



Identificação de problemas na produção de Pop Cork

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IDENTIFYING PROBLEMS IN POP CORK MANUFACTURING PROCESS

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ISEP – School of Engineering, Polytechnic of Porto
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KEYWORDS

Cork, Pop Cork, Granulates, Boilers pressure, Boilers temperature, Process optimization

ABSTRACT

The current context of the Europe, USA, China, India and worldwide industry is marked by an intense competition between producers to attract the customer's choice. The dynamic needs of client feed the competitiveness to the companies, pushing them to lower prices, high quality and better delivery conditions in terms of lead time and quantities.

The pop cork production makes more efficiency the production of larger amounts of granules in grain materials technology. Amorim cork industry is the biggest cork materials manufacturer company in the world and is located at Portugal, supplying to different fields such as aerospace, automobile industry, textiles and household things. Following this, innovation unit is embedded in the grain materials technology. This work expects to recognize the pop cork issues and to enhance the pop cork effectiveness by improving the cork expansion, as well as the equipment working conditions.

The case study provides detailed information about the granules units 1 and 3, at an operational level. In the GMT (Granules Materials Technology) units 1 and 3, analyses and improvements in the cork expansion were carried out, by identifying the boilers capacity limitations, controls of the equipment conditions, operational failures and available resources, such as natural cork waste, because different kinds of Cork Bark are used in the pop cork production. These sections were analysed collecting samples of different kinds of cork bark used in the pop cork production, at different temperatures, observing as well the variation of cork expansion in order to identify the problems occurred in the process. Errors displayed by the equipment and/or pointed out by operators in the GMT units 1 and 3 were recorded. Corporate changes to promote the standardization of procedures, from initial objectives to evaluation, considering the planning, execution and reports, were also identified.

At the end, the results of pop cork production in the GMT unit 1 and 3 were improved by 3%. Now, Amorim Cork Composites presents a more profitable process, which was proved. The regularity of maintenance operations should be undertaken to increase the granules production.

KEYWORDS

Cortiça, *Pop Cork*, Granulados, Pressão das caldeiras, Temperatura das caldeiras, Otimização do processo

RESUMO

O contexto atual da Europa, EUA, China, Índia e da indústria em todo o mundo, é marcado por uma intensa concorrência entre os produtores para conquistar a escolha dos consumidores. As dinâmicas dos clientes alimentam a competitividade das empresas, impelindo-as para a prática de preços mais baixos, alta qualidade e melhores condições de entrega em termos de prazos e quantidades.

A produção de *pop cork* torna mais eficiente a produção de grandes quantidades de grânulos na tecnologia de materiais granulados. O Grupo Amorim é o maior conjunto de empresas fabricante de materiais de cortiça do mundo e está localizado em Portugal, fornecendo as diferentes áreas, como a aeroespacial, indústria automobilística, têxteis e artigos domésticas. Para tal, a unidade de inovação está incorporada na unidade de tecnologia de granulados. Este trabalho espera reconhecer os problemas de produção da *pop cork* e melhorar a eficácia do processo de expansão da cortiça, bem como as condições de trabalho do equipamento.

O caso de estudo fornece informações detalhadas sobre as unidades de grânulos 1 e 3, ao nível operacional. Nas unidades 1 e 3 da GMT (*Granules Materials Technology*), foram realizadas análises e melhorias na expansão da cortiça, identificando as limitações da capacidade da caldeira, controlo das condições do equipamento, suas falhas operacionais e recursos disponíveis, como resíduos de cortiça natural, porque são usados diferentes tipos de casca de cortiça como matéria-prima na produção de *pop cork*. Essas unidades foram analisadas recolhendo as amostras de diferentes tipos de cortiça usados na produção de *pop cork* a diferentes temperaturas, observando também a variação da expansão da cortiça para identificar os problemas ocorridos no processo. Os erros exibidos pelo equipamento e/ou apontados pelos operadores nas GMT 1 e 3 foram registrados. Foram também identificadas mudanças na Organização para promover a padronização de procedimentos, desde objetivos até a correspondente avaliação, considerando o planeamento, execução e relatórios. No final, foi possível registar um incremento na produção de *pop cork* nas unidades 1 e 3, o qual atingiu os 3%. Agora, a Amorim Cork Composites apresenta um processo mais lucrativo, o que ficou provado. A regularidade da manutenção deve ser tida em conta, com vista a aumentar a produção de grânulos.

LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

ACC	Amorim Cork Composite
APCER	Portuguese Association of Certification
APCOR	<i>Associação Portuguesa da Cortiça</i>
BU	Business Unit
CIPR	International code of cork Stopper Manufacturing Practice
CSTB	<i>Centre Scientifique et Technique du Bâtiment (CSTB)</i> (English: Scientific and Technical Centre for Building)
CO ₂	Carbon dioxide
CTCOR	<i>Centro Tecnológico da Cortiça</i>
DBPT	Double Belt Press Technology
DMAIC	Define, Measure, Analyse, Improve and Control
ESA	European Space Agency
GMT	Grain Materials Technology
ICCSMP	International Code of Cork Stopper Manufacturing Practice
INE	<i>Instituto Nacional de Estatística</i> - National Statistics Institute
ISO	International Organization for Standardization
LNEC	Laboratório Nacional de Engenharia Civil
KPI	Key Performance Indicator
MDT	Shredder Mill
NASA	National Aeronautics and Space Administration
NP	Portuguese Standard
PP	Polypropilene
TPS	Toyota Production System

List of units

Bar	Unit of Pressure
°C	Grade Celsius
g	Grams
kg	Kilogram
l	Litre
m	Metre
mm	Millimetre
µm	Micrometre

List of symbols

%	Percentage
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GLOSSARY OF TERMS

Term	Meaning
Agglomerated Cork	Aglomerados
Composed Cork	Aglomerados Compostos
Pure Agglomerated Cork	Aglomerados Puros
Expanded pure agglomerated Cork (Black Agglomerates)	Aglomerados Puros Expandidos (Aglomerados Negros)
Unexpanded Pure Agglomerated Cork	Aglomerados puros não expandidos
Cork waste	Aparas
Bellies	Aparas de Barriga
Blocker Waste	Aparas de Broca
Disk Waste	Aparas provenientes de corte por disco
Robot Machine Waste	Aparas de Garlopa
Debarked Waste	Aparas Espaldadas
Cork Wood Pieces	Bocados de cortiça
Gleanings	Rebusca
Reproduction Cork (Second and subsequent stripping)	Cortiça de camada posterior
Summer Virgin (Augment)	Cortiça interior aumentada
Ordinary Virgin	Cortiça de desbaste
Summer Virgin	Cortiça interior
Winter Virgin (adze)	Cortiça de junção
Winter Virgin (hatchet)	Cortiça falsa
Reproduction Cork (First Striping after Virgin)	Cortiça Secundária
Virgin-Cork	Cortiça Virgem
Granulated Cork	Granulados de cortiça
Expanded granulated cork	Granulados expandidos
Cork Wool	Lã de Cortiça
Cork Paper	Papel de Cortiça
Cork Powder	Pó de cortiça
Corkwood in planks	Prancha
Corkwood refused	Refugo
Reg granulated cork	Regranulado

Reg granulated Cork Insolation	Regranulados Negros
Stoppers	Rolhas
Strips	Tiras
Simple cut pieces	Transformação por corte simples

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INTRODUCTION

1.1 Contextualisation

1.2 Main goals

1.3 Methodology

1.4 Structure of the thesis

1.5 About the welcoming company

1 INTRODUCTION

1.1 Main Goals

Cork is the bark of the cork oak which means that it is *100% natural tissues*. It consists of a numerous number of honeycomb of microscopic cells fitted with an air like gas inside and coated with a natural chemical substance called *suberin (waxy) and lignin (organic polymer)*. The cork tree has a bark that can be split, and then peeled off without damaging the tree which shown in the Figure 1.1. This unusual method of agriculture cork is then applied to make cork stoppers for wine bottles.



Figure 1.1 Cork Bark

The growth of cork tree can be found in various rural areas mainly in Europe and Africa. The cork has various shapes and different in their usages. The natural cork has a higher value than any other material like plastic or rubber and it can be sort out by recycling 100 %. The method of developing raw materials into granules substance can be combined with man-made materials like making of bags, belts, purses and flooring mates. Corks natural properties eminently has the characteristic of *heat resistant, and fireproof*. The cork tree can be grown in a dry land.

1.2 Main Goals

The pop cork process makes more efficiency in the production of larger amounts of granules in grain materials technology. Amorim cork industry is the biggest cork materials manufacturer company in the world and is located at Portugal, supplying to different fields such as *aerospace, automobile industries, textiles and household things*. The pop cork section consists of three steam vapor chambers where the cork is transmitted and enlarging process has occurred here. The section 1 undergoes *some*

troubles whose are caused by damages detected on the chambers, whose *leak steam through the holes*, therefore cork does not get *expansion as expected*. This problem induces less efficiency and poor economic performance. In section 3, the pop cork has expansion enough and no damages in pop cork chambers were detected.

1.3 Methodology

The methodology followed for the development of pop cork process is

- ✓ Collecting information of the present pop cork process as main concern of the work;
- ✓ Make the notes on the issues happened by equipment in this procedure and guide the kind of breakdown;
- ✓ Identify the failure and causes by other undesirable particles makes issue to the chambers;
- ✓ Checking the boilers work conditions and steam passage to the pop cork chambers. Also check the pressure level and temperature level in the display indicates exactly or not;
- ✓ Organise the collected information about pop cork process and discuss around the problems with managers and operators;
- ✓ Working on improvement ideas and make changes in the boilers controls to increase the pressure or temperature level of steam;
- ✓ Applying improvement ideas that may help to make more expandable granules output from the pop cork process in the right way;
- ✓ Writing the thesis.

1.4 Structure of the thesis

The structure of the thesis is mainly based on four parts:

- ✓ An initial Introduction is presented to make this issue familiar with the reader;
- ✓ A literature review is presented in Chapter 2, which aims to frame the reader with the issues involved in this master thesis, by reviewing the technical books and scientific developments that have been published in scientific books and journals dedicated to this issue;
- ✓ The Development of the Practical Work itself, with reference to the detailed approach held to problems experienced with different raw materials used in the two Granule sections in pop cork process is presented in Chapter 3;
- ✓ In Chapter 4, the main conclusions are presented, trying to resume the main achievements of this work.

1.5 About the welcoming company

This master thesis was carried out at Amorim Cork Composite Company, which is located at Mozelos. A case study about pop cork processing was presented, requiring the needed action to solve the Granules expansion problems in the Grain Materials Technology Section 1 and Section 3.

LITERATURE REVIEW

2.1_Cork tree

2.2_How cork is extracted from the oak tree?

2.3 Cork main properties

2.4 Cork solutions

2.5 Cork manufacturing process and products

2.6 Pop Cork

2.7 Methodology used in pop cork development process

2.8 Cork products quality requirements

2.9 Main Pop Cork properties and applications

2.10 Cork markets

2.11 Cork Grain Material Technology (GMT)

2 LITERATURE REVIEW

2.1 Cork tree (*Quercus Suber*)

The scientific categorization of this species was identified by *Carl Linnaeus*, which classifies genus and assigned the natural classification of the *Cork Oak – Quercus Suber* L [2] shown in Figure 2.1 and 2.2. The cork tree has a long-life span of 250 to 350 years with the extraction of outer bark several times and uses for modern applications [2]. The Cork Oak has a place with a little sub gathering of European and Asian Species whose nearest relatives are the Oaks of the Eastern Mediterranean Basin (*Quercus cerris*, *Quercus trojana*, *Quercus Macrolepis*) [3].



Figure 2.1 Cork Oak Forest



Figure 2.2 Cork Oak Tree

Qualities of the cork oak are:

- ❖ Prevents soil degradation;
- ❖ Makes soils more productive;
- ❖ Regulates the water cycle;
- ❖ Fights desertification;
- ❖ Provides retention and storage of carbon for very long periods of time generates high rates of biodiversity;
- ❖ Combats climate change;
- ❖ Creates employment and wealth in the country.

Over all world 90 % of the cork oak forest is planted in the region of Portugal, Spain, Morocco and Algeria mention in the Figure 2.3. Globally, Portugal is the top most country in production of raw cork and transports throughout world [4]. The cork oak plays vital role in *global warming it absorbs lots of carbon di oxide (Co₂)* and stored into a tissue. The cork oak forest prevents from the desertification [4] in a polite manner. Cork oak tree endures all climatic conditions.



Figure 2.3 Cork Oak growth in the Mediterranean

3.1.1 Growth period

The Cork Oak is native to the western Mediterranean Basin, [3] where there are ideal growing conditions and characteristics:

- ✓ Sandy, Chalk-free soils with low nitrogen and phosphorus content, high potassium level and pH from 4.8 to 7.0;
- ✓ Rainfall of 400-800 mm per year;
- ✓ Temperature from -5°C to 40°C;
- ✓ Altitude of 100-300 m.

3.1.2 The flowers

The male flowers have *4 to 6 greenish yellow petals* with a rosy tinge at the edge. The Females are protected by *a scaly dome* [5]. Cork oak produces male and female (unisexual) blooms in various inflorescences on a similar individual (monoecy). Stamina (male) blooms are conceived in catkins, while pistillate (female) blossoms develop in little gatherings, for the most part closed [5] which are viewed in the Figure 2.4

3.1.3 The leaf

The leaf of cork oak is dark green, ventricular and presents 5 to 8 pairs of secondary ribs branch of its winding midrib. It measures (2.5 cm to 10 cm) x (1.2 cm to 6.5 cm), as shown in the figures 2.5 and 2.6. New fallen leaves can be used for compost. Fermentation in ditches produces a product rich in potash with a reasonable content of nitrogen and phosphoric acid and fertilizer content above that of dead leaves which have decomposed on the soil surface. In the latter case, significant losses of nitrogen and tertiary compounds occur (cellulose, fat and pontoon substances).

