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Heavy Metals in Vehicles II

Final Report

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Executive Summary

Directive 2000/53/EC on End-of-Life Vehicles aims at the prevention of wastes from vehicles and at the reuse, recycling and other forms of recovery so as to reduce the disposal of waste, while at the same time improving the environmental performance of all of the economic operators involved.

More specifically, Art. 4 (1) of the Directive states that "in order to promote the prevention of waste Member States shall encourage, in particular, (a) vehicle manufacturers, in liaison with material and equipment manufacturers, to limit the use of hazardous substances in vehicles and to reduce them as far as possible from the conception of the vehicle onwards, so as to in particular prevent their release into the environment, make recycling easier, and avoid the need to dispose of hazardous waste (...)."

Art. 4(2)(a) continues that "Member States shall ensure that materials and components of vehicles put on the market after 1 July 2003 do not contain lead, mercury, cadmium or hexavalent chromium other than in cases listed in Annex II under the conditions specified therein."

Annex II contains a list of 13 applications of the four substances lead, mercury, cadmium and hexavalent chromium which are exempted from Article 4(2)(a) either generally, or up to a certain concentration or absolute mass limit. For five applications, the exemption is granted only under the condition that they will be "labelled or made identifiable in accordance with Article 4(2)(b)(vi)" with the purpose of stripping them from end-of-life vehicles before further treatment in order to avoid unwanted contamination of the material streams which result from the recycling operations. Annex II further mentions five applications which are to be examined as a matter of priority, three of which refer to potential additions to the list of 13 applications and two of them to potential deletions, in order to establish as soon as possible whether Annex II is to be amended accordingly.

The purpose of this study is to provide the Commission with technical information in view of possible amendments of Annex II of the Directive 2000/53/EC of the European Parliament and the Council of 18 September 2000 on End of Life Vehicles (ELVD).

The main results of the study presented herewith show that Art. 4(2)(a) of the ELV Directive has indeed highlighted an area where significant improvements with respect to reduced use of hazardous substances can be achieved, thus leading to an improved recyclability of vehicles and a better environmental performance in the recycling sectors, as well as resulting in "cleaner" waste to be disposed of. Many of today's applications of the problematic substances can in fact be avoided or substituted, even if this may require a certain period of time in some cases.

The discussions around the evolving ELV Directive have already exerted a strong stimulus on industry to avoid the problematic substances, either by directly substituting them, or at least by taking up research for alternatives which had been neglected in recent years.

In addition to the concepts of general exemption, exemption up to a certain limit, exemption with mandatory labelling and dismantling which are already contained in Annex II, the present report suggests the concepts of

- mandatory dismantling if a certain maximum allowable amount (of lead per car) is exceeded,
- temporary exemptions until a specified date,
- stepwise phase-out for complex fields of application where some uses of a substance are easier to avoid than others.

For a number of entries in the list of Annex II, some minor rewording is suggested in order to be technically more precise and avoid misunderstanding, and additional entries are suggested for the two applications of "lead in wheel balance weights" (temporary until 1/7/2004) and "electrical components which contain lead in a glass or ceramics matrix compound". Among the latter, PZT ceramics around the engine shall not be restricted, but mandatory labelling and dismantling is suggested for applications on the chassis if a maximum amount of 30 g lead from this source is exceeded, because applications on the chassis are likely to reach the shredder light fraction. A similar requirement for labelling and dismantling above a threshold value of 30 g per vehicle is proposed for "solder in electronic circuit boards and other electrical applications".

A deletion from Annex II is proposed for lead-containing coatings inside fuel tanks.

Several new applications were submitted by industry during the course of the study. For some of these, temporary exemptions until a specified date are proposed.

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1 Introduction

Directive 2000/53/EC on End-of-Life Vehicles aims at the prevention of wastes from vehicles and at the reuse, recycling and other forms of recovery so as to reduce the disposal of waste, while at the same time improving the environmental performance of all of the economic operators involved.

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Starting from January 2001 Ökopol has been performing this second study on heavy metals in vehicles which was commissioned by DG Environment of the European Commission.

The purpose of this study is to provide the Commission with technical information in view of possible amendments of Annex II of the Directive 2000/53/EC of the European Parliament and the Council of 18 September 2000 on End of Life Vehicles (ELVD).

This final report provides detailed information about possibilities for a substitution of cadmium, mercury, hexavalent chromium and lead contained in vehicles including:

- information concerning the quantity of heavy metals in the mentioned applications;
- the analysis whether technical alternatives to the use of heavy metals exist;

- the examination of the technical, environmental and economic implications of these alternatives;
- the examination of technical options for separation of heavy metal containing parts before shredding, description of technical recycling options, and the analysis of their economic implications.

This report deals with the five applications which are listed in the paragraph following the table in Annex II of the ELV Directive, with the items mentioned in the table of Annex II, and with some additional applications which were brought forward by industry representatives in the course of the study.

A previous study on the subject had been performed by Ökopol in the year 2000. On that study, the European Commission had received some reactions. Additionally every Member State was invited to send their reactions. Formal reactions on the 2000 study are documented in Annex IV.

During the work there have been numerous meetings and an intense information exchange with technical experts from car producers and supplier companies as well as with several industry associations. Annex II contains a list of official meetings, Annex III a list of official information requests which were sent out during the study, and Annex V shows a non-exhaustive list of companies, stakeholders and associations we have been in contact with.

Altogether, a very constructive working atmosphere has been established and we gratefully appreciate the very good support which we have received from industry.

2 Priority applications listed in the paragraph following the table of Annex II

2.1 Aluminium containing lead

Field of application and product description

Leaded aluminium alloys are used in a variety of applications in cars. Most of them are applications where lead is added for improved machinability. Additionally, some rare applications have been mentioned where lead is added because of decorative aspects (for example exterior trim parts of a car).

Annex II of the ELV-Directive mentions two different items:

- a general exemption for lead in Aluminium with a maximum lead content of 0.4% by weight (item 2);
- a more specified exemption for wheel rims, motor parts and window levers with a maximum content of 4% by weight (item 3).

Subject of this chapter are exclusively those applications where lead is deliberately added.

Conclusions of previous study

- There are sound reasons to allow a certain concentration of lead in secondary aluminium.
- No necessity was found to tolerate lead concentrations of 4% for wheel rims and window levers.
- A maximum lead content of 1% for Aluminium for machining purposes was found to be sufficient.

Work progress

One technical paper was presented by a supplier concerning master cylinder pistons, load apportion valves and drum brake wheel cylinder bodies. It was proposed to reduce the percentage mentioned in Annex II to 0.7% for vehicles put on the market after 1 July 2003 and to 0.4% for vehicles put on the market after 1 July 2007.

Another technical paper was presented by a non-ferrous metal producer association which proposes a rewording of the item in the Annex II to „Aluminium alloys for machining containing up to 2.5% lead by weight". There have been numerous discussions and intense information exchange with a non ferrous metal industry Association, producers of Aluminium, suppliers and car producers. On 16.3.2001 a meeting was held at the Ökopol office with representatives and experts from the non-ferrous metal industry.

Results

AMOUNTS

Leaded aluminium alloys are used in a wide variety of applications. Some examples from the field of free cutting aluminium are cylinders and pistons for brake systems (gross production of roughly 10,000 to 20,000 t/y in Europe), automatic transmission valves (5,000 to 10,000 t/y), hydraulic pumphouse for roof systems (>1,000 t/y), hydraulic clutch house and -ring (>1,000 t/y) or cylinders and pistons for air conditioning systems.

The following list gives different examples for the weight of some applications made of lead containing aluminium:

- master cylinder pistons = 60 g / car
- load apportion valves in a car = 200 g / car
- drum brake wheel cylinder bodies = 200 g / car

Obviously the given values are depending on the size of the car and brake system configuration. No overall estimations of ranges of lead in aluminium per car are available.

Standardised alloys are used (Table 1). Usually the maximum contents mentioned in the standards are not exhausted.

Table 1: Lead content in different aluminium standards [wt%]

	minimum content	maximum content	usual minimum content	usual maximum content
AA6012	0.4	2.0	1.2	1.5
AA6262	0.4	0.7	0.5	0.7
AA2011	0.2	0.6		
AA2030	0.8	1.5		
EN-AW 2007	0.8	1.5	1.0	1.4

The overall usage of lead alloyed aluminium for machinery purposes for European built cars can be roughly estimated between 25,000 t/y and 35,000 t/y in Europe. If a lead content between 0.4 % and 2 % is taken as a basis the lead amount will be between 100 t/y and 700 t/y.

Some rare cases have been reported where lead as an alloy might be added to achieve a certain decorative effect for example at decorative automotive exterior trim parts (lead content up to 3%). Discussions with experts exhibited that, in any case, the lead content in these applications is significantly lower than 3% (probably less than 0,4%).

No case was found where windows levers are made of aluminium with a relevant lead content aside of those parts where lead is added for machining purposes. In those cases the lead content corresponds to the above mentioned alloys.

Like in the previous study, it was not possible to identify wheel rims and motor parts as applications using aluminium alloy with 4% lead in current car production.

Alternatives

From a technical point of view machining of lead free aluminium was described as possible. One possibility is the full renunciation of lead without using substitutes. In this case far reaching changes will have to be made at the production process.

While a certain percentage of lead in aluminium may facilitate the production process, the characteristics of the finished product may be influenced in a negative way by the presence of lead. In the past this fact has already lead to a renunciation of lead even in some of those applications which are produced with a relevant part of machining. Those changes have been proven to be possible even at difficult applications (e.g. drilling of wholes with a length/diameter ratio of >60) and are realised in a mass production scale.

The second route is to substitute lead in free machining aluminium alloys by tin and / or bismuth. Those alternative alloys are already in use. Only one tin alloy (USA 6020) exists as a standard. It was said by some producers that in other alloys lead could be replaced 1:1 by tin.

Raw material costs for substitutes are higher than the costs of lead (see Annex I). If pure aluminium is used the raw material costs will be lower. The costs for the revamp of the production process which will occur in both cases. The real production costs will rise in those cases where lead is not replaced by substitutes and 'pure' aluminium is used.

Different actors pointed out that the price of the finished product may rise mainly during the phase of process revamp and may reach the same level as aluminium with lead as an alloy after some time.

Safety aspects are an important factor to consider for the timeframe which is needed for the phase-out. It is obvious that this period can be much shorter for parts which are not relevant for safety purposes (such as applications with a merely decorative effect). Three steps are to be distinguished in the phase out procedure before the part will be released by the manufacturer: further material testing, changes in the production process, testing of the part in cars.

Environmental relevance

No detailed balance data are known about the fate of aluminium with lead as an alloy during the recycling process. But in general, it is likely that most aluminium will end up in the shredder heavy fraction and as an impurity in the shredder scrap and in the shredder light fraction. Transfer of lead from this application into the ferrous scrap and the shredder light fraction is therefore considered to be of minor importance, and only the shredder heavy fraction respectively the fate in the secondary aluminium process needs to be further discussed.

The fact that lead is an unwanted tramp element with negative characteristics in secondary aluminium did not lead to a renunciation because a dilution has been always possible and the amount of lead is seen as too small to endanger the functionality of the aluminium cycle in the foreseeable future.

However the aluminium industry has an interest to keep the lead impurities in the secondary aluminium cycle as low as possible. Aluminium scrap containing elevated lead concentrations is therefore either not accepted at all by secondary smelters, or only at a reduced price because further addition of clean scrap is necessary.

Tin is also seen as an unwanted element in the recycling process because it lowers the product quality.. Contents below 0.3 % are most of the times tolerated for casting. Concerning the role in the aluminium cycle the same remarks as for lead are valid for tin. For tin containing shavings a lower price can be achieved. A secondary smelter described a reasonable route by keeping those shavings separately and use them in a recycling for tin alloys.

The tolerated bismuth content from a product quality point of view is around 100 ppm while most of the times 70 ppm are described as a maximum because of necessary tolerances. Concerning the role in the aluminium cycle the same remarks as for lead are valid for bismuth.

Summary and Conclusions

The overall amount of lead in aluminium for machinery purposes in European built cars can be estimated by below 700 t/y.

Technically a substitution of lead in aluminium for machining purposes is considered as possible by a wide range of actors. Either a renunciation of lead or its substitution are possible routes.

In effect, the presence of lead in the recycling process is not so much an environmental problem but rather a question of product quality which will require compensation by “dilution” with cleaner aluminium fractions. However, not much could be gained if lead were substituted by tin because the same problems will be encountered.

In conclusion, a phase-out of lead-containing aluminium alloys appears to be technically possible. In many cases the major environmental benefit will be in the stage of production of aluminium for machinery purposes rather than during the recycling phase.

A crucial point concerning costs is the fact of necessary process revamp.

No application with a lead content of 4% is known and there has been no evidence that aluminium window levers and wheel rims with a relevant lead content play a role in current car production.

A phase out of leaded aluminium alloys seems to be possible from a technical point of view by 2005. A review date shall be included for 2003.

Some rewording of entry N° 3 in Annex II to the ELV Directive is therefore proposed, with a more precise focus on “aluminium for machinery purposes containing up to 2 % lead by weight”.

2.2 Lead in batteries

Field of application and product description

All vehicles with a combustion engine contain a battery which is used as the energy storage system for starting, lighting and ignition (SLI). Casings and connections for these batteries are internationally standardised according to SAE, JIS or EN.

These automotive batteries are operating on the basis of the lead-acid/lead-oxide electrochemical system.

Conclusions of previous study

"No practicable alternatives for lead starter batteries are known that would be available at a mass production level."

Work Progress

In a meeting which was held on 16.03.2001 in Hamburg between Ökopol and a representative of the EUROBAT association, the background arguments behind the written submission of EUROBAT, ACEA and CLEPA were discussed in detail. Additional information was evaluated from recent studies on collection and recycling of lead-acid batteries. Recent trends in this field were evaluated from the proceedings of an expert workshop (RWTH Aachen 2001).

Results

AMOUNTS

According to a technical paper by EUROBAT which was submitted via ACEA / CLEPA / JAMA the average weight of a European lead-acid SLI battery is 13 kg, which corresponds to 8 kilograms of lead whereas Behrendt and Steil (1997) state an average weight of approximately 17 kg. In an average car the SLI contributes more than 90 % of the total mass of lead in a car.

ALTERNATIVES

In the foreseeable future, it is expected that higher voltage systems (42 V) will be introduced in the car´s electrical supply due to modern electronics demands. This may result in the introduction of a system with two separate batteries with different characteristics as an intermediate stage, i.e. one for starting (high power density) and a second one for continuous electricity supply (high energy content). In the long term perspective a general switch to the higher voltage is likely with introduction of an Integrated Starting Generator (ISG). According to experts it is not yet decided which battery technologies will be chosen for 42 V systems. Candidates are a lead acid battery with special performance (e.g. spiral cell constructions), NiMH, Li-ion or so called super capacitor cells. Lead acid-batteries have the advantage of low self-discharging characteristics when compared to other common battery systems which enables starting of the engine also after long parking periods of several month and may therefore be preferred for starting in the foreseeable future.

As a second tendency in the nearer future, it is observed that an additional small battery for purposes of burglar alarm and automatic emergency call will be introduced. This independent battery could be of the size of a torch battery, and for obvious reasons must be hidden in an area which is not easily accessible from outside the car. The aim to hide a battery for burglar alarm might collide with efforts to enable an easy dismantling procedure. Presently, lead batteries for these applications might be preferred by manufacturers because they have a proper ruggedness, a good performance which is relatively temperature independent even at low temperature, and a lower price. Furthermore, their charging voltage (14.3 V) is the same as for the starter battery and therefore no additional charging devices would need to be introduced. The possibility to dismantle these smaller lead batteries is an important issue and information must be available for the dismantler.

Environmental relevance

According to manufacturers the actual dismantling and subsequent recycling of lead-acid batteries is considered to be supported by market forces due to the financial revenue for lead scrap. However, at times of low lead prices (e.g. 1993 to 1995) the achievable payment for lead batteries can be small and thus motivation to remove the battery from each vehicle will be low. Therefore, a monitoring is necessary. However, at present monitoring data on the collection and recycling efficiency for lead-acid batteries are not available for most European Member States.

For Sweden, an increase of the recovery rate by 30 % was reported after implementation of a levy for car batteries (Behrendt & Steil, 1996). However there may have been a certain contribution from stockpiled old batteries which could have distorted the picture. Karlsson (1996) reports about concepts to achieve a closed technospheric flow of lead from lead acid batteries in a case study for Sweden. He concludes that the losses of lead during reprocessing (recycling and production) are small and that collection of old batteries is the main prerequisite to achieve a closed cycle.

Summary and Conclusions

No practicable alternatives for lead-acid starter batteries are expected to be available in the foreseeable future. Batteries based on NiMH and Li-ion have clear disadvantages for the purpose of starting batteries in terms of their technical functionality such as higher discharge currents and higher temperature dependence. Also the price of these might be more than twice that of lead acid batteries.

There is a tendency to introduce additional smaller batteries in vehicles for special applications. Additionally, the trend to split the battery system in continuous power supply and starting power supply may result in introducing two different battery techniques like one lead-acid plus a Ni-MH or Li-ion battery.

Dismantling of lead-acid batteries from ELV is mandatory under the existing Annex II.

Because of the large quantity of lead in these batteries the recovery rate should be as high as possible. Adequate reporting and monitoring systems should be introduced in all member states in order to ensure that dismantling and recycling are properly done. Within this monitoring, particular attention must also be paid to the introduction of small lead acid batteries for which dismantling is mandatory as well, and an information flow to the dismantlers via IDIS or equivalent information systems must be established.

References:

Behrendt H.P. and Steil H.U. (1997), Lead acid batteries: state of environmentally sound recovery and recycling, Proceedings of Recovery, Recycling, Re-integration´97.

Karlsson S. (1996), Closing the technospheric flows of toxic metals - Modelling lead losses from a lead-acid battery system for Sweden, submitted to Journal of Industrial Ecology

RWTH (Rheinisch Westfälische Technische Hochschule) Aachen (2001): Proceedings of 2nd International Congress on 42V PowerNet: preparing for mass production, 24.-25. April 2001

2.3 Lead in wheel balance weights

Field of application and product description

Wheel balancing weights are applied to wheel rims to compensate for static and dynamic unbalances and guarantee therewith true running of the tyres. Driving with unbalanced tyres results in higher fuel consumption and uncomfortable vibrations which can have implications on car safety and durability of chassi components at higher velocities.

Until today, these weights are made of lead in most cases.

To prevent corrosion of rims, weights can be provided with a coating.

Conclusions of previous study

“Wheel balancing devices made of steel are approved on a mass production level for weights up to 30 g. For bigger weights, major changes in balancing technique would be necessary which are not yet approved on a mass production level and which will have to be implemented also in service stations and garages.

Tin weights are about 1,5 - 3 times more expensive than lead weights whereas prices for steel weights are in the same range as for lead weights.“

Further Work Progress

A technical paper concerning wheel balance weights was presented by CLEPA during a meeting held in January 2001.

For further investigation in this field a questionnaire was submitted to associations ACEA, CLEPA, JAMA and BLIC but also to other actors who are not organised in these associations. Producers and suppliers of wheel balancing weights and their associations were contacted and asked to answer the questionnaire and/or specific questions on their products. Additionally several other experts were contacted (e.g. car, wheel and tyre producers, metallurgy) and a number of meetings were held. Reactions on Ökopol’s previous study and on the interim report were received from several actors from the automotive industry, suppliers and their associations.

Results

Alternative materials for weights evaluated so far are tin, steel, zinc, tungsten, plastic (thermoplastic PP) and ZAMA, which is an alloy of $ZnAl_4Cu_1$. For lead as well as for its alternatives, the properties of the manufactured products have to be taken into account rather than the properties of the base metal (raw material) because all of them are alloys or material composites.

