FINAL THESIS PROJECT

Degree in Mechanical Engineering

DESIGN OF A PUMP HEAD WITH AUTOMATIC GAS PURGE VALVE

Report and Annexes

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RESUM

El funcionament de les bombes dosificadores es pot veure indesitjablement interromput quan aquestes operen amb gasos que apareixen inoportunament al capçal d'aquestes bombes, invalidant completament la funció de dosificació d'aquests dispositius i suposant una major necessitat d'atenció per part de l'usuari.

En aquest projecte es mostren els resultats del disseny d'un capçal que permet l'evacuació de gasos mitjançant una vàlvula de purga automàtica.

El resultat obtingut es un capçal degasificador automàtic, efectiu, d'alt rendiment, econòmic i aplicable al món industrial. El projecte acaba amb un prototip en l'última fase de prova per una posterior homologació i comercialització.

Amb aquest projecte, es contribueix directament a l'empresa del sector de les bombes dosificadores ITC Dosing Pumps amb una solució que permet autonomia i un òptim funcionament de les bombes DOSMART ITC 13l/h D50 i D69.

Per últim, el projecte té en compte l'impacte ambiental del producte final, evaluant el seus efectes i adicionalment presentant i introduint el disseny d'una alternativa més sostenible a la solució plantejada amb l'oportunitat de poder ser desenvolupada per l'empresa en un futur.

RESUMEN

El funcionamiento de las bombas dosificadoras puede verse indeseablemente interrumpido cuando estas se ven operando con gases que aparecen inoportunamente en el cabezal de estas bombas, invalidando por completo la función de dosificación de estos dispositivos y suponiendo una mayor necesidad de atención por parte del usuario.

En este proyecto se muestran los resultados del diseño de un cabezal que permite la evacuación de gas mediante una válvula de purga automática.

El resultado obtenido es un cabezal degasificador automático, efectivo, de alto rendimiento, económico y aplicable al mundo industrial. El proyecto termina con un prototipo en la última fase de prueba para una posterior homologación y comercialización.

Con este proyecto, se contribuye directamente a la empresa del sector de las bombas dosificadoras ITC Dosing Pumps con una solución que permite autonomía y un óptimo funcionamiento de las bombas DOSMART 13l/h ITC D50 y D69.

Por último, el proyecto tiene en cuenta el impacto ambiental del producto final, presentando y introduciendo el diseño de una alternativa más sostenible a la solución planteada con la oportunidad de poder ser desarrollada por la empresa en un futuro.

ABSTRACT

The operation of dosing pumps can be undesirably interrupted when they are operating with gases that appear inopportunely in the head of these pumps, completely invalidating the dosing function of these devices and causing inconvenience and the need for attention by users.

This project shows the results of the design of a pump head that allows the evacuation of gas through an automatic purge valve.

The result obtained is an automatic, effective, high-performance, economical degassing head applicable to the industrial world. The project ends with a prototype in the last phase of testing for subsequent standardization and merchandising.

With this project, the company in the dosing pump sector ITC Dosing Pumps is directly contributed with a solution that allows autonomy and optimal operation of the DOSMART 13l/h D50 and D69 ITC pump.

Finally, the project takes into account the environmental impact of the final product, presenting and introducing the design of a more sustainable alternative to the proposed solution with the opportunity to be developed by the company in the future.

ACKNOWLEDGEMENTS

I would like to thank all the members of the ITC company for making this final degree project successful. Especially to Xavier Corbella for giving me the opportunity to start this project, to Oriol Montasell for his experience and knowledge, to Yeray Álvarez for his support, professionalism and camaraderie. I will remember my colleagues at ITC as people of great professionalism and great human quality.

On the other hand, thanks to Joan Grau and Ricardo Torres for their valuable advice during the realization of this project and for giving me the opportunity to go to them whenever I needed it.

Last but not least, I would like to thank those closest to me.

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1. Preface

1.1. Previous requirements

To fully understand this project requires some insight about physics, mostly thermodynamics, when tackling the theoretical part. However, a person without any physics education can glance over this thesis and get the main ideas about how it is developed and follow the different reasonings made and intuitively understand the functionality of the presented solution.

2. Introduction

2.1. Background

This final thesis projects aims to design a degassing valve in cooperation with ITC Dosing Pumps company for its DOSMART 13l/h D50 and D69 metering pump which shall allow the automatic purge of gases that stuck inside the pump head.

Many users of dosing pumps use these type of pumps to dosify chemically inestable products, such as hydrogen peroxide, which react easily outting gas. When gas inclusion in the dosing head, the dosing process can be disrupted which hinders the optimal operation of these pumps. Sometimes gases can merely enter via inlet, be produced due to cavitation or be found inside the pump chamber due to a long interruption of its operation.

By accomplishing the design of a degassing valve, dosing ITC pumps shall be able to perform in an optimal way when working with gas inclusions, improve the company competitiveness in the market and reach the technology that only few large companies in the market have.

2.2. Problem statement

A metering pump without an automatic purge valve does not work properly when gases are trapped inside the head chamber due to the compressibility of air bubbles.

In practice, dosing pumps are designed to work with incompressible fluids which guarantees pumps to reach the out pressure and hence to dosify. The presence of gas creates a compressible volume inside the pump head which may avoid the pump from reaching the out pressure (if the gas volume is too high) and cause the interruption of the dosing process.

It is important then to design a system which allows the purge of entrapped gases inside the pump head. Moreover, it is necessary that this system works in an automatical way to make it independent.

The objective of this thesis then is to propose a valid tested design of a pump head with an automatic gas purge valve that solves the following problem statement:

- Entrapped gases provoque an interruption of the dosing pump process.

2.3. Objectives

The final degassing valve prototype must meet the following objectives to be considered valid:

1. The degassing valve is able to turn the pump from a non-functional regime of operation due to entrapped gases to a functional regime.
2. The degassing valve shall not decrease the pump volumetric efficiency more than 20%.
3. The degassing valve can be implemented in a real situation.
4. The degassing valve is economic.

The three first points include the engineering angle of this project whilst the last one takes into consideration the economic angle of this project and the need of creating a competitive product.

All these points shall be evaluated on a Dosmart 13l/h D50 and D69, which is an ITC Dosing pump.

2.4. Scope

The following points are to be considered regarding the limitations of this project:

- The experiments are carried out using water instead of hydrogen peroxid or other inestable products due to its easy acces and manipulation. To emulate the gas presence produced by the reaction of these products, air has been let through the aspiration port manually. Fluids in the pump head are then a combination of air and water when referring to gas and liquid respectively.
- All experiments are carried out using a Dosmart 13l/h, which is a diaphragm pump that provides a maximum flow of 13l/h at a maximum pressure of 7 bar. The results can be extrapolated to similar pumps, that is, other ITC Pumps that provide similar flow.
- All parts of the valve, except the body piece, are printed in a 3D machine printer which allows to design easily and rapidly the different components without affecting the operation of the system.
- The experiments are carried out without considering exposure to high temperatures.

None of the above points are expected to have a big impact on the commercial prototype which will be designed with better manufacturing processes and quality materials.

3. Method

In this chapter the planification followed for the development of this thesis is shown. The project is splitted into three differentiated stages. Each stage represents a planned stage in the development of this project and have different blocks which represent activities that make up every stage (**Figure 1**).

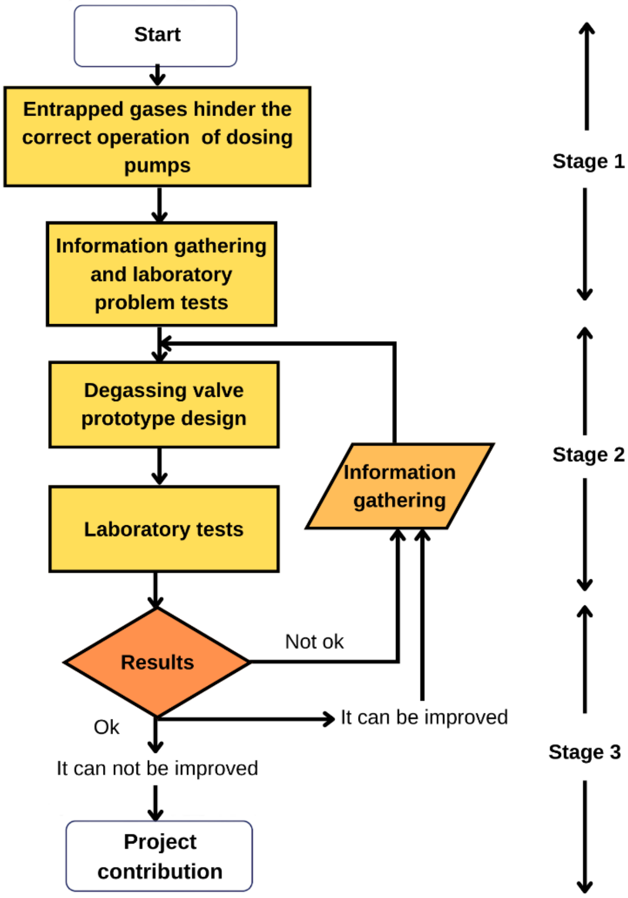


***Figure 1**: A general planification of the project*

3.1. Stage 1: The study and definition of the problem

This stage is made up of two blocks:

1. The first block refers to detecting the problem and the need to carry out this project.
2. The second block encompasses the gathering information process about the problem, first laboratory tests and calculations.

3.2. Stage 2: Design of a degassing valve

The next planned stage is to design a solution according to the information gathered in stage 1. Stage 2 is made up of three blocks:

The first block of the second stage is called “Degassing valve prototype design” which includes theoretical calculations, 3D design and the 3D printed process of the model.

The second block of stage 2 is named “Laboratory tests” and covers the testing process of the prototype.

The third block of stage 2 is named “Information gathering”. In this block information is gathered about how It is possible to improve the current design. This block comes from stage three after considering the prototype as non-valid or improvable.

3.3. Stage 3: Solution consideration

This third stage covers the verification process of the obtained results from stage two with the objectives set in the objectives chapter. If the results do not meet the objectives, I return to stage 2 to design a new prototype. If the results meet the objective, It is considered to improve them and decide accordingly as shown in **Figure 1**.

4. Research and Associated Literature

The degassing valve is used currently by two large companies in the market, these are ProMinent and WALCHEM IWAKI American Inc. The goal of this project is to design a degassing head according to ITC needs, however, the project started by learning from the solutions given by this two companies and served to start with the design process of this project.

In section 4.1 the purge valves of these two companies is analysed.

4.1. Related works

4.1.1. ProMinent Degassing Head

Prominent is the larger dosing pump company in the world. Its roots started in Heidelberg, Germany 60 years ago and currently more than 2700 employees work in this company.

Prominent built a degassing valve (**Figure 2**.**A**) situated at the top part of the pump head, this way they found an easy way to conduct the air (taking advantage of its low density) to the degassing valve which is always at atmospheric pressure. Dosing pumps usually work with the discharge valve at the top part of the pump head and use gravity to allow the return of the valve balls, in this case ProMinent opted to move the discharge valve to an horizontal position forcing to add a spring to allow the return of the discharge valve ball. Prominent degassing valve uses two balls, the combination of them allow the appropriate performance of the valve.

From **Figure 2.B** some conclusions can be drawn about the operation system of the valve. To start with, and focusing only on the auto-degassing valve, the lower ball has less displacement compared to the upper ball which is made to have a better control of the fluid losses. On the other hand, when suctioning, the balls are positioned on the shut element, which is made to avoid fluid from entering the pump head. When discharging, both balls move to position shown in **Figure 2**.**C.** At this position, the upper ball remains open because of the presence of a conus shaped conduct with lateral edges that avoid the closure of the ball. The lower ball instead, it is expected to shut at its top position, however, ProMinent does not represent the way of shutting of its lower ball degassing valve.

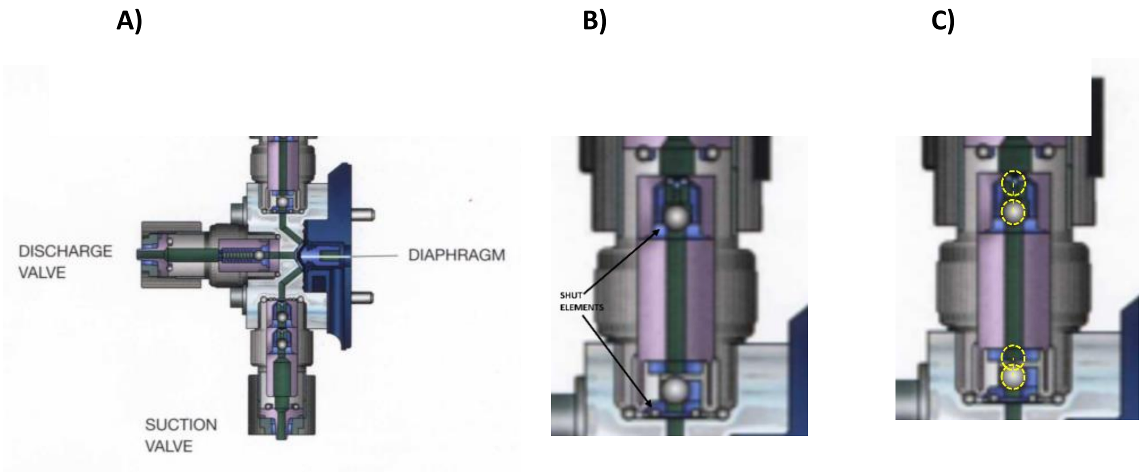


Figure 2: *A) A secton view of a Prominent degassing head; B) Prominent degassing valve when suctioning; C) Prominent degassing valve when discharging*

4.1.2. WALCHEM IWAKI Inc Auto Degassing Valve

Walchem IWAKI American Inc. is a leading manufacturer of electronic metering pumps based in Holliston Massachusett that designs, manufactures and distributes worldwide its Walchem pumps. This company designed a degassing valve which is parallel connected to the discharge port and kept the manual vent valve. The purge valve is inclined which is made because vertical conducts hinder the evacuation of air when two exits are connected in parallel. **Figure 3** shows that Walchem also uses two balls and their position when suctioning. As can be seen, the lower ball shuts on the shut element whereas the upper one can not be interpreted. When discharging the position of both balls is undefined as the rest of components are hidden to avoid other companies to interpret their way of operating.

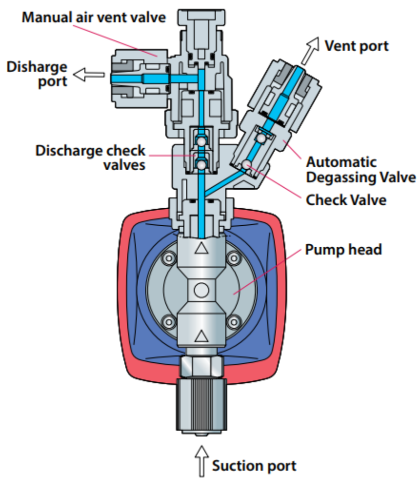


Figure 3*: A secton view of an IWAKI degassing head*

4.2. About dosing pumps

4.2.1. What are dosing pumps?

In order to design a degassing valve properly, it is important to know how dosing pumps operate to design accordingly. The degassing valve design shall be directly related to the pump operation given that a degassing valve is just a component that must improve the pump functionality.

Dosing pumps are classified as positive displacement pumps, that is, a mechanical device which injects a known quantity of liquid into a flow in every cycle. The flow rate provided by a positive displacement pump is directly proportional to its speed and number of cycles over a given period, these features make dosing pumps useful to a wide field of applications such as agriculture, medicine, water treatment, pharmaceutical and food industry.

Positive displacement pumps can be divided into three categories: Rotary, reciprocating and linear pumps. Each category has different type of pumps (**Figure 4**). This thesis only covers piston pumps and diaphragm pumps.

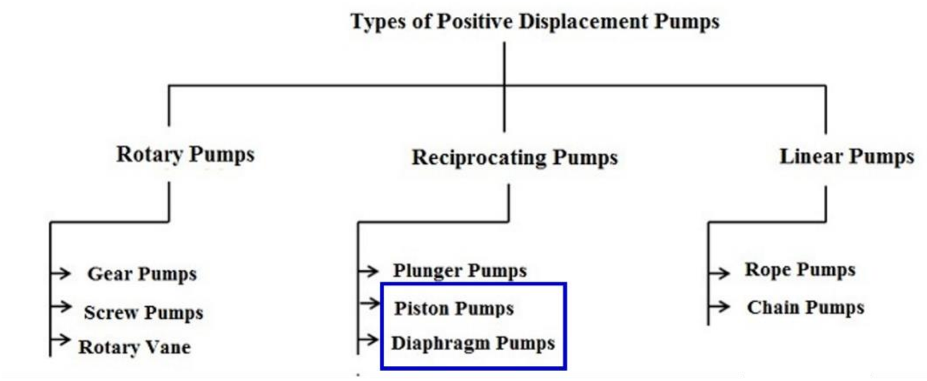


Figure 4: *Classification of Positive Displacement Pumps*

4.2.2. Examples of dosing pump applications

Positive displacement pumps are widely used in industry, refineries, agriculture, power plants, medical laboratories, water treatment, chemical, petrochemical plants and in most of manufacturing processes due to its accuracy to supply specific quantities of flow.

The most common applications where metering pumps are used include:

- Desinfection: The pump dosifies a precise quantity of chemicals such as sodium hypochlorite to a tank or a specific spot.

- pH adjustment: Specific acids, such as sulfuric acids and caustics are dosed to neutralize the pH in plants which increases the effective operation of these. The adjustment of pH also allows to avoid Legionella which can be resistant to standard desinfections treatments.

- Corrosion inhibitors: Boilers, cooling towers, steam turbines and other components of a plant need amines and other substances to prevent scaling and fouling, these are dosed using dosing pumps which helps to maintain the plant in optimal conditions.

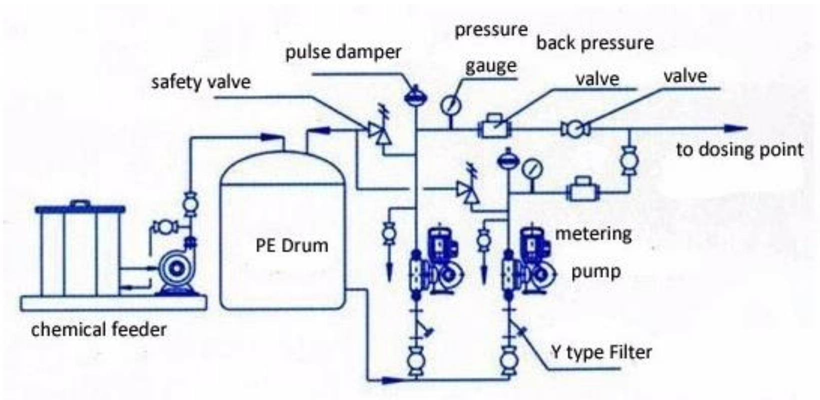


Figure 5: *Typical metering pump installation. From: https://instrumentationtools.com/*

4.2.3. Mechanism and parts of a dosing pump

For dosing pumps to develop their function, they need a combination of mechanical elements to transform the electrical power from the motor to the elastic deformation of the diaphragm. The pump selected is a DOSMART AC which is a specific model of ITC Dosing Pumps and the model used in this thesis.

As can be sensed in **Table 1**, the pump mechanical system is a combination of five elements which are labeled from A to F. The combined operation of this elements allow the effective transmission of the energy provided by the electric source and allow to dose.

Everything starts at the electric motor which transmits its power through a reducer, formed by a pinion and an eccentric crown that moves a connecting rod which is threaded to a membrane and transforms rotatory movement to linear. There is a spring which compresses during the suction cycle, storing energy, and releases it during the discharge cycle. The repetition of this cycle makes the dosing process possible.

Figure 6*: Main parts of an ITC pump mechanism. From: https://www.itc.es/*

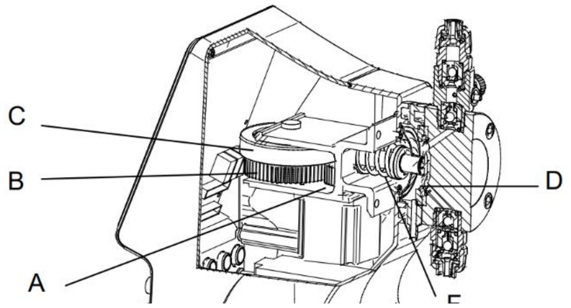


Table 1: *Components* of an ITC dosing pump mechanism

Designation	Component
A	Pinion
B	Eccentric crown
C	Rod
D	Membrane or diaphragm
F	Spring

4.2.4. Metering pumps operation

Metering pumps provide an accurate flow and can work against a wide range of discharge pressure including pressures of hundreds of bars.

Usually, there is a piston or diaphragm, which moves back and forth repeatedly during the process powered in most cases by an electrical motor (**Figure 7**).

