

# **Design of a Tissue Sample Grinder for Preparation in Biochemical Analysis**

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Biomedical Engineering Design 301  
University of Wisconsin – Madison  
March 15, 2002

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## Abstract

Our client desires a device that will prepare tissue samples used in biochemical analysis. This process includes freezing the sample in liquid nitrogen, grinding the sample to a fine consistency, and collecting it for later use. Our group brainstormed and tested various grinding mechanisms. Based on 8 criteria, we analyzed 3 main design alternatives. Using the score from a design matrix, the impact sampler was chosen as our final proposed design. Future work is needed to further develop this design, specifically the cooling mechanism and collection method.

## Design Problem

We need to design a device to complete the manual process for preparing a tissue sample for biochemical analysis. The device should freeze the tissue (with liquid nitrogen), grind it to a powder, and collect it in a vial.

## Background

### **Biological and Clinical Rationale**

When a tumor is removed from a patient during a surgical resection, a pathologist analyzes it with microscopy techniques. The information about the tumor cells obtained through this method is often insufficient to determine precisely what kind of treatment may be most effective for the patient. A more accurate and informative analysis of the tissue is often desired, and therefore, a tissue sample may be sent to a molecular biology laboratory for profiling of DNA, RNA, and protein. This information about the patient's tissue sample is important in determining a possible specific treatment that may inhibit or decrease tumor growth. However, before a profile can be completed, the tissue sample must be preserved and prepared for the molecular testing. The current preparation procedure involves freezing the sample with liquid nitrogen and using a mortar and pestle to grind up the sample to a fine powder, which can then be analyzed. This process is tedious and time-consuming, and a molecular biologist may spend several hours per day grinding samples. Our proposed device would replace the current manual preparation of tissue samples, thus allowing the researcher to spend his/her time on other tasks. Ultimately, this device would be placed in a clinical setting so that a physician or other health

care staff could simply insert the fresh sample and later remove the ground sample, which could be sent to a laboratory for testing.

## **Design Requirements and Constraints**

The final design of this device must fulfill several requirements, as given by the client. The device should freeze a tissue sample less than a gram in mass (most likely with liquid nitrogen) and subsequently grind the sample to a powder the consistency of powdered sugar. The sample should be collected efficiently (at least 38 mg of the sample) in a vial or other container that can be removed from the device for future biochemical analysis. When not in use, the device itself could be kept cold in order to facilitate the freezing process when it is in use. The device would be used to prepare up to 40 tissue samples per day. It is preferred that the processing time for a single sample be comparable to or less than the time necessary for the current manual process (15 minutes).

The constraints for the design of this device are relatively few. All materials that come in contact with the sample must be able to withstand the cold temperature of liquid nitrogen ( $-196^{\circ}\text{C}$ ). The device should fit on a laboratory bench. Also, the device should have removable components to aid in cleaning between sample processing. Finally, the total cost of the prototype should not exceed \$1,500. If this product were manufactured for use in a pathology lab or clinical environment, the cost for them would be greater, selling for around \$20,000.

## **Existing Products**

### *BeadBeaterä*

Biospec Products, Inc. currently produces the BeadBeater™ (Figure 1), a bead milling homogenizer. In the past this device has been used to disrupt small cells like yeast. This

disruption occurs when the machine stirs and agitates the glass beads, which collide with cells resulting in crushing. Recently researchers have begun using the BeadBeater™ to grind plant and animal tissue with bead sizes of 1.0 to 2.5 mm. The tissue is not frozen and the unit has no cooling unit. For grinding, the volume of beads should be greater or equal to the volume of the tissue sample. The beads are available in glass, stainless steel, zirconia, chrome steel, and tungsten. Tougher materials require beads with a higher density (Meyer, 2002).

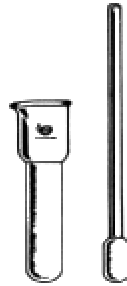


**Figure 1.** An image of the BeadBeater™ from <<http://www.biospec.com>>. The top unit spins the metal or glass beads to create collisions with the tissue particles. The collision force breaks apart the tissue. Beads must be cleaned after each use (Meyer, 2002).

