4.11 Exemption no. 8a – stakeholder proposal part C (ii)

"Lead used in compliant pin connector systems"

4.11.2 Description of exemption

ACEA et al. (2009f) ask for an exemption for lead use in compliant pin connector systems (pressfit technology). According to ACEA et al. (2009f), no expiry date can be defined, as a technical solution is not available, and they propose a review after 2015.

The requested exemption still exists in the current version of the RoHS Directive as exemption no. 11 (status May 2009).

Compliant pin connector or press-fit connectors systems provide a method of attachment and electrical contact between a connector and printed circuit board (PCB) which does not require a soldering operation. The pin contacts are inserted into plated through holes (PTH) in the PCB and the mechanical design of the pin provides reliable electrical contact. The compliant pins must be sufficiently flexible to deform as they are inserted into the holes without an excessively high force that might damage the plating in the holes (Gensch et al. 2009). The pressfit technology thus saves solder, but its applicability is limited. Its use is, e. g., impossible for high power electronics (ACEA et al. 2009f).

The tin-lead plating on the pins contains about 10% lead and is only about 1,5 microns thick. It is required to

- provide lubrication while the pins are inserted in order to reduce the insertion force;
- have an oxide on the surface that can be displaced during insertion;
- ensure good electrical contact once the pin has been inserted;
- prevent whisker growth.

Technologically, pin compliant connectors avoid the difficulties encountered in soldering a large number of closely spaced pins. The total thermal mass would be so large that it was difficult to achieve the correct temperature throughout the connector for the solder to flow and wet the surfaces. The situation would be even more difficult with lead-free solders due to their slower wetting and higher assembly temperature. As solder is not used, smaller pads can be used around each pin, so that they can be placed closer together (Gensch et al. 2009).

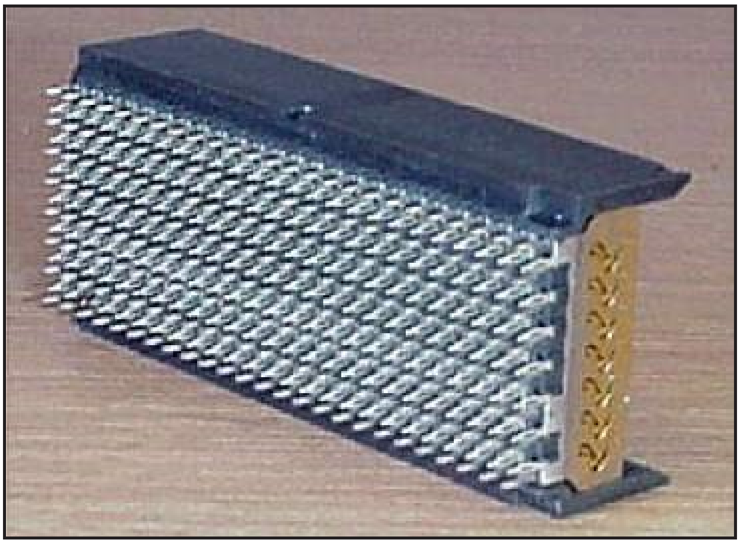


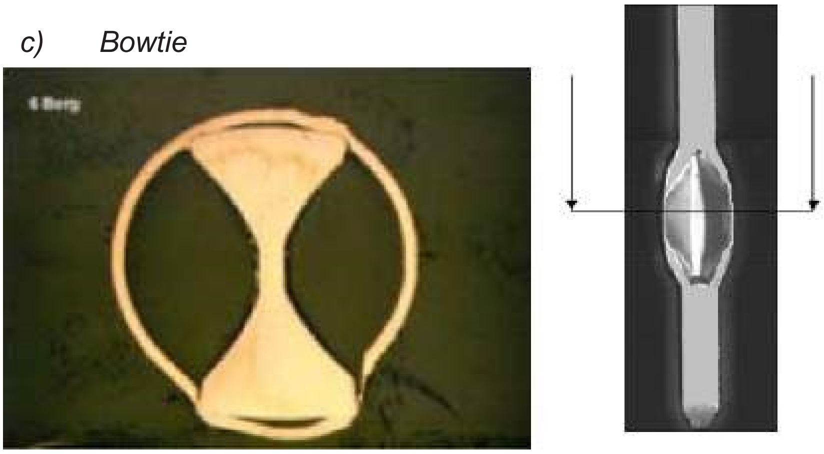
Figure 22 Example of a compliant pin connector system (Gensch et al. 2009)

