Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Wax Dispenser

Desgin and automation of a wax pouring station

Semester Thesis

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Abstract

The development of rapid Polymerase Chain Reaction (PCR) testing technologies necessitates enhancements in sample preservation and processing efficiency. Diaxxo is a spin-off of the functional Material Laboratory at the chemistry department of ETH, specializing in rapid PCR tests. The manual dispensation of paraffin wax into test cartridges, so-called diaxxoPods, presented challenges in scalability and process consistency, affecting the reliability of test results and sample integrity during shipping. This semester project aimed to automate the wax dispensing process, thereby increasing the production throughput and enhancing the quality of Diaxxo's PCR test cartridges.

The project was methodically approached through four main phases: initially, various wax dispensing techniques were explored to optimize the evenness and adhesion of wax within the diaxxoPods. Different orientations and mask designs were tested to determine the most effective method for wax deposition. Subsequently, the diaxxoPods underwent rigorous shock testing to evaluate the durability of the wax under simulated transport conditions. The selection and integration of mechanical components suitable for automating the wax dispensing process followed, focusing on precision and reliability. Finally, the entire system was automated, involving the automation of the wax dispensing via controlled motors and valves and the synchronization of diaxxoPod movement to ensure consistent wax deposition across all test diaxxoPods. The outcomes of these developments demonstrated a marked improvement in the deposition accuracy and uniformity of the wax, with the enhanced mechanical design proving resilient under stress tests. The automation of the dispensing process not only elevated the production rate but also significantly reduced manual handling errors, reinforcing the reliability of the PCR test diaxxoPods.

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Chapter 1

Introduction

Diaxxo is specialized in the production of rapid Polymerase Chain Reaction (PCR) tests. Polymerase Chain Reaction is a well-known technology that allows to create multiple copies of DNA. It consists of multiple heating and cooling cycles, which allow, at every cycle, the duplication of the DNA target sequence. The goal is to recreate enough DNA for multiple testing uses, such as sequencing or identifying infection and disease. These tests are critical for timely disease detection and management. Diaxxo aims at bringing their own PCR technology, particularly in fast-paced clinical settings or areas with limited access to traditional laboratory facilities.

Overview of the diaxxoCare Test Process

The diaxxoCare is a machine developed by Diaxxo that enables the user to perform DNA extraction and PCR tests on an all-in-one device. The diaxxoCare test incorporates a series of steps designed to facilitate efficient and safe PCR testing inside the so-called diaxxoPod (see Fig. 1.1). The utilization guide of the diaxxoCare is attached in the appendix (figure A.11). Below is a detailed panorama of each stage in the manufacturing process of the diaxxoPod, outlining the key features and inherent challenges:

Step 1: Diaxxopod and Wax Introduction

The process begins with the introduction of wax into the diaxxoPods. This step ensures that after the sequence testing, the reaction sites are sealed by the wax, minimizing the contamination of labware and environment and improving the usability and disposing of the test cartridge. (see fig. 1.3)

Step 2: PCR Mastermix Loading

PCR mastermix is carefully loaded into the wells. Precision is crucial here to prevent spills and ensure that the mastermix is contained within the designated reaction areas.

Step 3: Lyophilization Process

The contents are then lyophilized, or freeze-dried. This process is essential for preserving the PCR reagents, enabling long-term storage and stability under various temperature conditions.

Step 4: Vacuum packaging

The diaxxoPod is then packaged under vacuum to preserve the stability of the reagents in their dry form and guarantee long shelf life after packaging. (see Fig. 1.2)

Step 5: Sample Addition at the Time of the Test

In the diaxxoCare machine, during the test, a sample is added. This step requires careful handling to avoid introducing contaminants that could affect the test's accuracy.

Step 6: Oil Addition at the Time of the Test

Oil is added by the machine to the wells to prevent evaporation of the sample during the heating process, which is critical for consistent PCR performance.

Step 7: PCR Process

During the denaturation process of the PCR reaction, where the temperature rises above 90 degrees, the wax quickly melts and mixes with the oil, ensuring that the final sealing layer is homogeneous. This mixing process and its homogeneity are vital to prevent oil leakage afterward.

Step 8: End of the Reaction

After the PCR cycle, the wax and oil mixture cools down and solidifies, ensuring the sealing of the diaxxo-Pod. This step is critical for safely containing the used mixture, which is crucial to prevent contamination of the lab environment.
Highlighting the usability feature, it is important that the diaxxoPod is properly disposed of to maintain lab safety and integrity.

Figure 1.1: Image of a diaxxoPod

Figure 1.2: DiaxxoPod packaged under vacuum

1.1 Rationale for the Work

The core of Diaxxo's innovation lies in its proprietary PCR test cartridges, which are designed to hold samples in twenty individual wells (see figure 1.1). The PCR mix is located in the wells in a dry form. A notable feature of these diaxxoPods is the inclusion of paraffin wax, which is used to preserve the sample during the reaction and seal it at the end. Initially, the process of adding paraffin wax to the diaxxoPods was performed manually, involving the dispensation of liquid wax by means of a manual pipette at molten state into masks adjacent to the wells. This method, while functional, posed several challenges in terms of efficiency, consistency, and scalability.

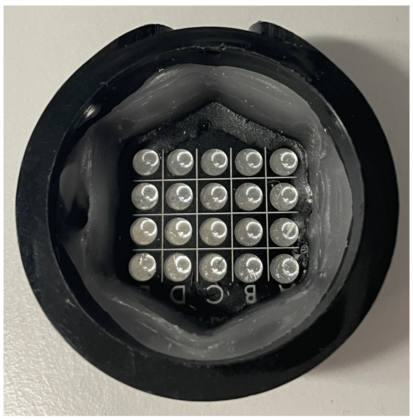


Figure 1.3: Image of a diaxxoPod before the step 7, with solidified wax deposited (step 1)

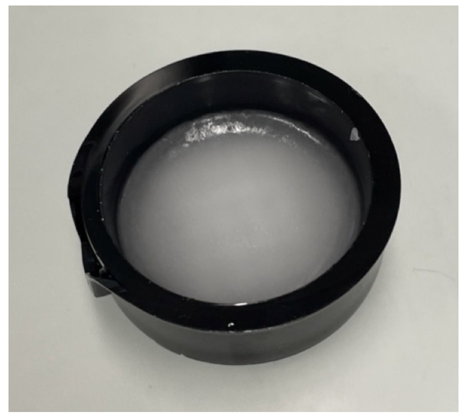


Figure 1.4: diaxxoPod after the step 7 : the wax melted during the process and solidified

The manual process not only required significant labor but also presented issues with uniformity and precision in wax deposition, which could potentially affect the stability of the wax and, consequently, the reliability of the PCR tests, as well as the integrity during transport. To address these challenges, the project was undertaken with three main objectives:

- Develop an improved method for dispensing paraffin wax that enhances the accuracy and uniformity of the deposition.
- To ensure the durability of the wax within the diaxxoPods, it is essential that the wax withstands the mechanical stresses commonly experienced during shipping to preserve the integrity of the samples: the wax should neither migrate into the wells nor detach from the diaxxoPods. Furthermore, the wax must maintain its stability amid temperature variations likely to occur during transit, which can range from below 0 to 50 degrees Celsius.
- Design and implement a mechanized system for wax dispensation to replace the manual pipetting process, thereby increasing production throughput and reducing human error.

1.2 Overall aproach

This thesis explores the aforementioned objectives through a systematic approach involving experimental design, prototype development, and testing. The study was structured around three principal phases:

- Experimentation with various dispensing techniques and mask geometries to identify optimal configurations that promote even wax distribution and adhesion.

- Conducting mechanical shock tests to determine the resilience of the wax within the diaxxoPod structure under conditions simulating transport stresses.
- Conceptualizing and engineering an automated dispensing machine capable of efficiently and reliably executing the wax deposition process.

Chapter 2

Related Work

Challenges and Groundwork in Automated Wax Dispensation

Although machines capable of dispensing small amounts of liquid at precise volumes exist, two primary challenges hinder their application to our specific needs: the typical dispensing medium is not wax, and these machines rarely operate at the high temperatures required for wax, specifically 95 degrees Celsius. At Diaxxo we use these high temperatures so the wax is liquid and easier to pour. It then solidifies and take the shape of the mask. Additionally, these dispensing systems are generally not open to inspection, meaning their internal workings are concealed, complicating any potential modifications for our use.

Existing Groundwork

Despite these challenges, substantial foundational work has been laid in related areas which can inform our approach:

Wax Characteristics and Selection

Research Background: Previous work conducted by predecessors in the field of chemistry, particularly on paraffin wax, provides a solid basis for understanding the physical and chemical properties relevant to our application.
Choice of Paraffin Wax: The precedents research in the lab on paraffin wax highlights its suitability due to its melting point, which aligns well with our temperature requirements for effective dispensation. The choice of paraffin wax was driven by its favorable properties, such as low reactivity, good thermal stability, transparency when melted, efficiency and biocompatibility.

Materials for mask Construction

Industry Standards: The mold industry is highly developed, offering a wide range of material choices that have been proven effective for high-temperature applications.
Selection of Teflon: Previous work at diaxxo prior use of masks specifically identifies Teflon as an optimal material. Teflon was chosen for its non-stick properties and its ability to withstand the high temperatures involved in wax dispensation without degrading. This choice ensures that the masks can be reused multiple times while maintaining the integrity of the wax shapes.

Fluid Dispensing Machines

Industrial Adaptation: Adapting existing fluid dispensing technologies to handle high-temperature wax involves several modifications. First, the machine's material components must be compatible with higher temperatures to prevent any mechanical failure or alterations in the fluid's properties.
Visibility and Accessibility: Addressing the issue of limited visibility in commercial dispensing machines, custom modifications or the development of a bespoke machine might be necessary. Such a development would allow for direct observation and adjustments during operation, crucial for ensuring the precision and reliability of wax deposition.

Chapter 3

Materials and Methods

3.1 Methods for Wax Dispensation in the diaxxoPods

The initial task was to identify a method to accurately pour paraffin wax into the peripheral area of the diaxxoPod without contaminating or covering the wells. Paraffin wax is a solid at room temperature and has a melting temperature that generally ranges between 40 and 60 degrees Celsius depending on the crystallization process. The chosen wax has a melting point between 51 and 53 degrees Celsius. Three primary methods were considered:

1) Angling the diaxxoPods.
2) Applying the wax onto a cap that covers the diaxxoPods post-testing and then melting it.
3) Utilizing a mask.

Method 1: Angling the diaxxoPod

The first approach involved tilting the diaxxoPods at an angle to facilitate side deposition of the melted wax (see Fig.3.1). Several experiments were conducted by adjusting the angle from 45 degrees to 70 degrees. However, the outcomes were unsatisfactory. The wax lacked uniformity in thickness and often breached the containment of the diaxxoPods, resulting in imprecise and inconsistent deposition. Consequently, this method did not consistently achieve the desired wax accumulation in the diaxxoPods (see Fig. 3.2).

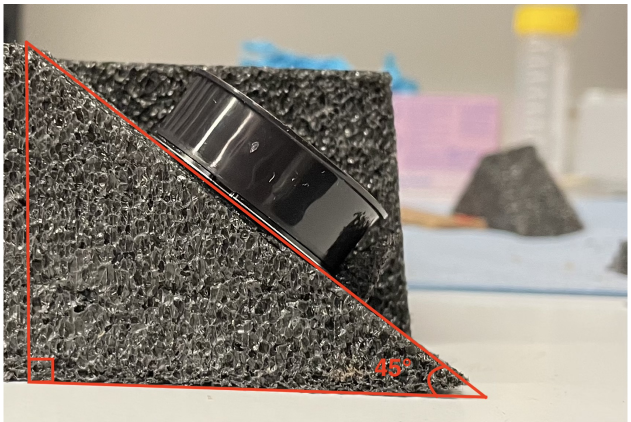


Figure 3.1: Test on a diaxxoPods with a 45 degrees angle

Figure 3.2: Wax disposition at 45 degrees angle

Method 2: Wax on the cap

The second strategy considered (the cap) was somewhat unconventional but feasible. We selected this method as a contingency plan should option A fail. We can see the process in figure 3.3. The goal would be to place the cap made of a mixture of oil and wax on the diaxxoPod (step1). Then heat the whole package (step2) : the cap would melt and seal the diaxxoPod (step 3). Then the diaxxoPod would be sealed. However, we ultimately dismissed it for several reasons: it required pre-mixing the wax with oil before deposition into a cap. This process proved to be lengthy and complex. Given the considerations of budget, time, and procedural complexity, this solution was not retained.

