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Team 517: Making the MagLab Greener: Optimizing the HVAC

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# Abstract

The Innovation Park houses world record holding magnets within the National High Magnetic Field Laboratory, commonly referred to as the MagLab. These magnets produce an enormous amount of heat and require an equally high amount of energy to cool. This makes the MagLab’s carbon footprint extremely large. Trane is the HVAC company that is responsible for cooling the MagLab. Team 517 will help Trane redesign the cooling system at the MagLab to lower the energy consumption and carbon footprint of the Innovation Park.

This team will accomplish this goal with two methods: cooling the magnets and sharing the MagLab’s cooling ability. Currently the magnets are cooled under the assumption they operate at full power. This is not the case. The magnets often use less power to run. The team will design a system that cools the magnets based on the percentage of power used. This will ensure the MagLab does not waste energy by overcooling a magnet; and the less energy the MagLab consumes, the lower its carbon footprint. When the magnets are not in use, the MagLab has a vast cooling potential sitting idly. The second way the team will reduce carbon emissions is using the MagLab’s idle cooling ability by sharing it with the rest of Innovation Park. A new building is coming to the park, and it will rely on the MagLab’s cooling capability for its air-conditioning. This team will design a way to transport the chilled water in the MagLab to the new building two hundred yards away. By relying on the MagLab’s chilling ability, the new building will consume far less energy. Running one system will use less energy than two, and the overall energy consumption of the Innovation Park will decrease thus lowering its carbon footprint.

# Disclaimer

Team 517 cannot be held responsible if our ideas are used with the result of serious repercussions as we didn’t have access to all the tools necessary to validate our technique and the risks associated with it.

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# Notation

|  |  |
| --- | --- |
| HVAC | Heating Ventilation Air Conditioning |
| MagLab | National High Performance Magnetic Laboratory |
|  |  |
|  |  |
|  |  |

# Chapter One: EML 4551C

## Project Scope

**Introduction**

Tallahassee’s Innovation Park is a campus that houses many research institutions. One of which is the National High Magnetic Field Laboratory, commonly referred to as the MagLab. The Innovation Park is constantly improving. One large, expensive component that can be improved is the air conditioning system. The Heating, Ventilating, and Air Conditioning (HVAC) company Trane is a partner with the FAMU-FSU College of Engineering and solicited the help of Senior Design students to explore the options for making the air conditioning system of the Innovation Park more energy efficient. The team must explore many options and propose a technical solution to decrease total cost and increase efficiency of the system.

**Project Description**

The Senior Design Team sponsored by Trane will explore options to lower the energy consumption and carbon footprint of the Innovation Park by redesigning the cooling system in the MagLab.

**Key Goals**

The following goals will focus the project objective to be more specific and expand the scope of the project lower the energy consumption and carbon footprint in Innovation Park.

* Conduct research for this project by collaborating with the different building faculties and Tallahassee Utility Company to gather existing information.
* Explore the current expenditures for Innovation Park
  + Innovate potential solutions for improving the HVAC efficiency at the Innovation Park
* Determine if the solutions are cost effective.
  + Conduct research for this project by collaborating with the different building faculties and Tallahassee Utility Company to gather existing information.

**Market**

The market for this product can be expressed in two sections: the primary market and the secondary market.

The primary market consists of the immediate beneficiaries of this project. The primary markets are the developers within the Innovation Park, the administration of the different buildings at the Innovation Park, and the sponsor company, Trane. The developers of Innovation Park can use the information to expand the park with the most cost-effective solution. The administrations of the different buildings on the campus can benefit by increasing efficiency of their facilities. Trane will benefit by receiving contracts to implement the process.

The secondary markets are those that indirectly benefit from the project. They are the FSU and FAMU main campuses, Tallahassee Utilities, and the company contracted to build the new building at the innovation park. If the project is successful, it may be implemented at the main campuses to reduce their energy consumption. The Tallahassee Utility Company will be able to allot less energy to the Innovation Park thus giving them more freedom to use that energy in other parts of the city. The contractors responsible for the new building may want to implement the new HVAC process into the new building to eliminate the cost of installing and running a separate HVAC system.

**Assumptions**

The assumptions for this project help outline the limitations of what the project entails. All information and data that we need is assumed to already exists. It is a matter of retrieving the data rather than collecting it. The energy usage of the Innovation Park is assumed to not go through any unexpected changes in the future such that the data can be used to interpolate the data usage in the future. The new building will have an energy usage estimate based on previous similar facilities. The project will not include any information on energy use besides HVAC systems.

**Stakeholders**

The stakeholders of this project include the following:

* Sponsor: Cameron Griffith is the company representative from Trane.
  + Adviser: Dr. Juan Ordonez is the faculty member that serves as the Project Advisor
  + Professor: Dr. McConomy is the professor that oversees the Senior Design course.
  + Other Individuals:  the Innovation Park will be affected by this project.
  + Project Team: Bianca Marius, Finnbar Rooney, and Nicholas Walker are all members of the project team. Their influence will lead the project to a successful solution.

Should the project be successful, the stakeholders will benefit from the increase in efficiency and the decrease in cost from the HVAC system. Additionally, the advisors, professor and the project team will be rewarded for a fruitful undertaking in education of the design process.

## 1.2 Customer Needs

**Investigating Needs**

To understand the customer needs the team met with Cameron Griffith. Cameron is a sales associate at Trane and serves as the company liaison for this project. He was able to give insight into what Trane wanted for this project by specifically requesting our team to reach out to Jim Stephens and John Kynoch. Jim is the Executive Director of Maintenance and Utilities at Florida State University. Our team is working closely with him to understand what FSU’s role will be in the utilities of the new building being built in the Innovation Park. John is the Head of the Facilities Management and Administration at the Magnetic Field Laboratory. He is helping our team understand how the magnets in the lab are cooled and how that energy can be harnessed to cool other parts of the laboratory or another building in the Innovation Park.

Our team asked Cameron several questions that are listed in Table 1. We left the questions open ended so not to steer the conversation. Cameron answered our questions, and we turned his answers into interpreted needs. His answers gave us helpful suggestions of how our project can impact not just the MagLab but other buildings as well. He has shown interest in each of our backgrounds to suggest how we can improve and provide new, innovative solutions to Trane’s work.

