

Expansible Injection Mould Design

Part 1 Technical Memory

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Abstract

Within the next project it is developed a breathing injection mould.

Its main purpose is to produce plastic pieces that utilize different injection foaming techniques such as MuCell® which suppose a great increase of physical properties regarding other foaming types as well as an important weight and material price reduction.

The piece it is going to be produced is designed to contain several future test samples for a better foamed polymer investigation.

The mould type is discussed and compared between the core pull system and the breathing system one. Once properly solved each type it is chosen the breathing mould due its cheaper cost and high quality direct piece production, although lack in terms of size versatility.

Then, that mould is exhaustively defined and evaluated with all the pieces costs as well as mechanizations and thermal treatments needed. The budget part is orientative due to the difficulties of properly predict all the timings and costs.

Index

Introduction	5
Objectives	6
1. Background	7
2. External conditioning	9
2.1. Injection machine characteristics.....	9
2.2. Material characteristics.....	10
3. Piece design	11
3.1 Technical limits.....	11
3.2 The geometry.....	13
3.2.1 <i>Flexion test ISO 178 [1]</i>	14
3.2.2 <i>Traction test ISO 527-2 [2]</i>	15
3.3 Volume.....	17
3.3.1 <i>Perimeter extensions</i>	17
3.3.2 <i>Overflow channel</i>	18
4. Mould design	20
4.1 Core pull system.....	21
4.1.1 <i>Mould operation</i>	21
4.1.2 <i>Piece position</i>	22
4.1.2.1 3rd plate.....	23
4.1.2.2 Decentered piece.....	23
4.1.2.3 Decentered nozzle.....	24
4.1.2.4 Decision.....	24
4.1.3 <i>Refrigeration</i>	25
4.1.4 <i>Ejection</i>	25
4.1.4.1 Core pull ejector.....	25
4.1.4.2 Plate ejection.....	26
4.1.4.3 Decision.....	26

4.1.5	<i>Compilation</i>	27
4.2	Precise opening system	27
4.2.1	<i>Mould operation</i>	27
4.2.2	<i>Piece position</i>	28
4.2.3	<i>Refrigeration system</i>	28
4.2.4	<i>Piece ejection</i>	29
4.2.5	<i>Compilation</i>	30
4.3	Final decision	31
5	Final mould development	32
5.1	Piece description	34
5.1.1	<i>Static part</i>	34
5.1.2	<i>Mobile part</i>	36
5.1.3	<i>Other elements</i>	40
6	Mechanization	42
7	Thermal treatment	43
8	Budget resume	44
9	Conclusions	45
	Acknowledgements	46
	Bibliography	47
	Extra: Ecological footprint	48

Introduction

Polymers are widely used in piece production industry but their first applications were back to the beginning of the last century. They represented a massive improvement for some consumption goods that were notably weight reduced and in some applications represented also an increase of mechanical properties due its ductility. This advantages lead many industry sectors to modify their products such as the automotive industry that began lightening its products in favor of a power increase. Nowadays the struggle is still the same. But in this case, a weight reduction represents more efficiency and material savings pleasing both consumers and the increasingly stringent environment regulations either in production or in product.

Not surprisingly, next step was lighten plastic parts which with some different techniques achieved an apparent density decrease by containing micro voids in the inside. Those techniques were called foaming and for that different injection moulds are being needed.

Today there are still numerous studies on foaming to improve its obvious resistance reduction due to the gas voids and to increase the material savings so moulds that can be used in research purposes are needed.

Objectives

The project is framed in an R & D project between the *Centre Català del Plàstic (CCP)*, *Seat* and *Volkswagen* which involves the development of foamed plastic pieces using different injection foaming techniques. The main objective is to design the maximum accurately mould possible for that goal.

Specifically, a breathing mould that consist in having a cavity that increases volume while opening the mould letting the polymer expand freely without changing the general shape.

That includes the initial evaluation of mould surrounding parameters and characteristics as well as multiple ways to resolve the mould and the plans for the chosen one. The piece produced needs to be designed as well to contain as much test specimens as possible and to resemble to large pieces.

It does not go further so it will not be produced. Solutions are subjectively chosen based in other examples, opinions and previous experiences. Foaming techniques are not discussed but taken in account for the design.

Project's main structure will be:

- Piece design, which has to adapt to the general project in terms of the specifications given and the CCP own machine disposal.
- Mould design, which includes several different possible variations on the mould, a conscious evaluation and the appropriate choice being aware of the different limitations.
- Piece description and elaboration of plans of the mould chosen.

1. Background

Foaming has been an object of study since the early 70's to produce large lightweight pieces compared to the completely solid ones. For that chemical blowing agents were added to the polymer that helped in completely filling the volume. That reduced the final weight, saved material and lightened machine characteristics, but often in exchange for mechanical properties and surface definition and quality.

Actually, chemical blowing agents are being replaced by physical ones that consist in a SCF (supercritical state fluid) addition in the melt polymer that expands when reducing pressure. Differences between both systems are being carefully analyzed [Jaime Francisco G.G., 2013] and suggest that the microfoaming obtained by the physical agents is the key to obtain better results in where chemical agents fail to achieve.

Some of the physical agents foaming characteristics are:

- Final piece weight reduction
- Lower processing temperatures and pressures
- Dimension stability
- Reduction of superficial voids
- Lower cycle time
- Physical properties enhanced compared to chemical obtained
- Usage of blowing agents respectful with the environment (N_2 y CO_2)

Some of those characteristics are a direct consequence of the substitution of the maintenance pressure in favor of the inner gas pressure. The structure obtained resembles to a sandwich one which have solid compact outer layers that provide good physical properties combined with a microfoamed core that saves in weight and material without reducing significantly the mechanical properties.

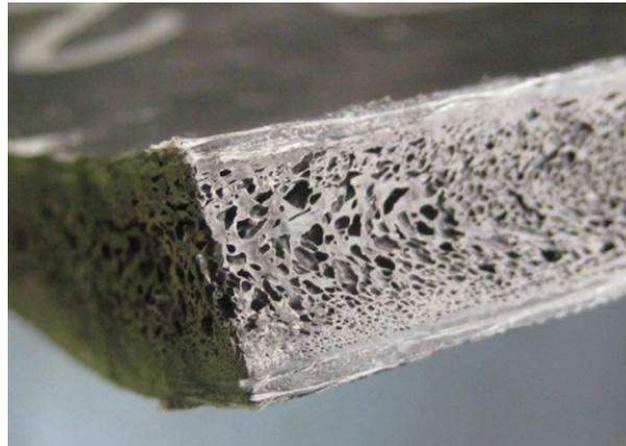


Figure 1 Sandwich structure

To make all the tests it is important to have smart designed moulds to empower that injection technology

Some studies [Spörrer, 2007] have proved the efficiency of the so called "breathing moulds" and their effect on pieces produced using physical blowing agents. Those moulds permit an opening of the machine to give space for the piece to decrease pressure and let injected gas adapt to the volume.

Although the foaming technology is still being studied, there are already some products produced by it such as automotive, medical and packaging parts. The responsible of that basically is the MuCell® technology by Trexel Inc. that allows SCF added injection molding.

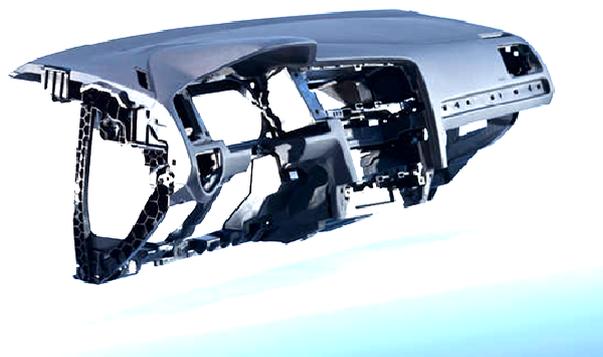


Figure 2 Automotive foamed piece

2.External conditioning

Some parts of the design of the mould are going to be limited by external agents such as the injection machine or the material used, so the proper understanding of these is essential to understand some decisions taken.

2.1.Injection machine characteristics

Centre Català del Plàstic Injection machine disposal characteristics:

- Injection machine *Engel Victory 110*, equipped with the *Supercritic Fluid System (SCF) MuCell®*.
- Clamping force: 1100 kN.
- Maximum overture: 507mm

Unidad de cierre:

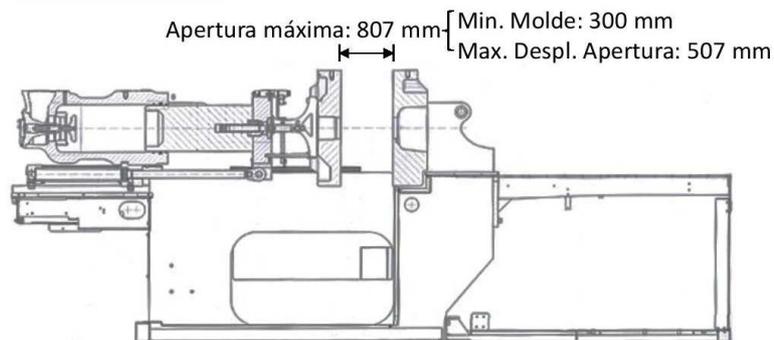


Figure 3 Clamping unit

- Maximum injection velocity: 754 cm³/s.
- Injection pressure: 1287 bar.
- Nozzle diameter: 40 mm.
- Maximum injection volume: 250 cm³.

- Without hydraulic slidings
- Cold runner preferred.
- Subjection plates size:

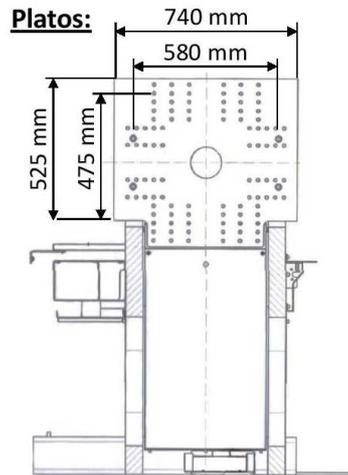


Figure 4 Subjection plates

Some of the previous information are maximum values taken by experimental tests. Of course with not every polymer can those values be achieved so it is very important also which material is going to be used to properly set the machine to its own possibilities.

The rest basically influence in maximum size and some characteristics for the mould to install.

2.2. Material characteristics

As said, this project develops a mould to experiment with so it is not destined to have only one type of polymer nor the same type of injection method. Viscosity, shrinkage and other material parameters are going to be changed frequently and that is what is needed to be taken in account while utilizing the mould. In many design terms raw PP values are taken because it is one of the most used material in that type of applications in automotive industry as well as because it has one of the greatest contractions of the used polymers.

3.Piece design

To know how the mould is going to be, it is needed first to completely and properly define and design the piece it is going to be produced, otherwise that could provoke mistakes while designing the mould.

The piece needs to be representative for large ones emulating their characteristics to properly take conclusions without having to actually produce large pieces.

Those pieces will be used to take out test specimens in normalized shapes so they will need to have some dimensions depending on that. Also it will be needed to see how can they be to resemble to large pieces in terms of flux and regularity that often lack in small ones.

3.1 Technical limits

For the first step is important to know in which conditions it is going to be worked at, that will lead us to some general dimensions to decide the final geometry of the piece.

We have a graph of the injection machine in which it can be seen the relation between the pressure given by the machine and the pressure in the material depending on the nozzle diameter. The nozzle utilized is the \varnothing 40mm one that consists in a barely 1:1 rate between the values in the graph. As it can be seen, the maximum of the machine is 1700bar, but a value of 1000bar (100Kg/cm²) is kept as the new working maximum.

1.3.11.2 Abaco presión de inyección. Meteor 440/90

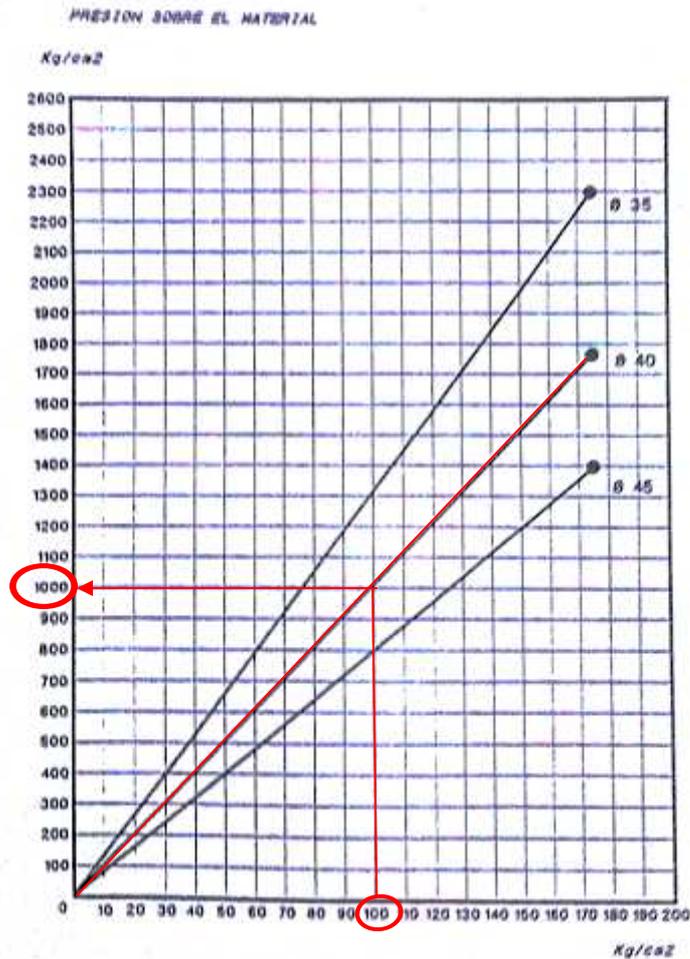


Figure 5 Graph with pressure relation

This value is set as the new maximum keeping in mind that more than one type of plastic is going to be used and the viscosity can be higher in some types causing an extra pressure need, but in similar characteristics pieces the work pressure has been usually near the 400bar.

In each of last decisions we assumed a high Security Factor in order to prevent the problems that appear when work is done near any limit and that also provides an assurance to minimize further flaws or mistakes.

Once the maximum pressure on the material is obtained and using the known maximum strength of the machine (1100 kN) we can obtain the maximum projected area of the piece we are designing.

$$\text{Projected Area} \times \text{Pressure on Material} \leq \text{Machine Strength}$$

$$A \times 1000\text{Kg/cm}^2 \leq 110000\text{Kg}$$

$$A \leq 110\text{cm}^2$$

As I said before, we were assuming a great SF and the values obtained are used as limit, so at last some variations are allowed.

3.2 The geometry

A rectangular shape is ideal for the test specimens extraction but other characteristics need to be also taken into account.

Next step then, is finally define the geometry wanted and discuss its measures to correctly satisfy the purpose of the project.

- Lateral entrance, preferred to a central entrance because permits a better distribution of the flux through the piece.
- "Fan" entrance, provides a better flux distribution especially in the near-entrance zone.
- No runners, fact that simplifies the mould as it is soon explained.

