UNIVERSITAT ROVIRA I VIRGILI

DEBOTTLENECKING OF THE SOLID PACKAGED RAW MATERIAL HANDLING

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Nomenclature

BU: Business Unit.

BOM: Build of Material.

F: Final material.

FT: Flow Transmitter.

I: Intermediate material.

IBC: Intermediate Bulk Containers.

ICS: Industrial and Consumer Specialties.

M: Motor.

OMS: Oil and Mining Service.

PCV: Pressure Control Valve.

PI: Pressure Instrument.

PT: Pressure Transmitter.

R: Raw material.

TI: Temperature Instrument.

TT: Temperature Transmitter.

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Summary

Throughout this project, an in-depth analysis and examination of the raw material fusion process have been conducted to tackle the existing bottlenecking. Initially, the materials under study were identified, taking into consideration certain properties, conditions, or characteristics that may impact the research. Once the study list and data for each of the materials have been obtained, the monthly movements of the last three years are analyzed. These values provide an estimate of the movements made in the production plant and different solutions are proposed that can achieve the main objective of this project. Once the various proposals have been made, the two that offer the greatest benefits and least effort to the company are studied. These are the design and implementation of a heated storage area to reduce movements to the chambers and the design and implementation of new fusion chambers.

In all the points that make up this report, the considerations made, and the steps taken have been explained in detail. An exhaustive analysis has been carried out on each of the materials, as well as their behavior in the production process. After analyzing all the proposals, the two options that offer greater benefits and less effort to the company have been selected. The first solution is the design and implementation of a heated storage area to reduce movements to the chambers. This will allow the raw materials to be stored closer to the melting point, which in turn will reduce the number of movements required to take them to the fusion chambers. The second solution is the design and implementation of new fusion chambers. These chambers will allow for greater production capacity, which will help reduce bottlenecks in the production process. In addition, the possibility of incorporating more advanced technologies in these chambers to improve the fusion process has been studied.

In conclusion, this project has been a great success and has allowed us to find solutions to improve the process of raw material fusion. A detailed and rigorous work has been carried out, which has allowed us to select the best options to solve the existing bottlenecking problem in the production plant.

1. Introduction

This chapter aims to introduce the world of chemical manufacturing in order to introduce the company, the problem defined in it and the solutions to be proposed and studied throughout this project.

1.1. Introduction to Clariant

Clariant Production S.A. is a Swiss multinational company that manufactures chemical products for different industrial areas. Clariant was founded in 1995 as a spin-off from the chemical company Sandoz. It has expanded over the years by incorporating the specialty chemicals business of Hoechst (Germany) in 1997, and the acquisitions of BTP plc (UK) in 2000 and Ciba's Masterbatches division in 2006.Since then, several acquisitions were made as well as the divestment of several bigger businesses until 2012, where Clariant was rebranded, presenting a new vision and mission.

Clariant is one of the world's leading specialty chemical companies present in 53 different countries with 154 companies around the world, having its Head Quarters in Muttenz, Switzerland. Clariant as a company creates value with innovative and sustainable chemical products and solutions designed for specific applications in raw materials.

Recently, Clariant has reduced its business units (BU) from five to three based on the nature of the business, similar market and industry dynamics, technology and applications used. These three are:

- Catalyst: is the combination of two BU, Catalyst and Business line biofuels derivatives.
- Adsorbents & Additives is the combination of Functional Minerals and Additives.
- Care chemicals: is the combination of BU Industrial and Consumer Specialties (ICS) and BU Oil and Mining Services (OMS).

The Tarragona production plant is responsible for the production of care chemicals, which includes the two business units of care chemicals mentioned above.

The Industrial and Consumer Specialties business unit creates innovative and sustainable chemical products and solutions for customers from different industries. The business unit ICS is one of the largest providers of specialty chemical industry knowledge with high-performance ingredients and formulation expertise, ICS delivers solutions with the best cost-performance ratios.

Clariant is committed to providing its partners with innovative ingredients that not only fulfill consumer needs but also deliver benefits during production. Therefore, manufacturing processes are continuously optimized to increase efficiency, safety and environmental protection.

As a key chemical manufacturer and supplier, Clariant offers products with consistent quality and stable properties, providing the required performance in formulation and application.

Within oil and mining services the company offers Oil Services, Mining Solutions and Refinery Services. This service offers solutions adapted to the needs within oil production, mining and refining. In addition, problem solving, innovation and practical solutions are sought to address the customer's challenges.

Clariant Oil Services is a world leader in the innovation, manufacture, application and supply of specialty chemicals and services to the oil and gas industry. The chemical products offered for oilfield production have an impressive reach extending from Enhanced Oil Recovery, Offshore and Deep Water, Conventional and Unconventional Oil & Gas, Heavy Oil, Paraffin Control Technologies, Well Services Additives to VERITRAX™, Clariant's intelligent chemical Management System.

Clariant Mining Solutions is the only supplier in the mining industry to offer customized chemical solutions for the end-to-end mining process, including leading technology in froth flotation chemistry and explosive emulsifiers. They concentrate on specific more applications such as copper and other sulfide ores, iron ore, phosphate, potash, calcite, silica sands and many other industrial minerals, as well as emulsifiers for explosives, serving mining customers worldwide.

The Refinery Services provided by Clariant include additives facilitate cold flow, prevent wax-settling, improve stability, and make the heaviest products transportable through depressing pour points. Clariant's process additives demulsify, block corrosion and control fouling. Whether you are at a refinery, a terminal, or a pipeline, Clariant's products and service teams optimize your middle distillates and crude transportation best.

1.2. Problem

In the Tarragona production plant, a large number of specific products from the care chemicals business unit are produced for external companies.

For this purpose, the raw materials used in the production plant are loaded into the reactor. These materials must be pumpable to be fed into the reactor and carry out the reactions involved. Many of these raw materials are not pumpable and must first pass through the fusion chambers to be melted and finally used to charge the tanks.

In practice, not only raw materials enter the production plant, but also intermediate materials or final materials.

Intermediate materials are sometimes used in production to obtain a new final material. Therefore, intermediate materials can either be a final product or be used in production to obtain a new final material.

Final materials when taken to the packaging area are usually in excess. In this way, the excess is kept in the most convenient storage and is used again when a new batch of the same final material is produced in production plant.

At present there exist seven different fusion chambers, some with steam heated systems and others with hot water heated systems. Depending on the packaging and the melting temperature of each material one or the other melting chamber is selected for each material.

Currently the production of the plant is slowed down by the waiting times and the large quantities of raw materials that must pass through the melting chambers, especially in the non-hot months, when most of the materials must be melted.

It is for this reason that in this project we want to study in detail all those factors that affect the operation of the melting chambers and slow down the production to perform an analysis of alternatives to solve this current bottlenecking.

1.3. Project

This project pretends to improve and help in the production system of the plant located in Tarragona. In this way, a management of melting chambers will be carried out to help with the existing bottlenecking.

In this project, thanks to the collaboration of Clariant, a study has been carried out on the materials to be melted for subsequent use in the production plant.

By means of the list of inputs to the plant and the analysis and study of this data we want to propose different proposals of solution to solve the current problem described.

1.4. Possible solutions

At first sight, when considering the object of study, two possible solutions are suggested based on the future results of this study. One possibility is to increase the number of melting chambers, while the other possible solution is to design and implement a heated warehouse. Both solutions would allow to unblock the melting chambers and therefore improve the waiting times that slow down the production processes in the plant.

In the case of a heated warehouse, different realistic warehouse temperature options would have to be considered. In addition to locating the warehouse within the Clariant site, this would be a realistic solution.

On the other hand, if it is desired to design and implement more fusion chambers it is proposed to implement better technologically equipped chambers with control systems.

Once the results of the present project have been analyzed, these two solutions will be considered if they can really overcome the current problem. Finally, the different solutions will be studied and the best solution for the company will be proposed.

2. Scope of the project and specific objectives

2.1. Scope

For the study of this project, all materials entering the production plant must be listed. Within the list should be separated between raw materials, intermediate materials and final materials.

Raw and intermediate materials are constantly used in production to obtain final materials. In the production plant, the final materials leave the plant in quantities that are not exact for the corresponding packaging. In other words, the final materials are taken to the packaging process where there is always excess material because there is not enough to fill a new package. This excess is called "peak" quantities. These are taken to storage and usually solidify at room temperature. Then, when a batch of the same material is produced again, the peak quantities are melted down and put into the reactor to homogenize the mixture and take it to the packaging process. In this way, the final materials will not be considered as part of the study as they are founded for organizational reasons.

Once all the raw and intermediate materials that enter the plant are listed, select those that have a melting point between 0 and 100 ºC and are therefore susceptible to be melted in the melting chambers. These materials will be the ones to be analyzed in order to study and solve the problem in the melting chambers.

Thus, the scope of this project is defined by the raw and intermediate materials that enter the production plant and have a melting point within the determined range (0-100 ºC). Final materials or materials that have a melting point outside the range defined above are excluded from the study and therefore outside the scope of this project.

Within this list of materials will be filtered according to whether or not they must pass through the fusion chambers for other aspects different from the fusion temperature.

In the case of those materials that are susceptible to melting but do not have a defined melting temperature will form part of our boundary between inside and outside the scope of the project and will therefore be discarded.

Once the definitive list has been obtained in order to make the appropriate calculations and analyses, a sequence of possible solutions will be proposed. The solutions that offer the best results for the company will be chosen and will be designed in more or less detail depending on the duration of the project.

2.2. Objectives

The main objective of this project is to debottleneck and therefore improve the melting process of the materials in the melting chambers of the company. The aim is to improve the current system, which has waiting times to enter the plant in addition to the energy costs involved, by using the specific values below. This will be achieved if the following points are reached:

- Obtain the list of materials that pass through the fusion chambers.
- Analysis and study of the current movements in the melting chambers depending on the time of the year.
- Propose possible solutions to the current problem with respect to the melting chambers.

- Analyze the proposals and select the most convenient according to the energetic and economic environment.
- Study and design a proposed solution.

3. Methods and Approach

This section of the project aims to define, identify, and analyze the data related to the problem of current fusion chambers.

First, the list of study materials is defined, according to the important characteristics of each one for the subsequent analysis.

And finally, the materials of the defined list are analyzed in order to visualize where the problem is, and which could be valid solutions for it.

The following are the points to be taken into consideration and the study list with the data obtained.

3.1. Selection of materials under study

The most relevant points to be taken into consideration for the project are presented below. Each one is defined, and their relevance is explained. Without this information it is not possible to define what is to be analyzed and what is not to be considered in the present study.

3.1.1. Melting Point

The melting point of a substance is the temperature at which a solid and liquid phase may coexist in equilibrium and the temperature at which matter changes from solid to liquid form or vice versa. The term applies to pure liquids and solutions.

This temperature is important to have defined. Thanks to this temperature, it is possible to know whether the material is in a solid or liquid state by comparing it with the storage temperature (which can be room temperature or not). Many of the raw materials required in production area are stored in a solid state and must be melted before being sent to the production plant.

3.1.2. Liquid phase in BOM

The materials required in the production plant must be pumpable to load the reactors with them. For this purpose, the material must be in a pumpable state. So, for a material to be loaded into the reactor, it is not strictly necessary for it to be in a liquid state. There are some materials, such as granulator solids, which, despite their melting temperature, do not need to be melted because they can be pumped.

It should be taken into account that there are certain products that cannot pass through conventional melting chambers. These products are special and need a special chamber for each of them. Therefore, these materials are not under the study.

3.1.3. Packaging in BOM

Each material arrives at Clariant in a different container depending on the supplier and type of material. Materials that must pass through the fusion chambers cannot come in just any container. These containers can be metal drums, plastic drums, or IBCs. There are other containers such as tanks, bags etc. but these products are either consumed in large quantities and are purchased in tanks or they do not need to be melted because they are granulated and come in bags or similar packages.

The packaging of each of the materials is an important point to take into consideration since with packaging volume and the density, the mass of each material on each pallet is calculated. With these quantities it is possible to estimate the occupancy required for each material in the melting chambers.

In addition, each package has its own limitations within the melting chambers. Both metal and plastic containers must be opened before being introduced into the chamber to avoid deformation of the container due to pressure or even overflowing. On the one hand, plastic containers cannot be exposed to a temperature higher than seventy degrees because the plastic starts to degrade and can contaminate the material. On the other hand, the temperature limitation for metal package is defined by the welds, but it is a temperature higher than two hundred degrees, a temperature that is never reached in the current chambers.

3.1.4. Heat capacity (Cp)

Thermodynamically, the specific heat of a substance is the amount of heat that must be added to a unit of mass of the material in order to increase a unit temperature.

This physical property is characteristic of each material. For pure and common materials, it is defined in any physical thermodynamic database. On the other hand, there are many products that are currently handled in industry that, being a composition of others, do not have this property defined. This is the case of Clariant.

The great majority of the products with which the company works do not have a defined heat capacity. This is a drawback in the study and analysis since this property is necessary to determine the time required to melt at a given temperature.

3.1.5. Relation between Temperature and density

The relationship between temperature and density of the material is an important point to take into consideration. The higher the temperature, the lower the density and therefore the greater the volume. So, for some materials, as the temperature increases on the melting chamber the containers overflow.

This is a dependency to be taken into consideration for the studies that can be performed.

3.1.6. Storage temperature of materials

The storage temperature of the materials varies according to the location of the materials in the storage areas and the time of the year in which they are required. It is not the same to introduce into the melting chambers, for example, a material at 5 ºC or at 20 ºC to melt it at 50 ºC.

Thus, this storage temperature of the materials depends on:

- The place where it is located (in closed storage, in open storage, in open storage without roof…).
- The season of the year in which the material is required and is taken to be melted.
- Type of packaging (metal, plastic...).

3.1.7. BULK and CAS number

The BULK code is a material identification code used internally at Clariant. This code is used to identify every material in the company. This internal code identifies each material with a minimum of six digits and a maximum of eleven digits. The first six digits are those that refer to a specific material. The remaining five digits indicate the type of packaging in which it comes and conditions of entry into the plant among others.

On the other hand, the CAS code is a material identification code assigned by the Chemicals Abstract Service, a division of the American Chemical Society. It is a unique numerical identification for chemical compounds, polymers, biological sequences, preparations, and alloys. Thanks to this number, the material properties such as melting temperatures or densities that are not defined in the corresponding safety data sheet can be found and can be found and determined.

3.1.8. Product quantity

The amount of product in mass units influences the study. A product that has to be melted a quantity of one hundred kilograms per year does not have the same impact as a product that has to be melted a thousand tons per year.

In the following points, once the data have been defined, this factor will be taken into account in the study.

3.2. Study of the movements of materials

At this point we intend to obtain the list of materials to be studied. In addition, the analysis of quantities and movements of these at monthly and annual level are shown below in order to have an overview of the process and the problem that is present.

In this way, once the definitive study list has been obtained, we intend to analyze the monthly movements according to ambient temperatures, quantities consumed, month of the year, etc.

3.2.1. Materials that must be melted

To define the study list, a list is taken from the current Clariant database where all plant inputs are present. In this list there are a total of 9,460 entrances. From these, all rows that do belong to materials necessary for the maintenance and/or cleaning of the plant are eliminated. In this way the list is reduced to only those products that enter the production plant.

Once the list of materials has been obtained, the safety data sheet of each one is consulted in order to define the melting temperature of each one. Some materials do not have their melting point defined in the corresponding safety data sheet and, since they are not pure materials, it is not possible to find them. For this reason, the materials for which the melting point cannot be determined are considered outside the scope of this project.

After this task, materials with a melting point between 0 and 100 degrees are considered. Thus, the materials are filtered according to the described melting temperature range.

The Table 26 in Appendix 1 shows the list of raw materials, intermediate materials and final materials with their own melting temperatures. In this list only those with a melting temperature between minus five degrees and one hundred and five degrees are shown. There are also materials that must pass through the melting chambers to fluidize regardless of their melting temperature. These materials are the materials numbered 1, 2 and 413. This leaves a list with a total of 447 different materials.

Then the materials are classified according to whether or not they are in a pumpable state. This sorting reduces the list of materials considerably. These materials discarded and removed from the list are those that are granular materials and do not require melting.

Thus, all the materials that are already pumpable by their state and do not require to be passed through the melting chambers are discarded and are not defined for further study. The list is thus reduced to those materials with a melting temperature between 0 and 100 ºC and which require the melting chambers to be then pumped and loaded into the reactors of the production process.

Furthermore, there are materials that, being special materials, cannot be part of the study and are eliminated. These subjects by their own characteristics must pass through special chambers enabled for them and therefore do not use the fusion chambers studied in this project. Examples are acrylic acid or methacrylic acid, which have their own chamber.

It is possible to know if the products pass or not through the melting chamber according to the package in which they are stored. The products that are not in a packaging equal to a metal drum, plastic drum or IBC are filtered, since these are the products that can be melted in the chambers.

