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MANAGEMENT OF TIME AND HUMAN RESOURCES FOR WEEE RECYCLING LINE MONITORING

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Abstract: *In this paper we report on our experience in WEEE recycling monitoring; authors present problems and solutions of recycling of waste from electrical and electronic equipment and they focused on the analyse of an Eldan S1000 shredder recycling line.*
Concerning the European Union's environmental policy, there are three aspects about: conservation, protection and improvement of the quality of the environment, protection of population health and the correct and rational use of natural resources with their reuse. Waste electrical and electronic equipment (WEEE) represents a domain with the fastest growing, both national and international level; Romania held the European Union last place in electronic and electrical equipment waste collecting in 2016, 1.6 kg per inhabitant, below the 8.9 kilograms European average, as it is shown in European Bureau for Statistics published data.
Electronics recycling provides precious and special metals to be recovered, it reduces the environmental impact associated to the electronics manufacture from raw materials and it ensures that electronics hazardous substances are treated properly. The reused products must be accordingly and efficiently recycled at the end of their useful life.
The WEEE components recycling process is a very complex one, each stage having its own importance, timing and steps required for recycling need to be respected according to national and European rules.
The Eldan S1000 shredder recycling line consists of many equipment and it has approximately 4 tonnes / hour processing capacity, function the type of material to be processed.
To solve the desired recycling problem by using Eldan line represents a possibility by a modular approach flexibility, which means that a number of combinations can be obtained, with variations from a single machine to complete systems. The WEEE Eldan recycling plants and lines are designed for automatic processing, with specialized personnel for supervision. They can be easily adjusted to reduce the material size, depending on its type and in accordance with the market requirements.
High performance, low processing and maintenance costs, low energy consumption, minimal metal losses and the appropriate mechanical technique for reducing and separating components recommend these equipment type for successful WEEE recycling, with a modern and flexible technology.
This type of modern WEEE recycling system solutions offers an innovative character, paying attention to main factors – human resources and time – their good management being important to the proper functioning of the Eldan recycling line.

Keywords*: Waste electrical and electronic equipment (WEEE), Environment, Recycling, Shredder recycling line*

1. Introduction

The aim of the paper is to analyse and report on Romanian experience in recycling monitoring, by considering problems and solutions of electrical and electronic equipment waste recycling, using an Eldan S1000 shredder recycling line.
Waste electrical and electronic equipment (WEEE) represents a domain with the fastest growing, both national and international level. Concerning the European Union's environmental policy, there are three aspects about: conservation, protection and improvement of the quality of the environment, protection of population health and the correct and rational use of natural resources with their reuse.
Waste is a major problem, but EEE has an impact on the environment during all stages of their life cycles: production, use, end-of-life. The WEEE components recycling process is a very complex one, each stage having its own importance, timing and steps required for recycling need to be respected according to national and European rules.

Since 2003, when it was published the Directive 2002/96 /EC, EuropeanUnion managed WEEE by the principle of producer extended responsibility, ensuring that producers can fulfill their obligations either individually or collectively. After numerous changes during the voting process, the final text of the new Directive (2012/19 / EU) was published in the Official Journal of the European Union on July 24, 2012 and it has been transposed in Romania by the Government Emergency Ordinance no.5 / 2015, [1-2].
One of the main changes introduced by the new Directive concerns the redefinition of the collecting target for the Member States. Table 1 provides a planning of the evolution of WEEE collection targets at country level, based on the provisions of the new WEEE Directive. Romania, together with other countries, due to the lack of necessary infrastructure and the low level of EEE consumption, has the possibility of derogating from the initial deadlines.

Table 1: Planning of the evolution of WEEE collection targets at country level, [3]

Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Target initially set by the WEEE Directive	Minimum 4 kg. per capita or the average quantity expressed in kg per capita annually collected in the previous 3 years.				Minimum 45% of the quantity placed on the market (annual average of the previous 3 years)			65% of the quantity placed on the market (annual average of 3 previous years) or 85% of the amount of generated WEEE.		
Target for România	Minimum 4 kg. per capita or the average quantity expressed in kg per capita annually collected in the previous 3 years.				Minimum 40% of the quantity placed on the market (annual average of the previous 3 years)					65% of the quantity placed on the market (annual average of 3 previous years) or 85% of the amount of generated WEEE.