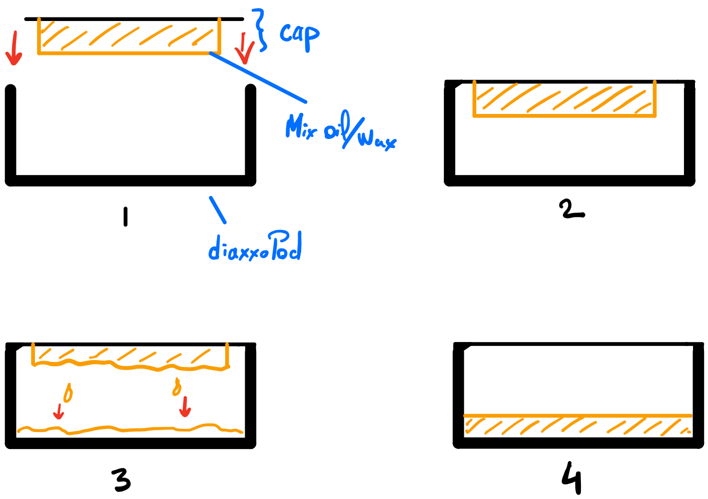


Figure 3.3: Process for the wax dispensation with a cap

Method 3: Using a mask

The final method implemented involved using a mask. The pre-existing mask had issues with wax adherence; upon removal, the wax would stick to the mask and break (see Fig. 3.4). The analysis indicated that this issue was primarily due to the mask's geometry ; specifically, the minimal thickness of the wax along the sides, which made it prone to breaking. To address this, I redesigned the mask to concentrate the wax accumulation on the two sides where there was more space. The mask's design was altered from the configuration shown in Fig. 3.3 to that of Fig. 3.5.

I conducted numerous tests, creating 15 different 3D-printed masks, varying in height, thickness, side angles, and using different materials (Teflon, PLA, and PETG).

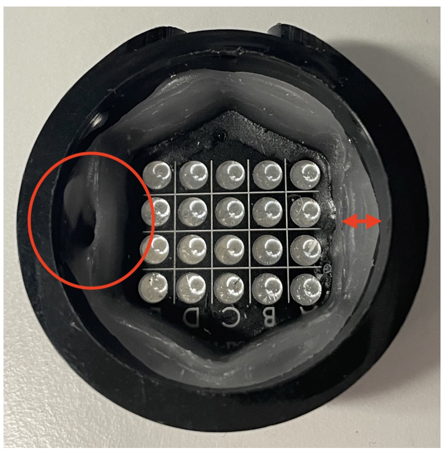


Figure 3.4: Previous wax deposition with an hexagonal shape

Figure 3.5: First mask prototype into a diaxxoPod

3.2 Shock test

The initial challenge was the shock test, which was critical to ensure the wax adhered firmly to the diaxxoPods during shipping. The wax needed to remain attached despite any acceleration or shock experienced during transport.

Description of the Shock Test: To perform the shock test, I held a diaxxoPod in my hand with wax deposited along its sides, rested my elbow on a table, and let my forearm fall so that the diaxxoPod would impact the table, simulating a shock. I had to repeat it 5 times to complete the test.

Shock Test Methodology

Person: Gabriel (me)
Height: Half arm: 40 cm
Repetition: 5 shocks
Force: Small/Medium/Hard x3
Success Criterion: Pass the first 3 shocks
Support: Rigid – Table/lab bench

Several strategies were evaluated to enhance wax adhesion during this shock test:

Surface Preparation (Scratching): Enhancing the surface texture of the diaxxoPods through scratching is a mechanical method aimed at increasing wax adhesion. The process involves creating small grooves on the diaxxoPod surfaces, which serve as physical anchors for the wax. These micro-abrasions increase the surface area and provide more points of contact for the wax, thereby improving its grip and preventing slippage. This method is particularly effective for materials that are otherwise smooth and non-porous, where wax may have difficulty adhering. For the tests, we used sandpaper foil to scratch manually the sides of the diaxxoPods.

Temperature Adjustment: Dispensing the wax at a higher temperature can significantly affect its adhesion properties. By increasing the temperature, the wax becomes more fluid, allowing it to flow into the micro-abrasions and other irregularities on the diaxxoPod surface more effectively. We can indeed see it in figure 3.6: the density of the wax decreases with the temperature. This improved flowability helps the wax to form a more comprehensive and cohesive bond with the diaxxoPod surfaces as it solidifies, embedding itself into the textures created by the scratching process. The key is to maintain a balance where the wax is hot enough to enhance adhesion without degrading the wax or the diaxxoPod materials.

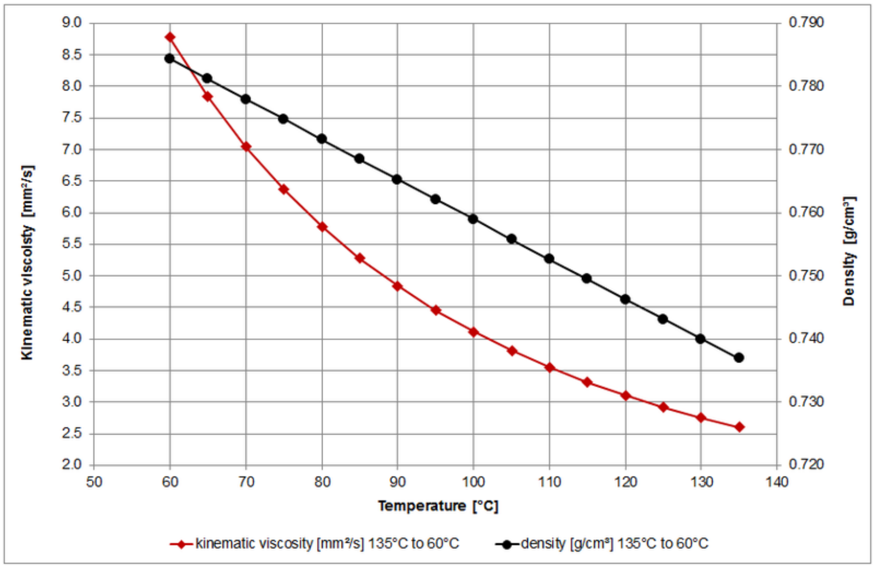


Figure 3.6: Wax - kinematic viscosity and density over temperature

Wax Quantity: Adjusting the quantity of wax used is crucial for optimizing coverage and adhesion without waste. By increasing the amount of wax, the contact surface area between the wax and the diaxxoPod is enlarged, which can potentially enhance adhesion. However, it is important to avoid excessive wax, which can lead to unnecessary material costs and may disrupt the balance and functionality of the diaxxoPod by adding excess weight or altering its thermal response. Careful calibration of wax quantity ensures effective adhesion while maintaining efficiency.

Mask Geometry: Redesigning the mask to incorporate an inward curve on the sides is a strategic adjustment aimed at improving wax coverage on the diaxxoPod surfaces. This geometric modification allows the wax to naturally rise up the curved sides during the dispensing process, thereby increasing the surface area covered by the wax without needing to increase the volume of wax used. The curved design helps in distributing the wax more evenly and in a controlled manner, which is critical for achieving consistent adhesion across all diaxxoPods.

Use of adhesive: Before wax deposition, applying a layer of epoxy glue to the diaxxoPod sides can greatly enhance adhesion. Epoxy glue is chosen for its robust properties, including high-temperature resistance and strong adhesive capabilities, which are essential for maintaining a durable bond between the wax and diaxxoPod surfaces. The glue acts as an intermediary adhesive layer that locks the wax in place, providing additional security against mechanical stresses that could dislodge the wax during handling or shipping.

Reheating Technique: Employing a reheating technique after the initial solidification of the wax involves carefully applying heat to the wax at the contact points with the diaxxoPods. This process allows the solidified wax to melt slightly and reform its bond with the DiaxxoPod surface. By reheating, the wax is encouraged to fill any gaps and to better integrate into the micro-textures of the diaxxoPod surface, ensuring a stronger and more resilient adhesion. This technique is particularly useful for correcting any inconsistencies in the initial wax deposition and solidification phases.

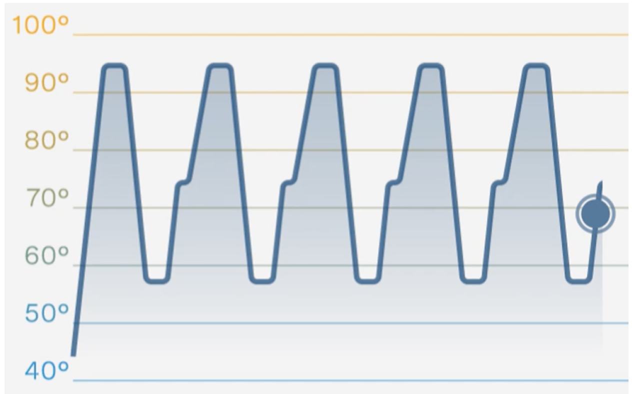


Figure 3.7: Heat cycles in the diaxxoCare process

3.3 Quantity of Wax and Oil

The second part was to find how much wax to pour into the diaxxoPods. The objective was to achieve an optimal mixture of oil and wax. This was accomplished by placing the diaxxoPods, with wax applied to their sides, into the diaxxoCare. To apply the wax, I kept it in a molten state by heating it up on a standard laboratory heating plate. Then the liquid wax was pipetted into the diaxxoPods.The machine then subjects these samples to a cycle of heating and cooling 45 times over a period of half an hour, as in a PCR test (see fig. 3.7). During the cycles, the wax melted and mixed with the oil. The aim was to pour the minimum amount of wax to ensure homogeneous mixing with the oil, which was previously fixed at 1000 uL by the Diaxxo team.

3.4 Automation of Wax Dispensation

The final phase of the project was to develop a method for the automatic dispensation of wax in an industrial setting. The goal was to transition from a manual, labor-intensive process to a more controlled, precise, and automated system. Previously, wax was pipetted manually into each diaxxoPod. Although effective, this method was time-consuming and lacked precision. To improve efficiency, the masks were attached to a grid, allowing simultaneous filling.

3.4.1 System Requirements

- The automated system needed to maintain the wax at a high temperature throughout the process to prevent it from solidifying and clogging the tubing or pipes.
- The system required high precision to ensure the correct amount of wax, accurate with a margin of 50 microliters, was precisely deposited into the diaxxoPod.
- Finally, in terms of performance, the aim of the system is to fill up to 18 diaxxoPod in 10 minutes.

3.4.2 Proposed Solutions

Two main alternatives were considered for automating the wax dispensation:

Mechanical Pipetting System

Description: A mechanical pipette system would individually pick and dispense wax into each diaxxoPod (see fig 3.8) :
Setp 1: The wax (orange) is picked by the pipette (purple).
Step 2 and 3: The motorized pipette moves up (step2) and then goes on top of the diaxxoPods
Step 4: The pipette goes down and dispense wax into the diaxxoPods.

