

Implementation of a Preventive Maintenance System in a Recycling Plant

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To my parents, sister e dear aunt Nela

Summary

BA Glass is the largest producer in Portugal of glass containers for food and beverages and one of the five largest players in this sector. Founded in 1912, the company expanded to 7 different countries and is now able to produce more than 8 billion bottles per year.

Because competitiveness in the glass industry has been increasing, no defects and producing large scale at a low cost is a requirement. Thus, the carrying out of preventive maintenance is essential and decisive.

This thesis was developed in a Curricular Internship at BA Glass's Recycling Plant, regarding the conclusion of the master's in mechanical engineering of Faculdade de Engenharia da Universidade do Porto, and its objective was precisely to implement a preventive maintenance system in that plant.

Firstly, the study of the production process and of the equipment manuals was made by doing a daily follow-up of the operation in the factory. This study was done to collect the necessary information to proceed to the preparation of the complete maintenance plans for all equipment, with complete data on procedures and periodicity.

With the definition of this maintenance plan fully established according to the requirements of the machines and the maintenance supervisor, all this information was digitalized in the information system SAP, namely the creation of the locations of the plant, equipment, sub equipment, bill of materials and work orders.

In order to maintain the maintenance policy, a reorganization of the spare parts warehouse was also carried out. Through the collection of all the equipment that existed there, a study was made of the best organisation according to demand and typology.

At the end of this dissertation BA Glass was left with a fully functional and operative preventive maintenance plan, which will increase the reliability, profitability and competitiveness in the market, through the decreasing of equipment downtime and number of interruptions of critical operations.

Also, after the warehouse has been organised, the company is equipped not only with valuable information about its assets, but also a support for maintenance management, since now it is possible to easily and quickly find the necessary repairable parts and components for maintenance and replacements.

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To all my friends, I express my deep and sincere thanks for their genuine friendship and for having the ability to make me relax and enjoy every moment of the academic journey and life in general.

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Abbreviations

BBIG – BA Glass’ Cullet Treatment Plant

BOM – Bill of Material

ERP – Enterprise Resource Planning

FMEA – Failure Modes and Effects Analysis

FMECA – Failure Modes, Effects, and Criticality Analysis

FR – Failure Rate

KPI – Key Performance Indicators

MWT – Mean waiting time

MTBF – Mean time between failures

MTTR – Mean time to repair

OEE – Overall Equipment Efficiency

PM – Preventive Maintenance

QM – Quality Maintenance

RCM – Reliability Centered Maintenance

SAP – Systems Applications and Products in Data Processing

TPM – Total Production Maintenance

5S – Sort, Set in Order, Shine, Standardize, Sustain

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1 Introduction

The present thesis was carried out within the scope of the 5th year course unit Dissertation, from the 2nd semester of the master's degree in Mechanical Engineering at Faculdade de Engenharia da Universidade do Porto. This project was developed over a period of 18 weeks in a corporate context at BA Glass focusing on the topic "Implementation of a Preventive Maintenance System in a Recycling Plant".

This chapter describes the context in which the thesis is structured. It aims to provide a framework about the company in question, the project to be developed and, finally, aims to expose the structure adopted for the dissertation.

1.1 The company

BA glass is the biggest glass packaging operator in Portugal, and it is one of the five most important European players in this sector.

This company was implemented in 1912 by Raul da Silva Barbosa and Domingos de Almeida and it consisted of the commercialization of bottles from Germany. The industrial activity by itself started in 1930 in Campanhã with semi-automatic technology. Over the years there was an investment in technology, allowing an improvement in productivity.

In the late '60s, the firm relocated to Avintes (Vila Nova de Gaia), which allowed a big development in the company, becoming the Portuguese leader in manufacturing glass packaging. Herewith, BA Glass acquired a new plant in Marinha Grande (CIVE - Companhia Industrial Vidreira, SA). From 1998 onwards, the firm acquired more factories in several European countries, becoming increasingly more successful in the glass industry, producing over 9 billion bottles and jars in 2020. Currently, BA Glass is present in seven countries, making a total of 12 factories: Portugal (Avintes, Marinha Grande, Venda Nova), Spain (Léon and Vila Franca de Los Barros), Germany (Gardelegen), Poland (Jedlice and Sieraków), Romania (Bucharest), Bulgaria (Sofia and Plovdiv) and Greece (Athens).

In 2020 BA Glass won the award of "The Most Sustainable Company in the Glass Industry" by World Finance, because of its excellence, innovation, and leadership in social and environmental commitments. The glass industry is among the most energy-intensive industries (U.S. Energy Information Administration, 2013) and the usage of renewable energy, reduction of gas, water usage, and CO₂ emissions allowed this recognition.



Figure 1 – BA Glass Key Indicators (BA Glass, 2020)

In order to meet the expectations set by customers and society in general, the group's factories are highly technological and specialized, including strict control of the quality of the final product.

1.1.1 The Department

One of the main differentiating features of BA Glass is the cullet treatment plant, also known as BBIG, because it allows the company to control the quality of the glass that arrives at the main factory.

Glass is a non-crystalline solid formed by the rapid cooling of a mixture of non-metallic oxides, mainly of vitrifiers, fluxing agents stabilisers, thinners and colourants.

A vitrifier is a "net-former" and is present in a percentage of 71 to 75%. Melters exist for the purpose of removing impurities in oxides and prevent oxidation of the base materials. They are present in a percentage of 11 to 14%. Stabilisers, as the name suggests, modify and stabilise the molecular network of the glass and are present in a percentage of 10 to 13%. For fine-tuning control of the colour of the glass, there are the remaining components, such as the thinners, colorants or bleaches.

The use of cullet as a raw material reduces melting losses and the energy consumed in the furnace. For this reason, BA has developed a company, now independent, specialized in the treatment of cullet, BBIG. This company collects glass from recycling bins or other sources, brought in from outside to the factory.

BBIG can produce about 35 tons of glass per hour. All these raw materials are fed, controlled, and stored in silos. They are then dosed, according to recipes defined by the different colours of glass, to the melting furnaces. The colours that glass can be produced are various, the most frequent being amber, white, emerald green, ultra-violet green, dark green, georgian green, black and light blue or bluish white.

There are 2 cullet treatment factories in the group, one located in Avintes and the other one located in Villafranca de Los Barros.

The factory in Avintes is organized in 3 lines. The Main Line has as its final product white cullet or coloured cullet, the Fine Line, in turn, provides glass of smaller dimensions, as the name says, and, finally, the Rejection Line was created to make use of some cullet that was

headed for the waste. The equipment of each line is connected to each other, so the degree of importance given to each machine is the same.

1.2 Project Framework and Purpose

As competition in the market grows, an urgent need to pursue new ways of differentiation to gain a better competitive position rises. Success in any competitive context depends on offering superior customer value or operating with lower costs or, ideally, both (Porter 1985).

The competitive advantages occur when a firm uses its resources and capabilities to develop organizational competencies that, in turn, create value for customers. Some of the most used changes in the internal environment of a company are robots, FMS- flexible manufacturing systems and automatic warehousing (Yamashina 1995). But these changes involve a lot of capital invested.

Therefore, the importance of the maintenance has been greater than before, due to its role in maintaining and improving availability, performance efficiency, quality products, on-time deliveries, the environment, safety requirements and overall plant productivity at high levels (Al-Najjar 1997).

A preventive maintenance system plays an important role in a factory because it keeps the equipment working efficiently, protects the employees, and allows the shortage of downtimes reserved for repairs. Adding to these advantages, this type of maintenance also allows a company to improve the quality of its product, keeping a good relationship with the customer. It is generally accepted that corrective maintenance costs three or four times more than preventive maintenance.

In the case of BA glass, BBIG expanded its production without giving due importance to preventive maintenance. The maintenance performed is based on corrective or 1st-degree maintenance, where all knowledge is centered on the team leader.

By generating a maintenance plan, this work aims to reduce the number of equipment breakdowns and consequently lower the costs of downtime and repairs. The creation of this documentation and its implementation in the management tool SAP will also allow for a decentralization of factory maintenance knowledge (more than one person is going to have access to this information).

1.3 Project Goals

The present project aims to achieve the following goals:

- Study the failure rate behaviour of the various equipment;
- Know in detail the machines that make up the BBIG plant;
- Plan the maintenance of all equipment and set performance dates;
- Scheduling a well-organized preventive maintenance plan in SAP;
- Register in SAP the information about the main consumables of each machine;
- Reduce unscheduled downtime and maintenance overhead.

1.4 Method Followed in the Project

In order to fulfil the present project of the implementation of preventive maintenance in the cullet treatment plant at BA Glass, there is the need to follow several methods.

In an initial phase, the method used consisted of an exploratory approach, whose focus was based on the exploration of all the equipment constituent of the station and respective locations, complemented with the reading of the respective technical manuals of each existing equipment.

In order to support this exploratory method, field visits were carried out daily, which made the understanding of the recycling process easier. During these visits, informal interviews were conducted with the operators and the maintenance manager whose practical experience could provide strong input prior to the preparation of the maintenance plans.

In addition, a documental analysis of the reports of each shift in 2021 was produced, in order to estimate the Mean Time Between Failures of each equipment and the availability of the cullet treatment plant between January 2021 and December 2021.

In a next step, the method of coding the plant equipment, locations, all consumables and all reserve equipment into the SAP information system.

Finally, the warehouse organisation method, which was based on collecting all the pieces and then reallocating them according to certain criteria.

1.5 Thesis disposition

Chapter one starts with an overview of the company, including the department that welcomed this project, and additionally introduces the purpose and conditions in which this dissertation is developed.

Chapter two reviews and summarises the literature to establish a frame for the present project. This chapter is important to give the reader a theoretical base to aid understanding of the next chapters.

Chapter three presents the factory's problem relating to the productive process of the glass recycling plant.

Chapter four explains the methodology and research methods used to find a solution for the main problem.

At last, chapter five presents the empirical results of the research and discusses the conclusions. Furthermore, presents future work to constantly improve the maintenance of the factory.

2 Foundation and Theoretical Background

This chapter covers fundamental concepts that formed the basis of the work developed in this dissertation, essentially highlighting the theoretical concepts related to maintenance variants.

This chapter contributed throughout the work carried out because it helped to understand and link theory to the case study. This is subdivided into two parts developing the following themes: Maintenance and Failures.

2.1 Maintenance

With the globalisation of the economy, and in search of improving total quality in services, products and environment, nowadays maintenance became a goal and it is recognized as one of the most important areas of industrial activity. (Nina, 2016) (Moro & Auras, 2007)

According to the European Standard EN 13306:2010, maintenance is a

“combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function.” (The British Standards Institution, 2013)

By assuring these conditions at a minimum global cost, it is possible to affirm that a good maintenance exists.

The maintenance always must start at the design stage and take part in the start-up of equipment or plant. After this, the functions of maintenance are surveillance, development of corrective or preventive actions. This must be done with constant monitoring, data collection and processing.

Nowadays, it is very common to have maintenance bordered by all sectors of a company, because it is a necessarily integrated activity.

Maintenance is a risk control activity

One of maintenance's major roles is to maintain quality, providing reliable equipment and reducing its process variation. Therefore, maintenance's priority should be maintaining the quality of the elements involved in production, instead of just jumping from one repair to another (Al-Najjar, 2007).

2.1.1 A Brief History of Maintenance

Repair operations on objects and tools, which have been going on since the earliest civilisations, were among the first forms of maintenance. But officially, the first records of maintenance date back to the era of the Vikings, as they needed to keep their ships operational.

Later, from the 16th to the 19th century, with the arrival of steam engines, industrial revolution and production lines, maintenance immersed itself in industry, since it was necessary to guarantee continuity in work. And, at this point, it had gone from being seen as an "unimportant task" to being understood as a differentiation strategy for companies (Wang, 2008).

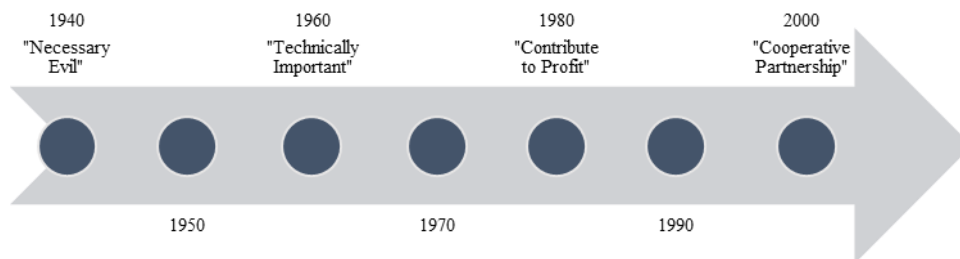


Figure 2 - Evolution of the terminology of Maintenance

Over the years and with the technological progress of industry, the equipment has also undergone many changes: from increased automation, to rising costs, to the elimination of machine problems. And for this very reason, maintenance has also had to keep up with this evolution, involving mechanical, electronic, hydraulic electromechanical and software tasks. (Alsyouf, 2009)

The evolution of maintenance went through four generations:

1st Generation (...-1950) - The first generation corresponds to the period that began in the industrial era and ended in the Second World War, where the industry was not highly mechanized and relied on simple and oversized equipment. Thus, maintenance actions were considered of low importance and focused on repairs after breakdowns, so there was no justification for systematized maintenance, mainly corrective, unplanned maintenance.

2nd Generation (1950-1980) - After the Second World War, this generation was marked by the increase in mechanization and complexity of the industry. The post-war increase in demand for goods and the fewer human resources meant that industry became more mechanized and complex. These obstacles led to the emergence of maintenance focused on the prevention of breakdowns, with preventive maintenance at fixed time intervals and systems to plan and control it. However, due to the rising cost of capital at the time, the life cycle of assets was maximized and, consequently, there was an increase in maintenance planning and control systems planning.

3rd Generation (1980-2000) - The third generation of maintenance emerged in the mid-80s and was characterized by a significant increase in equipment availability and reliability, and an improvement in the cost-benefit ratio of maintenance. This generation was also marked by the appearance of methodologies such as the "Just in time" (JIT) system, as well as customers' demand for higher quality standards. Nevertheless, in this period, maintenance management methodologies were developed, such as RCM (Reliability Centered Maintenance) and TPM (Total Productive Maintenance), which have ensured sophisticated reliability analysis and predictive technologies.

4th Generation (2000-...) - This phase starts in the year 2000 and aims to reduce organizations' costs by increasing the reliability of equipment. Predictive maintenance techniques are used effectively and there is great interest from everyone in the company, so

that equipment has greater reliability and availability. In this generation, maintenance has the challenge of minimizing premature failures.

2.1.2 Objectives and Function of Maintenance

With maintenance, the aim is to carry out lubrication, equipment observation, improvement, and repair operations, thus enabling the state of the equipment to be preserved and production quality to be maintained. Good maintenance is understood as carrying out all these operations at minimum global cost. In operational terms, maintenance is aimed at achieving:

- Good operation of the equipment or plant;
- Safety of people and goods;
- Preservation of the environment;
- High levels of quality;
- The best cost for the product or service.

According to the Portuguese standard NP EN 3306:2007, maintenance is the grouping of all management and administrative techniques during the life cycle of an asset, aimed at restoring or maintaining the equipment in question in a functional state. Currently, for a company to be successful, it is important to have a good intervention of maintenance (Didelet & Sena, 2016). The objectives of maintenance are defined as:

- **Cost** - The solutions sought by maintenance should minimize the overall costs of the product.
- **Quality** - Maintenance aims to achieve a good performance of the machines, with a reduced production defect and a good treatment of the environment.
- **Safety** - Maintenance seeks that the safety of equipment and people must be an omnipresent and non-negotiable reference.
- **Availability** - Maintenance ensures that equipment is operational for as long as possible.

Therefore, the objective of maintenance is not only to keep machinery and equipment in good condition. It consists in preventing failures and breakdowns, increasing the reliability and availability of the production system, thus maximizing production. Maintenance is also carried out to improve quality and increase productivity, enhancing capacity and achieving a decent output, reducing the spare part's inventory, and mitigating operating costs (Rotab Khan & Darrab, 2010).

Although it is very complex to jointly optimize all the factors mentioned above, maintenance should be responsible for achieving the best values depending on the objectives of each company.

2.1.3 Types of Maintenance

Conventionally, there can be two main strategies for maintenance activities. One is reactive maintenance, which focuses on repairing equipment after breakdowns. The other is proactive maintenance, which aims to reduce the likelihood of equipment failure. (Finch e Gilbert,

1986; Cordero, 1989; Hsu, 1991; Sheu e Krajewski, 1994; Loësten, 1999; Khazraei & Deuse, 2011)

The reactive maintenance can be planned corrective or non-planned corrective. The proactive maintenance can be predictive or preventive. In the next figure it is possible to observe the several types of existing maintenance.

