Supplemental information ("entry 8j details file")

As mentioned in the comprehensive submission for entry 8j this document gives some background information and details. To enable identification of different enclosures within this stakeholder consultation we give every enclosure of this document here the suffix 8j_detail_information. For making reading and transmission of this submission document easier, we embedded all enclosures into this document. For further publication we ask to separate the enclosures in own files.

The index of contents is:

1. Main glass panes types of automotive glazing

   1.1 Toughened glass [1]

   1.2 Non toughened, semi-toughened or laminated glass

2. Mechanical demands to laminated glass in a vehicle

   2.1 Additional demands to soldered joints in laminated glazing structures in a vehicle

2. Soldering of contacts in laminated glass structures of vehicles

3. Environmental aspects of used lead solder

The following enclosures are used:

Enclosure 8j D01: Application examples of contacts in laminated glazing structures.

Enclosure 8j D02: Test results solder joints leaded and lead-free for laminated and toughened glass.
(kindly provided by JAMA).

Enclosure 8j D03: Technical and legal demands (non exhaustive)

Enclosure 8j D04 : Literature /technology screening

Enclosure 8j D05: Critical review of indium life cycle assessment

Enclosure 8j D06: Results of previous consultations and annex II revisions

General remark:

The last assessment for lead in glazing applications was conducted around two years ago and the final report was finished in March 2012. This is why we consider our arguments sent to that consultation still as valid and wish to make reference to our last contributions.

[1] Source Wikipedia term toughened glass http://en.wikipedia.org/wiki/Toughened_glass; 21.09.2013.

1. Main glass panes types of automotive glazing

For automotive glazing mainly following glass variants are in use:

- Toughened or “tempered” or “single side safety” glass
- Laminated glass

The chemical basis are variants of sodium silicate glass. Additional functional layers may be applied on the glass e.g. for reflecting heat from sun radiation or heating purposes. For light weight demands a reduction of pane thickness is aspired. This may be in inference with vehicle torsional stiffness demands.

Vehicle glazing is safety relevant and regulated by different type approval demands (see Enclosure 8j D03: Technical and legal demands (non exhaustive)).

1.1 Toughened glass [2]

The mechanical strength of toughened glass is increased compared to regular glass by thermal or sometimes chemical treatment. By tempering the glass imbalanced internal stresses are formed. These stresses effect that if the glass is broken, it crumbles into small pieces, instead of shards[3]. The small pieces are less likely to cause injuries. Toughened glass can bear up to five times more mechanical stress than regular glass [4].

Toughened glass is used in architectural applications, household applications and in vehicles windows e.g. rear or side window screens or sunroofs.

Toughened glass is thermally and physically stronger than regular or non-toughened glass. This based on the effect that the higher contraction of the glass core during manufacturing induces compressive stresses on the surface of the glass balanced by tensile stresses in the body of the glass (see figures 1.1.1 and 2.1).

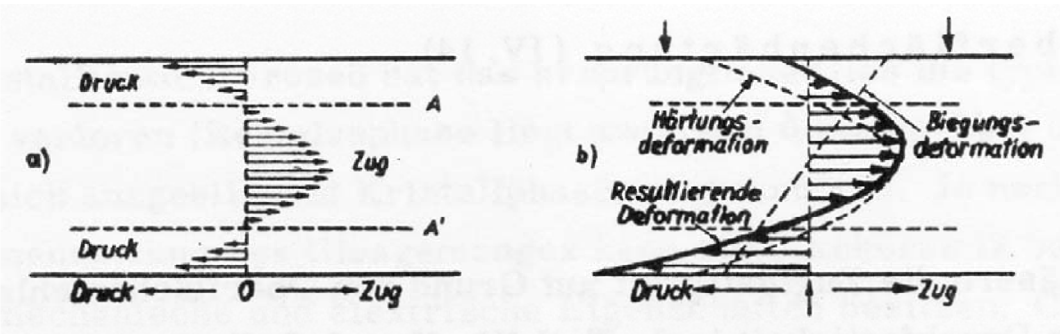

Figure 1.1.1: [5] *mechanical stress distribution in thermal toughened glass.*
left: specimen without external stress load
right: specimen under flexural stress.

These compressive stresses on the surface of a toughened glass also have the effect that a pane can bear more mechanical load. The stress level and the stress distribution depend on the thermal treatment and cannot be fixed to one exact value. The tensile stress has its highest values at the edge of a pane. So the

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[2] Source Wikipedia term toughened glass http://en.wikipedia.org/wiki/Toughened_glass; 21.09.2103.
[3] Web pages guardian https://www.guardian.com/GuardianGlass/GlassSolutions/LaminatedSafetyandSecurityGlass/index.htm 21.09.2013
[4] Web pages Pilkington http://www.pilkington.com/europe/uk+and+ireland/english/products/bp/bybenefit/safety-security/toughenedglass/default.htm 21.09.2013
[5] Source : University of Erlangen-Nürnberg: Oel, Schaeffer: Glas Leitfaden zur Vorlesung Glas und Keramik II Institut für Werkstoffwissenschaften Lehrstuhl III Glas und Keramik Abschnitt IV34 ; Erlangen 1981

glass is most susceptible to breakage due to damage to the edge of the glass where the tensile stress is the greatest.

The higher the surface tension, the smaller the glass particles will be when the glass is broken.

A toughened vehicle pane has a thickness typical around 3 mm [6]. Geometry of toughened glass has to be established before toughening.

1.2 Non toughened, semi-toughened or laminated glass

Glass for Europe gives following definition for laminated glass:

“Laminated glass is made of two or more layers of glass with one or more "interlayers" of polymeric material bonded between the glass layers. “ …

Laminated glass offers many advantages. Safety and security are the best known of these, so rather than shattering on impact, laminated glass is held together by the interlayer. This reduces the safety hazard associated with shattered glass fragments, as well as, to some degree, the security risks associated with easy penetration. But the interlayer also provides a way to apply several other technologies and benefits, such as coloring, sound dampening, resistance to fire, ultraviolet filtering and other technologies that can be embedded in or with the interlayer.” [7]

Vehicle applications of laminated glazing structures are e.g. windshields, safety and bullet proof glazing (details see Enclosure 8j D01: Application examples…).

The basis for production of laminated glass is annealed glass. Annealed glass is the basic flat glass product that is the first result of the float process.[8] Between two glass panes of non toughened glass a PVB foil is embedded and then normally assembled via an autoclave procedure at around 140 °C and 15 bar barrel pressure. Within the laminated glazing structure the PVB foil plays an active role.

Additional functional layers on the glass may be applied to enable specific properties like reduction of optical reflection, enhanced repelling of water, protection of adhesives by black ceramic prints against UV-radiation induced degradation, general reduction of transmission of solar radiation or for heating. [9]

There is a variance of values due to given and inevitable production tolerances and different production technologies. Typical values for thickness of laminated automotive glazing structures are 5 to 6 mm for the composite and around 2mm per pane.

So properties of laminated glass are different from toughened glass and laminated glazing structures are much more sensitive to mechanical load and mechanical stress. Further details and test results are given in enclosure 8j D02: test results solder joints leaded and lead-free for laminated glazing structures and toughened glass.

2. Mechanical demands to laminated glazing structures in a vehicle

The internal stress in laminated glass is not uniform and varies with the edge distance (see figure 2.1).

[6] Braess, Seiffert . Handbuch Kraftfahrzeugtechnik 2. Auflage vieweg Verlag Braunschweig /Wiesbaden 2001 S. 587 f

[7] Source: http://www.glassforeurope.com/en/products/main-types-of-glass.php#3 05.10.2013

[8] Source: http://www.glassforeurope.com/en/products/main-types-of-glass.php#3 05.10.2013

[9] Source: http://www.agc-automotive.com/english/products/amfm.html 05.10.2013

Positive results with the same solder and connector can fail with the change of the position of the solder joint on the same glass.