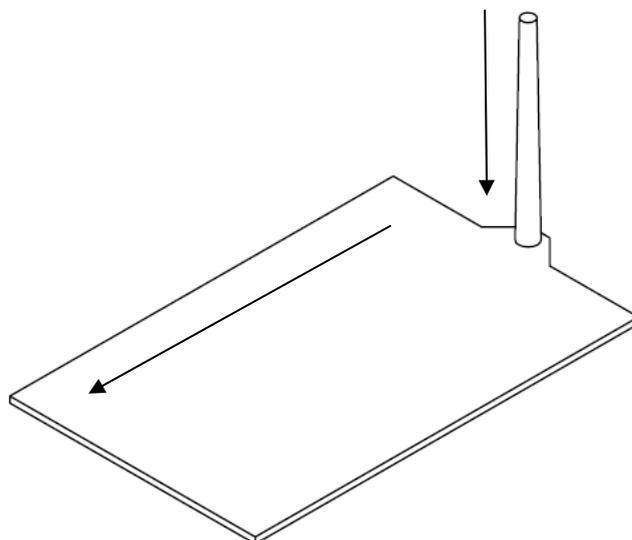


Figure 6 Approximate geometry and flux direction

It is good to remember that the aim of the piece is to represent large pieces so the design is often bad for its own production, but helpful to achieve its main goal.

It also have to be noticed some of the uses the piece is going to have such as test specimens which are regulated by ISO norms.

In those cases we have to take the expanded value of thickness for the calculations.

3.2.1 Flexion test ISO 178 [1]

The only specification for this test is that accomplishes:

$$l = 20h$$

Where

- l is the maximum length of the specimen

- h is the final thickness

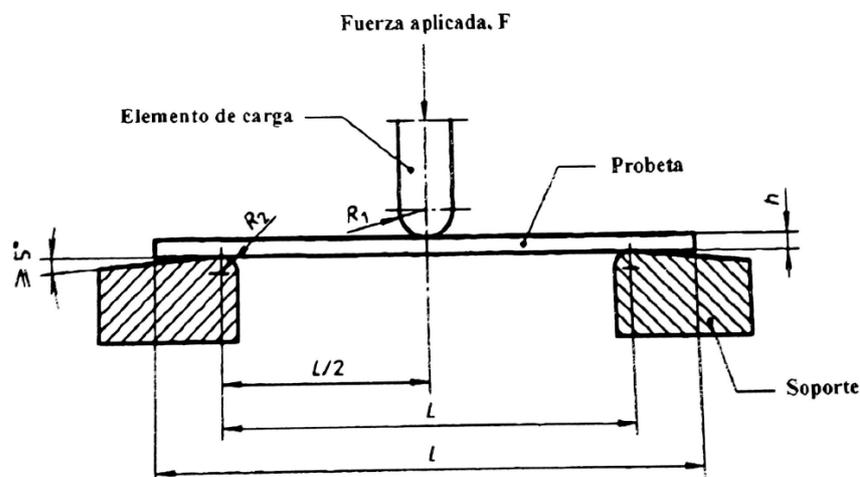


Figure 7 Flexion test

Therefore

Final thickness (mm)	Maximum length (mm)
3	60
4	80
5	100
6	120

3.2.2 Traction test ISO 527-2 [2]

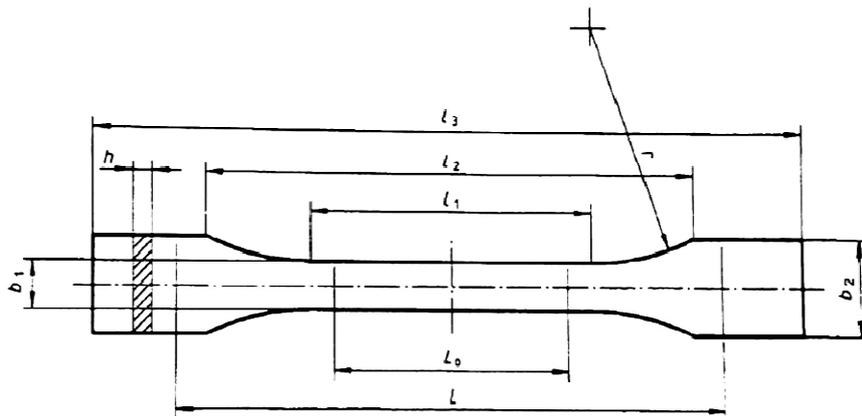


Figure 8 Traction test sample sizes

For type 1A the minimum length is 150 mm which is too much but for types 1BA, 1BB and 5A, 5B the requirements are

$$l_{max} > 35mm$$

$$l_{max} > 75mm$$

The rest of the measures are tabulated in the norm, maximum size is the value that can affect directly to the piece.

It is important to accomplish as much types as possible for being able to do as much tests as wanted.

With that in mind we begin to search for the optimum size of the piece, achieving the previous conditions and characteristics.

Side values		Projected Area
s1 (mm)	s2 (mm)	mm2
70	143	10000
80	125	10000
90	111	10000
100	100	10000
110	91	10000
120	83	10000

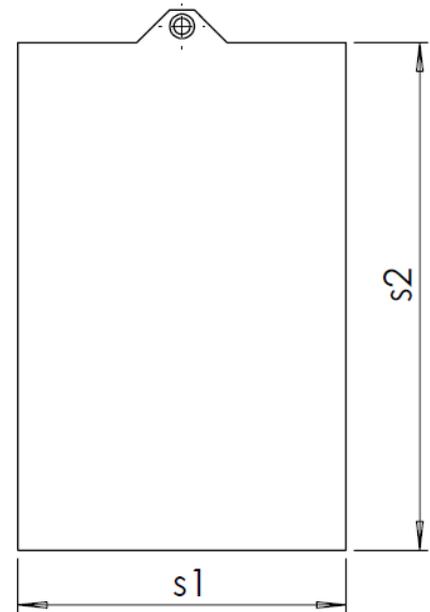


Figure 9 Size values

Maximum length (s2) is set at 150mm due to the increased amount of pressure needed in higher values in the injection process caused by an excessive path for the polymer and its overcooling effect.

- Highlighted values are preferred
- Pieces with a high length/wide relation are preferred

That is because it favor orientation effects, which means that most of the polymer used is oriented towards the same direction, also to achieve a fully developed flux, which will make it resemble to large pieces, and to homogenize the foam without "entrance effect", which consists in the non desirable effect of larger gas bobble size on the entrance.

It is needed to take in account the shrinkage of the material, which in terms of PP is around 1.2%, to properly oversize the mould injection cavity finally obtaining the desired dimension when cooled. When using other materials it is going to be taken into account

that part of the design because contractions are not the same so won't be the pieces neither.

3.3 Volume

Finally, we have to check if the volume reaches the experimentally obtained value of minimum volume in MuCell injection to make it reliable and constant of 50cm³.

Thickness(mm)	Volume(cm ³)
2	20
3	30
4	40

The value chosen in this case is the 2mm thick piece which means that we have a problem of injection volume, because the further expansion of 1 or 2 mm of the foam does not influence in injected volume, consequently some solutions are presented to try to solve that.

3.3.1 Perimetral extensions

It consists in aggregate perpendicular thin extensions to the piece along its perimeter in order to prevent a Projected Area increase, but they need to be cut afterwards.

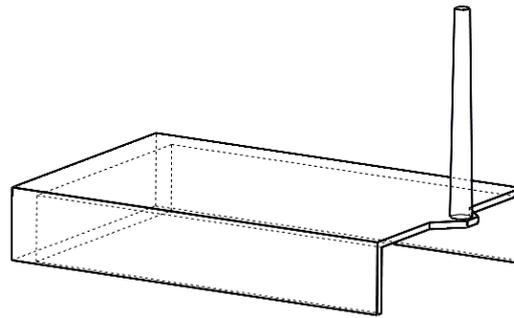


Figure 10 Piece with extensions

If we take the value of the perimeter of the preferred piece size and giving a constant wide and thick values of 20mm and 3mm respectively, we obtain a total length needed of

Thickness(mm)	Volume(cm ³)	Volume needed (cm ³)	Extensions total length(mm)	Perimeter(mm)
2	20	30	500	410
3	30	20	333	410
4	40	10	167	410

Which in our case surpasses the perimeter which means that larger extensions are needed.

As it can be seen, the large dimension needed and the further complicated process of cutting them off from each piece make this option less desirable. However, it is a good option for its easier production.

3.3.2 Overflow channel

Consists in an extra cavity added on the furthest part of the piece (considering "near" the entrance) to easily solve the volume problem.

It represents a great improvement to the extensions system in terms of facility of later treatment, a single cut would be enough.

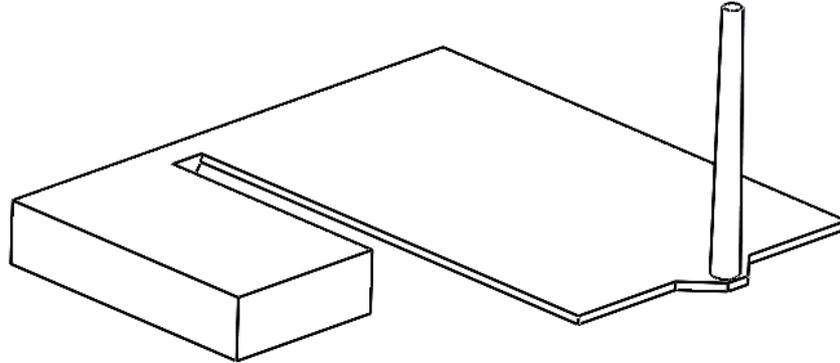


Figure 11 Piece with overflow channel

However, it is not possible to put it where it has no negative projected area effect without overcomplicating the mould so that is why it is placed on the furthest part of the piece where if there is not enough pressure it is not going to be filled. This solution represent the best option considering that it is still good because of all the SF taken on first steps of the design.

4. Mould design

In this part there are going to be developed some solutions for the mould as well as the reason for the chosen ones.

As it has been seen, the produced piece is simple and that simplifies the solution as well. It is taken the mould that typically produce it (without the foaming process of course) as the base to the solutions presented.

The traditional mould looks like

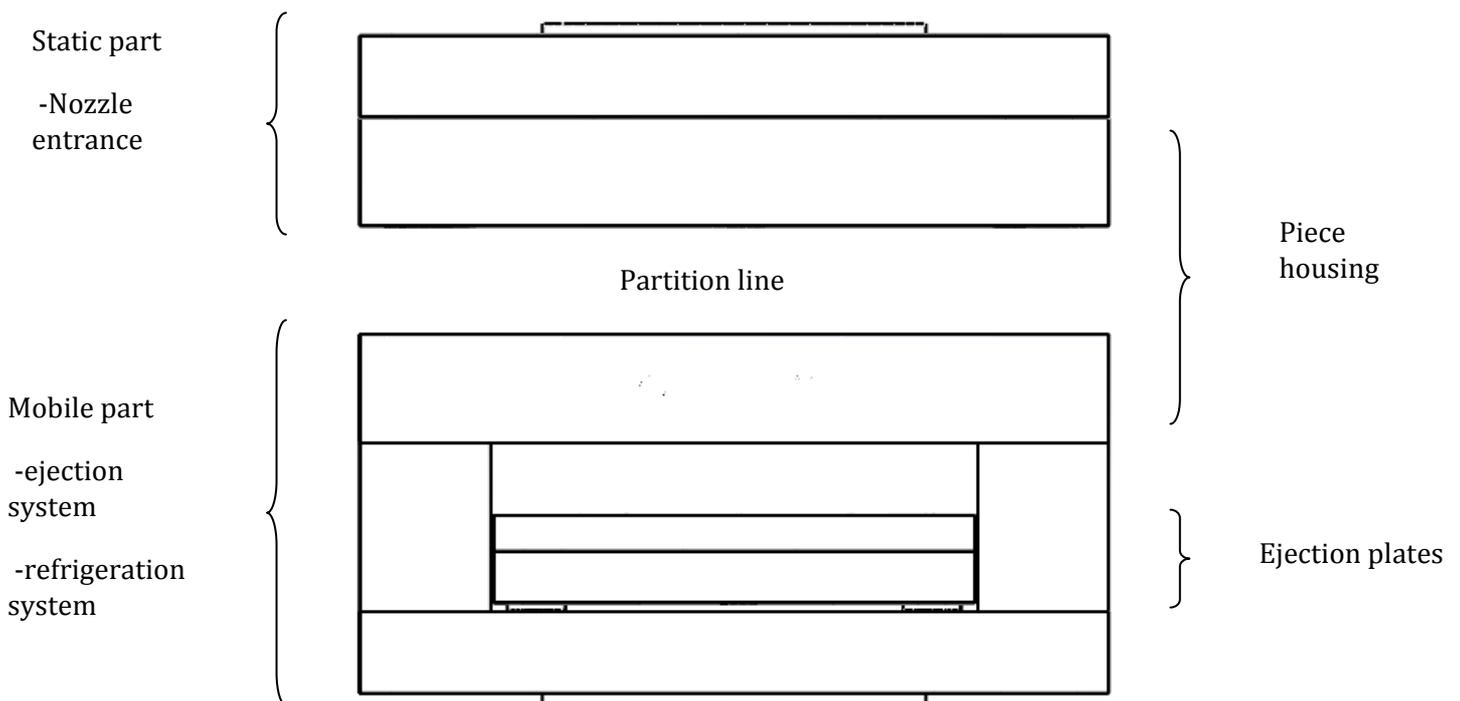


Figure 12 Mould structure

In which we can see the parts function-defined. Note that at least the piece housing part has to be changed in order to achieve the desired foaming technique. What is needed to be achieved is a foaming only in terms of thickness while conserving the other size values.

For that there are presented two general systems.

- Core pull system
- Precise opening system (also known as breathing system)

Each one have its own solutions for every part of the mould and in the end is able to do the job. In that point it is needed to properly evaluate the final characteristics and choose one which is going to be manufactured.

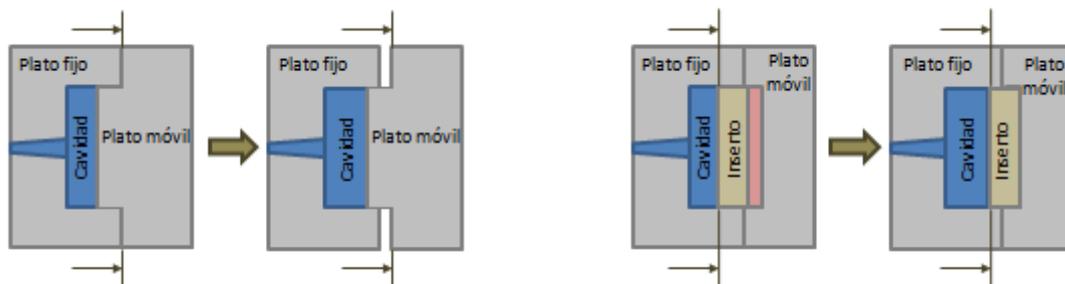


Figure 13 Breathing mould and cell pull foaming systems

4.1 Core pull system

4.1.1 Mould operation

Also known as "noyos", traditionally the system consists in having some mechanical guides to pieces or adding a piston conducted by the same machine or externally synchronized with it which controls directly a cell pull that moves when required.