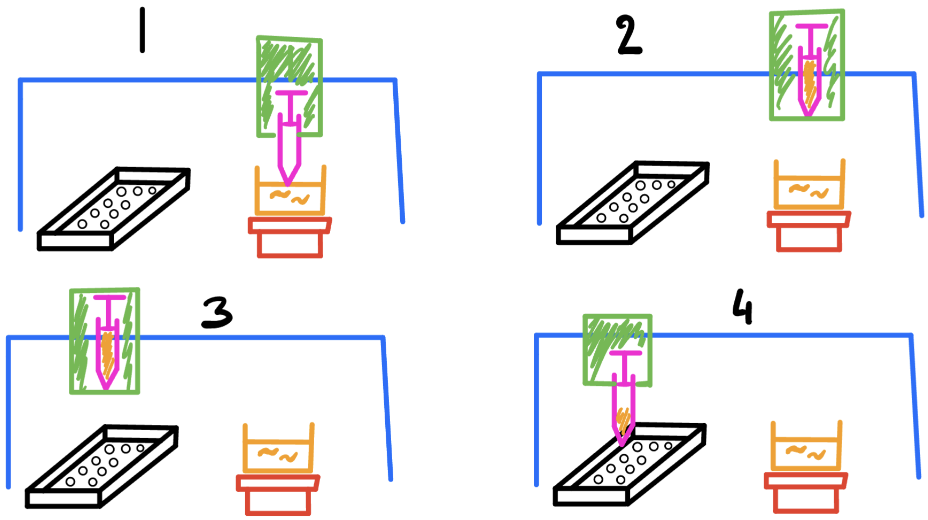


Figure 3.8: Mechanical Pipetting System

Advantages:

- High precision in controlling the quantity of wax deposited.

Disadvantages:

- The system is relatively slow.
- Requires a complex mechanism involving four motors to handle movements along the X, Y, and Z axes, and the operation of the pipette.

Valve-based Dispensing System

Description: This system employs fixed valves positioned above the diaxxoPods, which open to allow wax to flow by gravity into the diaxxoPods as they move underneath (see section 4.4.2).

Advantages:

- Simple design, requiring fewer motors and less mechanical complexity.
- Faster operation and more suitable for scaling up in an industrial context.
- Potential for higher productivity with the addition of multiple parallel valves.

Disadvantages:

- Challenges in maintaining the wax at a high temperature within the valves.
- Potential for wax solidification that could block or disrupt the valves.

Other ideas, such as a hybrid approach involving a large, fixed pipette, were considered but found impractical due to production constraints and efficiency concerns within the project's timeframe.

Chapter 4

Experiments and Results

4.1 Methods for Wax Dispensation in the diaxxoPods

The development of the wax dispensing machine involved iterative modifications and testing of mask designs to optimize wax deposition within the diaxxoPods. Key adjustments focused on the geometry of the mask and the timing of mask removal post-wax dispensation.

Figure 4.1: First design of the mask

Figure 4.2: Insufficient time before mask removal

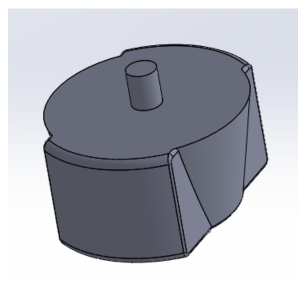


Figure 4.3: Mask design to increase the surface

Figure 4.4: diaxxoPod with wax pads

4.1.1 Geometry of the mask

Initial designs utilized a straightforward mask that directed wax solely to the sides of the diaxxoPods (refer to Fig. 4.1). Subsequent modifications aimed to enhance mask removal and increase wax surface contact with the diaxxoPods:

- **Thickness Adjustment:** To address the insufficient margin between the wax and the wells, the mask's thickness was increased by 5mm per side. This adjustment reduced the space available for wax but maintained functional integrity.
- **Side Angle Modification:** Angles were incorporated into the sides of the mask to facilitate easier removal (see angle in Fig. 4.3). Various angles were modeled, printed, and tested; however, these modifications did not significantly ease the mask removal process. Therefore, we finally kept a vertical wall on the mask.
- **Surface Area Enhancement:** To improve the results of shock tests, the mask's design was altered to increase the surface area of wax contact with the diaxxoPods. Despite these changes, as demon-

strated in the tests (discussed in subsection 4.2 'Shock Test'), the increased surface area did not yield successful outcomes, leading to a reversion to the original 'straight mask' design.

4.1.2 Timing of mask Removal

The timing of mask removal was critical to ensure that the wax did not adhere to the mask. Insufficient waiting times resulted in wax not solidifying adequately, adhering to the mask upon removal (refer to Fig. 4.2 with insufficient time before removing the mold (3.5minutes)). Conversely, excessive waiting allowed the wax to fully solidify, complicating the removal process and increasing the risk of wax fracturing. Extensive testing led to the optimal timing of 5 minutes for wax poured at 95 degrees Celsius and 1 minute and 30 seconds for wax poured at 67 degrees Celsius.

Experimental results (see Fig. 4.4) demonstrate that with the adjusted geometry and optimized timing, wax deposition on the diaxxoPod sides was precise, compact, and robust, meeting the project's requirements.

4.2 Shock test

However, the dispensing of the wax wasn't the unique consideration i had to take into account. The wax dispensed also had to resist the 'shock test' I described in Part 3.2. I changed different parameters, i.e., the geometry, temperature, surface (scratches), time before removal of the mask, utilization of a heater, surface preparation (epoxy glue), putting the diaxxoPods after the wax dispense and before the test in the lyophilization machine or in the freezer. The lyophilization is going to -50 degrees and down 0.005 bar; these are the minimum temperature and pressure. I tested all these parameters.

Test ID	Scratch	Temp (°C)	Time	Wax (uL)	Geo	Epoxy	Freez/LYO	Heater	Success
W1	NO	67	1min30	1000	S	NO	Freez	NO	0/5
W2	NO	67	1min30	1000	S	NO	Freez	NO	0/5
W3	YES	67	1min30	1000	C	NO	LYO	YES	1/1
W4	YES	67	1min30	1000	C	YES	LYO	NO	0/1
W5	NO	67	1min30	1000	C	NO	LYO	YES	0/1
W6	YES	95	7min	1000	S	NO	LYO	NO	1/1
W7	YES	95	4min	1000	S	NO	LYO	NO	1/1
W8	YES	95	5min	1000	S	NO	LYO	NO	1/1
W9	YES	95	4min30	1000	S	NO	LYO	NO	1/1
W10	YES	95	7min	1000	C	NO	LYO	NO	1/1
W11	YES	95	5min	1000	C	NO	LYO	NO	1/1

Table 4.1: Summary of wax adhesion test results

Caption:

GEO : Geometry : straight mask - S and Angle mask - C

Time : time letting the wax solidifying before removing the mask

Temp : Temperature in degrees Celsius, the temperature of the wax when pouring it.

Quantity of wax (uL) : Quantity of melted wax we pour per side of the mask. In Micro-Litter (the unit of the Pipette i used)

Lyophilisation/freezer: Before doing the shock test, we either put the diaxxoPods in the freezer (-20 degrees for 30 minutes) or in the lyophilization machine (going to very low temperatures (down to -60 degrees) and low pressure for 4 hours). We did this to recreate the real conditions: before the shipping, the diaxxoPods are going into the lyophilization to prepare the well's surface. The lyophilization machine wasn't always available, and therefore similar tests in the freezer had to be performed.

Conclusion of the shock test

Pouring the wax at 95°C with surface scratching on the diaxxoPod sides treatment proved most effective, even when followed by the lyophilization process. All tests passed the shock tests with high intensity without breaking.

4.3 Quantity of Wax and Oil

Figure 4.5: Inhomogeneus mix oil/wax

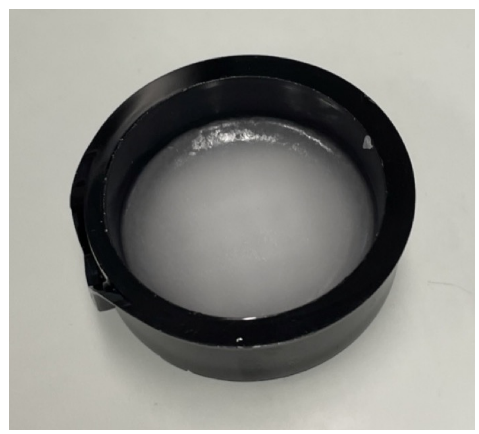


Figure 4.6: Homogeneus mix oil/wax

For the experiments conducted, the objective was to achieve an optimal mixture of oil and wax. This was accomplished by placing the diaxxoPods, with wax applied to their sides, into the diaxxoCare. The machine then performed multiple cycles of heating and cooling 45 times over a period of about half an hour.

The reference quantity was the oil; the quantity was fixed to 2x500 uL. The quantity of wax defined suits the requirements of the process. The aim was to pour the minimum amount of wax, but still enough to be able to mix with the 1000 uL oil.

After several tests, I concluded that the minimum amount of wax needed to homogeneously mix with oil is **700uL** per side of wax. We can see the difference in figures 4.5 and 4.6: on the first picture, we can see the oil concentrated at the center of the diaxxoPod and the wax all around. They didn't homogeneously mix, which can cause some oil leaks afterwards. This was done with 650 uL per side, a quantity inferior to the limit (700 uL per side of wax). And on the second picture, we can observe an homogeneous mix between the oil and the wax.

4.4 Automation of Wax Dispensation

Finally, the last part was to build the machine with the parameters we defined before :

1. Straight masks design
2. Defined volume of 700 uL of wax per side of the diaxxoPod
3. A pouring temperature of 95 degrees Celcius
4. Inner ring of the diaxxoPod with surface treatment
5. Automated with fixed valves on top of the moving diaxxoPods

4.4.1 Teflon valve in glass container

Experimental Setup and Preliminary Testing

The initial experimental setup involved utilizing a one-way T-shaped valve with hose connector connected to high-resistance wire for heating purposes (see Fig. 4.7). This setup aimed to control the temperature of wax within the valve to maintain it at approximately 95 degrees Celsius. The specific parameters for the voltage and current were 7.90 V and 1668 mA, respectively. Below are the details of the setup challenges and initial tests conducted:

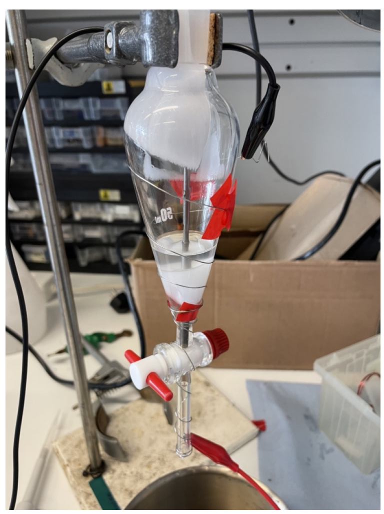


Figure 4.7: First set-up for the valve valve automation

Setup Challenges

1. **Wire Attachment:** Proper attachment of the wire to the valve was critical for uniform heating. The wire needed to make extensive contact with the valve's surface to distribute heat evenly. However, using tape for securing the wire ends proved problematic as it melted under high temperatures, although it was temporarily employed for initial setup.
2. **Wax Solidification:** After the experiments, the wax tended to solidify within the white portion of the valve. To address this issue, additional wire was wrapped around this area to ensure the wax inside could melt and flow freely upon reheating.

Automation and Flow Consistency Test

The objective of automating the valve operation was to achieve a consistent flow of wax. The test involved repeatedly opening the valve for 2-second intervals to determine if the same amount of wax was dispensed each time. I conducted multiple tests that were unsuccessful due to fluctuations in temperature (changing the viscosity) and the challenge of manually maintaining a consistent valve opening time of exactly two seconds. After addressing these issues, I proceeded with the final series of tests. Here are the results from the preliminary tests:

wax poured at each iteration [in mg]
352
412
309
350
336
337
317

Table 4.2: Repeatability of the valve's flow

Mean Calculation:

$$\text{Mean} = \frac{2413.2}{7} \approx 344.742857\text{mg}$$

Standard Deviation Calculation The standard deviation measures the amount of variation or dispersion in a set of values.

The maximum variation is 95mg, given the density of the Paraffin wax we used (see figure 4.8) at 95 degrees we have a density of 762.1 [kg/m3].

Temp. [°C]	Density [kg/m3]
60	784.4
65	781.2
70	778.0
75	774.8
80	771.6
85	768.5
90	765.3
95	762.1
100	759.0
105	755.8

Figure 4.8: Density of the paraffin wax in function of the temperature

With further calculations, we find that this is equivalent to 0.525 milliliters, which is acceptable for the requirements that we previously set.

