Temperature Programmed Desorption Secondary Ion Mass Spectrometer (TPD-SIMS)

Preliminary Report

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1 BACKGROUND

1.1 Introduction

The goal of this project is to modify and enhance a Time of Flight Secondary Ion Mass Spectrometer (TOF-SIMS). This device is used by scientists and researchers to analyze the amount of secondary ions removed from the surface of a sample [1]. One method of accomplishing this is called Temperature Programed Desorption (TPD). This technique requires the surface temperature of the sample to be increased to incredibly high temperatures [2]. Within the TOF-SIMS, an ion beam is shot at the surface of the material. When the two collide, secondary ions are released into the vacuum chamber. These secondary ions bounce into the flight chamber where the mass spectrometer is located. The mass spectrometer then collects the secondary ions using different, electric potentials to attract them, and then analyzes the ions to determine different properties and characteristics of the material.

The project's objectives are to keep the chamber at near vacuum while the system is running, make a sample holder with thermal and electrical insulation from the sample, and to heat the sample to 1450°C at a constant rate of 1°C /s while the sample is under the vacuum. As well as, find a way to measure the temperature from 20°C to 1450°C, and calibrate the electron gun and the sample so the desorbed ions go into the mass spectrometer. Other project objectives are to shield the turbo pump from secondary ions, measure the desorption data with a time resolution of 2 μs. Lastly the mass spectrometer should measure up to $m/z = 50$.

Dr. Michael Lee is the team’s advisor and Sandia National Laboratories (Sandia) is the team’s clients and sponsor for the project. Dr. Lee is an assistant professor and analytical chemist at Northern Arizona University researching organic electronics and photovoltaic cells. A TPD SIMS device will help Dr. Lee and his laboratory gain the ability to analyze different materials ions. Sandia is interested in this project, because one of their devices is working inefficiently running because chemicals are desorbing off their materials while running. Sandia wants to know what and at what temperature these chemicals are desorbing.

1.2 Project Description

The original project provided by the Sandia National Laboratory was to design, fabricate, and install a new sample holder and ionization mechanism. The sample holder must be re-designed to hold a larger, stainless-steel sample that could be compatible with TPD. The ionization mechanism must also be compatible with the current NAU time-of-flight (TOF) mass spectrometer system and with the new sample. It is required that the sample and the ionization source are aligned properly, and proper testing of the system has been performed. Overall, the main goal of this project is to modify the current TOF-SIMS chamber for use of TPD of a stainless-steel sample and compare with Sandia National Laboratory.

1.3 Original System

The original system of this project it last year’s TOF-SIMS capstone project. This TOF-SIMS includes a vacuum chamber, an ion gun, a sample holder with a ground attached, an ion funnel, a flight chamber, and a mass spectrometer. The setup of the original system can be seen in Figure 1.1 below.

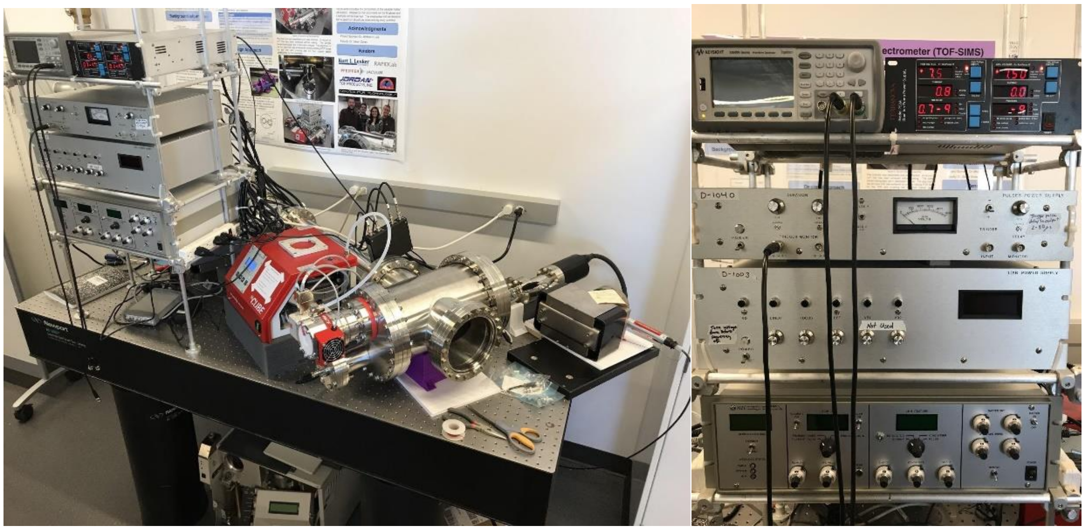

Figure 1.1: Current TOF-SIMS setup in the chemistry building. The left depicts the vacuum chamber and pumps. The right photo shows the electronics' setup.

1.3.1 Original System Structure

The original system was made up of many different parts that were custom made for this machine. The main instruments include the two ion pumps (one 30L/s and one 60L/s), the turbo pump, the stainless-steel vacuum chamber, the ion gun that discharges cesium ions at the sample, the sample holder, and the mass spectrometer. which came out of the top the main chamber. The entire system sits on top of a two-ton table to dampen any vibrations on the TOF-SIMS system. It is located in a Dr. Lee's lab in the Chemistry building.

1.3.2 Original System Operation

When the project first began, the TOF-SIMS system was not operational. This was because the power cable to the ion gun was damaged. The ion gun itself was operational but needed to be cleaned with joule heating. However, the turbo pump worked perfectly, along with the ion pump. The vacuum chamber held the 10^{-7} torr. This is every good and expected at it is an ultra-high vacuum chamber. However, this pressure is than the original capstone group before got to.

1.3.3 Original System Performance

The overall TOF-SIMS system did not work at the time the project began. This was because a power cable to the ion gun was damaged. Once the cord was fixed, the system was then turned on and tested. However, no data was collected by the computer at that time.

1.3.4 Original System Deficiencies

Last year's TOF-SIMS system does not meet any current customer requirements. It cannot heat a sample at a constant rate, it cannot support the new sample within the sample holder, and the ion gun cannot ionize the surface of the new sample. Also, TPD is not integrated into the original TOF-SIMS in any way. However, the original system can make the chamber an ultra-high vacuum, and the funnel can collect the activated ions. Overall, many modifications are necessary for the system to meet the current customer requirements.

