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Working Group on Waste Prevention and Recycling

TECHNICAL GUIDANCE FOR THE ENVIRONMENTALLY SOUND MANAGEMENT OF SPECIFIC WASTE STREAMS: USED AND SCRAP PERSONAL COMPUTERS

This document was adopted and declassified by the Delegates of the Environment Policy Committee in February 2003.

The document provides technical guidance for the environmentally sound management of used and scrap personal computers (PCs).

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FOREWORD

The OECD has focused on developing and promulgating international policies to promote the environmentally sound management (ESM) of waste since the 1980s. Considerable time and effort has been devoted to the development of appropriate measures for controlling transboundary movements of waste. This work has resulted in the adoption of eight Council Acts on transboundary movements of waste, in particular the operational Decision C(2001)107/FINAL (amendment of C(92)39/FINAL). Recently, it has been recognised that the level of environmental protection varies widely within the waste management facilities, even within the OECD Member countries. Therefore, the OECD decided in 1999 to start working towards international technical guidance for environmentally sound management of waste to improve and harmonise the environmental protection of waste management facilities within the OECD area.

The OECD is currently developing a comprehensive programme for ESM. Within this programme it has been widely recognised that for the time being the principal focus of ESM should be on recovery and related activities. However, to optimise resource efficiency, recovery should not be addressed in isolation, but rather in the context of fostering sustainable development, in particular encouraging waste minimisation and achieving a more level playing field within the OECD.

The scope and content of the overall OECD ESM programme are still under development. Most likely this programme would consist of two major components. One possible component would focus on enhancing industry progress toward sustainable practices by emphasising the use of existing Environmental Management Systems (EMS), such as ISO 14 000 series and the European Community Eco-Management and Audit Scheme (EMAS). Another component would possibly consist of technical guidance for ESM, including "core performance elements," to be used in conjunction with EMS, specifically relating to waste management activities. These "core performance elements" may be general in nature, but the covered wastes, as well as activities, are still under discussion. More specific technical guidance may be necessary for certain waste streams.

OECD Member countries have identified used and scrap personal computers as a waste stream for which specific guidance is appropriate. Thus, over the last three years, the OECD has developed this guidance as a pilot set of waste stream specific ESM guidance. This technical guidance was drafted by Mr. Robert Tonetti from the US EPA, assisted by Ms. Sonja Löw from the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management and the OECD Secretariat. This technical guidance will be periodically updated, as appropriate.

The Working Group on Waste Prevention and Recycling adopted this guidance document in September 2002 and recommended its declassification. The Environment Policy Committee adopted and released the document in February 2003.

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1. INTRODUCTION

1. Technological innovations in the field of computers continue to advance exponentially. Personal computers now available to citizens of OECD member countries at modest prices have more computing power than was available to their governments not very long ago. Connected to the internet, these computers provide access to sources of information and means of communication almost beyond imagination. This power and usefulness has resulted in an equally exponential increase in the demand for and proliferation of personal computers, in households as well as offices. They are now ubiquitous in developed societies.

2. This proliferation of personal computers has raised environmental concerns with their ultimate fate in the environment. Hundreds of millions of computers are now in the hands of citizens. And, with the astronomical pace of technological development, all of these personal computers are rapidly approaching obsolescence. Their owners need to dispose of them, to make room for the next model ... and the next ... and the next.

3. Within the context of the overall OECD programme on environmentally sound management of wastes and used and scrap materials, this paper provides a pilot set of waste stream specific ESM technical guidance that can be used to ensure environmentally sound reuse and recovery of used and scrap¹ personal computers (PCs), as well as components and materials thereof. This technical guidance is also applicable to transboundary movements of these appliances, components and materials for reuse and recovery purposes. This guidance does not address other environmental issues, such as product design, choice of materials and energy efficiency while in use, which may arise in the life cycle of a personal computer, at any time from design and manufacture through to the end of its life as an operating electronic device. However a closer co-operation between PC-manufacturers and recyclers (in areas such as identifying substances of concern in various models of PCs, as well as efforts toward design for recyclability) will be necessary in order to maximise the quantity of suitable material for recovery, and thus enhance contribution to waste prevention and minimisation. This guidance also does not address aspects pertaining to the collection of used PCs; rather this guidance focuses on the environmentally sound management of used PCs, once they have been collected for reuse or recycling. Much useful information on collection programs pertaining to many types of wastes can be found in the OECD publication of 2001: "Extended Producer Responsibility: A Guidance Manual for Governments".

2. DEFINITION AND CHARACTERIZATION OF "USED AND SCRAP PC'S"

4. This guidance encompasses personal computers, as well as portable computers (laptop and notebook), that have been used in homes and offices, consisting of:

a. Central processing unit (CPU): a case and all of its contents, such as the primary printed circuit board (the motherboard) and its components (chips, capacitors, connectors, etc.), additional printed circuit boards (daughter boards), one or more disc drives, a transformer (the power supply), interior wire, and a power cord. (This is the widely understood meaning of "CPU," however, it is recognized that within the PC manufacturing industry, "CPU" may apply only to the chips.);

1 . Scrap in this context is understood to mean off-specification products whose date for appropriate use has expired (overstocks), unusable parts, contaminated materials, etc. within industry and retailers.

- b. Monitor: a cathode ray tube (CRT), or flat panel display (also known as a liquid crystal display), its case, interior wires and circuitry, cable to the CPU, and a power cord;
- c. Printer: a case and its contents, such as an ink or laser cartridge, interior wire, cable to the CPU, and a power cord; and
- d. Miscellaneous peripheral devices: keyboard and mouse, scanner, CD writers, web camera, loudspeaker.

5. This guidance is written to address the management and disposition of used and scrap personal computers. Simply stated, "used PCs" are those PCs that have been used by an owner who no longer has a need for that PC. Used PCs are used materials; they are not necessarily waste. Used PCs may still have considerable life remaining, and can be used by another owner either "as is" or after repair or upgrading. It is common for used PCs to be aggregated and shipped to a location (either foreign or domestic) where they can be evaluated for their potential for reuse or refurbishment. This guidance is applicable to such movements of used PCs and their management at facilities that evaluate reuse potential, as well as those facilities that conduct refurbishment and materials recovery operations.