### *Pestle and tube homogenizer*

Pestle and tube homogenizers (Figure 2) consist of a Teflon pestle that precisely fits into a tube. The distance between the tube and pestle is specialized for the particular cell type to be homogenized. The pestle spins and grinds the sample with a shearing force. The pestle is pushed downward and the sample can only pass the spinning pestle if it is smaller than the clearance between the tube and pestle (Seetharam and Sharma, 1991). The tube is typically placed in a beaker of ice to keep the tissue cold. The main problem with homogenizers is that

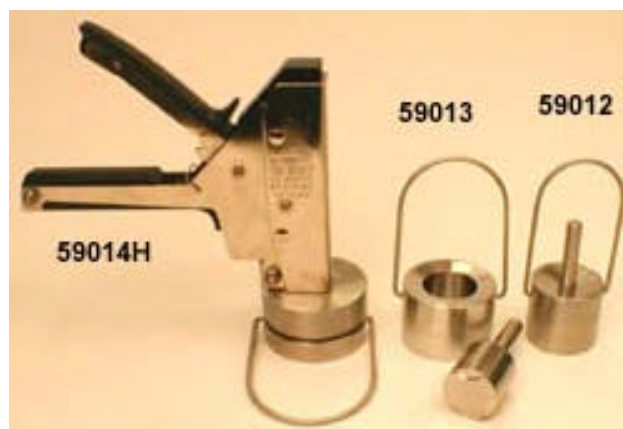
the tissue must be prepared ahead of time by grinding or shearing with a scissors (Burgess, 2002).



**Figure 2.** An image of the Potter-Elvehjem Homogenizer (LabGlass, 2002) from <<http://www.lab-glass.com>>. The precision-fit tube is on the left, and the pestle that is attached to a motor is shown on the right. To homogenize a sample, the pestle is forced downward to the bottom of the tube.

### *Bio-Pulverizer™*

The Bio-Pulverizer™ consists of a stainless steel base and a piston that uses freeze fracturing to grind a tissue sample. The tissue is pre-frozen with liquid nitrogen and inserted into a pre-cooled base. The piston and spring loaded hammer are connected via a trigger loaded mechanism (Figure 3). The sample is then pounded once or twice to achieve desired consistency. It is then inverted to drop sample into appropriate collection vial (Meyer, 2002).



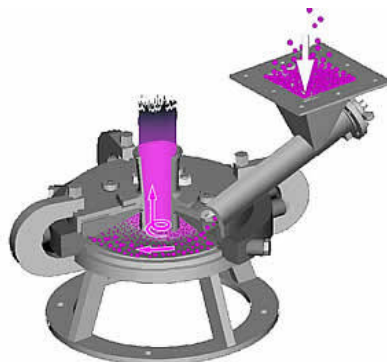
**Figure 3:** The spring loaded bio-pulverizer is shown on the left. The mortar and piston are shown individually on the right. This device grinds by freeze fracturing. Image taken from <http://www.biospec.com/Brochures/cryog/BioPulv.html>.

## *Jet Pulverizer*

One design currently on the market is the Jet Pulverizer™. It is designed to grind any type of crystalline or friable materials, producing product in the size range of 0.25 to 15 microns. The biological design of the pulverizer is able to process samples smaller than 1 gram into a small centrifuge tube with 80% collection efficiency. The device can operate to precise specifications with little or no contamination or additional heat (Jet Pulverizer Company, 2002).

Pulverization occurs in the central chamber of the jet energy mill (Figure 4). The process material approaches sonic velocity around the perimeter of the chamber by multiple jets of air or steam. No grinding media is involved. The high-velocity collisions between particles of the process material reduce the particle size. The interior of the chamber allows recirculation of over-sized particles, which enhances the incidence and the effect of collisions. As particles reduce in size and progressively lose mass, they naturally migrate toward the central discharge port. (Jet Pulverizer Company, 2002).

