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Environmental Footprint and Material Efficiency Support for Product Policy

Feasibility study for a standardised method to measure the time taken to extract certain parts from Electrical and Electronic Equipment

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Environmental Footprint and Material Efficiency Support for Product Policy

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Contents

Executive Summary

A study of the Joint Research Centre (JRC) on material efficiency ([1]) published in 2012 established a method for the identification and assessment of 'hot-spots' ([2]) for end-of-life (EoL) treatment of electric and electronic equipment (EEE), including televisions, washing machines and imaging equipment. The method has been applied since then to various other product groups (e.g. enterprise servers).

The improved extractability of target parts in energy-related products (ErP) could represent a potentially suitable requirement in the context of the Ecodesign Directive for various product groups. In the case of measures for the 'design for extraction of target parts in ErP', the 2012 JRC study identified the 'time for the extraction' as a good proxy to prove the 'easiness to dismantle'. However, the verification of the application of measures on extractability implies the availability of a method for repeatable measurements.

The present report intends to provide scientific evidence of the feasibility of defining extraction times for the dismantling of EEE and how the measurement method should be structured.

The development of a standardised method for measuring the extraction time of a product's target parts should allow the repeatability of measurements and the minimising of uncertainty by removing or decreasing the influence of uncontrolled experimental conditions.

The report includes a review of the relevant scientific references (including standards and scientific articles), discusses key issues for the measurement of the 'time for extraction' of product's target parts and proposes how such key issues can be integrated into an exemplary method for the measurement.

Key definitions to be provided in the measurement method have been identified and provided for the following terms: target parts, extraction, extraction sequence, extraction time, worker experience, and tools for the extraction of components/parts.

This report also establishes possible operating conditions such as the testing area and safety requirements for extracting parts contained in EEE.

The dismantling sequence has been identified as a crucial aspect. Detailed provisions on the dismantling sequence have been provided. The dismantling sequence to be used for the testing has to be predefined prior to the product dismantling.

Finally, a proposed measurement method has been developed as a proof of concept and is outlined in Appendix 1. The method has been structured to reflect the framework of a potential international standard.

([1]) Project — Integration of resource efficiency and waste management criteria in European product policies — Second phase (Administrative Arrangement No. '070307/2010/580887/CI; July 2011- December 2012).

([2]) 'Hot spots' are those product components and characteristics that are relevant for some criteria for the EoL processes under consideration.

Abbreviations

DfD — Design for Dismantling

EEE — Electric and Electronic Equipment

EoL — End of Life

ErP — Energy-related Product

IEEE — Institute of Electrical and Electronics Engineers

JRC — Joint Research Centre

PCB — Printed Circuit Boards

TFT — Thin Film Transistor

WEEE — Waste Electric and Electronic Equipment

1. Introduction

The Joint Research Centre (JRC), following methodological and experimental work on material efficiency ([3]), published in 2012 a method for the identification and assessment of 'hot-spots' ([4]) for end-of-life (EoL) treatments of electric and electronic equipment (EEE), including televisions, washing machines and imaging equipment (Ardente and Mathieux, 2012; Ardente and Mathieux, 2014). Among various possible product measures, the study highlighted that the design for dismantling (DfD) of some target parts (with the aim of recycling or treating them properly) ([5]) can improve the performance of treatment at the recycling plants, generating relevant environmental benefits in a product's life cycle.

Furthermore, the JRC's study identified target parts of some energy-related products (ErP) to be extracted, for example, printed circuit boards (PCB) and motor from washing machines and thin film transistor (TFT) panels for electronic displays ([6]). For electronic displays, a more recent study analysed further potential metrics and associated thresholds for the dismantlability of key parts (Ardente et al., 2014). Moreover, recent analysis has since shown the environmental relevance of dismantlability requirements for other product groups (e.g. enterprise servers (Talens Peiró et Ardente, 2015)).

Ecodesign requirements for the easier dismantlability of electronic displays to be proposed by the European Commission are actually explicitly mentioned in the EU Action Plan for a Circular Economy published in 2015 (EC, 2015a).

