2025 Marine Energy Collegiate Competition

Engineering Calculations Summary

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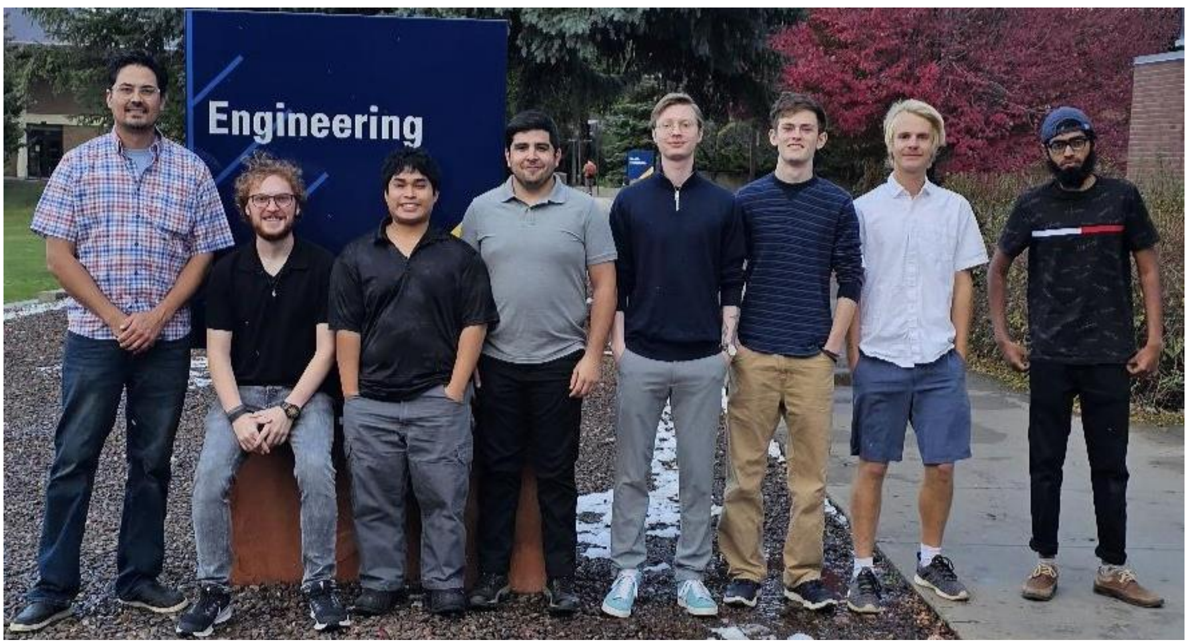
Fall 2024-Spring 2025



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1 Top Level Design Summary

The Marine Energy Collegiate Competition challenges teams to innovate renewable energy solutions. The team has designed a generator leveraging buoyancy, gravity, and a custom planetary gearbox to convert bidirectional buoy motion into unidirectional motor rotation while maintaining a stable electronic housing. The current CAD model incorporates additive manufacturing and features a watertight O-ring seal, custom mounting plates for electronics, and an internal gear assembly optimized for energy conversion. Planned improvements include refining the motor-to-gear axle for enhanced functionality, optimizing coupling materials, and developing a pressure testing system to ensure watertightness. Additionally, the team developed a House of Quality (QFD) diagram to prioritize engineering requirements based on customer needs, highlighting remote shutdown capability, marine durability, and testing as critical factors. These efforts align with stakeholder expectations and competition criteria, driving the team toward a sustainable and innovative marine generator solution.

1.1 Problem

The Marine Energy Collegiate Competition aims to inspire the next generation of renewable energy innovators through six distinct challenges. As part of the ME 486C - Mechanical Engineering Design II class, the team is focusing on two of these challenges for this report: the **Technical Design Challenge** and the **Build and Test Challenge**.

For the **Technical Design Challenge**, the team must evaluate their product's performance and market potential within the blue economy sector. This includes analyzing functionality, efficiency, market demand, and sustainability. To ensure the design aligns with industry needs, the team is required to engage with at least three key stakeholders through interviews, gathering user insights and refining the product based on feedback. The collected input is analyzed and incorporated to improve both the technical and practical aspects of the design. A comprehensive final report must be submitted, summarizing the design process, stakeholder feedback, and the product's market positioning.

The **Build and Test Challenge** focuses on demonstrating the team's testing methods and results. The report must detail the scaling factors used in model fabrication, the experimental plan, and how tests were conducted. The results are compared to initial design goals to evaluate performance. Additionally, the report should summarize data post-processing methods, highlight key lessons learned during the process, and propose potential modifications for future improvements. This challenge provides an opportunity to validate the product's effectiveness and identify areas for optimization.

1.2 Solution

The team has designed a generator that leverages buoyancy force, gravity, linear tension, an AC motor, a custom planetary gearbox, and a series of mounting plates to house the internal electronics. The positive buoyancy of the system drives the buoy upwards, while a string provides resistance to this upward force, causing the generator's main assembly to rotate. The custom planetary gearbox features sun gears equipped with one-way bearings, which act as clamping mechanisms to convert the buoy's bidirectional rotation into unidirectional rotation of the motor axle. This design ensures that the motor axle rotates consistently in one direction, regardless of the buoy's rotational direction. Additionally, the mounting plates for the electronics are securely fixed within the interior of the buoy, maintaining the components in a stable and protected position during operation.