**Explanation of Results**

We learned several things from the responses to the questions we asked. First there was a pressing importance on learning as much as we can about the project. Not only should we find out information about HVAC and the energy consumption at the MagLab, but also about working on a project. He made it clear during the meeting that he wants the senior design team to learn how to be good engineers more than anything else; and learn how to act like a company working along with Trane. He is anticipating that this team can become professional engineers working in a real-world environment to become more prepared for full-time careers. That is not to say that we should neglect the notion of producing a product. The best way to learn is to produce something that Trane can examine and then present to our stakeholders. He also needs our team to learn as much about how FSU maintains their utilities and the HVAC systems as we can. Therefore, he pointed us to Jim Stephens and John Kynoch.

Cameron made it clear that this project is to reduce the carbon emissions at the Innovation Park. Our work must be focused on that goal. He told us that we need to clearly define our scope so that we do not get bogged down by working on too large of a project. If we extend the scope too far, we will not have the resources to complete the whole project. The final goal for the project is to produce something that Cameron could present to Trane and FSU.

## 1.3 Functional Decomposition

Functional decomposition is a tool that engineers use to help reduce a complex system into subsystems to make solving problems easier. This project will take the scope of reducing carbon emissions in the Innovation Park and divide it into smaller parts to answer what does this have to do.

To start the functional decomposition process, the team asked the sponsor about what they want. The key goals were derived from his answers. The main goal is to reduce the carbon emissions in the Innovation Park. To make the project simpler it was divided into subsystems. The three subsystems are reduce, reuse, and recycle. Reduce means to reducing the energy consumption. This can take two forms. Either reduce the energy usage or increase the energy efficiency. Both concepts will reduce energy consumption. Reuse refers to reusing the energy set in place for one component and use it for another. This could translate to using energy from alternative sources because that energy would be reused for different purposes. Lastly, recycle will be taking the excess energy and using it at another part of the infostructure. All three of these subsystems serve to solve the objective of reducing the carbon emissions. Figure 1 is the functional decomposition for how the project will reduce carbon emissions. These functions were determined by answering question, “What does this have to do?” Table 1 is a cross reference table highlighting the relationships between the functions and subsystems. The three subsystems are closely related to each other and the functions overlap slightly. To reduce carbon emissions, there must be a reduction in energy consumption. To do this you can reuse the materials that you didn’t need and then recycle by giving the used materials a new purpose.

The subsystems that take the highest priority according to Table 1 are recycling and reducing energy. They each have 4 occurrences in the table. The project will focus on these two subsystems to maximizes the reduction in carbon emissions. The highest priority functions are reusing energy from components and increasing the efficiency of components. Both these functions are important to reducing carbon emissions. They will take priority when generating concepts that accomplish the goal for this project.

It can be seen in the table that the functions relate to each other. When a concept works to recycle energy, it will also reduce the energy consumption of that component. If alternative sources of energy are used the components will require less energy from traditional sources. This smart integration allows for innovation within the project. The concept generation process will facilitate more innovation by following these functions.

## 1.4 Target Summary

Targets are goals for how well a system operates and metrics are a method of measuring those goals. For our project the targets will be the specific goals we want to accomplish. They will each be assign to a function from the functional decomposition. The three functions are reduce, reuse, and recycle. Each function has several sub-functions that are associated with a metric.

The first function is reduce. The metric is electricity consumption. The target for this function to reduce the carbon emissions from the HVAC system in the MagLab by reducing the electricity consumption of the building by 15%. To do this, the team will need to find out how much electricity is being used by the current HVAC system. Reducing the emissions coincides with reducing the energy consumption because carbon emissions are a byproduct of transferring fossil fuels to electrical energy. The metric for this target will be kilowatt hours of power consumed.

The second function is reuse. The metric for this target is the volume of new raw material needed for a system. The target for this function is to reuse 10% of one system’s byproduct to run another system. This would cause the second system to run without producing that extra amount of the resource. For example, if hot water is needed for a system the heated water from the chiller could reduce the amount of raw material that needs to be heated for a separate system.

The third function is to recycle. The metric is volume of recyclable waste material. The target for this function is to recycle 25% of the byproduct waste that cannot be reused. The metric will be the volume of recycled material that is used. The recycled waste can help reduce carbon emissions by lower the amount of new material that will be used.

These three main targets and their metrics will serve as the critical targets and metrics. They are the main priority of this project. The targets and metrics for the sub-functions will be secondary to these but will be goals for the project as well.

Table 1: Critical targets and metrics

|  |  |  |
| --- | --- | --- |
| **Need** | **Critical Target** | **Critical Metric** |
| Reduce | Reduce energy usage by 15% | kW electricity used |
| Reuse | Reduce volume of raw materials for separate system by 10% | Volume of raw materials |
| Recycle | Recycle 25% of waste that can’t be reused | Volume of recycled material that is used |

Under the three main functions there are five sub-functions that will have targets and metrics associated with them. The first sub-function is reducing the amount of energy usage. This function is covered under the broader target of reducing the energy consumption of the HVAC system by 15%. The second sub-function under the function reduce is to increase the efficiency of components. The target for this function will be to increase the efficiency of one system by 10%. This would be that the system will return a 10% increase in power output for the same amount of power input. The metric for this target will be the power output measured in kilowatt hours.

The next main function is reuse. Under this the first sub-function is reusing the energy of one component for a different purpose. The target for this function is to reduce the amount of raw material another system requires by 10%. The metric is the volume of raw material required for the system that is being optimized. The second sub function is to capture energy from alternative energy sources. The target is to capture 10% of the energy required for the HVAC system to be powered with renewable sources. The metric is the kilowatt hours of electricity used from non-renewable sources.

The final main function is recycle. The sub-function to collect leftover energy and use it for other applications. The target is to collect 10% of the leftover energy from waste. The metric is the volume of waste that can be converted to recycled energy.

These targets and metrics go beyond the functions interpreted from the customer needs. Cameron Griffith at Trane listed three additional needs that are satisfied by our targets and metrics. First is that the Senior Design team should learn about project development and execution. By setting these targets and accomplishing them, the team will have an intricate knowledge of how a large scale project unfolds. The second need he described was that the solution must be economically feasible. Increasing the energy efficiency of a system reduces the energy consumption causing the MagLab to spend less money on energy. This is a relatively inexpensive way to save a large amount of energy cost. Finally, Cameron wanted the team to have a clear project scope and follow it rather than getting lost in different tangents. These targets and metrics give the team direction and allow for a clear goal for accomplishing this project.