In this case the cell pull need to be into a direction that cannot be controlled directly so the piston controls both the initial and the final thickness by actuating in a wedge that lifts or lowers the core pull.

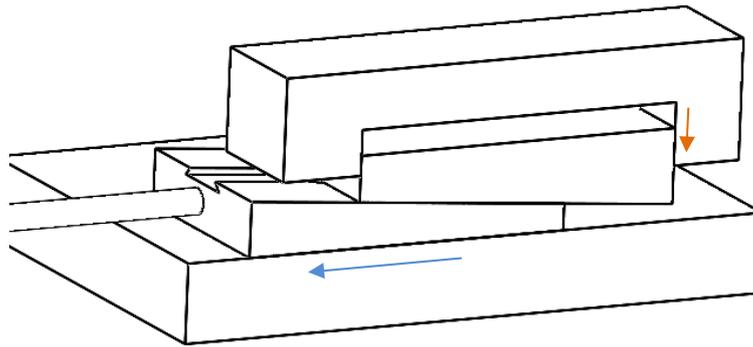


Figure 14 Cell pull/Wedge system

The wedge needs to be attached to the cell pull which at the same time needs to be driven through a cavity impeding unwanted movements. The union of both need to be specially thermally treated preventing the sliding surface from scoring due to the high pressures applied.

That leads to the need of a mechanical limit system for the piston to reproduce exactly the same size each time because when working in terms of few mm the mismatches of a control system can be very relevant.

This makes this system the most useful one providing endless possibilities in terms of different tests in both initial injection and foaming thickness. Also almost every machine with a foaming technique can adopt this system because it is the only thing that differs from the traditional injection process, the mould stay clamped and it is the piston what makes the rest.

Once described the main operation some other issues need to be solved

4.1.2 Piece position

Taking in account the piece size and the injection machine size, it is easy to conclude that it is only going to be produced one piece at a time.

In order to make the piece more suitable to its function the entrance was set on one side so it is going to be decompensated and there are three different solutions.

4.1.2.1 3rd plate

When a mould is decompensated, usually tends to get damaged by its use, having problems in closing basically. To solve that one what is needed is to balance the piece by centralizing the it to the entrance, but as it has been explained before, it is needed a lateral entrance for the flux to develop correctly through the piece so a corridor is added from the nozzle to the side of the piece.

In that case, what is done is add the called 3rd plate which have mechanized only the corridor and which have to be moved to remove it at the same time that it is extracted from the piece.

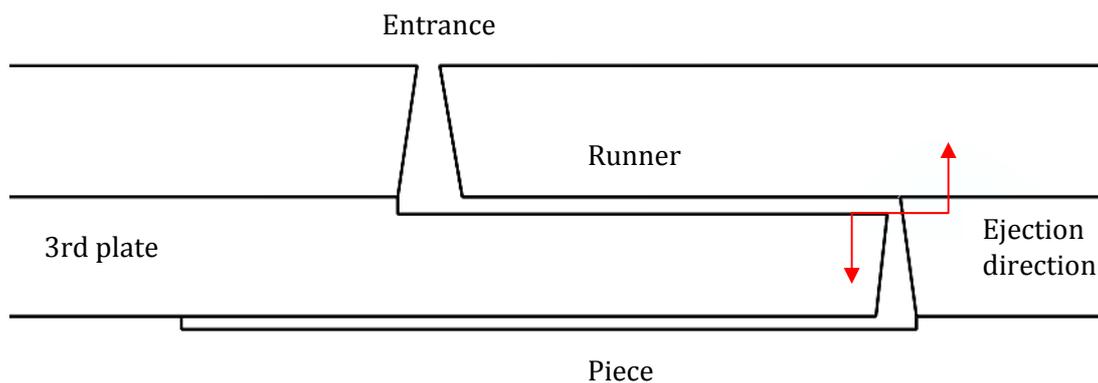


Figure 15 3rd plate operation scheme

This system adds some technical difficulties and extra pieces which can increase the whole price but it is an assurance for large production series which need good durability for the mould.

4.1.2.2 Decentered piece

Although it can be a cause of harm of the mould, having the piece decompensated is not that bad if only a few pieces are going to be produced and of this reduced sizes. A direct

entrance simplifies the mould but also presents some problems with its size and the fact that it has to be mounted into a machine with size limits.

However if needed, the entrance could be diagonally placed allowing to center a bit more the piece to the mould. That would be enough but would also add some difficulties to the extraction of the piece increasing the pulling force needed for the piece to not stick on the static part of the mould.

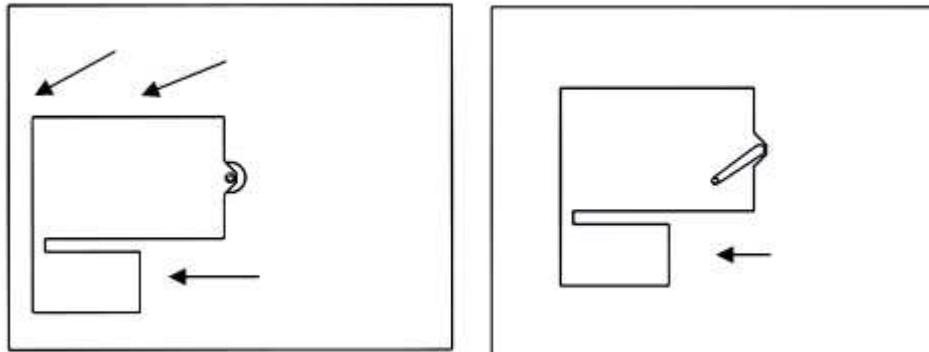


Figure 16 Piece layout within the mould

4.1.2.3 Decentered nozzle

Nothing prevents a change of the position of the nozzle more than the machine mould housing zone. If the mould size is not too large this simple solution is optimum because it permits to center the piece without complicating the system.

4.1.2.4 Decision

In this case the 3rd plate and the decentered nozzle are the best solution in terms of mould usage. Both decentered solutions are optimum in simplicity and price. The difference is very slight in every case. The 3rd plate option would have been the optimum in a case of a larger piece or a multiple piece production, the mould has reduced size so in this case the decentrage of the nozzle, as seen in other moulds in CCP, is the best option.

4.1.3 Refrigeration

The dynamic nature of the core pull difficults the refrigeration in the inner parts of the piece. There are no different solutions to choose from so the solution found consists in covering the perimeter and cooling indirectly the piece by cooling as much as possible the core pull and surrounding pieces.

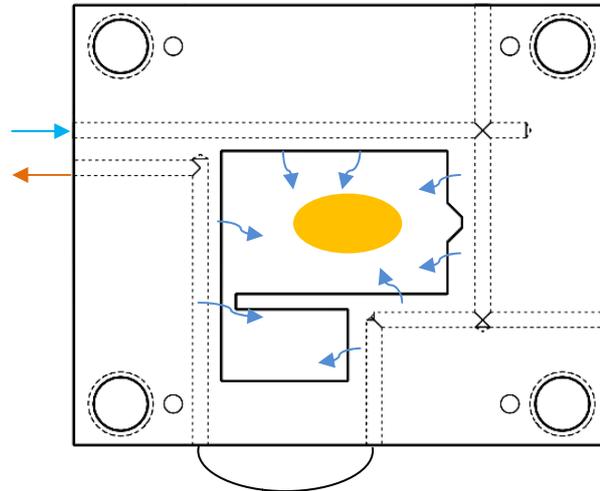


Figure 17 Perimeter refrigeration

Nevertheless in other moulds of similar characteristics this system has been proven enough by the fact that the piece is thin at least in the parts not supposed to be thrown away (overflow channel). The uneven cooling can be a problem for the characteristics differences between the inner and outer parts of the piece

4.1.4 Ejection

The traditional pin-ejection system has some problems to move along with the core pull taking in account that it is moving while the whole mould is clamped. To solve that there are two possible solutions.

4.1.4.1 Core pull ejector

The first thing it has to be assured is that the piece remains on the moving side of the mould by letting some material pass to an entrance to the cell pull while melt that would not let the piece stay once solidified. When ejecting the cavity no longer exists and permits the piece to fall off.

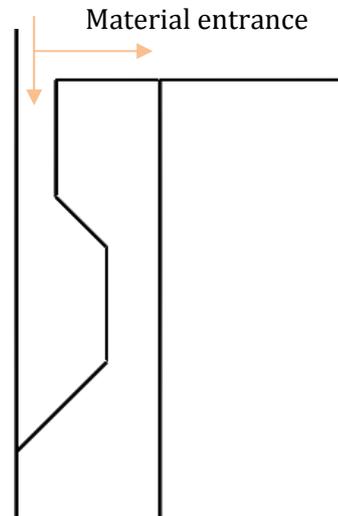


Figure 18 Cell pull extra cavity

Then what elevates the cell pull is the same wedge actuated by the piston that would need a third position. This is one of the easiest solutions but has some difficulties when trying to add a third position to the piston.

4.1.4.2 Plate ejection

This solution consists in binding the ejector plate with the base plate making it move along with the ejection movement. By itself only passes through but modifying the piece on its perimeter and adding some pieces fixed on the base plate interfering with the modification the result is an effective ejection.

The piece would also need to enter to the pull cell cavity in order to assure it does not stack on the nozzle side. This needs to be in a disposable part otherwise it will be an extra part to be taken out.

4.1.4.3 Decision

The problems with the piston dealing with more than two positions are big enough to think that a more expensive one with its control system is needed. In the other hand the plate ejection would increase a bit the after treatment for each piece by having to remove the extra parts. This time the budget determines the decision which is to eject the piece with the plate ejection.

4.1.5 Compilation

Pros

- Piece centered
- Ordinary machine needed
- Versatility in remodeling the piece

Cons

- Difficulties to refrigerate evenly
- Additional piece later treatment
- Additional thermal treatment for the friction parts
- Expensive piston addition*

*To reduce a bit more the total cost it would be possible to put a pneumatic piston instead of an hydraulic one by setting a low wedge angle making the piston need to support less force directly from the pressure on the mould.

4.2 Precise opening system

4.2.1 Mould operation

This system consists in precisely opening the mould by using the injection machine software, increasing the cavity in one direction while a spring system maintains the piece closed making it expand towards the desired direction

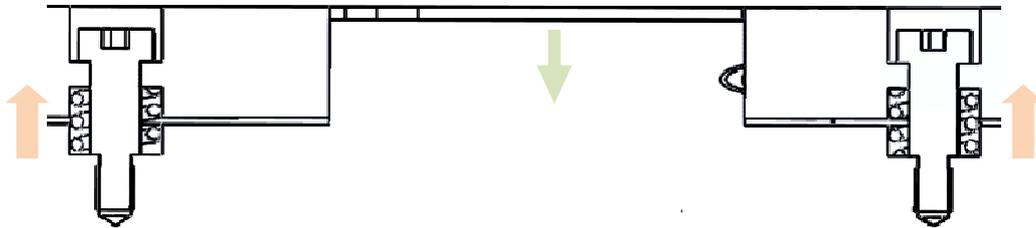


Figure 19 Spring system operation

The springs are always compressed and act until their limiter screw allows them making possible to eject the piece.

They work against the clamping force so it is important to work under the limits of the machine. Pressure inside the piece is lost in a greater way than the cell pull system so it is important to properly design, mechanize and thermally treat the parts involved to minimize its effect and prevent flaws on the piece.

4.2.2 Piece position

In terms of piece position conclusions are the same as the previous type of mould but with extra reasons in favor of the piece centering. Springs are not externally commanded and they are an extra mould harm if not evenly placed.

4.2.3 Refrigeration system

In this case the refrigeration system actuates equally both in the perimeter and in the inner piece through a refrigeration circuit beneath the protuberance that delimits the bottom of the piece. By doing this a better even cooling is achieved.

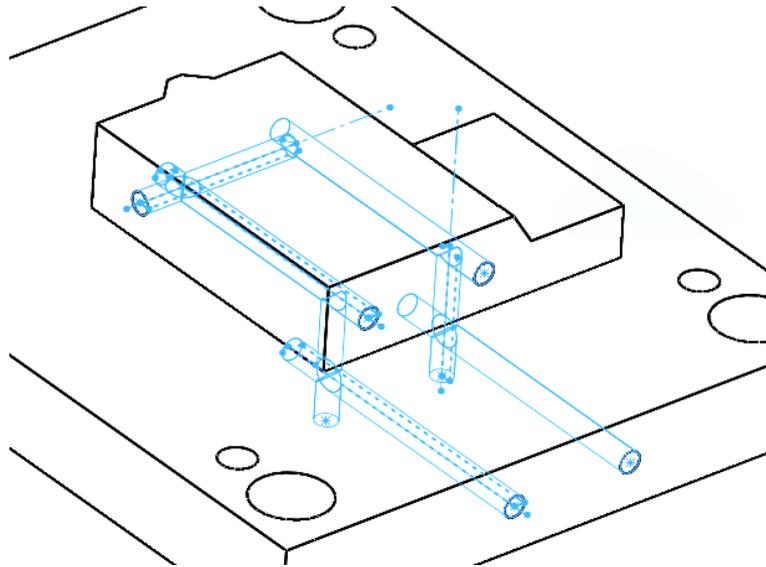


Figure 20 Inner piece refrigeration system

Because of the piece position the perimeter circuit cannot be continue and has to exit momentarily the solid plate to reenter in a more favorable position.

4.2.4 Piece ejection

The ejection pretty much resembles to the traditional non-foamed mould pieces which consist in a pin system ending on the surface of the piece bottom that move along with the ejection plate that move once the mould opening is complete.

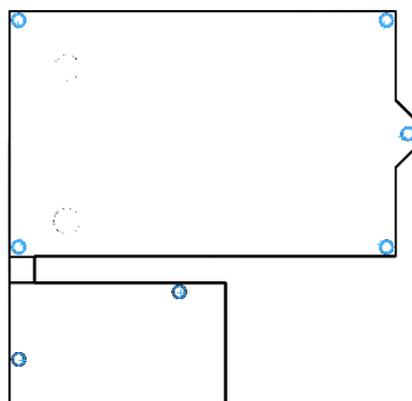


Figure 21 Pin layout

Pins are placed in the ends of the piece and in predicted trouble points such as the entrance and the overflow channel which have an extra amount of material as well.

To prevent flaws and marks in the piece it is important for them to be wide enough (i.e. 4mm Ø). Also, like in the previous mould, the ejection system needs to have an entrance that lets melt plastic enter and prevents the piece from stacking on the wrong side when solidified. When the pin is released also is the said entrance that falls along with the piece. It is important for that to use a pin in a non wanted part of the piece that was going to be taken out such as the overflow channel or the entrance.

4.2.5 Compilation

Pros

- Piece centered
- Even refrigeration
- Cheaper than other options

Cons

- High pressure drop when first opening the mould
- Limited piece versatility
- Difficulty in equally setting all the springs

4.3 Final decision

Both designs are equally valid for the project main purpose but with obvious differences. In the core cell mould the main advantage is its versatility however its elevated cost and difficult refrigeration reduces its value whereas the controlled opening system has fast and good quality ending pieces in exchange for versatility.

