Assistance to the Commission on Technological Socio-Economic and Cost-Benefit Assessment Related to Exemptions from the Substance Restrictions in Electrical and Electronic Equipment:

Study to assess renewal requests for 29 RoHS 2 Annex III exemptions [no. I(a to e -lighting purpose), no. I(f - special purpose), no. 2(a), no. 2(b)(3), no. 2(b)(4), no. 3, no. 4(a), no. 4(b), no. 4(c), no. 4(e), no. 4(f), no. 5(b), no. 6(a), no. 6(b), no. 6(c), no. 7(a), no. 7(c) - I, no. 7(c) - II, no. 7(c) - IV, no. 8(b), no. 9, no. 15, no. 18b, no. 21, no. 24, no. 29, no. 32, no. 34, no. 37]

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07 June 2016

Report for The European Commission

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Acknowledgements:

We would like to express our gratitude towards stakeholders who have taken an active role in the contribution of information concerning the requests for exemption handled in the course of this project.

23.0 Exemption 7c-II “Lead in Dielectric Ceramic in Capacitors for a Rated Voltage of 125 V AC or 250 V DC or Higher”

Declaration

In the sections that precede the “Critical Review” the phrasings and wordings of stakeholders’ explanations and arguments have been adopted from the documents provided by the stakeholders as far as required and reasonable in the context of the evaluation at hand. Formulations have been altered in cases where it was necessary to maintain the readability and comprehensibility of the text. These sections are based exclusively on information provided by applicants and stakeholders, unless otherwise stated, and the views presented should not be taken to represent the views of the consultants (authors of this report).

Acronyms and Definitions

HVC high voltage capacitor(s), capacitor(s) with rated voltage of 125 V AC or 250 V DC or higher

23.1 Description of the Requested Exemption

The current wording of exemption 7c-II in Annex III of the RoHS Directive is:

> *“Lead in dielectric ceramic in capacitors for a rated voltage of 125 V AC or 250 V DC or higher”*

Murata et al.[1246] apply for the renewal of Exemption 7c-II for five years with a modified wording to clarify the scope:

> *“Lead in dielectric ceramic in **discrete** capacitor **components** for a rated voltage of 125 V AC **or higher**, or **for a rated voltage of** 250 V DC or higher**”***

[1246] Murata et al. 2015a “Request for Renewal of Exemption 7c-II from 16 January 2015,” http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_7_c_-II/7c-II_RoHS_V_Application_Form_7c2_20140115_final.pdf

23.1.1 Background and History of the Exemption

When Directive 2002/96/EC (RoHS 1)[1247] was published in 2003, Exemption 7d covered the use of lead in ceramics of electronic components:

"Lead in electronic ceramic parts (e.g. piezoelectronic devices)"

In the 2008/2009 review[1248] of this exemption it was found that the substitution of lead is scientifically and technically practicable in the low voltage area and the wording detailed below was thereupon recommended and adopted to the Annex of RoHS 1 demarcating the lead-free ceramic low voltage ceramic capacitors from the high voltage ones that still required the use of lead:

> *"7(c)-II Lead in dielectric ceramic in capacitors for a rated voltage of 125 V AC or 250 V DC or higher*
>
> *7(c)-III Lead in dielectric ceramic in capacitors for a rated voltage of less than 125 V AC or 250 V DC"*

Exemption 7c-III was transferred without changes from the Annex of RoHS 1 to Annex III of RoHS 2 and expired on 1 January 2013.

Exemption 7c-II was also transferred without changes from the Annex of RoHS 1 to Annex III of RoHS 2 and would expire on 21 July 2016 if application for renewal had not been received.

23.1.2 Technical Description of the Exemption

Murata et al.[1249] explain that discrete ceramic capacitors for a rated voltage of 125 V AC or 250 V DC or higher (high voltage capacitors, HVD) bear the capability of storing and releasing electric charges (electrostatic capacitance) and are incorporated into high voltage circuits in a wide variety of electrical and electronic equipment. They are used in all types of markets and applications, for example: [1250]

- Social infrastructure systems;
- Industry automation;
- Oil and mineral exploration;
- Power conversion;
- High power supplies;

[1247] Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, RoHS 1, European Union (13 February 2003)

[1248] Gensch, Carl-Otto, Oeko-Institut e. V., et al. 20 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, Oeko-Institut e. V., and Otmar Deubzer, Fraunhofer IZM http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf

[1249] Op. cit. Murata et al. 2015a

[1250] Ibid.