Relevant aspects to consider for wheel weights made of lead as well as from other materials are the fixation technology, the material characteristics (also with respect to safety aspects), the availability of materials and the costs.

FIXATION

Two weights per wheel are used for balancing. Presently the great majority of balancing weights are fixed at the horn of the rim with a clip (clip-on weights). For design purposes new shapes of aluminium rims do not always have a horn on both sides for clip-on technique and balancing has to be done by adhesive weights (see Fig. 1). Experts state that, from the technical point of view, adhesive weights are not favoured because the plains of balancing come closer to each other and also closer to the centre of the rim, so that additional weight is needed. However, this is not seen as a major problem that would prevent the increasing use of adhesive weights.

A frequent design requirement is that the weight should be invisible. Therefore the combination of clip-on weight inside (towards the car body) and adhesive weight outside might be the most abundant one for aluminium rims.

Controversial information was received on the proportion of clip-on weights and adhesive weights in the European market. One weight manufacturer estimates the proportion of adhesive weights to be less than 5 % in the Original Equipment (OE) - market whereas another manufacturer gives figures of 40 %. While the latter figure may be an overestimation, both manufacturers agree that the amount of adhesive weights will increase in the future.

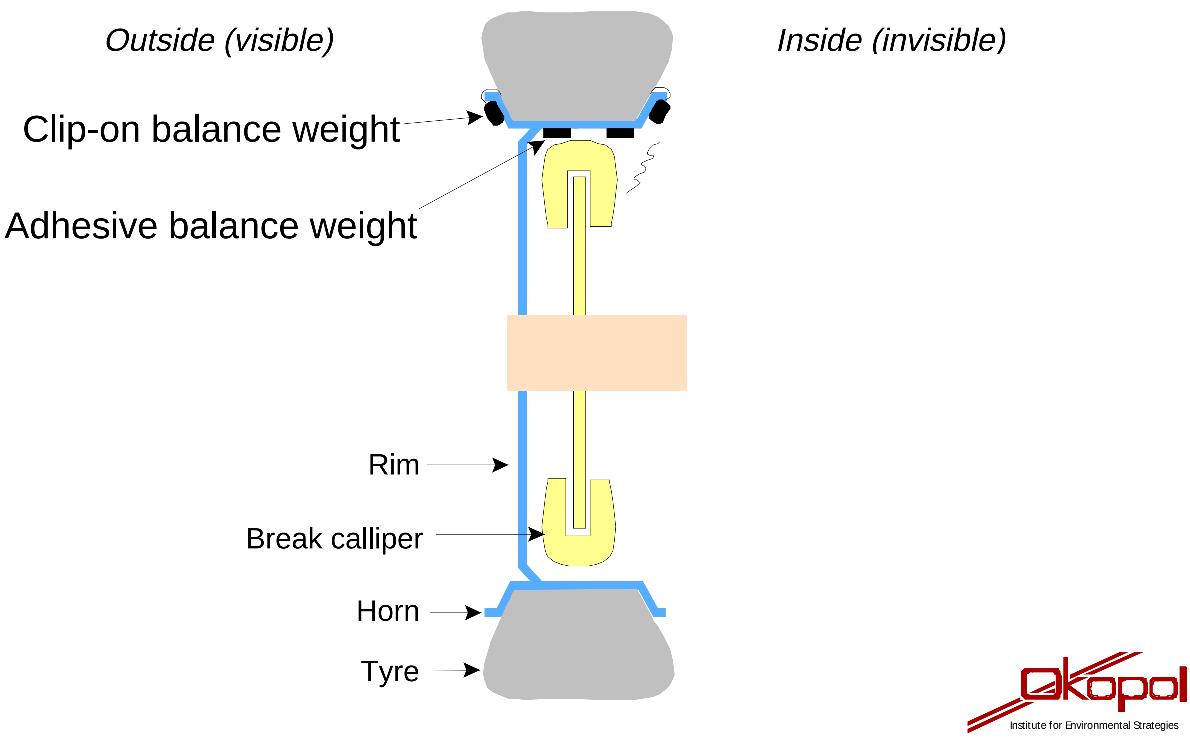


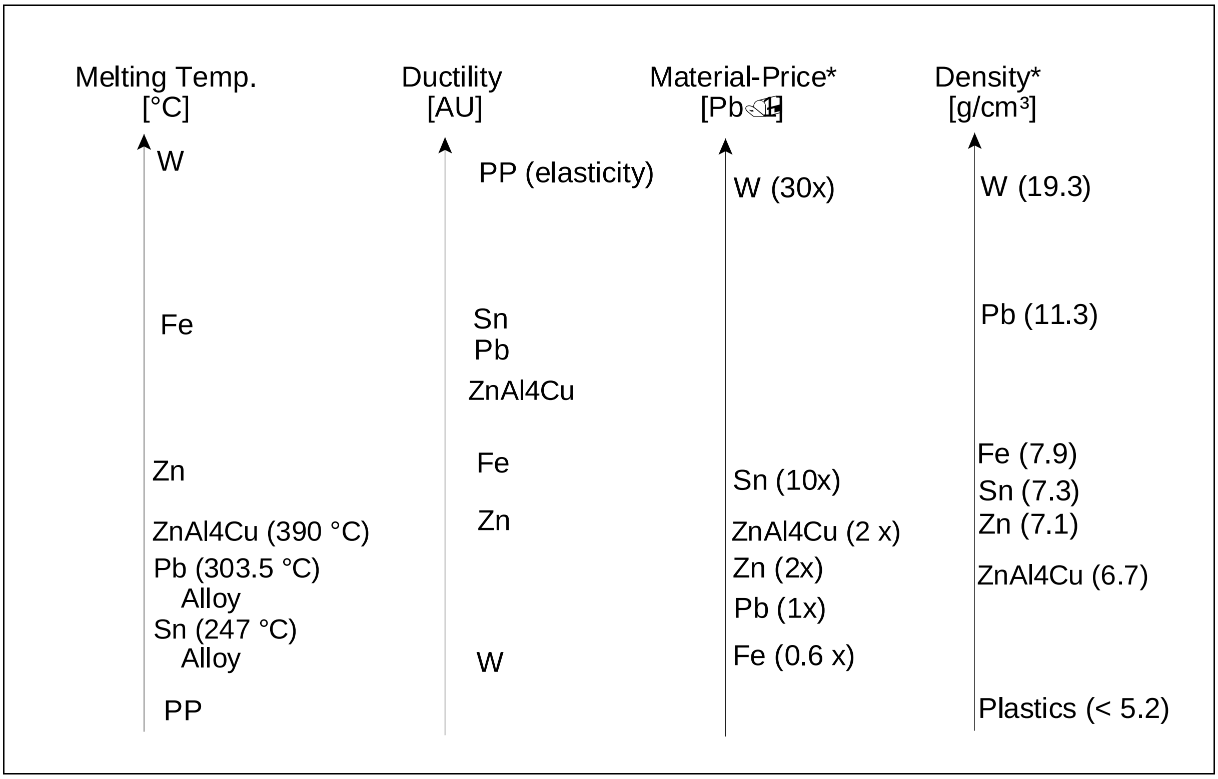
Fig. 1: Fixation of wheel balance weights to the rim

DESCRIPTION OF THE MATERIALS

Lead balancing weights are produced from an alloy which contains 3 to 5 wt% antimony and <0,1 wt% other elements as impurities. Candidates for tin alloys are materials with 1-5 % Cu (SnCu), and some maybe of SnSbCu. Tungsten may be introduced as a pure metal, as an alloy with other metals resulting in an overall density similar to lead, or as a filler implemented in plastic. Plastic wheel balance weights currently used for small weights are made of polypropylene with an additive of chalk. Also ZAMA, which is an alloy of $ZnAl_4Cu_1$ (EN 1774:1994), is presently sold by a major European supplier of wheel balance weights and is used by at least one car manufacturer for wheel balancing up to 15 g. Another car manufacturer will start an intensive testing programme of ZAMA wheel weights by September 2001 aiming to introduce ZAMA for clip-on weights for the full range of 5 to 50 g which will be sufficient for balancing all of their cars. ZAMA has a density of 6.65 g cm^{-3}.

There was only little information about the technical details of steel and zinc balance weights.

A comparison of the material properties is shown in Fig. 2.



* data for pure metal but expected similar to alloy

Fig. 2: Comparison of material properties

DIFFERENCES IN RELEVANT MATERIAL PROPERTIES

Density

The volume and therefore length / thickness of wheel weights will increase when materials with lower density are used. For metals with density between 7 and 8 an increase of approximately 50 % in volume will result compared to lead.

The impact on the balancing accuracy is expected to be small as the centre of gravity of the weight can be adjusted as good as for the lead weight. With increasing length of the weight the centre of gravity changes position towards the middle of the tire and therefore smaller effectiveness results which would result in a higher mass of weight needed for balancing. However, the effect is significant only for weights reaching approximately 1/8 of the rim´s circumference which is not relevant for common unbalances of tyres and common rim diameters presently offered on the market.

Noticeable increase of the amounts of material needed for balancing is therefore not expected and is not significant when compared to the extra amount of weight needed when changing from clip-on to adhesive weights.

Temperature

Even at high brake and/or rim temperatures, the weight material must still fulfill its function and should not disintegrate. For tin weights, melting and softening of the material could be found for lower temperatures as for lead. The relevance of temperature is different for the two fixing technologies:

A) Clip-on weights: Weights at the rim horn are not expected to reach temperatures above 120°C, because the distance to the brake line is greater and effectiveness of air cooling is higher. This is confirmed by the fact that also thermoplastic polypropylene (PP) clip-on weights are in use for very small weights of 5 to 15 g which would, according to the manufacturers, fail at temperatures above 120 °C due to softening. Measurements of ambient rim and weight temperatures in driving tests confirm this.

B) Adhesive weights: Adhesive weights are closer to the brake disc which can reach temperatures between 600 and 700 °C after long downhill tracks. As a trend in development of new car models brake discs become larger and so the space for adhesive weights inside the rim becomes smaller. However, also a trend towards bigger wheels and rim diameter is evident. The temperatures of weights used for front wheel drive cars might be higher as the brake line is closer to the rim for technical reasons.

The highest temperature reported from a recent test by the TÜV München in which a long downhill track was simulated with a front wheel drive car was 207 °C inside of the adhesive weight. The ambient temperature of the brake line was 620 °C.

Similar tests with ceramic brake linings which reach temperatures of approximately 900 °C have been said to give weight temperatures well below 200 °C. It was concluded that heat capacity of the brake disc, which is lower for ceramic brakes, is more relevant than absolute temperature.

Tyre manufacturers recommend to keep temperatures of the rim below 100°C in order to prevent pyrolysis of the tyre elastomer. Elastomer hoses directly connected to the brake are allowed to have maximum temperatures of 150 to 180 °C for short times only according to brake manufacturers.

Temperatures reported so far for adhesive weights are below the melting point of tin alloy and are not a matter for zinc and steel.

Susceptibility to deformation (malleability):

Susceptibility to deformation has different impact for the two balancing techniques.

A) For clip-on weights it is advantageous if the weight is malleable to give a sufficient adoption to different wheel diameters during fixation. Ductility of tin, lead and thermoplastic PP is reported to be sufficient for fixing clip-on weights to different rim diameters. Today approximately 60 different shapes of lead weights are required. The number is expected to increase if harder materials like steel or zinc are applied, as adaptation to the different rim diameters is not possible.

B) For adhesive weights the demand for ductility depends on the technical solution chosen:

   a) The normal shape of a metal bar with an adhesive tape which is common for lead weights is restricted to very ductile materials such as lead or maybe tin alloy.

   b) If adhesive weights of the form of a chocolate bar are used which are partitioned in segments of 5 or 10 g with intermediate parts with lower thickness also „semi-ductile“ materials like zinc alloy might be used.

   c) If the weight is constructed of separate small weights which are combined on the tape, the restrictions due to malleability are negligible. Fig. 3 shows a photograph of such weight which is manufactured by a Japanese company.

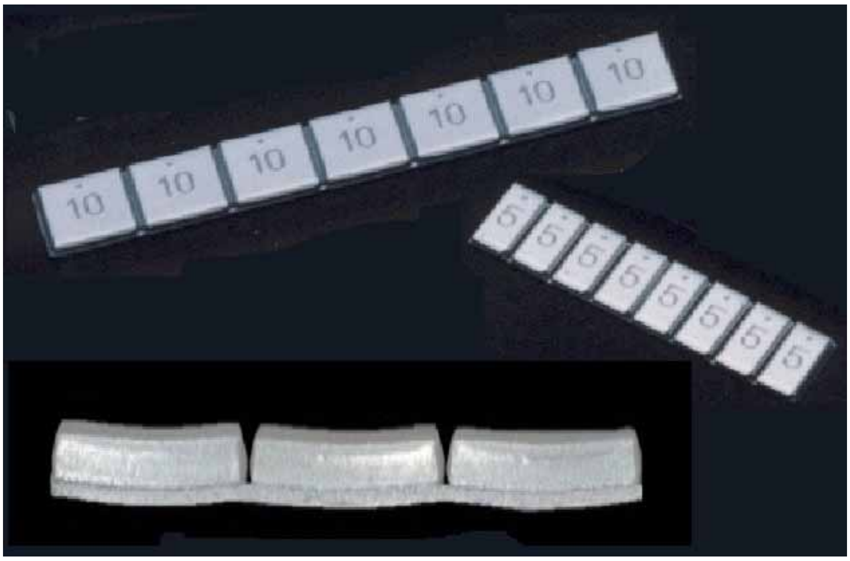


Fig. 3: Steel adhesive weight

Safety

Malleable weights have the advantage of being much weaker than all the construction materials of rim and brake. Potential safety problems are mainly seen if non malleable adhesive weights, which are close to the brakes, fall off. Although manufacturers state that adhesive weights do not get lost during driving due to centrifugal forces the impact of small steel weights in the surrounding of the brake on driving safety should be an issue for intensive testing. It has been suspected that steel or other harder weights might get wedged between rim and brake calliper which could result in wheel blockage. This scenario has to be compared with the incident of parts coming up from the road and getting into the surrounding of the brake which has been definitely tested for constructions on the market.

For weights which are fixed to the horn a harder material is not supposed to cause any danger when falling off because it is unlikely that they reach the brakes. This can be confirmed by the fact that also steel valve caps are in use which did not give rise to any security problems so far although they are even closer to the brakes.

Economic aspect

The price of a wheel weight results from material as well as from production, logistics and storage costs. Therefore the material price does not reflect the product cost, e.g. even if the material price of tin is approximately 10-fold that of lead the product price of tin weights is estimated to lie between 1.5 and 6 fold depending on weight size. A manufacturer of tin weights states that average balancing cost per vehicle might increase by approximately 2.00 EURO. The price of ZnAl4Cu1 weights is assumed to be competitive to lead weights because this material is already introduced on the market for small weights. Use of tungsten as a substitute material is not seen as realistic because its price is approximately 100-fold that of lead.

Steel clip-on weights would be favoured from a material price of view. Development of steel weights with integrated clips brought up technical problems due to corrosion at the point where the clip is connected to the weight bulk. However, this problem does not occur for a widely-used fixation technology where weight and clip are applied as separate components. Steel and / or zinc adhesive weights might be favourable also from a product price of view. Availability of the other metals is seen as a crucial point in case of tungsten because demand for wheel weights is approximately 12,000 t/a whereas the present world-wide tungsten production is estimated to be 31,500 t. For figures for the other metals the reader is referred to Annex I.

Which material and technique for balancing of wheel weights might be favoured in the future will be an issue that will be dominated by market forces and practical utility.

Amounts

The amounts of lead used for wheel balancing lie between 20 and 25 g as an average for Original Equipment (OE-) and aftersales market. As each car is equipped with 10 weights this sums up to 200 - 250 g lead per car. Approximately 3500 t/a of lead are presently used in the OE-market and 8600 t in the aftersales market.

Environmental relevance

The environmental relevance can be subdivided into two main aspects:

a) Relevance during usage: Data on the number of weights falling off are not available for Europe. Release of lead into the environment by lead weights fallen off the rim is reported to be significant in a report for the United States (Root, 2000) which is based on calculations from weights collected at roads in a restricted area. The relevance for Europe must be evaluated. The coating of a lead weight will prevent leaching of lead during usage when the weight is fixed to the rim but cannot prevent release of lead under environmental conditions on a long term basis from weights fallen off. The leaching of lead from uncoated lead weights is estimated to a max. of 7.3 g lead per square meter which is stated to contribute 0.088 g lead during the vehicles life time of 12 years when considering a surface area of 10 cm^2 [Steil 2000]. However, from our rough estimate the average (open) weights surface per vehicle should be as a minimum 32 cm^2. Advantages of the coating in the field of industrial safety are evident because worker get in direct contact with these weights. The same would be valid for the mentioned alternatives but the environmental impact is lower due to the lower toxicological / eco-toxicological relevance of these.

b) Recycling: When rims are taken off before shredding a dismantling of balance weights is likely to occur. Aluminium rims are assumed to be taken off before shredding as the rim is valuable and lead is not accepted by the aluminium recycler. If weights and / or rims are not dismantled the weights are expected to reach the iron- or shredder heavy fraction, depending on whether they keep connected to the rim during shredding.[1]

The rate of dismantling is expected to reach almost 100 % when tin wheel weights are used, as the higher material price will make dismantling a valuable procedure.

4.6 Summary and Conclusions

For weights which are fixed to the horn (clip-on weights) a change to alternatives is possible from a technical point of view. Weights made of ZAMA and PP are already in use. Clip-on weights made of tin are available from one manufacturer in Europe. For adhesive weights introduction of alternative materials might be more difficult but solutions have been developed. Product costs may increase to a certain extent for alternative weights. All of the mentioned materials, including lead itself, have certain limitations and disadvantages but these are possible to overcome by adaptation of tyres and rims to the specific material properties.

Development in weight manufacturing, build up of production capacities and introduction of the alternatives in the market is therefore expected to take more time.

As a conclusion, a temporary exemption until 1.7.2004 is seen as adequate to allow for the necessary adjustments and to leave time for the „alternative market“ to grow.

[1] For the impact of lead in the iron melting process the reader is referred to Chapter 5.

Dismantling of lead weights must be mandatory in order to enable effective recycling of this material flux. Additionally, the coating of lead weights should be mandatory for reasons of occupational safety and health.

Unlike the present wording, it is proposed that this item should be listed as a temporary exemption in Annex II as „Lead in wheel balance weights".

References

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2.4 Electrical components which contain lead in a glass or ceramics matrix compound

For practical reasons, this chapter is divided in four sub-sections. In the first sub-section, electrical glass components and ceramic capacitors are discussed jointly because they both have relatively low lead contents (mostly below 5 per cent w/w) and can be found as electronic components on printed circuit boards. The second sub-section covers lead-containing ceramic components. These are mostly piezo-ceramics which contain between 60 and 70 per cent lead, depending on the stochiometric composition of the crystalline matrix. The third sub-section deals with spark plug insulators (glaze contains approximately 50 per cent lead) whereas the last section is about lead glass in lighting bulbs.

2.4.1 Electrical components with minor content of lead in a glass or ceramics matrix

Field of application and product description

Lead is added to numerous glass and ceramic materials used in electronic compounds in order to achieve different electrical properties like e.g. a specific capacity, resistance or conductivity etc. At the same time, glasses containing lead fulfil specific requirements of physical stability, temperature independence of electrical properties or electronic functions, preciseness of the electrical function and good resistance even towards high temperatures. The lead content of these components is mostly below 5 % but in very rare cases up to 15 % were reported.