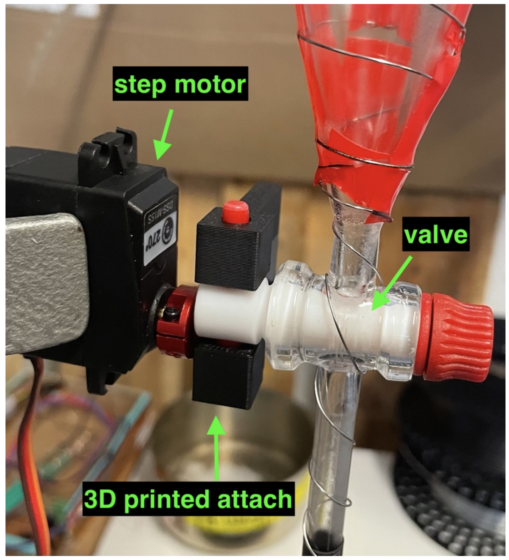


Figure 4.9: Motor fixation on the valve

Motorisation

After these experiments, I designed the black part shown in Figure 4.9. This component, 3D printed, links the valve to the motor. Subsequently, an electrical engineering student from the lab designed a switch to operate the motor for opening and closing the valve. However, parasitic movements when the motor operates led to imprecise flow and wax dispensing.

4.4.2 Solution 2: wax pool with solenoid valves

After completing these tests and analyzing the results, i concluded that there was a lack of flow consistency and the set-up was too complex and so not optimal for a large scale wax dispensation. So we developed the final solution, which involved designing a pool that contained the wax. This pool features three holes at the bottom for wax flow and incorporates solenoid valves, which we purchased.

The diaxxoPods and their holders are arranged in three rows. Using three valves ensures the diaxxoPods under the valves can move along a single axis. This movement is driven by the tray already used in the diaxxoCare machine. The entire configuration is illustrated in the figure below.

By using existing parts, I was able to implement a setup by designing the pool, a link to hold the pool to the slider, and purchasing parts to attach the valve to the bottom of the pool.

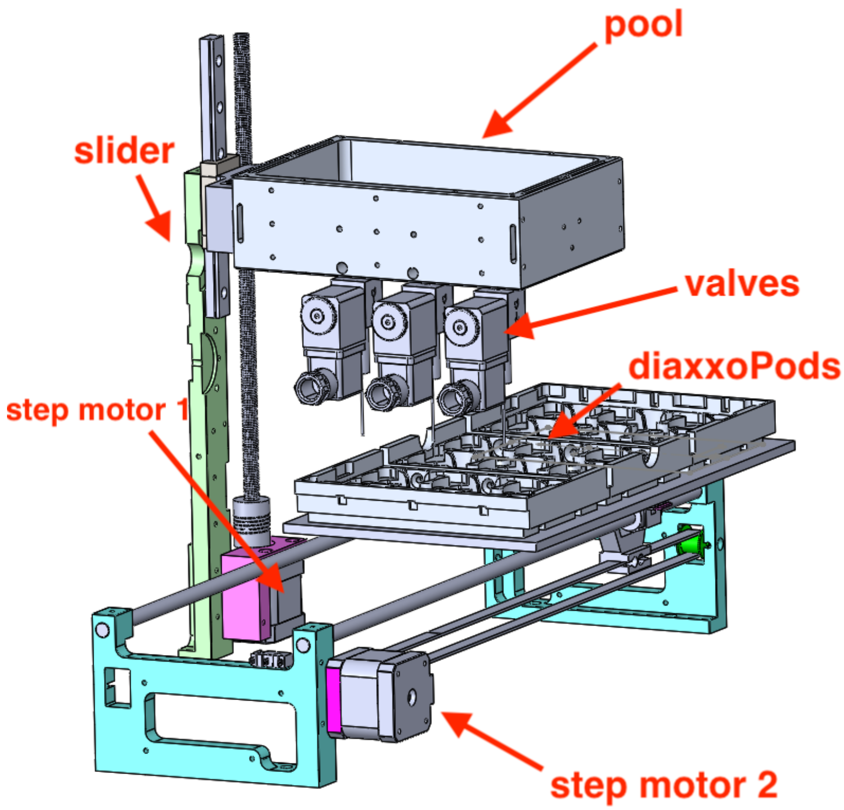


Figure 4.10: SolidWorks of the Final set-up for the wax dispensing

The Pool and link

Below are the design details for the figures referenced earlier (fig 4.11 and fig 4.12) and as seen in the assembly (figure 4.10). The pool is engineered with several key features:

- **Material :** The pool is in aluminum because of heat conductivity.
- **Valves :** It is equipped with three holes at the bottom (highlighted in purple) to accommodate the installation of three solenoid valves.
- **Heaters :** Two elongated holes (marked in blue) are included to house the cylindrical heaters.
- **Temperature sensor :** A pair of holes (marked in red) are designated for attaching a 3D printed part that secures the temperature sensor at the bottom of the pool, enabling precise temperature control of the wax. The datasheet of the sensor is attached in the appendix.
- **Sliders attach :** To facilitate attachment to the slider, the pool features four holes (illustrated in green) that align with and fasten to the corresponding holes in figure 4.11.

The features of the link connecting the pool to the slider include:

- **Material :** The part is in teflon because of heat conductivity : it will insulate the heated pool from the rest of the machine.
- **Pools attach :** Holes depicted in green are used for securing the link to the pool.

- **Sliders attach :** Yellow markings indicate the points where the link attaches to the slider.
- **Motorization :** Red denotes the location for connecting the motor's bar to the link.
- **Surface optimization :** The feature highlighted in purple minimizes the contact surface between the pool and the link. This design consideration is crucial since the pool operates at high temperatures (95 degrees Celsius or more), and minimizing heat transfer is essential for efficient operation.

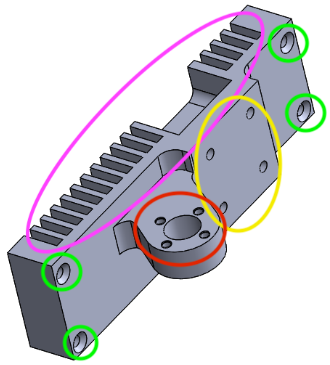


Figure 4.11: SolidWork of the linker between the pool and the slider

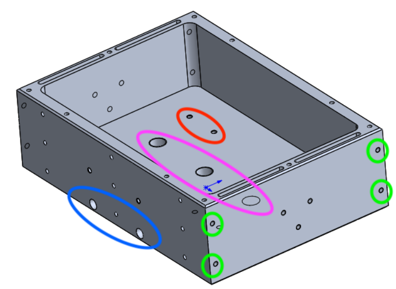


Figure 4.12: SolidWork of the pool

Assembling the set-up

Wax heating

To properly heat, I designed holes directly in the bottom of the pool to place two heaters (see fig. 4.13-red heaters). The pool, made of aluminum, ensures even heat distribution. I also made sure that the connecting part and the valve were also in metal, so wax would be heated during the whole flow, from the pool to the end of the tip.

I used two heaters with the following characteristics :

- 100W at 15V
- 6mm diameter

The Tips

Thin metal tips, available in the laboratory, were used. They are 5 cm long and 3 mm in diameter. Once mounted, the tip did not heat sufficiently, causing the wax to solidify and obstruct the flow. Upon analysis, we determined that the thinness of the tip facilitated rapid heat loss. By cutting the tip, we restored proper flow. Alternatively, maintaining the original tip while improving heat retention could be achieved by either augmenting the mass around the tip with a metal attachment or insulating the tip with insulating tape to reduce heat dissipation. (See Fig. 4.13, cut tip)

Pool stability

After assembling the setup, it became apparent that the mass of the pool was too great, causing it to bend. To rectify this issue, I installed an additional slider on the opposite side to keep the pool level, as shown in Figure 4.13.

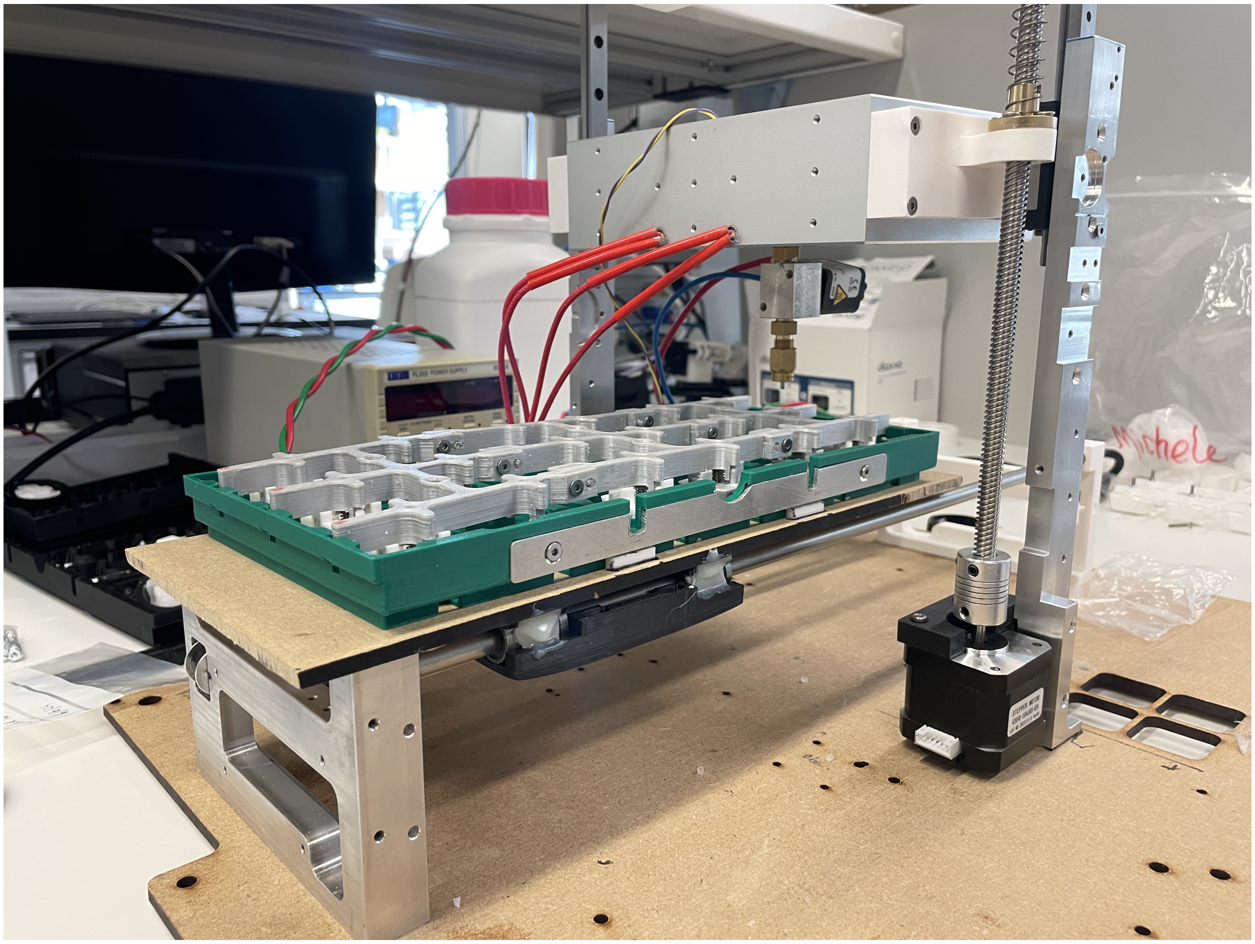


Figure 4.13: Final set-up for the wax dispensing

4.4.3 Final tests

After addressing the initial setup challenges, I conducted tests to evaluate the uniformity of the wax flow and volume dispensed. I requested the design of a button that would open the valve for one second and then close it. With the button implemented and the setup assembled containing wax heated to 95°C, I commenced testing. Here are the results of 20 repetitions (in mg) :

621, 632, 636, 639, 629, 640, 623, 619, 612, 614, 610, 601, 621, 605, 596, 530, 608, 612, 606, 604.