There are different types of compliant pin connector systems in use.

a) *eye of needle*

b) *C-press*

c) Bowtie



d) Action pin

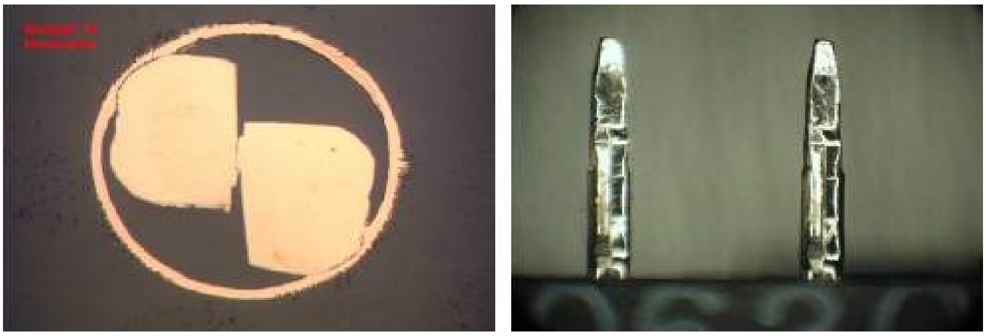


Figure 23 Types of compliant pin connector systems (Gensch et al. 2009)

Tin-lead plating covers only the termination portion of the contact, which includes the compliant section. The lead provides lubrication while the pin is inserted and withdrawn. The lead oxides on its surface are displaced during insertion enabling good electrical contact once the pin is inserted. Such connectors are used on printed circuit board assemblies contained in many types of computer and telecommunication equipment (Kadesch 2001).

ACEA et al. (2009f) calculate the amount of lead used in pressfits for automotive applications:

- The SnPb coating contains 5%–10% of lead.
- This results in around 0,0001 g of Pb per press-fit zone; around 100 pins per press-fit on average /vehicle.
- Around 16 000 000 cars are assumed to be built per year (ACEA 2007, EU27+ EFTA), equipped with 5 ECUs with an effected press-fit

Based on the above assumptions, the amount of lead used under this exemption would be around 0,8 t lead per year in Europe and the EFTA states (ACEA et al. 2009f).

4.11.3 Justification for exemption

ACEA et al. (2009f) say that lead is necessary to avoid whisker growth. Whisker problems appear if lead-free chemical tin finish on the PCB and galvanized tin surfaces on the press-fit pins are combined together (2 x pure tin layer). The probability of whisker growth increases by (ACEA et al. 2009f)

- large deformation in the entrance area of the press-fit zone;
- tin abrasion from the pin surface, adhering at the PCB-bushing surface.

The growth of whiskers thus is related to the insertion process, as the deformation as well as abrasions are caused during insertion. Whiskers can grow very fast, up to the range of millimetres per week. Whiskers are observed only in the entrance area of the press-fit zone (see REM pictures in Figure 26 below). Press-fit whiskers appear independent on PCB supplier and supplier of the chem. tin bath (ACEA et al. 2009f).

