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



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The recommendations given by the authors should not be interpreted as a political or legal signal that the Commission intends to take a given action.

### 4.29.5 References

[1] Öko-Institut / IZM Report 2006, Annex 1, Monthly Reports 4 and 9, downloadable from http://ec.europa.eu/environment/waste/weee/studies_rohs1_en.htm; last access July 2008

[2] Fine pitch HP; Stakeholder consultation no. 2, http://circa.europa.eu/Public/irc/env/rohs/library?l=/requests_exemptions/resistant_applications&vm=detailed&sb=Title; last access July 2008

[3] EICTA et al. on ex. 23 Stakeholder contribution exe 23; 1 April 2008

[4] HP Stakeholder contribution exe. 23; “HP Letter to the Oeko Institut – Rev3.1.pdf”

[5] ELCF Stakeholder contribution exe. 23; 31 March 2008

[6] NXP Pb-free Product/Process Change Notification, http://www.nxp.com/profile/corporate/environment/lead_free/cpcn/index.html, last access August 2008

[7] Commission FAQ-Document Frequently Asked Questions on Directive 2002/95/EC on the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE); http://ec.europa.eu/environment/waste/weee/pdf/faq_weee.pdf, last access July 2008

[8] Ringhal AB Stakeholder contribution exe.-7-11-12-14-15-23-24-27; 01 April 2008

## 4.30 Exemption No. 24

**“Lead in solders for the soldering to machined through hole discoidal and planar array ceramic multilayer capacitors”**

This exemption request was originally applied for by Syfer Technology in the first stakeholder consultation as exemption request no. 4. The evaluation of the request was published in the Öko-Institut Report 2006, Annex 1, Monthly Report 4 and in the Final Report [1]. The Commission followed the reviewers’ positive recommendation and granted the exemption without an expiry date.

### 4.30.1 Description of the requested exemption

Multi Layer Ceramic (MLC) discoidal capacitors and planar arrays are the heart of modern EMC discrete filters, filter assemblies and filtered connectors. They are manufactured in a similar manner to MLC chip capacitors, building up layers of ceramic dielectric material interlaced with precious metal electrodes. A hole, or array of holes, are drilled in the ceramic, and the internal and external diameters metallised or plated. The capacitance is thus formed between the bore of each hole and the outer diameter of the ceramic material. Their relatively high complexity and high cost is vindicated by their high performance, but leads them to be used primarily in areas where this performance is essential, and high reliability is critical. They do not tend to be used in high volume commercial applications.

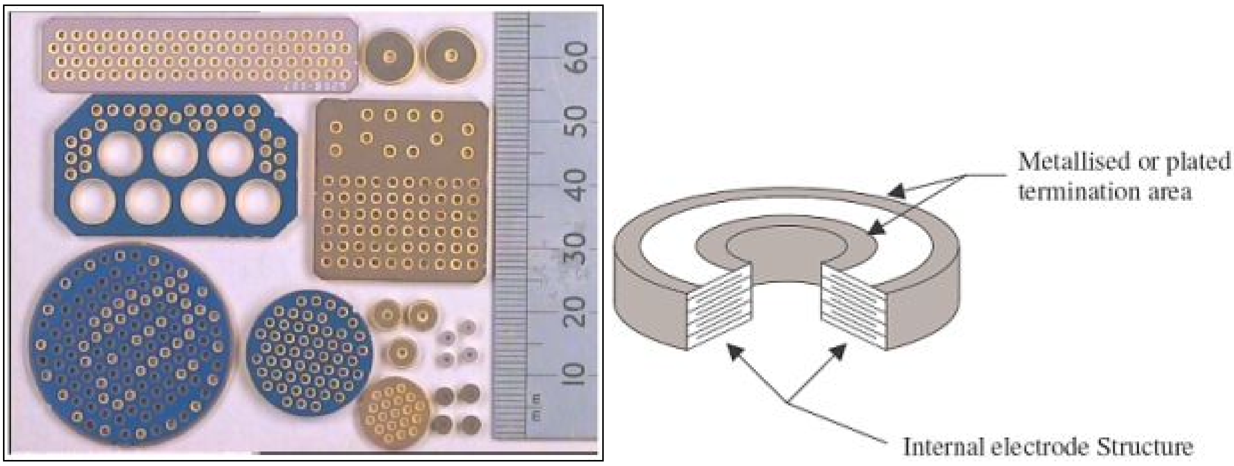


Figure 36 Examples of discoidal and planar array capacitors [2]

The machined through hole discoidal and planar array ceramic multi layer capacitors are contacted by soldering a copper pin into the central hole. The pin can then be contacted with wires as Figure 37 shows.