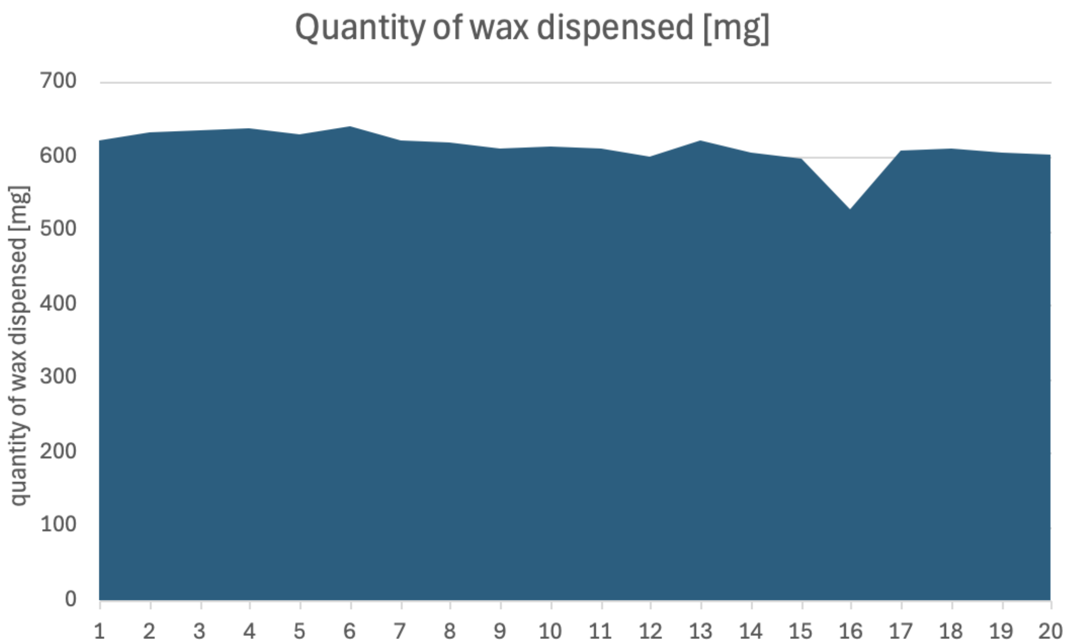


Figure 4.14:

These 20 values are the quantity of wax in milligrams that were dispensed by opening the valve for one second. The mean value of the wax quantities is 612.9 mg, and the standard deviation is approximately 22.8 mg. Which corresponds to $29.76\,\mu L$. This indicates that $29.76\,\mu L$ is approximately 4.25% of the total volume of $700\,\mu L$. Which proves the repeatability of the implemented solution when pouring the wax.

From the test results, it is evident that the quantity of wax dispensed begins to decline slightly from the ninth measurement onward. This reduction is likely attributable to the diminishing volume of wax in the pool, which in turn decreases the pressure proportionally and affects the volume dispensed within one second.

Although the observed fluctuations in wax quantity are minimal, they can be further minimized by ensuring the wax pool is adequately filled. During my initial tests, the wax pool was not completely filled, which led to a significant decrease in wax volume—approximately 30 percent—over the course of 10 tests. This reduction in volume lowers the pressure within the pool, influencing the dispensing rate.

By fully filling the wax pool, the reduction in volume—and consequently, the pressure—over the same number of tests can be substantially limited. This approach would result in fewer fluctuations in the quantity of wax dispensed per second, leading to more consistent outcomes.

Chapter 5

Discussion

The implementation of the automated wax dispensing system marks a step forward in the manufacturing process of DiaxxoPods. By transitioning from manual methods to a more automated system, we have not only improved the consistency of the wax deposits but also substantially increased production efficiency. This system allows for precise control of the wax deposition process, ensuring that the wax is dispensed accurately in terms of both placement and quantity.

The primary challenge in this project centered on the wax pouring process, specifically in optimizing the use of the mask and conducting the shock test. The key issue was balancing the wax's adhesion properties: reducing its adhesion to the mask to facilitate easy removal after the wax had been poured and solidified, while simultaneously increasing its adhesion to the DiaxxoPod to ensure it remained securely attached during the 'shock test'.

There is still some adjustment to make to operate at a larger scale.

Automation

A critical task is to automate the motor responsible for moving the tray to position the DiaxxoPods precisely under the valve. Although currently operable manually for production, achieving full automation involves the following key objectives:

- The motor must accurately halt at the designated spot to ensure wax is poured directly into the DiaxxoPods.
- The timing of the motor's stops must be synchronized with the valve operations—pausing exactly when the valve opens, allowing the wax to be poured, and then closing.

Structural improvement

The next step involves procuring and installing two additional valves. Initially, we tested one valve to evaluate its functionality and suitability for our needs. The results were positive, confirming that the valve meets our requirements. Moving forward, we face the challenge of alignment:

- The axes of all three valves must be perpendicular to the tray's movement axis. This alignment is crucial to ensure precise wax deposition into the DiaxxoPods.

Wax adhesion and mask removal

Even with the last successful shock test we did, there is still some improvement to make with the wax adhesion and mask removal :

- Evaluate some cost effective machinery techniques to consistently and systematically generate surface abrasions on the inner ring of the daixxoPods for better adhesion.
- Evaluation of chemical products for the adhesion of wax on the inner ring of the diaxxoPods
- Finally, evaluation of chemical products for the easy removal of the mask

Chapter 6

Conclusion

This project has not only demonstrated the feasibility of automating the wax dispensation process but has also highlighted the critical enhancements this automation brings to the production of PCR test diaxxoPods. By refining the deposition accuracy and production throughput, the automated system reduces potential manual errors significantly.

Future directions for this project include scaling the automated system for larger production volumes and integrating real-time quality control mechanisms. These advancements will help to meet the increasing demand for rapid PCR tests and could set new standards.

Further research will also focus on refining the mechanical components and control software to enhance the robustness and flexibility of the system, accommodating a wider range of PCR test types and sizes. The goal is to provide Diaxxo with a scalable, efficient, and error-minimized production line that can adapt to evolving needs.

Appendix A

The First Appendix

In the appendix, list the following material:

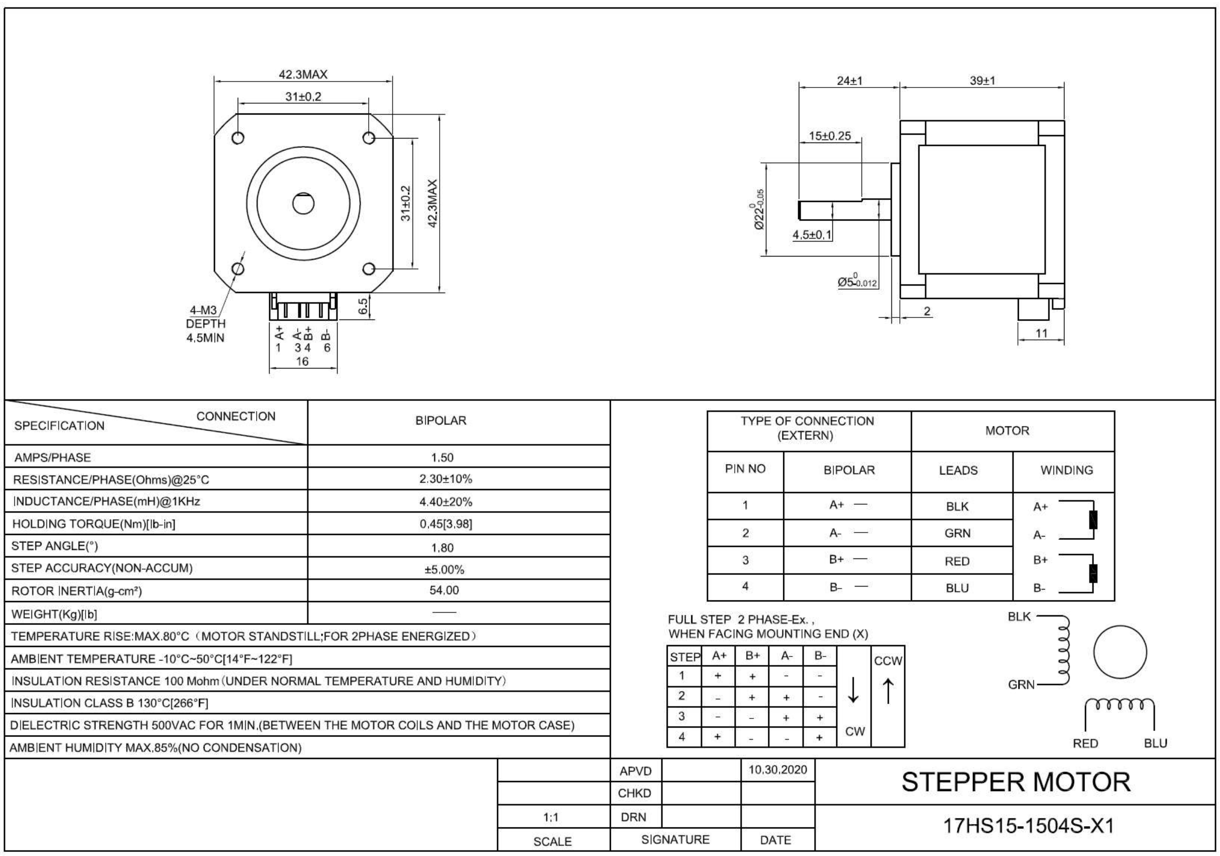
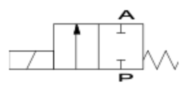


Figure A.1: STEP MOTOR

Datasheet

nieruf

2/2-way solenoid valve stainless steel type EV01



description:

2/2-way solenoid valve made of stainless steel, very compact design for high flow rates. Ideal for machine and plant engineering. This valve switches at 0 bar (directly acting solenoid valve)

features:

- Suitable for **liquid and gaseous media**
- Mounting position: any, preferably solenoid above

connection:	**control:**	**function:**	**pressure:**
1/8" inch	direct acting	NC – normally closed	0 – 16 bar – depending on design

design:	seat valve	
diameter:	DN 1,0 / DN 1,5 / DN 2,0 / DN 2,5	
body material:	Stainless steel 1.4305	
seal:	FKM	
voltage:	230V 50Hz	24V DC
voltage tolerance :	+/- 10% acc. VDE 0580	
power consumption:	230V 50Hz:	9,2 VA
	24V DC	6 Watt
duty:	100 % ED	
plug socket:	IP65 with plug socket mounted	
plug:	cable diameter 6-8 mm, thread PG 9, design B	
temperature:	ambient:	max. + 50°C
	media:	FKM – 10°C up to +130°C

DN	**max. pressure**	**connection**	**flow rate**
1,0 mm	0 – 16 bar	G 1/8" inch	0,5 l/min
1,5 mm	0 – 13 bar	G 1/8" inch	1,2 l/min
2,0 mm	0 – 10 bar	G 1/8" inch	2,1 l/min
2,5 mm	0 – 8 bar	G 1/8" inch	2,8 l/min

options:	without oil and fat	
	plug socket mounted with LED	
	Ex	II 2G Ex mII T4
		II 3D IP65 T130°C

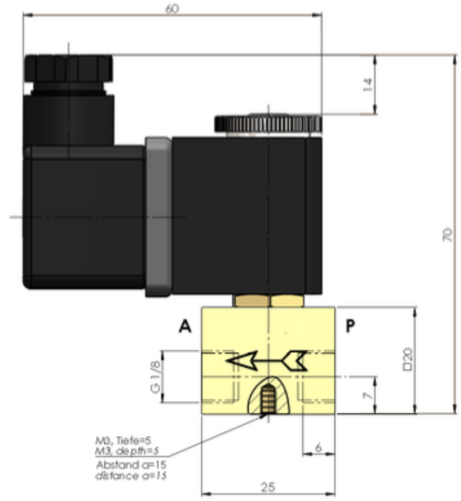
Fon: +49 7143/96669-00 **Index: 10/2015** **sales@nieruf.com** **www.nieruf.com**

Figure A.2: datasheet solenoid valve 1/2

Datasheet

nieruf

dimensions:



Test meeting the requirement of PED acc. to DIN EN 12266-1:

The tightness corresponds to the specified leakage rates*:

type	soft seat**
EV01	A

* acc. to EN 12266-1

** Soft Seat: FKM

article number:

Type	Voltage	Seal	Function	Version	Size
EV01	**1 – 230V 50Hz** 2 – 24V DC	**2 – FKM**	**0 – NC normally closed**	**0 – Standard**	**10 – DN 1,0** 15 – DN 1,5 20 – DN 2,0 25 – DN 2,5

Example No. EV01120010:

EV01	1	2	0	0	10

2/2 way solenoid valve stainless steel

Voltage:	230V 50Hz
Seal:	FKM
Function:	NC normally closed
Version:	standard
Size:	DN 1,0

Image similar, subject change without notice.