The method for testing the targets and metrics will be the same for most of the functions. It will require comparing the energy consumption data from before and after the changes are implemented. This data exists within the internal systems at the MagLab facilities. John Kynoch has agreed to provide the relevant data, including the power consumption of the HVAC system alone. The data is generated instantaneously but it is more accurate to look at the energy consumption over an allotted amount of time. John Kynoch has suggested that the data be examined monthly to monitor reduction in energy usage. This will cover the functions of reduce, increasing the efficiency of a system, reuse, and collecting leftover energy for another system. All these functions will reduce the energy consumption of specific systems in the MagLab.

The method for testing the reuse and recycle functions will be comparing the energy usage of a system before and after recycled energy is applied to the system. This will show if recycling and reusing energy has made an impact on how much new energy is consumed. In the example earlier about reusing heated water, the data would show less energy needed to heat another system. For capturing energy from alternative sources the method for measuring that target will be measuring the energy from alternative sources. If a particular pump requires 100 kilowatt hours to run, at least 10 kilowatt hours will be from an alternative, green energy source such as solar or wind.

The critical metric of the reduction in kilowatt hours is derived from a study in 2001 that requires a 25% increase in the efficacy of a chiller. This efficiency bump is increased by a variety of things including design of the chiller. However, since the design of the chiller isn’t being altered a 15% increase can be achieved and was set as a critical target. Kilowatt hours is used because it is the standard measure of electricity in the United States. It is an easy value to monitor (Design Brief Chiller Plant Efficiency, 2001).

The critical metric of reusing a volume of one system for another comes from cross system collaboration. It creates a junction between two systems and saves energy. This is similar to how Coast Guard boats have cross system connectors. For example, the fire main is connected to the counter nuclear washdown system and can pump either fresh or salt water through the system in case of emergency. Instead of having two pumps for separate instances, one pump and pipe system is used for both. This saves space and efficiency. The waste of one system can be used for another.

The critical method of recycling a specific volume also comes from a military source. A volume of the systems waste can be used to create something else. For example, the waste water from showers is used to balance a 210 foot coast guard cutter. The water goes to a tank that lowers the center of mass of the boat. Water can also be recycled using reverse osmosis to fresh water. This can be transferred to the chill water system by using 25% of the waste and recycling it for a different use.

## 1.5 Concept Generation

This step of our design process is critical because without it, there is no design. Conception generation is the process of combing the customer needs with the target specifications to generate design concepts. Our team used the following tools to generate 100 concepts: biomimicry, crap shoot, and anti-problem. Using these methods and our creative mindset, we were able to reach 100 ideas.

Biomimicry is generating ideas based off natural solutions found in plants and animals. One of the biggest usages of energy in the MagLab is keeping the building and the magnets cool. In Florida, the wildlife must also use energy to stay cool. Most plants and animals avoid direct sunlight or rest in the heat of the day to stay cool. This led to a stream of ideas about different ways to provide shade to the MagLab. Another source of ideas was observing animals use water to cool themselves during the day. This led to ideas of using water in creative ways to cool the MagLab such as an exterior sprinkler system for the building.

Crap shoot is using a list of words that relate to the project and a random number generator to combine terms. This led to several interesting and creative ideas because it challenged the team to think about solutions that would not normally flow from a more structured concept generation.

Forced analogy is putting terms that may not relate to the project on cards then flipping two random cards and deriving solutions with those terms. The team used this method and came up with many interesting solutions. Like crap shoot, this method encouraged the team to think about the problem differently.

Anti-problem created an interesting conversation. The team proposed the opposite problem, how to cause more carbon emissions. The solutions to this anti-problem were discussed and the conversation provided creative ways to look at the original problem. The solutions that came from this technique revolved around reducing the energy consumption by reducing the air conditioning in the building by a few degrees or keeping the building colder in the wintertime.

There are 5 medium fidelity ideas. They are adding another Trane chiller to the MagLab cooling facility, raising the temperature of the building by a few degrees in the summer, putting shades on the windows to keep the sun out, programming the thermostats to adjusts the temperature based on the people in the room, and building an additional cooling tower.

Adding another chiller would increase the cooling potential and the efficiency of the MagLab by spreading the heavy load of cooling the magnets across more systems. This way the chillers could run at their optimum efficiency while still providing enough cooling. Raising the temperature of the building in the summer would be an easy way to reduce the energy consumption on the HVAC system. Even if it is only a few degrees, it would reduce the power that the chillers would have to output to ensure everyone is comfortable. This idea may receive backlash if people feel that the building is not cool enough. Testing and feedback will be an important part of the implementation of this concept. Putting shades on the windows would keep the sunlight out during the warmer summer months. This would keep the building cool and decrease the need for central cooling. Along the same thought, having thermostats that could adjust the temperature based on the number of people in the building could reduce the need for air conditioning. If no one was working on the upper floors or in a large room, the thermostat could turn off the cooling for that area ensuring energy is not wasted in cooling places that are empty. One problem that could occur with this idea is that rooms would be warmer than the other parts of the building and may be uncomfortable to work in until it was sufficiently cooled. Building another cooling tower is an idea that would help the MagLab similarly to adding another chiller. An additional cooling tower would increase the cooling capacity of the system and allow the existing tower to run at the optimum power efficiency.

The 3 high fidelity concepts are operating the magnet cooling pumps on a temperature or magnet power basis rather than a fixed speed, changing the speed of the fans in the cooling towers based on the temperature of the environment and the temperature of the water, and operating the existing 4 Trane chillers at the optimum efficiency curve. Currently, the pumps that provide cooling to the magnets and HVAC system are run at 100% regardless of the needs of the MagLab. The magnets may go days without use and therefore require no cooling. The team could design a system that would change the power output of the pumps to reflect the needs of the facility. The same idea can be applied to the fans on the cooling towers. They have a high and a low setting. If they were replaced to fans with variable speeds, the cooling towers would consume less energy when the environment was cold or could run more efficiently when it is hot. The four chillers at the MagLab that are responsible for cooling the water used in HVAC have efficiency curves provided by Trane. Running these chillers at maximum efficiency would reduce the energy consumption and the carbon emissions of the MagLab.

Figure 1: Schematic of the MagLab Cooling System

**Diagram

Description automatically generated**

## 1.6 Concept Selection

To select the final concept, the team used a binary pairwise comparison, a house of quality, Pugh charts, and an analytical hierarchy chart.