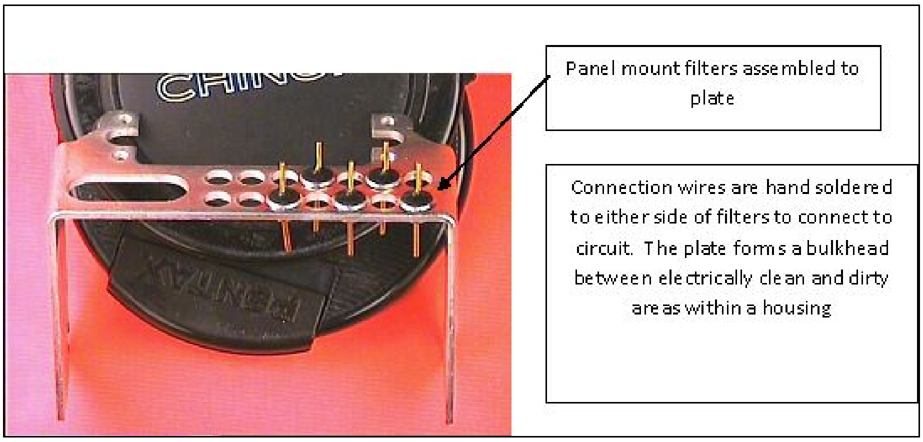


Figure 37 Partially populated complex filter plate [5]

Exemption 24 allows the use of lead solders for soldering the pin into the central hole. The lead-indium solders with 40% to 50% of lead content (PbIn60 or PbIn50) provide the combination of a suitable melting point and ductility. The ductility of this solder avoids cracking of the ceramic layer during and after soldering due to thermal mismatch between the ceramic capacitor and the copper pin.

The quantity of lead in the solder joints of each filter is estimated at around 5 mg per joint typically. Market growth has increased the total lead used in solder joints at Syfer to an estimated 5 kg in 2007 (previously estimated at 4kg in 2003).

The exemption affects a small number of manufacturers, and Syfer, the company that had originally applied for this exemption in 2005, claims to be the market leader. Therefore, it is estimated that the total amount of lead in such kind of components is in the same order of magnitude as the 5 kg.

### 4.30.2 Summary of justification for the exemption

Syfer states that the technological and scientific base for this exemption has not changed. The justification based on the 2005 and new information is summarized in short.

*Lead-free solder alloys*

According to the applicant, lead-free solders in connection with gold plated terminations cause cracking of the ceramic bodies after the soldering process due to thermal mismatch (CTE) with the copper pin.

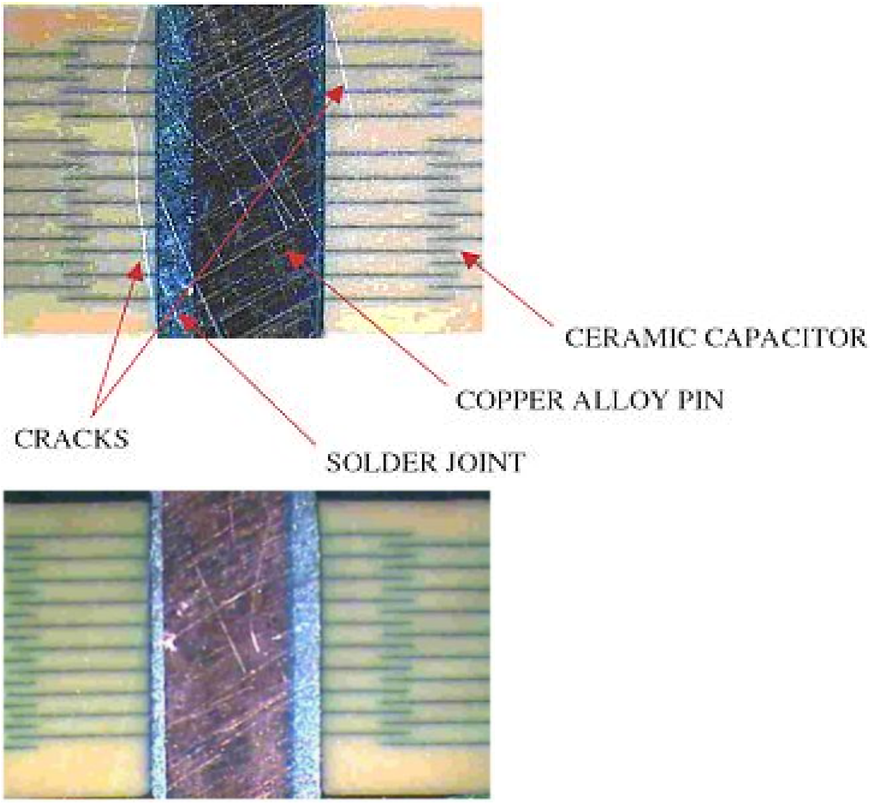


Figure 38 Defect capacitor soldered with SnPb36Ag2 lead-free solder (top) and correctly soldered with 50PbIn solder (bottom) [2]