The improvement of the extractability of these parts could enable the recycling of some substances otherwise dispersed in other recycled fraction ([7]) or an increase of the recycling yields of some relevant materials ([8]).

([3]) Project — Integration of resource efficiency and waste management criteria in European product policies — Second phase (Administrative Arrangement No. '070307/2010/580887/CI; July 2011-December 2012).

([4]) 'Hot spots' are those product components and characteristics that are relevant for some criteria for the EoL processes under consideration.

([5]) Key parts (also sometimes referred to as 'key components') are those product parts that are relevant during the product's end-of-life treatment for one or more ecodesign criterion (Ardente et al., 2013). These include, for example, parts containing precious or hazardous substances. These parts are generally the target of specific recycling treatments or measures and, for this, referred to also as 'target parts' (Ardente et al., 2013).

([6]) For further detail on key parts for resource efficiency in electronic displays see also the 'Report on benefits and impacts/costs of options for different potential material efficiency requirements for Electronic displays' ISBN: 978-92-79-33255-5 (September 2013), http://bookshop.europa.eu/en/environmental-footprint-and-material-efficiency-support-for-product-policy-pbLBNA26185.

([7]) As, for example, rare earths in washing machine motors that are dispersed into iron scraps, if not diverted from other waste material

The improved extractability of target parts in ErP could potentially represent a suitable strategy in the context of Ecodesign and other product policies ([9]). Some examples of design for dismantlability criteria have already been applied in environmental product labelling (although referring to the disassembly of the whole product more than to some target parts):

— EU Ecolabel Criterion for design for dismantling in personal computers: '*The manufacturer shall demonstrate that the personal computer/monitor can be easily dismantled by professionally trained personnel using the tools usually available to them, for the purpose of undertaking repairs and replacements of worn out parts, upgrading older or obsolete parts, and separating parts and materials, ultimately for recycling or reuse.*' (EC, 2011a)

— Criterion on the ease of dismantling (disassembly in that case) of televisions (environmental labelling scheme of the Institute of Electrical and Electronics Engineers (IEEE)): '*The product shall be designed for ease of disassembly within the recycler's processes, as follows: a) Ease of disassembly shall include the following disassembly steps in a total of at most 10 min. for products weighing less than 50 lb; and at most 10 min. plus 1 min. per each additional 5 lb of total product weight, for products weighing 50 lb or more (…)*' (IEEE, 2012)

One of the most important characteristics of Ecodesign measures to be applicable to product policies is to be *quantifiable* and *measurable*. Ecodesign measures 'shall be formulated so as to ensure that market surveillance authorities can verify the conformity of the product with the requirements' (EU, 2009). The measures should also specify 'whether verification can be achieved directly on the product or on the basis of the technical documentation' (EU, 2009).

For example the verification procedures set for the two previous criteria for design for dismantling are:

— Verification of the criterion for design for dismantling in personal computers: '*A test report shall be submitted with the application detailing the dismantling of the personal computer. It shall include an exploded diagram of the personal computer labelling the main components as well as identifying any hazardous substances in components. It can be in written or audiovisual format.*' (EC, 2011a)

— Verification of the criterion on the ease of disassembly of a product: '*Declaration by manufacturer b) Supporting documentation that shall include either: 1) A statement from at least one recycler who meets this standard's criterion for recyclers (…) and is experienced in processing products with similar design technology. The supporting documentation shall include a statement from the recycler confirming that all elements of this criterion are met in the product design. The certification shall state*

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before shredding.

([8]) As, for example, the percentage of recycled rare and precious metals (as platinum, palladium, gold and silver) in PCB, otherwise largely dispersed in the shredding dusts and residues when PCB are not separated preventively to shredding.

([9]) For example, the EU Ecolabel or the implementing measures under the European Ecodesign Directive (2009/125/EC).

that the recycler is experienced in processing products with that design technology and has determined that the product design provides for ease of disassembly. The statement may include a checklist of all of the elements listed above; or 2) Disassembly report prepared by testing laboratory (specialising in electronics equipment) that meets ISO/IEC 17025, confirming that the product design meets the requirements of this criterion,' (IEEE, 2012).

