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Mechanical Processing of EOL EEE

One chance for the Environmentally Sound Management of used personal computers and other IT-appliances

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A Background

The issue of separate collection and recycling of End-of-Life Electrical and Electronic Equipment (EOL EEE) has been a major point of discussion for the past several years in Europe and also in Austria. The main reasons for these discussions have been the

- pollutant content of certain components of the appliances
- large proportion of recyclable material contained in electrical appliances

To gather experience in the fields of separate collection, dismantling and mechanical processing several pilot projects were carried out in several European countries. In Austria there exist detailed results of the Bregenz pilot project [1], the WEIZ project [2] the Flachgau pilot project [3] and a comprehensive comparison of opportunities for the mechanical treatment [4].

Within these projects EOL EEE are distinguished and treated in the following way:

- **Large appliances** are mainly collected together with scrap metals at the municipal collection centers. After dismantling and removal of PCB-containing capacitors and mercury containing components (switches), this fraction is added to scrap metals and mechanically separated in coarse shredding facilities.
- **Appliances with screens** are gathered separately and dismantled. Casings (plastic and partly wood) are separated and presently still landfilled. Hazardous components like large capacitors and buffer batteries and accumulators as well as LCD are removed and specially treated as hazardous waste. The remaining plastic-metal-compounds are submitted to mechanical processing (see medium and fine shredding goods). Remaining questions refer to the environmentally sound recovery or disposal of glass from cathode-ray tubes (CRT) and the realization of a standardised dismantling depth.
- **Small electrical appliances** are at first submitted to a removal of hazardous components (for instance switches and relays containing mercury, capacitors containing PCB, batteries, etc) and these parts are forwarded to specific treatment options according to the special type of pollutant. The appliances of which the hazardous fractions were removed are mechanically processed. By this treatment procedure mainly metal-containing fractions are recovered. The remaining fraction containing mainly plastic are thermally treated or landfilled.

The **process of removing hazardous components** can be regarded as state of the art in Austria. For this purpose a standard was set (ÖNORM S 2106 Recycling and Disposal of Electrical and Electronic Appliances, 1998) which specifies the hazardous components and gives instructions for their removal. According to this standard for example the following **components are considered to be hazardous**:

- mercury containing components
- batteries and accumulators
- PCB-capacitors
- electrolyte capacitors
- printed circuit boards with components
- picture tube coatings and screen coatings as well as glass parts and broken glass with screen coatings
- liquid crystal displays

Also according to the standard OENORM S 2106 the following state-of-the-art **treatment options** should be chosen for the above mentioned hazardous fractions

- mercury containing components → recovery
- batteries and accumulators → recovery (non recoverable batteries→ treatment, recycling and diposal as hazardous waste)
- PCB-capacitors → thermal treatment
- electrolyte capacitors → recovery or thermal treatment
- printed circuit boards with components → dismantling of components or thermal treatment
- picture tube coatings and screen coatings resp. glass parts and broken glass with screen coatings → treatment, recycling and diposal as hazardous waste
- liquid crystal displays → treatment, recycling and diposal as hazardous waste

The remaining question concerning how to treat the appliances of which the hazardous fractions were removed was analysed in a currently published study [4].

B Mechanical processing

Opportunities for the mechanical processing were analysed in co-operation with recycling companies in Austria, Switzerland and Germany. Pilot processing's were carried out in specific companies and already existing data on processing were submitted to evaluation (input material and gained fractions) [4].

B.1 Technology

The mechanical processing of EOL EEE or waste in general, is a treatment procedure, which serves as preparation for the actual utilization of the gained fractions or concentrates. Several different size reduction aggregates like hammer mills, impact crushers, chippers, and different cutting mills like rotor scissors, rasp mills and rotary drum cutters are used. Existing separating units are sieves, air classifiers, cyclones, magnetic separators, eddy current separators, vibration sorters, air table separators, and more complex facilities like heavy media separators, up to even more sophisticated technologies, like linear motor plants, corona separators or micro sorters.

Typical plants for mechanical processing of materials containing metals are

- Coarse shredders
- Medium and fine shredders

Coarse shredders are hammer crushers with subsequently integrated separation processors like air classifier, magnetic separators, sieves and vibration sorters. One disadvantage of this technology is that non-ferrous metals are lost especially to the iron fraction and within this fraction especially copper is a limiting substance for the use in steel mills (quality of products). From the non-ferrous fraction non-ferrous metals can be separated by eddy current separators, a technology which is used in most coarse shredder plant. A significant process parameter regarding the recovery of non-ferrous metals is the suction capacity of the air classifier. Within „traditional" process management with low suction capacity, main parts of the non-ferrous metals remain in the heavy fraction and as they are small they flow into the residues (sifted material), which are then disposed of. In coarse shredders with special process management, which are operated with high suction capacity, part of the non-ferrous metals are found in the lightweight shredder fraction.