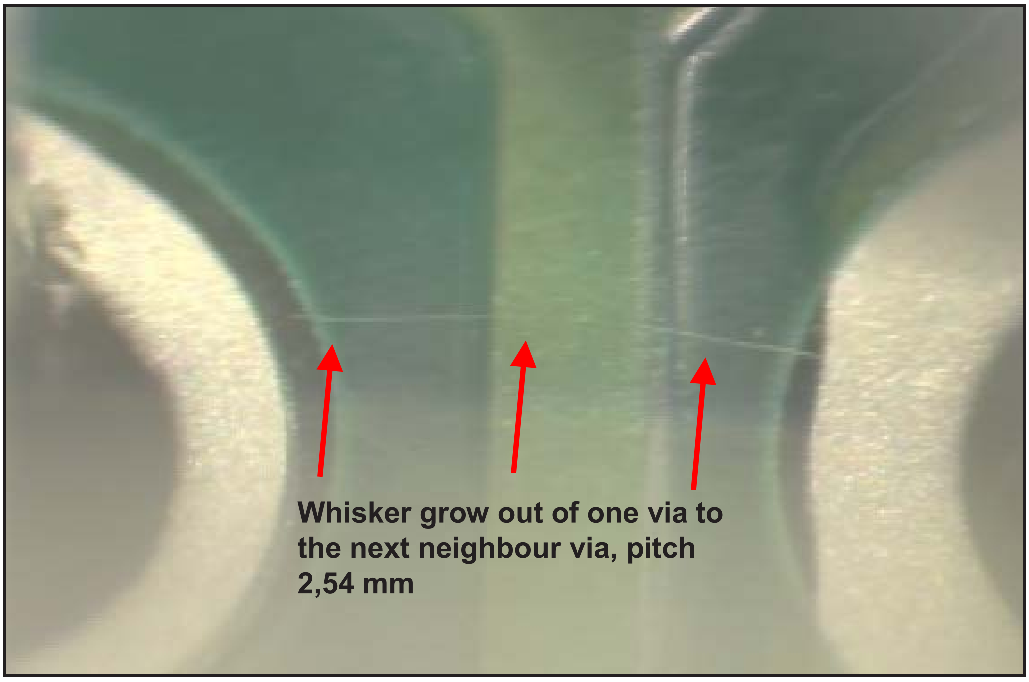
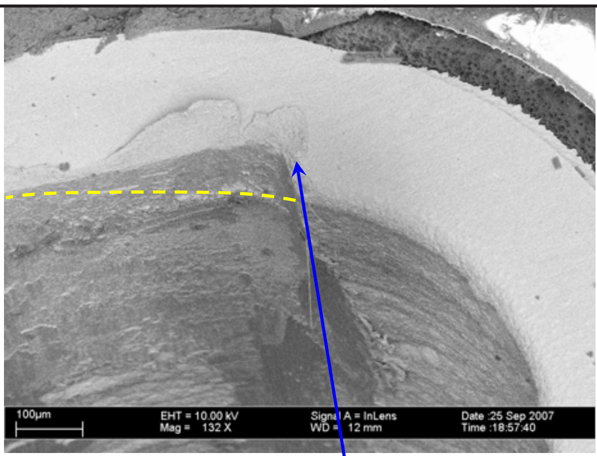
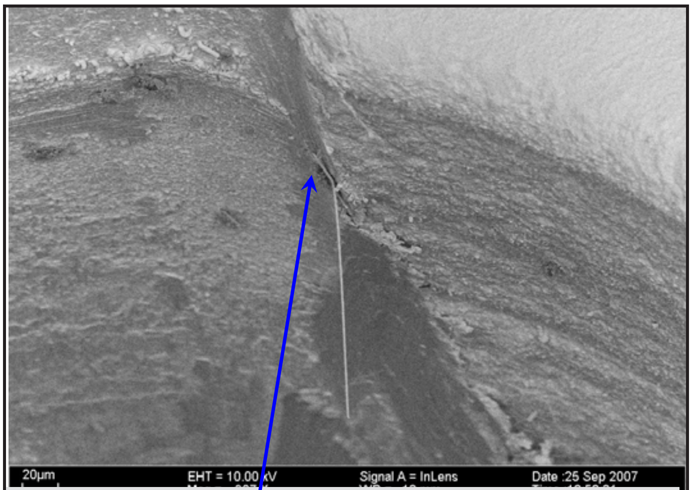