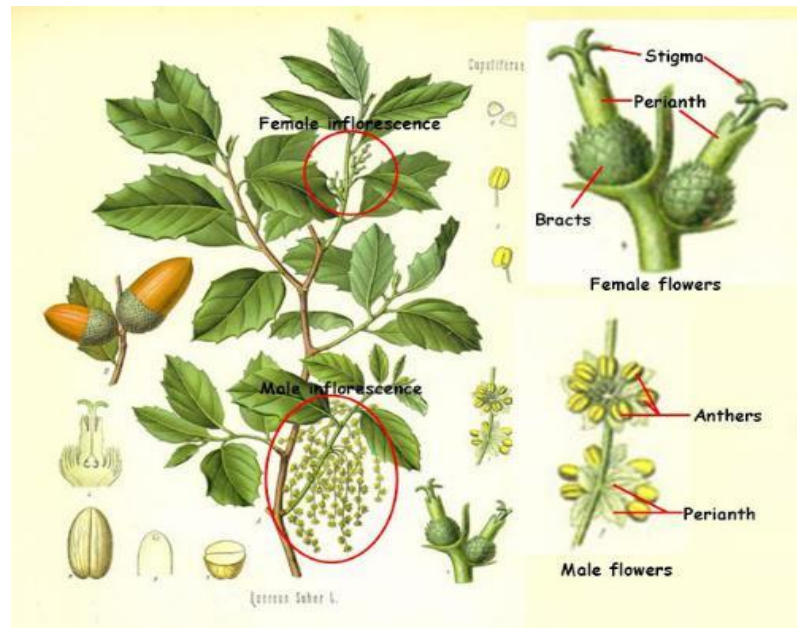


Figure 2.4 Shows the general difference of male and female flowers



Figure 2.5 Shows the small cork tree leaves



Figure 2.6 Shows the closer view of cork Leaves

3.1.4 The acorn

The cork oak begins to bear fruit at between *15 and 20 years of age*, but only when it reaches 30 or 40 years old does its production of acorns begin to be economic interest. Fruit crop per unit of crown surface is at its *highest* in communities *aged 50 to 150 years old* [6] which can have seen in the Figure 2.7 and Figure 2.8 mention about general description of fruit.

In Portugal, cork oak acorns, like those from sister species, are used almost exclusively for fattening swine. Fat stock being kept in the open air are allowed into the cork oak woods towards the end of October and leave, after *fattening towards the end of January*. They normally put on 30 kilograms, but there are recorded cases where this figure rises to 100 kilograms [6]. The species are generally perceived for delivering cork, which is expelled from grown-up trees at customary interims of no less than 9

years [7]. Africans wine fever was having repercussions on the use of acorns for fattening swine over the last few decades. As a result, more has been turned over to the production of food oils and the manufacture of animal's feeds.



Figure 2.7 Shows the Acorn in a cork tree

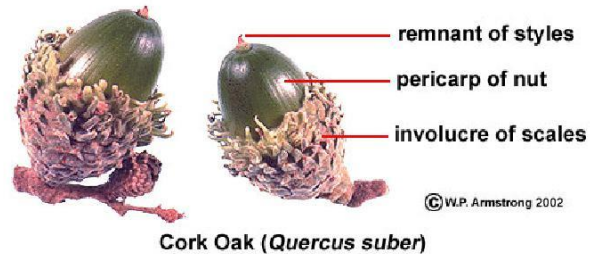


Figure 2.8 General Description of Acorns

3.1.5 The bark

The wood of the cork oak, notwithstanding its use in the production of cellulose, may likewise be given over to the *extraction of tannin*. The Cork bark is covering formed by the microcells that gives the name of cork quality [7].



Figure 2.9 The cork Bark

However, richer than the heartwood is the inner bark stored in the oak forests is shown in Figure 2.9. The inner bark of adult cork oaks which have never been stripped for their cork has the highest content of tannin materials. The demand from tanners of skins and hides led to the worldwide disappearance of centuries old cork oaks, once the pride of their native lands [7].

3.1.6 The wood

In days gone by, cork oak trunks were widely used in the golden age of ship building in the era of the discoveries. It is a good fuel for open fires and marking charcoal. Today, their economic value is very limited. They are used only in the manufacture of simple agricultural tools (hoes and harrows), door frames and chimney beams, etc. Ships, alas, are no longer built from wood. The smaller branches of the cork oak removed in pruning and thinning can be used as domestic fuel. Charcoal production, however, is the most important, if not the only, end to which the wood of the cork oak is put. *Cork oak charcoal, at 25% humidity, has an absolute calorific value in order of 7,000 calories* [7]. At the end of the nineteenth century, the ashes of cork oak wood were found to be a source of potash. At the time, this was a *profitable business*, but it resulted in irreparable devastation to *cork forests in Italy, Sardinia and Corsica*.

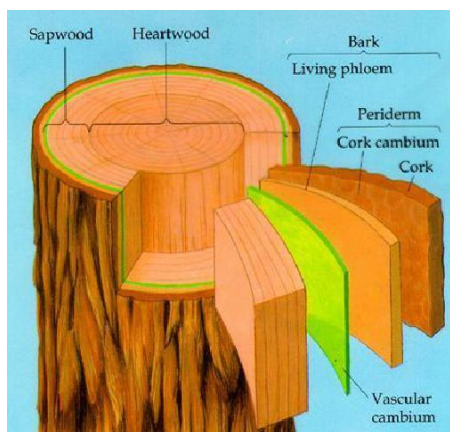


Figure 2.10 General Description of Bark



Figure 2.11 Shows Cork Wood Overview

Figure 2.10 explains about the parameters of cork wood and the Figure 2.11 shows the top of cork wood.

2.2 How is cork extracted from the oak tree?

The cork oak is yield for the outer bark for its highly profitable product. The cork bark develops lifetime of the cork oak tree [8]. The cork has natural characteristics of regrowth of outer layer after harvesting and balancing forests management [9].

3.1.7 Harvest time

The life cycle of cork as a raw material begins when it is stripped. When the tree is 25 years old and the *trunk circumference reaches 70 cm diameter at 1.3 metres height*

from the ground. Subsequent stripping take place at intervals of at least nine years, between the months of May and August [10].

3.1.8 A new harvest every nine years

The cork oak can be stripped 15-18 times throughout its life, at intervals of *nine years* which is shown in the Figure 2.12.

✓ Aged 25 years

The cork is stripped for the first time, obtaining *virgin cork (Desboia)*. The irregular structure and extreme hardness of this corks means it *doesn't* yet have the *ideal quality to produce cork stoppers*. This cork is used for other applications, such as flooring or insulation.

✓ Aged 34 years

The cork is stripped for the second time providing *secondary cork (Secundeira)*, which has a more regular structure and is less hard. This is also transformed into *agglomerates for construction and other materials*.

✓ Aged 43 years

The cork is stripped for third time providing *reproduction cork (Amadia)*, which has the ideal properties to *produce quality stoppers*. From this point onwards, and for about one century and a half, the cork oak will offer *cork of excellence quality for every nine years*.

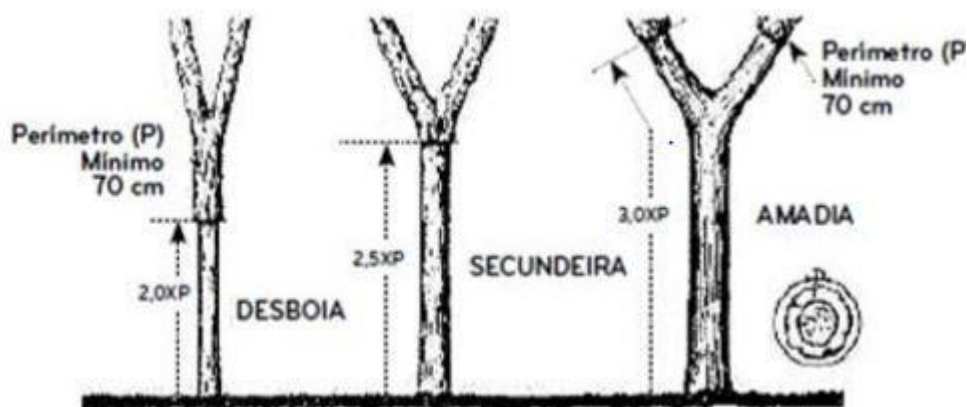


Figure 2.12 Distinct types of extraction of cork bark

3.1.9 The six stages of stripping cork bark from the oak tree

The power of the cork stripping introduces to the location of the tree where the cork layer is expelled, and it is characterized in connection to the tree estimate. The most regular approach to express the degree of cork evacuation is by utilizing the tallness until which the stripping of cork is made, the alleged debarking height [11]. Stripping

the cork oak is an ancient and manual process that requires very careful and experienced hands to prevent damage to the bark or the tree. The six stages of the cork oak stripping are:

✓ **Open**

A vertical cut is made in the cork, picking the most profound break in the cork bark. In the meantime, the edge of the *axe is curved* to isolate the external from the inward bark. The level of the extraction can be gauged from the '*vibe*' of the *axe*. At the point when the edge of the axe is connected to the strip, an empty sound of tearing is heard if the cork will fall off effortlessly. If it is going to be difficult, the axes emit a short, firm, dry sound. In the Figure 2.13 shows how they open the cork bark [11].

✓ **Separate**

The plank is separated by introducing the edge of the axe between the plank and the inner bark in a *twisting motion of the axe*. In the Figure 2.14 shows how to separate the cork bark [11].

✓ **Scribe**

The size of the cork plank being *pulled off the trunk* is defined by a horizontal cut or scribing. In the Figure 2.15 shows how to scribe on the cork bark [11].

✓ **Extract**

The plank is harvested from the tree very *carefully to avoid it breaking*. The *larger plank is greater commercial value*. In the Figure 2.16 shows how to extract the cork bark [11].

✓ **Remove waste**

Some fragments of cork are left at the base of the trunk and these are hammered several times to remove any parasites that may appear in it. In the Figure 2.16 shows how to remove waste from the cork bark [11].

✓ **Marking**

Finally make a *mark on the tree*, using the *last number of the year* which was extracted. Figure 2.17 shows how they are marking on the cork tree [11].

✓ **Rest period**

After the reap, the cork planks are stacked in heaps either in the backwoods or in yards at a processing plant shown in the Figure 2.18. They stay exposed to sun, wind and rain. Every one of the heaps are developed considering strict principles characterized by the *International Code of Cork Stopper Manufacturing Practice – ICCSMP*, to enable the cork to balance out. The heaps ought to be stacked on materials that don't taint the cork and avoid contact with the dirt. Wood, for instance, is explicitly disallowed because it can transmit growths. In this flavouring period, the fungi develop and the cork balances out.

As indicated by the ICCSMP, the seasoning period for the planks should never be less than six months [11].



Figure 2.13 Open the Cork Bark



Figure 2.14 Scribe the Cork Bark



Figure 2.15 Separate the Cork Bark



Figure 2.16 Extract the Cork Bark



Figure 2.17 Mark the Cork Oak by last Digit of the year



Figure 2.18 Rest the Cork Bark for a period

2.3 Cork Main Properties

Cork is a natural specie and none other material could match the properties of cork. Some properties of cork are described below [12].

✓ **Light weight**

50 % of cork is occupied by air which feels very light, its specific weight is 0.16 grams per cubic centimetre and it can float easily.

✓ **Density [12]**

1. Natural cork 160-260 kg/m³
2. Granulated cork 60-160 kg/m³
3. Agglomerated cork 140-600 kg/m³
4. Cork rubber 450-1200 kg/m³

As reference:

- Water 1000 kg/m³
- Human body 1010 kg/m³

✓ **Compressibility**

When it is compressed, the air inside the cell is squeezed to a smaller space. The cell walls are flexible, recovering the original shape.

✓ **Resilience**

When pressure is released, compressed cork will bounce back to its original shape.

✓ **Shock absorbent**

With impact, the cell walls deform, absorbing energy without damaging the cell structure.

✓ **Stability**

Temperature and humidity have a slight effect on cork, so it resists to deterioration and weathering.

✓ **Thermal Conductivity**

The air inside the cells makes it an excellent insulator, leading to very low thermal conductivity, over a wide range of temperatures.

✓ **Heat resistance**

Where most of the synthetic materials fail, cork retains its properties. Cork's thermal degradation begins only above 200°C.

✓ **Moisture proof**

Water absorption is avoided by the closed cellular structure. Water covers only the exposed surface.

✓ **Flexibility**

Cork is a flexible material, even at very low temperatures, because of the constituents (Suberine) and geometry of the cell walls.

✓ **Soft touch**

Due to its basic material and surface characteristics, cork transmits a smooth touch.

✓ **Warm feeling**

Cork's normal temperature is very close to the human body; it therefore feels warm to the touch.

2.4 Cork solutions

Some of the cork characteristics is mention below in the table 2.1

Table 2-1 Cork solutions and characteristics

Type of cork products	Characteristic
Agglomerated cork cylinders [12]	<input type="checkbox"/> Density :140-400 kg/m ³
	<input type="checkbox"/> Dimensions:0,78 m to 1,37 m
	<input type="checkbox"/> Grain dimension: 0,5 mm to 25 mm
	<input type="checkbox"/> Compatibility with other additives
	<input type="checkbox"/> Compressibility recuperation >70 %
Agglomerated cork blocks characteristics [12]	<input type="checkbox"/> High cork content (+90 %)
	<input type="checkbox"/> Wide range of thickness from 0,8 mm to 210 mm
	<input type="checkbox"/> Wide range of densities from 140 kg/m to 600 kg/m ³
	<input type="checkbox"/> Wide range of cork patterns
	<input type="checkbox"/> Different grain sizes
	<input type="checkbox"/> Possibility of adding colour
Agglomerated cork rolls characteristics [12]	<input type="checkbox"/> Compressibility recuperation > 70 %
	<input type="checkbox"/> High cork content (+90 %)
	<input type="checkbox"/> Minimum thickness – 0,8 mm
	<input type="checkbox"/> Maximum width of 1500 mm
	<input type="checkbox"/> Wide range of cork patterns
	<input type="checkbox"/> Colours available
	<input type="checkbox"/> Big length rolls
<input type="checkbox"/> Allows back printing	

Granulated cork [13]	<ul style="list-style-type: none"> □ Mostly granulated cork is made from recycle stoppers, industrial waste and forest waste such as young cork first extraction from the cork tree, second time extraction of cork has small damages and reproduction cork is the third extraction of cork tree. It grinds into small pieces and separated by size and density [13]
Cork rubber [12]	<ul style="list-style-type: none"> □ Lower cork content than agglomerated cork (up to 50 %) □ Wide range of patterns and colours □ Elastic properties (elongation and damping) □ Available in rolls and blocks: □ Minimum thickness: 0.8 mm □ Maximum thickness: 150 mm □ Heat resistance □ Low dimension variability □ Thermal and acoustic insulation □ Size at a diameter of 63.5 mm and 76.2 mm
Double Belt Process (DBP) Technology [12]	<ul style="list-style-type: none"> □ In Amorim has a new DBP technology specially optimized to produce high density rolls with a width of 2,1 m.
Cork Fabric [12]	<ul style="list-style-type: none"> □ Thin layer of decorative cork glued to a substrate □ Six different cork patterns □ Three different backing materials: cellulose, textile and artificial leather □ Available in rolls □ Easy gluing and sewing □ High flexibility □ Suitable for low and mid temperatures
Cork polymer composites [12]	<p>Polymer composites Thermoplastic materials with cork, suitable for injection and extrusion</p> <ul style="list-style-type: none"> □ Low cork content maximum 40 %

	<input type="checkbox"/> Limited ranges of five materials Rigid <input type="checkbox"/> Polyethylene polymer + cork <input type="checkbox"/> Polylactic acid + cork Semi – rigid Flexible <input type="checkbox"/> Polyvinyl chloride + cork <input type="checkbox"/> Thermoplastic elastomer + cork
Expanded Cork board characteristics [12]	<input type="checkbox"/> 100 % natural cork granules are combined by cork's natural resins <input type="checkbox"/> Available in different thickness: from 20 mm to 240 mm <input type="checkbox"/> Low density: 100 – 160 kg/m ³ <input type="checkbox"/> Low mechanical resistance <input type="checkbox"/> Great sound insulation properties <input type="checkbox"/> Good fire resistance

2.5 Cork products manufacturing process and products

The main types of cork products manufacturing processes are explained in the table 2.2.