6. The term "used PCs" is not intended to include PCs shipped by an owner for repair/refurbishment and return to that same owner, whether under warranty or not. The term also does not include PCs that are shipped ready for direct reuse, i.e., those that have already been evaluated or refurbished and are ready for use. Of course, "used PCs" do not include unused PCs that are shipped ready for their original use. Thus, this guidance does not address such PCs nor their shipment.

7. This guidance is applicable to any PC components arising directly from production facilities, i.e., off-specification or surplus personal computers and components. This guidance further addresses scrap, residues and waste arising from the disposition of used PCs, such as dust and slag generated in raw material recovery.

3. PRINCIPAL ENVIRONMENTAL CONCERNS²

3.1 Substances of Concern

- 8. A personal computer contains several substances of environmental concern:
 - a. Antimony: Antimony is a component in lead solder. CRTs may contain antimony in the screen and/or cone glass;
 - b. Barium oxide: Barium oxide is contained in the getter plate of the electron gun of CRTs; some of the barium oxide from the getter becomes deposited on the interior surface of the screen and cone glass;

2. Further information on some of these substances of concern can be found in the: "Proposal for a Directive of the Parliament and of the Council on Waste Electrical and Electronic Equipment (WEEE Directive), Brussels, 13 June 2000, COM(2000)347 final. For further progress of this issue, please see Directive 2002/96/EC of the European Parliament and of the Council at 27 January 2003 on waste electrical and electronic equipment (WEEE) and Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

c. Beryllium: There is a small amount of beryllium, in the form of a copper-beryllium alloy (typically 98% copper, 2% beryllium) in the motherboard, in the slots used for connection to daughterboards;

d. Cadmium: There is a small amount of cadmium in plated contacts and switches, and a very small amount of cadmium may have been used as a stabilizer in PVC wire insulation, which may have been used in a personal computer. Laptop computers often contain a rechargeable nickel cadmium (Ni-Cd) battery;

e. Chlorine and/or Bromine: Organic halogenated (brominated) flame retardants and inorganic flame retardants (e.g. antimony chloride) may be present in the plastic in printed circuit boards and cases. There is chlorine in any PVC insulation of wires and cables used in a personal computer;

f. Lead: There is a substantial amount of lead in the CRT, as a rough average perhaps two to three kg in older models and 1 kg in new models, encapsulated in the form of leaded glass. There is also a much smaller quantity of lead in printed circuit boards in the CPU, in the form of solder. Printers and miscellaneous peripheral devices will also contain a small amount of lead in solder. Some portable (laptop) computers contain a sealed lead acid battery;

g. Lithium: Lithium metal may be present in a small battery on a motherboard;

h. Mercury: In large flat panel displays, a small amount of mercury may be present in a lighting device used to illuminate the screen; and

i. Phosphors: A phosphor coating, typically zinc sulfide and rare earth metals, are used on the interior of a CRT screen to convert the kinetic energy of an electron beam to light. However, cadmium sulfide has also been used in older CRTs;

9. Although these substances can present risks in recycling or disposal of used personal computers, it is important to note that some of these substances are present in personal computers for the purpose of lowering risks to human health during product use. These include the use of lead shields in CRTs to protect users from harmful x-rays and the use of flame retardants in plastics to reduce the risk of overheating and potential fires. There is no technical substitute for lead in the CRT glass.

10. *In accordance with the national legislation, some Member countries may consider substances such as liquid crystals (contained in small amounts in flat panel (LCD) displays), arsenic (contained in small amounts in the form of gallium arsenide in light emitting diodes (LEDs)), liquid electrolytes (contained in small amounts in electrolyte capacitors), and powder toner (from printers) as substances of concern in personal computers³.*

3.2 Exposure to Substances of Concern

11. Nearly all of the substances of concern in a personal computer are in solid non-dispersible form, and there is no cause for concern for human exposure or release into the environment in ordinary use and handling of a personal computer. None of these substances will be released from a personal computer through normal contact, including transportation and manual disassembly.

3. The text printed in italics in this document refer to issues which are applied only by some Member countries or are required by national legislation.

12. Human health and environmental concerns related to the presence of these substances in a personal computer arise if this used equipment is land disposed or incinerated. In addition, concerns are present in certain reuse and recycling scenarios: for example, when its component parts are harvested using certain methods (such as melting of solder) or subjected to processing for metal or plastic reclamation using methods such as shredding, grinding, burning and melting. All of these exposures can be mitigated through appropriate work practices, combustion control, and air emission pollution control systems (Such practices are discussed in Section 5, to eliminate or mitigate possible adverse effects on human health and the environment):

a. Antimony: Antimony contained in the screen glass may leach out under certain land disposal conditions;

b. Barium oxide: Barium oxide dust can be released during the dismantling and handling of CRTs;

c. Beryllium: Beryllium in a copper-beryllium alloy may be released as beryllium oxide dust or fume during high temperature metal processing;

d. Cadmium: The small amount of cadmium in plastic may be released in the form of cadmium oxide dust if the plastic is burned prior to or in the course of metal reclamation. Cadmium in plated metal contacts and switches may be released as cadmium oxide dust or fume during high temperature metal processing. Incineration may also result in releases of cadmium to the environment;

e. Chlorine and Bromine: Bromine in plastics as brominated fire retardants, or chlorine in PVC insulation, may recombine with carbon and hydrogen in various disposal or recovery processes that involve heat, such as combustion or plastics extrusion, to form other halogenated organic compounds of environmental concern, particularly the chlorinated or brominated dibenzodioxins and -furans;

f. Lead: Lead in a CRT or printed circuit board may leach out of the leaded glass under certain land disposal conditions. Incineration can result in release of lead to the air as well as deposition of lead in the ash, which is then land disposed. The lead in a printed circuit board may also be released in the form of lead fume if the board is heated to facilitate harvesting of components, or in the form of fine particulate if the board is burned or shredded prior to metal reclamation. The lead in a CRT or a printed circuit board may be released as lead oxide dust or lead fume during high temperature metal processing, such as smelting;

g. Lithium: Lithium in a battery will be released if the battery is shredded with the circuit board to which it is attached. When released, it may react with oxygen and moisture, generating heat and potentially causing fire;