Regarding the heat capacity of the listed products, this is not defined in their corresponding safety data sheets. Therefore, the products in the list to be specified will not have this property defined. In terms of energy calculations there will be limitations.

On the other hand, although the density changes as a function of temperature, the variation of this property is not defined for the materials under study. For this reason, the density of the material will be taken as that defined in the safety data sheet in a fixed way for any temperature. Thus, this relationship, despite its importance, will not be taken into account as it is not defined, and is therefore outside the scope of the project.

The materials in the list extracted for the study have been classified according to their storage area, defining whether they are stored outside as “outdoor”, whether they are stored outside but under roof as “roof” and whether they are stored inside a closed warehouse as “indoor”.

Concerning the BULK code, in the filtering of the initial list of Clariant, all those that have the same first six digits are grouped together since they refer to a single material even if it is present in the plant in different ways. Thanks to this filter, the list is reduced to the number of materials that really need to be studied.

The CAS number allows the determination of certain properties that are not defined in the product’s own safety data sheets.

In order to take into account, the quantities of each product to be melted, the monthly consumption of the last three years will be extracted of each material that is present in the study list.

Then, after a long data cleaning, all the materials that enter the production plant are listed and depending on the parameters that can influence the study, the list is reduced to a final list to analyze the problem defined in this project.

Thus, Table 27 of Appendix 2 shows the final list of the study with a total of fifty-one products with their melting temperatures and their classification according to whether it is a raw material or an intermediate material.

3.2.2. Monthly material requirements

After analyzing all the inputs to the production plant and discarding those materials that do not pass through the melting chambers (the filters used for discarding have been described in the previous sections), a monthly study of the materials that pass through the melting chambers is carried out.

For this purpose, the minimum ambient temperature recorded that month, and the melting temperature of each material are taken into account to determine which materials are already in a liquid state and should not be melted and which should be melted. It is chosen to work with the monthly average minimum temperature since it presents the worst-case scenario and thus, the worst case that can occur in the plant will be considered.

The following table shows de monthly mean minimum temperature values used for the analysis.

Table 1. Monthly average minimum temperature for the years 2019, 2020 and 2021 in ºC.[1]

YEAR / MONTH	1	2	3	4	5	6	7	8	9	10	11	12
2019	3,8	5	7,4	10,3	12,5	16,2	21,5	21,3	18,1	14,6	8,9	8,1
2020	4,7	7,9	8,6	11,1	15,2	17,4	21,1	21,6	17,5	12,6	10,2	6,9
2021	4,2	8,7	7,8	9,7	13,8	18,7	20,8	21,2	19,5	13,9	8,1	7,4

These values have been extracted from the meteocat database for the Tarragona area where Clariant is located.

In the case of the 2022 annuity, the values are not available at the moment. For this reason, for 2022 has been taken the temperatures of the previous year of 2021 to carry out the study.

It should be taken into account that although in the previous sections the storage temperature to be taken into consideration has been defined and that this temperature varies according to the place where each material is stored. Even so, it can be observed that most of the materials in the study list are stored outdoors, while only seven are stored indoors and three are stored outdoors under a roof. Thus, it is considered that all materials are stored outdoors and are therefore at ambient temperature. In this way, the worst-case scenario in terms of storage temperature is taken into account.

Therefore, taking into consideration the materials in the list defined in Appendix 2, the monthly consumption of each one of them and according to the monthly ambient temperature, the monthly tons that must pass through the chambers are counted.

Thanks to this analysis, it is possible to see visually the quantities in tons of materials that move in the melting chambers each month. The twelve months of the year can be distinguished for 2019, 2020, 2021 and 2022. It can be seen in the following table the tons of product to be melted monthly for the last four years.

Table 2. Quantity of products (Tn) that must pass through chambers each month for the last four years.

YEAR/ MONTH	1	2	3	4	5	6	7	8	9	10	11	12
2019	141	131	189	165	138	101	60	32	52	110	149	111
2020	211	124	134	140	128	56	79	71	130	137	171	167
2021	202	225	134	159	124	56	56	67	101	96	172	135
2022	134	209	206	131	122	111	110	64	57	111	103	68

The following table shows the total number of different products that have passed through the melting chambers on a monthly basis over the last four years.

Table 3. Number of products passing through the melting chambers each month in the last four years.

YEAR/ MONTH	1	2	3	4	5	6	7	8	9	10	11	12
2019	20	18	18	22	14	13	5	9	7	17	22	17
2020	21	19	21	15	14	6	9	8	10	15	18	22
2021	24	22	21	25	16	13	8	6	13	15	20	16
2022	23	25	22	17	15	11	9	6	4	16	19	12

In Appendix 3 is the visual representation of the number of tons and products that have been consumed in the chambers monthly for each year.

In addition, the tons have been classified according to the temperature range in which the melting temperature of each material is located. These values can be seen in the following tables.

Table 4. Quantity (Tn) to be melted each month in 2019 divided according to the melting temperature.

T_f/ Month	1	2	3	4	5	6	7	8	9	10	11	12
0-5ºC	0	0	0	0	0	0	0	0	0	0	0	0
5-10ºC	21	20	17	0	0	0	0	0	0	0	2	1
10-15ºC	33	24	25	32	1	0	0	0	0	15	37	27
15-20ºC	33	28	69	41	69	29	0	0	8	45	36	21
20-25ºC	0	0	0	0	0	5	0	1	5	18	10	10
25-30ºC	0	0	0	0	5	0	5	0	0	5	0	0
30-35ºC	0	0	0	0	0	0	0	0	0	0	0	0
35-40ºC	0	8	12	16	17	3	9	17	9	6	11	6
40-90ºC	6	5	0	4	6	18	0	6	4	4	8	0
To fluidize	49	46	66	71	39	46	46	7	27	17	43	47
Total	141	131	189	165	138	101	60	32	52	110	149	111

Table 5. Quantity (Tn) to be melted each month in 2020 divided according to the melting temperature.

T_f/ Month	1	2	3	4	5	6	7	8	9	10	11	12
0-5ºC	0	0	0	0	0	0	0	0	0	0	0	0
5-10ºC	29	2	11	0	0	0	0	0	0	0	0	3
10-15ºC	49	20	35	20	0	0	0	0	0	18	33	32
15-20ºC	42	23	36	68	60	33	0	0	41	46	63	61
20-25ºC	16	5	5	0	1	0	0	0	15	17	15	15
25-30ºC	5	0	0	4	5	0	6	5	0	0	0	1
30-35ºC	0	0	0	0	0	0	0	0	0	0	0	0
35-40ºC	9	17	9	17	11	0	16	8	11	5	6	14
40-90ºC	8	4	4	1	7	23	5	1	9	1	8	7
To fluidize	54	51	34	29	43	0	52	57	53	51	47	34
Total	211	124	134	140	127	56	79	71	130	137	171	167

Table 6. Quantity (Tn) to be melted each month in 2021 divided according to the melting temperature.

T_f/ Month	1	2	3	4	5	6	7	8	9	10	11	12
0-5ºC	0	0	0	0	0	0	0	0	0	0	0	0
5-10ºC	28	9	25	1	0	0	0	0	0	0	0	1
10-15ºC	24	33	34	37	0	0	0	0	0	15	32	16
15-20ºC	73	68	45	50	41	7	0	0	9	27	64	47
20-25ºC	4	11	0	1	1	1	2	2	6	18	18	0
25-30ºC	5	5	0	0	0	7	0	0	5	0	5	0
30-35ºC	0	0	0	0	0	0	0	0	0	0	0	0
35-40ºC	17	3	21	27	6	19	17	18	9	3	8	6
40-90ºC	5	5	4	6	16	8	1	0	9	4	11	2
To fluidize	46	91	4	39	59	13	36	47	63	28	35	63
Total	202	225	133	159	124	56	56	67	101	96	172	135

Table 7. Quantity (Tn) to be melted each month in 2022 divided according to the melting temperature.

T_f/ Month	1	2	3	4	5	6	7	8	9	10	11	12
0-5ºC	0	0	0	0	0	0	0	0	0	0	0	0
5-10ºC	17	30	22	21	0	0	0	0	0	0	9	0
10-15ºC	18	24	39	15	0	0	0	0	0	5	9	14
15-20ºC	57	54	54	45	30	18	0	0	10	21	29	3
20-25ºC	5	6	5	0	1	1	9	0	0	7	5	6
25-30ºC	5	0	5	0	0	0	0	10	0	0	5	0
30-35ºC	0	0	0	0	0	0	0	0	0	0	0	0
35-40ºC	9	6	17	20	14	5	17	7	9	3	3	3
40-90ºC	5	5	16	9	6	8	21	4	0	7	7	7
To fluidize	18	84	48	21	70	80	63	43	38	69	37	36
Total	134	209	206	131	122	111	110	64	57	111	103	68

In this way it is possible to see what melting temperatures the materials to be melted have each month of the year.

Visual plots of these data are also shown in Appendix 3.

All these values can help to carry out a study and propose a real solution to the current problem.

3.2.3. Monthly requirements of fusion chambers

Once the quantities in tons that are consumed each month of each of the materials in the list have been defined, the occupancy of each one is calculated. That is to say, the number of chambers that each material occupies is estimated.

This calculation is made by means of the quantity in tons, the density of this material, and the container in which it is stored. Once the quantity of containers that must pass through the chambers is obtained, their occupancy is calculated. The chambers are divided into four sections. Each section of the chamber has the capacity to melt one pallet. Depending on the container in which each product is stored, the pallet is more or less containers. For metal or plastic drums, four drums are equivalent to one pallet and therefore a total of sixteen drums fit in a chamber, distributed as four drums per compartment. However, if the packaging is IBC, there is one IBC on each pallet and a total of four IBCs fit in a chamber, one per compartment.

In the following image it can be seen half of a Clariant fusion chamber. Pallets with metal drums have been inserted in it. This chamber was occupied and in the process of fusion with a total of sixteen metal drums, distributed in four per compartment.

Figure 1. Picture of half of a fusion chamber in operation occupied by metal drums of product.

Thus, the total number of chambers that would be occupied if all the products to be melted were put into the chambers at the same time is shown. In addition, the pallets have been classified according to the temperature range in which the melting temperature of each material is located. The following tables show these values for each of the annual periods studied.

Table 8. Number of pallets passing through the melting chambers each month in the last four years.

YEAR/ MONTH	1	2	3	4	5	6	7	8	9	10	11	12
2019	40,50	116,00	55,75	51,00	41,25	35,25	19,75	11,75	18,75	38,75	48,25	33,50
2020	66,00	38,50	40,75	48,75	43,50	19,50	26,75	23,50	45,00	47,00	55,75	55,75
2021	67,50	70,00	44,00	54,00	41,50	19,75	17,25	22,00	34,50	32,25	60,00	41,00
2022	44,25	67,75	66,50	43,00	43,25	32,75	36,75	21,50	20,00	37,75	35,50	21,25

Table 9. Number of pallets to be melted each month in 2019 divided according to the melting temperature.

T_f / Month	1	2	3	4	5	6	7	8	9	10	11	12
0-5ºC	0,25	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5-10ºC	6,75	6,00	5,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00	0,25
10-15ºC	8,50	6,25	6,50	8,50	0,50	0,00	0,00	0,00	0,00	6,00	10,50	8,25
15-20ºC	11,00	8,75	20,50	13,00	20,25	10,50	0,00	0,00	2,50	16,25	12,00	7,25
20-25ºC	0,00	0,00	0,00	0,25	0,00	2,25	0,00	0,50	2,00	6,75	4,25	4,00
25-30ºC	0,50	0,50	0,50	0,25	1,75	0,00	1,50	0,25	0,00	1,50	0,00	0,00
30-35ºC	0,00	0,00	0,00	0,25	0,00	0,00	0,00	0,00	0,00	0,25	0,00	0,00
35-40ºC	0,00	3,50	4,50	6,25	6,75	1,00	3,50	7,00	3,50	2,50	4,50	2,25
40-90ºC	1,75	1,50	0,00	1,25	2,00	5,25	0,00	2,00	1,25	1,25	2,50	0,00
To fluidize	11,75	89,50	18,75	21,25	10,00	16,25	14,75	2,00	9,50	4,25	13,50	11,50
Total	40,50	116,00	55,75	51,00	41,25	35,25	19,75	11,75	18,75	38,75	48,25	33,50

Table 10. Number of pallets to be melted each month in 2020 divided according to the melting.

T_f / Month	1	2	3	4	5	6	7	8	9	10	11	12
0-5ºC	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5-10ºC	8,75	0,50	3,25	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,25
10-15ºC	14,50	6,50	10,00	5,50	0,00	0,00	0,00	0,00	0,00	6,75	10,50	10,75
15-20ºC	14,00	7,50	12,00	25,00	21,50	12,50	0,00	0,00	15,00	17,00	22,25	21,25
20-25ºC	6,00	2,00	2,00	0,00	0,50	0,00	0,00	0,00	6,00	6,25	6,00	6,00
25-30ºC	1,50	0,25	0,25	1,25	1,50	0,00	1,75	1,50	0,00	0,25	0,00	0,25
30-35ºC	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,25	0,00	0,00	0,00	0,00
35-40ºC	3,50	6,75	3,50	6,75	4,50	0,00	6,50	3,25	4,25	2,25	2,25	5,75
40-90ºC	2,50	1,50	1,50	0,25	2,25	7,00	1,75	0,75	2,75	0,25	2,50	2,25
To fluidize	15,25	13,50	8,25	10,00	13,25	0,00	16,75	17,75	17,00	14,25	12,25	8,25
Total	66,00	38,50	40,75	48,75	43,50	19,50	26,75	23,50	45,00	47,00	55,75	55,75

Table 11. Number of pallets to be melted each month in 2021 divided according to the melting.

T_f / Month	1	2	3	4	5	6	7	8	9	10	11	12
0-5ºC	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5-10ºC	8,50	2,75	7,50	0,50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,75
10-15ºC	7,25	9,75	8,75	9,50	0,00	0,00	0,00	0,00	0,00	6,00	10,00	4,00
15-20ºC	25,00	23,75	16,25	18,00	14,75	2,50	0,00	0,00	2,75	9,75	23,00	16,00
20-25ºC	1,75	4,25	0,00	0,25	0,25	0,50	0,75	0,75	2,25	6,75	6,75	0,00
25-30ºC	1,50	1,50	0,25	0,00	0,25	2,00	0,00	0,00	1,50	0,00	1,50	0,00
30-35ºC	0,00	0,00	0,00	0,00	0,25	0,00	0,00	0,00	0,00	0,00	0,00	0,00
35-40ºC	6,75	1,25	8,25	10,50	2,25	7,75	7,00	7,00	3,50	1,25	3,50	2,25
40-90ºC	1,75	1,75	1,50	2,00	4,75	2,50	0,50	0,25	3,00	1,50	3,25	0,75
To fluidize	15,00	25,00	1,50	13,25	19,00	4,50	9,00	14,00	21,50	7,00	12,00	17,25
Total	67,50	70,00	44,00	54,00	41,50	19,75	17,25	22,00	34,50	32,25	60,00	41,00

Table 12. Number of pallets to be melted each month in 2022 divided per melting temperature.

T_f / Month	1	2	3	4	5	6	7	8	9	10	11	12
0-5ºC	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5-10ºC	5,00	9,25	7,00	6,50	0,00	0,00	0,00	0,00	0,00	0,00	2,75	0,00
10-15ºC	5,75	7,25	10,75	4,25	0,00	0,00	0,00	0,00	0,00	2,00	3,50	4,25
15-20ºC	20,50	19,00	18,50	15,50	10,75	5,75	0,00	0,00	3,00	7,00	9,50	1,00
20-25ºC	2,00	2,50	2,00	0,00	0,50	0,25	3,25	0,00	0,00	2,50	2,00	2,50
25-30ºC	1,50	0,25	1,50	0,00	0,25	0,00	0,00	2,75	0,00	0,00	1,50	0,00
30-35ºC	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,25	0,00	0,00	0,00	0,00
35-40ºC	3,50	2,25	6,50	8,00	5,75	2,00	6,75	2,75	3,50	1,25	1,25	1,25
40-90ºC	1,50	1,75	5,00	3,00	2,00	2,25	6,25	1,25	0,00	2,25	2,00	1,75
To fluidize	4,50	25,50	15,25	5,75	24,00	22,50	20,50	14,50	13,50	22,75	13,00	10,50
Total	44,25	67,75	66,50	43,00	43,25	32,75	36,75	21,50	20,00	37,75	35,50	21,25

The number of cameras is decimal with the decimals rounded to 0, 25, 50 or 75. This means that if you need 40,25 chambers you really need 40 chambers and one more chamber compartment. In this way, the number of chambers compartments that have been occupied has actually been counted, taking into account that each melting chamber has a total of four compartments.