2. Goals and scope of the report

In the case of measures for the 'design for extraction of target parts in ErP', the JRC study identified the 'time for the extraction' as a good proxy for proving the 'easiness to dismantling' (Ardente and Mathieux, 2012). This has been recently complemented by evidence collected at a representative recycling plant that was used to define potential thresholds for time for extraction, either in the context of the Ecodesign Directive or in the context of the EU Ecolabel, or both (Ardente et al., 2014). However, the verification of the application of such potential measures on extractability implies the availability of a method for repeatable measurements.

The present report intends to provide scientific evidence on the feasibility of this method and to make a proposal on how the method should be structured.

The report includes a review of the relevant scientific references (including standards and scientific articles), discusses key issues for the measurement of the 'time for extraction' of product target parts and proposes how such key issues could be integrated into an exemplary method for the measurement.

Within this feasibility study, the backbone of a measurement method will be proposed and discussed (Annex 1).

3. Analysis of the scientific and technical literature

The relevance of the easiness to dismantle (or disassemble) products has been recognised in European product policies as, for example, in some Ecodesign implementing measures (based on criteria for the provision of information for circulators ([10]), motors ([11]), fluorescent lamps without integrated ballast ([12]) and fans driven by motors ([13])).

([10]) To increase the re-use and recycling of circulators, manufacturers should provide information on the assembly and dismantling of circulators (EC, 2009a).

([11]) In order to further limit the environmental impact of motors manufacturers should provide relevant information on disassembly, recycling or disposal at end-of-life (EC, 2009b).

([12]) Manufacturers of luminaires for fluorescent lamps without integrated ballast (…) must provide at least the following information: (…) disassembly instructions (EC, 2009c).

([13]) In order to further limit the environmental impact of fans driven by motors (…), manufacturers should provide relevant information on disassembly, recycling or disposal at end-of-life of such fans (EC, 2011b).

Abundant academic literature argues that the improvement of manual dismantlability of EEE is crucial to enable maintenance, enhance serviceability and/or to affect EoL objectives such as component reuse, remanufacture and recycling (Williams, 2006; Masanet, 2007; Duflou et al., 2008).

In the last decade, product dismantling times have been reduced by the implementation of ecodesign strategies such as the reduction of the number of screws, the number of materials in components and assemblies (Hatchera, 2011; Borchardt, 2011). Although several scientific articles have reported the implementation of some specific measures for the improvement of dismantlability (e.g. Williams, 2006; Borchardt, 2011), measuring and evaluating whether a given improvement was significant — and, if so, how significant — is still not possible due to the lack of a standardised method (Desai, 2003).

The dismantlability of a product is a function of several parameters such as: exertion of manual force to dismantle; degree of precision required for effective tool placement; weight, size, material and shape of components being dismantled, use of hand tools, etc. (van Schaik, 2004).

Another key factor influencing product dismantlability is the dismantling sequence to be followed (Boothroyd, 1992; Kara and Kaebernick, 2006; Li et al., 2013). The need to define the proper dismantling sequence for material separation or the extraction of target parts has been underlined since the first research on DfD more than 20 years ago (Boothroyd, 1992). The dismantling sequence to be followed has a great influence on the time needed to extract components, which can easily double or triple (Li et al., 2013). Particularly important for cost-efficient dismantling is the provision of a suitable dismantling plan based on the test results for each product.

Although automatic dismantling is seen as a desirable option, it is not yet a well-established process mainly due to the complexity, diversity and size of most of the components embodied in EEE and the other technological limitations to separating them out (Williams, 2006). Manual dismantling is still indicated as the preferred option for higher material recycling (Duflou et al., 2008).

A recent report by the iNEMI Recycling and Repair Metrics consortium clearly demonstrates the need for a ‘quantifiable set of metrics or tools for measuring an electronic product’s true recyclability, reusability, reparability and refurbish-ability’. Among all the listed potential metrics, the topic of ‘ease of disassembly/dismantling’ is identified as critical for the electronic industry (iNEMI, 2015).