In these applications, the glasses are applied onto the printed circuit boards either in the form of electrical components or in thick film compositions which are applied directly on ceramic circuit boards. Thick film components are preferably used whenever reliability, ruggedness and safety are key requirements.

The electrical components can be subdivided in precision resistors, PTC-(positive temperature coefficient) thermistors and ceramic capacitors. Lead may either fulfil an electrical function within the matrix and / or be present in the glass coating of these applications.

Conclusions of previous study

"Although substitution of lead in certain electronic components is possible, no overall recommendation can be given. Besides technical reasons (mainly electrical properties of lead in certain applications) the lack of information plays an important role here."

Work Progress

In February 2001, a meeting was arranged on the premises of Siemens AG in Munich, in which more than 20 experts from the electronics and ceramics supplier industries, the automotive industry and from four research institutes discussed the issues with Ökopol's project team. Two participants submitted lists of specific applications of lead-containing glass and ceramics components in the automotive industry, including information about quantities and location of lead. Gathering of information was complemented by numerous bilateral contacts and by a literature survey.

Reactions on the previous study and the interim report were received from the automotive industry and their associations (ACEA, CLEPA, JAMA, VDA, PSA), from several suppliers and from the Liaison Office of the European Ceramic Industry (Cerame-Unie).

Results

FIELD OF APPLICATION AND AMOUNTS

According to an Asian and one European supplier typical applications of electrical components with low lead content in a glass or ceramics matrix are:

a) PTC thermistors for over-current protection in: radio, car navigation and burglar alarm, door lock motor and side mirror protection (each contains between 10 and 40 milligram of lead);

b) PTC thermistors: heater for air conditioner and air intake (contains 950 mg lead per vehicle, but present in approximately 0.1 % of all cars only);

c) ceramic capacitors used in the following applications: speedometer, airbag, engine control, fuel injector, power window, power steering (each contains 0.03-1.8 mg lead);

d) lead glass used in: resistor and hybrid-IC for the engine (each contains 0.1 to 0.3 mg lead).

It is confirmed from many sides that these are illustrative examples from an open, non-exhaustive list and there may be more applications present in vehicles today or in the future.

One Asian and one European supplier arrived at the concordant estimation that PTC applications (item a & b) contribute between 22 and 50 milligram of lead per vehicle, but excluding the fairly rare application of heater devices. On these heater devices, no additional information was available regarding the estimated installing rate and possible alternatives.

Lead in ceramic capacitors (item c) contribute a subtotal of 0.6 to 3 mg lead per vehicle. The lead glass listed under item d) is added with the purpose to achieve physical strength and/or specific electrical properties of electrical components and contributes between 100 and 300 mg lead per vehicle.

As a subtotal the applications mentioned under item a to d contribute between 120 and 1,300 mg lead per vehicle.

Alternatives

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. Manufacturers state that there is no technical solution available to achieve complete replacement of lead.

Manufacturers also state, that in several electronic applications lead is the key functional ingredient and the lead additives ensure the reliability of these electrical components at high temperature and vibration in the environment of the engine compartment. According to them this electronic function could not be realised without the thick film components containing lead in several cases.

Environmental Relevance

Most of the application in this field are embedded in electronic devices and these are assumed to end up predominantly in the shredder light fraction (SLF). At the present stage of knowledge, quantities of lead from these devices are relatively low. Since the total amount of lead in these applications is currently not restricted, special attention must be drawn to new upcoming applications in the future which may contain significant amounts of lead like e.g. heater devices mentioned in b), which would result in a drawback for the aim of preventing high contamination of shredder wastes.

Summary

Relatively small amounts of lead are present in the items such as precision resistors, PTC thermistors and ceramic capacitors with approximately 0.1 to 1.3 g per vehicle. The impact on contamination of the shredder light fraction is therefore believed to be relatively low. However, the total amount of lead in these applications is currently not restricted and the list provided by manufacturers might not be complete. Special attention must be drawn to new upcoming applications in the future which might contain larger amounts of lead since this would result in conflict with target of non-contaminated SLF (see also Chapter 7 on lead in shredder light fraction). A restriction of the total amount of lead per car in these applications is therefore recommended (see overall conclusions 2.4.5).

2.4.2 Piezoelectric components where lead is the major constituent in the ceramics matrix

Field of application and product description

Apart from capacitors, resistors and thermistors which were already discussed under sub-section 2.4.1, ceramic components which contain lead are almost exclusively ferroelectric ceramics which belong to the group of piezoelectric materials. In these materials, an electrical voltage is induced when the material is mechanically deformed ("sensor" mode), or on the other hand they undergo a mechanical deformation when an electrical voltage is applied ("actuator" mode).

An important application of actuators based on piezo-ceramic materials is their use as high dynamic valves for sophisticated fuel injection. A similarly important use of sensors is the knock-sensor for the engine. Other wide-spread applications of piezo ceramics include their use as ultrasonic actuators or sensors.

The available piezo ceramics are dominated by lead zirconate titanate (PZT), on which most research was done in the past. Lead is the main element of these by weight with a lead content between 58 and 68 % (depending on the proportion of Zr to Ti).

Applications of PZT in the car can be divided according to their location in the car for engine (high temperatures), power train excluding engine, and chassis (lower temperatures).

Conclusions of previous study

"Although substitution of lead in certain electronic components is possible, no overall recommendation can be given. Besides technical reasons (mainly electrical properties of lead in certain applications) the lack of information plays an important role here."

Work Progress

Additionally to the meeting in Munich in February 2001 which is mentioned in chapter 2.4.1, another meeting on the issue of piezo ceramics was held with representatives of a ceramic manufacturer from UK on 30 May 2001 in Hamburg. Since not all stakeholders who are potentially affected by the Directive 2000/53/EC had an opportunity to participate in these meetings, a formal request for information was additionally sent to ACEA, and further bilateral contacts were established with suppliers' companies as well as with companies from the recycling sector. Gathering of information was complemented by numerous bilateral contacts and by a literature survey.

Reactions on the previous study and the interim report were received from the automotive industry and their associations (ACEA, CLEPA, JAMA, VDA, PSA), from several suppliers and from the Liaison Office of the European Ceramic Industry (Cerame-Unie).

Results

APPLICATIONS AND AMOUNTS

Typical application fields of piezo ceramic components include:

- Engine: high pressure direct diesel injection (expected to penetrate 30 % on the EU-market by 2005, contributing 40 to 120 grams of lead per car; introduction for gasoline injection under development);

- Engine: Knock sensors (already on the market, 3.5 g lead per car);
- Shock sensor for air bag (already on the market, 0.3 g per car);
- Resonators, frequence filters and buzzers in electronics like radio/stereo, keyless entry, burglar alarm, car navigation etc. (between 0.5 and 1.6 g lead per car);
- Reversing sensor (0.35 g lead per car);
- Active noise reduction (not yet available, large amounts of > 500 gram up to 1 kg of lead per car expected according to a car manufacturer and a supplier).

Applications which are presently under development include vibration damping of engine vibration (free floating engine), pressure sensor for tyre pressure, window jamming protection and occupant sensing, measurement of oil viscosity, active suspension (presently used for Formula 1) and fuel level sensors. It was not possible to quantify the amounts of lead in these applications.

In summary, the total amount of lead per vehicle due to piezo ceramics is estimated to lie between 4 and 125 grams. Including future applications, the quantity of lead may increase to 0.5 kilograms and more.

Alternatives

Materials showing the piezoelectric effect are mainly metal oxides with a specific crystalline structure, the perovskite structure (Haertling 1999). The piezoelectric property disappears above the so-called Curie temperature which is material-specific. Recent literature on the subject exhibits that research on lead-free alternatives has been stimulated in the last 4-5 years (e.g. Takenaka et al. 1999, Knowbel 1997). Not all of the ferroelectric ceramics known today do contain lead, but all of the lead free alternatives (e.g. bariumtitanate, quartz) have restrictions in terms of a lower Curie temperature, smaller mechanical deformation, concerning their electric parameters (such as the relative permittivity, charge constant, the piezoelectric coupling factor etc.) or a lower physical stability (Haertling 1999, PI ceramics 2001). In specific cases, substitution of lead-containing piezo ceramics by another technical alternative has been reported: e.g. in certain airbags, the piezoelectric shock sensors used in earlier models have recently been displaced by a technique based on micro electro-mechanical system (MEMS) which is based on a silicon waver and is lead-free.

The available piezo ceramics are dominated by lead zirconate titanate (PZT), on which most research was done in the past. The strong covalence of the Pb-O bond contributes to the positive properties of this material.

For applications at higher temperatures (e.g. around the engine) all experts stated that no lead-free alternatives are available. Concerning the potential replacement of lead in chassis applications (sensors and oscillators), controversial reactions were received, some stating that there are no alternatives, while others confirm that sensors and some oscillators can be produced from other, lead-free piezoelectric materials (including also quartz and barium titanate).

Manufacturers state that use of piezo sensors and actuators at the engine are the only possible strategies to control emissions and reduce fuel consumption according to Euro norms 4 and 5. However, not all applications listed above are related to safety requirements and / or fuel saving and many are merely introduced for comfort reasons.

Environmental relevance

The main aspects to be considered are related to waste management and the possibilities of recycling, since release from PZT during usage is not expected.

Waste Management:

- Since PZT are still not very common in older vehicles, there is little empirical knowledge concerning the question in which material fraction they will end up after shredding. Also motor shredding companies have been contacted but lack of information on the fate of PZT was evident. Additional investigations on the partitioning of PZT during shredding and on its behaviour in the different fractions will therefore be necessary.
- If PZT components remain in the metal fraction with the engine, they will presumably end up in a steel smelter.
- There is some probability that PZT especially when integrated in the chassis will

end up in the shredder light fraction (SLF). Under present conditions, the biggest part would end up in landfills.

- Considerable leaching of lead must be expected under conditions expected for landfills (Bauer and Nowak, 1982 and recent results of PZT leaching studies from independent laboratories).
- unlike leaching from lead containing glasses where the release is restricted to diffusion of lead through the solid state matrix, continuous leaching of lead from the piezo ceramics under environmental conditions must be assumed because the PZT matrix dissolves over time.

Three potential routes for recycling could be identified so far, two of which are based on processes presently used only for production waste and one is not used in practice:

- One route could be the incorporation of PZT in the lead smelting process with subsequent recycling of lead with the other metals titanium and zirconium remaining in the slag.
- A second route could be a recycling of precious metals (Pd, Ag) which are used as electrode materials in PZT. However, the amount of these valuable metals in modern PZT decreases. More information on the environmental and economic characteristics of this process is needed.
- The reuse and recycling of already sintered PZT seems to be possible on a chemical route but has only been tested in laboratory scale.

The question remains if these routes will ever be appropriate for recycling of PZT from ELV. Manufacturers state that reuse of already sintered PZT is not a suitable route especially for safety related applications for reasons of reliability as well as for economic reasons. A reuse of PZT material for other purposes or even for other products than vehicles could be considered by the recyclers / car manufacturers due to the high value of this material.

Summary

The lead content in PZT and consequently the total amount of lead from this source in a car is quantitatively significant and will be of increasing relevance in the future. For many applications of piezo-ceramics, lead-free materials are presently not available on the market. The key limiting factors preventing the aptitude of substitutes are the maximum operating temperature, the mechanical deformation which can be achieved, and the force which needs to be exerted in the actuator mode.

For applications with lower requirements in those key features, like sensors and oscillators integrated in the chassis (such as e.g. reversing sensor in rear bumper, outside mirror adjustment, etc.), lead-free alternatives are certainly possible even if they are not yet fully available in each case. It is expected that the number of PZT in cars will increase, including numerous functions which are presently enabled by other (lead free) techniques (like mirror adjustment) or which are related to merely comfort purposes.

As a conclusion PZT ceramics around the engine shall not be restricted, but mandatory labelling and dismantling is suggested for applications on the chassis if a maximum amount of lead from this source is exceeded, because PZT-applications on the chassis are likely to reach the shredder light fraction. Details of this recommendation are outlined in Chapter 2.4.5.

References

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2.4.3 Lead in spark plugs

Field of application and product description

In spark plugs, lead is used in the glaze around the ceramic insulator at the top in order to achieve a sufficient mechanical strength which is mainly needed during fitting of the spark plug.

Conclusions of previous study

"At the moment, no alternatives are known for a production scale level. Nevertheless it is remarkable that in the light of the oncoming ELV-Directive one of the biggest European producers took up again his research for a lead-free glaze at the beginning of 1999 which he had stopped 5 years ago."

Work Progress

Three of the main manufacturers of spark plugs were contacted on a bilateral basis. Additionally, the comprehensive statement of ACEA / CLEPA and JAMA from 11.6.01 contained a short statement on lead in spark plugs.

Results

AMOUNTS

The glaze contains around 50 w% lead in the lead silicate glass of the glaze. The overall amount in one spark plug is around 0.15 g, which sums up to an amount of 0.6 to 1.8 g lead per vehicle.

ALTERNATIVES

Lead free glazes which also give the required physical strength are available. However, the processing of these in one step together with a resistor sealant is more difficult as the process parameters (e.g. temperature) have to be controlled more precisely than for lead glaze. The difficulties could be overcome by introduction of a two step process but this is not favoured due to economic reasons.

From a technical point of view, a phase out of lead in glaze of spark plugs seems to be possible also for mass production in the near future. Two main manufacturers state to develop lead free alternatives and predict that these techniques will have been introduced by 1.7.2003 on mass production level. However, still some uncertainties remain whether the step to mass production will bring up unexpected difficulties. Representative information on the full impact and time scale of the phase out can therefore hardly be evaluated because a high portion of spark plugs are imported, but in the technical paper of ACEA / CLEPA / JAMA an additional time of 18 month is requested for which would result in a phase out of lead in spark plugs by 1.1.2005.

ENVIRONMENTAL RELEVANCE

Spark plugs will usually not be removed at the dismantling site. Because of its high specific density of 3.7 the plug will remain in the heavy fraction after shredding.

Summary

After research on lead substitutes had been stimulated by the upcoming ELV Directive, lead free glazes for spark plugs are now developed and likely to be introduced in mass production by 1.7.2003. However, some uncertainties about the success of the phase-out remain, and the automotive associations request for a delay of 18 months, which in our view may be an appropriate timescale for a change to lead free glazes.

2.4.4 Lead in lighting bulbs

Field of application and product description

Application of lighting bulbs in vehicles can be divided in three groups, the headlamps, signal lamps and interior lamps. Headlamps are normally lead-free whereas interior and signal lamps contain lead glass and many of these additionally contain solder with a lead content of approximately 60 %. According to lamp manufacturers an average car is equipped with 30 to 40 lamps depending on the type and model.

Conclusions of previous study

This topic was not included in the final report 2000.

Work Progress

Reactions were received from the European Lighting Companies Federation (ELC) and from two main bulb manufacturers who both submitted a detailed technical paper on this issue. Based on this information, additional information exchange was held with several experts from the industry.

Results

AMOUNTS

According to lamp manufacturers lamps in cars contain between 0.2 and 0.75 g lead in the glass bulb. The majority of the lamps additionally contain lead solder which contributes up to 0.2 g lead per lamp. As an average value 0.4 - 0.5 g lead per bulb is stated. An average car is equipped with 30 to 40 lamps.

According to a calculation based on one special car model (Renault Megane 1,9D RTE 99) the lead glass from lamps contributes approximately 12 g lead per vehicle.

ALTERNATIVES

Lead is present in lighting bulbs in the following parts:

A) Signal and interior lamps in cars contain lead glass in:

- the bottom part (exhaust tube),
- the glass bulb,
- the bead.

B) Depending on the type of lamp also lead containing solder is used for electronic and physical contacting[2]:

- In the electronic contact of the socket
- In the interior of the lamp for electronic contacts of the wires.

Although lead glass is just needed in the bottom part of the bulb, most of the bulbs used in cars are fully made of lead glass because the production process is cheaper and easier for such small lamps when just one type of glass is used. Traditionally, the

[2] Solder in lamps should be considered under entry 11 as solder in other electrical applications.

production process has been well adapted to lead glass which has the advantage to melt in a wide temperature range and the production process is therefore easier. Lead in the bead of a lamp fulfils an electronic function.

As lead free glass has been developed and introduced for bigger household lamps in the past, the main efforts for substitution can be seen in the adjustment of machines for the lead free product. Manufacturers state that the main efforts need to be done in the revamp of production processes and test programmes for ensuring a long life time of the bulbs.

Contrary statements were received concerning the time needed for introducing lead free alternatives in car lamps. Whereas one manufacturer states to need a temporary exemption until 1.1.2008, another manufacturer confirmed that a conversion of all lamp types might be possible earlier and before 2003, including substitution of lead in the solder.

ENVIRONMENTAL RELEVANCE

Upon car shredding glass from bulbs is likely to enter the shredder wastes and therefore contributes to the overall lead content of this fraction. During the life time of the lamp no impact on the environment is expected due to the fixation of lead in the inert glass matrix. Life time of bulbs in the cars must exceed the vehicle´s life time because exchange is often complicated and expensive. Therefore ELVs will normally contain the lamps applied by the OEM and influence of after sales market is expected to be low.

Summary

From a technical point of view lead in the form of lead glass and as part of solder can be phased out in lamps used in cars. The lead-free glass has been introduced in production of bigger household lamps and will also be introduced in the series production of small car lamps. The time needed for changing from lead-containing to lead free glass will be mainly needed for adaptation of the production machines to the new raw material. Controversial statements were received on the time this process is going to take, as reactions were received with dates of 1.7.2003 and 1.1.2008. As present production technologies differ between the individual suppliers, a phase-out of lead in glass bulbs and the solder is seen as possible in a similar time scale as for spark plugs, i.e. with a delay of 18 month from 1.7.2003.

2.4.5 Overall Conclusions for electrical components which contain lead in a glass or ceramics matrix compound

For analytical purposes, the category of electrical components which contain lead in a glass or ceramics compound was divided into the four sub-categories of various components with lead as a minor constituent, piezoelectric components (PZT), spark plugs and lighting bulbs. Of these applications, spark plugs and lighting bulbs are expected to become lead-free within a few years' time.

PZT make up by far the largest contribution to the overall lead content from this category. All applications known so far where the PZT is closely connected to the engine have direct environmental advantages. In these applications, the lead cannot be substituted, and the PZT are expected to finally end up in metallurgical processes. Therefore an exemption of PZT which are directly connected to the engine from the general phase-out of lead is suggested.

The other sub-categories, including most electrical components with a minor content of lead and PZT which are attached to the chassis, will most likely end up in the shredder wastes. In order to restrict uncontrolled contamination of shredder wastes by lead from these applications, it is proposed that dismantling should be mandatory if a maximum allowable amount of 30 g is exceeded.[3]

The purpose of this proposal is mainly to either prevent the steadily increasing introduction of high amounts of lead contained in electronic parts in the future, or otherwise to ensure that "design for recycling" is considered by car manufacturers already in the early stages of developing such new applications.

[3] For detailed justification of the proposed threshold limit value see chapter 7.

2.5 Cadmium in batteries for electrical vehicles

Field of application and product description

An electrical vehicle (EV) is a vehicle with a battery for on-board storage of energy, a DC electric motor with a control system, and a battery charger.

The hybrid electric vehicle (HV) is running on a combination of two aggregates, i.e. a thermal engine and an electric motor, which are operating simultaneously or alternatingly. The electric motor serves to improve the efficiency of the thermal unit, and/or to reduce emissions e.g. in inner city traffic.