A) **B)**

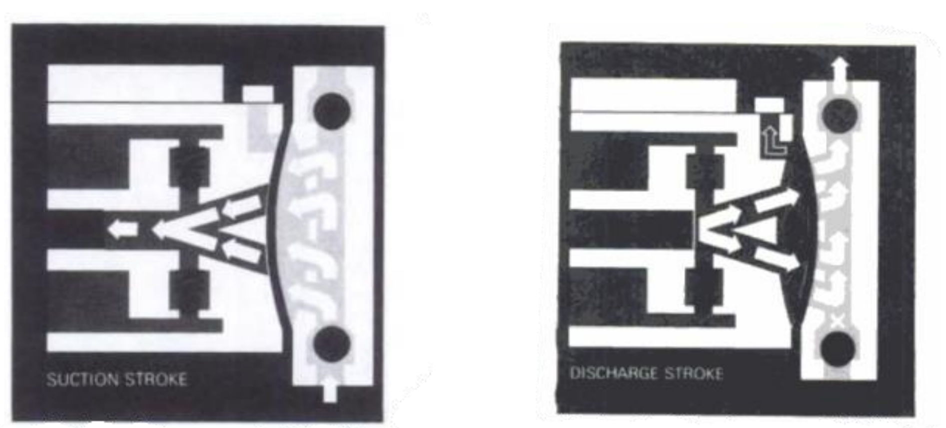


Figure 7: *A) Suction process stroke; B) Discharge stroke process. From:* (“Metering Pump Handbook - Robert E. McCabe, Philip G. Lanckton, William V. Dwyer - Google Llibres” n.d.)

There are two check valves (often ball check valves) represented **Figure 8** as the discharge valve and suction valve. The inlet valve allows flow from the inlet line into the chamber but not in the reverse direction. The outlet valve allows flow to go out from the chamber to the outlet line but not in the reverse direction, meaning that when one of them is open the other one is shut ensuring flow either goes into the chamber or out of it.

When the piston withdraws, it creates depression in the chamber and product is suctioned through the inlet valve, whilst the outlet valve remains shut due to the higher pressure in the outlet line.

When the piston or diaphragm moves into the chamber, the inlet valve shuts, and the outlet valve automatically opens when the inside pressure is higher than the outlet line. These alternating suction and discharge strokes are repeated over and over to dosify the product.

The choice between diaphragm or piston dosing pumps is usually made depending on the product used. Diaphragm pumps are normallly used to avoid lekeage or seal particularly when a liquid is dangerous, toxic or noxious.

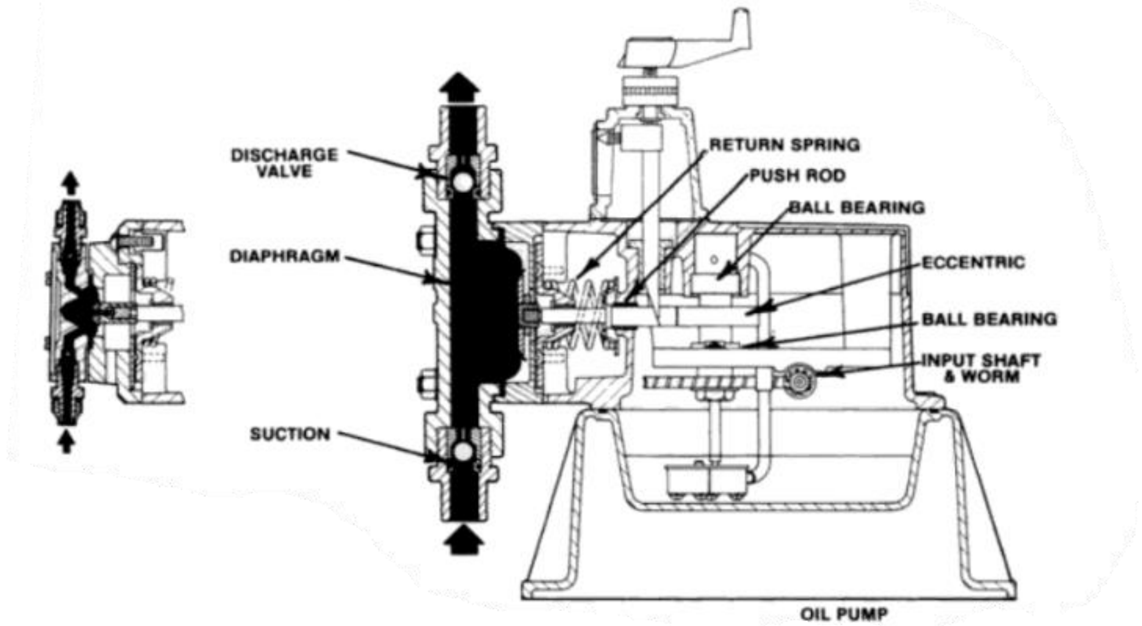


Figure 8: *A diaphragm metering pump dosing process. From:* ("Metering Pump Handbook - Robert E. McCabe, Philip G. Lanckton, William V. Dwyer - Google Llibres" n.d.)

5. Purge Valve Design

This section corresponds to the second stage planned in **Method** section. In this section the components process design of the degassing valve is performed. The different components of the valve are designed using SolidEdge which helps to preview and create a model virtually before printing it in a 3D printer and test it.

The elements that are to be designed using 3D tools are:

- Body piece
- Guide pieces
- Groove pieces

Whereas O-Rings and balls are bought directly from a supplier.

The design method started as a reverse engineering on the conclusions drawn from looking at **Figure 2** and **Figure 3**. Initial experiments shown that the main design variables to take into account were:

- Ball displacement: The quantity of fluid evacuating the valve increases with the ball displacement.
- Ball material: Specially because of its density, it was observed that heavy balls fail when working with low volumetric flows.
- Grooves and O-rings design: An incorrect design hinders the sealing of the system, which nullifies the proper valve operation.

In the following subsections, the design of the elements that make up the system is described and analysed.

5.1. Body piece

The body piece (**Figure 9**) contains all the parts and threads into the pump head to compress the joints and assure their right performance. At the bottom there is a ½ thread and at the top a conus shaped exit to connect a hose.

A)

B)

Figure 9: A) Body piece; B) 10 Body piece sectioned

This piece is designed so that the other elements can fit into it. Thus, it is the last part designed of the assembly as its dimensions are dictated by the other components, making the inner hole equally large as the sum of the total height of the inner components.

To ensure the correct positioning and seailing of the valve, this elements threads at its bottom part into the pump head and compresses the inner system, deforming the O-Rings and allowing to prevent the entrance and exit of fluid from outside.

Finally, the upper shaped conus exit allows to connect a hose to reconduct fluid losses back to a tank.

5.2. Guide piece

The guide piece (**Figure 11**) is situated outside the ball and has two main objectives:

- Its inner edges guide the movement of the ball, ensuring the right movement of the ball in each cycle.

- Its length determines the displacement of the ball and hence the volume of fluid evacuated. The larger the length the larger ball displacement.

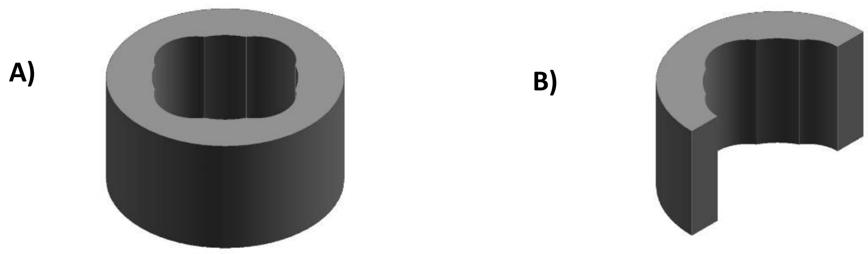


***Figure 11: A)** Guide piece; **B)** Guide price sectioned*

The guide piece is designed according to the displacement of the ball which is related to the volume evacuated.

The design of these piece is crucial when designing to reduce liquid losses, by reducing the height of this piece the ball displacement reduces which provokes a rapid shut of the ball. That is, when liquid pushes the ball, it shuts faster than when gas is pushing due to the differences in density. The length of this piece is crucial to regulate the volumetric losses.

It is also important to have a certain control of the ball movement, whit the inner edges of this element, the ball is guided during its path to ensure a good sealing with the O-Rings.

5.3. O-Rings

O-rings are simple mechanical gaskets in the shape of a torus; it is a loop of elastomer with a round cross-section, designed to be seated in a groove and compressed during the groove piece and the ball forming a seal at the interface. O-Rings dimensions are normalized and can be easily found in the market.

***Figure 12**: 6x2,5 O-Ring*

The material used is FPM mainly due to its great mechanical strength which allows to compress them without suffering permanent deformation, its excellent chemical affinity with other type of products (**Table 2**).

The O-Rings chosen are a 6x2,5 (**Figure 12**) to make the ball closure and a 11,11x1,78 to ensure no entrance of fluid from the inner sides of the inner parts of the valve.

Table 2: *FPM Physical, Chemical properties and Applications. From: https://jiorings.com/*

Feature	Value
Hardness Limit	50 to 90° Shores
Specific Weight	2,00 grs/cm^3
Field of temperature	-30 +250 °C
Breaking Load	70 kg/cm^2
Applications	Excellent in: Water, Acids, Oil, Ozone

5.4. Balls

Balls are used as movable elements that serve to shut or let the flow through. Every automatic system need an element or variable that changes the configuration of it, in the design of the purge valve, balls are the elements that make the valve automatic, by the swap of their position they change the configuration of the valve and the way it is performing.

Ball materials have to be carefully chosen to avoid chemical reactions with certain products and ensure the good performance of the system. Glass, stainless steel and ceramic balls are the most used materials when working with dosing pumps.

Figure 13: *Glass balls. From: https://www.luisapariciosl.com/es/*

Selecting the appropiate ball material is essential. Their density, chemical affinity and cost need to be taken into account before deciding the material.

Glass balls (**Figure 13**) are the most suitables in this case because of its low density compared to the other materials which allow to work with low volumetric flows and permit a rapid shut of the balls to avoid/reduce liquid losses . Moreover, it is the most chemical affine and cheap.

Table 3: Ball materials and their main properties

MATERIAL	Density (g/cm^3)	Chemical Affinity	Cost
Glass	2,5	High	Cheap
Ceramic	6,0	High	Expensive
Stainless steel	7,5	Medium	Expensive

Ceramic and stainless steel balls density are high and need a higher force to be moved, because of its high density, when the pump is working at low volumetric flow rates they remain floating and do not shut during the impulsion phase (**Table 3**).

On the other hand, chemical affinity is important for some users who work with corrosive, acid or other products that can react with the ball.

5.5. Groove pieces

Groove pieces (**Figure 14** and **Figure 16**) are designed as a placement for O-Rings. They have to be thoroughly designed so that O-Rings can expand and compress appropriately, thus its dimensions have to ensure a good positioning of the correspondent O-Rings and allow a correct deformation of them. Excessive space to deform may lead to the entrance of external fluid whereas little dimensions in the placements may lead to not being able to place correctly the O-Rings.

A bad design can affect the sealing of the system which would hinder the correct operation of the valve.

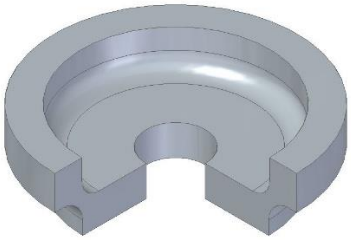


Figure 14 Lower O-Ring groove piece sectioned

Figure 15 Lower O-Ring groove piece

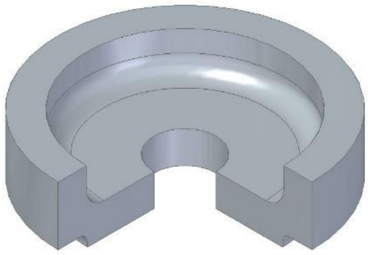


Figure 16 Upper O-Ring groove piece sectioned

Figure 17 Upper O-Ring groove piece

As can be seen in the previous figures, different pieces have to be designed as they work with different O-Rings, their dimensions have to adjust to the normalised dimensions of the O-Rings.

The dimensions of groove walls must allow a 20% of interference with a normalized O-ring to ensure a correct compression, sealing and pression distribution (**Figure 19** and **Figure 18**).

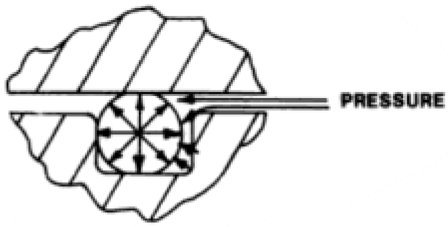


Figure 18 Pressure distribution around the O-Ring. From: Metering pump Handbook

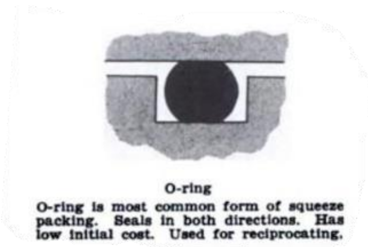


Figure 19 Correct position of the O-Ring in a groove where the O-Ring exceeds the gland depth allowing a 20% of compression ratio. From: Metering pump Handbook

5.6. Failed prototypes

This report only explains two of the most significant prototypes and explain their operation, features, failures, and modifications. However, throughout this thesis several prototypes of degassing valves have been designed with lots of modifications that were necessary to fix errors that arose when testing these models. Some of the alternatives that were considered were (see also ANNEXES):

- Elimination of O-Rings after several sealing problems: The prototype considered to replace O-Rings by a conus shaped piece that would allow the ball to shut due to its interference. The prototype failed as the 3D printed materials used did not allow enough tolerance in the printed pieces to ensure a right closure between the ball and the conus shaped piece.

- The use of a simple ball: This prototype is discussed in section 5.7.
- The use of a simple ball with a spring: This prototype was initially thought to solve the problems that arose with the entrance of air when working with only one ball. The design was complicated and was parallel done with the final design. The success of the final design and its added simplicity ruled out this alternative.

5.7. First prototype: One-ball degassing valve

In this system there is a ball that swaps between two O-Rings situated above and below the ball, see (**Figure 21** and **Figure 20**).

The process starts when the ball is on the lower O-Ring, during the discharge stroke, the fluid enters through the purge valve and displaces the ball which shuts at the top O-Ring. While this ball displacement, a portion of fluid is able to escape, in the ideal case, this fluid would be gas but liquid can also evacuate.

When the discharge stroke ends, the ball is situated at the upper O-Ring. Then the suction stroke begins making the ball to return to the lower position.

The weakness of this prototype was during the suction stroke, during this process air entered through the degassing valve when the ball moved from the upper O-Ring to the lower one. The solution seeked then had to avoid the entrance of air when suctioning, which led to the placement of a second ball in the final prototype.

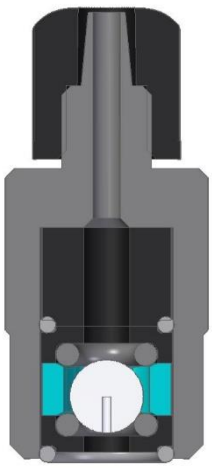


***Figure 21** First prototype*

***Figure 20** First prototype exploded*

5.8. Second and final prototype: Two-balls degassing valve

This system was designed to enhance the one-ball system. There is a low ball that shuts at its top and bottom O-rings and allows purging when transitioning between these two points (as explained in section First prototype: One-ball degassing valve). To solve the entrance of air when suctioning, another ball was added to the system.

The function of both balls can be described as follows:

- Lower ball: This ball has a little displacement and shuts at both ends. That is, when the pump is suctioning, the ball shuts down and remains in the lower position. During the discharge stroke, the pressure moves up the ball whilst allowing the entry of fluid into the degassing valve (when the ball transitions from the lower part to the top part). When the suction stroke process starts, the ball which was at the top (because of the previous discharge stroke) is moved downwards because of its weight and the depression caused by the suction process.

Upper ball: This ball moves up and down but only closes at its bottom position. When the lower ball displaces, the fluid coming out the first ball moves the upper ball up which finally lets fluid through the outside. Then, the upper ball returns to its down position because of gravity and shuts even before the suction stroke begins which avoids the entry of external fluid when suctioning.

This way, the two balls control the passage of fluid that enters and exits the degassing valve making the hole system functional and automatic. The combination of the two balls has to be coordinated, and this can be set by designing correctly the displacement of the two balls.

To ensure the closure of the lower ball before the upper one (so that the fluid can exit the valve) the upper guide piece is designed to be shorter than the top one.

Figure 23 Final prototype exploded

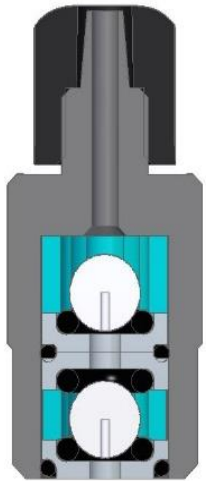


Figure 22 Final prototype sectioned

As can be seen, the final prototype is a combination of simple elements without any electronic device or complex part. The air evacuation system presented is made just by controlling the passage of fluid with two balls, the movement of these balls automate the whole process for each cycle.

5.9. Materials

Polypropylene (PP) and polyvinylidene fluoride (PVDF) are the most common used materials when designing valves and other components for metering pumps. These are thermoplastics polymers which properties suit chemically, mechanically and economically.

In most cases PP is used over PVDF due to its low cost. However, when working with products that are corrosive, PVDF is used because of its excellent corrosion resistance. In addition, both materials have good thermal resistance and can be easily found in the market (see **Table 4**).

Table 4 *PP and PVDF material properties. From: https://omnexus.specialchem.com/*

Full name	**Polypropylene Reinforced Glass-Fiber**	**Polyvinylidine Difluorider**
Short name	PP or Poly-Glass	PVDF or Kynar
Max operating temperature	83 °C	123°C
Corrossion Resistance	High	Superior
Applications	Pre-Treatment Metal cleaning Tank mixing and Cleaning Dust control Moisture control General spraying	Food and beverage process Chemical processing industry High temperature spraying

5.10. Fabrication Process

The continuous changes in the purge valve design made 3D printing the best solution when producing the different components. As the experiments were carried out with water, the 3D printed components could fulfill their function without affecting the functionality of the valve.

The different components were designed to be easily mechanized and also be produced by plastic injection as they are simple pieces. The chose between these two fabrication processes shall depend on the units that are expected to be sold. At first, if the built units are small, machining process is preferred as it is cheaper. However, if the demanded units are large, investing to create a mould for plastic injection is the best choice in the long run.

Balls and O-Rings are the only pieces that are provided from external companies. The other valve components are to be fabricated either by machining processes or by plastic injection.

6. Pump Head Design

The design part of the thesis covers mainly the purge valve design, however, adding a new valve to a pump requires modifying the pump head and adding a placement to connect the purge valve. The design of the pump head **focuses on the adaptation** of the pump head used in a DOSMART 13l/h D50 (**Figure 24**) and D69 (**Figure 25**) so that the pump head and the purge valve can be assembled together.

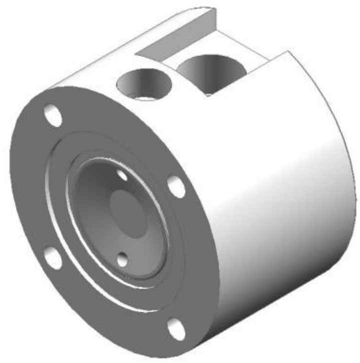


Figure 24 *D50 Degassing Pump head*

The design of the pump head takes into account the placement of the purge valve, creating an additional hole in the pump head and the proper conducts design. The two parts are finally assembled by a thread.

For optimal purging, it is not only necessary to be able to evacuate the air but also to ensure that the air reaches the place of the purge valve to be evacuated. That is, air is needed to be driven to the purge valve easily which is made by designing correctly the pump head.

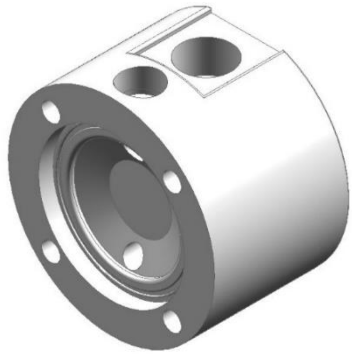


Figure 25 *D69 Degassing Pump head*

The design considers mainly two points:

1. The valve has been placed as the closest exit considering the flow motion, this way the air can reach the purge valve easily (**Figure 26**).
2. The vertical discharge conduct is a harmful place for the evacuation of air as stuck air can hardly flow from that spot to the purge valve spot. To reduce this volume of air, the vertical conduct is reduced and hence the quantity of air is also reduced.