Table 2-2 Cork products manufacturing processes and their characteristics

Manufacturing Process	Characteristics
Die cutting [12]	<input type="checkbox"/> Available for rolls and sheets <input type="checkbox"/> Maximum thickness of 7 mm <input type="checkbox"/> Maximum area of 1200 mm x 700 mm <input type="checkbox"/> Not suitable for high density materials <input type="checkbox"/> Low – cost tools <input type="checkbox"/> High cadence
Machining stickle board milling [12]	<input type="checkbox"/> Thicknesses from 5 mm to 30 mm <input type="checkbox"/> Diameter from 90 mm to 300 mm <input type="checkbox"/> Rectangular shape till 600 mm x 450 mm <input type="checkbox"/> Low cost tools <input type="checkbox"/> Good for fast prototyping
Machining process [12]	<input type="checkbox"/> Huge amount of waste material <input type="checkbox"/> Suitable for high density materials

	<ul style="list-style-type: none"> <input type="checkbox"/> Low costs tools <input type="checkbox"/> Small grain size <input type="checkbox"/> Suitable for sample or prototype production
Cylindrical Cutting process [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Maximum height of 180 mm <input type="checkbox"/> Irregular interior finishing
Turning process [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Maximum height of 300 mm <input type="checkbox"/> Maximum diameter of 300 mm
Computer Numerical Control (CNC) Machining [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Allows more complex shapes than conventional milling <input type="checkbox"/> Best surface finishing with small size granules <input type="checkbox"/> Suitable for high and mid density materials <input type="checkbox"/> High-Tech process
Lamination (Wood, Foams, Plastics, Rubber, Metal, etc) [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Suitable for sheets and rolls <input type="checkbox"/> Easy gluing (Woods, Textiles, and Foams) <input type="checkbox"/> Gluing to plastics is conditioned to the plastic type (e.g. polypropylene) <input type="checkbox"/> Possible with rigid and flexible surfaces <input type="checkbox"/> Multi – materials possible.
Compression moulding [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Maximum area of 450 mm x 900 mm <input type="checkbox"/> Maximum height of 95 mm <input type="checkbox"/> Complex geometries possible with no material waste <input type="checkbox"/> Faster production cycles than machining <input type="checkbox"/> Refined grain size is used (0,5 mm to 1 mm) <input type="checkbox"/> Mostly suitable for high quantities (requires investment in moulds)
Plastic injection moulding [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Allows more complex geometries <input type="checkbox"/> Possibility of adding colour <input type="checkbox"/> Possibility of over moulding with other materials <input type="checkbox"/> Possible to adapt cork rubber composition <input type="checkbox"/> Suitable for big production batches

	<ul style="list-style-type: none"> <input type="checkbox"/> To be used under injection moulding technologies <input type="checkbox"/> Good grip for demanding applications.
Glass Fibre Re-Enforced Plastics (GFRP) [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Cork is used as middle layer between GFRP surfaces <input type="checkbox"/> Suitable for big and rigid structures <input type="checkbox"/> Suitable for the usual composite processes <input type="checkbox"/> Cork may be visible <input type="checkbox"/> Low cost moulds
Board on frame [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Light weight <input type="checkbox"/> Rigid <input type="checkbox"/> Possible to work with a wide range of geometries <input type="checkbox"/> Core with a honey comb structure <input type="checkbox"/> Stiff surfaces layers <input type="checkbox"/> Compatibility with other materials (examples: metal, wood)
Laser engraving [12]	<ul style="list-style-type: none"> <input type="checkbox"/> High cadence <input type="checkbox"/> Possible to be used in several materials <input type="checkbox"/> No limit of batches dimensions <input type="checkbox"/> High resolution
Silk screen printing [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Maximum area of 900 mm x 600 mm <input type="checkbox"/> Maximum height of 80 mm for small components <input type="checkbox"/> Maximum height of 30 mm for wide sheets <input type="checkbox"/> Only used up to two colours
Offset printing [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Maximum area of 600 mm x 400 mm <input type="checkbox"/> Maximum thickness of 0,8 mm
Digital printing [12]	<ul style="list-style-type: none"> <input type="checkbox"/> Maximum area in sheets: 1900 mm x 3000 mm and in rolls: 1450 mm width <input type="checkbox"/> Maximum thickness of 30 mm

2.5.1 Cork stoppers

Cork stopper is the perfect natural material to closing the wine bottles. Based on the physical properties which make dynamic improvement in ageing of wine, *improves the quality of wine* [14].

2.5.2 Cork mixed on rubber

In the past few years, the cork use was developed in different sectors such as *natural cork mix* with rubber to give a product namely *agglomerated cork*. Comparing plentiful application developing in cork materials such as artificial cellular materials using expanded *polypropylene and expanded polystyrene products* emerging in modern world [15]. The natural cork is a recycling material so there are many benefits to uses in different areas. The agglomerated cork is used in the *automotive industries* and natural cork presents *good thermal conductivity* and uses for several purposes such as in a *bus or house roofing, as a thermal insulating material* [16].

2.5.3 Cork mixed on cement

In the recent years cork has developed in construction fields, because the expandable granules are used for most popular eco-flooring solutions which is lightest material and easy to apply inside the house and it has good thermal conductivity and acoustic behavior by nature [17]. The cork has lighter weight characteristics makes key role to form a concrete and makes *lighter weight of concrete panels* and uses for fitting *floating floors and sound proof wall* [18]. Cork gypsum composite is developed for *constructing a concrete block* for the building applications. The cork has excellent mechanical properties, acoustic properties, micro structure and thermal conductivity for cork gypsum composites [19]. The *semi hydrated material gypsum* plays vital role for *plaster* in building areas [20].

2.5.4 Cork with plastics

In the modern world, the cork plays vital role in developing new products such as *cork powder mix with polypropylene and polyethylene pultrusion process*. Cork polymer composite is processed by compressed and injection moulding [21].

2.5.5 Other items

A few items created for the young's generations, for example, *cork wallet*, *cork handbook*, *cork shoes*, *cork surf board*, *household things* and *serpentine pavilion gallery in London* are shown in the Figure 2.19, 2.20, 2.21 and 2.23. The cork products are slowly emerging in the innovation to attract the people to feel good and enjoy the softness of the cork products [22]. The cork products are used in different sectors also as a sub product are mention in the Figure 2.20.



Figure 2.19 Cork daily uses



Figure 2.20 House hold products



Figure 2.21 Cork Surf Board



Figure 2.22 Cork raw Materials used in Aerospace Industry



Figure 2.23 Serpentine Gallery pavilion in London

2.6 Pop Cork

2.6.1 What is Pop Cork?

The cork cells are grouped into a characteristic honey comb structure. Each cell has the form of a minute pentagonal or hexagonal prism that can measure between *10 to 50 Micrometres* describe in Figure 2.24. Each cubic centimetre of cork contains around *40 million cells* which are laid out in rows perpendicular to the trunk of the cork oak.

- ✓ Pop cork is the word inspiration from *POP CORN*.
- ✓ *Pop Cork is the process of passing steam on the cork inside the chambers. Cork absorbs steam from the chamber and it expands bit larger than the actual size. It has more economic value when it expands larger. This process known as pop cork. Pop Cork is the internal process of Amorim Cork Composite Company (ACC).*

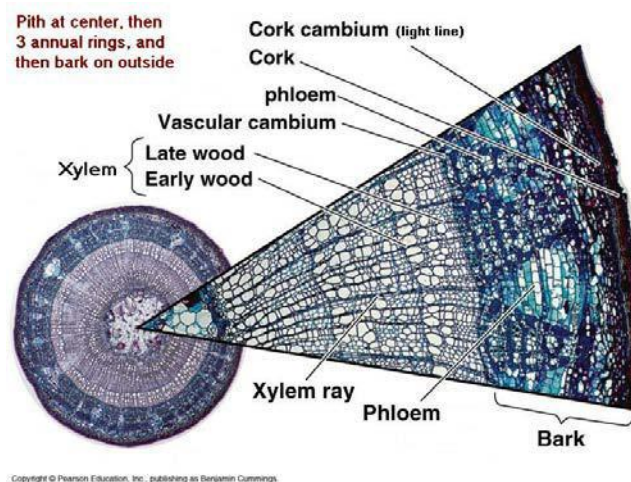


Figure 2.24 Microscopic view of cork

2.6.2 Pop Cork chemical properties

The great secret of cork lies on the gas mixture like air that fills each cell and the percentage of suberin in the cell walls. The high percentage of gas of each cell is responsible for the extraordinary lightness of cork, while the association of these cells as if they were small pillows joined together is responsible for its elasticity and compressibility [23]. The composition of cork may be broadly defined as follows:

- ✓ 45 % Suberin,
- ✓ 27 % Lignin,
- ✓ 12 % Cellulose and Polysaccharides,
- ✓ 6 % Tannins,
- ✓ 6 % Ceroids,
- ✓ 4 % Other compounds.

All these elements have been extracted from cork since 1942, given their growing application in industry. Cork is specified by strong alkalis, dissolved by nitric acid and halogens oxidants. Cork can be compressed to half its size without losing any flexibility [23].

2.7 Methodology used in the Pop Cork development process

The methodologies used for improving the pop cork process are mention as follows.

2.7.1 Six Sigma (DMAIC - Define, Measure, Analysis, Improve and Control)

Six Sigma can be viewed as a standout amongst the most imperative advancements in quality administration and process change of the most recent decades [24]. An essential piece of the Six Sigma procedure is DMAIC, which refers to the utilization of five calculated advances, bringing about a methodical change of issues and procedures [24].

This philosophy developed at Motorola in the 1980s and immediately pulled considering a legitimate concern for the majority of the world's biggest organizations centred around enhancing their execution [25].

In factual terms, sigma (σ) is utilized to speak about the variety of factors and, when connected to quality control, permits to gauge the variety in a procedure or its yields [26].

Notwithstanding being a measure of process fluctuation, Six Sigma is proposed as an administration logic and system that enables associations to minimise costs, and additionally a philosophy for ceaseless change and critical thinking that can be connected to the most various procedures to dispose of deformities, concentrating on the main driver [27].

Concentrating on the basic attributes that are important to clients, utilizing Six Sigma, imperfections, mistakes or disappointments that might be available in the procedures under examination are distinguished and dispensed. Therefore, the fundamental advantages anticipated from the utilization of this procedure are: decrease of costs, reducing the process durations, disposal of imperfections and resulting increment of fulfilment and level of client certainty, and additionally increments in benefits [28].

Recommends Six Sigma procedure is generally utilized as a part of mechanical applications with the goal of accomplishing defect reduction, its application can be stretched out to procedures and plans of action. Because of this application can be relied upon to know better and enhance Templates, have more noteworthy association of representatives and consequent preparing in critical thinking [29].

It helps to analyses and finds some solutions and suggestions for the improvement in the process of the Expansion Cork. The stages are as follows:

- ✓ Define (Characterize): This phase of the procedure characterizes the group's part, the objective and farthest point of the undertaking, the necessities and determinations of the customer [30];
- ✓ Measure: Determination and estimation of variables to be enhanced, and additionally observing, correlation and assessment of their ability [31];
- ✓ Analysis: (Break down): Assurance of underlying drivers of deformities [26];
- ✓ Improve: Plan of action to factual examination and experimentation, lessening malfunctioning and errors [26];
- ✓ Control: In the last phase of the procedure, the maintainability of the changes completed in the past stage and the observation of process execution are guaranteed [31].

2.7.2 Five why root causes

The five why root causes have used for the detailed analyses of problems occurred in pop cork process in terms of equipment errors and other external problems are identified easily.

- ✓ Powerful investigation is significant for finding and understanding the numerous potential reasons for the issue [32]
- ✓ The main important work to limit the field and concentrate on the worthiest cause first [32]
- ✓ This way makes easy to analyses and find many solutions for the problems that occurs in the Pop cork process.

2.8 Cork products quality requirements

2.8.1 Certifications usually required

The company has recognised accreditation of

- ✓ Quality Management Systems (ISO 9001);
- ✓ Environmental Management Systems (ISO 14001);
- ✓ Food safety Management Systems (ISO 22000);
- ✓ Hazard Analysis and Critical Control Point (HACCP).



Figure 2.25 ISO Standards Certification got by ACC

ISO standards are awarded by the Portuguese Certification Association (APCER) and certified company which has ambitious standards of food and reduction of health risks for consumers [35] mentioned in the Figure 2.25. In Corticeira Amorim, the grain materials technology follows ISO 2190 standards for the Granulated Cork which determines the moisture content present in the pop cork process.

Quality requirements for the cork are thermal conductivity tested by the independent laboratories: CSTB (France) and LNEC (Portugal).

2.8.2 Tests made on Cork

There are research facility labs worldwide able to perform tests and examinations on the cork is ordering to evaluate if the standards (ISO, NP, and CTCOR), quality control rules are correctly followed. Testing is performed in grouping (from raw material to finished item): raw material (cork bark) test is carried out to guarantee revised security and curing, appropriate bubbling, dampness, thickness, and grade order. Testing item and materials amid different generation stages to guarantee high quality levels. Assessing and surveying mechanical offices and working conditions ensure consistence to assembling measures and directions [33]. Test and review of cork items are carried out to guarantee adjustment to tests and details, including as required:

- Quality grade levels;
- Sizes;
- Densities;
- Moisture content;

- Weights;
- Treatments and coatings;
- Custom work conformity;
- Quantity counts.

For granulated cork, it has three main type of tests, whose are explained below:

- ✓ Size analysis of mechanical sieving method;
The formula is followed by the international standards of granulated cork – size analysis by mechanical sieving - ISO 2030:1990 (E)
 - The mass of the granulated cork, as percentage is given by the sieve (i)
$$m_i/m_o \times 100$$
where,
 m_o is the mass in grams of the test portion;
 m_i is the mass in grams of the granulated cork held by the sieve(i).
 - The mass of the cork powder as a percentage is given by the formula
$$m_f/m_o \times 100.$$
Where,
 m_o is as in 7.1;
 m_f is the mass in grams of the powder cork gathered at the base.
 - Express the results as the arithmetic means of the values arrived for the three test samples, rounding them to the nearest integer value.
- ✓ Determination of moisture content.
- ✓ Determination of bulk density.

2.9 Main Pop Cork properties and applications

The main parameters of pop cork are presence of moisture content level; the mixture of sand with cork passed to steam in pop cork Process from the boiler section. It also makes a note on temperature and pressure levels in the boiler section, which is used to transmit the steam through the channels from boiler section to pop cork chambers.