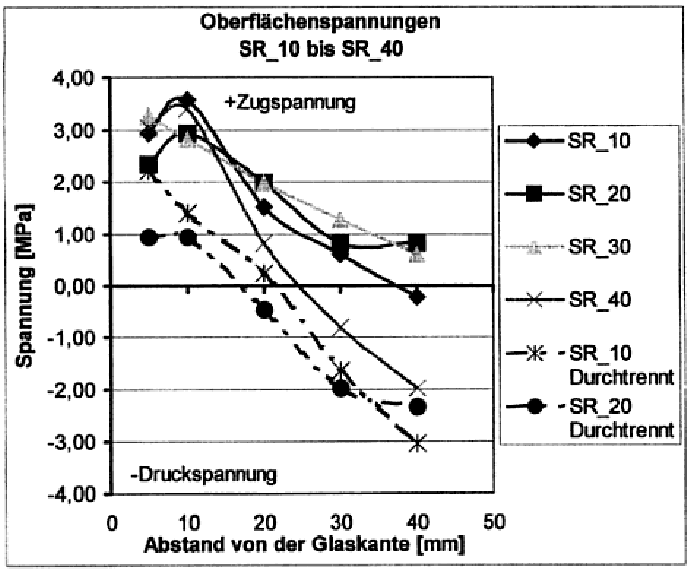

Figure 2.1 : Stress versus edge distance in laminated glazing (source: Georg Bauer, Opel Rüsselsheim 2003;use here with permission of the author; graph also published in G. Teicher et alt : "Glas im Automobil" [10])

There are limited areas (e.g. not in screen field of vision, packaging constraints, design requirements for hiding contacts /making contacts invisible) on the glass pane where a contact can be located. So it may be compulsory to locate the position of contacts in an area of higher stress levels (or in addition to narrow the size of contacts). That area may have high values of mechanical tensile stress and in consequence cause a failure of electrical contacts, because the composite is limited in bearing mechanical loads.

For use of laminated glazing structures in vehicles different types of mechanical stress have to be considered, like:

- "Static" stress from production (glass residual stress e.g. caused by temperature gradients)
- Different mechanical stress levels of mechanical load on a windshield from car body and windscreen mounting in a car body
- Stress of thermal expansion of glass, foil, contacts and surrounding materials and car body
- "Dynamic" stress by operational loads of vehicle use like wind, rain, snow, vibrations and of torsional stress from vehicle body movements during vehicles operation
- Dynamic working load of assembled components e.g. windscreen wiper, mirrors or camera systems during vehicle operations
- Temperature load of heating devices and caused sharp temperature gradients
- Different types and intensity of defrost systems
- Impacts of particles, like small stones, meeting the windscreen.
- Stress distribution over area and wall thickness (-> torsion stiffness) of glass pane

These operational stresses are in interference with specific complex geometries and mechanical stress on contacts. Therefore tests on component and on vehicle level under different climates are necessary to scrutinize the reliable function of the laminated glass system and of the electrical contacts.

[10] G. Teicher: Glas im Automobil ; Haus der Technik Fachbuch Band 23 Expert Verlag 2003

2.1 Additional demands to soldered joints and contacts in laminated glazing structures in a vehicle

Beside the thermo-mechanical stress endurance further aspects have to be considered. So the reliability of joints may not be constraint by corrosion of the solder or by failure via low cycle thermo-mechanical fatigue.

Furthermore different electrical load levels on the contacts e.g. heater or specific antenna functional demands need to be respected.

All contacts have to fulfill the specifications of the vehicle producer, who is responsible for the long term vehicle reliability and endurance of safety relevant electrical functions of vehicles on the road.

On vehicle level there is an ongoing target to minimize vehicle and vehicle component weight in order to reduce CO2 emissions of a vehicle. In future this can effect the use of even more thinner glass panes and reduced stiffness of the thinner glass panes in laminated glazing structures. The lower resulting stiffness will sharpen the risks of glass breakage in sequence of CTE mismatch.

3. Soldering of contacts in laminated glazing structures of vehicles

For soldering in laminated glass structures lead-based solder has been the standard solder technology for several decades and extensive knowledge has been gained on the practical and theoretical aspects of its use. So the use of lead-based solder is state of the art today for contacts in laminated glazing structures of vehicles. Lead-based solder can compensate thermo-mechanical stress resulting from different coefficients of thermal expansion (glass, lead-free ceramic prints, polymer foils, solders, metallic contacts) and has good wettability properties. To relieve the thermo-mechanical stress solders with a lead content of around 60 to 70% wt are in use. Figure D 3.1 and D 3.2 picture the differences in stress levels on soldered contacts for toughened and non-toughened (annealed) glass.

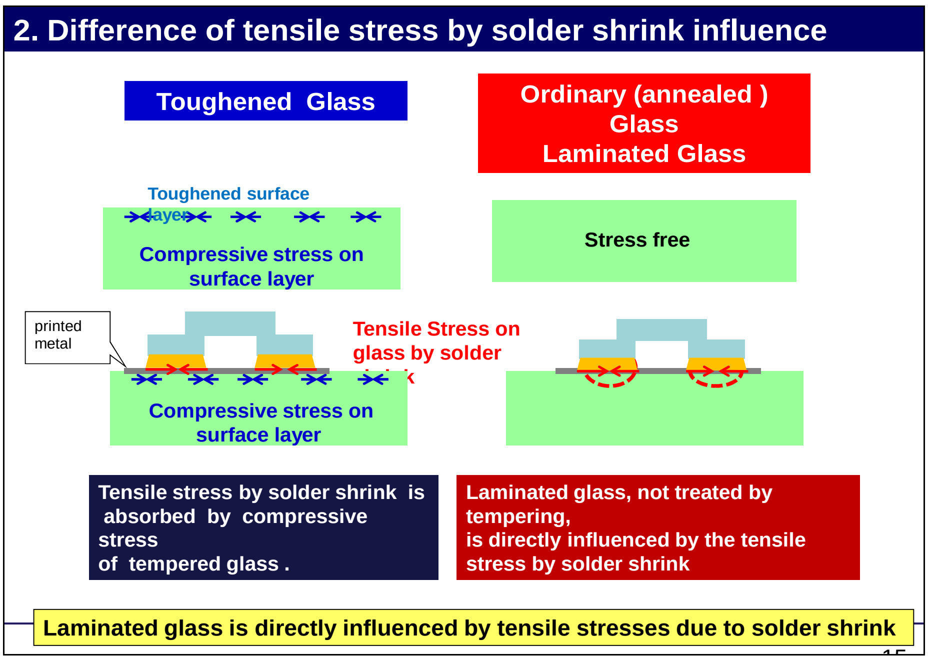

Figure D 3.1: Distribution of thermo-mechanical stress in toughened glass and non toughened laminated glazing structures (schematic) source JAMA

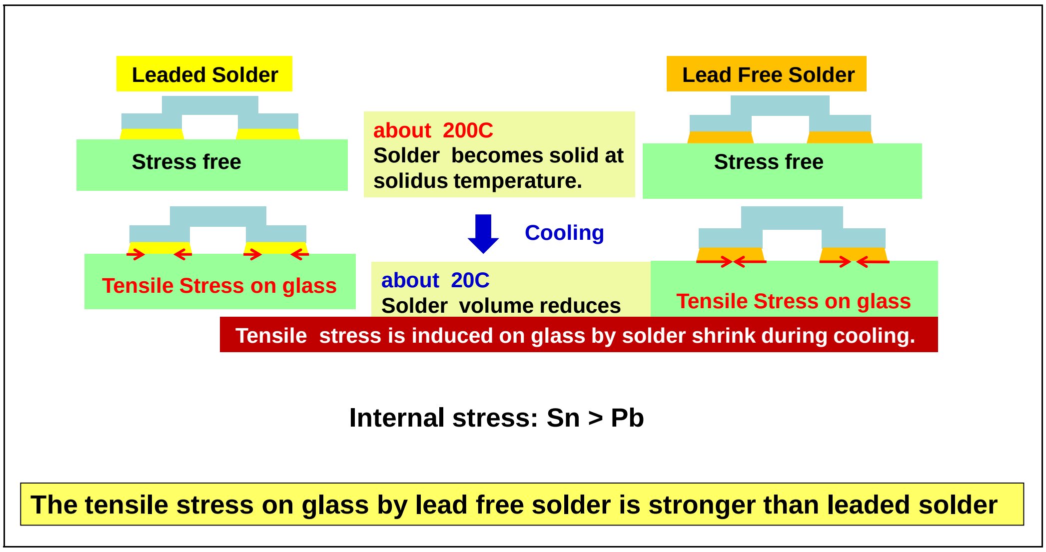

Figure D 3.2: Difference in tensile stress between lead- and lead-free solders (schematic) source JAMA

In some applications of laminated vehicle glazing use of lead-free solders could be established yet but for the majority of applications use of lead-free soldering technology is still a very challenging issue and needs to be solved component and vehicle specific due to the reasons specified above.

The situation seems to be similar to attaching contacts to photovoltaic cells, where lead free soldering of busbars is also reported as an issue that has not yet been resolved sufficiently. Pb solders are still widely used.

During last revision of entry 8i Indium-based solders could not prove suitability for a generic solution for lead free soldering for vehicle glazing. The study of PE International on Life Cycle Assessment of the indium production process in the meantime has undergone and successfully passed on May 14th 2012 an external critical review (see Enclosure 8j D05) by Prof. Finkbeiner from University of Berlin according ISO 14040 and ISO14044 principles. It can be provided on request. At our opinion any potential substituting solution ending in higher overall lead emissions compared to the existing one is no option and offends the aim of the substance restrictions in the ELV directive.