Figure 27 *view of the degassing head, purge, suction and aspiration valves*

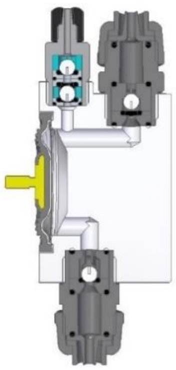


Figure 26 *Section view of the degassing head, purge, suction and aspiration valves*

6.1. A Sostenible Alternative to the Design of the Degassing Head

Implementing the proposed degassing head in chapter 6 implies manufacturing new pump heads of PP and PVDF which unfortunately has a negative impact on the environment. However, because of operating conditions and economic reasons, these materials are widely used in the dosing pump sector. Hence, reduction of the material may help to reduce its impact on the environment and even to reduce costs.

As a proposal to reduce the environmental project impact, I briefly present the design of an accessory that would allow to reduce the pump head volume of used material per unit without altering the good performance of the system.

This alternative is made of a unique piece that threads into a normal pump head, that is, a pump head without a port to connect a degassing valve. The alternative piece parallel connects both degassing valve and impulsion valve acting as a type of "parallel strip". To optimize its functionality, the degassing valve is situated as the first exit for the entering fluid easing the evacuation of air.

The total volume saved is 181 cm^3 of plastic which is around 35% of the total volume of the degassing pump head in section 6(**Figure 29** and **Figure 28**).

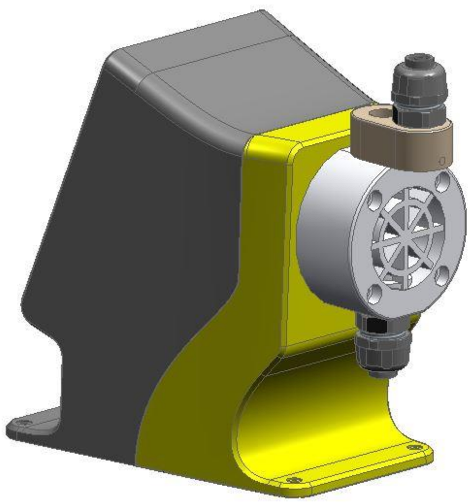


Figure 29 *Assembly of the pump, degassing head, purge valve, admission and impulsion valve. Proposal to reduce the environmental impact.*

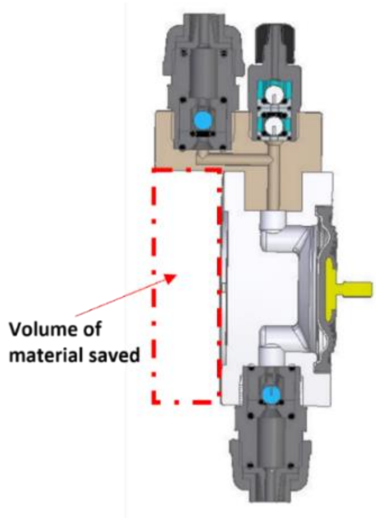


Figure 28 *Volume of material saved*

7. Metrics

This section aims to explain how the objectives set in chapter 2.3 are approached during the realization of this project.

Table 5 *Objectives and Approach*

OBJECTIVE	***APPROACH***
1. The degassing valve is able to turn the pump from a non-functional regime of operation due to entrapped gases to a functional regime.	The purge valve is tested filling a methacrylate pump head with air (the methacrylate pump head allows to see the process of purge directly and permit to evaluate the process visually). The valve must evacuate the air under normal operating conditions. That includes different pump speeds, different configuration of the installation and different pump heads.
2.The degassing valve shall not decrease the pump volumetric efficiency more than 20%.	The lossess on volumetric efficiency are required to be less than 20% of the flow provided by the pump under normal operating conditions. This objective is discussed in section 8.8. The experiments measure the flow of liquid exiting the purge valve with a test tube for a specific quantity of flow suctioned by the pump for different flow rates and diaphragms D50 and D69 and allow to determine the fluid losses.
3.The degassing valve can be implemented in a real situation.	As the project covers both design and experimentation realms, this objective meets automatically by meeting the other 3 objectives. The carried experiments are always under normal operating conditions.

4.The purge valve is economic.	To meet this objective the valve is designed using only mechanical components to make the system easier and cheaper. The project does not include any electronic components and the pieces are designed in order to ease their manufacturing costs which shall allow the total cost of the valve. As can be seen in section 5.8, the whole system is a combination of simple elements

8. Results

8.1. How gas affects a pump without a degassing valve?

Theoretical solutions help to contrast the information that one obtains experimentally. In this section calculations are made to aproximate the effects of having gas inside the pump head, study the different pump operating situations, and conclude in which situations a purge valve is needed.

Having entrapped gases in a pump head leads to a different pump operation. The volume occupied by gas reduces the volume occupied by product which implies a loss on flow and precision. Moreover, when dealing with compressible fluids, the pressure inside the chamber depends on the gas volume which may lead to not reaching the outlet pressure and the interruption of the dosing process.

8.2. Theoretical view of the effects of having gas inside the pump head without a degassing valve.

To analyse the effect of having gas inside a pump head, let us consider a piston metering pump with a total volume V_t, a dead volume V_d and the volume that can be compressed by the cylinder V.

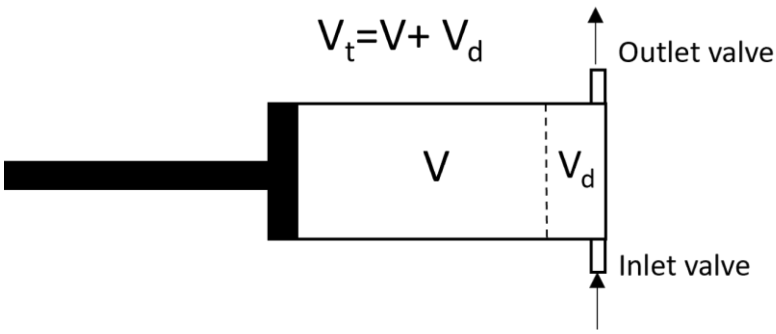


Figure 30 Piston cylinder model of a metering pump that is used to tackle this section

The movement of the piston is limited, that is, there is a volume that can not be compressed called dead volume V_d.

V is the initial volume that can be compressed when the piston is completely withdrawn as shown in **Figure 30**.

V_t is the total volume and equal to the sum of V and V_d.

Three different cases may take place depending on the quantity of gas inside the pump head.

1. The pump head is filled with liquid
2. The pump head is filled with gas
3. The pump head is partially filled with liquid and gas

8.2.1. Case 1

This is the ideal case where a pump is working with an incompressible fluid, a liquid. In this case, the pump can always reach the outlet pressure in each discharge stroke and hence to dosify. This scenario would be the ideal performance of a dosing pump. The theoretical graph in **Figure 31** shows how pressure inside the cylinder equalizes instantly the out pressure (due to the incompressibility of the fluid) when the piston starts moving. In this scenario no purge valve would be needed.

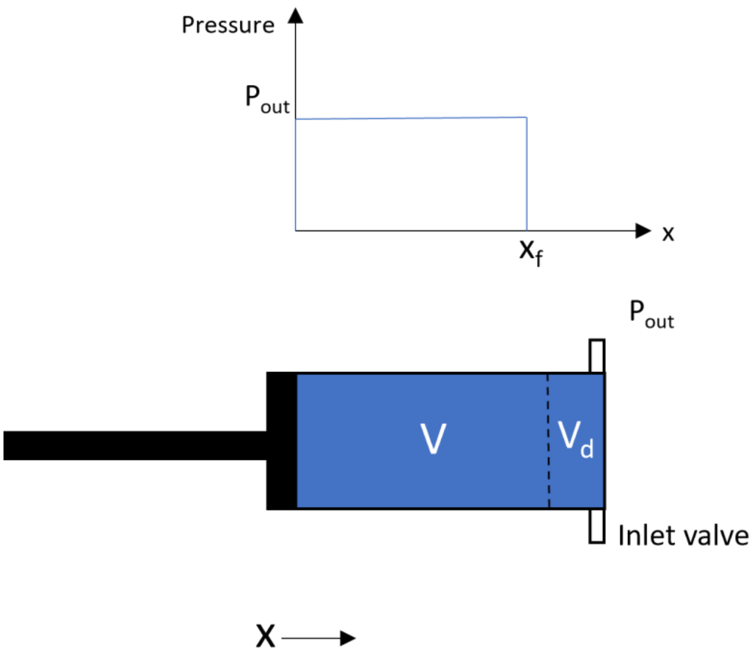


Figure 31 Cylinder filled with liquid. Pressure equalizes instantly the out pressure

Pressure in the pump head when discharging is constant. See eq. (*1*).

$$P(x) = P_{out} \tag{1}$$

8.2.2. Case 2

This is the most critical case. In this case we have a pump where its head is filled with gas. The piston compresses gas in each discharge stroke and therefore the pressure inside the chamber increases very little, that is, there is a portion of volume that can not be compressed which means pressure inside the chamber shall reach a maximum value of $\mathrm{P}(\mathrm{x}_f)$ and dosing shall occur only if $\mathrm{P}(\mathrm{x}_f) > \mathrm{P}_{out}$ (see **Figure 32**)

In practice, it is usual for users to have a P_{out} greater than $\mathrm{P}(\mathrm{x}_f)$ (when the head is filled with gas), that would lead to a non-functional pump that only compresses and expands the gas in each cycle with no dosing process taking place. In this scenario, a purge valve is needed.

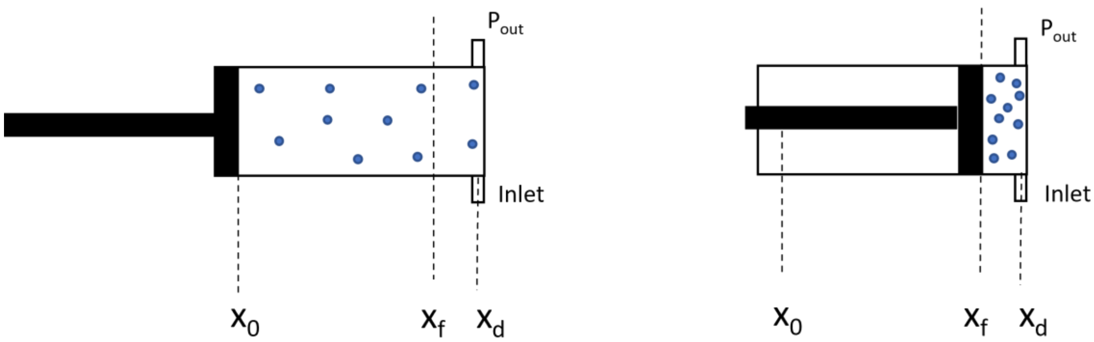


Figure 32 Initial and final position of the piston when the cylinder is completely filled with gas

Considering the compression cycle fast enough to avoid heat transfer across the piston wall, the compressiond/expansion process of the air can be considered as an adiabatic process.

Considering a thermodynamic adiabatic transformation for an ideal gas in a closed system, the pressure inside the cylinder is governed by eq. (2)

$$Pv^k = ct \tag{2}$$

$$P = \frac{ct}{v^k} \tag{3}$$

Figure 33 shows how pressure increases slowly with the piston movement. The pressure follows an adiabatic curve that has a maximum pressure at x_f.

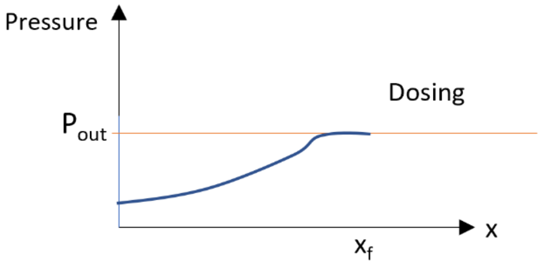


Figure 33 Theoretical graph. Pressure versus position of the cylinder in a pump head fully of gas. The out pressure is low enough to be equalized with the internal pressure of the head. Dosing process takes place when reaching the out pressure.

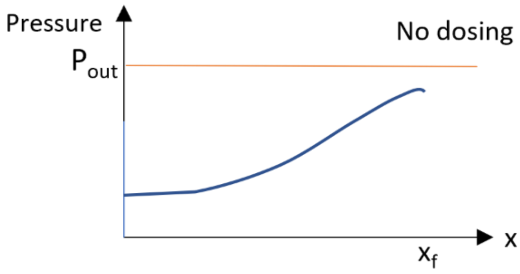


Figure 34Theoretical graph. Pressure versus position of the cylinder in a pump head fully of gas. The out pressure is too great to be equalized with the internal pressure at xf. No dosing takes place.

If there were no dead volume there would not be any entrapped gas problem, that is the gas would be compressed by the piston until reaching a very little volume which would cause an extreme pressure.

8.2.3. Case 3

In this case part of the cylinder is filled with liquid and the rest with gas. Dosing shall depend on the volume of gas inside the cylinder and the outlet pressure. To simplify the study I consider a model in which both phases are clearly separated so that is easier to understand the proportion of volume occupied by each one, although in real life the gas bubbles would be located at the top part of the pump head because of its low density.

This third case can be divided into two other cases depending on the volume of gas.

8.2.3.1. Case 3.1 $\mathbf{Volume\ of\ gas\ \leq\ V}$

If the gas volume is smaller than V (see **Figure 35**), the piston can compress all the initial gas volume, that would imply a high pressure and therefore the pump can reach the out pressure independently of its value and hence to dosify. In this case no degassing valve is needed.

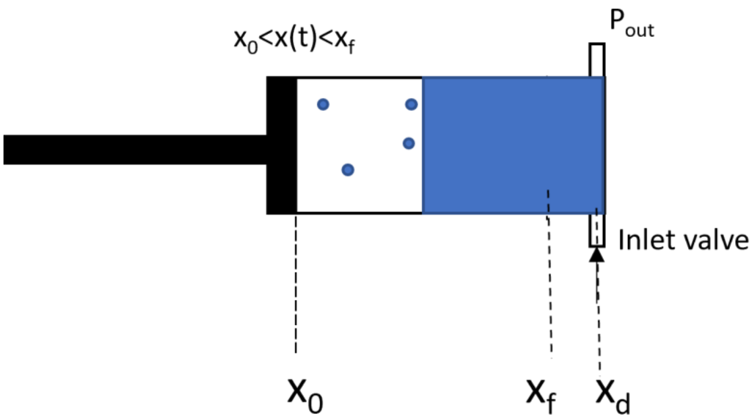


Figure 35 Piston pump with volume of gas lower than V

8.2.3.2. Case 3.2 Volume of gas $> V$

If the gas volume is greater than V (see **Figure 36**), that would allow part of the initial gas volume to not be compressed and hence reaching the out pressure is not secured, that is, dosing shall be possible only if $P(x_f) < P_{out}$. In this scenario a degassing valve is needed.

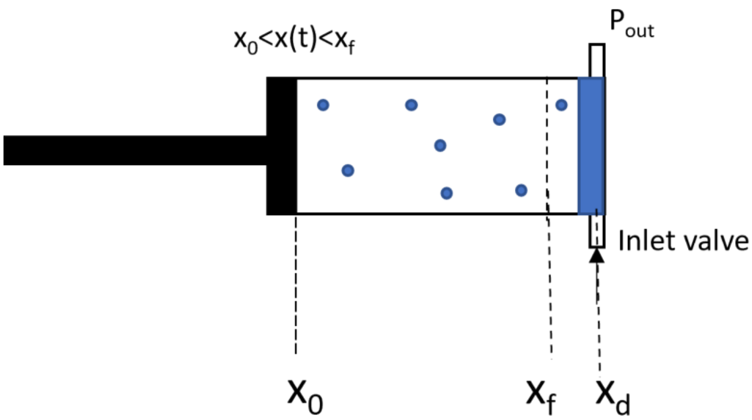


Figure 36 Piston pump with gas volume higher than V

Expression eq. (2) allows to determine pressure in function of gas. Knowing the pump head maximum pressure allows to understand the effect of dealing with air and its perturbance reaching the backpressure.

The following study considers the maximum pressure inside the pump head in case 3.2 and 2, as they are the ones susceptible of interrupting the fluid vein.

To use eqn(*2*) it is needed to define two diferent states (1 and 2) which shall be related with the constant. Considering state 1 as the moment when the piston is withdrawn (see Figure 37) and state 2 when the piston is completely inside the chamber (see Figure 38)

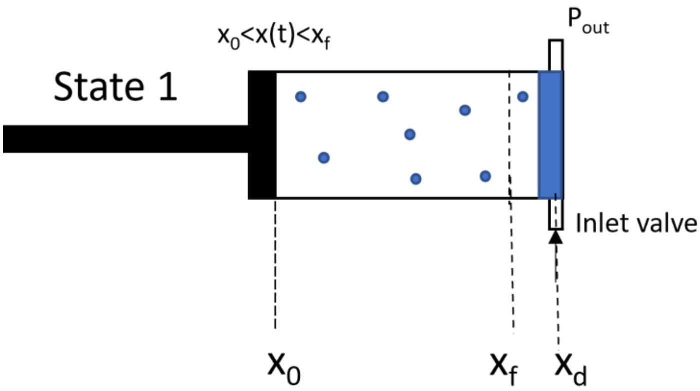


Figure 37 *State 1. The piston is completely withdrawn*

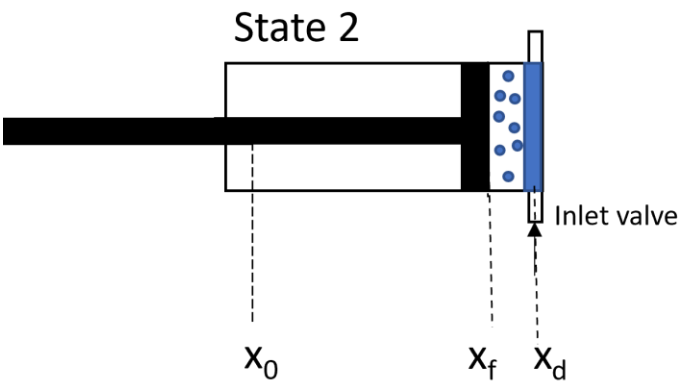


Figure 38 *Stage 2. The piston is inside*

Using eqn(*2*) in state 1

$$P_1 {v_1}^k = ct \tag{4}$$

Pressure in state 1 can be assumed as atmospherical, that is, the tank is levelled with the aspiration valve.

Defining i as the initial volume of gas over the initial total volume

$$i = \frac{V_{gas}}{V_t}; \qquad 0 \leq i \leq 1 \tag{5}$$

Thus,

$$v_1 = \frac{V_{gas}}{m_{gas}} = \frac{i \cdot V_t}{m_{gas}} \tag{6}$$

$$\mathrm{ct} = \mathrm{P_1}\left(\frac{\mathrm{i} \cdot \mathrm{V_t}}{\mathrm{m_{gas}}}\right)^{\mathrm{k}} \tag{7}$$

The constant then is defined.

Considering now State 2:

$$\mathrm{P_2 v_2}^{\mathrm{k}} = \mathrm{ct} \tag{8}$$

The specific volume occupied by the gas in this case is:

$$\mathrm{v_2} = \frac{\mathrm{i} \cdot \mathrm{V_t} - \mathrm{V}}{\mathrm{m_{gas}}} \tag{9}$$

The constant relates both states, that is:

$$\mathrm{P_2}\left(\frac{\mathrm{i} \cdot \mathrm{V_t} - \mathrm{V}}{\mathrm{m_{gas}}}\right)^{\mathrm{k}} = \mathrm{P_1}\left(\frac{\mathrm{i} \cdot \mathrm{V_t}}{\mathrm{m_{gas}}}\right)^{\mathrm{k}} \tag{10}$$

$$\mathrm{P_2} = \mathrm{P_1}\left(\frac{\mathrm{i} \cdot \mathrm{V_t} \cdot \mathrm{m_{gas}}}{(\mathrm{i} \cdot \mathrm{V_t} - \mathrm{V})\mathrm{m_{gas}}}\right)^{\mathrm{k}} \tag{11}$$

$$\mathrm{P_2} = \mathrm{P_1}\left(\frac{\mathrm{i} \cdot \mathrm{V_t}}{\mathrm{i} \cdot \mathrm{V_t} - \mathrm{V}}\right)^{\mathrm{k}} \tag{12}$$

This last expression can only be used when V_{gas} is greater than V (case 3.2), that is, $i \cdot V_t > V$ so that the denominator is greater than 0.

Considering k=1,4 and P_1 the atmospheric pressure:

$$\mathrm{P_2} = 101325 \cdot \left(\frac{\mathrm{i} \cdot \mathrm{V_t}}{\mathrm{i} \cdot \mathrm{V_t} - \mathrm{V}}\right)^{1,4} \tag{13}$$

V_t and V are given values from pumps datasheets and i is the initial volume relation between V_{gas} and V_t, see eq. (5).

Note that eq. (13) can be used in any kind of metering pump that meets $i \cdot V_t > V$ and does not take into consideration geometric aspects. This allows to use the expression for diaphragm dosing pumps.