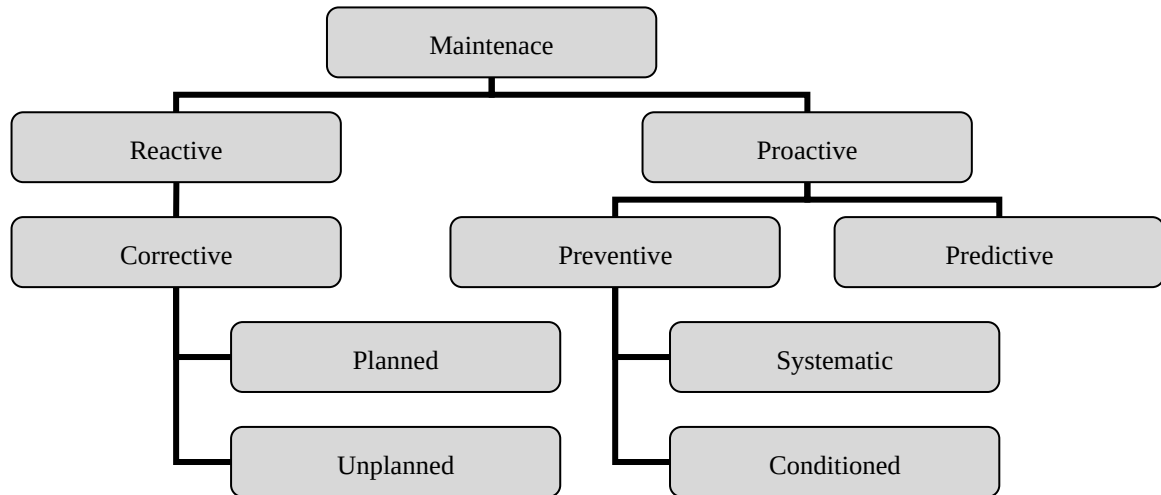


Figure 3 – Types of Maintenance

Corrective Maintenance is conducted after the occurrence of a breakdown and is intended to put an item performing its required function. Although simple, this type of maintenance may require excessive costs (about 3 times higher than repairs done within a preventive mode) because of the machine downtime, spare parts inventory, and low production availability (ALMEIDA, 2000).

This type of maintenance task can be planned or unplanned:

The unplanned one occurs after a normally working equipment fails. In this case, there isn't any maintenance planning, because there wasn't any warning before the malfunction.

The planned one is used to improve the performance, safety, and maintainability of the equipment, to correct design errors and to adapt the equipment to new functions (Faria, 2013; Pinto, 2013).

Predictive Maintenance, according to the European standard EN 13306:2010, is based on the condition of the equipment, being carried out according to the prediction obtained by repetitive analysis of the operating parameters. Sometimes this type of maintenance can be confused with preventive maintenance, but the substantial difference is that predictive maintenance goes beyond the simple monitoring of the parameters, it makes use of the data to predict the future state of the equipment and calculate the time before a failure.

Some of the widely used technologies of predictive maintenance are: mechanical vibration analysis, ultrasound testing, analysis of lubricating oils and thermography.

Preventive Maintenance is the regular and routine maintenance, in which tasks are performed in predetermined intervals, according to prescribed criteria. The aim is to reduce the probability of failure or degradation of an equipment (Lafrai, 2001). This type of maintenance is divided in two models:

- Systematic Preventive Maintenance – Consists of carrying out maintenance operations at constant and predetermined time intervals. To determine the optimal timing of each maintenance operation, this type of philosophy studies the reliability of the equipment

components, analyzes the probability of occurrence of breakdowns (as function of use and wear), and studies the equipment's failure records (Pinto, 2013).

Some of the main advantages are: the prevention of breakdown, increase of the availability of the equipment, better organization of maintenance resources (reducing the associated costs), reduction of production loss and decrease in risk of accidents (Pinto, 2013);

- Conditioned Preventive Maintenance – This is a technique that predicts malfunctions by monitoring the operation of equipment and trend analysis. The interventions are carried out when the parameters are close to the predefined alarm levels (Pinto, 2013).

Some of the main advantages are: reduction of costs associated with breakdowns, an increase in quality, productivity and reduction of interventions (Pinto, 2013).

Table 1 - Corrective Maintenance vs. Preventive Maintenance (adapted from Safety Culture)

	<i>Corrective Maintenance</i>	<i>Preventive Maintenance</i>
<i>Main Purpose</i>	For restoring machine operability	For continuous system operation
<i>Nature of Task</i>	Unplanned or Unscheduled	Planned and Scheduled
<i>Frequency</i>	Every time equipment breaks down	Regularly conducted at a set time
<i>General Protocol</i>	Implement repairs: part replacement, reassembly, adjustment, and testing	Perform inspections: impending failure detection and prevention

2.1.4 Maintenance Management Models

The importance given to good maintenance management has grown since the 1950s. With the increase of the systems complexity, the strategies also needed to evolve, so they could lead to the increase of the equipment availability and to the continuous improvement, always guaranteeing minimum costs.

To satisfy these growing requirements some maintenance strategies, which differ in method, have naturally arisen, such as TPM (Total Productive Maintenance) and RCM (Reliability Centered Maintenance). These are not mutually exclusive, although both are integrated management methodologies.

RCM is a more operational technique for the reliable analysis of equipment and systems. TPM is a philosophy of service management within the organization, although it also addresses the study of equipment and its efficiency.

2.1.5 Total Productive Maintenance - TPM

TPM is a maintenance system based on the 5S and defined by Nakajima (Chan, 2005) in Japan in the 70s, which covers the entire life of equipment at all stages, including planning, manufacturing and maintenance. It describes a synergistic relationship between all organizational functions, more particularly between production and maintenance, for continuous improvement of product quality, operational efficiency, safety and guarantee of productive capacity (Chan & Kong, 2005).

To support this strategy, it is necessary to implement daily maintenance, time-based maintenance, predictive maintenance, an improvement to increase life expectancy, a spare parts control, failure analysis and recurrence prevention and lubrication control (Silva & Ferreira, 2019).

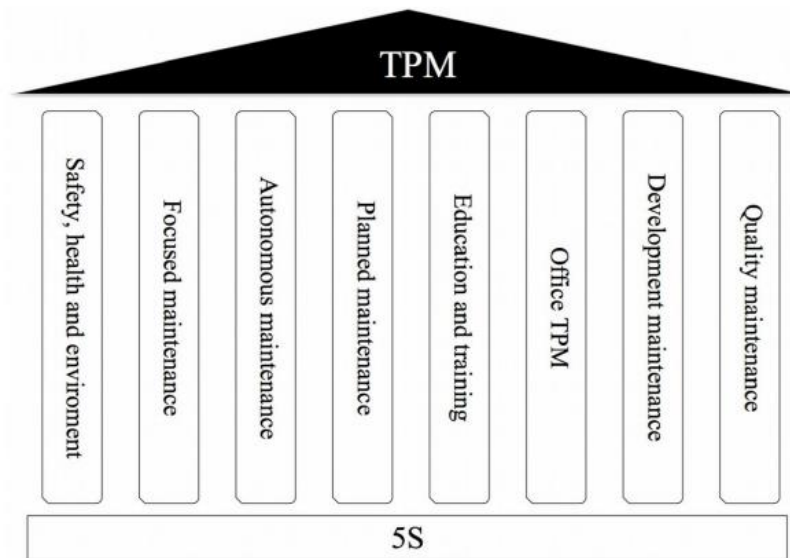


Figure 4 – The Eight Pillars of TPM (Pacaiova & Izarlkova, 2019)

Fundamental to TPM, 5S is a system of organizing workplace to achieve stable performance, involving with the employees (Singh, 2017). The five main topics are (Harun Habidin & Latip, 2019):

- **Sort** – remove the unnecessary items from the workplace and clean up the work area;
- **Set in Order** – determine the location and quantity of needed items;
- **Shine** – clean and improve the workplace, identifying irregularities;
- **Standardize** – use standard tools and procedures to standardize documents and the work method;
- **Sustain** – maintain improvement, enabling employees to develop good work habits.

Table 2 – TPM's Pillars

<i>Pillar</i>	<i>Explanation</i>
Safety, Health, and Environment	This pillar is based on the creation of a safe and appropriate workplace and a surrounding area that is not damaged by the processes carried out. Nevertheless, this pillar aims to achieve zero accidents, zero health-related harm and zero fires.
Focused Maintenance	Focus maintenance underlines kaizen projects to identify and eliminate the major losses (Shinde & Prasad, 2017).
Autonomous Maintenance	Operators should take responsibility for maintenance tasks, and this will relieve the burden on skilled maintenance technicians. This way, they can concentrate on more value-added activities and technical repairs. The activities involved are of a simple nature, such as cleaning, lubrication, visual inspection and tightening of screws.

Planned Maintenance	Planned Maintenance is a proactive approach that uses a trained maintenance team to maintain their equipment. In this way, this pillar focuses on maintaining machine availability, improving reliability and maintainability, achieving zero equipment failure and ensuring the availability of spare parts at all times.
Education and Training	To reduce defects, training and education should focus on information about the technology, quality control and interpersonal skills. Thus, this pillar is central and is supported by the execution of a periodic skills assessment and by an alignment of the operators with the organizational goals.
Office TPM	Office TPM addresses nine major losses which are: processing losses, cost losses (which includes areas such as purchasing, accounts, marketing), communication losses, idle losses, configuration losses, accuracy losses, office equipment interruption, communication channel interruption, lines and telephone and fax time spent retrieving information.
Development Maintenance	Development maintenance applies the knowledge and experience gained from maintaining existing equipment to the design of new equipment (Adesta, 2018). It helps to reduce the time it takes to receive, install, and set up newly purchased equipment (Kumar, Singh & Khan, 2016).
Quality Maintenance	Through the focus on improvement, defects are eliminated from the process after identifying the machine parameter by which product quality is affected. Kharub and Sharma (2015) consider strategic quality planning, supplier quality, process monitoring and control and strategic QM as key activities to implement QM.

2.1.6 Reliability Centered Maintenance - RCM

According to Moubray, Reliability Centered Maintenance is a process used to determine what must be done to ensure that any physical asset continues to do what its users want it to do in its present operating context.

The aim is therefore to optimize the cost/effectiveness of maintenance in order to lead to high levels of safety and simultaneously to adequate availability of equipment. The analysis seeks to answer the following questions: (SAE JA1011, 1998)

1. What is the system supposed to do and its associated performance standards?
2. In what ways can it fail to provide the required functions?
3. What are the events that cause each failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What systematic task can be performed proactively to prevent, or to diminish to a satisfactory degree, the consequence of the failure?
7. What must be done if a suitable preventive task cannot be found?

2.1.7 Key Performance Indicators - KPIs

Increasingly dynamic and competitive markets result in a high complexity of production. Despite these challenges, a production system needs to perform well in all aspects and circumstances. To ensure this, the performance needs to be measured correctly (Dornfeld, 2017).

Nevertheless, a system can be measured and characterized by analyzing a set of indicators. The usual indicators are called key performance indicators (KPI's), which are defined by Eckerson (2006) as *"a metric that measures how well an organization or an individual performs an operational, tactical or strategic activity that is critical to the current and future success of the organization"* (Umeda, 2015). Performance indicators should be integrated to provide an overview of the company's specific goals, business strategies and objectives.

KPIs are important measures not only in manufacturing operations, but also during the development of the product and of the manufacturing system, where the future performance of the operational process is defined (Wiktorsson & Turunen, 2018).

According to the NP EN 15341 Standard, maintenance performance can be measured with a system of indicators, under the influence of economic, technical, and organizational factors, so that they can be used to improve efficiency and effectiveness in order to achieve excellence in the maintenance of fixed assets. These indicators, according to the standard, should be used to (Sequeira, Didelet, & Sena, 2019):

- Measure status;
- Establish comparisons (internal and external Benchmarking);
- Diagnose (analysis of strengths and weaknesses);
- Identify/Define objectives and goals to be achieved;
- Plan actions and improvement;
- Monitor the results of changes over time.

To measure the maintenance performance is used the Overall Equipment Efficiency (OEE),

$$OEE = Quality * Efficiency * Availability * 100 [\%] \quad (1)$$

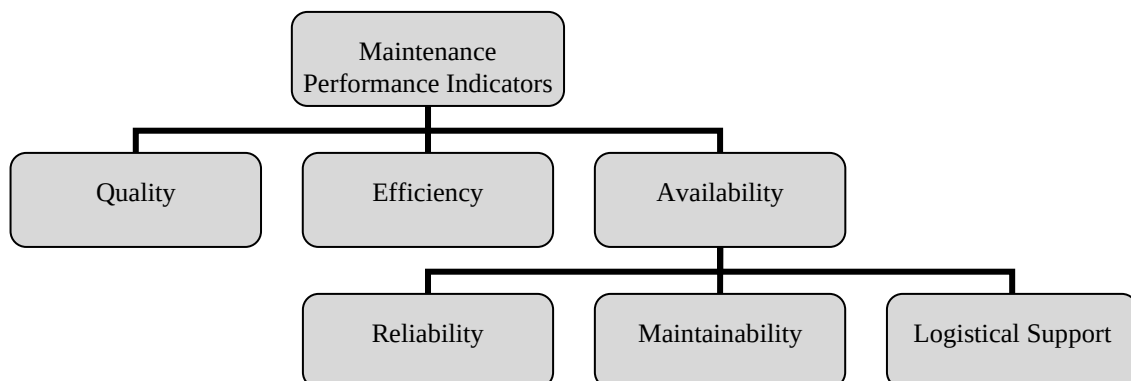


Figure 5 – Maintenance Key Indicators

Quality- A maintenance service done with quality is, according to Pinto (2013), a service without errors, which does not threaten the safety of goods or people and that is performed according to the procedures stipulated.

Efficiency- According to Pinto (2013) efficiency measures the aptitude of maintenance to meet its objectives. Efficiency can be measured as to the amount of work performed, or as to the time required for a given maintenance task.

In the first case, efficiency is obtained by dividing the number of jobs performed by the maintenance team in a given time interval by the number of jobs that were planned for that same interval, as seen in equation (2).

$$E = \frac{\text{Work Done}}{\text{Planned Work}} * 100 [\%] \quad (2)$$

In the second case, efficiency is measured by the ratio of the time used to perform a given task and the standardized time for that same task, as stated in equation (3).

$$E = \frac{\text{Time Spent on a Task}}{\text{Standardized Time for a Task}} * 100 [\%] \quad (3)$$

Availability- According to the European standard EN 13306:2010, availability can be defined as the "*ability of an asset to perform its function, how and when it is required, under given conditions, and assuming that all necessary external resources are provided*".

Pinto (2013) states that availability is dependent on the concepts of reliability, maintainability, and logistical support. Therefore, it can be calculated from equation (4).

$$D = \frac{MTBF}{(MTBF+MTTR+MWT)} * 100 [\%] \quad (4)$$

MTBF – Mean time between failures

MTTR – Mean time to repair

MWT – Mean waiting time

There are also authors, for instance Ebeling (1997), who state that the total repair time may not only include the time in which maintenance technicians are effectively repairing the equipment, but may also include waiting times, travel times and administrative times. Then, the MWT is already included in the MTTR (5).

$$D = \frac{MTBF}{(MTBF+MTTR)} * 100 [\%] \quad (5)$$

Table 3 – KPIs

Indicators	Unit	Description
MTTR	Hours	Repairing time/number of failures
MTBF	Hours	Mean time between failures
MWT	Hours	Mean waiting time to solve the failure

When there is no data to calculate these indicators, formula 6 also allows the calculation of the availability value using only the production time and the total time.

$$D = (\text{Total Monthly Time} - \text{Average Stopped Monthly Time}) / \text{Total Monthly Time} * 100 \quad (6)$$

Although these formulas (4), (5) and (6) result in different values, it allows us to understand that there are different estimators for the same concept.

2.2 Failure

According to the standard IEC 60050-191, failure is defined as “*the termination (exceeding of the acceptable limits) of the ability of an item to perform a required function*”. This term is easily confused with fault or error, but according to the standard referred before they are different.

Error is the difference between an observed or measured value or condition and the true, specified or theoretically value or condition. The difference between an error and a failure is that an error is still within the acceptable limits of deviation from the target values.

In turn, according to IEC 50(191) fault is “*the state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources*”. Whereas a failure is an event that occurs at a specific point in time, a fault is a state that will last for a shorter or longer period.

The "bathtub curve", shown in Figure 5, represents the various phases of RF during the life of a equipment.