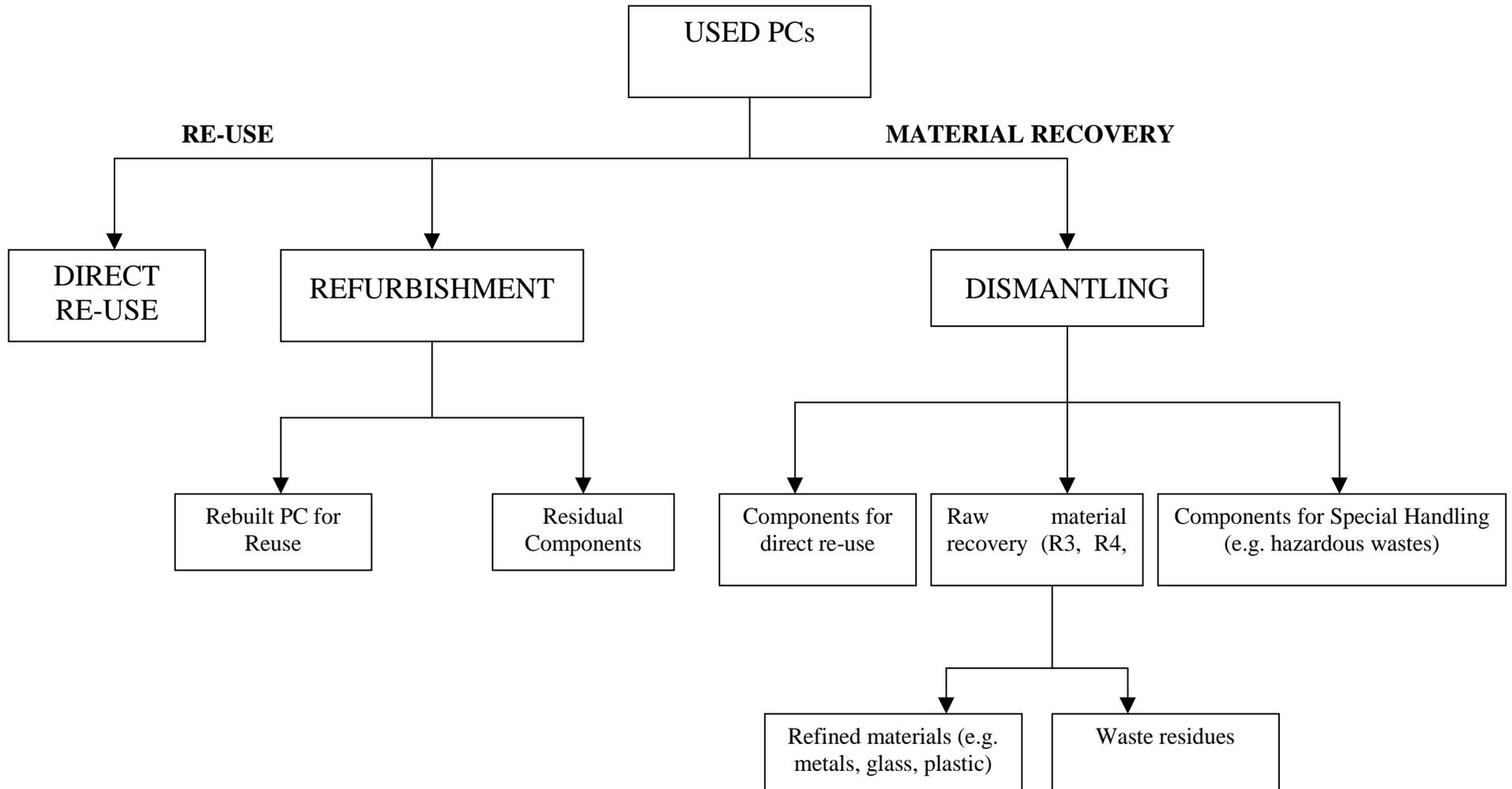
h. Mercury: Mercury can be released from certain flat panel displays upon the shredding and subsequent handling of this equipment. Landfilling and incineration of flat panel displays can also result in the release of mercury to the environment; and

i. Phosphors: Cadmium in the phosphor coating of some older CRT screens could present an inhalation hazard to workers in CRT glass breaking operations. Cadmium can also be leached in a landfill environment.

4. OVERVIEW OF REUSE/RECYCLING PRACTICES

13. Once collected, used PCs should be routed to either reuse or recycling opportunities. The following flow diagram shows the steps in the reuse and material recovery processes. The remainder of this section provides further elaboration.

PROCESS FLOW DIAGRAM



4.1 Overview of Reuse

14. With the rapid advances in computer technology, it is clear that a personal computer becomes obsolescent long before it has lost any capability of performing all of its essential functions. Continued use as a computer is, therefore, an obvious and desirable disposition, and includes a number of options:

a. Direct Reuse: A used personal computer can be used by another person, without change. This is the most common first disposition of a personal computer. It will be reassigned to another user in the same organization or family, or will be given or sold directly to the next user.

b. Refurbishment and Reuse: A personal computer can be refurbished or upgraded, and used by another person. All personal computers are modular to some extent, i.e., at least some parts can be replaced, either with the same parts or with upgraded parts. The useful life of a personal computer can, therefore, be extended, and it can continue to be used.

c. Component Reuse: A personal computer can be disassembled for recovery of working electronic components. A used personal computer for which complete refurbishment and repair are not economically efficient may still contain one or more components that can be reused, such as a disc drive or memory device.

15. These activities are principally conducted by a new industry that has sprung up as personal computers have become more prevalent--the used computer industry. This industry has for at least the last decade collected, refurbished, upgraded and resold used computers and computer components. This industry has somewhat informal origins--people with expertise would swap components or build computers from scratch with used components--and has expanded to consist of a relatively large number of individuals, small businesses and, increasingly, charitable organisations.