**Binary Pairwise Comparison**

This table is used to determine what customer needs are most important. The need along the row is determined to be less or more important than the one on the column. If the need on the row is more important a 1 is given and if it is not, a 0 is given. The totals are used to assign a weight to the customer needs when they are evaluated along with engineering characteristics in the house of quality.

Table 2: Binary Pairwise Comparison

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Binary Pairwise Comparison** | | | | | | |
| **Customer Requirements** | Learn engineering tools | Reduce power consumption | Implemented at the MagLab | Benefit the COE | Low Initial Cost | Total |
| Learn engineering tools | - | 1 | 0 | 1 | 0 | 2 |
| Reduce power consumption | 0 | - | 1 | 1 | 1 | 3 |
| Implemented at the MagLab | 1 | 0 | - | 0 | 1 | 2 |
| Benifit the COE | 0 | 0 | 1 | - | 0 | 1 |
| Low Initial Cost | 1 | 0 | 0 | 1 | - | 2 |

**House of Quality**

This table is a product planning matrix that’s built to show how ranking engineering characteristics (EC) can help us to identify our constraints or design variables whose values can be used to make decisions. Highly ranked ECs will have only a few numbers of candidate values, so they’ll provide the constraints. Low ranked ECs show us which decisions aren’t critical to our process and while they won’t be forgotten, they allow us to have more freedom by focusing on the more pressing matters that will take priority.

The ECs were chosen based on their relevance to the concepts. For example, mass would not be a valuable EC because processes for improving energy usage do not have a mass. The ECs needed to relate to processes without eliminating other solutions like new variable speed fan motors. The ECs that were chosen are implementation, sustainability, price, and life span. Implementation is the feasibility that the team could implement the solution. For example, if the solution was to rebuild a new building, it would have a low implementation score. The team does not have the means for that solution. Sustainability is the ability for the solution to be self-sustaining. This means how much maintenance and additional resources would be associated with the solution. Price is the cost of the initial installation or implementation of the solution and the cost incurred over the solutions lifetime. Life span is the amount of time that the solution would be beneficial. How long until the solution would become obsolete.

Table 3: House of Quality

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **House of Quality** | | **Engineering Characteristics** | | | |
| Improvement Directions | |  |  |  |  |
| Units | | n/a | Joules | $ | Years |
| Customer Requirements | Importance Weight Factor | Implementation | Sustainable | Price | Life Span |
| Learn Engineering Tools | 2 | 9 | 3 | 1 | - |
| Reduce Power Consumption | 3 | 1 | 9 | 3 | - |
| Implemented at the MagLab | 2 | 3 | - | - | - |
| Benefit the COE | 1 | - | 3 | 3 | 1 |
| Low Initial Cost | 2 | 3 | - | 3 | - |
| **Raw Score (78)** | | 33 | 27 | 17 | 1 |
| **Relative Weight %** | | 42.3 | 34.6 | 21.7 | 1.28 |
| **Rank Order** | | 1 | 2 | 3 | 4 |

The raw scores from each of the ECs was normalized and a rank order was assigned to show what ECs would contribute most to the customer needs. The rank is implementation, sustainability, price, and life span. It is most important to our customer that the solution can be implemented and will be sustainable.

**Pugh Chart**

The Pugh chart’s purpose here is to help us refine our options for our concept selection process so we can identify what ideas are most successful. It helps us to compare the important weight factors to choose high and medium fidelity concepts; in the chart below plusses (+), minuses (-), and same (S) are the symbols used to compare several concepts to the chosen datum. The datum that was chosen is alternating the pumps used to transport the chilled water. This is a technique that is common in commercial buildings to save energy because you only need to run a fraction of the pumps at a time. This technique is used aboard Coast Guard vessels to save on energy while they are out to sea.

Table 4: Pugh Chart

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Pugh Chart | | | | | |
|  | Datum | Concepts | | | |
| Selection Criteria | Alternate Pumps | Optimizing Pumps | Variable Speed Cooling Fans | Optimizing Chillers | Adding a 5th Chiller |
| Implementation | S | - | S | - |
| Sustainable | + | - | + | + |
| Price | S | + | S | - |
| **Life Span** | - | + | + | + |
| **Number of Pluses** |  | 1 | 2 | 2 | 2 |
| **Number of Minuses** | 1 | 2 | 0 | 2 |

The Pugh chart shows that adding a fifth chiller is a concept that has the most middle ground. It has two minuses and two pluses. This means it is great in some areas but bad in others. This makes it the best candidate to rate the other solutions against.

Table 5: Pugh Chart with one concept for the datum

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Datum | Concepts | | |
| Selection Criteria | Adding a 5th Chiller | Optimizing Pumps | Variable Speed Cooling Fans | Optimizing Chillers |
| Implementation | + | S | + |
| Sustainable | + | S | + |
| Price | + | + | + |
| Life Span | - | - | - |
| **Number of Pluses** |  | 3 | 1 | 3 |
| **Number of Minuses** | 1 | 1 | 1 |

The Pugh chart leaves the team with two viable options. The team could either optimize the pumps that move the chilled water around the plant or optimize the chillers that cool the water.

**Analytical Hierarchy Process**

The analytical hierarchy process is a process that will show how the ECs rate against each other. Not only to see the importance of ranking, but also to see how much more important one EC is to another. The normalized Analytical Hierarchy Process makes the data easier to digest by making the sum of each column 1. This allows the criteria weights to be determined. Table 9 shows the implementation of the AHP. It uses individual selection criteria to determine how each idea compares values each individual criteria. This along with the with the criterion weights allows the final choi ce to be determined

Table 6: Analytical Hierarchy Process

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **AHP Table** | Implementation | Sustainable | Price | Life Span |
| Implementation | 1 | 5 | 7 | 7 |
| Sustainable | 0.2 | 1 | 9 | 9 |
| Price | 0.14 | 0.11 | 1 | 0.33 |
| Life Span | 0.14 | 0.11 | 3 | 1 |
| **Sum** | 1.49 | 6.22 | 20 | 17.33 |