- Telecommunication;
- Medical.

Typical applications are: [1251]

- Power electronic inverters;
- Pulsed power electronics and pulse forming networks;
- Capacitive discharge units;
- Transient high voltage suppression;
- Magnetization/demagnetization devices;
- Plasma generators;
- High-energy flashes;
- Lamps;
- Radio frequency interference suppression and electrical safety.

Murata et al.[1252] say that the above are nothing more than representative examples only partially showing markets and applications in which the exemption is used.

Murata et al.[1253] state that even though the major trend is miniaturization with low voltage rating and low power, other optimization parameters are often required for HVC, for example the need for high capacitance at high voltage and high power. The function of lead in the dielectric ceramic is to obtain:[1254]

a. High dielectric constant at high operating voltage;
b. High energy storage capability (also at high temperatures);
c. Low leakage at high voltage and high temperatures; and
d. Low loss at high current, frequency, and temperatures.

Murata et al.[1255] indicate that design engineers frequently call upon these parameters to meet technical requirements. Lead-containing dielectric ceramic has the outstanding feature of stably bringing out the above functions.

23.1.3 Amount of Lead Used under the Exemption

In Table 23-1, Murata et al.[1256] present a rough estimate of the total amount of lead included in glass/ceramic of the main electrical and electronic components. These figures were estimated from the production and sales results of electrical and electronic component manufacturing companies from Japan and Europe.

[1251] Ibid.
[1252] Ibid.
[1253] Ibid.
[1254] Ibid.
[1255] Ibid.
[1256] Ibid.

Table 23-1: Estimated amount of lead used in HVC

2007					2013				
Number of pieces placed on the market (G[*5] pcs)		Lead use amount[*2] / Per piece unit (mg)	Lead use amount (t) / Total amount placed on the market		Number of pieces placed on the market (G[*5] pcs)		Lead use amount[*2] / Per piece unit (mg)	Lead use amount (t) / Total amount placed on the market	
World[*1]	Europe[*4]		World[*3]	Europe[*4]	World[*1]	Europe[*4]		World[*3]	Europe[*4]
1.3	0.39	78	100	30	1.6	0.38	30	50	11.9

Source: Murata et al.[1257]

**1: Estimate by JEITA.*
**2: There are components with several different shapes and masses. We have estimated the lead use amount of an average component.*
**3: Rough estimate from *1 and *2.*
**4: Estimated from the EU/World GDP ratio.*
**5: G = 10^9 pieces.*

Murata et al.[1258] state that HVC are used in large quantities in a wide range of final products. It is impossible to provide an actual estimate of the amount of lead included in dielectric ceramic entering the EU. The above presented numbers result from an estimate concerning HVC for which production figures are comparatively easy to obtain by JEITA. It should also be noted that there may be capacitors for high voltage applications with lead-containing dielectric ceramic which are not included in the calculation. For this reason, although the estimates were done in good faith with the data resources available, the values shown here are provided strictly for reference purposes, and Murata et al.[1259] shall bear no responsibility concerning their accuracy or enforceability.

The around 12 t of lead indicated by the applicants should be considered as a minimum and the actual amount could be much higher given the fact that high volumes of EEE are imported into the EU.

[1257] Ibid.
[1258] Ibid.
[1259] Ibid.

23.2 Applicants' Justification for the Renewal of the Exemption

23.2.1 Clarification of the Exemption Scope

Murata et al.[1260] and JEITA et al.[1261] clarify that in the existing wording electronic components expressed as "capacitors" are precisely speaking "discrete capacitor components". They propose the underlined additions to the current wording for clarification of the technical scope of 7(c)-II.

> *Lead in dielectric ceramic in <u>discrete</u> capacitor <u>components</u> for a rated voltage of 125 V AC <u>or higher</u>, or <u>for a rated voltage of</u> 250 V DC or higher*

Murata[1262] and JEITA et al.[1263] explain that the current wording may be understood as also covering lead-containing dielectric ceramic in other components aside from discrete capacitor components, e.g. lead containing dielectric ceramic incorporated in ICs, boards, etc. These dielectric ceramic materials as well can store and release electricity, which is technically determined as capacitance. Those materials are, however, already in the technical scope of exemption 7(c)-I.