2 REQUIREMENTS

The requirements for this project were given to by the faculty advisor, Dr. Michael Vernon Lee. These requirements will guide us in designing and building a sample holder that will allow for temperature programmed desorption (TPD) within the ultra-high vacuum chamber.

2.1 *Customer Requirements (CRs)*

In order to improve upon and develop a TDP SIMS device the group was given requirements to meet from Dr. Lee and Sandia. The requirements received from the client were based on the project objectives specified in the section 1.1. From the project objectives, the requirements were selected upon based on the most prominent and critical objectives to the system. Each requirement approaches the project objectives clearly and precisely and will help the team create innovating designs that the clients requested.

The customer requirements for the project are as followed:

- Heat sample
- Heat sample at a constant rate
- Measure desorption data
- Monitor the mass
- Shield the turbo pump from secondary ions within the chamber
- Design a new functional sample holder

2.2 *Engineering Requirements (ERs)*

The project will provide Sandia and Dr. Lee with a device that meets all the project objectives. In order to obtain this device, the criteria set but the clients must be met. The engineering requirements are specifications that give the customer requirements quantitative and qualitative goals. The requirements are based on what best fits for the customer requirements and project objectives. The team analyzed and used specified conditions set by Dr. Lee and Sandia, to determine an effective approach the the customer requirements.

Customer requirements will be met through the following engineering requirements:

- Heat Sample to 1450 ^{o}C
- Heat sample at a constant rate of 1 ^{o}C/s
- Project Cost should not be greater than $16,500
- Time Resolution of 2 nanoseconds
- Monitor the mass (m/z=50)
- Electrically and thermally insulated sample holder
- Safety for both user and device

2.3 House of Quality (HoQ)

The House of Quality (HoQ) is a diagram used for defining the relationship between customer requirements and the firm/product capabilities. The HoQ helped the team understand the important customer and engineering requirements, through comparison and reasoning (Figure A1). Each customer requirement was given a weight from one to ten, ten being the most important and one the lowest. Then each customer requirement was given a score to signify a collaboration to the engineering requirements; A score of either nothing, one, three, or nine were given, where nine is an exact correlation. The engineering requirement of absolute technical importance (ATI) is the material needed to withstand thermal heat. This implies that the team will develop concepts around this important aspect. Project cost and heating a sample at a constant rate of 1 ºC/s were the next highest rated requirements in relative technical importance (RTI). The RTI score is based on the score received in ATI and provides the team with two more requirements that will be considered when developing designs. Overall the HoQ provides the team with a basic knowledge of the most important requirements to meet for this project.

3 EXISTING DESIGNS

TOF-SIMS systems have been around for over 20 years and have greatly developed in concept and in design [3]. Because TOF-SIMS have been developed over many years, many other TOF-SIMS systems have been created and are available for researching this project. By using multiple sources of research such as professors, scholarly articles, and physical interaction with last year's project, a lot has been learned about the TOF-SIMS systems.

3.1 Design Research

The design research done for this project has been done both online and in person. Much of our understanding of last year's capstone has come from physical interaction with the system itself. Through weekly meeting with Dr. Lee in the chemistry building, we have been able to experiment with and analyze the TOF-SIMS system. The locations of the ion gun, turbo pump, ion pump, flight chamber, and sample holder have been observed through this physical interaction. Personal interaction with Dr. Lee has been tremendously helpful in understanding the project. During the weekly meetings, he explained in detail how every piece of the system operates and what it does. He demonstrated this using drawings, examples, and references to the physical TOF-SIMS system.

Online research has also allowed us to gain a better understanding of the existing design. Each member was asked to research a particular topic in regards to the system. This allowed for all to share our individual findings and compile the research as a team. After background research on how each piece of the system works, team members used the internet to search for other existing ion guns, sample holders, and turbo pump shields.

3.2 System Level

The team used last year's information to understand the existing designs and subsystems on the original system that may need to be changed. The subsystem analyzed include the sample holder, Ion gun, and turbo pump.

3.2.1 Existing Design #1: Sample Holder

The sample holder currently being used in the TOF-SIMS is a long rectangular piece of steel. At the end of the steel plate, the actual sample holder, a small receptacle, holds the material at a 45 degree angle using a spring to hold it steady and in place. This allows the ions that discharge out of the ion gun to hit the sample and bounce into the flight chamber. This entire system pulls out linearly from the left side of the chamber. A goal of our project is to redesign and create a sample holder that can withstand high temperatures and is electrically insulated. Because our sample with be electrically heated, the sample holder must be properly insulated in order to keep the user safe from any harm.

3.2.2 Existing Design #2: Ion Gun

An ion gun refers to an instrument that generates a beam of heavy ions with a well-defined energy distribution. The beam is produced from a plasma confined within a volume, and the ions of the energy are extracted and accelerated. The original TOF-SIMS project used an ion gun that discharged Cesium ions. However, due to the change in sample, these ions are too large. The team will need to seek other alternatives for the new project.

3.2.3 Existing Design #3: Turbo Pump

The turbo pump is above the sample insertion plate. Its main role is to help the ion pumps with dropping the pressure when the pressure is relatively high. Since this pump is attached directly to the main chamber it may be damage when the system is running due to the hot ions hitting its blades. To keep the turbo pump working properly a shield may need to be placed within the vacuum chamber. In order to determine if a shield is needed, the current turbo pump will run with any new updates to the design. If the pump blades accumulate damage then the team knows to add a shield to protect it.

3.3 Functional Decomposition

Making a black box model helps the team understand what the system is supposed to do overall. Creating a functional model helps the team understand how each subsystem is connected and what each subsystem does within the overall function of the system. Making a functional model for this project tell the team how many different subsystems there are and helps teach how the system works. With this information the team is able to develop sufficient design concepts. Both models glimpse into the UHV chamber and the processes generated by TPD SIMS.