Table 7: Normalized Analytical Hierarchy Process

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Normalized AHP** | Implementation | Sustainable | Price | Life Span | **Criteria Weights** |
| Implementation | 0.67 | 0.80 | 0.35 | 0.40 | 0.555 |
| Sustainable | 0.13 | 0.16 | 0.45 | 0.52 | 0.315 |
| Price | 0.1 | 0.02 | 0.05 | 0.02 | 0.0475 |
| Life Span | 0.1 | 0.02 | 0.15 | 0.06 | 0.0825 |
| **Sum** | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |

Table : Implementation AHP

|  |  |  |  |
| --- | --- | --- | --- |
| **Implementation** | Optimizing Pumps | Variable Speed Cooling Fans | Optimizing Chillers |
| Optimizing Pumps | 1 | 0.33 | 3 |
| Variable Speed Controlling Pumps | 3 | 1 | 0.2 |
| Optimizing Chillers | 0.33 | 5 | 1 |
| **Sum** | 4.33 | 6.33 | 4.2 |

Table : Normalized Implementation AHP

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Implementation** | Optimizing Pumps | Variable Speed Cooling Fans | Optimizing Chillers | **Total** |
| Optimizing Pumps | 0.231 | 0.052 | 0.714 | 0.33 |
| Variable Speed Controlling Pumps | 0.692 | 0.1854 | 0.048 | 0.30 |
| Optimizing Chillers | 0.08 | 0.789 | 0.238 | 0.37 |

Table : Criterion Weights

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Optimizing Pumps | Variable Speed Cooling Fans | Optimizing Chillers | Weight |
| Implementation | 0.333 | 0.299 | 0.368 | 0.555 |
| Sustainable | 0.140 | 0.574 | 0.286 | 0.315 |
| Lifespan | 0.649 | 0.136 | 0.215 | 0.0475 |
| Price | 0.714 | 0.143 | 0.143 | 0.0825 |

Table : Final Concept Selection Table

|  |  |  |  |
| --- | --- | --- | --- |
| Concepts | Optimizing Pumps | Variable Speed Cooling Fans | Optimizing Chillers |
| Alternative Value | 0.371 | 0.364 | 0.253 |

**Final Selection**

The final selection is the solution that has the highest rating for implementation. Both optimizing the chillers and optimizing the pumps will be similarly implemented so the team may choose either concept. The team will choose to optimize the pumps that move the chill water around the system. There are a few ways that the team can accomplish this objective. Currently the pumps run at 100% power without being changed for any reason. The team will analyze the efficiency and capability of running the system at a lower power when the building does not need to be cooled or when the magnets do not require cooling. Running these pumps at a lower power or turning off pumps when the demand for cooling is low will reduce the energy consumption of the MagLab and reduce their carbon emissions.

The project sponsor, Cameron emphasized the importance of ensuring that the Innovation Park benefited from this senior design project. He suggested designing the cooling system of the new building coming to the park. The Interdisciplinary Research and Commercialization Building, IRCB, will be built without an HVAC system in place. The current idea is to cool the building with the cooling capability of the MagLab when the magnets are not in use. The team agreed with Cameron and has undertaken the responsibility of designing a way to bring chill water to the new building. This will allow IRCB to borrow the MagLab’s cooling equipment. Running one cooling system will consume less energy than running two. This will allow the team to lower the carbon footprint of not just the MagLab, but the whole Innovation Park.

## 1.8 Spring Project Plan

Table 12: Spring Project Plan

|  |  |
| --- | --- |
| **DATE** | **MILESTONE** |
| 5-Jan | Classes Begin |
| 7-Jan | Meet with Sponsor |
| 14-Jan | Meet with John Kynoch |
| 14-Jan | Analyze Pump Optimization Data |
| 20-Jan | Calculate ICRB Pipe Cost |
| 21-Jan | Order all parts for validation technique |
| 28-Jan | January Advisor Meeting |
| 28-Jan | Have a 1st Draft for Website Done |
| 4-Feb | Foundation for the 3-D Model of Validation Done |
| 8-Feb | Meet with Sponsor |
| 11-Feb | Finalize Recommendation for Pump Optimization |
| 18-Feb | Finalize Recommendation for ICRB Chilled water Transport |
| 25-Feb | February Advisor Meeting |
| 1-Mar | Meet with Sponsor |
| 8-Mar | Finalize 3-D Model |
| 25-Mar | March Advisor Meeting |
| 25-Mar | Finish Fabricating Validation Technique |
| 8-Apr | Engineering Design Day |
| 25-Apr | Finals Week |
| 30-Apr | Graduation |

# Chapter Two: EML 4552C

## 2.1 Spring Plan

### Project Plan

The project has two main objectives: determine a method of transporting chill water to IRCB and optimize the magnet cooling pumps at the MagLab. Optimizing the cooling pumps will lower the electricity usage therefore lowering the carbon footprint of the MagLab. The optimization will look into the utilization of the variable speed cooling pumps. For example, when the magnets aren’t being run at full power, the pumps will be run at a lower level as well. This will save a lot of energy. The second aspect of the project is to transport chilled water to the IRCB. The goal will be to connect it as a system, The plan is to simulate the combining of the HVAC systems throughout Innovation Park. This can also help decrease the energy usage of Innovation Park by negating the need to build a completely new HVAC system at the new building. The project looks into a 30-year examination of the energy savings. The final part of the project is the validation technique. The validation technique will be a way to show and justify the amount energy saved through the project. It is a visual representation of how the pumps will be optimized.

The second aspect of the plan to transport chilled water to the IRCB started with looking at how much cooling capacity it would take or what is the amount of cooling required to keep its contractors comfortable and experiments running safely. Then we needed to find out how much chill water would be needed for this cooling capacity. Then we designed a method to get this chill water from the Maglab to IRCB. From the report done by the affiliated engineers it was found to need 800 tons of cooling capacity and 1371 gpm of chilled water being pumped to keep up with this cooling capacity. Then research was done on what types of pipes should be used for this system and it was found that it should use pipes of roughly 6.5” for the inner diameter.

### Results

The team found that the power usage was 449 kilowatts for the month of February. Extrapolating out meant that 5,390 kW of power is used to cool the magnets in a year. The maximum cooling required was roughly 115 Btu per hour. However, the average required cooling was only around 12%. This meant that on average nearly 88% of the power that is being used to cool the magnets is wasted. Multiplying the percentage of cooling required by the amount of power that is used in a year returns the power that is required to cool the MagLab magnets. Only 644 kW are required annually. This is a savings of nearly 4,725 kW over the course of a year. The city of Tallahassee charges the MagLab $1.88 per kW of power. This equates to an average savings of $8,884.06 per year.