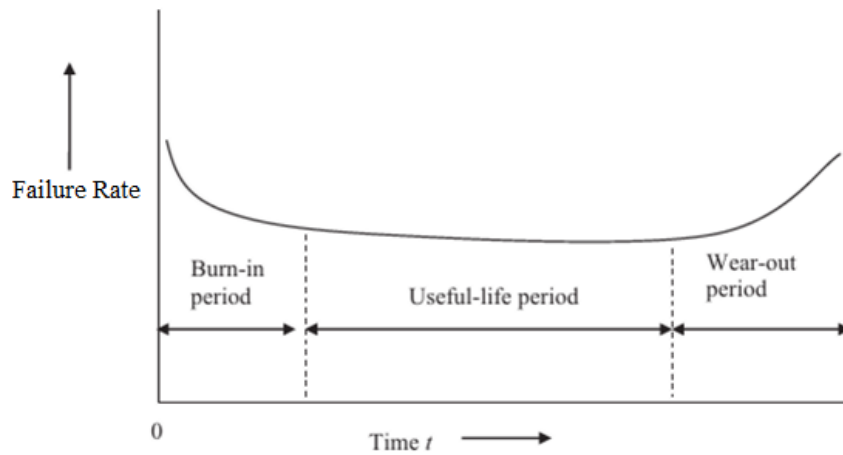


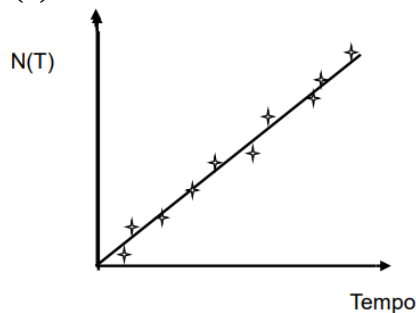
Figure 6 - Typical bathtub curve (Adapted from Dhillon, B.S. “Applied Reliability for Engineers”. 2021)

Failure rate is one of the most used parameters and represents the frequency at which a system fails. This parameter is defined as follows:

$$\lambda(T) = \frac{d}{dT} [E\{N(T)\}] \quad (7)$$

Whereby, $[E\{N(T)\}]$ represents the expected value of the number of failures and T represents failure time variable. Failures can occur in three different ways:

1. **Linear trend**, which means that the failure rate is constant and is given by the formula (8) below:



$$\lambda(T) \rightarrow \hat{\lambda} = \frac{N(T)}{T} \quad (8)$$

Figure 7 – Linear Trend of Failure Rate (Leitão, Armando. 2019)

2. **Logarithmic trend**, where the number of failures is decreasing, causing the growth of reliability, in other words, a system will better its performance at an intended function for the intended period of time under certain operating conditions. The failure rate, in this case, is a decreasing function and its estimator can be obtained by the model of Crow:

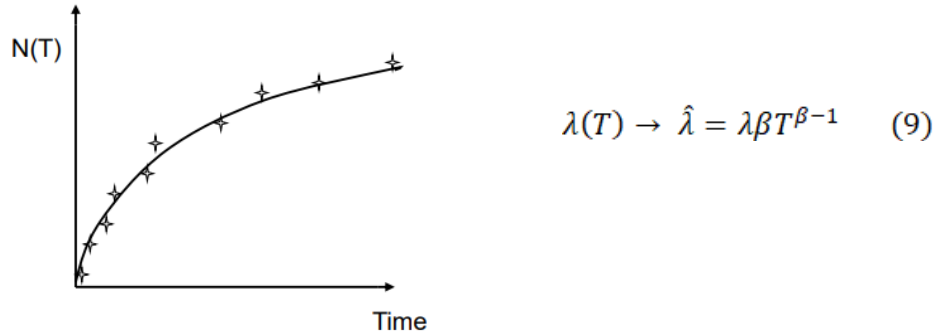


Figure 8 – Logarithmic Trend of Failure Rate (Leitão, Armando. 2019)

3. **Exponential trend**, where the number of failures is increasing, causing a reliability decay. The failure rate is an increasing function and the estimator can be calculated as presented below. It is significant to note that the parameters α (shape factor > 1) and η (scale) can be obtained by the maximum likelihood method (Weibull distribution). (Leitão, 2012)

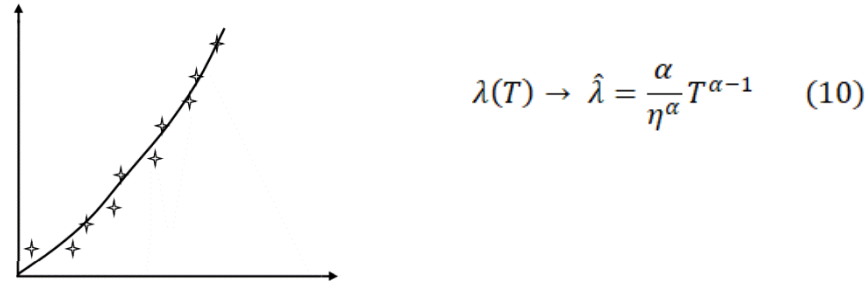


Figure 9 – Exponential Trend of Failure Rate (Leitão, Armando. 2019)

2.2.1 FMEA

Before FMEA is discussed, it is important to be familiar with the term Failure Mode. This can be explained as “*The way a failure is observed on a failed item*” (IEC 191-05-22), therefore a description of a possible state of the item after it has failed.

FMEA (Failure modes and effect’s analysis) or FMECA are used as synonyms, but the C on FMECA indicates that the criticality of the various failure effects is considered.

FMEA is a methodology used to identify and analyze not only all potential failure modes of the parts of the system, but also the effects these failures may have. It also identifies how to avoid failures and how to mitigate the effects of one that may occur.

There is 3 types of FMEA, in particular:

- **Design** – during the design of the equipment, this method is undertaken to eliminate failures of all types during the entire lifetime of the equipment;

- **Process** – focus on the problems caused by the manufacture, maintenance or operation of the equipment;
- **System** – searches for problems and bottlenecks in production lines.

Finally, to perform this methodology there's 2 approaches. The Bottom-up one considers all components on the lowest level of indenture, being used when the system concept has been decided. The Top-down approach focus on the analysis of how the system functions may fail, being used in an early design phase, before the system structure is decided.

Briefly, the FMEA is one of the most reliable methods for evaluating systems, since it enables the evaluation of complex systems in an accessible way.

3 Study of the Process and Analysis of the Problem

Throughout this chapter, an analysis of the current situation of the recycling plant maintenance will be made, in order to define the points of improvement where the solution proposal should be focused. To this end, the challenge proposed at the start of this project was to significantly reduce production stoppages due to breakdowns and to organize reserve equipment so that, in times of need, the response is fast and effective.

3.1 The Machinery

The recycling plant consists of a factory of about 700 m². This factory is organized in some floors in which about 115 machines are distributed.

These machines were one of the main focuses of this thesis and, therefore, the study of the operation of each one was crucial.

Feed Hoppers are pyramidal or cone-shaped containers that hold matter and deliver large quantities of bulk material to the production line, in constant and regulated flow. One of the biggest advantages is the ease which workers can control the input of material from the hopper to the production line.

Vibrating feeder is an equipment used in the most diverse industries to realize the automatic operation of feeding and transporting bulk materials by means of a controlled vibratory force system and gravity.

The main component for this machine to work consists of a drive unit that generates the vibratory action with horizontal and vertical force components, which causes a straight-line motion.

Weight Scale, normally called belt weigher, is used to measure the mass of the material transported in a conveyor. Belt weighers are most commonly used in production and logistics, for measuring throughput and consumption in production plants.

Conveyors are one of the most versatile modes of mechanical conveying systems that transport material horizontally or inclined. They consist of a belt that runs on some idler rolls. The outer rollers are sloping upwards to form the shape of the trough.

Some of the main components of this machine are: The idlers, rollers with bearings that give the shape of the belting; The belting, normally made from a rubber or plastic compound combined with layers of fabric or steel cables; And the drive, used to move the belt.

A **Burner** is designed to burn gas and provide the resultant heat to a drying system. When the temperature sensor, which is mounted on the burner, registers abnormal temperatures, the operation of the plant is interrupted, so that there is no reduction in the quality of the final product or problems for the safety of the workers.

Ventilator is a flow machine that performs steam extraction with or without dust concentration. It relies on blades to drag air into a circular motion with centrifugal forces speeding up airflow radially and outwards. These fans move air outward thorough ducts or tubes, and they provide a strong and stable air flow.

A **Dryer** is a machine whose purpose is to dry the cullet that enters the plant. The material to be dried is sent to the interior of the equipment, depositing itself on the entry floor, where it is passed upwards through the drying air. Since the interior base of the dryer is vibrating, the material leaves the machine, continuing on the production line.

Delabelling Machine. The presence of labels on the shards makes their optical sorting process difficult. It is, therefore, important that the label remover scrapes off the adhesive paper labels and dirt.

The cullet enters the lower part of the machine and, during transportation, the friction of the shards with each other removes the residue from the glass surface.

Screen Vibrating Feeders are used to transport materials and to separate them by size. They're used in the most diverse industries, such as chemical, pharmaceuticals, and recycling. These use gravity and mesh screens to separate the particles

Screw Conveyor is an industrial equipment used to transport bulk material of variable particle size. This machine, that can be mounted vertically, horizontally, or at an incline, is composed of a pipe with a welded steel strip, forming a continuous helix (called flight), as the screw shaft rotates, the material moves linearly. The material to be conveyed is placed in the inlet nozzle and will be carried by the propellers to the discharge location, in a continuous and cyclical movement, providing a regular flow of material.

Roller Glass Crushers are designed to pulverize glass until it's of very small dimensions. The working principle consists of two roller shafts that crush the material by the impact, shear and compression forces generated by the relative rotation.

Cyclone uses cyclonic separation as its method of removing particles from an air stream, without the use of filters. Their working method is similar to a centrifuge, because the inside of the chamber creates a spiral, similar to a tornado.

Clarity is an optical sorting device, composed of a high-speed sorting valve technology that guarantees high separation grades and high throughput. This machine allows the increasing of the production volume and quality with the decrease of processing costs (like water and energy).

Inductive Separator is a belt separator with inductive sensors that identify the presence of metallic materials in the cullet. When the sensors detect metal, a signal is sent to a control unit that activates pneumatic rejecter valves that expel this unwanted material.

Bucket Elevators are designed for the vertical lifting of raw materials, in this case glass. Since the factory has several floors, this allows the transport of the material without interrupting the linearity of the production process.

A **filter** is a machine that receives contaminated air into the sleeve compartment through a side duct. There, the particulates are retained in the fabric of the sleeves and are eliminated by the hopper. The clean air is directed into the nozzles at the top of the filter.

Magnetic Separator consists of a suspended magnet with a continuously running belt, fixed over a moving conveyor. The magnet lifts the magnetic materials that are mixed with the cullet and discharges them to the side. This allows a continuous and effective removal of unwanted metal.

3.2 Productive Process

The cullet treatment plant consists of three production lines. The Main Line produces white cullet or colored cullet, the fine line, in turn, provides glass of smaller dimensions, as the name says, and, finally, the rejection line was created to make use of some cullet that was headed for the waste. The equipment of each line is connected to each other, so the degree of importance given to each machine is the same.

When the material arrives at the recycling plant, it is unloaded into the threshing floor. In this place, the material is divided by type and supplier. The material is then loaded by a wheel loader from these locations into the hoppers.

The glass cullet enters the factory through two input hoppers (hopper 1 and hopper 2) and each one of them has a capacity of 60 tons/ hour, being the input feed is around 17000 tons per month.

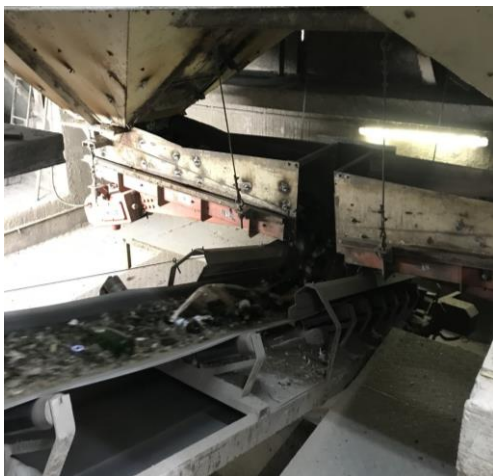


Figure 11 – Entry of material in the factory



Figure 10 – Magnetic Sorting Machine

The cullet arrives at a conveyor passing through vibrating chutes (Figure 11) and, during the transportation, the material is sorted in an automatic magnetic sorting machine that withdraws ferrous materials (Figure 11).

Arriving at the screen vibrating feeder, the material is separated into 2 exits: bigger than 50mm or smaller than 50mm.

- The material that is bigger than 50mm continues in the same line, going through a manual sorting process, where the workers separate visually the unwanted plastics and ceramics. After this, it goes into a roll crusher that, with the compression of two rolls rotating about a shaft towards the gap between them, reduces the size of the glass.
- The material that is smaller than 50mm falls into a conveyor that reunites this material with the cullet that went through the roll crusher.

Afterwards, this material is introduced into an intermediate hopper, with an input bigger than the output. A very important detail about this hopper is that when its capacity is close to being reached, the input of material into the plant stops, causing no more material to arrive at this equipment.

The hopper releases material into a vibrating chute which, in turn, dumps the material into a conveyor. This conveyor reunites material not only from the intermediate hopper but also from another input hopper of pre-treated thin glass. The previously mentioned fines hopper is filled with material smaller than 10mm.

In the conveyor, the material is weighed and dropped in an elevator that transports the cullet into a dryer, in order to decrease the humidity of the glass. The dryer receives heat from the burner through a red sleeve located on the bottom of the machine.

Subsequently, the cullet is conducted to a label removal machine, that helps clean the surface of the glass particles by abrasion. When the material leaves this machine, its temperature is around 78°C. The next machine is the resonance screen 323, which separates the material bigger than 7mm and smaller than 7mm (Fine Line):

- Continuing in the Main Line and following the glass bigger than 7mm, the material arrives at the inductive zone. This zone removes ferrous material with the help of a magnet and also the nonferrous material with an inductive separator. Afterward, the cullet ascends into the resonance screen 30, which separates the material into 5 criteria:
 1. Material smaller than 7mm that escaped the resonance screen 323: this material goes directly to the fine line's conveyor 340 (that will be discussed later);
 2. Material bigger than 50mm: that is usually contaminated material like plastic bags;
 3. Material from 7 to 50mm goes to three clarities. The clarity for material from 7-12 mm, from 12- 25 and 25-50, respectively;

The clarities are optical inspection machines that reject contamination to the Rejection Line, through the reflection of light on the cullet. If there is no reflection, clarities activate its pneumatic valves to blow out the cullet, thus rejecting the contaminants. After these 3 clarities, there are 3 more that reject not only contamination but also separate white glass.

The mix cullet that comes from the clarities goes from the conveyors 54 and 58 (going through a magnet) to the exit of the final product.



Figure 12 - Clarity

White Glass Treatment

White glass is recycled separately from the mixed cullet and because of that there's the flint exit (exit of white glass). The white glass travels through conveyors being filtered with magnets and arriving at a resonance screen that separates the material smaller than 10mm (that goes to the resonance screen 30 again to be reused) and bigger than 10mm, that goes to a clarity that works in a slightly different way. This clarity instead of rejecting contamination, rejects colored glass that goes also to the resonance screen 30. This process allows this machine to separate the white glass, finishing the Flint Line. It is important to refer that this clarity integrates a metal detector to collect glass with wire and other types of "metallic glass".

Rejection Line

The previously mentioned rejection line has as its purpose the recovery of cullet particles improperly separated in previous operations, therefore takes the contamination from the clarities to a resonance screen that filters the smallest particles (0-6mm) into the garbage and sends the rest of the product to a clarity that recovers some glass. The recovered cullet is forwarded to the resonance screen 30.

- Going back to the resonance screen 323 and regarding the Fine Line, the material smaller than 7mm goes directly to a smaller dryer. This dryer is partially different from the one mentioned above, because it only dries thin cullet, so it has a residence time, creating a layer of cullet in order to dry all the small particles.

After this the material goes throw a magnet and is lifted in an elevator to arrive at the resonance screen 342. This machine separates the cullet from 3-7mm and smaller than 3mm. The material smaller than 3mm goes into a roll crusher to make the pieces smaller than 1mm. The material bigger than 3mm goes into 2 clarities to remove contamination.

The resulting cullet gets together with the cullet smaller than 1mm and is driven to the exit of final mix cullet.

The final product exits are taken or directly to the glass plant or to the threshing floor of final product, whereby the output of the mix cullet is around 23 tons per hour and of white cullet is around 2.5 tons per hour.



Figure 13 – Threshing Floor of Final Product

Every hour a 30 kg sample is taken from the final treated product to analyze its quality. This procedure is necessary to ensure that the technical specifications, internally regulated by BA Glass, are being followed.

The regulation establishes the parameters for the evaluation of the compliance of treated cullet. The average quantity (g/ton) of each type of contaminant in the treated cullet must respect the following conditions, in order to be compliant:

Table 4 – Contamination Parameters

Level of Contamination		
Contaminants	Examples	Specification (g/t)
Ferrous Metals	Caps; Cans; Iron Fragments	<5
Non-ferrous Metals	Aluminium; Lead; Tin	<10
Stones, Ceramics and Porcelains	Stones; Porcelain; Argil; Clay	<50
Opals	Opal Glass	<90
Organic Components	Paper; Wood; Fabrics	Not desirable and only traces will be accepted
Plastic	Containers; Bags; Wires	
Other Glass	Glass from laboratories, Lamps and TV; Vitroceramics	

The reference values used by BA Glass are more demanding than the European ones defined by the Commission Regulation No 1179/2012, in order to provide a higher quality than the one found on the market.

3.3 Initial State of the Company

After some time of integration in the plant, it was possible to get to know the organizational and operational procedures that existed at BBIG. This survey on the company provided the identification of opportunities for improvement and enabled the creation of intervention plans, related to the maintenance area.

Firstly, it was immediately possible to identify potential for development at BBIG, in the sense of the organization of maintenance since the equipment under study was not referenced. That is, there was no report of the equipment in the Maintenance Software, since they were not codified. Thus, besides the lack of registers of equipment and their information system (such as location, characteristics and components), there were no registers of maintenance actions or breakdowns.

Added to this, there was an absence of a preventive maintenance plan, which, as explained in chapter 2, is fundamental in the daily life of a competitive and growing company. The predominant maintenance was corrective and autonomous, and all the knowledge of these procedures was centralized in a single worker, the maintenance manager.

The daily production reports, filled in by the shift leaders, do mention the breakdowns, but they are not very detailed and not very intuitive, and there is no breakdown report that is easy and quick to consult.

Finally, the spare parts warehouse was in a state of disorganization that delayed maintenance stoppages.

Initially, the maintenance of the factory was guaranteed in 2 ways; one of them was done by the workers of the 3 shifts and another one was prepared by the maintenance manager.

The autonomous maintenance carried out by the workers was done in a 30-minute stop of each shift and consisted of the following interventions:

- Cleaning the dryers;
- Testing valves, cleaning and resetting clarities;
- Cleaning the permanent magnets;
- Cleaning the screen vibrating feeder grids.

On the other hand, the maintenance carried out by the manager encompasses more technical actions, focusing mainly on corrective procedures.

The cullet treatment plant has a high workload of around 22.5 hours per day, making maintenance stops of more than 30 minutes impossible. In cases of longer stoppages for the repair of equipment, the time is used for more time-consuming maintenance actions.

3.3.1 Failure Analysis

In order to understand what the history of breakdowns was like before the existence of a maintenance plan, a study was made of the daily records for the year 2021.