The main reason for the CTE is the copper alloy pin. Alternative pin materials have been tested, but are not a viable substitute. The alternative materials do not provide suitable resistivity to allow sufficient current flow without excessive temperature rise.

Some companies may intend using PdAg terminations replacing gold together with lead-free solders. This avoids the cracking of the ceramic bodies. Tests, however, show that such devices show considerable deviations from the designed capacitance causing unacceptable losses of the filtering properties beyond the acceptable tolerances. The reason is the weaker – compared with gold terminations – adhesion between the ceramic and the AgPd plating causing lift-offs and/or the leaching of the PdAg layer in combination with lead-free solders. As state of the art, lead-free solders hence are not recommended to be used with AgPd platings neither. The problem does not exist with lead-containing solders. The loss of capacitance due to these failure modes affecting the filtering performance of the device may result in severe medium- and long-term reliability problems. [6]

Syfer says that some of its customers are tending towards using higher lead alloys (typically 95% lead rather than 50% lead) to overcome the limitations of the RoHS Directive. This was one option Syfer discussed in the original application, but considered to represent a negative environmental impact. High melting point lead solders (HMP, currently still exempted under exemption 7a) with Pb content > 90% also tend to have the ductility demanded, 92.5Pb/5In/2.5Ag or 95Pb/5In being the most likely solutions. These are deemed acceptable as the current directive annex exempts HMP alloys with >85% or more of Pb. However, alloys with this content of lead have much higher reflow temperatures - 92.5Pb/5In/2.5Ag has a liquidus temperature of 310ºC compared with 210ºC for 50Pb/50In. This will demand new equipment capable of reaching much higher temperatures. Trials have shown that an inert atmosphere will also be necessary to prevent oxidisation problems. The use of these HMP solders thus would increase the use of lead as well as the energy consumption due to the higher soldering temperatures and for the production of the inert gas. Syfer confines, however, that some applications require the use of HMP solders in such capacitors [2], [3].

Syfer says to have information that ductile lead-free solder alloys are being considered for development at Indium Corporation, one of Syfer's suppliers. [3]

Indium Corporation confirms that ductile high temperature alloys are needed and are therefore the subject of research. The solution cannot be easily achieved. "Classical" or simple alloy combinations are not likely to be effective and a more complex solution is most likely to succeed. This has the effect of widening the number of research avenues considerably. Several approaches have already been followed but have proved blind. The alloys either do not deliver their initial promise or are not capable of being transferred to production. In addition, as the result needs to be a novel material, a comprehensive test program will also be required. Research continues, but production is estimated to be several years off. [5]

Syfer concludes that it is presently confined to conventional, existing alloys. The ductility necessary for Syfer's application ultimately relies on the use of indium in high percentages, as indicated. Tin based alloys with high Indium content have very low melting points making them unsuitable. The use of lead is therefore necessary to both raise the melting point to an appropriate level and to maintain the ductility. [5]

*Use of spring clips*

Syfer [3] states an increased interest in the possibility of using spring clip contacts to replace the inner solder joints. The driver behind the use of spring clips is to reduce the assembly time and scrap costs relating to multi-way filter connectors & assemblies. Using spring clips allows the soldering operation of the assembly – in case of soldered-in clips – to take place away from the connector shell and pins. Working outside the connector shell makes the assembly easier, quicker and there is no risk of accidental contamination of mating surfaces with solder. After initial assembly, the individual capacitor elements can be tested and checked before installation into the housing. Testing of the connector after installation of the clipped array also allows any damage during insertion to be identified and reworked before the connector is finally sealed.

Fully soldered assemblies are harder to assemble and, in the case of a failure being identified, are generally not re-workable thus carrying a far greater scrap cost. On the other hand, the tooling cost (for solderless clips) and the cost of a soldered clip are higher compared to a solder solution without using pins. Syfer did not provide an overall cost calculation, as this would have to take the anticipated yield, cost of piece parts and potential cost of re-work into account.