16. A personal computer can, for the most part, be disassembled and reassembled using hand tools, e.g., a screwdriver, and there are no special environmental concerns with such repair and refurbishment. However, this disposition will inevitably give rise to some personal computers and components that cannot be repaired, or for which refurbishment and repair are not economically efficient. Such personal computers and components will require further disposition, with associated environmental concerns for protection of workers and release of substances into the environment.

17. Electronics dismantlers, who tend to process larger volumes of used equipment more quickly than repair and refurbishment companies, also perform some reuse activities. They may resell some equipment, with or without repair, such as whole PC systems, monitors, etc. However, their main reuse activity is the harvesting and resale of the most valuable components of used PCs, such as integrated circuits ("chips"), disk drives, etc. However, the bulk of the materials processed by a dismantler go to raw material recycling, rather than reuse.

18. The harvesting of some components for reuse raises worker and environmental concerns that need to be addressed. For example, some components have been soldered into printed circuit boards. removal of such components requires the application of heat to loosen the solder and, thus, there are concerns with emissions of lead from the solder to the air. This type of component removal requires application of controlled heat, appropriate ventilation, consideration of emissions, and careful attention to worker health and safety.

4.2 Overview of Raw Material Recovery

19. If a personal computer, or any of its component parts, can not be reused, it should be disassembled and processed for recovery of much of its contained raw materials – i.e., metals, glass and plastics. In addition, any components that are considered hazardous and required to be removed by the competent authority should also be separated for special handling.

20. Ferrous and non-ferrous materials, including steel, aluminum and copper and resulting from the dismantling of computer cases and frames, wires and cables are sold to smelters for the production of raw materials. The nonferrous metal industry reclaims precious metals and copper from printed circuit boards, wires and cables, and other computer components such as chips, connectors, and CRT copper yokes.

21. Leaded glass from CRTs generated by dismantlers can be processed and sold to CRT manufacturers for use in new CRTs. This is a relatively new and growing market, existing both in OECD and non-OECD countries. Leaded CRT glass can also be sent to lead smelters for lead recovery, with the added benefit of the use of the glass as a fluxing agent in the smelting process. In addition, leaded CRT glass can be used in non-ferrous metal smelters.

22. The market for the recycling of plastics is slowly developing and will develop more as a result of eco-design of PCs. A market exists for energy recovery of plastics.

5. TECHNICAL GUIDANCE FOR FACILITIES

23. The necessary measures for assuring environmentally sound recycling of used personal computers are, to a large degree, facility-specific. This is because the potential for adverse impacts on worker health and the environment is very much dependent upon the nature of the refurbishment, dismantling or materials recycling activities that are used at a particular facility. Similarly, the appropriate degree of governmental control and oversight is dependent upon which of these activities are engaged in, as well as the magnitude of the operations. National, regional and local government programs, therefore, need to be tailored to the nature and size of these operations. The following general guidance is provided:

5.1 Refurbishment

24. Facilities that are principally engaged in the refurbishment of used PCs derive their principal source of revenue from the resale of used PCs for reuse. Any revenues from the sale of unusable components to dismantlers or raw material recovery firms are only a secondary, and generally minor, source of income. Workers at a refurbishment facility have been trained specifically for PC repair. Some hold technical licenses and professional diplomas in their field, while others have received on-the-job training.

25. The risks posed to workers and the environment at refurbishment facilities are generally quite small. This is because used PCs are manually repaired or upgraded with great care, i.e., destructive means are not used which would make used PC components unusable and could result in the release of hazardous constituents to the workplace or surrounding environment. The principal environmental issues posed by refurbishment facilities relate to the adequacy of storage of PC components on site and the adequacy of off-site destinations for unusable components.

26. Refurbishment facilities, especially those engaging in the import of used PCs, should fulfil the applicable core performance elements (CPEs) for ensuring environmentally sound management of wastes, and used and scrap materials, set out in the document [ENV/EPOC/WGWPR(2001)4/REV2]. The

refurbisher should be properly authorised by the local, regional or national governments. Such authorisation may take the form ranging from a local business license (in the case of rather small facilities) to a license or permit that provides worker health and safety guidance or very basic provisions for environmental protection (for larger facilities). The authorisation for larger facilities should specifically address the management of processed and unprocessed components, with limits on the amount of hazardous waste that may be accumulated on site. Processed components should be regularly sent off-site to authorised recycling or disposal facilities.

27. Large refurbishment facilities should be inspected on a regular basis by the competent authority for compliance with the conditions of the facility authorisation.

28. Refurbishment facilities that handle a significant volume of used PCs should maintain a financial instrument that will assure that, in the case of (1) gross mismanagement of used PCs or components or (2) closure of the facility, the facility will be properly cleaned up.

29. Business transactions that involve the transboundary movement of used PCs and components should be based on contracts (or equivalent commercial arrangements) made in advance that detail the quantity and nature of the materials to be shipped. Through the keeping of records, a refurbishment facility should be able to characterise, on at least an annual basis, the percent (by volume or weight) of used PCs and components that are refurbished, sent for recycling and sent for disposal.

30. Refurbishment operations, including storage of inventory and unusable components, should be conducted indoors, with impervious floors. Storage areas should be adequate to hold all inventory and waste materials.

5.2 Material Recovery

5.2.1 Dismantling - General Guidance for Facilities

31. Facilities that are principally engaged in the dismantling of used PCs for recovery of usable parts and/or materials for raw material recovery range from very small operations to those that are quite large. They also range from those that extensively utilise manual labour for disassembly to those that are highly automated. The degree of hazard posed to workers and the environment also varies greatly and is dependent upon the specifics of individual facility operation. For example, some manual disassembly operations pose few worker or environmental issues, while others that involve, for example, the melting of lead solder, the breaking of CRTs or the use of shredders present a wider array of potentially more serious concerns.

32. Dismantling facilities should fulfil the appropriate core performance elements (CPEs) for ensuring environmentally sound management of wastes, and used and scrap materials, set out in the document [ENV/EPOC/WGWPR(2001)4/REV2]. Such elements would require e.g that dismantling facilities be properly authorised by the local, regional or federal competent authorities. If the dismantling is manual and only involves hand tools (not involving heat or shredding, for example), the degree of worker and environmental risks may be on a level similar to a refurbishment operation and, thus, it may be appropriate to authorise such a dismantling facility on a par with refurbishment facilities, as described above.