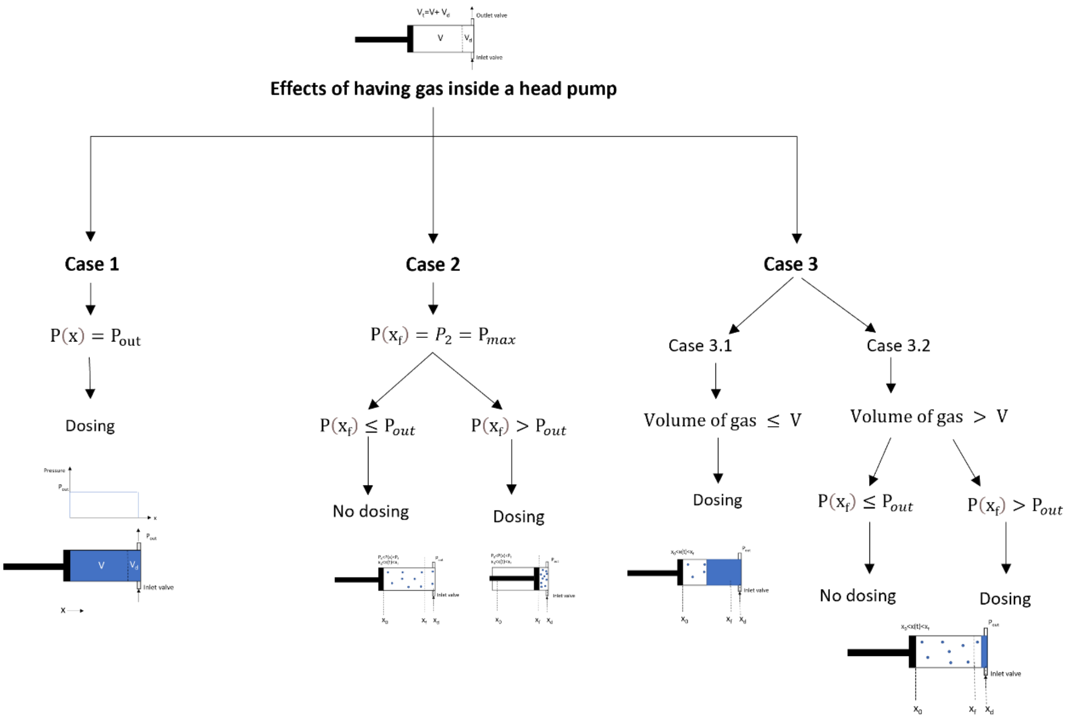


***Figure 39** Scheme of the different cases when having air inside the pump head*

Only cases that can not ensure reaching the backpressure need a purge valve as it evacuates the air and replaces it by liquid, this replacement of fluid will lead to a case where $V_{gas} < V$ which would ensure reaching the backpressure (see **Figure 39** as a summary of the different cases).

8.3. Experimental results of the effect of having gas inside the pump head without a purge valve

To have a greater variety in the experimental results, two different pump heads (it is possible to change the pump head without changing the pump) are used allowing to vary the values of the volumes in eq. (13) and get more results. When changing the pump head it is necessary to change also the diaphragm as every pump head has its own related diaphragm. Diaphragms used are D50 and D69 and its pertinent volumes are shown in **Table 6.**

Table 6 Volumes associated to D50 and D69 pump heads

Diaphragm	V_t (ml)	V (ml)	V_d (ml)	V_d (%)
D50	10,4	2,9	7,5	72
D69	24,8	6,3	18,5	75

As **Table 6** shows, most of the total volume of diaphragm pumps is dead volume, meaning that only a little portion of the total volume can be compressed and hence problem gas is more accentuated in diaphragm pumps.

Intending to confirm the theoretical results, experiments are set up allowing to determine the pressure inside the pump head by connecting a pressure transducer (passive sensor) into the pump head.

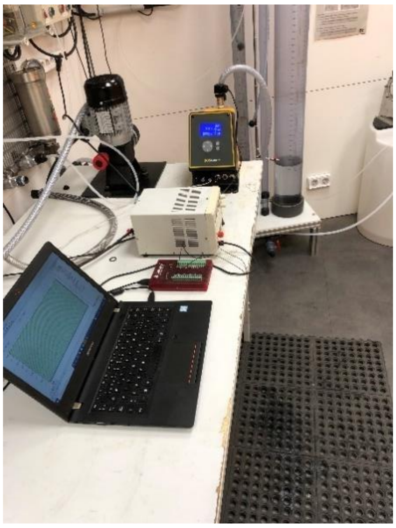


Figure 41 Set up of the experiment

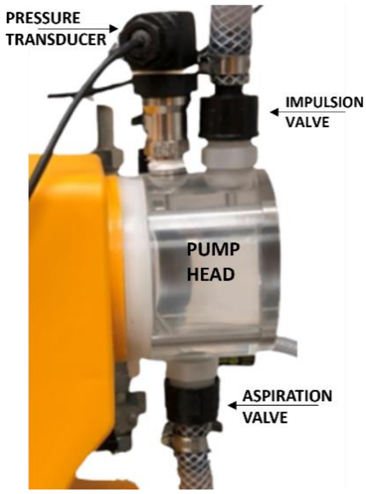


Figure 40 Pressure transducer connected to the pump head

The pressure transducer acts as a variable resistor connected to a voltage source which gives a 4-20mA signal read by a DAQ System and the signal is then plotted (see **Figure 40** and **Figure 41**). The results obtained can be approximated by eq. (13)

8.4. D50 Theoretical results

Taking a DOSMART AC D50 (diaphragm pump) which volumes are $V_t = 10{,}4\, ml$ and $V = 2{,}9\, ml$ and using eq. (13) the results shown in Table 7 are obtained.

Table 7 *Maximum absolute theoretycal pressure for a specific quantity of gas in a D50 head.*

D50

i	$P_{max,absolute}$ (bar)
0,28	477,82
0,50	1,36
0,75	0,62
1,00	0,40

Concentration of gas is defined in eq. (14) as volume of gas over total volume.

The value of i starts at a near point around $\frac{V}{V_t} = 0{,}28$ meaning V is filled with gas and the rest of liquid, in this case, the piston would be able to compress the gas to a very little volume which would cause an extreme pressure.

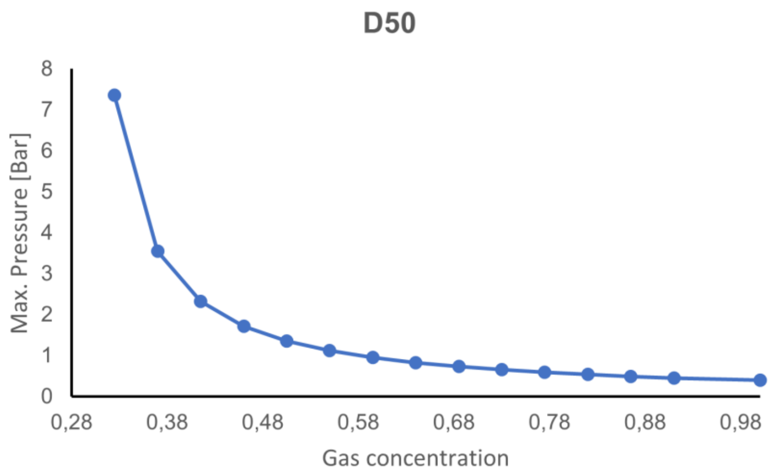


Figure 42 *Maximum theoretycal pressure VS gas concentration for a D50 head.*

Figure 42 plots the values in Table 7 and shows the different maximum pressures corresponding to the different gas concentrations for a D50 head. The result is an adiabatic curve.

8.5. D50 Experimental Results

Graphs obtained experimentally are different from those obtained theoretically. Theoretical graphs show maximum pressure for a specific gas concentration whereas experimental graphs show the evolution of the pressure inside the pump head for a specific quantity of gas. The relation between the theoretical and experimental graphs is the maximum pressure, in each experimental graph the maximum pressure should be approximately the pressure obtained in theoretical calculations for the specific gas concentration and pump head.

In this section the results of the experimental tests in chapter 8.3 are shown for the D50 head.

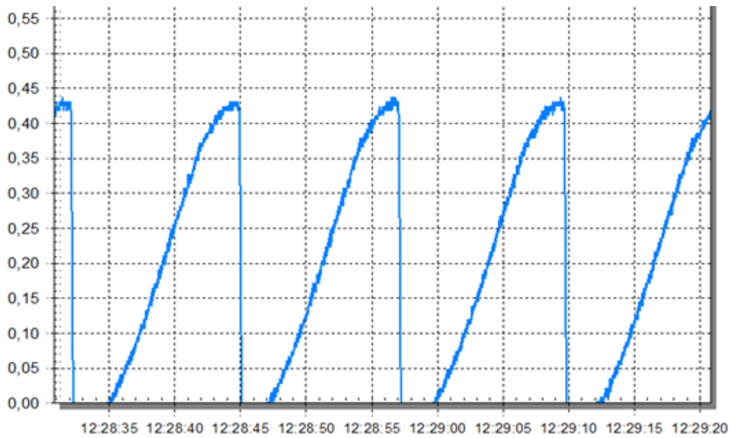


***Figure 43** Pressure (bar) vs Time in a D50 head filled with air.*

Figure 43 shows how pressure evolves in each cycle when the pump head is filled with air. The graph shows an adiabatic curve and the maximum pressure is 0,42 bar. **Table 7** predicted a value of 0,40 bar.

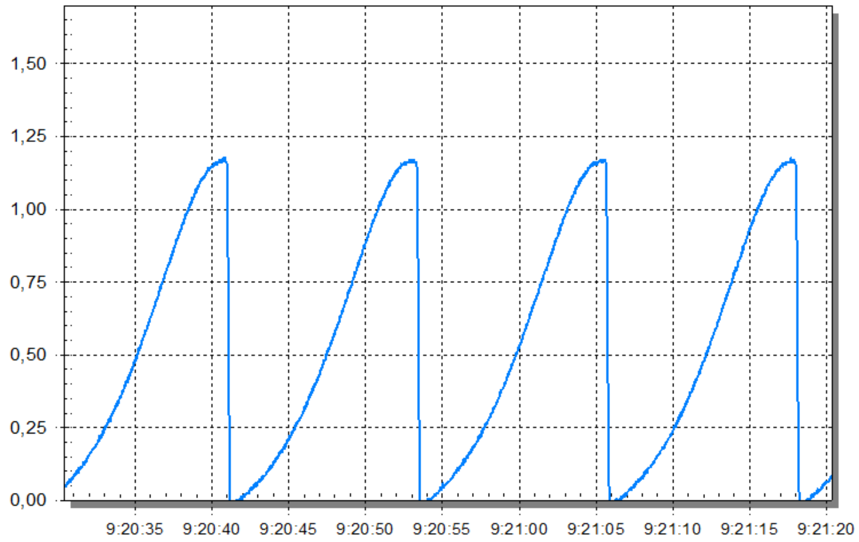


Figure 44 *Pressure (bar) vs Time when half of the D50 pump head is filled with gas and half with liquid*

Figure 44 shows the adiabatic curve expected theoretically when the pump head is half filled with gas and half filled with liquid. The maxim pressure value obtained is 1,20 bar . The theoretical calculations in Table 7 predicted 1,36 bar. As the experiment is carried out with a backpressure higher than 1,20 bar no dosing process takes place and hence the curve does not turn constant .

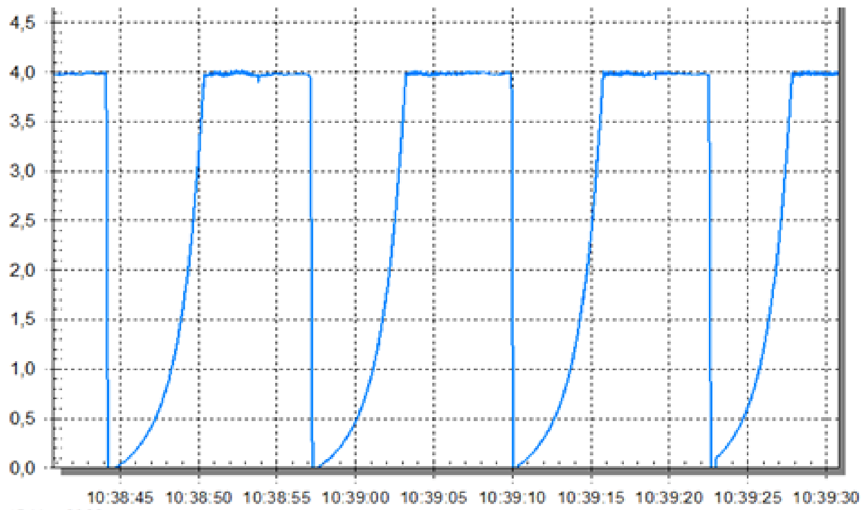


Figure 45 *Pressure (bar) vs Time when the pump head is partially filled with liquid and gas*

Figure 45 Pressure (bar) vs Time when the pump head is partially filled with liquid and gasshows the mixed effects of having a pump head filled with gas and liquid corresponding to case 8.2.3.1. The process starts with an adiabatic curve due to the presence of gas until it reaches the backpressure, then the dosing process takes place and the curve turns constant. The experiments with the pressure transducer allow to corroborate the theoretical maximum pressure values. Something to take into account is that Figure 45 shows an iterative cycle which was provoked because of a stuck bubble air. In reality, when reaching the backpressure the air should exit and the graph should have a similar aspect to Figure 46, however in this case the air was situated away from the discharge port which caused to not be able to evacuate.

Table 8 *Comparison between experimental and theoretical maximum pressure values for a D50 head*

D50			
Concentration of gas (%)	**Theoretical P_{max} (bar)**	**Experimental P_{max} (bar)**	**Error (%)**
100	0,40	0,42	5

Table 8 shows only a 100% of concentration of gas other concentrations are not compared as knowing exactly the quantity of air inside the pump head when is partially filled with liquid and gas is difficult. However, a concentration of 1 can be easily assured by dissassembling the pump head and drying it.

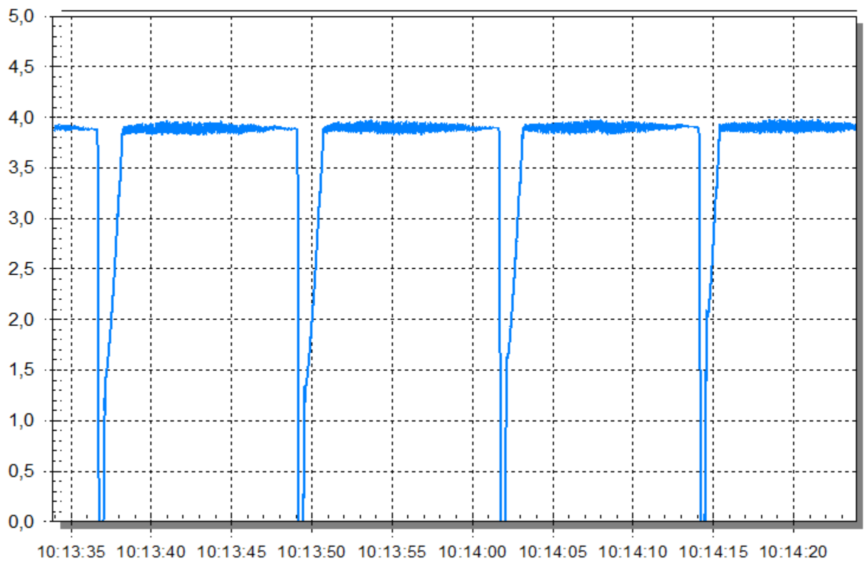


Figure 46 *Pressure (bar) vs Time when no air is inside the pump head. Ideal case*

Figure 46 shows the ideal case when the pump head is filled completely with liquid. The pressure is rapidly equalized to the backpressure and the constant region indicates that dosing process is taking place.

8.6. D69 theoretical results

In this section a D69 head which allows to move higher volumes than a D50 one is tested to study the effects of dealing with higher volumetric flow ranges.

Taking a DOSMART AC D69 (diaphragm pump) which volumes are $V_t = 24{,}8\ ml$ and $V = 6{,}3\ ml$ and using eq. (13) results in **Table 9** are obtained.

Table 9 *Maximum theoretycal absolute pressure for a specific quantity of gas in a D69 head.*

D69	
i	**P_{max}(bar) absolute**
0,26	431,33
0,50	1,13
0,75	0,54
1,00	0,34

Figure 47 shows the adiabatic curve obtained theoretically from Table 9 Maximum theoretycal absolute pressure for a specific quantity of gas in a D69 head.values. As can be seen, the larger the quantity of gas the less pressure can be reached inside the pump head. The x axis starts at a near point of 0,26 which would correspond to a volume of gas equal to V.

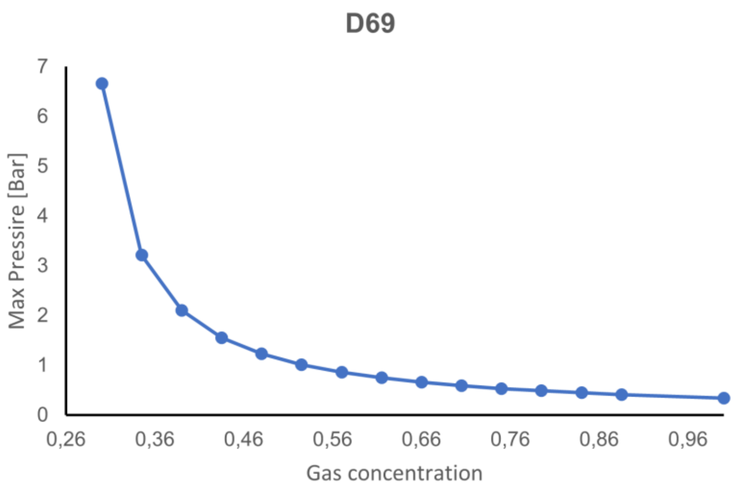


Figure 47 *Maximum theoretycal pressure VS gas concentration for a D69 head.*

8.7. D69 Experimental results

The same tests done with the D50 pump head are repeated with the D60 pump head. In Figure 48, when a D69 pump head is filled with liquid, the same behaviour is shown.

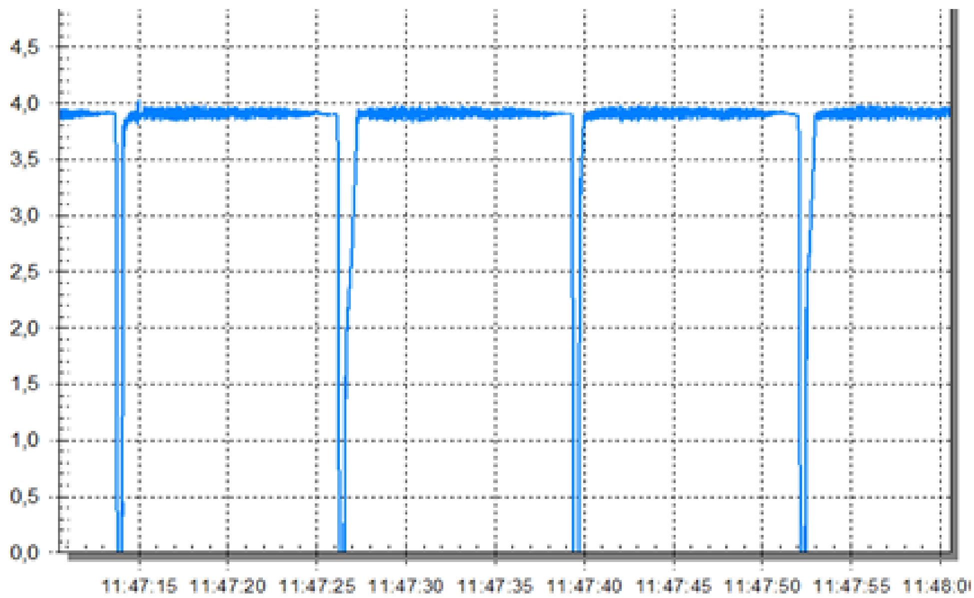


Figure 48 *Pressure (bar) vs Time when a D69 head is filled with liquid*

When letting some aire through the pump head, the curves in Figure 49 show the adiabatic curves expected theoretically. Dosage is produced when the curve turns horizontal and reach the backpressure.