Figure 24 Whisker formation on pressfits I



- Area with high deformation
- Large strain/compression of the surface of the copper bushing in the entrance area of the press-fit pin
- Surface tension is a well known driving force for whisker growth

Figure 25 Whisker formation on pressfits II



- observed whiskers caused by press-fit origin only in the area of large deformation (entrance side of press-fit pin)
- whisker starts at PCB
- whiskers grow spontaneously in short time scales

Figure 26 Whisker formation on pressfits III

ACEA et al. (2009f) state that the mechanism of whisker building is not fully understood today. They claim that there is no known alternative to the lead use in compliant pin connector systems to avoid whisker growth. Some pre-studies were conducted for SnAg and SnCu platings, but no reliability study with satisfying results is available. Suitable lead-free alternatives for new types are under further development and qualification. A substitution of lead in compliant pin connector systems hence is not possible (ACEA et al. 2009f).

The stakeholders explain that soldering is not an alternative interconnection technology that would allow eliminating the use of lead. Compliant pin connector systems have the following advantages compared to soldering (ACEA et al. 2009f):

- "simple" mechanical process;
- no additional thermal stress to PCB and components;
- no risk of solder bridges or open solder joints;
- higher FPY (first pass yield, number of PWBs without failures after processing);
- lower dpm rate (defects per million, field returns/band returns);
- less solder needed per contact;
- less energy consumption of process.

ACEA et al. (2009f) point out that a failure in electronics may endanger life and health of the driver. A short cut due to whiskers might lead to serious malfunction of the device, e.g. by wrong sensor signals or even a failure of the whole device.

ACEA et al. (2009f) conclude that only lead avoids rapid whisker growth resulting from the press-fit process. Pure tin surfaces therefore cannot substitute the tin-lead surfaces. Design and technology alternatives like soldering cannot replace compliant pin connector systems. The use of lead in compliant pin connector systems must therefore be exempted.

ACEA et al. (2009f) add that the latest Commission proposal on new RoHS (COM(2008) 809/4) exempts press-fits in Annex V: “11. Lead used in compliant pin connector systems”. They claim that this would be a further proof that feasible substitutes do not exist.

4.11.4 Critical review of data and information

Compliant pin connector systems under the RoHS Directive

ACEA et al. (2009f) put forward that the Commission proposal on the recast of the RoHS Directive exempts the use of lead in compliant pin connector systems (exemption 11), and that this would prove that feasible substitutes are not available. This is not correct. The exemptions listed in this proposed recast just reflect the current status of the RoHS Annex (status May 2009).

As a matter of fact, the Annex of the RoHS Directive was reviewed until end of 2008. Exemption 11 of the RoHS Directive allowing the use of “Lead in compliant pin connector systems" was recommended to be adapted to the scientific and technical progress as follows (Kadesch 2001):

11 a) Lead used in C-press compliant pin connector systems until 30 June 2010, and for the repair, or to the reuse, of electrical and electronic equipment put on the market before 1 July 2010.

11 b) Lead used in other than C-press compliant pin connector systems until 31 December 2012, and for the repair, or to the reuse, of electrical and electronic equipment put on the market before 1 January 2013.

The reviewers' recommendation to restrict the use of lead in compliant pin connectors reflects the fact that viable lead-free solutions are available or foreseeable in the near future for the equipment under the scope of the RoHS Directive (for details see review of exemption 11 in the final review report; Gensch et al. 2009).

The question is whether and how far the scientific and technical assessment resulting in the proposed rewording of exemption 11 of the RoHS Directive is transferable to compliant pin connector systems used in vehicles under the scope of the ELV Directive.