1.3.1 Current CAD Design & Description

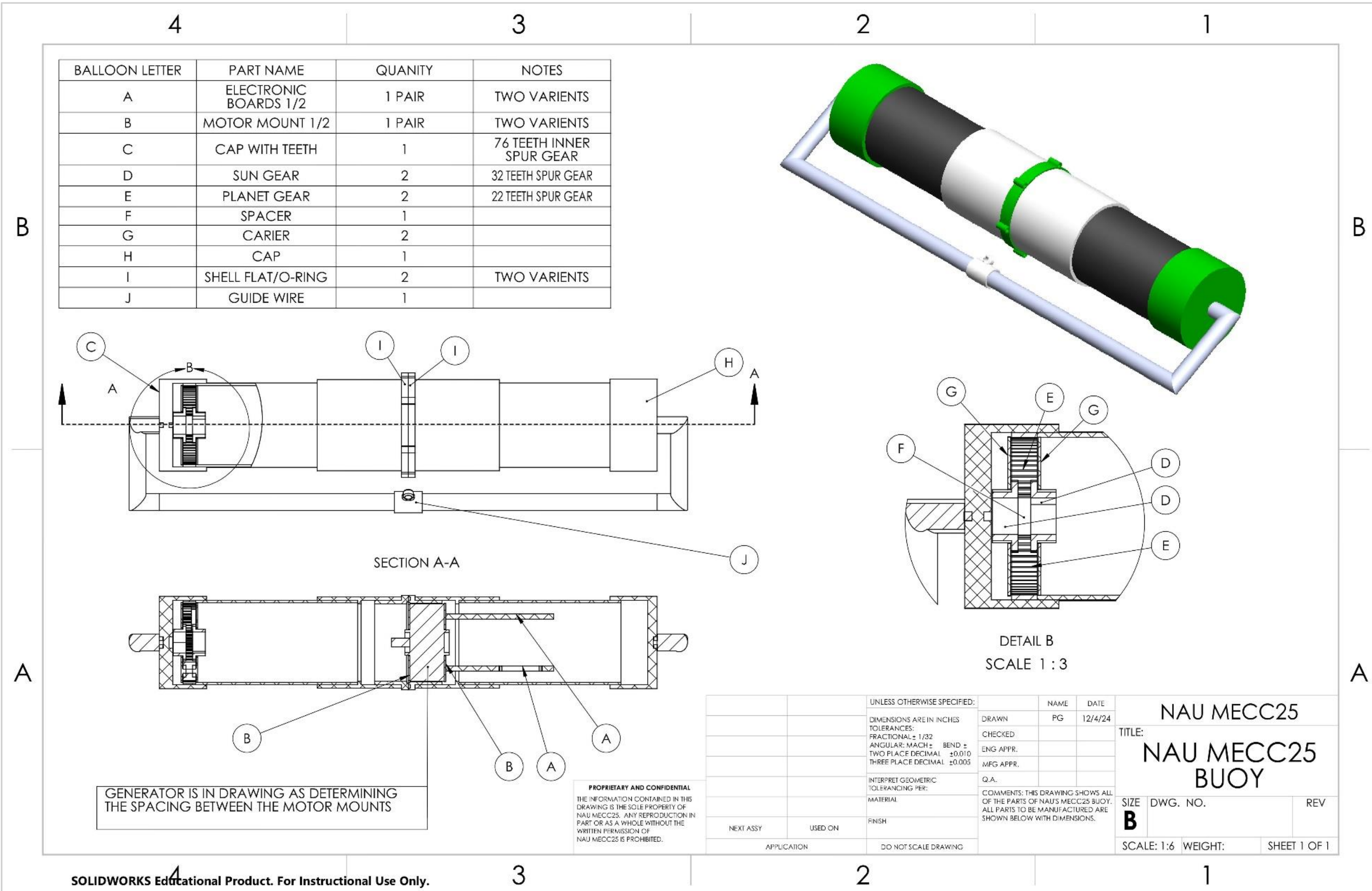

Figure 1.2.A: NAU MECC CAD Blueprint

Figure 1.2.A illustrates the current model of the NAU MECC Buoy, with all components explicitly designed for additive manufacturing. The buoy is divided into two distinct sections to streamline assembly: one side accommodates the electronics, while the other contains the mechanical components.

Detail B provides a cross-sectional view of the internal gear assembly. This mechanism converts the device's bi-directional rotation into unidirectional rotation. The center gear is equipped with two one-way bearings that lock in opposite directions, while planetary gears simultaneously engage with both the inner and center gears to complete the motion conversion.

Part I serves as a fixture with a cavity on one side to hold an O-ring, while the opposite side is flat. This configuration ensures that when pressure is applied evenly, the O-ring forms a watertight seal, effectively preventing water ingress into the buoy.

In collaboration with the electrical engineering team, custom mounting plates (**Part A**) have been incorporated to support the electronics. These plates not only aid in data collection but also facilitate the conversion of the main motor's rotation (not depicted in **Figure 1.2.A**) into usable energy.

1.3.2 Planned Improvements for Future Iterations

- **Motor-to-Gear Axle Design:** To enhance the functionality of the Sun Gear, which will incorporate a one-way bearing, the motor-gear axle will include a flat section. This design will allow for a keyway to secure the direction of the bearing, ensuring consistent performance.
- **Coupling Material Optimization:** To improve cost efficiency, the couplings in the drawing will be fabricated entirely from ABS plastic rather than using conventional PVC materials from a local dealer.
- **Testing Enhancements:** A secondary cap and shell will be fabricated to facilitate air pressure testing. This iteration will include a Schrader valve to introduce positive pressure inside the buoy, enabling precise leak detection and ensuring the generator's watertightness.

1.4 Current House of Quality

In our pursuit of designing an efficient and well-structured marine generator, we have developed a House of Quality (QFD) diagram, which is shown as Figure 1.3.A. This tool has provided us with key insights into the technical priorities of the engineering requirements, as they relate to customer needs, highlighting the core challenges and objectives of our project. Our initial analysis focused on evaluating the correlations between each engineering requirement and how they impact other technical criteria. By using a structured rating system—positive correlations ("+"), no correlation (blank cells), and negative correlations ("-")—we were able to determine the degree to which each requirement influences other aspects of the design. Understanding these interdependencies is essential for making informed decisions throughout the design and development process, as changes to one requirement may significantly affect others.