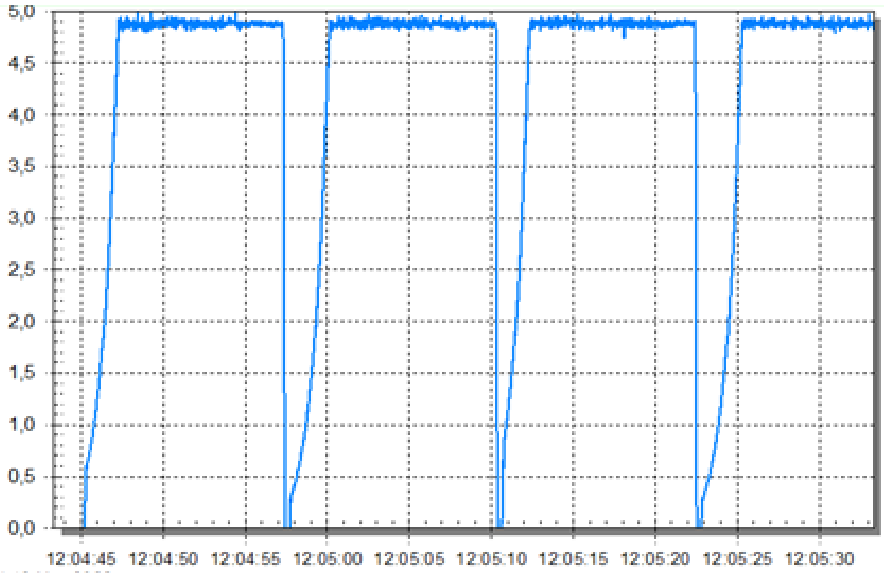


Figure 49 *Pressure (bar) vs Time when a D69 is partially filled with gas and liquid*

The most significant difference between the D50 and D69 head is the maximum pressure when they are filled with gas, in a D50 head the maximum pressure when filled with gas is 0,42 bar (see **Figure 43**). For a D69 **Figure 50** indicates a 0,35 bar maximum value, the teorical value expected is 0,34 bar (see **Table 9** and **Table 10**).

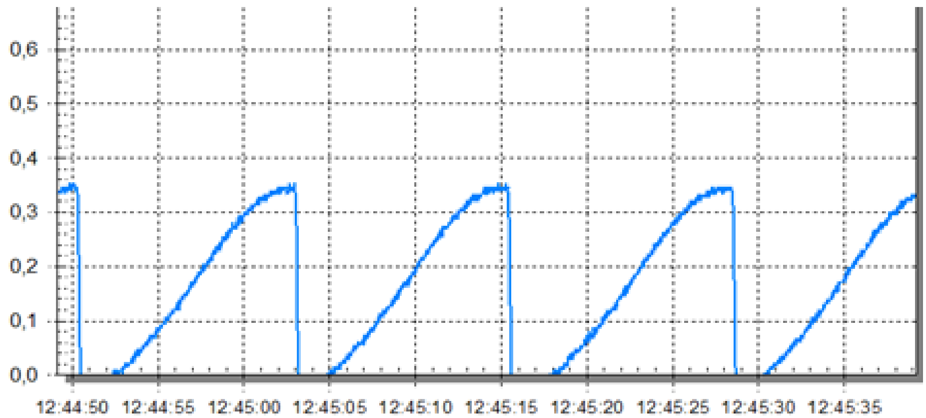


Figure 50 *Pressure (bar) vs Time when a D69 head is filled with gas*

Table 10 *Comparison between experimental and theoretical maximum pressure values for a D69 head*

D69			
Concentration of gas (Decimal)	Theoretical P_{max} (bar)	Experimental P_{max} (bar)	Error (%)
1	0,34	0,34	≈0

8.8. Volumetric efficiency

In this section objective number two regarding the volumetric efficiency of the purge valve is approached and shown to be met.

The design of the automatic purge valve is to be suitable to allow the purge of air but at the same time to reduce product loss. Keeping the volumetric efficiency high is important as it is the main feature for positive displacement pumps. In order to measure the product loss, the flow of product exiting the purge valve is measured with a graduated cylinder which is compared with the suctioned volume, defining the pump volumetric efficiency as shown in eq. 14.

$$\eta_v = 1 - \frac{V_{purge\ valve}}{V_{suctioned}} \tag{14}$$

As marked in the Purge Valve Design chapter, the ball material and the guide piece design are crucial aspects when designing to improve the valve volumetric efficiency. When testing volumetric efficiency, the main variable regarding the pump operation is the operating volumetric flow, as the force exerted by the fluid to the ball is related to it.

Table 11 shows no losses in volumetric flow for a 13l/h D50 pump for all its range of operation flow from 100% to 1% of the maximum flow given by the pump, which meets the objective set in Objectives chapter.

Table 11 Volumetric efficiency results for a 13l/h D50 pump

13l/h D50 *Pump*						
P (bar)	Speed (%)	$V_{aspiration}$ (ml)	V_{valve} (ml)	Time (s)	η_v	Flow (l/h)
4	100	200	0	55	1,00	13,09
4	1	10	0	54	1,00	0,67

Table 12 shows volumetric flow values for a D69 Pump head. The result is a 99% volumetric efficiency which also meets the volumetric efficiency objective in Objectives chapter.

Table 12 Volumetric efficiency results for a 13l/h D69 pump

13l/h D69 *Pump*						
P(bar)	Speed (%)	$V_{aspiration}$ (ml)	V_{valve} (ml)	Time (s)	η_v	Flow (l/h)
2	5	100	0,5	211	0,995	1,71
2	100	200	0,6	22,00	0,997	32,73

9. Environmental Impact Analysis

The development of this thesis is done intending to reduce, as much as possible, its environmental impact. The most relevant impacts and measures taken during the realization of this project are:

- Due to the location of ITC company, driving 80km to the company was necessary every three days a week during three months. Using public transport to get to ITC was difficult because of its location.

- This thesis needed 216 hours of experimental tests in which electric power was needed to feed the pumps and the laboratory equipment, as well as the computers and other type of machinery.

- Usage of water was also taken into account when experimenting, to avoid the use of corrosive and acid chemicals, laboratory tests were carried out with water from a closed circuit which took water from a tank and returned it to the same tank reducing water waste.

- The design impact of the valve took several different prototypes printed in 3D and made of PETG, which is a plastic that can be 100% recycled. Moreover, some components from past experiments were reused when needed to reduce cost and material.

- The valve is made in a way that can be disassmbled, components can be changed if needed, which allows the replacement of its different parts without needing to replace the entire valve. In addition, the valve was built to use the minimum required material making the whole symmetric and avoiding extra pieces or unnecessary material.

- The materials used to build the valve are mainly PP and PVDF. The implementation of this valve shall avoid hours of wasted energy consumption when the operation of the pump is disrupted. In addition, to reduce the material used to build the pump head, an accesory has been designed as an alternative to reduce the material used when manufacturing a degassing pump head.

10. Normative

During the development of this thesis, two spanish ISO standards were followed, these are:

1. **UNE-EN-ISO 14001:2015**. Environmental management systems. Requirements with guidance for use. This standard approaches themes as environmental policy, environmental objectives and planning to achieve them, environmental objectives, action planning to achieve environmental objectives among others.
2. **UNE-EN-ISO 9001:2015**. Quality management systems. Requirements. This standard approaches themes as leadership, commitment, customer focus, policy, establishment of quality policy, communication of quality policy, support, resources, creation and updating, design and development of products and services, design changes and development, design planning and development among others.

CONCLUSIONS

As seen during this thesis, entrapped gases disrupt the operation of dosing pumps which turn them into inefficient and sometimes even useless machines for their purpose. The effect o having entrapped gases inside the pump head led to a major problem that was stated as follows:

- Entrapped gases provoke an interruption of the dosing pump process.

Air inclusions nullify the optimal operation of dosing pumps, which makes users to dedicate more resources to control possible gas inclusions, leading to an increase in economic costs and user dissatisfaction with the product. The aim of this thesis was to design a pump head with automatic purge valve to allow the automatic evacuation of gas inclusions for a DOSMART 13l/h D50 and D69.

After three months of intensive testing and designing, the solution is a valve which contributes to this thesis in the following ways:

1. The degassing valve can turn the pump from a non-functional regime of operation due to entrapped gases to a functional regime.

2. The result is a highly efficient valve that allows the purge of gas with a volumetric efficiency of 98-99% for a DOSMART 13l/h D50 and D69.

3. The valve can be implemented in a real situation.

4. The purge valve is economical and highly valuable for their users.

This way the final purge valve meets the objectives set at the beginning of the project and shall allow users to solve the problem related to entrapped gases automatically. In addition, ITC Dosing pumps shall achieve a technology that only few companies in the market have.

At the end of this project, the purge valve presented is prepared to carry out the last experiments before standardizing the product for a subsequent sale by ITC Dosing Pumps.

ECONOMIC ANALYSIS

The devolpment of the thesis is associated with the use of several resources that were necessary to fulfill the project. **Table 13** shows the most important costs associated to the realization of this project.

To launch the project, a PC computer was needed as well as a Solid Edge license to execute the designing part of the project and a Microsoft Office license to manage the data and word the report. The study considers a draft part which is related to the information gathering process done outside ITC facilities.

Table 13 Economic costs associated to the development of the project

Product or Service	Quantity	Price per Quantity	Total price without VAT (€)	Total price with 21% VAT (€)
PC	1 unit	1630€/unit	81,50	98,62
Solid Edge license (1 year)	3 monts	2700€/year	675,00	816,75
Microsoft Office (1 year)	3 monts	101,91€/unit	25,48	30,83
Methacrylate pump head D69	1 unit	550€/unit	550,00	665,50
Methacrylate pump head D50	1 unit	500€/unit	500,00	605,00
3D Printing	13 units	0,20€/unit	2,60	3,15
Engineer	208 h	25 €/h	5200,00	6292,00
Transport	50 travels	6€/travel	300,00	363,00
Report	400h	8 €/h	3200	12000
Others	-	10% of the total cost	733,46	887,48
		Total (€)	11268	13634

The fact of working with a degassing valve needed to design new pump heads which were mechanized and made of methacrylate. As the project approached D50 and D69 pump heads, a unit per head was needed. The other components were printed in 3D which helped to reduce the total cost without affecting the experimental results.

As commented in page 45, driving to ITC was needed. The study considers 50 travels during the total period of the development of the project.

Wording this thesis is counted as a 400h time job which contributes a cost of 3200 €.

Finally, other costs are considered as a 10% of the sum of the total costs to take into consideration some costs and expenses that were indirectly associated with the resolution of this thesis.

The result is an investment of 13634€. Considering a 5 year investment horizon, an aproximated benefit of 3€ per unit of degassing head and valve sold, an interest rate of 4% and a constant demand of 1500 units per year, the following results of the investment study are obtained:

Table 14 *Study of the investment*

Period		0	1	2	3	4	5
Units sold			1500	1500	1500	1500	1500
Investment (€)		-13634					
Benefit (€)			4500	4500	4500	4500	4500
Cash Flow (€)		-13634	4500	4500	4500	4500	4500
Cash Flow acumulated (€)		-13634	-9134	-4634	-134	4366	8866
Cash Flow updated (€)		-13634	4327	4161	4000	3847	3699

Benefit per unit (€)	3
i (%)	4
NPV (€)	6399
PayBack (years)	3,03
IRR (%)	19,4

The results in **Table 14** show a safe investment in which the horizon period is actually expected to be larger. The return of the investment would be in 3,03 years and the net present value of the investment in the 5th year is 6399€ which is roughly half of the amount invested. The internal rate of return is 19.4% which is a figure that indicates a strong probability of success.

It is important to remark that figures in Table 14 are results of an aproximation. **The demand and benefit are approximated figures according to the price and demand of other valves.**

BIBLIOGRAPHY

1. "A simple Approach to Thesis Writing" – Tim. B- Adapted from "The Guaranteed Mackworth Thesis Formula, by Alan Mackworth. https://web.cs.dal.ca/~eem/gradResources/ThesisHints.html

2. "A Textbook of Engineering Thermodynamics - R.K. Rajput - Google Llibres." n.d.

3. Auto Degassing Valve (ADV), *Walchem IWAKI America Inc*. Apr 2014. Accessed 9 April 2022 https://files.valinonline.com/userfiles/documents/walchem-auto-degassing-valve-2014.pdf

4. Auto-Degassing Liquid Ends For Chemical Metering Pumps, *ProMinent*, the only choice for pumping fluid that out-gas. Accessed 11 April 2022. http://prominent.us

5. Chemical metering pumps applications and meeting criteria for efficiency, *Process Instrumentation*, Finding the right metering pump starts with understanding the key role it plays in a plant's operation and what criteria it ust adhere to. Accessed 10 May 2022. https://www.piprocessinstrumentation.com/pumps-motors-drives

6. DOSMART-AC-EN-17-02-2021*, ITC Dosing Company*, DOSMART Datasheet, Accessed 9 April 2022 https://www.itc.es

7. "Make it clear, speak and write to persuade and inform" – P.H. Winston – PDF Book.

8. "Metering Pump Handbook - Robert E. McCabe, Philip G. Lanckton, William V. Dwyer - Google Llibres." n.d.

9. Raton, Boca, London New, and York Washington. 1999. "Centrifugal & Rotary Pumps : Fundamentals With Applications." *Centrifugal & Rotary Pumps*, March.

10. Siev, R., and B. G. Lipták. 2020. "Metering Pumps." *Flow Measurement*, June, 73–78.

11. "The Theory of Rings - Nathan Jacobson - Google Llibres" n.d.

ANNEXES

In this section, information about O-Rings and Grooves are attached, as well as purge valve components, pump head drawings and documents about experiment tracking.

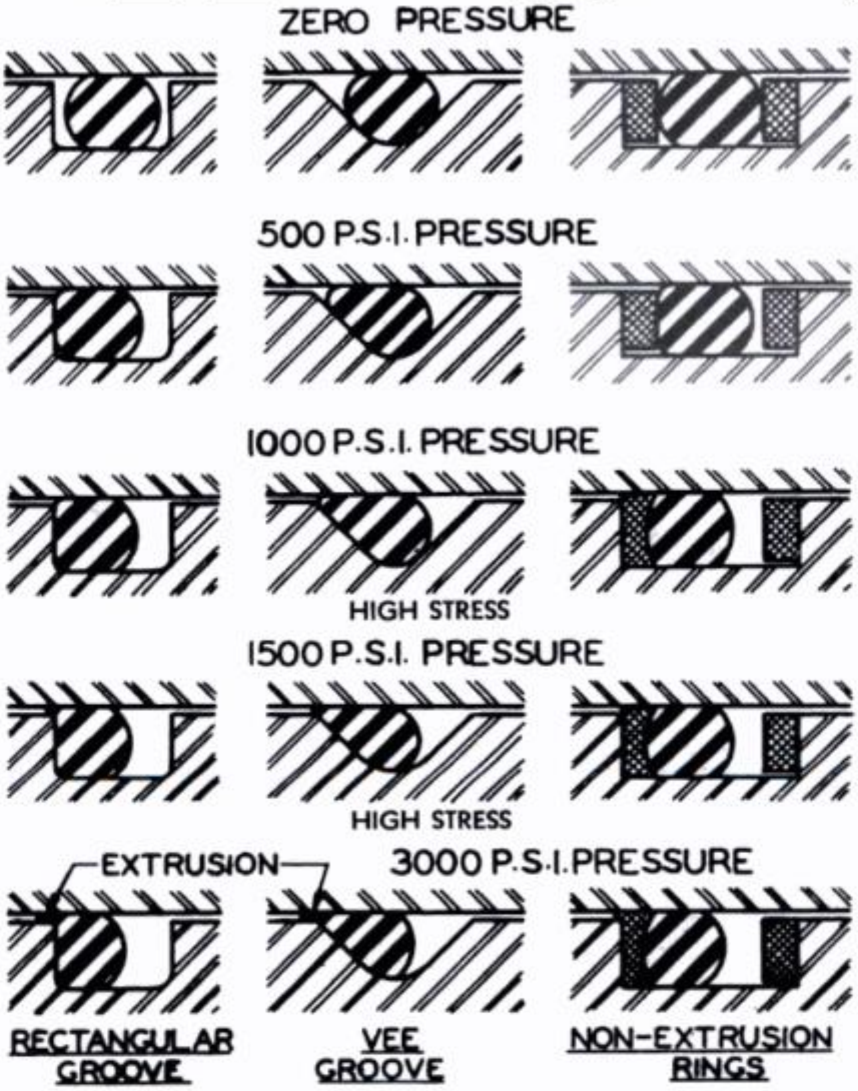
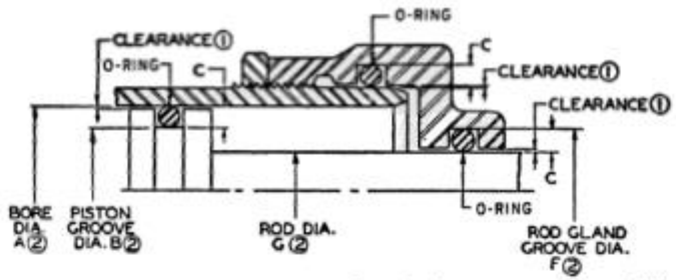
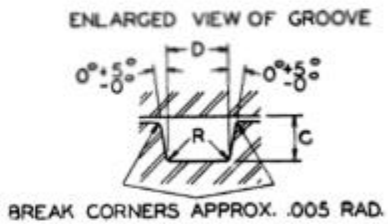


Fig. 3-9. Positions of O-rings at different pressures (Courtesy, E.F. Houghton & Company).

Figure 51 *Positions of O-Rings at different pressures*





Packing Size		Cross Section Diametral Squeeze (Min.)		"C" Gland Width		Groove Length "D"	"R" Radius	Diametral Clearance Max. (1)	Eccentricity Max (3)
Dash No.	Section Dia. Actual	Moving Seals	Static Seals	Moving Seals +.000 -.001	Static Seals +.000 -.005				
001	.040 ± .003	.005	.005	.032	.032	.063	.01	.004	.002
002	.050 ± .003	.006	.006	.041	.041	.073	.01	.004	.002
003	.060 ± .003	.008	.008	.049	.049	.085	.02	.005	.002
004 thru 045	.070 ± .003	.010	.015	.057	.052	.09	.02	.005	.002
110 " 163	.103 ± .003	.010	.017	.090	.083	.14	.02	.005	.002
210 " 281	.139 ± .004	.012	.022	.123	.113	.19	.03	.007	.003
325 " 349	.210 ± .005	.017	.032	.188	.173	.28	.05	.010	.004
425 " 460	.275 ± .006	.029	.049	.240	.220	.38	.06	.014	.005

NOTES:

1. Clearance must be held to an absolute minimum consistent with design requirements for temperature variations, and should not exceed values shown in table except at zero or low pressures.

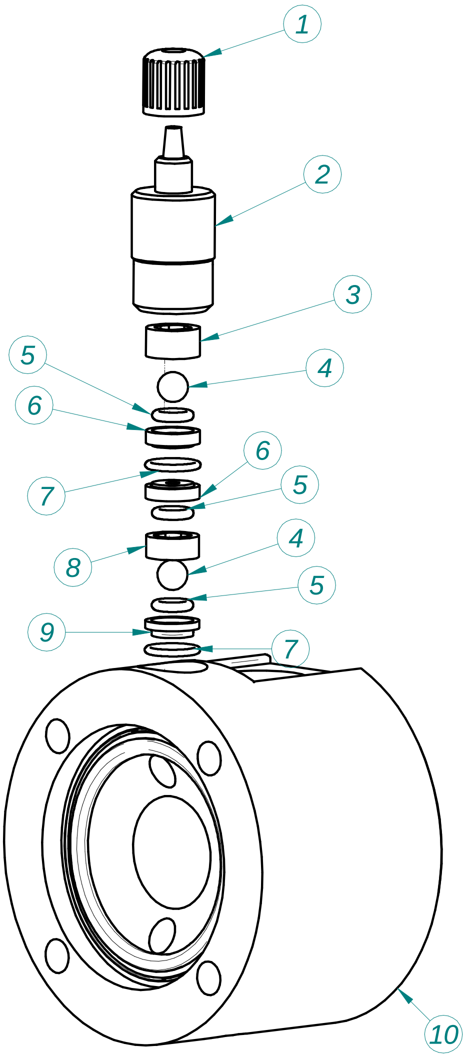
2. Piston groove diameter "B" equals "A" (at plus tolerance) minus 2 "C". Rod gland groove diameter "F" equals "G" (at minus tolerance) plus 2 "C".

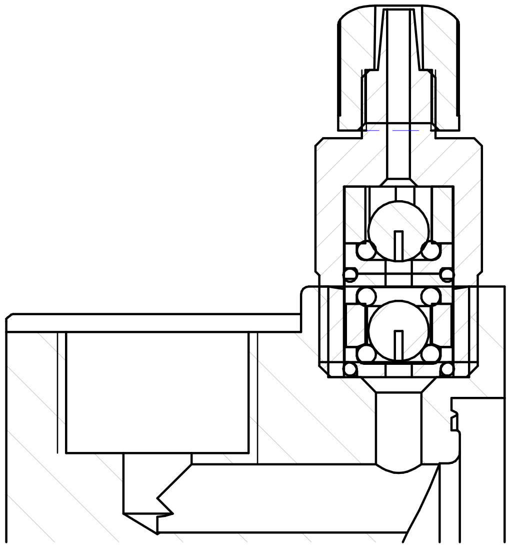
3. Total indicator reading between groove and adjacent bearing surface.