The process involves no moving parts and is suitable for many materials, including cryogenic ones. Laboratories can process just a few grams of a compound in the 1-in. jet mill, the smallest of its kind. These mills are small, easy to disassemble and easily cleaned with. Disassembly requires no hand tools (Jet Pulverizer Company, 2002).

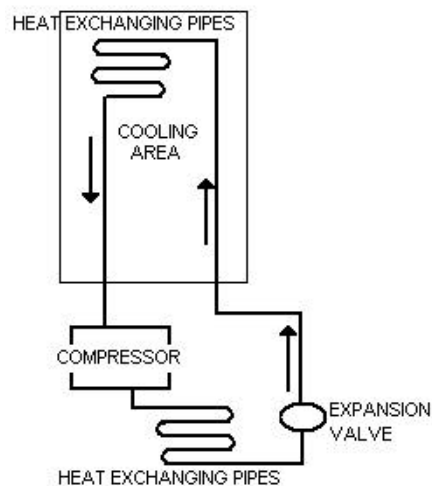


**Figure 4.** The material is placed into the jet energy mill where it is propelled by compressed gas at near sonic velocities. The material collides with other particles and breaks apart. When the particle is small enough, it is able to exit through the center port (Jet Pulverizer Company, 2002). Image from <http://www.jetpul.com>.

## Literature Research

### *Refrigerators*

As seen in Figure 5, refrigerators have 5 basic components including a compressor, internal heat exchanging pipes, an expansion valve, external heat exchanging pipes, and refrigerant. The refrigerant cycles throughout the entire system absorbing or dissipating heat. The cycle begins with the compressor raising the pressure and temperature of the refrigerant. The refrigerant travels to the external heat exchanging coils and the excess heat is dissipated. The refrigerant moves through the expansion valve and evaporates after entering a low- pressure area. Absorbing heat while in the internal heat exchanging pipes, the refrigerant cools the internal unit (where food or laboratory samples are typically stored). The hot refrigerant then enters the condenser and the cycle repeats (Brain, 2002). Laboratory quality refrigeration and freezer units are expensive. A 0.12 m<sup>3</sup> (3.8 ft<sup>3</sup>) –30° C Biopac laboratory freezer costs \$1,160.00 (BioCold Scientific, 2002).



**Figure 5. A schematic of a refrigeration system.** The arrows indicate the direction of the refrigerant flow. The refrigerant is recycled in a continuous loop either absorbing heat from the cooling area or dissipating heat in the external heat exchanging pipes.

### *Cryogenic System Properties*

A cryogenic storage device must be designed to withstand forces resulting from internal pressure, the weight of contents, and bending stresses. Most cryogenic devices are based on the concept of a dewar flask principle – a double walled container with the inner space being well insulated. In this design, the inner vessel must be constructed of a material compatible with the cryogenic fluid, making the material compatibility a major factor in designing a system. The properties and behavior of the materials included must be considered at low temperatures since they often vary significantly from room temperature. These factors include its thermal properties such as its ability to conduct heat as well as its thermal expansivity, a material's cyclic expansion and contraction due to a change in temperature from low to room temperature, as well as its mechanical properties such as ductility and brittleness. Lastly, the compatibility of materials with the cryogenic fluid being used must also be considered.

If a material exhibits low-temperature embrittlement, the material should not be used in a cryogenic system. When a material is subjected to a force of high enough stress level, the elastic behavior of the material will no longer hold. The material will become brittle, breaking without any more deformation, or it will become ductile, becoming permanently deformed. Both will lead to a system failure and inadequate performance. A material's brittleness is related to its ability to dislocate under stress, which is related to its structure. Metals, specifically the face-centered cubic (fcc) metals and their alloys, are most often used in cryogenic equipment. These include metals such as aluminum, copper, and nickel. The body-centered cubic and the hexagonal close packed metals are less desirable low-temperature devices because they are more apt to become brittle. Plastics and glass are less desirable materials because they tend to be very brittle and can shatter upon contact with a substance as cold as liquid nitrogen. When stress is

applied to glass, the atomic bonds in the structure rupture causing the propagation of a crack resulting in a fracture of the glass piece (Flynn, 1997).