The plan to move water to IRCB found that 1371 gpm of chill water was required to meet the new building cooling requirement. Using standard 6.5 inch diameter PVC pipes, 9.5 kW is required to pump that amount of water to IRCB. The Affiliated Engineers study evaluated the savings over a 30 year period and found the plan would save 16 million kWh of electricity and $2 million (Affiliated Engineers, 2019). The original plan for the study was for the team to confirm these numbers. Unfortunately, the study did not disclose where they found the information that was used for the study. The team could not locate key documents including a building blueprint and the number of people that were expected to occupy the building daily. This information is required to determine the cooling requirement of a space.

### Conclusion

The next step in this process is to develop an implementation plan. This plan and the values that the team found would be presented to the MagLab and Innovation Park facilitators. The facilitators will then decide if the savings are worth implementing this plan. This project concluded before a plan to implement the design was made. The future work of this project would be to determine a way to limit the pumps at the MagLab.

The next step for the plan to move chill water to IRCB would be to design a piping network. The goal of this network would be to minimize the construction time and cost. The team would then determine if the MagLab had the pumping power to provide the water to IRCB. If not, an additional pump would need to be purchased. Like the magnet cooling plan, the MagLab and Innovation Park facilitators would need to decide if this plan is worth implementing or if it is more feasible pursue another plan.

The team achieved the goal of determining a way to save 10% of the energy of a system in the Innovation Park. The current plan saves nearly 90% of the power for the magnet cooling pumps. This is a significant achievement, and the team is proud of their accomplishment. However, the team failed to determine a way to implement this plan. At this point, no savings have been made. The team provided evidence that energy saving is possible in the MagLab and at IRCB. More time and resources must be contributed to reduce the energy consumption and carbon emissions of the Innovation Park.

There are several reasons why Team 517 failed to reach the conclusion of this project. The main reason was the failure to work quickly enough given the scope and the time constraints of this project. The team did not properly budget their time to finish their objectives before a final conclusion was due. If the team were to continue this project, they would be able to formulate a complete plan to reduce the carbon emissions of the Innovation Park and present it in its entirety to the Innovation Park facilitators.

### Future Work

The next step in this project is to design a method of implementation for this project. The calculations have shown that Team 517’s concept works in theory, but there is not practical evidence to support their claims. Once a method of implementation is made, that plan will be brought to the MagLab and Innovation Park facilitators. They will make the decision to determine if the savings outlined in this report are worth the costs of implementation.

The next step for the plan to move chill water to IRCB would be to design a piping network. The goal of this network would be to minimize the construction time and cost. The team would then determine if the MagLab had the pumping power to provide the water to IRCB. If not, an additional pump would need to be purchased. Like the magnet cooling plan, the MagLab and Innovation Park facilitators would need to decide if this plan is worth implementing or if it is more feasible pursue another plan.

The implementation of these two projects will ensure a more sustainable future for the Innovation Park.

# Bibliography

Affiliated Engineers. (2019). *Florida State University Research Park Central Utilities Study.* Tallahassee.

*Design Brief Chiller Plant Efficiency.* (2001, October 22). Retrieved from Data Centers: https://datacenters.lbl.gov/sites/default/files/Design%20Brief\_Chiller%20Efficiency.pdf

McConomy, S. (2021, September 17). *Eng Design Methods (F20).* Retrieved from Canvas: https://famu-fsu-eng.instructure.com/courses/4472/files/166143?module\_item\_id=41341

# Appendices

# Appendix A: Code of Conduct

This document will serve as the Team Contract for Team 517 during the entire Senior Design period lasting from the fall of 2021 through the spring of 2022. This document was revised in December of 2021. In January of 2022 the team reviewed the Code of Conduct again but did not find anything that needed changing.

# Mission Statement

The mission for this group is to complete the Senior Design project assigned to us with the professionalism that is expected by our future employers. This includes completing assignments on time, working as a group, and acting professional at all times during this project. We will attempt to reduce the carbon emissions from the National High Magnetic Field Laboratory known commonly as the MagLab.

# Outside Obligations

All team members will provide their work schedules so that team meetings will not interfere with prior obligations. All military obligations, extracurricular curricular activities, and club events will be added to Outlook Calendar to avoid conflicts. If conflicts do arise team members will communicate their conflicts.

# Team Roles

Finnbar will handle the bulk of the material science work as the materials engineer. Bianca will function as the systems engineer. Nicholas will serve as the fluids and design engineer. As more information is known about the project, team roles can shift. The default notetaker will be Finnbar. The person to turn in and do a last review of the assignments will be Bianca.

# Communication

The team will maintain thorough communication throughout the entire project. The primary communication will be in person, Basecamp, and email. If an important conversation is held there will be an email sent after the conversation, so the information is not lost or forgotten. This will ensure the whole team is up to date on the status of the project. At each meeting, notes will be taken and those notes will be shared with the whole team via OneNote. The meeting note taker will be decided at the beginning of each meeting. If there is no time to discuss a note taker Finnbar will take notes. When communicating with people outside the team, any team member may contact the person, but they must CC all other members of the group with their FSU email address. The emails must all be business professional; every email must include a subject, formal greeting with the name of the person addressed, and a signature. If no response is received in 24 hours for team members and 72 hours (about 3 days) for non-team members a follow-up email must be sent by the original sender of the email. Weekly group meetings will be held Wednesdays 9:00-10:00 AM at the COE. If there is a conflict it must be communicated to the rest of the team before the meeting.

For virtual meetings that occur on Zoom or Microsoft Teams, each member will be seated in a professional setting with their camera on and participating in the meeting. If this is not possible, the team member will need to notify the rest of the team that they cannot fulfil these requirements one day prior to the meeting.

# Dress Code

For normal class the dress code will be casual but not informal. This means no graphic or offensive shirts, no tank tops, and no unsightly ripped jeans. For presentations or special events in class the dress code will be business casual or nicer. Business casual entails a button down, long sleeve, collared shirt with a tie for males and a professional blouse for females. Males will not wear denim for presentations, but females may if the outfit is formal enough. Shorts are not permitted during presentations. Shoes will be professional for both males and females, but dress shoes are not required. When meeting with the sponsor, the team will dress in polo and professional trousers. If a more formal dress code is needed, the team will discuss it before the event and decide if they should dress in formal business attire. If a less than business casual event takes place, the team can discuss wearing a collared t-shirt and jeans. If time permits, two team members can ask the third to change if they believe the third's outfit is below standards. When traveling inside and around COE facilities masks are required to be worn over the nose and mouth. Masks are also required during group presentations at COE facilities. Masks are not required for online presentations. Masks must be one solid color.