In the applicants' opinion[1264, 1265] the rated voltage limits in the current wording do not clearly determine the limits with respect to 125 V AC and 250 V DC resulting in an ambiguous wording. The proposed additions would clearly determine those limits.

Murata[1266] and JEITA et al.[1267] assure that their proposal only targets a more precise and less ambiguous wording and does not intend to enlarge the technical scope of Ex. 7(c)-II.

23.2.2 Substitution of Lead

Murata et al.[1268] claim that they had investigated the substitution of lead in lead-containing dielectric ceramic in discrete ceramic capacitor components for a rated voltage of 125V AC or higher, or for a rated voltage of 250 V DC or higher before the last review and continued the investigation after 2009 as well. Nevertheless, no substitution technology has been found up to the present day and there are no prospects of finding it within the foreseeable future. The reasons for the exemption presented by the

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[1260] Ibid.
[1261] JEITA et al. (Japan 4EEE) 2015 "Request for renewal of exemption 7c-II" unpublished manuscript, http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_7_c_-II/7c-II_RoHS_Exemption_Renewal_Request_7_c_I_Japan4EEEassociations.pdf
[1262] Op. cit. Murata et al. 2015a
[1263] Op. cit. (JEITA et al. (Japan 4EEE) 2015)
[1264] Op. cit. Murata et al. 2015a
[1265] Op. cit. (JEITA et al. (Japan 4EEE) 2015)
[1266] Op. cit. Murata et al. 2015a
[1267] Op. cit. (JEITA et al. (Japan 4EEE) 2015)
[1268] Op. cit. Murata et al. 2015a

stakeholders in 2009 are still valid. Consequently, it is necessary to extend the exemption.

Of central importance, as stated above, according to Murata et al.[1269] lead-containing dielectric ceramic has the outstanding feature of stably bringing out all of the below functions:

a. High dielectric constant at high operating voltage;
b. High energy storage capability (also at high temperatures);
c. Low leakage at high voltage and high temperatures; and
d. Low loss at high current, frequency, and temperatures.

Design engineers frequently call upon these parameters to meet technical requirements. Even for use at the condition of a rated voltage of 125 V AC or higher, or 250 V DC or higher, lead elimination can be achieved in practice for some partial applications, nevertheless in applications requiring all of the functions (a)-(d) the addition of lead is indispensable.

For example, in ceramic capacitors composed of barium titanate, which is known for its high dielectric constant and, which is used in lower voltage capacitors, these functions cannot be achieved without the addition of lead. If high voltage is applied to electrical and electronic equipment containing barium titanate capacitors, the equipment becomes unstable and even breaks down in the worst cases due to heat dissipation through energy loss and mechanical distortion due to electrostriction, the conversion of electric energy into mechanical distortion. Lead is added to suppress energy loss and electrostriction at the time when high voltage is applied. [1270]

Murata et al.[1271] report that ceramic capacitors having a material composed of strontium titanate show low energy loss and low electrostriction characteristics when high voltage is applied, meaning that functions (b)-(d) can be achieved. In spite of that, function (a) cannot be achieved due to a small dielectric constant, and so addition of lead becomes indispensable in order to increase the dielectric constant and have such capacitors operable in practice.

Murata et al.[1272] state that according to Pauling's rules, in order to form the same crystal structure, the constituent elements of ceramic, which can substitute lead, are restricted to those having a divalent valence and an ionic radius of 0.93-1.81 Å. The elements, which meet these conditions, are restricted to cadmium and alkaline-earth metals. Among those, cadmium has a higher toxicity than lead, and thus is not appropriate as a substitute material. In the case of alkaline-earth metals other than strontium (calcium, barium) are added, energy loss and electrostriction increase and therefore they cannot be used as substitute materials.

[1269] Ibid.
[1270] Ibid.
[1271] Ibid.
[1272] Ibid.

Murata et al.[1273] report that for particular use conditions, the required functions can be achieved with lead-free dielectric ceramic, however lead-containing dielectric ceramic is indispensable in applications for which it is necessary that multiple parameters coexist. It is required that the lead-containing dielectric ceramic used in ceramic capacitors for utilization at the condition of rated voltages of 125 V AC or higher, or 250 V DC or higher, must have a high dielectric constant capable to produce the required electrical capacitance in circuits of electrical and electronic equipment, as well as low energy loss and low electrostriction characteristics when high voltages are applied.[1274]

Lead is indispensable for the stable achievement of excellent functionality (high dielectric constant, low energy loss) over a wide range of use conditions (temperature, voltage, frequency). Moreover, as these use conditions vary during the use of electrical and electronic equipment, it is impossible to specify a technical range for elimination of lead with values based on a single condition. Consequently, there are no technical prospects for the general elimination of lead from dielectric ceramic materials in high voltage capacitor applications.[1275]

For further information, Murata et al. reference the 2008/2009 review report[1276] and the input from JBCE[1277] to the 2008/2009 review.