So there are no better or worse moulds in absolute terms and that implies to make a decision.

In that case it is decided to put the economic and final quality piece factors as preferred and, in consequence, choose to develop the precise opening mould system which will not differ a lot in a possible future decision to produce the cell pull one.

5. Final mould development

Once fully-defined the mould, it is time to evaluate its production needs. The following parts are taken complete or partially almost exclusively from HASCO catalog which have their own naming and price for them. Note that if taken other brand product some shapes and sizes may change and with that the solution needed.

Pieces can be ordered by the following topics:

Structural:

- K12- Plate 1
- K20- Plate 2
- K20- Plate 3
- K30- Plate 4
- K60- Plate 5
- K70- Plate 6
- K40- Plate 8
- K12- Plate 7

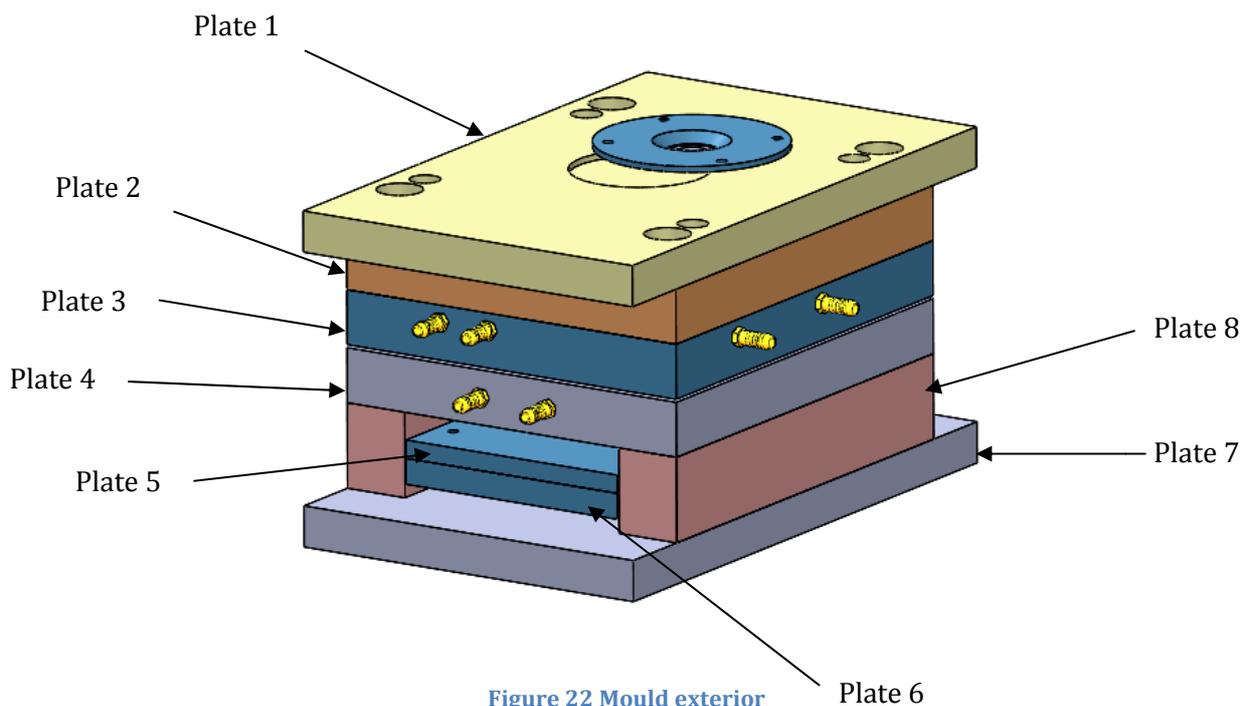


Figure 22 Mould exterior

Refrigeration:

- Z87 refrigeration male nozzle
- Z94 threaded plug

Ejection:

- Z40 ejector
- Z60 spring

Placers and guidance:

- Z1000 centering disk
- Z38 limiter screw
- Z31 allen screw with cylindrical head
- Z33 countersunk screw
- Z691 spring washer with detent
- Z00 column guide
- Z10 bushing guide
- Z20 centering bush
- Z55 stop washer
- Z70 transport flange
- Z51 nozzle

Then it is time to proceed to an exhaustive definition of each piece as well as thermal treatment and mechanization if needed.

5.1.Piece description

5.1.1.Static part

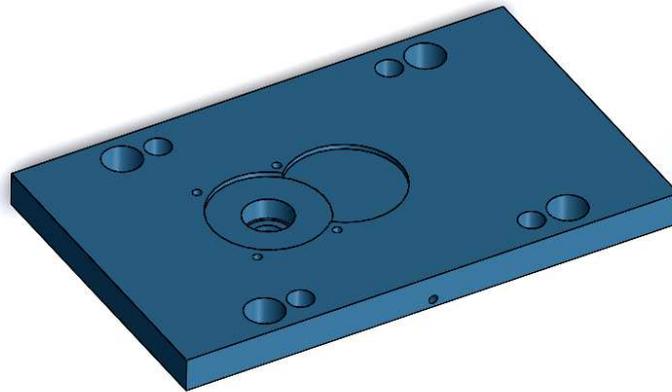


Figure 23 Plate 1: Nozzle support

- **Name:** Plate 1
- **Code and size:** K12-246x296x27
- **Price:** 173.03€
- **Mechanization:** Yes
 - Decentered nozzle drilling
 - Centering disk housing milling and position screws thread drilling
 - Transport flange drilling
- **Thermal treatment:** Quench and Temper
- **Material:** DIN 1.1730
- **Quantity:** 1
- **Use and position:** First plate of the mould, subjects Plate 2 and is being subjected directly by the injection machine

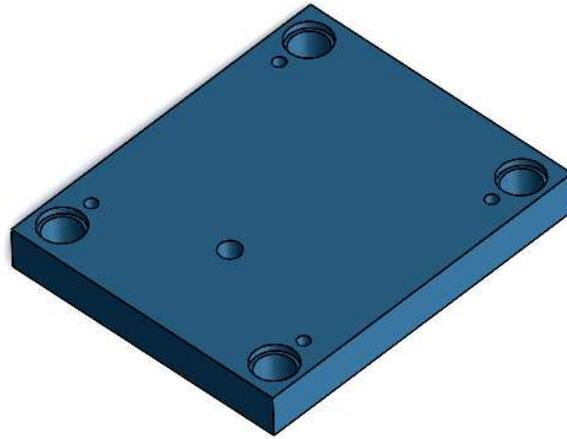


Figure 24 Plate 2: Upper piece delimiter

- **Name:** Plate 2
- **Code and size:** K20-246x296x36
- **Price:** 114.23€
- **Mechanization:** Yes
 - Decentered nozzle small diameter drilling
- **Thermal treatment:** Quench and Temper
- **Material:** DIN 1.1730
- **Quantity:** 1
- **Use and position:** Is subjected by Plate 1 and consists in the upper limit for the piece produced. Is bound together with Plate 1 and holds the Z00 column guides that guides the mould

5.1.2. Mobile part

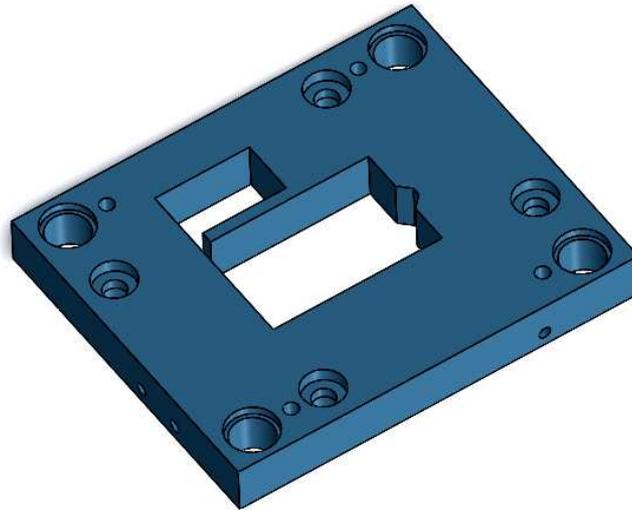


Figure 25 Plate 3: Piece shape retainer

- **Name:** Plate 3
- **Code and size:** K20-246x296x36
- **Price:** 114.23€
- **Mechanization:** Yes
 - Piece shape milled trough the piece
 - Z60 spring and Z38 limiter screw housings drilling
 - Refrigeration drilling
- **Thermal treatment:** Quench and Temper
- **Material:** DIN 1.1730
- **Quantity:** 1
- **Use and position:** Limited by the Plate 4 and the Z38 limiter screw. Stays in the steady part until the 2 mm expansion reached due to the Z60 spring action making the piece retain its general shape. Guided by Z00 column guides and Z10 bushing guide.

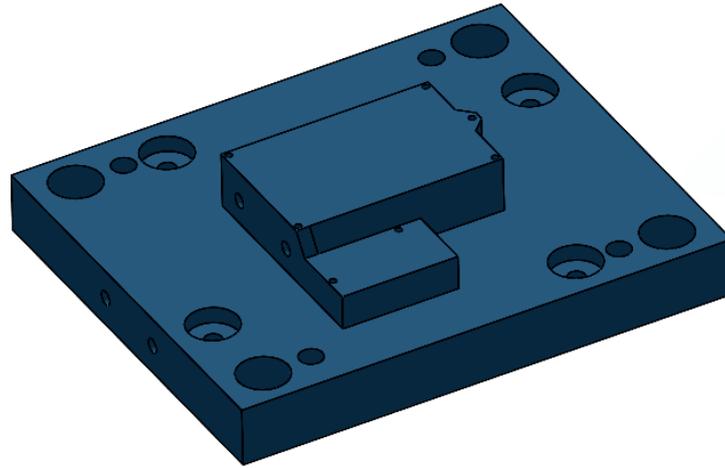


Figure 26 Plate 4: Piece bottom expander

- **Name:** Plate 4
- **Code and size:** Hole position based on K30-246x296x36
- **Base material block size:** 246x296x70
- **Price:** 250.00€
- **Mechanization:** Yes
 - Piece shape milling until desired height
 - Guide drilling
 - Z38 limiter and Z31 allen screw thread drilling
 - Z40 Pin and drilling
 - Z60 spring housing drilling
 - Refrigeration drilling
- **Thermal treatment:** Quench and Temper
- **Material:** DIN 1.1730
- **Quantity:** 1
- **Use and position:** Bounded with Plate 8 x2 in the mobile part with the Z31 screws. Act as the piece bottom limiter that moves when precisely opening the mould. Spring-limiter screws are bound in that plate.

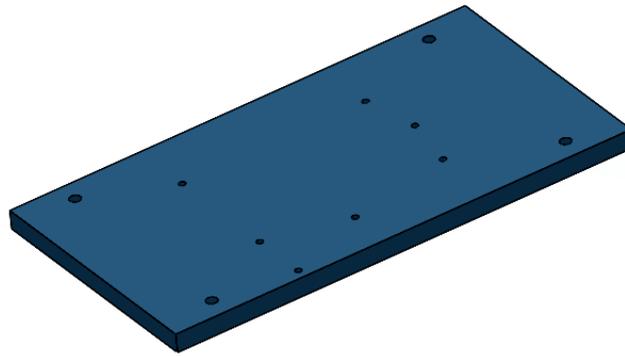


Figure 27 Plate 5: Ejection pins housing

- **Name:** Plate 5
- **Code and size:** K60-246x296x12
- **Price:** 63.90€
- **Mechanization:** Yes

-Z40 ejectors housing drilling

- **Thermal treatment:** Quench and Temper
- **Material:** DIN 1.1730
- **Quantity:** 1
- **Use and position:** Bound with Plate 6 and controlled directly by the machine it holds the Z40 ejector pins that will take out the piece. It is guided by those ejectors.

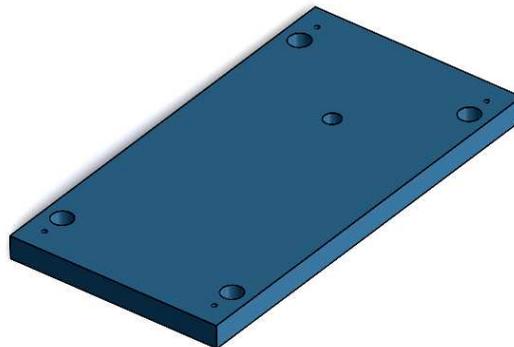


Figure 28 Plate 6: Ejector pins retainer

- **Name:** Plate 6
- **Code and size:** K70-246x296x17
- **Price:** 80.47€
- **Mechanization:** Yes

-Machine ejection screw thread drilling

- **Thermal treatment:** Quench and Temper
- **Material:** DIN 1.1730
- **Quantity:** 1

- **Use and position:** Bound with Plate 5 with Z31 screws and centered with Z33 screws. It receives directly the threaded rod from the machine related to the ejection.

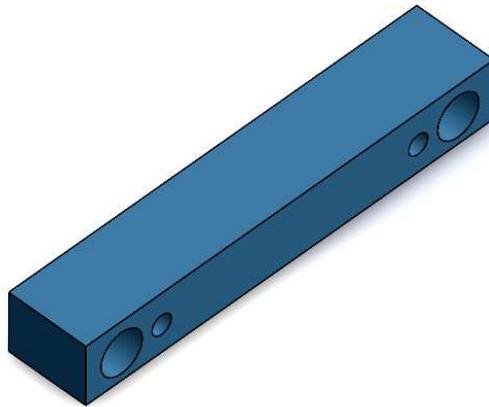


Figure 29 Plate 8: Structural limiter

- **Name:** Plate 1
- **Code and size:** K12-246x296x17
- **Price:** 173.03€
- **Mechanization:** Yes
 - Decentered nozzle drilling
 - Centering disk housing milling and position screws drilling
 - Transport flange drilling
- **Thermal treatment:** Quench and Temper
- **Material:** DIN 1.1730
- **Quantity:** 2
- **Use and position:** Bound between Plates 4 and 7 with Z31 screws passing through and positioned by Z20 centering bushes. It gives space for the ejection system to move and retains the plates on the mobile part.

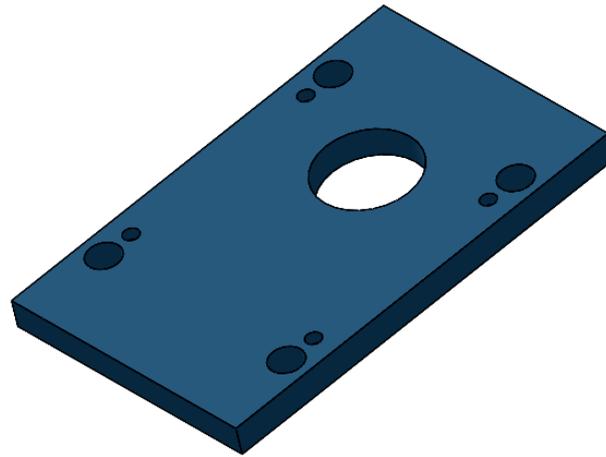


Figure 30 Plate 7: Mobile part support

- **Name:** Plate 7
- **Code and size:** K12-246x296x27
- **Price:** 173.03€
- **Mechanization:** Yes
 - Decentered machine ejection rod position drilling
 - Transport flange drilling
- **Thermal treatment:** Quench and Temper
- **Material:** DIN 1.1730
- **Quantity:** 1
- **Use and position:** Last plate bound to the mobile part of the machine. Sustains the mould mobile part and retains the Z20 centering bush.