# Attendance Policy

Attendance for normal class falls under personal responsibility. Unless the team discussed working on the project prior to class, team members are not required to attend Dr. McConomy’s lectures. For team meetings attendance is mandatory. If a team member needs to miss a team meeting, they must notify at least one other team member. If a team member misses more than three team meetings, they must provide a written response explaining what the problem was and how they will change to make the remainder of the meetings. If a member missed five meetings the team will discuss approaching a TA or Dr. McConomy himself to discuss possible repercussions. If a team member would like to use a vacation day, they need to have it approved by the team before they submit a request to Dr. McConomy.

# Contacting Dr. McConomy

If any member of the team feels that they need to contact Dr. McConomy, they will do so through email. If it concerns the behavior of another team member, they must make their intentions clear 24 hours before they contact Dr. McConomy. It is encouraged that the team goes to Dr. McConomy together but it is not necessary.

# Amendments

This document is a living document and can be amended by a unanimous agreement within the team. The team must meet and discuss the amendment. All must agree and the amendment must be clear to all members of the team. There is no need to re-sign if an amendment is made.

# Statement of Understanding

By signing you agree to the entire document and will uphold all that is said above.

Signatures: Date:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_

# Appendix B: Functional Decomposition Charts

Figure 2: Functional Decomposition

Table : Functional Decomposition Cross Reference table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Reduce | Reuse | Recycle | Number of Occurrences |
| Reuse the energy of one component for different purposes | x | x | x | 3 |
| Capture energy from alternative energy sources | x |  | x | 2 |
| Reduce the amount of energy usage | x |  |  | 1 |
| Increase the efficiency of components | x | x | x | 3 |
| Collect left over energy and use it for other applications |  | x | x | 2 |
| Number of Occurrences | 4 | 3 | 4 |  |

# Appendix C: Target CatalogAppendix D: Operations Manual

# Appendix E: Engineering Drawings

# Appendix F: Calculations

Part of the calculations done on this project were spent on trying to find out how much power it takes a pump to keep up with a 1371 gpm flow rate so we used the equation for work done by the pump on the fluid, the volumetric flow(V̇) rate multiplied by the pressure loss(Δp). In order to find the pressure loss we used a modified version of the Bernoulli’s equation and made some assumptions to get rid of some terms. We assumed there would be no minor losses due to entries, exits, valves, elbows, etc. in order to get rid of the terms including the coefficient of friction. We also assumed there would be no change in height from where the fluid entered the pipe to where it left the pipe in order to get rid of the terms including z. The equation came out to be Δp= (16ƒL ṁ2 )/(2 π2 D3 ρ). Most of the terms were known or given to us but the friction factor (ƒ) needed to be calculated.

In order to use an equation to figure out the friction factor, you first need to know if the flow is laminar or turbulent. We found this out by calculating the Reynold’s number using the formula 4ṁ/πµD. The number found was high enough to consider the flow turbulent so from there we needed to choose what formula to use for the friction factor. There were several options (i.e. Darcy friction factor, Moody plot, and the Chen’s Correlation) and we used the Chen’s correlation to find it; it’s a function of the Reynold’s number, the relative roughness of the pipe material, and the diameter of the pipe. The last quantity we needed to find was the volumetric flow rate which is equal to the Area of the pipe multiplied by the velocity of the flow. The velocity of the flow was calculated by ṁ/(ρA). The power required was found to be 9,630 W.

A cost analysis was done on the different types of materials that could be used for this system including PVC, HDPE, Stainless Steel, and Carbon Steel by finding the average lowest and highest cost for each material. And then multiplying the cost by the appropriate number to find out how much it would cost to make the piping of that material reach from the Maglab over to IRCB.







# Appendix G: Risk Assessment

**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 :
   1. Performing periodic laboratory visits to prevent the development of unsafe practice.
   2. Quick reviewing of the safety rules and precautions in the laboratory members meetings.
   3. Assigning a safety representative to assist in implementing the expectations.
   4. 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.: Mech Eng | Start Date: 11-MAR-2022 | Revision number: 2 |
| Project: Reducing Carbon Emissions at the MagLab | | | Location(s): Tallahassee, FL | |
| Team member(s): Finnbar Rooney, Bianca Marius, Nicholas Walker | | | Phone #: 518-320-5382 | Email: frr17@my.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** |
| Gather data in the mechanical room at the MagLab. | MagLab | Finnbar Rooney | Moving parts in a Mechanical space can cause injury. | Follow the instructions of the safety officers within the MagLab mechanical room.  Understand and follow the safety policies of the MagLab facilities. | Long pants, close toed shoes. | There is no hazardous waste. | HAZARD: 4  CONSEQ: Significant | No team members will enter a mechanical space without supervision from the faculty at the MagLab. |
| Residual: Med High |
| Determine how to run the pumps in relation to the magnet power. | MagLab | Nicholas Walker | Getting incorrect values from our calculations can cause error. | Verify all values found with every team member and faculty member involved with the project at the MagLab | No PPE | There is no hazardous waste. | HAZARD: 4  CONSEQ: Moderate | The team will not make any changes to the way that the pumps are run without explicit permission from John Kynoch. |
| Residual: Medium |
| Run the pumps at a lower power. | MagLab | Finnbar Rooney | Pumps shut down incorrectly rather than run at lower speeds | Have MagLab facilities employees present for all testing, preferably John Kynoch but potentially other engineers | Long pants and closed toe shoes. | There is no hazardous waste. | HAZARD: 4  CONSEQ: Severe | Do not do initial testing while the magnets require cooling. Do initial testing while the magnets are idle. Do later testing when results are more definite. |
| Residual: High |
| Design a scale model | COE | Finnbar Rooney | Incorrect dimensions, because of improper calculations, cause discrepancies in the design. | Have all three team members check over the final numbers to make sure they are correct. | No PPE. | There is no hazardous waste. | HAZARD: 3  CONSEQ: Minor | Ensure the calculations reflect the model. |
| Residual: Med Low |
| Create a scale model | COE | Finnbar Rooney | There could be potential injury while machining the scale model. This could include but not limited to cutting ourselves when we cut the parts, burn ourselves on the hot glue gun or soldering gun, or other injuries related to simple construction. | The team will follow all the procedures associated with the lab that we fabricate the system in. | Long pants in the labs, eye protection when using any saws, gloves when soldering. | Hazardous waste from soldering will be discarded in the Senior Design Lab. | HAZARD: 3  CONSEQ: Minor | At least two team members must be in the lab during the fabrication of the scale model. |
| Residual: Low Med |
| Validate the project | COE | Finnbar Rooney | Any of the mechanical or electrical components could malfunction and harm a team member. | Testing will be conducted in a lab with proper safety equipment. Once the validation system is determined to run consistently and safely, safety measures will be revaluated as a team. | Eye protection, Plexiglas shields, close toed shoes, gloves. | Do not anticipate hazardous waste. If there is hazardous waste, we will dispose of it at the COE in hazardous waste bins. | HAZARD: 3  CONSEQ: Moderate | At least two team members will be present for testing the validation technique. The results will be evaluated by the whole team and we will decide when it is safe to demonstrate in front of an audience. |
| Residual: Medium |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name** | **Signature** | **Date** | **Name** | **Signature** | **Date** |
| \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | \_\_\_\_ |