23.2.3 Elimination of Lead

Murata et al.[1278] explain that there are cases when substitution is possible in specific fields, as for example, film capacitors. There may exist other cases as well. However, to their knowledge, no product exists, which can substitute the advantages obtained in practice by lead-containing ceramic capacitors.

23.3 Roadmap for Substitution or Elimination of RoHS-Restricted Substance

Murata et al.[1279] report about technical advances to reduce the amount of lead. The electrical and electronic equipment industry has enhanced the performance of discrete ceramic capacitors for high voltage applications in relation to their size. This has been achieved by improving the dielectric constant through the addition of lead, by using the multilayer technology, which takes advantage of the characteristic that lead-containing

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[1273] Ibid.
[1274] Ibid.
[1275] Ibid.
[1276] Op. cit. (Gensch, Carl-Otto, Oeko-Institut e. V., et al. 20 February 2009), in particular page 104 et sqq.
[1277] C.f. JBCE, http://rohs.exemptions.oeko.info/fileadmin/user_upload/Stakeholder_comments/Exemption-7c_JBCE_1_April_2008.pdf
[1278] Murata et al. 2015b "Answers to questionnaire 1 (clarification questionnaire)" unpublished manuscript, http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_7_c_-II/7c-II_Questionnaire-1_ZVEI-et-al_2015-09-06_final.pdf
[1279] Op. cit. (Murata et al. 2015a)

ceramic can be densely sintered over a wide range of sintering conditions and by promoting miniaturization.

At the same time, with the advance of IT/wireless technology in recent years and the increase of high-frequency equipment associated with it, the number of electrical and electronic components per unit of electrical and electronic equipment has drastically increased. Overall, industry has nevertheless been successful in reducing the total amount of lead included in the ceramic of discrete ceramic capacitors for high voltage applications placed on the world market, including Europe.[1280] Table 23-1 on page 505 shows the detailed figures calculated by Murata et al.[1281]

Murata et al.[1282] conclude that although it is impossible to completely cease the use of lead under the scope of exemption 7(c)-II, improvements concerning its use have been implemented within their power, and industry is engaged in the reduction of the environmental burden as well as the amount of lead brought into the EU.

Concerning further stages for establishing possible substitutes and respective time frames needed for their completion, Murata et al.[1283] claim there are no prospects for substitution for the foreseeable future because of the technical reasons explained in their request for the renewal of exemption 7c-II.

23.4 Critical Review

23.4.1 REACH Compliance - Relation to the REACH Regulation

Barium titanate, strontium titanate and lead are used in the ceramics according to the applicants and therefore need to be evaluated whether their use weakens the environmental and health protection afforded by Regulation (EC) No 1907/2006 (REACH Regulation).

Appendix A.1.0 of this report lists various entries in the REACH Regulation annexes that restrict the use of lead in various articles and uses.

Annex XIV contains several entries for lead compounds, whose use requires authorization:

- 10. Lead chromate
- 11. Lead sulfochromate
- 12. Lead chromate molybdate sulphate red

In the applications in the scope of the reviewed exemption, lead is used in electronic components that become parts of articles. None of the above listed substances is

[1280] Ibid.
[1281] Ibid.
[1282] Ibid.
[1283] Ibid.

relevant for this case, neither as directly added substances nor as substances that can reasonably be assumed to be generated in the course of the manufacturing process.

Annex XVII bans the use of the following lead compounds:

- 16. Lead carbonates in paints
- 17. Lead sulphate in paints

Neither the substances nor the application are, however, relevant for the exemption in the scope of this review.

Appendix A.1.0 of this report lists Entry 28 and Entry 30 in Annex XVII of the REACH Regulation, stipulating that lead and its compounds shall not be placed on the market, or used, as substances, constituents of other substances, or in mixtures for supply to the general public. A prerequisite to granting the requested exemption would therefore be to establish whether the intended use of lead in this exemption request might weaken the environmental and health protection afforded by the REACH regulation.