House of Quality (QFD)

#	Technical Requirement	1	2	3	4	5	6	7
1	Resistance to Marine Environment							
2	Energy Output							
3	Continuous Operation	+						
4	Efficiency	+		+				
5	Laboratory/Controlled Testing Compatability	+	-					
6	Compatibility with Diverse Marine Conditions		+	+		-		
7	Majority Use of Marine Energy	+	-					
8	Remote Shutdown Capability	+	+	+				

#	Customer Needs	Customer Weights	Weight %	Resistance to Marine Environment	Energy Output	Continuous Operation	Efficiency	Laboratory/Controlled Testing Compatability	Compatibility with Diverse Marine Conditions	Majority Use of Marine Energy	Remote Shutdown Capability	CorPower	Sea Wave Energy Limited SWEL	Eco Wave Power
1	User Safety	5	6.60	4							9	7	7	6
2	Design Presentation	2	16.50	6	6			5	5	5	5	8	6	6
3	Cost Efficiency	4	8.25				7	6				4	8	7
4	Environmental Safety	4	8.25	5					6	6	8	5	7	8
5	Aesthetically Appeal	3	11.00	6	6	6				6	6	6	6	4
6	Adaptability Across Climates	5	6.60	7	7	8	9	7	8	8	8	7	7	5
7	Ease of Manufacturing	5	6.60	8	8	8	8	8	8	8	8	4	3	7
8	Grid Integration	5	6.60	7	7	7	7	6	6	7	7	7	4	8

(Technical Requirements: columns Resistance to Marine Environment through Remote Shutdown Capability; Bench Marking: CorPower, Sea Wave Energy Limited SWEL, Eco Wave Power)

	Resistance to Marine Environment	Energy Output	Continuous Operation	Efficiency	Laboratory/Controlled Testing Compatability	Compatibility with Diverse Marine Conditions	Majority Use of Marine Energy	Remote Shutdown Capability
Technical Requirement Units	IPXX	W	W/ day	%	CM	Varity	%	t,d
Technical Requirement Targets	IPX7	60	1440	> 50%	0.7	>= 6	>= 51%	10s, 5m
Absolute Technical Importance	180	140	133	148	139	144	167	220
Relative Technical Importance	4	7	8	3	2	6	5	1

Figure 1.3.A House of Quality Chart

To quantify the relative importance of each engineering requirement, we assigned numerical values based on their associations with customer needs: strong correlations rated at 9, medium at 6, weak at 3, and none represented by blank cells. These values were calculated from the QFD analysis, reflecting the strength of each requirement's relationship to customer needs. Notably, remote shutdown capability holds the highest technical importance score of 220, underscoring its critical alignment with customer priorities. This feature addresses safety concerns, such as the need for emergency shutdowns during major storms or maintenance, which are vital to customer risk management. Similarly, marine durability ranked highly due to its direct relevance to customer expectations for longevity and minimal repair needs. Additionally, 13 a high score for laboratory and controlled testing emphasizes the importance of the generator's volume and performance for the Build and Test Challenge. These findings are invaluable for prioritizing technical efforts and effectively allocating resources to meet both customer expectations and competitive benchmarks. The QFD diagram not only clarifies the relationships between customer needs and engineering requirements but also guides us in setting project goals, constraints, and design targets. This structured approach will remain a critical tool for monitoring our progress, ensuring alignment with stakeholder requirements, and successfully delivering a hydropower project that meets both customer and competition criteria.

2 Summary of Standard, Codes, and Regulations

The design adheres to several industry standards, competition codes, and regulatory requirements to ensure safety, functionality, and sustainability. Standards like AGMA 2001, ANSI/AGMA 6123-C16, ASME B18.6.3, and ASME Y14.5 address gear design, material selection, fastener specifications, and dimensioning for reliable and precise manufacturing. Competition codes mandate that over 50% of the energy generated must come from marine sources, prohibit open water testing, and require testing in controlled environments. Regulatory compliance includes meeting Bureau of Ocean Energy Management (BOEM) requirements for site selection, environmental assessments, and operational safety, as well as adhering to the Marine Mammal Protection Act (MMPA) to minimize ecological impact. These measures collectively ensure a robust, sustainable, and environmentally responsible wave energy device design.

2.1 Standards

The design incorporates several industry standards to ensure safety, reliability, and precision. The AGMA 2001 standard provides guidelines for the design, analysis, and rating of gears, covering key parameters such as gear geometry, strength, and durability [10]. ANSI/AGMA 6123-C16 focuses on materials and lubrication requirements for reliable gear performance in high-load applications [7]. ASME B18.6.3 outlines specifications for machine screws, tapping screws, and metallic drive screws, ensuring compatibility and standardization for mechanical fasteners [8]. Additionally, ASME Y14.5 provides guidelines for dimensioning and tolerancing, enabling precise and consistent part production and assembly [9]. By adhering to these standards, the design achieves compliance with recognized engineering practices and promotes functionality and manufacturability.

2.2 Codes

The codes that were used for this project come from the competition rule book. The most important code from the rule book is that our design needs to be greater than 50% marine energy. Meaning we could use solar panels and wind energy if we needed to produce more energy but 50% of the energy produced must come from a marine energy source [11]. Another code that we have been using from the competition is that we cannot do open water testing. This means we will need to do testing within a secured facility or a tank.

