INSTITUTO DE PESQUISAS TECNOLÓGICAS

COMUNICAÇÃO TÉCNICA

Nº 178689

Recycling of materials from led lamps: investigating the mechanism of the dismatling of lamps led bulb type

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Palestra apresentado: ABM ANNUAL CONGRESS INTERNATIONAL; CONGRESSO ANUAL DA ABM, 76., 2023, São Paulo. 19 slides.

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RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE

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August 2, 2023

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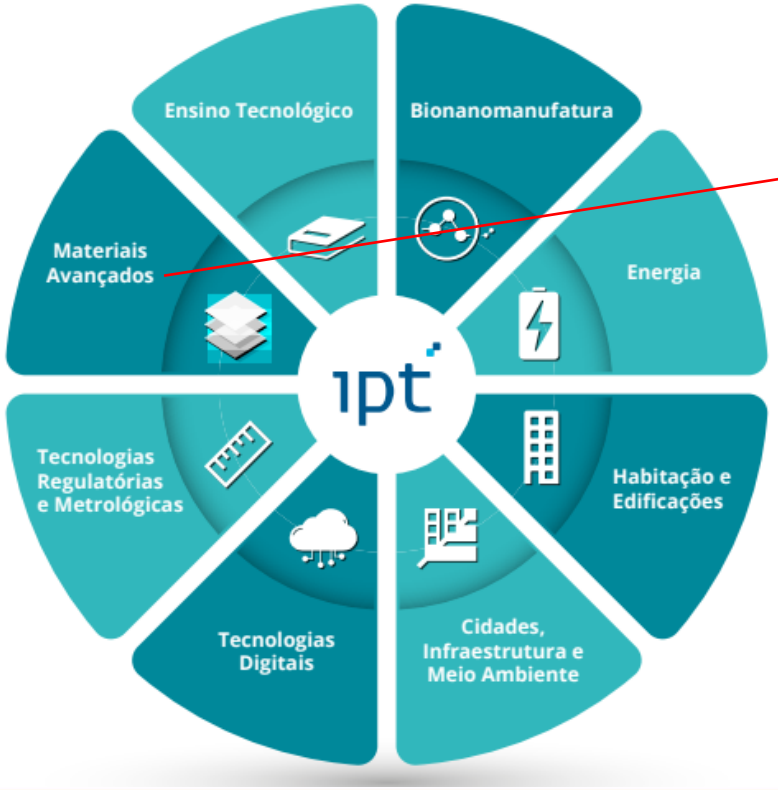
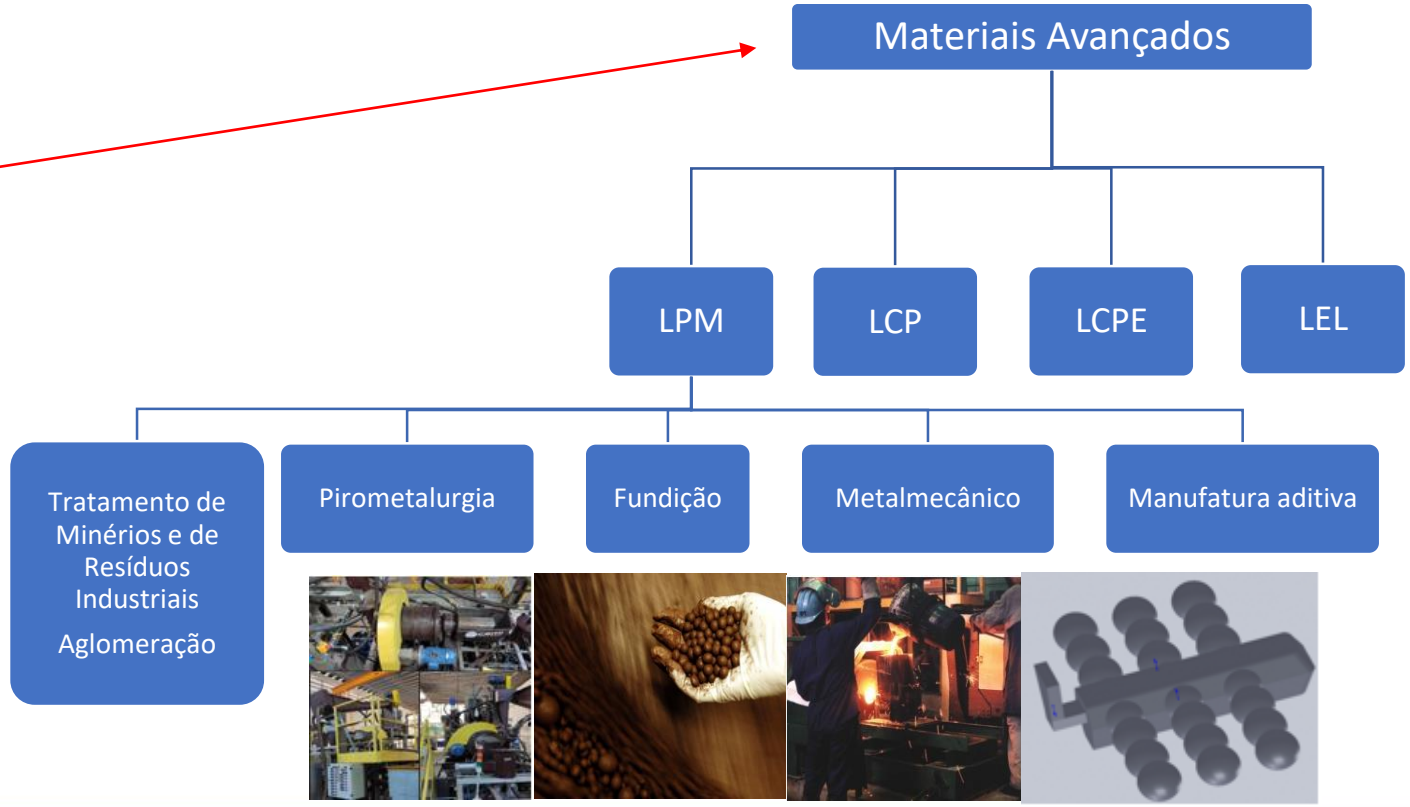
Unidades de Negócios





RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE

Growing demand from modern society for digital technologies, energy transition and decarbonization: consumption of various metals such as copper, lithium, cobalt, nickel, rare earth elements, in addition to the traditional iron and aluminum.

Primary sources: mineral deposits

Secondary sources: electronic waste

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE

LED lamp, advantages over conventional ones (incandescent and fluorescent):

- Energy-efficient lighting technology.
- Longer service life.

LED Market:

- 2019: >10 billion units sold.
- 2022: 76 billion dollars.2032: an estimated 191.8 billion dollars.

Types of LED lighiting

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE

In view of the high sales projections of LED lamps in the coming years, it is expected that waste from these products will also increase in the coming decades.

As a result of this, studies are being conducted in several countries:

- Generation and disposal of this waste, which necessarily involves the development of characterization methods and processing routes.
- Most studies: extractive metallurgy routes without prior physical processing.

In Brazil:

- Tramppo Indústria e Comércio: the need to develop a specific process for this type of lamp and, therefore, in 2018, sought assistance from the IPT to assist in the development of this process.
- Since then, IPT, in partnership with the company Tramppo, has been developing research into recycling LED lamps, supported by development agencies: Embrapii, Sebrae and FAPESP.

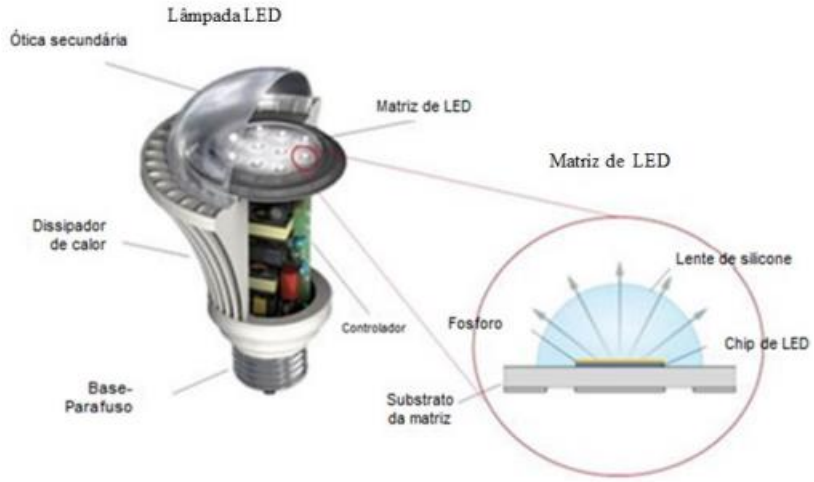
RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE

Due to their versatility, there are several types of LED lamps divided into lamps and luminaires.

Tramppo:

- 6 types of LED lamps.
- 2 tons per month.
- Bulb and tubular type represent the vast majority.

Thus, bulb-type lamps were the object of the first study to define the physical separation processing route.



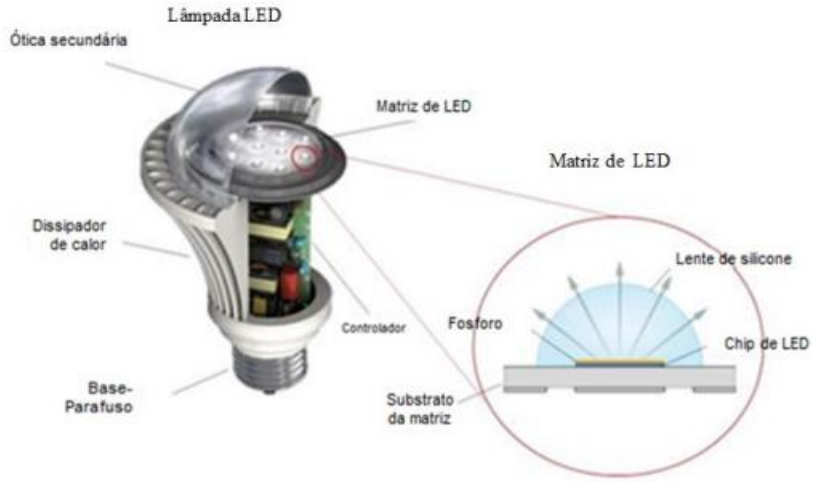
Bulb type LED lamp

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE

The development of the recycling route for LED lamps begins with the operation of dismantling the lamps, aiming at releasing their components so that they can be physically separated, generating suitable products to be used as raw materials in other industries or purified products for extractive metallurgy operations.

Selecting the dismantling method that maximizes the release of components from LED lamps is a challenge, as these materials have distinct characteristics of resistance to dismantling.

The present study aims to investigate several breakage mechanisms, which are traditionally applied in the comminution of fragile materials and plastics in the dismantling of LED lamps, in order to maximize the release of their components for subsequent physical separation operations.



Lâmpada de LED do tipo bulbo

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE - MATERIALS AND METHODS

Sampling: sample of 176 kg of bulb-type LED lamps at Tramppo company.

Homogenization and split: construction of a “conical” pile with the aid of a forklift and a bigbag and the collection of the 4 quadrants (subsamples).

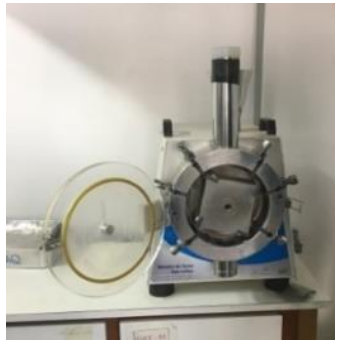
Construction of a conical stack for homogenizing the sample of LED lamps

Splitting of LED lamps

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE - MATERIALS AND METHODS

In order to evaluate the dismantling of LED bulb type lamps, several equipment that are traditionally used in the comminution and mixing of ores were explored:

Jaw crusher



Bench “knife” mill

Pilot knife mill

Roll mixer
(bench and pilot)

Ball mill

Tumbler

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE – RESULTS

Ensaio	Equipamento	Imagem	Mecanismo	Resultado
01	Britador de Mandíbulas		Compressão e esmagamento	As lâmpadas foram desmontadas parcialmente, mas componentes plásticos foram esmagados.
02	Moinho de Facas		Fragmentação por facas	Devido ao tamanho do equipamento, foi necessário moer cada componente separadamente. Os componentes foram totalmente picados, em partículas menores que 0,6 mm.
03	Picador		Fragmentação por facas	As lâmpadas foram totalmente picadas, mas se observou diversas frações granulométricas no produto.
04	Misturador de rolo pequeno e grande		Compressão vertical	As lâmpadas foram desmontadas parcialmente.
05	Moinho de bolas com carga		Abrasão	Lâmpadas permaneceram inalteradas após o ensaio.
06	Tambor (*Tumbler test*)		Impacto decorrente de queda	As lâmpadas foram completamente desmontadas, apresentando todos os componentes individualizados.

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE – RESULTS AND DISCUSSION

Autogenous mill (Djordjevic, 2004):

- Cylindrical geometry with a diameter/length ratio (D/L) between 1.5 and 3.0.
- Internal lifthers.
- Filling 7 to 20%.
- 70 to 80% of critical speed.

Parâmetros internos do tambor	
Diâmetro (D)	0,915 m
Comprimento (L)	0,449 m
Relação D/L	2,04
Volume	0,296 m³
Potência	1,5 cv
Velocidade	25 rpm

Tumbler parameters used as autogenous grinding

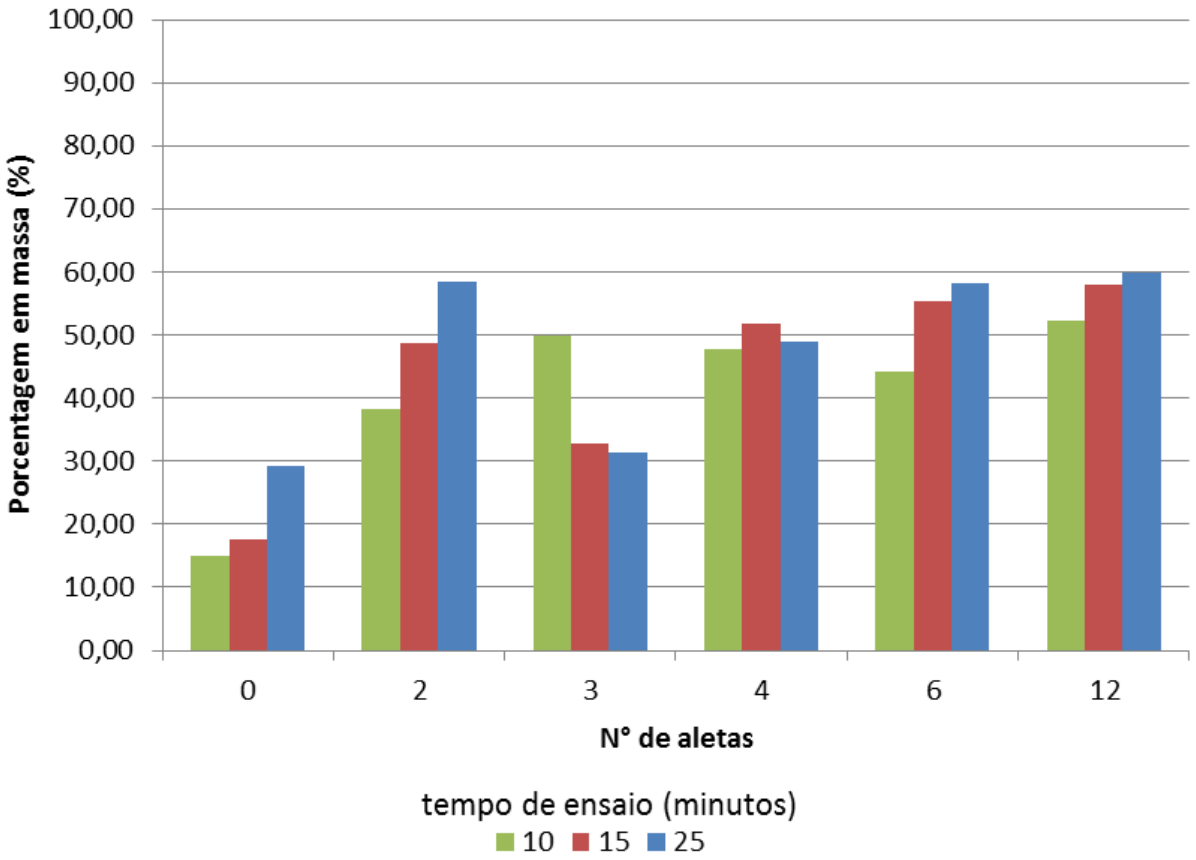
Ensaio	Número de aletas	Tempo de ensaio (min)	Disposição das aletas
1	12	25	
2	12	15	
3	12	10	
4	6	25	
5	6	15	
6	6	10	
7	2	25	
8	2	15	
9	2	10	
10	4	25	
11	4	15	
12	4	10	
13	3	25	
14	3	15	
15	3	10	
16	0	25	
17	0	15	
18	0	10	

Tests conditions

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE – RESULTS AND DISCUSSION

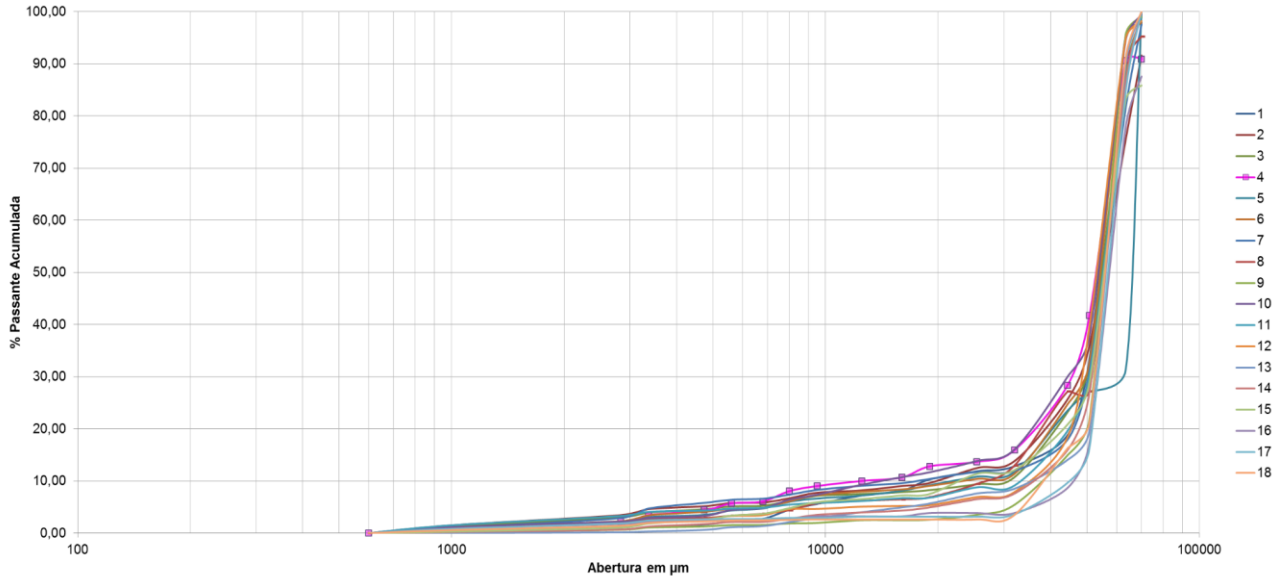
Ensaio	Número de aletas	Tempo de ensaio	Rendimento (%)	Consumo de energia (kWh)
1	12	25	59,77	0,110
2	12	15	58,03	0,067
3	12	10	52,20	0,044
4	6	25	58,17	0,097
5	6	15	55,41	0,067
6	6	10	44,17	0,043
7	2	25	58,36	0,109
8	2	15	48,62	0,069
9	2	10	38,20	0,045
10	4	25	49,02	0,108
11	4	15	51,86	0,062
12	4	10	47,84	0,041
13	3	25	31,26	0,099
14	3	15	32,77	0,057
15	3	10	50,01	0,041
16	0	25	29,19	0,096
17	0	15	17,64	0,060
18	0	10	14,97	0,041