There are two versions of spring clips. [5] [6]

- Soldered spring clips mounted into the capacitors using InPb solders as for standard solder joints, however, with smaller amounts of solder compared to the soldered clipless version.
- Mechanical clips to make a solderless connection, this development is providing the main interest with regard to the exemption.

Syfer [5] confines that the use of spring clips has technical limits. Modern technology needs higher capacitances and working voltages to meet electromagnetic compatibility (EMC) requirements. At the same time, physical size is reduced to satisfy the push for lower weight and smaller equipment. The problem with spring clips is that they reduce the available capacitance and working voltage, and physically increase the size of the filters. [5] The conditions of their use thus may withstand the requirements in many applications.

Syfer [5] gives an example: A standard filtered connector with hole to hole pitch of 0.130" using a size 20 pin contact at 0.040" diameter will be soldered into a hole typically 0.045" diameter. A spring clip to suit the same application requires a hole diameter of 0.102" minimum and has a mounting flange of 0.126" diameter. The capacitance achievable is negligible and the clips will almost touch rendering them unsuitable. Spring clips would not be suitable for the majority of single line filters as space constraints would prevent their use. [5]

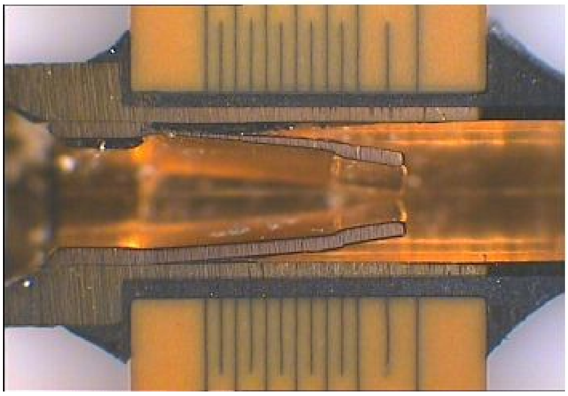

Figure 39 Cross section of a spring clip connection

The reduced capacitance and voltage rating of a part by imposing limitations on the hole dimensions has limited the use of spring clips to applications where this is not important. There are, however, more limitations to be taken into account.

Calculating the available capacitance requires a complex calculation with a number of variables to take into account. Syfer [5] explains that the available capacitance is a function of the area of electrode overlap in the capacitor and the dielectric thickness separating the electrodes (see Figure 36 on page 215). In a discoidal capacitor, the difference between the outer diameter and the hole diameters define the area of electrode overlap, bearing in mind that minimum insulation margins are required between the inner and outer diameters. The same rule applies to multi line planar arrays with more holes, but increasing the number of holes increases the complexity of the electrode design. [5] In most applications, the pin through the centre of the filter must have a defined size, based on physical strength and current carrying capacity. Using spring clips at a given pin size increases the hole diameter, which reduces the electrode overlap area and the available capacitance at a given total size of the capacitor, and it thus narrows the technical limits for the use of spring clips. [5]

In addition to the reduction in overlap area, there will also be a similar reduction on the creepage (transfer of electricity across a surface) and clearance (transfer of electricity in free air) across the surface of the capacitor. In many cases the spring clip will not physically fit in the spacing available. [5]

Syfer [6] explains that the spring clip itself has increased resistance and inductance over a standard solder joint, as a result of the contact area between the capacitor and the pin being reduced and the fact that the connection is purely mechanical. Typically, the joint resistance of a soldered line is less than 5 mOhm, compared to a similar design clip connection resistance of 20mOhm. If there is a risk of the contact moving due to vibration, or there is a risk of contamination getting between the clip fingers and the pin (such as epoxy encapsulation placed directly onto the capacitor) then the contact resistance can increase, adversely affecting performance.

Each connector manufacturer uses their own through pin dimensions, meaning each will demand different size clips to meet their own requirements. As the supplier of the ceramic Syfer [6] was in contact with a number of clip manufacturers to try and produce a standardised clip covering multiple pins diameters based on existing commercial designs. So far the manufacturers have told this is impractical. There are also issues with approvals - most of these types of component are being used in high reliability applications where a change of technology would require a full re-approval which is not always possible. [6]

Syfer concludes that spring clips offer a possibility to reduce the total lead usage, or to even avoid it. They are, however, not suitable for all applications and have technical constraints. Their applicability has to be assessed on a case by case base due to the multitude of production and application specific requirements to be taken into account.