2.3 Regulations

The design of the wave energy device must comply with regulations established by the Bureau of Ocean Energy Management (BOEM) to ensure environmentally responsible development [5]. Key statutes include adherence to BOEM's leasing and permitting requirements for renewable energy projects, which govern site selection, environmental impact assessments, and operational safety. Additionally, the design must align with the Marine Mammal Protection Act (MMPA), which mandates minimizing disruptions to marine mammal populations and habitats during installation, operation, and maintenance activities [6]. These regulations ensure that the device operates sustainably while balancing energy production with marine ecosystem preservation.

3 Summary of Equations and Solutions

In this section, mathematical models and data analysis tools are used to validate the maximum weight our generator can support and to analyze the variable impact forces it will encounter when deployed in the ocean. The process begins with the development of a MATLAB code, which calculates the device's overall volume and determines the buoyant force acting on it at the sea's surface. Key mathematical equations and assumptions are then applied to estimate the forces generated by waves and the intensity of different wave conditions. This modeling establishes the foundation for calculating the maximum energy the generator can harness, offering a systematic, data-driven approach to refining the dataset and ensuring a concise, region-specific datasheet.

3.1.1 Buoyancy Force Calculation in MATLAB – Patrick Grosse

As our device is currently in the early stages of development, accurately determining the buoyancy force is essential for guiding the design process and ensuring the system achieves neutral buoyancy. Neutral buoyancy is crucial for the device's operational stability, allowing it to remain suspended in water without sinking or floating uncontrollably. By applying Archimedes' Principle, we can calculate the buoyant force exerted on the device, which must counterbalance its weight.

Given the dimensional constraints of the testing environment, we can make reasonable assumptions about the device's overall volume. This volume, combined with Archimedes' Principle [Eq. 1], allows us to derive the total upward force that will act on the submerged portion of the device. Understanding this relationship is critical for establishing the maximum allowable weight of the device while ensuring it remains near positive buoyancy in the water.

$$F_{Buoyancy} = \rho_{seawater} * g * V_{Buoy} \qquad \text{[Eq. 1]}$$

To facilitate this analysis, we have developed a MATLAB script (referenced in **Figure A.1.1 Appendix A.1**) that allows for the remote adjustment of the buoy's cylindrical volume. By inputting various geometric parameters and other given parameters, the code calculates both the total volume and the corresponding buoyant force. This approach provides the flexibility to quickly iterate through design variations and evaluate their performance in real-world conditions, ensuring that the buoyancy force will adequately counter the device's weight when submerged in water.

3.1.2 Morison Equation: Force of a Wave – Aiden Lee

The Morison Equation is an equation that is used in the offshore construction industry to find the forces of waves. The full equation is as follows:

$$F = \frac{1}{2}\rho_w C_D D|U| + \rho_w C_M \left(\frac{\pi D^2}{4}\right)\frac{\partial U}{\partial t} \qquad \text{[Eq. 1]}$$

The constants and equations for variables are explained in **Appendix A.1.2**. The Morison equation has many different forms depending on the shape of the body in the flow. Equation 1 is for a cylindrical body in an oscillating flow. Equation 1 simplifies to equation 7 after substituting equations 2-7 as seen in **Appendix A.1.2** and the drag coefficient $\boldsymbol{C_D}$ going to zero.

$$F = \rho_w (\frac{mD^2}{6})(\frac{\pi D^2}{4})(-A\omega^2 \sin(k - \omega t - \varphi)) \quad \text{[Eq. 8]}$$

The drag coefficient goes to zero because the equation for drag in oscillatory flow, as seen in **Appendix A.1.2,** uses velocity relative to flow. Since, our design is a buoy it will be moving with the flow making its velocity relative to the flow zero.

The Morison equation is a very useful equation for our design and can be used for many different occasions. Our design will be anchor in some capacity so the force of the wave will be useful to find the force of tension in our anchor. The equation will also be used to find the power generated once our gear design is completed.

3.1.3 Wave Intensity – Asher Aspili

With the design of our device being based around wave energy, it is reasonable to look at how waves generate power per unit of area. Determining the intensity is the basis of solving the mechanical power generated through the modeling of ocean waves measured across a surface. The intensity of a wave is the energy per unit time that is transported across a unit area normal to the direction of energy flow. If a wave is moving across a large area, it will then decrease in its intensity. The equation of intensity of a wave is:

$$I = 2\pi^2 \upsilon \rho f^2 A^2$$

The υ is the velocity of the wave.

f is the frequency of the wave.

A is the amplitude of the wave.

To show the wave intensity an analysis through a MATLAB file in **Appendix A.1.3** was generated. This allows us to simulate the wave intensity by assuming wave amplitudes and wave frequencies. Modeling this equation gives us a better understanding of the mechanical energy that is being generated, in which we can use to convert this energy into electricity.

3.1.4 Collection of Environmental Data – Patrick Grosse

To ensure the buoy's resilience and functionality, the team combines simulation techniques with physical testing, leveraging innovative tools and real-time environmental data.

The team sources critical oceanographic data, such as wave heights, swell periods, and wind speeds, from NOAA's National Data Buoy Center (NDBC). A MATLAB script (**Appendix A.1.4**) streamlines this process by automating the retrieval and organization of buoy-specific datasets. The script processes raw data, filters for essential variables like wave amplitude and wind speed, and formats it into Excel spreadsheets for use in simulations and analysis. This automation eliminates manual errors and ensures quick access to location-specific data. Any supplementary or non-relevant information is preserved for future reference, allowing flexibility in testing and modeling.

As shown above, the team used MoodyMarine, a simulation tool recommended by our mentor, Dr. Leixin Ma of Arizona State University. MoodyMarine simulates the prototype's response to real-world forces, generating detailed graphs and metrics, including horizontal and vertical velocity profiles and mooring line tension under dynamic wave scenarios. These outputs help the team evaluate the buoy's stability, energy efficiency, and durability across various ocean conditions. Dr. Ma has also provided access to her lab facilities for physical testing, complementing the virtual simulations.