In the consultants' understanding, the restrictions for substances under Entry 28 and Entry 30 of Annex XVII do not apply. The use of lead in this RoHS exemption in the consultants' point of view is not a supply of lead and its compounds as a substance, mixture or constituent of other mixtures to the general public. Lead is part of an article and as such, Entry 28 and 30 of Annex XVII of the REACH Regulation would not apply.

Entry 63 of Annex XVII stipulates that lead and its compounds

1) *"shall not be placed on the market or used in any individual part of jewellery articles if the concentration of lead (expressed as metal) in such a part is equal to or greater than 0.05 % by weight."*
   This restriction does not apply to internal components of watch timepieces inaccessible to consumers;
2) *"shall not be placed on the market or used in articles supplied to the general public, if the concentration of lead (expressed as metal) in those articles or accessible parts thereof is equal to or greater than 0.05 % by weight, and those articles or accessible parts thereof may, during normal or reasonably foreseeable conditions of use, be placed in the mouth by children."*
   This restriction, however, does not apply to articles within the scope of Directive 2011/65/EU (RoHS 2).

The restrictions of lead and its compounds listed under entry 63 thus do not apply to the applications in the scope of this RoHS exemption. Should HVC actually be used in watch timepieces, this use of lead would be allowed.

Appendix A.1.0 of this report lists various entries in the REACH Regulation annexes that restrict the use of barium, strontium and compounds in various articles and uses.

Nickel barium titanium primrose priderite is specified for Annex XVII entry 28. This barium-containing substance is, however, not relevant for the ceramics in the scope of Exemption 7c-II. The same applies to strontium chromate, which is listed in Annex XIV.

No other entries, relevant for the use of substances relevant for the requested exemption could be identified in Annex XIV and Annex XVII (status February 2016). Based on the current status of Annexes XIV and XVII of the REACH Regulation, the requested exemption would not weaken the environmental and health protection afforded by the REACH Regulation. An exemption could therefore be granted if other criteria of Art. 5(1)(a) apply.

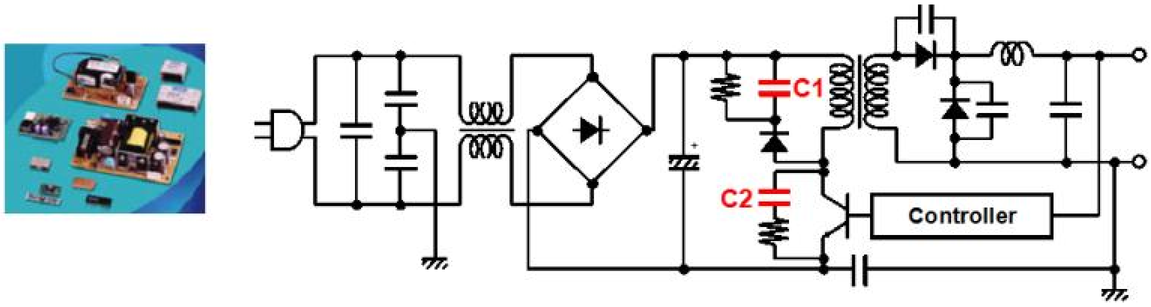
23.4.2 Substitution and Elimination of Lead

Murata et al.[1284] stated that HVC applied at a rated voltage of 125 V AC or higher, or 250 V DC or higher, lead elimination can be achieved in practice for some partial applications. They were asked to explain this in more detail with respect to applications that do not require the full range of properties that lead-containing dielectric ceramics can provide:

1) High dielectric constant at high operating voltage;
2) High energy storage capability (also at high temperatures);
3) Low leakage at high voltage and high temperatures;
4) Low loss at high current, frequency, and temperatures.

Only upon repeated requests[1285] [1286] [1287] Murata et al finally presented two examples of lead-free HVC snubber capacitors that are used in switching power supplies (C1, C2 in Figure 23-1).