Some more specific working definitions are useful to distinguish between the various categories of EV and HV:

- A pure Electric Vehicle (EV) has a minimum operating range of 80 km (presently up to 150 km radius)
- An EV with a "range extender" has a small combustion engine (but not designed as the single source of traction energy) and a fuel tank of less than 15 litres
- The term "hybrid vehicle" can cover a broad range of different concepts. True hybrid vehicles are equipped both with an electric motor and a combustion engine. Either aggregate can provide traction energy, the battery can be charged externally or from the combustion engine.
- In a "power assisted" hybrid car, the main traction energy comes from a combustion engine which is assisted by an electric motor. The battery is recharged exclusively from the combustion engine (e.g. Toyota Prius, Honda Insight).

Conclusions of previous study

"Because of the high environmental relevance of cadmium, substitution of cadmium containing batteries in vehicles should be aimed at with high priority."

Work Progress

Reactions on the previous study were received from several associations and individual companies, including ACEA, CLEPA, EUROMETEAUX, PSA, and one battery manufacturing company (SAFT). Further information was collected from automobile manufacturers as well as from battery suppliers to evaluate the perspectives of battery systems to be introduced in electric vehicles and/or hybrid vehicles. Reactions were received from a number of companies, and a meeting was held with representatives of SAFT and the French car manufacturing industry which was followed by a continuous process of information exchange and discussion. Additional reactions on Ökopol's Interim Report of April 2001 came from the "Association of European cities interested in electric vehicles" (CITELEC) and the "European Electric Road Vehicle Association" (AVERE).

Results

MARKET SURVEY OF ELECTRIC VEHICLES IN EUROPE

The present number of electric vehicles registered and in circulation in Europe is estimated at circa 11,000 [SAFT, 2000]. According to figures submitted by SAFT, more than 60 per cent of these electric vehicles are registered in France. SAFT states that 5,300 out of 5,600 electric vehicles (94,6 %) registered in France are equipped with NiCd batteries, while the figures for Sweden are NiCd 67%, lead-acid 25%, NiMH 1% and "not known" 7%.

An updated investigation and inquiry among car manufacturers and other experts performed in the course of this study has yielded the following results:

- Toyota have introduced a number of hybrid cars and electric cars which are equipped with NiMH, Li-ion and lead-acid batteries. The most prominent one is the "Prius" launched in 1997 which is a hybrid car with a NiMH battery. A pure electrical vehicle by Toyota is the RAV4 which is also powered by a NiMH battery.
- The PSA Group have sold circa 5,000 Peugeot and Citroen models which are equipped with NiCd batteries to commercial and private users, including local authorities, in several European countries.
- Renault have started activities in electric vehicles with two models, Clio and Express, and a third model based on the Kangoo is put on the market in 2001 all of which are operating in NiCd batteries.
- The 2-seated Panda Elettra by Fiat which was put on the market in 1990 was equipped with lead-acid batteries.

- In 1998, the pure EV Seicento Elettra was launched which has 4 seats and offers an extended operating range of 80 kilometers. The ordinary Seicento Elettra which is equipped with a lead-acid battery is listed in regular price lists and can be purchased from Fiat retailers. The car has won the European ZEUS (Zero and low Emission vehicles in Urban Society) award. A test fleet of 16 Seicento Elettrica equipped with Ni-MH, allowing for an operating range of 135 km, is tested with the Municipality of Naples. Fiat explicitly states that NiCd was not used due to environmental reasons.
- On the U.S. market, the Ford Motor Company are offering a model which is equipped with a NiMH battery. In 1999, Ford have acquired the small Norwegian manufacturer (ex-Pivco) of the Th!nk City electric vehicle which operates with a NiCd battery. Ford have internal plans to switch to another technology later in 2002, however they state that, in order to service these vehicles after 2003, they must have the possibility to install NiCd batteries after that date.[4]
- In 1997, DaimlerChrysler were examining a research car with a sodium-nickelchloride battery system. DaimlerChrysler stopped working on this type of battery because it had significant technical disadvantages[5]. Present development is pushed towards vehicles equipped with fuel cells which contain a NiMH battery. The Chrysler voyager which is marketed in the U.S. is operating on lead-acid batteries.
- In the years from 1995-98, Volkswagen offered a microseries of EV's based on the "Golf 3" model which were equipped with a lead-gel battery. NiCd batteries were not used for environmental reasons. For reasons of insufficient demand, this vehicle is not offered on the market any longer, neither does Volkswagen presently offer any other electrical vehicle. Ongoing research focuses on batteries based on Li-ion technology, which however are in competition with hybrid and fuel cell car concepts.

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[4] As in this case the battery would be a "spare part", the question arises whether this will be a subject of the ban or not.

[5] In their reaction to our Interim Report (April 2001), CITELEC have pointed out that the ZEBRA battery has in fact been further developed by a Swiss company who has largely solved the technical problems, thus allowing for the use of this battery in a number of demonstration projects, e.g. minibuses in Trento / Italy as well as in the EVD project of the German Post.

- Some other European car manufacturers presently do not work on electric vehicles at all.

The main arguments brought forward in favour of EVs in general are their "zero emissions" at the location of use, their low noise, low running costs and low costs of maintenance.

Especially the French automobile manufacturers see electric vehicles as a strategic development in order to collect experience with electrical traction and electrical drive, which are considered to be key elements of future innovative concepts such as e.g. fuel cell-driven cars.[6] PSA and Renault also pointed out the difference between series production and prototypes or fleets, stating that for series production, the state of quality and security needed to be much higher, the price must be lower, and spare parts must be available over more than 10 years.

AMOUNTS

The weight of a NiCd battery for an electric vehicle is 255 kg [SAFT, 2000] with a cadmium content of circa 15 % or 38 kg.

ALTERNATIVES

Lead-acid batteries were used since 1990 by Fiat in their 2-seated model Panda Elettra. Pb batteries are also the standard equipment of the 4-seated Seicento Elettra which was launched in 1998. Concerning this type of battery, advocates of NiCd batteries state that their higher weight, their lower performance, and the lower number of operating cycles are major disadvantages of Pb-acid batteries.

In all reactions received from car manufacturers as well as battery suppliers, there was no doubt that for hybrid vehicles (HV), nickel metal hydride batteries are readily introduced on the market as a replacement for NiCd batteries. Therefore, one remaining key aspect to be examined was the question by which date NiCd batteries in pure electrical vehicles (EV) can be substituted.

While NiMH are well developed for HV, SAFT, PSA and Renault claim that EV with

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[6] However, we could not identify specific R&D programmes concerning fuel cell-powered vehicles in the French automobile industry.

their much higher demand for power density and performance still need NiCd batteries. Also according to SAFT, the main disadvantages of the NiMH battery are its higher price, and the lower recycling rate which can be achieved in comparison to NiCd (at least as long as the cadmium from NiCd can be recycled). Nilsson (2001) states that the NiMH requires a technologically more sophisticated charger with sensors for monitoring of cell temperature (to prevent overcharge and overdischarge), current, and voltage. Also according to Nilsson, additional disadvantages of NiMH are their narrow operating temperature range, relatively short cycle life, and the high heat dissipation during charging.

Controversial information was obtained on the number of recharging cycles of NiMH vs. NiCd batteries (Table 2).

Table 2: Reported N° of cycles for NiCd and NiMH batteries

Battery type	**N° of cycles [Noréus, 2000]**	**N° of cycles [SAFT, 2000]**
NiCd	1000	2000
NiMH	1500	1500

Lithium-ion batteries are expected to be a long-term solution because their performance is superior to NiCd and the raw materials are comparatively cheep. However, Li-ion batteries are not considered to be technically mature today, rather it will take five years or longer (up to estimated 10-15 years according to AVERE) until they become available. During dismantling and recycling of Li-ion batteries care needs to be taken of flammable and toxic constituents.

In contrast to the position of the French industry concerning NiMH, Panasonic Batteries OEM Group have introduced a NiMH battery for pure Electrical Vehicles already in 1992 (Panasonic, 2001). In 1995 the electric car "Toyota RAV4-EV" which is powered by such a battery won the International Scandinavian EVs Ralley Championship. Since then, the RAV4-EV has been sold over 2000 times. Concerning the temperature operating range, Panasonic see no problems at low temperatures, while the upper temperature should not exceed 60 °C. Constructive solutions have been developed for electric vehicles to ensure that this condition is safeguarded (Panasonic pers. comm.).

Ultra Force Battery Co. (UFBC) are another supplier who offer nickel metal hydride batteries which, according to B.A.T. Advanced Transportation and Energy Technology, "are ideally suited for use in electric vehicles and scooters". Referring to the competitive market situation, B.A.T. state that "SAFT, and most other NiCd batteries, require maintenance, which adds to cost and reduces reliability" [B.A.T. Annual Report, 2001].

To summarise, availability of NiMH for series production of electrical vehicles is seen controversially by different stakeholders, which appears to be mainly the result of the competitive situation and economic considerations rather than a real technical problem.

Environmental relevance

NiCd batteries are listed as being hazardous waste under entry 160602* in the list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste. The CITELEC association considers NiCd traction batteries as one of the most environmentally friendly ways to use cadmium, given the fact that, being a by-product of zinc mining and refining, the supply of cadmium is quite inflexible and the metal should therefore "be used in an environmentally sensible way".

Saft claim that collection of NiCd batteries is facilitated by the fact that many users are public authorities, the batteries are often lent but not sold to the customers, and it is also claimed that all NiCd batteries from electric vehicles are recycled. National collection points for NiCd batteries were identified to us for 13 EU Member States and also for Norway and Switzerland. Upon random spot-checks, such collection points did confirm that they do in fact organise the collection and transportation of NiCd batteries from stationary sources, however they were not aware that a relevant number of these batteries should originate from electrical vehicles.

A consistent set of reliable monitoring data which would allow for calculation of collection rates does not exist yet because the market is still rather young.

Recycling capacities for NiCd batteries exist in France, Sweden and Germany. Whether these capacities will be adjusted to a growing number of NiCd from ELV, and whether they will be able to operate under economically viable conditions, will depend strongly on the question whether there will be a future market for cadmium.

In the future, the economic situation of NiCd recycling which is already difficult may change fundamentally if, due to upcoming legislation, the cadmium would have a negative market value rather than being a valuable material for recycling. In that case, relevant economic actors who play a crucial role in present collection and recycling schemes may no longer be able to carry out the recycling of NiCds, thus leaving some open questions concerning battery ownership and concerning the physical and financial responsibility for collection and recycling of NiCd traction batteries from vehicles. One car manufacturer argued that, if this scenario should become reality, then the disposal costs related to NiCds would be included in the overall costs for ELV recycling, but it was not specified how this should work in practice.

Summary and conclusions

Electric and hybrid vehicles make up a very small percentage (0.007%) of the total number of vehicles presently registered in Europe. NiCd batteries are used in the majority of these cars, but vehicles powered by lead-acid and NiMH technology are also available on the market.

NiMH batteries which do not contain cadmium are well established on the market for hybrid vehicles. Their availability for series production of pure electrical vehicles is seen controversially by different stakeholders, which appears to be mainly the result of economic considerations rather than a technical problem. Our research results show that several battery manufacturers do offer NiMH batteries for electric vehicles, and several car manufacturers to rely on this battery type even for series production of electrical vehicles.

Li-ion batteries are said to have the greatest potential for the future, even if their price is presently still high and the technology still needs to be improved over another five or even 10-15 years.

In conclusion, it can be stated that

- no technical reason was identified to add a derogation for "cadmium in batteries for electrical vehicles" to Annex 2 of the Directive 2000/53/EC;
- the necessity to phase out NiCd batteries by 2003 will require considerable organisational and economic efforts for some of the companies concerned.
- in the light of the assumedly growing market for Electric Vehicles, a temporarily continued use of NiCd batteries would create severe economic disturbances in the future when cadmium is expected to have a negative market value, thus leaving open questions as to how the collection and recycling of these batteries should be guaranteed and financed.

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3 Items mentioned in the table of Annex II

3.1 Steel containing up to 0.35 % lead by weight

Field of application and product description

Lead is used in steel for an improved machinability. A better chip fracturing, longer tool life and a better surface finish and dimension tolerances can be achieved by those machinability enhancers.

Leaded steel is used in a broad variety of applications in a car, for example for fittings and high pressure fuel injector parts. In cars manufactured in Japan also crankshafts are often made of leaded steel.

The wording of the current entry in Annex II is: “Steel (including galvanised steel) containing up to 0.35 % lead by weight.”

Conclusions of previous study

“A substitution of lead in steel for machinery purposes is possible from a purely technical point of view.”

Economically the material costs for potential substituting elements are less important than necessary changes in machinability of the material and revamp of production process.

If an improved machinability cannot be achieved by substituting elements to the same extent as it is reached by lead, some environmental burdens can increase (higher power consumption, shorter lifetimes of tools).

In the very broad application field of leaded steel it was not possible to examine every application in depth. A case specific examination would be necessary.

Concerning the maximum lead concentration of 0.3 % or 0.35 %, car manufacturers stated that normally 0.3 % are sufficient. The main reason for making amendments concerning the concentration of lead may be that in the European standards for steel 0.35 % are mentioned.

Work Progress

Comments on the previous study were received from EUROFER dated 16.5.2000 and from Saarstahl AG dated 22.5.2000. Intense information exchange was realised with different associations and companies and other experts for production and processing of machining steel as well as with research institutions. A meeting with several European steel producers was held in Hamburg in June 2001.

Results

Metal cutting processes are influenced by numerous factors. Starting with the workpiece itself (alloy, structure, strength, geometry), the tools (cutting material, geometry), cutting parameters (cutting speed, feed rate, depth of cut), the process (turning, milling, drilling) and the machine (rigidity, capacity, speed) are important factors.

AMOUNTS

Leaded steel is used in a broad variety of different applications in a car. The amount of lead used in machining steel per car can be estimated between 10 g and 50 g and might rise up to 100 g for some cars produced in Japan. So the total lead amount from these kind of applications in cars produced in Europe can be estimated between 160 t/y and 800 t/y.

Table 3 describes current leaded steels.

Low carbon steel makes up approximately 80% of the total European production.

Usually the factual maximum content of lead is not higher than 0.3 % by weight.

Table 3: Current types of leaded steel

EN 10087	ASTM/SAE	C	Si	Mn	S	Pb	Al
Low carbon free-cutting steels							
11 SMnPb 30	12L14	0.1		1.1	0.3	0.3	-
11 SMnPb 37		0.1		1.1	0.37	0.3	-
Case-hardening free-cutting steels							
10 SPb 20	11L08	0.1	0.3	1.0	0.2	0.25	-
15 SMnPb 13	11L17	0.15	0.3	1.2	0.13	0.25	
Quenched and tempered free-cutting steels							
35 SPb 20	11 L37	0.35	0.25	1.3	0.2	0.25	-
38 SMnPb 26	11L39	0.35	0.25	1.3	0.26	0.25	-
46 SPb 20	11 L46	0.45	0.25	1.3	0.2	0.25	-
44 SMnPb 28	11 L44	0.45	0.25	1.3	0.28	0.25	-
60 SPb 20 (DIN 1651)		0.60	0.25	1.3	0.2	0.25	-
C-Steels with Pb							
C 10 Pb	M10L10	0.1	0.25	0.4	0.03	0.25	0.03
C 15 Pb	M10L15	0.15	0.25	0.5	0.03	0.25	0.03
C 35 Pb	M10L35	0.35	0.25	0.7	0.03	0.25	0.03
C 45 Pb	MI0L45	0.45	0.25	0.7	0.03	0.25	0.03
Cm 45 Pb	M10L45	0.45	0.25	0.7	0.03	0.25	0.03
C 60 Pb	MI0L60	0.60	0.25	0.7	0.03	0.25	0.03
Alloyed-Steels with Pb and Bi							
13 NiCr 6 Pb	31L15	0.13	0.3	0.9	0.03	0.2	0.03
16 MnCr 5 Pb	51L15				0.03	0.2	0.03
18 NiCrMo 6 4 Pb	86L20	0.18	0.3	0.7	0.03	0.2	0.03
20 MnPb 5	15L20				0.03	0.2	0.03
25 CrMo 4 Pb	41L30	0.25	0.3	0.7	0.03	0.2	0.03
27 MnMo 3 3 Pb	40L27				0.03	0.2	0.03
36 CrNiMo 4 Pb	98L40	0.36	0.3	0.7	0.03	0.2	0.03
42 CrMo 4 Pb	41L42	0.42	0.3	0.7	0.03	0.25	0.0

Alternatives

Non-lead machinability enhancers are already in use in various steel grades for different purposes. Calcium is used in Al-killed grades, bismuth, selenium and tellurium for example in alloyed and C-steels. Tin is in use as an alternative in low carbon free cutting steels.

Intense research started in recent years[7].Currently two American car manufacturers are already using a steel grade where tin is used for an improved machinability for power steering components, transmission channel sleeves and rack pistons (total amount around 2,000 t/y). Further parts with an amount of around 5,000 to 6,000 t are projected.

Further research is going on[8].

An overall description of cost relevance of substituting lead is not possible because of the great variety of parts and the complexity of metal cutting processes (see above).

The material price for substitutes is often higher than the price of lead. The additional demand must be seen as a factor of price development especially in the case of bismuth (see Annex I). Process costs may rise on the level of steel plants and at the machining stage especially because of necessary process redesign and revamp of machines. The machinability of steel is of great importance not at least because around 50% of the value of a machined automobile component is due to machining costs.

In those cases where the same machinability cannot be achieved by substitutes production costs may rise because of more expensive tools, shorter tool life and higher energy demand.

ENVIRONMENTAL RELEVANCE

Environmental relevance of a changed machinability as well as the environmental relevance of production and recycling of machining steel must be taken into consideration. A reduced machinability may lead to an increased energy demand during the production process. Therefore appropriate substitutes are important from

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[7] For example concerning the question whether 12T(tin)14 can be a substitute to 12L(lead)14 respectively 9SMn28/36Pb. 30 production heats have been produced to date, mainly in Canada. 12T14 has recently been granted SAE specification as a 'Potential Standard Grade' (PS 68) listed in SAE standard J1081

[8] E.g. research at Centre technique de l´Industry du Décolletage Cluses, France and the ECSC research >technically and commercially viable alternatives to lead as a machinability enhancer in steel for automotive component manufacture= (2001 ECSC Steel Research Programme P 4402 Sept. 2000) concerning the role of tin in free cutting steel, engineering steel, quenched and tempered grade.

an environmental point of view. However no overall analysis on these aspects which gives an overview for different steel grades is presently available.

Different sources estimate that between 90 % and 96 % of steel of an end of life vehicle end up in shredder scrap. The remaining 4 % to 10 % will be transferred into the shredder light fraction and the shredder heavy fraction. This refers to 0.4 g to 5 g of lead.

Concerning the role of lead, tin and bismuth in the steel recycling process see Chapter 5.

Summary and Conclusions

Non-lead machinability enhancers are already in use in different steel grades for different purposes.

However presently a full phase out of lead as a machining enhancer for all grades and applications is not (yet) seen as possible.

As a conclusion the entry for leaded steel in Annex II is still justifiable.

A more precise focussing of the wording on free machining steel shall be chosen (e.g. lead in steel for machinery purposes and galvanised steel with a lead content up to 0.35%)

Even when the actual lead content is mostly below 0.3 % by weight an exemption for 0.35 % seems to be appropriate because allowance of a higher lead content in Annex II will not lead to a higher lead content in factual products.

A review in the year 2003 is considered to be appropriate to include the results of recent research.

3.2 Copper and its alloys containing lead

Field of application and product description

In this chapter lead containing copper alloys and bearing shells and bushes are dealt with together because they have many overlapping aspects.