The combined use of real-time data, advanced simulations, and physical validation supports the team's goal of creating a high-performance device tailored to the needs of the marine energy sector. By advancing their understanding of wave, wind, and current dynamics, the NAU MECC team is making significant strides toward sustainable energy innovation.

3.1.5 Mooring Line Analysis – Aiden Lee

The mooring line is an important part of an ocean buoy as it keeps the buoy anchored so that it does not flow away. The mooring line for this buoy design was analyzed using the Morrison equation from Equation 1. The ultimate tensile strength was found from the forces using Equation 9 in **Appendix A.1.2** from this Figure 4.1.A was produced. Figure 4.1.A is the ultimate tensile strength vs diameter. This graph was used to choose what size of diameter would be need for this.

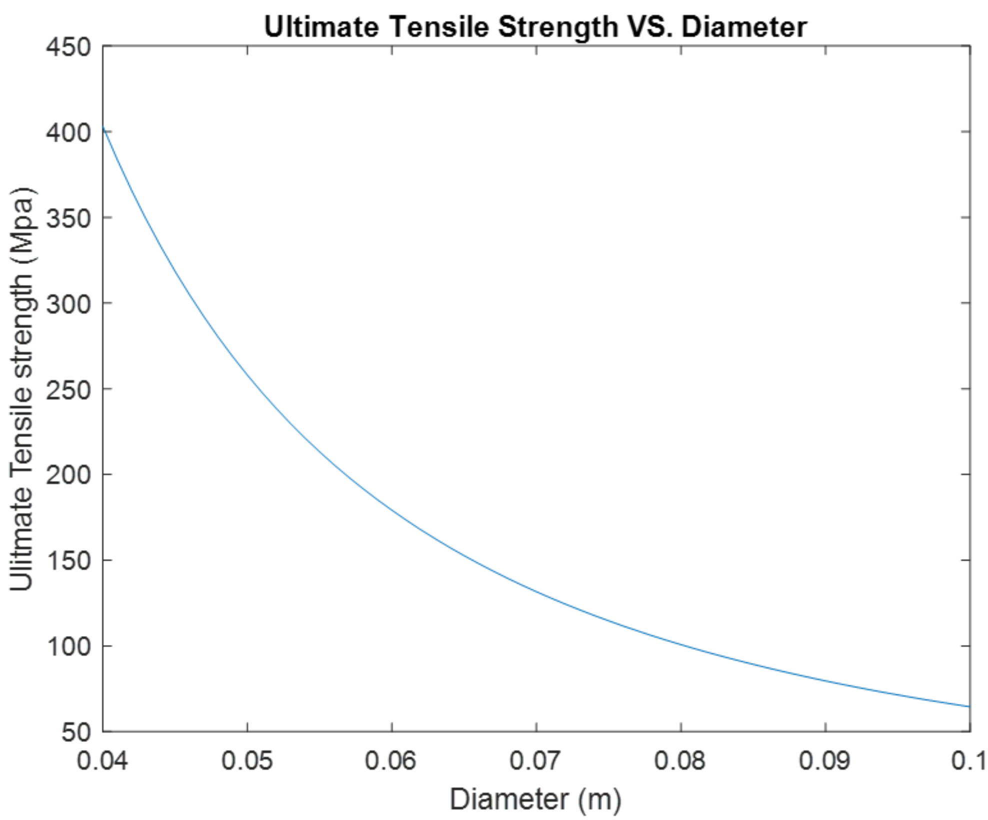

Figure 3.1.A: Ultimate Tensile Strength Vs. Diameter

Using an ultimate tensile strength of 400 Mpa we can find a diameter of 0.04 m for the mooring line. Using this data and the data calculated in in section 3.3.2 a grad 43 chain was selected as the mooring line we can use for our initial prototype design. Grade 43 chain has a ultimate tensile strength of 430 Mpa for a 1/4 in diameter chain. This chain however would not work the best for if this design was to go to market which is where a wire rope dyform 6-PI would be used as it would mitigate bunching and allow for more marine safe coatings to be used.

3.1.6 Power Take-Off Systems – Asher Aspili

Performance of Power Take-Off (PTO) systems under different wave conditions were simulated as this determines if energy harvest is possible regarding the resource applications of the waves. Focusing on how wave amplitude and frequency affect torque and power output were observed. The results provide valuable insights into optimizing the system's design.

Torque and power both show a strong quadratic relationship with wave amplitude. As the wave height increases from 0.1 to 3 meters, the torque generated by the buoy grows significantly. This is because wave energy and torque available is proportional to the square of the amplitude. Extractable power increases rapidly with wave amplitude, meaning even a small rise in wave height can greatly boost energy output. These findings highlight the potential benefits of deploying the system in areas with larger waves to maximize performance.

Wave frequency also has an impact on torque and energy harvest. Higher frequencies lead to an increase in both torque and extractable power. This indicates that choosing deployment sites with higher-frequency waves can significantly improve the system's ability to generate and transmit energy effectively.