The main applications of pop cork process are expandable to cork which is mainly used to make insulation products in an Agglomerated cork cylinders. Expandable cork is used to mix with rubber to make larger cylinders for other purposes.

2.10 Cork markets

Portugal is the leading country producing and exporting cork substances, around 65% of global market. Cork is 100% natural species and 100% recyclable products, so it plays vital role in the world market due to its physical and chemical properties, and it is used in different applications for different purposes. APCOR is trying to enlarge its commercial markets in France, Spain, Italy, Germany, USA, United Kingdom and later it will promote cork on foreign markets in Asia, North America, Canada and New Zealand are shown in the figure 2.26 [34]. It is known that there are more than 2.2 million hectares of cork forests. Around 33 % (roughly 730 000 hectares) is arranged in Portugal, which corresponds to 23% of the national forest region. More than 50 percentage of cork is produce by Portugal. The rest originates from Spain, Italy, France, Morocco, Tunisia and Algeria.



Figure 2.26 Cork Markets

2.11 Cork Grain Materials Technology (GMT)

The grain material technology is a unit which works all automated flow of raw material into grinding process for cork from start to end. The GMT unit consists of three automatic equipment whose make a vital role in the production of Granules output. The details of equipment explained briefly explained in this dissertation.

2.11.1 Grinding Machine

The cork grinding machine is classified into four main parts: feeding unit; Grinding unit; Power unit and Machine frame work [36]. The operator feed the raw material into the grinding machine every 15 minutes. Engineers design the shredder machine by

reduction of energy consumption and limited maintenance mainly. The machine has low speed and produces high torque electromechanical drive to make perfect cutting in a closed chamber. Sometimes, the cutter struck with the granules, the machine automatically removes the particles by operating in reverse rotation of the cutter. The shredder machine gives superior quality, trouble free usage and for a long-lasting period [37] figured out in the Figure 2.27.

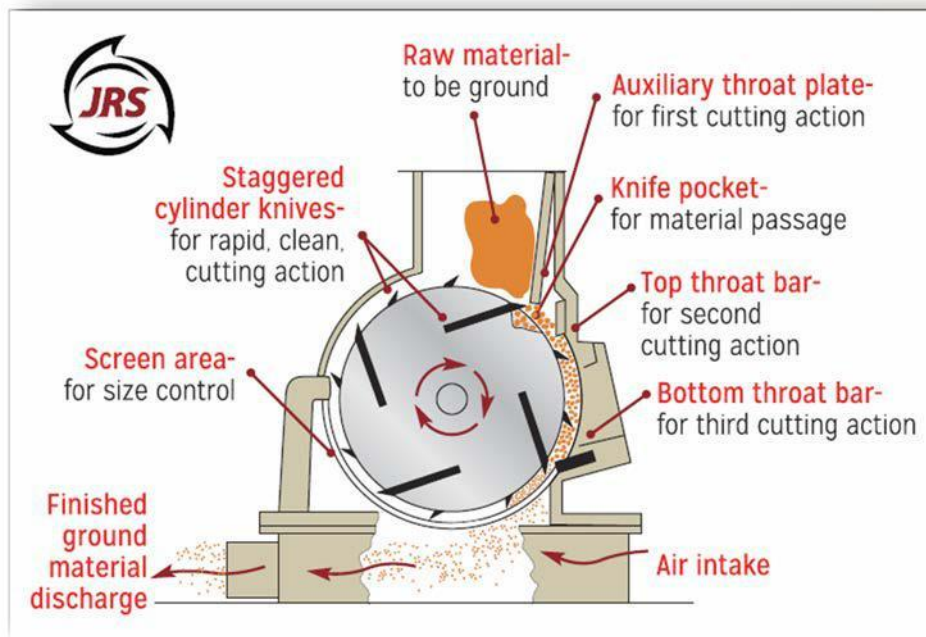


Figure 2.27 Grinding machine grinds the cork into small pieces (JRS ,2017)

2.11.2 Boiler and Pop Cork chambers

Boilers is the most key area in the cork industries, it generates steam at high pressure. Steam is produced by the heating source in the boiler by a natural gas fired burner. Boilers can achieve efficiencies up to 95 % and more. Boilers are the component which uses more energy and regular maintenance is required. If the maintenance is delayed, repair costs is higher [38]. The steam generated from the boiler is sensible to heat, because energy is proportional to the temperature [38].

The main components of the boiler whose involve the process are the burners, combustion chamber, heat exchanger and controls. This process is explaining in a detail view in Figure 2.28:

- ✓ The burner mixes the fuel and oxygen together and with the assistance of an ignition device, provides the combustion.
- ✓ The combustion takes place in the combustion chamber, the heat is generated and transferred to the water from the heat exchanger. Controls regulate the

ignition, burner firing rate, fuel supply, air supply, exhaust draft, water temperature, steam pressure and boiler pressure.

CUT AWAY VIEW

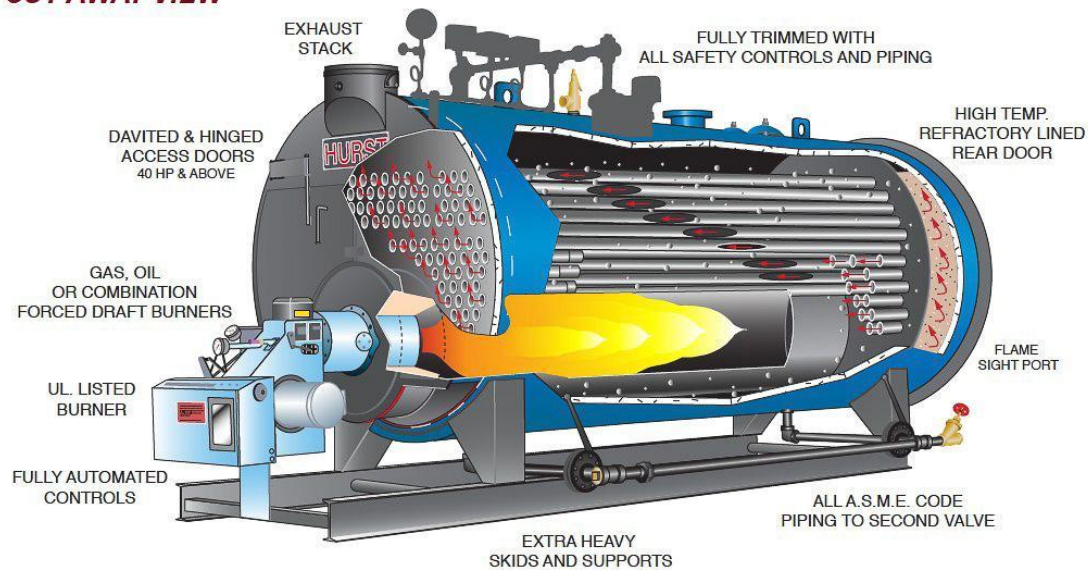


Figure 2.28 Inner view of Boiler

2.11.3 Dryer

To reduce the moisture content of cork, the rotary dryer is used in this process. The dryer is used for high efficiency and economic fuel consumption. It uses to apply the heat directly to the material, which is due to the rotation of the dryer continually, so the material will get heat on it directly and the moisture content also reduces in this process, shows the general function of Rotary dryer in Figure 2.29.

2.11.4 Sieving machine

Sieving machine (Figure 2.30) is used to remove the sand in the granules production. It has three rotation Axis to rotary movement help to remove stones and sand in each stage. After that process, the granules are distributed to the packing section. In packing section, the granules are separate by the size and shape of the granules, and packed into two types of packages in bags and compressed blocks.

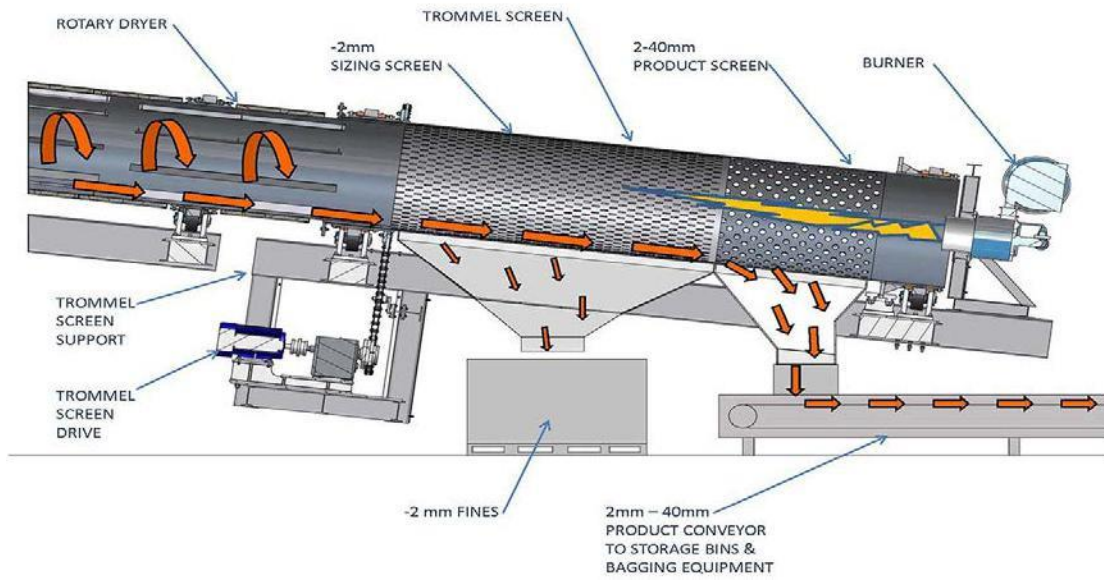


Figure 2.29 Working of Rotary Dryer in internal view



Figure 2.30 Sieving machine which separates the stones

THESIS DEVELOPMENT

3.1 Corticeira Amorim

3.2 How to produce Pop Cork?

3.3 Main equipment used in Pop Cork process

3.4 Technical diagram of process layout

3.5 Initial survey of Pop Cork process

3.6 Expansion of Pop Cork analysis

3.7 Main types of damages of the chambers

3.8 Brain storming

3.9 Production of Granules

3 THESIS DEVELOPMENT

3.2 Corticeira Amorim

3.2.1 Overview

In the previous Twenty years, Amorim Cork Company has contributed 56 million euros crosswise over six correspondence crusades including twenty nations are shown in the Figure 3.1. In 2000, it began a battle focused on solely at the UK showcase – Cork 2000, preceding stretching into different markets. The advancement of cork container corks was the main concentration; however, this was soon stretched out to development of raw materials made up of a pop cork process which transforms into granules in shapes and sizes which is used in different areas such as in construction, insulation materials for automotive industries. (1).



Figure 3.1 Revenue chart of Amorim cork composite of past 10 years

Corticeira Amorim is presently the world’s largest producer of cork products and it has a history of almost 150 years of operations in this sector. Antonio Alves de Amorim founder of the company in the year 1870, opened the factory with the purpose of providing cork stoppers to wine producers in Porto, Portugal. The current chain of the company is illustrated in Figure 3.2.



Figure 3.2 Company Value Chain

3.2.2 Amorim Cork Composite main markets

Cork is a natural material, with wonderful haptic in nature and olfactory (smell) qualities with the versatility to be easily carved, cut, shaped and formed [1].

✓ Construction

Nowadays, the usage of organic materials (cork) increases to prevent the environment damages and brings the sustainability to the surroundings. This natural substance has their own values in improving the quality in fractures, increasing the comfort to users, and can be used as an energy efficiency material. Cork can be used as a sound-proof, it has an ability to manipulate sound waves from the external source. These materials can even withstand a high range of heat source or radiation and has an excellent influence in vibration absorber. Within this brand, the product has a various application solution such as:

- Subfloors;
- Floating screeds;
- Floor heating systems;

- Light partitions;
- Water proofing;
- Anti-vibration insulations in floors and buildings.

This segment overviews a short brief about expandable cork with a variation of products specially formulated to fill spaces of expansion joints between rock slabs. This product has a greater influence in civil engineering in building of tunnels, bridges, aqueducts, water supply systems, reservoirs, dams and airports as can be seen in Figure 3.3 and 3.4

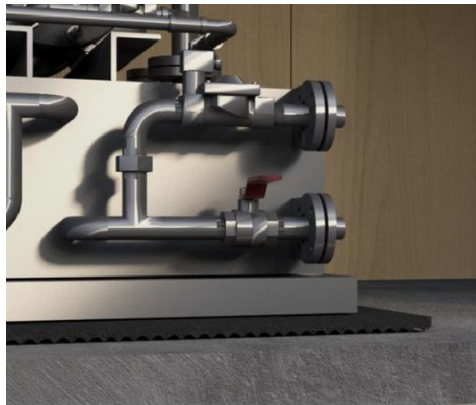


Figure 3.3 Cork used in construction for prevent vibrations



Figure 3.4 Cork material used in flooring and wall covering

✓ **Industries:**

In the field of automotive industries, The Toyota production system (TPS) offers the possibility to create innovative products and demanding thermal insulators requirements in terms of quality. Products such as gaskets and inlet rings are used in the automobile industries are displays in Figure 3.5 and 3.6

In Aerospace industries, the thermal protection systems make aerospace vehicle shields the most efficient way to reduce the consumption of fuel. Foot Cork presents solutions in the segment of footwear and leather goods. Core Cork is aimed at offering products to the composite industry.



Figure 3.5 Cork used in automotive industry



Figure 3.6 Cork used as inlet coverings

✓ **Consumer goods:**

In the modern world, cork makes perfect harmony of design and the cork material brands by Amorim cork composite. The cork has many collections of household’s products to integrate environments of our daily life.

✓ **Transport:**

The cork has key role in the mode of transportation, cork has leading solutions which allows to increase the performance and comfort of the transport. The cork products have various uses such as rail infrastructures and rail tracks in the Figure 3.7 and 3.8.

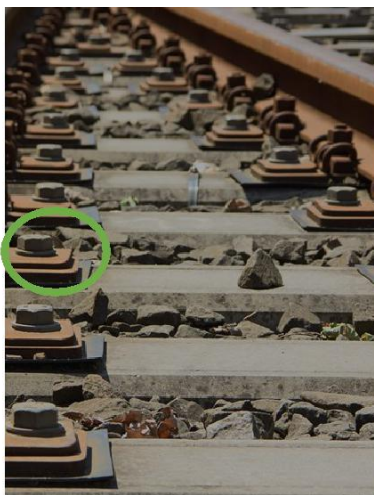


Figure 3.7 Cork is used for rail tracks



Figure 3.8 Cork is used in rail tracks in a larger way

3.2 How to produce Pop Cork?

3.2.1 Raw Materials

The Raw Materials (Business Unit) has enabled a standard quality to be created, which is essential to meet market requirements. In the Grain material technology section works with two sections of POP CORK that is granule section 1 and granule section 3. In the company uses various kinds of raw materials based on the controls and conditions of the sections are processing are seen in the figure 3.9.