Some considerations must also be taken into account concerning the use of liquid nitrogen in this proposed device. In general, the container that holds liquid nitrogen must be a good insulator. A dewar is a specially made container designed to hold substances as cold as liquid nitrogen; unfortunately, most are expensive. A thermos is an alternative container for liquid nitrogen; however, the liquid nitrogen will evaporate faster, and the outside of the thermos will become very cold to touch (University of IL Physics Dept., 2002). Evaporation of the liquid nitrogen will cause a high pressure to build up inside the thermos. Drilling a hole in the thermos can allow the nitrogen vapor to escape; otherwise, it may explode. Care must also be taken when handling liquid nitrogen to prevent serious frostbite burns. Safety goggles and waterproof welder's gloves should be worn (K3PGP Experimenter's Corner, 2002).

## Design Alternatives

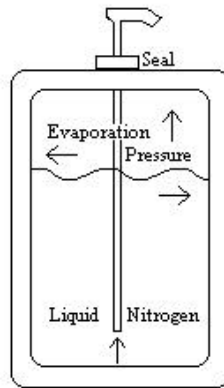
To simplify our task of designing the tissue grinder, we broke the design into 3 parts: cooling, collection, and grinding. Brainstorming was primarily focused on possible devices for grinding the frozen tissue sample. Future development will include integrating the cooling and collection processes into our final design.

### **Cooling**

#### *Transporting Liquid Nitrogen*

Two methods for the delivery of liquid nitrogen to the sample were considered. One method incorporates the evaporation pressure to drive the flow of liquid, while the other method uses non-pressurized liquid nitrogen. The evaporation pressure method uses climatic

temperature to drive evaporation. When the storage tank is sealed, the evaporation pressure rises within the tank. The pressure expels liquid out of the tank through a tube inserted into the liquid nitrogen (see Figure 6). This pressure driving the flow is not constant. As the liquid nitrogen level drops, the pressure decreases. A constant amount of fluid is not precisely determined by the fluid withdrawal time. This method is good for imprecise withdrawal.



**Figure 6.** The pressure developed inside the tank pushes the liquid nitrogen out. The tube provides a seal at the opening allowing pressure to build. It can be selectively inserted when liquid nitrogen is needed.

The alternate delivery method uses a liquid nitrogen pump (LNP), which allows quantified flow from an un-pressurized liquid nitrogen container. Two tubes are attached to the LNP pump. One is a double walled tube, which draws the liquid nitrogen, while the other carries the returned nitrogen gas. This gas can be used to flush moisture from the proposed device. The storage tank can be filled and flow control can be regulated easily.

### *Application of Liquid Nitrogen*

To cool-down equipment and keep tissue samples frozen, there are two techniques: immersion into a pool of liquid nitrogen and spraying liquid nitrogen particles. Immersing an unfrozen item will create a thin crust by freezing the outer layers of the material. The thin crust formed by immersion can be beneficial since it would prevent the material from sticking to the

sides of the container (Agnelli and Mascheroni, 2000). Care must be taken so that the liquid nitrogen pool does not completely evaporate, if this happens, the tissue may freeze to the surface it is resting on.

Liquid nitrogen spray can be created with liquid nitrogen and helium gas. The helium is pushed into the gas chamber of an injector at a higher pressure than the liquid nitrogen is stored at. This forces the liquid nitrogen through a nozzle where tiny liquid nitrogen droplets spray down onto a sample (Felizsaz *et al.*, 2000).

### *General Cooling*

Before the tissue sample is added, all materials that contact the tissue must be cooled. If the tissue will be stored in the device for any extended amount of time longer than 5 minutes, the device must have an additional system to keep the tissue frozen. This would be an additional feature that would not force the user of the device to wait for the sample to be processed. Pre-cooling and cold storage of the device could be accomplished by either periodic liquid nitrogen application or an additional cooling system. Two options exist for cooling systems, dependent storage of the device in a freezer, or an independent cooling system with refrigerant, heat exchanging pipes, a compressor and an expansion valve.