The wordings of the entry in Annex II of the ELV-Directive are

- Copper alloy containing up to 4 % lead by weight (item 4).
- Lead/bronze bearing-shells and bushes (item 5)

Lead containing copper alloys are used in cars for a great variety of applications like e.g. nozzles, connection parts, fixtures or locks.

Bearing shells and bushes are used as small end bushes, big end bearings or main bearings in crank spins in combustion engines, or bushings in hydraulics and pneumatics. Lead is added for emergency lubrication purposes.

Conclusions of previous study

“A case specific examination is necessary.

The applicability of lead free solutions for bearing shells and similar antifrictional parts can only be proven in some application fields.

When substitution of lead by other alloying elements is considered, the main criteria are functional requirements during the use of the product (emergency lubrication) rather than costs.”

Work progress

Information exchange has been established with industry associations, supplier and car manufacturers. Two experts from the copper industry and a representative of their association attended a meeting in Hamburg in March 2001.

Results

AMOUNTS

The amount of lead containing copper alloys in cars can be roughly estimated at 8 kg to 12 kg. Their lead content varies between 0.2 % and 10 %. The lead amount contained in those applications will be around 50 g to 1,000 g per car.

An amount of 30 g lead was estimated by one producer only for bearing shells and bushes.

ALTERNATIVES

Even if some new developments or considerations took place since the previous study no alternatives are known so far that could be generally adopted.

In those cases where it is technically possible, lead containing bearings may be replaced by e.g. needle bearings or by AlSn-bearings. But those solutions were not found to be generally applicable.

ENVIRONMENTAL RELEVANCE

No detailed mass balance about the fate of lead containing copper alloys and bearing shells and bushes in the ELV recycling process is available. But it can be assumed that the vast majority will end up in the shredder scrap and shredder heavy fraction and will be transferred into metallurgical processes.

Recycling of lead in secondary copper process is possible in those cases where appropriate techniques are used.

Copper is seen as an unwanted element in the aluminium recycling process where it can end up via the processed shredder heavy fraction. Under this aspect the lead content is a minor issue.

Even in low amounts copper is seen as a disturbing element in the steel recycling process which can accumulate in the steel cycle. However this is not an item specific to lead-containing copper alloys.

Conclusions

Even if some new developments took place since the previous study a removal of the entry is not seen as appropriate.

3.3 Coatings inside petrol tanks

Field of application and product description

Automobile fuel tanks can be made using terne metal, which is steel sheet that has been coated with a lead-tin alloy in hot dip process.

Work progress

Reactions on this topic were included in the technical papers submitted by ACEA / CLEPA / JAMA on 31.1.01 and in a technical paper by VDA. The issue was also discussed with experts from steel and automobile industry on bilateral basis.

Conclusions of previous study

“Presently there are several car producers who do not use lead coated tanks. There are sufficient alternatives available which are also economically feasible.”

Results

Amounts

Like in the previous study, no data are available concerning the amount of lead used in lead coated tanks.

Alternatives

Several lead free alternatives are available and widely used by car producers:

- galvannealed[9] steel sheets with an additional organic coating
- galvanized steel with a nickel flash plating
- tin-zinc alloy coated steel sheet
- aluminium plated steel
- zinc nickel alloy with a chromium oxide film
- zinc plate coated with epoxy resin
- plastics.

[9] Galvanized steel with a following thermal treatment.

Most of the European companies changed to lead-free steel tanks already several years ago. Other companies only use plastic tanks or a mixture of plastic and steel tanks.

Plastic tanks have the advantage that they can be fitted even in complicated shapes. On the other hand, fuel permeability can lead to problems especially on the North American market where stricter permeability standards have been introduced.

The costs of non-leaded steel tanks are in the same range or lower than for leaded tanks. In Europe, zinc coatings are easily applicable. In other countries, a higher water content of fuel or the use of alcohol fuels (attract water from air) may cause problems because the zinc coating will be consumed upon contact with water. Requiring non-leaded steel tanks may cause problems when cars are imported to Europe from countries like e.g. Brazil. Organic coatings may sometimes not be satisfying as an alternative because of their solubility in gasoline.

ENVIRONMENTAL RELEVANCE

Leaded steel tanks will usually not be dismantled. The lead content runs back to the steel works (see chapter 5).

Organic coatings will be burned off in the steel process. Plastic tanks will end up in the shredder light fraction. The recycling of plastic tanks still remains difficult although this route was followed intensively in projects in the present and past. The diffusion of fuel into the material results in a contamination which is a drawback for recycling on a higher level.

Summary and Conclusions

Steel tanks with a lead free coating as well as plastic tanks are available and have been widely introduced in the series production of cars and these lead free alternatives are economically feasible. Difficulties with the lead free alternatives have been overcome. No technical reasons can be seen for a prolongation of this derogation.

3.4 Vibration dampers

Field of application and product description

Vibration dampers made of lead are used in various applications including balancing devices on the axle from gearbox to wheel, the steering column and vibration damping of different elements of the chassis. The weight is connected to the vibrating part via a spring or other elastic element in which the vibration energy is annihilated. Wheel balancing devices as well as lead containing elastomers for vibration damping of the engine are not covered by this entry.

Principally, such vibration dampers are not favoured by the manufacturers themselves, because they contribute significantly to the overall weight of a car and thus are in conflict with the targets of weight reduction and fuel saving. Manufacturers therefore try to improve their mathematical vibration modelling during the conceptual phase of a new model in order to avoid the necessity to use vibration dampers.

Nevertheless, in the development of a new model they may become necessary at a rather late stage, e.g. when certain noise problems cannot be solved otherwise, or when a test driver of a prototype reports about unstable behaviour at high velocity.

Conclusions of previous study

“Substitution of lead has been successfully practised in standard models and should be possible for new models of all manufacturers within two or three years' time. Certain problems may exist for special vehicles (e.g. open sports cars where the car body gives less rigidity), but also for other cars where plastics are increasingly used as construction materials.

Because of the large quantities of lead contained in them, vibration dampers appear to be a high priority for future efforts to minimise the presence of toxic heavy metals in vehicles. As long as they are still in use, dismantling of lead-containing vibration dampers is very important to avoid lead contamination of the shredder light fraction.

Under present circumstances, however, it cannot be expected that all vibration dampers will be dismantled because of insufficient information to dismantlers, and because market forces often will not support complete dismantling.

Consequently,

- vibration dampers made of lead should be avoided wherever possible;
- "design for recycling" must be improved for lead which cannot be avoided;
- it should be mandatory for manufacturers to offer information to car dismantlers about the presence and location of vibration dampers containing lead;
- incentives and / or controls are needed to ensure that dismantling is actually done."

Work Progress

Not much information is available here because the presence of vibration dampers might give a kind of bad reputation to the engineering performance. One official reaction to Ökopol's request on this topic was received by ACEA/CLEPA/JAMA dated from 11.6.2001.

Information is therefore based mainly on personal communication held with different technical experts in the field of car engineering and weight manufacturers.

Results

AMOUNTS

The quantity of lead used in vibration dampers can be significant. Typical weights are said to lie around 100 - 300 grams, but heavier weights up to 4.7 kilograms and even 20 kg in new car models (where the increased use of plastics led to serious noise problems) have been reported. As a general tendency the usage of vibrational dampers is more frequent in sports and open cars where the absence of the roof decreases internal stability. Additionally the mass of vibrational dampers increases with efforts in light weight construction where the passenger weight comes closer to overall car weight.

ALTERNATIVES

Vibration dampers made of lead are a fairly easy solution to vibration problems, but at the same time they are in conflict with the aim of weight reduction.

In some new models, lead used for balancing devices on the axle from the gearbox has been successfully substituted by cast iron. Other solutions could be found using highly filled polyacrylates. Presently, this substitution is not possible in all existing models for space reasons. Furthermore, cast iron does not absorb vibrations as effectively as lead and can give rise to secondary vibration problems. The engineering problems related to vibrations are said to increase with the upcoming developments in the field of light weight construction.

Substitution of vibration dampers is often possible but specially adapted solutions need to be found, e.g.:

- In some cases, use of the airbag module for vibration compensation has turned out to be a successful construction alternative for the use of mounted vibration dampers in the steering column.
- With a system called AIntegrated Starter Alternator Damper (ISAD)@[10] in some cases the mass damper in the drive train has been successfully substituted.

ENVIRONMENTAL RELEVANCE

Although massive lead will have a tendency to accumulate in the non-ferrous heavy fraction after shredding, experts from car manufacturers have confirmed to us that vibration dampers may contribute significantly to the lead contamination of the shredder light fraction.

The obligation to dismantle lead from vibration dampers as stated in Annex II is therefore also proposed by some manufacturers, however the effort to dismantle all damper weights is not expected to be economically covered by the material value of the weights in all cases. The reason herefore is that the balancing devices used as vibration dampers are often not at all easily accessible, and the dismantler has no information about the presence of vibration dampers in an old car, and the position where they are located. Availability of information about presence, location and dismantling procedure of these weights during the construction phase of a new car should be of interest for the car manufacturers to minimise costs for dismantling of ELV. The associations of ACEA, CLEPA and JAMA state that manufacturers intend

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[10] While usually cars use two separate electrical machines B one for starting up and one for power supply -, the ISAD system provides one unit that replaces the automotive vehicle's starter, generator and flywheel. Working as generator, ISAD controls the electric energy supply. Drive train vibration B and thus vibration in the vehicle as well B are reduced electromagnetically.

to register these parts in the IDIS system in order to route them in a controlled material stream.

Summary and Conclusions

No new evidence can be brought forward that would go beyond the conclusions of our previous study. Dismantling of vibration dampers is mandatory, and car manufacturers should establish a concept how to make information about the presence and precise location of weights in cars available to dismantlers. The implementation of lead weights in the information system IDIS (which is proposed by ACEA / CLEPA / JAMA) or an equivalent information system could be a suitable solution and should be mandatory. Additionally, some monitoring will be necessary here because publishing the damper locations is not in the natural interest of car manufacturers and could result in some resistance. As an indirect effect, such an obligatory publication may stimulate efforts to minimise the usage of these weights or to use alternative materials which do not have to be dismantled and made identifiable.

3.5 Vulcanising agents for high pressure or fuel hoses

Field of application and product description

Lead compounds are used as vulcanising agents for high pressure and fuel hoses with high safety demands (e.g. in power steering, fuel tubes, hydraulic applications etc.).

These lead containing vulcanising systems (epichlorohydrin and chlorosulphonated polyethylene) provide a good resistance towards heat ageing which is necessary for applications around the engine. Additionally these materials perform better than other rubber to compression set and swelling in water.

Applications not covered by this item are vent hoses used for de-aeration of various parts e.g. crank case, air ducts which are used for example in turbo devices and emission tubings, because all these do not refer to high pressure applications or fuel hoses. Lead in adhesives for silent blocks which isolate vibrations of e.g. engines are also not covered by this item.

Conclusions of previous study

`Irrespective of costs, no technical alternatives for substitution of lead as a vulcanising agent for high pressure and fuel hoses could be identified during this study.

The environmental relevance is considered to be relatively small due to the rather small amounts of lead in this application.A

Work Progress

Questions on this topic were send to ACEA / CLEPA / JAMA / BLIC and a detailed response was received by BLIC. Additionally the WdK (Wirtschaftsverband der deutschen Kautschukindustrie e.V.) was contacted and experts from their member companies were consulted on a bilateral basis. The issue was also discussed with experts in the field of car shredding from the automotive industry.

Results

AMOUNTS

The lead content in the material is reported to be up to 4.7 % by weight. The total quantity of lead in this application in an average car has not been reported, but lead in fuel hoses alone is reported to contribute 4 - 40 g lead per vehicle depending on the length of the hose. As fuel hoses are just one item in this field, the overall amount will be higher.

ALTERNATIVES

Lead compounds are used in epichlorohydrin and chlorosulphonated polyethylene to provide resistance against rough conditions like high temperature. The lead compound reacts as a vulcanisation activator and acid acceptor and prevents reaction of double bonds by complexation. According to manufacturers a trend to higher temperatures of the engine can be seen which resulted in the past in introduction of high temperature resistant epichlorohydrin rubbers. Presently in some models steel tubes are used for fuel, so that the hose is mainly used to dampen engine vibrations and its length is reduced to a few centimetres.

According to information submitted by BLIC, manufacturers are developing alternative rubber which is free of lead but moulding and extrusion processes need to be changed which is a very cost intensive action. BLIC states that this will take additional time and asks for a prolongation of the 2003 deadline to 1.7.2005 which is, still according to BLIC, not only related to technical problems but also to the time consuming approval procedures.

ENVIRONMENTAL RELEVANCE

Fragments of high pressure hoses will leave the shredder process via the shredder light fraction (SLF) or shredder heavy fraction (SHF) and will subsequently be deposited on landfills or incinerated. Since amounts of lead are estimated in the range of 4 to 100 g, the content of lead from this application reaching the SLF is assumed to be potentially significant. For a detailed discussion of the environmental relevance of lead in shredder light fraction the reader is referred to chapter 7.

Summary and Conclusions

Lead free alternatives are available for high pressure and fuel hoses but long term experiences do not exist so far. Special requirements due to approval procedures in this safety relevant field have to be acknowledged and a temporary exemption is a reasonable route.

BLIC states that lead-free alternatives are in the stage of development and are likely to be introduced by 1.7.2005. It is therefore supported to maintain this derogation in Annex II until 01.07.2005.

3.6 Stabilisers in protective paints

Field of application and product description

The first of several layers of protective paints on the car body is the electrodeposited coating (E-coat) whose main function is to protect the metal against corrosion. In a cathodic bath, lacquer particles are deposited on the metal surface by application of an electrical field. After removal of excess paint material, the lacquer is fixed by heating, yielding a lacquer thickness of circa 18 µm.

Lead containing parts / coatings outside the field of sub layers for corrosion protection in painting procedure are not covered by this item.

Conclusions of previous study

“The conversion of existing paint shops in which lead-containing protectives are still applied should be possible within a couple of years. A similar period may be required for necessary changes along the supply chain until all suppliers will fully meet the specifications requiring the use of lead-free protective paints.”

Work Progress

The evaluation in this field was focussed on the present state of introduction of lead free protective paints in the European automotive industry. A request on this topic was submitted to ACEA/CLEPA/JAMA however no reaction was received. Our evaluation was therefore based on literature survey, internal information from parallel projects, and bilateral contacts with several experts in this field.

Results

AMOUNTS:

The thickness of the E-coat layer is approximately 18 µm. From this figure the amount of lead is estimated to lie between 0.2 and 0.4 g/m², giving an estimated total mass of lead between <10 and 50 grams per vehicle.

ALTERNATIVES

Lead-containing protective paints are gradually being phased out in the automobile industry. The principal motivation for this change is to reduce hazardous waste problems, both in waste-water discharge and filter disposal.

Apparently, the aim is to substitute the use of lead and chromium-VI during E-coat application simultaneously. Where this has been achieved, the lead-free paints safely meet the high quality requirements of the car manufacturing industry. The costs are competitive with the lead-based paints (the slightly higher price of the paint is compensated by the greater yield and by savings on waste management) provided that either the paint shop is newly constructed, or the conversion is carried out simultaneously with some other retrofitting or repair measures. Most car manufacturers are presently either applying lead-free protective paints in full scale production or are at least in the process of conversion in most of their paint shops.

The conversion of existing paint shops in which lead-containing protectives are still applied is possible but rather expensive. If it is accepted that the conversion is economically feasible only in combination with some other retrofitting or repair measures, the complete phase-out of lead-containing E-coats will be possible within a few years. Several manufacturers state that they need a prolongation for this derogation in Annex II to Directive 2000/53/EV until 2004, because not all paint shops will have been changed by 2003. Some others will completely phase out lead and hexavalent chromium by 2003.

ENVIRONMENTAL RELEVANCE

Upon shredding of the car body, some of the lead-containing E-coat may remain in the steel fraction (for further fate in steel plants see chapter 5) while the majority will end up in the shredder light fraction (for environmental relevance see chapter 7).

Summary and Conclusions

Lead-containing protective paints are gradually being phased out as it is the interest of the automotive industry to reduce their hazardous wastes, and performance of alternative paints is sufficient. Complete phase-out of lead until 1.7.2003 will be achieved by at least one manufacturer. However, other manufacturers state that they need a prolongation until 1.7.2004.

In order to allow for the necessary conversion of existing paint shops along the supply chain, we propose to allow a prolongation until 1.1.2005 taking into account the same deadline as proposed for substitution of Cr VI in fixation grounds (see Chapter 3.8).

3.7 Solder in electronic circuit boards and other applications

Field of application and product description

Soldering in the automotive industry includes a number of issues, ranging from soldering of printed circuit boards to electric connections at different parts within the car (`other applications”) like antennas. Brazing of components is not covered by this item. For brazing lead free solders are available and presently being used.

Technical progress leads to an increasing use of electronic devices in automobiles, some of them under extreme conditions such as strong vibrations and high temperatures (e.g. when applied directly on the engine block) which require solders with a higher melting point.

With respect to lead-containing solder in `other applicationsA three examples were described in a technical paper submitted by ACEA/CLEPA/JAMA on Ökopols request. These applications include e.g. the connection of wires to vehicle glazings (like heating of the rear window, antennae and alarm systems). One car manufacturer provided Ökopol with a list of `other applicationsA which includes bolts, nuts and screws for cable sockets, crimping of cable sockets and soldering of electrical components etc.

Conclusions of previous study

“Presently extensive investigations to find lead-free alternatives are carried out by several car manufacturers and suppliers, and replacement of lead is already possible in several application fields. But it has to be considered that there is no universal solution that would be suitable for all cases. Unlike consumer electronics like TV or hifi systems, safety requirements in cars, in combination with temperature and mechanical stress and corrosive conditions, make replacement more problematic.

Lead-free soldering in the automotive industry can only be implemented stepwise. Experiences from applications with moderate safety demands and ongoing research will lead to transfer of lead-free soldering technology from automotive parts with less adverse conditions (e.g. interior) to those with more demanding requirements.

A total ban of lead containing soldering cannot yet be recommended in the present situation.”

Results

AMOUNTS

Total amounts of electronics differ widely between manufacturers and different car models but can be estimated to lie around 4 to 8 kg excluding electronic housings. The total lead amount in printed circuit boards in Japanese middle class cars is roughly estimated at 50 g. Solder for rear window heater, antenna and windscreen heater may contain between 0.3 and 1.5 g of lead each. More detailed figures on amounts of electronics and their lead content have been evaluated by the car manufacturers but were not submitted to Ökopol.

ALTERNATIVES

Phase out of lead in solder of printed circuit boards is an objective of ELV and WEEE-Directive. This gave research a new impulse. Large companies like Motorola, Philips, Siemens, Matsushita, Fujitsu and Nortel are already investigating the feasibility of lead free soldering technologies. It has to be acknowledged, that change to lead free systems has an impact on the full process which includes fluxes, surface-coatings and the solder itself. The special technical demands in production due to sequential soldering, which requires the introduction of several solder types with different melting temperatures have also to be taken into account. A summarising study for car electronics has not been worked out yet. Therefore, it is difficult to quantify the environmental impact from lead in solder and the proposed alternatives.

There is no universal solution for replacing leaded solders that would fit for every application in cars and in some applications a replacement will not be possible at reasonable costs. As some substitutes may contain up to four or five different elements, the list of potential alternatives is very long.

ENVIRONMENTAL RELEVANCE

Car Shredding: Lead from solder of printed circuit board will leave the shredder process mainly via the shredder light fraction (SLF) whereas solder from other applications is expected to be distributed over several shredder fractions depending on the type of material they are connected to (e.g. steel, non-ferrous metal, glass etc.). According to dismantlers and car manufacturers the lead input into the SLF from electronic solder is significant and is presently apart from antimony one of the main reasons which hinders the use of this shredder fraction in metallurgical or similar processes. Lead contents of the SLF are said to vary widely between 4,000 and 25,000 ppm.

