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Recycling of rare earth elements — Requirements for providing information on industrial waste and end-of-life products

Recyclage des terres rares — Exigences pour la mise à disposition de données relatives aux déchets industriels et aux produits en fin de vie

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 298, *Rare earth*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Rare earth elements (REEs) comprise the lanthanoid series elements plus scandium and yttrium, which have similar chemical and physical properties and are often found in the same ores and deposits. The importance of REEs has increased greatly due to their important role in high performance and functional applications in permanent magnets, electric vehicles, motors, wind generators, light-emitting diodes (LED), nickel-metal hydride (NiMH) batteries, etc. Magnets can be also classified into manufacturing methods. The type of magnet is useful information for recycling procedures.

Magnets account for the highest market share of REEs by value. REE-containing multi-component alloys can have a complex compositional make-up. The variants include compositions such as $Sm_{62}Co_{38}$, $Sm(Co_{0.69}Fe_{0.2}Cu_{0.1}Zr_{0.01})_{7.2}$, $Sm(Co_{0.67}Fe_{0.22}Cu_{0.1}Zr_{0.07}Ti_{0.01})_{7.1}$, $Sm_2Fe_{17}N_x$, $Nd(Fe,Mo)_{12}N_x$, $Sm_3(Fe,M)_{29}N_x$, sintered $Nd_2Fe_{14}B$/α-Fe, $Sm_2Fe_{17}N_x$/α-Fe, PrFeCuB, $Tb_xDy_{1-x}Fe_2$ (x ~0,3) and others are used in permanent magnets. Due to the complexity involved in processing of these magnets, several different manufacturing routes are used. During the production stages, industrial waste containing REEs is produced and often recycled. Magnets found in end-of-life (EOL) or broken electronics, hard disk drives, motors, generators, etc. also contribute to waste.

Phosphors and luminescence applications of REEs constitute about a one-third share of the total demand for REEs. REEs contained in $(La_{0.6}Ce_{0.27}Tb_{0.13})PO_4$, $(Y_{1.94}Eu_{0.06})O_3$, $(Ba_{0.9}Eu_{0.1})MgAl_{10}O_{17}$, $Ca_{0.98}Eu_{0.02}AlSiN_3$, $(Y_{0.98}Ce_{0.02})_3Al_5O_{12}$, etc. are important materials used in phosphor and LED semiconductor technology. The LED manufacturing process is complex and is undergoing much change with the growth of the industry and the changes in demand patterns of associated commodities. During the production stages of LEDs, a lot of waste is created, which is recycled. EOL LEDs found in broken smartphones, TVs, display panels, cameras, etc. also contribute to waste.

Batteries make up a relatively lower amount of the total demand for REEs. REEs contained in multi-component alloys such as $LaNi_5$, $La_{0.8}Nd_{0.2}Ni_{2.5}Co_{2.4}Si_{0.1}$, $La_{0.8}Nd_{0.2}Ni_{2.5}Co_{2.4}Al_{0.1}$ and $MmNi_{3.5}Co_{0.7}Al_{0.8}$ are used in rechargeable NiMH batteries due to their superior hydrogen storage properties. The production of these NiMH batteries produces waste, which is generally recycled. EOL batteries also contribute to waste.

Numerous categories are schematically illustrated in Figure 1 in which waste can be generated during manufacturing to the EOL stage for magnets, LEDs and batteries.