This calculation does not consider the melting time of the materials. Depending on their melting temperature it will be a shorter or longer time.

The graphs in which the values shown above are represented can be found in Appendix 3 of this thesis.

4. Results and discussion

Once the problems of the process and the energetic results have been exposed, different possible solutions are proposed. As possible solutions to the problem to be solved, a series of options are presented that must be analyzed and discarded or selected.

Some raw materials used in the production plant come from tanks. These tanks are located at a defined point in the plant, where large quantities of raw materials are stored. Each raw material has an associated tank. In addition, depending on the melting temperature of the raw material, it is covered by a heating system if required by the ambient temperatures. The plant is supplied with this material directly from the tank. Thus, one option could be to move some raw materials to tanks and avoid passing through the melting chambers.

Thanks to the extracted list of materials that pass through the melting chambers, it can be seen that there are a number of materials that must be melted only in the coldest months. These materials have low melting point and therefore in the warmer months they are in a liquid state and ready to be pumped into the reactors. This difference could be solved by a heated warehouse at a temperature that allows that these materials never have to pass through the melting chambers. Likewise, just as these materials do not pass through the melting chambers during the hot months, they will not pass through during the cold months, which is when there is a lack of melting chambers for all the materials required in the plant.

At Clariant’s plant, there are a total of seven melting chambers. All of them have the same capacity and can melt the same amount of raw material. These seven chambers are not sufficient in the cold months and therefore the option of designing and implementing new chambers is proposed, despite the fact that these will not be used in the hot months since it is not necessary to melt so many tons of raw material.

These melting chambers work with either hot water or medium pressure saturated steam. The possibility of using high pressure saturated steam can be considered in order to increase the temperature of the chamber and to melt the raw materials passing through it faster.

Another solution or possibility for improvement is the implementation of control systems in the fusion chambers. These chambers do not have automatic temperature regulation. That is to say, the heating system of the chamber is opened in its entirety and therefore rises to its maximum temperature allowed by the heating fluid, without taking into account the temperature required by the material to be melted. Therefore, implementing temperature control systems and consumption meters to regulate and control the chambers will help to control and regulate the process in an efficient way.

On the other hand, in the case of needing a small amount of raw material for the production plant, electric blankets can be used to melt and finally pump the material to the reactor.

Finally, it is also proposed to change the packaging of raw materials from drums to IBCs in order to gain kilograms with each unit of material and therefore reduce the number of melting chambers needed for melting.

In addition, the following proposed solutions are presented:

A. Use of tanks for storage of raw materials.

B. Design and implement a heated warehouse.

C. Design and implement more melting chambers.

D. Increase the temperature of the melting chambers using high pressure steam.

E. Improvement of existing melting chambers.

F. Use of electric blankets to heat the fluidizing materials.

G. Change products in drums to IBC to increase the quantity of raw material.

Option A is a valid solution that would reduce the list of raw materials that must pass through the melting chambers. It is a good option if the cost of the tank and its maintenance is amortized. In the case of the current list of raw materials, there is no raw material that moves in such large quantities that it would be economical to transfer it to a tank. For this reason, it is considered to be a very high effort and a very low profit.

The heated storage option B should take into consideration several conditions in order to be able to melt and keep in a pumpable state the materials with low melting temperature. Therefore, it must contemplate the number of drums or IBC that it must hold, the maximum temperature at which it can be, and the time required for each raw material in solid state to melt at warehouse temperature. This option allows to greatly reduce the list of raw materials passing through the melting chambers in the cold months and therefore solves the problem of chambers bottleneck.

Option C, the implementation of new melting chambers, offers the possibility of not generating waiting times in the production plant during the cold months. On the other hand, these new melting chambers will not be used during the hot months as there is no need for them in this period.

Increasing the temperature of the chambers by using high pressure saturated steam, option D, does not offer total safety to plant operators, and not all the materials to be melted and their packaging could be subjected to such high temperatures. Moreover, it involves a higher utilities consumption.

Option E of improving the existing chambers in the plant offers the possibility of having a control of consumption, temperature and use of the melting chambers. The installation of a control system and regulation of steam to the chamber according to the desired temperature will greatly reduce the current energy consumption, since they are more adjusted and will allow a control of the consumption and the use of the chamber from the Clariant control system.

The electric blankets described as option F, are an unrealistic alternative. They could only be used to melt small quantities of raw materials that are needed at a specific moment or already melted materials that, due to their melting temperature, can solidify while waiting to be pumped to the production plant.

The last option, option G, proposes the change of packaging from drums to IBCs in order to gain quantity of raw material in each container. In this way, at the moment of entering the raw materials in the melting chambers it is possible to melt a little more quantity of material since each chamber can hold 4 m^3 in IBC or 3,2 m^3 in drums.

By analyzing the different proposals, each can be assigned a monetary cost and an effort on a scale of one to ten.

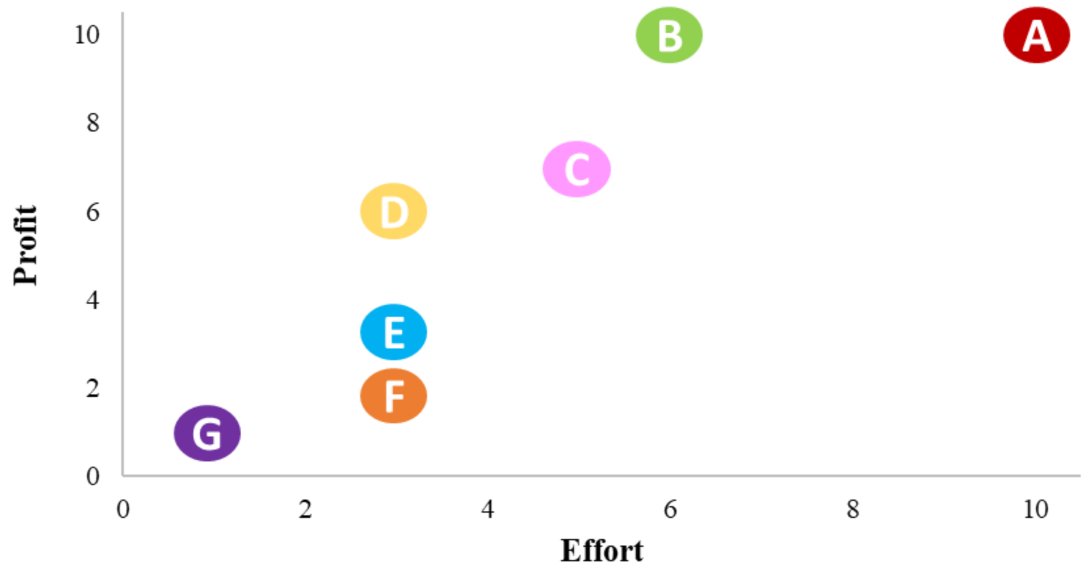

Figure 2. Effort-Profit graph.

In addition to taking into account the benefit and effort associated with each of the proposed solutions, the risk associated with each must also be taken into account.

As for option A, there is a risk that once the tank is created for a specific material, that material will no longer be consumed in Clariant, and the tank will become totally obsolete.

For option B, the associated risk is quite low. This is because it is a flexible solution. If at some point in time, the list of materials that must go through the fusion chamber changes, this heated warehouse can still be used. Its use can be the same as described but also for new materials or for materials with high melting temperatures to reduce their temperature difference before passing through the chambers.

Option C, on the other hand, has the risk that the new chambers will not be used constantly and therefore will not be amortized.

Option D has the risk of damaging and/or changing the properties of the materials by exposing them to too high temperatures. In addition to exposing the packaging of the materials to temperatures that may cause a risk to operators.

Unlike the other options, option E of upgrading the existing chambers does not present any risk, but just the opposite. This option reduces the risks that currently exist with the company's existing fusion chambers.

Finally, options F and G present health and safety risks for workers and installation and generation of the peak quantities explained at the beginning of the project, respectively.

Thus, the last graph can be divided into two zones. On the one hand, a zone where the proposals involve a high effort and a low benefit, and on the other hand, the zone where the options involving a high benefit and a low effort are present.

In the following figure the zones where the benefit is below the value of 6 and the effort is above 7 are colored in red. Thus options A, D, E, F and G are discarded. The rest is colored in green where options B and C are located. These two options are the ones that present the best results taking into account the benefit they can bring, and the effort associated with them.

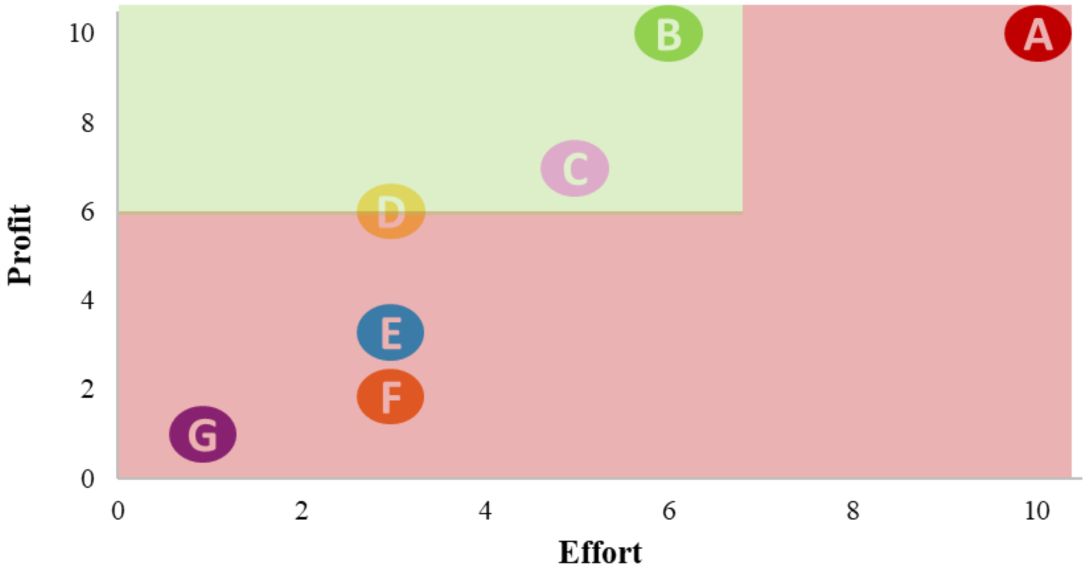

Figure 3. Effort-Profit graph with the classified zones.

After studying the effort involved in each of the options and the benefits they can provide, it is decided to study the two options that offer the greatest benefits for the company without entailing a high level of effort.

The options are therefore option B of Design and implement a heated warehouse and option C of Design and implement more melting chambers. These two options are studied below in the following sections.

4.1. Heated warehouse

One of the best options proposed to solve the existing problems and achieve the proposed objectives is the design and implementation of a heated warehouse.

Thanks to the monthly analyses carried out in previous points, it is proposed to reduce the number of materials that must pass through the melting chambers. Therefore, the materials with the lowest melting temperature are selected down to those with a melting temperature lower than the storage temperature. In this way, the number of materials to be melted in the melting chambers during the cold months will be reduced, thus reducing the production waiting times they generated.

Different factors must be considered for the design of the heated warehouse. First, it is necessary to define the storage temperature and see if it is possible for an operator to work under these thermal conditions. Also, the time of fusion of these materials inside the heated warehouse, the space that can be allocated to the warehouse and the service supply for heating must be taken into account.

The following sections are intended to analyze and define each of the factors that are important in defining a heated warehouse solution.

4.1.1. Melting times

In this section the calculation of the time it takes for the materials to melt at different temperatures is carried out.

These calculations have been made for four different raw materials from the list in Appendix 2 Table 27. These are 258, 259, 293 and 313 and their melting temperatures are 20.5, 21, 27 and 31.7ºC respectively.

Within the list of materials passing through the melting chambers there are a total of fifty-one materials. There are three of these materials that must pass through the chambers to be fluidized (materials 1, 2 and 413) and the rest to be melted. Fusion temperatures of these materials range from zero to fifty-two degrees Celsius. It is not possible to calculate the time required to melt each material since most of them are not pure products and many physical, chemical, and thermodynamic properties are not defined. Therefore, we are looking for materials within the list that are pure and have their characteristic properties defined.

For the implementation of the heated storage as a solution to the overbooking of the melting chambers, it is important that the storage temperature be as high as possible in order to avoid melting as many of the listed materials as possible on the faces. For the study, the melting times of 4 strip materials are calculated. These four materials are pure materials and therefore we can obtain their properties for the energetic study. With the values obtained for these four materials the melting times for the materials in the list with melting temperature equal to less than theirs will be represented.

Thus, with the times required to melt these four materials, the maximum time required for a material within the heated storage can be established. If this time is in which Clariant has the materials stored until they are consumed, the warehouse will be a valid solution.

Currently, the materials are usually stored for a month to a month and a half. Therefore, the necessary times for the four materials are calculated for a heated warehouse at 20, 25, 30 and 35ºC.

On the one hand, the time necessary to melt in the current melting chambers has been calculated. In this way, it will be possible to compare with the experimental values that the company has and to see if the calculations really agree with reality.

For this purpose, the internal temperature of the chamber of 110ºC has been previously determined for the energetic calculations. The estimation of this temperature has been carried out experimentally. The temperature of 110ºC is an average of the daily values of the chamber temperature. Only the temperature of one of Clariant's melting chambers was taken into account. This is always in operation, especially during the last and first months of the year. These values can be seen in Appendix 4. Experimental data of the melting chambers.

For the energetic calculations, on the one hand, it is calculated for each material what is the necessary energy that must be supplied to melt it. This calculation is made using the following equation:

$$\boldsymbol{Q = m \cdot c_e \cdot \Delta T + m \cdot L_f} \qquad \textbf{Equation 1}$$

Where,

Q is the amount of heat in kJ.

m is the mass of the substance in kg.

ΔT is the temperature variation experienced by the substance in K.

c_e is the specific heat of the substance in kJ/kg·K.

L_f is the latent heat of fusion of the substance in kJ/kg.

For the calculation, the mass equivalent to filling an entire fusion chamber is considered. A melting chamber has four compartments. Each compartment of the chamber can hold one pallet of material. Depending on the packaging of each material, a pallet can hold either one IBC or four metal or plastic drums.

Thus, thanks to the type of container and the density of the material, the mass that would be melted inside the chamber is obtained.

The following table shows the type of container in which each of the study materials is stored.

Table 13. Mass of each material per unit of container.

Nº material	Mass (kg/ud)	Packaging
258	220	metallic drum
259	166,2	metallic drum
293	215	metallic drum
313	178	plastic drum

It has been assumed that both metal and plastic drums have a capacity of 0.2 m^3 of material inside. Likewise, by means of the volume of the container and the density of each material, the mass of material to be melted described as the previous variable m is obtained.

Different temperature increments have been considered depending on the month of the year. For each month of the year a different ambient temperature has been taken into account. This value has been taken from the Servei Meteorològic de Catalunya database.[1] The minimum median temperature value for each month has been chosen. In this way the most limiting conditions of each month are taken into account. The minimum median ambient temperatures used are the temperatures of the year 2021 (last published values). These values can be seen in Table 1.

Thanks to safety data sheets and physical and chemical properties, the specific heat in solid state and the latent heat of fusion of each material to be analyzed can be obtained.

Once all the variables of the equation have been defined and obtained, the following amounts of heat are found to be necessary to rise from room temperature according to the month to melting.

The following table shows the energy required to melt each material according to the ambient temperature of each month.

Table 14. Energy required to melt each material from room temperature.

Month	T_{amb} (ºC)	Material 258 Q (kJ)	Material 259 Q (kJ)	Material 293 Q (kJ)	Material 313 Q (kJ)
1	4,2	46623	41218	46038	42260
2	8,7	44572	39782	44777	40049
3	7,8	44983	40069	45029	40491
4	9,7	44117	39462	44497	39558
5	13,8	42249	38154	43348	37543
6	18,7	40016	36590	41976	35135
7	20,8	39196	35920	41387	34103
8	21,2	39196	35856	41275	33906
9	19,5	39651	36335	41752	34742
10	13,9	42203	38122	43320	37494
11	8,1	44846	39973	44945	40344
12	7,4	45165	40196	45141	40688

On the other hand, the energy transferred from the outside to the inside of the drums of each material must be calculated. This energy is defined by the following equation:

$$\boldsymbol{Q' = U \cdot A \cdot \Delta T} \qquad \textbf{Equation 2}$$

Where,

Q' in the energy transferred in kW from the outside of the container to the center of the material containing the drum.

U is the coefficient of heat transfer by conduction and convection in kW/(m^2·K).

A is the heat exchange area in m^2 defined in this case as the area of the metal or plastic drum having an outer and inner diameter of 585 and 571.5mm respectively and a height of 885 mm.

ΔT Is the temperature difference in K between the temperature set in the chamber and the ambient temperature which is equivalent to the material temperature. The set chamber temperature is 110ºC while the material temperature varies according tot the minimum ambient temperature of each month.