These daily records are drawn up by the person in charge of each eight-hour shift and consist of reports in which the amount of treated cullet and any incidents that may have occurred during the respective working hours are recorded. In addition, this report also contains the amount of contamination analyzed every hour, and an indication of the autonomous maintenance procedures that were carried out.

Although it is a slightly incomplete and not user-friendly record, it was possible to extract the number of breakdowns per equipment.

The document produced for this analysis can henceforth be used to make a more ergonomic daily record. This document contains vertically all the days of the year (working days) and horizontally all the machines in the plant. In this way, the shift manager only has to look for the present day and the respective machine where the fault occurred and leave his record.

2021	Máquinas ->	Clarity	Secador	Crivo	Mangueira de distribuição	Mesa vibratória	Tapete	Alcatraz
Jan	1	40 - problema no carril						
	2	38/42/46 - falha c/ paragem						
	3		305 - mangueira derreteu					
	4			30 - mudança tela				
	5				soltou-se			
	6			323 - mudança de 2 telas		301 - falha		
	7			323 - mudança de tela				
	8							
	9							
	10					301 - não arrancava	63 - Retirar rolo	
	11							26 - Falha
	12							
	13			323 - mudança de telas				
	14			30 - mudança de tela				
	15							
	16							
	17							
	18							
	19							303 - avaria no monitor de rotação
	20							
	21							303 - desvio da tela
	22							
	23			323 - mudança de tela			5 - trocar rolo	
	24			323 - mudança de tela				

Table 5 – Failure Record Table

As can be seen from Figure 14, the equipment that suffered the greatest number of breakdowns were Screen Vibrating Feeders, Filters and Clarities, representing around 60% of the total of failures.

Representing about 30% of the total number of breakdowns, it can be explained that Screen Vibrating Machines, for example, are damaged due to the high temperature of the cutting material. This is common in the glass recycling industry and can be controlled by a more frequent overhaul of the screens.

It is also important to refer claritys, because this value is explained by their technological complexity and by the fact that its maintenance must be carried out by the manufacturer's technical representatives, not allowing a revision as frequently as necessary.

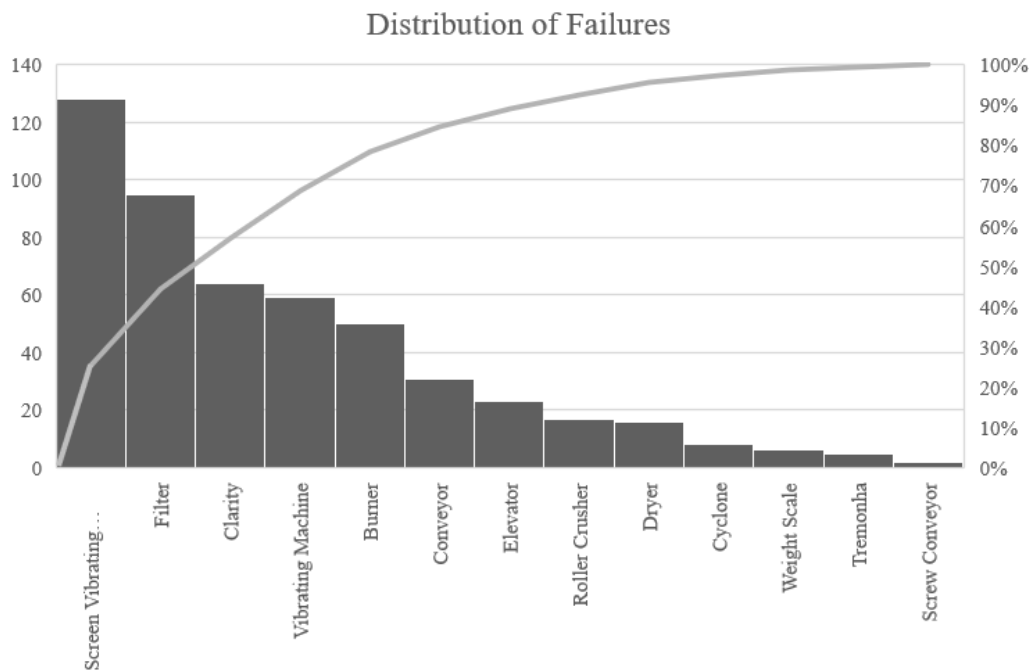


Figure 14 - Distribution of Failures

By analyzing this high number of failures, it is possible to verify that preventive maintenance is necessary and can bring a decrease of the number of failures. This maintenance must be planned for all equipment since, although some machines fail only a limited number of times, their breakdowns will also cause the plant to stop operating, once the production is continuous and in series.

Using the data collected about the failures of the year 2021, it was possible to calculate some of the indicators that allow monitoring maintenance, optimizing and increasing the efficiency and productivity of a company. There are several maintenance indicators and the usefulness of each one of them is directly related to the objectives intended by the company at a certain moment.

Of the various indicators discussed in chapter 2.1.7, it was only feasible, during the dissertation, to measure the reliability and availability represented in Table 6 and Table 7, respectively. The tables used to calculate the availability can be found in Appendix B.

Table 6 - Reliability of the Equipment with the Most Failures

Machine	MTBF (days)	λ
Filter	3,138	0,319
Screen Vibrating Machine	4,150	0,241
Clarity	5,714	0,175
Vibrating Machine	6,121	0,163
Burner	6,939	0,144
Conveyor	10,667	0,094

Elevator	22,864	0,044
Dryer	24,400	0,041

Table 7 shows the values of the availability of the production line in the year 2021, calculated by the equation 6, presented in chapter 2.1.7.

Normally the months of May and November are the months of lower availability, due to the production stoppage week for external maintenance, but due to the pandemic situation experienced last year, in the month of May there was no such maintenance and the November one was postponed to the month of December.

As it is possible to see below, in December the availability was lower, around 83%, since the number of working hours was lower than usual, proving that there was indeed a stoppage.

Table 7 – Availability of the Production Line

Month	Total Monthly Time (H)	Total Monthly Time – Average Stopped Monthly Time (H)	Availability (%)
January 2021	697,50	663,83	95,17
February 2021	630,00	588,17	93,36
March 2021	697,50	649,67	93,14
April 2021	675,00	628,33	93,09
May 2021*	697,50	647,67	92,86
June 2021	675,00	645,33	95,61
July 2021	697,50	666,33	95,53
August 2021	697,50	664,50	95,27
September 2021	675,00	631,67	93,58
October 2021	697,50	659,00	94,48
November 2021	675,00	637,50	94,44
December 2021*	675,00	563,83	83,53

3.4 Management Software SAP

SAP stands for System Analysis Program Development, and it is one of the world's leading producers of software for the management of business processes, developing solutions that facilitate effective data processing and information flow across organizations.

By centralizing data management, this software provides faster workflows, improves operational efficiency, raises productivity and brings innumerable advantages for the structuring of data from areas like Finance, Human Resources, Production, Marketing, and Maintenance.

This ERP is made up of a set of modules connected in real time, each one destined for a different company process, and by small applications, called transactions. The maintenance

module allows all the activities of the maintenance function to be interconnected with other modules, such as Production or Resource Management.

With regard to preventive maintenance tasks, their management is ensured by periodic launching of maintenance orders, manually generated, based on the predefined maintenance plans inserted in the platform's database. In these plans it is possible to establish which equipment will be subject to maintenance, as well as the operations to be performed and the respective frequency of execution.

So far, at BBIG the SAP functionalities are under-utilized, as only a few test records are present in the system.

Therefore, aware of the potential in terms of profitability and productivity that this ERP would bring, the company intends to invest in the implementation of a preventive maintenance plan for this system.

4 The implementation of the preventive maintenance plan

In order to plan maintenance and record it in SAP, it was necessary to go through several preparatory steps. These will be addressed in this chapter so that there is a rational follow-up of the elaboration process of this thesis.

4.1 Information Gathering

In any project, before starting its development, it is important to get to know all the details of the production process and manufacturing organization.

Therefore, a daily follow-up of the operation and maintenance in the factory was carried out. This accompaniment was important to get to know the plant and understand the problems it was facing.

Alongside this, an exhaustive consultation of the manuals of all the machines was performed in order to find out the maintenance procedures recommended by the manufacturers and the respective periodicities.

After organizing the information taken from the manuals it was necessary to check, with the maintenance manager, the conformity between the listing and what was actually doable by the team. He also helped to complement the plan with the information he had been given during maintenance by the manufacturers' representatives.

4.1.1 Maintenance list

Maintenance scheduling is planned work that specifies when common elements will be routinely inspected, adjusted and repaired. This has as its objective to guarantee the maximum efficiency and availability of the equipment at minimum costs.

As previously mentioned, a list of the maintenance plan was made based on the information contained in the manuals.

As it is possible to see in Table 8, this list is composed of the name and number of each machine, the procedure and the respective periodicity, and it is organized by the typology of the different pieces of equipment. In order to make the list as realistic as possible for 1 or 2 people to carry out, the preventive tasks are not exaggerated in number, focusing precisely on the essential (the full list can be found in Appendix A).

After this list was finalized with a periodicity for each equipment, meetings were held with the plant maintenance manager to perform the necessary changes to make this plan realistic and in accordance with the needs of the plant. This verification is of great importance, once over the years, upgrades and changes were made in some machines and, therefore, the

manuals may not be totally accurate. In addition, the vast experience of the operator allows the list to be completed with possible opportunities to improve maintenance processes.

Table 8 – Maintenance plan

Machine	Procedure	Periodicity
Tremonha1	Verificar corrosão	Anual
	Verificar estado dos mosaicos	Anual
	Verificar estado da Rosca	Anual
Tremonha 3	Verificar corrosão	Anual
	Verificar estado dos mosaicos	Anual
	Verificar estado da Rosca	Anual
Tremonha de Finos 350	Verificar corrosão	Anual
	Verificar estado dos mosaicos	Anual
	Verificar estado da Rosca	Anual
Tremonha 301	Verificar corrosão	Anual
	Verificar estado dos mosaicos	Anual
	Verificar estado da Rosca	Anual
Calha vibratória 2	Verificar forras bi-metálicas	Anual
Calha vibratória 4	Verificar forras bi-metálicas	Anual
Calha vibratória/Canal vibrado 322	Verificar forras bi-metálicas	Anual
Calha vibratória/Canal vibrado 300	Verificar forras bi-metálicas	Anual
Calha vibratória/Canal vibrado 21	Verificar forras bi-metálicas	Anual

The preventive tasks mainly focused on five main procedures, in accordance with the recommendation:

- Inspections by checking the condition of some equipment;
- Bearing lubrication and oil substitutions;
- Temperature control;
- Preventive replacement of components;
- Cleaning;
- Calibrating.

Some of the operations are performed by the company's own operators, internal interventions, and others are carried out by subcontracted companies, external tasks. The second case encompasses the more technical and precise procedures, that normally are performed by the technicians of the manufacturer. This highlights the great importance of this planning. A high degree of organization is required to match the availability of subcontractors (which is sometimes very restricted and expensive) with the plant's schedule.

Since the workers performing the maintenance tasks have a qualification that must be improved, it is necessary to supplement the plans with clear and illustrative work procedures to avoid any doubts arising. In addition, training sessions given by the maintenance manager will be necessary to ensure that the maintenance is carried out flawlessly.

After the review by the head of maintenance is done, the listing has to receive the approval of the company management as it has to be in accordance with all their requirements. When the answer is affirmative, the next phase starts: Implementation in SAP of the maintenance plan, which includes the equipment coding, sub equipment coding and scheduling of the preventive actions.

4.2 Implementation in SAP

As mentioned in chapter 3.4, SAP is a software for the management of business processes, which develops solutions that help data processing and information flow across different organizations. (SAP Website, 2022)

In order to create a maintenance plan in SAP, you must create locations for the equipment, create the equipment itself (with its additional information), and create and schedule the maintenance plans. To standardize data, speed up the identification and location of equipment, it is necessary to create coding systems, shared across the BA Glass group.

4.2.1 Location of the Equipment

The functional location is a tree based structure used to display categorizes items like plants, locations, equipment's, systems, materials and others. It is the building block and main organizer of the plant's assets.

The structure has 7 main structured levels categorized with Functional Labels and specific rules for each level regarding the number of characters and format. The procedure of creating locations was elaborated for all the machines present in the BBIG and, for this, the SAP transaction used was "IL01 - Create Functional Location".

The 1st, 2nd and 3rd levels are standard and a requirement in any plant's structure. These levels were created by the IT Team to all plants and can only be changed by IT if requested. Even though the remaining levels are not standard, some items are already defined by the Technical Office. Other items may be created but are required to follow the same principles and structure etiquette.

Table 9 - Functional Location Categories

Level	Description
F	Plant
A	Area
I	Installation
Z	Zone
S	System Type
E	Function Machine
U	Equipment
M	Materials

For the definition of a functional location there are six levels. The first level, related to the location of the plant, consists of 2 letters that represent the different cities where there is a BA factory. Since this project is being developed in Avintes, the code is AV. The second level consists of 1 letter that represents the area of the chosen plant. In this case, the letter L represents the cullet treatment plant.

The third level is a 2 digit number and represents the floor/area of the plant. As can be observed in the next figure, nine areas have been created, which indicate the old or new area of the factory and the respective floor.

The fourth level represents a more precise zone of the factory and it is denoted by 2 numeric characters. The fifth level, in turn, is a 2 letter character which comprises the typology of the equipment (for example a conveyor is denoted by TA – from “tapete” in Portuguese). Finally, the sixth level represents each machine of the previously defined typology and it is a 2 number code.

Plant's Area	Zone	Equipment	Installation	Description	Code
AVL	AVL00			Estação Tratamento de Casco	AS011
	AVL000			Parte Antiga Piso 0	AS011
				Tapete de produto final	AS011
				Balança 80	AS011
				Tapete 58	AS011
				Localização Inexistente	AS011
		AVL01		Parte Antiga Piso 1	AS011
		AVL02		Parte Antiga Piso 2	AS011
		AVL03		Parte Antiga Piso 3	AS011
		AVL04		Parte Antiga Piso 4	AS011
		AVL10		Parte Nova Piso 0	AS011
		AVL11		Parte Nova Piso 1	AS011
		AVL12		Parte Nova Piso 2	AS011
		AVL13		Parte Nova Piso 3	AS011

Figure 15 – Location Codes and Levels

4.2.2 Coding of the Equipment

After defining the locations, the coding of the equipment needs to be done. To do this, it is necessary to use the information collected about the equipment and create codes to identify each one.

The equipment code is composed of a 4 letter class that defines and identifies the type of equipment and an international sequential numbering, formed with 5 numbers. New equipment can only be registered with existing standardized classes, which codes are already defined for all group BA Glass.

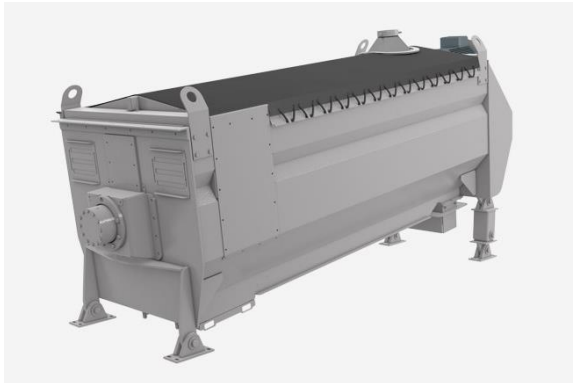
Table 10 - Equipment Class + Number Code (CONV00526)

	Class ID	Sequential Numbering
Characters	Alpha (4)	Num (5)
Code Mask	XXXX	YYYYY
Example	CONV	00526

When the equipment we want to insert in SAP does not yet have a class standardized by BA Glass, it is necessary to proceed with its creation and, for that, the technical office must be informed to give authorization, because it's a very restrictive operation.

To create new classes, first an informative table must be made with the name of the Class, its description, a photo and detailed information.

Table 11 – New equipment classes

DRYE	Dryer		The mixture of materials enters this automated equipment to be dried.
DELA	Delabelling		Equipment used to clean the surface of the glass particles by abrasion. The result is optimum abrasion and gentle treatment of the cullet without producing fine-grain particles.
Clarity	Clarity		Optical inspection machine that with stable detection automation and speed sorting valves, separates the contamination from the glass, directing the non-glass materials to a recovery line.
ORGS	Organic Separator		A conveyor that separates organics with the help of a ventilator.

CYDI	Cyclone Discharge		Equipment used to discharge material/contamination by gravity. Expelling it from the factory.
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Subsequently, this table must be approved by the technical office and only then, using transaction “CL02”, the creation of the new classes in SAP is possible. In this transaction is necessary to:

1. Define the name of the new class;
2. Identify the class type (which in this case is 002-Equipment);
3. Give a brief description of the class.

For the present project five classes had to be created, as they are exclusive to the recycling plant (underlined in the table below): Dryer, Delabelling Machine, Clarity, Organic Separator and Cyclone Discharger.

Table 12 - List of Classes

Class	Description
VIBF	Vibrating Feeder
CONV	Conveyor
BURN	Burner
VNTL	Ventilator
<u>DRYE</u>	Dryer
<u>DELA</u>	Delabelling Machine
SIEV	Screen Vibrating Feeder
SWCV	Screw Conveyor
CLCH	Roller Glass Crusher
INCY	Cyclone
<u>GSMC</u>	Clarity
<u>ORGS</u>	Organic Separator
FHOP	Hopper
INDS	Inductive Separator

BUEL	Bucket Elevator
DRVV	Directional Valve
WSCA	Weight Scale
DUST	Filter
MAGS	Magnetic Separator
CYDI	Cyclone Discharge
MTVV	Rotating Valve

4.2.3 Database of the Equipment

In order to enter all equipment into SAP in a more agile manner, an excel template has been created that is compatible with the system's information input, therefore allowing mass creation according to certain rules.

