**Operation Manual**

**Team 517**

**Spring 2022**

Note: at the time of writing (24-MAR-2022), the Team 517 has not completed. It has not built the validation technique or begun testing. This manual will include what is needed to complete the project to the best of the author’s ability. It will be revised at a later date when the project is complete.

There are three main parts of Team 517’s project. The first is devising a plan to cool the magnets at the MagLab more efficiently thus reducing the energy consumption of the facility. The second part of the project is to create a way to deliver chilled water from the MagLab to the Interdisciplinary Research and Commercialization Building (IRCB). IRCB is a new building that is being built in Innovation Park. The current plan is for the building to not have its own chillers for HVAC. Instead, it will “borrow” the Maglab’s facility. The idea is that one cooling facility will use less energy than running two separate systems. Finally, the third piece is a validation system that the team will make to demonstrate the project during Senior Design Day.

The magnets at the MagLab are cooled by deionized water that is pumped through the coils of the magnets. This amount of water used is based on the cooling needed for the magnets when they are operating at maximum power. The magnets at the MagLab however are not always used at their peak power. Often only 50% or lower of the total power is used in experiments. When less than 100% of the magnet power is utilized, the excess cooling is wasted. The team set out to ensure that the magnets were not overcooled, thus saving energy. The team was able to determine the ratio of energy that the magnets used in megawatts to the voltage provided to the magnet cooling water pumps. This meant that when a scientist requested to use a magnet, they would list how many megawatts they intended to use, and the appropriate voltage would be provided to the cooling pumps. There would need to be an operator in the control room that could set the voltage to the correct value.

This plan was never tested in the MagLab. On paper, the plan is adequate. There is space for factors of safety for cooling amounts and redundancy in the operation in the control room. The reality is that the MagLab houses magnets that are worth millions of dollars. The faculty would rather lose money in overcooling the magnets then risk a meltdown if the magnets were undercooled. The concept was proven by the Senior Design team, but the implementation requires supervision by professional engineers with extensive experience. The MagLab did not want to introduce another layer of complexity to an already complex system.

Moving the chill water from the MagLab to IRCB was a less complex engineering problem. The first part of the problem is finding the cooling need of IRCB. This is a valued measured in tons of cooling (1 ton of cooling = 12,000 Btu/hr = 3.5 kW). It is a function of several factors including the number of floors, the number of separate rooms, the average square footage of rooms, and number of occupants. From the cooing requirement, the amount of chill water that was needed for that cooling was determined. Once the amount of chill water needed was found, the team calculated the power it would require to pump that water from the MagLab to IRCB. IRCB requires 800 tons of cooling capacity, 1371 gpm of chilled water, and the standard water pipes are 6.5 in diameter PVC pipes. These values were taken from an Affiliated Engineers Study that was provided to the Senior Design Team (Affiliated Engineers, 2019). The original intent was for the team to confirm these values with their own calculations. However, the team was unable to find blueprints to the new building and could not check the study’s numbers because they had insufficient information about the new building.

The calculations first started with using the modified Bernoulli’s equation.

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|  |  | (1) |

In equation (1), L is the distance between the two buildings, D is the diameter of the pipes, and rho is the density of water. The mass flow rate is known to be 1371 gpm from the report. Once the amount of chill water was known, the team calculated the power required to pump water from the MagLab to IRCB. Then ƒ (the friction factor) needed to be calculated. Because there are multiple equations for friction factor based on whether the flow is laminar or turbulent, the Reynold’s number needed to be found to determine this answer. The formula that we used to determine the Reynolds Number was equation (2).

|  |  |  |
| --- | --- | --- |
|  |  | (2) |

The dynamic viscosity of water, µ, was found to be 8.9 x 10-4 Pa s. The Reynolds Number was found to be high enough to consider the flow is turbulent. The Chen’s Correlation equation used to find the friction factor for turbulent flows was used.

|  |  |  |
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|  |  | (3) |

In this equation relative roughness, ε, was based on the material of the pipe which was assumed to be PVC and found to be 1.5 x 10-6 m. Lastly, the coefficient of flow resistance needed to be found. However, this parameter is based off the minor losses of the whole system, these minor losses would come from the elbows, bushing and expansion, and valves throughout the piping. To know this, we would require a diagram of how exactly the piping will be built from the Maglab to IRCB and this still isn’t known yet. We assumed there would be no minor losses and the pressure loss in the system was found to be 111858 kg m2/s3. Next the equation to find power ΔpV̇ was used. The V̇ (volumetric flow rate) needed to be found so V̇=AV was used. And the velocity in this equation was found using ṁ/(ρA). The pump power required was calculated to be 9664 W.

The validation technique is designed to show the judges on Senior Design Day what the goal of the project is. The ultimate goal is to reduce the carbon emissions of the Innovation Park. The validation technique illustrates this by showing how reducing the voltage to a water pump can provide adequate cooling while saving energy. The basic layout reservoir filled with ice water that is pumped through cooling block over a hot plate. The hot plate has a thermocouple that is wired to an Arduino Mega. As the temperature reading of the thermocouple increases, the Arduino will increase the voltage of the pump. Similarly, as the temperature decreases, the voltage will decrease simulating the energy saving plan in the MagLab.

The problems that the team expects to encounter when building the validation project are correctly wiring the electronics of the system and coding the Arduino Mega. The code for running the pump is open source and on the Arduino website. The team will have to code the thermocouple component themselves. The idea is to code a statement that prompts the pump to run at a higher frequency when the thermocouple outputs a higher value. To wire the system’s electronics correctly, the team will reference the Arduino website page and other online sources. Special consideration will be taken into account before providing voltage to ensure the safety of the components.

# Bibliography

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