4.0 Environmental aspects of used lead solder

Use of lead and lead emissions during production procedures are very well covered by European occupational health legislation and binding limit values therein. There is no significant lead fume emitted at soldering temperatures that are used for Pb containing solders. During product use there is no release or leaching of lead. In vehicle recycling operations the lead solder applied in laminated glazing structures will mainly stick to the metallic contacts and enter existing metal recycling procedures. In difference to electronic scrap in Europe end-of –vehicles enter well defined utilization routes starting with a certificate of utilization which is issued by registered vehicle dismantlers. In addition there are defined procedures for ELV´s material fractions in combination of codes for waste fraction categories. Only companies who are allowed to process a waste fraction may process the material and any residue from treatment operations may go to specific treatment or disposal only.

Enclosure 8j_D01: ***Application examples of contacts in laminated glazing structures.***

Below the different electrical contacts in laminated glazing structures are listed and detailed.

(1) Heated Wire Windshield or Backlite:
The technology is used to defrost/defog the entire windshield or backlight.
Thin tungsten wires are embedded onto the interlayer materials (e.g.: polyvinyl butyral (PVB)) with solder connections to copper strip bus bars. All is assembled between two plies of glass.

(2) Windshield Wiper De-icer Wire:
The technology is used to defrost the windshield wiper area in rest position.
Thin tungsten wires are embedded onto the interlayer materials (e.g.: PVB). Connectors are soldered to the busbar plate in a local area at the edge of the screen. Then connectors are covered by sealant.

(3) Wire Antenna:
The technology is used for radio/TV reception system on windshield.
A metallic wire (usually made of copper) is embedded on the surface of the interlayer material (e.g; PVB) that is between the two plies of glass. A connector is soldered to the metallic wire.

(4) Heated Coated Windshield:
The technology is used to defrost/defog the entire windshield.
A metallic coating is heated by an electrical current. The electricity is applied through connectors soldered/ welded on busbars in contact with the coating. All is assembled between two plies of glass including an interlayer material (e.g.: PVB)

(5) Windshield Wiper De-icer Printed:
The technology is used to defrost the windshield wiper area in rest position.
Silver ceramic grid lines are printed on inner glass surface and heated up by an electrical current. Connectors are soldered to the silver ceramic bus bar in a local area at the edge of the screen. Then connectors are covered by sealant.

(6) Antenna Printed:
The technology is used for radio/TV reception system on windshield, laminated sidelite or laminated backlite.
A silver print conductive pattern is printed on the occupant compartment side surface. A connector is soldered to the antenna on glass.

(7) Heating Device Circuit on surface 4:
The technology is used to defrost the windshield on a local surface, for instance a heating pattern for camera area on windshield.
A silver print conductive pattern is printed on the occupant compartment side surface. A connector is soldered to the silver print pattern on glass.

(8) Heating pattern on backlight:
The technology is used to defrost/defog the laminated backlight.
A silver print conductive pattern is printed on the occupant compartment side surface. Connections are soldered to the silver print busbar on glass.

(9) Capacitive Coupling Connectors Soldered on Position 4

This is a new development which is the final stage of development and intended to be introduced in a pilot application into the European market during the year 2014. A capacitive coupling connector is soldered on side 4 but not directly connected with used silver structure reception inside the glass pair. The connector therefore interacts like a capacitor.

Application examples cont´

In the following section for visualization purposes by hand of some graphics application examples of electrical contacts in laminated glass structures are pictured:

Integration of digital antenna

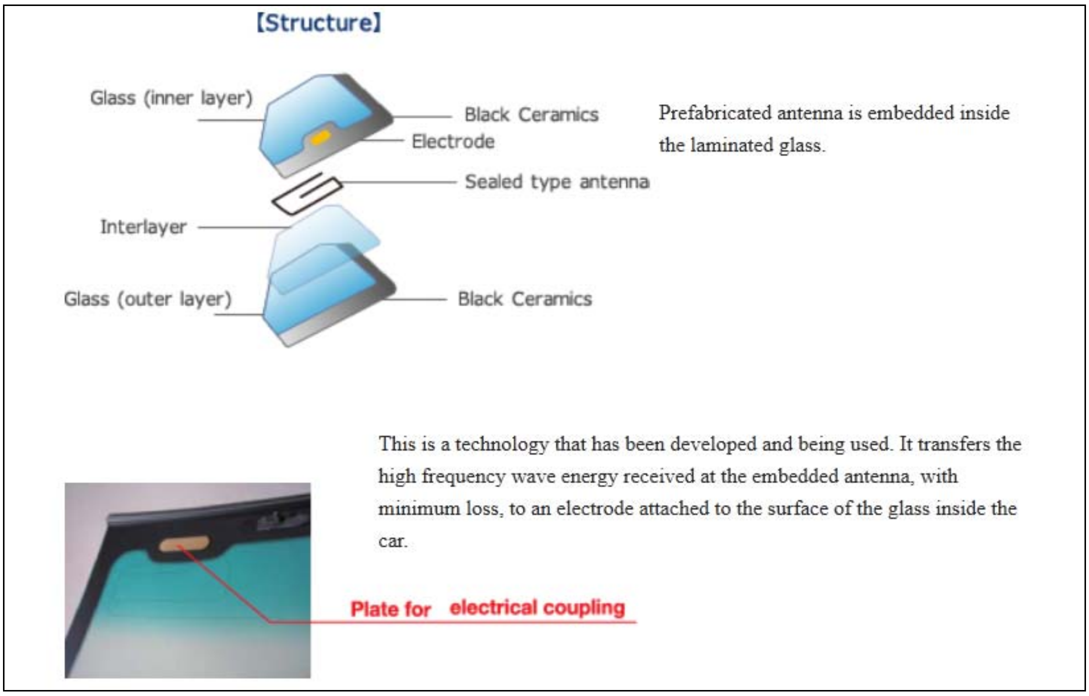

Figure D 01-1: Integration of digital antenna ; source AGC webpages : http://www.agc-automotive.com/english/products/dtv.html 05.10.2013 use with permission of AGC;

Heated Coated Windshields

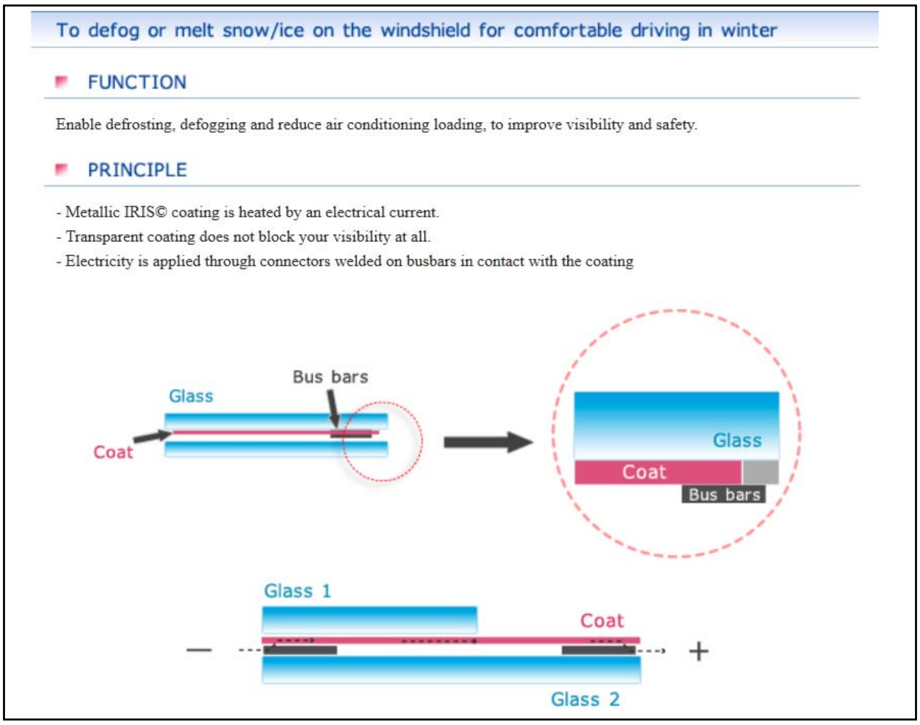

Figure D 01-.2: Heat Coated Windshield ; Source: AGC webpages http://www.agc-automotive.com/english/products/coated.html 05.10.2013; use with permission of AGC;