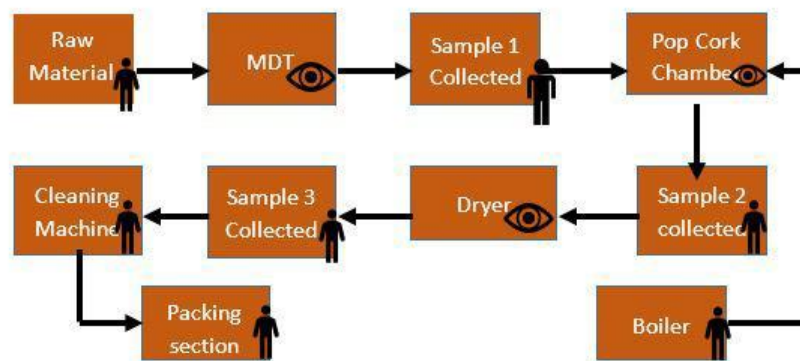


Figure 3.9 Process Mapping of Pop Cork Process

In Granule Unit 1

This unit consumes 50% of boiled cork (wet cork) and 50 % of not boiled cork (dry cork) in the pop cork process. The raw materials which mainly uses are mentioned below:

- ✓ Apará Cozida – wet cork;
- ✓ Refugo cru - wet cork;
- ✓ Lote A- dry cork;
- ✓ Lote B – type of Recycle cork from Lote A;
- ✓ Argelia 6/15 - boiled cork;
- ✓ Barrigas (bottom part of cork)- boiled cork.

These are the natural raw material present in large bark which mixed with wet and dry cork:

- Apará cozida, refugo cru and Lote A;
- Refugo cru and Lote B;
- Argelia 6/15, Lote B and Barriga.

In Granule Unit 3

This section is using 90% of not boiled Cork and 10 % of Recycle Cork in the pop cork process. The raw material which are mainly used is mentioned below:

- ✓ Refugo cru – dry cork;
- ✓ Rolhas – recycle stoppers;
- ✓ Virgem (virgin cork) – dry cork;
- ✓ Lote A – dry cork;
- ✓ Especial (middle part of cork) – dry cork;
- ✓ Respeladada – dry cork;
- ✓ L.Directo – dry cork.

These are the natural raw material present in large bark and it mixes with dry cork and recycling cork to give small granules:

- Refugo cru and Recycle cork;
- Refugo cru and Virgem;
- Especial, Respeladada and L.directo.

3.3 Main equipment used in the Pop Cork process

In Grain material technology, both section 1 and 3 has five kinds of machine for the pop cork manufacturing process, such as:

- ✓ Grinding machine;
- ✓ Boilers section;
- ✓ Pop cork chambers (Steam and sand mixture);
- ✓ Dryer Machine;
- ✓ Centripetal rotating machine with three Axis Sieving machine by size and shape;
- ✓ Packing section by bags and cubes.

3.3.1 Grinding machine

The raw materials are dropped into the shredder machine which is currently used for Grinding process. Thus, it turns the long cork bark into granules, which can be called final product which can be seen in the Figures 3.10, 3.11, 3.12, 3.13, 3.14, 3,15, 3.16 and 3,17.

In the grain materials technology the grinding process has shredder machines that ensure:

- ✓ Grinding of raw materials;
- ✓ Particle size separation of the fragments obtained in grinding;
- ✓ Densiometric separation, that defines the density of granules;
- ✓ Drying the granules which gives adequate moisture for their use;
- ✓ Handling, transportation and final stage.



Figure 3.10 Shredder Machine in GMT Section 3 Raw materials dropped into it



Figure 3.11 In GMT section 3 shredder machine getting into the blades



Figure 3.12 In GMT section 3 shredder machine grains cork into small pieces



Figure 3.13 In GMT section 3 shredder machine grained into small size of cork



Figure 3.14 In GMT section 1 how raw materials is dropped into shredder machine



Figure 3.15 In GMT section 1 over all view of the grinding machine



Figure 3.16 In GMT section 1 shows how the cork bark is dropped into the grinding machine

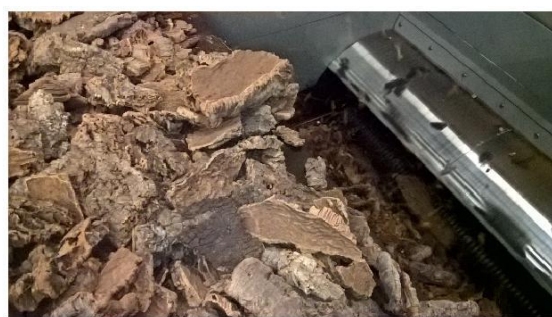


Figure 3.17 In GMT section 1, shows how the grinding machine grains the cork into small pieces

3.3.2 Boiler

Pop cork section consists of a small boiler in the GMT section 1 in Figure 3.18 and GMT section 3 in Figure 3.19, which helps to emit steam and transmits vapour at a high pressure to the pop cork chambers. Here, vapour transmits to the pop cork chambers, which helps in the cork expansion. Boilers are the main key equipment of the Pop Cork process.

3.3.3 Pop cork chambers

The main working area of the pop cork process are chambers present in the GMT section 1 and 3 pop cork chambers it can be seen in the Figure 3.21 and 3.22, here steam passes to the chambers with the mixture of sand and grinded cork, to absorb steam from the process to occupies more moisture content which mention in the figure 3.20. The cork consumes steam becomes larger than actual size, it is known as expanded cork. The expanded cork is used in construction fields for prevention of vibrations in concrete, industries areas for thermal conductivity and sound proof surfaces.



Figure 3.18 Boiler installed in GMT section 1



Figure 3.19 Boiler installed in GMT section 3

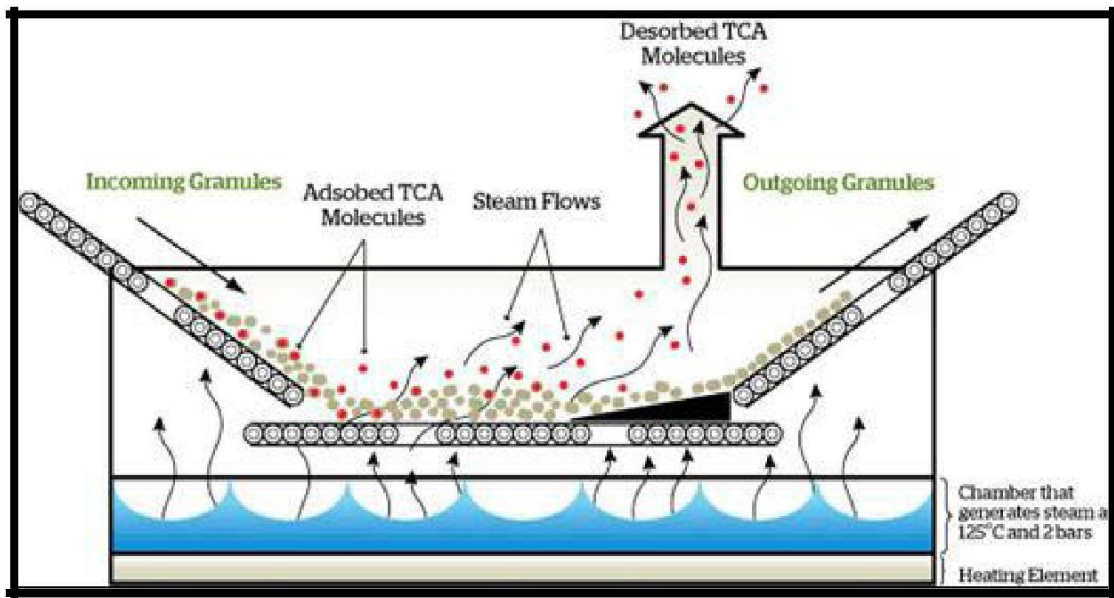


Figure 3.20 Working of Pop Cork Chambers

3.3.4 Dryer

After the pop cork manufacturing process, the expanded cork is transmitted to dryer. The dryer dries the cork at a higher temperature to remove the moisture content from granulated corks. Granulated cork has various size and density to separate for the cleaning process shown in the Figure 3.23 and 3.24.



Figure 3.21 Shows the pop chambers present in GMT section 1 it has 3 chambers



Figure 3.22 Shows the pop chambers present in GMT section 3 it has 2 chambers



Figure 3.23 Dryer in GMT section 1



Figure 3.24 Dryer in GMT section 3

3.3.5 Sieving machine by size and shape

After the drying process, the granulated cork is passed to cleaning machine in three stages for unwanted particles removal as follows:

- ✓ In the first stage, the sieving machine removes the unwanted particles such as stones and other external particles present in the granulated cork. Due to the air flow in the channels, some small size of stones passes to the granules;
- ✓ In second stage, the sieving machine rotates in three directions and separates the muds and split the granule cork depending on the low density, average density and high density of granulated cork;
- ✓ In the final stage, the cleaning machine checks for presence stones or mud in the granulated cork;
- ✓ After this stage, cleaned and pure granulated cork is transferred to the packing unit for different uses.

3.3.6 Packing section

The granulated cork is used to packs in diverse ways:

- ✓ The granulated cork is compressed in a rectangular shape and packed in two distinct sizes: one is 25 kg block and another one is 30 kg, based on client demands Granulated cork is packed and shipped to clients;
- ✓ The granulated cork is packed in a large bag of 30 kg and delivery to the clients
- ✓ Some granulated cork is pass to the cork rubber section for internal use.

3.4 Technical diagram of process layout

Here shows the technical view of grain material technology sections and the equipment working area in detail technical specifications are shown in Figure 3.25.

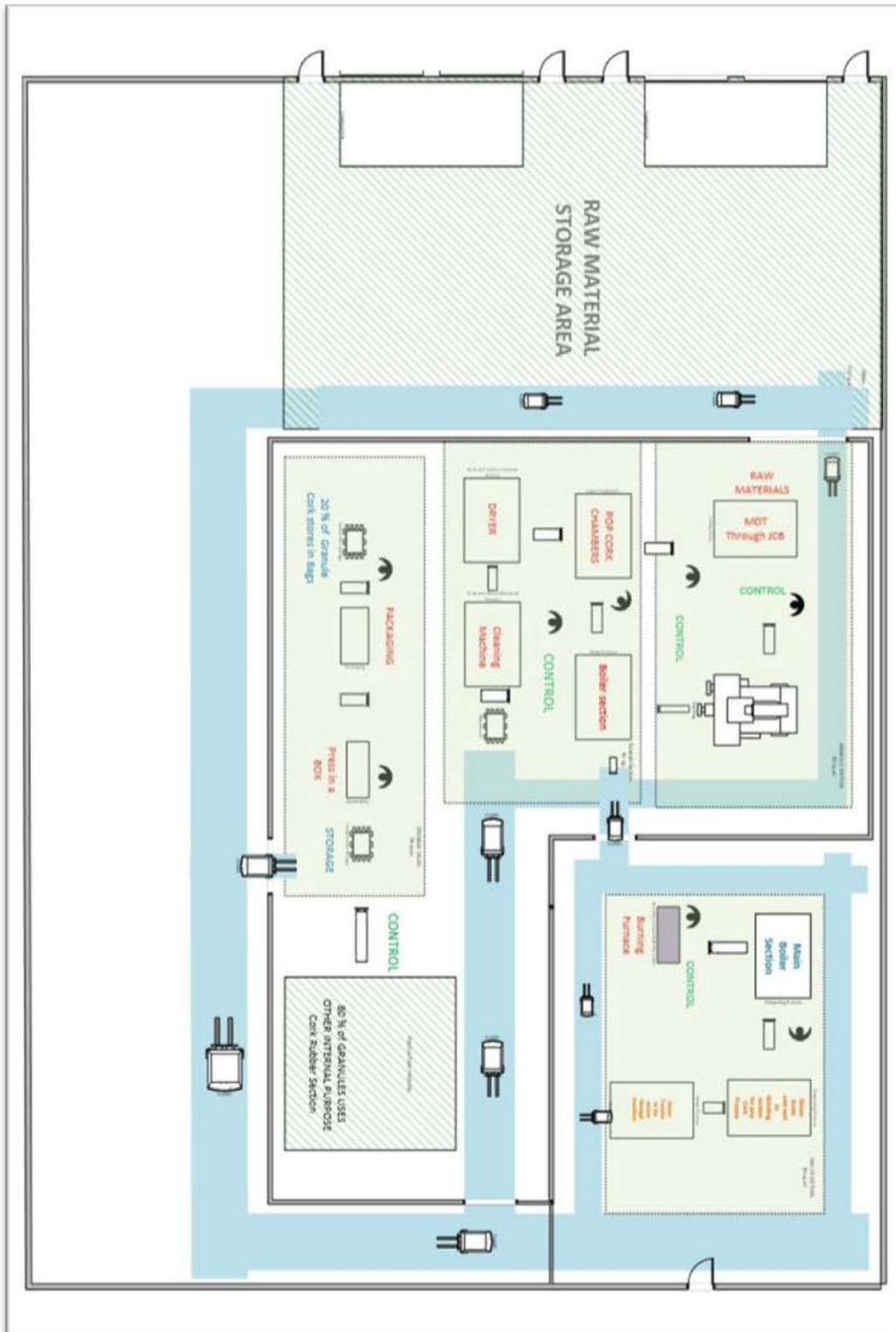


Figure 3.25 Technical drawings of GMT unit

3.5 Initial survey of pop cork process

Initially, the pop cork process was studied by:

- ✓ What is happening in the process?
- ✓ What are the main requirements for process?
- ✓ Collecting the data of initial stage normally.
- ✓ Make a graph of survey data about expansion level.

In the initial week, chief engineer explained the process of pop cork and its procedure of the Analysis and how to test the granules. There is three separate ways that are the following ones:

- ✓ Sample 1 is collected in a rectangular box and measured the volume of the granulated cork present in the Figure 3.26 and Figure 3.27 and named as Before in a data book. A small amount granulated cork is taken in a tray which can be seen in Figure 3.28 and 3.29 and measured the volume and noted as first value in the data sheet and kept inside the over heater at a 100-150 °C for more than 6 hours to reduce the moisture content in the collected sample 1 (Before) and after 7 hours completed take out from the over heater and note down the new reading as last value.



Figure 3.26 Sample 1 (Before) is collected



Figure 3.27 Before value is noted



Figure 3.28 Small amount of cork is taken, and first value noted



Figure 3.29 Sample 1 is kept in super heater

- ✓ After the grinding process, sample 2 is collected 15 minutes later, because granulated cork takes to reach the pop cork chamber to absorb steam and gets the cork expansion and sample 2 is named as After shown in Figure 3.30 and 3.31, take a small amount granule in a tray as in Figure 3.32 kept inside the

over heater at a 100 °C to 150 °C in for more than 6 hours to reduce the moisture content in the collected sample 2 as shown in the Figure 3.33 and note the reading as first value and after 7 hours completed take out from the over heater and note down new reading as last value.