3.3.1 Black Box Model

The Black Box model is a system evaluation used to determine the inputs and outputs of a device without knowledge of the internal workings. The model requires energy, mass, and sensor input and outputs. Figure 3.3.1, shows the team's Black Box model for the TPD SIMS device. The energy inputs consist of initial human and electrical interactions. The mass inputs are the steel sample and the electrons from the electron gun. The sensor input is the on/off process. The energy output corresponds with the inputs and produces an electrical output. The mass output is the product of secondary ions from the sample. The sensor output is similar to the input; the device uses an on/off process and produces noise. The primary function of the TPD SIMS device is to test dissertation data gathered in the ultra-high vacuum chamber.

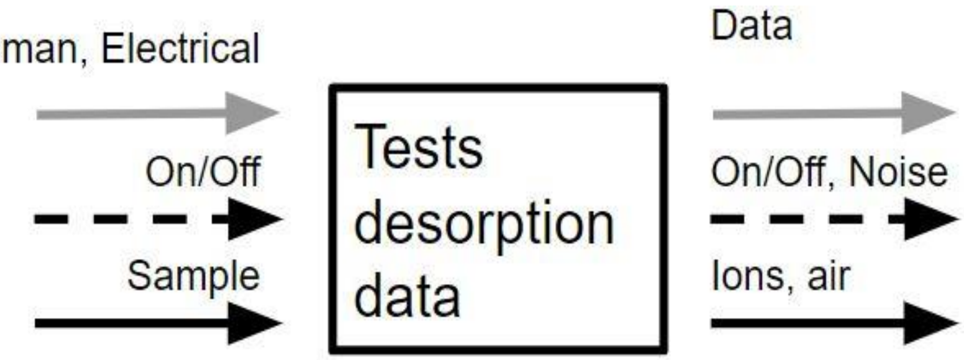

Figure 3.3.1: Black box model

3.3.2 Functional Model

The team is redesigning a sample holder, updating an electron gun, and adapting a pump shield within the vacuum chamber. A functional decomposition model or functional model is a structured representation of the functions within the modeled system. The team designed the functional model based on the original design with additional components. Figure 3.3.2 shows a complete list of components and how they integrate. All components will need to be functioning together with the new additions, so it is important to understand each component and all of its functions within the device. Although the chamber is the only TPD SIMS system being looked at, most of the team's updates will appear within the device. The parts that will be purchased are the electron gun and a possible turbo pump shield. The two pumps attached to the vacuum chamber, computer/computer program, and TOF SIMS are already in the team's possessions thanks to the previous team's work. Figure 3.3.2 show the functional model for the TPD SIMS with the updated electron gun. It is important to fully understand the device and all the components within it in order to develop solutions to the improvements needed to be made.

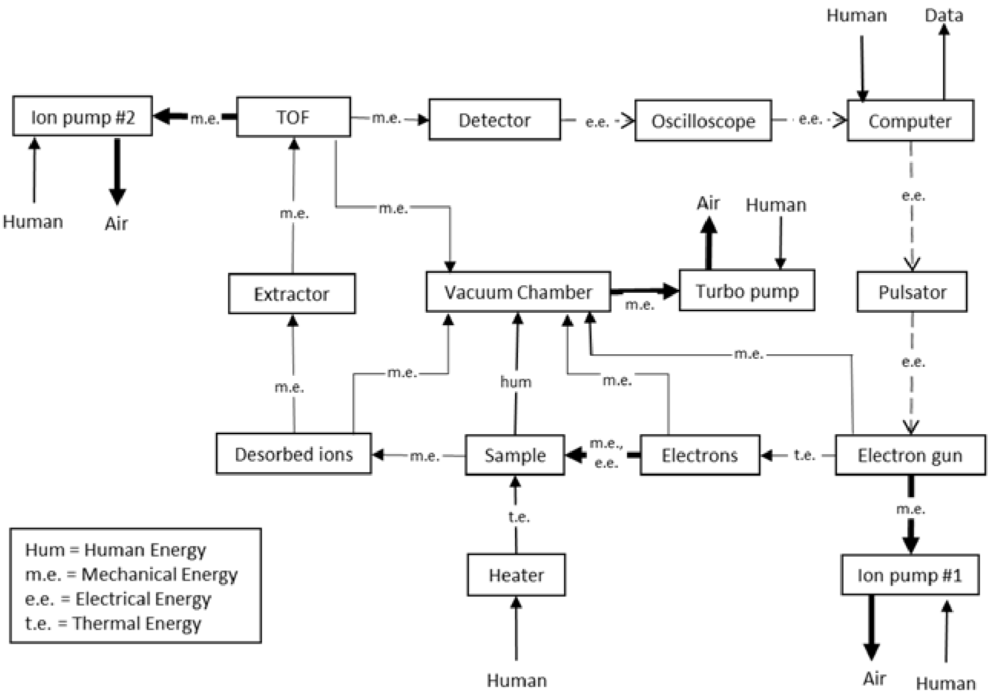

Figure 3.3.2: Functional model

3.4 Subsystem Level

Subsystems of the overall TOF-SIMS system were identified using the functional model combined with the customer needs. Defining these subsystems helped to identify individual parts that need improvement. The three main subsystems we will be analyzing include the sample holder, the source of ionization, and shielding of the turbo pump. Through online research, various existing designs for each subsystem were found and studied.

3.4.1 Subsystem #1: Sample Holder

Dr. Lee requires a new sample holder that can hold a sample of a larger size and material. The sample must be able to be changed with another sample if desired. This is to say the design should not permanently hold one specific sample. Also, the holder must be thermally and electrically insulated. This is needed due to the sample being heated up using an electrical current. If the holder is not insulated, the chamber would be subjected to electricity and thermal activity. The new sample holder must be able to be connected to the wires in order to keep them in place without excess movement. This subsystem is important to the overall project because the sample needs to be held steady and aligned perfectly with the ion gun in order for the machine to work properly.

3.4.1.1 Existing Design #1: Translucent Sampling Fixture

One example of a sample holder is a translucent sampling fixture. This sample holder allows for linear adjustment in relation to the placement of the sample (Figure 3.4.1). It is manually adjusted and gives a ruler at the bottom for reference. This type of sample holder is mainly used to measure translucence of oddly shaped samples [4]. This design is helpful for our project with respect to its linear movement.