Heated Wire Windshields

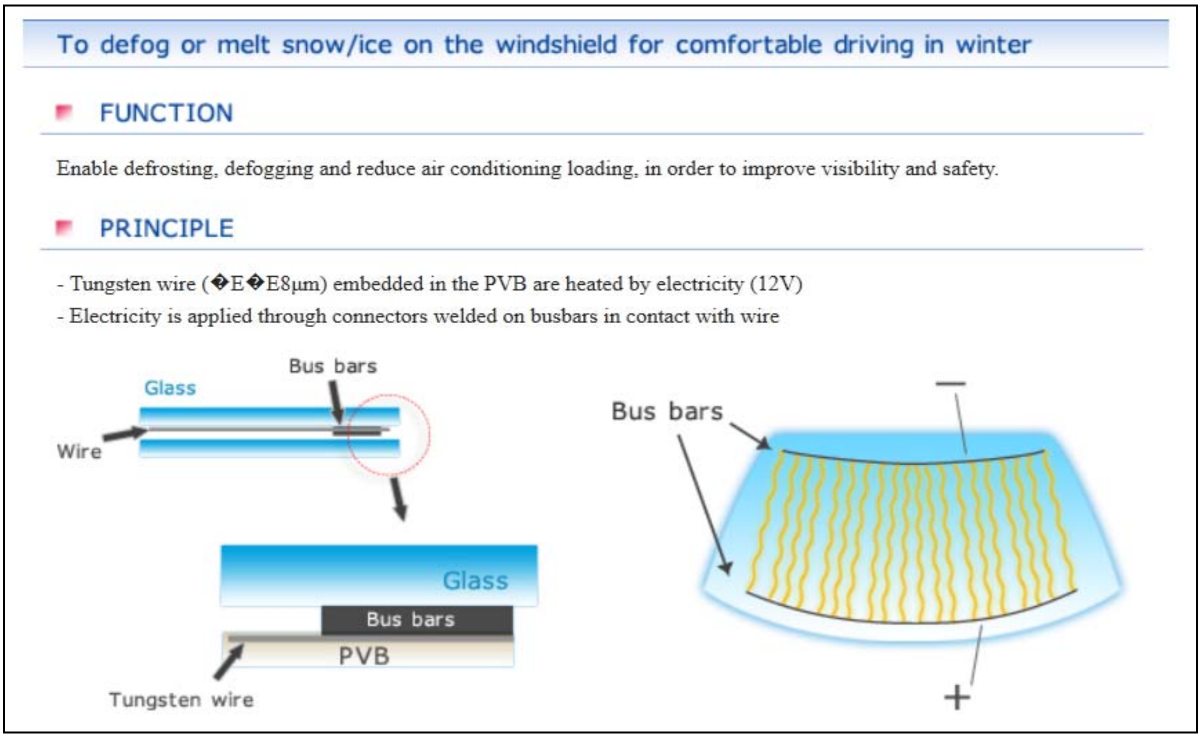

Figure D 01 -3: Heated wire windshield; source: AGC webpages http://www.agc-automotive.com/english/products/ wires.html 05.10.2013; use permitted by AGC;

De-Icer Windshield

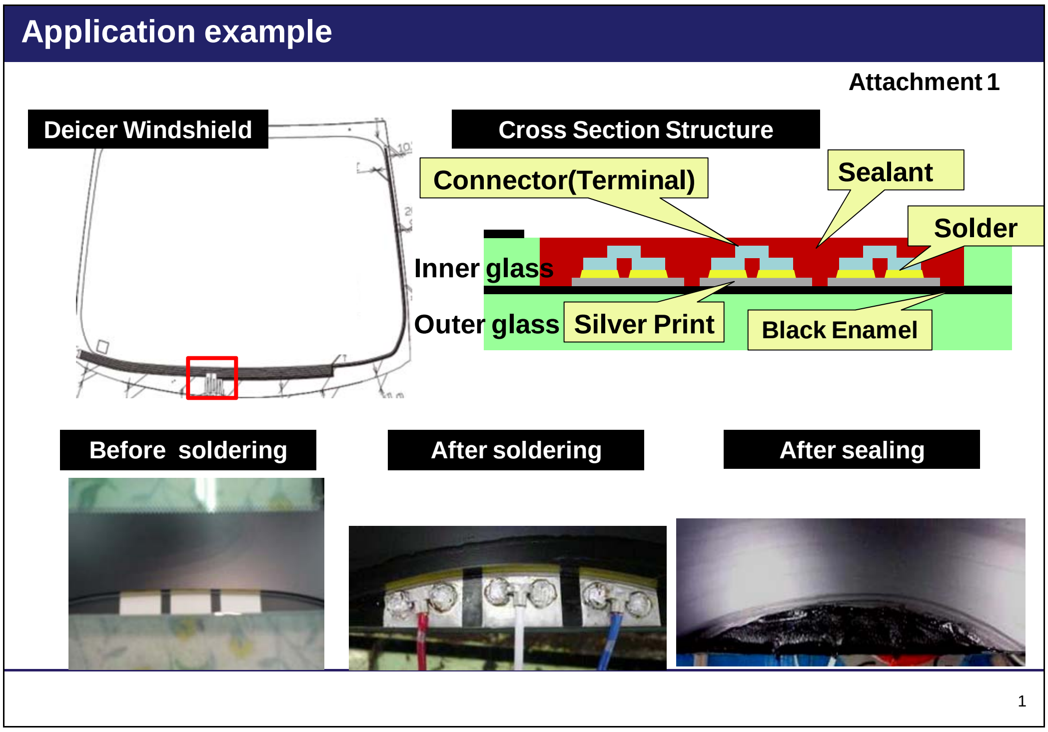

Figure D 01-4: Application example de-icing of windshield (kindly provided by JAMA)

Windshields with heated wiper /Camera area

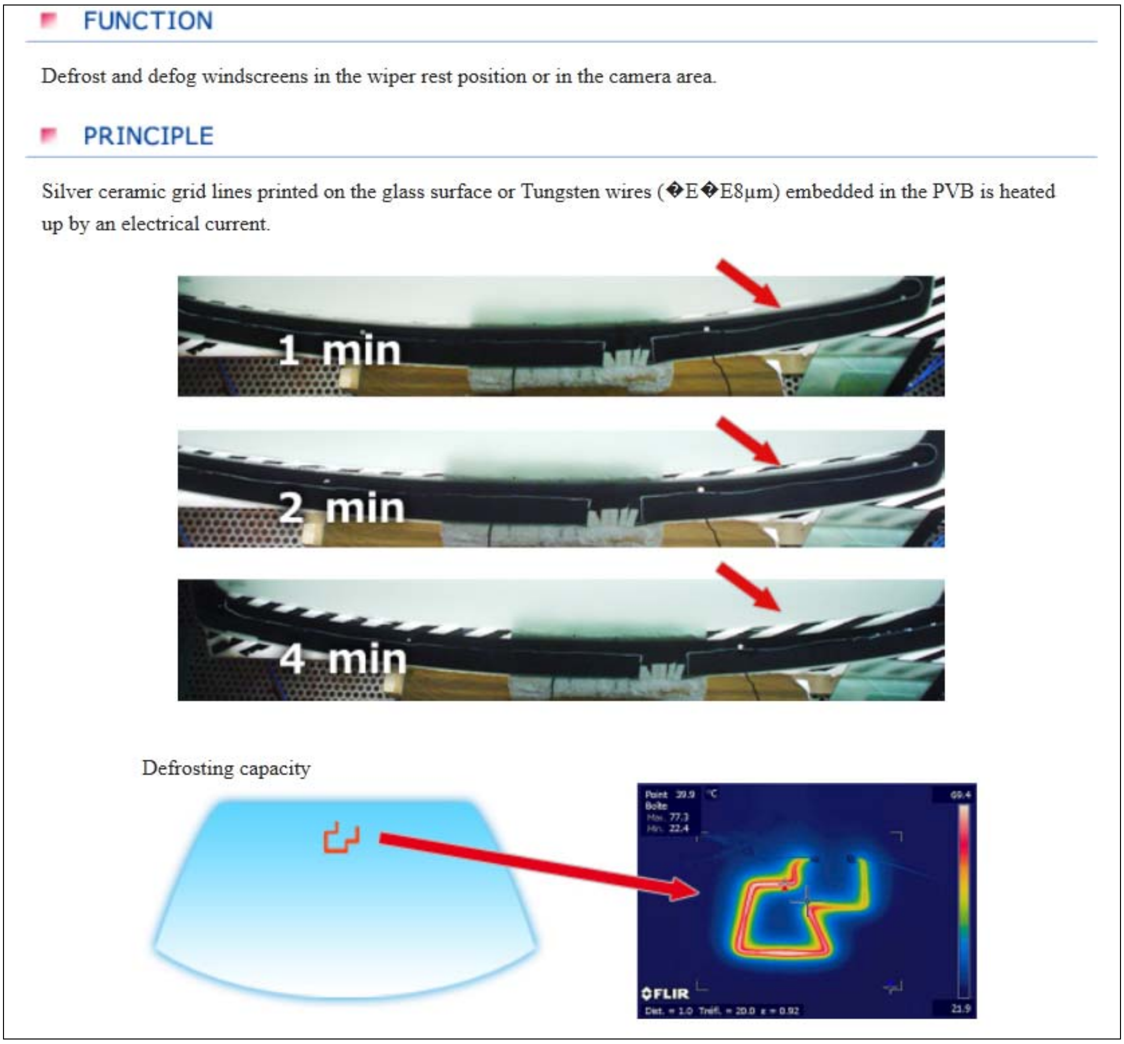

Figure D 01-5: Heated wire windshield; source: AGC webpages http://www.agc-automotive.com/english/products/ wires.html 05.10.2013; use permitted by AGC;