The residues (heavy and light) can be submitted to further separation steps (on site or in other processing companies), where non-ferrous metals can be recovered. To what extent further separation is carried out, depends on the metal proceeds and on the requirements of the disposal facilities for these fractions (landfill, thermal treatment).

In **medium and fine shredders** size reduction procedures and separation of the input material is carried out in several steps and size reduction and separation procedures are applied and combined depending on the conception of the plants. In these plants the processing is accomplished with significantly smaller and homogenous grain sizes, and for example pelleting steps for metal particles are included. Thus a significantly higher enrichment of metals is reached and the remaining materials only show a relatively low content on metals.

B.2 Input Material

According to the material properties like size and content of recoverable fractions, the following input material can be distinguished:

- Typical **coarse shredder goods** are large household appliances and non-ferrous pre-shredder materials (like parts from dismantling procedures of large plants or parts from dismantling of EOL EEE).
- The term **medium shredder goods** is used for small electrical appliances with an edge extension smaller than 50 cm or plastic-metal-compounds from dismantling procedures of EOL EEE. These materials are characterised by a high content of non-ferrous metals of 10 to 20% (max 30%). ***Used personal computers and other IT-appliances*** can be classified as medium shredder goods. The processing is explained in detail in chapter B.3.
- The term **fine shredder goods** is used for fractions with a high content of non-ferrous metals from dismantling procedures of EOL EEE (printed circuit boards, deflection units or cables), with a non-ferrous-metal content of 30 to 60%. The same processes as for medium shredder goods are used but different process management is applied.

B.3 Processing of medium shredder goods

The processing of small electrical appliances predominantly takes place in medium shredder facilities. If small electrical appliances are treated in a coarse shredder, special process management (high suction capacity) is necessary. Coarse shredders applying "traditional" process management are not recommended for the processing of these materials (high loss of non-ferrous metals).

Figure 1 gives a view on the treatment methods, the achieved products and their utilization or disposal possibilities.