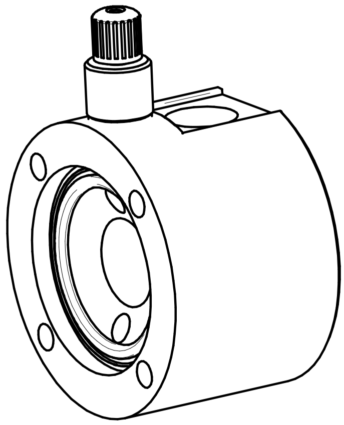
ALL SURFACES AND CORNERS MUST BE WITHOUT TOOL MARKS, NICKS OR SCRATCHES

Fig. 3-8. O-ring application (Courtesy, E.F. Houghton & Co.).

Figure 52 *Grooves and O-Rings configuration*







No.	DRAWING NUMBER	PART NAME	MATERIAL	QUANTITAT
1	1	Hose female thread 1/8"	PP or PVDF	1
2	2	Body	PP or PVDF	1
3	3	Upper guide	PP or PVDF	1
4	4	Ball	Glass	2
5	5	O-Ring 6,0x2,5 mm	FPM	2
6	6	Upper groove piece	PP or PVDF	1
7	7	O-Ring 11,11x1,78 mm	AFLAS	2
8	8	Lower guide	PP or PVDF	1
9	9	Lower groove piece	PP or PVDF	1
10	10	D69 Pump head	PP or PVDF	2

Design of an automatic degassing head for dosing pumps

DELIVERY DATE:	12/06/2022	MATERIAL:	PVDF or PP	MASS:	
DRAWN:	Mounir Ghailan Tribak	DRAWING DATE:	12/06/2022		
REVIEWED:	Joan Grau Barceló	REVIEW DATE:	13/06/2022		

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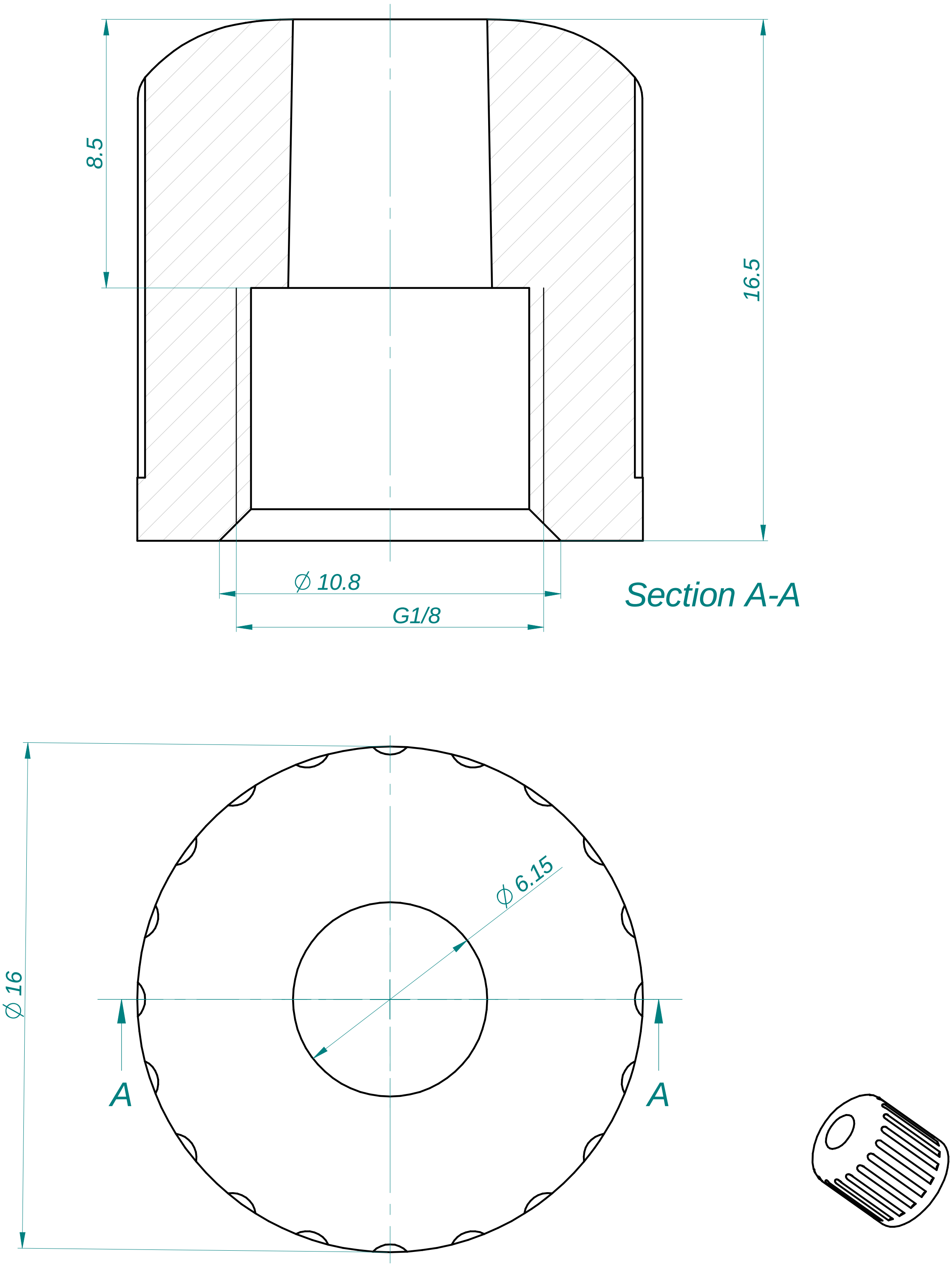
BARCELONATECH
Escola d'Enginyeria de Barcelona Est

SCALE: 1/2	Automatic Degassing Head	QUANTITY:	01
		FORMAT:	DIN A4
		No. Drawing:	12



Design of an automatic degassing head for dosing pumps

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DRAWN:	Mounir Ghailan Tribak	DRAWING DATE:	12/06/2022				
REVIEWED:	Joan Grau Barceló	REVIEW DATE:	13/06/2022				
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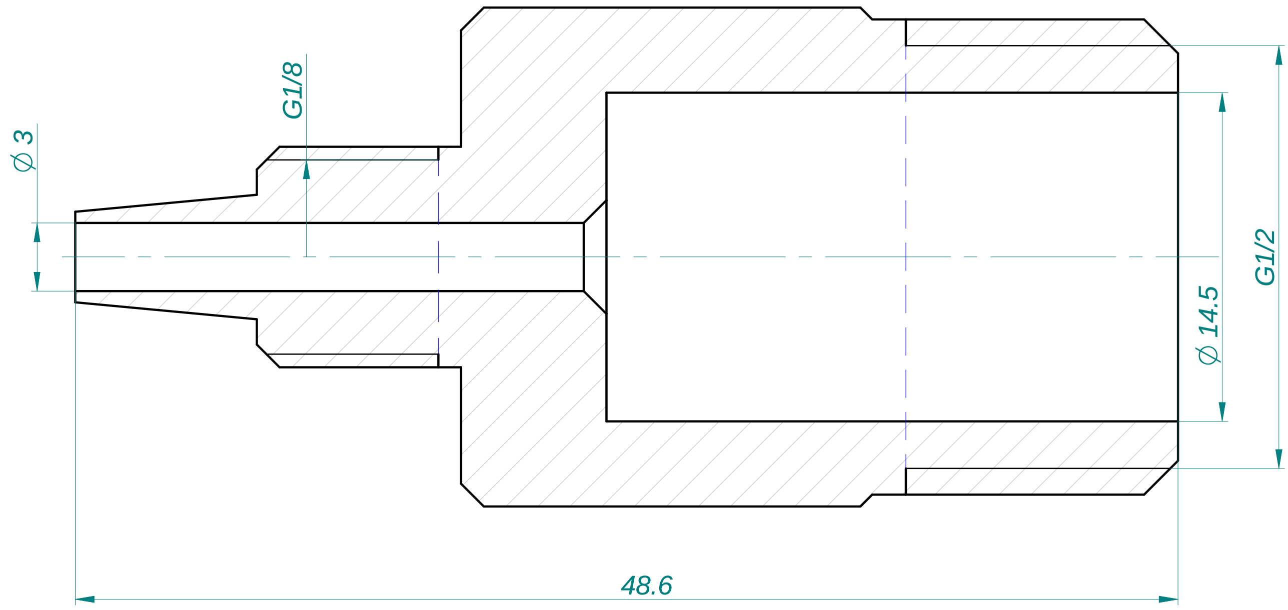
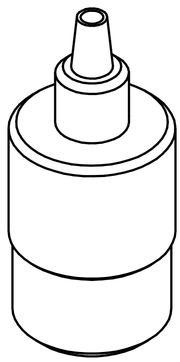
						FORMAT:	DIN A4
						No. Drawing:	01





Design of an automatic degassing head for dosing pumps

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DRAWN:	Mounir Ghailan Tribak	DRAWING DATE:	12/06/2022				
REVIEWED:	Joan Grau Barceló	REVIEW DATE:	13/06/2022				

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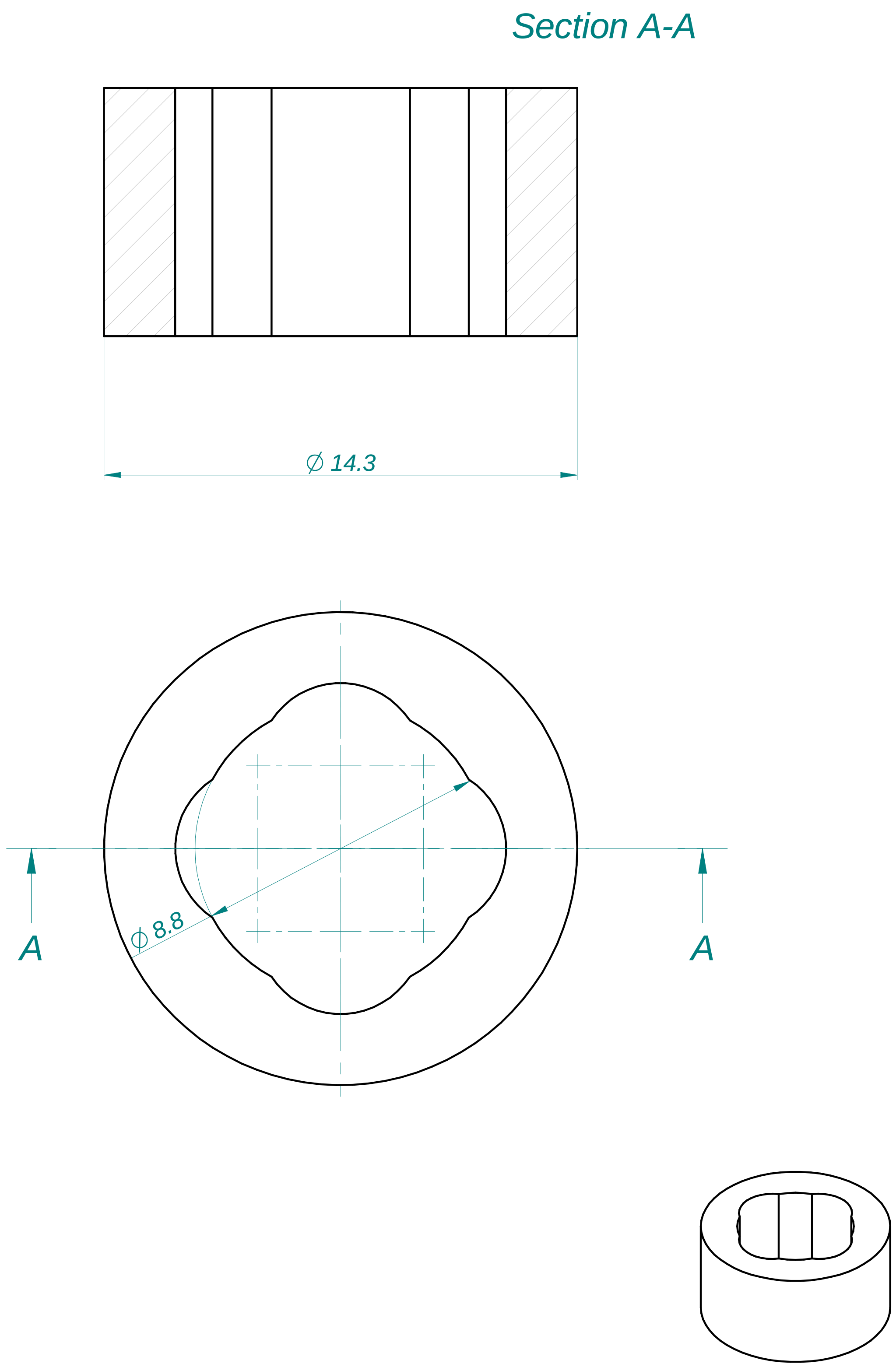
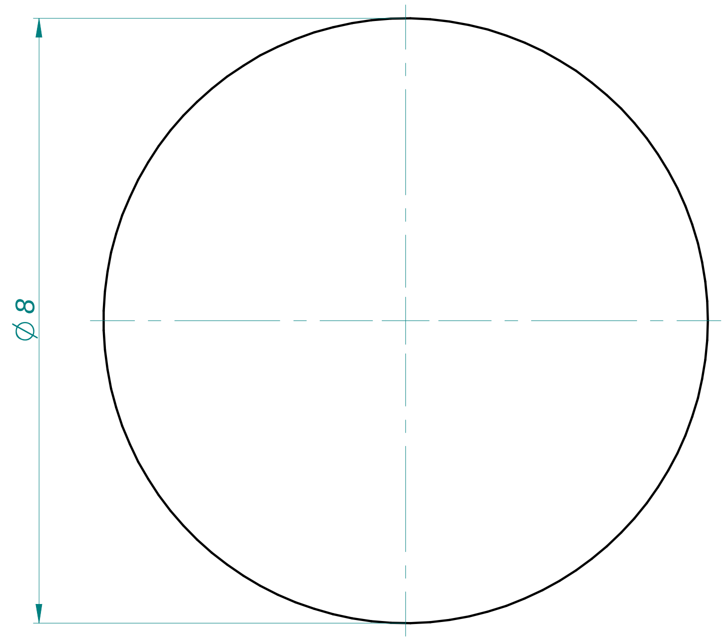
SCALE: 3/1	Body piece

QUANTITY:	01
FORMAT:	DIN A4
No. Drawing:	02



Design of an automatic degassing head for dosing pumps

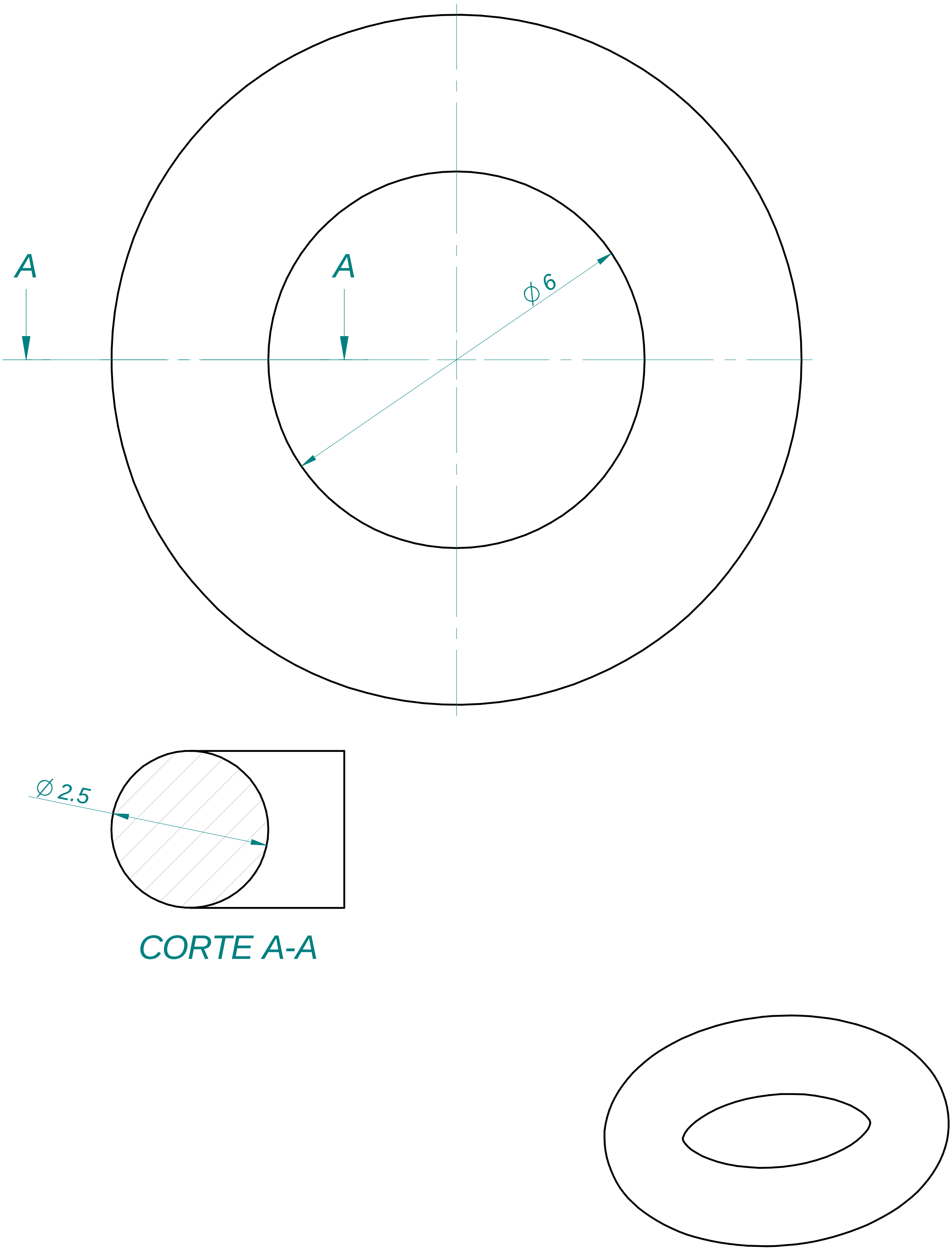
DATA D'ENTREGA:	12/06/2022	MATERIAL:	PVDF or PP	MASSA:	0,8 g	UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH UPC Escola d'Enginyeria de Barcelona Est	
DIBUIXAT:	Mounir Ghailan Tribak	DATA DIBUIXAT:	12/06/2022				
REVISAT:	Joan Grau Barceló	DATA REVISAT:	13/06/2022				
ESCALA: 5/1	Upper guide piece					QUANTITAT:	01
						FORMAT:	DIN A4
						Nº PLANO:	03



Design of an automatic degassing head for dosing pumps

DELIVERY DATE:	12/06/2022	MATERIAL:	Glass	MASS:	0,6 g	UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH Escola d'Enginyeria de Barcelona Est
DRAWN:	Mounir Ghailan Tribak		DRAWING DATE:	12/06/2022		
REVIEWED:	Joan Grau Barceló		REVIEW DATE:	13/06/2022		

SCALE: 10/1	Ball	QUANTITY:	02
		FORMAT:	DIN A4
		No. Drawing:	04



Design of an automatic degassing head for dosing pumps

DELIVERY DATE:	12/06/2022	MATERIAL:	FPM	MASS:	0,2 g
DRAWN:	Mounir Ghailan Tribak	DRAWING DATE:	12/06/2022		
REVIEWED:	Joan Grau Barceló	REVIEW DATE:	13/06/2022		