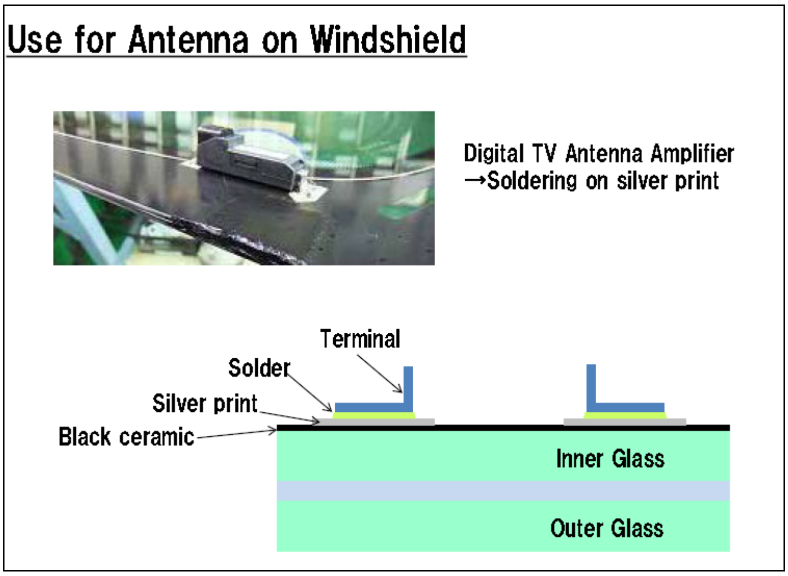

Figure D 01-6: Application example contacting antenna on windshield (kindly provided by JAMA)

Enclosure 8j D02: Test results leaded and lead-free solder joints for laminated and toughened glass (kindly provided by JAMA).

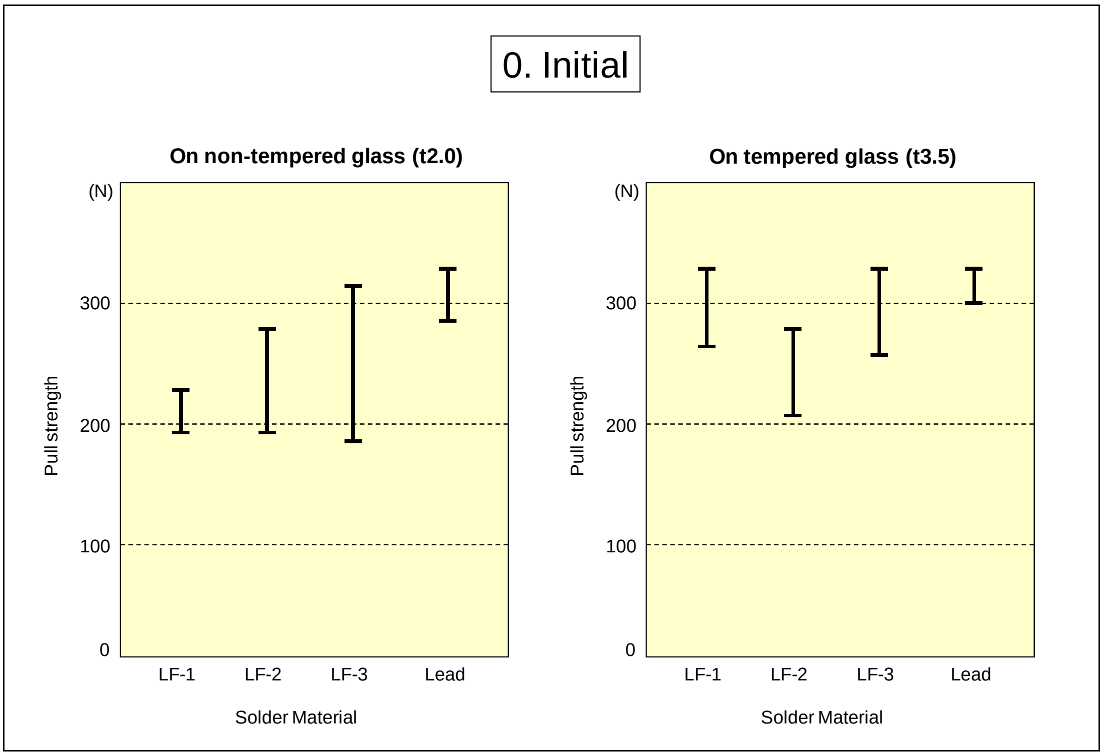

Figure D02-1: Results of pull tests; left: non-tempered glass right: tempered glass (LF = lead-free)

Figure D02-1 shows that solder joints on non-tempered (= non-toughened) glass have a lower pull strength level and a broader range of deviations compared to solder joints on tempered glass. Highest levels of pull strength are achieved with lead based solder and lead based solder joint have lower scattering of values. The specimens are illustrated in figure D02-2.

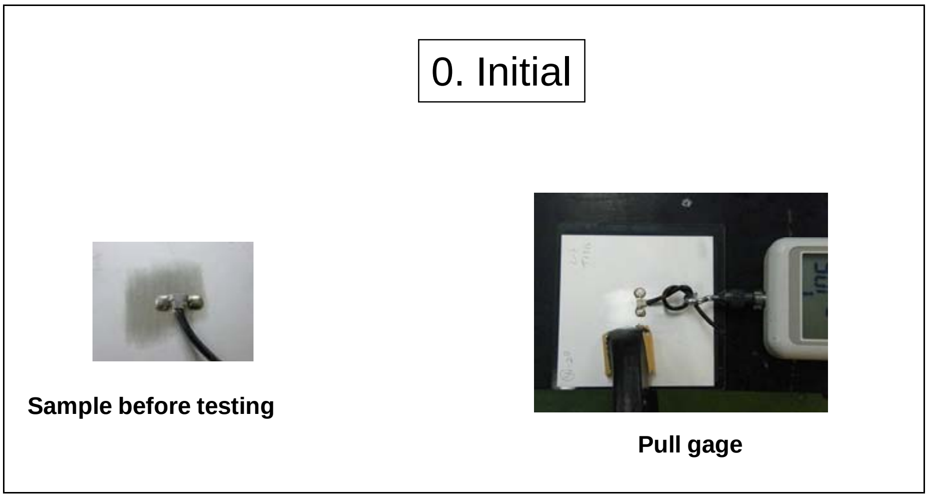

Figure D02-2: Test specimen details

A significant change in pull strength behavior results after physical ageing by heat cycle (see figure D02-3).

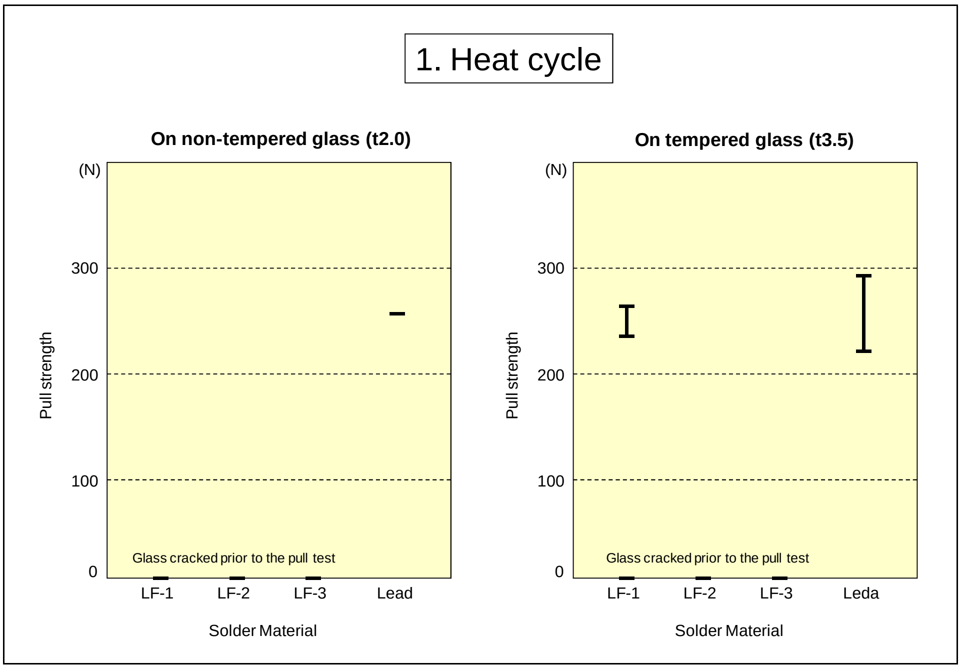

Figure D02-3: pull strength test results after heat cycle.

