our products is an important element of our philosophy, so obviously the research into possible alternatives for CrVI is important to us. We are aware of the regular revision of Annex II of the ELV, and we are also aware that the exemption for CrVI could end some time in the future. We intend to replace CrVI as a corrosion inhibitor as soon as an alternative can be found that has a significantly lower environmental impact than the current solution.”

As concerns the availability of substitutes, Thetford claims that “To-date, no other substance has been able to produce the same effect while keeping sufficient inhibitor in solution to insure long life of the refrigerator.”

4.14.3 Critical review

Evaluating the above-mentioned arguments the following can be concluded:

Comprehensive evidence was given on Dometic’s past and current commitment to investigate alternatives to CrVI. Many alternatives have been looked at such as oxidising and non-oxidising inhibitors as well as changes in material and design of the product itself. A roadmap

has been provided showing that more time is needed for research. In its contribution, Thetford supports this statement.

Concerning possible disadvantages of using an alternative substance, the following can be concluded:

Reduction of lifetime: while it is true that a reduced lifetime generates negative environmental impacts (e.g. waste of resources, higher need of energy for production of more appliances, more impacts during recycling) it also has to be stated that most of the environmental impacts of an absorption refrigerator is generated through the energy consumption during use. Thus, a certain reduction in lifetime could be acceptable when using an alternative corrosion inhibitor. However, current lifetime is estimated at 15 years and lifetime with most promising inhibitor at 3-5 years, still being a rather large difference. As a conclusion it is recommended to review progress on life time issues with alternative inhibitors during the subsequent review.

Reduction of product safety: leakage is a general safety problem with absorption refrigerators. With CrVI it is less likely to occur during use phase since the chromium is consumed slowly and can last for more than 15 years. A reduction of product safety is regarded less critical if a certain reduction in lifetime is accepted and communicated to customers. Manufacturers should inform consumers that the product has a certain lifetime after which risk of leakage occurs. This aspect is however linked to an improved life length with an alternative inhibitor as stated above.

Reduction of product performance / energy efficiency: since cooling performance may decrease with an alternative inhibitor and this would lead to a higher energy need to achieve the same level of cooling down, it is indeed a negative environmental effect. Furthermore, existing standards would not be met which is clearly an argument in line with Article 5 (1) (b). However, the higher energy need has not been quantified by stakeholders and can therefore not be assessed.

From the above it can thus be concluded that currently substitution at substance-level is not practicable and that it would have negative environmental, health and safety effects.

With regard to substitution at application level it can be concluded that compressor-based refrigerators are more energy efficient than absorption refrigerators. According to Swiss studies ([4] and [5]), this difference is particularly significant for small-scale appliances. However, small-scale compressor-based refrigerators are only available for a small number of applications (starting with approximately 80 l and thus not suited as e.g. built-in minibars of approximately 40 l) and have the negative (health and environmental) effect of higher noise generation. Whether the effects due to higher noise generation outweigh the benefits of reducing energy consumption through the use of compressor-based refrigerators cannot be estimated since no reliable data is available. On the one hand the Swiss studies explicitly conclude that large energy saving potentials exist through substitution of absorption refrigerators with compressor-based ones. On the other hand this is apparently only applicable to

refrigerators above minibar size. The only hindrance is noise which can be a negative effect when the refrigerator is used in small living spaces. Nevertheless, the Swiss studies state that even for compressor-based refrigerators technological improvement in this respect is feasible and also partly available on the market. Furthermore, one of the Swiss studies analysed that thermoelectric cooling (using the Peltier effect) is a viable energy-saving alternative to absorption refrigerators leading up to 30% savings [5].

As a conclusion it should be the goal to use compressor-based or thermoelectric refrigerators instead of absorption refrigerators wherever possible (e.g. through design changes in hotel rooms or similar areas of applications like putting the fridge in a small separated space). This is the case where electricity can be used as energy source for cooling (either through the electricity grid, batteries, solar energy or any other source of electricity).

In the framework of this contract it is however not possible to do a full market analysis on available low-noise energy efficient compressor-based refrigerators as well as on available low-noise and energy efficient thermoelectric refrigerators compared to absorption-based refrigerators. Furthermore, it should be noted that minimum energy efficiency requirements – applying also to absorption refrigerators – will be set under the EuP Directive thus possibly leading to a partial substitution of CrVI-using applications.

4.14.4 Recommendation

The argumentation of Dometic and Thetford in favour of an extension of the current exemption with regard to the use of CrVI in the cooling system of absorption refrigerators is well documented and sound with regard to the non-practicability of substitution at substance-level. However, substitution at application level is indeed possible in many cases and has been confirmed and recommended by independent Swiss studies. An exemption should thus only be granted for areas of application where the use of a compressor-based or thermoelectric refrigerator is not practicable and has negative impacts. Since in the framework of this study it is not possible to identify these areas of application as an exhaustive list of applications, the following new wording for exemption 9 is recommended:

Hexavalent chromium as an anti-corrosion agent of the carbon steel cooling system in absorption refrigerators up to 0,75 weight-% in the cooling solution except for applications where the use of other cooling technologies is practicable (i.e. available on the market for the specific area of application) and does not lead to negative environmental, health and/or consumer safety impacts.

Transition period and expiry date

Assuming that the amendment of the Annex in the RoHS Directive will be officially published end of 2009, new exemption 9 should come into force on 30 June 2011, allowing for a 1½ year transition period. Since research into alternatives is stated to last for 10 more years

before being able to phase out CrVI, the expiry date is proposed to be set at the time of the next revision. Here again assuming an official publication of an amended RoHS Annex by end 2009, the expiry date would be four years later 31. July 2014.

Spare parts

Furthermore, a clause should be added to the new exemption 9 explicitly mentioning that spare parts for what used to be applications covered by exemption 9 are exempted from substance use restrictions.

Category 8&9

Since the technological principle and the production lines are the same, an inclusion of category 8&9 into the scope of the RoHS Directive would not have any effect on the manufacturers.

Alignment RoHS & ELV

In addition, it is recommended to align with exemption 13, Annex II ELV Directive. Since the production lines of manufacturers are identical for RoHS applications (be it category 1 or 8&9) and ELV applications, a phase-out of CrVI in the cooling unit will be either feasible for all areas at the same time or for none. Therefore, there should be a common exemption for both ELV and RoHS with the same expiry date, the same spare parts provision and the same review cycle. The above proposed new wording for exemption 9 will only have an impact on promotion of substitution if it is also taken over into Annex II ELV Directive.

4.14.5 References

[1] Dometic stakeholder contribution. exe. 9;" Exemption-9_Dometic_31_March_2008.pdf" 31 March 2008

[2] Discussion at stakeholder meeting between Dometic and Öko-Institut; Freiburg, 4 July 2008

[3] Thetford Stakeholder comment upon request by Öko-Institut; 25 July 2008

[4] Swiss federal Agency for economic activity: Kühlschränke für Hotelzimmer und Studios, 1992

[5] Swiss federal Agency for economic activity: Energieeffiziente Hotel-Minibar; 2004