5.1.3.Other elements

<u>Name</u>	<u>Code/Size</u>	<u>Price/u(€)</u>	<u>Qty.</u>	<u>Material</u>	<u>Therm. T.</u>	<u>Mechanization</u>	<u>Use</u>
Centering disk	K100 - 125x8	25.25	1	1.1730	-	-	Nozzle holder
Allen screw	Z31 - 12x120	2.11	4	12.9	-	-	Bound permanently
Spring washer with detent	Z691 - 12x5	0.13	8	DIN 17221	-	-	Impede screw going back
Allen screw	Z31 - 12x30	0.52	4	12.9	-	-	Bound permanently
Stop washer	Z55 - 18x3	0.62	4	1.0711	-	-	Limit

							ejection movement
Spring washer with retent	Z691 - 12x2	0.13	4	DIN 17221	-	-	Impede screw going back
Countersunk screw	Z33 - 4x8	0.25	4	8.8	-	-	Bound permanently
Allen screw	Z31 - 8x16	0.22	4	12.9	-	-	Bound permanently
Centering bush	Z20 - 30x100	6.44	4	1.0401	Nitriding	-	Decrease friction
Bushing guide	Z10 - 36 - 24	12.62	4	1.0401	Nitriding	-	Decrease friction
Column guide	Z00 - 36 - 24x55	17.10	4	1.0401	Nitriding	-	Guide every plate
Refrigeration male nozzle	Z87	0.76	8	2.0401	-	-	Connect mould to refrigeration
Threaded plug	Z94	0.30	7	2.0401	-	-	Plug refrigeration holes
Ejector	Z40 - 4x100	2.83	7	1.2516	Nitriding	2 cut 7mm, 1 piece retainer mechanization	Retain and eject piece
Spring	Z60 - 25x30	18.50	4	2098	-	-	Maintains Plate 3 at place
Transport flange	Z70	209.73	1		-	-	Maintain mould closed and transport
Limiter screw	Z38 - 16x30	5.69	4	12.9	Nitriding	-	Limit spring stroke
Nozzle	Z51 - 18x27	36.46	1	1.2826	-	Cut in Plate 1 +2 distance	Connect machine end with mould

6.Mechanization

Although most pieces are directly taken from catalogs with standardized models, only with them is not enough. Pieces such as guides and screws don't need changes but plates do. Standardized plates have only the guidance and thread holes and lets the design up to you. For that, mould plates need to be mechanized.

The mechanization processes needed are:

- Milling. The main way to achieve the shapes wanted in the piece. Cutting off in different roughnesses helps achieving both low time and good finishing for the piece

- Drilling. Way to obtain the round shapes through the pieces

- Grinding. It is important for a mould to fit perfectly to produce regular and good quality pieces as well as for its health.

In the mould there is a non standardized piece (Plate 4) which have to be mechanized completely, first roughing until there is little thickness left to take out, then a finishing rough and finally grinding it.

7. Thermal treatment

For the thermal treatment there are basically two types to be taken in account:

-Quench and temperate. It consists in hardening the piece and then releasing the tension the first treatment provoked. The result is a harder steel than the one in the beginning with good ductile properties. Is done basically in the structural pieces to make them last without degrading excessively by its use. The final hardness is measured by Rc (Rockwell hardness). Higher values are needed in pieces that slide to minimize friction degradation such as Plate 3 and 4, but being careful not to harden it too much to prevent brittle behaviors of the pieces.

-Nitriding. It consists in a superficial treatment that deposits nitrides in the very first layers of material in the surface preventing them from the harm of friction. That is why is done at the parts that move guided such as ejection pins or column guiders.

Depending on where normalized pieces bought those thermal treatments may be already done but depending on the situation a different treatment would be needed anyway due to mould singularities such as our example that need different Rc in some pieces.

8. Budget resume

Extra pieces	250€
Standardized pieces	1.558€
Thermal treatments	600€
Mechanized and finishing	12.000€
Other costs	1.230€
+21% IVA	3.284€
<u>Total Mould Cost</u>	18.922€

The final cost is totally approximated and may change significantly depending on the mechanizing hours which have a huge weight in the final price. Depending on the quality of the standardize items the hours can be reduced also.

9. Conclusions

As it has been seen, breathing mould is a simple idea mould with a not so simple application. The spring system may not be technically the best for testing but surely it is the cheapest and assures good quality pieces. The project could had been completely personalized simplifying things such as refrigeration, but in the end the price increase would had been huge.

This project stopped in the design state defining (or approximately defining) all the things a mould designer have to do before beginning to produce any piece. Next step would be buying all the normalized items and beginning to thermally treat and mechanize the ones which need that.

Finally just a reminder of what this technology represents, a whole new spectrum of products can be improved and that begins with big investing companies such as the automotive ones doing what this project is aimed to, testing new technologies and bringing them to the industry first making profit of it but inevitably spreading it to the other companies.

Acknowledgements

I would like to specially thank to my project tutor Miguel Sánchez for being comprehensive of my mistakes and for guiding and helping me entering this world of plastics which I was recently presented with.

Also, of course, my family that gave me support every moment.

And to my recent English teacher Nicky who I hope never reads this project or else I will be degraded to a lower course.

Finally I would like to thank to all the other people in CCP and friends that helped me in a more external way but enough to make me think twice and improve what I was doing.

Bibliography

References

GÓMEZ, J.F. (2013) Caracterización y estudio comparativo de materiales celulares poliméricos obtenidos mediante moldeo por inyección con espumación física o química. Doctoral Thesis.

SPÖRRER, N.J. (2007) Controlling Morphology of Injection Molded Structural Foams by Mold Design and Processing Parameters. *JOURNAL OF CELLULAR PLASTICS* Vol. 43

Norms

- [1]UNE-EN ISO 178 Plastics. Determination of flexural properties
- [2] UNE-EN ISO 527-2 Plastics. Determination of tensile properties

Notes

- The injection moulding machine / Miguel Sánchez-Soto

Catalogs

- HASCO catalog

Websites

TREXEL INC. *MuCell Molding Technology*

[Online]Available from:

<http://www.trexel.com/en/mucell-injection-molding>

[Accessed on 10th May]

Extra: Ecological footprint

In this chapter it is determined the environmental impact associated to this project in particular.

The CCP has a system of environmental management which controls several parameters regarding final projects done in their installations.

In the beginning of a new PFG student, he is given a questionnaire where he has to fill with the different activities which have their energetic consumption and the equivalent in environmental surface impact.

Objectives:

- Determine the environmental impact of each PFG done in CCP
- Sensitize the students regarding environmental impact of their project and the implantation of the environmental management system.

Electrical consume

1 KwH = 0,264 KG of CO2

Quantity of CO2 absorbed per hectare and year= 4,58 Tn of CO2

Place	Concept	Time in h	Power in Kw	Kwh		
Desk	Computer	40	11	440		
Various	Lights	100	0.1	10		
TOTAL ESTIMATED				Kwh	Kg CO2	Hectares
				450	118.8	0.026

Mobility

1 l of gasoline = 0,88 kg CO2

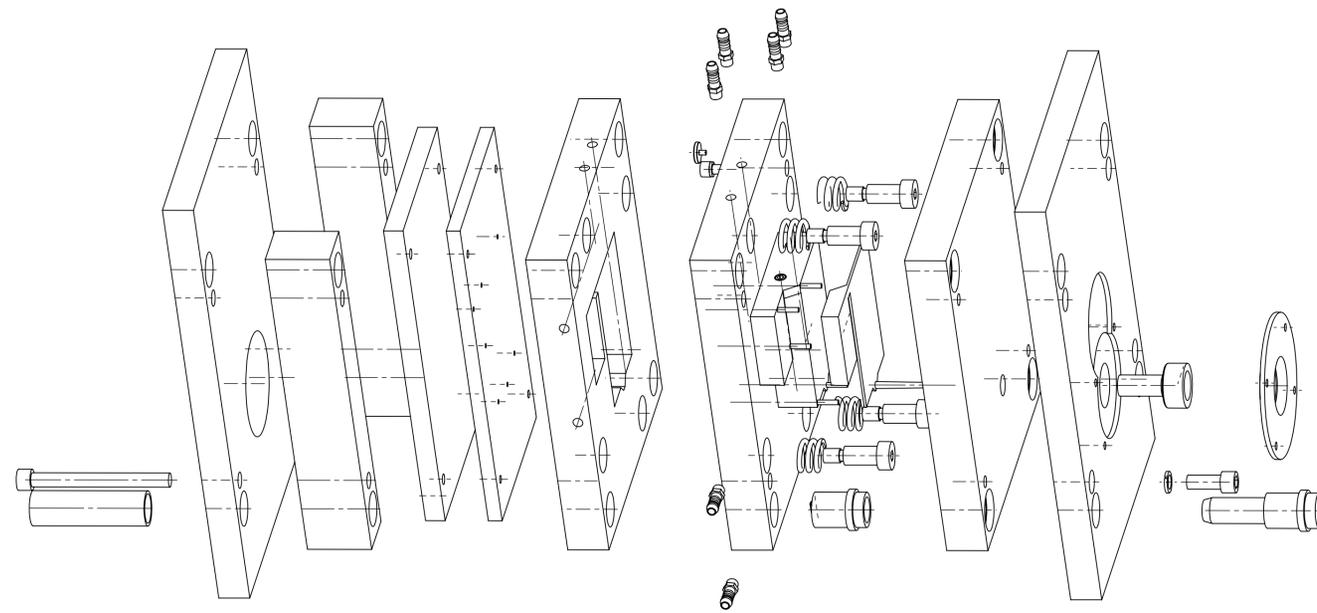
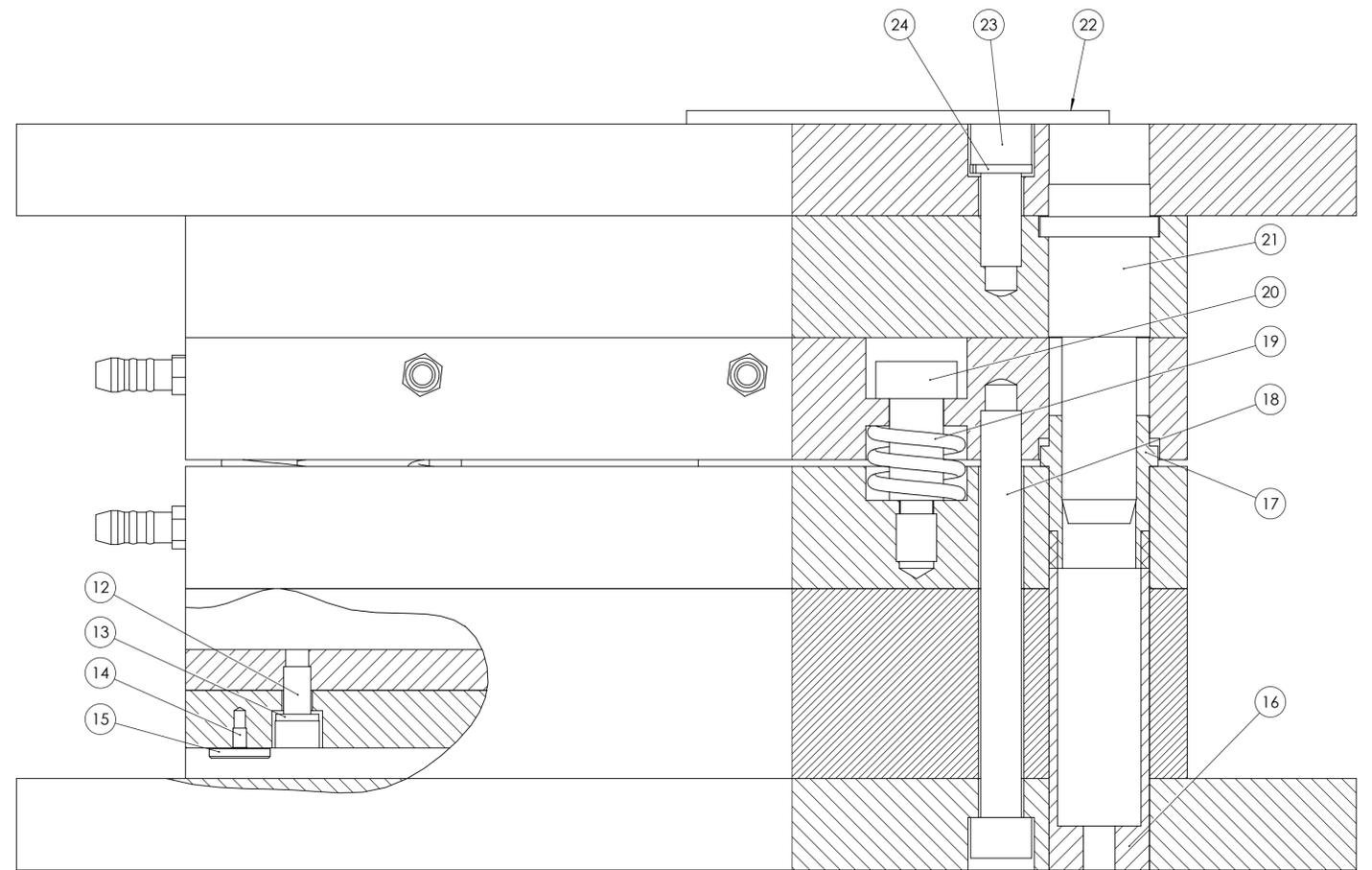
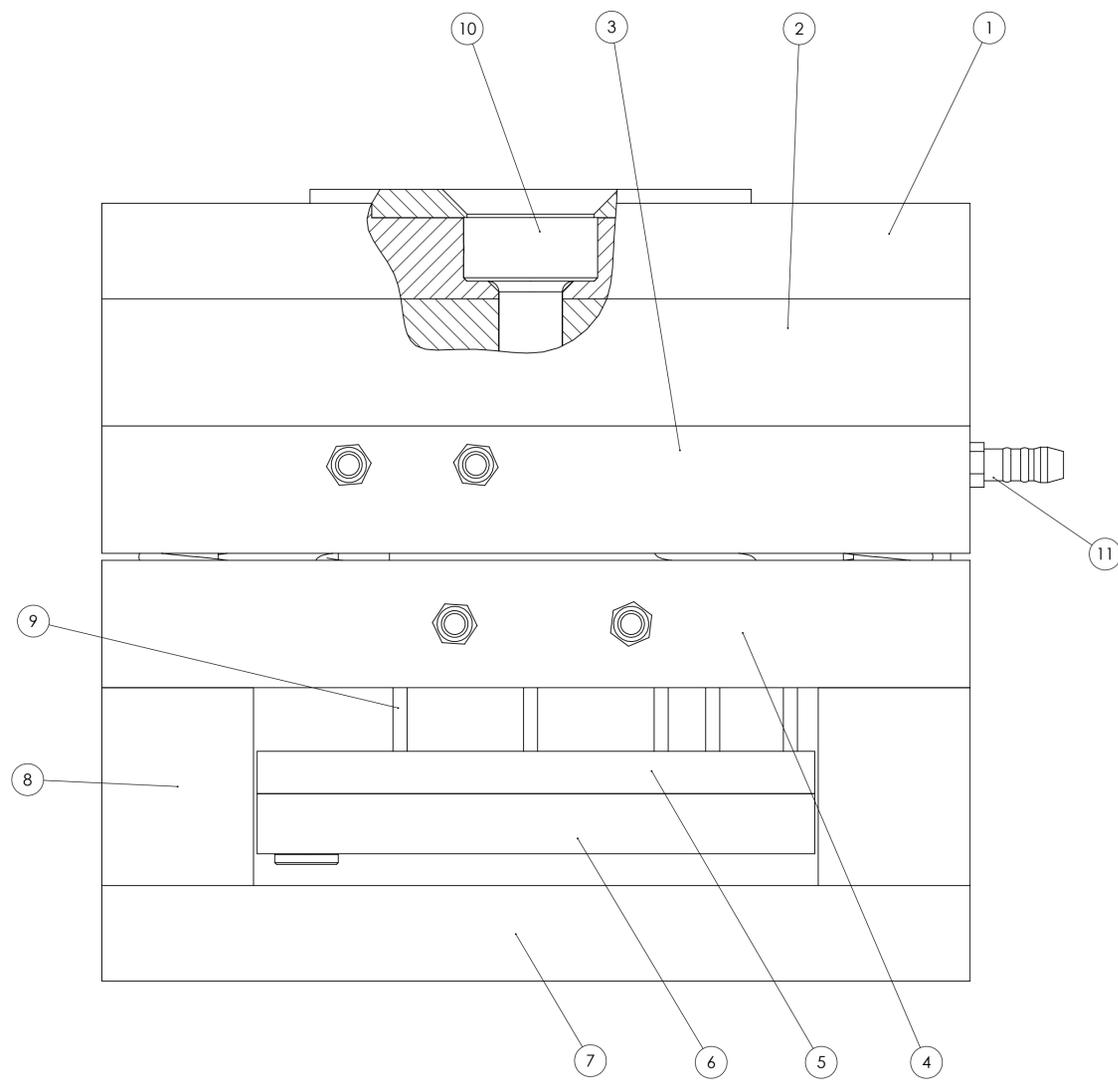
1l of gasoline = 40MJ