The heat transfer coefficient by conduction and convection U is defined by the following equation:

$$\boldsymbol{U = \frac{1}{1/h_{air} + e/k_{drum} + d/k_{material}}} \qquad \textbf{Equation 3}$$

Where,

h_{air} is the coefficient of thermal conduction of air in W/(m^2·K).

e is the thickness of metal or plastic drum in which the material is stored in m.

k_{drum} is the thermal conductivity of the drum in W/(m·K). For plastic drum is equal to 0.5 W/(m·K) while for metal drum is equal to 50 W/(m·K).

d is the thickness of the material in the drum in m through which there is thermal conductivity.

$k_{material}$ is the thermal conductivity in W/(m·K) of materials 258, 259, 293 and 313.

The thermal conductivity of these materials has been obtained from research bibliography since it was not referenced in any of the descriptive documents of the materials.

In the following table the values or formulas that offer obtaining the thermal conductivity of each one of the materials are shown.

Table 15. Thermal conductivity values for the materials under study.[2]–[10]

Material	Thermal conductivity (W/m·K)
258	$0.1313 \cdot T_{amb} + 151.53$
259	0.1665
293	$-0.0677 \cdot T_{amb} + 238.39$
313	0.372

Once obtained the values of heat necessary to melt each material and the heat that is transmitted to it, the time is obtained by dividing Q by Q'. In this way, the melting times for each material in a chamber at 110ºC are obtained, depending on the monthly ambient temperature.

Table 16. Melting times in days for materials 258, 259, 293 and 313 for a 110ºC chamber.

Month	T_{amb} (ºC)	Material 258 t (days)	Material 259 t (days)	Material 293 t (days)	Material 313 t (days)
1	4,2	3,68	3,66	3,12	1,76
2	8,7	3,66	3,69	3,18	1,74
3	7,8	3,67	3,68	3,16	1,74
4	9,7	3,66	3,70	3,19	1,73
5	13,8	3,64	3,73	3,24	1,71
6	18,7	3,62	3,76	3,31	1,69
7	20,8	3,63	3,78	3,35	1,68
8	21,2	3,64	3,79	3,35	1,68
9	19,5	3,62	3,77	3,32	1,69
10	13,9	3,64	3,73	3,24	1,71
11	8,1	3,67	3,68	3,17	1,74
12	7,4	3,67	3,68	3,16	1,74

The values obtained for the melting time of the materials match the experimental values used as a reference in the company. Thus, the materials melt in less than 4 days inside the chambers.

The following table shows the average values of melting times.

Table 17. Average melting times in days for the materials under study at 110ºC.

T (ºC)	Material 258 t (days)	Material 259 t (days)	Material 293 t (days)	Material 313 t (days)
110	3,65	3,71	3,21	1,72

Likewise, the same calculations were performed but for a storage temperature of 20, 25, 30 and 35ºC. In this way, the times in days necessary to melt each material at each of the defined temperatures are found.

In order to perform the calculations, it must be taken into account that when the heating temperature of study changes, the values obtained previously for the temperature increase ΔT change.

The following table shows the average values of time in days necessary to melt each of the materials depending on the selected storage temperature.

Table 18. Average melting times in days for the materials under study at different storage temperature.

T (ºC)	Material 258 t (days)	Material 259 t (days)	Material 293 t (days)	Material 313 t (days)
110	3,65	3,71	3,21	1,72
20	NOT MELTED	NOT MELTED	NOT MELTED	NOT MELTED
25	59,58	62,06	NOT MELTED	NOT MELTED
30	31,21	32,51	28,66	NOT MELTED
35	21,14	22,02	19,41	9,85

As it can be seen, at a temperature of 20ºC the materials do not melt. This is coherent since the melting temperatures of the materials are higher than 20ºC and therefore they would not melt at this storage temperature. The same happens with materials 293 and 313 at 25ºC and with material 313 at 30ºC.

Analyzing the time values obtained, it can be concluded that a heated storage at 35ºC could melt materials with a melting temperature below the heating temperature, obtaining melting times between ten and twenty-two days. These values are considerably low and offer the possibility of designing a heated storage as they allow to melt the materials in the time that these are stored by the Tarragona site of Clariant before being needed in production.

Likewise, by means of the energy calculations and the melting times obtained, it can be concluded that a storage at 35ºC could melt the materials in less than one month. That is to say, it is possible that materials with melting temperatures lower than these times could melt in less than one month. At this point it depends on the whether or not this storage temperature is possible for the working conditions of the operators.

4.1.2. Heated storage temperature

By defining the temperature of the heated storage, the limit of materials to be stored is established. If the defined temperature is 30ºC, the materials to be stored will be materials with lower melting temperatures.

Thus, it is important to define well the temperature of the storage in order to define which materials should be stored. This temperature must be selected according to the times in which the material melts once stored and the working conditions of the operators.

It is important that the raw materials can be melted in the warehouse in times around thirty days. If it is much longer than this, it will not be possible to set this temperature since Clariant does not have the raw materials more than about one month before it needs them in production.

On the other hand, the storage temperature must take into account the thermal conditions involved for the workers who must access the area. Prevention measures must be contemplated according to occupational risk prevention regulations for thermal stress.

In the previous section the melting times have been calculated for four representative materials of the analysis list for different storage temperatures which could be the storage temperature to be established. These temperatures studied are 20, 25, 30 and 35 degrees.

It can be seen in Table 4, Table 5, Table 6 and, Table 7 that at the monthly level the largest quantities of material to be melted come from the materials to be fluidized. Since these materials must pass through the chambers, it is proposed to show the values as a percentage without taking into account these quantities in the total.

In this way it is possible to see the percentage of materials with a melting temperature range between zero and twenty degrees, between zero and twenty-five degrees, between zero and thirty degrees and between zero and thirty-five degrees. In these ranges the limit temperature is the temperature at which the heated warehouse is planned to be established.

Table 19. Number of tons of materials in percentage for different melting temperature ranges of 2019.

T_f/ Month	1	2	3	4	5	6	7	8	9	10	11	12
0-20ºC	93,5	83,7	90,3	78,4	70,9	53,1	0,0	0,0	30,7	64,8	71,6	75,4
0-25ºC	93,5	83,7	90,3	78,5	70,9	62,6	0,0	5,4	50,5	84,1	81,3	91,3
0-30ºC	94,0	84,2	90,6	78,9	76,3	62,6	37,4	6,9	50,5	89,3	81,3	91,3
0-35ºC	94,0	84,2	90,6	78,9	76,3	62,6	37,4	6,9	50,5	89,4	81,3	91,3

Table 20. Number of tons of materials in percentage for different melting temperature ranges of 2020.

T_f/ Month	1	2	3	4	5	6	7	8	9	10	11	12
0-20ºC	76,2	62,6	81,4	79,6	71,4	58,6	0,0	0,0	53,9	73,9	76,7	72,2
0-25ºC	86,2	69,3	86,6	79,6	72,9	58,6	0,0	0,0	73,9	93,0	89,1	83,7
0-30ºC	89,2	69,9	87,0	83,5	78,5	58,6	21,2	36,7	73,9	93,1	89,1	84,3
0-35ºC	89,2	69,9	87,0	83,5	78,5	58,6	21,2	37,3	73,9	93,1	89,1	84,3

Table 21. Number of tons of materials in percentage for different melting temperature ranges of 2021.

T_f/ Month	1	2	3	4	5	6	7	8	9	10	11	12
0-20ºC	79,9	82,3	80,1	72,5	64,3	16,4	0,0	0,0	23,5	63,4	69,5	89,2
0-25ºC	82,7	90,4	80,4	73,1	65,4	19,6	10,0	10,4	38,8	89,4	82,3	89,2
0-30ºC	85,8	94,0	80,7	73,1	66,0	34,9	10,0	10,4	51,9	89,4	86,0	89,2
0-35ºC	85,8	94,0	80,7	73,1	66,4	34,9	10,0	10,4	51,9	89,4	86,0	89,2

Table 22. Number of tons of materials in percentage for different melting temperature ranges of 2022.

T_f/ Month	1	2	3	4	5	6	7	8	9	10	11	12
0-20ºC	79,4	85,7	72,8	73,5	56,7	56,3	0,0	0,0	53,4	61,3	70,2	50,3
0-25ºC	83,9	90,8	76,0	73,5	59,2	58,5	18,1	0,0	53,4	77,2	78,2	70,3
0-30ºC	88,4	91,1	79,0	73,5	60,0	58,5	18,1	45,3	53,4	77,2	85,5	70,3
0-35ºC	88,4	91,1	79,0	73,5	60,0	58,5	18,1	46,5	53,4	77,2	85,5	70,3

It should be noted that these percentages do not take into account the quantities of materials that pass through the chambers to be fluidized. Also note that in the melting temperature range between 30 and 35ºC there is only one material, and it is precisely the material number 313 studied previously for the melting times.

With these percentages over the total, it can be seen the amount of materials that can avoided to occupy the melting chambers and therefore not delay the production process. In addition to being able to define the ideal temperature of the heated warehouse so that these materials do not go to the melting chambers.

Likewise, as can be seen in the previous tables, it is of interest that the materials in the melting list with temperatures below 35ºC are taken to the heated storage.

In spite of obtaining high percentages, these values do not take into account that these are the materials that require less melting time and that therefore keep the melting chambers occupied for less time. Thus, the time of occupation of the chambers is reduced in proportion.

Since the aim is to reduce as much as possible the number of materials that must pass through the fusion chambers by means of a heated storage, a storage temperature as high as possible is requested, but which allows working activities.

For this reason, given the results of fusion times of the Table 18 and that the materials that have a fusion temperature between zero and thirty-five degrees represent the highest percentage of movements, a storage temperature around these thirty-five degrees centigrade is studied.

It should be considered that the selected storage temperature must comply with the Royal Decrees on the prevention of occupational hazards. Royal Decree 486/1997, which establishes the minimum health and safety provisions for workplaces, does not define a temperature limitation. Even so, it specifies that environmental conditions should not pose a risk to the employee.[11]

Thus, the Technical Prevention Notes (NTP) number 322 on the assessment of the risk of heat stress are consulted.[12]

In this document there is a figure that shows the temperature limit values according to the metabolic heat of the worker. (See Figure 4).

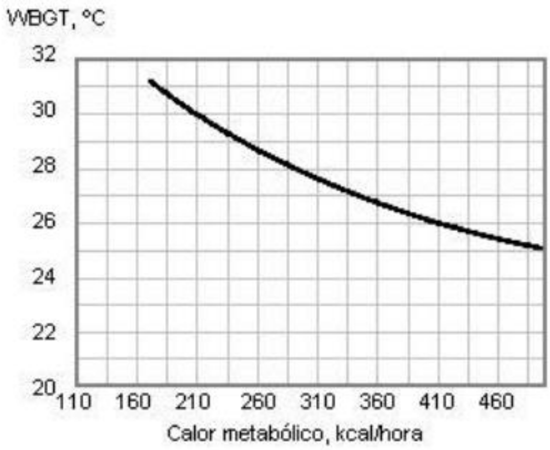

Figure 4. WBGT limit values as a function of metabolic heat.[12]

The WBGT index is calculated from the combination of two environmental parameters, the globe temperature, and the natural wet temperature. Sometimes the dry air temperature is also used.

To make it simpler, the WBGT limit that the operator can tolerate in order not to be at risk of heat stress is selected based on the metabolic consumption of the operator.

The following table shows the different values of the WBGT index for different metabolic consumptions.

Table 23. Reference limit values for the WBGT index.[12]

Metabolic consumption (kcal/hour)	WBGT limit (ºC)
≤ 100	32
100 - 200	29
200 - 310	26
310 - 400	22
≥ 400	18

In this case, we consider an operator who enters the warehouse with a forklift truck long enough to load it with a pallet of material and leave to take it to the melting chambers. Thus, the minimum metabolic consumption of 100 kcal/hour is considered, which establishes a WBGT index limit of 32ºC according to a table of values defined in the NTP.

The ideal temperature for the heated storage to be implemented is therefore 32ºC. In this way, it is possible to eliminate the need to pass through the melting chambers to all those materials in the list with a melting temperature lower than 32ºC.

Thus, using the procedure described in the previous section, the melting times for each of the materials under study at the established storage temperature of 32ºC were calculated.

Table 24. Average melting times in days for the materials under study at 32ºC.

T (ºC)	Material 258 t (days)	Material 259 t (days)	Material 293 t (days)	Material 313 t (days)
32	24,65	25,49	22,39	11,45

The table above shows the melting times required for the heated storage to be defined. These values correspond to the premises initially established, without exceeding thirty days and therefore, it is an optimal and coherent solution.

4.1.3. Heated warehouse design

In order to be able to design the heated warehouse, an area of Clariant industrial park has been defined as a very good option.

In the following figures you can see a real image from the sky of the Clariant polygon with the described location marked with a red circle. It can also be seen the plan of the placement with more detail.

Figure 5. Real image of the location of the heated warehouse from the sky.

Figure 6. Plan of the location defined for the implementation of the heated warehouse.

The defined area allows the warehouse to be sized to store six pallets wide and twelve pallets long. For the distribution of the pallets, it must be considered that a total of three pallets per row can be stored vertically for safety reasons. So, a total of 216 pallets can be stored.

Once The place to implement the warehouse and its maximum capacity have been defined, it is necessary to calculate the number of pallets that are required in the warehouse monthly.

For this purpose, a study of the number of pallets that must be passed through the storage chambers is carried out.

The first step is to analyze whether the raw material passes through the melting chambers monthly. Materials pass through the melting chambers if they need to be melted because the ambient temperature. (See Table 1) Once the materials to be melted have been selected according to the monthly ambient temperature, thanks to the list of material consumption where the monthly tons consumed are specified, the number of pallets to which these tons are equivalent is calculated. Thus, the number of pallets is calculated according to the tons consumed per month, the density of each material and the type of packaging. The type of packaging makes a difference since a pallet can be an IBC or four metal or plastic drums. In this way, the number of monthly pallets is calculated for the years 2019, 2020, 2021 and 2022 for the materials with a melting temperature below 32ºC and which need to be melted.

Table 25. Monthly values of the pallets needed to melt of the materials listed in Appendix 2 Table 27 with a melting temperature up to 32ºC.

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2019	108	89	135	92	92	51	6	4	18	125	116	84
2020	182	69	114	128	96	50	8	7	85	124	159	159
2021	179	172	135	117	64	22	4	4	27	93	170	86
2022	142	155	161	106	48	25	14	12	12	50	79	33

With these values, an average of 106 pallets is obtained, taking into account a maximum of 182 pallets (value obtained for the January 2020). This defines a minimum occupancy of 200 pallets necessary to cover the company's demand. This value comes out of the maximum value of 182 pallets plus a 10% of margin. Thus, a heated warehouse with space to store 200 pallets is required.

The selected location can store a maximum of 216 pallets. Hence, it is defined as a suitable location for the implementation of the warehouse.

4.1.4. Service supply for heating

In order to be able to heat the warehouse, different heating options are considered. One option can be the use of low-pressure steam, another can be the condensate outlet line and the last option is the cooling water return line. In addition, there is also the possibility of heating the warehouse with the installation of photovoltaic panels on the roof of the warehouse. All the options offer the correct heating performance required and would therefore achieve the objective of avoid waiting times in the current chambers.

Using low pressure steam would mean installing lines from the existing rack to the warehouse. For this location the distance between the warehouse and the rack is very close. In the Figure 6 it can be seen the service pipe rack in green color, accessible for use in the storage. The same distance applies to the other two options, the condensate outlet line and the cooling water return line. These two options, make it possible to maintain the heating of the warehouse by using energy coming from the plant. Therefore, it would be more convenient and energetically friendly to make use of the plant's condensate outlet line or the cooling water return line generating savings in carbon dioxide emissions and monetary gains to the plant.

On the other hand, the use of photovoltaic panels allows heating by means of green energy. So, it is a good way to improve Clariant installations and to maintain the energy consumption of the warehouse itself. It is also important to mention that Clariant has a project underway for the installation of a photovoltaic park that could supply the energy demand of the warehouse as well as other plant consumptions.

Thus, from material number 102 with melting point of 0ºC to material number 313 with melting point of 31,7ºC from the list of Appendix 2 Table 27, should be stored in the heated warehouse. In this way, a total of 40 materials with low melting points are to be placed in the warehouse so that they do not have to pass through melting chambers. The selected location is suitable for the warehouse site as it has easy access to heating services, both saturated steam and hot water (condensate outlet line and refrigeration return line). In addition, the location is close to the production plant.

Therefore, thanks to this warehouse, the current production waiting times will not be generated. Consequently, a noticeable change can be observed especially during the cold months of the year, when the existing melting chambers are busiest. In other words, the existing bottleneck, mentioned in the initial section of the project as a problem to be solved, will be eliminated.