### **Collecting Sample**

We have developed two ideas for containers to collect the sample: A removable plate with indentation, and a miniature collection vial. The removable plate would have a slight indentation, allowing the sample to fall onto a large surface. A miniature collection vial similar to the tubes currently used to store the tissue could also be used to contain collected sample. The

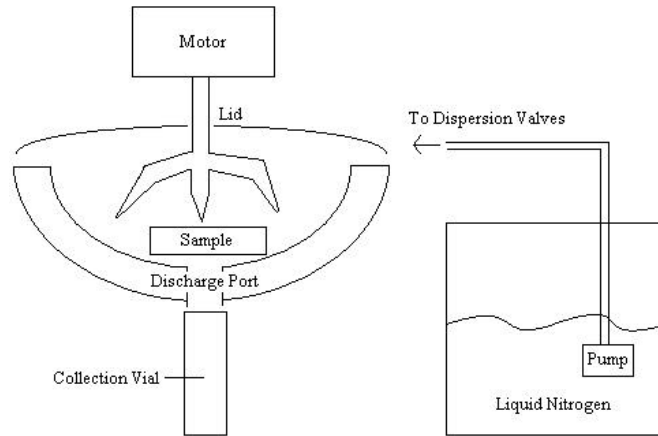
container must be made out of a material able to withstand the cryogenic environment and forces of the grinder. Pyrex and stainless steel are both viable options for the container.

## **Grinding**

During the first half of this semester, our group focused on brainstorming potential mechanisms for grinding. Our preliminary design solutions included a plethora of mechanisms such as sliding plates, beads, pressurized air, pounding hammers, blenders, and funnels. From these designs, we chose to focus on three main ones to seriously consider and develop further.

### *Design Option 1: Blender*

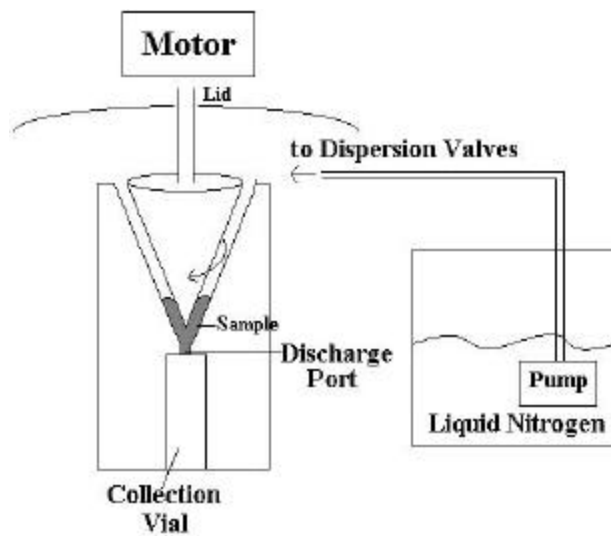
One design option explored was the blender (Figure 7). It operates similar to a household blender by using sharp blades to break the frozen sample into fine particles. Liquid nitrogen is delivered to the blending chamber through a pump to allow proper cooling, keeping the sample frozen throughout the blending process. The blades are connected through a metal shaft to a motor, which supplies the energy needed to break the sample. By covering the blending area with a lid, sample loss is prevented. After the sample is broken, it can be washed through the discharge port with small amounts of liquid nitrogen into the collection vial (see Figure 7). The discharge port is selectively opened when the sample has finished blending.



**Figure 7.** The sample is cut into smaller pieces by the spinning blades of the blender. The liquid nitrogen spray will wash the sample through the discharge port and into the collection vial.