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

**Table

Description automatically generated with medium confidence**

**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.
   1. Negligible: minor injury resulting in basic first aid treatment that can be provided on site.
   2. Minor: minor injury resulting in advanced first aid treatment administered by a physician.
   3. Moderate: injuries that require treatment above first aid but do not require hospitalization.
   4. Significant: severe injuries requiring hospitalization.
   5. 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.

|  |  |
| --- | --- |
| **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  Twisting the body  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 |
| Chemical hazards | Effects on central nervous system, lungs, digestive system, circulatory system, skin, reproductive system. Short term (acute) effects such as burns, rashes, irritation, feeling unwell, coma and death.  Long term (chronic) effects such as mutagenic (affects cell structure), carcinogenic (cancer), teratogenic (reproductive effect), dermatitis of the skin, and occupational asthma and lung damage. |
| 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.  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. |
| Radiation | Radiation can have serious health effects. Skin cancer, other cancers, sterility, birth deformities, blood changes, skin burns and eye damage are examples. |
| 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. |

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name of Project: Trane:** Carbon Footprint and Energy Usage at MagLab | | | | **Date of submission:** 11-MAR-2022 | |
| **Team member** | | **Phone number** | | **e-mail** | |
| Finnbar Rooney | | 518-320-5382 | | frr17@my.fsu.edu | |
| Nicholas Walker | | 424-202-7667 | | ncw19@my.fsu.edu | |
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|  | |  | |  | |
|  | |  | |  | |
| **Faculty mentor** | | **Phone number** | | **e-mail** | |
| Dr. Juan Ordonez | | 850-644-8405 | | ordonez@eng.famu.fsu.edu | |
| Dr. Shayne 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”).** | | | | | |
| While gathering data in and mechanical space, the team will follow all the standard rules and procedures set in place by the MagLab facilitators. The team will always follow the directions of the MagLab faculty and will not enter any mechanical space without supervision from the MagLab faculty until the faculty feel that the team knows enough about the space to operate in it unsupervised.  Doing to calculations to determine how hard and when to run the chill water pumps will have consequences if the calculations are wrong. To make sure the calculations are valid, the whole team will look over them and then present them to the MagLab faculty to evaluate. If they are wrong the team will have to re-evaluate the conclusions.  Running the pumps at lower power could cause strain on the system. If at any case the HVAC system cannot keep up with the desired temperatures. The pumps must be returned to full plant immediately until the problem is resolved. If at any point the magnets are scheduled to run an experiment the pumps must be set to full power an hour before the experiment to ensure the safety of the magnets. The team must wear proper attire in the given space such as long pants and tied back hair in accordance with OSHA standard 1910. This standard explains the Personal Protective Equipment (PPE) that must be used in a laboratory setting. Pumps can only be lowered while a safety observer is present.  Designing a scale model will require calculations to be done effectively. If the calculations are done incorrectly, they can skew the model and cause hazards like having the pressure too high, the velocity of flow too fast, or other issues. Every step of the design process must be vetted by the whole team.  Creating the scale model must be a careful process. Whenever anything is being worked on, the proper personal protective equipment must be worn at all times. Supervision must be maintained at all times while potentially hazardous machining is being done. Know where all the emergency equipment around any lab space in case of emergency. If an accident occurs immediately notify the supervisor and follow instructions given. Remove yourself from the hazardous situation if possible.  Running the scale model requires completion of the model. Safety measures must be taken to ensure the model was assembled correctly. Ensure all connections are secure before anything is shown or presented. Ensure no moving objects can harm anyone nearby. | | | | | |
| **Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.** | | | | | |
| * Ensure the scene is safe to enter * Maintain the safety of the team members and others present * Alert emergency personnel * Gather the emergency safety equipment * If you are alone, get another person to help * Power down all power tools * Unplug all electrical equipment * If the victim is conscious, try to move them away from the scene. * If the victim is unconscious, do not move them to avoid further harm | | | | | |
| List emergency response contact information: | | | | | |
| * Call 911 for injuries, fires or other emergency situations * Call your department representative to report a facility concern | | | | | |
| **Name** | **Emergency Contact:** | **Phone number** | **Faculty or other COE emergency contact** | | **Phone number** |
| Finnbar Rooney | Melissa Rooney | 978-618-2310 | Dr. Shayne McConomy | | 850-410-6624 |
| Nicholas Walker | Nicole Walker | 478-320-0808 | Dr. Juan Ordonez | | 850-644-8405 |
| Bianca Marius | Jeanne Marius | 954-478-0402 | John Kynoch | | 850-644-8965 |
|  |  |  |  | |  |
| Safety review signatures: | | | | | |
| **Team member** | **Signature** | **Date** | **Faculty mentor** | | **Date** |
| Finnbar Rooney | Shape  Description automatically generated with medium confidence | 3/11/22 |  | |  |
| Nicholas Walker | Shape  Description automatically generated with medium confidence | 3/11/22 |  | |  |
| Bianca Marius |  | 3/11/22 |  | |  |
|  |  |  |  | |  |
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**Report all accidents and near misses to the faculty mentor.**