It is also worth mentioning that this heated warehouse can store off-list materials if there are empty spaces. In this way, it helps with the melting process by decreasing the temperature difference of that material. Therefore, if a material of one melting temperature is heated in the heated warehouse, it will take less time to melt in the melting chambers. Hence, the warehouse is conceived as an enclosure where to store firstly the selected materials of the list and secondly the other materials that must pass through the melting chambers but have a melting temperature higher than the storage temperature.

4.2. More melting chambers

Clariant has a total of seven melting chambers. During the coldest months of the year, but these chambers are not sufficient to supply the demand of the production plant. Of these seven chambers, five are heated with low pressure saturated steam (six bar atmospheric) and the other two are heated with hot water at a maximum of seventy or eighty degrees Celsius.

All these chambers are old chambers which do not have any kind of control system. There is no way to control the consumption of any of the chambers and they do not have internal temperature control system. In addition, there is no internal ventilation system, so that the materials in the upper part of the chamber melt before those in the lower part of the chamber.

In order to be able to supply the current annual demand of the production plant, it is proposed to implement new chambers. These chambers will have control systems and improvements compared to the current ones. In this way, it is proposed to implement a series of instruments to optimize and improve the operation.

An approximate calculation of the number of new fusion chambers required at Clariant is made in order not to create waiting times in the production process. This takes into account the number of chambers required for materials with melting temperatures between zero and thirty-five degrees. These are the materials that if they were not passed through the fusion chambers there would be no bottlenecking problems.

In addition, a monthly chamber count is made for each year, necessary for materials in this melting temperature range. For the calculation of the number of days that these materials require to melt, the previous calculations made to obtain the melting time are taken into account. (See Table 17). Considering that the materials analyzed with the defined melting time are the materials that have a higher melting temperature and therefore take a greater number of days to melt, this value is considered as the time necessary to melt all the materials with same or lower temperatures. Thus, the melting time of the above mentioned table of 3,8 days is selected as it is the most limiting.

These calculations give an average value of 81 days per month to melt these range of materials with a maximum of 170 days. Taking into account that a month has approximately 30 days, the number of chambers necessary to cover the melting needs is obtained. Thus, the highest value of 6 new chambers is obtained for the coldest months of the year with a minimum need of 1 melting chamber in the hottest months of the year.

Taking into account that the melting time value used is that of the materials with the highest melting temperature and that the rest of the materials will not have such high melting times, the calculations are oversized. On the other hand, since in the summer months there is no bottlenecking problem and in the cold months there is, the values of the necessary chambers in summer and in winter will be taken. The values that have come out of the calculations are 3 new chambers for the warm months and 6 new chambers for the cold months. Thus, it is considered that the number of new chambers needed to achieve the project objective is 3 new melting chambers. In this way, the debottlenecking of the fusion chambers will be achieved in the cold months, the months in which there is generation of waiting times in the production process.

In this way, the design of the new fusion chambers is proposed in order to be able to control and monitor their exact consumption as well as to improve their energy efficiency with respect to the current ones.

The plan of the fusion chamber design is shown in Appendix 5. Melting chamber design.

In the current chambers, the air inside is not thermally homogeneous and therefore the materials in the hottest area, which is the upper part of the chambers, melt earlier. To solve this problem, the installation of ventilation system is proposed.

In the drawing can be seen a series of green lines that refer to the ventilation system of the chamber. This system is intended to extract the air from the lower part of the chamber by means of a motor defined with the acronym M to recirculate it through the upper part.

Since the hot air physically rises upwards, the ventilation system ensures that this does not happen and that the temperature inside the melting chamber is as homogeneous as possible. In addition, this system has a couple of outlets to the outside to be able to open the circuit without pressure problems. Furthermore, the system is complemented by a series of manually operated butterfly valves.

A butterfly valve is a type of valve that is used to regulate the flow of liquids or gases in a pipe. It is composed of a circular disc that rotates on an axis perpendicular to the direction of the fluid and is located inside the pipe.

The position of the disc can be adjusted to control the amount of fluid flowing through the pipe. When the disc is fully open, it allows for maximum flow, and when it is fully closed, no fluid can pass. Additionally, the intermediate position of the disc allows for more precise flow adjustment.

Butterfly valves are used in a wide variety of applications, from industrial processes to water and gas supply systems in buildings. Some of the benefits of their use include their simplicity, compact size, low cost, and ease of installation and maintenance.

In summary, a manual butterfly valve as the ones of our drawing, can be a useful tool for controlling the flow of gases, allowing to adjust the flow to a specific level and shut off the flow in case of an emergency or maintenance.[13], [14]

Take into consideration that, all lines have a thermal insulation marked with a kind of cut grid to keep the system as adiabatic as possible. In addition, this insulation provides safety for the worker handling the chambers, as there is no direct exposure to pipes that can cause damage.

On the other hand, a number of instruments are proposed that represent an improvement over the current cameras. Thus, the design chamber has different instruments and valves. Thanks to these it is possible to control certain variables such as temperature, flow or pressure.

Most of the valves present in the design are of ball and manual wheel type. However, a diaphragm valve is also present to control the line pressure. The last one is also called pressure control valve.

Ball valves are a type of valve used to regulate the flow of liquids or gases in a pipeline. They are composed of a perforated sphere that rotates in a valve body, and their operation is based on the movement of this sphere to open or close the fluid flow through the pipeline. Ball valves are also useful in high-pressure and high-temperature applications, due to their ability to withstand high pressures and extreme temperatures. In general, ball valves are a reliable and effective solution for controlling the flow of liquids and gases in a variety of industrial and commercial applications.

Manual wheel valves are a type of valve used to control the flow of liquids or gases in a pipeline. As the name suggests, these valves are manually operated using a wheel or lever that is turned to open or close the valve.

The wheel is a component located at the top of the valve and is used to rotate the valve steam and open or close the fluid passage. The wheel is connected to the steam via a coupling located inside the valve housing. By turning the wheel in one direction or another, the steam is moved up or down, allowing the fluid to flow or stop.

Manual wheel valves are widely used in a variety of industrial applications, such as in the chemical, petrochemical, food, pharmaceutical, water, and wastewater treatment industries, among others. They are a popular choice due to their simplicity, durability, and low cost.

Ball valves are mostly used in condensate lines. Whereas manual wheel valves are used in steam lines as they provide safety and more precise flow control in high-pressure lines.

On the other hand, pressure control valves (PCV) are used to maintain the pressure of a liquid or gas in a system within certain limits. These valves work by adjusting flow resistance in response to changes in pressure, allowing the pressure of the system to be maintained within a specific range. So, pressure control valves are used in a variety of applications, from water supply systems to industrial process control systems. By maintaining pressure within a specific range, these valves help protect the system and ensure safe and efficient operation.[15]

In this case, the pressure control valve is linked by means of a PLC to the temperature instruments. In this way, it is possible to define the internal temperature of the chamber, regulating the pressure of the heating flow line.

In the design of the fusion chamber, the installation of indicators and transmitters of both pressure and temperature is proposed in order to obtain these values and o be able to have a control of the values registered for each variable. In this way, a data record is obtained that will allow the regulation, monitoring and control of the chamber.

An indicator of temperature (TI) is a device used to display the current temperature in an application. Temperature indicators can be digital or analog and are commonly used in a variety of industries such as food, pharmaceutical, chemical, petrochemical, automotive, and aerospace.

A temperature transmitter (TT), on the other hand, is a device used to measure the temperature in an application and transmit that information to a control system or data acquisition system. Temperature transmitters can be analog or digital and are commonly used in industrial processes that require precise temperature control. Similarly, a pressure indicator (PI) is a device used to display the current pressure in an application, while a pressure transmitter (PT) is a device used to measure the pressure in an application and transmit that information to a control system or data acquisition system. Both are widely used in industry to control and monitor processes.[16]–[18]

Moreover, the GOS system has been selected, which allows the chamber to operate only when the chamber door is closed. In this way, there are fewer energy losses and the operators are kept safe from the risk of burns due to high temperatures.

Thus, in the design, there are also other colored lines different from the previously described ventilation system. The red line in the drawing is the high-pressure saturated steam supply line. This line thanks to the PCV reduces the steam pressure and the line becomes yellow. The pressure of the second line (yellow line) is regulated according to the temperature set inside the chamber by the PCV described above.

In addition, the condensate return system, the blue line, is equipped with a series of valves and purges.

A purge is a mechanical device used in steam systems to remove accumulated condensate and air in steam lines and boilers. When steam condenses in a system, water accumulates which must be removed to prevent piping blockage and improve system efficiency. The steam purge is used to remove the condensate and any air present in the line, ensuring that the steam flows freely through the system.

There are different types of purges, but all serve the function of removing condensate and air from the steam system. In general, purges are an important part of steam systems and help ensure efficient and reliable operation.

Summarizing, with this design, the fusion chamber has a control of the internal temperature of the chamber. It also has a record of the flow rate of steam entering the chamber, the pressure of this steam and the chamber temperature. These data will be stored in the company's database and can be used for energy studies and consumption control. It also has a safety interlock that allows the operation of the chamber only when the doors are closed. It also has a ventilation system to homogenize the temperature inside the chamber so that the materials melt equally regardless of their position inside the chamber.

5. Conclusions

In this Project, two solutions have been proposed. Both options allow for no bottlenecking and therefore improve the process of material fusion in the company's fusion chambers. Thus, these two options improve the current system by avoiding waiting times to enter the production plant and the associated energy costs.

Firstly, a list of materials that pass through the fusion chambers has been obtained. In addition, the materials have been analyzed and certain characteristics such as their melting temperature that influence the analysis and study have been defined.

Next, the movements in the fusion chambers have been analyzed and studied based on the month of the year. In this way, values such as the number of tons and the number of pallets that enter the fusion chambers monthly have been obtained. These values have been classified according to different melting temperature ranges of the material. This classification has confirmed that, in the months with higher ambient temperature, certain materials do not pass through the chambers due to their melting temperature. This is consistent with the initially raised issue, and therefore the appearance of waiting times in production is generated in the months with lower ambient temperature, when all materials need to be melted using the chambers. Therefore, solutions are proposed to eliminate these materials that must be melted only in the colder months and that generate waiting times.

In total, and after analyzing all the data, a total of seven possible solutions are proposed. These solutions are classified on a scale of one to ten in terms of the benefit they can provide and the effort they can involve for the company. Thanks to this classification, two options are selected to be studied as a solution to the existing problem. These two options are the design and implementation of a heated warehouse and the design and implementation of more melting chambers.

The heated warehouse allows the storage of materials that only need to be melted during the cold months. Once this option has been studied, a storage temperature of 32ºC is defined. This temperature does not represent a risk for the operators and allows to eliminate the mentioned materials from the list of materials that must pass through the melting chambers. In addition, Clariant has enough space in the industrial site of Tarragona to create this warehouse and cover the demand for these materials. This storage temperature allows the materials to be melted in a maximum of 26 days. This time is in line with the time that the materials spend in Clariant's facilities before being consumed. Thus, the warehouse approach allows eliminating these extra materials that melt in the cold months and therefore debottlenecks the melting chambers.

On the other hand, the design and installation of new melting chambers is proposed. These chambers have pressure, temperature, and flow control, which will always allow control of the consumption and variables of the chambers. In addition, it has safety systems that will provide more security and therefore less risk to operators. It also has a ventilation system that ensures a homogeneous fusion of the material inside the fusion chamber.

Between these two proposed options, it is possible to appreciate the difference in risks between them. That is, in the case of the implementation of a heated warehouse, this has no risk while the implementation of new cameras does. This is because the heated warehouse, even if it is not filled with materials that have a melting temperature below 32ºC, other materials from the list can be stored in order to reduce their temperature difference and "save" time and money in the melting process. In this way, the warehouse will in any case be used. On the other hand, the new melting chambers only have the function of helping to melt the monthly materials in the months when the current chambers cannot supply all the demand. Therefore, these melting chambers remain unused during the warmer months of the year when there is no such need.

In addition, on the energy side, the heated warehouse offers better conditions. The proposal for this warehouse has been designed as a zero-energy consumption warehouse. That is, it will make use of green energy such as that extracted from photovoltaic panels or by using condensate or cooling water return lines that come from the plant at high temperatures. The melting chambers do not allow this zero-energy consumption but would be "conventional" chambers with a steam consumption that will have associated energy costs higher than those of the warehouse.

Consequently, in terms of benefits to be obtained, effort involved, energy consumption and associated risks, the best option between the two studied is the design and implementation of a heated warehouse. For this reason, it is proposed as next steps to study from an engineering point of view the design and implementation of this proposal, which provides a solution to the current existing problem of the Tarragona production plant of the Clariant company. In this way the main objective of this project is achieved and opens the door to an engineering project for a better production process.

6. References

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7. Appendices

Appendix 1. List of raw, intermediate, and final materials codes.

This first list shown in the table below contains a total of those materials that enter the production plant but are likely to pass through the melting chambers first. In this list there are raw materials as well as intermediate and final materials. All types of materials with different melting temperatures between -82ºC and 106ºC are also listed.

Table 26. Materials susceptible to be melted

Nº	T_f (ºC)	I/R/F
1	-82	R
2	-10	R
3	-6	I
4	-5	R
5	-5	R
6	-5	R
7	-5	R
8	-5	R
9	-5	R
10	-5	R
11	-5	R
12	-5	R
13	-5	R
14	-5	R
15	-5	R
16	-5	R
17	-5	R
18	-5	R
19	-5	R
20	-5	R
21	-5	R
22	-5	R
23	-5	R
24	-5	R
25	-5	R
26	-5	R
27	-5	R
28	-4	R
29	-4	F
30	-4	R
31	-4	R
32	-4	R
33	-3	R
34	-3	R
35	-3	R
36	-3	R
37	-1	R
38	-1	R
39	-1	R
40	-1	R
41	0	I
42	0	I
43	0	I
44	0	I
45	0	I
46	0	I
47	0	F
48	0	F
49	0	I
50	0	I
51	0	I
52	0	F
53	0	I
54	0	F
55	0	R
56	0	R
57	0	R
58	0	R
59	0	F
60	0	F
61	0	F
62	0	F
63	0	I
64	0	F
65	0	R
66	0	F
67	0	R
68	0	F
69	0	I
70	0	R
71	0	F
72	0	R
73	0	F
74	0	F
75	0	F
76	0	F
77	0	F
78	0	F
79	0	F
80	0	R
81	0	R
82	0	R
83	0	R
84	0	F
85	0	R
86	0	F
87	0	F
88	0	R
89	0	F
90	0	F
91	0	F
92	0	F
93	0	R
94	0	F
95	0	R
96	0	F
97	0	F
98	0	F
99	0	F
100	0	F
101	0	R
102	0	R

Nº	T_f (ºC)	I/R/F
103	1	R
104	1	R
105	1	F
106	1	F
107	2	F
108	2	R
109	2	R
110	2	F
111	2	R
112	3	F
113	3	I
114	3	I
115	3	R
116	3	I
117	4	R
118	4	R
119	4	F
120	4	F
121	4	F
122	4	R
123	5	R
124	5	F
125	5	I
126	5	F
127	5	I
128	5	I
129	5	F
130	5	F
131	5	F
132	5	F
133	5	R
134	5	R
135	6	I
136	6	I
137	6	I
138	6	F
139	6	F
140	6	R
141	6	R
142	6	R
143	7	R
144	7	I
145	7	R

Nº	T_f (ºC)	I/R/F
146	7	R
147	7	R
148	8	R
149	8	R
150	9	R
151	9	R
152	10	F
153	10	R
154	10	I
155	10	I
156	10	R
157	10	F
158	10	R
159	10	F
160	10	I
161	10	I
162	10	I
163	10	I
164	10	R
165	10	F
166	10	R
167	10	R
168	10	R
169	10	R
170	11	R
171	11	R
172	11	I
173	11	R
174	11	R
175	11	R
176	11	R
177	12	R
178	12	I
179	12	I
180	12	R
181	12	R
182	12	I
183	12	I
184	12	I
185	12	R
186	12	R
187	12	R
188	12	R

Nº	T_f (ºC)	I/R/F
189	12	R
190	12	I
191	12	R
192	12	R
193	12	R
194	13	R
195	13	R
196	13	R
197	13	R
198	13	F
199	13	R
200	14	F
201	15	R
202	15	R
203	15	F
204	15	I
205	15	I
206	15	F
207	15	I
208	15	R
209	15	I
210	15	I
211	15	F
212	15	R
213	15	R
214	15	R
215	15	R
216	15	I
217	15	F
218	15	R
219	15	R
220	15	R
221	16	R
222	16	R
223	17	R
224	17	R
225	18	R
226	18	R
227	18	R
228	18	R
229	18	I
230	18	I
231	18	I