Figure D 02-3 gives test results after physical ageing by heat cycle. The pull strength level is lower in general. The heat cycle load caused crack of non-tempered glass for lead-free soldered contacts whereas the lead-based solder is still OK (left picture). On tempered glass one lead-free solder and the lead-based solder passed the test and two lead-free solder failed resp. caused crack of glass.

In figure D02-4 cracks in the screen starting from the solder joint – caused by CTE mismatch and application of lead-free solder are shown.

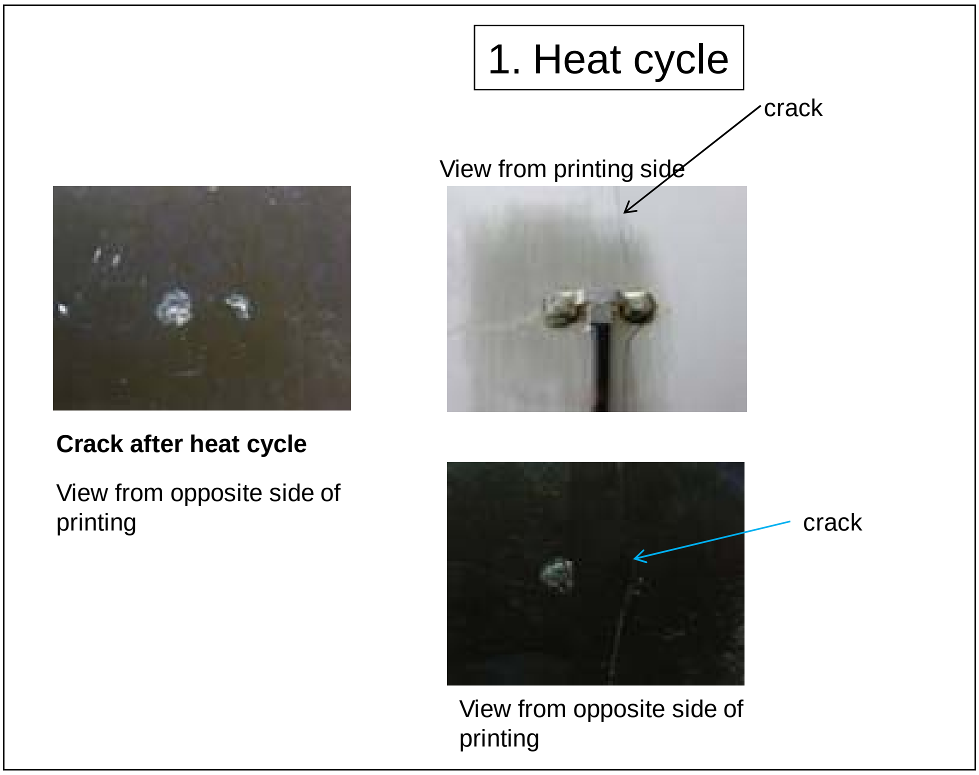

Figure D02 -4: failure of non- toughened glazing structure (LF soldered) after heat cycle.

Also heat shock test resulted in a failure of lead-free soldered joints on non tempered glazing structure (figure D02-5).

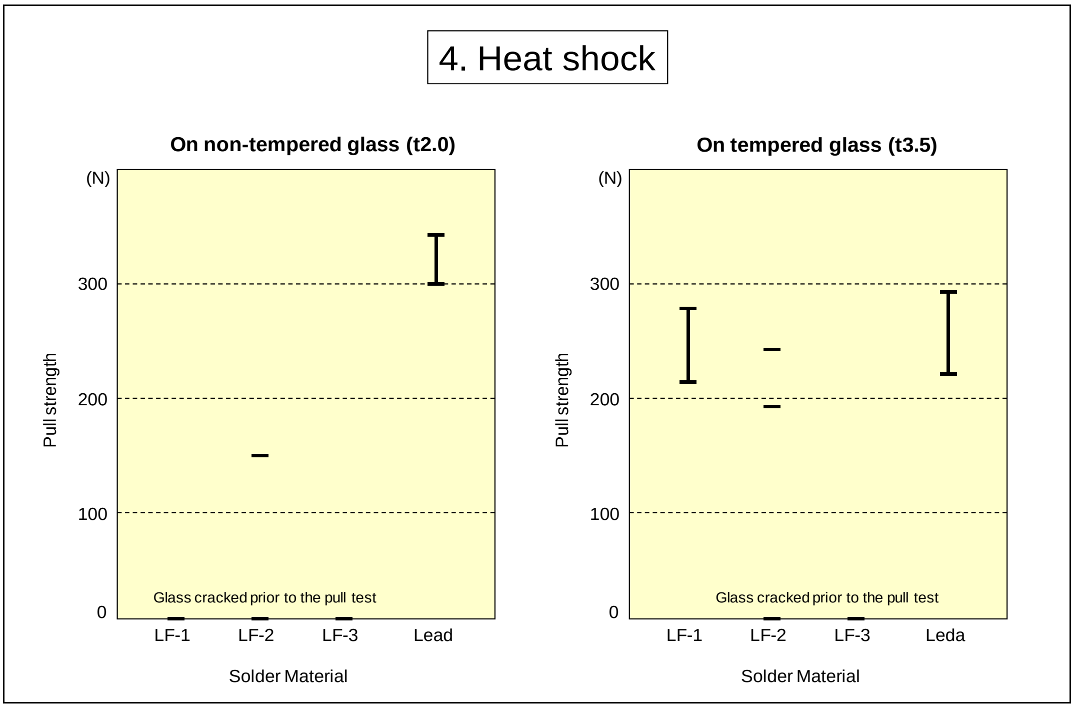

Figure D02-5 pull strength test results after heat shock

Figure D02-6 gives pictures of the broken laminated glazing structure after the heat shock test. The cracks start from the lead-free solder joint.

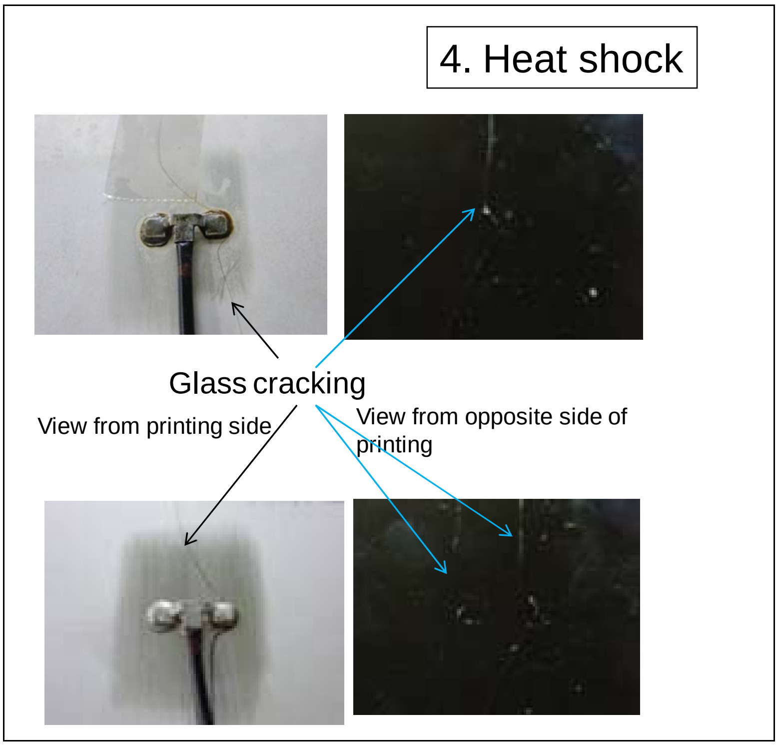

Figure D02-6: failure of glass after heat shock test.

It has to be stated that no lead-free solder was able to achieve the same performance as the reference lead-based solder (state of the art).

The test results are summarized in figure D02-7. The crucial point for lead-free solders in laminated glazing structure was the heat shock test and the heat cycle.

Test Result (3-Companies)

Test Item #→Pull test *(judge@50N)*	3.5t Tempered		2.0t Non-tempered	
	Leaded solders	Lead-free solders	Leaded Solders	Lead-free solders
0:Initial	Passed Passed Passed	Passed Passed Passed	Passed Passed Passed	Passed Marginal Passed
1:Hear cycle	Passed Passed Passed	Marginal Marginal Marginal	Marginal Passed Marginal	Failed Failed Failed
2:Heat soak →High temp.	Passed Passed Passed	Passed Passed Passed	Passed Passed Passed	Marginal Marginal Passed
3:High temp (long time)	Passed Passed Passed	Passed Passed Passed	Passed Passed Passed	Marginal Marginal Passed
4:Heat shock	Passed (N/A) Passed	Marginal (N/A) Marginal	Passed (N/A) Passed	Failed (N/A) Failed
5:Humidity	Passed Passed Passed	Passed Passed Passed	Passed Passed Passed	Marginal Marginal Passed

Figure D02-7: failure of glass after heat shock test.