One of the first follow-up actions of the EU Action Plan for a Circular Economy has been the publication by the European Commission of a mandate to European Standardisation Organisations (ESOs, i.e. (i.e. CEN and Cenelec) to better define and measure the material efficiency of products (EC, 2015b); one of the required standardisation items concerns the ‘ability to access or remove certain components or assemblies from products to facilitate their extraction at the end-of-life for ease of treatment and recycling’.

After the analysis of the scientific literature on the subject and the identification of the need for a standard method to evaluate the dismantling time of product, the following paragraphs seek to analyse the key aspects necessary to develop such a standard and demonstrates its feasibility.

As the method is intended to be implemented for the extraction of target parts and components, from now on we refer to ‘extraction time’ instead of ‘dismantling time’.

4. Requirements for a standardised measurement method

The development of a standardised method for measuring the extraction time of a product’s target parts allows the repeatability of measurements and the minimising of uncertainty by removing or decreasing the influence of uncontrolled experimental conditions.

Measurements are fully comparable with each other (or against predefined requisites) only under certain conditions. As described in the previous sections, extraction time can be influenced by various aspects related to product characteristics, external conditions, measurements conditions and to the dismantling procedure:

- Product characteristics:
    - mass,
    - number of parts,
    - number of fasteners,
    - type of fasteners.
- Product dismantling:
    - extraction sequence,
    - used tools for dismantling operations,
    - ability/skills of the worker.
- External conditions:
    - measurement area,
    - implementation of safety requirements for workers.
- Time measurement:
    - operations included in the measurement,
    - tools used for measurement,
    - instrumental accuracy.

Product dependent parameters have an influence on the measurement of the extraction time influencing the ease with which the product can be dismantled. Some other parameters, although external (i.e. not directly related to the product), can influence the extraction time measurement and affect the product's performance.

In order to characterise the measurement of the extraction time, the following sections provide a detailed analysis of key aspects of that measurement, including key definitions and a set of operating conditions for the dismantling procedure. These key aspects will be integrated into a proposal for a measurement method as presented in Appendix 1. Moreover, the following sections and Appendix 1 are structured in order to directly feed into the development process of a potential international standard.

4.1. Terms and definitions

In order to develop a robust standardised measurement method, some key definitions have to be provided in order to minimise variability in extraction time measurement. The method should be generically applicable to all EEE. Taking into account the analysis of the scientific and technical literature made in section 2, definitions should be provided at least for the following terms:

— *Target parts:* these should be defined according to the objectives to be achieved during the extraction operations; the identification of components to be extracted should be considered as a pre-condition for measuring the extraction time. The method should therefore prescribe the prior setting of target parts.

— *Extraction*: the possible processes to be implemented during the extraction of target parts should also be defined. In this context, considering that, by definition, a standardised method deals with well-established processes, automatic dismantling should probably be explicitly excluded for now as manual dismantling is still indicated as the preferred option for higher material recycling (Duflou et al., 2008).

— *Extraction sequence:* this should consist of the list of operations to be executed during the extraction of the target parts of the EEE. The sequence ends when the target part is separated at the desired (pre-set) level and orientated in the appropriate stream. The extraction sequence (or, at least, the way it should be documented) should be described by the standardised method. An example on how to define and present the extraction sequence is provided in Table A.1 of Appendix 1.

— *Extraction Time:* operations to be included in the extraction process time measurement (and those to be excluded) should be defined at this stage as well as the initial and final stages. The extraction time should consist of the time elapsed between the start of the first operation and the end of the last operation as listed in the extraction sequence documentation.

— *Worker ability/skills:* the worker experience could potentially be a good proxy; the definition of the work experience of dismantlers should be set according to the Directive 2005/36/EC.

— *Tools for extraction*: only commonly available tools should be allowed to be used during the extraction process. The set of acceptable tools should be defined in accordance to available ISO standards.

Preferably, definitions for the method should refer, as far as possible, to already existing definitions as provided by current standards and directives (e.g. EU, 2009; EU, 2012; EN 50574, 2012).