Correlation of exemptions in the RoHS and the ELV Directive

It needs to be clarified whether and how far an exemption for lead in pressfit connectors is justified under the ELV Directive, while solutions are available or foreseeable for equipment under the RoHS Directive.

The different role of the cold welding effect

Compliant pin connectors in most "RoHS" equipment, in particular on complex PWBs like in high end servers, are used among other reasons because pin connections can be repaired and replaced. For repair, rework and upgrade e. g. of servers, the compliant pin connectors must be removable and reinsertable without causing damages to the pins or the plated through holes, and still work reliably (Gensch et al. 2009). Any bonding of the pins to the plated through hole (PTH) due to cold welding effects must be avoided in such uses under the scope of the RoHS Directive (Gensch et al. 2009).

This is a crucial difference between automotive and non-automotive pressfit applications. While cold welding must be avoided in RoHS equipment, it is the aspired effect in automotive pressfit applications. Cold welding of the pins to the pin walls is necessary that the pin connector systems can reliably withstand the mechanical forces enacted onto them due to vibration and temperature changes, and the combination thereof. Pin movement in the holes would result in unreliable functionality.

To achieve the cold welding effect, a higher pressure of the pin to the pin wall is required. This higher pressure entails a higher force to insert the pins into the holes. ACEA et al. (2009o) claim that for pin connectors in telecom equipment typical insertion forces are 20 to

50 N/pin, while automotive pin connectors are inserted with 120 to 150 N/pin. The stronger force, which the pin applies to the wall to induce cold welding, also explains why automotive pressfits generally and in particular with tin surfaces are more prone to whisker growth compared to pressfits in RoHS equipment. Whiskers are a consequence of internal or external compressive stress onto the surface tin layer. The higher compressive stress onto the pin and the wall surfaces in automotive applications increases the risk of whisker growth.

Next to increased forces, only specific combinations of metallizations are appropriate to achieve cold welding. In case of lead-free surfaces, the stakeholders claim chemical tin surfaces on the printed wiring board in combination with galvanized tin on the pin to be the metallization combination warranting efficient cold welding with superior processability. As, according to the stakeholders, this combination results in whisker growth under the described automotive conditions, leaded metallizations are without alternative for the time being and for the near future in automotive applications of compliant pin connectors. Lead-containing metallizations combine moderate insertion forces due to the lubrication effect of lead with efficient cold welding properties and higher whisker resistance compared to lead-free surface metallizations. The lubrification effect of lead improves the ratio of insertion force to the force the pin enacts onto the pin walls. The insertion force at identical force between the wall and the pin is lower compared to lead-free surfaces.

Gold surfaces, which are more resistant to whisker growth, would increase the insertion forces even more. Given the already higher insertion forces in automotive applications, gold surfaces may even more easily result in damages during the insertion process. The higher insertion forces of gold surfaces are a problem already in RoHS equipment at lower, but still increased insertion forces compared to lead-containing pin connectors (Gensch et al. 2009).

What remains to be clarified is why the automotive industry rejects gold surfaces due to their insufficient cold welding properties (ACEA et al. 2009n), while the stakeholders in the RoHS Annex review reject gold surfaces with the argument that they would result in bonding of the pin to the PTH of the PWB (Gensch et al. 2009). Possibly, the RoHS stakeholders were talking about gold surfaces without nickel underlayer between the gold and the copper, while the ELV stakeholders refer to nickel gold surfaces. The nickel underlayer between the copper and the gold surface reduces diffusion between the gold and the copper. During the review of the RoHS Annex in 2008/2009, the gold surfaces were not further investigated, as the RoHS stakeholders had announced lead-free substitutes until end of 2012, and as gold surfaces had been rejected due to the higher insertion forces compared to tin-lead or pure tin surfaces.