✓



Figure 3.30 Sample 2 is collected as shown in figure



Figure 3.31 Sample 2 reading noted



Figure 3.32 Sample 2 small taken and noted first value



Figure 3.33 Sample 2 is kept in a super heater

✓ Sample 3 is collected after 15 minutes gap between sample 2, it passes to the dryer machine at a higher temperature and sample 3 in Figure 3.34 and 3.35 is named as dryer, take a tray and keep small amount of granule present in sample 3 as in Figure 3.36 and 3.37 inside the over heater at a 100 – 150 °C for more than 6 hours to reduce the moisture content in the collected sample 3 and note the reading as first value; After 7 hours completed take out from the over heater and note down new reading as last value.



Figure 3.34 Sample 3 is collected



Figure 3.35 Sample 3 value is noted



Figure 3.36 Sample 3 small taken and noted first value



Figure 3.37 Sample 3 is kept in a super heater

- ✓ The last value of the three samples kept in the super heater present in section 1 and 3 reduced the moisture content in granules shown in Figure 3.38,3.39 and 3.40; Now make a graph between first value and last value to find humidity level present in it and another chart comparing the values of temperature, pressure and expansion of cork.



Figure 3.38 sample 1 after 7 hrs taken out from the super heater



Figure 3.39 sample 2 after 7 hrs taken out from the super heater



Figure 3.40 sample 3 after 7 hrs taken out from the super heater

- ✓ Discussion with supervisor, chief engineer and operators about if the values were taken in a correct way.

After this process, the density of granulated cork was calculated and found the expansion value. Checking different raw materials used in the pop cork process in GMT section 1 and GMT section 3, all values were registered and form a graph to find deviation of moisture content and expansion of cork by cadence.

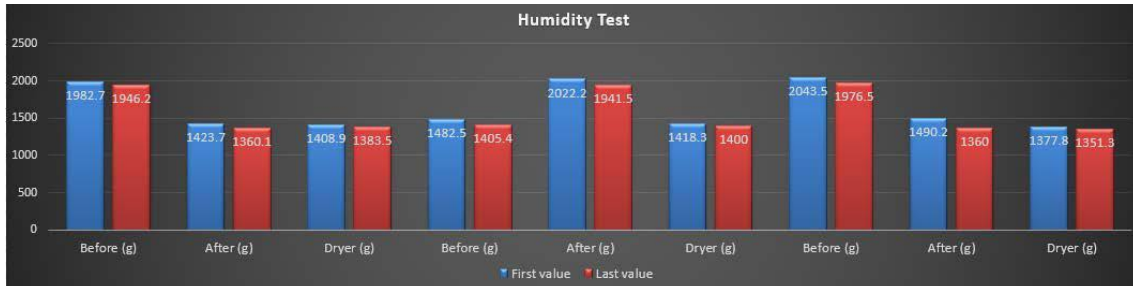


Figure 3.41 Data analysis for the week 1 and week 2 – Humidity Test

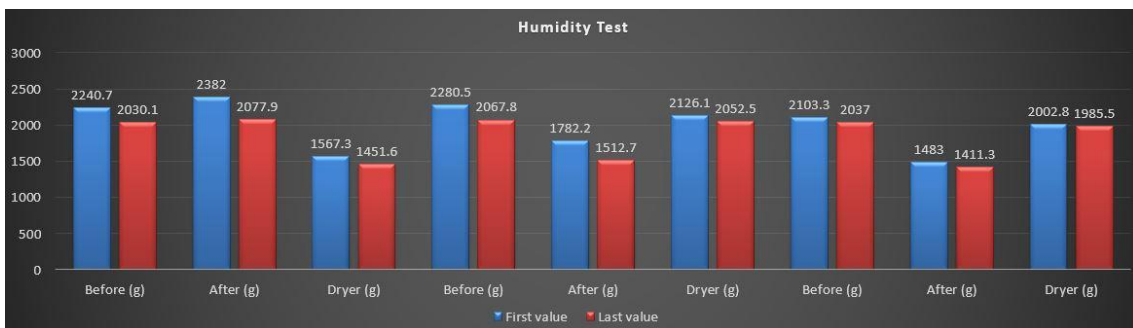


Figure 3.42 Data analysis for the week 4 and week 5 – Humidity Test

The data shows about the moisture content in the granules before keeping the samples in over heater and after taken out from the super heater.

The Figure 3.41, shows the moisture content level after the super heater with the low level of cork expansion and the Figure 3.42 mention the higher and lower level of expansion of cork in a regular interval.

- In the beginning, the samples are kept in super heater for less than 4 hours. The results in the granulated cork expansion are lesser only. When the samples are kept for more than 7 hours in the super heater shows the results for the cork expansion in a satisfactory level.
- When the boiled cork and not boiled cork is mixed, the results will show low expansion of cork.
- The next step taken to find the relation between temperature, pressure levels and cork expansion.

The observation of the cork expansion is described in Figure 3.43 and 3.44 with the error and some problems are identified by analyses.

Volumes (g/Cubic L)			% (Dryer/Before)	Humidity Test (g)			Comments about Observations
Batches	Values	Density (g/cubic L)	Expansion	First value	Last value	Humidity Difference	
Before (g)	4292.1	214.605	0.4%	1335.3	1309.1	26.2	1.Error in values
After (g)	4273.8	213.69		1404.5	1357.2	47.3	2. moisture content is high 3.Out of control
Before (g)	5162.7	258.135	10.4%	1667.6	1464.9	202.7	Here the cork expansion
After (g)	4624	231.2		1442.7	1378.1	64.6	
Before (g)	4573.8	228.69	-10.8%	1519.4	1419.8	99.6	1. No Expansion of cork 2.Due to high moisture
After (g)	5069.1	253.455		1570.2	1444.9	125.3	
Before (g)	4204.1	210.205	0.0%	1982.7	1946.2	36.5	Here expansion of cork is zero. Due to high moisture.
After (g)	4371.3	218.565		1423.7	1360.1	63.6	
Dryer (g)	4202	210.1		1408.9	1383.5	25.4	
Before (g)	4542.3	227.115	8.0%	1482.5	1405.4	77.1	Here Cork expands little.
After (g)	4389.6	219.48		2022.2	1941.5	80.7	
Dryer (g)	4179.5	208.975		1418.3	1400	18.3	
Before (g)	4581.3	229.065	7.4%	2043.5	1976.5	67	Here Cork expands little.
After (g)	5042.3	252.115		1490.2	1360	130.2	
Dryer (g)	4244.5	212.225		1377.8	1351.3	26.5	

Figure 3.43 Data collected for the week 1 and week 2

Before (g)	4508.2	225.41	7.0%	1458.8	1422.5	36.3	Here Cork expands little.
After (g)	4573.8	228.69		2075.7	2001.4	74.3	
Dryer (g)	4191.8	209.59		1447.8	1433.3	14.5	
Before (g)	4443.6	222.18	4.0%	1521	1460	61	Here Cork expands less.
After (g)	4212.5	210.625		2028.5	1951	77.5	
Dryer (g)	4264.5	213.225		1440.3	1415	25.3	
Before (g)	5514	275.7	11.0%	1618.5	1463	155.5	Here Cork expands higher amount.
After (g)	5462.5	273.125		1641.2	1473	168.2	
Dryer (g)	4910.1	245.505		2076	2003	73	
Before (g)	4753	148.53125	4.8%	1548.9	1458.8	90.1	Temperature is low but Expansion of cork moderate
After (g)	4696	146.75		2117	2026.2	90.8	
Dryer (g)	4525.6	141.425		2010.3	1978.6	31.7	
Before (g)	4728	147.75	4.0%	1608.9	1508.3	100.6	Temperature is low but Expansion of cork moderate
After (g)	4732.5	147.890625		2026	1925.2	100.8	
Dryer (g)	4537	141.78125		2056	2048.4	7.6	
Before (g)	5453.4	170.41875	13.3%	2240.7	2030.1	210.6	Temperature is high but Expansion of cork is good
After (g)	5677	177.40625		2382	2077.9	304.1	
Dryer (g)	4725.8	147.68125		1567.3	1451.6	115.7	
Before (g)	6610.4	206.575	10.9%	2280.5	2067.8	212.7	Temperature is high but Expansion of cork is Moderate
After (g)	6376.1	199.253125		1782.2	1512.7	269.5	
Dryer (g)	5887.2	183.975		2126.1	2052.5	73.6	
Before (g)	4434.5	138.578125	6.8%	2103.3	2037	66.3	Temperature is high but Expansion of cork is Moderate
After (g)	4204	131.375		1483	1411.3	71.7	
Dryer (g)	4133.2	129.1625		2002.8	1985.5	17.3	

Figure 3.44 Data collected for the week 3 and week 4

3.6 Pop Cork expansion analysis

Comparing the initial data, the new set of results shows more variations of expansion of pop cork results because the temperature increased in GMT section 1 to the maximum level of 120 °C and in GMT section 3 to the maximum level of 150 °C. The complete analysis of cork expansion was expressed with the help of charts below.

3.6.1 In Granule Unit 1

In the Figure 3.45 the raw materials of lote A, Refugo cru and apara cozida are passed at the normal temperature of 102.5°C in the pop cork process has more cork

expansion values shown in the chart expansion. Due to the raw materials used in the pop cork process, Refugo cru is not boiled cork and apara cozida and Lote A is boiled cork. Boiled cork consists moisture content more than not boiled cork. This is main reasons of cork expansion level variation at same temperature.

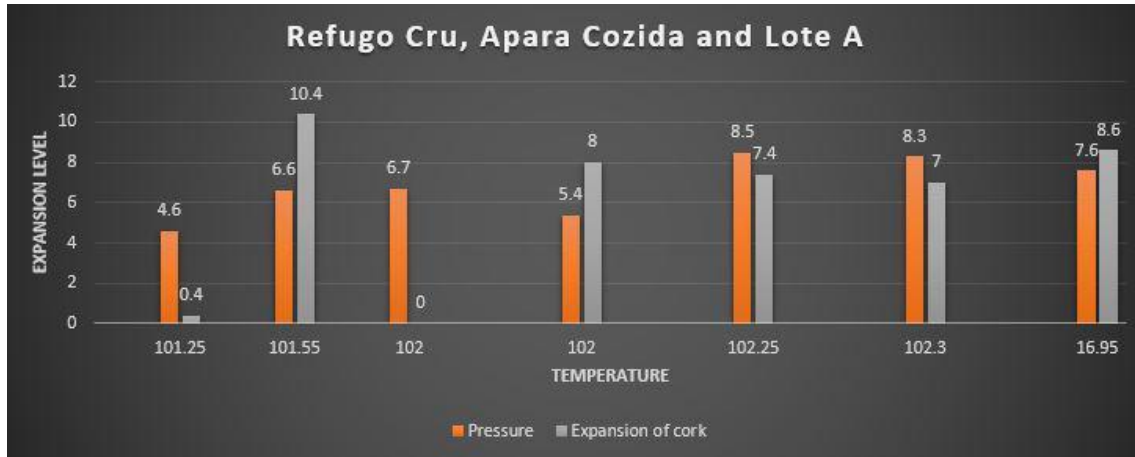


Figure 3.45 Refugo Cru, Apara Cozida, Lote A in GMT Section 1

In the Figure 3.46, the first set of readings shows expansion of cork is high comparing with other reading because of boiled and not boiled used in this process. Here dampness content is low, and it absorbs more steam in pop cork process brings the expansion level in an effective way.

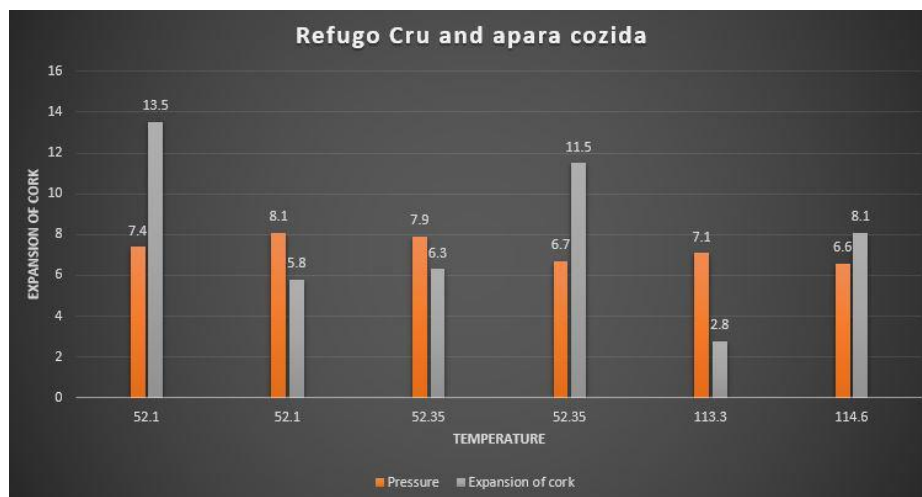


Figure 3.46 Refugo Cru and Apara Cozida In GMT sections 1

In the chart 3.47 explains the expansion of cork is high and low at same level of temperature. It indicates some equipment is malfunctioning due to the inappropriate maintenance.

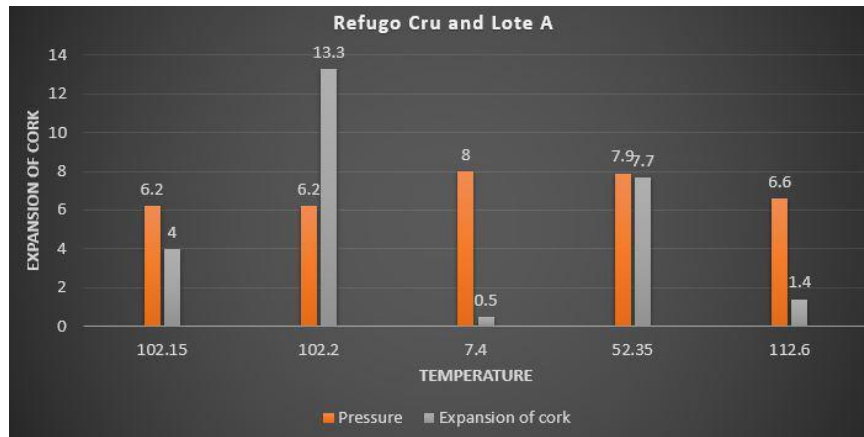


Figure 3.47 Refugo Cru and Lote A in GMT section 1

In the graph 3.48 Refugo cru is the raw materials used with and without pop cork process. The variant in expansion with pop cork results good expansion and without pop cork has low expansion in the chart.