4.2. Operating conditions

Some external aspects can have a crucial influence on the extraction time of target components and they should reflect the conditions of a typical Waste Electric and Electronic Equipment (WEEE) treatment facility that includes manual dismantling and manual depollution processes.

The tools to be used for the extraction operations should be placed adjacent to the measurement area and accessible to the worker. The testing area should have enough free space available to allow manoeuvre and placement of the components extracted during the measurement.

The safety requirements have to be defined according to the type of EEE being dismantled ([14]).

The worker's ability/skills in dismantling can influence the extraction operation and so also the measurement of its time. A standardised method for the measurement of the extraction time should provide minimum requirements on this issue. In order to decrease the variability of the process related to the worker, we suggest that the extraction of target components should be performed by a sufficiently experienced worker, defining 'experienced' as any worker with at least two years' experience in a typical WEEE treatment facility that includes manual dismantling and manual depollution processes.

As described above, the extraction sequence affects significantly the extraction time. Although the issue of the extraction sequence has been studied extensively it has not been possible to define a universally applicable method (Santochi and Failli, 2002). A standardised method for the measurement of the extraction time has to define the dismantling sequence as a pre-requisite to the product dismantling.

In a case where this extraction sequence is to be used as part of the verification process for potential Ecodesign requirements, the sequence should be provided by the product manufacturer at the time of the introduction of the product to the market. The documentation provided could be produced according to the provisions set out in Table A.1 of Appendix 1. In this proposal, the extraction sequence is set by listing dismantling operations grouped in larger tasks (Santochi and Failli, 2002; Letcher, 2011; Pérez-Belis and Gómez, 2013) together with additional information related to the:

([14]) For example the Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres in case of household appliances containing volatile fluorocarbons or volatile hydrocarbons (EN 50574, 2012).

— operation number,

— operation name,

— fastener(s) (type and numbers) to be removed,

— tool/tools to be used,

— component/part to be extracted.

The characterisation of dismantling operations should include information on the time needed for each single operation, illustrated in a figure or a diagram (Letcher, 2011).

In order to provide some useful information on the preferred treatment of individual components a further characterisation of the EEE should include information on the presence of precious or hazardous materials in the components (Pérez-Belis and Gómez, 2013; Li et al., 2013).

4.3. Measurement of the extraction time

A standardised method for the measurement of the extraction time should include minimum requirements for: measurement of the time, tools to be used and accuracy. A suitable standard should include a section defining all these aspects.

Additionally, such a standard could suggest the provision of a video of the extraction sequence (as performed by an experienced worker) to be added to the documentation as proof of the feasibility of the sequence. Such a video could also help a worker to perform a verification test.

5. Conclusions

An initial feasibility study on the development of a method to measure the extraction time of certain parts from an EEE has been carried out and described in this report. This study complements the findings of various reports published by the Joint Research Centre (JRC) on the material efficiency of various product groups. The aim of these reports is to support the development of potentially suitable design measures for product policies (in particular under Ecodesign) with particular focus on the EoL stages. The present study argues that there is a need to develop a standard method to measure the extraction time of certain parts and components of ErP (and particularly of EEE). Key aspects influencing extraction time have been identified and analysed and the development of a measurement method is judged by the authors of this report to be feasible.

A measurement method has been developed as proof of concept and is attached in Appendix 1. The method has been structured in order to reflect the framework of a potential international standard.

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(EC 2009c) Commission Regulation (EC) No 245/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps, and repealing Directive 2000/55/EC of the European Parliament and of the Council.

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Appendix 1: Proposal of a standardised method for repeatable measurements of the time taken to extract certain target parts from Electrical and Electronic Equipment

1. Foreword

This document was prepared by the Institute of Environment and Sustainability of the DG JRC, European Commission, as an Appendix to a study into the feasibility of a standard repeatable measurement method for measuring the extraction time of certain parts. Such a method, when developed further by e.g. CEN/Cenelec, could be used to establish product requirements in product policies such as the Ecodesign Directive ([15]).

2. Scope

This document defines requirements for a repeatable method for measuring the extraction time of certain target parts from electrical and electronic equipment (EEE).