In Europe there were produced around 9 million tonnes of WEEE in 2005 and the estimated data show that by 2020, the quantity generated will exceed 12 million tonnes.
Romania held the European Union last place in electronic and electrical equipment waste collecting in 2016, with 1.6 kg per inhabitant, below the 8.9 kilograms European average, as it is shown in European Bureau for Statistics (Eurostat) published data.
Electronics recycling provides precious and special metals to be recovered, it reduces the environmental impact associated to the electronics manufacture from raw materials and it ensures that electronics hazardous substances are treated properly. The reused products must be accordingly and efficiently recycled at the end of their useful life.
Within the manufacturing process, there are a number of dangerous and toxic substances that are used for integrated circuits, capacitors, screens. For the manufacture of a computer there are required 22 kg of chemicals products, 1.5 tonnes of water and a significant amount of lead, cadmium and mercury; these substances can have adverse effects on human health and environmental factors, in general,
The WEEE recycling is an important subject from the point of view of the waste treatment and from the point of view of the valuable materials recovery, being divided into 3 major phases:

- the disassembly, that can be selective and manual,
- the improvement using mechanical, physical and / or metallurgical processes, in order to mend the content of unwanted materials.
- the refining - the recovered materials return to their life cycle.

The large number of Electric and Electronic Equipment and their waste variety complicate the treatment and the management of WEEE. Technological development and more new equipment constantly provide more services and encourage consumers to quickly replace their old devices.
As a result, the quantities of Electric and Electronic Equipment waste are increasing every year, around 20 to 50 million wastes are worldwide generated (non-ferrous and ferrous metals, inert-glass, wood,

concrete, plastics, dangerous parts-batteries, cathode-ray tubes, capacitors, liquid crystal displays, mercury switches). These wastes can pose major risks to human health and to the environment, [3].
Also, electric and electronic equipment are high energy users, requiring a considerable amount of electricity during their lifetime. Their improper usage can increase energy consumption. Every year, in the field of computers, it is consumed an amount of electricity as a 155 million inhabitants country consumes.
WEEE contains a number of useful materials: metals and non-metals, precious metals (gold, silver, platinum), plastics, other materials. By their recycling important raw materials and energy savings are made, their treatment being carried out in specialized and authorized centers. Recycling procedures that are not based on best practices waste precious metals and recyclable plastics, generating energy consumption and environmental damage as a result of the pure materials production. The benefits concern the environment, also, the WEEE ecological treatment brings significant social benefits by increasing the number of jobs in this treatment sector, [4-5].

2. About treatment, recovery, recycling and revaluation techniques

The electrical and electronic equipment waste recycling represents an important subject, considering the waste treatment point of view and also, considering the valuable materials recovery.
The major phases of WEEE are:
• the disassembly, that can be selective and manual;
• the improvement, by using mechanical, physical and /or metallurgical processes in order to improve
the content of undesirable materials;
• the refining - the recovered materials return to their life cycle.
Considering the electronic waste management for life, this one includes:
• The reuse of functional electronics;
• The rehabilitation and repair of electronics;
• The reuse and the recovery of electronic components;
• The processing for metal recovery
• The elimination.
Electronics recycling provides precious and special metals to be recovered, it reduces the environmental impact associated with the electronics manufacture from raw materials and it ensures that hazardous substances from electronics are properly treated. The reused products must be properly and efficiently recycled at the end of their useful life. According WEEE Directive, the systems available for the WEEE treatment must use the best techniques of treatment, recovery and recycling, but there is no reference document for the best techniques available for their treatment, recovery and recycling (according to the procedures in Directive 96/61/EC), [1].
To give an example for the treatment of small and large household appliances, the steps to follow are:

- Preparation of the devices for treatment - it consists in removing the external electrical cables and the elements with dangerous contents.
- Primary seeding - the primary grinder performs the devices fractionation, for easier manual sorting of the resulting materials and components.
- Manual sorting - there are sorted certain components to be treated on other lines (capacitors, coils and transformers, printed circuit boards) etc.
- Secondary milling - it has the role of bringing the fractions to smaller dimensions.
- Fraction separation
  a) magnetic separation: the ferrous metal fractions are separated from the obtained fractions;
  b) inductive separation: from the remaining fractions, the non-ferrous metal fractions (e.g. aluminium and copper) are separated from the non-metallic fractions (e.g. plastic, wood, rubber).