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Figure A.3: datasheet solenoid valve 2/2

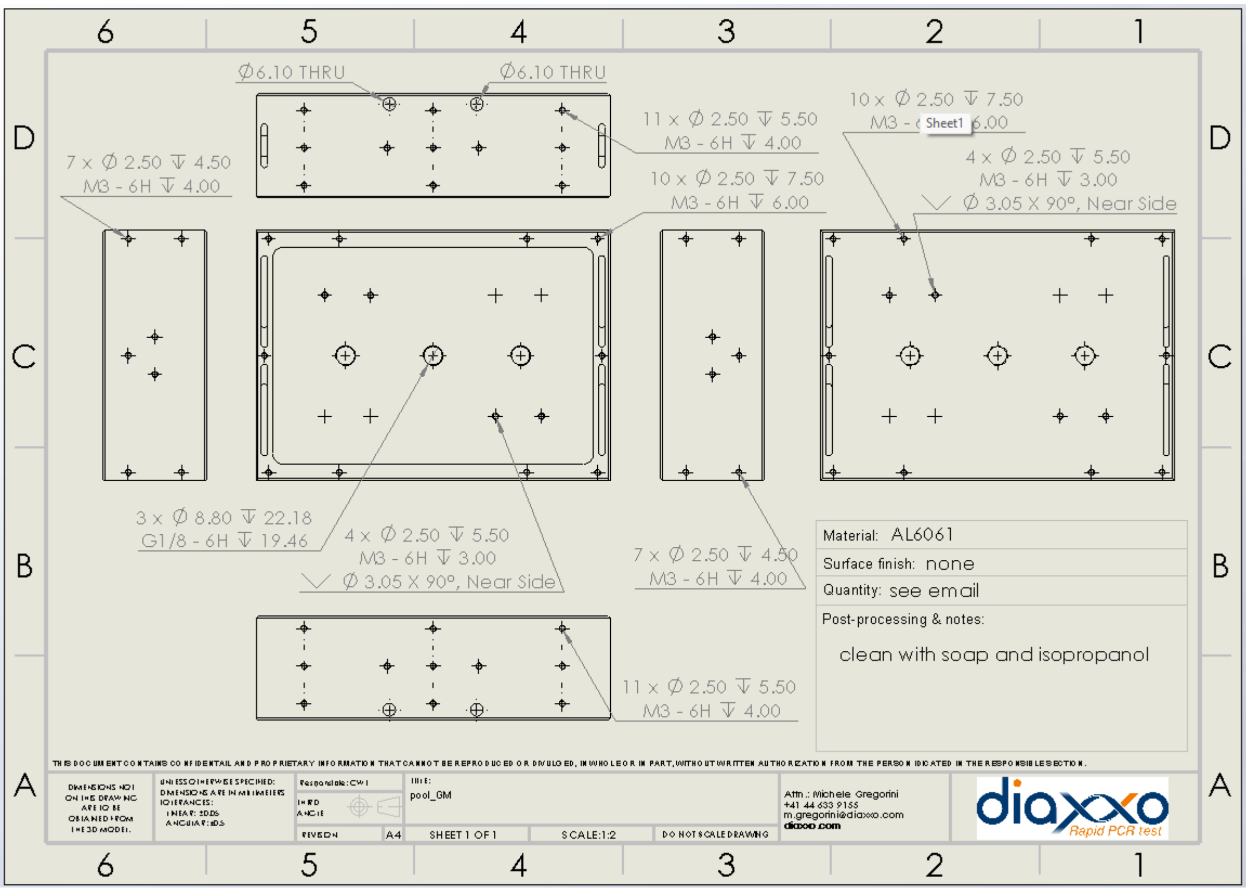


Figure A.4: drawing of the pool

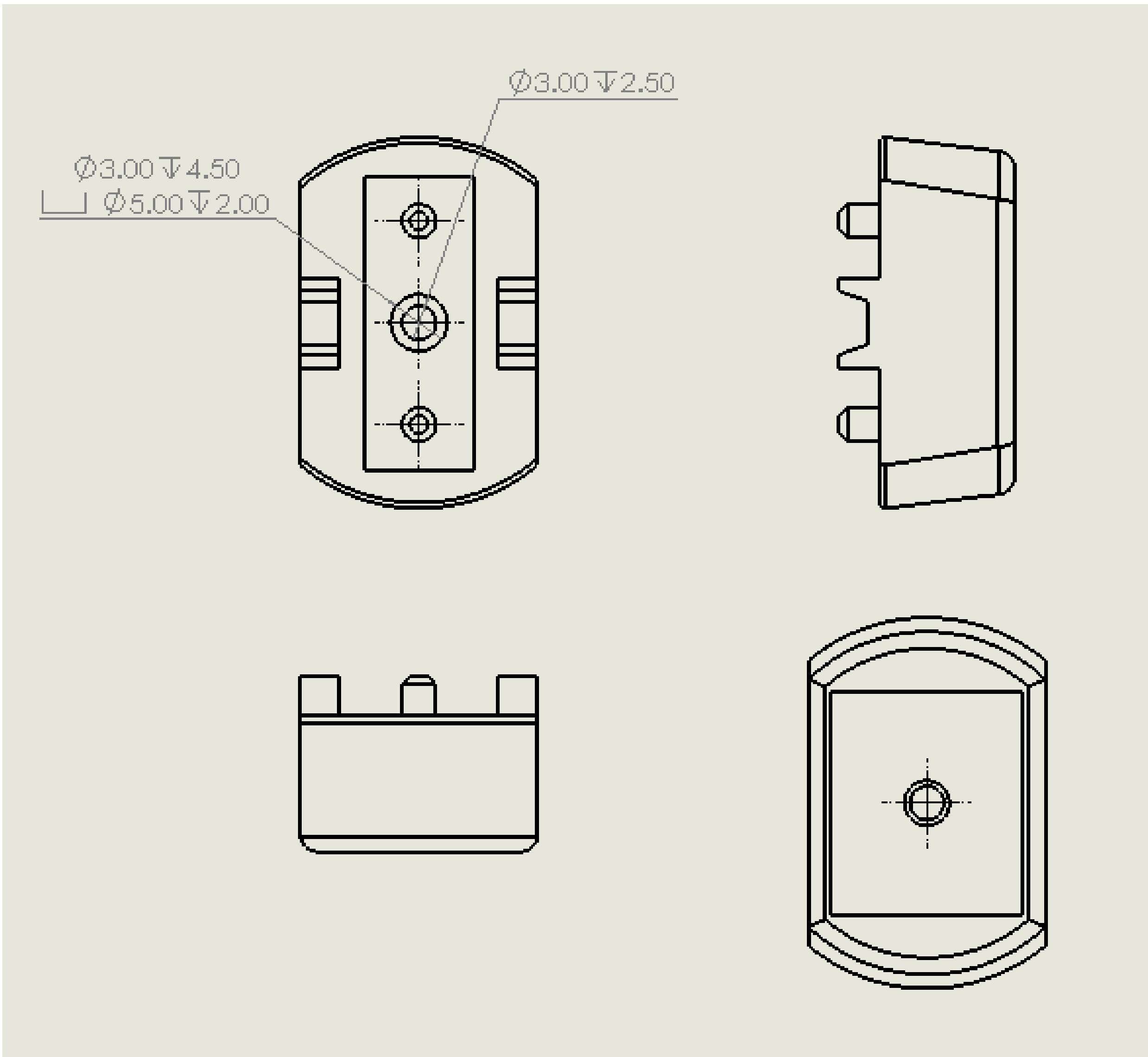


Figure A.5: drawing of the final mask

TEWA TEMPERATURE SENSORS

HIGH PRECISION NTC THERMISTORS AND TEMPERATURE SENSORS

Specification of Thin Film NTC Thermistor

PART NUMBER: **TT6-100KC3L-5-AUR**

No. of pages: 5

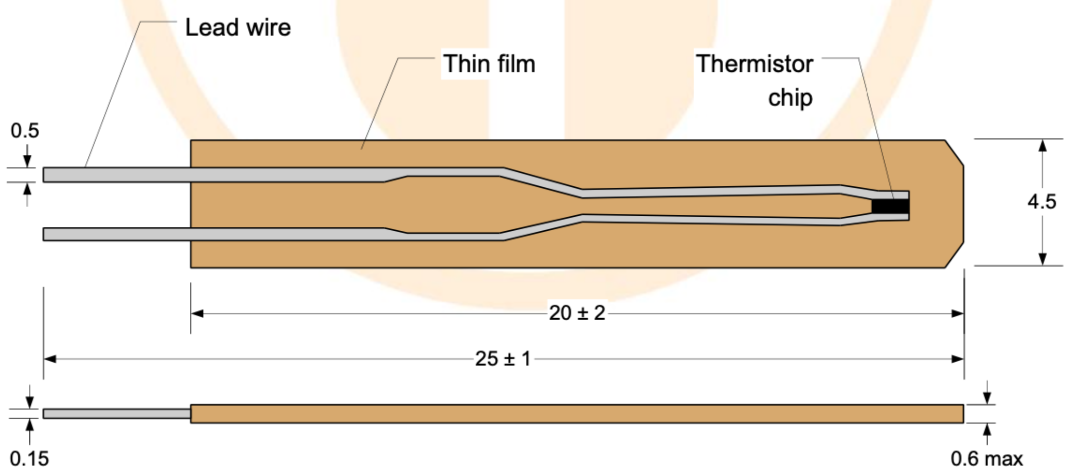
Date: **19.02.2019**

Revision: **00**

FEATURES:

Element	Thin Film NTC Thermistor
No-load resistance at 25°C	100 000 Ω
Tolerance at 25°C	± 1%
Beta(25/50) Constant	3 950K ± 1%
Operating temperature range	-30°C ÷ 120°C

DRAWING:



UNITS: [mm]

Tewa Temperature Sensors Ltd.
Przeskok 18,
20-403 Lublin,
Poland

Tel. 00 48 81 532 10 79
website: www.tewa-sensors.com
email: info@tewa-sensors.com