Geometrical changes to reduce insertion forces

The insertion and retention forces could in principle also be aligned changing the geometrical dimensions of the pins and the pin hole. The pins could be made smaller, and the holes be made bigger. Lead-free materials with a higher friction (no lubrication from lead) could thus be inserted at lower forces. The higher friction would result in higher static friction increasing the retention forces, which could then promote the cold welding effect. It is, however, not clear if cold welding would still occur under these conditions.

The stakeholders explain that there are narrow limits to geometrical adaptations (Warburg 2009b). The pin hole diameters as well as the pressfit diameters are well aligned to each other in order to balance insertion forces and the pressure required to achieve the cold welding effect. The printed wiring board manufacturers can only change the hole diameters in steps of 0,05 mm. For example, the pin hole diameter may be 1,00 to 1,09 mm, the pin diagonal 1,16 to 1,24 mm. An increase in the pin hole diameter for 0,05 mm would result in an overlap of only 0;02 mm. Such a pin connect would not be reliable (Warburg 2009b).

It could not be clarified whether and how far further adaptations of the pin diameter might allow a better alignment. It is, however, clear that the automotive industry in this case depends on the supplies and on the technical possibilities and limits of their suppliers. The state of technology and the specific requirements of pressfit applications in the vehicle industry put limits to geometrical changes.

Environmental impacts of gold

The stakeholders explain that, besides the adverse properties described above, is not a viable option from the environmental point of view (Warburg 2009a). Gold is – due to its physical properties and excellent conductivity – the material of choice in some applications within electronics. Anyway, the replacement of other materials by gold should be assessed carefully before realization. The production of gold causes significant emissions and requires huge amounts of energy. This might overcompensate environmental benefits due to reduced lead content. The production of 1 kg gold consumes approx. 400 000 MJ of primary energy, compared to e.g. 20 MJ for lead (Warburg 2009a).

Within the MEEuP Project, carried out for the European Commission in connection with the EuP legislation, experts stated reduction of gold as clear goal for environmental friendly design of electronics (Warburg 2009a).

From the review point of view, the above would only justify an exemption if the environmental impact from substituting lead by gold would outweigh the environmental benefits of the substitution. As gold is not considered as a technically viable substitute, such environmental aspects were not further investigated and clarified in this review process.

4.11.5 Final recommendation exemption 8 C (ii)

It is recommended to grant the exemption. The specific operational conditions – vibration and thermomechanical stress – in automotive applications of compliant pin connector systems require cold welding between the pins and the hole surfaces. Cold welding, in contrary, must be avoided in pin connector systems used in RoHS equipment. This application specific difference justifies a continued exemption for the use of lead in line with Art. 4 (2) (b) (ii), although the equivalent exemption no. 11 in the RoHS Directive is recommended to expire in 2012 latest.

The reviewers recommended the following wording for the exemption:

Lead in compliant pin connector systems; review in 2014.

The review in 2014 is recommended as the stakeholders state that lead-free alternatives are under development.

4.12 Exemption no. 8 a – stakeholder proposal part C (iii)

"Lead used in soldering on glass for non glazing application"

4.12.2 Description of exemption

ACEA et al. (2009d) apply for an exemption for "Lead used in soldering on glass for non glazing applications". "Non-glazing applications" demarcates the requested exemption from exemption 8b, currently still exempting the use of lead for soldering on glass in vehicles. The stakeholders propose the review of the exemption after 2015 (ACEA et al. 2009d).

The exemption is applied in Mass Airflow Sensors (MAF) used to measure the mass of air entering an internal combustion engine, mainly in diesel engines. The engine management system needs the airflow information to optimize the engine with regard to fuel efficiency and emissions.

The typical method of mass-airflow sensing is hot-film or hot-wire anemometry: A flow sensing element consisting of an electrically heated hot film or hot-wire is heated to a defined offset temperature relative to the ambient temperature, which is determined by a separate temperature sensor. As the airflow cools the hot film or hot wire, the power needed to keep the sensing element at the offset temperature is a measure of the mass air flow passing the sensor (ACEA et al. 2009d).