Dismantling: One manufacturer states, that presently just a small portion of electronics are easily accessible and therefore suitable for dismantling. The electronics are widely distributed over the car. The location of electronics is not only determined by functional but also by design purposes. A design for dismantling would imply a combination of most of the electronics in one easily accessible location which would be possible in principle.

Summary and Conclusions

Presently extensive investigations to find lead-free alternatives are carried out by several car manufacturers and suppliers, and replacement of lead is already possible in several application fields. A total ban of lead containing soldering cannot be recommended in the present situation.

All applications of solder in `other applications" known so far are all related to electrical applications where the solder has at least partly a conductive function. To help this derogation becoming more precise and transparent, it is recommended to change the wording of Annex II in ASolder in electronic circuit boards and other electric applications".

A mandatory dismantling of the main part of electronics would have a positive impact on the reduction of hazardous substances in the SLF. Therefore it is proposed that dismantling should be mandatory if a maximum allowable amount of 30 g lead per vehicle from this category is exceeded[11]. An adequate monitoring and reporting procedure should be established in Member States.

[11] For detailed justification of the proposed threshold limit value see Chapter 7

3.8 Hexavalent chromium in corrosion preventive coatings

Field of application and product description

Zinc chromate and chromium chromate are used in car manufacturing as anti-corrosion pigments with active corrosion-preventive properties. Hexavalent chromium is used in two main fields: The cathodic corrosion prevention which is applied mainly for smaller steel parts and the rinsing solutions containing hexavalent chromium which are used in paintshops after phosphatisation as a fixation ground before additional layers of paint are applied.

Protective coatings based on hexavalent chromium are very effective because of their "self-healing" properties after small injuries of the surface layer.

In entry 12 a threshold limit value of 2 g Cr VI per vehicle is implemented. The original wording is:

- Hexavalent Chromium in corrosion preventive coating (maximum 2 g per vehicle)

Conclusions of previous study

`It is possible to produce cars without chromium-VI in most applications already, with some remaining problems concerning the supply chain. Corrosion-free screws which are required to be disconnectable even after many years may be particularly difficult to substitute.

Because of the technical importance and the variety of application fields, a general ban of zinc and chromium chromates may not be appropriate. Rather, the applicability of alternative materials or processes should be examined on a case-by-case basis, and substitution should be done wherever possible.

Work Progress

On 02 March 2001, Ökopol attended a meeting with circa 20 materials specialists from the automotive industry and affected supply sectors who are experts on corrosion protection. In response to our request, after the meeting additional information was submitted and evaluated.

Additionally, literature and ongoing discussions at technical workshops have been followed.

Reactions on this issue were submitted by ACEA/CLEPA/JAMA[12], VDA/WVM, PSA, Renault and EUROFER.

Results

AMOUNTS

According to the automotive industry 4 to 8 g hexavalent chromium is used per car as an average but some will contain more than 10 g.

ALTERNATIVES

Cathodic Coatings: In present car manufacture, corrosion-preventive coatings containing hexavalent chromium are applied on numerous parts made mainly from steel beside other materials like aluminium, zinc and magnesium:

- Ca. 2500 small connecting elements per car like screws and clips etc.
- Ca. 100 middle sized steel parts like V-belt discs or mechanical levers etc.
- Ca. 50 bigger parts like radiator, rims and steel tubes for brake liquids etc.

Additionally to corrosion protection some parts must fulfill requirements like disconnectability even after several years of use or special sealing or similar function in high pressure liquid system applications (e.g. high pressure fuel injection, brake liquids). For these applications which are also safety relevant, extensive time for introduction of alternative corrosion or sealing systems will be needed. In some other cases, it cannot be excluded that certain parts are chromated for merely decorative purposes today (e.g. to yield a blue, black or yellow surface colour).

A range of strategies to substitute hexavalent chromium have been developed, including thick layers based on zinc combined with an organic coating, and zinc powder alloys in duplex lamina which give a better corrosion protection.

For small parts like screws, alternative processes which are free of hexavalent chromium have been principally developed. However, these screws are often galvanised in small companies who are running only one production line, thus being

[12] This submission assumed that the quantitative limit of "maximum 2 g per vehicle" set by Annex II to Directive 2000/53/EC was based on Ökopol's previous study but in fact this was not the case.

unable to offer two different qualities of screws. After the change, screws are estimated by car manufacturers to be 30% more expensive, in other words one kilogram of screws would cost 3.20 Euro instead of 2.40 Euro.

The change to alternatives will require significant reconstruction of galvanic plants, many of which are located outside the European Union, whose operators presently are hesitant to invest as long as there is no clear orientation concerning the substitutes. As soon as these suppliers have changed their processes, it can be expected that phase-out of hexavalent chromium by the car manufacturers will occur almost immediately. Suppliers state, that the development of new protective systems would not have been developed without the upcoming EU-directive as the higher prices of these alternatives would not have been accepted by the automotive industry.

Rinsing Solutions: For chromium containing solutions used in paintshops after phosphatisation, alternatives are readily available for steel and aluminium and are in widespread usage for car bodies.

In July 2000, the German automobile industry has set up an internal working group which has submitted a list of coating systems in descending order of priority for phase-out of hexavalent chromium in a case by case process.

The working group suggests to implement a total phase out of Cr VI by 1.1.2007 with a review date on the 31.12.2004 which is consistent with the technical paper submitted by European associations ACEA / CLEPA / JAMA at 31.1.2001. However in an information submitted by ACEA / CLEPA / JAMA at 11.6.2001 the total phase out of Cr VI by 2007 is described as being unlikely.

The priority list submitted by the industry is shown below and dates were added for the single steps by Oekopol after consultation of experts from the industry (see Table 4).

Table 4: Industry proposal and Ökopol comments on phase out plan for Cr VI

N°	Application of Cr VI	Industry proposal	Ökopol assessment
I.	Transparent and blue chromated systems	01.07.2002	agree
II.	Yellow chromated systems and sealings	31.12.2004	01.07.2003
III.	Zinc lamella systems	31.12.2004	agree
IV	Electrophoretic paints for corrosion protection	31.12.2004	agree
V	Black and olive-chromated surfaces	01.01.2007	agree
VI	Corrosion protection systems for aluminium	01.01.2007	01.07.2003
	Corrosion protection systems for magnesium	01.01.2007	agree
	Fixation ground for additional layers of paint	01.01.2007	01.01.2005

All applications with a phase out date after 2003 are due to revision before end of 2004.

This step-wise phase out should enable the market to change in an appropriate time scale. Taking into account the time required for diffusion of information, reconstruction of galvanic plants, creation of full capacity, qualification and validation of parts and components for series manufacturing phase out on a case-by-case basis is a reasonable route.

Differences to the phase out plan proposed by the experts from industry (entry II and VI) are suggested by Ökopol for those systems where alternatives are well established and already in use. Chromated surfaces on aluminium e.g. on wheel rims might fulfil merely decorative purposes to yield special optical effects. For magnesium, alternatives are not yet available but research is said to be promising.

Analysis of Cr VI

The analytical procedure for determination of the Cr VI content is not sufficiently harmonised yet, and although car manufacturers are interested, it is not expected that a reliable and straight forward analytical procedure to be used directly in the production process will soon be available.

ENVIRONMENTAL RELEVANCE

The main concerns about Cr VI are related to occupational safety and health issues, and to production waste and discharge waters. For these reasons, its use has already been significantly reduced by car manufacturers in recent years.[13]

Zinc chromate and chromium chromate are cancerogenic substances which upon inhalation cause cancer to the bronchial tract. Skin contact may cause sensitization towards allergical reactions. Human exposure can occur mainly during production, in repair shops during grinding, and in recycling processes.

Summary and Conclusions

It has to be acknowledged that corrosion protection needs to be tested on a long time basis. The widespread usage of chromium VI in the car makes this field a rather complex one. The different functions of Cr-VI in addition to corrosion protection and some safety relevant applications make a phase-out of Cr VI following a case-by-case process reasonable.

We therefore recommend to follow the phase out plan in Table 4 as proposed by Ökopol with a

- phase out of transparent and blue chromated systems by 01.07.2002,
- phase out of yellow chromated systems and sealings, corrosion protection systems for aluminium by 01.07.2003,
- phase out of Cr VI in zinc lamella systems, electrophoretic paints and in fixation ground for additional layers of paint by 01.01.2005 with a review date in 2003,
- and phase out of Cr VI in black and olive-chromated surfaces, and corrosion protection systems for magnesium by 01.01.2007 with a review date in 2003.

This will result in a total phase out of chromium VI by 2007 with a revision date in 2003.

The threshold value of 2 g chromium-VI per vehicle should be deleted because a standardised analytical procedure for chromium-VI is difficult to establish.

[13] Some years ago, hexavalent chromium was still deliberately applied on the surface of brakes, thus leading to direct losses to the environment.

3.9 Mercury in bulbs and instrument panel displays

Field of application and product description

Some bulbs for headlights are gas discharge bulbs filled with a mixture of sodium, scandium and mercury as an illuminant, and very small amounts of thorium oxide and sometimes of thallium (0.2 µg/bulb). To reach the necessary voltage, additional devices are necessary. Mercury containing light systems have a very strong light intensity and a long life span. One disadvantage (during the use of those bulbs) is the subjective glare effect for oncoming drivers.

Besides their application in headlights, mercury containing lamps are used for background illumination of displays in automobiles (e.g. in navigation systems).

In rare cases, mercury containing lamps are also used for lighting inside the car (e.g. in the loading compartment).

Conclusions of previous study

Concerning gas discharge devices for headlamps we concluded:

"During use, mercury containing gas discharge bulbs have clear advantages over halogen bulbs in terms of light intensity, whiter light and lower power consumption. Halogen bulbs cannot combine all these aspects but can exhibit only single ones.

During ELV disposal, mercury containing bulbs are rather time-consuming to dismantle and very expensive to dispose of. High dismantling quota can therefore only be expected when the dismantling and/or disposal will be subsidised.[14]

Balancing up the environmental hazard of mercury containing bulbs (plus their necessary periphery) versus the environmental benefit of reduced energy consumption will only be possible on the basis of validated LCA data."

On other discharge lamps we concluded:

"While there are no mass production approved alternatives for background illumination yet, mercury containing bulbs for lighting of the passenger room or

[14] But even then the export of cars e.g. into Eastern European countries ouside the EU will remain as a problem.

loading compartment are replaceable."

Work progress / Results

In spite of several requests among the associations of ACEA, CLEPA and JAMA as well as among the leading suppliers of these mercury containing lights, no new information was obtained. More specifically, no LCA data were submitted which would allow for a balanced judgement on the environmental hazard of mercury containing bulbs (plus their necessary periphery) versus the environmental benefit of reduced energy consumption.

Conclusions

It is presently recommended to keep this derogation. It is to be underlined that Annex II to Directive 2000/53/EC requires these applications to be "labelled or made identifiable in accordance with Article 4(2)(b)(iv)", and because of the time-consuming dismantling and expensive disposal an adequate monitoring will be required to ensure that this is actually done before shredding.

4 Additional applications brought forward by industry

4.1 Brake linings

Field of application and product description

Brake linings are the factual friction material applied on the surface of metallic carriers in brakes. They contain lead and lead compounds (like lead sulphide) as performance enhancers. Additionally brass shavings are used which contain a relevant percentage of lead.

Brake linings are not mentioned in Annex II to Directive 2000/53/EC.

Work progress

Written, personal and phone information exchange took place with several car producers and the Federation of European Manufacturers of Friction Materials (FEMFM).

Results

AMOUNTS

According to Federation of European Manufacturers of Friction Materials (FEMFM) friction material itself contains as an average 2 % lead by weight in metallic or compound form (maximum value for 'best in class' friction material 10%). Table 5 describes portions of lead in typical break linings according to FEMFM (data submitted in July 2001).

In Europe around 100,000 t of brake linings are produced per year for vehicles of the category M1 and N1 (40,000 t friction material, 60,000 t carrier material) containing 800 t of lead according to the first submission of FEMFM.

Table 5: Portions of lead in a typical brake lining

Formula			
	Portion in the formula (%)	**Portion of lead in the raw material (%)**	**Portion of lead in the formula (%)**
Components without lead (bonding agents. fibres. friction modifiers like graphite or coke)	30	--	--
Brass chips	20	2.30	0.460
Iron powder	10	0.35	0.035
Steel wool	22	0.35	0.077
Antimony compounds	10	0.60	0.060
Friction modifiers with lead impurities	8	0.60	0.048
Total	100		0.680
Completed Brake Lining			
	Weight (g)	**Weight content of lead (g)**	**Portion of lead (ppm)**
Formula	100	0.68	6800
Backing plate	200	0.7	3500
Total brake lining weight	300	1.38	4600

ALTERNATIVES

Lead free friction materials are already in use and the majority of new cars from different manufacturers are already equipped with lead-free brake linings. One alternative in use is for example graphite. However in most cases a 1:1 replacement of lead by one alternative material is not possible but it will be necessary to develop fully new recipes because properties of brake linings are determined by a complex interaction of different materials.

FEMFM sees a major problem in the time period needed for testing and getting a type approval.

FEMFM holds the opinion that in a first step an exemption until 2008 is necessary.[15]

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[15] *"After the mentioned 5 years we again should prove whether the responsibility for a complete renunciation of lead in brake linings can be taken. If this still is not possible we again should decide for which further transition time brake linings should remain in the exemption list" [Statement of FEMFM*

ENVIRONMENTAL RELEVANCE

Materials in brake linings have a direct environmental relevance because during use they are worn off and directly released to the environment.

According to FEMFM 26,000 t of friction material are worn off during use in Europe per year. Based on these data and on an estimated lead content of 2 % the released lead amount can be estimated around 520 t per year.

A study by the Swedish EPA[16] released in 2000 showed lead emissions from brakes of 560 kg/y in Stockholm alone. Table 6 shows the results relative to other releases to the environment.

Table 6: Major goods emission sources in Stockholm, 1995 - Lead

	Goods	**Calculated emissions (kg/y)**	**Remarks**
Vehicles	Tyres	300	
	Brakes	560	
	Petrol	100	
	Car wash	300	
Buildings	Chimney collars	6-70	
	Wood preservative	200-1200	
Infrastructure	Road pavements	100	
Specials	Ammunition	5500	Mostly shooting grounds
	Sinkers, sport fishing	5000	Mostly Norrström
Total Pb emissions	(except ammunition and sinkers)	1700-2700+?[1]	

[1] Unquantified emission sources: Balance weights, miniated steel bridges, paints/pigments

During the ELV recycling process the vast part of brake linings will end up in the metal recycling processes.

Summary and Conclusions

Lead contained in brake linings is directly released to the environment.

from May 2001].

[16] B. BERGBÄCK, K. JOHANSSON, U. MOHLANDER: URBAN METAL FLOWS - A CASE STUDY OF STOCKHOLM, Stockholm, 2000

One major obstacle for a shift to lead free brake linings as stated by the FEMFM is the time needed for testing and type approval.

Because of the significant release directly into the environmental a phase out of lead in brake linings should be aimed at as fast as possible.

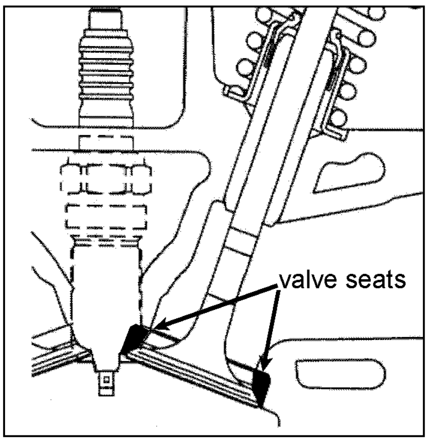
The ELV directive may give a fresh impetus to promote and speed up the development.

Replacing lead is seen as technically possible for newly developed brakes. For existing models we propose to allow a temporary derogation until 01.07.2004 with a review date by 01.07.2003.

However if an exemption is taken up in Annex II of the directive it seems to be appropriate that the public, the buyer and the owner of the respective car shall be informed about the presence of lead in the brake linings (in correspondence to Article 9.2 of the directive) and that the exemption is marked in Annex II. Appropriate monitoring should be established.

4.2 Valve seats

Field of application and product description



Lead-containing valve seats are used in engines in the intake and exhaust where it is added as a kind of lubricant.

This item is not covered by the present Annex II of 2000/53/EC.

While the item of lead in valve seats of engines powered by gaseous fuels was presented to Ökopol already in January 2001, the first information about the use in conventional powered cars was not submitted before early July 2001.

Work progress

Written, personal and phone information exchange took place with car producers and producers of valve seats.

Results

Amounts

The lead content of valve seats ranges between 8 % and 18 % which means between 1.4 g and 1.5 g lead per valve seat. A car with 16 valves contains around 24 g lead in valve seats.

Alternatives

Lead is currently already replaced in different engine types by other substances with a similar lubricating characteristic (e.g. MnS, MoS_2, CaF_2, graphite). As far as it is known until now those alternatives are not yet available or tested for all kind of engines but development and especially testing is under way.

Environmental relevance

It is unlikely that valve seats are separated from the motor metal during usual shredder processes. Therefore valve seats will end up in metallurgical processes with shredder scrap or with aluminium.

Conclusions

It seems to be justifiable that no exemption for lead containing valve seats will be included in Annex II for newly developed engines but only for current ones. Therefore a temporary exemption until 1.7.2005 with a review date 1.7.2003 seems appropriate.

4.3 Lead in pyrotechnic initiators

Field of application and product description

Pyrotechnic initiators are used for air bags and seat belt pre-tensioners. In 75 % of the European cars, lead styphnate is the chemical compound used to initiate ignition.

Conclusions of previous study

This topic was brought forward by the suppliers of the car industry and their associations and was not included in the previous study.

Work Progress

Information was received from ACEA/CLEPA/JAMA and a paper was submitted by the French Vehicle Equipment Industries association (FIEV) together with the French association in the field of pyrotechnics (SFEPA). In addition a very detailed technical report and phase out plan has been submitted to Ökopol by two manufacturers of pyrotechnic chemicals.

Results

AMOUNTS

Lead is present in minor quantities of 50 to 310 mg lead per car in this application.

ALTERNATIVES

At present two different ignition systems are used in European cars, the low and high energy systems which are ignited by a small or high electrical current respectively. For high energy systems, which are used in 25 % of the European cars, lead free ignition chemicals are available and presently used. Alternative techniques and / or chemicals for low energy systems are presently under investigation but uncertainties remain whether this will be successful. The original equipment manufacturers (OEM) play a crucial role here because their specification requirement of a small electrical energy for ignition (low energy systems) is an important factor for the availability of alternatives. Manufacturers state that presently it is not decided whether the change to lead free initiators will be made by change to high energy systems or by developing new pyrotechnic chemicals. In either case, considerable time will be needed for the change because of the necessary development, validation and qualification procedures in these safety sensitive applications. The consequences of the substitution for electronic equipment, inflating system and the technical periphery cannot be considered independently. A change of the ignition chemical will have an influence on the whole ignition train because it is an integrated part of the vehicle occupant protection system. One manufacturer requested a temporary exemption until 1. July 2007.

ENVIRONMENTAL RELEVANCE

Lead from pyrotechnic initiators is expected to end up in the shredder light fraction or as dust when air bags are initialized before shredding. The impact on the environment is expected to be relatively low due to the small quantities involved.