This table is composed by 36 columns and the most fundamental are the following:

- **Equipment Category** – this is a mandatory parameter and because the intention is to insert equipment, the category is an “E”;
- **Description** – information regarding the designation of the equipment, it is normally composed of its name and numbering;
- **Valid-From Date** – consists of the date which the respective equipment becomes valid in SAP;
- **Object Type** – this is the column where the class should be indicated;
- **Authorization Group** – should be completed with the word “MAIN”;
- **Weight and Unit of Weight** - in this column the weight of the equipment must be indicated, if there is any information about this parameter;
- **Size/Dimension** – in this column the dimensions of the equipment must be indicated;
- **Manufacturer and Manufacturer Country** – the manufacturer and his information should be indicated in this columns;
- **Model Number, Construction Year, Month of Construction, Manufacturer Part Number and Manufacturer Serial Number**- By consulting the rating plates, it is possible to obtain the model of the equipment, the date of construction, part number and the serial number;
- **Maintenance Plant** – gives information of the plant where the equipment is mounted. In the case of this project we should put “AV”, since the recycling plant is located in Avintes;
- **Company Code and Cost Center**– in the case of BA Glass the code is “BA” and the cost center for the recycling plant is “AS011”;
- **Functional Location and External Equipment Number** - When creating equipment, there's the need to fill the functional location with the respective location created previously and the need to create the equipment code as explained before.

Table 13 - Functional Location and External Equipment Number

Functional location	Superordinate Equipment	External Equipment Number
TPLNR	HEQUI	EQUNR
CHAR(30)	CHAR(18)	
Optional	Optional	
AVL0402MV01		VIBF00303
AVL0300MV01		VIBF00304
AVL0402MV02		VIBF00305
AVL0302ME01		VIBF00306
AVL0203ME01		VIBF00307
AVL0302ME02		VIBF00308
AVL0203ME02		VIBF00309
AVL0302ME03		VIBF00310
AVL0203ME03		VIBF00311
AVL0102ME01		VIBF00312

To ensure that the mass insertion of equipment will work it is necessary to ensure that no columns have been added, deleted, or changed and it is also necessary to guarantee that no data is inserted in other cells than the ones designated in the structure.

Another detail of great importance is to make sure that the name of the excel sheet is the class of the equipment. This excel file only works for classes that are already created in SAP, so if some of the equipment has a new class, they need to be created individually after the class is in the SAP system.

4.2.4 Database of Sub-Equipment

Before talking about sub equipment, it is important to be able to distinguish between components or repairable systems.

A component can be defined as an item that would, upon failure, be removed from the system in which it was installed. A repairable system is an item that would, upon failure, be repaired by replacing the components that caused the system failure, as the name implies.

Therefore, the term used in BA Glass "sub equipment" corresponds to a repairable system, such as engines, valves, industrial computers and filter control units. For the present thesis and following recent literature on the subject, the definition of repairable system is going to be expanded to include the possibility of additional maintenance actions which aim at servicing the system for better performance. This preventive maintenance (PM) may be distinguished between conditioned PM and systematic PM. The former type of maintenance is due when the system exhibits inferior performance, while the latter is performed at predetermined points in time, as mentioned in chapter 2.1.3.

In what concerns the sub equipment, an exhaustive collection of these was made in order to obtain a complete list with the characteristics of each one. The main repairable systems are represented in the Table 14 and Table 15.

This list has a high importance when it comes to maintenance, since it facilitates the logistics in case of emergency, avoiding prolonged production stoppages. Besides this, this list will facilitate the function of ordering, since the information relative to each equipment will be accessible in SAP. To increase profitability, in a way, an adequate control of consumables is assumed, with a consequent improvement in the stock of the parts in the warehouse.

Table 14 – List of Engines

Engine	Model Number	Engine	Model Number
Vibrations motor 21	FPF4	Vibrations motor 300, 322	F 95-4-2.2
Drive 63	BF5 100L 24	Vibrations motor 304	F 200-4-2.1
Drive 8	IEC-Motor B3, 132 M4, 4-pol.	Vibrations motor 305	F 1400-8-7.0
Drive 9, 64	IEC-Motor, 2-pol.	Drive 309, 381	FA77/G DRN100LS4
Drive 11	KA77 DRN132S4/TF	Drive 310, 335, 382, 386	FA57 DRN80M4
Drive 30	IEC-Motor B3, 160M 4-pol.	Geared motor 340, 302, 321, 324, 351.b	FH57 DRN90L4/BE2
Vibrations motor 37, 39, 41,43, 45,47, 65, 66, 202	F 150-4-2.4	Geared motor 358	FH47 DRN80M4BE1
Drive 204	FH37 FRE90M4	Vibrations motor 330	F 400-8-3.1
Drive 205	FA47-DRS90MS/BE2	Drive 320	IEC-Motor 225S, B3
Drive 206	FA37-DT80K4	Geared motor 5	FA77 DV100L4-BMG
Drive 208	FA37/GDRS71M4BE05/TF	Vibrations motor 323	F 1000-6-4.7
Drive 384, 380	WT260M-4; P=125cv; n=1470rpm; 3 fases	Vibrations motor 337	F 250-6-2.3
Drive for belt conveyor 63.1	KA47 DV100L4	Vibrations motor 207	BM 1100/15
Drive for drum 63.2	KA47 DT71D4	Vibrations motor 342	F 680-6-3.4
Drive 339.2	FH57 DRE90L4	Vibrations motor 343, 345	FT 125-4-2.4
Geared motor 33	FA37 DT71D4	Drive 22	SK 100L/40
Drive 339, 339.1	FH37 DRS71S4	Vibrations motor 354	F 235-4-3.4
Geared motor 54	FA 47DT90L4	Drive 355	PTC, reversible
Geared motor 58	FA57 DT90L4	Vibrations motor 356	F 850-6-4.7
Geared motor 302, 351, 16	FH67 DRN90L4BE2-43 rpm	Drive 308	PE30 250M-4 B3
Vibrations motor 201	F500-6-3.4	Drive 307	1LA5 220-4AA60 2255
Geared motor 10	FA57 DT80 N4	Drive 303, 26	FH97 DV160M4/RS; 11kW; n=1440rpm
Geared motor 15, 61	FA47 DT90S4/BMG	Drive 332	3 AL160M/L-02
Geared motor 24,68	FA47 DT80N4	Drive 383	Star-delta start/ 3 x PTC
Drive 341, 353	FH67 DRN100L4/RS; 1456 rpm; 50Hz; M3	Vibrations motor 301	090VRT 17.0C - 01

Table 15 – Other Repairable Systems

Sub Equipment	Model Number
Solenoid Valve - sprinkling 63.1	21A2KV20D 24V G1/4"
Solenoid valve 305	CPE18-M1H-5L-1/4
Electro valve 357	5/2-1/8-24 Vcc
Industrial Touch PC 38, 40, 67, 203, 344	6181P-12TS2KH
Filter control unit	RM-300C

380, 308, 384

The procedure to insert this information in SAP is very similar to the equipment upload explained in chapter 4.2.3, since the base excel table is the same. The only difference is that in this case there is no functional location, but a superordinate equipment, which is the equipment that accommodates this sub equipment. Therefore, in SAP these repairable systems are automatically placed in the constituents of the equipment in question.

For the present project, four types of classes have been inserted: engines (EMOT), valves (VALV), industrial touch PCs (ITPC) and control units (CTLU) and, from these classes, 2 had to be created in system, by the same “CL02” transaction mentioned in the equipment chapter.

Table 16 – New Sub equipment Classes

ITPC	Industrial Touch PC		Industrial PCs are used for process control and data acquisition. Sometimes can be used as a front-end to another control computer in a distributed processing environment.
CTLU	Control Unit		This is a system that adjusts, visualizes and controls the equipment to which it is connected.

4.2.5 Bill of Materials

The bill of material (BOM) is a technique document used to demonstrate the structure and relationship between the final product (never processed in current enterprises), sub-assembly (composed of other parts, and used by other sub-assembly or final product within current enterprise), parts or materials (produced outside), as well as the corresponding quantities of the subordinative parts and materials of each assembly.

Usually, a new BOM is generated by creating a set of single level BOMs, each of which contains a parent item and its direct children.

For example, to obtain a skateboard you need a board, two axles, four wheels and eight screws. To obtain each wheel you need one tire, one rim and four screws. In this way, the BOM of the skateboard is composed of 3 levels. Level 0 is the final product, i.e. the skateboard. At level 1 the board, 4 wheels, the axle and the screws. At level 2, the tires, the rim and the 4 screws.

Figure 16 shows the BOM of the stated example.

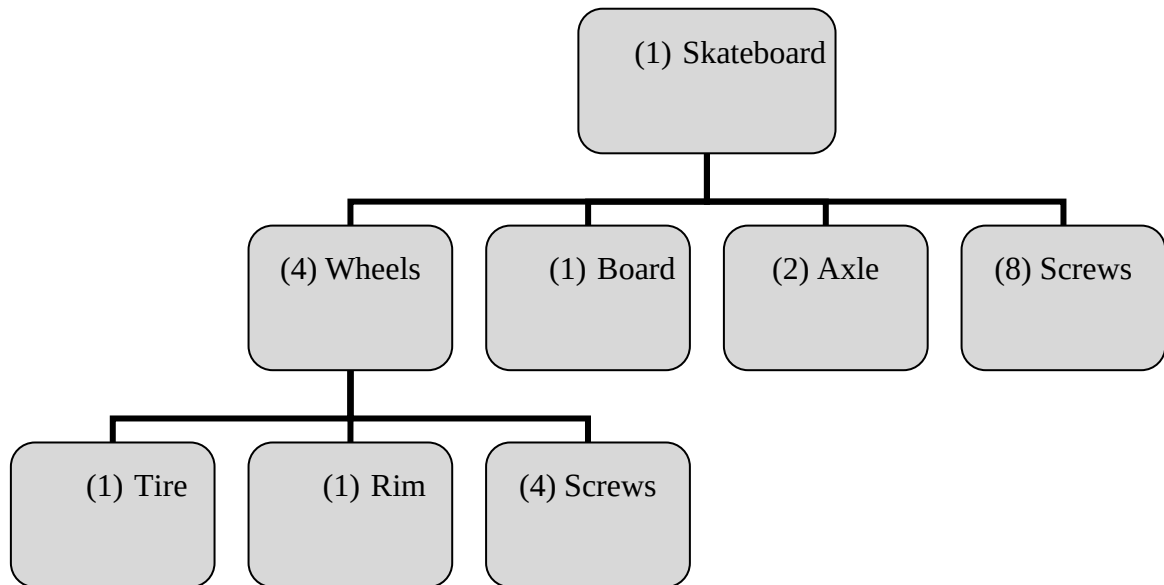


Figure 16 – Example of a BOM

Besides its great importance for planning, since through this deconstruction we can identify the needs of materials for assembly, the BOM can also be used in the identification of families of products, since it contains information not only about the similarity of the products and their components, but also about their structure.

These product families are extremely relevant in the manufacturing process, as the similarity between the 'assembled' products directly affects the efficiency and effectiveness of the production lines (Kashkoush and Elmaraghy, 2015).

Regarding the BOM developed for this project, the main purpose was to describe the structure of the technical objects and to allocate the spare parts for maintenance purposes.

Initially, a survey was made of all the most important level 1 constituents of each piece of equipment, referred to in chapter 4.2.2. When all the information was collected, SAP's transaction "IB01" was utilized.

In this transaction the following information needs to be filled:

- **Equipment**
- **Plant**
- **BOM usage**

The BOM usage has several options, as the next table represents:

Table 17 – BOM usage codes

1	Production
2	Engineering/design
3	Universal
4	Plant Maintenance
5	Sales and Distribution
6	Costing
7	Returnable Packaging

As shown in the figure below, in the “Component Description” column we must explain all the information collected about the spare part, including model and manufacturer. After the filling in is complete, an item ID is automatically assigned to the component.

Table 18 – BOM of the Screen Vibrating Feeder 8

Item	ICt	Component description	Quantity	U...	A...	Sls	Valid From	Valid to	Change No.	P...	SortStrng	Item ID
☐ 0010	T	Sieve mat 8 - Binder 45x45	1	ST	☐	☐	30.05.2022	31.12.9999		☐		00000001
☐ 0020	T	Wooden "fuse" 8	1	ST	☐	☐	30.05.2022	31.12.9999		☐		00000002
☐ 0030	T	Eccentric Exciter 8	1	ST	☐	☐	30.05.2022	31.12.9999		☐		00000003
☐ 0040	T	V-belt pulley 4-grooves 8 - Binder	1	ST	☐	☐	30.05.2022	31.12.9999		☐		00000004
☐ 0050	T	Rubber block 2-laps (Sinoblocos grandes)	1	ST	☐	☐	30.05.2022	31.12.9999		☐		00000005
☐ 0060	T	Rubber block 2-laps (Sinoblocos peq) 8	1	ST	☐	☐	30.05.2022	31.12.9999		☐		00000006
☐ 0070	T	Rubber Curtain 8	1	ST	☐	☐	30.05.2022	31.12.9999		☐		00000007
☐ 0080	T	Sieve Grids 8	1	ST	☐	☐	30.05.2022	31.12.9999		☐		00000008

Equipment BOMs must be updated as necessary and reviewed periodically to ensure its continued accuracy.

4.2.6 Maintenance Plan Creation

Maintenance strategies and task lists are the most important elements required to build a preventive maintenance program for a plant. Understanding how these strategies work and how to create them is crucial to assure the integrity of the maintenance plan.

A maintenance plan is responsible for arranging the scheduling of planned maintenance for a technical object, and for generating call objects (e.g., orders, notifications, etc).

The primary purpose of maintenance plans is to produce different types of call objects that will be generated at a specific time for performance intervals, and a technical object.

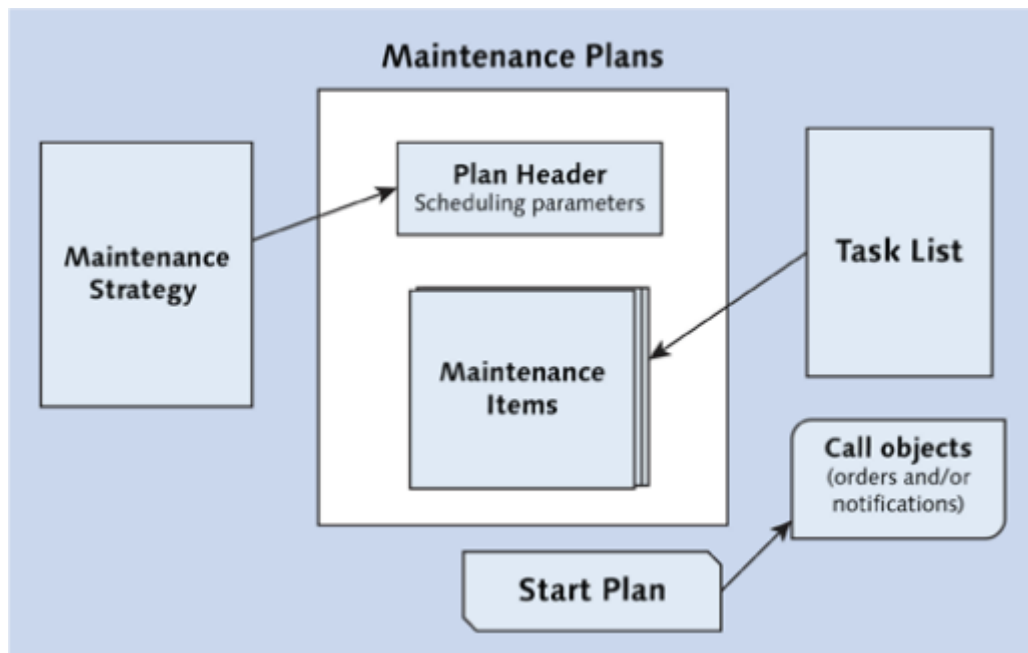


Figure 17 – Maintenance Objects Relationship

The maintenance plan generates orders automatically or manually and ties all the planned maintenance objects together:

- Maintenance strategy
- Task lists
- Maintenance items
- Maintenance scheduling

To create the maintenance plan in SAP, the transaction “IP01 – Creation of a Maintenance Plan” is used. The first thing to do is to define the maintenance plan category, which indicates the type of call object the maintenance plan should generate. For this project the call object was “Maintenance”.

When the General Data screen appears the plan’s main tabs need to be filled properly. The name of the maintenance plan is composed as follows “BBIG – Man.” + Equipment name and number. To each new maintenance plan is automatically assigned a number, which must be registered so that adjustments can be made in the future.

In the Reference Object section, the selection of the equipment must be done to associate this plan to the respective machine.

The fields filled in the Planning Data section will be copied to the call object generated by the maintenance plan. To be able to fulfill this section, the creation of a work center was necessary. A work center is a group of people, technicians or experts who physically carry out maintenance activity on different areas like mechanical, electrical and instrumentation. For this purpose, it was necessary to resort to transaction “IR01”.

Continuing with the creation of the plan, the Task List section is found, which includes the maintenance activity scope of work, materials required, tools and is where a new list can be created with its tasks and respective periodicities or a previously created list can be selected. This second option was used when different plans of the same equipment class were created (e.g. some conveyors have the same maintenance plan, so only one list was created and then was associated to each maintenance plan of every conveyor).

It is worth noting that when establishing the periodicities it is necessary to respect the following periodicity package. The following table shows the periodicities used in the maintenance plans of the recycling plant.