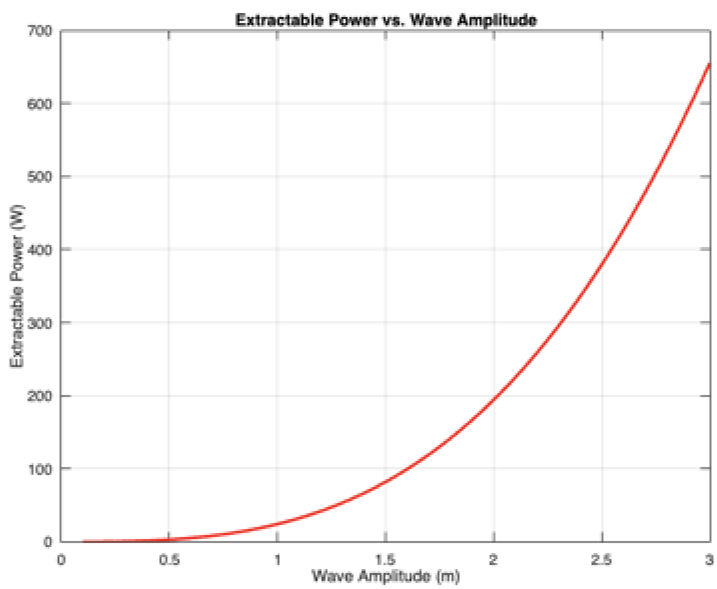

Figure 3.1.B: Amplitude and Energy Harvest

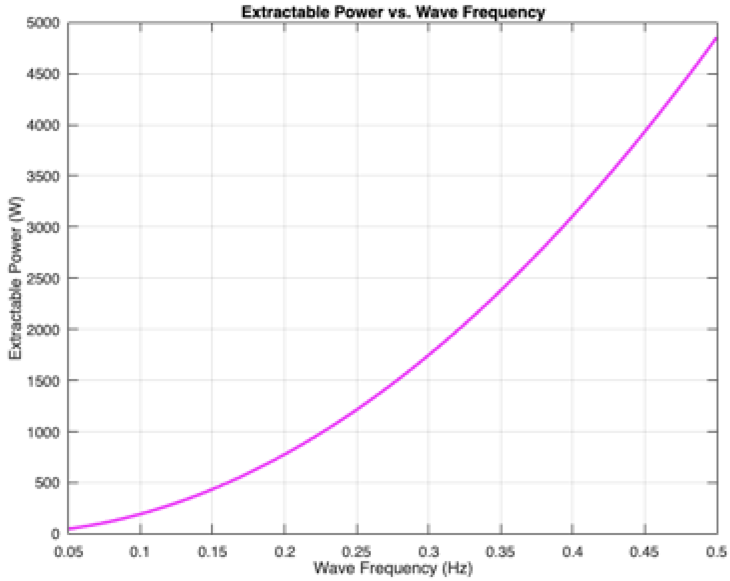

Figure 3.1.C: Frequency and Energy Harvest

analysis shows that both wave amplitude and frequency are critical factors for optimizing PTO performance. By targeting locations with larger and more frequent waves, the system can achieve higher efficiency and energy output.

3.1.7 Factor of Safety

Table 1.3 Factor of Safety Table for Sub Assembly

Sub System	**Part**	**Load Case Scenario**	**Material**	**Method of Calculating FOS**	**Minimum FOS**
Electrical (Aiden)					10
	Generator	The generator has the maximum torque of 193 Nm	Steel	Hand Calculation	12.4
	Sensors	The voltage of 12 V is passed through circuits	Copper wires	Hand Calculation	10
Gear Box (Patrick)					1.3

	Gears	Maximum torque of 193 Nm is applied to 3D printed Gears	ABS Plastic	Solid works FEA	17.1
	Bearings	Maximum velocity of 0.9 m/s or 14.5 rpms	Steel Ball Bearings	Hand calculations	172
	Shaft	Maximum torque of 193 Nm applied to the shaft	Stainless Steel	Solid works FEA	1.3
Housing (Asher)					1.4
	Couplings	Max wave force of 300 kN is applied to the housing	ABS Plastic	Hand Calculations	1.4
	Caps	Max wave force of 300 kN is applied to the housing	ABS Plastic	Hand Calculations	1.4

The load case for the torque was found using equations 10-13 in **Appendix A.1.3** [3]**.** The 12 volts for the load case of the wires was found from the generator specs being a maximum of 12 volts [1]. The maximum velocity was found from Figure 4.3 using MoodyMarine [2]. The wave force for the case scenarios were found using the force on a wave calculation in Figure 4.1.

4 Flow Charts and other Diagrams

Figure 5.1 shows the forces that a wave will produce on a buoy in kN. This diagram was created from the MATLAB code used in **Section 4.1.5**. This figure was then used to find what type of material would be able to withhold these forces if the design were to be manufactured.