As a result of the complex treatment operations, different fractions with positive economic value are obtained, such as:
• ferrous and non-ferrous metals (aluminium, copper, brass)

• various types of plastic:
  - o ABS / PS mixes from small electronic refrigerators;
  - o PVC and PE from cables, monitor housings, TVs or printers;
  - o ABS and PP from washing machines.

• various electrical and electronic components (motors, transformers, compressors, coils).

These fractions are carefully sorted and traded, both at home and abroad, [4-5].
They are considered secondary raw materials and re-enter in the industrial circuit for the new products manufacture, saving a large amount of the natural resources. They can also be used as an alternative fuel (the wood from dismantling, the pelletized polyurethane foam).

2.1 Functional scheme of waste recycling line

The Eldan S1000 shredder recycling line (Figure 1) has the processing capacity about 4 tonnes / hour, function the type of processed material and it consists in modern equipment, as: a load conveyor belt (1), a S1000 chopper (2), a vibrating conveyor belt to eliminate waste, an electromagnet (an electromagnetic separation band) type 451-60 / 140-290-S0, which separates the iron particles from the material stream (4), a discharge conveyor belt (5), a load conveyor belt with magnetic cylinder (6), an Eddy separator (non-ferrous metal separator) 0428-25 / 90 (7), a conveyor belt (8), a reverse rotary distributor for supplying the multifunctional scraper with a controllable quantity of materials (9), a MPR120 multifunctional scraper (10), a service platform used during the operation and scraper's maintenance operations (11), a vibrating discharge conveyor (12), a magnetic strip for separating the ferrous fraction (13), a conveyor belt to load, with magnetic cylinder (14), an Eddy non-ferrous metal separator, type 0428-25 / 90 (15), a conveyor belt (16), a loading conveyor belt (17), a SMV silage 1m3 volume (18), a HG169 industrial granulator (19), a pneumatic transport system (20), a pneumatic transport system (21), a SMV silage 1m3 volume (22), a C22 separation table (23), a flexible helical conveyor (24), a PC12 sorter (25), a power supply unit for positions 1-7 and 28 (26), an electrical and control panel for positions 8-25 and 29 (27), JM 21 / 45-06 4TR T3 type air filter (28 - 30), JM 70 / 40-06 4TR T3 type air filter (31 - 33).
As it is seen the main equipment used in waste recycling line consist in:

- the S1000 chopper (2),
- the Eddy separator (non-ferrous metal separator) 0428-25 / 90 (7),
- the MPR120 multifunctional scraper (10),
- the Eddy non-ferrous metal separator, 0428-25 / 90 type (15),
- the HG169 industrial granulator (19) and
- the C22 separation table (23).

The conveyor belts are used to transport the material, to charge or to discharge it, also the transport pneumatic systems.
The C22 separation table (23) has the role to separate the metal fraction from the rest of the insulation materials.
The sorter (25) will effectively remove the fine copper and aluminium particles from the plastic fraction. It consists of two layers of griddles and a tray at the bottom.
The purpose of the silages (18 and 22) is to balance the flow from the granulator by the maximum feed rate of the separation table, thus ensuring the quality of the separation, [6].