Given the above constraints and limitations, Syfer [3] cannot see how the wording could be phrased to ensure that clips are used wherever possible. Each application has to be judged individually on merit and a decision made at the design stage. Solder is still the preferred method of joining the capacitor to the surrounding metalwork. [3]

*Conductive epoxies*

Syfer could not identify any conductive epoxy with the appropriate flow characteristics to flow into the space where the joint is to be made. [3]

*Conclusion*

Syfer states that the search for alternatives to lead based solders is continuing, but that solder currently is the only connection method that fulfils all the technical requirements. Until a new solder alloy can be developed offering the critical ductility, Syfer does not see any lead-free alternative for this application. [3] [5] Syfer therefore asks for the continuation of exemption 24.

No opposing stakeholder opinions were submitted during this review process.

### 4.30.3 Critical review

Syfer plausibly explains that viable lead-free substitutes for the lead-indium solders are not available, neither currently nor within the near future.

Spring clips soldered into the hole of the discoidal capacitor in principle are a way to reduce the use of lead solders. Solderless spring clips even could be a way towards RoHS-compliance without an exemption. Their usability, however, is limited to individual cases, which cannot be categorized. Several parameters affect the applicability of spring clips:

- The available space to build in the capacitor, as spring clip capacitors need more space to achieve the same capacitance.

- The maximum possible inner hole diameter, as spring clips require more space.
- The pin size in dependence of the current carrying capacity required.
- The capacitance required, as the achievable capacitance at a given capacitor size is limited.
- The tolerable resistance and inductance of the capacitor connection, as clipped capacitors have a higher resistance and inductance.
- Application-specific influences like e. g. vibration or contaminations that influence the resistance and of the clip connection and adversely affect the performance.
- The tolerable creepage and clearance of the capacitor, as this is different for clipped capacitors from soldered ones.
- Non-standardized pin and clip sizes requiring individual spring clip solutions for each manufacturer.
- Single line or multi-line applications, as the available spacing is smaller in multi-line applications so that a minimum distance between the clips might be fallen below.

Besides this multitude of influencing parameters, the single parameters partially interact. It is thus not possible to clearly define application fields allowing the use of spring clips, and if possible solderless ones, as otherwise the exemption would be needed further on.

High melting point solders with 85% or more of lead (HMP solders) currently are exempted from the RoHS Directive. Syfer [5] states that *"It has become more apparent that some of our customers are tending towards using higher lead alloys (typically 95% lead rather than 50% lead) ….". "…[we] have actively encouraged switching the lower lead content In/Pb solder alloys allowed by exemption 24."* As these solders technically are an alternative to the indium-lead solders with 40% or 50% of lead, a limitation of exemption 24 could be an additional incentive for manufacturers to use these HMP solders thus increasing the amount of lead in this application. This would not be in line with the spirit of the RoHS Directive and pose additional burdens on the environment from the use of additional lead and increased energy consumption for the processing of these HMP solders.

The overall situation, as Syfer describes it, and the absence of any opposing stakeholder views, would justify the continuation of exemption 24 in line with the requirements of Art. 5 (1) (b). It is therefore recommended to continue the exemption until the next review in 2014. Until then, in case the Commission follows the consultants' recommendation, exemption 7 a allowing the general use of HMP solders will have been expired. The HMP solders would no longer be a general fallback option, but their use would be restricted to the cases where alternative solutions are not available. In the next review, it should be checked whether and how far new and more ductile lead-free alloys or progress in the spring clip technology allow restricting or repealing exemption 24.

#### 4.30.4 Recommendation

The stakeholder's arguments and the overall situation justify the continuation of the exemption in line with Art. 5 (1) (b). The consultants therefore recommend continuing this exemption until the next review in 2014. Presuming that the Commission will require expiry dates to be set for each exemption, the reviewers propose 31 July 2014 for the expiry of this exemption.

The new wording of exemption 24 is proposed as follows:

*Lead in solders for the soldering to machined through hole discoidal and planar array ceramic multilayer capacitors until 31 July 2014, and for repair and reuse of equipment put on the market before 1 August 2014.*

#### 4.30.5 References

[1] Öko-Institut e.V., Fraunhofer IZM;
document "exemption-24_results_previous-evaluation.pdf"

[2] Syfer stakeholder document
"Application for exemption for through hole ceramic devices.pdf"

[3] Syfer online stakeholder document
"Exemption_7a_24_Syfer-Technology_31_March_2008.pdf"

[5] Steve Hopwood, Syfer; information sent via e-mail to Dr. Otmar Deubzer, Fraunhofer IZM, on 26 June 2008

[6] Syfer stakeholder document "Oct 2008 answers.doc"