33. However, many dismantling facilities also use some practices or equipment that will result in hazards to workers or the environment if the proper safeguards are not taken. This is because dismantling operations generally involve destructive means of disassembly that can result in the release of hazardous

constituents from various PC components. Destructive disassembly also permits a higher rate of used PC processing than can be achieved in refurbishment; therefore, larger volumes of potentially hazardous materials are generally on site at dismantling facilities. Thus, dismantling facilities, in general, require closer governmental oversight than is described above for refurbishment facilities.

34. In general, a dismantling facility should have the appropriate equipment for proper processing of the incoming materials as well as controlling environmental releases. A system needs to be in place for identifying and properly managing hazardous components (e.g., batteries) that are removed from used PCs during disassembly. The facility needs to assure that personnel are properly trained with regard to material and equipment handling, worker exposure, controlling releases and safety and emergency procedures.

35. The facility should have procedures for monitoring, reporting and responding to pollutant releases and other emergencies, such as fires. A financial instrument shall be maintained that will assure that, in the case of (1) major pollutant releases or gross mismanagement of used PCs and scrap or (2) closure of the facility, the facility will be properly cleaned up.

36. The facility authorisation (license or permit) should describe the capacity of the operation, particularly the amount of hazardous wastes that are allowed to be kept on site. This will assure that the capacity of storage areas is not exceeded and hazards to human health and the environment during operation or, in the case of unexpected facility closure, are minimised.

37. Dismantling operations should be inspected on a periodic basis by the competent authority for compliance with the facility license, as well as other safety, health and environmental requirements. The facility itself should conduct regular audits and/or inspections of its environmental compliance.

38. Facilities should manage all materials to minimise adverse exposures to workers and releases to the environment. Dismantling operations, as well as storage of any components that contain hazardous substances, should be conducted indoors, with impervious floors. Storage areas should be adequate to hold all processed and unprocessed inventory. As discussed above, dismantling facilities that use heat to soften solder or that shred various PC components should design their operations to control hazardous air emissions.

39. *Independent from the hazard classification the following components will have to be removed from used PCs and managed separately in certain Member countries (required by the draft WEEE Directive – see footnote 2, page 5):*

- *Mercury containing components such as lamps and switches;*
- *Batteries;*
- *Printed circuit boards (if the surface of the printed circuit board is greater than 10 square centimeters);*
- *Toner cartridges, liquid and pasty, as well as colour toner;*
- *Plastic containing brominated flame retardants;*
- *Cathode ray tubes;*
- *Liquid crystal displays (together with their casing where appropriate) of a surface greater than 100 square centimetres and all those back-lighted with gas discharge lamps;*
- *External electric cables;*
- *PCB-capacitors, if present in old PC-peripherals; and*
- *Electrolyte capacitors containing substances of concern (if height is greater than 25 millimeters or the diameter is greater than 25 millimeters, or is of proportionally similar volume).*

40. For business purposes, many facilities engaged in dismantling keep close track, on a shipment specific basis, of the fate of used PCs and components that are received. Not only is this good business practice for purposes of understanding and optimising the efficiency of the flow of inputs and outputs, but many dismantlers will offset the fees charged for receipt of the used PCs by giving a credit for the value of reusable or recyclable components. Using this data, it should be relatively easy for dismantlers to have information, on at least an annual basis, indicating the percent of used PCs and components that are sent for reuse, recycling and disposal.

41. Transactions that involve the transboundary shipment of used PCs and components should be conducted based on contracts (or equivalent commercial arrangements) made in advance that describe the quantity and nature of the materials to be shipped.

5.2.2 Raw Material Recovery - General Guidance for Facilities

42. Facilities that engage in raw material recovery, e.g., smelting, will require a higher degree of governmental environmental oversight, commensurate with the environmental concerns that arise from their activities. Raw material recovery often involves the generation of emissions or residues that require careful control in order to avoid adverse impacts on worker health, as well as human health generally, and the environment.

43. With regard to metal recovery facilities, the metals contained in personal computers do not raise unusual or special environmental concerns, i.e., concerns which are different from those encountered in other metal and ore processing activities. However trace metals in PC-scrap (e.g. Beryllium), which are not normally present in ores and emissions resulting from organic compounds, should be taken into consideration.

5.2.3 Treatment of Specific Components

5.2.3.1 Circuit Boards and Board Components

44. Printed circuit boards are particularly valuable components of a used PC, as they may contain marketable chips that can be removed and sold for reuse, and because they contain valuable metals that can be recovered in a smelter. Dismantling facilities that recover marketable chips utilise heat to soften the solder holding the chips to the printed circuit boards. In this heating process, lead contained in the solder is emitted as a fume and must be captured to protect both workers and the environment. Equipment for the capture of the lead fumes includes the use of vacuum hoods and filters for removal of lead from the exhaust. The facility license should specifically address these required safeguards at facilities where the heating of lead solder is utilised.

45. Printed circuit boards contain a substantial quantity of copper and valuable concentrations of gold, silver and palladium. These metals are usually recovered through copper smelting followed by metal-specific refining. In almost all respects printed circuit boards serve as a substitute for primary copper concentrates from ore, because they contain not only a high concentration of copper, but also contain many other metals commonly found in copper ore, such as lead, cadmium, gold and silver.

46. However, because of high economic value, a batch of circuit boards is often processed in advance of smelting, by shredding and burning of some or all of the batch at suitable facilities, in order to obtain a representative sample and metal assay. The shredded boards and components and ash are then smelted.

47. Shredding of circuit boards gives rise to dust, of which some fraction will be the metals of concern. Burning of circuit boards, whether before or during smelting, gives rise to concern regarding the release of these metals in furnace exhaust emissions, as well as the release of other products of combustion. Facilities that shred and/or burn printed circuit boards and non-ferrous smelters require attention to these concerns. Workers require training in management of hazardous materials (e.g., handling of dusts and ashes), as well as personal protection from exposure. Furnaces require proper furnace combustion conditions (e.g., temperature, residence time, oxygen levels), and furnace emission control systems appropriate for their feedstocks (such as acid gas scrubbers and particulate controls, or both). The facility permit regarding air emission controls should specifically authorize the processing of electronic scrap.