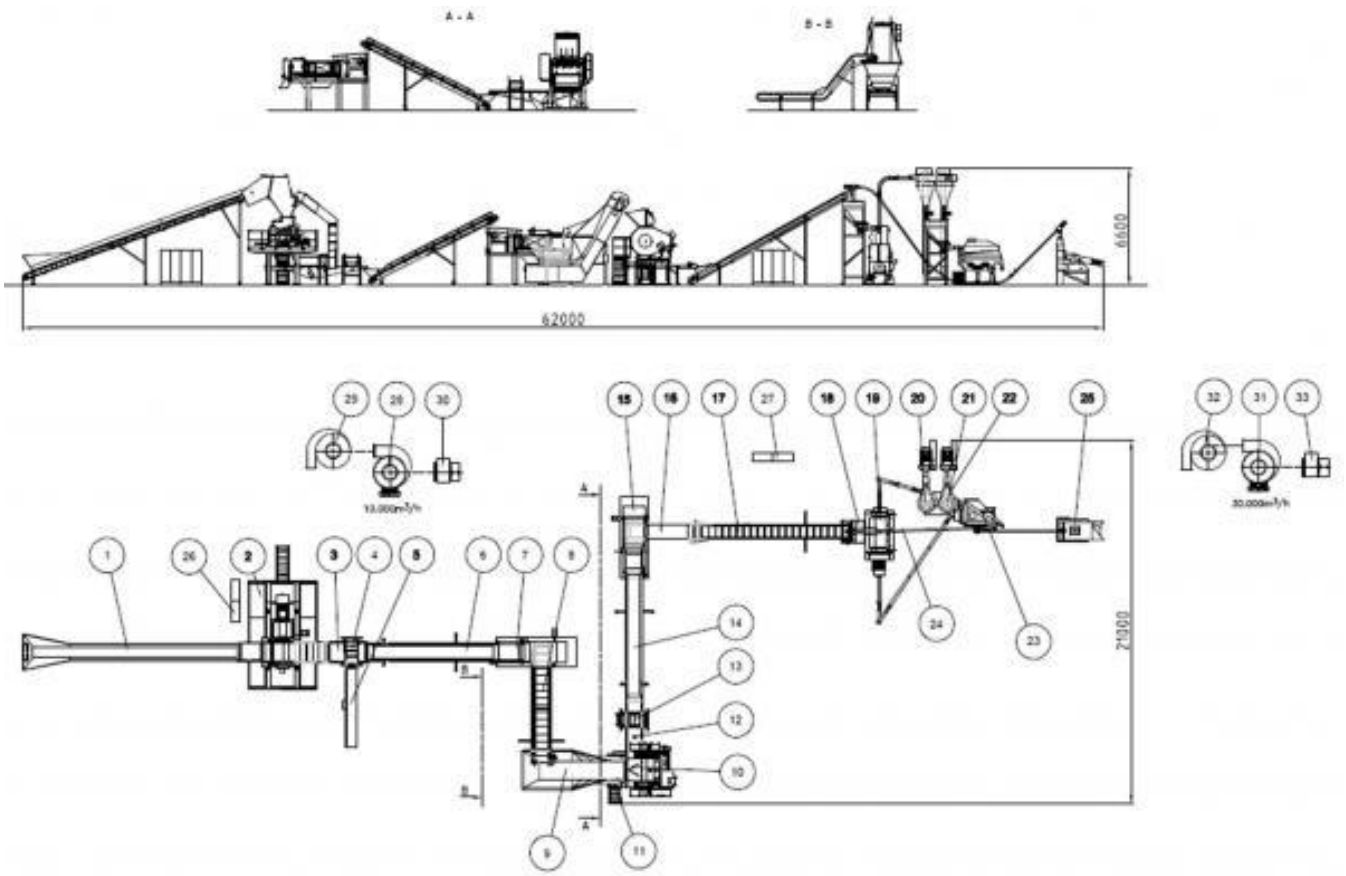

Fig. 1. Eldan Shredder S1000 WEEE Recycling Plant, [6]

2.2 Main components of the waste recycling line

The main components involved in waste recycling line and their utility are presented in next descriptions.

The S1000 shredder (Figure 2) is the first line equipment and it performs the main operation – the WEEE material size reduction. Components are reduced to a size that allows most ferrous materials to be separated from non-ferrous or plastic fractions. After reducing the dimensions by cutting with a chopper, the resulting mixture is transported under a magnetic strip, achieving separation of the metal fraction from the rest of the contents, [6].

For the separation of non-ferrous metals, Eldan firm incorporated two Eddy separators (ECS) (Figure 3) at different points in the line. The first equipment is responsible for separating the non-metalliferous fraction from the rest of the heavy mixture. After reducing the mixture size in the multifunctional scraper, the second Eddy separator separates the non-metalliferous fraction from the rest of the light mixture, [6].

The MPR120 multifunctional scraper (Figure 4) is responsible for the second step of WEEE material shredding. It is an effective medium-speed granulation device, a dual processing unit, specially designed for WEEE recycling. The multifunctional scraper ensures the individual reduction of the material size up to about 12 mm. The material is passed under another magnetic strip where the metal component is again separated. The second Eddy separator ensures the separation of the medium size non-ferrous fraction from the remaining organic fraction, [6].