Source JAMA

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Enclosure 8j D03: Technical and legal demands (Non exhaustive)

Please note that tests have to be passed successfully on component and on vehicle level. At any case positive tests of substitutes in a vehicle are the prerequisite for introduction of a new technology.

Europe (see http://ec.europa.eu/enterprise/sectors/automotive/documents/directives/motor-vehicles/)

- Council Directive 78/317/EEC of 21 December 1977 on the approximation of the laws of the Member States relating to the defrosting and demisting systems of glazed surfaces of motor vehicles.
- Commission Directive 81/643/EEC of 29 July 1981 adapting to technical progress Council Directive 77/649/EEC on the approximation of the laws of the Member States relating to the field of vision of motor vehicle drivers.
- Commission Directive 88/366/EEC of 17 May 1988 on the adaptation to technical progress of Council Directive 77/649/EEC on the approximation of the laws of the Member States relating to the field of vision of motor vehicle drivers.
- Commission Directive 90/630/EEC of 30 October 1990 adapting to technical progress Council Directive 77/649/EEC on the approximation of the laws of the Member States relating to the field of vision of motor vehicle drivers.
- Council Directive 92/22/EEC of 31 March 1992 on safety glazing and glazing materials on motor vehicles and their trailers.
- Commission Directive 2001/92/EC of 30 October 2001 adapting to technical progress Council Directive 92/22/EEC on safety glazing and glazing materials on motor vehicles and their trailers and Council Directive 70/156/EEC relating to the type-approval of motor vehicles.
- Commission Regulation (EU) No 672/2010 of 27 July 2010 concerning type-approval requirements for windscreen defrosting and demisting systems of certain motor vehicles and implementing Regulation (EC) No 661/2009 of the European Parliament and of the Council concerning type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor.

USA

- ***FMVSS 103*** "Windshield Defrosting and Defogging Systems" U.S. DEPARTMENT OF TRANSPORTATION, NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION (specifies requirements for windshield defrosting and defogging systems to ensure that each vehicle shall have a windshield defrosting and defogging system).
- ***FMVSS 205*** "Federal Motor Vehicle Safety Standard 205 – Glazing Materials" (reduce injuries resulting from impact to glazing surfaces, to ensure a necessary degree of transparency in motor vehicle windows for driver visibility, and to minimize the possibility of occupants being thrown through the vehicle windows in collisions)
- ***FMVSS 212*** "Windshield Mounting" (establishes windshield retention requirements for motor vehicles during crashes. The purpose of this standard is to reduce crash injuries and fatalities by providing for retention of the vehicle windshield during a crash, to keep vehicle occupants within the confines of the passenger compartment.
- ***FMVSS 226*** "Ejection Mitigation" This final rule establishes a new Federal Motor Vehicle Safety Standard No. 226, "Ejection Mitigation" to reduce the partial and complete ejection of vehicle occupants through side windows in crashes, particularly rollover crashes.

Japan

- Attachment 29 “Technical Standard for Direct Front Field of Vision” to the Announcement that Prescribes Details of Safety Regulation for Road Vehicle
- Attachment 37 “Technical Standard for Window Glass” to the Announcement that Prescribes Details of Safety Regulation for Road Vehicle
- Article 68 “Rear-View Mirrors, etc.” of the Announcement that Prescribes Details of Safety Regulation for Road Vehicle.
- Attachment 84 “Technical Standard for Windshield Wiping and Washing Systems for Passenger Motor Vehicles, etc.” to the Announcement that Prescribes Details of Safety Regulation for Road Vehicle
- Attachment 86 “Technical Standard for Defrosting and Demisting Systems” to the Announcement that Prescribes Details of Safety Regulation for Road Vehicle

China

- ***China CNCA-04C-028:2006*** IMPLEMENTATION RULE FOR COMPULSORY CERTIFICATION OF SAFETY GLASS PRODUCTS Implemented on Jul.12, 2006 Certification and Accreditation Administration of the People's Republic of China

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OEM specific test routines (example; source VDA/ OEMs)

Requirements for electrical contacts with lead-free soldering at toughened and laminatead glass

1. **Temperature cycling test**
according to DIN EN ISO 16750-4-H section 5.3.1.2

Temperature of climate chamber -40 to +105 °C,
humidity not controlled (dry)
Min. 60 cycles
Electrical current loading with 14 V (+/- 0.2) starting at end of low temperature phase
Temperature-time following current loading eg. acc. VW 80101

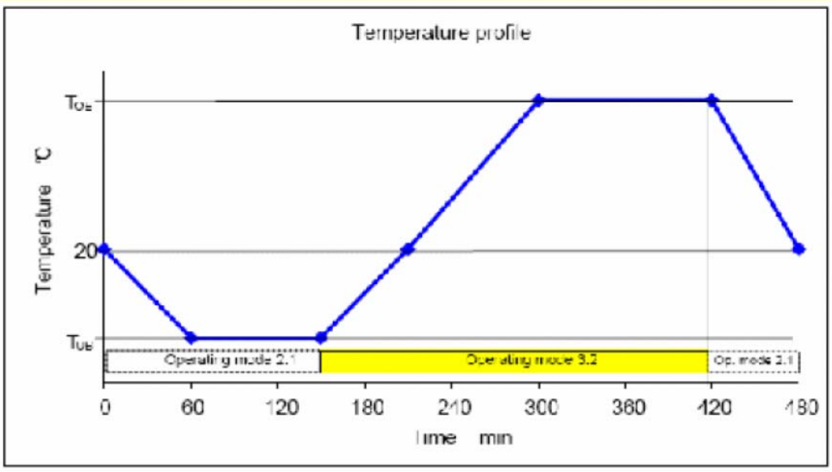

Figure 19 – Temperature profile

Table 21 - Temperatures and durations of a temperature cycle

Time (min)	Temperatures (℃)
0	20
60	T_{uB}
150	T_{uB}
210	20
300	T_{oB}
420	T_{oB}
480	20

T_{uB} : - 40 °C
T_{oB} : +105 °C

2. Heat soak test
according DIN EN ISO 16750-4-K, section 5.1.2.2

Temperature of climate chamber: 105 °C
Test time at 105 °C inside chamber: 96 hours
Electrical current loading with 14 V (+/- 0.2) throughout the test for heater connectors, only

Mechanical load to soldering joints during heat storage:
position of screen horizontally, inside down
Mechanical load: vertical down, directed as acceleration of gravity
Pull forces: 3 N for antenna connectors, DWA
10 N for heater connectors (14 V)

3. High temperature storage test
Considers recent investigated max. data for thick dark tinted glass and requirements for adhesives testing (Polurethane for glass bonding).
Duration: 24 h
Temperature: 120 °C

4. Long term test without electrical load
(purpose of test: Dissolution of silver print and solder)
Temperature of climate chamber: 105 °C
Test time at 105 °C inside chamber: 500 hours
Electrical current loading with 14 V (± 0.2) throughout the test

5. Heat shock test
following DIN EN ISO 16750-4-H

Splash water test following section 5.4.2
Temperature of climate chamber: 105 °C, 1 hour
Temperature of splash water: 23 °C ± 5 °C or lower (from refrigerator)
Number of cycles: 10, checks after 5, 10
Dry samples after every cycle.
Can be done on lab samples (difficult with backlites).

6. High Humidity test: constant climate
following DIN EN ISO 6270-2-CH

Storage at constant climate: 80 °C, humidity >96 %RH)
Duration: 500 hours
electrical load: 14 V 15 min. every 24 h, first cycle after 10 hours

7. Resistance to screen washer fluids:

Test fluid: Immersion in or continuous wetting with glass washing liquid consisting of:

- 69,5 Vol% water
- 20 Vol% ethanol
- 10 Vol% Isopropoanol
- 0.09% weight %sodium lauryl sulphate
- 0.5% Vol% ethylene glycol

Duration of immersion or wetting: 24 hours at 23 °C
pre-conditioning: 24 hours at 23 °C

8. Salt spray test
according to DIN EN ISO 9227

Salt spray test (neutral): duration: 96 hours

After every test 1-7:
Test of the mechanical stability of the soldered contacts
pull test perpendicular to glass surface/to contact surface: 10 N for antenna, DWA
50 N for heater connectors (14 V)
no failure at the soldered contacts (test is also passed by breakage of the connector cable)

Enclosure 8j D04: Literature /technology screening

Whereas several technologies proposals can be found in the correspondent technical literature this technology screening had the target to identify, if there is an approved solution for lead-free soldering technologies in laminated glazing structures outside the automotive industry available in volume production thus enabling a technology transfer. Outside of the automotive industry only one application for soldered electrical applications in laminated glazing structures could be identified. This is the production of photovoltaic cells. According to our findings for current PV volume production using lead-free soldering technology is still an R&D issue.