Figure 3.4.1: Translucent Sampling Fixture [4]

3.4.1.2 Existing Design #2: Variable Angle Transmission Holder

Another example of an existing sample holder is the variable angle transmission holder (Figure 3.4.2). This device can hold various samples sizes at various angles. The angle changes with human interaction twisting the sample mounting stage. This device is mainly used to measure transmission [5]. It could be used in this experiment by allowing us to accurately angle the sample at the ion gun while still being able to move it around when needed.

Figure 3.4.2: Variable Angle Transmission holder [5]

3.4.1.3 Existing Design #3: Multi-Purpose Specimen Mount

Lastly, the multi-purpose specimen mount can hold many different shapes of specimen. This includes irregular shaped or perfectly cylindrical specimen up to one inch in diameter as seen in Figure 3.4.3 [6]. This may be useful in designing the new sample holder because it can hold many different material shapes non-permanently.

Figure 3.4.3: Multi-Purpose Specimen Mount [6]

3.4.2 Subsystem #2: Ionization Mechanism

Currently an ion gun is used in the TOF-SIMS system. This ion gun shoots out large Cesium ions at the material. It is located to the right of the system. As per Dr. Lee's requirements, we need a source that has a much smaller ion or electron to ionize the material. This includes flood guns, a smaller ion gun, or an electron gun. This source must work at least at 70 eV, 50 µA and have an ion beam diameter of about 5mm. This will allow for a more efficient ionization operation for our new material of steel. All while staying within budget, specifically under $10,000.

3.4.2.1 Existing Design #1: Flood Gun FS 100

A flood gun is an electromechanical device that provides a steady flow of low energy electrons to a desired target. Figure 3.4.4 shows Flood gun FS 100; this flood gun is distributed by OmiVac, a science equipment developer and supplier. This flood gun has a range of 0 to 500 eV, a max beam diameter of 11 mm, and a range of 0.1-1500 µA. This flood source is used to neutralize positively charged samples in SIMS systems [7]. This could be a potential source used in the project because it meets all the requirements as stated earlier.

Figure 3.4.4: Flood Gun FS 100 [7]

3.4.2.2 Existing Design #2: Ion Gun Package

This existing design includes an ion gun and an electronic control unit (Figure 3.4.5). It can operate at voltage as low as 100 eV, with a 10mm beam diameter, and has a range of 1 to 18 µA. This ion gun is

UHV compatible and is used to remove surface material [8]. This source also falls in the range of requirements and may be used in this project.

Figure 3.4.5: Ion Gun Package [8]

3.4.2.3 Existing Design #3: Model: ELS100

This last ionization source is very similar to the ion gun package. However, it is an electron gun rather than an ion gun. This gun is mainly used in energy loss spectroscopy. It has a range of 5 to 100 eV, a 1mm beam diameter, and is UHV compatible [9]. Given its specification, this source may be of potential use for our project.

Figure 3.4.6: Electron Source ELS100 [9]

3.4.3 Subsystem #3: Shielding Apparatus

The turbo pump within the TOF-SIMS system is prone to being destroyed if any ions were to hit its blades. This means that the turbo pump cannot interact with stray ions and must be shielded. Currently, there is no turbo pump shield apparatus. It is not known whether or not this is needed for our project. Extensive testing must be done prior to understand its necessity. There may or may not be ion gas build-up within the TOF-SIMS chamber. This shield, if needed, will be located in front of the turbo pump intake pipe at an angle that will keep out any ion gas, yet will not totally cover the entrance.

3.4.3.1 Existing Design #1: Magnetic Shield

A magnetic shield is used to reduce in a space by blocking the particles with a barrier made of conductive or magnetic material. This design uses a magnetic field to shield a turbo molecular pump from plasma gas. This plasma gas may be produced by the electron gun interacting with the sample. This magnetic shield. However, it is still in experimental stages and is not durable, yet it seems to work well [10].

3.4.3.2 Existing Design #2: Splinter Shield

Splinter shields consists of a cone structure made out of a durable material that can withstand UHV pressure and protect the pump from ions. The Splinter shield device is shown in Figure 3.4.7. This shield is mainly used to protect a pump from large, coarse objects. It collects these foreign objects and keeps them from entering the suction chamber. Due to its design, it will cause a loss in efficiency of the pump [11].

Figure 3.4.7: Splinter Shield [11]

3.4.3.3 Existing Design #3: MicroMesh Screens

Lastly, a micromesh screen may be used to protect the turbo pump from large ions, while also letting small secondary ions through. It is similar to any other screen as it has small square holes, but on the scale of 8 microns. It has a smooth surface that is easy to clean. Many micro mesh screens can be made out of gold, nickel, and copper. This type of shield has many applications including, electron ion separation, mass spectrometry, and nuclear particle sorting [12].

4 DESIGNS CONSIDERED

Understanding and utilizing the past device through a functional model allowed the team to develop ten concept designs that help the system meet the customer requirements. Each design takes a close look at the potential subsystems within the TPD SIMS. The team gathered to brainstorm and develop each design in order to produce innovative and creative outcomes that still meet the project objectives.

4.1 Sample Holder Designs

4.1.1 Design #1: Insulated sample holder coming in from the side

This design insulates the chamber from heat and electricity from the sample. The secondary arm that holds the sample is insulated thermally from the sample by a material with a high heat resistance and that can withstand a temperature of 1500 oC. The primary arm is insulated electrically from the secondary arm by electrically insulated washers between the two arms and the bolt. The bolt is also surrounded by a sleeve so that electricity cannot run through it.

Table 4.1.1: Pros and Cons for Design 1

Pros	Cons
Could reuse same secondary that is already holding the sample	Cantilever beam could cause high amounts of stress in the arms
No wasted energy while heating up the sample holder	Secondary arm has an electrical potential
Holds sample stationary	Would be difficult to manufacture electrically insulated sleeve

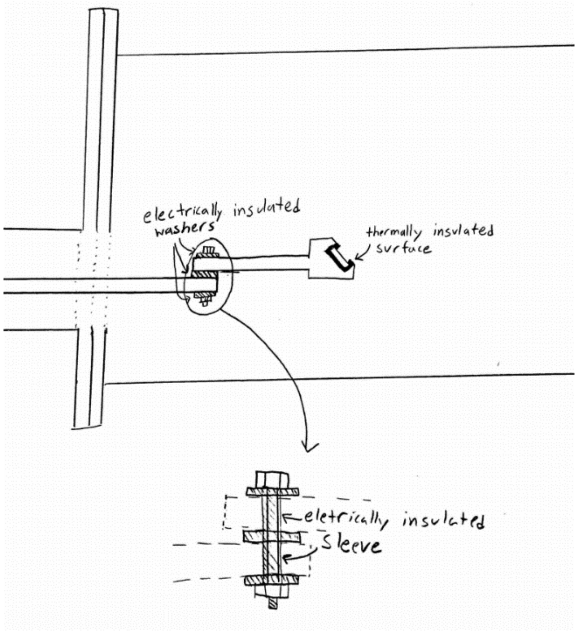

Figure 4.1.1: Insulated sample holder coming in from the side

4.1.2 Design #2: Carousel sample holder

This sample holder has four samples on the holder with each of them thermally insulated and the motor rod is electrically insulated. When the data for one sample is collect the motor is turned until the next sample is in place and then the next test is done. The design can be located in Appendix B, Figure B1.