48. The presence of halogens (chlorine and bromine) in plastics which will be burned during metal recovery raises concerns which differ from those most commonly associated with copper ores. Attention must be given with such electronic scrap feedstocks to the possibility of creation of dibenzofurans and -dioxins in burning processes. The first consideration is in the burning itself, which most OECD member countries require to be at a temperature of 850 °C. (1600 °F.) or higher, with a residence time of 2 seconds, with excess oxygen. Complete thermal destruction of hydrocarbons will substantially reduce the possibility of formation of dibenzofurans and -dioxins in the furnace emission stream. Halogens will be converted to acids, and then to salts in an acid gas scrubber. *For waste containing more than 1% of halogenated organic substances, expressed as chlorine, the EC waste incineration directive requires 1100 °C. A final consideration, deemed to be maximum achievable control technology in the United States, is control of the exhaust gas temperature at the inlet to a dry particulate control device (i.e., electrostatic precipitator or fabric filter) at or below 200 °C (400 °F). Dioxin emission measurements would guarantee the efficiency of specific measures or gas cleaning units⁴.*

5.2.3.1.1 Batteries

49. A personal computer motherboard contains a small battery to maintain electrical energy to computer settings such as the time and date. By far the most common type is a lithium cell, approximately the size of a small coin, and referred to as a coin cell. A coin cell contains less than a gram of lithium, encased in solid form as the anode.

50. The coin cell should be removed from the motherboard prior to shredding. If a cell remains on a board, the shredding operation will open the cell, exposing the lithium anode. If some of the lithium is unreacted, it may then react with oxygen in the air or with moisture, generating heat and, potentially, hydrogen gas. A fire may be started immediately in the shredding operation, or the lithium may smolder and a fire may occur at a later time. Such a fire, in the midst of burnable circuit board fragments, may be difficult to control, and may cause hazardous air pollution.

51. A facility which shreds printed circuit boards requires visual inspection of motherboards for the presence of a coin cell, and removal if a cell is present. A coin cell may be removed without tools if it has been inserted into a mechanical holder. If, as in more recent computers, the coin cell has been soldered onto the board, hand tools will be required for removal.

4. Further information is provided in i): "Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the Incineration of Waste, Official Journal L 332, 28 December 2000, pp. 91-111"; ii) "Draft Technical Guidelines for the Identification and Environmentally Sound Management of Plastic Wastes and for Their Disposal, Draft 12 December 2001, UNEP/CHW/TWG/19/6, Geneva, or in any subsequent version.

52. Once separated, coin cells should not be accumulated in quantity without physical separation from each other, so that uncontrolled electrical discharge will not occur. Coin cells may be thermally processed with other components of a personal computer, as always with appropriate combustion and emission controls. A lithium coin cell does not present an additional problem in combustion or smelting. A coin cell can not be recharged, but its lithium can be recovered, after it has been fully discharged to eliminate potential reactivity, by shredding and gravity separation.

5.2.3.1.2 Capacitors

53. Capacitors are also present on the circuit boards of personal computers and are solid state devices. *Small electrolyte capacitors, still used in PCs, may contain corrosive liquids and therefore are classified as a hazardous component by some Member countries.*

54. There is some concern that PCB capacitors may have been used in personal computers in the past. Although their historic use in personal computers is not clear, it is known that PCB capacitors have been used in larger computer equipment such as mainframes and large printers, which are not the subject of this guidance.

55. *Regardless, some Member countries require the removal of electrolyte capacitors larger than 25 square millimeters, as well as any PCB capacitors, from any electronic equipment prior to shredding and recovery. Electrolyte capacitors can be sent for metal recovery. PCB capacitors and electrolyte capacitors not sent for metal recovery should be thermally treated in a state-of-the-art facility.*

5.2.3.1.3 Light Emitting Diodes

56. Light emitting diodes (LEDs) are also present on some of the circuit boards in personal computers. *Some countries may require removal of LEDs from the circuit boards, as they contain gallium arsenide.*

5.2.3.2 Cathode Ray Tubes

57. A CRT contains by far the greatest amount of all substances of concern in a personal computer. An older polychrome CRT can contain some 2-3 kilograms of lead while a new one typically contain no more than 1 kg of lead. The cone glass (or funnel glass) contains about 20-24% PbO, the neck glass about 28-30 % PbO and the glass frit about 80% PbO, whereas the screen glass (or panel glass) normally contains no lead. The lead is encapsulated in glass, and cannot be released unless and until the glass is broken. However, the glass must be broken into relatively small pieces before significant levels of lead would be available for release into the environment. A CRT will also contain a small amount of copper in its yoke and internal wiring, but little if any other metal value. There are several options for environmentally sound management of the leaded glass in a CRT.

58. The leaded glass in a CRT can be recovered in new CRT manufacture. This can be done by removal of all non-glass components of the CRT, including the plastic monitor case, CRT yoke and electronics. These steps require aeration (release of the vacuum) by drilling into the CRT. This may be followed by the breaking of the bare CRT and careful separation of the glass parts, i.e., the faceplate, funnel and neck, according to their respective lead concentrations (which vary from CRT to CRT). Workers shall be protected from inhalation of dust that may contain lead or barium oxide as a result of CRT breaking.

59. The CRT glass is cleaned and the phosphor coatings are removed. The cleaned, leaded glass fractions, with assayed lead concentrations, can then be used as a feedstock in the manufacture of new leaded glass components in the CRT manufacturing industry.

60. The lead in a CRT can also be recovered as lead by a lead smelter. This requires preliminary disassembly, particularly removal of the plastic monitor case, because lead smelters do not usually have pollution control systems suitable for burning of plastic. The glass also serves as a silicate flux in the lead smelting process, and is a substitute for silicate which the smelter would otherwise acquire and use. The glass used for lead smelting may be mixed and dirty CRT glass which is generally not acceptable by CRT glass manufacturers.