Figure A.6: Data-sheet of the sensor 1/5

TEWA TEMPERATURE SENSORS

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Temp.	Resistance(kΩ)			resistance tol.（%）		Temp.tol.（℃）	
℃	Rmin	R(t)Normal	Rmax	MIN	MAX	MIN	MAX
-30	1719,785	1787,980	1858,693	-3,8%	4,0%	-0,59	0,62
-29	1616,551	1679,602	1744,937	-3,8%	3,9%	-0,59	0,61
-28	1520,194	1578,506	1638,891	-3,7%	3,8%	-0,58	0,60
-27	1430,213	1484,158	1539,985	-3,6%	3,8%	-0,58	0,60
-26	1346,146	1396,066	1447,693	-3,6%	3,7%	-0,57	0,59
-25	1267,568	1313,775	1361,532	-3,5%	3,6%	-0,57	0,59
-24	1194,086	1236,869	1281,056	-3,5%	3,6%	-0,56	0,58
-23	1125,338	1164,960	1205,856	-3,4%	3,5%	-0,56	0,58
-22	1060,991	1097,694	1135,553	-3,3%	3,4%	-0,55	0,57
-21	1000,736	1034,743	1069,799	-3,3%	3,4%	-0,55	0,56
-20	944,287	975,804	1008,272	-3,2%	3,3%	-0,54	0,56
-19	891,382	920,596	950,673	-3,2%	3,3%	-0,54	0,55
-18	841,775	868,862	896,729	-3,1%	3,2%	-0,53	0,55
-17	795,243	820,360	846,186	-3,1%	3,1%	-0,52	0,54
-16	751,575	774,871	798,809	-3,0%	3,1%	-0,52	0,53
-15	710,579	732,189	754,381	-3,0%	3,0%	-0,51	0,53
-14	672,074	692,124	712,700	-2,9%	3,0%	-0,51	0,52
-13	635,895	654,500	673,581	-2,8%	2,9%	-0,50	0,51
-12	601,888	619,154	636,851	-2,8%	2,9%	-0,50	0,51
-11	569,909	585,935	602,350	-2,7%	2,8%	-0,49	0,50
-10	539,826	554,702	569,930	-2,7%	2,7%	-0,48	0,49
-9	511,515	525,325	539,453	-2,6%	2,7%	-0,48	0,49
-8	484,861	497,682	510,791	-2,6%	2,6%	-0,47	0,48
-7	459,759	471,662	483,825	-2,5%	2,6%	-0,46	0,47
-6	436,107	447,160	458,447	-2,5%	2,5%	-0,46	0,47
-5	413,815	424,078	434,552	-2,4%	2,5%	-0,45	0,46
-4	392,797	402,326	412,046	-2,4%	2,4%	-0,45	0,45
-3	372,972	381,820	390,840	-2,3%	2,4%	-0,44	0,45
-2	354,265	362,482	370,852	-2,3%	2,3%	-0,43	0,44
-1	336,608	344,238	352,004	-2,2%	2,3%	-0,43	0,43
0	319,936	327,020	334,226	-2,2%	2,2%	-0,42	0,43
1	304,188	310,764	317,451	-2,1%	2,2%	-0,41	0,42
2	289,307	295,412	301,616	-2,1%	2,1%	-0,40	0,41
3	275,242	280,908	286,663	-2,0%	2,0%	-0,40	0,40
4	261,942	267,201	272,539	-2,0%	2,0%	-0,39	0,40
5	249,363	254,243	259,193	-1,9%	1,9%	-0,38	0,39
6	237,460	241,988	246,577	-1,9%	1,9%	-0,38	0,38
7	226,194	230,394	234,648	-1,8%	1,8%	-0,37	0,37
8	215,528	219,422	223,365	-1,8%	1,8%	-0,36	0,37
9	205,425	209,036	212,689	-1,7%	1,7%	-0,35	0,36

Tewa Temperature Sensors Ltd.
Przeskok 18,
20-403 Lublin,
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Tel. 00 48 81 532 10 79
website: www.tewa-sensors.com
email: info@tewa-sensors.com

Figure A.7: Data-sheet of the sensor 2/5

TEWA TEMPERATURE SENSORS
HIGH PRECISION NTC THERMISTORS AND TEMPERATURE SENSORS

10	195,854	199,201	202,584	-1,7%	1,7%	-0,35	0,35
11	186,784	189,884	193,017	-1,6%	1,6%	-0,34	0,34
12	178,184	181,056	183,955	-1,6%	1,6%	-0,33	0,34
13	170,030	172,688	175,370	-1,5%	1,6%	-0,32	0,33
14	162,294	164,754	167,234	-1,5%	1,5%	-0,32	0,32
15	154,954	157,229	159,522	-1,4%	1,5%	-0,31	0,31
16	147,987	150,090	152,208	-1,4%	1,4%	-0,30	0,30
17	141,372	143,314	145,269	-1,4%	1,4%	-0,29	0,30
18	135,089	136,883	138,686	-1,3%	1,3%	-0,29	0,29
19	129,120	130,775	132,438	-1,3%	1,3%	-0,28	0,28
20	123,448	124,973	126,505	-1,2%	1,2%	-0,27	0,27
21	118,056	119,461	120,871	-1,2%	1,2%	-0,26	0,26
22	112,930	114,222	115,518	-1,1%	1,1%	-0,25	0,25
23	108,054	109,242	110,432	-1,1%	1,1%	-0,24	0,24
24	103,415	104,505	105,597	-1,0%	1,0%	-0,24	0,24
25	99,000	100,000	101,000	-1,0%	1,0%	-0,24	0,24
26	94,715	95,713	96,713	-1,0%	1,0%	-0,24	0,24
27	90,638	91,633	92,631	-1,1%	1,1%	-0,25	0,25
28	86,758	87,749	88,743	-1,1%	1,1%	-0,26	0,26
29	83,066	84,051	85,039	-1,2%	1,2%	-0,27	0,27
30	79,550	80,527	81,509	-1,2%	1,2%	-0,29	0,29
31	76,201	77,171	78,145	-1,3%	1,3%	-0,30	0,30
32	73,012	73,972	74,937	-1,3%	1,3%	-0,31	0,31
33	69,972	70,922	71,878	-1,3%	1,3%	-0,32	0,32
34	67,075	68,014	68,960	-1,4%	1,4%	-0,33	0,33
35	64,313	65,241	66,176	-1,4%	1,4%	-0,34	0,35
36	61,680	62,595	63,518	-1,5%	1,5%	-0,36	0,36
37	59,168	60,071	60,981	-1,5%	1,5%	-0,37	0,37
38	56,771	57,661	58,559	-1,5%	1,6%	-0,38	0,38
39	54,484	55,360	56,246	-1,6%	1,6%	-0,39	0,40
40	52,300	53,164	54,035	-1,6%	1,6%	-0,40	0,41
41	50,216	51,065	51,924	-1,7%	1,7%	-0,42	0,42
42	48,225	49,060	49,905	-1,7%	1,7%	-0,43	0,43
43	46,323	47,144	47,975	-1,7%	1,8%	-0,44	0,45
44	44,506	45,313	46,130	-1,8%	1,8%	-0,45	0,46
45	42,770	43,562	44,365	-1,8%	1,8%	-0,47	0,47
46	41,110	41,888	42,676	-1,9%	1,9%	-0,48	0,49
47	39,522	40,286	41,061	-1,9%	1,9%	-0,49	0,50
48	38,004	38,754	39,514	-1,9%	2,0%	-0,51	0,51
49	36,552	37,288	38,034	-2,0%	2,0%	-0,52	0,53
50	35,163	35,884	36,616	-2,0%	2,0%	-0,53	0,54
51	33,834	34,541	35,259	-2,0%	2,1%	-0,54	0,55
52	32,561	33,254	33,958	-2,1%	2,1%	-0,56	0,57

Tewa Temperature Sensors Ltd.
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Tel. 00 48 81 532 10 79
website: www.tewa-sensors.com
email: info@tewa-sensors.com

Figure A.8: Data-sheet of the sensor 3/5

TEWA TEMPERATURE SENSORS

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53	31,342	32,021	32,712	-2,1%	2,2%	-0,57	0,58
54	30,175	30,841	31,518	-2,2%	2,2%	-0,58	0,59
55	29,058	29,710	30,373	-2,2%	2,2%	-0,60	0,61
56	27,987	28,625	29,275	-2,2%	2,3%	-0,61	0,62
57	26,961	27,586	28,223	-2,3%	2,3%	-0,62	0,64
58	25,977	26,590	27,214	-2,3%	2,3%	-0,64	0,65
59	25,034	25,634	26,245	-2,3%	2,4%	-0,65	0,66
60	24,130	24,717	25,316	-2,4%	2,4%	-0,66	0,68
61	23,263	23,838	24,424	-2,4%	2,5%	-0,68	0,69
62	22,432	22,994	23,568	-2,4%	2,5%	-0,69	0,71
63	21,634	22,184	22,745	-2,5%	2,5%	-0,71	0,72
64	20,868	21,406	21,956	-2,5%	2,6%	-0,72	0,73
65	20,133	20,659	21,198	-2,5%	2,6%	-0,73	0,75
66	19,427	19,942	20,469	-2,6%	2,6%	-0,75	0,76
67	18,750	19,254	19,769	-2,6%	2,7%	-0,76	0,78
68	18,099	18,592	19,097	-2,7%	2,7%	-0,78	0,79
69	17,474	17,956	18,450	-2,7%	2,7%	-0,79	0,81
70	16,874	17,345	17,828	-2,7%	2,8%	-0,80	0,82
71	16,297	16,758	17,230	-2,8%	2,8%	-0,82	0,84
72	15,742	16,193	16,655	-2,8%	2,9%	-0,83	0,85
73	15,209	15,650	16,102	-2,8%	2,9%	-0,85	0,87
74	14,696	15,128	15,570	-2,9%	2,9%	-0,86	0,88
75	14,203	14,625	15,058	-2,9%	3,0%	-0,88	0,90
76	13,729	14,142	14,565	-2,9%	3,0%	-0,89	0,91
77	13,273	13,676	14,091	-3,0%	3,0%	-0,91	0,93
78	12,834	13,229	13,634	-3,0%	3,1%	-0,92	0,95
79	12,412	12,798	13,194	-3,0%	3,1%	-0,94	0,96
80	12,005	12,383	12,770	-3,0%	3,1%	-0,95	0,98
81	11,614	11,983	12,362	-3,1%	3,2%	-0,97	0,99
82	11,237	11,598	11,969	-3,1%	3,2%	-0,98	1,01
83	10,874	11,227	11,590	-3,1%	3,2%	-1,00	1,02
84	10,525	10,870	11,225	-3,2%	3,3%	-1,01	1,04
85	10,188	10,525	10,873	-3,2%	3,3%	-1,03	1,06
86	9,864	10,194	10,533	-3,2%	3,3%	-1,04	1,07
87	9,551	9,874	10,206	-3,3%	3,4%	-1,06	1,09
88	9,250	9,565	9,890	-3,3%	3,4%	-1,07	1,11
89	8,959	9,268	9,586	-3,3%	3,4%	-1,09	1,12
90	8,679	8,981	9,292	-3,4%	3,5%	-1,10	1,14
91	8,409	8,704	9,009	-3,4%	3,5%	-1,12	1,15
92	8,149	8,437	8,735	-3,4%	3,5%	-1,13	1,17
93	7,898	8,180	8,471	-3,4%	3,6%	-1,15	1,19
94	7,655	7,931	8,216	-3,5%	3,6%	-1,17	1,20
95	7,421	7,691	7,970	-3,5%	3,6%	-1,18	1,22

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Figure A.9: Data-sheet of the sensor 4/5

TEWA TEMPERATURE SENSORS

HIGH PRECISION NTC THERMISTORS AND TEMPERATURE SENSORS

96	7,196	7,460	7,732	-3,5%	3,7%	-1,20	1,24
97	6,978	7,236	7,503	-3,6%	3,7%	-1,21	1,26
98	6,768	7,020	7,281	-3,6%	3,7%	-1,23	1,27
99	6,565	6,812	7,067	-3,6%	3,8%	-1,25	1,29
100	6,369	6,610	6,860	-3,7%	3,8%	-1,26	1,31
101	6,179	6,416	6,660	-3,7%	3,8%	-1,28	1,32
102	5,996	6,227	6,467	-3,7%	3,8%	-1,29	1,34
103	5,820	6,046	6,280	-3,7%	3,9%	-1,31	1,36
104	5,649	5,870	6,099	-3,8%	3,9%	-1,33	1,38
105	5,484	5,700	5,925	-3,8%	3,9%	-1,34	1,39
106	5,325	5,536	5,756	-3,8%	4,0%	-1,36	1,41
107	5,170	5,378	5,592	-3,9%	4,0%	-1,38	1,43
108	5,021	5,224	5,434	-3,9%	4,0%	-1,39	1,45
109	4,877	5,076	5,281	-3,9%	4,1%	-1,41	1,46
110	4,738	4,932	5,133	-3,9%	4,1%	-1,43	1,48
111	4,603	4,793	4,990	-4,0%	4,1%	-1,45	1,50
112	4,473	4,659	4,852	-4,0%	4,1%	-1,46	1,52
113	4,347	4,529	4,718	-4,0%	4,2%	-1,48	1,54
114	4,225	4,403	4,588	-4,0%	4,2%	-1,50	1,56
115	4,106	4,281	4,462	-4,1%	4,2%	-1,51	1,57
116	3,992	4,163	4,340	-4,1%	4,3%	-1,53	1,59
117	3,881	4,048	4,222	-4,1%	4,3%	-1,55	1,61
118	3,774	3,938	4,108	-4,2%	4,3%	-1,57	1,63
119	3,671	3,831	3,997	-4,2%	4,3%	-1,58	1,65
120	3,570	3,727	3,890	-4,2%	4,4%	-1,60	1,67