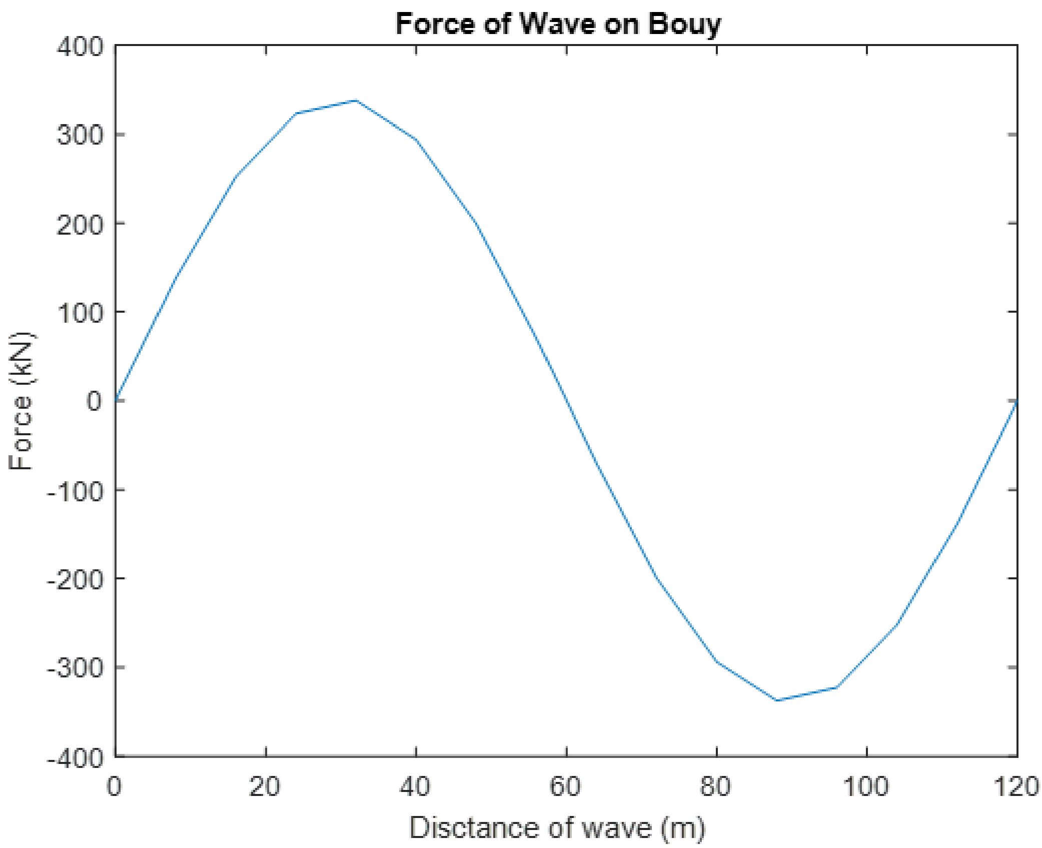

Figure 4.1: Force Diagram of a Wave on Buoy

Figure 4.2 is a black bock model of the marine energy device. The inputs for the black box model are waves tides and currents. The constraints on the model are that it needs to be remotely monitored and have control data accessible. The output of the black box model is electricity and other performance metrics resulting in the generators efficiency.

Figure 4.2: Black Box Model of Marine Energy Devices

Figure 4.3 shows the velocity that the buoy will experience in a standard wave off the coast of San Diego. The velocities are inversely related to the waves motion. The greatest velocity of the buoy is when it is at the trough of the wave. These velocities are used when calculating the factor of safety of the bearings.

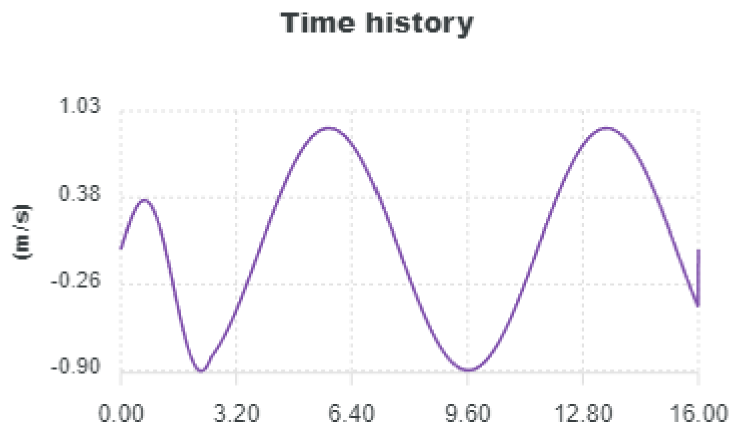

Figure 4.3: Velocity of Bouy Over Time

5 Moving Forward

As our team approaches bench testing for the device, a few additional calculations are required to ensure its structural integrity and to prevent corrosion of the electronics. These calculations will be conducted following the completion of most "wet" and "dry" tests on the device:

- **Buoyancy Force and Counterweight/Anchor Weight Calculations:** By determining the true weight of the buoy, we can accurately calculate the buoyancy force acting on the generator. This information will enable us to determine the necessary weights for both the anchor—semi-fixed to the sea floor—and the counterweight, which will offset any positive buoyancy forces.
- **Power Output Calculations at Variable Speeds:** With all electronic components integrated into the circuit, we will analyze data collected during simulated extreme weather conditions to calculate the power generated under varying environmental scenarios.
- **Localized Cost of Energy:** Using data from testing, we will assess the cost-effectiveness of the device within specific geographic regions, factoring in local energy markets and deployment conditions.
- **Future Scaling Factors:** With the generator currently sized for testing in a controlled environment, we will use data from the "wet" tests to determine the scaling requirements for transitioning the device to an industry-ready version that can achieve commercial profitability.

6 REFERENCES

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7 Appendix A.1: Referenced Figures & Equations

```matlab
clear
clc
%Fixed Numbers
rho = 1025; %kg/m^3
g = 9.807; %m/s^2

%Input Numbers
r = input("Enter the radius of the cylinder in centimeters: ");
h = input("Enter the heigth of the cylinder in centimeters: ");

%Calculations
V = (pi*h*r^2); %Volume of buoy in CC
F = (rho)*g*(V)/(10^6); %buoyance force (conversion from CC to CM)

%Output Calculation
fprintf('Your buoy volume in cubic centimeters (cm^3) is: %.3f\n',V);
fprintf('Your buoyancy in Newtons (N) is: %.3f\n',F);
```

Command Window

```
Enter the radius of the cylinder in centimeters: 15.24
Enter the heigth of the cylinder in centimeters: 50
Your buoy volume in cubic centimeters (cm^3) is: 36482.938
Your buoyancy in Newtons (N) is: 366.733
fx >>
```

Figure A.1.1: Buoyancy & Volume MATLAB Calculation

A.1.2 Morison Equation:

$$F = \frac{1}{2}\rho_w C_D D|U| + \rho_w C_M (\frac{\pi D^2}{4}) \frac{\partial U}{\partial t} \quad \text{[Eq. 1]}$$