61. The leaded glass in a CRT can also be used as a silicate flux by a copper smelter, again as a substitute for silicate which the copper smelter would otherwise acquire and use. The copper smelter may also have a subsequent procedure in which the byproducts from copper smelting and electrorefining are treated for lead recovery. A copper smelter may also have a pollution control system which permits it to burn plastic and, therefore, may be able to treat the monitor from a personal computer without preliminary disassembly.

62. If the lead in a CRT is not recovered as leaded glass, but instead is placed in a smelting process, some or all of the lead may remain in the slag produced in that process. Lead in silicate slag is immobilized and may be disposed of in an environmentally sound and appropriately authorised landfill. Such disposal will require specific licensing by the competent environmental authority with oversight responsibility for the smelter.

63. Practices that would be considered as non-environmentally sound include the use of leaded CRT glass in construction materials (as a substitute for sand) and its use as blasting grit or other abrasive material. *Some countries also consider the use of CRT glass in making tiles and other ceramics as non-environmentally sound.* The contamination of other glass which does normally not contain lead, especially container glass, should be avoided. Lead free CRT-screen glass could be used e.g. in building products (e.g. mineral wool).

5.2.3.2.1 Phosphors

64. The phosphor coatings on CRT glass can present an inhalation hazard if managed in a dry state. Wet processes are often used to remove the phosphors. The phosphors ultimately require either thermal treatment for destruction or stabilization prior to secure disposal in an environmentally sound and appropriately authorised landfill or storage in an adequate underground storage facility. Currently, there is very little recovery of phosphors practised. Glass fines and filters generated during the cleaning process can be sent to a lead smelter.

5.2.3.2.2 Getter

65. The electron gun of the CRT contains a small getter plate, weighing approx. 1-2 grams including frame and bears barium and barium compounds (barium oxide is classified as a harmful substance). *Depending on national legislation the removal of the getter may be required prior to any mechanical processing (shredding) in order to avoid the release of harmful barium-dusts.* The getter shall be stored separately, any contact with water or humid air should be avoided as barium reacts with water and disintegrates (leachate; easily soluble). Presently no recovery activities of Barium oxide, other than on a test basis, are known. Preferably the separately collected getters should be sent to an underground storage

facility or incinerated in an environmentally sound and appropriately authorised incinerator with modern flue gas cleaning systems.

5.2.3.3 *Flat Panel Displays and Portable Computers*

66. Flat panel screens and portable computers contain liquid crystal displays, which should be either sent for recovery operations (recently glass recovery involving the catalytic destruction of liquid crystal substances has started) or thermal treatment at an environmentally sound and appropriately authorised incinerator with modern flue gas cleaning systems.

67. *Some countries require that liquid crystal displays of a surface area greater than 100 cm² shall be managed separately as they are back lighted with gas discharge lamps containing mercury. If these discharge lamps are removed, they shall be sent to a specialised mercury recovery facility or to an environmentally sound and appropriately authorised hazardous waste incinerator with modern flue gas cleaning systems including iodated activated carbon filters or equivalent measures guaranteeing separation or immobilisation of mercury.*

68. Portable computers (excluding batteries and, if applicable, gas discharge lamps containing mercury) can be sent to a smelter for recovery of non-ferrous metals on the condition that the smelter is equipped with flue gas cleaning systems for minimizing dioxin emissions and for separation or immobilization of mercury (e.g. iodated carbon filters). To increase the recycling rate, it is suggested that circuit boards and casings could be removed prior to processing.

69. Batteries used in portable (notebook/laptop) computers include rechargeable nickel cadmium (Ni-Cd), nickel metal hydride (NiMeH) and lithium ion batteries. Some lead acid batteries are also used. These batteries are all removable by hand, and should be removed in the dismantling process and then sorted by type. All battery cells shall be managed to avoid inadvertent external short circuits and current flows. Large inventories of batteries should be avoided, and batteries that cannot be reused shall be sent for metal reclamation. Ni-Cd and NiMeH batteries can be recycled for recovery of nickel, and by some companies for recovery of cadmium. Lithium ion batteries do not have the fire hazard problem associated with lithium metal batteries because the lithium is in the stable form of lithium hydroxide. Care should be taken by workers if lithium ion batteries are opened or broken, as lithium hydroxide is somewhat corrosive. The lithium contained in these batteries can be recycled.

5.2.3.4 *Insulated Wire*

70. Insulated electrical wire accompanying a personal computer, such as its power cords, may be covered with polyvinylchloride (PVC), or with a plastic elastomer, or with some other plastic. The substance of concern is PVC, because of its chlorine content. In the past, the insulation was removed by burning, sometimes in uncontrolled combustion. This shall not be considered environmentally sound, because the burning may be incomplete, emitting a variety of particles of incomplete combustion, and chlorinated dibenzofurans and dibenzodioxins may form in the exhaust emissions.

71. Insulated electrical wire should be separated from a personal computer if the wire is accessible during dismantling, such as with computer power cords. It is not practical, however, to attempt to remove all insulated wire from the inside of a personal computer. The separated wire should then be shredded or chopped (or both) to a relatively small size (typically between one to ten centimeters in length). It can then be burned under controlled combustion with an air emission control system designed to prevent formation of chlorinated dibenzofurans and dibenzodioxins. Shredded or chopped wire can also be granulated to separate the insulation from the copper. The resulting mixed material can be separated by a variety of

physical means, using water or air. The entire process, when properly executed, will produce clean copper and a plastic fraction which is suitable for recycling in plastic. Other options for the separated plastic, although lower in waste hierarchy, include burning for energy recovery in an environmentally sound and appropriately authorised incinerator with modern flue gas cleaning systems and deposit residues on an environmentally sound and appropriately authorised landfill. *However, some countries may prohibit landfilling of this waste.*

5.2.3.5 *Ferrous- and Non-ferrous Metals*

72. In addition to the recovery of metals from circuit boards, as discussed above, both ferrous and non-ferrous metals from other components of used PCs should be recovered. For example, PCs contain substantial quantities of steel, aluminium, copper and other non-ferrous metals that can be relatively easily separated from other PC components, using manual or mechanical means. These metals can be sold to smelters who should be equipped with state-of-the-art flue gas cleaning systems.