Nº	T_f (ºC)	I/R/F
232	18	R
233	18	I
234	18	R
235	18	I
236	18	R
237	18	R
238	18	R
239	18	R
240	19	R
241	19	F
242	20	R
243	20	R
244	20	R
245	20	F
246	20	I
247	20	I
248	20	F
249	20	I
250	20	R
251	20	R
252	20	R
253	20	I
254	20	R
255	20	F
256	20	R
257	20	F
258	21	R
259	21	R
260	21	I
261	21	R
262	21	I
263	21	R
264	21	I
265	21	F
266	21	I
267	21	I
268	21	R
269	21	F
270	21	R
271	21	I
272	21	R
273	21	R
274	22	I
275	22	R
276	22	I
277	23	R
278	23	I
279	23	F
280	23	R
281	24	R
282	24	I
283	24	I
284	24	I
285	24	R
286	25	R
287	25	I
288	25	I
289	26	R
290	26	R
291	26	I
292	26	R
293	27	R
294	27	F
295	27	R
296	27	I
297	27	R
298	27	R
299	27	R
300	28	R
301	28	R
302	28	R
303	29	R
304	30	R
305	30	I
306	30	R
307	30	I
308	30	I
309	30	F
310	30	R
311	30	R
312	31	I
313	32	R
314	34	I
315	34	F
316	34	R
317	35	I
318	35	F
319	35	R
320	35	I
321	36	R
322	36	F
323	36	R
324	36	R
325	36	I
326	36	R
327	36	R
328	36	F
329	37	R
330	38	F
331	38	R
332	39	R
333	39	R
334	40	R
335	40	I
336	40	R
337	40	I
338	40	F
339	40	R
340	40	F
341	40	R
342	41	I
343	42	I
344	42	R
345	42	I
346	43	I
347	43	R
348	43	R
349	44	I
350	44	R
351	44	R
352	44	I
353	44	F
354	44	I
355	44	R
356	45	R
357	45	F
358	45	F
359	46	I
360	47	R

Nº	T_f (ºC)	I/R/F
361	47	I
362	48	F
363	49	R
364	49	I
365	49	R
366	50	R
367	50	I
368	50	I
369	50	I
370	50	I
371	50	I
372	50	F
373	50	I
374	50	F
375	50	F
376	50	F
377	50	I
378	50	F
379	50	R
380	50	F
381	50	F
382	50	R
383	50	R
384	51	R
385	52	R
386	52	R
387	52	I
388	52	R
389	52	R
390	52	F
391	52	F
392	52	R
393	53	R
394	53	R
395	53	R
396	53	R
397	55	R
398	55	R
399	55	R
400	55	F
401	55	F
402	55	F
403	55	R
404	56	R

Nº	T_f (ºC)	I/R/F
405	56	R
406	56	F
407	57	F
408	57	R
409	57	R
410	58	R
411	58	R
412	58	R
413	58	I
414	62	R
415	62	F
416	62	R
417	63	R
418	64	R
419	64	R
420	64	R
421	65	R
422	66	R
423	67	R
424	67	F
425	69	R
426	69	R
427	70	R
428	70	R
429	70	R
430	70	R
431	71	R
432	75	R
433	76	R
434	80	R
435	81	R
436	82	R
437	85	R
438	85	R
439	87	R
440	91	R
441	92	R
442	96	R
443	98	R
444	100	R
445	102	R
446	104	R
447	106	R

Appendix 2. List of materials which need to pass through the melting chambers.

The following table has been filtered from the Table 26 in the previous appendix. Those materials that are solids and can be pumpable, final materials that are "peak" quantities described in the report and special materials that must have their own special melting chamber, have been deleted from the list. In this way, a more reduced list is left with all those materials that, depending on the ambient temperature at which they are found, must pass through the fusion chambers.

Table 27. Final list of materials that need to pass through the fusion chambers.

Nº material	T_f (ºC)	I/R/F
1	-82,0	R
2	-10,0	R
102	0,0	R
103	1,0	R
122	4,0	R
134	5,0	R
140	6,0	R
141	6,0	R
145	7,0	R
146	7,0	R
147	7,0	R
151	9,0	R
153	10,0	R
167	10,0	R
168	10,0	R
169	10,0	R
170	10,5	R
175	11,0	R
176	11,0	R
177	12,0	R
193	12,0	R
194	13,0	R
199	13,0	R
201	15,0	R
220	15,0	R
223	16,5	R
225	17,5	R
226	18,0	R

Nº material	T_f (ºC)	I/R/F
227	18,0	R
228	18,0	R
238	18,0	R
240	19,0	R
242	20,0	R
243	20,0	R
244	20,0	R
258	20,5	R
259	21,0	R
286	25,0	R
293	27,0	R
295	27,0	R
302	28,0	R
313	31,7	R
321	36,0	R
332	39,0	R
334	40,0	R
341	40,0	R
343	42,0	I
359	46,0	I
366	50,0	R
386	52,0	R
413	58,0	I

Appendix 3. Graphical representation of monthly movements in the melting chambers.

The following figures show a visual representation of the number of tones and products that have been consumed in the chambers on a monthly basis for each year.

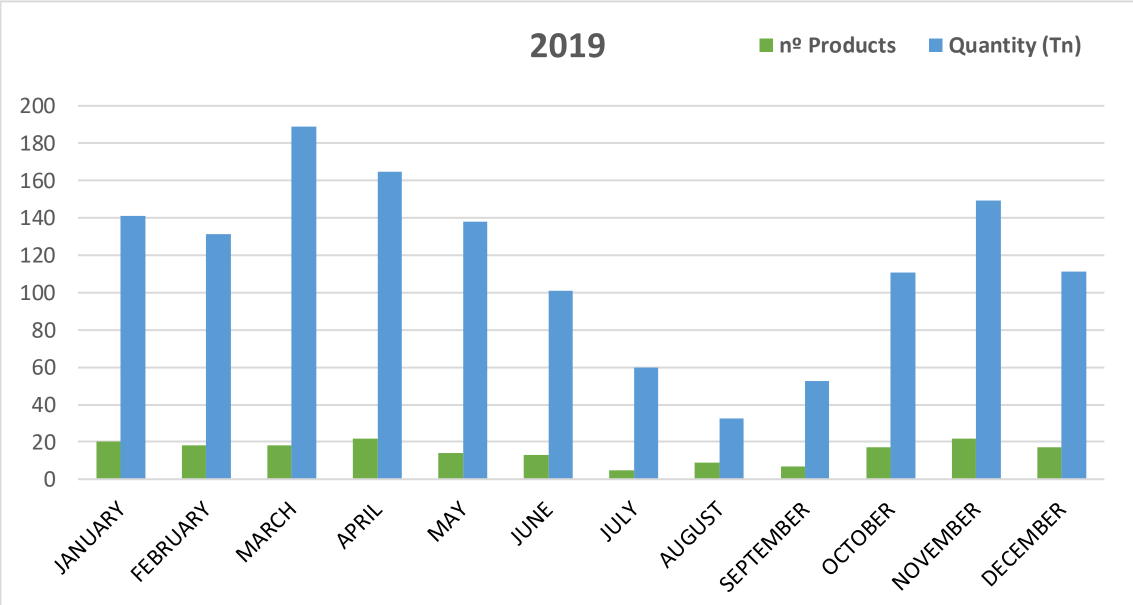


Figure 7. Number of products and monthly tons consumed in melting chambers in 2019.

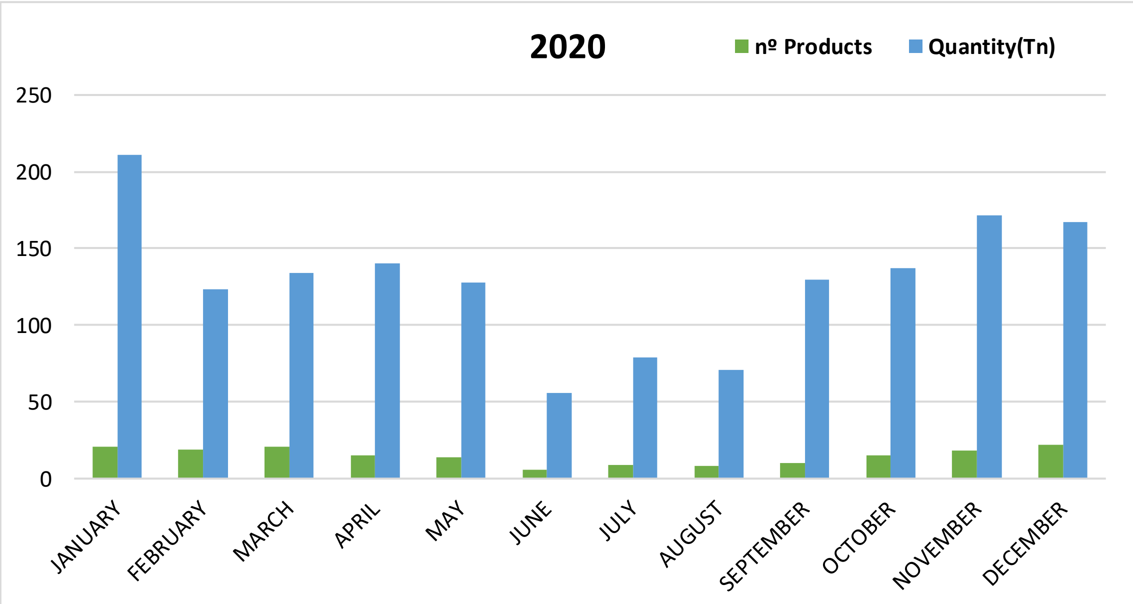


Figure 8. Number of products and monthly tons consumed in melting chambers in 2020.

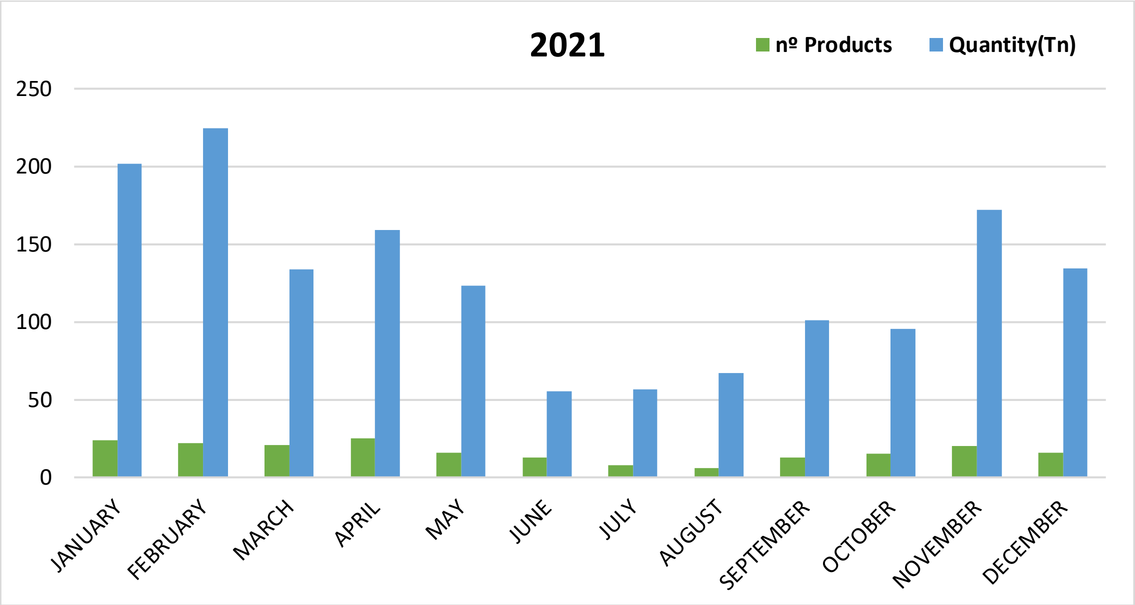


Figure 9. Number of products and monthly tons consumed in melting chambers in 2021.

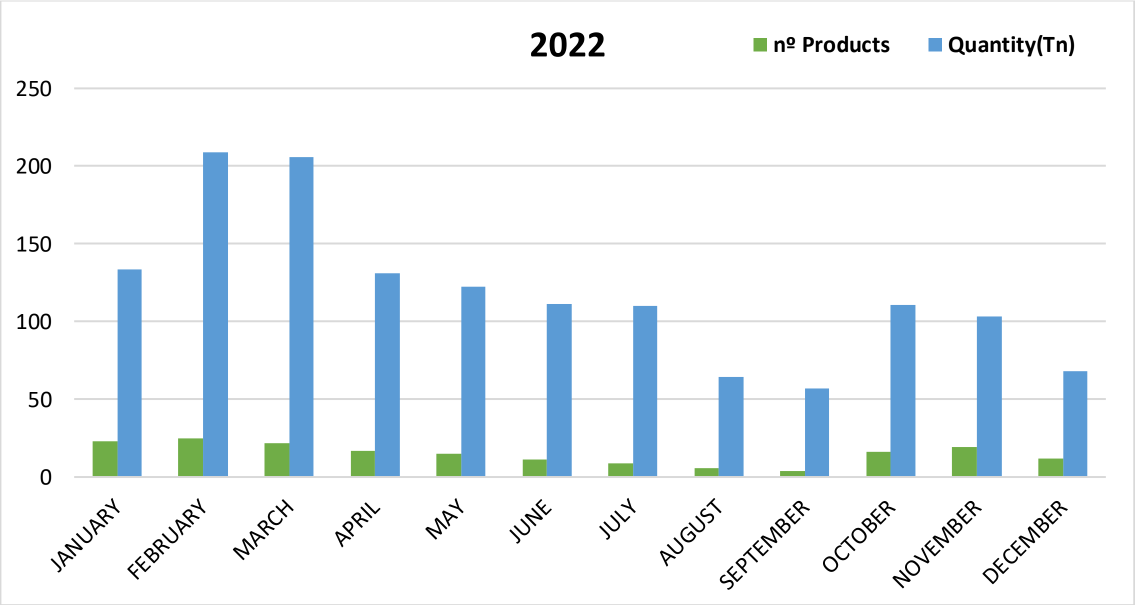


Figure 10. Number of products and monthly tons consumed in melting chambers in 2022.

The following figures show the quantities of material in tons passing through the melting chambers monthly for each year. Compared to the previous graphs, in these it can be seen the distinction between the materials according to the range of their melting temperature. In this way it is also possible to know if materials with very low melting temperatures should or should not pass and analyze it to propose solutions.

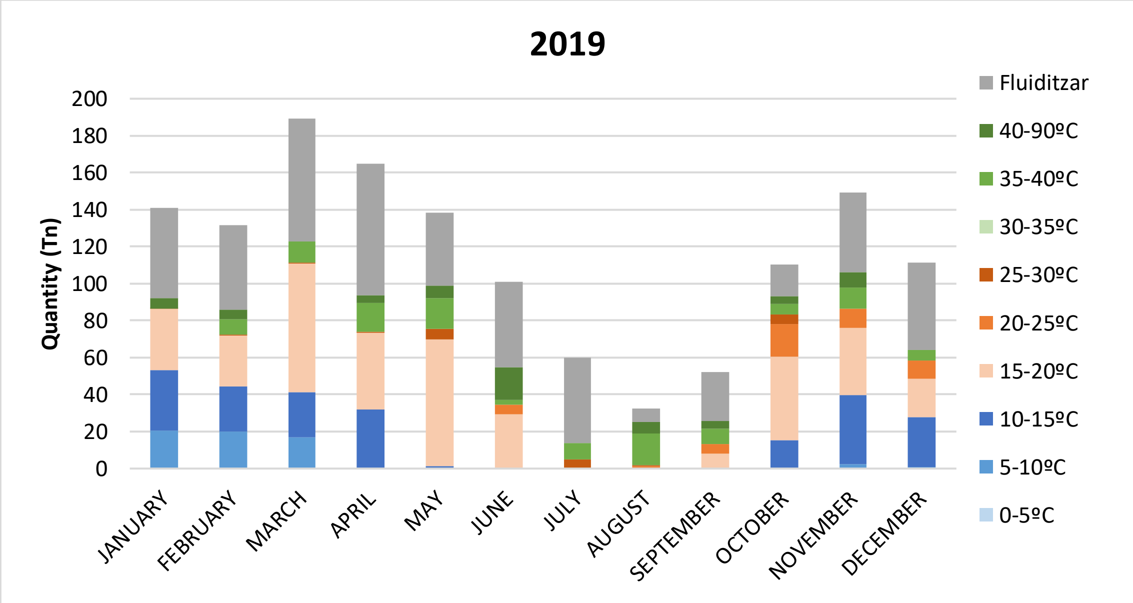


Figure 11. Quantity in tons (Tn) to be melted each month in 2019 divided according to the melting temperature of each material.