Summary and Conclusions

The phase out of lead in pyrotechnic initiators is technically possible. 25 % of the European cars contain a high energy system which is already lead free. The change to lead free systems for the low energy systems (75 %) is likely to need more time due to long development, validation and qualification procedures in these safety relevant applications. The amounts are low with a maximum of 310 mg lead per car.

A temporary exemption for lead in pyrotechnic initiators appears reasonable and does not give rise to a considerable drawback for the aim of reducing lead in the shredder light fraction, because the amounts of lead are relatively low.

4.4 Electrical components which contain Cd in a glass matrix

In numerous electronic components, including those for safety applications like ABS or airbag electrics, thick film compositions are used which contain cadmium. Cadmium is intentionally applied in a glass matrix which contains 1 % cadmium. Cadmium enhances the adhesion properties of the thick films. For the applications mentioned a high reliability is required. Amounts are very low with appr. 2 to 10 micro gram per car which would add up to a total amount of 10 to 20 kg per year in Europe. Cadmium free alternatives are known and are presently introduced but a delay is requested until 2006 due to long validation and qualification procedures in such safety relevant applications.

It is recommended to tolerate this application temporarily because the quantities involved are small, some of the applications are safety relevant and the substitution is presently going on. The success of the ongoing substitution should be verified in the further revision steps of Annex II.

4.5 Lead in carbon brushes of electric motors

Field of application and product description

Lead is an ingredient in the copper / graphite brush recipes in most of the automotive electric starter motors which are run at high DC voltage (high current electric motors). Additionally smaller amounts of lead are contained in low current electric motors such as blower motor, wiper motor and power steering motor. Single representatives of the automotive and electronic industry state that nearly all cars are affected. Carbon Brushes are not covered by item 4 (`copper alloy containing up to 4 % lead by weightA) as mentioned in a statement from 11 June 2001 by ACEA/CLEPA/JAMA.

Work Progress

Although CERAME-UNIE had mentioned this item in a paper dated 22 May 2000 already, no association or company from the automotive sector submitted technical information or requested for a derogation. Since no information was received, we included the issue in our information request to ACEA/JAMA/CLEPA on 6 April 2001. Even then the associations did not submit technical information until today, but one ceramics manufacturer who was originally contacted on another issue submitted technical information on 6 June 2001.

Results

AMOUNTS

According to a manufacturer a typical starter motor, which uses four brushes, will contain approximately 10 g of lead. Low current motors like blower motor, wiper motor and power steering ,motor might contain 0.1 g lead each.

ALTERNATIVES

Lead is used in the copper / graphite mixture of the brush. Lead is added to improve the tribological characteristics of the brush by increasing the film formation on the commutator. This has a positive effect as friction and wear of both commutator and brush is reduced. Additionally, the presence of lead does not influence the electrical properties of the brush since lead does not form an alloy with copper. Lead is therefore stated to enable an increased life time of the starter motor. Life time of the starter might be an important factor in the future development as new designs of automotive switch engine off when car stops and have therefore to use the starter more often.

According to one manufacturer developments were followed on two routes: On the one hand replacement of lead by other elements like tin or zinc was tried and on the other hand replacement by compounds like zinc oxide, molybdenum disulphide and others have all been tested. In both cases, alternatives are stated to show decreased performance in electrical characteristics and a reduced life time.

However, some starter motors do not require lead but the tribological characteristics of these systems are not fully understood. These alternatives might be produced by using elements such as chromium, bismuth and antimony some of which are also environmentally relevant. One important manufacturer of starter motors decided to change to lead free carbon brushes before 1.7.2003 instead of asking for a new derogation in Annex II.

Environmental relevance

During the life time of the starter motor lead will gradually be lost to the environment. One manufacturer states that after the typical life time of 10 years approximately 6 of the 10 g lead incorporated will be released to the environment in form of particle emission. Emission from low current motors will be smaller.

This application can thus be described as open to the environment because more than half of the lead incorporated is discharged to the environment. Additionally, the discharge of copper from the brushes needs to be considered. Upon shredding of the car body or engine, some of the lead-containing brushes may remain in the steel fraction (for further fate in steel plants see chapter 5) while the majority will end up in the shredder light fraction.

For a detailed discussion of the environmental relevance of lead in shredder light fraction the reader is referred to section 7.

Summary and Conclusions

The quantity of lead in carbon brushes is relatively high. It seems worth noting that approximately 60 % of the lead in this application will be released to the environment and will therefore contribute significantly to the diffuse transport of lead into the environment. Some starter motors do not require lead and this route will be followed by the manufacturers. At least one OEM manufacturer stated that he will use lead-free brushes by 1.7.2003. For low current electric motors alternatives are quite well developed.

The environmental impact of the alternatives should also be taken into account, but at present information on these is limited.

The information on the subject was submitted to Ökopol at a very late stage and a detailed technical analysis and establishment of bilateral contacts was therefore not possible. Impact of the considered alternatives on environment and public health should be subject to further investigation. The information submitted so far is not sufficient to make a qualified proposal for a possible derogation in Annex II.

4.6 Hexavalent chromium in adsorption fridges of caravans

Adsorption fridges of caravans contain Cr-VI as corrosion protection agent in the cooling liquid. The amount of Cr VI is between 1.6 and 6.4 g per fridge, i.e. per vehicle. 600,000 pieces of these fridges are produced annually. The main manufacturer of these fridges has performed research on Cr- VI free fridges, but at the present stage no adequate alternative could be found and is not expected in the near future. Fridges in caravans are recommended to be dismantled before shredding and to be treated jointly with similar household appliances according to regulations under WEEE Directive on Waste from Electrical and Electronic Equipment.

4.7 Additional applications in cars which contain heavy metals

I. Vulcanising agents in general rubber goods: Some elastomers within the car contain lead but are not covered by entry 9. Applications known so far include:

a) vent hoses used for de-aeration of various parts e.g. crank case

b) air ducts which are for example used in turbo devices

c) emission tubings.

The lead content of these elastomers is stated to be around 5 %. The overall amount of lead containing rubber per car is not known. No technical information was received on this item.

II. Lead in adhesives for silent blocks: Silent blocks isolate vibrations of e.g. engines from the cars chassis. Adhesives presently used for connection to fittings made of steel do presently contain lead. This item is not covered by entry 9 or 8 of Annex II. No technical information was received on this item.

5 Heavy metals in the steel recycling process

In this chapter, a brief outline of the effects of heavy metals in the steel recycling process is given in order to avoid frequent repetition concerning environmental aspects in the sub-chapters on individual heavy metal applications.

The biggest part of alloyed steel will end up in Europe as scrap in electric arc furnaces (EAF).

Lead

Even though a detailed balance of the fate of lead from alloyed steel in the recycling process is not known physical properties make it likely that most of the lead will be extracted into the off-gas. Where state of the art abatement techniques are installed the predominant part will be captured in the dust filters of the off gas cleaning system. The captured dust may be transferred to recycling facilities where lead may be won back.

Different statements were received how likely it is that the dust will be recycled. The most important influence with respect to economic factors is the zinc content in the dust and the content of accompanying elements.

While dust recycling companies stated that recycling is the standard path for dust disposal EUROFER pointed out that some time zinc recovery is not economic unless the zinc content is at least 30 %. This was confirmed by some steel producers.

A smaller part of the lead will diffuse into and / or through the furnace lining.

Tin

Just a minor part of tin from scrap will be evaporated or slagged in the EAF process. Tin will remain predominately in the steel bath and thus must be seen as impurity. It is mainly problematic in a view of stabilizing the steel cycle and reducing the need of Aclean@ primary metal for dilution.

Bismuth

The recovery of pure bismuth (which is also evaporated from the steel bath) from EAF dust is unlikely in the present configuration of the steel dust recycling chain. If EAF dust contains both zinc and bismuth, zinc recovery will only be possible after an additional refinery step which will increase the costs of treatment.

6 Impurities

Background

According to Article 4.2 (b) (i) of Directive 2000/53/EC maximum concentration values shall be established up to which the existence of lead, mercury, cadmium or hexavalent chromium in specific materials and components of vehicles shall be tolerated.

This chapter discusses the problem that traces of the four mentioned heavy metals may be found in products as impurities without having them intentionally added during the production process. This could be mainly problematic for secondary materials. Aside from the fact that a zero level of the four heavy metals is a theoretical value which is impossible to achieve in practice, material cycles could be endangered if no appropriate and practicable solution can be found.

The level of impurities in primary raw materials can be described in more precise ranges than those of secondary raw materials As a result of different processes respectively refining steps, variations in the impurity content of primary materials can occur.

In secondary raw materials the levels of impurities change in wider ranges, sometimes from batch to batch, depending on the input material.

Another aspect to consider is the fact that the level of tramp elements may rise during the years because they are accumulating in the cycle. [17]

Currently maximum tolerable values are mostly set from a product quality point of view. Therefore only very few data exist about the factual level of some elements (e.g. cadmium in aluminium).

[17] One example could be lead in the aluminium cycle which cannot be removed from the aluminium melt.

Focussing

Of the four heavy metals mentioned in the Directive, two are of lower relevance concerning the question of impurities: Hexavalent chromium is unlikely to occur as a tramp element in metals because it will be reduced to Cr^{III} in most thermal processes. Metallic mercury is also unlikely to occur in products as an unwanted tramp element because of its volatility.[18]

Cadmium as an impurity may be relevant mainly in zinc and aluminium, while lead is an impurity in aluminium. Only very little is known about impurities in non-metallic materials.[19]

Discussion process so far

The issue of impurities was raised by ACEA / CLEPA / JAMA at a meeting in January 2001. The industry associations promised to come up with their own ideas on the issue, however no proposal was made since then.

We nevertheless discussed the issue with individual stakeholders, some of whom did come up with their own proposal.

Most known proposals are going the way via a threshold value:

- The Danish lead ban strategy is targeting at materials or substances with more than 100 ppm lead in homogeneous material.
- The German Association of aluminium recycling industry (Verband der Aluminiumrecycling-Industrie e.V.- VAR) propose a Cd threshold value in a range which is tolerated for casting aluminium which may come in contact with food (0.05 %) as mentioned in EN 601 (draft).
- The German Association of Non Ferrous Metal Industries (Wirtschaftsvereinigung Metalle - WVM) propose a threshold in the range of 0.1 % of the levels mentioned in the Directive 1999/45/EEC[20] on Classification, packaging and labelling of

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[18] For its compounds the situation may be different when no thermal processes are step of the production.

[19] For example it hass been reported that secondary polypropylene from recycling of battery housings is contaminated with lead.

[20] Directive 1999/45/EEC on classification, packaging and labelling of dangerous preparations

dangerous preparations.

- Two car manufacturers stated that, from their point of view, targeting at >intentionally added materials= may not be helpful, because traces of catalytic substances which do not remain in the final product could become problematic. They would prefer threshold values.
- Some rubber manufacturers proposed a formulation like `not intentionally addedA.

Preliminary Conclusions

Two main directions are currently in the discussion:

- fixing a threshold value
- aim at substances and / or materials which are deliberately added.

Both approaches may be used in a complementary way in order to best achieve the aim of Directive 2000/53/EC to reduce the amount of heavy metals in cars. The wording should probably refer to homogeneous material, and threshold values should refer to metal contents if also metal compounds are included.

A further intense discussion of the issue is necessary. Especially more specific data are needed about factual level of impurities in products and materials. In this discussion process a broad variety of stakeholders should be involved to cover all relevant materials, products and processes.

includes threshold limit values above which labelling is mandatory.

7 Lead in shredder wastes

One of the main aims of the Directive 2000/53/EC on End-of-Life Vehicles is to reduce the contamination of shredder wastes from car recycling, in order to render them in a condition in which they can be more easily recycled or recovered without posing harm to the environment, or to render them less harmful if disposed of in landfills.

In the shredding operation, three material fractions are normally generated, i.e. the ferrous scrap fraction, the shredder light fraction (SLF) and the (non-ferrous metal) heavy fraction (SHF). The arising amounts and proportions between the different fractions depend on the specific design of the car, but also on the design and the specific process parameters of the shredder installation. An exemplary situation is shown in the following diagram, in which a modern middle class car is used as an example.

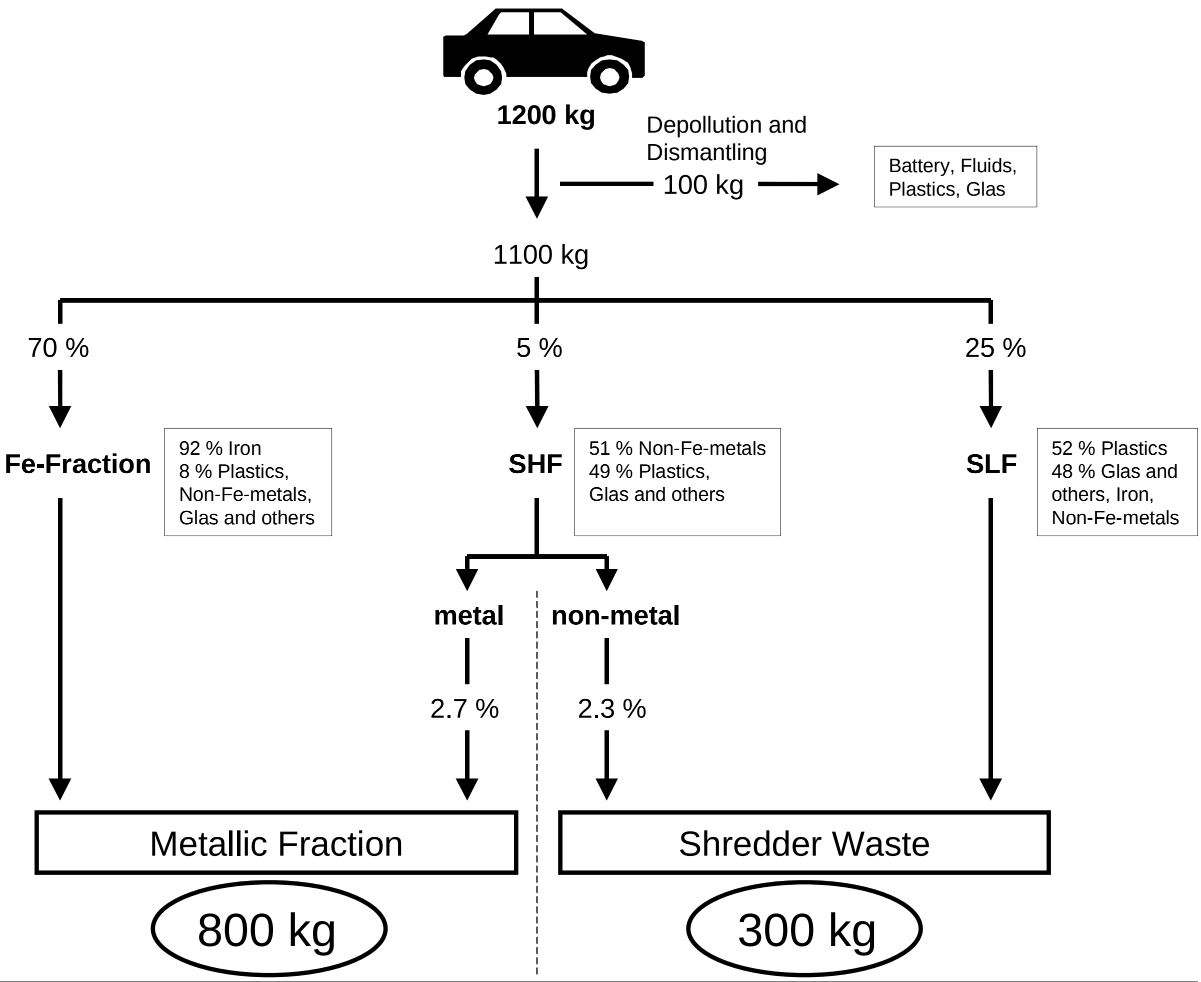

Fig. 4: Description of material flows in the car shredding process

As can be seen, none of the three fractions contains „pure“ material, but rather each of them is a material mixture of ferrous and non-ferrous metals, plastics and others. For the following considerations, the shredder light fraction (SLF) and the non-metallic fraction of the heavy fraction (SHF) are further considered as „shredder wastes“. In the example presented, these shredder wastes sum up to 300 kilograms from one vehicle.

Shredder wastes from end of life vehicles make up 10% of all hazardous wastes generated annually in Europe. They are classified as hazardous according to the European Waste Catalogue and to the Basel Convention if they contain dangerous substances (such as e.g. lead).

To our knowledge, all attempts to further fractionate these shredder wastes with the aim to concentrate lead and other heavy metals in one small fraction while at the same time yielding „cleaner“ separate fractions for recycling or recovery have not yet reached technical maturity to allow for large-scale operation (Pruckner & Gorzawski, 2000). Under present conditions it can therefore be assumed that the shredder wastes as such must be „clean“ enough, i.e. they must contain sufficiently low contents of lead and other heavy metals in order to allow for subsequent recycling or recovery operations.[1]

Under present conditions, the lead content of shredder wastes from car scrapping varies between 4,000 and 25,000 mg/kg while the lower calorific value falls in a range between 9 and 21 MJ/kg.

These characteristics of SLF can be compared to typical limit values or tolerated levels for the lead content in various wastes destined for recycling or recovery operations (see BOX 1):

[1] As long as the processing technologies for fractionation of SLF are not fully developed, little environmental benefit is expected to be achievable via material recycling, which means that also recovery options are important to consider.

BOX 1:

Typical limit values or tolerated levels for the lead content in various wastes destined for recycling or recovery

- 8 mg/MJ which is equivalent to 200 mg/kg in wastes for coincineration with a calorific value of 25 MJ/kg [Swiss Ordinance on Waste Disposal in Cement Kilns, 1998]
- 50 mg/kg in wastes as raw meal substitute and 75 mg/kg in wastes used as additives in clinker grinding [Swiss Ordinance on Waste Disposal in Cement Kilns, 1998]
- 100 mg/kg as maximum value for coincineration of wastes in the cement industry [StUA Münster, 2000]
- 70 mg/kg for production specific wastes for coincineration [Bundesgütegemeinschaft für Sekundärbrennstoffe, 2000 (draft)]
- 190 mg/kg for high-calorific fraction of municipal urban wastes for coincineration [Bundesgütegemeinschaft für Sekundärbrennstoffe, 2000 (draft)]
- 200 mg/kg in wastes for co-incineration [suggested by EURITS, 1996].

Most of the tolerance levels from comparative cases fall in a range between 100 and 200 mg/kg. This range is therefore proposed as a first orientation for a target describing the maximum tolerable level of lead also in shredder wastes.

For comparison, recent surveys report the following lead contents in regular fuels (BOX 2).

BOX 2:

Typical lead concentrations in regular fuels:

- circa 5 mg/kg in fuel oil [Ökopol, 1997]
- 10 – 19 mg/kg in coke [Ökopol, 1997]
- 9 – 70 mg/kg in coal [Nottrodt, 2001]

As can be seen, our proposed range of 100 – 200 mg/kg lead for a maximum tolerable level in shredder light fraction destined for recycling or recovery already lies significantly higher than the lead contents in regular fuels. Allowing still higher tolerance levels would mean to accept levels of lead which are normally only encountered in wastes for disposal or even hazardous wastes (BOX 3).

BOX 3:

Typical lead concentrations in wastes for disposal:

- 390 – 1830 mg/kg in household wastes [Nottrodt, 2001]
- 206 – 390 mg/kg in sewage sludge [Nottrodt, 2001]
- 309 – 1700 mg/kg in mixed hazardous wastes [Lahl, 2000]
- 2569 – 15700 mg/kg in paint and laquer sluges [Lahl, 2000]
- 276 – 1182 mg/kg in petroleum sludges [Lahl, 2000].