Table 4.1.2: Pros and Cons for Design 2

Pros	Cons
Multiple samples remain inside vacuum	Difficult to heat up each sample individually
No human interaction with inside of chamber required, until a sample is not available	More weight on cantilever beam
Can be angled at 45° easily	More energy sources into the vacuum
Not bulky and could reduce costs	Difficult to align very precisely

4.1.3 Design #3: Hanging sample holder with wires being the heating source

This sample holder is held at the top of the chamber with a wire that will be used for joule heating the sample with the holder thermally insulated with a material that has a low electrical resistance. To implement this design, a hole would have to be drilled into the top of the chamber and then sealed again. Drilling then sealing the chamber would be both costly and time-consuming. Also, the ion cone is directly above the sample making inserting the sample harder.

Table 4.1.3: Pros and Cons of hanging sample design.

Pros	Cons
Sample holder doubles as the heat source	Costly
No need for electrical insulation	Not very stable within chamber, variation in sample location, not very precise
Very minimal design, not a lot of bulk or materials	Chamber will need to be modified to facilitate
Ease of attaching sample to holder	Will be difficult to orient sample and keep at 45°

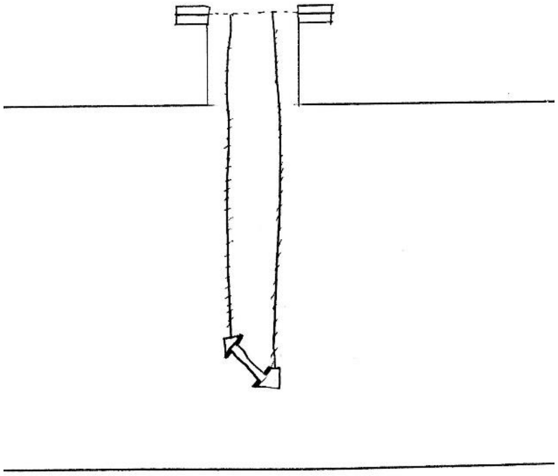

Figure 4.1.3: Hanging sample holder

4.1.4 Design #4: Remote controlled robot with rack of extra samples

This sample holder is a robot that is remotely controlled. It heats the sample by using a lazar and it can also grab other samples and place them into the chamber before running the experiments. The pros and cons are listed in Table 4.1.4 and a picture of the design is in Appendix B, Figure B2.

Table 4.1.4: Pros and Cons of remote controlled robot and a rack of samples within the chamber.

Pros	Cons
Multiple samples without breaking the vacuum	Very expensive
Robot is thermally insulated	The sample is subject to a lot of movement, variation in placement
One cord connected to robot	Chamber is curved, could be difficult to control robot
Holds the sample stationary while in position	Samples on rack may heat up during testing and produce gases

4.1.5 Design #5. Sample Introduction Chamber System

This design features an introductory vacuum chamber that has a gate between the introductory chamber and the testing chamber. First, the introductory chamber is brought to a vacuum. Next, the gate is opened from the main chamber into the introductory chamber, and the sample is extracted into the introductory chamber. After this, the gate is closed and the vacuum in the introductory chamber is relieved so the sample can be changed. After the sample is changed, the introductory chamber is brought to a vacuum, the gate is opened, the sample is put in the main chamber, and the gate is closed again. For this design, a secondary pump will be needed as well as a magnet that will control the sample holder while inside the chamber. This design is pictured below in *Figure 4.1.5* and is based off similar designs used at Sandia National

Laboratories and on the TOF.SIMS5 commercial setup [sims5 cite]. The pros and cons of this design are also summarized in *Table 4.1.5*.

Table 4.1.5: Pros and Cons of a sample introduction chamber system.

Pros	Cons
Never have to break the vacuum in the testing chamber	Very expensive
Easily change sample	A lot of materials, bulky and has space requirements
Degassing time decreased	Magnetic control may interfere with experiment and turbo pumps

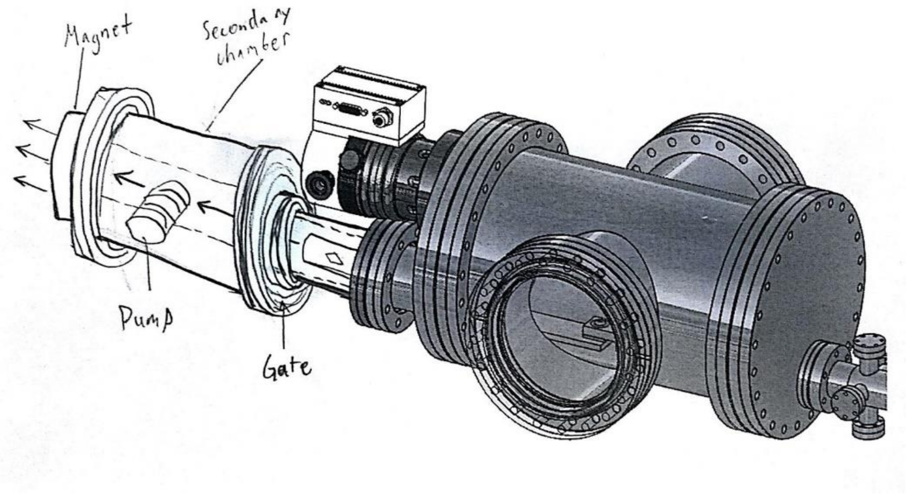

Figure4.1.5: Sample Introduction Chamber system.