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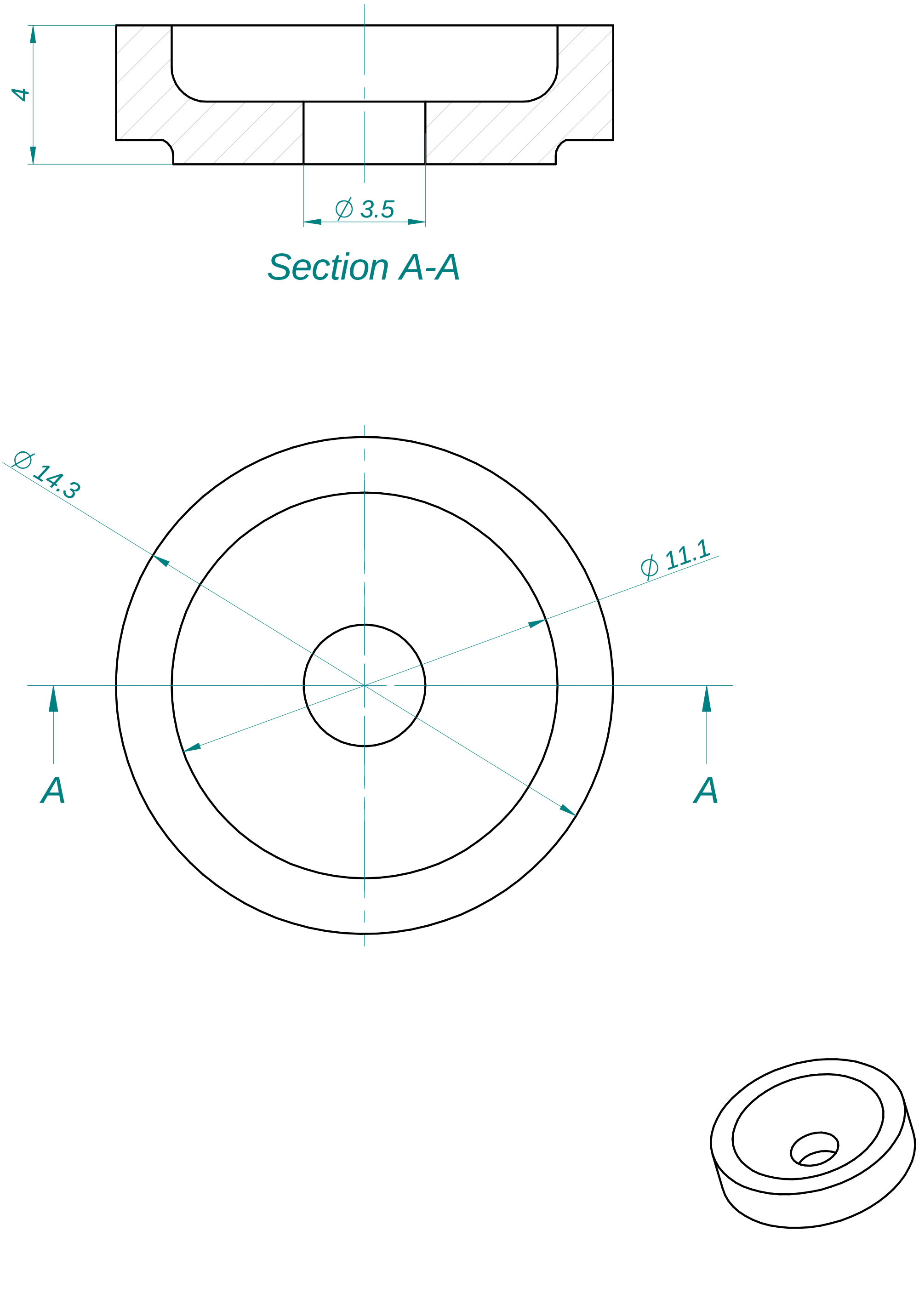
SCALE: 10/1	6,00 x 2,50 O-Ring	QUANTITY:	02
		FORMAT:	DIN A4
		No. Drawing:	05



Design of an automatic degassing head for dosing pumps

DELIVERY DATE:	12/06/2022	MATERIAL:	PVDF or PP	MASS:	0,5 g
DRAWN:	Mounir Ghailan Tribak	DRAWING DATE:	12/06/2022		
REVIEWED:	Joan Grau Barceló	REVIEW DATE:	13/06/2022		

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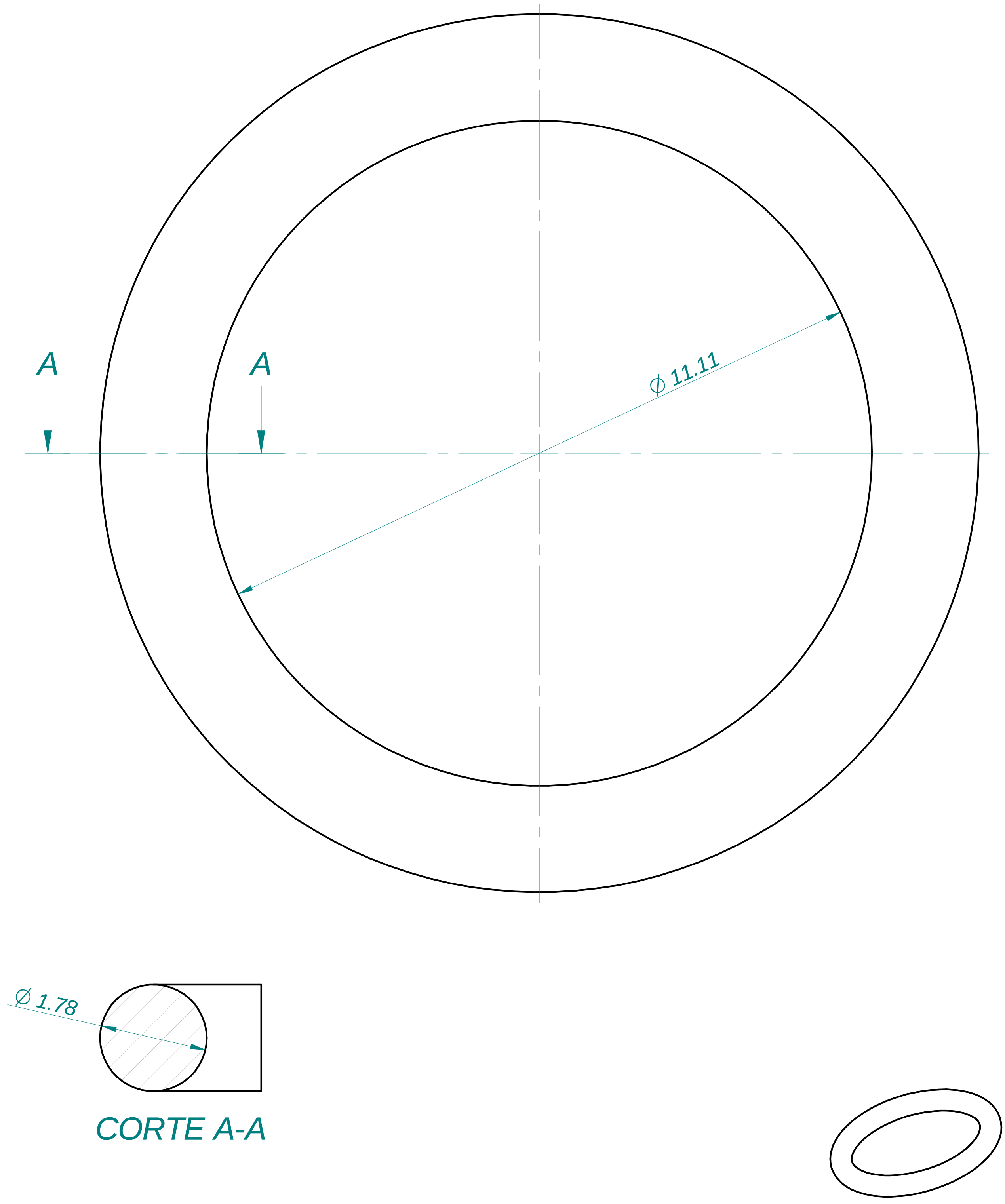
SCALE: 5/1	Upper groove piece	QUANTITY:	02
		FORMAT:	DIN A4
		No. Drawing:	06



Design of an automatic degassing head for dosing pumps

DELIVERY DATE:	12/06/2022	MATERIAL:	FPM	MASS:	0,2
DRAWN:	Mounir Ghailan Tribak	DRAWING DATE:	12/06/2022		
REVIEWED:	Joan Grau Barceló	REVIEW DATE:	13/06/2022		

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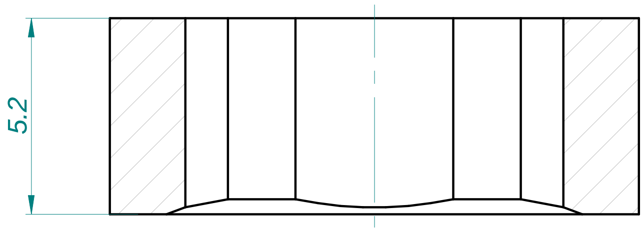
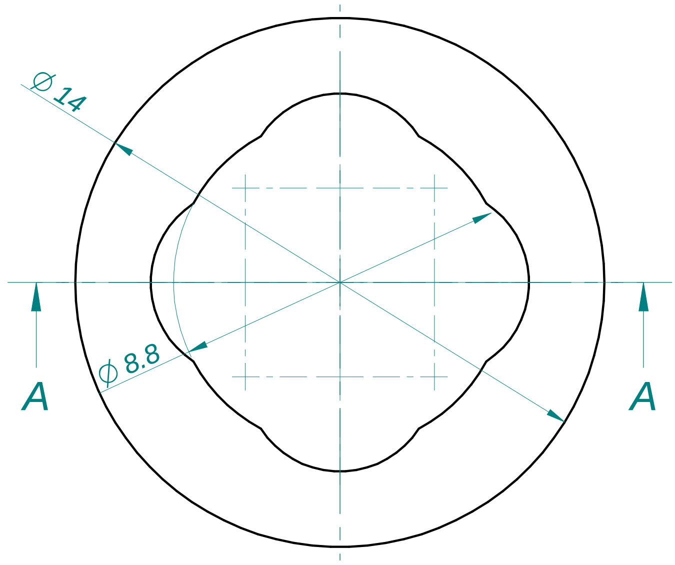
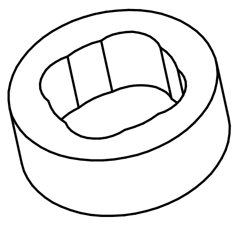
Escola d'Enginyeria de Barcelona Est

SCALE: 10/1	11,11 x 1,78 O-Ring	QUANTITY:	02
		FORMAT:	DIN A4
		No. Drawing:	07

Section A-A







Design of an automatic degassing head for dosing pumps

DELIVERY DATE:	12/06/2022	MATERIAL:	PVDF or PP	MASS:	0,5 g	UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH Escola d'Enginyeria de Barcelona Est
DRAWN:	Mounir Ghailan Tribak		DRAWING DATE:	12/06/2022		
REVIEWED:	Joan Grau Barceló		REVIEW DATE:	13/06/2022		

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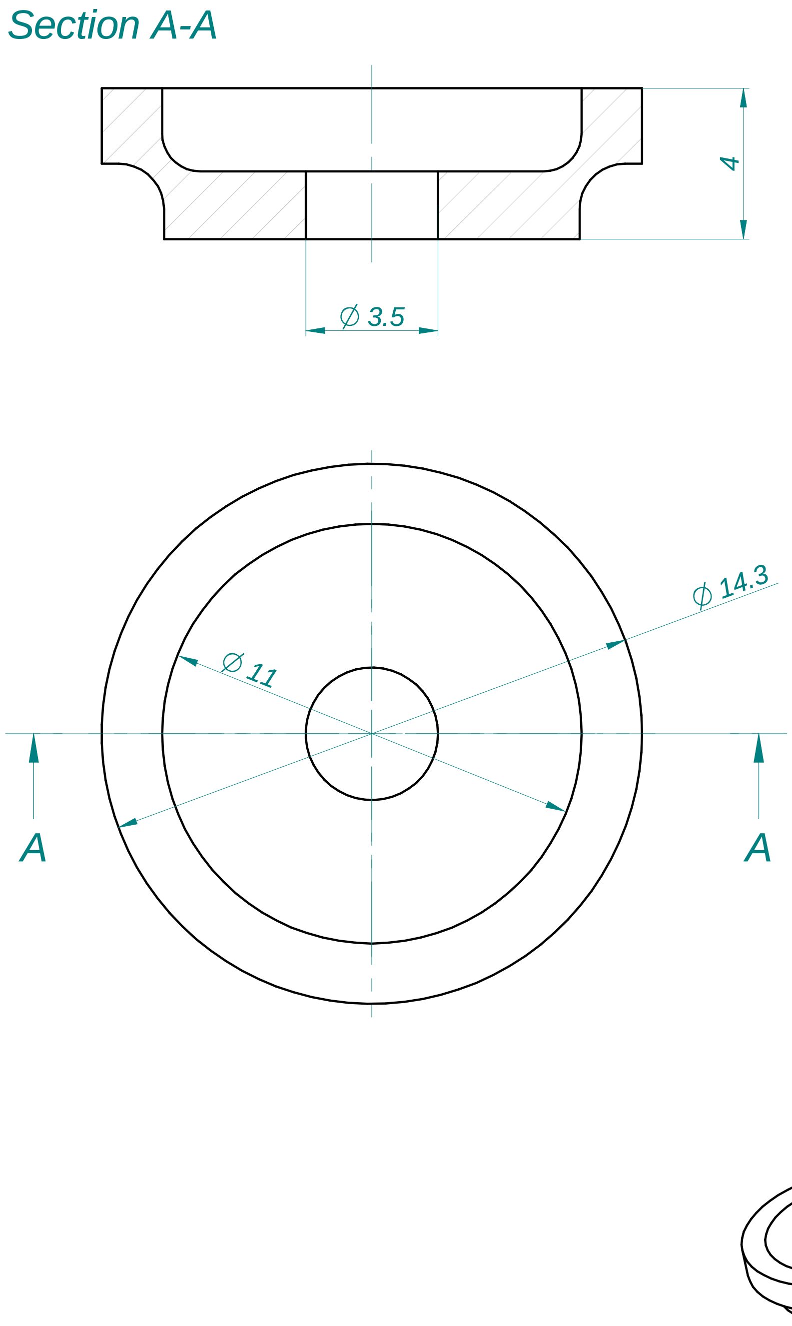
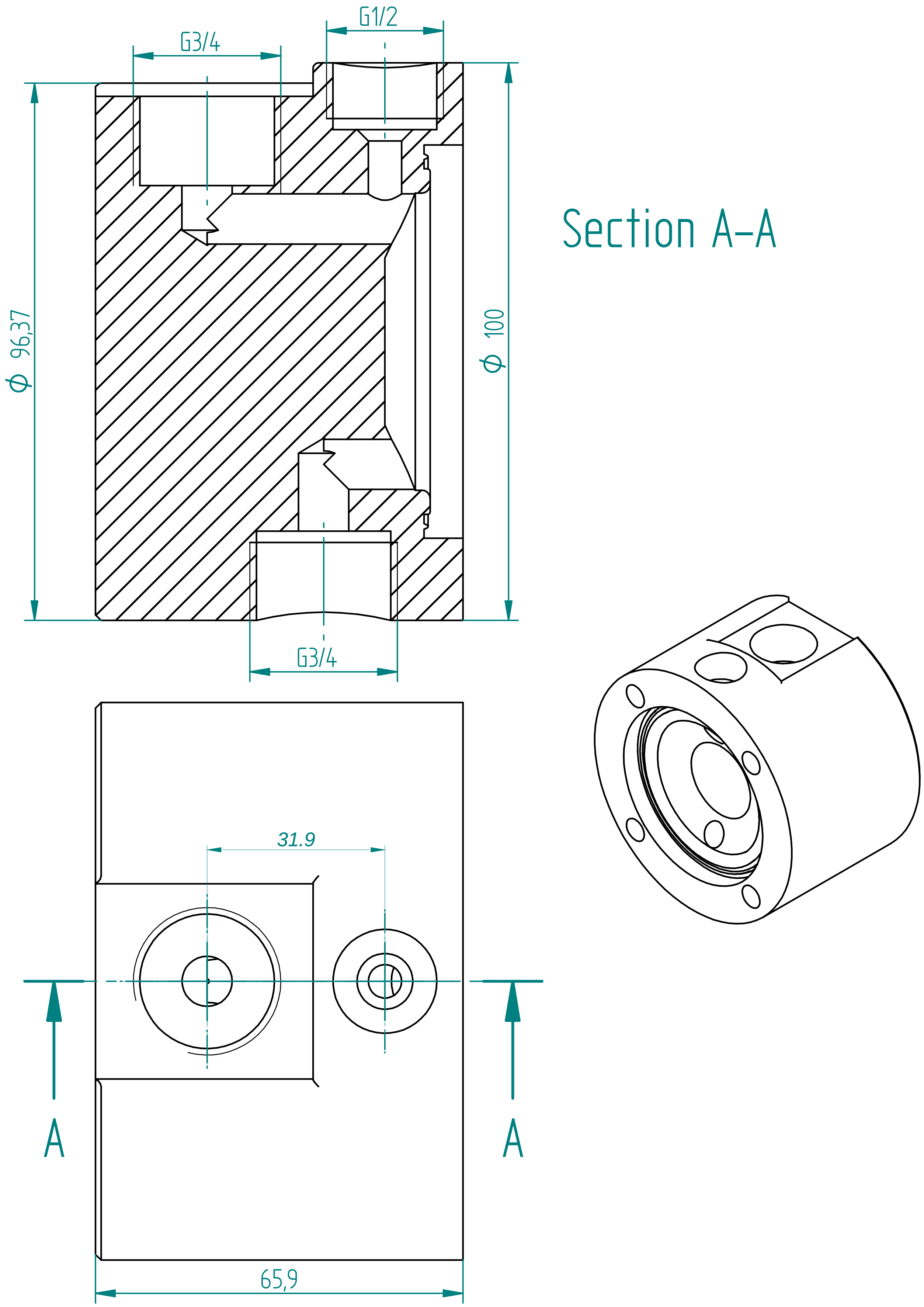


Design of an automatic degassing head for dosing pumps

DELIVERY DATE:	12/06/2022	MATERIAL:	PVDF or PP	MASS:	0,4 g
DRAWN:	Mounir Ghailan Tribak	DRAWING DATE:	12/06/2022		
REVIEWED:	Joan Grau Barceló	REVIEW DATE:	13/06/2022		

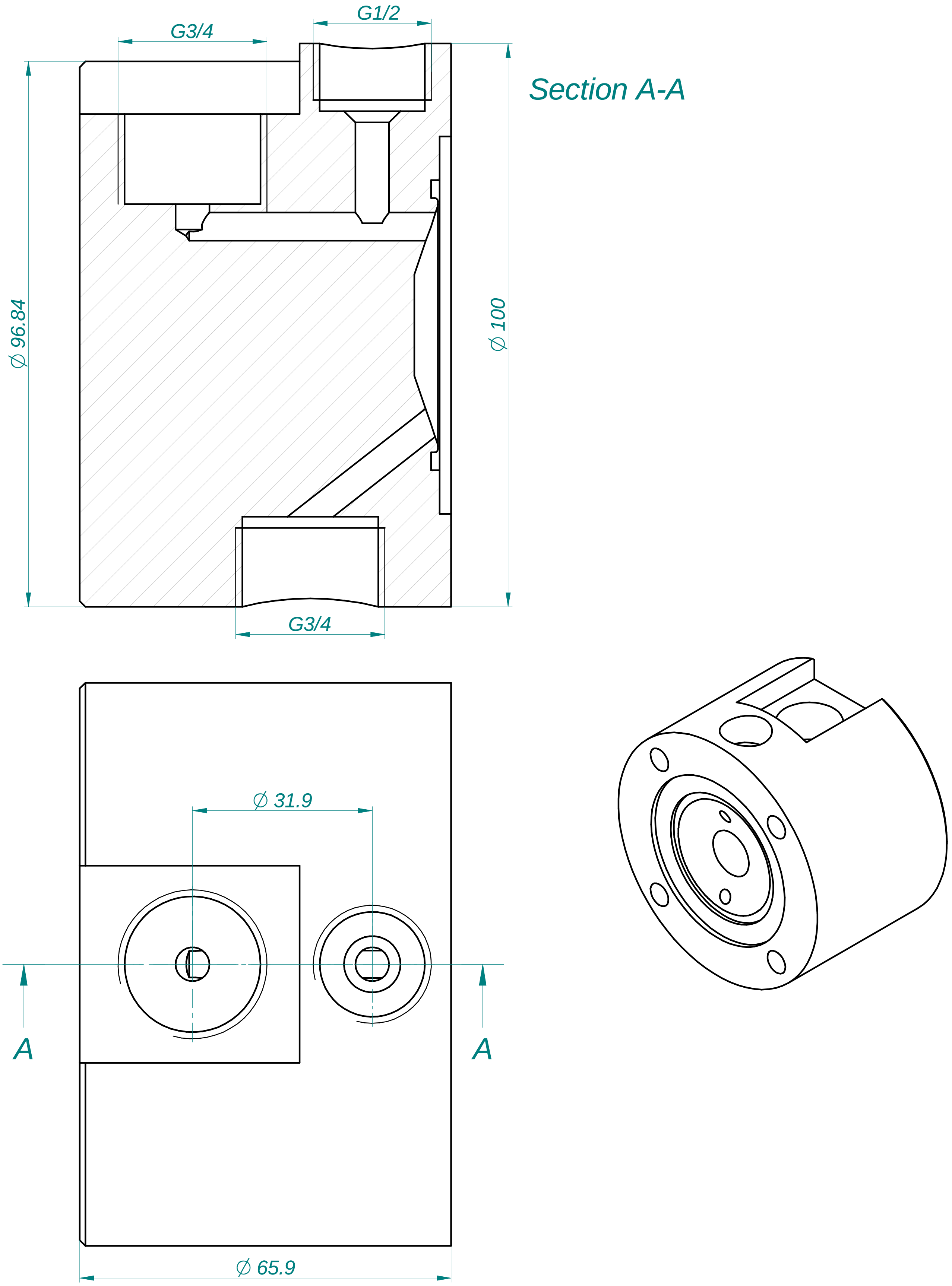
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Escola d'Enginyeria de Barcelona Est