Transport	Km.	MJ/Km.	MJ	Equivalent in l of gasoline	Kg CO2
Walking	15	0,16	2.4	0,48	0,4224
Train	3200	0,35	1120	28	24.64

TOTAL ESTIMATED	MJ	Kg CO2	Hectares
	1122.4	25.06	0.0055

Final values

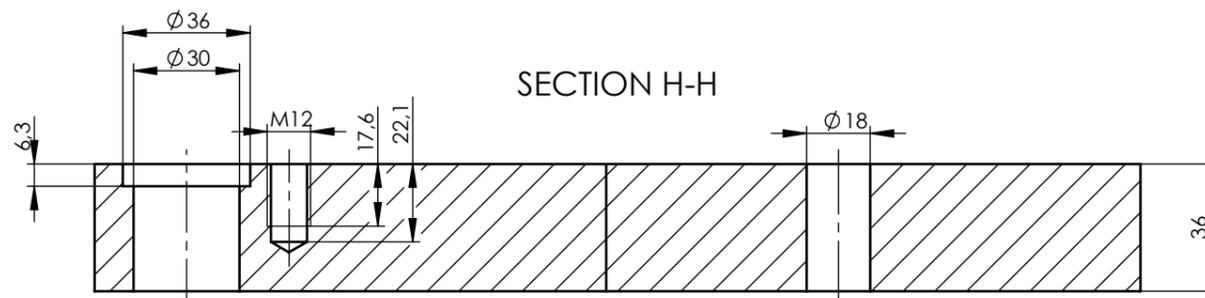
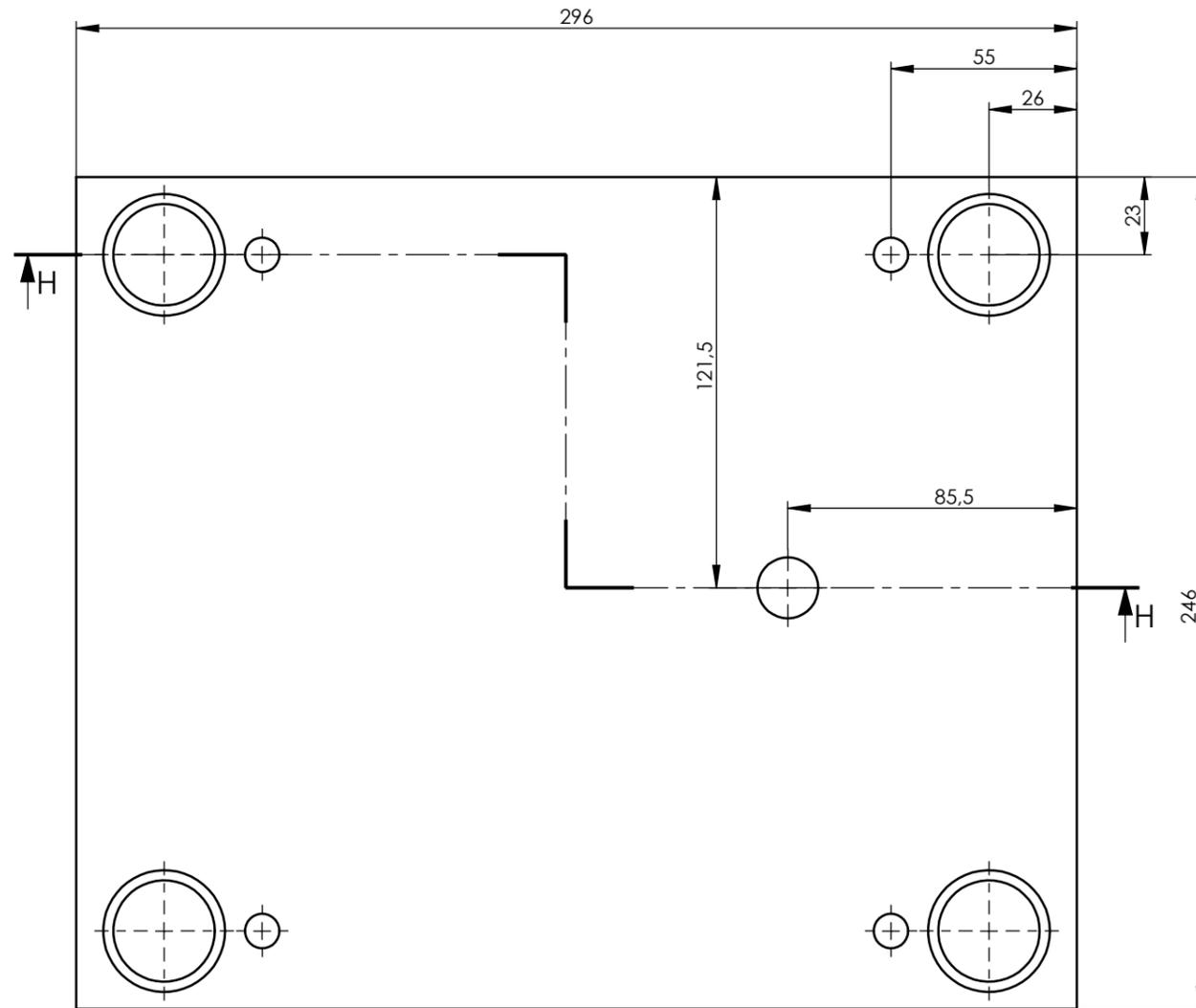
Environmental Aspect	kg CO2/Project	Hectares
<i>Electrical consume</i>	118.8	0.026
<i>Mobility</i>	25.06	0.0055
TOTAL ESTIMATED	143.86	0.0315



Mark	Name	Code/Size	Price/u(€)	Qty.	Material	Therm. T.
1	Plate1	K12-246x296x27	173,03	1	1.1730	Q & T
2	Plate2	K20-246x296x36	114,23	1	1.1730	Q & T
3	Plate3	K20-246x296x36	114,23	1	1.1730	Q & T
4	Plate4	246x296x36	250	1	1.1730	Q & T
5	Plate5	K70-246x296x17	80,47	1	1.1730	Q & T
6	Plate6	K12-246x296x17	173,03	2	1.1730	Q & T
7	Plate7	K12-246x296x27	173,03	1	1.1730	Q & T
9	Ejector	Z40 - 4x100	2.83	7	1.2516	Nitriding
10	Nozzle	Z51 - 18x27	36.46	1	12.826	-
11	Refrigeration male nozzle	Z87	0.76	8	2.0401	-
12	Allen screw	Z31 - 8x16	0.22	4	12.9	-
13	Spring washer with retent	Z691 - 12x2	0.13	4	DIN 17221	-
14	Countersunk screw	Z33 - 4x8	0.25	4	8.8	-
15	Stop washer	Z55 - 18x3	0.62	4	1.0711	-
16	Centering bush	Z20 - 30x100	6.44	4	1.0401	Nitriding
17	Bushing guide	Z10 - 36 - 24	12.62	4	1.0401	Nitriding
18	Allen screw	Z31 - 12x120	2.11	4	12.9	-
19	Spring	Z60 - 25x30	18.50	4	2098	-
20	Threaded plug	Z94	0.30	7	2.0401	-
20	Lim iter screw	Z38 - 16x30	5.69	4	12.9	Nitriding
21	Column guide	Z00 - 36 - 24x55	17.10	4	1.0401	Nitriding
22	Centering disk	K100 - 125x8	25.25	1	1.1730	-
23	Allen screw	Z31 - 12x30	0.52	4	12.9	-
24	Spring washer with detent	Z691 - 12x5	0.13	8	DIN 17221	-
-	Transport flange	Z70	209.73	1		-

Escola d'Enginyeria de Terrassa - EET		Denominación proyecto: Expansible Injection Mould Design		A1	Buch Cardona, Eloi	
 UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH		Denominación plano: Mould assembly		Est. sup UNE 10337/Id.gal.ISO 2778 A/Id.gom.ISO 2778 m		
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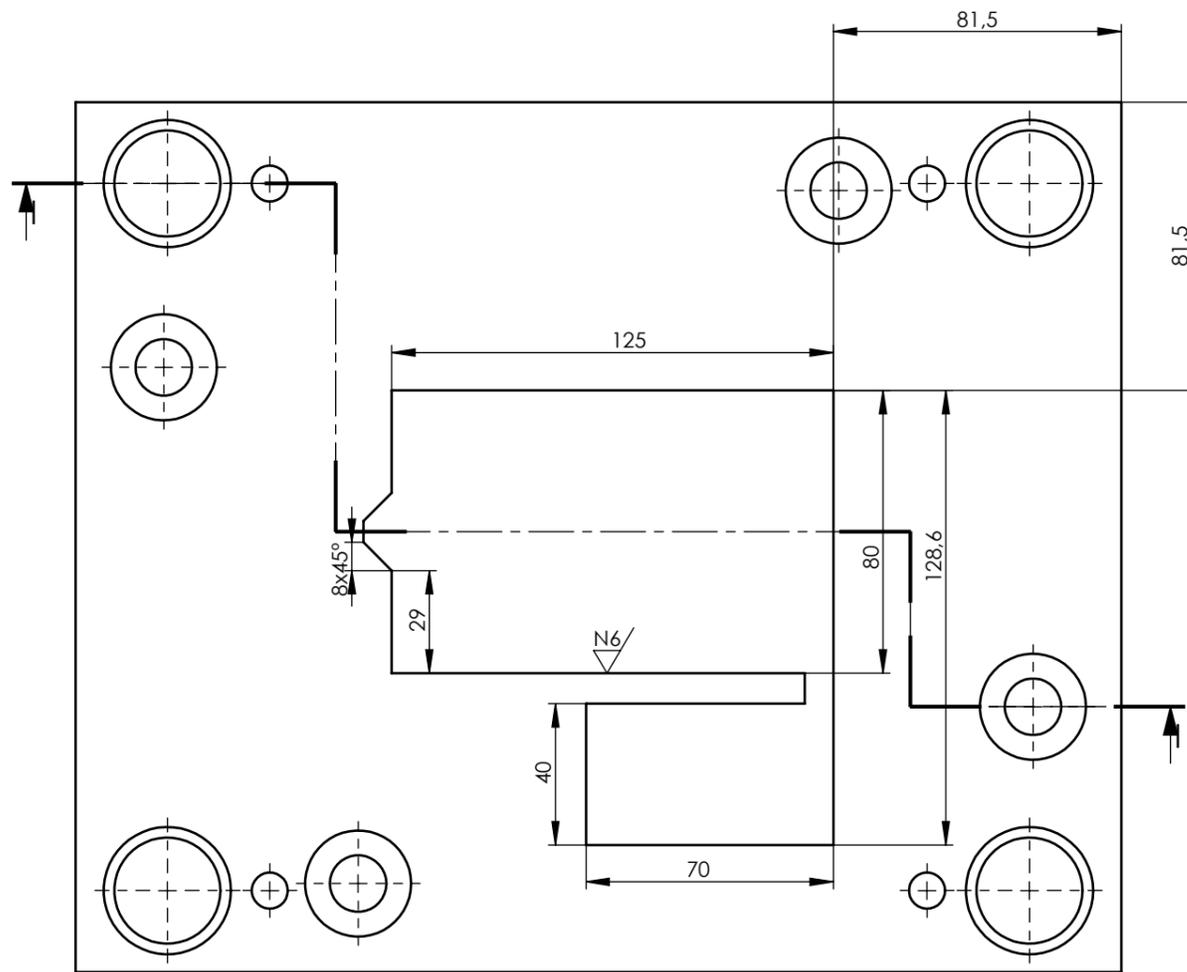