The HG169 industrial granulator (Figure 5) is responsible for the last step of material dimensions reduction. The device is a high speed granulator, with a single axis, capable of reducing the material size with values between 6 mm to 10 mm, depending on the material type. After processing in the industrial granulator, the material is passed into separation table for the final separation process, [6].

The C22 separation table (Figure 6) is used in the separation process of the final mixture into an organic (plastic) fraction and a complex metalliferous fraction. The exit of the separation table includes four fractions, [6]:

Powders	- eliminated through the suction system
Metallic fraction	- Is present at the top of the collection area. - At this point, the metallic fraction purity is almost 100%
Plastic fraction	- is eliminated through the bottom of the collection area
Mixing fraction	- is present in the middle part of the collection area. This fraction is sent back in the separation process.

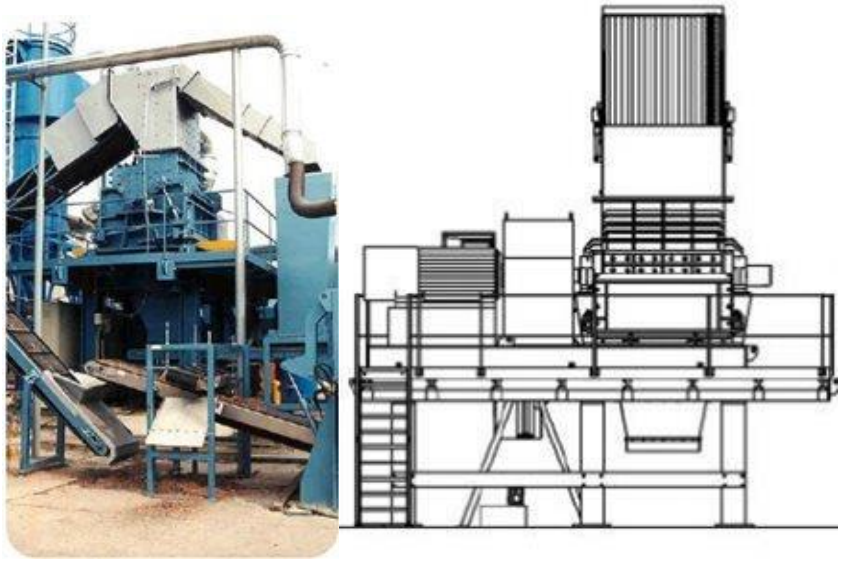

Fig. 2. Shredder S1000, [5]

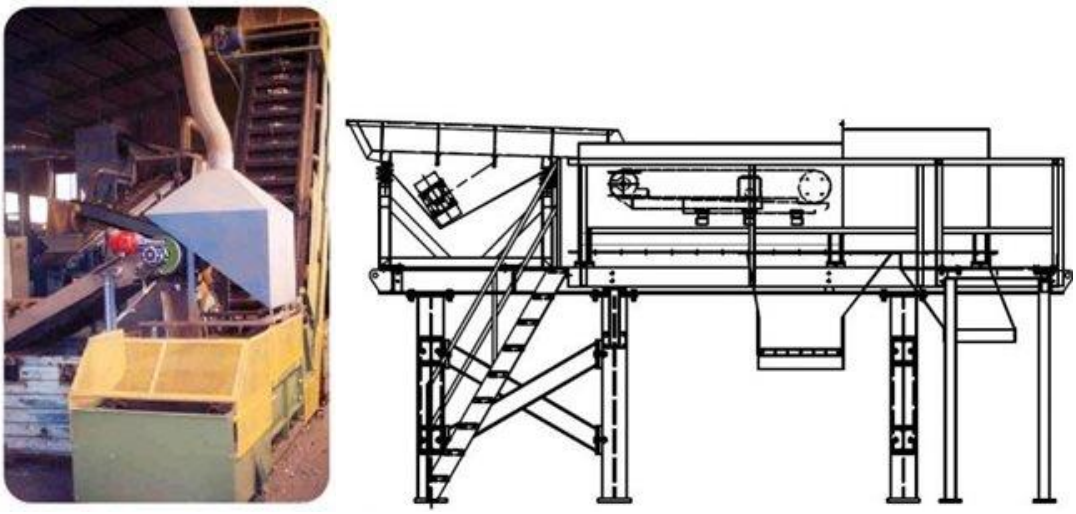

Fig. 3. Eddy Separator, [5]