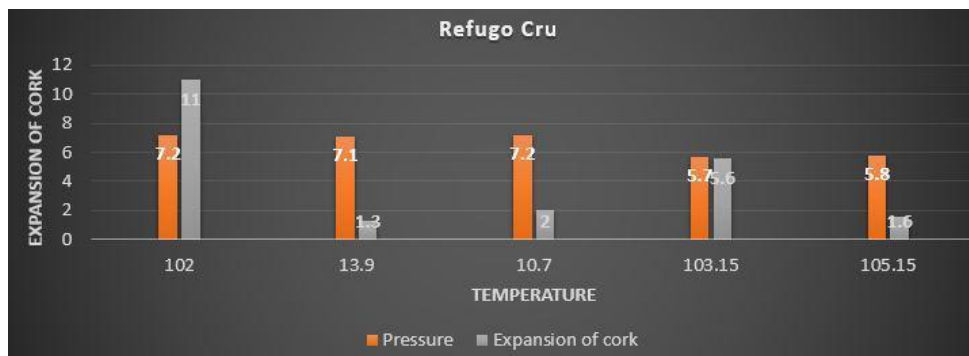


Figure 3.48 Refugo Cru in GMT section 1

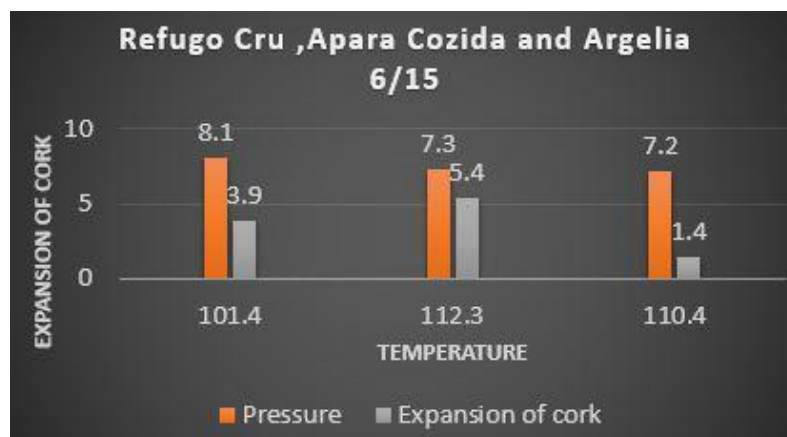


Figure 3.49 Fifth set of raw materials In GMT 1

In this graph 3.49 indicates the expansion of cork is normal at *higher temperature*. This set of raw materials has *proficient level of expansion of cork* in the pop cork process.

In the Chart 3.50 describe about separate set of raw materials are mixed and uses for the process of *Expansion and varies up and down level of expandable of cork*.

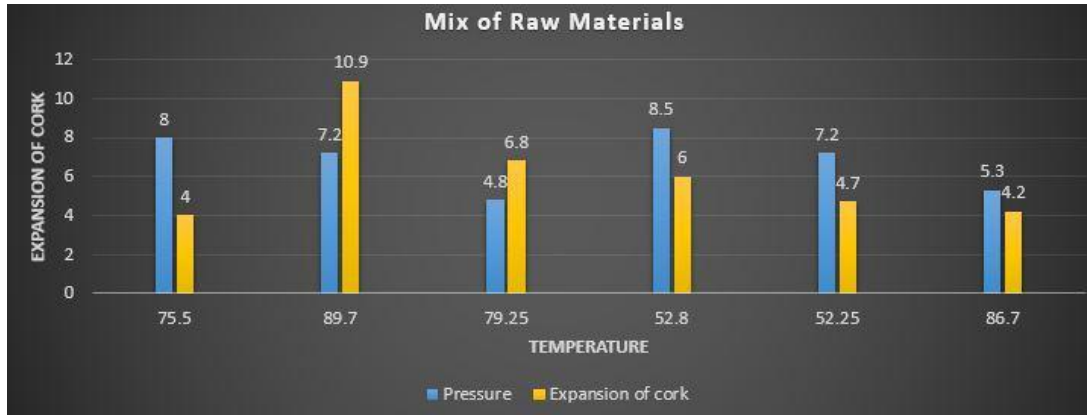


Figure 3.50 Mixed Raw materials in GMT section 1

In GMT Unit 3

In the plot 3-51 shows the satisfactory level of expansion, the raw material uses in the process is not boiled cork.

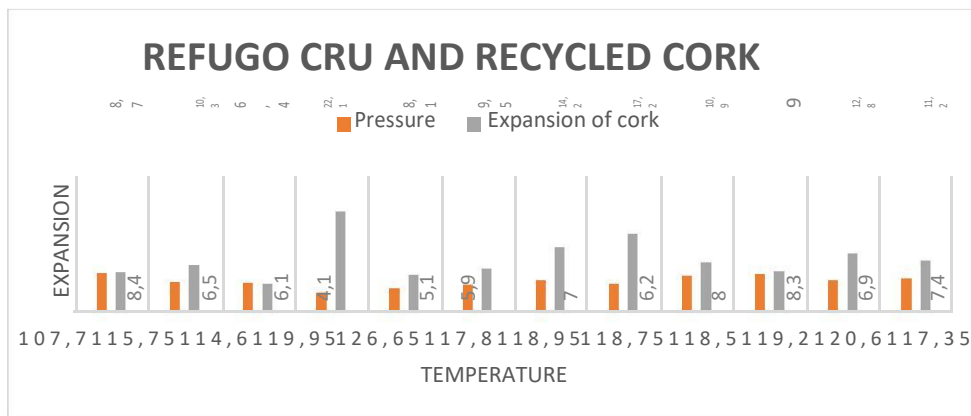


Figure 3.51 First set of raw materials in GMT 3

Here the graph 3.52 shows the passing of elevated temperature to the pop cork chamber it helps in increase the expansion level in a well organised way.

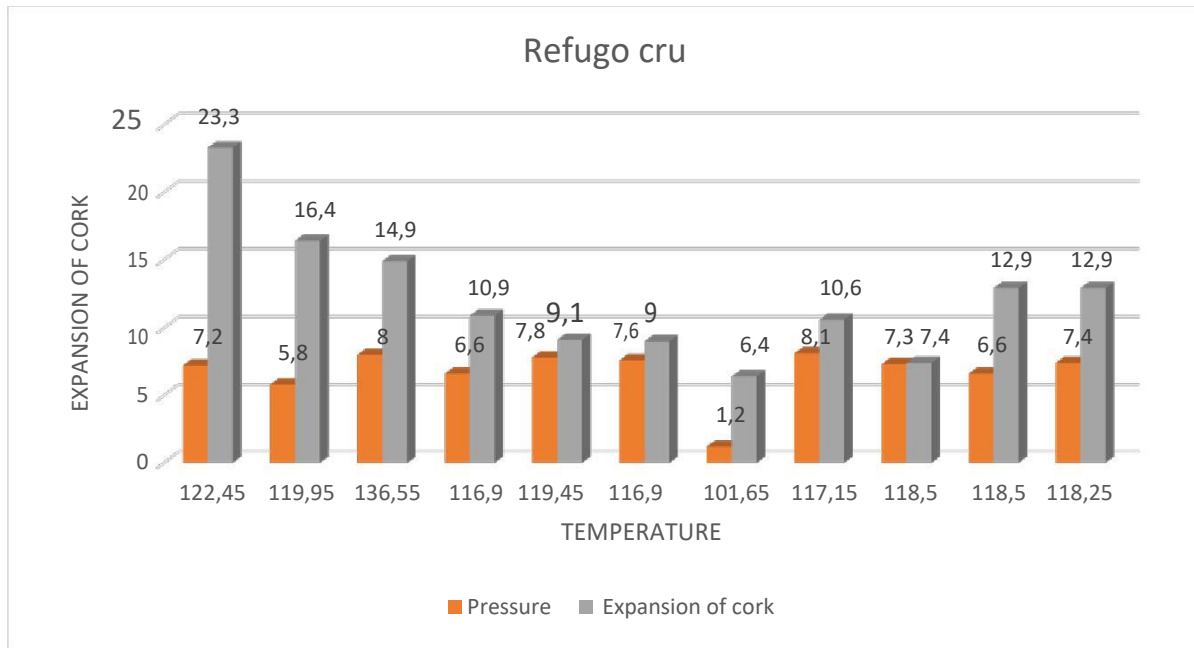


Figure 3.52 Second set of raw material in GMT 3

The chart 3-53 indicates very good level of expansion the raw materials are not boiled and cork bark young this set of cork uses in pop cork process gains more efficient way of expandable cork.

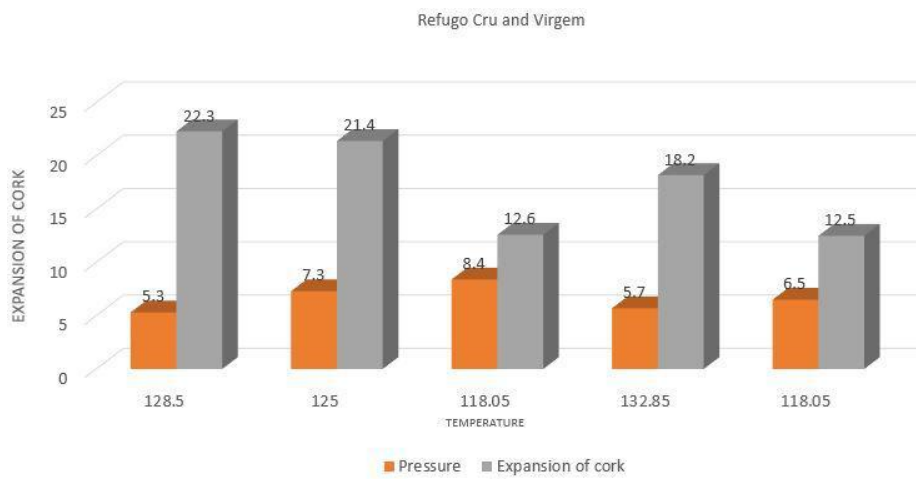


Figure 3.53 Third set of raw materials in GMT 3

In the bar graphs 3-54 shows the *expansion of cork is very good due to less amount of moisture content* present in the raw materials which helps to absorb steam in the pop cork process. Expression of the variant level of temperature has different expansion of cork because cork raw materials has *typical features and physical properties*.

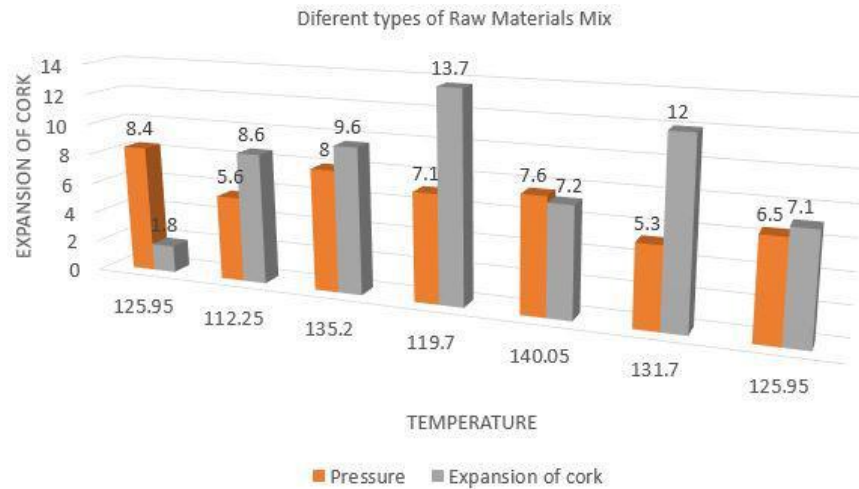


Figure 3.54 Fifth set of raw materials in GMT 3

3.7 Main damage types in chambers

In GMT section 1 there are problems in the pop cork process because of raw materials used in section 1 is 50 % of boiled and 50 % of not boiled cork. When the sand is mixed with steam, the chamber and pipes are affected which can be seen in the Figure 3.55 detail views in grain material technology section 1



Figure 3.55 Pop cork chamber in GMT section 1 indicates hole on the chambers

In the Figure 3.55 it is shown the small hole on the pop cork chamber which makes often steam leaks from the hole and affects the cork expansion. The pop cork chamber should be keep clean and in good working conditions. Then, effeciency of cork increases in a economic way.



Figure 3.56 Shows totally damages of pop cork chamber in GMT section 1

The Figure 3.56 shows that one of the pop chamber is completely damaged and not working in good conditions. So, there is another problem because one of the chamber is not being used for the pop cork process.



Figure 3.57 Shows breakages in the pipe lines of cork passing in pop cork chambers

The pipes helps to transfers granules to all working areas. There are a lot of damages in GMT section 1 because the stones mixed with the pop cork process damage the pipes and give rise to a lot of staem leaks in the pop cork section 1,as can be seen in Figure 3.57.



Figure 3.58 Show detail views of dislocation of pipes in pop cork chamber present in GMT section 1

The Figure 3.58 explains the damages occurred by the mud and stones in the pop cork chamber. This is due to the movement of cork with the help of air passing through the channels.

3.7.1 Brain Storming

In order to carry out a more detailed analysis about the pop cork manufacturing process, three different methodologies were adopted as follows.

3.7.1.1 Five why analysis

Using five why? root cause analysis the pop cork problems are pointed in the sequencing way and trying to find a workable solution for the process improvement in a polite manner. Figure 3.59 shows the sequence of five question used through this methodology in this case,



Figure 3.59 Five why analysis for pop cork section

3.7.1.2 Six sigma (DMAIC – Define, Measure, Analysis, Improve and Control)

The six sigma (DMAIC) methodology is used to apply and find improvements in the process for the cork expansion in an effective way.

- ✓ Define: Identify the problems of pop cork manufacturing process;
- ✓ Measure: Measure the working conditions pop cork boilers;
- ✓ Analysis: Analyses the process of Pop Cork using five why analysis;
- ✓ Improve: Change the controls and condition of pop cork, by increasing the temperature level:
 - Temperature is directly proportional to the pressure; so, any of one can changes will affect the boiler conditions;
- ✓ Control: If Pop cork is under control, keep these steps once a month otherwise repeats the work from the beginning of this method to find improvement in the process to control of Pop cork in an efficient way.

3.7.1.3 Fishbone diagram

The fishbone diagram is analyses all potential causes for problems which leads to possible improvement in the pop process. The fishbone diagram analysis and gives

useful way for find major causes to be reduce and the process flow of pop cork good way.