4.2 Turbo Pump Shielding Designs

4.2.1 Design #6: Disconnecting the turbo pump while system is running

This design cuts the turbo pump off of the vacuum with a vacuum gate. This allows the pump to be turned off. With it being disconnected the chamber can be dropped to a lower pressure, since it is thought that the turbo pump is the limiter on the pressure. The pros and cons have been listed in Table 4.2.1 and a visual representation in Figure B3 in Appendix B.

Table 4.2.1: Pros and Cons of using a pressure gate to shield turbo pump from shock.

Pros	Cons
Turbo pump may be turned off during testing	Ion pumps have to pull all the secondary ions out
When turbo pump is disconnected, the chamber can reach a lower pressure	Pressure gates are expensive

4.2.2 Design #7: Splinter Shield

The design in Figure 4.2.1 utilizes a splinter shield designed specifically for this turbo pump to shield the pump from shock due to foreign particles. The manufacturer of the turbo pump company, Pfeiffer Vacuum, produces a splinter shield for this pump that would work well. [K8]. This design is pictured in Figure 4.21 below. A table with the main pros and cons is also below in Table 4.2.2.

Table 4.2.2: Pros and Cons of splinter shield design to shield the turbo pump from shock.

Pros	Cons
Turbo pump is constantly shielded under vacuum	Reduction in pumping speeds due to poor conductance
No accumulation of particles or debris in suction chamber	Lifecycle could be reduced if large particles get caught in shield

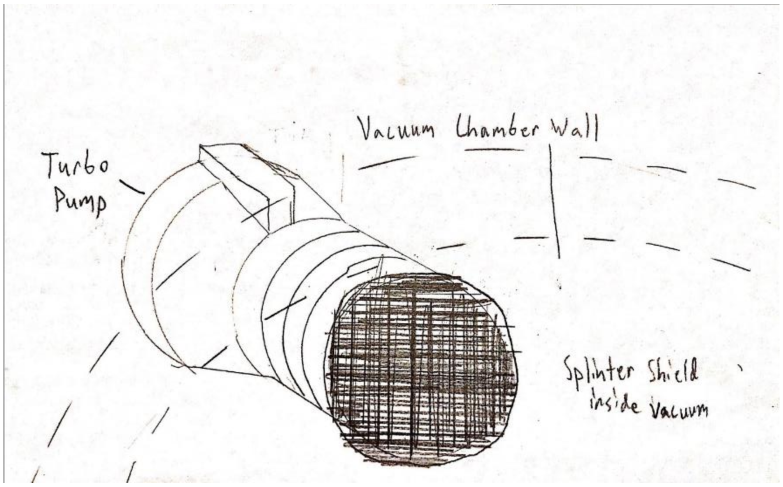

Figure 4.2.1. Turbo pump shielded from shock using a splinter shield

4.2.3 Design #8: Curved entry into the turbo pump

In this design the pipe leading into the turbo pump is turned upward. The curved pipe would make any atoms that get into the turbo pump lose most of its energy before reaching the pump. The design can be located in Appendix B, Figure B4.

Table 4.2.3: Pros and Cons of curved entry into the turbo pump design

Pros	Cons
Easy to implement	May not be completely protected
Inexpensive	
Does not restrict flow	

4.3 Electron Gun Designs

4.3.1 Design #9: Electron Gun

An electron gun is used to accelerate electrons off a sample at a high velocity. In Section 3.4.2, existing flood guns and electron guns on the market were discussed and researched. The four vendors mentioned have been contacted and two have responded with prices. While it is possible to construct an electron gun from various components, for this experiment, Dr. Lee and the team have chosen to purchase an electron or flood gun. The reason behind this decision is designing and building an electron gun for use in TOF SIMS experiments to get precise measurements, is not in the scope of this project. Using a homemade electron gun can also be dangerous and would be difficult to produce, in order to meet the precise requirements detailed in Section 2.2. Therefore, the team has done research on the four options in Section 3.4.2 and will select one to purchase with Dr. Lee's approval based on the required beam current, beam diameter, and electron voltage.

4.4 Total Redesign of System Setup

4.4.1 Design #10: Vertical TOF-SIMS Vacuum Chamber

In Figure 4.4.1, the existing system setup has been reoriented and remanufactured to have a vertical time of flight chamber. Since the chamber is at a low pressure creating a UHV of around 10-9 Torr, gravity will not affect a small particle in it's flight path. This information allows for the flight chamber to be redesigned with an upwards orientation. Overall, the design saves a physical space in the laboratory. This design is a potential design for the secondary phase of the project which is initializing the research and design phases of a nanosecond resolution temperature programmed desorption (TPD) TOF-SIMS vacuum chamber. This design also features the sample introduction chamber to easily change samples.

Table 4.4.1. Pros and Cons of a vertical TOF-SIMS setup

Pros	Cons
Reduces physical space needed for test setup	Could become off balance
Utilizes an introduction chamber system	Very expensive (two turbo pumps, ion pumps, ion or electron gun, sample holder, etc.)
Two turbo pumps will accelerate pumping speed	Difficult to orient ion pumps in good positions