We refer to actual webpages of the Fraunhofer Center for Silicon Photovoltaic (Fraunhofer-Center für Silizium-Photovoltaik CSP)[11] informing that lead-free soldering of photovoltaic modules is still subject of research projects. As well University of Saarbruecken runs a projects until 2015 for the development of RoHS compatible solder technology for contacts of solar cells[12] .

According to further findings of the Fraunhofer ISE published during an researchers workshop, which took place in Constance on May 7th and 8th, 2013 (see http://www.metallizationworkshop.eu/), as paper http://www.secondmetal.eu/fileadmin/secondmetal/docs/Session6/4_Mondon.pdf adding of an additional Nickel layer may have a potential for solving the issue. This metallization conference project reports give further interesting and promising triggers for further approaches in identification of the right solutions for laminated automotive glazing structures. It may be estimated that the outcome of actual research project results enables a sufficient solution within a few years and helps solving the issue finally.

[11] http://www.csp.fraunhofer.de last accessed 2013 10 03; **Silizium-Solarzellen**: Bei der Produktion von Solarzellenmodulen entsteht ein nicht unerheblicher Anteil von Ausschuss durch Prozessfehler in der Fertigung. Besonders beim Löten der Kontakte im Tabber/Stringer-Verfahren zerbrechen die Solarzellen häufig. Dieses Kontaktierverfahren wird umso anfälliger, je dünner die Siliziumzellen sind, oder wenn nichttoxische, bleifreie Lote genutzt werden. Im Rahmen des Projektes werden besser geeignete Kontaktierungsprozesse für die Serienverschaltung von kristallinen Solarzellen erarbeitet. Dazu wird ein Simulationstool entwickelt, mit dem die entsprechenden physikalischen Prozesse und werkstofftypischen Reaktionen abgebildet werden können. Gleichzeitig werden experimentelle Prüfstände entwickelt, um beispielsweise die Kriecheigenschaften der eingesetzten Lote zu bestimmen. Das Projekt läuft bis Mai 2013 am Fraunhofer-Center für Silizium-Photovoltaik CSP in Halle. http://de.wikipedia.org/wiki/Fraunhofer-Center_f%C3%BCr_Silizium-Photovoltaik; 2013/10/03

[12] **BMU-Verbundprojekt:** Entwicklung einer Verfahrenstechnik und -ausrüstung zur Verschaltung von Rückseitenkontaktsolarzellen auf flexiblen Verdrahtungsträgern unter der Verwendung einer ROHS-konformen bleifreien Löttechnologie; **Teilvorhaben:** Simulation mechanischer Beanspruchungen während der Bearbeitung; **Laufzeit:** 1.12.2012 – 30.11.2015; **Projektpartner:** Siemens, Krempel, Seho, Fraunhofer CSP; Universiät des Saarlandes; Förderkennzeichen 0325376A; 0325376C; 0325376F; 0325376G; 0325376H

Enclosure 8j D05: critical review of indium life cycle assessment

Details can be provided on separate request.

Critical Review of the study

LIFE CYCLE ASSESSMENT OF THE INDIUM PRODUCTION PROCESS

Commissioned by:	The European Automobile Manufacturers Association - ACEA Brussels, Belgium
Reviewer:	Prof. Dr. Matthias Finkbeiner, Berlin, Germany
Reference	ISO 14040 (2006): Environmental Management - Life Cycle Assessment - Principles and Framework ISO 14044 (2006): Environmental Management - Life Cycle Assessment – Requirements and Guidelines

The Scope of the Critical Review

The reviewer had the task to assess whether

- the methods used to carry out the LCA are consistent with the international standards ISO 14040 and ISO 14044
- the methods used to carry out the LCA are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the goal of the study,
- the interpretations reflect the limitations identified and the goal of the study, and
- the study report is transparent and consistent.

The review was performed according to paragraph 6.2 of ISO 14040 and ISO 14044, because the study is not intended to be used for comparative assertions intended to be disclosed to the public.
This review statement is only valid for this specific report received on 11.05.2012 with the exception of Supplement B, which provides information which goes beyond the cradle-to-gate study of Indium.
The analysis and verification of individual datasets is outside the scope of this review.

***Enclosure 8j D06:* Development of results of previous consultations and annex II revisions**

Development Lead in solder	
2000/53/ EC 18.09.2000	*Lead and lead compounds in components:* 11. Solder in electronic circuit boards and other applications unlimited exemption
ekopol I study: Lohse, Sander, rntke: Heavy metals in vehicles; page ff 27.03.2000; Oekopol Hamburg	“There is no solution for replacing leaded solders that would fit..” “ A total ban of lead containing solder cannot be recommended”
Oekopol II study: Lohse, Sander, Wirts: Heavy metals in vehicles II; page 24 ff July 2001; Oekopol Hamburg	“electrical components which contain lead in a glass or ceramics matrix compound”. Proposed as new entry; “ “Due to the variety of applications with widespread functions in this field a general substitution of lead is not expected to be possible. Alternatives have to be proven on a case by case basis. “
2002/525/EC 27.06.2002 1 revision annex II	*Lead and lead compounds in components:* 11. Solder in electronic circuit boards and other electric applications; unlimited exemption; 14. Electrical components which contain lead in a glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs; unlimited exemption
2005/673/EC 20.09.2005 2nd revision annex II	*Lead and lead compounds in components:* 8. Solder in electronic circuit boards and other electric Applications; unlimited exemption 11. Electrical components which contain lead in a glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs; unlimited exemption
2008/689/EC 01.08.2008 3 rd revision annex II	8(a). Solder in electronic circuit boards and other electrical applications except on glass Vehicles type approved before 31 December 2010 and spare parts for these vehicles (review in 2009) **8(b). Solder in electrical applications on glass Vehicles type approved before 31 December 2010 and spare parts for these vehicles (review in 2009)** 10. Electrical components which contain lead in a glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs; unlimited exemption
2010/115/EU 23.02.2010 4th revision annex II	“ split into 10 more specific applications. Out of these, five materials and components containing lead should continue to be temporarily exempted from the prohibition set out in Article 4(2)(a) of Directive 2000/53/EC, since the use of these substances in those specific materials and components is still technically or scientifically unavoidable. It is therefore appropriate to prolong the expiry date of these exemptions until the use of the prohibited substances becomes avoidable.” *Lead and lead compounds in components* 8(a). Lead in solders to attach electrical and electronic components to electronic circuit boards and lead in finishes on terminations of components other than electrolyte aluminum capacitors, on component pins and on electronic circuit boards; Vehicles type approved before 1 January 2016 and spare parts for these vehicles ; 8(b). Lead in solders in electrical applications other than soldering on electronic circuit boards or on glass Vehicles type approved before 1 January 2011 and spare parts for these vehicles. 8(c). Lead in finishes on terminals of electrolyte aluminium capacitorsVehicles type approved before 1 January 2013 and spare parts for these vehicles; 8(d). Lead used in soldering on glass in mass airflow sensors Vehicles type approved before 1 January 2015 and spare parts of such vehicles; 8(e). Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead); unlimited exemption and review; 8(f). Lead in compliant pin connector systems; unlimited exemption and review; 8(g). Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages; unlimited exemption and review 2014; 8(h). Lead in solder to attach heat spreaders to the heat sink in power semiconductor assemblies with a chip size of at least 1 cm^2 of projection area and a nominal current density of at least 1 A/mm^2 of silicon chip area; unlimited exemption and review 2014;

	8(i). Lead in solders in electrical glazing applications on glass except for soldering in laminated glazing; Vehicles type approved before 1 January 2013 and spare parts for these vehicles (2012) 8(j). Lead in solders for soldering in laminated glazing unlimited exemption and review 2014; 10. Electrical components which contain lead in a glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs; unlimited exemption;
2013/28/EC	Expiry date of entry 8i amended to 1.1.2016 due to technical needs

⇨ 2003 unlimited exemption for all electrical lead in solder applications.
2008 application for glass separated
2010 split of solder for glass applications into entry 8i (exp. date 1.12013) and 8j (revision in 2014)
2013 expiry date entry 8i changed from 1.12013 into 1.1.2016.

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__Consultant Position on laminated glass from 2008:__

In the 2008 Oeko-Institute report we find on page 59:

"…

For soldering on printed silver layers, it must be further on distinguished between laminated and tempered glass products. Soldering on tempered glass is much more difficult than on laminated glasses, as tempered glass is much stronger than laminated glass.

…

The opinion that soldering on toughened glass is much more difficult is estimated to be based on a misunderstanding.