Table 19 – Periodicity Packages

Periodicity package	Real Periodicity
2	1 week
6	4 weeks = 1 month
20	13 weeks = 3 months
28	26 weeks = 6 months
32	52 weeks = 1 year
38	104 weeks = 2 years
44	208 weeks = 4 years

Finally, it is necessary to set some scheduling parameters, which define how the scheduling will be calculated:

- **Tolerance for Late Completion (%)** – when the real completion date is after the planned date, the tolerance consists of the period that won't affect the next planned date for a maintenance plan.
- **Shift Factor for Late Completion (%)** – When the real completion date is out of late tolerance, the shift factor for late completion will determine the period that will shift forward the subsequent schedules for a maintenance plan as a result of late completion.

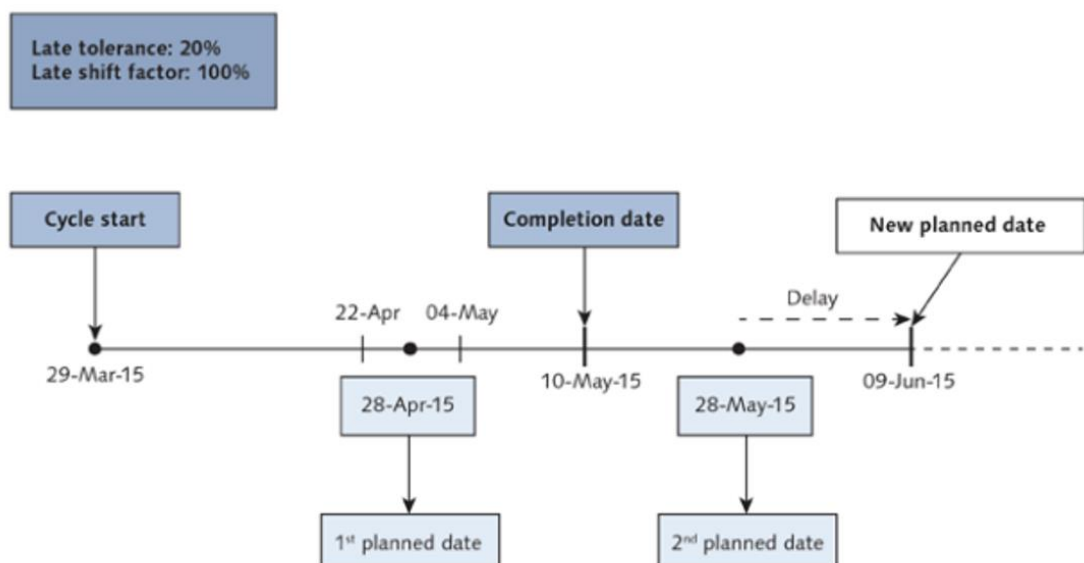


Figure 18 – Scheduling Parameters

The values chosen in this project were 20% for the late tolerance and 100% for the late shift factor. Therefore, as can be seen in the example in the Figure 18, for a monthly maintenance plan, if the completion date is more than 20% late, the subsequent schedules will be shifted

forward as a result of the different shift factors for late completion. In Figure 18, the current completion date is 12 days ahead of the original planned date and the next planned date is shifted forward 12 days, since the late factor is 100%.

Similarly, there also exist:

- **Tolerance for Early Completion (%)** – when the real completion date is before the planned date, the tolerance consists of the period that will not affect the next planned date for a maintenance plan.
- **Shift Factor for Early Completion (%)** – When the completion date is out of early tolerance, then the shift factor for early completion will determine the period that will revise a maintenance plan's subsequent schedules as a result of early completion.

The values chosen in this project were 100% for the early tolerance and 100% for the early shift factor.

Using SAP to manage maintenance plans offers the following advantages:

- Automation of the planned maintenance scheduling;
- Automating the generation of work orders and notifications to the work center;
- Easier planning and controlling of the manpower, tools, and spares required to perform planned maintenance;
- A simplified process for determining which equipment is due for maintenance;
- Improving regulatory compliance with environmental, health and safety issues;
- A clear statistical analysis and trending of the planned maintenance process.

4.2.7 Schedule Maintenance Plan

After creating a maintenance plan and assigning it to an appropriate maintenance strategy and task list, there's the need to schedule the plan. This section will go through the different techniques used when scheduling maintenance plans.

To proceed with this programming the transaction used should be the "IP10 - Schedule Maintenance Plan", where the maintenance plan SAP number we want to schedule should be entered. Then the desired date for starting preventive maintenance must be indicated.

The scheduling call list will be available in the following screen, according to the parameters filled in when creating the plans.

Call number	Planned date	Scheduling type/status	Call date	Called from
1	16.06.2022	New start Called		IP1020220523
2	14.07.2022	Scheduled Hold	16.06.2022	
3	11.08.2022	Scheduled Hold	14.07.2022	
4	08.09.2022	Scheduled Hold	11.08.2022	
5	06.10.2022	Scheduled Hold	08.09.2022	
6	03.11.2022	Scheduled Hold	06.10.2022	
7	17.11.2022	Scheduled Hold	03.11.2022	
8	01.12.2022	Scheduled Hold	17.11.2022	
9	29.12.2022	Scheduled Hold	01.12.2022	
10	26.01.2023	Scheduled Hold	29.12.2022	
11	23.02.2023	Scheduled Hold	26.01.2023	

Figure 19 – Screen Vibrating Feeder 8 Schedule Plan

The methodology chosen for scheduling maintenance respects certain rules:

- 1) Maintenance should be carried out by zones, since, as explained in chapter 4.2.1, the location of the equipment is based on factory zones;
- 2) Procedures that require long downtime, were allocated to the “stop for maintenance” weeks (mid-May and mid-November);
- 3) Lubrication routes were proposed, since it is an action that can be performed with the plant running.

Taking into account these three main considerations, an Excel calendar was made with all the actions scheduled for the year 2023. Some versions were made and presented to the plant manager, and the chosen proposal can be found in Appendix C. The scheduling in SAP is based on this calendar.

It should be noted that after the implementation of these schedules, some adjustments should be made so that it is in accordance with the technicians' work rhythm.

4.2.8 Work Orders

After the maintenance plan is scheduled, it is obligatory on a daily basis to “Call the Orders” of that day. This procedure must be carried out by the engineer in charge and, in addition to this, he must also print out and give the work order forms to the person who will carry out the maintenance.

These forms can be found in Appendix D are divided into four sections:

- In the header is the general order information, such as the name, factory to which it applies and SAP code of the plan;
- In the second section it is possible to find more information including the type of order, workshop, machine where the maintenance is done and the start date. Here also the closing date has to be filled in manually by the engineer;
- The next section is reserved for operations, giving information on the procedures that must be carried out.
- Finally, the last section of the forms is an area for the employee to fill in. Here the employee must ensure that he/she completes the maintenance leaving the site clean and tidy. He can also leave a remark along with his signature.

When the form is fully completed it should be delivered to the engineer in charge, so that he closes the order in SAP. After the order is closed, the system calculates the next maintenance date based on the periodicity.

4.3 Spare Parts Warehouse Organization

At BA Glass, the organization of spare parts is essential to maintain its maintenance policy. It is crucial to be aware of all the material in the company's possession and where it is organized.

Manzini (2012) affirms that through time, the importance of warehousing and material handling has increased, becoming one of the most critical aspects of the global supply chain. Additionally, since this warehouse functionality is essential for the business to run, it becomes one of the most challenging to operate (Bartholdi & Hackman, 2017, p. 8).

Rouwenhorst et al. (2000) states that the redesign of a warehouse is quite complex, since there are a large number of alternative solutions, as well as the presence of trade-off decisions between objectives.

The BBIG spare parts warehouse is located in one of the BA Glass warehouses. It contains 6 pallet racks with 5 levels each (represented in blue rectangles). As represented in the figure below, the initial state of the organisation was poor, with most parts scattered on the warehouse floor. Each object in the warehouse was numbered and each number presents its description in table 20.

Initially, it was necessary to make an intensive collection of all the sub-equipment and components that were stored in the warehouse, not only to link it to the respective mother equipment, but also to provide more grounds for a reasoned reorganisation. Meetings had to be held with the more experienced staff in order to obtain confirmation of the information drawn.

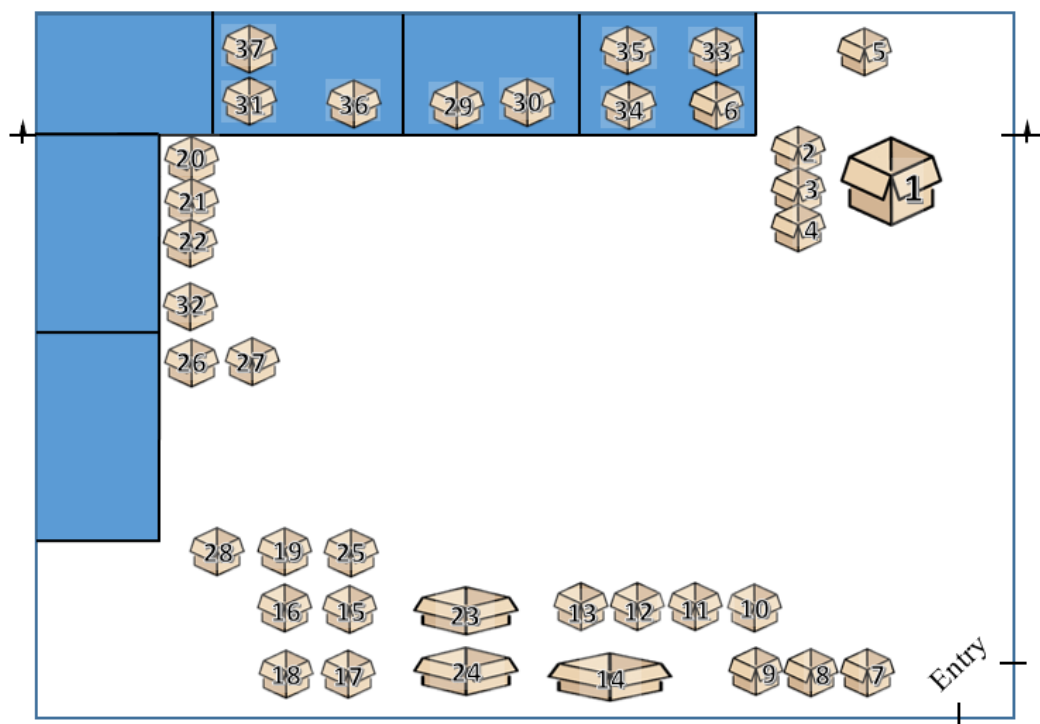


Figure 20 – Initial State of the Warehouse

Table 20 – Spare Parts List

ID	Spare Part	ID	Spare Part
1	Famanfil 34 boxes: PE HIP 550; Qnt.: 30; measurement: 167x4530 c/ snap + fundo c/ ref 60mm + prot. Linhas	20	Vibrations motor 337 F 250-6-2.3; 1,0 kW power, n=980R/min
2	Vibrations motor 300 F95-4-2.2; 1500 rpm; 50 Kg	21	Vibrations motor 342 F 680-6-3.4; 1,7 kW power, 980 rpm
3	Vibrations motor 323 F1000-6-4,7; P=2,7 kW	22	Vibrations motor 343/345 FT 125-4-2.4; P:0,6kW
4	Vibrations motor 304 F200-4-2.1; P:1,1KW	23	Lamps and Glazing

5	Wam Group WDF 17202021	24	Valve Block from line 1 clarity 6
6	Anti-wear blinding back wall CLN10; XUYT2525	25	Screen Vibrating Feeder's Eccentric 8 e 30; xoe102507; s1000 E= 16,sl
7	Screws M20 e Washers	26	Large Roller Glass Crusher 11 Binder WGB 470/710; n° series B- 0135; 2007
8	Shaft with flange WGB 470/710 – XUWB 1026	27	Bearings X-life 22316-E1-XL X4
9	Blue PC Cabin	28	Engine 3 AL160M/L-02 do small burner's ventilator
10	Vibrations motor 354 F235-4-3.4; P:1,4KW; n:1460rpm	29	Engine SEW from roller crusher 11 KA77 DRN132S4/TF
11	Vibrations motor 356 F850-6-4,7; p:2,7KW	30	Engine SEW from roller crusher 11 KA77 DRN132S4/TF
12	Vibrations motor 343/345 FT 125-4- 2,4; P:0,6kW	31	Engine Screw Conveyor SEW FA77/G DRN100LS4; 1450rpm; 2,2kW; Position M3
13	CENEMESA Engine WT260M-4; P:125cv; n=1470rpm; 3 phases (Belongs to filters 384/380 – ventilator's suction)	32	Delabelling Blades 320
14	Screw Conveyor Shafts SC 250	33	Engine 355/11 SEW KA77 DRN132S4/TF; 5,5kW
15	Engine SEW FA57 DRN80M4	34	Conveyor Rolls
16	Engine PE30-250 M-2; 55kW; 2980 rpm; 468kg	35	Crossbars for attaching grids from screen vibrating feeders 8/30
17	Engine Universal Motors SK 100L/40 (belongs to filter 308 – suction of hot ventilators)	36	Delabelling Blades 320 (newer than 32)
18	Ventilator 's engine Siemens 1LA5 220-4AA60 2255; 37kW, Rotor (Big burner 306)	37	Conveyor belt EP250/2 6+2
19	Engine 26/303 SEW SEW FH97 DV160M4/RS; 11kW; n=1440rpm (pink)		

In a first analysis of the information gathered, it was possible to note the following points:

- The non-utilization of the racks jeopardized space optimization and hampered movement around the warehouse;
- There was no type of methodology in the organization;
- There was no record of the equipment in the warehouse, which often led to unnecessary purchases of spare parts.

That said, the drafting of the new organization sought to address these initial problems. To this end, a virtual draft was made, which allocated all the material to their new locations.

OUT OF SERVICE MATERIAL			OUT OF SERVICE MATERIAL		
		EXTRAS			
CLARITY	CONVEYOR		VIBRATIONS	MOTOR DE VIBRATION	FEEDER
SCREEN-FEEDER	DELABELLING	VENTILATOR	FAN		CRUISHER
SCREW CONV				BURNER	

Figure 21 – New Warehouse Organization Map

As it is possible to verify, all the material will now be organized in the shelves, except for materials number 1 and 9, since they consist of large components. One of the main focuses was to keep the spare parts grouped by typology, so that in each region there will be an indicative plaque of the equipment to which it belongs.

In addition to this, the equipment with higher turnover and larger dimensions were placed on the lower shelves for easy access. The upper rows were used for out-of-order materials or extras that are not so popular.

Using a forklift, the warehouse was then reorganized, and the current locations are, therefore, documented in a file, which should always be updated when anything changes. In this way, any employee can be informed about the stored spare parts.

4.4 Results of the Implementations

This chapter is intended to demonstrate the results obtained during the elaboration of the dissertation. It seeks to clarify how the objectives expressed in Chapter 1 have been effectively met.

Regarding equipment, maintenance plans and equipment repairable parts and BOMs:

- 1 plant area was created, with 9 installations and 34 zones per installation;
- 118 equipment with all the most important information regarding references and codes for ordering;
- 18 different maintenance lists and that completed 102 maintenance plans;
- 97 engines and 12 other repairable parts with all the most important information regarding references and codes for ordering;
- 240 components that are part of the BOMs of the equipment.

The creation of this equipment in SAP was based on the need to have access, on a centralised platform, to relevant information. Now this information is easily found, also speeding up the process of ordering new equipment.

Essentially, the task lists enable the identification of the operations to be carried out for the various typology of equipment. Thus, maintenance plans associate a piece of equipment with

a given task list, that is to say that they identify which operations are to be performed on that equipment.

By time this dissertation was published, the company was already using this new preventive maintenance system. Daily, the planned maintenance orders are released with information of the actions to take. In order to inform the operators on what to do, Work Orders, like the one presented in Appendix D are downloaded from SAP, printed and delivered to the maintenance manager. After the procedure is completed, the order is closed in SAP by the Engineer and the periodicity starts recounting. With this project there is more control on this type of actions and, with time, effects like the ones mentioned through this dissertation are going to be realities.

Since this project has not been under development for a long time and since preventive maintenance does not produce visible results in the short term, it is not possible to demonstrate the new values for the key performance indicators.

5 Review, Conclusions and Future Work Perspectives

This chapter outlines the conclusions of the work developed in this project, with a final revision of the obtained results. Future work forecasting is also addressed by following up on technology development, with the final goal of increasing efficiency.

5.1 Review and Conclusions

The importance of the maintenance in the structure of a company is related to the way it's organized which, in turn, depends on the nature of the production process and the size of the organization. With the growing concern of the companies' productive sector in maximizing the profit from their operations, it is essential to look for new ways to reduce losses, in order to increase revenue and reduce costs. Maintenance in one hand requires spending on technicians capable of carrying out the precise tasks, on the other, the scope of this function in an organization is to reduce indirect costs derived from productivity losses, or higher costs derived from the loss of functionality of the equipment.

A more adequate maintenance policy is one that seeks to balance these costs optimally, ensuring the best relationship between equipment availability and its performance. Additionally, it is widely accepted that a successful preventive maintenance program in conjunction with well-trained and motivated workers allows the optimization of efficiency and a good relation cost/benefit.

The initial problem proposition motivating the elaboration of this dissertation respects equipment downtime analysis, due to lack of control over the event, which impacts availability. Therefore, there was a need to study in more detail the historical failures and elaborate the preventive maintenance plan.

To this end, all the information related to the equipment was gathered, including locations, manufacturers' recommendations on maintenance and list of consumables. All this information, taken from manuals and the actual monitoring of the production line, allowed the drawing of a plan that corresponded to BBIG's needs.