*Design Option 2: Funnel Grinder*

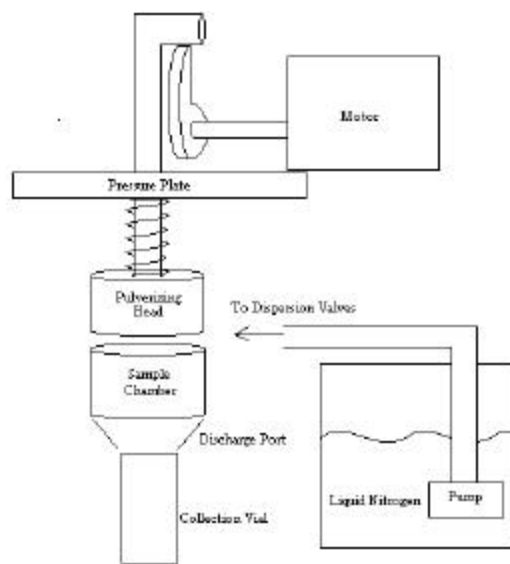
This design uses a metal cone that rotates around its central axis to grind the sample. After the sample is inserted, the lid is closed and liquid nitrogen is pumped into the sample collection chamber. The motor rotates the cone creating a shear force against the sample. After the sample is completely ground, the discharge port opens and the sample is collected in the vial (Figure 8).



**Figure 8.** The motor spins a cone shaped grinder to break apart the sample by shear forces. When the sample reaches the appropriate size it enters the collection vial through the discharge port.

### *Design Option 3: Impulse Sampler*

The impulse sampler design incorporates the same catabolic mechanism as the cryogenic pulverizer, but attempts to further the process using automation (see Figure 9). The sample is first placed inside the sample chamber. Liquid nitrogen is dispensed into this chamber by a pump in order to cool the device and freeze the sample. The sample is then pulverized and consequently broken into smaller particles by impulses from the pulverizing head. A motor controls the impulses through a spiral gear, raising the head with each turn of the motor. When the sample is sufficiently pulverized, the discharge port is opened and the sample chamber is flushed with small amounts of liquid nitrogen to wash the frozen sample into the collection vial.



**Figure 9.** The single-sampler freezes tissue samples with liquid nitrogen and processes them with impulses delivered by the motor. The processed tissue is collected in the collection vial.

## **Evaluation of Designs**

To better evaluate our designs, our group decided that it was necessary to conduct some initial testing. We tested the following methods: two plates sliding past each other, a shaker with metal beads, a rotating pestle and a pounding hammer. First, we tested the two flat surfaces that provided a shearing force to the frozen tissue sample. The sample was not being adequately

ground up, merely just shedding a small layer of cells each time. This was not an efficient method of grinding nor did it work that well. Next, we looked at metal beads in a confined container. This also was not an ideal method since the sample would stick to the beads and was hard to isolate. Next we tried the hammering method. This test led to the conclusion that the sample needed to be in a tightly fitting container and hammer set. If not, since the sample was so hard – it tended to project bits outward and was not easily contained. With an enclosed container, it was broken up into smaller pieces, but not to a fine powder. Next, we decided to try the rotating pestle motion. When tested, it did not do as well with the initial breaking of the sample, but was the best method once the sample was in smaller pieces. Therefore, based on these results, a hybrid design incorporating a pounding hammer motion first, and then switching into a rotating pestle motion later would be the best grinding method to use for the preparation of the frozen tissue.

Another point to mention about testing deals with the coolness of the sample. During testing, the group experiences trouble keeping the sample adequately cold. This led to thawing and refreezing of the sample, which then led to the sample sticking to the surrounding surfaces. The tissue remained frozen for around 3 – 5 minutes after being exposed to room temperature directly after immersion in liquid nitrogen. For our final design, it is necessary that we address this concern.

## **Evaluation of Cooling Mechanisms**

### *Transporting Liquid Nitrogen*

The advantages of evaporation pressure method for distributing liquid nitrogen include simplicity and cost. Since evaporation occurs naturally, only a hose and valve tolerant to cryogenic conditions are needed to release pressure and to transport the liquid nitrogen into the

grinder device. This is a simple device exploiting the pressure change caused by evaporation requiring no external energy source. It is also less expensive than pumps. The disadvantage to this design is that the amount of liquid nitrogen dispersed is dependant upon external conditions and cannot be precisely controlled.

The advantages of the liquid nitrogen pump are easy filling of the storage tank and precise control of flow. The disadvantages include complexity and cost. Additional tubes are required for transporting liquid nitrogen out and nitrogen gas into the storage tank. These tubes must also be hooked up to a pump. This may be more expensive than a single tube and valve.

#### *Application of Liquid Nitrogen*

The advantages to liquid nitrogen immersion include stable temperature and a thin crust to prevent sticking. The main disadvantage to this method though is cost since more liquid must be used. Liquid nitrogen spray is advantageous because it uses less liquid nitrogen. The disadvantages of liquid nitrogen spray are added complexity, cost of equipment, unstable temperature, and the frequency of spraying. Developing the spraying system is more complicated than simply adding liquid nitrogen to form a pool. This equipment makes our design more complicated and adds to the price. Spraying does not provide the constant temperature that immersion does. Additionally, spraying must be performed more often to keep the sample cold. Due to these overwhelming disadvantages of spraying, the concept of spraying liquid nitrogen will not be included in our final design.

#### **Evaluating Sample Collection Designs**

A sample plate with a recessed area is advantageous because it allows for easier sample collection. The user of the device merely needs to only scrape or brush the sample off of the plate into the next temporary storage device or next step of the biochemical analysis. Since the

plate is removable it is easy to clean. The main disadvantage of the recessed plate is the amount of ground tissue it can hold. Since the plate is not as deep as a vial, overflow could become a problem for the plate. We would need to make sure the plate could hold the maximum tissue sample.

The advantages of the vial include: pre-existing vials on market, deeper storage allows more sample to be stored, and possible screw on tops for storage after tissue grinding. One disadvantages of the vial concept is the ergonomics associated with scraping a sample out of a tub. Also even though vials exist, they are not necessarily tolerant of cryogenic conditions. Currently available, Nunc tubes, can withstand liquid nitrogen. We would need to test these tubes to determine if the tubes could also tolerate any forces from the tissue grinder while under extreme cold temperatures.

### **Evaluating Grinding Designs**

Each grinding design had different advantages and disadvantages. We used the following criteria to judge each design: grinding efficiency, simplicity, sample collection efficiency, durability, noise acceptability, ease of cleaning, processing time, and effectively pressure release. Grinding efficiency was weighted by a factor of 4.

Criteria	Blender	Funnel Grinder	Impulse Sampler
Grinding Efficiency (4x)	-	-	0
Simplicity	+	+	0
Sample Collection Efficiency	-	+	+
Durability	0	+	+
Noise Acceptability	0	+	0
Cleaning	-	0	+
Processing Time	0	+	+
Pressure Release	+	+	+
Total +	2	6	5
Total 0	3	1	3
Total -	-6	-4	0
<b>Total Score</b>	<b>-4</b>	<b>2</b>	<b>5</b>

**Table 1: Design Matrix.** Eight criteria were used to evaluate the three grinding designs, with grinding efficiency weighted by a factor of 4. A plus (+) was given when the design met the criteria. A zero (0) was given when the design neither met the criteria nor failed. A minus (-) was given to the design if it failed the criteria. The total score was obtained by adding all criteria with pluses equal to 1, zeros equal zero, and minuses equal to -1.

The blender's main advantages were its effective pressure release and simplicity. It would not be an efficient grinder since the ground mixture would not be homogenous in particle size, making that a strong disadvantage to this device. It would also have excessive noise and require blade maintenance. The second design, the funnel grinder, was a durable, simple design. It would have an acceptable noise level, pressure release, and sample processing time. This mechanism would not be an efficient grinder though, since only shear forces are used for grinding. Another disadvantage would be cleaning difficulties associated with this design. The last design, the impact sampler, had several advantages including: good sample collection efficiency, easy cleaning, adequate processing time, and pressure release. It was not as simple of a device and perhaps noisy. Based on the results from the design matrix, the impact sampler was the best design alternative and our proposed final design.

## **Proposed Final Design**

Our proposed final design solution incorporates a liquid nitrogen pump system with the impulse sampler grinding method. These are both the best alternatives from their respective design applications. The liquid nitrogen pump will be able to control the flow of liquid nitrogen ensuring the sample remained frozen. The impulse grinder will then efficiently grind the sample due to the combination of a pounding and rotating force on the sample (Refer back to Figure 9).

## **Future Work/Potential Problems**

At the current point in our project we have focused mainly on grinding and have not given much consideration to the cooling and refrigeration aspects of the project or the method of collection. The decision as to whether the device will rely solely on liquid nitrogen for cooling or need additional cooling components will be a part of future development for this project. This system potentially could be rather complex, and problems might arise such as with pressure build up from the liquid nitrogen evaporation. Also, the method of collection will need to be designed and tested. One problem that may need to be addressed is the collection efficiency. In initial testing, we observed tissue sticking to the materials it was in contact with. This ultimately led to collection problems.

Further development of the grinding mechanism is still needed. Dimensions and scaled drawings will need to be done. Also, the materials used in the design will need to be chosen while considering the properties of a cryogenic environment. Lastly, the force and angular velocity of the pulverizing head will need to be determined via testing.

Once the design is finalized, it can be presented to our client for feedback, and then work on a prototype can begin.

## Appendix A - References and Resources

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## Appendix B - PDS

### Tissue Sample Preparation Device for Biochemical Analysis

Version 2 - March 1, 2002

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Ryan Roth

**Client: Jeff Ross and Charles Tessier**

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Department of Oncology

Advisor: Mark Nicosia

**Function:** The device will freeze a tissue sample, grind it into a fine powder, and collect it in a small vial ready for further biochemical analysis. It will replace the manual mortar and pestle grinding technique currently used.

**Client Requirements:**

- Sample and tools used must be kept cold at all times during process
- Must salvage as much as tissue sample as possible
- Prefers time to be near time for manual process (~15 minutes)
- Expects to be used for 30-40 samples/day
- Grind tissue to the consistency of powdered sugar

**Design requirements:**

**1. Physical and Operational Characteristics**

**a. Performance requirements:** Tissue should be easily inserted in device. After completion, tissue remains should be removed, and grinding area cleaned before next sample. Device will be in operation 3 - 5 hours per day. On average the device may have to be turned on 1 -3 times per day.

**b. Safety:** Liquid nitrogen should not be exposed to flesh or clothing. Instrument may be cold.

**c. Accuracy and Reliability:** Technique should grind sample to a powdered-sugar consistency. Collection method should gather the majority of the sample, at least 38 mg, in the vial.

**d. Life in Service:** It will be used 5 days a week through out the year, lasting at least that year. Around 30-40 samples will be analyzed daily.

**e. Shelf Life:** Stored on a laboratory bench at room temperature.

**f. Operating Environment:** Device would work in a normal room temperature biochemistry laboratory. Alternative to laboratory bench storage may be storing the entire device or certain components in a -20 or -80 °C freezer. The interior will be exposed to extremely cold (-196

degrees Celsius) temperatures. The exterior may be exposed to freezer conditions (-20 or -80 °C). The device will be handled by laboratory technicians.

**g. Ergonomics:** Sample should be easy to insert, and hand should not be subjected to cold when inserting the sample.

**h. Size:** The device should fit on a laboratory bench with a maximum volume of 0.61x0.61x0.61 m (2x2x2 ft).

**i. Materials:** Only materials that can be subjected to extremely cold temperature such as metal or Pyrex glass should be used. Regular glass and plastic should be avoided.

**j. Cleaning:** The parts of the device that come in contact with the sample should have removable parts to allow simplify cleaning process (soap and water).

## **2. Production Characteristics**

**a. Quantity:** 1

**b. Target Product Cost:** If a pathology lab would purchase the device, a reasonable range would be \$5000 - 20,000. For our client's biochemistry laboratory, a reasonable price is \$1000 - 1500.

## **3. Miscellaneous**

**a. Standards and Specifications: Unknown.**

**b. Competition:**

- Polytron system - a homogenizer that operates at room temperature to grind up sample.
- Biospec BeadBeater - uses glass or stainless-steel balls to break apart sample, operates at room temperature.
- Biospec Cryo genic Pulverizer - uses hammer to crush pre-frozen sample in mortar.
- Jet Pulverizer - use air pressure to pulverize sample.