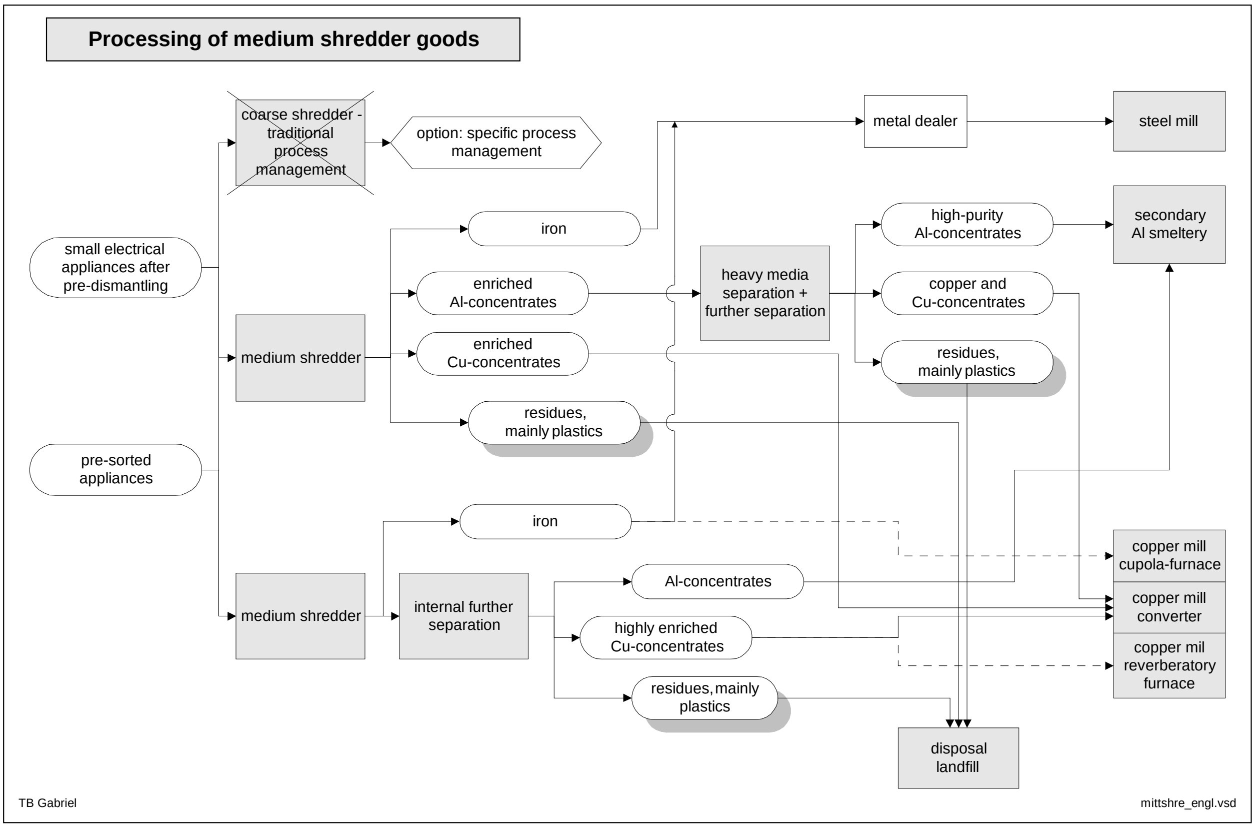

Fig. 1: Processing of medium shredder goods

The result of mechanical processing of medium shredder goods are metal concentrates and residues. To which extent the separation of achieved mixed fractions is carried out in the different processing plants, is an enterprising decision. All depends on the processing costs and the possible proceeds for the respective products (for instance metal concentrates).

In general, size reduction and separation plants can be operated with different speed and settings. Intermediate fractions can be additionally processed by other operation settings. Accordingly the quality and purity of the fractions is dependant on the choice of processing steps and on the aspired output. By selecting of process parameters different targets can be aimed at.

- Enrichment to **non-ferrous concentrates**: the gained fractions containing a high rate of aluminium are submitted to a further separation step applying heavy media separator (big pieces) or high energy eddy current separators; enriched copper fractions are delivered to copper mills and can be processed within the converter step.
- In-plant processing towards **high-purity single fractions** and **optimal marketable non-ferrous fractions**: in this case the aluminium fractions can be subsequently handed over as input-material to secondary aluminium smelteries; copper concentrates can be forwarded to copper mills and processed within the converter step.
- In-plant processing towards **high-purity non-ferrous concentrates**, which can be processed at high utilization level: the recovered aluminium fractions can be used as input-material in secondary aluminium smelteries and the copper concentrates can be processed in the converter step or even in the reverberatory furnace of the copper mills.

Usually the remaining residues show a metal content of < 2%. Facilities operating internal further separation can reach a metal content of << 0,5%, this means the recovery of metals can be almost entirely achieved.

B.4 Results

Table 1 shows results out of the routine processing of electrical appliances, which consist mainly of **IT-appliances** [4]. Within this plant different hammer mills, magnetic separators, eddy current separators, air classifier and sieves are used. The fractions NF I and NF II which mainly contain aluminium and copper resp. copper alloys are further separated in external plants applying heavy media separators or high-energy eddy current separators. Fractions NF III and NF IV containing mainly copper resp. copper alloys with a content of non-metals of less then 1 % are processed in copper mills.

	electrical appliances – mainly IT-appliances		
fractions	**min. weight-%**	**max. weight-%**	**∅ weight-%**
∑ iron-fractions	**48%**	**54%**	**51%**
NF I	8%	12%	10%
NF II	3%	4%	3,5%
NF III	5%	7%	6%
NF IV	1,5%	2,2%	1,8%
∑ NF-fractions	**18%**	**22%**	**21%**
residues	17%	18%	18%
filter material	8%	12%	10%
∑ residues	**26%**	**30%**	**28%**

NF ....fractions containing non-ferrous metals

Table 1: Yield IT-appliances

As the results show, 28 % residues and about 72 % metal concentrates arise in the processing of IT-appliances. Ferrous and copper fractions show a high purity rate concerning the content of foreign substances and plastics and can therefore be processed in steel and copper mills by

- **avoiding negative impacts** from copper in the steel industry and
- **avoiding emissions** like mercury, cadmium, nickel, lead and dioxins because of the previous dismantling of hazardous components and
- **avoiding emissions** out of flame retardants containing halogens used in plastics because of the separation of plastics.

After further separation of mixed non-ferrous fractions, aluminium concentrates and additional copper concentrates can be achieved. Aluminium concentrates of high purity can be processed in secondary aluminium smelteries and further copper fractions can be delivered to copper mills.

The additional advantage of the mechanical separation of electrical appliance and the following carefully directed processing in metal mills and smelteries is, that - compared with the direct input of appliances in e.g. copper mills -

- **valuable metals** like aluminium are **not lost** through residues of these technologies (e.g. dross, slag or ash)

B.5 Recommendation

A recommended treatment of small electrical appliances consists of the following steps:

⇒ Separate collection of small electrical appliances

⇒ Dismantling of hazardous components

⇒ Mechanical processing of the appliances: the generated ferrous fraction can be utilized in the steel industry. Mixed fractions with a higher content of non-ferrous metals can be separated into copper and aluminium concentrates and residues. These steps can be integrated into operations for mechanical processing or can be carried out in other recycling plants. The copper and aluminium concentrates can be processed by copper mills and aluminium smelteries avoiding negative impacts, negative emissions and the lost of valuable materials.

⇒ Thermal treatment of the residual fractions originating from mechanical processing: these residues and those resulting from further separation steps should be submitted to thermal treatment to destroy organic pollutants and to use the high calorific value of these materials (mainly plastic).

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