F = Force

ρ_w= Density of water

C_D= Drag Coefficient

D = Diameter

U= Velocity of fluid

C_M= Inertia Coefficient

$\frac{\partial U}{\partial t}$ = Acceleration of wave

$$\frac{\partial U}{\partial t} = -A\omega^2 \sin(k - \omega t - \varphi) \quad \text{[Eq. 2]}$$

A= Amplitude of wave

k= Wave number

ω = Angular Frequency of wave

t= Time for one period

φ= Phase shift angle

$$k = \frac{2\pi}{\lambda} \quad \text{[Eq. 3]}$$

λ= Wavelength of wave

$$C_D = \frac{1}{2} F_D \rho v^2 A_r \quad \text{[Eq. 4]}$$

F_D=Force Drag

A_r= Area relative to flow

ρ= Density of fluid

v= Velocity of flow

$$F_D = 6\pi\mu r v \quad \text{[Eq. 5]}$$

μ=Dynamic Viscosity of Fluid

r=Radius of Object in Fluid

v= Velocity relative to flow

$$C_M = \frac{mD^2}{6} \quad \text{[Eq. 6]}$$

m= Mass of object

$$m = \rho\pi r^2 h \quad \text{[Eq. 7]}$$

ρ= Density of material

r= Radius of cylinder

h= Height of cylinder

$$F = \rho_w(\frac{mD^2}{6})(\frac{\pi D^2}{4})(-A\omega^2 \sin(k - \omega t - \varphi)) \quad \text{[Eq. 8]}$$

$$\sigma = \frac{F}{A} \quad \text{[Eq. 9]}$$

```
% Intensity of a Wave

% Arbitrary Numbers Assumed
rho = 1025; % Density of ocean water in kg/m^3
f = 0.1;    % Frequency of waves in Hz
v = 0.6;     % Speed of waves in m/s
A = 0.2;   % Amplitude of waves in m

% Formula for intensity
I = 2 * pi^2 * v * rho * f^2 * A^2;

% Display the result
disp(['The intensity of the wave is: ', num2str(I), ' W/m^2']);
```

```
The intensity of the wave is: 4.8558 W/m^2
```

Figure A.1.3: Wave Intensity MATLAB Model

A.1.3 Torque Calculations:

$$E = \frac{\rho g^2 H^2 D}{32\pi} \quad \text{[Eq. 10]}$$

E= Wave Energy

ρ=Density of water

H= Wave Hight

D= Diameter of device

$$E_c = EDCwr \quad \text{[Eq. 11]}$$

E_c= Energy Captured

Cwr = Capture Width Ratio

$$f = 1/T \quad \text{[Eq. 12]}$$

f=Frequency

T= Period

$$\omega = 2\pi f \quad \text{[Eq. 13]}$$

ω= Angular velocity

$$\tau = E_c \omega \qquad \text{[Eq. 14]}$$

τ= Torque

```
%buoy ID number from ndbc.noaa.gov site
buoyID = input(['what buoy would you like the information from? use this site to find the buoy'...
    ' https://www.ndbc.noaa.gov/data/realtime2/ '],'s');
url = sprintf('https://www.ndbc.noaa.gov/data/realtime2/%s.txt', buoyID);

%File name for the Excel spreadsheet
outputFile = sprintf('%s.xlsx', buoyID);

%Download and process data
try
    opts = weboptions('Timeout', 20); %cancels code if takes loger than 20 seconds
    data = webread(url, opts);

    %Parse data using textscan, skipping header lines
    rawData = textscan(data, '%f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f', 'HeaderLines', 2, 'TreatAsEmpty', 'MM');

    %Check lengths of all columns and find the minimum valid length
    columnLengths = cellfun(@length, rawData);
    minLength = min(columnLengths);  %Find minimum length across columns

    %Ensure all columns are the same length by trimming to minLength
    for k = 1:length(rawData)
        if length(rawData{k}) > minLength
            rawData{k} = rawData{k}(1:minLength);  %Trim each column to the minimum length
        end
    end

    %Convert to a data matrix after trimming
    dataMatrix = cell2mat(rawData);

    %Create a excel sheet with column names
    buoyDataTable = array2table(dataMatrix, 'VariableNames', ...
                            {'YY','MM','DD','hh','mm', ...
                             'WDIR','WSPD','GST', ...
                             'WVHT','DPD','APD', ...
                             'MWD','PRES','ATMP','WTMP', ...
                             'DEWP','VIS','PTDY', 'TIDE'});
    %Write the table to an Excel file
    writetable(buoyDataTable, outputFile);

    %Display success message if successful
    fprintf('Data has been successfully saved to %s\n', outputFile);

    % Calculate and print the average needed values, ignoring empty cells
    avgWVHT = mean(buoyDataTable.WVHT, 'omitnan'); %average wave height
    avgADP = mean(buoyDataTable.APD, 'omitnan'); %average wave period
    ampWVHT = avgWVHT/2; %average wave amplitude
    avgWSPD = mean(buoyDataTable.WSPD, 'omitnan'); %average wind speed
    avgWDIR = mean(buoyDataTable.WDIR, 'omitnan'); %average wind direction

    fprintf('Average wave amplitude for buoy %s: %.2f meters\n', buoyID, ampWVHT);
    fprintf('Average wave period for buoy %s: %.2f seconds\n', buoyID, avgADP);
    fprintf('Average wind speed at buoy %s: %.2f knots\n', buoyID, avgWSPD);
    fprintf('Average wind direction at buoy %s: %.2f degrees from North\n', buoyID, avgWDIR);

catch ME
    fprintf('Data retrieval failed for buoy %s\n', buoyID); %reads error if failed
    disp(ME.message); %displays error reason
end
```

Figure A.1.4 MATLAB code of Ocean data collection