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Figure A.10: Data-sheet of the sensor 5/5

diaxxo**Care** - AIV 8x2

Quick Guide

All-in-One Sample Extraction and PCR Amplification instruement for RT-qPCR diagnostics.
Document Issued on Novembre 30th, 2023 by Diaxxo AG

Figure A.11: Quick guide of the diaxxoCare 1/5

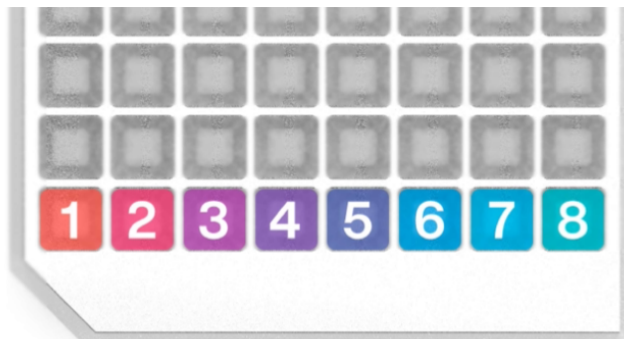
●1

⚠ Wear **gloves** throughout the whole procedure.

You will need:
- DiaxxoExtract [1] with DiaxxoSleeve [2]
- DiaxxoPod [3]
- DiaxxoTips [4]

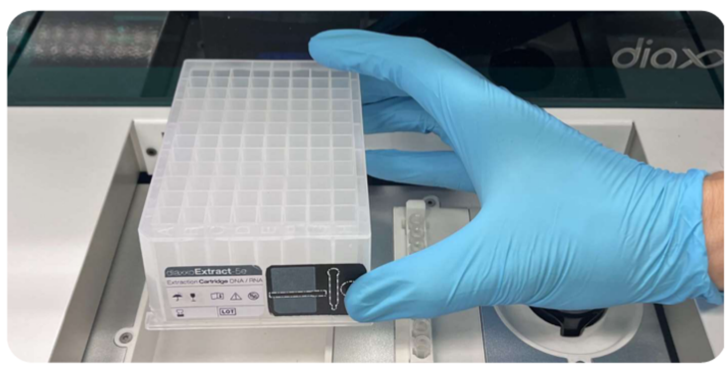
●2

Take Diaxxo**Extract**, shake it, **peel** the aluminium foil.
Load up to **8** samples (**200 µL** each), in the **wells** from 1 to 8.



●3

Place Diaxxo**Extract** inside the tray. The **label** should be facing you.



●4

Insert one Diaxxo**Sleeve** in the **6th** row from the bottom.

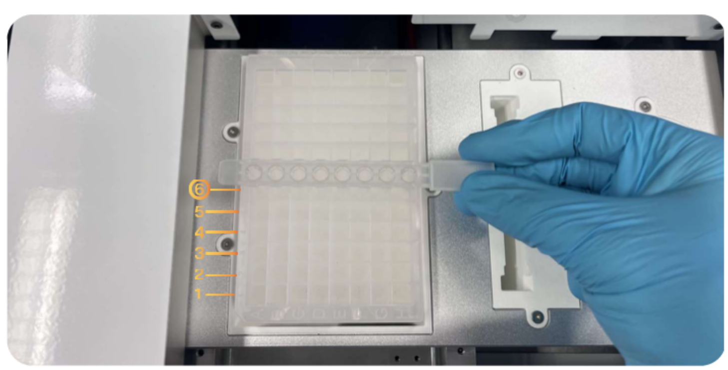
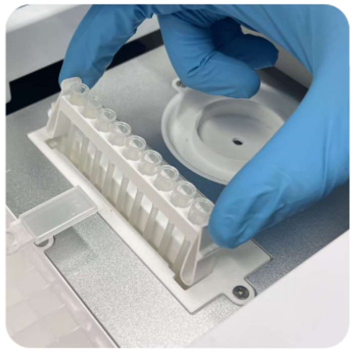
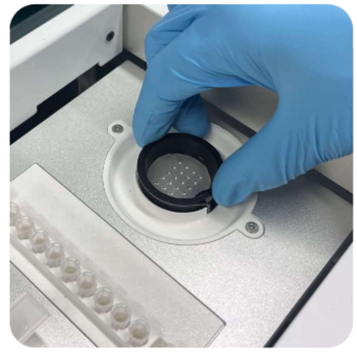


Figure A.12: Quick guide of the diaxxoCare 2/5

●5

Load diaxxo**Tips** in the central slot.
Load the diaxxo**Pod AIV-8x2** on the right.

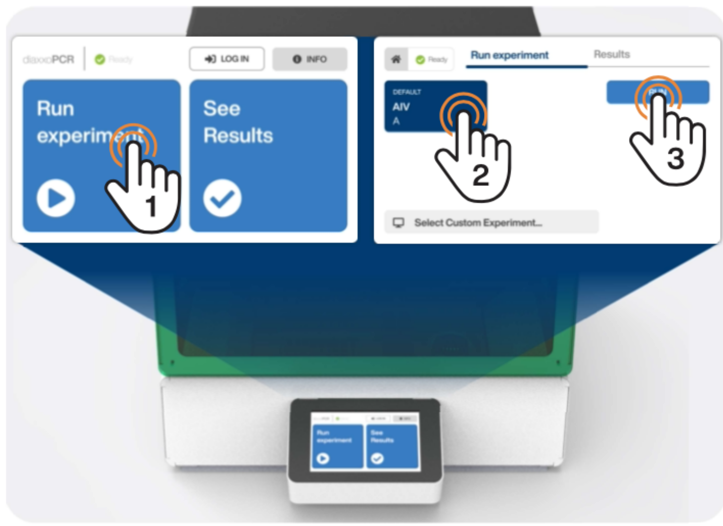




●6

Close diaxxo**Care**'s door.

Select the desired experiment and press **run**.



●7

Check the options in the screen as in the picture.
Wait **1 hour** for the results.

[When finished, **trash the consumables**, if you wish to run **H5 diagnosis**, go straight to the next page instead]

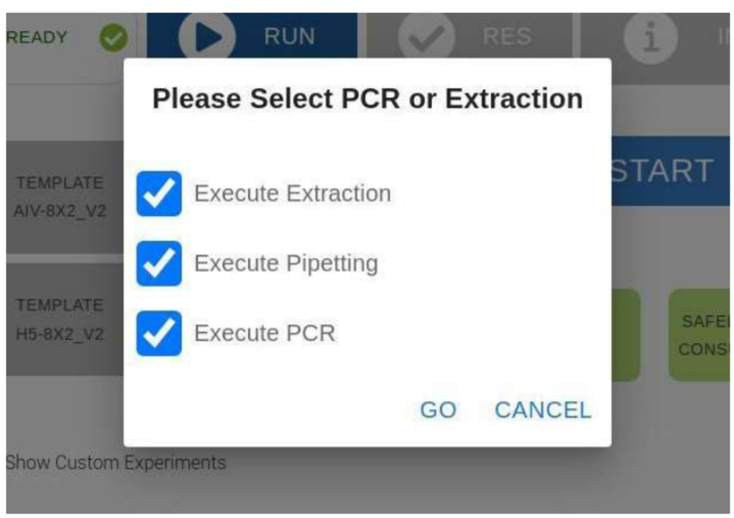


Figure A.13: Quick guide of the diaxxoCare 3/5

Figure A.14: Quick guide of the diaxxoCare 4/5

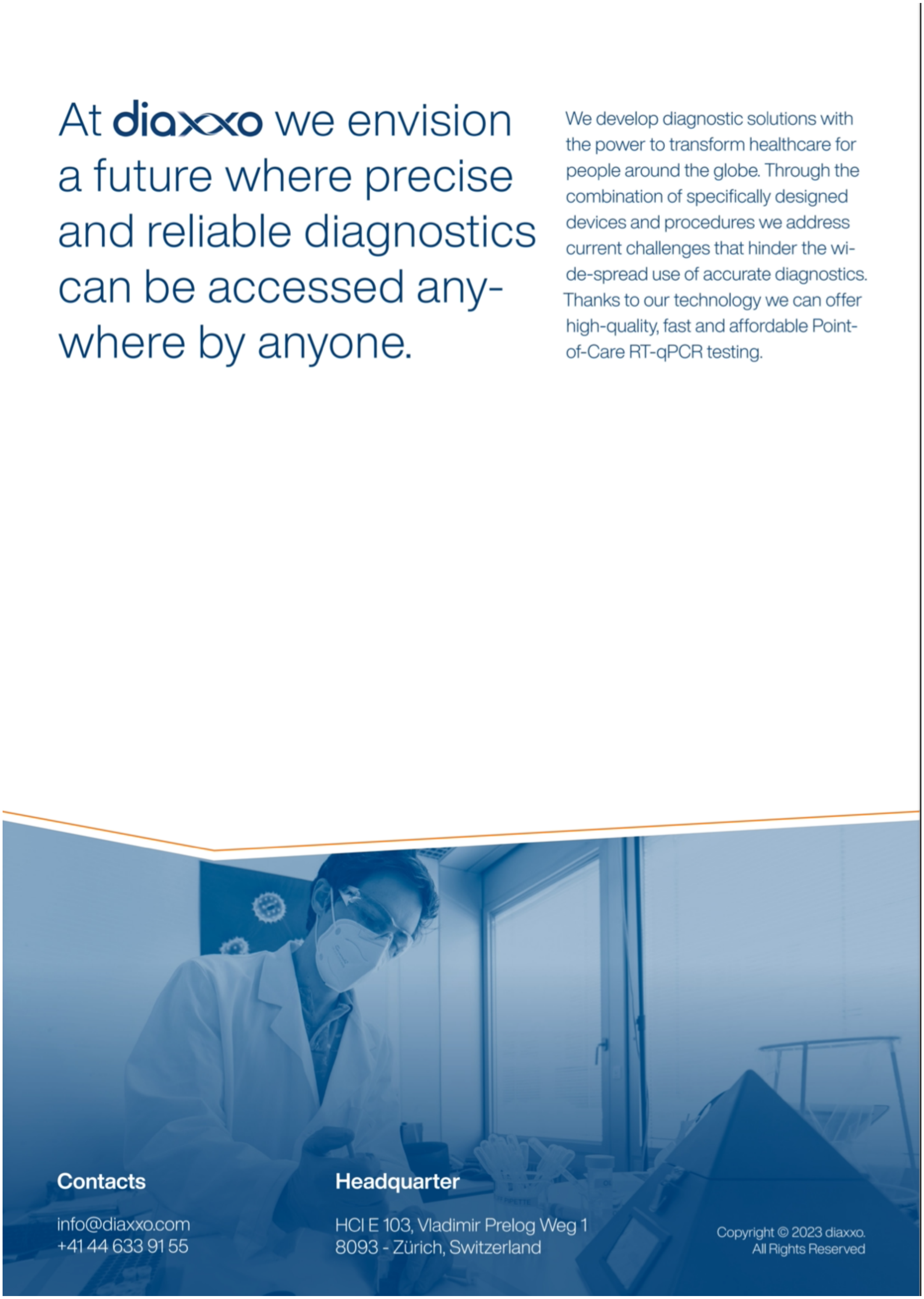


Figure A.15: Quick guide of the diaxxoCare 5/5

Bibliography