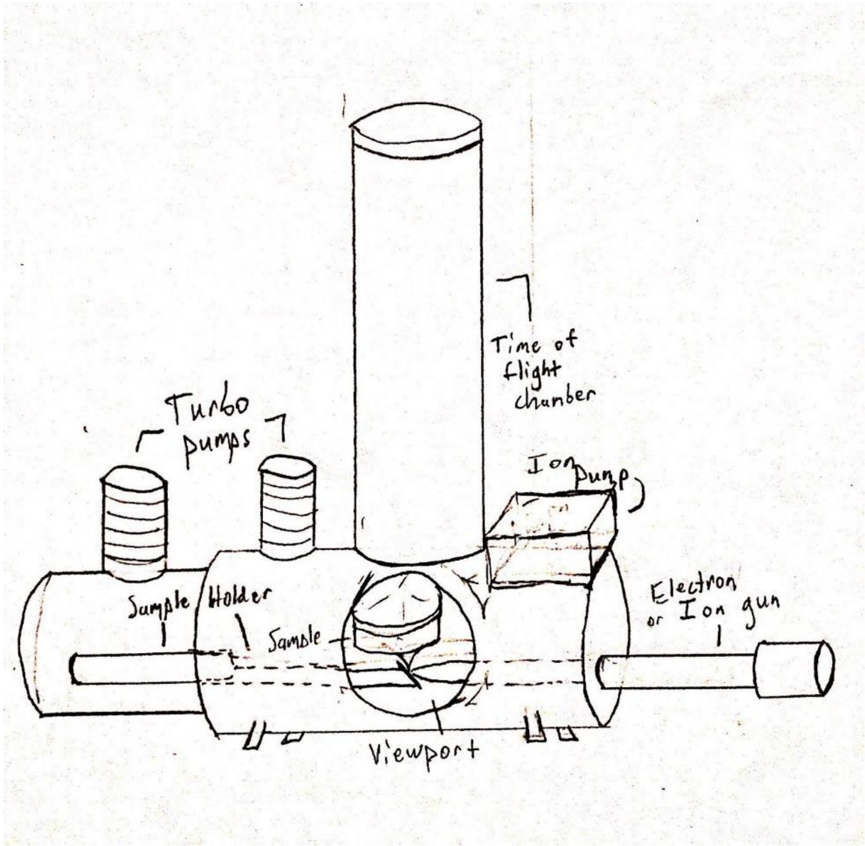

Figure 4.4.1. Vertical TOF-SIMS experiment setup

5 DESIGN SELECTED

For this report, this chapter will discuss the team's rationale for selecting a design in the near future. The methods utilized will be discussed to validate our decision on a final design.

5.1 Rationale for Design Selection

The team will analyze each design considered in Chapter 4 and come to a final design decision. To do this, we must assess how well each design performs to meet the customer needs and engineering requirements mentioned in Chapter 2. Dr. Michael Vernon Lee will be of help to our team as well in selecting a final design that is capable of meeting all needs and requirements. Constructing a decision matrix as well as a Pugh chart to help narrow down the best designs considered is the next step in our project. Along with this, the team will present the designs from above to Dr. Lee and discuss the drawbacks, improvements, and experimental limitations these designs have. As seen in the House of Quality in Appendix A Figure A1, the most important engineering requirements are thermal insulation of sample holder up to 1450 ºC, heat sample at a rate of 1ºC/s, and project cost. The project cost is still tentative so we will not worry about this just yet.

6 REFERENCES

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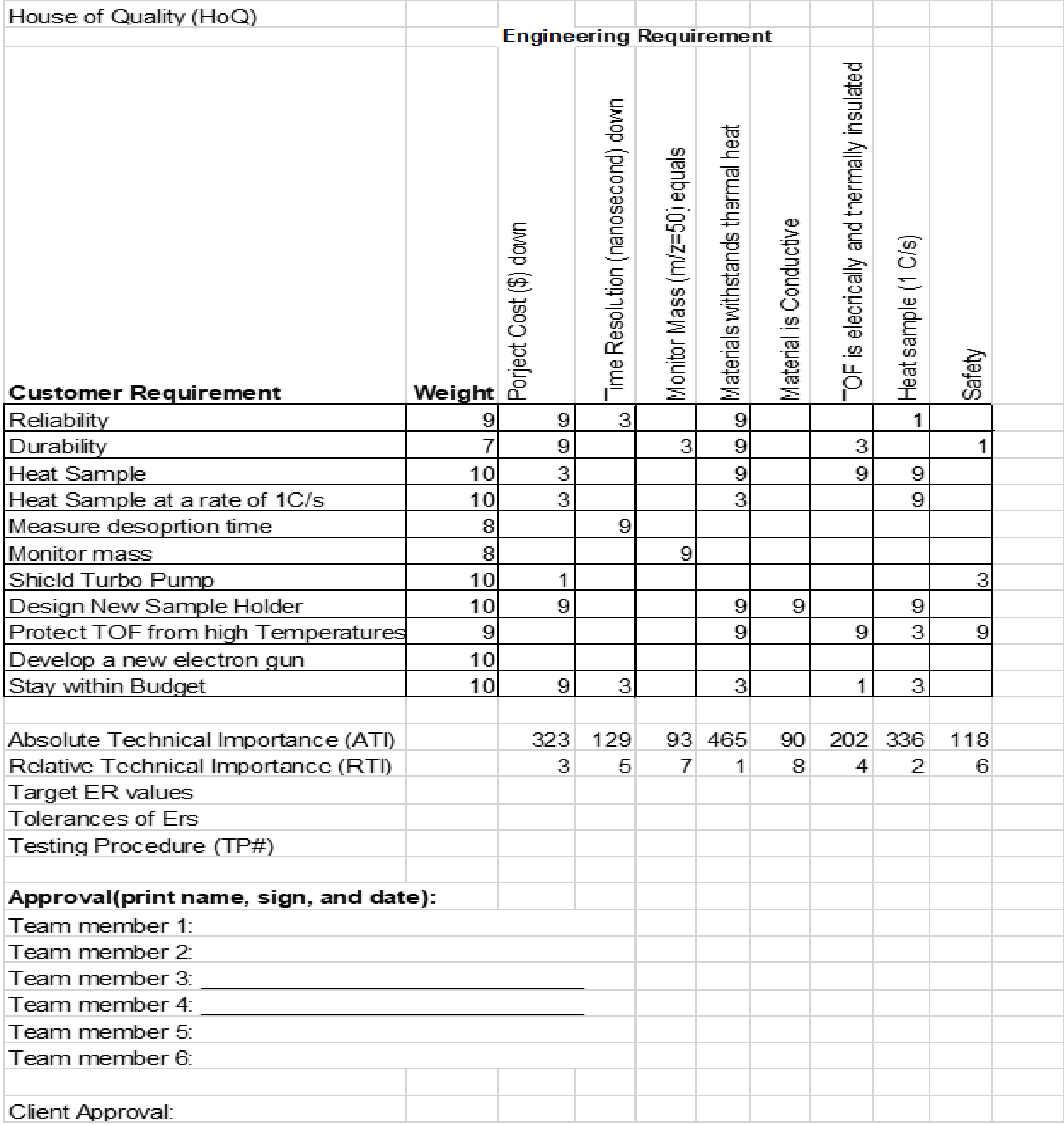
7 APPENDICES