This method is generally applicable to all EEE.

3. Normative references

No normative references are cited. Informative references are noted in the bibliography.

4. Terms and definitions

4.1 Electrical and electronic equipment (EEE) ([16])

EEE is defined as equipment which is dependent on electric currents or an electro-magnetic field in order to work properly and equipment for the generation, transfer and measurement of such currents and fields falling under the categories set out in Annex I of Directive 2012/19/EU and designed for use with a voltage rating not exceeding 1 000 V for alternating current and 1 500 V for direct current.

4.2 Target parts

Target parts are those parts and/or components that are targeted for the extraction process. Target parts are usually identified for a given EEE according to the objectives which are intended to be achieved. The definition of target parts is a pre-condition of the measurement

([15]) Ecodesign Directive (2009/125/EC)
([16]) Source: EN 50419 — Marking of electrical and electronic equipment in accordance with Article 11(2) of Directive 2002/96/EC (WEEE)

of the extraction time and they must be defined in any document referencing this present document (e.g. an implementation measure under Directive 2009/125/EC).

4.3 Extraction ([17])

Extraction is defined as a process that results in the extraction of unbroken target parts from the given EEE and the creation of one or more identifiable streams. Manual dismantlability of some components contained in EEE has been identified as crucial by many authors ([18]) ([19]), to enable maintenance, enhance serviceability, and/or to achieve EoL objectives such as component reuse and recycling

4.4 Extraction sequence

The extraction sequence, as defined by the literature ([20]) ([21]), consists of the list of operations to be executed during the extraction of the target parts of the EEE. The sequence ends when the target part is separated at the desired (pre-set) level and orientated in the appropriate stream.

4.5 Extraction Time

The extraction time is the time elapsed between the start of the first operation and the end of the last operation as listed in the extraction sequence documentation.

4.6 Worker experience

The length of the professional experience required is quantified in accordance with Directive 2005/36/EC.

4.7 Tool for extraction

A tool is any manual or power-driven device used to perform one or more operation listed in the extraction sequence.

5. Operating conditions

5.1 Measurement area

The measurement area should reflect the conditions of a typical WEEE treatment facility that includes manual dismantling and manual depollution processes. The tools to be used for the extraction operations should be placed adjacent to the measurement area and accessible to the

([17]) Adapted from: TC111x WG6
([18]) J.R. Duflou, G. S., S. Kara, Y. Umeda, A. Ometto, B. Willems (2008). 'Efficiency and feasibility of product disassembly: a case-based study.' Manufacturing Technology 57(583-600).
([19]) E. Masanet, A. H. (2007). 'Assessing the benefits of design for recycling for plastics in electronics: A case study of computer enclosures.' Materials & Design 28(6): 1801-1811.
([20]) S. Kara, P. P., H. Kaebernick (2006). 'Selective disassembly sequencing: a methodology for the disassembly of end-of-life products.' CIRP Annals—Manufacturing Technology 55(1): 37-40.
([21]) G. Boothroyd, L. A. (1992). 'Design fo Assembly and Disassembly.' CIRP Annals—Manufacturing Technology 41(2): 625-636.

worker. Enough free space should be available around the testing area to accommodate the components extracted during the measurement.

5.2 Safety requirements

Employers should ensure that they are familiar with the general requirements for health and safety as laid down in Directive 89/391 EEC. More specific safety measures might need to be followed depending on the particular EEE being treated (e.g. Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres in case of household appliances containing volatile fluorocarbons or volatile hydrocarbons) ([22]).

5.3 Minimum worker experience

The worker executing the extraction operations must have a minimum experience of 2 years in the sector of EEE waste treatment. The experience should be evaluated according to Directive 2005/36/EC.

5.4 Extraction sequence to be followed

The extraction sequence to be followed has to be set prior to the measurement. The sequence has to be documented as shown in the Table A.1 of Annex A.

5.5 Tools for extraction

The extraction operations should be performed using manual or power-driven standard tools. The list of the tools to be considered is provided in Annex B.