In order to map and simplify the individual processes of maintenance orders as precisely as possible, the implementation in SAP was crucial. To this end were created:

- 1 Plant's Area AVL, 9 Installations, 34 Installation's zones and 118 Equipment;
- 18 Maintenance lists and 102 maintenance plans.

By creating new equipment and its locations in the SAP structure, it is now possible to access to relevant information about each of these on a centralized platform. With the creation of maintenance plans in SAP, the company is now preventively acting in the occurrence of equipment failures, which makes it possible to drastically reduce the need to resort to corrective maintenance, implementing a zero-failure philosophy.

In addition, the reorganization of the spare parts warehouse was also carried out in order to maintain the maintenance policy. Now it is possible to easily and quickly find the necessary sub-equipment for maintenance and replacements.

It should be noted that the plan was presented and given applicability, it was implemented, making all the initially proposed objectives to be accomplished, notably:

- The study the failure rate behavior of the various equipment, presented in chapter 3.3.1;
- The knowledge on the machines that make up the BBIG plant, in chapter 3.1;
- The planning of the maintenance of all equipment and setting of performance dates, presented in chapter 4.1.1;
- The scheduling in SAP, including the addition of information about the main consumables of each machine, in chapter 4.2;

Finally, it is expected that over time investment and improvements will be made, in order to achieve the highest possible OEE value: the "world-class" OEE above 80.00%.

5.2 Future Work Perspectives

Since, when it comes to preventive maintenance, a constant evolution is possible and necessary, there are some proposals for future work that will be interesting to be analyzed for future implementation in the context of this project. Namely:

- The implementation of a warehouse management system that has all the important information on the available inventory and records an accurate historical stock log. This allows the management to assign stock turnover parameters, controlling supply and avoiding stockouts.

This system is a necessity for the current organization of the warehouse, because although there is a mapping of the entire stock, it is not automated in order to update it whenever a part is used.

- Adapt the maintenance applications created in SAP to Fiori. Fiori is a set of cross-device applications that address the most used SAP's functions, allowing the users to start a process in a desktop and continue it on a smartphone.

The properties of this application will make it possible to digitalize and speed up the closing of work orders, making it unnecessary to print them out for filing. The closing of the order can be done directly through the mobile phone of the workers, and they must insert important photographs and relevant notes for future maintenance.

- It is suggested that a continuous review be carried out to the SAP structure, so that it always remains updated regarding equipment, its locations and sub-equipment. In this way, it is advisable that the company continues to improve its structure using the methodology described in this dissertation.

The codification of the BOMs in SAP should be completed, since this way the whole process of purchase, stock management and monitoring of consumption will become more responsive.

- Another key aspect for the future is the contracting of a qualified professional to support maintenance tasks, in order to decentralize them. This allows faster and more effective maintenance actions and will increase equipment availability and reduce indirect costs, as well as the number of breakdowns.

- Something very important would be to educate workers in SAP, so that they can consult the work to be done directly from the system and so that the task of closing work orders becomes something more environmentally friendly, without paper prints and without having to go through the chief engineer.
- Finally, another proposal for future work would be the elaboration OEE reports. Through the daily registration of parameters, which allow the calculation of Quality, Efficiency and Availability (mentioned in subchapter 2.1.7), an automatic chart would be generated, using the programming tool Node Red.

Node Red is a tool used for wiring hardware devices, APIs and online services. It uses a visual programming approach that allows developers to connect predefined code blocks (nodes) together to perform a task.

The base idea would be to create a MQTT (a lightweight, publish-subscribe network protocol that transports messages between devices) with the information related to the production processes, including the production time, downtimes, quantity produced,...

With this MQTT and some simple programming skills, using Node-Red, it is possible to work this information into charts. This data analysis is important to increase production efficiency, so that a company can deliver maximum value for the least possible cost.

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Appendix A: Maintenance Plan

Machine	Procedure	Periodicity
Tremonha1	Verificar corrosão	Anual
	Verificar estado dos mosaicos	Anual
	Verificar estado da Rosca	Anual
Tremonha 3	Verificar corrosão	Anual
	Verificar estado dos mosaicos	Anual
	Verificar estado da Rosca	Anual
Tremonha de Finos 350	Verificar corrosão	Anual
	Verificar estado dos mosaicos	Anual
	Verificar estado da Rosca	Anual
Tremonha 301	Verificar corrosão	Anual
	Verificar estado dos mosaicos	Anual
	Verificar estado da Rosca	Anual
Calha vibratória 2	Verificar forras bi-metálicas	Anual
Calha vibratória 4	Verificar forras bi-metálicas	Anual
Calha vibratória/Canal vibrado 322	Verificar forras bi-metálicas	Anual
Calha vibratória/Canal vibrado 300	Verificar forras bi-metálicas	Anual
Calha vibratória/Canal vibrado 21	Verificar forras bi-metálicas	Anual
Calha vibratória/Canal vibrado 207	Verificar forras bi-metálicas	Anual
Balança 6	Limpar Balança	Semanal
	Calibração da Balança	Mensal
Balança 302.2	Limpar Balança	Semanal
	Calibração da Balança	Mensal

Balança 80	Limpar Balança	Semanal
	Calibração da Balança	Mensal
Canal de alimentação 351	Verificar forras bi-metálicas	Anual
Canal de alimentação 302	Verificar forras bi-metálicas	Anual
Tapete 351.b	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 302.1	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 320.1	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 321	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 58	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal

	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 15	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 16	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 22	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 24	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 68	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 54	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 204	Verificar limpeza do motor do tapete	Mensal

	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 205	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 206	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 208	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 340	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 5	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 10	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal

	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 324	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 33	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 61	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Tapete 358	Verificar limpeza do motor do tapete	Mensal
	Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete	Mensal
	Verificar existencia de rasgões ao longo da tela e no empalme do tapete	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Lubrificar rolamentos localizados no tapete	Mensal
Queimador 331	Limpar a vela	Semestral
	Limpar o eletrodo	Semestral
Queimador 306	Limpar a vela	Semestral
	Limpar o eletrodo	Semestral
Ventilador 332	Limpar pás interiores	Semestral
	Verificar estado do motor	Semestral
	Verificar vibrações	Semestral
Ventilador 307	Limpar pás interiores	Semestral
	Verificar estado do motor	Semestral
	Verificar vibrações	Semestral

Ventilador 9	Limpar pás interiores	Semestral
	Verificar estado do motor	Semestral
	Verificar vibrações	Semestral
Ventilador 311	Limpar pás interiores	Semestral
	Verificar estado do motor	Semestral
	Verificar vibrações	Semestral
Ventilador 383	Limpar pás interiores	Semestral
	Verificar estado do motor	Semestral
	Verificar vibrações	Semestral
Ventilador 387	Limpar pás interiores	Semestral
	Verificar estado do motor	Semestral
	Verificar vibrações	Semestral
Ventilador 64	Limpar pás interiores	Semestral
	Verificar estado do motor	Semestral
	Verificar vibrações	Semestral
Sem fim 339	Verificar estado do motor	Mensal
	Mudar óleo da caixa redutora	Anual
	Trocar hélices	4 em 4 anos
	Lubrificar rolamento lado do motor/ outro lado e rolamento intermédio	Mensal
Sem fim 339.1	Verificar estado do motor	Semestral
	Mudar óleo da caixa redutora	Anual
	Trocar hélices	4 em 4 anos
	Lubrificar rolamento lado do motor/ outro lado e rolamento intermédio	Mensal
Sem fim 339.2	Verificar estado do motor	Semestral
	Mudar óleo da caixa redutora	Anual
	Trocar hélices	4 em 4 anos
	Lubrificar rolamento lado do motor/ outro lado e rolamento intermédio	Mensal
Sem fim 309	Verificar estado do motor	Semestral
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Trocar hélices	4 em 4 anos
	Lubrificar rolamento lado do motor/ outro lado e rolamento intermédio	Mensal
Sem fim 336	Verificar estado do motor	Mensal
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Mudar óleo da caixa redutora	Anual
	Trocar hélices	4 em 4 anos
	Lubrificar rolamento lado do motor/ outro lado e rolamento intermédio	Mensal
Sem fim 381	Verificar estado do motor	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Trocar hélices	4 em 4 anos
	Lubrificar rolamento lado do motor/ outro lado e rolamento intermédio	Mensal

Sem fim 385	Verificar estado do motor	Mensal
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Trocar hélices	4 em 4 anos
	Lubrificar rolamento lado do motor/ outro lado e rolamento intermédio	Mensal
Rascador 320	Verificar estado do motor	Trimestral
	Verificar estado do veio	Trimestral
	Mudar óleo da caixa redutora	Anual
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Verificar estado das pás	Trimestral
	Verificar fitas	Trimestral
Secador 330	Verificar estado dos empalmos	Semestral
	Verificar estado das chapas	Semestral
Secador 305	Verificar estado dos empalmos	Semestral
	Verificar estado das chapas	Semestral
Crivo 337	Verificar sino-blocos	Semestral
	Verificar moto-vibradores	Semestral
		Mensal
Crivo 338	Verificar sino-blocos	Semestral
	Verificar moto-vibradores	Semestral
		Mensal
Crivo 323	Verificar sino-blocos	Semestral
	Verificar moto-vibradores	Semestral
Crivo 65	Verificar sino-blocos	Semestral
	Verificar moto-vibradores	Semestral
		Mensal
Crivo 201	Verificar sino-blocos	Semestral
	Verificar moto-vibradores	Semestral
		Mensal
Crivo 359	Verificar sino-blocos	Semestral
	Verificar moto-vibradores	Semestral
		Mensal
Crivo 8	Verificar sino-blocos	Semestral
	Verificar moto-vibradores	Semestral
	Lubrificar rolamentos	Mensal
Crivo 356	Verificar sino-blocos	Semestral
	Verificar moto-vibradores	Semestral
		Mensal
Crivo 30	Verificar sino-blocos	Semestral
	Verificar moto-vibradores	Semestral
	Lubrificar rolamentos	Mensal
Crivo 342	Verificar sino-blocos	Semestral

	Verificar moto-vibradores	Semestral
		Mensal
Elevador 303	Verificar danos na estrutura	Semestral
	Verificar copos	Trimestral
	Verificar estado do motoredutor do elevador	Semestral
	Mudar óleo da caixa redutora	Anual
Elevador 26	Verificar danos na estrutura	Semestral
	Verificar copos	Trimestral
	Verificar estado do motoredutor do elevador	Semestral
	Mudar óleo da caixa redutora	Anual
Elevador 341	Verificar danos na estrutura	Semestral
	Verificar copos	Trimestral
	Verificar estado do motoredutor do elevador	Semestral
	Controlo de temperatura motor/ caixa redutora/ rolamentos	Mensal
	Mudar óleo da caixa redutora	Anual
Elevador 353	Verificar danos na estrutura	Semestral
	Verificar copos	Trimestral
	Verificar estado do motoredutor do elevador	Semestral
	Mudar óleo da caixa redutora	Anual
Mesa vibrada 304	Verificar forras bi-metálicas	Semestral
mesa 66	Verificar forras bi-metálicas	Semestral
Mesa vibrada 301	Verificar forras bi-metálicas	Semestral
Mesa vibrada 202	Verificar forras bi-metálicas	Semestral
mesa 39	Verificar forras bi-metálicas	Semestral
mesa 43	Verificar forras bi-metálicas	Semestral
mesa 47	Verificar forras bi-metálicas	Semestral
Mesa vibrada 345	Verificar forras bi-metálicas	Semestral
mesa 37	Verificar forras bi-metálicas	Semestral

mesa 41	Verificar forras bi-metálicas	Semestral
mesa 45	Verificar forras bi-metálicas	Semestral
Mesa vibrada 343	Verificar forras bi-metálicas	Semestral
Mesa vibrada 354	Verificar forras bi-metálicas	Semestral
Clarity 67	Substituir vidro	Trimestral
	Trocar o elemento filtrante do ar comprimido	Anual
	Trocar dissipador de condensado	Anual
Clarity 203	Substituir vidro	Trimestral
	Trocar o elemento filtrante do ar comprimido	Anual
	Trocar dissipador de condensado	Anual
Clarity 40	Substituir vidro	Trimestral
	Trocar o elemento filtrante do ar comprimido	Anual
	Trocar dissipador de condensado	Anual
Clarity 44	Substituir vidro	Trimestral
	Trocar o elemento filtrante do ar comprimido	Anual
	Trocar dissipador de condensado	Anual
Clarity 48	Substituir vidro	Trimestral
	Trocar o elemento filtrante do ar comprimido	Anual
	Trocar dissipador de condensado	Anual
Clarity 346	Substituir vidro	Trimestral
	Trocar o elemento filtrante do ar comprimido	Anual
	Trocar dissipador de condensado	Anual
Clarity 38	Substituir vidro	Trimestral
	Trocar o elemento filtrante do ar comprimido	Anual
	Trocar dissipador de condensado	Anual
Clarity 42	Substituir vidro	Trimestral
	Trocar o elemento filtrante do ar comprimido	Anual
	Trocar dissipador de condensado	Anual
Clarity 46	Substituir vidro	Trimestral
	Trocar o elemento filtrante do ar comprimido	Anual
	Trocar dissipador de condensado	Anual
Clarity 344	Substituir vidro	Trimestral
	Trocar o elemento filtrante do ar comprimido	Anual
	Trocar dissipador de condensado	Anual
Estrutura 371	Verificar danos na chapa	Semestral
Estrutura 101	Verificar danos na chapa	Semestral

Moinho 11	Lubrificar rolamentos	mensal
	Substituir rolos	2 em 2 anos
Moinho 355	Lubrificar rolamentos	mensal
	Substituir rolos	2 em 2 anos
Corpo 100	Verificar buracos na chapa da estrutura metálica	Semestral
Corpo 370	Verificar buracos na chapa da estrutura metálica	Semestral
Filtro 308.1	Verificar condições da chapa	Semestral
	Trocar mangas	Semestral
Filtro 308.2	Verificar condições da chapa	Semestral
	Trocar mangas	Semestral
Filtro 380	Verificar condições da chapa	Semestral
	Trocar mangas	Semestral
Filtro 384	Verificar condições da chapa	Semestral
	Trocar mangas	Semestral
Quadro elétrico	temperatura 22 graus	Semestral
	Temperatura 24 graus	Semestral
Empilhador	Revisão	A cada 250h
Pá carregadora 1	Revisão	A cada 500h
	Substituição do equipamento	A cada 5 anos/10000h
Pá carregadora 2	Revisão	A cada 500h
	Substituição do equipamento	A cada 5 anos/10000h
Ar condicionado	Externo (Subcontratado)	Semestral
	Interno (canina e gabinete do sr. Vitor)	Semestral

Appendix B: Availability Calculation (Example Jan 2021)

Data	Fabrica	Turno	Verde Ton/8H	Verde Horas Trab	HORAS	MINUTOS
2021-01-01	BBIG	3	193,2	8	8	0
2021-01-01	BBIG	1	176	7,3	7	30
2021-01-01	BBIG	2	182,1	7,3	7	30
2021-01-02	BBIG	3	184,1	7,5	7	50
2021-01-02	BBIG	1	164,8	7,2	7	20
2021-01-02	BBIG	2	162,7	7,2	7	20
2021-01-03	BBIG	3	179,4	8	8	0
2021-01-03	BBIG	1	153	7,1	7	10
2021-01-03	BBIG	2	149,3	7,1	7	10
2021-01-04	BBIG	3	167,5	8	8	0
2021-01-04	BBIG	1	143,4	7	7	0
2021-01-04	BBIG	2	154,3	7,2	7	20
2021-01-05	BBIG	3	164,5	7,1	7	10
2021-01-05	BBIG	1	116,8	4,3	4	30
2021-01-05	BBIG	2	164,6	7,3	7	30
2021-01-06	BBIG	3	176,4	7,3	7	30
2021-01-06	BBIG	1	159,8	7,1	7	10
2021-01-06	BBIG	2	154,9	7	7	0
2021-01-07	BBIG	3	184,3	8	8	0
2021-01-07	BBIG	1	165,5	7	7	0
2021-01-07	BBIG	2	167,6	7,1	7	10
2021-01-08	BBIG	3	187,9	8	8	0
2021-01-08	BBIG	1	157,2	6,5	6	50
2021-01-	BBIG	2	165,5	7,2	7	20

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08							
2021-01-09	BBIG	3	171,6	7,3	7	30	
2021-01-09	BBIG	1	161,3	7	7	0	
2021-01-09	BBIG	2	166,4	7,2	7	20	
2021-01-10	BBIG	3	170,6	7,5	7	50	
2021-01-10	BBIG	1	156,5	7,1	7	10	
2021-01-10	BBIG	2	163,2	7,1	7	10	
2021-01-11	BBIG	3	163,1	7,1	7	10	
2021-01-11	BBIG	1	154,9	7,3	7	30	
2021-01-11	BBIG	2	153,8	7,3	7	30	
2021-01-12	BBIG	3	163	8	8	0	
2021-01-12	BBIG	1	139,7	7,1	7	10	
2021-01-12	BBIG	2	149,1	7,2	7	20	
2021-01-13	BBIG	3	163	8	8	0	
2021-01-13	BBIG	1	139,4	7,1	7	10	
2021-01-13	BBIG	2	152	7,2	7	20	
2021-01-14	BBIG	3	169,2	8	8	0	
2021-01-14	BBIG	1	137,5	7	7	0	
2021-01-14	BBIG	2	157,3	7,3	7	30	
2021-01-15	BBIG	3	162,6	7,4	7	40	
2021-01-15	BBIG	1	162,6	7,2	7	20	
2021-01-15	BBIG	2	166,5	7,2	7	20	
2021-01-16	BBIG	3	173,9	8	8	0	
2021-01-16	BBIG	1	152,5	7,2	7	20	
2021-01-16	BBIG	2	158,3	7,3	7	30	
2021-01-17	BBIG	3	175,9	8	8	0	
2021-01-17	BBIG	1	154,8	7,3	7	30	
2021-01-17	BBIG	2	129,2	7,2	7	20	
2021-01-18	BBIG	3	163,3	8	8	0	
2021-01-18	BBIG	1	145,7	7,3	7	30	
2021-01-18	BBIG	2	157,3	6,5	6	50	
2021-01-19	BBIG	3	178,6	8	8	0	