Figure 23-1: Switching power supply



Source: Murata et al.[1288]

Murata et al.[1289] explain that the lead-free HVC C1 and C2 in the above figure eliminate high-frequency noise, for which ceramic HVC are generally used. C1 and C2 are operated

[1284] Ibid.
[1285] Op. cit. (Murata et al. 2015b)
[1286] Murata et al. 2016a "Answers to second questionnaire, document "Exe_7c-II_Questionnaire-2_ZVEI-et-al_2015-01-25_answers_final.pdf", received via e-mail from Walter Huck, Murata, by Dr. Otmar Deubzer, Fraunhofer IZM, on 1 February 2016" unpublished manuscript,
[1287] Murata et al. 2016b "Answers to third questionnaire, document "Exe_7c-II_Questionnaire-3_ZVEI-et-al_2016-03-14.DOCX", received via e-mail from Walter Huck, Murata, by Dr. Otmar Deubzer, Fraunhofer IZM, on 24 March 2016" unpublished manuscript,
[1288] Ibid.

with high frequencies and high voltages. However, in case “lead-free” HVCs are used, there is the possibility of a short circuit failure occurring over a short period of time depending on the voltage conditions of the equipment and use conditions in the market. In practice, according to Murata et al., equipment using “lead-free” HVCs have recently caused short failure accidents in the market. The applicants did not provide further information substantiating this statement.

Murata et al.[1290] state that in recent years, as voltage and use conditions become more severe, high reliability and longer longevity of the equipment are being required by society in order to promote accident prevention in the market and reduce maintenance burdens including environmental aspects. “Lead-free” HVCs cannot fulfill the requirements of high reliability and longevity, thus there is the risk that they may cause serious accidents in the market.

Murata et al.[1291] ask to note that the use conditions required by equipment applications utilizing snubber capacitors C1 and C2 stretch over a very wide range as shown below, and moreover, there are applications requiring compatibility to further high frequency trends and high voltage.

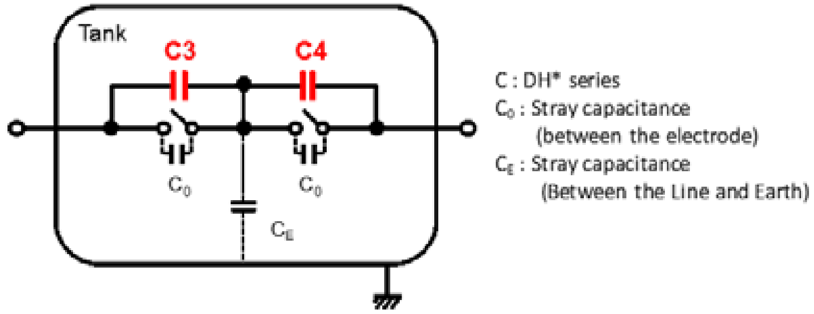
- Frequency: Generally 50 - 150kHz; there are market trends of shifting to higher frequencies.
- Voltage: Generally 150Vp-p - 1000Vp-p, however there are cases exceeding 1000Vp-p depending on the input voltage to the equipment and noise conditions.
  Vp-p = Volt peak to peak (electrical potential difference between minimum and maximum values of AC voltage).

Murata et al.[1292] indicate that in order to fulfill these use conditions, capacitance (electrostatic capacity) and nominal voltage are listed as performance parameters required for C1 and C2, however neither of them can be specified. The capacitance changes according to the noise frequency to be eliminated, so that the capacitance range cannot be specified. Besides requirements that change depending on the input voltage and noise conditions, safety design conditions of equipment are diverse. As there are cases where higher nominal voltages are (also) required, it is not possible to specify the voltage range.

As a second example of lead-free HVC uses, Murata et al.[1293] present circuit breakers of power (C3 and C4 in Figure 23-2).

[1289] Ibid.
[1290] Ibid.
[1291] Ibid.
[1292] Ibid.
[1293] Ibid.

Figure 23-2: Circuit breaker



Source: Murata et al.[1294]

Murata et al.[1295] explain that C3 and C4 are capacitors used dividing voltage and reducing restriking voltage. The voltage of these subparts is some hundreds of kilovolts AC at 50/60Hz with multiple capacitors being used in series. Therefore, the applied voltage onto individual capacitors is a high voltage (maximum AC40kV) at 50/60 Hz.

However, as high voltage noise is generated when switching the circuit breaker, high resistance to surge (impulse) voltage performance is required. There are cases when "lead-free" HVCs are used in this subpart. As impulse (surge) resistance performance of "lead-free" HVCs is low compared to lead-containing HVC, it is necessary to increase the thickness of the ceramic element or to increase the number of serial HVC in order to adopt those "lead-free" HVC. This results in the upsizing of the equipment as a whole. In order to reduce the environmental load, including the amount of lead used, and promote the downsizing of the entire equipment, lead-containing ceramic materials, which have excellent surge (impulse) resistance performance, are indispensable.