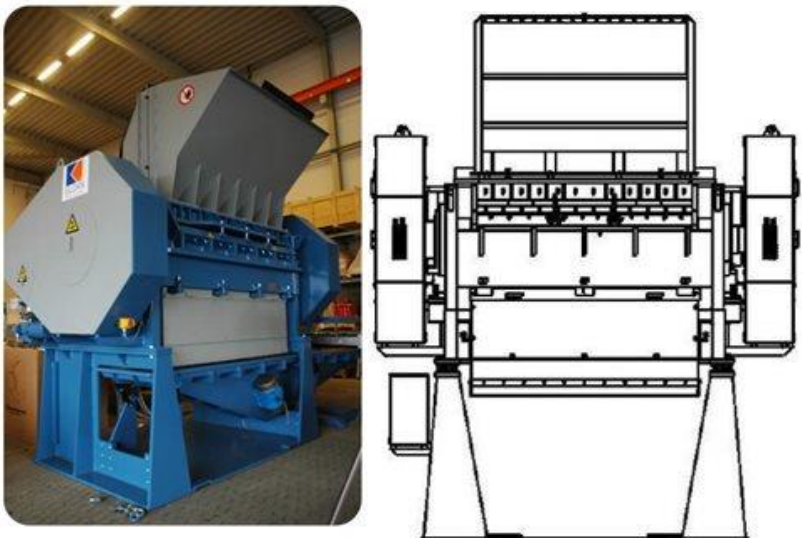

Fig. 4. MPR120 Multifunctional scraper, [5]

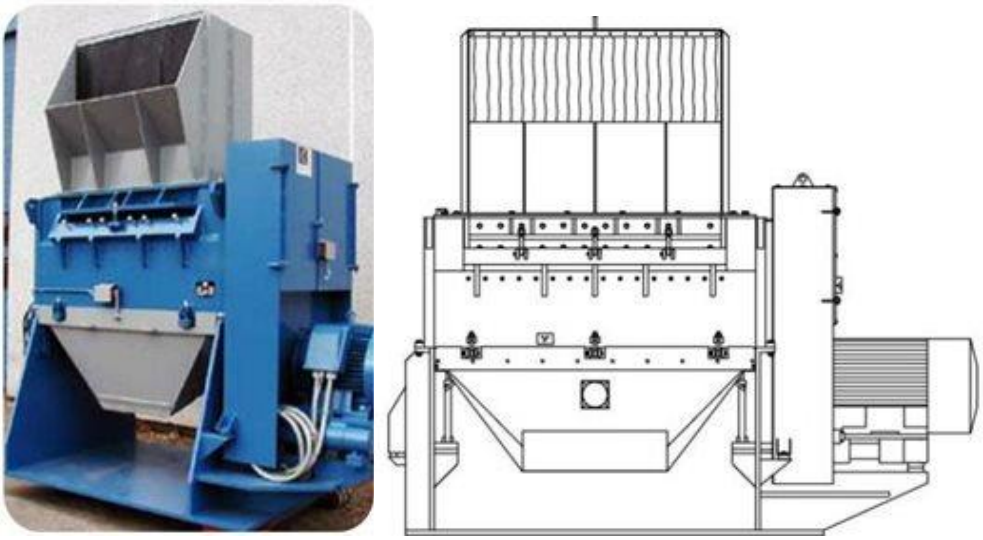

Fig. 5. HG169 Industrial granulator, [5]

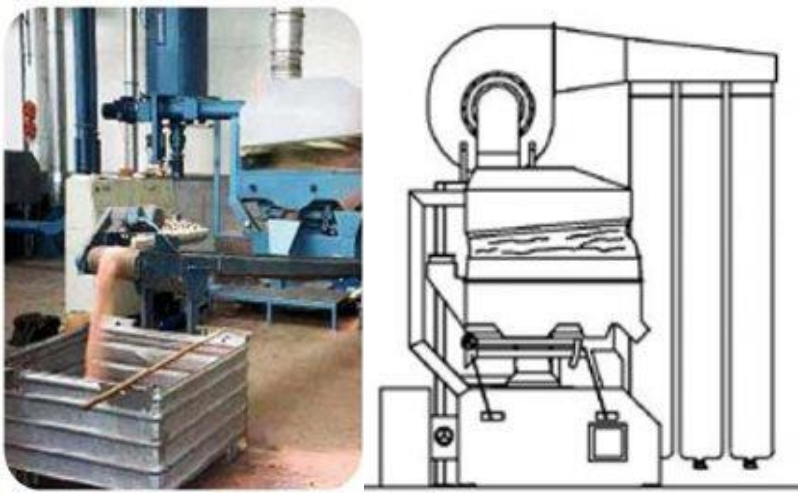

Fig. 6. C22 Separation table, [5]