6. Extraction time measurement

6.1 Measurement sample ([23])

The sample of EEE to be used for the measurement will be undamaged (i.e. based on a visual inspection, the sample must not present evidence of damage that could affect the extraction process).

If, during the test, an appliance is identified as having missing or seriously damaged components, the sample EEE must be substituted by an undamaged one.

6.2 Measurement

The extraction time measurement will consist of the measurement with an instrument of the time elapsed between the start of the first operation listed in the extraction sequence documentation and the end of the last one.

([22]) EN 50574:2012 — Collection, logistic & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons.

([23]) EN 14899:2005 — Characterisation of waste. Sampling of waste materials. Framework for the preparation and application of a sampling plan

6.3 Measurement accuracy

The total extraction time will be measured using an instrument with an accuracy of at least ± 1s.

Annex A

Documentation of the extraction sequence

The extraction sequence to be followed during the extraction operation must be set prior to the measurement of the extraction time. This annex contains a description of the required information to be provided to the worker carrying out the extraction.

An example of the table that must be used to define the extraction sequence to be followed during the extraction time measurement is provided (Table 1).

A.1 EEE-related information

The extraction sequence must be accompanied by the following product related information:

- brand,
- model,
- weight,
- size (e.g. size of the diagonal of the screen for electronic displays),
- technology (e.g. 'LCD', 'Plasma', 'LED', 'OLED', 'QD' or any other technology for electronic displays).

A.2 Extraction sequence related information

The operations to be performed during the EEE extraction must be described in order of execution. For simplicity, single consecutive operations with a common objective can be grouped in tasks ([24]), as proposed by some authors ([25]).

Each single operation description will contain the following information:

- operation number (ascendant starting from 1),
- operation name,
- number of all types of fastener(s) to be removed (if any),
- tool/tools to be used,
- component/part do be extracted (if any),
- direction of removal of the component/part.

Each single operation description should contain the following information:

- hazardousness of the component(s) do be extracted (e.g. according to WEEE Directive),
- operation time,
- operation illustration.

([24]) Letcher, B. (2011). Old and new LCD Television Assemblies — Disassembly differences. Report of the project 'Sustainable recycling of Flat Panel Displays — Project HÅPLA a Swedish initiative towards a comprehensive solution'.

([25]) M. Santochi, G. D., F. Failli (2002). 'Computer Aided Disassembly Planning: State of the Art and Perspectives ' CIRP Annals—Manufacturing Technology 51(2): 507-529.

The following Table A.1 provides an example on how to list operations to be executed during the extraction.

An exploded view of the product should be added to the documentation.

A video of the extraction sequence performed by an experienced worker can be added to the documentation to illustrate and clarify the operations.

Table A.1: Extraction sequence

Task no	Task description	Operation no	Operation description	Tool	Type of fastener to be removed/ broken	Number of fasteners to be removed	Direction of extraction of the component	Extracted component	Target part? (Y/N)	Precious/rare /critical materials? (Y/N)	Hazardous ([26])? (Y/N)	Time (s)	Illustration

([26]) V. Pérez-Belis, M. D. B., A. Gómez (2013). 'Waste electric and electronic toys: Management practices and characterisation.' Resources, Conservation and Recycling 77: 1-12.

Annex B

List of the tools to be used for extraction operations

The following Table A.2 lists the tools that can be used during extraction operations and related ISO standards.

Table A.2: accepted tools list

Tool category	Related standard
Assembly Tools For Screws And Nuts	ISO 10914 ISO 1174 ISO 1711 ISO 2351 ISO 2380 ISO 2725 ISO 3315 ISO 3316 ISO 3317 ISO 8764 ISO 10102 ISO 10104 ISO 1085 ISO 1174 ISO 6787 ISO 6788 ISO 8774 ISO 8764
Spanners and Wrenches	ISO 5742 ISO 5745 ISO 5746 ISO 5747 ISO 5749 ISO 8976 ISO 8979

	ISO 9242 ISO 9243 ISO 9654 ISO 9655 ISO 9656 ISO 9657 ISO 4228
Pliers and Nippers	ISO 5742
Hammers	ISO 15601

Annex C

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