With this target range between 100 and 200 mg/kg for a maximum tolerable concentration of lead in shredder wastes destined for recycling or recovery, a total lead content of 30 to 60 grams at maximum in the 300 kilograms of the shredder waste from one vehicle could be acceptable.

For practical purposes, we propose to establish a benchmark at 60 grams of lead per vehicle from the two specific applications which are likely to end up in shredder wastes. This is particularly the case when they are connected with the chassis rather than the engine (which is expected to end up in metallurgical processes).

The two specific applications to which we refer here are „electrical components which contain lead in a glass or ceramics matrix compound“ and „solder in electronic circuit boards and other electrical applications“. Both applications are found in very complex and diverse application fields distributed over the whole car, and they are increasingly introduced in car manufacturing as a result of scientific and technological progress.

As long as the amount of lead from the two sources of ceramics and solder which is expected to enter the shredder wastes lies below the above-mentioned benchmark of 60 grams, we propose to tolerate that the ceramics and solder-containing components are not dismantled even if their presence in the shredder wastes is not favourable at all.

If, however, the benchmark of 60 grams of lead entering the shredder wastes from these sources is likely to be exceeded, we propose that dismantling should be mandatory in order to prevent further lead contamination of the shredder wastes. Adequate treatment and recycling of the dismantled electronics fractions will then best be performed jointly with the similar waste streams arising under the upcoming Directive on Waste Electrical and Electronic Equipment.

With this proposal, manufacturer will have several options to react, including either the reduction of the overall amount of lead in these applications (substitution is already under way in several cases) and / or labelling and dismantling of the lead-containing components prior to shredding.

In our opinion, it should be left up to the manufacturers which strategy they wish to follow, however the respective strategy should be communicated so that some verification is possible.

In our specific recommendations dealing with the applications of „ceramics“ and „solder“, we have equally split the 60 gram-benchmark, allowing 30 grams for each type of application.

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8 Summary of results and overall conclusions

The main results of the study presented herewith show that Art. 4(2)(a) of the ELV Directive has indeed highlighted an area where significant improvements with respect to reduced use of hazardous substances can be achieved, thus leading to an improved recyclability of vehicles and a better environmental performance in the recycling sectors, as well as resulting in "cleaner" waste to be disposed of. Many of today's applications of the problematic substances can in fact be avoided or substituted, even if this may require a certain period of time in some cases.

The discussions around the evolving ELV Directive have already exerted a strong stimulus on industry to avoid the problematic substances, either by directly substituting them, or at least by taking up research for alternatives which had been neglected in recent years.

Additional entries are suggested for the two applications of "lead in wheel balance weights" (temporary until 1/7/2004) and "electrical components which contain lead in a glass or ceramics matrix compound". No technical reason was identified to add a derogation for "cadmium in batteries for electrical vehicles". For some existing entries in Annex II, a schedule for phase-out is proposed. A deletion from Annex II is proposed for lead-containing "coatings inside fuel tanks".

Several new applications were submitted by industry during the course of the study. For some of these, temporary exemptions until a specified date are proposed.

For a number of entries in the list of Annex II, some minor rewording is suggested in order to be technically more precise and avoid misunderstanding, e.g. "solder in electronic circuit boards and other electrical applications".

A depollution prior to shredding plays an important role aiming at reduction of environmental relevance of heavy metals in cars. Intensified controls of the dismantling quality will be needed to ensure that removal of the respective application is actually done. With a view on amounts of heavy metals, dismantling of large and small lead batteries, lead containing ceramics, mercury containing bulbs and vibration dampers is particularly important. To ensure that this removal is effectively done, reporting and monitoring will be crucial and should be implemented by member states.

In addition to the concepts of general exemption, exemption up to a certain limit, exemption with mandatory labelling and dismantling which are already contained in Annex II, the present report suggests the concepts of

- mandatory dismantling if a certain maximum allowable amount is exceeded,
- temporary exemptions until a specified date,
- stepwise phase-out for complex fields of application where some uses of a substance are easier to avoid than others.

Mandatory dismantling above a certain maximum allowable amount

With respect to "electrical components which contain lead in a glass or ceramics matrix compound", PZT ceramics around the engine shall not be restricted, but mandatory labelling and dismantling is suggested for applications on the chassis if a maximum amount of 30 g lead from this source is exceeded, because applications on the chassis are likely to reach the shredder light fraction. A similar requirement for labelling and dismantling above a threshold value of 30 g per vehicle is proposed for "solder in electronic circuit boards and other electrical applications".

Temporary exemptions

As during the previous study it became clear that some manufacturers need additional time to realise a phase out. A way must be found to take those justified requests into consideration without undermining the general goal and to prevent a roll-back of the generally positive trend which can presently be observed.

In many cases some new car models are produced without the use of heavy metals in specific applications, but manufacturers claim to need an interim phase-out period for older models which will be further produced.

Interim periods are said to be needed by car producers not only because of the car model cycles, but also because the immediate reconstruction of complex production equipment may not be appropriate for both economic and environmental reasons (e.g. conversion of paint shops is so expensive and resource consuming that it should preferably not be done as an isolated action, but rather in combination with other retrofitting measures).

<u>Stepwise phase-out</u>

One possible step for an adequate solution may be the inclusion of differentiated phase out deadlines which are combined in some cases with review dates. This concept is proposed in case of Cr VI in corrosion preventive coatings.

Table 7 gives an overview of our proposals concerning how Annex II could be adapted to scientific and technological progress in the future.

Table 7: Summary of results of the different chapters

Materials and components *(chapter in this report)*	phase out of heavy metals	costs effect on final product	interims period ends ...	review date	marking in Annex II	remarks
Priority items						
a lead as an alloy in aluminium in wheel rims, engine parts and window levers *(2.1)*	replace by entry 3a					
b lead in batteries *(2.2)*	Presently not possible	/	/	/	yes	Monitoring
c lead in balance weights *(2.3)* Rewording: Lead in <u>wheel</u> balance weights	Technically possible	Neutral to slight increase	1.7.2004	/	yes	Rewording Monitoring
d electrical components which contain lead in a glass or ceramics matrix compound *(2.4)*	Presently not always possible	/	PZT at engine not restricted; for PZT at chassis and other glass / ceramics compounds dismantling mandatory if allowed amount of 30 g lead per car is exceeded			Monitoring
Lead glass in bulbs and glaze of spark plugs	Technically possible	/	1.1.2005	/	/	/
e cadmium in batteries for electrical vehicles *(2.5)*	Technically possible	Not possible to verify	/	/	/	/

Materials and components *(chapter in this report)*	phase out of heavy metals	costs effect on final product	interims period ends ...	review date	marking in Annex II	remarks
Lead as an alloying element						
Steel (including galvanised steel) containing up to 0.35% lead by weight (3.1) Rewording: Steel for machinery purposes and galvanised steel containing up to 0.35 % lead by weight	Presently not possible	/	/	/	/	Rewording
Aluminium containing up to 0.4% lead by weight (2.1)	Replace by entry 3a					
3. Aluminium (in wheel rims, engine parts and window levers) containing up to 4% lead by weight (2.1)	Replace by entry 3a					
3a (new): aluminium for machining purposes with a lead content up to 2 % by weight (2.1)	technically possible	Neutral to slight increase	1.7.2005	1.7.2003	/	/
4. Copper alloy containing up to 4% lead by weight (3.2)	Presently not possible	/	/	/	/	Case by case examination necessary
5. Lead/bronze bearing-shells and bushes (3.2)	Presently not possible	/	/	/	/	/
Lead and lead compounds in components						
6. Batteries (2.2)	Presently not possible	/	/	/	yes	Monitoring
7. Coating inside petrol tanks (3.3)	Technically possible	neutral	/	/	/	Entry to be cancelled
8. Vibration dampers (3.4)	Presently not always possible	/	/	/	yes	Monitoring

Materials and components *(chapter in this report)*	phase out of heavy metals	costs effect on final product	interims period ends ...	review date	marking in Annex II	remarks
9. Vulcanising agent for high pressure or fuel hoses (3.5)	Technically possible	neutral	1.7.2005	/	/	/
10. Stabiliser in protective paints (3.6)	Technically possible	increase	1.1.2005	1.7.2003	/	/
11. Solder in electronic circuit boards and other applications (3.7) Rewording: Solder in electronic circuit boards and other electric applications	Presently not always possible	/	Labelling and dismantling mandatory if allowed amount of 30 g lead per car is exceeded			Rewording Monitoring
Hexavalent chromium						
12. Corrosion preventative coatings on numerous key vehicle components (max 2g/v)(3.8) Rewording: Corrosion preventive coatings	technically possible	/	differentiated time schedule for phase out 1.7.2003 1.1.2005 1.1.2007	 1.7.2003 1.7.2003	/	Rewording
Mercury						
13. Bulbs and instrument panel displays (*3.9*)	not appropriate	/	/	/	yes	Monitoring

Materials and components *(chapter in this report)*	phase out of heavy metals	costs effect on final product	interims period ends ...	review date	marking in Annex II	remarks
Additional items						
Brake linings *(4.1)*	technically possible	/	1.7.2004	1.7.2003	yes	Monitoring
Valve seats *(4.2)*	technically possible	/	1.7.2005	1.7.2003	/	/
Pyrotechnic initiators *(4.3)*	Technically possible	Neutral to slight increase	1.7.2007	/	/	/
Cadmium in thick film pastes (4.4)	technically possible	/	1.7.2006	/	/	/
Lead in Carbon Brushes of starter motors *(4.5)*	technically possible	/	/	/	/	limited information
Hexavalent chromium in adsorption fridges of caravans *(4.6)*	Presently not possible	/	/	/	Yes	Monitoring

Annexes I to V

Annex I: Alternative materials: Resources, production, price

This annex shows data about some materials mentioned in different chapters as possible alternatives to lead. Production and consumption give an impression about the relevance of the additional demand from the field where the material is discussed as a possible alternative (Table 8). The column Areserve@ respectively Areserve base" gives an impression about the long term availability of the material.

It is important to notice that the given figures just give a snapshot of the current situation. The production amount of the metals must be seen as a function of demand and price and can therefore vary quickly if production capacities are existing or can be built up. In the following table data on >Reserve Base= describe the reserves using a certain methodology. The factual reserve base will be bigger if the price for the metal rises. For example the reserve base for lead is described with 130 million t while the total identified lead resources of the world are described in the same source with more than 1.5 billion tons. For zinc the relation is 430 million t to 1.9 billion t.

Additionally it must be acknowledged that alternative materials are often by-products from other processes. Whether those by-products will be extracted - which means additional processing and refining efforts - is once again a question of prices.

However if these data are taken not as final facts but if they are taken for comparison purposes they can give a rough orientation.

Table 8: Summary of results of the different chapters

	world mine production (t/y*1000)	**world re-fined pro-duction (t/y*1000)**	world re-fined con-sumption **(t*1000)**	**Reserve (t*1000)**(4)	**Reserve base (t*1000)** (5)	**Metal Price ($/t)**	**Metal Price Range ($/t)**
Bi	3.8(3)	4(6)		110 (3)	260 (3)	8,000	5,500 – 11,000(7)
Pb	2,980(3)			64,000(3)	130,000(3)	500 (2)	400-600 (2)
Sn	200(3)	254(1)	243(1)	9,600(3)	12,000(3)	5,400 (2)	4,800 - 6,200 (2)
W	31.5(3)			2,000(3)	3,200(3)		
Zn	8,000(3)			190,000(3)	430,000(3)	1,000 (2)	900 - 1,250 (2)

Legend

1 World Bureau of Metal Statistics, 9/2000, base year 1999

2 LME Daily price, average and min-max in the time period from 1/1998 to 6/2001

3 U.S. Department of the Interior, U.S. Geological Survey: MINERAL COMMODITY, SUMMARIES 2001

4 That part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials.

5 That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reason-able potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics.

6 Industry Survey 2000

7 Pers. Com., data for granulated bismuth delivered to steel plant, average and min-max in the time period from 1/1995 to 3/2001

A conclusion in a way that by a substitution of lead there will be a demand in the same range for the substitute element cannot be drawn. The content of bismuth in free cutting steel for example can often be lower than the content of lead.

According to U.S. Department of the Interior [U.S. Geological Survey: MINERAL COMMODITY, SUMMARIES 2001] world reserves of bismuth are usually associated with lead deposits, except in China and North Korea, where economically recoverable bismuth is found with tungsten ores, and in Australia, where it is found with copper-gold ores. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products, except in Bolivia and possibly in China. Bismuth is potentially recoverable as a by-product of the processing of molybdenum and non-Asian tungsten ores, although extraction of bismuth from these ores usually is not economic.

As a conclusion it can be stated that for zinc the possible additional demand will be of low relevance. For tin a temporary market distortion may occur if the additional demand from different applications fields (wheel balance weights, steel, solder) occur simultaneously in a short time period. A more severe supply shortage and sharply rising prices can be expected if bismuth is used to a great extent e.g. to replace lead in steel for machining and when tungsten would be used for wheel balance purposes.

Annex II: Meetings of Ökopol with different experts during the revision process

Date	Location	Topic (n° in table annex II)	Participants
31.1.01	Brussels	Discussion of technical papers covering the full range of Annex II plus additional applications	Representatives of ACEA, CLEPA, JAMA, EUROBAT, various automotive companies
16.2.01	Hamburg	steel, aluminium and copper alloys, lead in wheel balance weights	Representatives of WVM, EAA, copper and lead industry
23.2.01	Munich	Electrical components which contain lead (or cadmium) in a glass or ceramics matrix compound, special focus on piezo-ceramics	Representatives of ceramic industry, automotive industry, electronic industry and experts from universities and research institutes
2.3.01	Frankfurt	hexavalent chromium for corrosion prevention	VDA workshop with experts in this field from the automotive and galvanic industry
16.3.01	Hamburg	lead-acid batteries	Representatives of EUROBAT
22.3.01	Hamburg	lead in wheel balance weights	Wheel weight manufacturer
7.3.01	Hamburg	lead in wheel balance weights	Representative of tin industry
28.3.01	Brussels	TAC-Meeting, presentation of preliminary results	
11.4.01	Hamburg	Cadmium in batteries for electrical vehicles, lead in wheel balance weights, and several other applications	Representatives of French automotive industry (FIEV, PSA, Renault) and battery manufacturer (SAFT)
30.5.01	Hamburg	Electrical components which contain lead in a glass or ceramics matrix compound	Manufacturer of piezo ceramics from UK
31.5.01	Hannover	Lead in wheel balance weights	Experts from automotive, rim, brake, wheel and weight manufacturers
20.6.01	Hamburg	Steel containing lead	Experts from steel industry from Germany, UK, Spain

Annex III: Official Information Requests to European associations

Adressee	Topic (n° in table annex II)	Date
ACEA, BLIC, JAMA, CLEPA	lead in balance weights	15.02.2001
ACEA	2, 3, 12, Electrical components which contain lead in a glass or ceramics matrix compound,	08.03.2001
ACEA, CLEPA, JAMA	11, Carbon Brushes, Impurities	06.04.2001
ACEA, CLEPA, JAMA, BLIC	Spark Plugs, lead in engine valve seats, 8, 9, lead in clutch linings, 10, 12, 13, Lead in lighting bulbs, 3	25.04.2001

Annex IV: Reactions received on previous study

Sender	Topic (n° in annex II)	Date
CERAME-UNIE	electrical components which contain lead in a glass or ceramics matrix compound, lead-containing carbon brushes for automotive starter	22.05.2001
Dionys Hofmann GmbH	Lead in balance weights	30.03.2001
Eurofer	1, 7, 12	16.05.2000
Eurometaux	1, 3 - 5, lead in balance weights, cadmium in batteries for electrical vehicles	Febr. 2001
ITRI	Lead in balance weight	Febr. / April 2000
Ministere de l'amenagement du territoire et de l'environment, Republic of France	cadmium in batteries for electrical vehicles (SAFT), 1, 3 - 5, lead in balance weights, cadmium in batteries for electrical vehicles (EUROMETAUX), comments on all topics (PSA Peugeot Citroen & various suppliers) pyrotechnic initiators (SFEPA, FIEV)	27.11.2000
PSA Peugeot Citroen	Remarks on all topics of the Heavy Metal I final report	27.02.01
Saarstahl AG	Lead as an alloying element in steel	22.05.2001
TRAX	Lead in balance weight	11.04.2001
VDA, WVM	1 - 8, 10 - 12, lead in balance weights, electrical components which contain lead in a glass or ceramics matrix compound	17.04.2000 and 10.05.2001

WVM:	WirtschaftsVereinigung Metalle
ACEA:	European Automobile Manufacturer Association
CLEPA:	European Association of Automotive Suppliers
JAMA:	Japan Automobile Manufacturers Association, INC.
SAFT:	(Battery manufacturing company)
EUROMETAUX:	European Association of Metals
FIEV:	Federation des Industries des Equipements pour Vehicules
CERAME-UNIE:	Bureau de Liaison des Industries Ceramiques Europeennes
VDA:	Verband der Automobilindustrie

Annex V: Non exhaustive list of companies and associations contacted during the study in alphabetic order

ACEA (European Automobile Manufacturer Association), Adam OPEL AG, AHC Oberflächentechnik, AIRVERTlimited, Alcoa, Altenloh, Brinck & Co, AUDI AG, Autoliv, AVERE, BAS (Brinker Aluminium Schmelzwerke GmbH), Berzelius Metall GmbH, Bismuth Institute, Bleistahl AG, BLIC, BMW Group, BSB Recycling GmbH, Ceram Tec AG, CERAME-UNIE (Bureau de Liaison des Industries Ceramiques Europeennes), Champion Deutschland, Chemetal Oakite Inc., CLEPA (European Association of Automotive Suppliers), Continental AG, Continental TEVES, Continuum Control Cooperation, CORUS Engineering Steels, Daimler Chrysler AG, Denso Europe B.V., DIEHL Metall, Dionys Hofmann GmbH, DMC², DuPont, EAA (European Aluminium Association), EFR (European Ferrous Recovery & Recycling Fedeation), ELC, Electrolux GmbH, EPCOS AG, ETRTO, EUROBAT, EUROFER , EUROMETAUX (European Association of Metals), FIAT AG, FEFM (Federation of European Manufacturer of Friction Materials), FIEV (Federation des Industries des Equipements pour Vehicules), FORD, Franken Industrie, FTE Automotive GmbH, GRS (Gemeinsames Rücknahmesystem Batterien), Heraeus, Hoerbiger, Honda AG, INA Wälzlager Schaeffler oHG, Introni, G. & C.snc, Ispat Stahlwerk Ruhrort GmbH, ITRI Ltd. (International Tin Research Institute), JAMA (Japan Automobile Manufacturers Association, INC.), Kolbenschidt Pierborg GmbH, LDA international, LNP Engineering Plastics, Morgan Automotive, Murata Europe Management GmbH, NGK, NISO Teknik AB, NISSAN, OSRAM GmbH, Panasonic, Philips Lighting BV, Phoenix AG, Pierburg AG, PORSCHE AG, PSA Peugeot Citroen, Radsystem GmbH, Renault, Robert Bosch GmbH, Saarstahl AG, SAFT, SFEPA, Sidenor I+D, Siemens AG, TRAX, TRW, Tungsten Powders Ltd, University of Pittsburgh, VARTA AG, VDA (Verband der Automobilindustrie), Veritas AG, Volkswagen AG, VOLVO, WdK, Wieland Werke AG, Wirtschaftsvereinigung Stahl, Woco Franz Josef Wolf & Co, WVM (WirtschaftsVereinigung Metalle), ZVEI.

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