3. Management of time and human resources for WEEE recycling line monitoring

The WEEE components recycling process is a very complex one, each stage has its own importance, that is why all times and steps required for recycling need to be respected, according national and European standards.

The first step of Eldan recycling line is to reduce the WEEE materials size on the S1000 chopper; this operation takes about 2 hours and it needs to be supervised by a qualified person, who knows very well the process and the machine.

The second step is equally important and it involves the non-metalliferous fraction separation from the rest of the heavy mixture, on the Eddy separator; this operation lasts 1 hour and it is also performed by a specialized person.

After this step, the second shredding of the WEEE material is made on the MPR120 multifunctional scraper; this operation leads to obtaining a finer and easier to process WEEE material. The action takes approximately 2 hours and it is performed by another qualified worker.

The fourth stage is very similar to the second stage, as the third one was similar to the first one. It aims a more detailed sorting of the WEEE material, by passing onto the magnetic stripe and separating the medium size non-ferrous fraction from the organic fraction, that remained on the second Eddy separator, all operation lasts 1 hour.

The fifth operation works to reduce the dimensions of the materials to be processed on the HG169 industrial granulator; this stage lasts 2 hours and it is performed by trained personnel.

The last step is the most detailed one because it involves the separation of the final mixture into organic fraction and complex metalliferous fraction, on C22 separation table, this action is lasting 2 hours.

It is very important that every step is supervised by qualified personnel, who respect the process and equipment specifications.

The Gantt chart for the WEEE recycling line is presented in Figure 7, where there are figured the duration of components size reducing and separation process and the operation persons in charge for each activity.

Gantt chart for the WEEE recycling line

No.	Activity	Time in (hour)	Time out (hour)	Duration	Operation person in charge	Timings 8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00
1	Reducing the size of WEEE materials on the S1000 chopper	8:00	10:00	2:00	Qualified Worker Workstation 1											
2	Separating the non-metalliferous fraction from the rest of the heavy mixture on the Eddy separator	10:00	11:00	1:00	Qualified Worker Workstation 2											
3	The second step of the WEEE material grind on the MPR120 multifunctional scraper	11:00	13:00	2:00	Qualified Worker Workstation 3											
4	The material displacement on a magnetic strip, with the separation of the medium size non-ferrous fraction from the organic fraction remaining on the Eddy separator 2	13:00	14:00	1:00	Qualified Worker Workstation 4											
5	Reduction of the dimensions of the processing materials on the HG169 industrial granulator	14:00	16:00	2:00	Qualified Worker Workstation 5											
6	Separation of the final mixture into organic fraction and complex metalliferous fraction on C22 separation table	16:00	18:00	2:00	Qualified Worker Workstation 6											
	Total hours			**10:00**												

Fig. 7. The Gantt chart for the WEEE recycling line

4. Conclusions

Electronics recycling provides precious and special metals to be recovered, it reduces the environmental impact associated with the electronics manufacture from raw materials and it ensures that electronics hazardous substances are properly treated.
The recycling using the Eldan lines complies with the elements mentioned in the WEEE Directives of European Union. The existence of standard recycling facilities, as those presented in the paper, represents the starting point in factories adjustment, to meet the customers' specific requirements.
To solve the desired recycling problem represents a possibility by a modular approach flexibility, which means that a number of combinations can be obtained, with variations from a single machine to complete systems. The WEEE Eldan recycling plants and lines are designed for automatic processing, with specialized personnel for supervision. They can be easily adjusted to reduce the material size, depending on its type and in accordance with the market requirements.
High performance, low processing and maintenance costs, low energy consumption, minimal metal losses and the appropriate mechanical technique for reducing and separating components recommend these equipment type for successful WEEE recycling, with a modern and flexible technology.

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