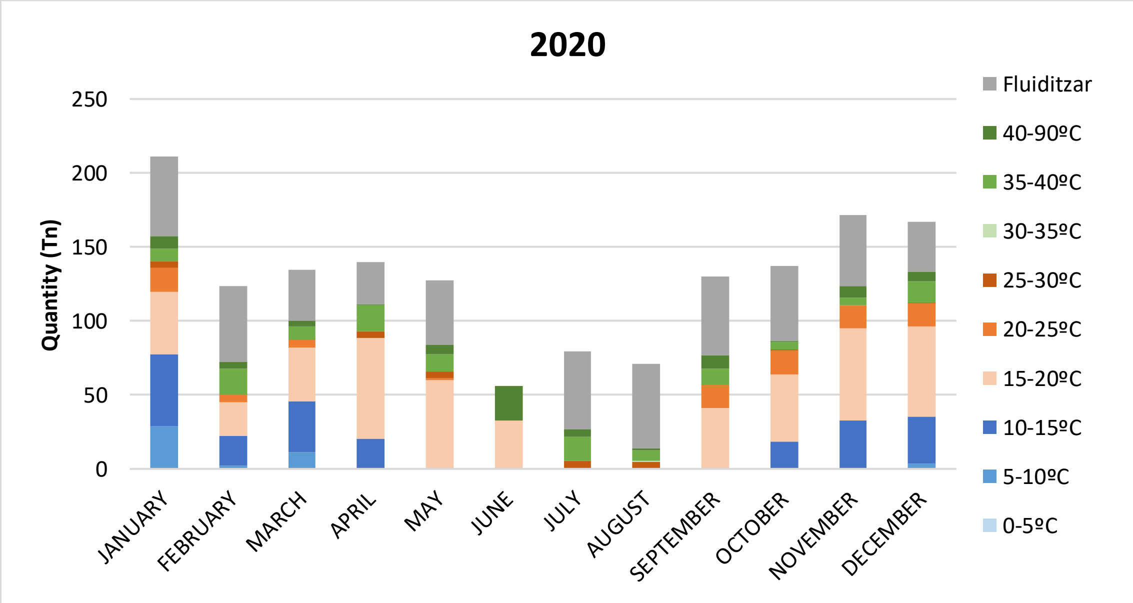


Figure 12. Quantity in tons (Tn) to be melted each month in 2020 divided according to the melting temperature of each material.

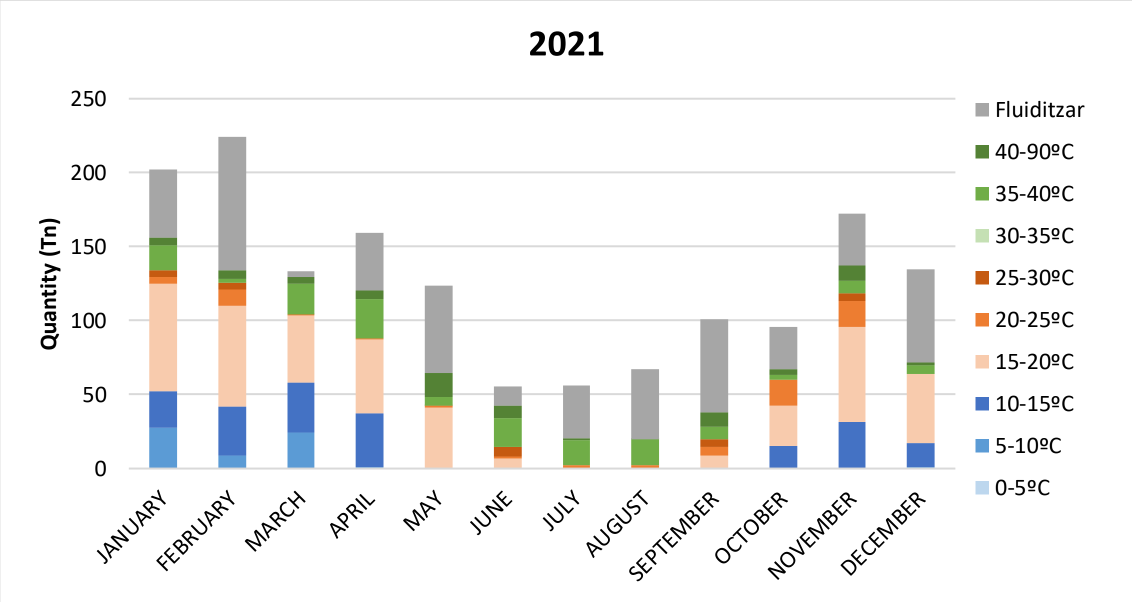


Figure 13. Quantity in tons (Tn) to be melted each month in 2021 divided according to the melting temperature of each material.

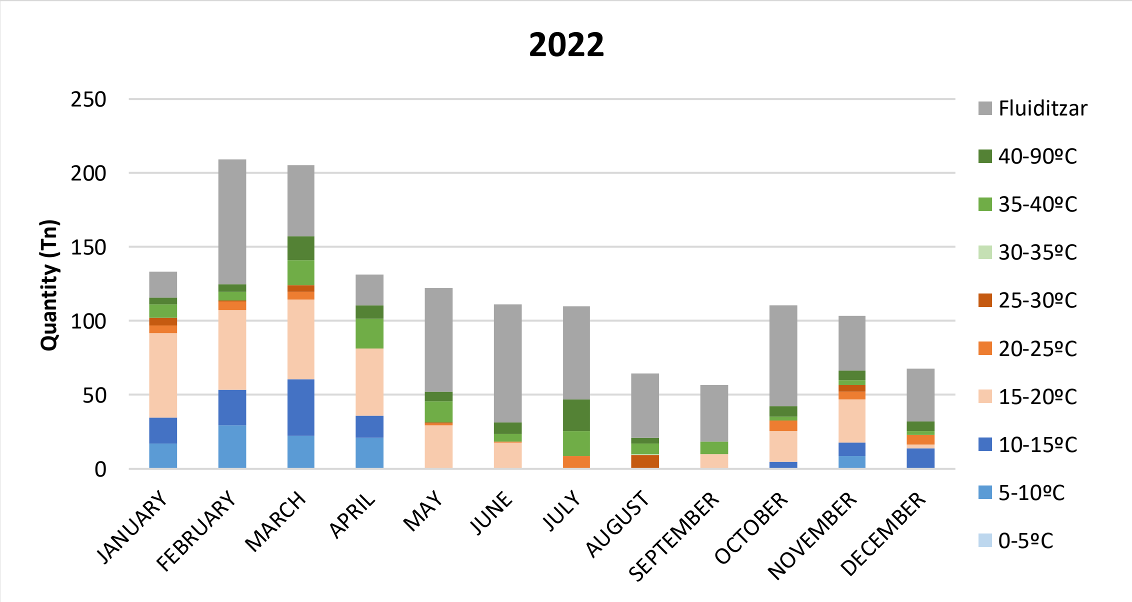


Figure 14. Quantity in tons (Tn) to be melted each month in 2022 divided according to the melting temperature of each material.

Also shown are the following figures which represent the data of the total number of chambers occupied monthly in a graphical manner. These values have been described and determined in section 3.2.3 of the memory.

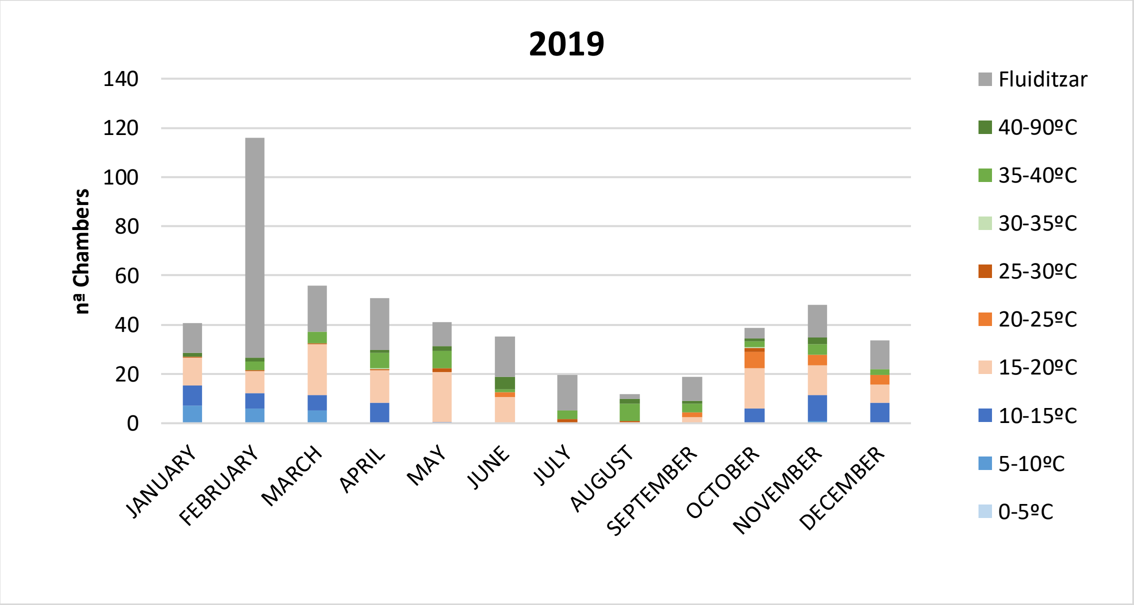


Figure 15. Number of Chambers occupied monthly during 2019 classified according to the melting temperature of the materials.

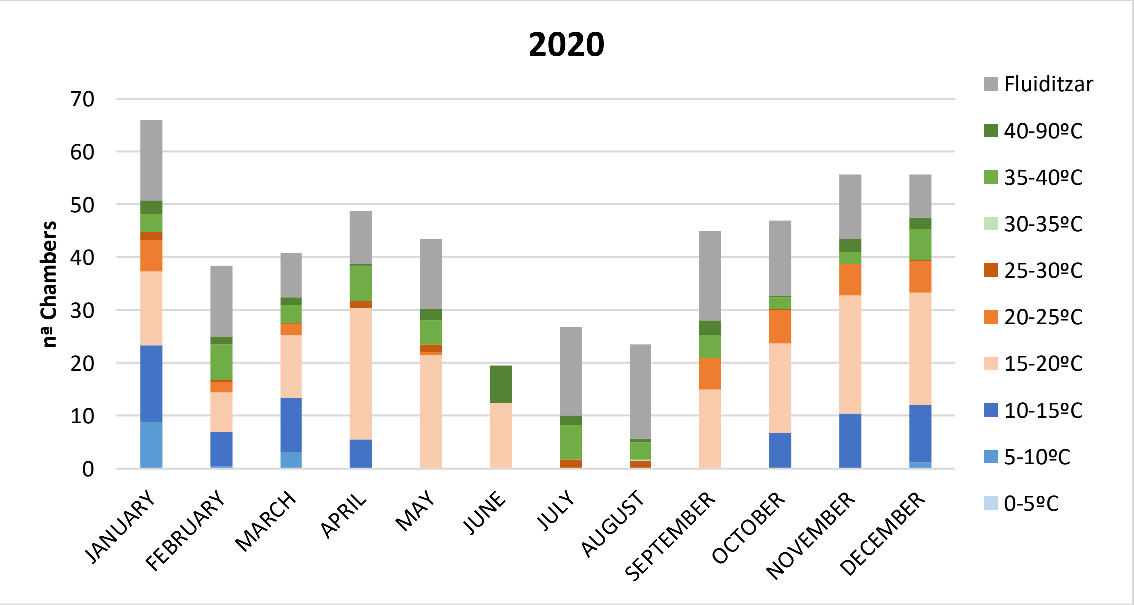


Figure 16. Number of Chambers occupied monthly during 2020 classified according to the melting temperature of the materials.

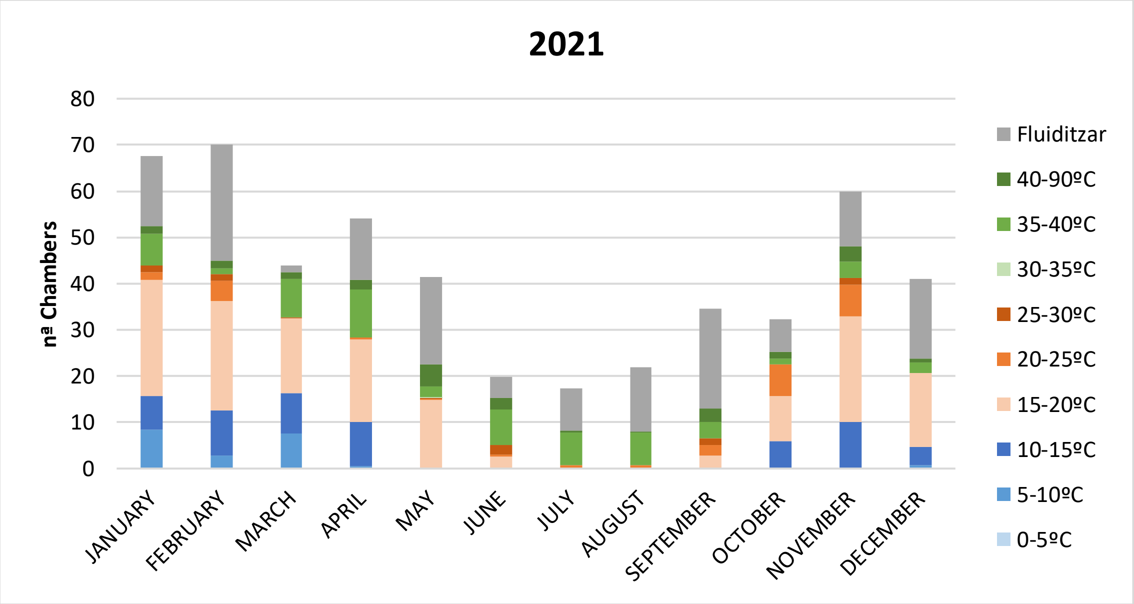


Figure 17. Number of Chambers occupied monthly during 2021 classified according to the melting temperature of the materials.

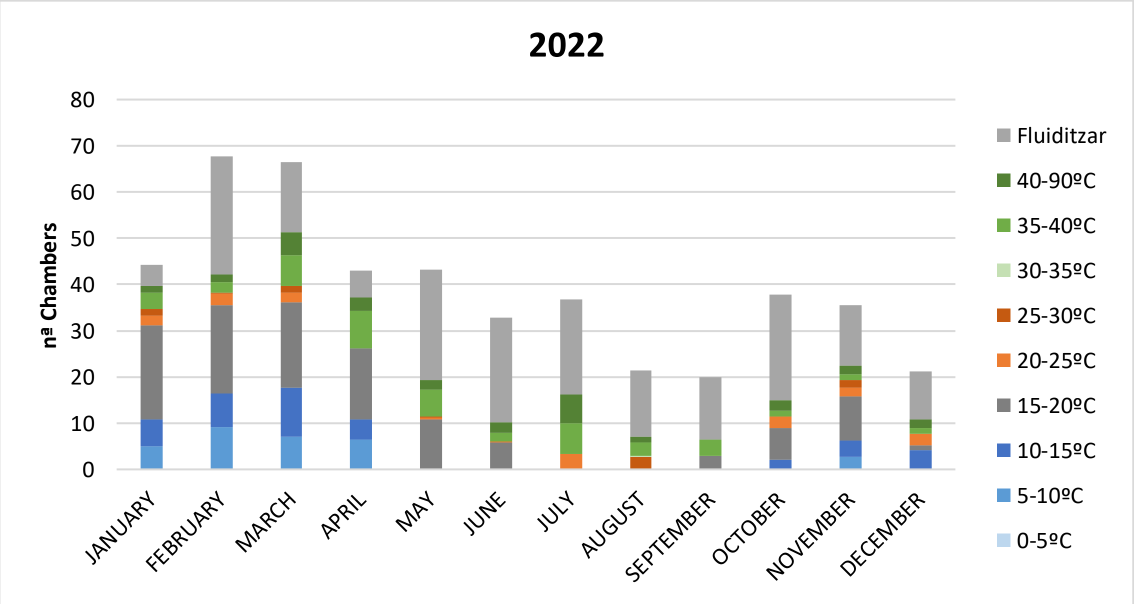


Figure 18. Number of Chambers occupied monthly during 2022 classified according to the melting temperature of the materials.

Appendix 4. Experimental data of the melting chambers.