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2021-01-19	BBIG	1	137	7,2	7	20
2021-01-19	BBIG	2	151,1	7,2	7	20
2021-01-20	BBIG	3	171,9	8	8	0
2021-01-20	BBIG	1	157,1	7,2	7	20
2021-01-20	BBIG	2	149,7	7,2	7	20
2021-01-21	BBIG	3	158,3	8	8	0
2021-01-21	BBIG	1	0	8	8	0
2021-01-21	BBIG	2	102,7	5,3	5	30
2021-01-22	BBIG	3	163,8	8	8	0
2021-01-22	BBIG	1	145,8	7,2	7	20
2021-01-22	BBIG	2	130,8	7,2	7	20
2021-01-23	BBIG	3	158,7	8	8	0
2021-01-23	BBIG	1	144	7,2	7	20
2021-01-23	BBIG	2	138,4	7	7	0
2021-01-24	BBIG	3	149,5	6,4	6	40
2021-01-24	BBIG	1	144,6	7,2	7	20
2021-01-24	BBIG	2	142,8	7,2	7	20
2021-01-25	BBIG	3	155,7	8	8	0
2021-01-25	BBIG	1	133,1	7	7	0
2021-01-25	BBIG	2	138,4	7,2	7	20
2021-01-26	BBIG	3	157,2	7,3	7	30
2021-01-26	BBIG	1	153,7	7,3	7	30
2021-01-26	BBIG	2	138,4	7,1	7	10
2021-01-27	BBIG	3	154,9	8	8	0
2021-01-27	BBIG	1	146,1	7,3	7	30
2021-01-27	BBIG	2	121,5	5,5	5	50
2021-01-28	BBIG	3	156,2	7,3	7	30
2021-01-28	BBIG	1	120,8	6	6	0
2021-01-28	BBIG	2	152,4	7,2	7	20
2021-01-29	BBIG	3	166,2	8	8	0
2021-01-29	BBIG	1	152,5	7,2	7	20
2021-01-	BBIG	2	160,6	7,2	7	20

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29						
2021-01-30	BBIG	3	174	8	8	0
2021-01-30	BBIG	1	152,2	7,1	7	10
2021-01-30	BBIG	2	156,7	7,2	7	20
2021-01-31	BBIG	3	172,1	8	8	0
2021-01-31	BBIG	1	158	7,2	7	20
2021-01-31	BBIG	2	148,3	7,1	7	10
						1430
					640	23,83333333
				Montly Production Hours=	663,83333	
				Montly Total Hours=	697,5	
		1,5		Availability=	95,173238	

Appendix C: Maintenance planning for the year 2023

January

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
	Weight Scale: 302.2/6/80	Vibrating Feeder: 21; Coveyor: 22/24	Conveyor: 22/24; Screen Vibrating Feeder: 353	Conveyor: 68; Screen Vibrating Feeder: 30; Bucket Elevator: 26	Screen Vibrating Feeder: 356/345	
8	9	10	11	12	13	14
	Weight Scale: 302.2/6/80	Conveyor: 54/58	Conveyor 205/206/208	Conveyor: 58	Delabeling Machine: 320; Conveyor: 320.1	
15	16	17	18	19	20	21
	Weight Scale: 302.2/6/80	Conveyor: 204/33	Screen Vibrating Feeder: 8; Roller Glass Crusher: 11/355	Conveyor: 5/10/324	Conveyor: 358	
22	23	24	25	26	27	28
	Weight Scale: 302.2/6/80; Conveyor lubrication route	Conveyor: 15/16/61	Vibrating Feeder: 302; Conveyor: 302.1	Screw Conveyor- lubrication route	Conveyor: 321/351b	
29	30	31				
	Weight Scale: 302.2/6/80; Vibrating Feeder: 300	Cyclone Discharge: 371/101; Conveyor: 340; Cyclone: 100/370				

February

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
			Screen Vibrating Feeder: 65; Vibrating Feeder: 66/343/354	Conveyor: 68; Screen Vibrating Feeder: 30; Bucket Elevator: 341/353	Vibrating Feeder: 37/41/45	
5	6	7	8	9	10	11
	Weight Scale: 302.2/6/80	Conveyor: 22/24	Conveyor: 54/320.1	Screen Vibrating Feeder 201; Vibrating Feeder: 207/202	Conveyor: 205/206/208	
12	13	14	15	16	17	18
	Weight Scale: 302.2/6/80; Conveyor: 58	Conveyor: 204	Screen Vibrating Feeder: 8; Roller Glass Crusher: 11/355; Conveyor: 33	Conveyor: 5/10/324;	Burner: 331/306;	
19	20	21	22	23	24	25
	Weight Scale: 302.2/6/80; Conveyor: 358	Conveyor: 15/16/61	Vibrating Feeder: 302; Conveyor: 302.1	Screw Conveyor- lubrication route	Conveyor: 321/351b	
26	27	28				
	Weight Scale: 302.2/6/80; Conveyor lubrication route	Conveyor: 340;				

March

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1 Conveyor: 68; Screen Vibrating Feeder: 30; Bucket Elevator: 26	2 Screw Conveyors	3 Bucket Elevator: 303; Vibrating Feeder: 304	4
5	6 Weight Scale: 302.2/6/80	7 Conveyor: 22/24	8 Conveyor: 54/320.1	9 Conveyor: 205/206/208;	10 Conveyor: 205/206/208;	11
12	13 Weight Scale: 302.2/6/80; Conveyor: 58	14 Conveyor: 204	15 Screen Vibrating Feeder: 8; Conveyor: 33	16 Roller Glass Crusher 11/355	17 Conveyor: 5/10/324	18
19	20 Weight Scale: 302.2/6/80; Conveyor: 358	21 Conveyor: 15/16/61	22 Vibrating Feeder: 302; Conveyor: 302.1	23 Conveyor: 321;	24 Screw Conveyor- lubrication route	25
26	27 Weight Scale: 302.2/6/80	28 Conveyor- lubrication route	29 Conveyor: 340;	30 Conveyor: 351b;	31 Screen Vibrating Feeder: 323	

April

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
2	3 Weight Scale: 302.2/6/80	4 Conveyor: 22/24	5 Conveyor: 68; Screen Vibrating Feeder: 30	6 Conveyor: 205/206/208	7	8
9	10 Weight Scale: 302.2/6/80	11 Hoppers	12 Vibrating Feeder: 54	13 Conveyor: 204/58	14 Delabelling Machine: 320; Conveyor: 320.1	15
16	17 Weight Scale: 302.2/6/80; Vibrating Feeder: 39; Conveyor: 358;	18 Conveyor: 15/16/61	19 Screen Vibrating Feeder: 8; Roller Glass Crusher: 11/355; Conveyor: 33	20 Conveyor: 5/10/324	21 Vibrating Feeder: 302; Conveyor: 302.1	22
23	24 Weight Scale: 302.2/6/80; Conveyor: lubrication route	25	26 Conveyor: 340; Screen Vibrating Feeder: 337/338	27 Conveyor: 321/351b	28 Screw Conveyor- lubrication route	29
30						

May (Underlined in blue is the production stoppage week, dedicated to maintenance only)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1	2	3	4	5	6
		Conveyor: 68; Screen Vibrating Feeder: 30	Screen Vibrating Feeder: 342; Bucket Elevator: 341/353	Bucket Elevator: 341/353	Vibrating Feeder: 43/47	
7	8	9	10	11	12	13
	Weight Scale: 302.2/6/80	Conveyor: 22/24;	Conveyor: 54	Conveyor: 204/320.1	Conveyor: 05/206/208	
14	15	16	17	18	19	20
	Weight Scale: 302.2/6/80; Conveyor: 58	Claritys	Claritys	Ventilators	Filters; Screw Conveyor- lubrication route	
21	22	23	24	25	26	27
	Weight Scale: 302.2/6/80	Conveyor: 15/16/61/358	Screen vibrating Feeder: 8; Roller Glass Crusher: 11/355; Conveyor: 33	Conveyor: 5/10/324	Vibrating Feeder: 302; Conveyor: 302.1	
28	29	30	31			
	Weight Scale: 302.2/6/80; Conveyor: lubrication route	Conveyor: 340	Conveyor: 321/351b			

June

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				1	2	3
				Conveyor: 68; Screen Vibrating Feeder: 30; Bucket Elevator: 26	Bucket Elevator: 303; Dryer: 305	
4	5	6	7	8	9	10
	Weight Scale: 302.2/6/80	Conveyor: 22/24	Conveyor: 54/320.1		Conveyor 205/206/208	
11	12	13	14	15	16	17
	Weight Scale: 302.2/6/80	Conveyor: 204/33/58	Screen Vibrating Feeder: 8; Roller Glass Crusher: 11/355		Conveyor: 5/10/324	
18	19	20	21	22	23	24
	Weight Scale: 302.2/6/80	Conveyor: 358/61	Conveyor: 15/16	Vibrating Feeder: 302; Conveyor: 302.1	Screw Conveyor- lubrication route	
25	26	27	28	29	30	
	Weight Scale: 302.2/6/80; Conveyor: lubrication route	Conveyor: 340	Conveyor: 321/351b			

July

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
2	3	4	5	6	7	8
	Weight Scale: 302.2/6/80	Conveyor: 22/24	Conveyor: 68; Screen Vibrating Feeder: 30/356	Bucket Elevator: 26	Screen Vibrating Feeder: 356; Vibrating Feeder: 345	
9	10	11	12	13	14	15
	Weight Scale: 302.2/6/80	Conveyor: 54/58	Conveyor: 204/205	Conveyor: 206/208	Delabelling Machine: 320; Conveyor: 320.1	
16	17	18	19	20	21	22
	Weight Scale: 302.2/6/80; Conveyor: 358	Conveyor: 15/16/61	Screen Vibrating Feeder: 8; Roller Glass Crusher: 11/355	Conveyor: 5/10/324	Vibrating Feeder: 302; Conveyor: 302.1/33	
23	24	25	26	27	28	29
	Weight Scale: 302.2/6/80; Conveyor: lubrication route	Conveyor: 340	Conveyor: 321/351b	Cyclone Discharge: 371/101	Screw Conveyor- lubrication route	
30	31					

August

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1	2	3	4	5
		Screen Vibrating Feeder: 65; Vibrating Feeder: 343/354	Conveyor: 68; Screen Vibrating Feeder: 30	Bucket Elevator: 341/353	Vibrating Feeder: 374/145	
6	7	8	9	10	11	12
	Weight Scale: 302.2/6/80	Conveyor: 22/24	Conveyor: 54/320.1	Screen Vibrating Feeder: 201; Vibrating Feeder: 207/202	Conveyor: 205/206/208	
13	14	15	16	17	18	19
	Weight Scale: 302.2/6/80; Conveyor: 58	Conveyor: 204/33	Screen Vibrating Feeder: 8; Roller Glass Crusher: 11/355	Conveyor: 5/10/324	Burner: 331/306	
20	21	22	23	24	25	26
	Weight Scale: 302.2/6/80	Conveyor: 358/61	Conveyor: 15/16	Vibrating Feeder: 302; Conveyor: 302.1	Screw Conveyor- lubrication route	
27	28	29	30	31		
	Weight Scale: 302.2/6/80; Conveyor: lubrication route	Conveyor: 340	Conveyor: 321/351b			

September

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1 Conveyor: 68; Screen Vibrating Feeder: 30; Bucket Elevator: 26	2
3	4 Weight Scale: 302.2/6/80	5 Conveyor: 22/24	6 Conveyor: 205/206/208	7 Bucket Elevator: 303; Vibrating Feeder: 304	8 Conveyor: 320.1	9
10	11 Weight Scale: 302.2/6/80	12 Conveyor: 54/58	13 Conveyor: 204/33	14 Screen Vibrating Feeder: 8; Roller Glass Crusher: 11/355	15 Conveyor: 5/10/324	16
17	18 Weight Scale: 302.2/6/80	19 Conveyor: 358/61	20 Conveyor: 15/16	21 Vibrating Feeder: 302; Conveyor: 302.1	22 Screw Conveyor- lubrication route	23
24	25 Weight Scale: 302.2/6/80	26 Conveyor: lubrication route	27 Conveyor: 351b/340	28 Screen Vibrating Feeder: 323; Conveyor: 321	29	30

October

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2 Weight Scale: 302.2/6/80	3 Conveyor: 22/24	4 Conveyor: 68; Screen Vibrating Feeder: 30	5	6 Vibrating Feeder: 322; Dryer: 330	7
8	9 Weight Scale: 302.2/6/80; Conveyor: 58	10 Vibrating Feeder: 54; Conveyor: 204	11 Delabelling Machine: 320; Conveyor: 320.1	12 Conveyor: 205/206/208	13 Conveyor: 61/358	14
15	16 Weight Scale: 302.2/6/80; Vibrating Feeder: 39	17 Conveyor: 15/16	18 Screen Vibrating Feeder: 8; Roller Glass Crusher: 11/355; Conveyor: 33	19 Conveyor: 5/10/324	20 Vibrating Feeder: 302; Conveyor: 302.1	21
22	23 Weight Scale: 302.2/6/80	24 Screen Vibrating Feeder: 337/338	25 Conveyor: lubrication route	26 Conveyor: 340	27 Screw Conveyor- lubrication route	28
29	30 Weight Scale: 302.2/6/80	31 Conveyor: 321/351b				

November (Underlined in blue is the production stoppage week, dedicated to maintenance only)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
				Conveyor: 68; Screen Vibrating Feeder: 30	Screen Vibrating Feeder: 342; Bucket Elevator: 341/353	
5	6	7	8	9	10	11
	Weight Scale: 302.2/6/80	Conveyor: 22/24/54	Vibrating Feeder: 43/47	Conveyor: 204; Delabelling Machine: 320	Conveyor: 205/206/208	
12	13	14	15	16	17	18
	Weight Scale: 302.2/6/80; Vibrating Feeder: 358	Claritys	Claritys	Ventilators	Filters	
19	20	21	22	23	24	25
	Weight Scale: 302.2/6/80; Vibrating Feeder: 358	Conveyor: 15/16/61	Screen vibrating Feeder: 8; Roller Glass Crusher: 11/355; Conveyor: 33	Conveyor: 5/10/324	Vibrating Feeder: 302; Conveyor: 302.1	
26	27	28	29	30		
	Weight Scale: 302.2/6/80; Conveyor: lubrication route	Conveyor: 340/321	Conveyor: 351b; Feeder Chane: 351	Screw Conveyor- lubrication route		

December

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
3	4	5	6	7	8	9
	Weight Scale: 302.2/6/80	Conveyor: 22/24; Bucket Elevator: 303	Conveyor: 68; Screen Vibrating Feeder: 30	Conveyor: 205/206/208		
10	11	12	13	14	15	16
	Weight Scale: 302.2/6/80	Conveyor: 54/58	Conveyor: 204	Bucket Elevator: 303; Dryer: 305	Conveyor: 320.1/358	
17	18	19	20	21	22	23
	Weight Scale: 302.2/6/80; Conveyor: lubrication route	Conveyor: 15/16/61	Screen Vibrating Feeder: 8; Roller Glass Crusher: 11/355	Conveyor: 5/10/324	Vibrating Feeder: 302; Conveyor: 302.1	
24	25	26	27	28	29	30
		Conveyor: 340/33	Vibrating Feeder: 2/4	Conveyor: 351b/321	Screw Conveyor- lubrication route	
31						

Appendix D: Work Orders

BA		ORDEM DE TRABALHO: 8231344 PLANO: 6567		1/1
BA-AV		BBIG- Manutenção Tap 24		
<i>Tipo de ordem:</i>	PREV Manutenção Preventiva	<i>Nota:</i>		
<i>Oficina:</i>	AV17 AV	<i>Emissor:</i>	240	Technical Office
<i>Loc. instalação:</i>	BBIG - Central de Tratamento de	<i>Prioridade:</i>	Baixa	
<i>U.F./Equipamento:</i>	AVL0101TA02 Tapete 24	<i>Semana:</i>	25	
	CONV00305 Mat Conveyor 24	<i>Data início:</i>	21.06.2022	
		<i>Data fecho:</i>	__-__-__	
<i>Operação</i> 0010				
Verificar limpeza do motor do tapete				
<i>Operação</i> 0020				
Verificar limpeza dos veios				
Verificar limpeza do veio dos rolos do lado do motor/ lado do sensor de rotação do tapete _				
<i>Operação</i> 0030				
Verificar existencia de rasgões				
Verificar existencia de rasgões ao longo da tela e no empalme do tapete _				
<i>Operação</i> 0050				
Controlo de temperatura motor/ caixa red				
<i>Operação</i> 0060				
Lubrificar rolamentos localizados no tap				
Após realização da ordem, verificar se o local se encontra limpo e removidos os potenciais contaminantes. Averiguar perda/extravio de ferramenta ou equipamentos no local: Executado ☐ Não executado ☐ OBS: _____				
<i>Data Fecho:</i>	<i>Nr. Colaborador:</i>	<i>Assinatura:</i>		
_____	_____	_____		
Prazo de devolução máximo ao GT: Uma semana depois de sua execução. Em caso de atraso, deverá ser justificado pelo técnico ou pelo Departamento na folha da ordem de trabalho com data e assinatura.				