Test conditions and mass yield data of disassembled lamps and energy consumption in each test.



Yield of lamp disassembly tests

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE – RESULTS AND DISCUSSION



Product size distribution of all tests (% acumulated passing)

	Número de aletas/tempo de ensaio		
	12 aletas	6 aletas	4 aletas
Malha (mm)	15 minutos	25 minutos	25 minutos
70	91,61	90,92	99,42
63,5	75,45	90,64	94,51
50,8	35,98	41,73	37,72
44,4	25,68	28,37	30,01
32,0	*13,82*	*15,92*	*16,03*
25,4	*12,49*	*13,69*	*13,84*
19,0	*9,64*	*12,82*	*11,69*
16,0	*9,04*	*10,69*	*10,75*
12,5	8,22	10,02	9,29
9,5	7,75	9,04	7,39
8,0	6,69	8,05	6,42
6,8	5,88	6,10	4,81
5,6	5,78	5,70	4,44
4,74	5,17	4,42	3,33
3,36	4,61	3,46	2,92
2,83	3,47	2,24	2,23
1,0	*1,51*	*0,87*	*1,16*
0,6	0,00	0,00	0,00

Product size distribution of the best tests (% acumulated passing)

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE – RESULTS AND DISCUSSION

	Número de aletas/tempo de ensaio		
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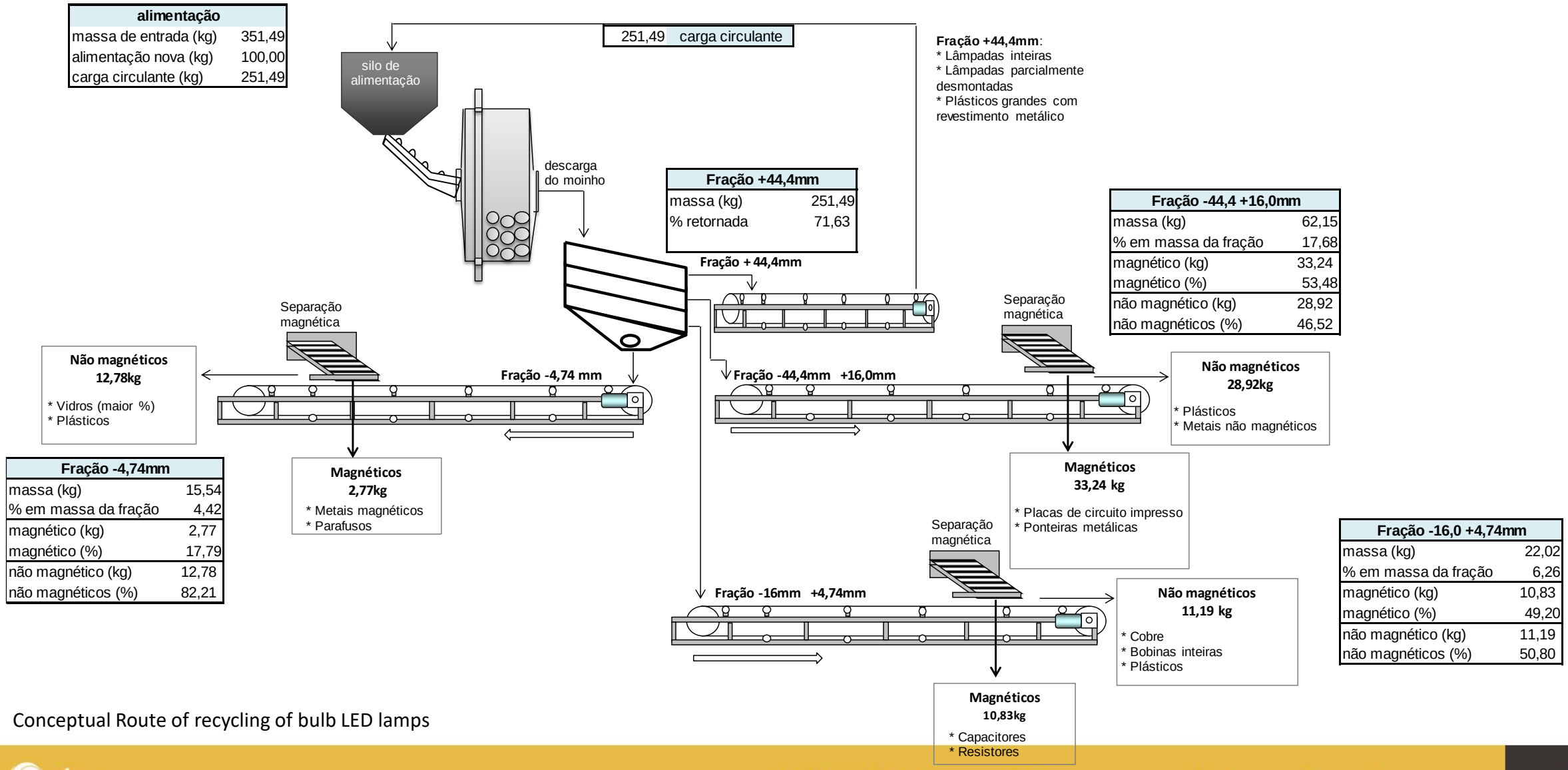
1,0	*1,51*	*0,87*	*1,16*
0,6	0,00	0,00	0,00

Product size distribution of the best tests (% acumulated passing)