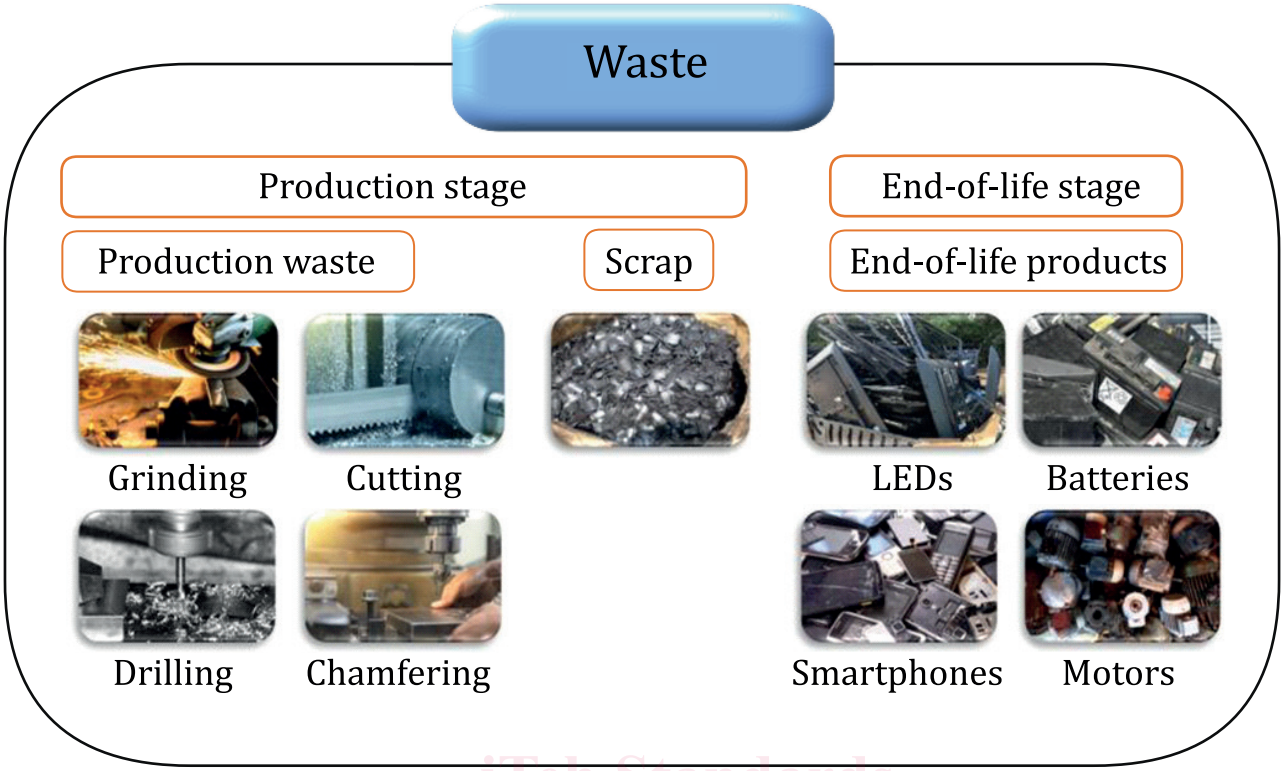


Figure 1 — Waste generation during various processes

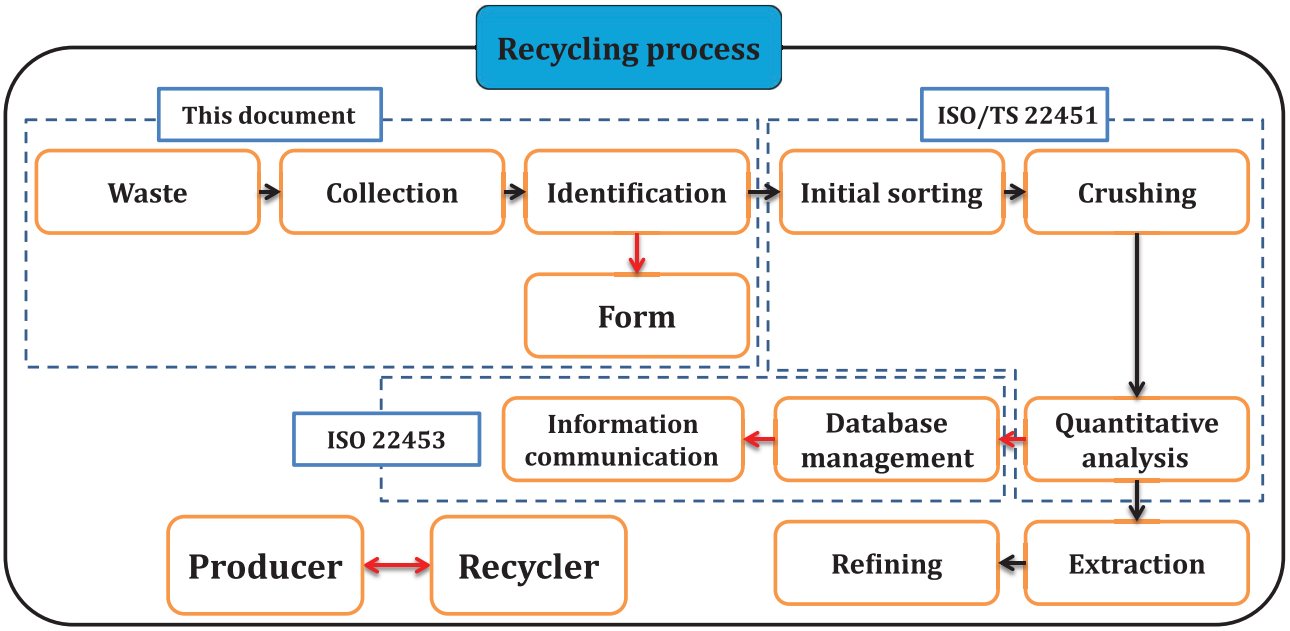
Resource scarcity of these valuable commodities is inevitable. Furthermore, the accumulation of waste materials creates environmental and economic problems. A viable option to ensure a smooth balance of supply and demand is to recycle these elements.

Table 1 summarizes the expected REE waste stock that will be accumulated until 2020[3]. It also gives the indication of recycled REE stock until 2020 by keeping in view the maturity of recycling techniques and industry.