Murata et al.[1296] summarize the use conditions required by the equipment application concerning C3 and C4 listing capacitance, nominal voltage and surge (impulse) resistance as performance parameters required for C3 and C4. However, regardless of the parameters it is not possible to specify a technical scope for which "lead-free" HVC may be utilized.[1297]

- **Frequency**: 50/60Hz
- **Voltage**: some hundreds kV AC as a circuit
  As multiple capacitors are used connected in series, the applied voltage changes according to the circuit design and thus cannot be specified.
- **Capacitance**
  As capacitors are used as multiple units in a series, the capacitance of the equipment is the total sum of those capacitances. Consequently, it is not

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[1294] Ibid.
[1295] Ibid.
[1296] Ibid.
[1297] Ibid.

possible to specify the capacitance values required by each individual capacitor.

- **Nominal Voltage**

  As capacitors are used as multiple units in a series, the required nominal voltage changes with the circuit design. The safety design conditions of the equipment are diverse, and as there are also cases when higher nominal voltages are required it is not possible to specify them. For this reason, it is not possible to specify the nominal voltage of the individual capacitor units.

- **Surge (Impulse) Resistance Performance**

  There is a correlation between surge (impulse) resistance performance and nominal voltage, and as the safety design conditions of equipment are set for surge (impulse) performance and nominal voltage respectively, it is not possible to determine a specification for surge (impulse) performance individually.

There are cases when it is not possible to fulfill the required performance of the product with “lead-free” HVC depending on the applied voltage conditions. For this reason, it is impossible to comprehensively substitute specific applications by “lead-free” HVC.[1298]

23.4.3 Rewording of the Exemption

Murata/JEITA et al.[1299] [1300] propose a slight modification of the exemption wording (c.f. Section 23.2.1 on page 506) to clarify that actually the discrete capacitor components are in the scope and not other dielectric ceramic materials that may also have a capacitance, but that are covered by exemption 7c-I. As this was actually the intended scope of exemption 7c-II, the consultants recommend to adopt the proposed wording based on the applicants’ assertion that these modifications clarify, but do not change the technical scope of the exemption.

According to the applicants, such dielectric ceramic materials are not only used in discrete ceramic capacitors. The consultants therefore wonder whether in the low voltage area below 125 V AC or 250 V DC the substitution of lead would not be scientifically and technically practicable in all dielectric ceramic materials with capacitance or where the capacitance is the reason for their use. As this question arose, however, at the very end of the review process, it could not be discussed with the stakeholders and shall need to be followed up in the next evaluation.

23.4.4 Conclusions

The applicants provide plausible information that the substitution of lead is scientifically and technically impracticable in HVC for applications that require all of the properties which currently only lead-containing dielectric ceramics can deliver. In the absence of

[1298] Ibid.
[1299] Op. cit. (Murata et al. 2015a)
[1300] Op. cit. (JEITA et al. (Japan 4EEE) 2015)

contrary information, granting an exemption would therefore be in line with RoHS Art. 5(1)(a).

In the light of the stipulations for exemptions in Art. 5(1)(a) the core criterion is, however, where the substitution or elimination of lead is scientifically and technically practicable. This raises the question whether all ceramic capacitors in all applications in the high voltage area actually need the combination of all properties of the leaded dielectric ceramics.

The applicants did not provide information on lead-free HVC or possible other alternatives to substitute or eliminate the use of lead, e.g. where not all of the leaded ceramics' properties are required. Only upon repeated request[1301, 1302, 1303] did they submit two examples of lead-free HVC and where they are used. The declaration as "examples" suggests that there are other lead-free HVC as well.

It is comprehensible that the applicability of such lead-free HVC depends on multiple parameters that may be difficult to be linked to criteria, which would allow a clear demarcation of application fields, where such lead-free HVC can be used. It can be assumed that such lead-free HVC have certain performance parameters such as rated voltages, temperature and frequency ranges, which circuit designers need to know in order to decide about their usability to verify certain requirements. Furthermore, electronic circuits could at least in part be redesigned to better accommodate the limits of such lead-free HVC and allow their use to thus reduce the amount of lead-containing HVC. The applicants did not provide information to clarify these questions.