Fração granulométrica	
+44,4mm	
-44,4mm +16,0mm	
-16,0mm +4,74mm	
-4,74 mm	

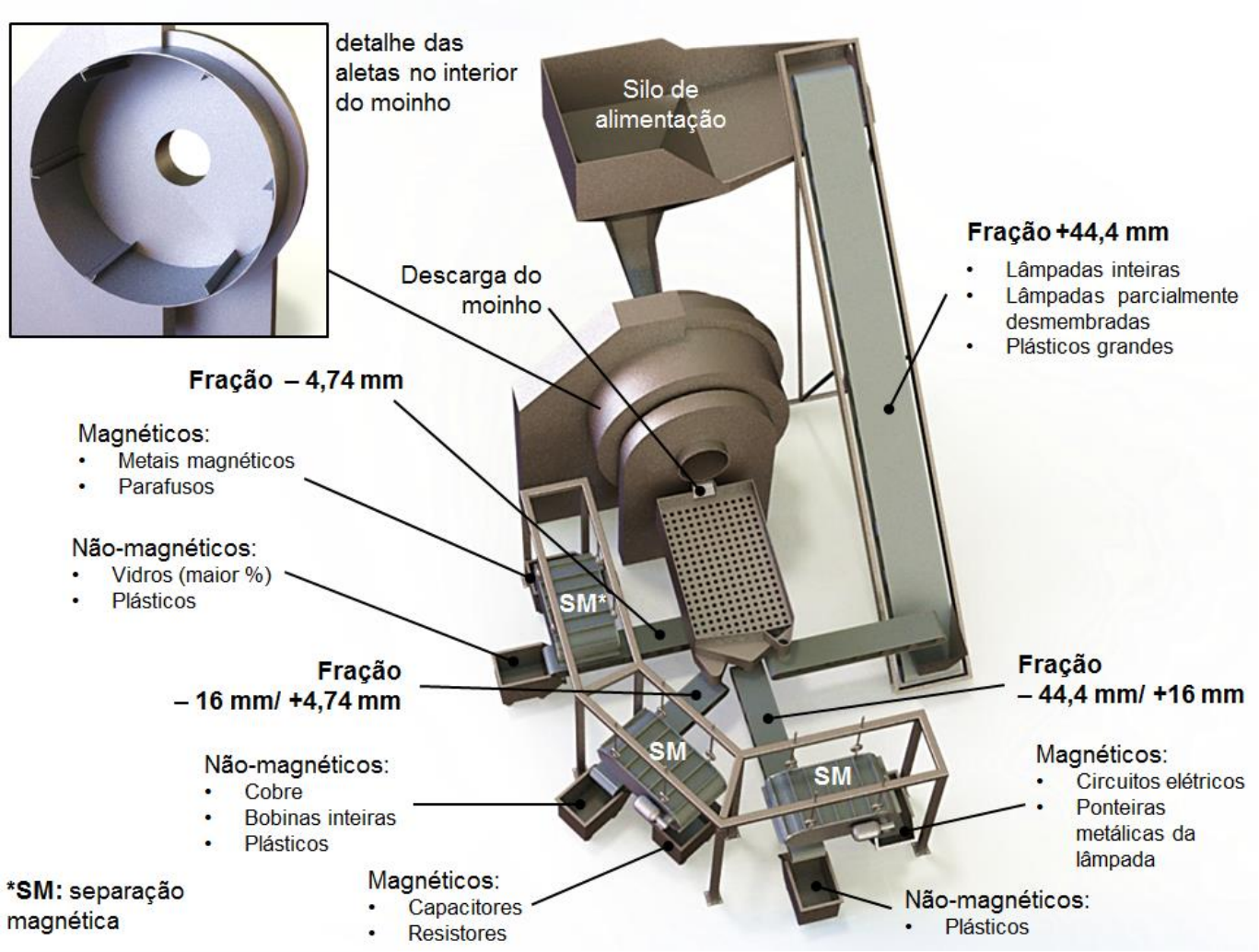
Granulometric size fractions separated under test conditions with 6 fins and dismantling time of 25 minutes

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE – RESULTS AND DISCUSSION



Conceptual Route of recycling of bulb LED lamps

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE – RESULTS AND DISCUSSION



Conceptual Route of recycling of bulb LED lamps

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE – RESULTS AND DISCUSSION

Autogenous mil appliead on recycling of bulb LED lamps

RECYCLING OF MATERIALS FROM LED LAMPS: INVESTIGATING THE MECHANISM OF THE DISMANTLING OF LAMPS LED BULB TYPE – CONCLUSIONS

- Several pieces of equipment were evaluated: jaw crusher, roller mixer, ball mill, knife mill and autogenous mill.
- Qualitative analysis of products: autogenous drum milling is the one that promotes the highest degree of dismantling.
- In view of this, new tests of autogenous grinding in drums were carried out in order to optimize the operational conditions, aiming to maximize the release of the components of the lamps, without excessively fragmenting them, which could impact the subsequent separation processes.
- Excess of fins promotes a higher rate of dismantling however; excessive fragmentation hinders the granulometric separation of the final products.
- Test with 6 fins and residence time of 25 minutes was the one that presented the best level of separation, in such a way that the materials (plastics, metals, glasses, capacitors, printed circuit and resistors) could be separated by granulometric ranges, which comprised a: 44mm; -44+16mm; -16 +4.74 mm and -4.74 mm.

APROVEITAMENTO DE MATERIAIS DE LÂMPADAS LED: INVESTIGANDO OS MECANISMOS DE DESMANTELAMENTO DE LÂMPADAS DO TIPO BULBO

AKNOWLEDGMENT

Materiais Avançados

Tramppo
GESTÃO SUSTENTÁVEL DE LÂMPADAS

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