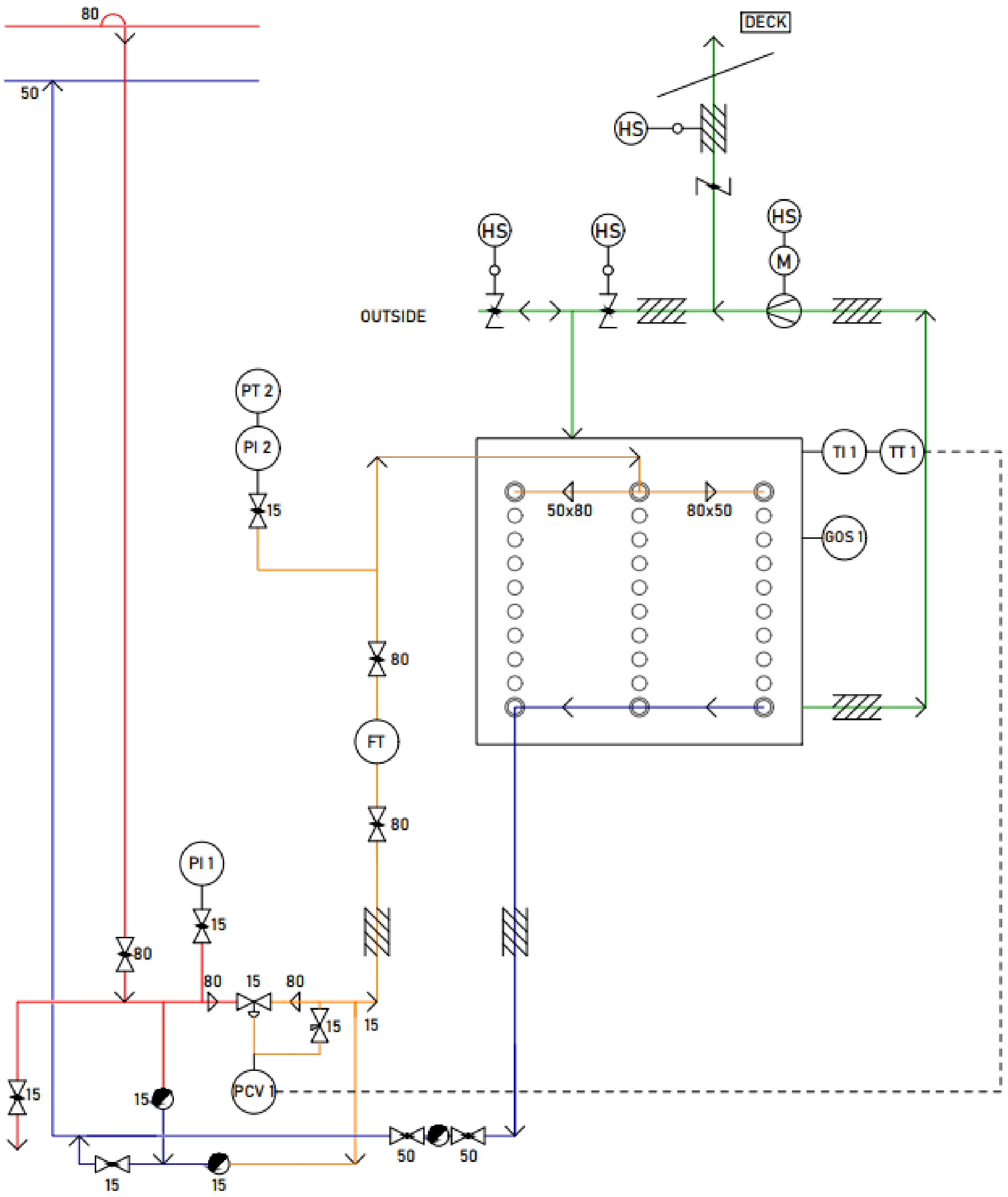
The following table shows the experimental data on the temperature of the fusion chambers. These data have been collected during twenty-seven days of operation of the saturated steam fusion chambers. For each day, two samples have been collected at different times. These data allow to stipulate a reference temperature of the fusion chambers in operation in order to perform energy calculations.

Table 28. Experimental data collected from the temperature of the fusion Chambers.

Date	hh:mm	T (°C)
28/11/2022	8:30	112
	13:30	111
29/11/2022	8:30	109
	13:30	110
30/11/2022	8:30	109
	13:30	109
01/12/2022	8:30	111
	13:30	112
02/12/2022	8:30	111
	13:30	110
13/12/2022	8:30	109
	13:30	110
14/12/2022	8:30	110
	13:30	112
15/12/2022	8:30	110
	13:30	109
16/12/2022	8:30	111
	13:30	109
19/12/2022	8:30	109
	13:30	108
21/12/2022	8:30	110
	13:30	111
22/12/2022	8:30	109
	13:30	108
27/12/2022	8:30	110
	13:30	112
28/12/2022	8:30	110
	13:30	109
03/01/2023	8:30	110
	13:30	109
04/01/2023	8:30	110
	13:30	109
05/01/2023	8:30	111
	13:30	111
09/01/2023	8:30	108
	13:30	109
10/01/2023	8:30	110
	13:30	110
11/01/2023	8:30	111
	13:30	112
16/01/2023	8:30	110
	13:30	111
18/01/2023	8:30	112
	13:30	110
19/01/2023	8:30	109
	13:30	109
20/01/2023	8:30	111
	13:30	112
23/01/2023	8:30	110
	13:30	110
24/01/2023	8:30	110
	13:30	109
25/01/2023	8:30	109
	13:30	110

Appendix 5. Melting chamber design.

The following page shows the plan of the fusion chamber described in section 4.2 of the memory. It can be seen the design of a fusion chamber with all its services and instruments connected for its correct operation.


DECK
HS
HS
HS
HS
M
OUTSIDE
80
50
PT 2
PI 2
15
TI 1
TT 1
50x80
80x50
GOS 1
80
FT
80
PI 1
15
80
80
15
80
15
15
15
PCV 1
15
15
15
50
50

Appendix 6. Student’s role in company

The partnership agreement signed with the company Clariant established the student’s stay in the company to carry out the internship and the final master’s thesis. Thus, the agreement defined the beginning of the stay on Monday, October 10, 2022, ending on Monday, March 20, 2023. From the outset, the objective has been the execution of the final master’s project.

During the stay at Clariant, the project was defined and carried out. Before starting it, it was intended to reach a solution to the existing problem in the plant and its corresponding design for a later implementation. This, due to the problems encountered throughout the process and the limited time to do so, has not been possible. For this reason, the project has a draft design of two possible solutions. This design has been done in a superficial way specifying details in an explanatory way and without design calculations beyond the justifications due to the lack of time.

First, a filtering had to be done in an excel of the company’s internal data to obtain the materials that enter the production plant. Later, characteristics data such as densities, packaging and melting temperatures were searched for each of the materials. Once this was done, the materials that did not require melting could be eliminated from the list. In this way, the final list of materials that pass through the melting chambers was obtained.

These materials pass through in different quantities depending on the month of the year, since the production works according to the order. Thus, the values of material consumed are collected in a monthly basis for different years. In this way, a study is made of the number of tons passing through the melting chambers depending on the month of the year depending on the ambient and melting temperatures of each material on the list.

Thanks to this analysis, monthly consumption values are finally obtained for different yearly periods in units of tons or pallets. The occupancy of the chambers is also calculated in the event that all these materials were to be placed at the same time in the current melting chambers.

Based on the results obtained, it is proposed to design and implement a heated warehouse or a new melting chamber.

Regarding the heated warehouse, a study of the heating temperature, the materials to be stored in it and the space required to solve the problem of overcrowding of the chambers is carried out. In addition, a location close to the production plant within the Clariant industrial park was sought.

On the other hand, the new melting chamber is defined as a totally modernized chamber. It features control and technological systems that improve the performance with which the current chambers are totally obsolete. Thus, building a new chamber with the defined temperature control system means energy savings and better control of the process. By means of control system, the workers will be able to see with Clariant’s internal system whether it is operating or not and which operating temperature is defined, among other functions.

In addition, for the realization of energy calculations to justify the heated warehouse, experimental temperature measurements of the current chambers have been taken. Furthermore, thermodynamic formulas and equations were used to determine the time required to melt the materials to be transferred to a heated warehouse.

Therefore, during the stay in the company, different tasks have been carried out for the approach development and realization of the final project of the master’s degree.

This project has had its share of complexity in terms of data extraction necessary for the study and analysis. Even so, it is a project that benefits both the student and the company. Doing a project within a company in the chemical and industrial sector is an opportunity for professional growth. In addition, for the company this project is useful and necessary because they do not have time to make a study, but it is something that can improve and solve current problems in the production of the plant.

Appendix 7. Self-evaluation Questionnaire

a) Evaluate the acquired **competences** according to the **tasks** you have carried out.

Degree Competences		Task in which you have observed the competence	Self-evaluation [Rank 1 to 10]	Aspects to be improved
SPECIFIC COMPETENCES				
A1.1	Effectively apply knowledge of basic, scientific, and technological materials pertaining to engineering.	In daily task and problems to solve.	7	To have a better knowledge of the operation of the fusion chambers.
A1.2	Design, execute and analyze experiments related to engineering	Within the same master's degree final thesis project.	8	To have at disposal for example more theories and energetic calculations for the realization of most of the thermodynamic calculations.
A1.3	Be able to analyze and synthesize the continuous progress of products, processes, systems, and services, whilst applying criteria of safety, economic viability, quality and environmental management. (G6)	It was done in daily tasks focused on the development of the study of the present project.	8	Improve the relationship between the project objectives and the entire study carried out subsequently.
A1.4	Know how to establish and develop mathematical models by using the appropriate software in order to provide the scientific and technological basis for the design of new products, processes, systems and services and for the optimization of existing ones. (G5)	Excel has been used mainly for the calculations and the analysis of the results. Autocat has also been used.	7	Access and learn how to use some of the company's internal tools.
A2.1	Be able to apply the scientific method and the principles of engineering	Scientific methods and engineering principles have been	8	Using it more often in order to solve problems fester.

	and economics to formulate and solve complex problems that arise in processes, equipment, installations, and services, in which the material undergoes changes to its composition, state or energy content, these changes being characteristic of industrial chemistry and other related sectors such as pharmacology, biotechnology, materials sciences, energy, food and the environment. (G1)	used for the thermodynamic calculations of the project.		
A2.2	Conceive, project, calculate and design processes, equipment, industrial installations, and services in the field of chemical engineering and related industrial sectors in terms of quality, safety, economics, the rational and efficient use of natural resources and the conservation of the environment. (G2)	Calculations made for the justification of the heated storage where the melting times are obtained.	7	More information about the process of melting and thermodynamic properties in the company.
A2.3	Lead and technically and economically manage projects, installations, plants, companies, and technological centers in the ambit of chemical engineering and related industrial sectors. (G3)	Defining the process of blending raw materials in chambers. (Theoretical project)	2	To be involved in lead and technically manage projects.
A3.1	Apply knowledge of mathematics, physics, chemistry, biology, and other natural sciences by means of study, experience, practice and critical reasoning in order	Applied for project calculations and solutions proposals.	7	Access to experimental data of the studied processes.

	to establish economically viable solutions for technical problems (I1).			
A3.2	Design and optimize products, processes, systems and services for the chemical industry on the basis of various areas of chemical engineering, including processes, transport, separation operations, and chemical, nuclear, electrochemical and biochemical reactions engineering (I2).	Optimization of the plant's fusion process. General design of the two proposed solutions.	8	Project with base data collected in order to fully design a solution to the problem.
A3.3	Conceptualize engineering models and apply innovative problems solving methods and appropriate IT applications to the design, simulation, optimization and control of processes and systems (I3).	Use of Microsoft Excel, Autocat, Power BI database and SAP data extraction with tutors.	7	Implementation in a thermodynamic simulator.
A3.4	Be able to solve unfamiliar and ill-defined problems by taking into account all possible solutions and selecting the most innovative. (I4)	In the final master's thesis.	6	Learn about other ways to do it.
A3.5	Lead and supervise all types of installation, process, system and service in the different industrial areas related to chemical engineering (I5).	There has not been any type of supervision of the processes within the company.	5	A higher involvement of the student in the daily tasks of the company.
A3.6	Design, construct and implement methods, processes and installations for the integrated management of waste, solids, liquids and gases, whilst also taking into account the	During the definition of the solutions to the problem presented to solve by the project.	5	Have more experience.

	impacts and risks of these products (I6).			
A4.1	Lead and organize companies and production and service systems by applying knowledge and abilities regarding industrial organization, commercial strategy, planning and logistics, mercantile and labour legislation, and financial and costs accounting (P1).	Beyond the project there is no task of leading and organizing.	2	Higher involvement in production and service systems.
A4.2	Lead and manage the organization of work and human resources by applying criteria regarding industrial safety, quality management, occupation risk prevention, sustainability and environmental management (P2).	Beyond the project for the study of the storage temperature that influences the organigram and the activities performed by the company's employees.	5	Higher involvement and more experience.
A4.3	Manage research, development and technological innovation whilst ensuring the transfer of technology and taking into account property and patent rights (P3).	While melting chambers design	7	Read more literature.
A4.4	Adapt to structural changes in society caused by economic, energy or natural factors so as to be able to solve any resulting problems and to contribute technological solutions with a high commitment to sustainability (P4).	The process to be improved allows the production of materials that are required by other companies as raw materials for their final products. These final products are for the consumer and are trying to be more and more sustainable.	8	Further research and improvement with respect to sustainability.
A4.5	Lead and monitor the control of installations, processes, products,	Beyond the project there is no task of leading.	2	Gain more experience.

	certification, auditing, verification, testing and reports (P5).			
A5.1	Carry out, present and defend (once all the curriculum credits have been obtained) an original individually produced piece of work before a university panel. The work will consist of a professional integrated Chemical Engineering project that synthesizes (TFM1)	Presentation of the TFM at the university.	8	Apply it to other future projects.
TRANSVERSAL COMPETENCES				
B1.1	Communicate and discuss proposals and conclusions in a clear and unambiguous manner in specialized and non-specialized multilingual forums (G9).	Presentation of data analysis and discussion of results in follow-up meetings with tutors.	6	Involve co-workers more.
B1.2	Adapt to changes and be able to apply new and advanced technologies and other important developments with initiative and entrepreneurial spirit. (G10)	The structure of the project has been adapted and changed as unforeseen events have arisen.	8	Take changes and unforeseen events as something real that happens, it does not matter if the objectives initially set cannot be met as long as it is justified.
B2.1	Lead and define multidisciplinary teams that are able to make technical changes and address management needs in national and international contexts. (G8)	No group work has been done apart from the project that has been shown to the two tutors of the company. Even so, plant supervisions have been consulted and asked for information and data for the realization of the project.	5	To be part of a team and to be more involved in the company. In addition to the presence of multicultural teams.
B3.1	Work in a team with responsibilities shared among multidisciplinary,	No group work has been done apart from the project that has	2	To be part of a team and to be more involved in the

	multilingual and multicultural teams	been shown to the two tutors of the company.		company. In addition to the presence of multicultural teams.
B4.1	Be able to learn autonomously in order to maintain and improve the competences pertaining to chemical engineering that enable continuous professional development. (G11)	In the realization of the project calculations and the operation of the fusion chambers.	8	More access to literature of melting chambers and all the movements.
B5.1	Carry out and lead the appropriate research, design and development of engineering solutions in new or little understood areas, whilst applying criteria of creativity, originality, innovation and technology transfer. (G4)	While developing proposed solutions and in the two selected solutions.	7	In-depth investigation.
B5.2	Bring together knowledge, make judgements and take decisions on the basis of incomplete or limited knowledge whilst taking into account the social and ethical responsibilities of professional practice. (G7)	During the proposal and development of the solutions proposed in the project.	8	Need for more information.
NUCLEAR COMPETENCES				
C1.1	Have an intermediate mastery of a foreign language, preferably English	All the discussions and analysis of the project have been carried out in English.	7	An improvement would be to be able to orally practice English in the company.
C1.2	Be advanced users of the information and communication technologies	Applied everyday	8	Lear about internal control and management programs such as SAP.
C1.3	Be able to manage information and knowledge	In the analysis done.	6	The student does not have access to the company's

				information, so sometimes my work was limited.
C1.4	Be able to express themselves correctly both orally and in writing in one of the two official languages of the URV	Applied in daily activities and tasks	8	An improvement in both oral and written expression in English.
C2.1	Be committed to ethics and social responsibility as citizens and professionals	Applied in daily activities and tasks	8	Continue to carry out this competence.
C2.2	Be able to define and develop their academic and professional project	Applied in daily activities and tasks	8	Continue to carry out this competence.

b) Evaluate the final master project and suggest improvements.

Key steps	**Evaluation [Mark 1 to 10]**	**Improvement proposed**
Selection/assignment of the project (dissemination, communication, assignment requirements...)	7	Many inconveniences throughout the project's implementation
Stay (welcome, length, relationship, follow-up made by the company...)	7	To have more information about the project experimental and theory before beginning it
Follow-up made by URV tutor	9	Despite assigning my tutor very late, he has been available at all times to follow up on the thesis.
Other aspects to be considered (which ones...)		Provide access to Clariant's date bases. This will facilitate the learning and assimilation of the processes and procedures carried out in the plant. In addition, it is a good way to introduce the student to the world of chemical industry in an autonomous way. Thus, self-learning and autonomy of the student will be facilitated.