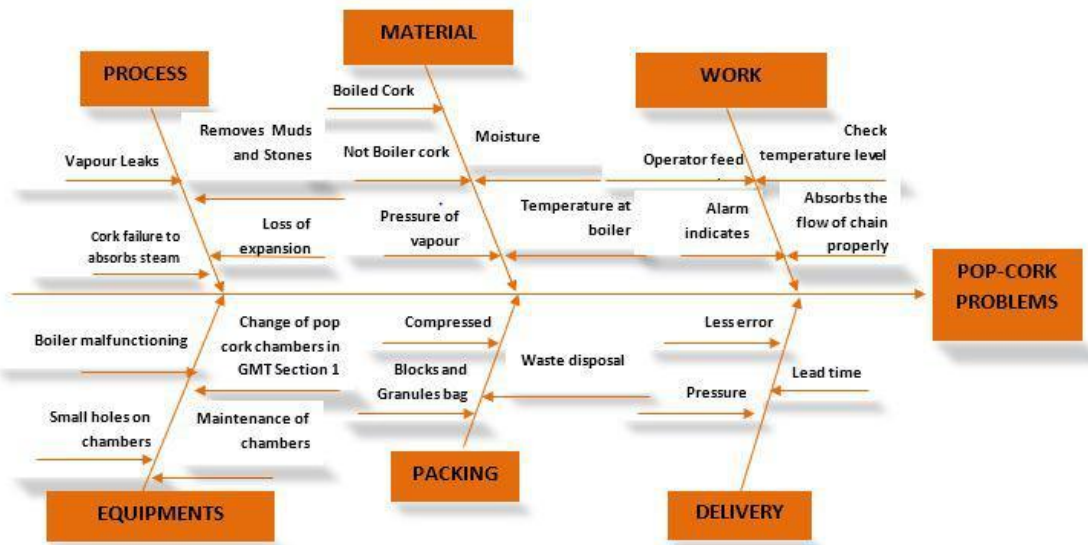


Figure 3.60 Fishbone diagram of pop cork process

In the fish bone diagram 3.60, Identifying main root causes of cork expansion problems in a well-organized way and helps to eliminating some of them and exploring the results.

3.8 Production of Granules

Last 4 months, the analysis of Pop Cork process has proved some profits i.e., 3% grade points (Internal calculations) achieved based on the density

1. With Pop Cork
 - at the density of 65-85 g/mm³; achieved profits of 3 %
 - at the density of 90-100 g/mm³; losses 8 %
2. Without Pop Cork
 - at the density of 65-85 g/mm³; losses 4 %
 - at the density of 90-100 g/mm³; achieved profits of 9%.

Here describes that at low density of 65-85 g/mm³ of pop cork will achieve profits is proved.

CONCLUSIONS

4.1 CONCLUSIONS

4.2 PROPOSALS OF FUTURE WORKS

4 CONCLUSIONS AND PROPOSALS OF FUTURE WORKS

4.1 CONCLUSIONS

After four months of internship, many tasks were performed and several tests were carried out such as:

- ✓ Many production observation were performed;
- ✓ Several tests were carried out regarding pop cork process such as types of raw material used, dry cork or wet cork, equipment gauges errors all are absorbed to point out exact solutions to the company;
- ✓ Problems were identified, and suggestions were provided to the company in order to solve problems. The main problems identified were: boilers are not work properly, chambers of pop cork are completely damaged in GMT 1 and the cork mixer with boiled and not boiled also causes the cork expansions;
- ✓ After that some improvements were implanted, such as the production of granules at the density of 65-85 g/mm³ giving rise to a profit increase of 3 % by overall production;
- ✓ At last the pop cork has profitable process was clearly proved.

4.2 PROPOSALS OF FUTURE WORKS

The regularity of maintenance operations should be undertaken to increases the granules production in pop cork chambers.

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SOURCES OF INFORMATION**

5 REFERENCES AND OTHER SOURCES OF INFORMATION

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ANNEXES

6.1 Results of Granule section 1 in GMT unit 1

6.2 Results of Granule section 3 in GMT unit 3

5 ANNEXES

Here the datas of pop cork process measured in the different raw materials mixed readings are noted and mention some important problems in the Granule section 1 and section 3 in the Grain material technology unit.

5.1 Granule section 1 in GMT unit 1

Table 6-1 Refugo Cru,Apara Cozida,Lote A in GMT section 1

Batches	Values	Density	Temperature	Pressure	Expansion of cork
Before	4292.1	214.605			
After	4273.8	213.69	101.25	4.6	0.4
Before	5162.7	258.135			
After	4624	231.2	101.55	6.6	10.4
Before	4204.1	210.205			
After	4371.3	218.565	102	6.7	0
Dryer	4202	210.1			
Before	4542.3	227.115			
After	4389.6	219.48	102	5.4	8
Dryer	4179.5	208.975			
Before	4581.3	229.065			
After	5042.3	252.115	102.25	8.5	7.4
Dryer	4244.5	212.225			
Before	4508.2	225.41			
After	4573.8	228.69	102.3	8.3	7
Dryer	4191.8	209.59			
Before	4876.7	243.835			
After	Nil	Nil	16.95	7.6	8.6

Dryer	4456.3	222.965			
Before	4779.3	238.965			
Batches	Values	Density	Temperature	Pressure	Expansion of Cork
After	Nil	Nil	8.4	6.5	9.1
Dryer	4345.6	217.28			
		Average	79.6	6.8	6.4

Table 6-2 Refugo Cru and Apará Cozida In GMT sections 1

Batches	Values	Density	Temperature	Pressure	Expansion of cork
Before	4830.2	241.51			
After	4340	217	52.1	7.4	13.5
Dryer	4178.7	208.935			
Before	4465	223.25			
After	4219	210.95	52.1	8.1	5.8
Dryer	4205	210.25			
Before	4760	238			
After	5018	250.9	52.35	7.9	6.3
Dryer	4458	222.9			
Before	4906.4	245.32			
After	4952.3	247.615	52.35	6.7	11.5
Dryer	4342.4	217.12			
Before	4671.8	233.59			
After	4664.2	233.21	113.3	7.1	2.8
Dryer	4543.1	227.155			
Before	4484.5	224.225			

After	4108.9	205.445	114.6	6.6	8.1
Dryer	4120.6	206.03			
		Average	72.8	6.6	8.1

Table 6-3 Refugo Cru and Lote A in GMT section 1

Batches	Values	Density	Temperature	Pressure	Expansion of cork
Before	4443.6	222.18			
After	4212.5	210.625	102.15	6.2	4
Dryer	4264.5	213.225			
Before	5453.4	272.67			
After	5677	283.85	102.2	6.2	13.3
Dryer	4725.8	236.29			
Before	5192.8	259.64			
After	Nil	Nil	7.4	8	0.5
Dryer	5164.4	258.22			
Before	4443.7	222.185			
After	4418.6	220.93	52.35	7.9	7.7
Dryer	4100	205			
Before	4450	222.5			
After	4277.3	213.865	112.6	6.6	1.4
Dryer	4387.5	219.375			
		Average	75.34	7	5.4

Table 6-4 Refugo Cru in GMT section 1

Batches	Values	Density	Temperature	Pressure	Expansion
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of cork					
Before	5514	275.7			
After	5462.5	273.125	102	7.2	11
Dryer	4910.1	245.505			
Before	4602.1	230.105			
Batches	Values	Density	Temperature	Pressure	Expansion of cork
After	Nil	Nil	13.9	7.1	1.3
Dryer	4541.9	227.095			
Before	4655.2	232.76			
After	Nil	Nil	10.7	7.2	2
Dryer	4562.6	228.13			
Before	4835.9	241.795			
After	4753.6	237.68	103.15	5.7	5.6
Dryer	4565.7	228.285			
Before	4883.6	244.18			
After	4710	235.5	105.15	5.8	1.6
Dryer	4803.9	240.195			
		Average	67	6.6	4.3

Table 6-5 Refugo cru, Apara Cozida, Argelia 6/15 in GMT Section 1

Batches	Values	Density	Temperature	Pressure	Expansion of cork
Before	4496	224.8			
After	4799.6	239.98	101.4	8.1	3.9
Dryer	4319.9	215.995			
Before	4345.2	217.26			

After	4225.2	211.26	112.3	7.3	5.4
Dryer	4109.9	205.495			
Before	4255.5	212.775			
After	4280.2	214.01	110.4	7.2	1.4
Dryer	4194.6	209.73			
		Average	108	7.5	3.6

Table 6-6 Mixed Raw materials in GMT section 1

Batches	Raw materials	Values	Density	Temperature	Pressure	Expansion of cork
Before	RF Cru L.esq	4728	236.4			
After	L.Direito	4732.5	236.625	75.5	8	4
Dryer	Lote A	4537	226.85			
Before	RF Cru L.esq	6610.4	330.52			
After	L.Direito	6376.1	318.805	89.7	7.2	10.9
Dryer	Lote A	5887.2	294.36			
Before	Refugo Cru	4434.5	221.725			
After	Refugo Cozida	4204	210.2	79.25	4.8	6.8
Dryer	Lote A	4133.2	206.66			
Before	Refugo Cru	4496	224.8			
After	Barrigar	4648.2	232.41	52.8	8.5	6
Dryer	Apara Cozida	4228.1	211.405			
Before		4553.1	227.655			

After	Apara Cozida	4533	226.65	52.25	7.2	4.7
Dryer		4337	216.85			
Before	Apara Cozida	4522.7	226.135			
After	Refugo Cru	4449.7	222.485	86.7	5.3	4.2
Dryer	Lote B	4331.3	216.565			
			Average	76.9	6.9	3.7

5.2 Granule section section 3 in GMT unit 3

Table 6-7 Refugo Cru and Recycle corks in GMT Section 3

Batches	Values	Density	Temperature	Pressure	Expansion of cork
Before	4482.9	224.145			
After	3868	193.4	107.7	8.4	8.7
Dryer	4093.4	204.67			
Before	4328.5	216.425			
After	3759	187.95	115.75	6.5	10.3
Dryer	3883	194.15			
Before	5722.3	286.115			
After	6185.9	309.295	114.6	6.4	6.1
Dryer	5372.2	268.61			
Before	5230.5	261.525			
After	3970	198.5	119.95	4.1	22.1
Dryer	4074.1	203.705			
Before	4216	210.8			

After	3343.9	167.195	126.65	5.1	8.1
Dryer	3873.5	193.675			
Before	4305.2	215.26			
After	3640.2	182.01	117.8	5.9	9.5
Dryer	3897.1	194.855			
Before	4997.7	249.885			
After	4205.6	210.28	118.95	7	14.2
Dryer	4290.4	214.52			

Batches	Values	Density	Temperature	Pressure	Expansion of cork
Before	4931.6	246.58			
After	4038.2	201.91	118.75	6.2	17.2
Dryer	4082.8	204.14			
Before	4343	217.15			
After	3782.7	189.135	118.5	8	10.9
Dryer	3869.7	193.485			
Before	4176.5	208.825			
After	3662.5	183.125	119.2	8.3	9
Dryer	3799	189.95			
Before	4225.2	211.26			
After	3598.4	179.92	120.6	6.9	12.8
Dryer	3683.9	184.195			
Before	4268.9	213.445			
After	3827.9	1191.395	117.35	7.4	11.2
Dryer	3788.9	189.445			
		Average	118	6.7	11.9

Table 6-8 Refugo Cru in GMT section 3

Batches	Values	Density	Temperature	Pressure	Expansion of cork
Before	5522.1	276.105			
After	4580.2	229.01	122.45	7.2	23.3
Dryer	4236.7	211.835			
Before	4901.6	245.08			
Batches	Values	Density	Temperature	Pressure	Expansion of cork
After	4400	220	119.95	5.8	16.4
Dryer	4097.6	204.88			
Before	4863.7	243.185			
After	4570.2	228.51	136.55	8	14.9
Dryer	4138.3	206.915			
Before	4393.5	219.675			
After	3797.4	189.87	116.9	6.6	10.9
Dryer	3916.2	195.81			
Before	4374	218.7			
After	3872.4	193.62	119.45	7.8	9.1
Dryer	3975.3	198.765			
Before	5417.4	270.87			
After	4383	219.15	116.9	7.6	9
Dryer	4929.3	246.465			
Before	4285.4	214.27			
After	4033.7	201.685	101.65	1.2	6.4
Dryer	4009.5	200.475			
Before	4640.9	232.045			

After	4139.2	206.96	117.15	8.1	10.6
Dryer	4149.7	207.485			
Before	4340.4	217.02			
After	3848.9	192.445	118.5	7.3	7.4
Dryer	4017.2	200.86			
Before	4552.3	227.615			
After	3808.8	190.44	118.5	6.6	12.9
Dryer	3967.3	198.365			
Before	4311.4	215.57			
After	3793.1	189.655	118.25	7.4	12.9
Dryer	3754.7	187.735			
		Average	108.12	6.7	12.2

Table 6-9 Refugo Cru and Virgem in GMT Section 3

Batches	Values	Density	Temperature	Pressure	Expansion of cork
Before	5367	268.35			
After	4355.9	217.795	128.5	5.3	22.3
Dryer	4172.3	208.615			
Before	4597.2	229.86			
After	3959	197.95	125	7.3	21.4
Dryer	3613.2	180.66			
Before	4416	220.8			
After	4024.3	201.215	118.05	8.4	12.6
Dryer	3859.4	192.97			
Before	4717.3	235.865			
After	3956.3	197.815	132.85	5.7	18.2

Dryer	3857.5	192.875			
Before	5493	274.65			
After	5136.6	256.83	118.05	6.5	12.5
Dryer	4807	240.35			
		Average	124.5	6.6	17.4

Table 6-10 Refugo Cru and Brancos in GMT section 3

Batches	Values	Density	Temperature	Pressure	Expansion of cork
Before	4343	217.15			
After	3782.7	189.135	118.5	8	10.9
Dryer	3869.7	193.485			
Before	4176.5	208.825			
After	3662.5	183.125	119.2	8.3	9
Dryer	3799	189.95			
Before	4225.2	211.26			
After	3598.4	179.92	120.6	6.9	12.8
Dryer	3683.9	184.195			
Before	4268.9	213.445			
After	3827.9	191.395	117.35	7.4	11.2
Dryer	3788.9	189.445			
		Average	118.91	7.65	10.96

Table 6-11 Mixed raw materials in GMT section 3

Raw materials	Batches	Values	Density	Temperature	Pressure	Expansion of cork
Esp.Rolhas	Before	4367.7	218.385			
14/25	After	4043.4	202.17	125.95	8.4	1.8
	Dryer	4291.2	214.56			
Virgem	Before	4241.5	212.075			
	After	3777.5	188.875	112.25	5.6	8.6
	Dryer	3876.8	193.84			
REF-CA	Before	4571.7	228.585			
	After	3986.8	199.34	135.2	8	9.6
	Dryer	4132.7	206.635			
Refugo Cru	Before	4450	222.5			
Rolhas	After	3802	190.1	119.7	7.1	13.7
	Dryer	3842.5	192.125			
Refugo Cru	Before	4217	210.85			
Rolhas	After	3633.3	181.665	140.05	7.6	7.2
	Dryer	3911.3	195.565			
Refugo cru	Before	4392.6	219.63			
Vizagen	After	3843.4	192.17	131.7	5.3	12
Esp.Rolhas	Dryer	3866.1	193.305			
	Before	3948.8	197.44			
Especial	After	3561.5	178.075	125.95	6.5	7.1
respaldada	Dryer	3669.3	183.465			
			Average	127.25	6.92	8.57