SCALE: 5/1	Lower groove piece	QUANTITY:	01
		FORMAT:	DIN A4
		No. Drawing:	09



Design of an automatic purge valve for metering pumps

DELIVERY DATE:	12/06/2022	MATERIAL:	PVDF or PP	MASS:	539,1 g	UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH Escola d'Enginyeria de Barcelona Est	
DRAWN:	Mounir Ghailan Tribak	DRAWING DATE:	12/06/2022				
REVIEWED:	Joan Grau Barceló	REVIEW DATE:	13/06/2022				
SCALE: 1/1	D69 Pump Head					QUANTITY:	01
						FORMAT:	DIN A4
						No. Drawing:	10



Design of an automatic degassing head for dosing pumps

DELIVERY DATE:	12/06/2022	MATERIAL:	PVDF or PP	MASS:	568
DRAWN:	Mounir Ghailan Tribak	DRAWING DATE:	12/06/2022		
REVIEWED:	Joan Grau Barceló	REVIEW DATE:	13/06/2022		

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
UPC
Escola d'Enginyeria de Barcelona Est

SCALE: 1/1	D50 Pump Head	QUANTITY:	01
		FORMAT:	DIN A4
		No. Drawing:	11

ITC DOSING PUMPS	**PLA DE CONTROL**		
PROTOTIP	x	**PRODUCTE: DEGASSING**	Pàgina 1 de 9
HOMOLOGACIÓ		**CODI:**	**Data: 01/03/22**

NIVELL	COMPONENT/ASSAIG	ESPECIFICACIÓ	MÈTODE	DATA	RESUL.	PERSONA
0	Càlculs teòrics: pressió dins del capçal amb diferents concentracions de gas Bomba 13l/h D50 D69	Determinar pressió als capçals D50 D69 amb gas. x=100% (concentració gas) $P_{D50,100\%}$ $P_{D69,100\%}$	Teòric .\Calculs\MaxPressureVSConcentrationOfGas (version 1).xlsb.xlsx	01-03-22 04-03-22	Inici Fi $P_{D50,100\%,teòrica}$=0,40 bar $P_{D69,100\%,teòrica}$=0,34 bar	Mounir Mounir
0	Proves experimentals: pressió dins del capçal amb diferents concentracions de gas Bomba 13l/h D50 D69	Corroborar càlculs tèorics. $P_{D50,100\%,experimental}$ (±5%) $P_{D69,100\%,experimental}$ (±5%)	Experimental Proves Pressió D50 .docx Proves Pressió D69.docx	11-03-22 18-03-22	Inici $P_{D50,100\%,experimental}$ = 0,42 bar(OK) $P_{D69,100\%,experimental}$ = 0,35 bar(OK) Fi	Mounir Mounir
0	Prova temps cebat sense degassing Bomba 13l/h D50 D69 Hasp=Hdiposit	Temps, 100% gas P_{D50}=0,4 bar P_{D50}=1 bar P_{D69}=0,34 bar P_{D69}= 1 bar	Cronometratge temps de cebat	18-03-22 23-03-22	Inici $t_{D50,0.4bar}$= 5min $t_{D50,1bar}$= No ceba $t_{D69,0.34bar}$=1 min $t_{D69,1bar}$= No ceba Fi	Mounir Mounir
0	Prova temps cebat amb degassing i capçal ple d'aire Bomba 13l/h D50 D69 Caudal= 1l/h Hasp=Hdiposit	Temps, 100% gas P_{D50}=1 bar P_{D69}= 1 bar	Cronometratge temps de cebat	23-03-22 25-03-22	Inici $t_{D50,0.4bar}$=30 s $t_{D69,0.34bar}$=20 s $t_{D50,1bar}$=19 s $t_{D69,1bar}$=39 s Fi	Mounir Mounir

PLA DE CONTROL

PROTOTIP	x	**PRODUCTE: DEGASSING**	
HOMOLOGACIÓ		**CODI:**	**Data: 01/03/22**

0	Prova rendiment volumètric amb degassing per a diferents regulacions Bomba 13l/h D50 D69 P=3 bar Hasp=Hdiposit	Rendiment volumètric al 100% i 50% de la velocitat màxima de la bomba. Mesurar sortida degassing amb una proveta fins 200ml amb diferents velocitats	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	22-03-22	$\eta_{D50,100\%}$=60% (NO OK) $\eta_{D69,100\%}$=88% (OK) $\eta_{D50,50\%}$=0% (NO OK) $\eta_{D69,50\%}$=33% (NO OK)	Mounir
0	Prova rendiment volumètric amb degassing per a diferents pressions Velocitat=100% Bomba 13l/h D50 D69	Rendiment volumètric a 1bar y 2bar $\eta_v = V_{degassing}/V_{aspirat}$ $\eta_{v,admissible} > 0,80$ Mesurar sortida degassing amb una proveta per a diferents pressions de sortida	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	22-03-22	$\eta_{D50,1bar}$=38% (NO OK) $\eta_{D69,1bar}$=73%(NO OK) $\eta_{D50,2bar}$=63%(NO OK) $\eta_{D69,2bar}$=88%(OK)	Mounir
0	Conclusions		Conclusions_PrimerDissenyDegassing.docx	25-03-02	NO OK	Mounir
1	Prova rendiment volumètric amb degassing per a diferents regulacions **amb recorregut 6mm** P=3 bar Bomba 13l/h D50 D69	Rendiment volumètric al 100% i 50% de la velocitat màxima de la bomba Mesurar sortida degassing amb una proveta fins 200ml amb diferents velocitats. **La bola no tanca i surt tot el caudal per al degassing**	Mesura de volums amb proveta	01-04-22	$\eta_{D50,100\%}$=0%(NO OK) $\eta_{D69,100\%}$=0%(NO OK) $\eta_{D50,50\%}$=0%(NO OK) $\eta_{D69,50\%}$=0%(NO OK)	Mounir
1	Prova rendiment volumètric amb degassing per a diferents pressions **amb recorregut 6mm** Velocitat=100% Bomba 13l/h D50 D69	Rendiment volumètric a 1bar y 2bar $\eta_v = V_{degassing}/V_{aspirat}$ $\eta_{v,admissible} > 0,80$ Mesurar sortida degassing amb una proveta per a diferents pressions de sortida **La bola no tanca i surt tot el caudal per al degassing**	Mesura de volums amb proveta	01-04-22	$\eta_{D50,1bar}$=0%(NO OK) $\eta_{D69,1bar}$=0%(NO OK) $\eta_{D50,2bar}$=0%(NO OK) $\eta_{D69,2bar}$=0%(NO OK)	Mounir

1	Prova rendiment volumètric amb degassing per a diferents regulacions **amb recorregut 4mm** P=3 bar Bomba 13l/h D50 D69	Rendiment volumètric al 100% i 50% de la velocitat màxima de la bomba **La bola no tanca i surt tot el caudal per al degassing**	Mesura de volums amb proveta		$\eta_{D50,100\%}$=0%(NO OK) $\eta_{D69,100\%}$=0%(NO OK) $\eta_{D50,50\%}$=0%(NO OK) $\eta_{D69,50\%}$=0%(NO OK)	Mounir
1	Prova rendiment volumètric amb degassing per a diferents pressions **amb recorregut 4mm** Velocitat=100% Bomba 13l/h D50 D69	Rendiment volumètric a 1bar y 2bar $\eta_v=V_{degassing}/V_{aspirat}$ $\eta_{v,admissible}>0,80$ Mesurar sortida degassing amb una proveta per a diferents pressions de sortida **La bola no tanca i surt tot el caudal per al degassing**	Mesura de volums amb proveta		$\eta_{D50,1bar}$= 0%(NO OK) $\eta_{D69,1bar}$= 0%(NO OK) $\eta_{D50,2bar}$= 0%(NO OK) $\eta_{D69,2bar}$= 0%(NO OK)	Mounir
1	Conclusions	S'ha de minimitzar el recorregut de la bola		05-04-22		Mounir
1	Prova rendiment volumètric amb degassing i recorregut de la bola de vidre de **1,5mm** Velocitat=100% Bomba 13l/h D50 D69 P= 2bar	$\eta_v=V_{degassing}/V_{aspirat}$ $\eta_{v,admissible}>0,80$ Mesura del volum que surt pel degassing i del volum aspirat	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	(Inici) 05-04-22 11-04-22 (fi)	$\eta_{D50,2bar}$= 95% $\eta_{D69,2bar}$= 99%	Mounir

1	Prova rendiment volumètric amb degassing i recorregut de la bola de vidre de **0,5mm** Velocitat=100% Bomba 13l/h D50 D69 P= 2bar	$\eta_v=V_{degassing}/V_{aspirat}$ $\eta_{v,admissible}>0,80$ Mesura del volum que surt pel degassing i del volum aspirat	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	(Inici) 05-04-22 11-04-22 (fi)	$\eta_{D50,2bar}$= 98%(OK) $\eta_{D69,2bar}$= 99%(OK)	Mounir
1	Prova temps de cebat. Capçal ple de gas. Recorregut bola de vidre 0,5mm P=5bar Bomba 13l/h D50 Velocitat 100% $H_{asp}=H_{diposit}$	Mesura del temps que tarda en cebar la bomba amb el capçal completament ple de gas	Mesura de volums amb proveta	05-04-22	t= ∞ (NO OK) corroborat	Mounir
1	Prova mínim caudal per a bola de vidre Recorregut=0,5mm	Mesura el caudal mínim per la qual la bola de vidre del degassing deixa de tancar	Visual	11-04-22	V_{min}=260ml/h (2%) (OK)	Mounir
1	Conclusions bola de vidre recorregut 1,5 i 0,5mm	Els rendiments son bons però en ocasions la bola es queda bloquejada a la tòrica de dalt.		11-04-22	NO OK	Mounir
1	Prova mínim caudal per a bola ceràmica. **Recorregut=0,5mm**	Mesura el caudal mínim per la qual la bola de vidre del degassing deixa de tancar.	Visual	11-04-22	V_{min}=5,2l/h(40%)	Mounir
1	Prova **bola de Polipropilè**	La bola flota i no hi han pèrdues de producte. En el procés d'aspiració permet la entrada de aire dins del capçal	Visual	11-04-22	NO OK	Mounir
1	Càlcul rendiment volumètric amb degassing i bola de vidre **per a velocitat 5%** Recorregut 1,5mm i 0,5mm Bomba 13l/h D50 D69 P=2bar	$\eta_v=V_{degassing}/V_{aspirat}$ $\eta_{v,admissible}>0,80$ Mesura del volum que surt pel degassing i del volum aspirat.	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	11-04-22	$\eta_{D50,0,5mm}$= 98%(OK) $\eta_{D50,1,5mm}$= 95%(OK) $\eta_{D69,0,5mm}$= 99%(OK) $\eta_{D69,1.5mm}$= 99%(OK)	Mounir

1	Conclusions	Els rendiments son correctes. La bola segueix bloquejant-se independentment del material		11-04-22	NO OK	Mounir
1	Prova temps de cebat. Capçal ple de gas. Recorregut bola de vidre 0,5mm i 1,5mm P=5bar Bomba 13l/h **D69** Velocitat 100% $H_{asp}=H_{diposit}$	Mesura del temps que tarda en cebar la bomba amb el capçal completament ple de gas $t_{0.5mm,D69}$ $t_{1.5mm,D69}$	Cronometratge	12-04-22	$t_{0.5mm,D69}=\infty$ NO OK $t_{1.5mm,D69}=\infty$ NO OK	Mounir
1	Càlcul rendiment volumètric amb degassing i bola de vidre **per a velocitat 100% 75% i 50%** Recorregut 4mm Bomba 13l/h **D50** P=2bar	$\eta_v=V_{degassing}/V_{aspirat}$ $\eta_{v,admissible}>0,80$ Mesura del volum que surt pel degassing i del volum aspirat. $\eta_{D50,100\%}$ $\eta_{D50,75\%}$ $\eta_{D50,50\%}$	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	13-04-22	$\eta_{D50,100\%}$=94%(OK) $\eta_{D50,75\%}$=74%(NO OK) $\eta_{D50,50\%}$=61%(NO OK)	Mounir
1	Càlcul rendiment volumètric amb degassing i bola de vidre **per a velocitat 100% 75% 50% 25%** Recorregut 4mm Bomba 13l/h **D69** P=2bar	$\eta_v=V_{degassing}/V_{aspirat}$ $\eta_{v,admissible}>0,80$ Mesura del volum que surt pel degassing i del volum aspirat. $\eta_{D69,100\%}$ $\eta_{D69,75\%}$ $\eta_{D69,50\%}$ $\eta_{D69,25\%}$	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	13-04-22	$\eta_{D69,100\%}$=99%(OK) $\eta_{D69,75\%}$=98%(OK) $\eta_{D69,50\%}$=94%(OK) $\eta_{D69,25\%}$=88%(OK)	Mounir
1	Prova temps de cebat. Capçal ple de aire. Recorregut bola de vidre 1,5mm P=4bar Bomba 13l/h **D50** Velocitat 100% $H_{asp}=H_{diposit}$	Mesura del temps que tarda en cebar la bomba amb el capçal completament ple de gas $t_{1.5mm,D50}$	Cronometratge	13-04-22	$t_{1.5mm,D50}=\infty$(NO OK)	Mounir

1	Prova temps de cebat. Capçal ple de aire. Recorregut bola de vidre 4mm P=4bar Bomba 13l/h **D50** Velocitat 100% $H_{asp}=H_{diposit}$	Mesura del temps que tarda en cebar la bomba amb el capçal completament ple de gas $t_{4mm,D50}$	Cronometratge	13-04-22	$t_{4mm,D50}$= 3s (OK)	Mounir
1	Prova temps de cebat. Capçal ple de aire. Recorregut bola de vidre 4mm P=4bar Bomba 13l/h **D69** **Velocitat 50%** $H_{asp}=H_{diposit}$	Mesura del temps que tarda en cebar la bomba amb el capçal completament ple de gas $t_{4mm,D69}$	Cronometratge	13-04-22	$t_{4mm,D69}$=5 sec (OK)	Mounir
1	Prova temps de cebat. Capçal ple de aire. Recorregut bola de vidre 3mm P=4bar Bomba 13l/h **D69** **Velocitat 100%** $H_{asp}=H_{diposit}$	Mesura del temps que tarda en cebar la bomba amb el capçal completament ple de gas $t_{3mm,D69}$	Cronometratge	13-04-22	$t_{3mm,D69}$=	Mounir
1	Càlcul rendiment volumètric amb degassing i bola de vidre **per a velocitat 100% 75% 50% 25% Recorregut 3mm** Bomba 13l/h **D69** P=2bar	$\eta_v=V_{degassing}/V_{aspirat}$ $\eta_{v,admissible}>0,80$ Mesura del volum que surt pel degassing i del volum aspirat. $\eta_{D69,100\%}$ $\eta_{D69,75\%}$ $\eta_{D69,50\%}$ $\eta_{D69,25\%}$=	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	13-04-22	$\eta_{D69,100\%}$=99%(ok) $\eta_{D69,75\%}$=99%(ok) $\eta_{D69,50\%}$=98%(ok) $\eta_{D69,25\%}$=96%(ok)	Mounir
1	Prova mínim caudal Bola de vidre **D69** **Recorregut= 3mm**		Visual		$Caudal_{min,D69,3mm}$=	
1	Prova temps de cebat. Capçal ple de aire. Recorregut bola de vidre 3mm P=4bar Bomba 13l/h **D50** **Velocitat 100%** $H_{asp}=H_{diposit}$	Mesura del temps que tarda en cebar la bomba amb el capçal completament ple de gas $t_{3mm,D69}$	Cronometratge	13-04-22	$t_{3mm,D50}=\infty$(NO OK)	Mounir

PLA DE CONTROL

PROTOTIP	***x***	***PRODUCTE: DEGASSING***	
HOMOLOGACIÓ		***CODI:***	***Data: 01/03/22***

1	Càlcul rendiment volumètric amb degassing i bola de vidre **per a velocitat 100% 75% 50% 25%** **Recorregut 3mm** Bomba 13l/h **D50** P=2bar	$\eta_v=V_{degassing}/V_{aspirat}$ $\eta_{v,admissible}>0{,}80$ Mesura del volum que surt pel degassing i del volum aspirat. $\eta_{D69,100\%}$ $\eta_{D69,75\%}$ $\eta_{D69,50\%}$ $\eta_{D69,25\%}$	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	13-04-22	$\eta_{D50,100\%}$=(NO OK) $\eta_{D50,75\%}$=(NO OK) $\eta_{D50,50\%}$=(NO OK) $\eta_{D50,25\%}$=(NO OK) La bola no tanca	Mounir
1	Conclusions	Creiem que la bola s'encalla en la tòrica superior. Es treu la tòrica superior i es crea un nou disseny que permeti tancar sense tòrica.		20-04-22		
1	Prova funcionament sense la junta tòrica de dalt. Recorregut=2.7mm D69 13l/h	Observem si s'encalla la bola	Visual	22-04-22	OK	Mounir
1	Prova temps de cebat. Capçal ple de aire. Recorregut bola de vidre 2.7mm **Sense tòrica superior chaflàn 1mm** P=4bar Bomba 13l/h **D69** **Velocitat 100%** $H_{asp}=H_{diposit}$	Mesura del temps que tarda en cebar la bomba amb el capçal completament ple de gas $T_{2.7mm,D69}$	Cronometratge	22-04-22	$t_{2.7mm,D69}$=4s(OK)	Mounir
1	Càlcul rendiment volumètric amb degassing i bola de vidre **per a velocitat 50% 25%** **Sense tòrica superior** **Recorregut 1.7mm** Bomba 13l/h **D69** P=4bar	$\eta_v=V_{degassing}/V_{aspirat}$ $\eta_{v,admissible}>0{,}80$ Mesura del volum que surt pel degassing i del volum aspirat. $\eta_{D69,50\%,4bar}$ $\eta_{D69,25\%,4bar}$	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	26/04/22	$\eta_{D69,50\%,4bar}$=63%(NO OK) $\eta_{D69,25\%,4bar}$=27%(NO OK)	Mounir
1	Conclusions degassing 1 bola	El degassing aspira aire dins del capçal quan es treballa amb depressions de a partir de 0,5m de altura d'aigua			NO OK	

2	Degassing amb dues boles	Disseny del degassing amb dues boles per evitar la entrada d'aire per al degassing				
2	Prova temps de cebat. Capçal ple de aire. Recorregut bola de vidre 0,5mm P=4bar Bomba 13l/h **D50** **Velocitat 1% i 100%** H_{asp}=$H_{diposit}$	Mesura del temps que tarda en cebar la bomba amb el capçal completament ple de gas	Visual	03/05/22	$T_{0,5mm,1\%}$=4s(OK) $T_{0,5mm,100\%}$= ∞ (NO OK)	
2	Prova temps de cebat. Capçal ple d'aire. Recorregut bola de vidre 1,5mm P=4bar Bomba 13l/h **D50** **Velocitat 1% i 100%** H_{asp}=$H_{diposit}$	Mesura del temps que tarda en cebar la bomba amb el capçal completament ple de gas	Visual	03/05/22	$T_{1,5mm,1\%}$=190s (OK) $T_{1,5mm,100\%}$= 3s(OK)	
2	Càlcul rendiment volumètric amb degassing i bola de vidre **Recorregut 1,5 mm** Bombes 13l/h 60l/h 1,5l/h 4l/h	η_v=$V_{degassing}$/$V_{aspirat}$ $\eta_{v,admissible}$>0,80 Mesura del volum que surt pel degassing i del volum aspirat.	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	04/05/22	$\eta_{13l/h}$= OK $\eta_{60l/h}$= OK $\eta_{1,5l/h}$= NO OK $\eta_{4l/h}$= NO OK	
	Càlcul rendiment volumètric amb degassing i bola de vidre **Recorregut 0,5 mm** Bombes 13l/h 60l/h 1,5l/h 4l/h	η_v=$V_{degassing}$/$V_{aspirat}$ $\eta_{v,admissible}$>0,80 Mesura del volum que surt pel degassing i del volum aspirat.	Mesura de volums amb proveta P:\ENGINYERIA\55 DOSMART\1-Disseny\Proves\Rendiments_volumetrics_degassing.xlsx	10/05/22	$\eta_{13l/h}$=NO OK $\eta_{60l/h}$=NO OK $\eta_{1,5l/h}$=OK $\eta_{4l/h}$= OK	
	Conclusions	Bombes 60l/h i 13l/h amb recorregut 1,5mm Bombes 4l/h i 1,5l/h amb recorregut 0,5mm	Degassing_Presentació.pptx	13/05/22		

VERIFICACIÓ DEL DISSENY / HOMOLOGACIÓ				
CONCLUSIÓ: - ACCEPTAT: ____ - REBUTJAT: ____ - ACCEPTAT CONDICIONAL: ____		OBSERVACIONS:		
Gerència	**Comercial**	**Qualitat**	**Enginyeria**	**Producció**
Firma i data:	Firma i data:	Firma i data:	Firma i data:	Firma i data: