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# Team 512: Danfoss – Mini-TT Shaft

# Stub Bearing Press

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**Abstract**

The abstract is a concise statement of the significant contents of your project. The abstract should be one paragraph of between 150 and 500 words. The abstract is not indents.



*Keywords*: list 3 to 5 keywords that describe your project.

# Disclaimer

Your sponsor may require a disclaimer on the report. Especially if it is a government sponsored project or confidential project. If a disclaimer is not required delete this section.

## Acknowledgement

These remarks thanks those that helped you complete your senior design project. Especially those who have sponsored the project, provided mentorship advice, and materials. 4

- Paragraph 1 thank sponsor!
- Paragraph 2 thank advisors.
- Paragraph 3 thank those that provided you materials and resources.
- Paragraph 4 thank anyone else who helped you.

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## Notation

| | |
|---|---|
| A17 | Steering Column Angle |
| A27 | Pan Angle |
| A40 | Back Angle |
| A42 | Hip Angle |
| AAA | American Automobile Association |
| AARP | American Association of Retired Persons |
| AHP | Accelerator Heel Point |
| ANOVA | Analysis of Variance |
| AOTA | American Occupational Therapy Association |
| ASA | American Society on Aging |
| BA | Back Angle |
| BOF | Ball of Foot |
| BOFRP | Ball of Foot Reference Point |
| CAD | Computer Aided Design |
| CDC | Centers for Disease Control and Prevention |
| CU-ICAR | Clemson University - International Center for Automotive Research |
| DDI | Driver Death per Involvement Ratio |
| DIT | Driver Involvement per Vehicle Mile Traveled |

| | |
|---|---|
| | Difference between the calculated and measured |
| Difference | BOFRP to H-point |
| DRR | Death Rate Ratio |
| DRS | Driving Rehabilitation Specialist |
| EMM | Estimated Marginal Means |
| FARS | Fatality Analysis Reporting System |
| FMVSS | Federal Motor Vehicle Safety Standard |
| GES | General Estimates System |
| GHS | Greenville Health System |
| H13 | Steering Wheel Thigh Clearance |
| H17 | Wheel Center to Heel Pont |
| H30 | H-point to accelerator heel point |
| HPD | H-point Design Tool |
| HPM | H-point Machine |
| HPM-II | H-point Machine II |
| HT | H-point Travel |
| HX | H-point to Accelerator Heel Point |
| HZ | H-point to Accelerator Heel Point |
| IIHS | Insurance Institute for Highway Safety |
| L6 | BFRP to Steering Wheel Center |

## Chapter One: EML 4551C

### 1.1 Project Scope

#### 1.1.1 Project Description

The objective of this project is to redesign a bearing press that can press bearings of various sizes onto studs and can be easily manipulated.

#### 1.1.2 Key Goals

After meeting and discussing the project with the sponsor, the team was able to determine a list of primary goals and requirements that need to be achieved in the design. The primary object of the project is to create a working machine that can press a bearing on a shaft stud and be used in production while minimizing the cost. The current version of the press does this by applying pressure using a pneumatic tube and two buttons that have to be pressed at all times. Another goal is to have the press apply pressure to the bearing for a period of 1~5 minutes without the need for buttons to be continually pushed, making the process automatic. Some other goals are to have modular base plates so that bearings of different sizes can be used in production and to increase the press's working space. Currently there are some constraints and spacing limitations that will affect the team's overall design. One goal affected by this is to have the press be in a case with a door interlock switch with a safety relay to increase the safety of anyone using the press. The team will have to fit the new design of the press to work within these spacing parameters. The design will be made for under 10,000$.

**1.1.3 Markets**

The primary market for this project will be Danfoss Turbocor Compressors, Inc., who is the project manager and may use the project upon completion. Secondary markets include any corporations or individuals that desire a variable bearing press in terms of the size of the bearings, these could include Siemens AG, Honeywell International, Inc., Bosch Rexroth, and the Federal Signal Corporation.

**1.1.4 Assumptions**

Assumptions need to be made to make this project possible in the given time frame. It is assumed that we will have access to the previous machine and will be able to use some of the parts from it. Access to a machine shop and the ability to have parts manufactured for the team's use are also assumed. The product also must be able to withstand temperatures as high as 600°F, which the bearing will be heated to before being pressed.

**1.1.5 Stakeholders**

The major stakeholders for this project include the sponsors from Danfoss Turbocor Compressors Inc., William M. Bilbow and Kevin Lohman. The FAMU-FSU College of Engineering stakeholder will be Dr. Shayne McConomy. Every one of these stakeholders is monetarily involved and may benefit from the project upon completion.

## 1.2 Customer Needs

To gain awareness of the needs and wants of Danfoss for the Mini shaft bearing press project, Team 512 met with William Bilbow and Kevin Lohman, the project sponsors. During the meeting, the team asked numerous questions to both William and Kevin about the current iteration of the device and possible improvements that can be made. The feedback the team received helped in the design of the device's functions and constraints. The team was also given a list of Danfoss safety standards that the team was instructed to follow during the design and construction of the machine.

### 1.2.1 Customer Needs Table

***Table 1***

| Number | Question | Sponsor Response | Interpretation |
|---|---|---|---|
| 1. | What do you like about the current press design? | The system can apply 6 tons of pressure when activated. | The new press can apply at least 6 tons of pressure when activated. |
| 2. | What creates the pressure in the press? | Compressed air is used to create the pressure in psi. | The air supply will be used in the new press as well. |
| 3. | What temperature will the bearing be heated to? | The bearing will be heated to 600 degrees Fahrenheit before being pressed into the stud. | The press is made of materials that can withstand high temperatures. |
| 4. | What kind of bearings will the machine be able to handle? | The press can only fit one type of bearing at the moment. | The press has modular base plates that can fit a variety of bearings. |

| Number | Question | Sponsor Response | Interpretation |
|---|---|---|---|
| 5. | What safety features would you like to be improved on the new shaft press? | Rounded corners, emergency stop, no bypass, door interlock switch, improved plexiglass, but do not overcomplicate it. | The press needs to meet various safety criteria to ensure the safety of the user and functionality of the press. |
| **Number** | **Question** | **Sponsor Response** | **Interpretation** |
| 6. | Do you want the improved press to be larger or smaller? | The parts have now outgrown the current iteration of the press. | The press stands taller to allow for larger studs to be pressed into bearings. |
| 7. | What about the existing press's operation process do you not like? | I do not like that I have to press and hold both switches to operate the press for a large amount of time. | Implement a way for the press to become hands free for a certain amount of time after the process is started. |
| 8. | How long is the machine expected to apply pressure to the bearing and the stud? | The press can currently apply pressure for as long as someone holds down the buttons, but most bearing have pressure for 1~5 minutes. | The press applies pressure for 1~5 minutes and is determined by the user. |

| Number | Question | Sponsor Response | Interpretation |
|---|---|---|---|
| 9. | Do you want the press to be entirely enclosed? | Enclosing the press would increase the safety of using the press. | The press has something that shields the user from the press and its contents. |
| 10. | Is there a cooling process implemented on the press? | No, the press needs to allow ventilation but there is no existing cooling system. | If the press is enclosed, add a cooling system, if not there is an opening to prevent overheating. |
| 11. | What is the intended budget for the project? | $5,000 – $10,000 | The budget is 5,000-10,000 dollars, but the cheaper the better. |

**1.2.2 Explanation of Results**

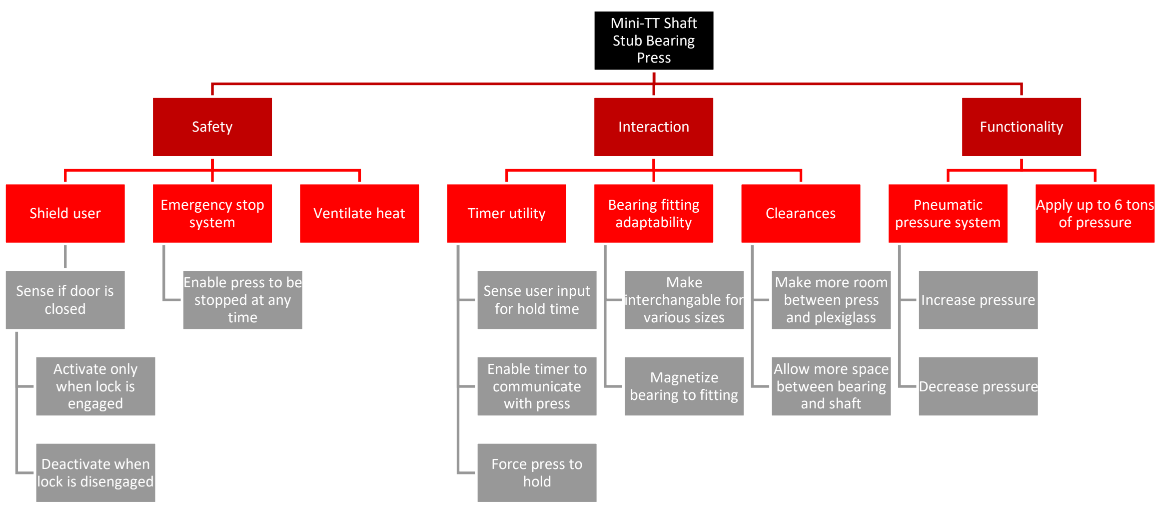
In the inaugural team meeting with the project sponsor, valuable customer feedback was gathered. Team 512 diligently presented targeted inquiries to the sponsor and meticulously documented the responses provided. The sponsor has entrusted the team with the responsibility of integrating the antiquated mini shaft bearing press, necessitating modifications to align with both longstanding and contemporary requirements. Additionally, our team has been charged with the crucial task of enhancing its safety protocols and ensuring user-friendly functionality. A comprehensive list of customer requirements was compiled, underscoring the significance of queries raised by our sponsor, including adherence to Danfoss safety specifications, necessary updates, and feasible modifications derived from the previous machine's design.

## 1.3 Functional Decomposition

### 1.3.1 Introduction

Team 512 did a functional decomposition by analyzing the Mini-TT Shaft Stub Bearing Press and breaking down its key components into categories. The 3 major categories that were analyzed were safety of the press, human interaction of the press, and functionality of the press. The 3 categories were then broken down by the key components that integrate into each category. The overall functional decomposition is outlined by the chart below.

### 1.3.2 Functional Decomposition Hierarchy Chart




### 1.3.3 Explanation of Functional Decomposition

The functional decomposition of the Mini-TT Shaft Bearing Press is structured around three fundamental aspects: safety, interaction, and functionality. Each aspect plays a crucial role in shaping the design and operation of the press. The first branch (safety) is divided into three separate areas: shield user, emergency stop system, and ventilate heat. When the user interacts with the system, they must have protection in case of emergencies. The shield user works when the user wants to interact with the device, the system should be able to tell if the door is closed to allow for operation of the device. If the door is closed, operation can begin, but if the door is open, it cannot begin. The emergency stop system is in place to allow the user to stop the press immediately if something has gone wrong during standard operation. The ventilation of heat allows for heat to escape from the system since bearings will be heated to nearly 600F when in operation, preventing heat buildup in the system.

The second branch (interaction) is divided into three key areas: timer functionality, bearing fitting adaptability, and clearances. These aspects were meticulously designed to cater specifically to our client's requirements. Following in-depth discussions with the client, it was crucially identified that the new bearing press needed to address both emerging and existing constraints. During these conversations, the concept of implementing a sensor capable of holding down the press for a specific duration (x amount of time) was introduced. This innovative feature was aimed at significantly reducing operational time, thereby optimizing efficiency for our clients. Additionally, it was decided to increase the clearance between the press and the plexiglass, enhancing safety and creating a more streamlined working environment.

The third branch (functionality) is only split into two systems. The user can apply up to 6 tons of pressure when the device is operating. The user can communicate to the system about how much pressure to apply by telling it when to increase or decrease the pressure.

### 1.3.4 Connection to System

| | Safety | Interaction | Functionality | **Total** |
|---|---|---|---|---|
| Shield user | X | | | 1 |
| Sense if door is closed | X | | | 1 |
| Ventilate heat | X | | X | 2 |
| Sense user input | | X | | 1 |
| Enable timer to communicate with press | | X | X | 2 |
| Force press to hold | X | X | | 2 |
| Make interchangeable for various sizes | | X | X | 2 |
| Magnetize bearing to fitting | | X | | 1 |
| Make more room between press and plexiglass | X | X | | 2 |
| Allow more space between bearing and shaft | | X | | 1 |
| Increase/Decrease pressure | | X | X | 2 |
| Apply up to 6 tons of pressure | | | X | 1 |
| **Total** | 5 | 8 | 5 | |

### 1.3.5 Integration

The table above shows the three main operations of the mini-TT shaft stud bearing press, broken down into three systems: safety, interaction, and functionality. The system of safety relies on keeping the user safe while the press is in operation. The system has five functions, broken into three sub-systems, that keep the user safe from any danger when the press is active. The first sub-system shields the user from the press when active. This works by detecting if the door is closed and stopping the press when the door is opened. The second sub-system allows for an emergency stop and releases the pressure on the press when activated. The final sub-system keeps the user safe by keeping the heat from press and bearing away from the user.

The system of Interaction will rely on the physical actions of the user for the press to operate. This system relies on eight functions, broken into three sub-systems, that force the user to interact with the press before, during, and after the device operates. The sub-system for timer utility allows the user to set the amount of time the press should be active for and communicate that to the press. The sub-system for bearing fitting adaptability allows the user to change the type of bearing that will be pressed and keep it in place during operation. Finally, the sub-system for clearances allows for more room between the shaft and bearing and between the shield and the device.

The system of Functionality allows the user to modify the operation of the press. This system relies on five functions, broken into two sub-systems. The first sub-system incorporates the pneumatic pressure system, letting the user tell the press how much pressure to apply to the shaft and the stud. The second sub-system works with the first one, keeping track of how much pressure can be applied and stopping it when it reaches 6 tons of pressure

**1.3.6 Action and Outcome**

The mini-TT shaft stud bearing press will be a physical machine that uses the three main systems of safety, interaction, and functionality. The press will use the user's physical inputs to apply up to 6 tons of pressure to press a bearing into a shaft. The press will detect if the door is closed, shielding the user and allowing for operation. The pressure applied by the user can be increased, decreased, or stopped all together by the user. The press will allow for bearings of various sizes to be pressed and have them remain on the press when in operation. Once the intended pressing time set by the user is finished, the press will release all pressure on the bearing and shaft.

## 1.4 Targets and Metrics

### 1.4.1 Target Summary

The targets and metrics mainly come from the three systems listed in the functional decomposition hierarchy chart. There are also some additional functions that go beyond those listed in the functional decomposition. The metrics will be used to validate that the targets have been satisfied to the necessary extent. Team 512 has collectively chosen the targets and metrics, which are subject to change.

### 1.4.2 Target Table

***Table 2***

| System | Function | Target | Metric |
|---|---|---|---|
| Safety | System can operate if the door is closed | 1 | Binary |
| Safety | System won't operate if the door is open | 0 | Binary |
| Safety | System can be stopped at any time | 0 | Binary |
| Safety | Ventilate heat | | |
| Interaction | Enable timer to communicate with press | 1 | Binary |
| Interaction | Force press to hold | Equal to user input for hold time | Time |
| Interaction | Make bearing interchangeable for various sizes | 2-6 cm | Diameter Range |
| Interaction | Make more room between press and plexiglass on all sides | 20 cm | Distance |

| | | | |
|---|---|---|---|
| Interaction | Make more room between bearing and shaft | 30 cm | Distance |

| System | Function | Target | Metric |
|---|---|---|---|
| Functionality | Increase applied pressure | Up to 120 psi | Pressure |
| Functionality | Decrease applied pressure | Down to 0 ~ 20 psi | Pressure |
| Functionality | Apply up to 6 tons of force with press | Up to 6 tons of force | Weight |

### 1.4.3 Critical Targets and Metrics

There are various targets and metrics that we aim to satisfy in order to meet our project's needs. The first target is to create a pneumatic baseplate that fluctuates the working space from 0 to 16 inches. Another critical target is to apply 6 tons of pressure to the bearing and shaft. The safety of the user is also a major target that will be accomplished by the usage of sensors to ensure the door is closed during operation of the press and is accompanied by an emergency stop. The target budget of the project is anything below 10,000 dollars.

### 1.4.4 Method of Validation

A variety of tools will be used to examine and verify the system targets. These tools encompass a ruler, caliper, and a force gauge. The raw data from the sensors will be analyzed by coding software to ensure the logic and validation of assignment. Financial assessment will be evaluated before the purchase of goods to ensure they fit in with the set budget. If feasible, consultations with Danfoss will be pursued to facilitate discussions regarding the prototype as well as demonstrations.

### 1.4.5 Derivation of Targets/Metrics

All targets and metrics were chosen collectively by Team 512, the Danfoss sponsors, and through research. A safety checklist provided to Team 512 by Danfoss played a big role in determining the targets and metrics. Due to the fact that some ideas and methods have not yet been finalized, some targets and metrics were chosen based on educated guesses.

### 1.4.6 Discussion of Measurements

Binary measurements are collected from code. Time measurements are taken with a clock. Lengths are measured with a caliper or tape measure. Pressure is measured using a pressure gauge. Weight is measured with a scale.

### 1.4.7 Summary

The project outlined focuses on specific targets and metrics derived from a functional decomposition hierarchy chart. These targets are primarily associated with three key systems: Safety, Interaction, and Functionality. Safety targets include the system's ability to operate with a closed door, halt operation when the door is open, and enable stopping at any time. Interaction targets involve sensing user input, enabling timers, and ensuring proper spacing between components. Functionality targets revolve around applied pressure, weight, and force capabilities. Critical targets include creating a pneumatic baseplate with adjustable working space, applying 6 tons of pressure, ensuring user safety through sensor-based door checks, and adhering to a budget below $10,000. The validation process involves various tools such as rulers, calipers, and force gauges, along with coding software for sensor data analysis and financial assessments.

### 1.4.8 Catalog

The catalog provides a detailed overview of the project's targets and metrics, categorizing them under Safety, Interaction, and Functionality systems. Safety targets include binary operations based on door status and emergency stops. Interaction metrics involve binary responses for user input, time-based measurements, and specific distance requirements. Functionality targets encompass pressure measurements in psi, weight in tons, and diameter ranges in centimeters. The validation methodology integrates physical tools like rulers and calipers, software for sensor data analysis, and financial assessments for budget adherence. All targets and metrics were collaboratively chosen by Team 512, Danfoss sponsors, and through research efforts. The safety checklist provided by Danfoss guided the determination of critical targets. Measurements include binary outputs from code, time measured with clocks, lengths measured with calipers or tape measures, pressure gauged with pressure gauges, and weight determined using scales.

## 1.5 Concept Generation

Concept generation involves collaborative efforts within the team to brainstorm potential solutions for our design challenge. The team's objective was to generate a total of 100 ideas, which can be seen in Appendix E, aiming to foster innovative perspectives on effectively addressing engineering problems. Various methods were employed to stimulate diverse and creative ideas.

### 1.5.1 Concept Generation Tools

The team initially used brainstorming to create ideas that could solve at least one of the main problems. Most of the early concepts came from this. Using biomimicry, the team analyzed how plants and animals encounter similar problems and how they use their abilities to counteract them. For instance, the plant mimosa pudica retracts its leaves when it feels physical touch. This inspired the concept of having a sensor in the handle that detects when a person touches it and retracts the press. The team also used the crapshoot method to create concepts based on other members' ideas that solved one of the problems for the project.

### 1.5.2 Medium Fidelity Concepts

Following the creation of more than 100 concepts in the generation phase, our team narrowed down the options to five medium-fidelity concepts. These medium-fidelity concepts were chosen because each demonstrated the capability to address at least one of the project's challenges.

***Table 3: Medium Fidelity***

| Concept Number | Description |
|---|---|
| 6 | Magnetic Door Lock |
| 11 | Ventilation Fan |
| 24 | Electrical Powered |
| 32 | Adjustable Chuck |
| 26 | Easily Maintainable |

**1.5.3 High Fidelity Concepts**

For the high-fidelity concepts, our team chose three concepts that we believed would meet the crucial criteria of safety and aligned with our sponsor's requirements. These concepts were developed with the assistance of the company's standard evaluation sheet, which outlines the essential features all their products must meet.

***Table 4: High Fidelity***

| Concept Number | Description |
|---|---|
| 1 | Wire Mesh: Cage |
| 28 | Timer/ Emergency Stop |
| 54 | Adjustable Press |

**High Fidelity Concept #1**

*Figure 1: High Fidelity Concept #1*

Having a wire mesh cage offers several advantages for various applications. Firstly, wire mesh cages provide excellent visibility and ventilation, allowing easy monitoring of the contents inside while ensuring proper airflow. Additionally, these cages are durable and long-lasting, being made from sturdy materials like stainless steel or galvanized steel. They offer a secure enclosure, preventing unauthorized access and safeguarding valuable or sensitive items. Despite their durability, wire mesh cages are relatively lightweight, making them easy to handle and transport. Cleaning and maintenance are hassle-free due to their open structure. They also meet regulatory standards for Danfoss, ensuring compliance with its guidelines. Furthermore, their modularity allows for easy expansion or reconfiguration as storage needs change, enhancing their flexibility and usability.

**High Fidelity Concept #28**


*Figure 2: High Fidelity Concept #28*

Danfoss recommended the addition of an emergency stop, citing numerous advantages associated with its implementation. Incorporating an emergency stop feature provides crucial safety benefits in various contexts. It serves as a vital precautionary measure, enabling immediate halting of operations in the event of a critical issue or hazard, thereby preventing accidents and minimizing potential damages. This safety mechanism enhances the overall security protocols, ensuring a prompt response to unforeseen situations. Furthermore, having an emergency stop aligns with industry best practices and regulatory standards, demonstrating compliance with safety guidelines. It not only safeguards personnel and equipment, but also underscores the commitment to creating a secure working environment.

**High Fidelity Concept #54**

Figure 3: High Fidelity Concept #54

Having an adjustable press offers a multitude of advantages. Its versatility allows for seamless adaptation to diverse production requirements, accommodating various materials and processes with ease. With a variety of different shaft sizes, an adjustable press is needed for the new constraints as well as the old constraints.

## 1.6 Concept Selection

### 1.6.1 Introduction

The process of concept selection initiates by pinpointing high and medium fidelity concepts. Following their identification, the selection process is guided by the utilization of comparison tools such as the house of quality, Pugh charts, AHP charts, and binary pairwise comparison. These tools play a crucial role in evaluating the merits and drawbacks of different ideas. Parameters were established to meet customer requirements, and targets and metrics were employed to assess the effectiveness of each specific design.

### 1.6.2 Weighting the Design Parameters

Through meetings with our sponsors at Danfoss, we were able to determine the desired parameters for our shaft bearing press. In the binary pairwise comparison chart, ideas were compared through the usage of 1's and 0's. A 1 signifies that the idea is more significant than the other idea it is being compared to. This weighting is used to determine the ranking order of each individual idea.

### 1.6.3 House of Quality

Leveraging the importance weight factor obtained from the pairwise analysis, we formulated the House of Quality (HOQ) to establish rankings for the engineering characteristics of the device. Within the HOQ, the correlation between the weighted customer needs and the engineering characteristics aligned with the project targets is scored. This correlation score is then multiplied by the weight factor assigned to each customer need, resulting in a weighted ranking of the team's engineering characteristics. Notably, this ranking revealed that the most crucial characteristics were implementing a safety feature, withstanding high temperatures, and incorporating a modular baseplate. These findings serve as a valuable guide in prioritizing and selecting key features for further consideration and development in the conceptualization and design process.

*Table 5: House of Quality*

| | | Engineering Characteristics | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Improvement Direction** | | | ↓ | ↓ | ↓ | ↓ | ↑ | ↑ | ↑ |
| **Units** | | *n/a* | *lbs* | *sec* | *sec* | *in* | *in* | *psi* | *°F* |
| Customer Requirements | Importance Weight Factor | Sense Door Status | Weight | Emergency Stop Actuation Time | Hold Error | Baseplate Diameter Inverval | Clearances | Pressure Applied | Withstandable Temperature |
| Modular Baseplate with Adjustable Height | **5** | 0 | 3 | 0 | 0 | 9 | 3 | 0 | 3 |
| Apply Pressure | **4** | 1 | 3 | 3 | 3 | 0 | 0 | 9 | 1 |
| Implement Safety Features | **7** | 9 | 9 | 9 | 0 | 0 | 1 | 1 | 1 |
| Withstand High Temperatures | **6** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| Provide Ventilation | **1** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 9 |
| Increase Clearances | **3** | 0 | 1 | 0 | 0 | 1 | 9 | 3 | 1 |
| Hands-Free Automation | **2** | 3 | 0 | 1 | 9 | 1 | 0 | 1 | 0 |
| **Raw Score** | 323 | 73 | 93 | 77 | 30 | 50 | 50 | 54 | 92 |
| **Relative Weight %** | | 22.60 | 28.79 | 23.84 | 9.29 | 15.48 | 15.48 | 16.72 | 28.48 |
| **Rank Order** | | 4 | 1 | 3 | 2 | 6 | 6 | 5 | 2 |

Table 6 shows the binary pairwise comparison of our customers' needs. The binary pairwise comparison uses a 1 to signify what is more important in comparison of two individual customer needs. The sum of the 1's is collected to show the ranking order of each customer need. In this table, Safety was the highest customer need. Safety is always the number one priority of the user and outweighs the other customer's needs.

*Table 6: Binary Pairwise Comparison*

| # | Customer Needs |
|---|---|
| 1 | Apply Pressure |
| 2 | Implement Safety Feature |
| 3 | Withstand High Temperature |
| 4 | Modular Baseplate |
| 5 | Increase Clearances |
| 6 | Hands Free-Automation |
| 7 | Provide Ventilation |

Binary Pairwise Comparison

| Customer Needs | #1 | #2 | #3 | #4 | #5 | #6 | #7 | SUM |
|---|---|---|---|---|---|---|---|---|
| #1 | - | 0 | 0 | 0 | 1 | 1 | 1 | 3 |
| #2 | 1 | - | 1 | 1 | 1 | 1 | 1 | 6 |
| #3 | 1 | 0 | - | 1 | 1 | 1 | 1 | 5 |
| #4 | 1 | 0 | 0 | - | 1 | 1 | 1 | 4 |
| #5 | 0 | 0 | 0 | 0 | - | 1 | 1 | 2 |
| #6 | 0 | 0 | 0 | 0 | 0 | - | 1 | 1 |
| #7 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |

### 1.6.4 Pugh Chart

The Pugh chart provides a clear and systematic approach to assess high and medium fidelity concepts, streamlining the process of refining potential designs to create a more manageable selection suitable for feasible testing within the project's time constraints. The analysis begins by selecting a datum, an established entity with functions similar to the project, and comparing it to the high and medium fidelity concepts. Each concept undergoes evaluation based on its effectiveness in meeting customer needs relative to the datum, receiving designations of plus (+), minus (-), or satisfactory (s). This iterative process continues, eliminating concepts with more negative ratings in successive rounds of evaluation. The ultimate aim is to narrow down the concept pool to a select group for further testing and consideration within the project's timeframe. Following a comprehensive assessment of each idea's potential performance, scores were tallied, resulting in the elimination of the Ventilation Fan, Adjustable Chuck, and Electrical Powered concepts based on the results.

*Table 7:* **Initial Pugh Chart**

| | | Concepts | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Selection Criteria** | | Magnetic Door Lock | Ventilation Fan | Electical Powered | Adjustable Chuck | Easily Maintainable | Wire Mesh Cage | Timer/ Emergency Stop | Adjustable Press |
| Modular baseplate with adjustable height | DATUM: Current System | S | S | S | + | + | S | S | + |
| Apply Pressure | | S | S | + | S | S | S | + | S |
| Implement Safety Features | | + | S | + | + | + | + | + | S |
| Withstand High Temperatures | | S | + | S | S | S | + | S | S |
| Provide Ventilation | | S | + | - | S | S | + | S | S |
| Increase Clearances | | S | - | S | + | + | S | S | + |
| Hands Free-Automation | | + | S | + | - | + | S | S | S |
| # of Pluses | | 2 | 2 | 3 | 3 | 4 | 3 | 2 | 2 |
| # of Minuses | | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| # of Satisfactory | | 5 | 4 | 3 | 3 | 3 | 4 | 5 | 5 |

In the Final Pugh chart, as presented in Table 8, it was determined that the Magnetic Door Lock, Easily Maintainable, Wire Mesh Cage, Timer/Emergency Stop, and Adjustable Press concepts emerged as the most suitable choices for satisfying customer needs.

*Table 8:* **Final Pugh Chart**

| | | Concepts | | | | |
|---|---|---|---|---|---|---|
| **Selection Criteria** | | Magnetic Door Lock | [redacted] | Wire Mesh Cage | Timer/ Emergency Stop | Adjustable Press |
| Modular baseplate with adjustable height | DATUM: Current System | S | | S | S | + |
| Apply Pressure | | S | | S | + | S |
| Implement Safety Features | | + | | + | + | S |
| Withstand High Temperatures | | S | | + | S | S |
| Provide Ventilation | | S | | + | S | S |
| Increase Clearances | | S | | S | S | + |
| Hands Free-Automation | | S | | S | S | S |
| # of Pluses | | 1 | | 3 | 2 | 2 |
| # of Minuses | | 0 | | 0 | 0 | 0 |
| # of Satisfactory | | 6 | | 3 | 5 | 5 |

### 1.6.5 Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) stands as another methodology integrated into the concept selection process, employing mathematical assessments to gauge the significance of each criterion in the project. This approach serves to eliminate potential personal biases that the team might harbor towards specific concepts. In implementing the AHP, a comparative analysis is conducted for each of the customer's needs, assigning scores of 1, 3, 5, 7, or 9 to reflect their relative importance. A score of 1 signifies equal significance, while 9 denotes a substantial difference in importance. This systematic process ensures an impartial and objective evaluation, allowing for a more informed selection of concepts based on their weighted criteria. The total scores for each need are applied in the Normalized Comparison Matrix, as depicted in Table 9.

***Table 9: Normalized Comparison Matrix***

| Normalized Criteria Comparison Matrix [Norm C] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Criteria Weights [W] |
| 1) Apply Pressure | 0.0811 | 0.0751 | 0.0224 | 0.174 | 0.231 | 0.04 | 0.0545 | 0.096871 |
| 2) Implement Safety Feature | 0.405 | 0.376 | 0.204 | 0.523 | 0.231 | 0.28 | 0.164 | 0.31185 |
| 3) Withstand High Temperature | 0.243 | 0.124 | 0.0678 | 0.0244 | 0.0254 | 0.2 | 0.273 | 0.1368 |
| 4) Modular Baseplate | 0.0811 | 0.124 | 0.475 | 0.174 | 0.385 | 0.2 | 0.273 | 0.24458 |
| 5) Increase Clearances | 0.0267 | 0.124 | 0.204 | 0.0348 | 0.0769 | 0.12 | 0.164 | 0.1072 |
| 6) Hands Free-Automation | 0.0811 | 0.0526 | 0.0136 | 0.0348 | 0.0254 | 0.04 | 0.018 | 0.037928 |
| 7) Provide Ventilation | 0.0811 | 0.124 | 0.0136 | 0.0348 | 0.0254 | 0.12 | 0.0545 | 0.064771 |
| SUM | 0.9991 | 0.9997 | 1.0004 | 0.9998 | 1.0001 | 1 | 1.001 | 1 |

Within the Normalized Criteria matrix, the scores assigned in each comparison are divided by the sum of scores for each need. The resulting average value is calculated to establish the Criteria weights. These Criteria weights are subsequently employed in the Consistency Check listed below in Table 11, to generate the weighted sum as well as the consistency vector. The table is located in Appendix E.

***Table 10:*** **Consistency Check**

| | Consistency Check | | |
|---|---|---|---|
| Engineering Characteristics | Criteria Weight {W} | Weighted Sum Vector $\{Ws\} = [C]\{W\}$ | Consistency Vector $\{Cons\} = \{Ws\}./\{W\}$ |
| 1) Apply Pressure | 0.154929941 | 1.291216787 | 8.334197866 |
| 2) Implement Safety Feature | 0.033001916 | 0.276600587 | 8.381349406 |
| 3) Withstand High Temperature | 0.127264187 | 1.218066958 | 9.571168353 |
| 4) Modular Baseplate | 0.059611802 | 0.456402907 | 7.656250852 |
| 5) Increase Clearances | 0.142267536 | 1.205484422 | 8.473362616 |
| 6) Hands Free-Automation | 0.291420024 | 2.61305971 | 8.966644355 |
| 7) Provide Ventilation | 0.191504595 | 1.902791442 | 9.936009349 |

| | |
|---|---|
| Average Consistency | 8.760 |
| Number of Criteria | 7 |
| Consistency Index | 0.293 |
| Random Index Value | 1.350 |
| Consistency Ratio | 0.217 |

Table 10 shows the consistency check of our applied parameters to our customer's needs. The individual customer needs are weighed to show the importance of each feature in comparison to each other.

### 1.6.6 Analytical Hierarchy Process Alternatives

In the conclusion for the concept selection, the top four concepts are systematically compared against each other for each engineering requirement. This analysis provides insights into the comparative strengths of each concept, highlighting how one design outperforms the others. Ratings of 1, 3, 5, 7, or 9 are assigned to the designs based on their effectiveness in satisfying each of the customer's needs. We created the same process as the analytical hierarchy process except we used the design concepts rather than the needs to figure out which design concept is best used for a specific need and compared it to another concept in how it rated against it. We then created a final selection matrix for the concept using the criteria weights found during the process.

| Final Rating Matrix | | | | |
|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press |
| 1) Apply Pressure | 0.241741742 | 0.191441441 | 0.241741742 | 0.325075075 |
| 2) Implement Safety Feature | 0.102820923 | 0.348275468 | 0.102820923 | 0.446082686 |
| 3) Withstand High Temperature | 0.305159205 | 0.17968928 | 0.388492538 | 0.126658977 |
| 4) Modular Baseplate | 0.325075075 | 0.241741742 | 0.241741742 | 0.191441441 |
| 5) Increase Clearances | 0.325075075 | 0.241741742 | 0.241741742 | 0.191441441 |
| 6) Hands Free-Automation | 0.124530075 | 0.375469925 | 0.124530075 | 0.375469925 |
| 7) Provide Ventilation | 0.30640015 | 0.14329955 | 0.30640015 | 0.24390015 |

### 1.6.7 Final Selection Concept

For the final selection method, we created 7 normalized comparison matrix charts, 7 Comparison Checks, 7 consistency charts. With these numbers we can find the criteria weight. Overall, we found that the top four concepts that we selected were the magnetic door lock, wire mesh cage, timer/emergency stop, and adjustable press.

## 1.7 Risk Assessment

## Project Hazard Control- For Projects with Medium and Higher Risks

| | | |
|---|---|---|
| **Name of Project:** Team 512 – Danfoss Mini TT Shaft Bearing Press | | **Date of submission:** November 17, 2023 |
| | | |
| **Team member** | **Phone number** | **e-mail** |
| Cassie Bentley | 850-879-5713 | Crbentley@fsu.edu |
| Clark Cooley | 813-382-1567 | Ccc19f@fsu.edu |
| Colby Gullo | 561-601-9103 | cag20@fsu.edu |
| Brent Mynard | 850-612-3616 | bsm20bh@fsu.edu |
| **Faculty mentor** | **Phone number** | **e-mail** |
| Dr. McConomy | 850-410-6624 | smcconomy@eng.famu.fsu.edu |
| | | |

**Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").**

**Step 1: Assembly** – Tubing could create physical obstacles for people to trip over. It is also important to note that the presses material is made of heavy steel. Therefore, is important to use teamwork when lifting heavy parts to avoid injuries.

**Step 2: Mechanical & Environment Testing** – The device has sharp edges that might cause minor skin cuts. Therefore, warning labels and PPE are needed, and the edges are rounded. When bearings are heated, the temperature will be high and can cause high-temp burns if mishandled or not wearing proper PPE. If when testing a bearing is pressed incorrectly user is to press the emergency stop.

**Step 3: Transport of Device** – To prevent heavy lifting, devices over 100+ lbs. Press will be transported into parts and will be handled by 3+ people. The edges of the device will be rounded, if possible, PPE will be required to prevent sharp edges. And to avoid problems for user everything will be well labeled.

**Step 4: Fabrication of Physical System** – Cuts/bruises/punctures are foreseen if proper precautions are not met for the handling of the Press. All fabrication of complex or too-hazardous parts will be outsourced to machine shops.

**Device Operations** – The device has sharp edges that might cause minor skin cuts/bruises. Therefore, warning labels and PPE are needed, and the edges are rounded down. When bearings are heated, the temperature will be high and can cause high-temp burns if mishandled or not wearing proper PPE. If when testing a bearing is pressed incorrectly user is to press the emergency stop In rare situations, the temperature of the sensor may be high and can cause high-temp burns.

**Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.**

Revised 08-2019

1.Contact relevant authorities (911, supervisor, facilities, etc..) based upon severity of risk.
2. For Meduim injuries contact the corresponding emergency number(s) of user, and inform response contact information.
3. Inform cooperate.
A) If at Danfoss with and follow any directions from supervisors and/or authorities as they arrive. And write up an accident report with all involved members and deliver it to Principal Investigator.
B)Contact faculty or other COE emergency contacts.

**List emergency response contact information:**

- Call 911 for injuries, fires or other emergency situations
- Call your department representative to report a facility concern

| Name | Phone number | Faculty or other COE emergency contact | Phone number |
|---|---|---|---|
| **Kevin Lohman** | **850-504-2111** | **Dr. Shayne McConomy** | **850-410-6624** |
| | | | |

**Safety review signatures**

| Team member | Date | Faculty mentor | Date |
|---|---|---|---|
| **Cassie Bentley** | **11/1/2023** | | |
| **Brent Mynard** | **11/17/2023** | | |
| **Colby Gullo** | **11/17/2023** | | |
| **Clark Cooley** | **11/17/2023** | | |
| | | | |
| | | | |
| | | | |

**Report all accidents and near misses to the faculty mentor.**

**FAMU-FSU College of Engineering**
**Project Hazard Assessment Policy and Procedures**

## INTRODUCTION

University laboratories are not without safety hazards. Those circumstances or conditions that might go wrong must be predicted and reasonable control methods must be determined to prevent incident and injury. The FAMU-FSU College of Engineering is committed to achieving and maintaining safety in all levels of work activities.

## PROJECT HAZARD ASSESSMENT POLICY

Principal investigator (PI)/instructor are responsible and accountable for safety in the research and teaching laboratory. Prior to starting an experiment, laboratory workers must conduct a project hazard assessment (PHA) to identify health, environmental and property hazards and the proper control methods to eliminate, reduce or control those hazards. PI/instructor must review, approve, and sign the written PHA and provide the identified hazard control measures. PI/instructor continually monitor projects to ensure proper controls and safety measures are available, implemented, and followed. PI/instructor are required to reevaluate a project anytime there is a change in scope or scale of a project and at least annually after the initial review.

## PROJECT HAZARD ASSESSMENT PROCEDURES

It is FAMU-FSU College of Engineering policy to implement followings:

1. Laboratory workers (i.e. graduate students, undergraduate students, postdoctoral, volunteers, etc.) performing a research in FAMU-FSU College of Engineering are required to conduct PHA prior to commencement of an experiment or any project change in order to identify existing or potential hazards and to determine proper measures to control those hazards.
2. PI/instructor must review, approve and sign the written PHA.
3. PI/instructor must ensure all the control methods identified in PHA are available and implemented in the laboratory.
4. In the event laboratory personnel are not following the safety precautions, PI/instructor must take firm actions (e.g. stop the work, set a meeting to discuss potential hazards and consequences, ask personnel to review the safety rules, etc.) to clarify the safety expectations.
5. PI/instructor must document all the incidents/accidents happened in the laboratory along with the PHA document to ensure that PHA is reviewed/modified to prevent reoccurrence. In the event of PHA modification a revision number should be given to the PHA, so project members know the latest PHA revision they should follow.
6. PI/instructor must ensure that those findings in PHA are communicated with other students working in the same laboratory (affected users).
7. PI/instructor must ensure that approved methods and precautions are being followed by :
    a. Performing periodic laboratory visits to prevent the development of unsafe practice.
    b. Quick reviewing of the safety rules and precautions in the laboratory members meetings.
    c. Assigning a safety representative to assist in implementing the expectations.
    d. Etc.
8. A copy of this PHA must be kept in a binder inside the laboratory or PI/instructor's office (if experiment steps are confidential).

**Project Hazard Assessment Worksheet**

| PI/instructor: Dr. Shayne McConomy | Phone #: 850-410-6624 | Dept.: Mechanical | Start Date: 09/12/2023 | Revision number: N/A |
|---|---|---|---|---|
| Project: Team 512 – Danfoss Mini TT Shaft Bearing Press | | | Location(s): Danfoss/FAMU-FSU College of Engineering | |
| Team member(s): Colby Gullo, Cassie Bentley, Clark Cooley, Brent Mynard | | | Phone #: 561-601-9103 | Email: cag20@fsu.edu |

| Experiment Steps | Location | Person assigned | Identify hazards or potential failure points | Control method | PPE | List proper method of hazardous waste disposal, if any. | Residual Risk | Specific rules based on the residual risk |
|---|---|---|---|---|---|---|---|---|
| Observe existing press and other applicable machines | Danfoss production floor | All | Flying projectiles, high temperatures, loud noise, bodily harm, machine entanglement | Danfoss safety standards | Pants, safety glasses, steel toes | N/A | HAZARD: 3 CONSEQ: Medium<br>Residual: Low-Med | Must wear proper PPE |
| Disassemble, Transport, and Reassemble Existing Press | Danfoss production floor and FAMU-FSU College of Engineering | All | Sharp corners, heavy weights | Use multiple people | N/A | N/A | HAZARD: 2 CONSEQ: Low-Med<br>Residual: Low-Med | Safety controls planned by worker and supervisor, buddy system, supervisor authorization |
| Fabrication of Parts | Machine shop | All | Flying projectiles, machine entanglement, sharp edges, powerful machines | Lab safety expectations/ rules | Safety glasses, pants, closed-toe shoes | N/A | HAZARD: 2 CONSEQ: Moderate<br>Residual: Low-Med | Safety controls well guided, and supervisor did a final check |
| Testing of Press | Danfoss production floor/ SD Lab | All | Flying projectiles, high temperatures, compressed air, sharp edges | Danfoss safety standards, ventilation, wire metal cage, emergency stop | Safety glasses | N/A | HAZARD: 3 CONSEQ: Medium<br>Residual: Low-Med | Must wear proper PPE and follow safety standards |

**Principal investigator(s)/ instructor PHA:** I have reviewed and approved the PHA worksheet.

| Name | Signature | Date | Name | Signature | Date |
|---|---|---|---|---|---|
| | | | | | |

**Team members:** I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

| Name | Signature | Date | Name | Signature | Date |
|---|---|---|---|---|---|
| Cassie Bentley | [signature] | 11/16/23 | Clark Cooley | [signature] | 11/17/23 |

_____Colby Gullo_______________ Colby Gullo __11/16/23________ Brent Mynard___________________ Brent Mynard _11/17/23____

Copy this page if more space is needed.

## DEFINITIONS:

**Hazard:** Any situation, object, or behavior that exists, or that can potentially cause ill health, injury, loss or property damage e.g. electricity, chemicals, biohazard materials, sharp objects, noise, wet floor, etc. OSHA defines hazards as "*any source of potential damage, harm or adverse health effects on something or someone"*. A list of hazard types and examples are provided in appendix A.

**Hazard control:** Hazard control refers to workplace measures to eliminate/minimize adverse health effects, injury, loss, and property damage. Hazard control practices are often categorized into following three groups (priority as listed):

1. **Engineering control:** physical modifications to a process, equipment, or installation of a barrier into a system to minimize worker exposure to a hazard. Examples are ventilation (fume hood, biological safety cabinet), containment (glove box, sealed containers, barriers), substitution/elimination (consider less hazardous alternative materials), process controls (safety valves, gauges, temperature sensor, regulators, alarms, monitors, electrical grounding and bonding), etc.
2. **Administrative control:** changes in work procedures to reduce exposure and mitigate hazards. Examples are reducing scale of process (micro-scale experiments), reducing time of personal exposure to process, providing training on proper techniques, writing safety policies, supervision, requesting experts to perform the task, etc.
3. **Personal protective equipment (PPE):** equipment worn to minimize exposure to hazards. Examples are gloves, safety glasses, goggles, steel toe shoes, earplugs or muffs, hard hats, respirators, vests, full body suits, laboratory coats, etc.

**Team member(s):** Everyone who works on the project (i.e. grads, undergrads, postdocs, etc.). The primary contact must be listed first and provide phone number and email for contact.

**Safety representative:** Each laboratory is encouraged to have a safety representative, preferably a graduate student, in order to facilitate the implementation of the safety expectations in the laboratory. Duties include (but are not limited to):

- Act as a point of contact between the laboratory members and the college safety committee members.
- Ensure laboratory members are following the safety rules.
- Conduct periodic safety inspection of the laboratory.
- Schedule laboratory clean up dates with the laboratory members.
- Request for hazardous waste pick up.

**Residual risk:** Residual Risk Assessment Matrix are used to determine project's risk level. The hazard assessment matrix (table 1) and the residual risk assessment matrix (table2) are used to identify the residual risk category.

The instructions to use hazard assessment matrix (table 1) are listed below:

1. Define the workers familiarity level to perform the task and the complexity of the task.
2. Find the value associated with familiarity/complexity (1 – 5) and enter value next to: HAZARD on the PHA worksheet.

**Table 1. Hazard assessment matrix.**

| | Complexity | | |
|---|---|---|---|
| | Simple | Moderate | Difficult |

| | | | | |
|---|---|---|---|---|
| **Familiarity Level** | Very Familiar | 1 | 2 | 3 |
| | Somewhat Familiar | 2 | 3 | 4 |
| | Unfamiliar | 3 | 4 | 5 |

The instructions to use residual risk assessment matrix (table 2) are listed below:

1. Identify the row associated with the familiarity/complexity value (1 – 5).
2. Identify the consequences and enter value next to: CONSEQ on the PHA worksheet. Consequences are determined by defining what would happen in a worst case scenario if controls fail.
    a. Negligible: minor injury resulting in basic first aid treatment that can be provided on site.
    b. Minor: minor injury resulting in advanced first aid treatment administered by a physician.
    c. Moderate: injuries that require treatment above first aid but do not require hospitalization.
    d. Significant: severe injuries requiring hospitalization.
    e. Severe: death or permanent disability.
3. Find the residual risk value associated with assessed hazard/consequences: Low –Low Med – Med– Med High – High.
4. Enter value next to: RESIDUAL on the PHA worksheet.

**Table 2. Residual risk assessment matrix.**

| **Assessed Hazard Level** | **Consequences** | | | | |
|---|---|---|---|---|---|
| | Negligible | Minor | Moderate | Significant | Severe |
| 5 | Low Med | Medium | Med High | High | High |
| 4 | Low | Low Med | Medium | Med High | High |
| 3 | Low | Low Med | Medium | Med High | Med High |
| 2 | Low | Low Med | Low Med | Medium | Medium |
| 1 | Low | Low | Low Med | Low Med | Medium |

**Specific rules for each category of the residual risk:**

Low:
- Safety controls are planned by both the worker and supervisor.
- Proceed with supervisor authorization.

Low Med:
- Safety controls are planned by both the worker and supervisor.
- A second worker must be in place before work can proceed (buddy system).
- Proceed with supervisor authorization.

Med:
- After approval by the PI, a copy must be sent to the Safety Committee.
- A written Project Hazard Control is required and must be approved by the PI before proceeding. A copy must be sent to the Safety Committee.
- A second worker must be in place before work can proceed (buddy system).
- Limit the number of authorized workers in the hazard area.

Med High:
- After approval by the PI, the Safety Committee and/or EHS must review and approve the completed PHA.
- A written Project Hazard Control is required and must be approved by the PI and the Safety Committee before proceeding.

- Two qualified workers must be in place before work can proceed.
- Limit the number of authorized workers in the hazard area.

High:

- The activity will not be performed. The activity must be redesigned to fall in a lower hazard category.

**Appendix A: Hazard types and examples**

| Types of Hazard | Example |
|---|---|
| Physical hazards | Wet floors, loose electrical cables objects protruding in walkways or doorways |
| Ergonomic hazards | Lifting heavy objects Stretching the body<br>Twisting the body<br>Poor desk seating |
| Psychological hazards | Heights, loud sounds, tunnels, bright lights |
| Environmental hazards | Room temperature, ventilation contaminated air, photocopiers, some office plants acids |
| Hazardous substances | Alkalis solvents |
| Biological hazards | Hepatitis B, new strain influenza |
| Radiation hazards | Electric welding flashes Sunburn |
| Noise | High levels of industrial noise will cause irritation in the short term, and industrial deafness in the long term. |
| Temperature | Personal comfort is best between temperatures of 16°C and 30°C, better between 21°C and 26°C.<br>Working outside these temperature ranges: may lead to becoming chilled, even hypothermia (deep body cooling) in the colder temperatures, and may lead to dehydration, cramps, heat exhaustion, and hyperthermia (heat stroke) in the warmer temperatures. |
| Being struck by | This hazard could be a projectile, moving object or material. The health effect could be lacerations, bruising, breaks, eye injuries, and possibly death. |
| Crushed by | A typical example of this hazard is tractor rollover. Death is usually the result |
| Entangled by | Becoming entangled in machinery. Effects could be crushing, lacerations, bruising, breaks amputation and death. |
| High energy sources | Explosions, high pressure gases, liquids and dusts, fires, electricity and sources such as lasers can all have serious effects on the body, even death. |
| Vibration | Vibration can affect the human body in the hand arm with `white-finger' or Raynaud's Syndrome, and the whole body with motion sickness, giddiness, damage to bones and audits, blood pressure and nervous system problems. |
| Slips, trips and falls | A very common workplace hazard from tripping on floors, falling off structures or down stairs, and slipping on spills. |
| Physical | Excessive effort, poor posture and repetition can all lead to muscular pain, tendon damage and deterioration to bones and related structures |
| Psychological | Stress, anxiety, tiredness, poor concentration, headaches, back pain and heart disease can be the health effects |
| Biological | More common in the health, food and agricultural industries. Effects such as infectious disease, rashes and allergic response. |

## 1.8 Spring Project Plan

| Team Name | | | | |
|---|---|---|---|---|
| Mini TT Shaft Bearing Press | | | | |
| Semester | | | | |
| Spring | | | | |
| Group- Company | | | | |
| 512 Danfoss | | | | |
| **ASSIGNMENT** | **TASKS** | **TASK OWNER** | **START DATE** | **DUE DATE** |
| Finalize Frame | | TBD | 12/1/2023 | TBD |
| | Send Email Kevin with Update of 2 frames | | 12/7/2023 | |
| | Validate if CAD Drawings Need to be Implemented | | 12/11/2023 | |
| | Order Frame- Verify CAD drawings are Correct | | 12/15/2023 | |
| | Submit Drawings to Danfoss | | 12/18/2023 | |
| Finalize Bill of Materials | | TBD | 1/8/2024 | TBD |
| | Recheck Bill of Materials | | 1/8/2024 | |
| | Add New Materials | | 1/9/2024 | |
| | Check List and Avaliability of Products | | 1/10/2024 | |
| | Order Materials | | 1/11/2024 | |
| January Sponsor Meeting | | TBD | 1/12/2024 | TBD |
| | Schedule Meeting with Assigned Advisor | | 1/13/2024 | |
| | Meeting Minutes | | 1/14/2024 | |
| | Combine Notes | | 1/15/2024 | |
| | Submit Documentation | | 1/16/2024 | |
| Machine Shop | | TBD | 1/17/2024 | TBD |
| | Check CAD Drawings | | 1/18/2024 | |
| | Review Drawings | | 1/19/2024 | |
| | Submit to Machine Shop | | 1/19/2024 | |
| Before Feb | | TBD | 1/22/2024 | TBD |
| | Order The Remaining Parts From Machine Shop | | 1/26/2024 | |
| | Make Sure Frame Will Be Delivered in Time | | 1/26/2024 | |
| Initial Construction | | TBD | 1/29/2024 | TBD |
| | Build Base | | 1/29/2024 | |
| | Get Air Compressor | | 1/29/2024 | |
| | Construct Parts That Have Been Ordered | | 1/29/2024 | |
| February Sponsor Meeting | | TBD | 2/1/2024 | TBD |
| | Schedule Meeting with Advisor | | 2/1/2024 | |
| | Meeting With Sponsor | | 2/1/2024 | |
| | Problems/ Challenges | | 2/1/2024 | |
| Initial Testing | | TBD | 2/5/2024 | TBD |
| | Connect Air to System | | 2/5/2024 | |
| | Test Electric | | 2/6/2024 | |
| | Test Pneumatic | | 2/7/2024 | |
| | Record Data | | 2/7/2024 | |
| | Check Pressure | | 2/7/2024 | |
| | Challenges | | 2/7/2024 | |

| | | | | |
|---|---|---|---|---|
| Fix Issues | | TBD | 2/11/2024 | TBD |
| | Identify Issues | | 2/11/2024 | |
| | Identify Solutions | | 2/11/2024 | |
| | Perform Fix | | 2/11/2024 | |
| Spring Break | | TBD | 3/11/2024 | TBD |
| Final Testing | | TBD | 3/11/2024 | TBD |
| | Perform Tests | | 3/18/2024 | |
| | Record Data | | 3/18/2024 | |
| | Input Data to Excel/Matlab | | 3/18/2024 | |
| | Analyze Data | | 3/18/2024 | |
| | Present Data to Sponsor | | 3/18/2024 | |
| Prep for Senior Design Day | | TBD | 3/25/2024 | TBD |
| | Analyze Data | | 3/26/2024 | |
| | PowerPoints/Poster | | 3/27/2024 | |
| | Practice Presentation | | 3/27/2024 | |
| | Finalize Evidence Manual | | 3/27/2024 | |
| | Engineering Design Day | | 4/1/2024 | |
| | Present | | 4/1/2024 | |
| Finals | | TBD | 4/29/2024 | TBD |
| Graduation | | TBD | 5/4/2024 | TBD |

## Appendices

### Appendix A: Code of Conduct

This document will serve as the team contract for Team 512 during the entire Senior Design period lasting from the Fall of 2023 through the Spring of 2024.

#### Mission Statement

To work collaboratively as a team to produce the best solution for Danfoss in the creation of a Mini-TT Shaft Bearing Press. The team will use the engineering design principles, knowledge, and experience learned throughout our undergraduate careers to find a solution to the outstanding problem. This will be conducted in a professional manner with the collaboration of Danfoss and its employees.

#### Outside Obligations

The Senior Design team should meet twice weekly at a minimum, during the remaining lecture time every Tuesday and Thursday, these will be the general team meetings. Microsoft teams is used to communicate weekly availability best for meeting. Allocated time will be set aside for team meetings with team sponsors and faculty. Changes in one's personal schedule shall be communicated with the group and displayed in teams. All team members should be present at the general meetings except for situations which are effectively communicated prior to the meeting time.

## Team Roles

Team Roles have been divided as such:

| Name | Role | Description |
|---|---|---|
| Brent Mynard | CAD Coordinator | Primary CAD operator and manager of revisions. |
| Cassie Bentley | Fluids Coordinator / Point of contact lead | Primary researcher of fluids and air compression/ communication |
| Clark Cooley | Systems engineer / submission manager | Primary researcher of fluid mechanics and system analysis of stress and strain/ submitting |
| Colby Gullo | Safety Coordinator | Primary Researcher of safety in a mechanical system and prevention of injury during usage. |

As more information regarding the project is acquired, amendments will be made to assign team members to more specific roles. Overall, the above team roles serve as a general basis for the preferred role each team member has.

## Communication

The team should put the necessary files, scheduling, and communication primarily on the Microsoft Teams site. The iMessage group chat should only be used to communicate informally. Official communication with Sponsors, Dr. McConomy, and other mentors should primarily be communicated through email and should have all the group members copied. If no response is received in 24 hours for team members and 72 hours for non-team members a follow-up email must be sent by the original sender of the email.

When responding in a professional setting be polite and understanding. Meeting notes will be taken in every meeting, and everyone will upload their notes to one document on Teams. If a team member misses a meeting for whatever reason, it is their responsibility to look at the recorded notes from the other team members and stay up to date with all project details.

## Group Communication Agreement

Parties: This agreement is entered into on [9/13/2023] by and between the following parties: Brent Mynard, Cassie Bentley, Clark Cooley, Colby Gullo
Collectively referred to as the "Group".
Our main means of communication is as follows:

1. Informal Communication: *Messages* (Group Chat: Senior Design Team)
2. Links: *GroupMe*
3. Projects: *Microsoft Teams* (Senior Design 512)

## Dress Code

For general meetings between team members, there is no formal dress code. For presentations, business professional will be worn (suits color scheme of black or navy). For sponsor/professional interactions, business casual will be worn (jeans, slacks, and a polo shirt).

## Attendance Policy

In the event that a Group member cannot attend a scheduled meeting, class, or activity, they are responsible for notifying the Group as soon as possible via Group Chat Messages. The absent Group member should provide a brief explanation for their absence and an estimate of when they expect to resume participation. Upon receiving a notification of absence, the Group will acknowledge receipt of the message and discuss any necessary adjustments to the work plan, deadlines, or responsibilities to accommodate the absence. The Group member who missed the session is responsible for catching up on any missed discussions, tasks, or materials shared during their absence.

## How To Notify Group

Notification of any meeting or event will take place on Teams. If for any reason sponsors or advisors are in need to notify the group all communication can be done through the university's email.

### How To Respond to People in Professional Meetings

Regarding professional meetings, language that is rude or demeaning will not be accepted. All ideas will be considered, and team members must remain civil during arguments. During the event of a disagreement votes can be enacted and the results will be respected. If an issue arises within a group, all parties are in preference of direct communication.

### Dr. McConomy or TA Intervention

In cases where conflict needs resolving, the following steps need to be taken before an intervention is needed:

1. Exhaust all available options and attempt to resolve issue
2. Hold a vote
3. Ask advisor on what best suits the project

### At What Point Do We Contact Dr. McConomy

If any of the following occurs, it is in the Groups best interest to seek further help from Dr. McConomy.

1. Unable to contact Group Members for 72 hours
2. Death in the family
3. Medical Emergency
4. Physical Altercation
5. Unable to contact Advisor

### What Do We Want Dr. McConomy to Do

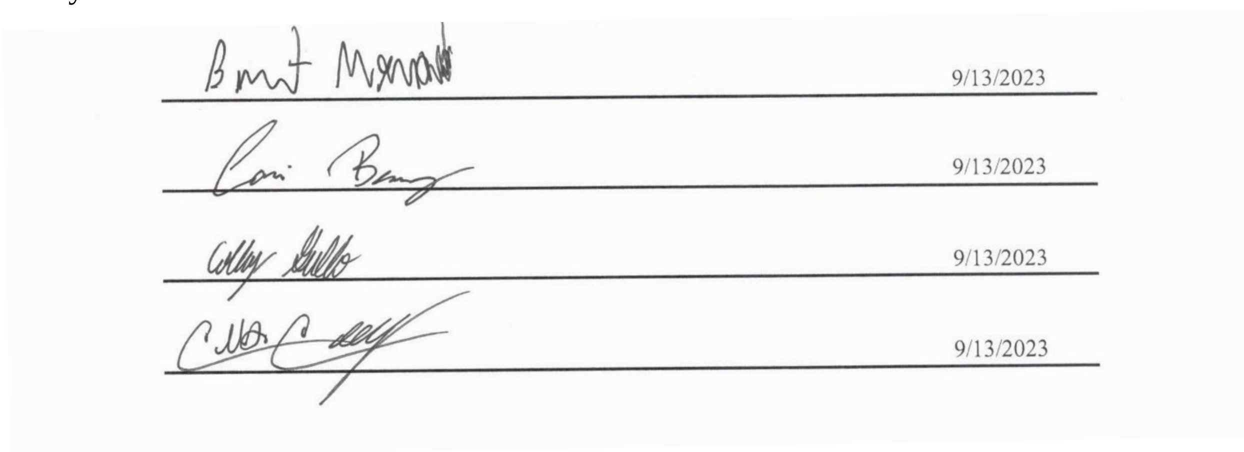
We want Dr. McConomy's honest input and necessary assistance to resolve the issue that is occurring within the team.

### Amendments

This document can be amended at any point during the project duration with unanimous agreement of the team. The amendment must be clearly communicated and understood by all members. There is no need to resign the document if a change is made.

**Statement of Understanding**

By signing the Code of Conduct, you agree to the document and will follow it to the best of your ability.



## Appendix B: Work Breakdown Structure

| Project Phase | Deliverable/Milestone | Work Package | Owner | Status | Date Completion | Notes |
|---|---|---|---|---|---|---|
| | | | | | | *Subject to change |
| | Code Of Conduct | | | In Progress | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | Layout | Colby | | | |
| | | Mission Statement | Clark | | | |
| | | Outside obligations | Brent | | | |
| | | Team Roles | Colby | | | |
| | | Communication | Cassie | | | |
| | | Dress Code | Clark | | | |
| | | Attendance Policy | Colby | | | |
| | | How to notify group | Cassie | | | |
| | | How to respond in a meeting | Clark | | | |
| | | Statement of Understanding | Cassie | | | |
| | | What do we do before Dr. McConomy | Clark | | | |
| | | When do we contact Dr. McConomy | Colby | | | |
| | | What do you want Dr. McConomy to do | Brent | | | |
| | | How to amend | Colby | | | |
| | | Proofread | Brent | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| | Work Breakdown Structure | | | In Progress | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | Create, Format, and Share Excel | Colby | | | |
| | | Evidence Book | Brent | | | |
| | | Tasks | Colby | | | |
| | | Asignee | Cassie | | | |
| | | Completion | Colby | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Proofread | Brent | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| 1- Scope | Sponsor Meet and Greet | | | Upcoming | 9/15/2023 | |
| | | When2meet for Availability | ALL | | | |
| | | Reply All to Initial Email | Cassie | | | |
| | | Conduct Meeting | ALL | | | |
| | | Take Meeting Minutes | ALL | | | |
| | | Submit Meeting Minutes | Colby | | | |
| | | Attendance of Meeting Notated | Colby | | | |
| | | Date of Meeting Notated | Colby | | | |
| | | Action Items Notated | Cassie | | | |
| | | | | | | |
| | Sponsor Meeting 2 | | | Not Started | | *Roles will be the same for all meetings |
| | | Make an Agenda | ALL | | | |
| | | Schedule Meeting Time | Cassie | | | |
| | | Present Findings | Clark | | | |
| | | Take Meeting Minutes | ALL | | | |
| | | Submit Meeting Minutes | Colby | | | |
| | | | | | | |
| | | | | | | |
| | Project Scope | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | List Sponsors and Advisors | Clark | | | |
| | | Project Description | Brent | | | |
| | | Key Goals | Colby | | | |
| | | Assumptions | Cassie | | | |
| | | Primary/Secondary Markets | Clark | | | |
| | | Stakeholders | Colby | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| | Customer Needs | | | Not Started | | |
| | | Schedule Meeting | Cassie | | | |
| | | Record Customer Statements | ALL | | | |
| | | Team Meeting | ALL | | | |
| | | Interpret Needs | Brent | | | |
| | | Verify Interpreted Needs | Colby | | | |
| | | Explanation of Results | Clark | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Submit | Clark | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| | **Functional Decomposition** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | Make Graphics | Cassie | | | |
| | | Explanation of Results | Colby | | | |
| | | Connection to Systems | Clark | | | |
| | | Smart Integration | Brent | | | |
| | | Action and Outcome | Cassie | | | |
| | | Function Resolution | Colby | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Proofread | Brent | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| **2 - Concept Selection** | **Virtual Design Review 1** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | Create and Share PowerPoint | Brent | | | |
| | | Introduction | Cassie | | | |
| | | Project Brief | Colby | | | |
| | | Background | Clark | | | |
| | | Project Scope | Brent | | | |
| | | Functional Decomposition | Cassie | | | |
| | | Customer Needs | Colby | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Proofread | Brent | | | |
| | | Submit | Clark | | | |
| | | Practice Presentation | ALL | | | |
| | | | | | | |
| | **Targets and Metrics** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | Define Targets/Metrics | Colby | | | |
| | | Method of Validation | Brent | | | |
| | | Derivation of Targets/Metrics | Cassie | | | |
| | | Discussion of Measurement | Clark | | | |
| | | Determine Critical Targets/Metrics | Clark | | | |
| | | Summary and Catalog | Brent | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Proofread | Colby | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| | **Concept Generation** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming Meeting | ALL | | | |
| | | 100 Ideas Generated | ALL | | | |
| | | 5 Medium Fidelity Concepts | Clark | | | |
| | | 3 High Fidelity Concepts | Colby | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Proofread | Brent | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| | **Concept Selection** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Create, Setup, and Share Excel | Colby | | | |
| | | House of Quality and Discussion | Colby | | | |
| | | Pugh Charts and Discussion | Cassie | | | |
| | | AHP and Discussion | Brent | | | |
| | | Final Selection and Discussion | Clark | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Proofread | Clark | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| **3- Evaluate Selection** | **Virtual Design Review 2** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | Create and Share PowerPoint | Brent | | | |
| | | Introduction | Cassie | | | |
| | | Project Brief | Colby | | | |
| | | Targets and Metrics | Clark | | | |
| | | Concept Generation | Brent | | | |
| | | Concept Selection | Cassie | | | |
| | | Customer Needs | Colby | | | |
| | | Check Against Rubric | Cassie | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Proofread | Brent | | | |
| | | Practice Presentation | ALL | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| | **Risk Assessment** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | What can go wrong | Brent | | | |
| | | Accidents Identified | Cassie | | | |
| | | Steps to Avoid Hazards | Colby | | | |
| | | Safety Measures | Clark | | | |
| | | Emergency Response | Brent | | | |
| | | Emergency Contact | Colby | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Proofread | Brent | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| | **Bill of Materials** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | Line Items | Colby | | | |
| | | Order Needs | Cassie | | | |
| | | Explanation of Parts | Brent | | | |
| | | Vendor Identification | Colby | | | |
| | | Line Item Maturity | Clark | | | |
| | | Project Maturity | Clark | | | |
| | | Project Cost | Cassie | | | |
| | | Unit Cost | Cassie | | | |
| | | Labor Cost | Brent | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Proofread | Colby | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| | **Virtual Design Prototype** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | Prototype | ALL | | | |
| | | Report | ALL | | | |
| | | Presentation | Colby | | | |
| | | Clarity of Work | Cassie | | | |
| | | Practice Presentation | ALL | | | |
| | | Check Against Rubric | Brent | | | |
| | | Proofread | Brent | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| | **Spring Design Plan** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Create List of Milestones | Colby | | | |
| | | Create Timeline for Milestones | Cassie | | | |
| | | Report | Clark | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Proofread | Brent | | | |
| | | Submit | Clark | | | |
| | | | | | | |
| | **Poster** | | | Not Started | | |
| | | Team Meeting | ALL | | | |
| | | Brainstorming | ALL | | | |
| | | Appearance | Cassie | | | |
| | | Organization | Cassie | | | |
| | | Graphics | Colby | | | |
| | | Text | Brent | | | |
| | | Check Against Rubric | Cassie | | | |
| | | Proofread | Colby | | | |
| | | Submit | Clark | | | |

## Appendix C: Functional Decomposition

## Appendix D: Target Catalog

| System | Function | Target | Metric |
|---|---|---|---|
| Safety | System can operate if the door is closed | 1 | Binary |
| Safety | System won’t operate if the door is open | 0 | Binary |
| Safety | System can be stopped at any time | 0 | Binary |
| Safety | Ventilate heat | | |
| Interaction | Enable timer to communicate with press | 1 | Binary |
| Interaction | Force press to hold | Equal to user input for hold time | Time |
| Interaction | Make bearing interchangeable for various sizes | 2-6 cm | Diameter Range |
| Interaction | Make more room between press and plexiglass on all sides | 20 cm | Distance |
| Interaction | Make more room between bearing and shaft | 30 cm | Distance |
| Functionality | Increase applied pressure | Up to 120 psi | Pressure |
| Functionality | Decrease applied pressure | Down to 0 ~ 20 psi | Pressure |
| Functionality | Apply up to 6 tons of force with press | Up to 6 tons of force | Weight |

## Appendix E: Concept Generation

### Safety

| | |
|---|---|
| 1)Wire Mesh: Cage | • **Advantages:** Offers visibility, good airflow, and impact resistance. Provides protection while allowing visibility of the enclosed area.<br>• **Suitable For:** Guards for machinery, equipment, or conveyor belts where ventilation and visibility are important. |
| 2)Use steel cage around press | |
| 3)Nylon or Plastic Mesh: | • **Advantages:** Lightweight, durable, and resistant to corrosion. Provides protection against small debris while allowing visibility and airflow.<br>• **Suitable For:** Guards in areas where lightweight protection and visibility are required, such as conveyor systems. |
| 4)Safety Glass: | • **Advantages:** Similar to regular glass but designed to break into small, less sharp pieces for safety. Provides visibility and protection.<br>• **Suitable For:** Guards in areas where impact resistance and visibility are crucial. |
| 5)Bulletproof Glass: | • **Advantages:** Resists penetration by projectiles. Will not shatter when failure occurs.<br>• **Suitable For:** Withstanding high pressures and impacts. Typically used in windows and doors. |
| 6)Magnetic lock on door | |

| | |
|---|---|
| 7)Foot pedal initiation: | • Add a foot pedal to operate the machine hands free to eliminate being close to the machine. |
| 8)Air cutoff: | • Add a valve to cutoff the air supply at any time to limit the ability of the press. |
| 9)Cooling Fans: | • Install cooling fans near the press components that generate heat. Fans can help circulate air and dissipate heat. Consider using axial fans or centrifugal fans depending on the specific requirements and space constraints |
| 10)Heat Exchangers: | • Use heat exchangers to transfer heat away from the press components. These devices can either air-cool or liquid-cool the press, depending on the application. Liquid cooling is more efficient but requires a cooling fluid circulation system. |
| 11)Enclosures with Ventilation: | • If the press is enclosed, ensure the enclosure has proper ventilation holes or slots. The ventilation openings should be strategically placed to allow the hot air to escape and fresh air to enter, creating a natural airflow. |
| 12)Wire Safety: | Make wire holes bigger |
| 13)Add support cap for wire hole | |
| 14)Button on handle to press down to fully unlock door | |
| 15)Force and Distance Monitoring: | • Use sensors to monitor the force applied during pressing or the distance traveled by the pressing mechanism. If the force or distance exceeds the predetermined limits, the press can automatically shut down to prevent damage to the components or tooling |

| | |
|---|---|
| 15)Visual and Audible Alarms: | • Install visual and audible alarms to indicate when the press is about to operate or when it has completed a cycle. These alarms can alert nearby workers to stay clear of the press during operation. |
| 16) Keyed Lockout Switch: | • A keyed lockout switch requires a physical key to enable or disable the press. Only authorized personnel with the key can operate the press, adding an extra layer of security. |
| 17)Pressure Relief Lock: | • A pressure relief lock ensures that the pressurized system cannot be released or depressurized without proper authorization. It prevents accidental release of pressure, reducing the risk of unexpected movements. |
| 18)Time Delay Lock: | • A time delay lock introduces a delay between pressing a button and the initiation of the press operation. This delay allows operators to react and cancel the operation if they accidentally press the button. |
| 19)RFID Magnetic Door Lock: | • The RFID magnetic door lock will ensure that the door is closed prior to the operation beginning. Using RFID will negate any way for the press to begin without the door being closed. The magnetic door then does not allow the door to be opened from the time the operation begins to when it is completed. |
| 20)Door Indicator Light: | • Light will be red if the door is not closed, so the press cannot be started. Light will be green if the door is closed, signaling that the press is ready and waiting for the user to start. |
| 21)Anti-Tie Down Two Hand Actuator: | • The two-handed start will negate any accidental starts of the press. Both buttons must be pressed at the same time and held for a set amount of time. |
| 22)Built in water cooling: | • Add a water pump to cool the system. |

| | |
|---|---|
| 23)Rounded Corners | • Round off the corners of the machine to prevent injury |

**Attachments**

| | |
|---|---|
| 24)Adding Electric Power | |
| 25)Use hydraulics to press down | |
| 26 )Easily Maintainable | |
| 27)Dump valve for air in use | |
| 28)Emergency stop | |
| 29)Fingerprint starter | |
| 30)Hamster power | |
| 31)Dampeners | To reduce vibration |
| 32)Adjustable Chuck | Instead of magnet |
| 33)Hydraulic Power Pack: | • Hydraulic systems use fluid pressure to generate force. A hydraulic power pack consists of a hydraulic pump, |

| | |
|---|---|
| | motor, reservoir, and control valves. Hydraulic presses are known for their high force capabilities and precise control, making them suitable for various pressing applications. |
| 34)Spring-Loaded Systems: | • Spring-loaded presses use stored mechanical energy in springs to generate force. When released, the springs exert force on the press. Spring-loaded systems are often used for repetitive, low-force tasks. |
| 35)Touchscreen Control Panels: | • Upgrade the control panel to a touchscreen interface that provides intuitive controls, visual feedback, and customization options for various pressing tasks. |
| 36)Data Logging and Reporting Systems: | • Integrate data logging and reporting systems that capture information about pressing operations, including force applied, cycle times, and successful assemblies. This data can be valuable for quality control and process optimization. |
| 37)Size Dial on Baseplate: | • A dial on the baseplate will allow for the bearing slot to get larger or smaller, changing the diameter. This will allow for various sizes of bearings to be used. |
| 38)Timer Dial: | • The dial will have 6 notches, one for every minute from 0 to 5. The press will then know how long to continue applying pressure for. |
| 39)LCD Timer Screen: | • Add an LCD that counts down the time until the press is completed depending on what value the hold timer was set to. |
| 40)Height Dial on Baseplate: | • A dial on the baseplate will allow for the height of the baseplate to be increased or decreased. This will allow for a variable clearance between the press and the baseplate. |
| 41)Swing Door: | • The door will open via hinges on one of the sides. This will open towards |

| | |
|---|---|
| | the user, which can cause an obstacle, but will allow for a large area to work in. |
| 42)Roll up Door: | • The door will open as a warehouse door does. This would take up a decent amount of room in the press enclosure and would not be only one piece, but it would provide a large area to work through. |
| 43)Garage Door: | • The door will open by rolling up and stopping becoming horizontally flat. This could be hindered by the height of the press, but would give a large workable area. |
| 44)Sliding Door: | • This door acts as a sliding glass door or drive-through window. It does not require extra room to open, but it only will open to about half of the area as other styles of door would. |
| 45)Window Door: | • This door would act as a window in a house, where the bottom half opens, and the top half stays stationary. This does not require any extra room in the enclosure, but the working area will only be half the height. |
| 46)Peep hole in metal caging: | • Add a small cutout to the metal caging that surrounds the press to allow easy access while the door is closed. |
| 47)Magnetic baseplate: | • Add a small magnetic baseplate to allow parts to be held to the machine during operation. |
| 48)Magnetic chuck: | • Allows for the shaft stub to be held upside-down prior to the press being started. |
| 49)Programmable Logic Controller (PLC): | • The PLC will be used to store program instructions and send output signals. |
| 50)Pressure gauge: | • Add a pressure gauge on the front of the press to show how much pressure the bearing and shaft are under. |

| | |
|---|---|
| 51)Temperature Gauge: | • Add a thermometer to see the temperature of the bearing before removing it. |
| 52)Hydraulic baseplate: | • Add a Hydraulic baseplate that can be raised and lowered |
| 53)Bell: | • Have a bell that rings when the press is finished. |
| 54) Adjustable Press | • Add a lever to adjust the baseplate to various heights. |
| 55)Laser sensor to determine centering: | • Add a laser sensor on both the X and Y axis to help with centering the bearing to prevent shearing. |
| 56)Put the press on wheels: | • Add wheels to the base of the machine to allow it to be moved around the factory. |
| 57)Key start: | • Make the machine initiate by a key to ensure only certain people can use it. |
| 58)lights: | • Add lights in the press to light up the working space. |
| 59)Easy disconnect valve: | • Easy disconnect valve to take the airlines off at any time. |
| 60)Larger frame: | • Create a larger frame for a larger press and to increase the size of the working area. |
| 61)Camera: | • Add a camera to the inside of the press to see the press functioning |
| 62)Color coded airlines: | • Add airlines of. Various colors to see the difference. |
| 63)Easily removable housing: | • Add housing that's easy to remove to work on the press. |
| 64)Quick release for chucks: | • Add a quick release to exchange chucks quickly for various sized bearings. |
| 65)Hydraulic press height | • Increase the height of the press as a whole using hydraulics. |
| 66)Measuring tape inside the press | • Add a ruler to measure the size of the shaft and bearing. |

| | |
|---|---|
| 67)Use high pressure gas canisters to use on the press | • |
| 68)Use a thermal camera in the press to keep track of where pressure is being applied on the bearing and shaft | |
| 69)Night vision camera with titanium walls that encase the press area & stops operation if light is detected | |
| 70)Light sensitivity Curtain | |
| 71)Ziptie down press | Could be cheaper |
| 72)Self clean mode | |
| 73)Baseplate spins 360 deg | |

**Problems 2 Solve**

| | |
|---|---|
| 74)Swappable plates for bearings | |
| 75)Press down after receiving an electric signal | |
| 76)Press down using timer | |
| 77)Button releases all air from press | |
| 78)Press senses when procedure is unstable | |
| 79)Hold activation button down for a short time to confirm operation | |
| 80)Extend press height up | To allow for larger shaft sizes |
| 81)Extend press height down | To allow for larger shaft sizes |

| | |
|---|---|
| 82)Baseplate Bearing holder | Have the baseplate hold in place an adjustable holder that tightens bearing in place |
| 83)Sensor on the door handle that detects human touch to begin disengaging the press | |
| 84)Keyboard with different buttons to set timer, lock, and activation | |
| 85)Making press communicate with other sensors | Coding using Siemens software has been described as an easy way to process inputs, compute them, and output signals. |
| 86)Screw off the top nut of the housing | Take the bearing and shaft out of the large enclosure while under compression. |
| 87)Pneumatically powered | Use only pneumatics to run all operations. |
| 88)Electrically powered | Use only electrical power to run all operations. |
| 89)Combination of pneumatic and electric | Use both pneumatic power and electrical power to run all operations. Perhaps |

| | |
|---|---|
| | the press being pneumatically powered, but the sensors being powered electrically. |
| 90)Pneumatic to electric converter | Using primarily pneumatics, the converter will allow for electrical signals to be sent to various components of the design. |
| 91) Solar powered | Use solar power to run all operations. |
| 92) Hydro powered | Use fast-running water, converted into electrical signals, to run all operations. |
| 93)Gas powered | Use gas to run all operations. |
| 94)Protection for cylinder of press | Use material selected to keep press enclosed in order to protect the top part of the cylinder that sticks out of the top of the current protection. |
| 95)Weight of the press | Use lighter materials to make the press easier to transport. |
| 96)Adjustable baseplate hole for different bearing sizes rubber | |
| 97)Press stops action if door is unlocked | |
| 98) robot that holds down press | |
| 99) super glue frame together | |

| | |
|---|---|
| 100)3D print out press | |

## Appendix F: House of Quality

*Binary Pairwise and Customer Needs*

| # | Customer Needs |
|---|---|
| 1 | Apply Pressure |
| 2 | Implement Safety Feature |
| 3 | Withstand High Temperature |
| 4 | Modular Baseplate |
| 5 | Increase Clearances |
| 6 | Hands Free-Automation |
| 7 | Provide Ventilation |

| Binary Pairwise Comparison | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Customer Needs | #1 | #2 | #3 | #4 | #5 | #6 | #7 | SUM |
| #1 | - | 0 | 0 | 0 | 1 | 1 | 1 | 3 |
| #2 | 1 | - | 1 | 1 | 1 | 1 | 1 | 6 |
| #3 | 1 | 0 | - | 1 | 1 | 1 | 1 | 5 |
| #4 | 1 | 0 | 0 | - | 1 | 1 | 1 | 4 |
| #5 | 0 | 0 | 0 | 0 | - | 1 | 1 | 2 |
| #6 | 0 | 0 | 0 | 0 | 0 | - | 1 | 1 |
| #7 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |

*House of Quality*

| | | Engineering Characteristics | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Improvement Direction** | | | ↓ | ↓ | ↓ | ↓ | ↑ | ↑ | ↑ |
| **Units** | | *n/a* | *lbs* | *sec* | *sec* | *in* | *in* | *psi* | *°F* |
| Customer Requirements | Importance Weight Factor | Sense Door Status | Weight | Emergency Stop Actuation Time | Hold Error | Baseplate Diameter Inverval | Clearances | Pressure Applied | Withstandable Temperature |
| Modular Baseplate with Adjustable Height | **5** | 0 | 3 | 0 | 0 | 9 | 3 | 0 | 3 |
| Apply Pressure | **4** | 1 | 3 | 3 | 3 | 0 | 0 | 9 | 1 |
| Implement Safety Features | **7** | 9 | 9 | 9 | 0 | 0 | 1 | 1 | 1 |
| Withstand High Temperatures | **6** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| Provide Ventilation | **1** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 9 |
| Increase Clearances | **3** | 0 | 1 | 0 | 0 | 1 | 9 | 3 | 1 |
| Hands-Free Automation | **2** | 3 | 0 | 1 | 9 | 1 | 0 | 1 | 0 |
| **Raw Score** | 323 | 73 | 93 | 77 | 30 | 50 | 50 | 54 | 92 |
| **Relative Weight %** | | 22.60 | 28.79 | 23.84 | 9.29 | 15.48 | 15.48 | 16.72 | 28.48 |
| **Rank Order** | | 4 | 1 | 3 | 2 | 6 | 6 | 5 | 2 |

# Appendix G: Pugh Charts

## *Pugh Chart Iteration 1*

| | | Concepts | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Selection Criteria** | | Magnetic Door Lock | Ventilation Fan | Electical Powered | Adjustable Chuck | Easily Maintainable | Wire Mesh Cage | Timer/ Emergency Stop | Adjustable Press |
| Modular baseplate with adjustable height | DATUM: Current System | S | S | S | + | + | S | S | + |
| Apply Pressure | | S | S | + | S | S | S | + | S |
| Implement Safety Features | | + | S | + | + | + | + | + | S |
| Withstand High Temperatures | | S | + | S | S | S | + | S | S |
| Provide Ventilation | | S | + | - | S | S | + | S | S |
| Increase Clearances | | S | - | S | + | + | S | S | + |
| Hands Free-Automation | | + | S | + | - | + | S | S | S |
| # of Pluses | | 2 | 2 | 3 | 3 | 4 | 3 | 2 | 2 |
| # of Minuses | | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| # of Satisfactory | | 5 | 4 | 3 | 3 | 3 | 4 | 5 | 5 |

## *Pugh Chart Iteration 2*

| | | Concepts | | | | | |
|---|---|---|---|---|---|---|---|
| **Selection Criteria** | | Magnetic Door Lock | [redacted] | Easily Maintainable | Wire Mesh Cage | Timer/ Emergency Stop | Adjustable Press |
| Modular baseplate with adjustable height | DATUM: Current System | S | | + | S | S | + |
| Apply Pressure | | S | | S | S | + | S |
| Implement Safety Features | | + | | + | + | + | S |
| Withstand High Temperatures | | S | | + | + | S | S |
| Provide Ventilation | | S | | S | + | S | S |
| Increase Clearances | | S | | + | S | S | + |
| Hands Free-Automation | | S | | + | S | S | S |
| # of Pluses | | 1 | | 5 | 3 | 2 | 2 |
| # of Minuses | | 0 | | 0 | 0 | 0 | 0 |
| # of Satisfactory | | 6 | | 2 | 3 | 5 | 5 |

## *Pugh Chart Final Iteration*

| | | Concepts | | | | |
|---|---|---|---|---|---|---|
| **Selection Criteria** | | Magnetic Door Lock | [redacted] | Wire Mesh Cage | Timer/ Emergency Stop | Adjustable Press |
| Modular baseplate with adjustable height | DATUM: Current System | S | | S | S | + |
| Apply Pressure | | S | | S | + | S |
| Implement Safety Features | | + | | + | + | S |
| Withstand High Temperatures | | S | | + | S | S |
| Provide Ventilation | | S | | + | S | S |
| Increase Clearances | | S | | S | S | + |
| Hands Free-Automation | | S | | S | S | S |
| # of Pluses | | 1 | | 3 | 2 | 2 |
| # of Minuses | | 0 | | 0 | 0 | 0 |
| # of Satisfactory | | 6 | | 3 | 5 | 5 |

# Appendix H: Analytical Hierarchy Process

*Target Comparison*

| Criteria Comparison Matrix [C] | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Apply Pressure | Implement Safety Feature | Withstand High Temperature | Modular Baseplate | Increase Clearances | Hands Free-Automation | Provide Ventilation |
| 1) Apply Pressure | 1 | 5 | 3 | 1 | 0.33 | 1 | 1 |
| 2) Implement Safety Feature | 0.2 | 1 | 0.33 | 0.33 | 0.33 | 0.14 | 0.33 |
| 3) Withstand High Temperature | 0.33 | 3 | 1 | 7 | 3 | 0.2 | 0.2 |
| 4) Modular Baseplate | 1 | 3 | 0.14 | 1 | 0.2 | 0.2 | 0.2 |
| 5) Increase Clearances | 3 | 3 | 0.33 | 5 | 1 | 0.33 | 0.33 |
| 6) Hands Free-Automation | 1 | 7 | 5 | 5 | 3 | 1 | 3 |
| 7) Provide Ventilation | 1 | 3 | 5 | 5 | 3 | 0.33 | 1 |
| SUM | 7.53 | 25 | 14.8 | 24.33 | 10.86 | 3.2 | 6.06 |

*Normalized Target Comparison*

| Normalized Criteria Comparison Matrix [Norm C] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Criteria Weights [W] |
| 1) Apply Pressure | 0.132802 | 0.2 | 0.202703 | 0.041102 | 0.030387 | 0.3125 | 0.165017 | 0.154929941 |
| 2) Implement Safety Feature | 0.02656 | 0.04 | 0.022297 | 0.013564 | 0.030387 | 0.04375 | 0.054455 | 0.033001916 |
| 3) Withstand High Temperat | 0.043825 | 0.12 | 0.067568 | 0.287711 | 0.276243 | 0.0625 | 0.033003 | 0.127264187 |
| 4) Modular Baseplate | 0.132802 | 0.12 | 0.009459 | 0.041102 | 0.018416 | 0.0625 | 0.033003 | 0.059611802 |
| 5) Increase Clearances | 0.398406 | 0.12 | 0.022297 | 0.205508 | 0.092081 | 0.103125 | 0.054455 | 0.142267536 |
| 6) Hands Free-Automation | 0.132802 | 0.28 | 0.337838 | 0.205508 | 0.276243 | 0.3125 | 0.49505 | 0.291420024 |
| 7) Provide Ventilation | 0.132802 | 0.12 | 0.337838 | 0.205508 | 0.276243 | 0.103125 | 0.165017 | 0.191504595 |
| SUM | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

*Consistency Check*

| | Consistency Check | | |
|---|---|---|---|
| Engineering Characteristics | Criteria Weight {W} | Weighted Sum Vector {Ws} = [C]{W} | Consistency Vector {Cons} = {Ws}./{W} |
| 1) Apply Pressure | 0.154929941 | 1.291216787 | 8.334197866 |
| 2) Implement Safety Feature | 0.033001916 | 0.276600587 | 8.381349406 |
| 3) Withstand High Temperature | 0.127264187 | 1.218066958 | 9.571168353 |
| 4) Modular Baseplate | 0.059611802 | 0.456402907 | 7.656250852 |
| 5) Increase Clearances | 0.142267536 | 1.205484422 | 8.473362616 |
| 6) Hands Free-Automation | 0.291420024 | 2.61305971 | 8.966644355 |
| 7) Provide Ventilation | 0.191504595 | 1.902791442 | 9.936009349 |

| | |
|---|---|
| Average Consistency | 8.760 |
| Number of Criteria | 7 |
| Consistency Index | 0.293 |
| Random Index Value | 1.350 |
| Consistency Ratio | 0.217 |

*Target 1 Comparison*

| Target 1: Applies Prsseure | | | | |
|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press |
| Magnetic Door Lock | 1 | 1 | 1 | 1 |
| Wire Mesh Cage | 1 | 1 | 1 | 0.33 |
| Timer/Emergency Stop | 1 | 1 | 1 | 1 |
| Adjustable Press | 1 | 3 | 1 | 1 |
| SUM | 4 | 6 | 4 | 3.33 |

*Target 1 Normalized*

| Target 1 Normailzed | | | | | |
|---|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press | Critera Weights [W] |
| Magnetic Door Lock | 0.25 | 0.166666667 | 0.25 | 0.3003003 | 0.241741742 |
| Wire Mesh Cage | 0.25 | 0.166666667 | 0.25 | 0.099099099 | 0.191441441 |
| Timer/Emergency Stop | 0.25 | 0.166666667 | 0.25 | 0.3003003 | 0.241741742 |
| Adjustable Press | 0.25 | 0.5 | 0.25 | 0.3003003 | 0.325075075 |
| SUM | 1 | 1 | 1 | 1 | 1 |

*Target 1 Consistency Check*

| Consistency Check Target 1 | | |
|---|---|---|
| Criteria Weight {W} | Weighted Sum Vector $\{Ws\} = [C]\{W\}$ | Consistency Vector $\{Cons\} = \{Ws\}./\{W\}$ |
| 0.241741742 | 1 | 4.136645963 |
| 0.191441441 | 0.7821997 | 4.085843137 |
| 0.241741742 | 1 | 4.136645963 |
| 0.325075075 | 1.382882883 | 4.25404157 |

| | |
|---|---|
| Average Consistency | 4.153 |
| Number of Criteria | 4 |
| Consistency Index | 0.051 |
| Random Index Value | 0.890 |
| Consistency Ratio | 0.057 |

*Target 2 Comparison*

| Target 2: Implement Safety Features | | | | |
|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press |
| Magnetic Door Lock | 1 | 0.2 | 1 | 0.33 |
| Wire Mesh Cage | 5 | 1 | 5 | 0.33 |
| Timer/Emergency Stop | 1 | 0.2 | 1 | 0.33 |
| Adjustable Press | 3 | 3 | 3 | 1 |
| SUM | 10 | 4.4 | 10 | 1.99 |

*Target 2 Normalized*

| Target 2 Normailzed | | | | | |
|---|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press | Critera Weights [W] |
| Magnetic Door Lock | 0.1 | 0.045454545 | 0.1 | 0.165829146 | 0.102820923 |
| Wire Mesh Cage | 0.5 | 0.227272727 | 0.5 | 0.165829146 | 0.348275468 |
| Timer/Emergency Stop | 0.1 | 0.045454545 | 0.1 | 0.165829146 | 0.102820923 |
| Adjustable Press | 0.3 | 0.681818182 | 0.3 | 0.502512563 | 0.446082686 |
| SUM | 1 | 1 | 1 | 1 | 1 |

*Target 2 Consistency Check*

| Consistency Check Target 2 | | |
|---|---|---|
| Criteria Weight {W} | Weighted Sum Vector $\{Ws\} = [C]\{W\}$ | Consistency Vector $\{Cons\} = \{Ws\}./\{W\}$ |
| 0.102820923 | 0.422504226 | 4.109126958 |
| 0.348275468 | 1.523691983 | 4.374962125 |
| 0.102820923 | 0.422504226 | 4.109126958 |
| 0.446082686 | 2.107834628 | 4.725210579 |

| | |
|---|---|
| Average Consistency | 4.330 |
| Number of Criteria | 4 |
| Consistency Index | 0.110 |
| Random Index Value | 0.890 |
| Consistency Ratio | 0.123 |

*Target 3 Comparison*

| Target 3: Withstand High Temperatures | | | | |
|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press |
| Magnetic Door Lock | 1 | 1 | 1 | 3 |
| Wire Mesh Cage | 1 | 1 | 0.33 | 1 |
| Timer/Emergency Stop | 1 | 3 | 1 | 3 |
| Adjustable Press | 0.3 | 1 | 0.33 | 1 |
| SUM | 3.3 | 6 | 2.66 | 8 |

*Target 3 Normalized*

| Target 3 Normailzed | | | | | |
|---|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press | Critera Weights [W] |
| Magnetic Door Lock | 0.303030303 | 0.166666667 | 0.37593985 | 0.375 | 0.305159205 |
| Wire Mesh Cage | 0.303030303 | 0.166666667 | 0.12406015 | 0.125 | 0.17968928 |
| Timer/Emergency Stop | 0.303030303 | 0.5 | 0.37593985 | 0.375 | 0.388492538 |
| Adjustable Press | 0.090909091 | 0.166666667 | 0.12406015 | 0.125 | 0.126658977 |
| SUM | 1 | 1 | 1 | 1 | 1 |

*Target 3 Consistency Check*

| Consistency Check Target 3 | | |
|---|---|---|
| Criteria Weight {W} | Weighted Sum Vector {Ws} = [C]{W} | Consistency Vector {Cons} = {Ws}./{W} |
| 0.305159205 | 1.253317954 | 4.107095359 |
| 0.17968928 | 0.739709999 | 4.116606173 |
| 0.388492538 | 1.612696514 | 4.151164709 |
| 0.126658977 | 0.526098556 | 4.153661813 |

| | |
|---|---|
| Average Consistency | 4.132 |
| Number of Criteria | 4 |
| Consistency Index | 0.044 |
| Random Index Value | 0.890 |
| Consistency Ratio | 0.049 |

*Target 4 Comparison*

| Target 4: Modular Baseplate with Adjustable Height | | | | |
|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press |
| Magnetic Door Lock | 1 | 1 | 1 | 3 |
| Wire Mesh Cage | 1 | 1 | 1 | 1 |
| Timer/Emergency Stop | 1 | 1 | 1 | 1 |
| Adjustable Press | 0.33 | 1 | 1 | 1 |
| SUM | 3.33 | 4 | 4 | 6 |

*Target 4 Normalized*

| Target 4 Normailzed | | | | | |
|---|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press | Critera Weights [W] |
| Magnetic Door Lock | 0.3003003 | 0.25 | 0.25 | 0.5 | 0.325075075 |
| Wire Mesh Cage | 0.3003003 | 0.25 | 0.25 | 0.166666667 | 0.241741742 |
| Timer/Emergency Stop | 0.3003003 | 0.25 | 0.25 | 0.166666667 | 0.241741742 |
| Adjustable Press | 0.099099099 | 0.25 | 0.25 | 0.166666667 | 0.191441441 |
| SUM | 1 | 1 | 1 | 1 | 1 |

*Target 4 Consistency Check*

| Consistency Check Target 4 | | |
|---|---|---|
| Criteria Weight {W} | Weighted Sum Vector $\{Ws\} = [C]\{W\}$ | Consistency Vector $\{Cons\} = \{Ws\}./\{W\}$ |
| 0.325075075 | 1.382882883 | 4.25404157 |
| 0.241741742 | 1 | 4.136645963 |
| 0.241741742 | 1 | 4.136645963 |
| 0.191441441 | 0.7821997 | 4.085843137 |

| | |
|---|---|
| Average Consistency | 4.153 |
| Number of Criteria | 4 |
| Consistency Index | 0.051 |
| Random Index Value | 0.890 |
| Consistency Ratio | 0.057 |

*Target 5 Comparison*

| Target 5: Increase Clearances | | | | |
|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press |
| Magnetic Door Lock | 1 | 1 | 1 | 3 |
| Wire Mesh Cage | 1 | 1 | 1 | 1 |
| Timer/Emergency Stop | 1 | 1 | 1 | 1 |
| Adjustable Press | 0.33 | 1 | 1 | 1 |
| SUM | 3.33 | 4 | 4 | 6 |

*Target 5 Normalized*

| Target 4 Normailzed | | | | | |
|---|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press | Critera Weights [W] |
| Magnetic Door Lock | 0.3003003 | 0.25 | 0.25 | 0.5 | 0.325075075 |
| Wire Mesh Cage | 0.3003003 | 0.25 | 0.25 | 0.166666667 | 0.241741742 |
| Timer/Emergency Stop | 0.3003003 | 0.25 | 0.25 | 0.166666667 | 0.241741742 |
| Adjustable Press | 0.099099099 | 0.25 | 0.25 | 0.166666667 | 0.191441441 |
| SUM | 1 | 1 | 1 | 1 | 1 |

*Target 5 Consistency Check*

| Consistency Check Target 5 | | |
|---|---|---|
| Criteria Weight {W} | Weighted Sum Vector $\{Ws\} = [C]\{W\}$ | Consistency Vector $\{Cons\} = \{Ws\}./\{W\}$ |
| 0.325075075 | 1.382882883 | 4.25404157 |
| 0.241741742 | 1 | 4.136645963 |
| 0.241741742 | 1 | 4.136645963 |
| 0.191441441 | 0.7821997 | 4.085843137 |

| | |
|---|---|
| Average Consistency | 4.153 |
| Number of Criteria | 4 |
| Consistency Index | 0.051 |
| Random Index Value | 0.890 |
| Consistency Ratio | 0.057 |

*Target 6 Comparison*

| Target 6: Hands-Free Automation | | | | |
|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press |
| Magnetic Door Lock | 1 | 0.33 | 1 | 0.33 |
| Wire Mesh Cage | 3 | 1 | 3 | 1 |
| Timer/Emergency Stop | 1 | 0.33 | 1 | 0.33 |
| Adjustable Press | 3 | 1 | 3 | 1 |
| SUM | **8** | **2.66** | **8** | **2.66** |

*Target 6 Normalized*

| Target 6 Normailzed | | | | | |
|---|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press | Critera Weights [W] |
| Magnetic Door Lock | 0.125 | 0.12406015 | 0.125 | 0.12406015 | 0.124530075 |
| Wire Mesh Cage | 0.375 | 0.37593985 | 0.375 | 0.37593985 | 0.375469925 |
| Timer/Emergency Stop | 0.125 | 0.12406015 | 0.125 | 0.12406015 | 0.124530075 |
| Adjustable Press | 0.375 | 0.37593985 | 0.375 | 0.37593985 | 0.375469925 |
| SUM | **1** | **1** | **1** | **1** | **1** |

*Target 6 Consistency Check*

| Consistency Check Target 6 | | |
|---|---|---|
| Criteria Weight {W} | Weighted Sum Vector $\{Ws\} = [C]\{W\}$ | Consistency Vector $\{Cons\} = \{Ws\}./\{W\}$ |
| 0.124530075 | 0.496870301 | 1.528478616 |
| 0.375469925 | 1.498120301 | 6.197193294 |
| 0.124530075 | 0.496870301 | 2.055376524 |
| 0.375469925 | 1.498120301 | 7.825475453 |

| | |
|---|---|
| Average Consistency | 4.402 |
| Number of Criteria | 4 |
| Consistency Index | 0.134 |
| Random Index Value | 0.890 |
| Consistency Ratio | 0.150 |

*Target 7 Comparison*

| Target 7: Provide Ventilation | | | | |
|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press |
| Magnetic Door Lock | 1 | 3 | 1 | 1 |
| Wire Mesh Cage | 0.33 | 1 | 0.33 | 1 |
| Timer/Emergency Stop | 1 | 3 | 1 | 1 |
| Adjustable Press | 1 | 1 | 1 | 1 |
| SUM | **3.33** | **8** | **3.33** | **4** |

*Target 7 Normalized*

| Target 7 Normailzed | | | | | |
|---|---|---|---|---|---|
| | Magnetic Door Lock | Wire Mesh Cage | Timer/Emergency Stop | Adjustable Press | Critera Weights [W] |
| Magnetic Door Lock | 0.3003003 | 0.375 | 0.3003003 | 0.25 | 0.30640015 |
| Wire Mesh Cage | 0.099099099 | 0.125 | 0.099099099 | 0.25 | 0.14329955 |
| Timer/Emergency Stop | 0.3003003 | 0.375 | 0.3003003 | 0.25 | 0.30640015 |
| Adjustable Press | 0.3003003 | 0.125 | 0.3003003 | 0.25 | 0.24390015 |
| SUM | **1** | **1** | **1** | **1** | **1** |

*Target 7 Consistency Check*

| Consistency Check Target 7 | | |
|---|---|---|
| Criteria Weight {W} | Weighted Sum Vector {$Ws$} = [$C$]{$W$} | Consistency Vector {Cons} = {$Ws$}./{$W$} |
| 0.30640015 | 1.286599099 | 4.199081164 |
| 0.14329955 | 0.589423799 | 4.113228553 |
| 0.30640015 | 1.286599099 | 4.199081164 |
| 0.24390015 | 1 | 4.100038476 |

| | |
|---|---|
| Average Consistency | 4.153 |
| Number of Criteria | 4 |
| Consistency Index | 0.051 |
| Random Index Value | 0.890 |
| Consistency Ratio | 0.057 |

# Appendix A: APA Headings (delete)

## Heading 1 is Centered, Boldface, Uppercase and Lowercase Heading

### Heading 2 is Flush Left, Boldface, Uppercase and Lowercase Heading

**Heading 3 is indented, boldface lowercase paragraph heading ending with a period.**

***Heading 4 is indented, boldface, italicized, lowercase paragraph heading ending with a period.***

*Heading 5 is indented, italicized, lowercase paragraph heading ending with a period.*

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## Appendix B Figures and Tables (delete)

The text above the cation always introduces the reference material such as a figure or table. You should never show reference material then present the discussion. You can split the discussion around the reference material, but you should always introduce the reference material in your text first then show the information. If you look at the Figure 1 below the caption has a period after the figure number and is left justified whereas the figure itself is centered.


Figure 1. Flush left, normal font settings, sentence case, and ends with a period.

In addition, table captions are placed above the table and have a return after the table number. The second line of the caption provided the description. Note, there is a difference between a return and enter. A return is accomplished with the shortcut key shift + enter. Last, unlike the caption for a figure, a table caption does not end with a period, nor is there a period after the table number.

Table 1
*The Word Table and the Table Number are Normal Font and Flush Left. The Caption is Flush Left, Italicized, Uppercase and Lowercase*

| Level of heading | Format |
|---|---|
| 1 | **Centered, Boldface, Uppercase and Lowercase Heading** |
| 2 | **Flush Left, Boldface, Uppercase and Lowercase** |
| 3 | ***Indented, boldface lowercase paragraph heading ending with a period*** |
| 4 | ***Indented, boldface, italicized, lowercase paragraph heading ending with a period.*** |
| 5 | *Indented, italicized, lowercase paragraph heading ending with a period.* |

## References

**There are no sources in the current document.**