Table 1 — Expected REE waste stock in the year 2020[3]

REE application	Expected REE stock in 2020 (tons)	Recycling process efficiency	Recycled REE in 2020 (tons)
Magnets	300 000	55 %	2 333
Lamp phosphors	23 000	80 %	6 600
NiMH batteries	50 000	50 %	1 750
NOTE This table presents the current distribution, however, markets and waste distribution can change over time.			

There is a big difference in amount of waste generated by REEs and what is recycled due to a lack of maturity of recycling technologies and communication formats between manufacturers/producers and recyclers. In the REE recycling process, an important initial step is the identification of products containing REEs. A typical recycling process is shown in Figure 2.



Key

black arrows forward steps

red arrows additional steps proposed in this document

NOTE This document, ISO/TS 22451 and ISO 22453 are documents for ensuring a smooth recovery of REE from waste.

Figure 2 — Typical recycling process

This document defines REE-related substances that are recycled at the product stage as waste or EOL products and suggests ways to facilitate their recycling through an identification of the waste composition. ISO/TS 22451 specifies measurement methods of REEs in industrial waste and EOL products. ISO 22453 focuses on the management of a database obtained from communication with the producer, recycler and a management agency for effective recycling. The simultaneous application of these three documents is necessary to ensure the complete and efficient recycling of valuable REEs.

Recycling of rare earth elements — Requirements for providing information on industrial waste and end-of-life products

1 Scope

This document specifies the recycling information to be provided for rare earth elements (REEs) in industrial waste and end-of-life (EOL) products from manufacturers/producers to recyclers. It includes a classification system and forms for providing the recycling information.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 21067-1, *Packaging — Vocabulary — Part 1: General terms*

ISO 22444-1, *Rare earth — Vocabulary — Part 1: Minerals, oxides and other compounds*

ISO 22444-2, *Rare earth — Vocabulary — Part 2: Rare earth metals and their alloys*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21067-1, ISO 22444-1, ISO 22444-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
rare earth element waste product
REE waste product
unusable substance containing rare earth elements

Note 1 to entry: REE waste products are generally generated during the production, processing or use of REE products such as magnets, *phosphors* (3.3), batteries, catalysts, lasers and others.

3.2
REE magnet
magnet that contains elements such as Nd, Sm and Dy

Note 1 to entry: REE magnets have a lot of application areas such as in parts of vehicles, home applications, wind turbine generators, high-performance AC servo motors and computer hard disk drives.

3.3
phosphor
fluorescent substance containing rare earth elements such as Y, La, Eu, Tb and Ce

Note 1 to entry: REE phosphors are widely used in LEDs and fluorescent lamps.

3.4
nickel-metal hydride battery
NiMH battery
battery that uses the hydrogen storage property of alloys containing rare earth elements such as La, Nd and mischmetal

Note 1 to entry: Rechargeable NiMH batteries are used for hybrid vehicles and as portable batteries for small home appliances.

3.5
industrial waste
waste produced by industrial activity, which includes any material that is rendered useless during a manufacturing process such as that of factories, industries, mining and milling operations

Note 1 to entry: The waste from mills and mining operations is not a subject of this document. The industrial waste dealt with in this document can be subdivided into two categories: *processing waste* (3.6) and *scrap* (3.7).

3.6
processing waste
waste that comes from preparation and processing operations with magnets, fluorescent powder, rare alloys, etc., including of chips, flakes, broken pieces, powders, etc., which could be recycled by metallurgical methods to get valuable elements

3.7
scrap
recyclable materials left over from product manufacturing

Note 1 to entry: Unlike waste, scrap has monetary value, especially recovered metals. Non-metallic materials are also recovered for recycling.

3.8
end-of-life product
EOL product
product that is at no longer useful or needed from the customer's point of view, because the product is broken, no longer functions properly or no longer satisfies the customer's requirements

4 Forms of REEs in industrial waste and EOL products

4.1 General

Significant quantities of REEs are present in industrial waste and in EOL products that can be recycled, to ensure a smooth balance between supply and demand chains. Representative forms of REEs in industrial waste are discussed in 4.2 to 4.6.

4.2 In REE magnets

During powder production, whether pre-alloyed or post-alloyed, lots of flakes are produced that are recycled. Similarly, powder of a size greater or smaller than the required size is also recycled. Later, screening operations also create waste powder, which is recycled along with cleaning solutions. Machining operations such as grinding, cutting (slicing), drilling and chamfering operations along the assembly line produce waste in the form of chips, flakes and broken magnet pieces. Extremely small chips are recycled along with coolants used during these manufacturing operations. During the fabrication of REE magnets, approximately 20 % to 30 % of the raw material in the form of processing waste and scrap can be recycled.

EOL REE magnets are found in broken motors, generators, hard disk drives, electronics, etc. Being relatively old, these magnets have often developed oxide layers, corrosion, etc.