Mecanization
-Hole for the nozzle

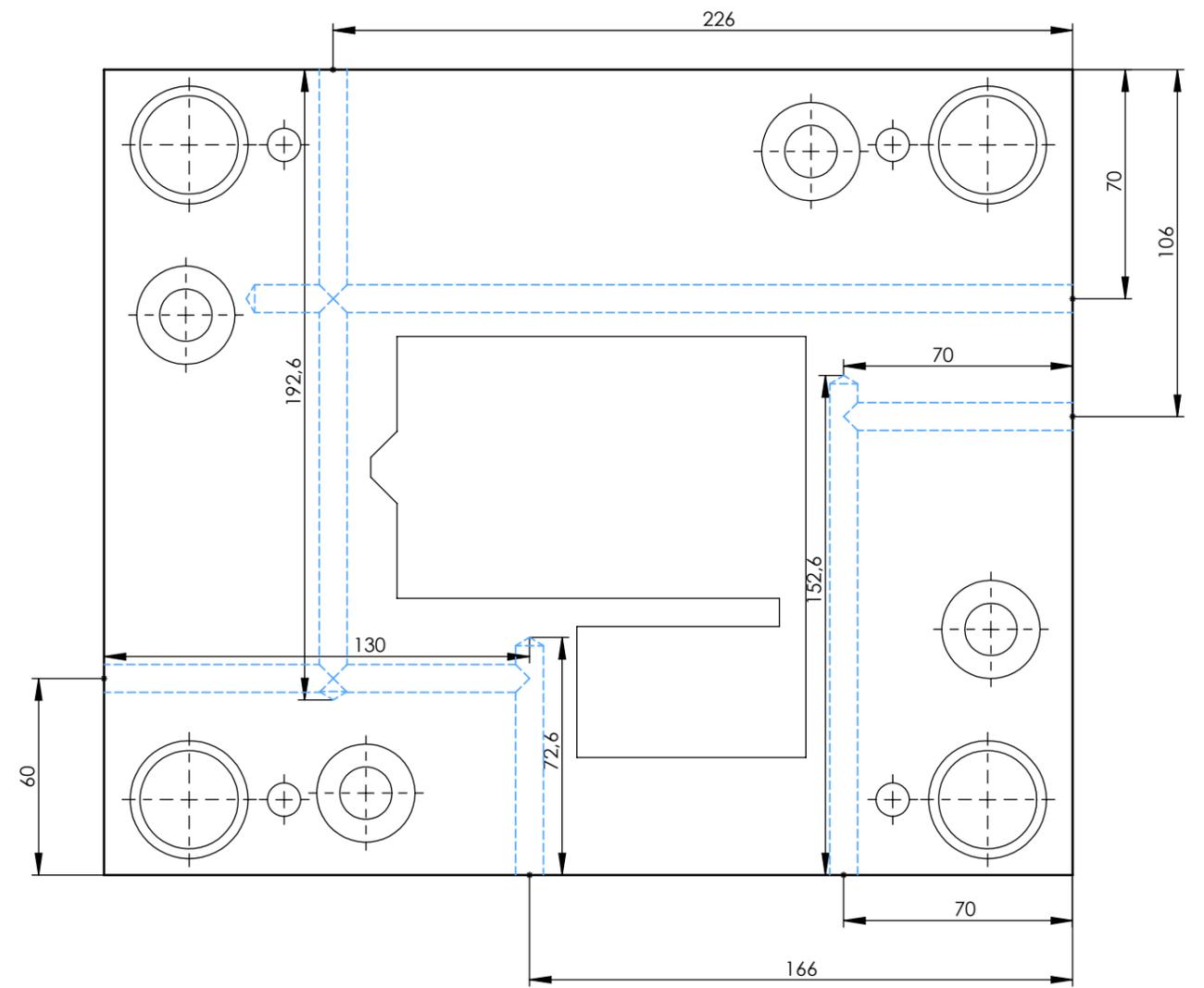
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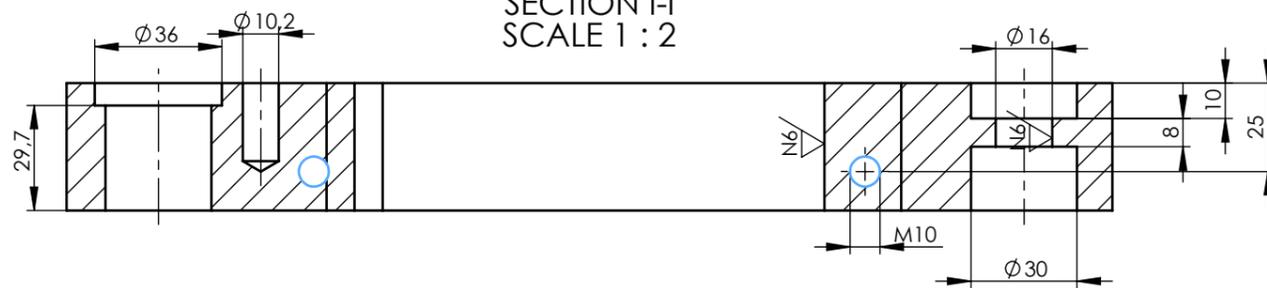
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Refrigeration view



SECTION I-I
SCALE 1 : 2

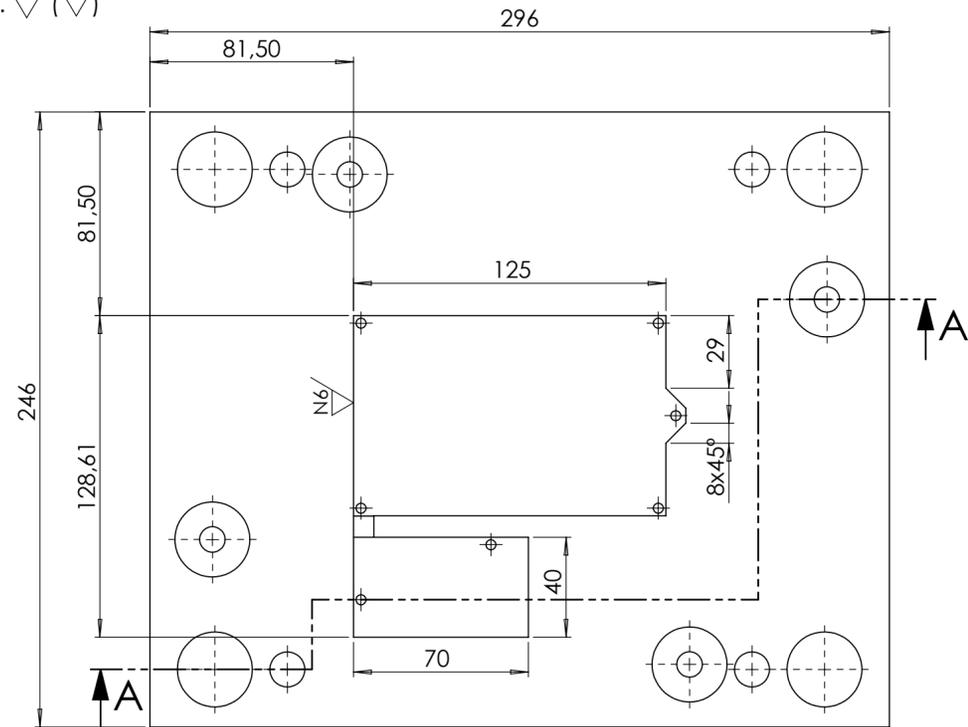


Mechanization
-Piece shape through
-Spring housing
-Refrigeration drills

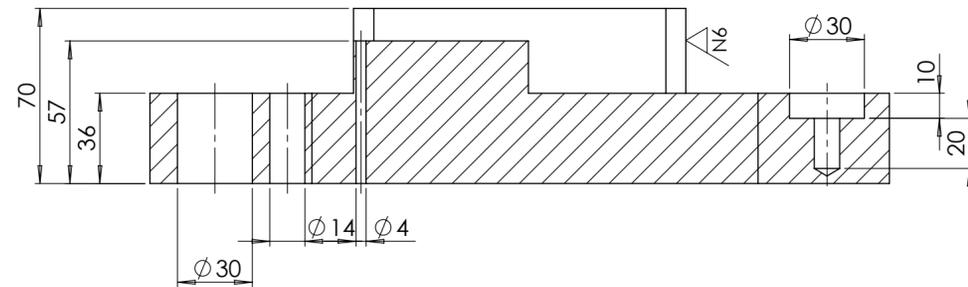
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	Denominación plano: Plate 3	Denominación proyecto: Expansible Injection Mould Design	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m		
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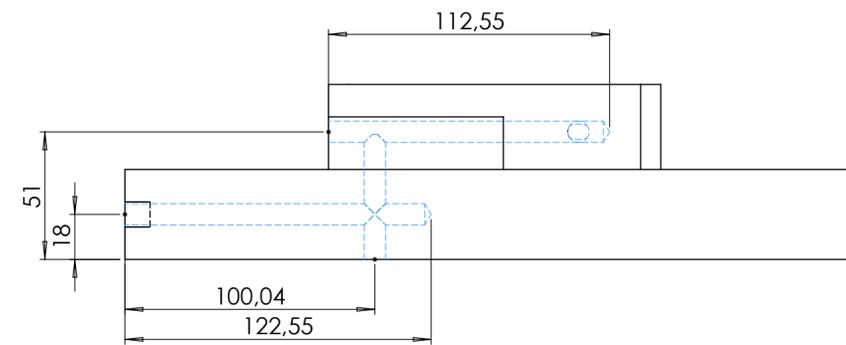
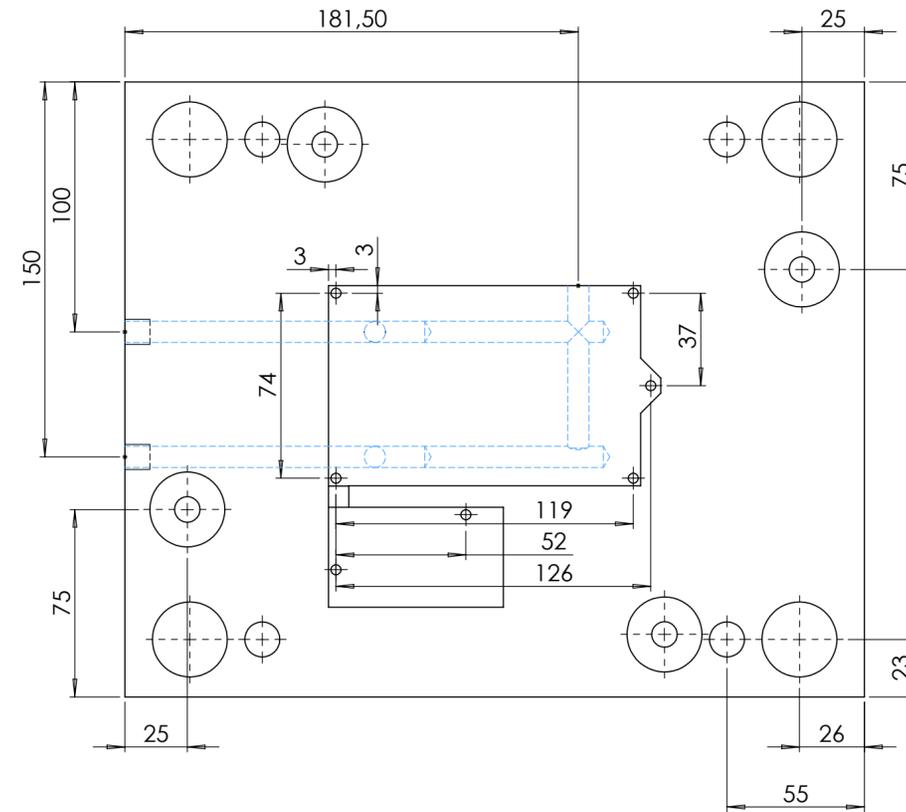
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SECTION A-A



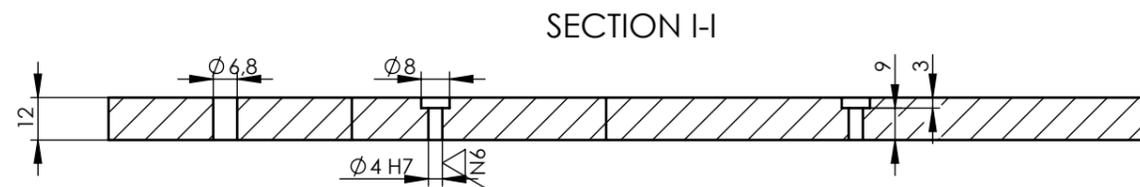
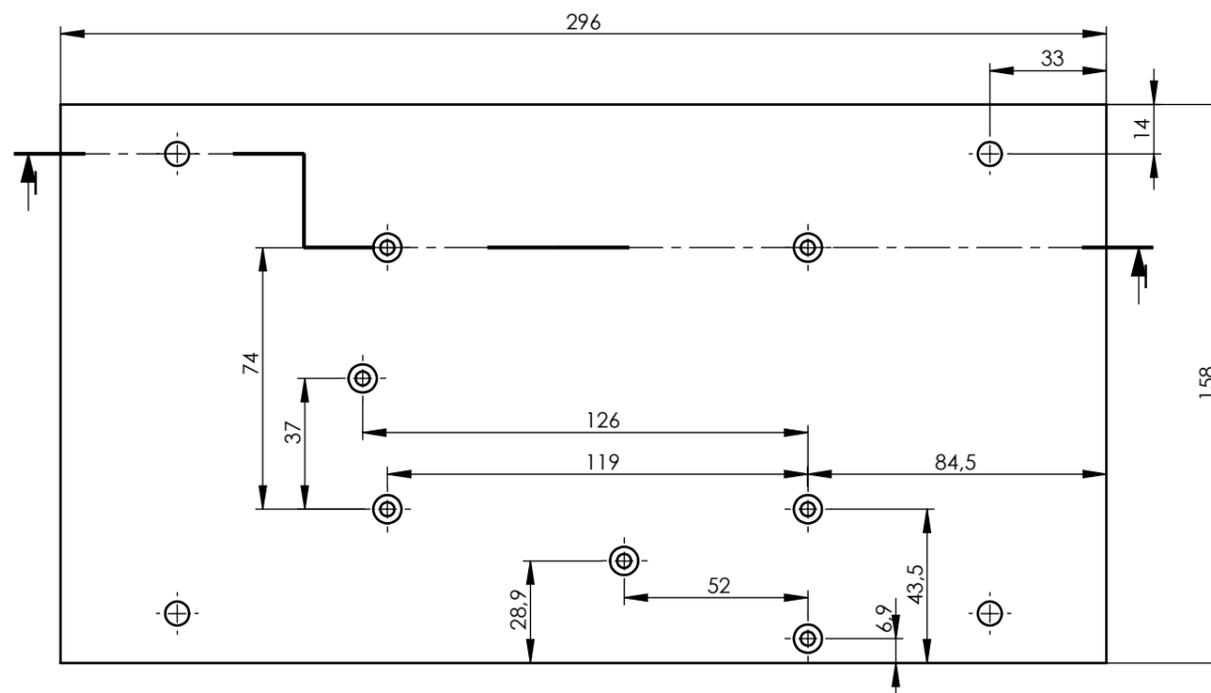
Refrigeration view



- Mechanization complete
- Mechanize inner protuberance
 - Drill guider holes
 - Drill screw threads
 - Drill ejectors path
 - Drill refrigeration
 - Drill spring housing

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	Código plano: p4	Escala: 1 : 2	Fecha: 16/05/15	Calificación:	

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Mechanization
-Ejector pins housing

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Escola d'Enginyeria de Terrassa - EET