5.2.3.6 *Plastics*

73. Plastics (such as equipment casings and bases) are the one major category of material components for which recycling opportunities are currently quite limited. This is because (1) numerous resin types are used in PC equipment, (2) plastic parts are not labeled according to their type and (3) the presence of chlorine and bromine compounds in some of the plastics requires measures for the protection of human health and the environment in operations where these plastics are shredded or heated. A wide variety of brominated flame retardants have been used as additives to some of the plastic components in PCs. Thus, opportunities for recycling need to regard not only the particular resin types of the various parts, but also the types of flame retardants that are present in the plastics, as the safety of the recycling may be affected.

74. When hard plastic components containing brominated flame retardants are shredded, workers can be exposed to dust containing these chemicals. Thus, workers in shredding areas should be protected through adaptations in shredder design, air flow controls, personal protective devices or a combination of these measures.

75. After preliminary processing, the recycling of plastics involves extrusion to make new products. The use of heat in the extrusion of plastics containing brominated flame retardants can cause the formation of brominated furans and dioxins. Thus, operations that involve the recycling of plastics from used PCs need to be carefully reviewed by the competent authority during the facility authorisation process.

76. *In some Member countries when destining PVC for recovery the presence of specific stabilisers (e.g. cadmium) shall be considered and bans on placing on the market plastic with such prohibited stabilisers shall be obeyed.*

5.2.4 *Energy Recovery and Disposal*

77. It is likely that some components of used PCs cannot be recycled. These components, likely to principally be plastics or resins with halogenated flame retardants, will need to be burned or landfilled in an environmentally sound manner (*although some countries may prohibit landfilling of such wastes*). Preferably, combustible fractions should be burned for energy recovery, as this method is higher in the waste management hierarchy than burning without energy recovery or landfilling. The incinerator or other combustion unit (with or without energy recovery) should be operated to minimise the formation of furans

and dioxins, as well as be equipped with state-of-the-art flue gas cleaning systems. Combustion ash, as well as materials from the processing of used PCs that cannot be recycled, should be disposed of in an environmentally sound and appropriately authorised landfill.

6. TRANSPORT

78. The existing infrastructure for materials recovery of used PCs and scrap involves a very significant international trade among OECD Member countries. Both whole PC components, such as CRTs, and specific metal-bearing scrap, such as shredded and/or burned printed circuit boards, are transported long distances for smelting, refining and manufacturing of new products. While raw material recovery (e.g., smelting and refining) itself raises issues of environmental concern (as discussed in section 5. above) the transportation of these materials, in most instances, poses few environmental concerns. Certainly, these used and scrap materials pose little, if any, additional risk in transportation beyond that posed by many other virtually identical materials (such as new CRTs or scrap metals from other sources) that are a common part of international commerce. International/national transport packaging requirements shall be fully respected. Transports to appropriate facilities, both domestic and foreign, are an essential part of any program for environmentally sound management of used and scrap PCs.

79. A facility that receives imported used PCs and scrap must be operated to optimise the opportunities for either (1) reuse of the used equipment (through repair or refurbishment) or (2) material recovery from the incoming materials. Import/export of used and scrap PCs is principally for the purpose of reuse or materials recovery.

80. Import by facilities that do not optimise reuse or material recovery (recognising the reality of both technologic and economic limitations) is not considered environmentally sound. However, it is common that material recovery at the initial importing destination may only be partial; that is, some materials may need to be sent to subsequent facilities for further processing and extraction of recyclable materials. These subsequent markets for partially processed materials should be known, at least in general, prior to export so that there is reasonable assurance that the export will occur principally for the purpose of environmentally sound reuse or material recovery.

81. Transboundary movements of recoverable wastes within the OECD area are governed by the revised OECD Council Decision [C(92)39/FINAL] on the control of Transboundary Movements of Wastes Destined for Recovery Operations [C(2001)107/FINAL]. Movement of used PCs and components that are considered Amber wastes by the country of export or import, will need to be notified to the competent authorities of countries concerned. Movements concerning Green wastes or non-wastes, need not be notified and are not subject to controls other than those normally applied to commercial transactions.

82. *However, some OECD countries have begun to use the OECD Council Decision C(2001)107/FINAL to control transboundary movements of used PCs and other used electronics and electronic wastes. For example, Switzerland has issued regulations and guidelines that require use of the Amber control procedure for all exports of used electronic appliances. Some member countries classify complete used PCs destined for recovery as Amber waste due to the separate listing of cathode ray tubes and other coated (activated) glass on the Amber List, or due to the presence of hazardous components in the scrap. Of course, other multilateral (e.g., EC Waste Shipment Regulation) and bilateral arrangements among specific OECD countries also govern waste movements. In addition, relevant international transport requirements may be applicable to the movement of used PCs and components between OECD countries.*

6.1 Removal of Hazardous Materials

83. Separation of hazardous materials from other components of whole used PCs is not necessary prior to a transboundary movement. However, the procedural and/or packaging requirements relating to a particular transboundary shipment are dependent upon the presence or absence of those hazardous substances and their potential for dispersion in the environment. That is, the greater the potential risks to human health and the environment, the more stringent are the applicable controls.

6.2 Packaging

84. Used and scrap CRTs and CRT glass should be packaged in a way that minimizes breakage during normal shipping conditions. In addition, the packaging should minimize releases to the environment if unintentional breakage does occur during transport. For example, if CRTs are shrink wrapped onto a pallet in such a way that broken pieces might not be contained, the pallet should be placed in an outside package that will minimize releases. CRTs with broken glass, glass pieces and glass cullet should be packaged in siftproof containers that prevent particles from being released from the package and whose effectiveness will not be reduced during normal shipping conditions.

85. Shredded circuit boards, not containing batteries (also see discussion in section 5 on the electrolyte capacitors and LEDs), should be packaged in containers that prevent particles from being released from the package and whose effectiveness will not be reduced during normal shipping conditions.