7.1 Appendix A: House of Quality



House of Quality (HoQ)									
		Engineering Requirement							
Customer Requirement	**Weight**	Porject Cost ($) down	Time Resolution (nanosecond) down	Monitor Mass (m/z=50) equals	Materials withstands thermal heat	Material is Conductive	TOF is elecrically and thermally insulated	Heat sample (1 C/s)	Safety
Reliability	9	9	3		9			1	
Durability	7	9		3	9		3		1
Heat Sample	10	3			9		9	9	
Heat Sample at a rate of 1C/s	10	3			3			9	
Measure desoprtion time	8		9						
Monitor mass	8			9					
Shield Turbo Pump	10	1							3
Design New Sample Holder	10	9			9	9		9	
Protect TOF from high Temperatures	9				9		9	3	9
Develop a new electron gun	10								
Stay within Budget	10	9	3		3		1	3	
Absolute Technical Importance (ATI)		323	129	93	465	90	202	336	118
Relative Technical Importance (RTI)		3	5	7	1	8	4	2	6
Target ER values									
Tolerances of Ers									
Testing Procedure (TP#)									
Approval(print name, sign, and date):									
Team member 1:									
Team member 2:									
Team member 3: ______________________________									
Team member 4: ______________________________									
Team member 5:									
Team member 6:									
Client Approval:									

Figure A1: HoQ Fall 2017

7.2 Appendix B: Designs Considered

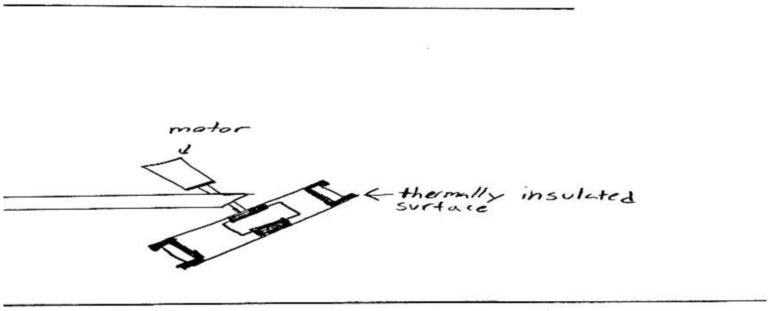


Figure B1: Carousel sample holder (design #2)

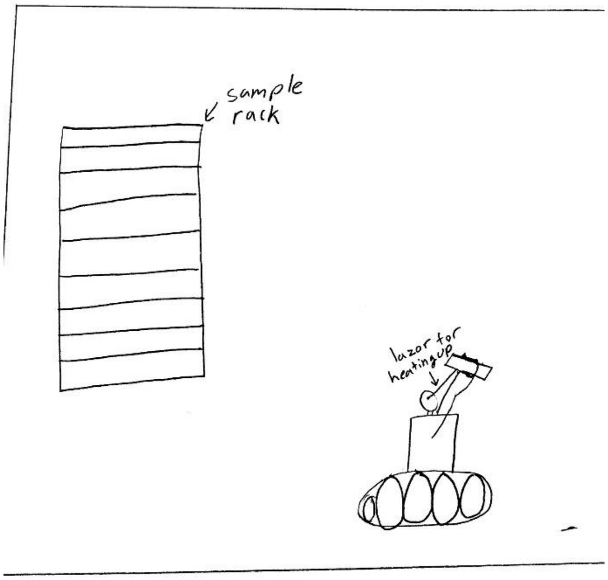


Figure B2: Remote controlled robot with rack of extra samples (design #4)

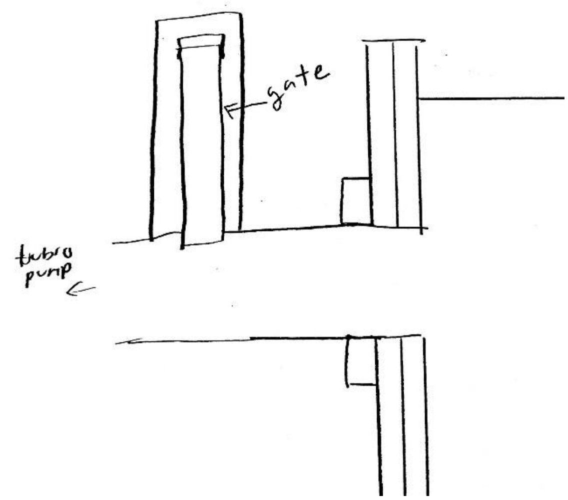


Figure B3: Disconnecting the turbo pump while system is running (design #6)

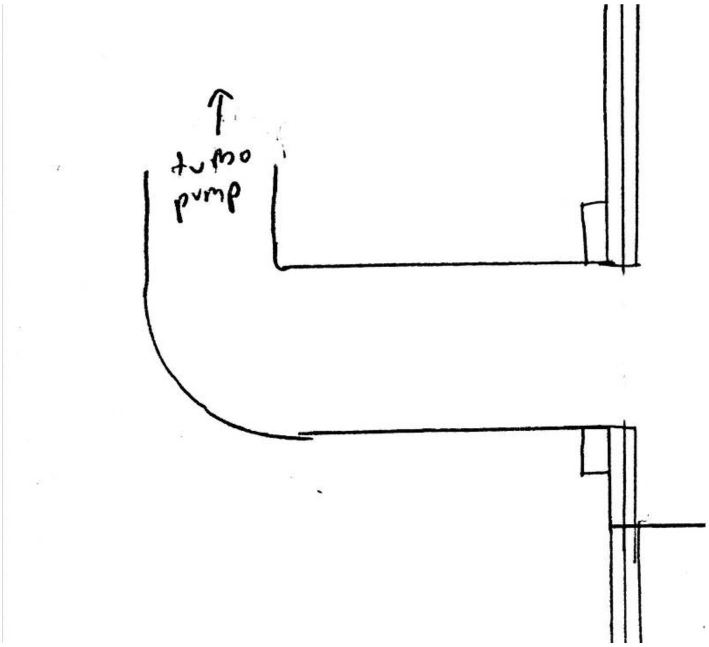


Figure B4: Curved entry into the turbo pump (design #8)