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BARCELONATECH**

Denominación proyecto:
Expansible Injection Mould
Design

A3

Buch Cardona, Eloi

Denominación plano:
Plate 5

Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m

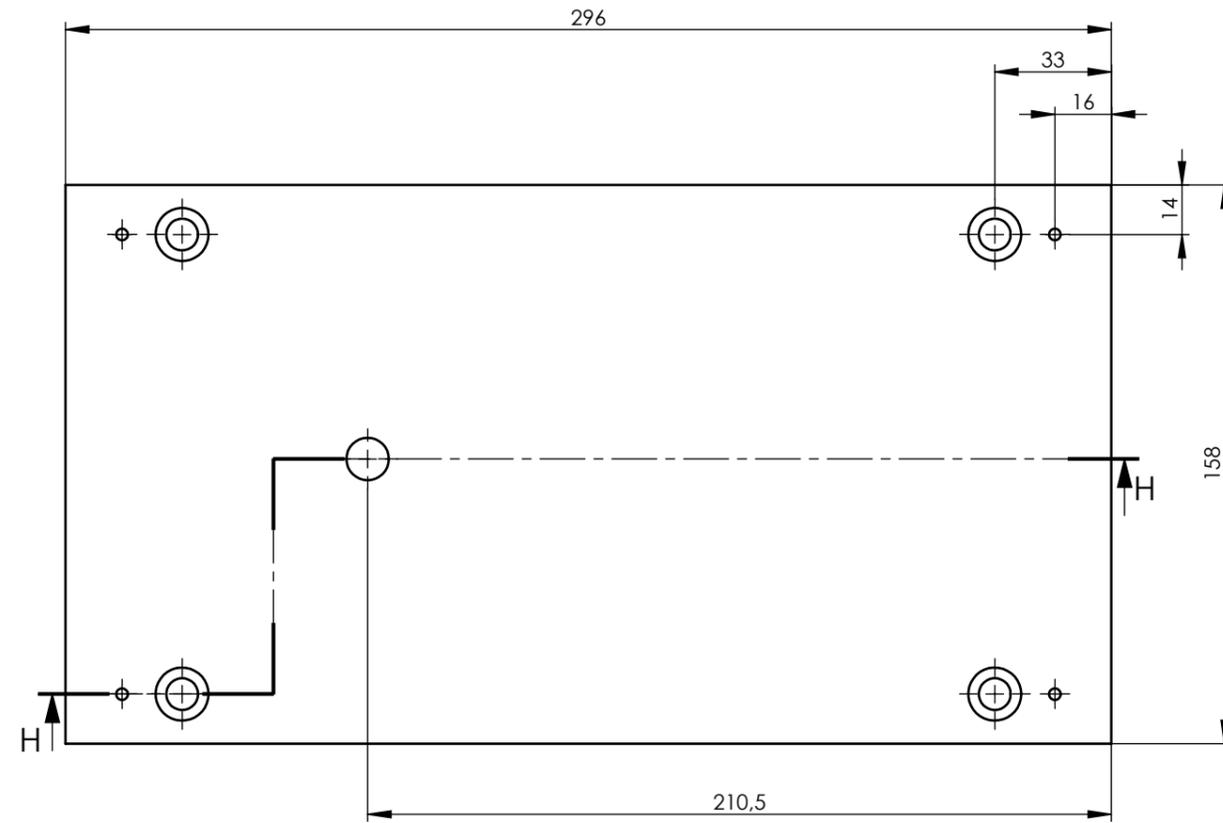
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Escala: 1 : 2

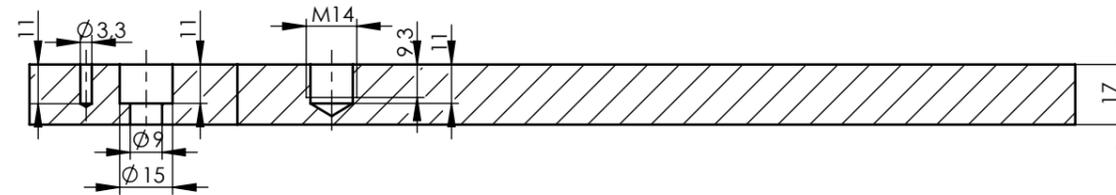
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Calificación:

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SECTION H-H

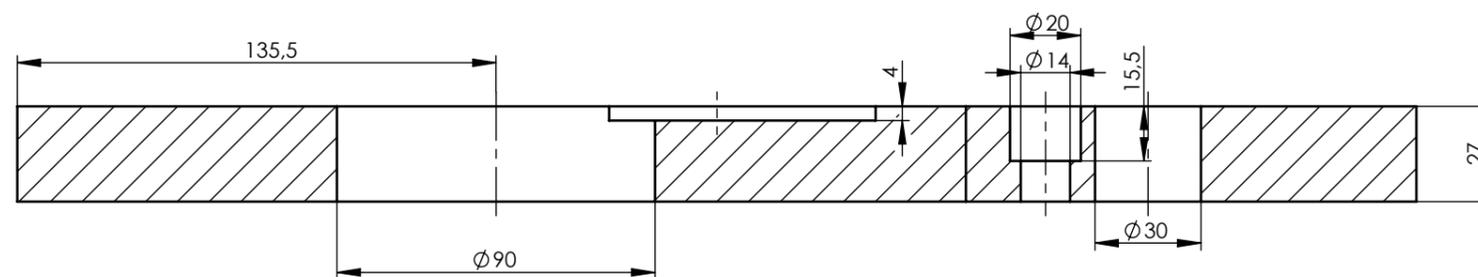
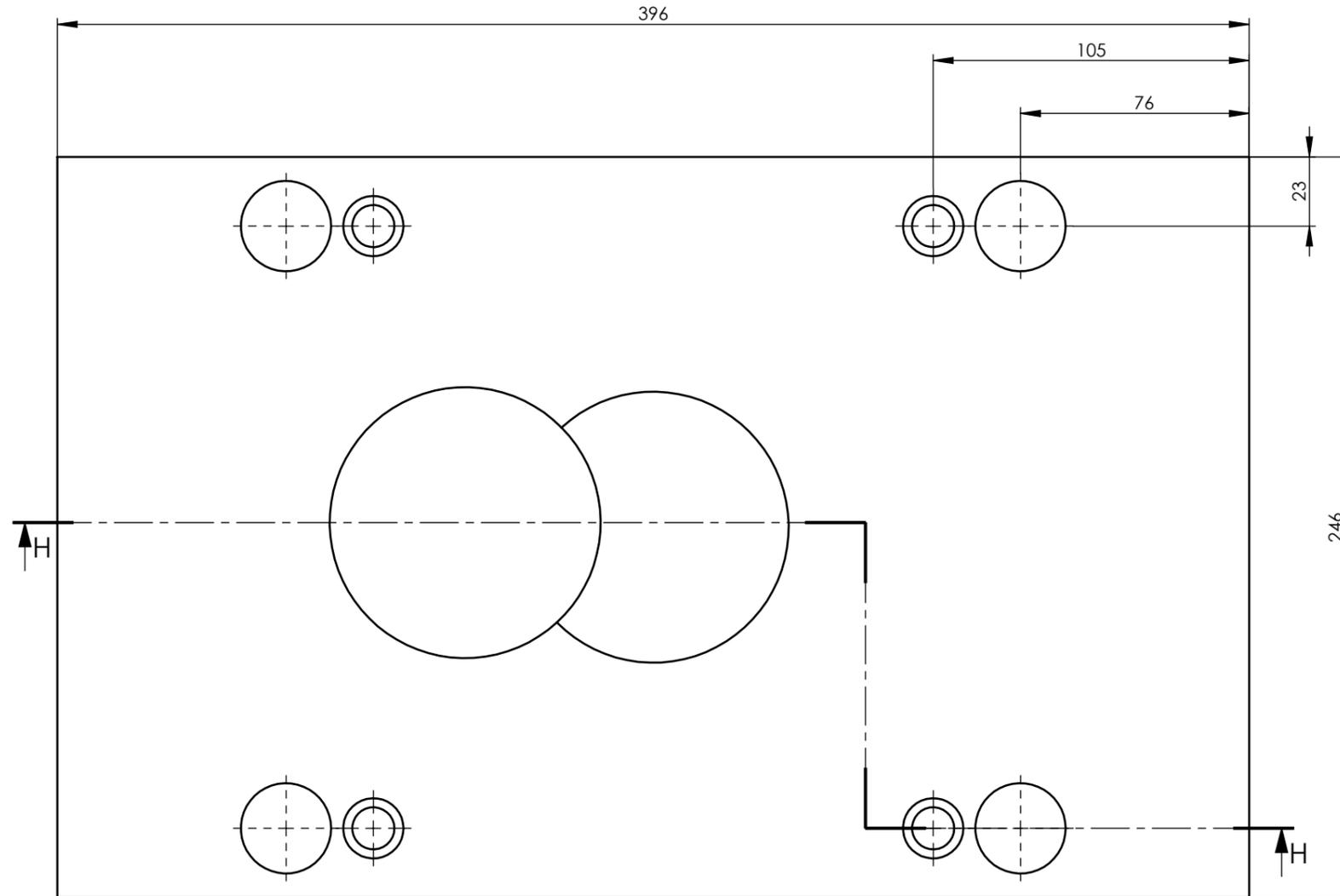


Mechanization
-Expulsion rod thread

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	Denominación plano: Plate 6		<small>Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m</small>		Escala: 1 : 2
Código plano: p6		Fecha: 16/05/15		Calificación:	

7. $\nabla \frac{N8}{}$



SECTION H-H

Mechanization
 -Space for the installation
 and acting of the ejection rod

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 UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH	 Escola d'Enginyeria de Terrassa - E E T	Denominación proyecto: Expansible Injection Mould Design	A3	Buch Cardona, Eloi	
	Denominación plano: Plate 7		Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m		
Código plano: p7		Escala: 1 : 2	Fecha: 16/05/15	Calificación:	



Escola d'Enginyeria de Terrassa

UNIVERSITAT POLITÈCNICA DE CATALUNYA

Expansible Injection Mould Design

Part 2 Budget

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Index

<i>Standardized pieces</i>	3
<i>Extra pieces</i>	4
<i>Mechanization</i>	5
<i>Thermal treatments</i>	6
<i>Other costs</i>	7
<i>Final budget</i>	8

Standardized pieces

Usually in moulds some standardized pieces are used such as guides, screws, retainers and so, but other items like plates are often fully personalized to have a bigger freedom to design their own mould. That also increases the price so in this case if possible it has been taken the maximum standardized pieces by the fact that the mould is not being designed to produce many pieces and the lower quality provided by the standard elements are enough for what is wanted.

<i>Name</i>	<i>Code/Size</i>	<i>Price/u(€)</i>	<i>Qty.</i>	<i>Price(€)</i>
Centering disk	K100 - 125x8	25,25	1	25
Allen screw	Z31 - 12x120	2,11	4	8
Spring washer with detent	Z691 - 12x5	0,13	8	1
Allen screw	Z31 - 12x30	0,52	4	2
Stop washer	Z55 - 18x3	0,62	4	2
Spring washer with retent	Z691 - 12x2	0,13	4	1
Countersunk screw	Z33 - 4x8	0,25	4	1
Allen screw	Z31 - 8x16	0,22	4	1
Centering bush	Z20 - 30x100	6,44	4	26
Bushing guide	Z10 - 36 - 24	12,62	4	50
Column guide	Z00 - 36 - 24x55	17,1	4	68
Refrigeration male nozzle	Z87	0,76	8	6
Threaded plug	Z94	0,3	7	2
Ejector	Z40 - 4x100	2,83	7	20
Spring	Z60 - 25x30	18,5	4	74
Transport flange	Z70	209,73	1	210
Limiter screw	Z38 - 16x30	5,69	4	23
Nozzle	Z51 - 18x27	36,46	1	36
Plate1	K12-246x296x27	173,03	1	173
Plate2	K20-246x296x36	114,23	1	114
Plate3	K20-246x296x36	114,23	1	114
Plate5	K70-246x296x17	80,47	1	80
Plate6	K12-246x296x17	173,03	2	346
Plate7	K12-246x296x27	173,03	1	173
TOTAL				1.558€

Extra pieces

In this mould the only customized piece is the Plate4 which have a huge protuberance in the middle and any standard item have enough dimensions to take it and then mechanizing it. The piece would also had been possible to produce with a standardized plate with a thin housing for a steel block that would be bounded by screws in the bottom of the plate.

<u>Name</u>	<u>Code/Size</u>	<u>Price/u(€)</u>	<u>Qty.</u>	<u>Price(€)</u>
Plate4 block	246x296x70	250	1	250

A regular 1.1730 steel is used taking the other plates as similars. The price includes the exterior sizing.

In this case the decision of taking standardized elements really reduces the final price although some design changes have to be done in terms of piece position, refrigeration and spring position for example.

Mechanization

Although most pieces are directly taken from catalogs with standardized models, only with them is not enough. Pieces such as guides and screws don't need changes but plates do. Standardized plates have only the guidance and thread holes and lets the design up to you. For that, mould plates need to be mechanized.

The mechanization processes needed are:

- Milling. The main way to achieve the shapes wanted in the piece. Cutting off in different roughnesses helps achieving both low time and good finishing for the piece

- Drilling. Way to obtain the round shapes through the pieces

- Grinding. It is important for a mould to fit perfectly to produce regular and good quality pieces as well as for its health.

The non standardized piece (Plate 4) which have to be mechanized completely, first roughing until there is little thickness left to take out, then a finishing rough and finally grinding it.

The approximate number of hours working in Plate 4 are **100h**.

The approximate number of hours working in the standardized elements including plates are **200h**.

Workshop cost per hour is **40€**

The amount in hours is approximate and depend on the final finishing wanted in pieces as well as tolerances. Pieces entering or being entered need special care and that requires several tool changes that increase the final hour amount.

TOTAL COST OF MECHANIZATION: 12000€

Thermal treatments

For the thermal treatment there are basically two types to be taken in account:

-Quench and temperate. It consists in hardening the piece and then releasing the tension the first treatment provoked. The result is a harder steel than the one in the beginning with good ductile properties. Is done basically in the structural pieces to make them last without degrading excessively by its use. The final hardness is measured by Rc (Rockwell hardness). Higher values are needed in pieces that slide to minimize friction degradation such as Plate 3 and 4, but being careful not to harden it too much to prevent brittle behaviors of the pieces.

-Nitriding. It consists in a superficial treatment that deposits nitrides in the very first layers of material in the surface preventing them from the harm of friction. That is why is done at the parts that move guided such as ejection pins or column guiders.

Depending on where normalized pieces bought those thermal treatments may be already done but depending on the situation a different treatment would be needed anyway due to mould singularities.

Nitriding the mobile parts have an approximate cost of 200€.

Quenching and tempering all the plates have an approximate cost of 400€

TOTAL COST OF THERMAL TREATMENTS: 600€

Other costs

In extra costs there are design and mounting.

In design, combining the model design, 3D CAD development, CAD-CAM evaluation and work related to the production previous work, the amount of hours dedicated are 35h.

With the technical office base pay of 30€ per hour it makes a total of 1050€

Transporting and mounting the mould is set at 6h at a price of 30€ makes a total of 180€

TOTAL COST OF DESIGN AND MOUNT: 1230€

Final Budget

Extra pieces	250€
Standardized pieces	1.558€
Thermal treatments	600€
Mechanized and finishing	12.000€
Other costs	1.230€
+21% IVA	3.284€
<u>Total Mould Cost</u>	18.922€

The final cost is totally approximated and may change significantly depending on the mechanizing hours which have a huge weight in the final price. Depending on the quality of the standardize items the hours can be reduced also.