Murata et al.[1304] also mention film capacitors as another example to substitute or eliminate lead and mention that there may be other options as well, but do not provide more comprehensive information about the properties of such devices.

Appraising the overall situation against the criteria stipulated in Art. 5(1)(a), the consultants recommend granting the exemption. The information available shows that lead-free alternatives are available for some applications, even though it was not possible to clarify with the available resources and time whether these lead-free alternatives would allow restricting the scope of the exemption. Substitution or elimination of lead thus may be scientifically and technically practicable in some cases within the maximum five years validity period. According to Art. 5(1)(a), it would not be justified to grant the maximum validity period of five years. The consultants propose to continue the exemption for three years only. This would on the one hand accommodate the scientific and technical impracticability to substitute or eliminate lead in HVC and give the applicants sufficient time to apply for the renewal of the exemption 18 months

[1301] Op. cit. (Murata et al. 2015b)
[1302] Op. cit. (Murata et al. 2016a)
[1303] Op. cit. (Murata et al. 2016b)
[1304] Op. cit. (Murata et al. 2015b)

prior to its expiry. On the other hand it would facilitate a further clarification of those areas where lead can already be substituted or eliminated.

23.5 Recommendation

The information which the applicants submitted suggests that many if not most applications require HVC containing lead in the dielectric ceramic material so that the substitution or elimination of lead in those HVC is scientifically and technically impracticable. In the absence of contrary information, granting an exemption would therefore be justified in line with Art. 5(1)(a). For some applications, alternative components such as lead-free HVC are, however, available on the market. The applicants did not provide comprehensive information about these components. In light of the lacking data related to availability of alternatives, the consultants would recommend a short term renewal, restricting the validity period of the exemption to three years. Should industry fail then again to provide substantiated information about specific research and available lead-free HVC in the future, the consultants recommend cancelling the exemption in the next review.

Exemption 7c-II	**Expires on**
Lead in dielectric ceramic in capacitors for a rated voltage of 125 V AC or 250 V DC or higher	*21 July 2021 for medical equipment in category 8 monitoring and control instruments in category 9*
	21 July 2023 for in vitro diagnostic medical devices in category 8
	21 July 2024 for industrial monitoring and control instruments in category 9
Lead in dielectric ceramic in discrete capacitor components for a rated voltage of 125 V AC or higher, or for a rated voltage of 250 V DC or higher	*21 July 2019 for categories 1-7 and 10*

The modified wording to clarify the scope of exemption 7c-II should also be reflected in exemption 7c-III, whose current wording is:

> *"Lead in dielectric ceramic in capacitors for a rated voltage of less than 125 V AC or 250 V DC"*

The table below proposes a modified wording for exemption 7c-III.

Exemption 7c-III	Expires on
Lead in dielectric ceramic in discrete capacitor components for a rated voltage of less than 125 V AC, or for a rated voltage of less than 250 V DC	*1 January 2013 and after that date may be used in spare parts for EEE placed on the market before 1 January 2013*

23.6 References Exemption 7c-II

Gensch, Carl-Otto, Oeko-Institut e. V., et al. 20 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, Oeko-Institut e. V. and Otmar Deubzer, Fraunhofer IZM. http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf.

JEITA et al. (Japan 4EEE) 2015 Request for renewal of exemption 7c-II. http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_7_c_-II/7c-II_RoHS_Exemption_Renewal_Request_7_c_I_Japan4EEEassociations.pdf.

Murata et al. 2015a Request for Renewal of Exemption 7c-II from 16 January 2015. http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_7_c_-II/7c-II_RoHS_V_Application_Form_7c2_20140115_final.pdf.

Murata et al. 2015b Answers to questionnaire 1 (clarification questionnaire). http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_7_c_-II/7c-II_Questionnaire-1_ZVEI-et-al_2015-09-06_final.pdf.

Murata et al. 2016a Answers to second questionnaire, document "Exe_7c-II_Questionnaire-2_ZVEI-et-al_2015-01-25_answers_final.pdf", received via e-mail from Walter Huck, Murata, by Dr. Otmar Deubzer, Fraunhofer IZM, on 1 February 2016.

Murata et al. 2016b Answers to third questionnaire, document "Exe_7c-II_Questionnaire-3_ZVEI-et-al_2016-03-14.DOCX", received via e-mail from Walter Huck, Murata, by Dr. Otmar Deubzer, Fraunhofer IZM, on 24 March 2016.