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WIND TURBINE DESIGN AND IMPLEMENTATION

Major Qualifying Project Report:
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By

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Abstract

This project examined the design of a land-based wind turbine considering various alternatives including soil and foundation type, turbine size and type, tower design, type of site, and wind speeds. In addition, a cost analysis of the chosen wind turbine design was completed. An integrated design sheet was produced for the development of a wind turbine. Once the primary factors in the design of a land-based turbine were determined, the implications for an offshore turbine were investigated. Based on research and the cost and structural analyses, conclusions and recommendations for appropriate designs were established.

Authorship

All members of the project group, Bethany Kuhn, Julie Marquis and Hilary Rotatori, made an equal contribution to the major qualifying project. The following sections were written by the specified person:

Section	Author
Capstone Design	Hilary Rotatori
Introduction	Julie Marquis
Background	Bethany Kuhn, Julie Marquis, Hilary Rotatori
Methodology	Bethany Kuhn, Julie Marquis, Hilary Rotatori
Tower Design	Julie Marquis
Foundation Design	Hilary Rotatori
Project Analysis	Bethany Kuhn
Offshore Turbine Design	Bethany Kuhn, Julie Marquis, Hilary Rotatori
Conclusions	Julie Marquis, Hilary Rotatori

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Capstone Design Statement

This project addressed the design constraints set by the Accreditation Board for Engineering and Technology (ABET) in order to meet the requirement of capstone design experience for the Major Qualifying Project. As stated by ABET General Criterion 4, "Student must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political."[1] In addition to these constraints, this project considered the American Association of Civil Engineers (ASCE) Commentary on "Engineering Design."

Economic

One of the more important constraints on large-scale civil engineering projects is economic feasibility. The design of the project considered the cost of construction and the materials used. In order to ensure that the project is affordable, a cost analysis of alternative designs and materials was performed to help choose a design. A cost analysis of the final design was also conducted to determine the economic impact of the turbine once it is in operation.

Environmental

The environmental impacts of projects have been a rising concern in the civil engineering industry in recent years. It is important to protect the land surrounding the construction site and to investigate the affects of the wind turbine on wildlife. This project addressed environmental constraints by reviewing environmental codes and regulations regarding the construction and operation of the turbine. The codes that were reviewed involved studies that must be performed in order to obtain a permit for the wind turbine project. These studies include avian and bat interaction; wildlife, plants and wetlands studies; archaeological and historical reviews; stream crossing and soil disturbance. [2] This investigation allowed the group to review the typical regulations that should be considered before a turbine is constructed.

[1] *UCSC CE Department's fulfillment of the Major Design Experience*. abet.soe.ucsc.edu/design.html (2009, February 20).

[2] National Wind. (September 2009), www.nationalwind.com

Sustainability

Sustainability is an important aspect of the design of the wind turbine because the design should be durable as well as economical and environmentally-friendly. The installation of a wind turbine itself is sustainable as it is a source of renewable energy. This project addressed sustainability by considering the maintenance to be done on the turbine in the future. The availability of the materials used was also taken into account. By using innovative designs such as offshore turbines land can be preserved. In addition, a life-cycle cost analysis was conducted, including an estimation of the "payback" time for the construction of the turbine.

Constructability

The constructability of the project addressed the feasibility of the design and construction of the turbine. This project addressed this constraint by considering ease of construction when choosing building materials, and researching the most practical methods for the construction of a turbine tower and foundation. The group considered using standard dimensions for the tower height and cross-section and a standard turbine power so that the turbine could be easily constructed and replicated if successful. In addition, the tower was designed using a modular approach to facilitate the construction process and limit the necessary site operations.

Ethical

In order to address the ethical constraints, the group used the principles outlined by the American Society of Civil Engineers (ASCE) Code of Ethics which states, "Engineers uphold and advance the integrity, honor and dignity of the engineering profession by using their knowledge and skill for the enhancement of human welfare and the environment, being honest and impartial and serving with fidelity the public, their employers and clients, striving to increase the competence and prestige of the engineering profession, and supporting the professional and technical societies of their disciplines."[3] This project considered these principles in all aspects of the design and construction plans.

Health and Safety

In order to address health and safety considerations, a structural analysis of the tower and foundation design materials under different forces was performed. The research performed on zoning and location restrictions was considered in the design process to ensure that the turbine is an appropriate distance from its surroundings.

[3] *Code of Ethics,* (September 2009), www.asce.org/inside/codeofethics.cfm

Social and Political

Since wind energy is a relatively new technology, society has not fully embraced the idea of wind turbines being constructed in their communities. This project addressed social and political constraints by considering the process of installing a wind turbine in a specific community and by researching the people and steps involved. Once these processes were understood, a flow chart of the process the in terms of people or organizations who are involved was prepared. In addition, the group examined case studies in order to determine strategies by which wind turbines have been successfully integrated into various communities.

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Chapter 1: Introduction

As the demand for more environmentally-friendly energy resources grows, energy providers have recognized the importance of wind power and have invested in the development of wind turbines. In fact, wind energy is the only renewable resource that has grown faster than predicted.[4] At the end of 2007, the wind energy generating capacity in the United States was 16,818 MW.[5] In 2008 alone, 8,358 MW of wind energy was added[6] and in 2009, an additional 9,922 MW of wind energy was added.[7] As of the start of 2010, the wind generating capacity increased to 35,098 MW, more than doubling the wind energy capacity since 2007. The U.S. Department of Energy predicts that wind energy will provide at least 20 percent of the nation's electricity by 2030.[8]

The primary reason behind the recent peak of wind energy capacity is due to improved turbine technology.[9] Several components of a wind turbine must be taken into account, including the tower, blades, nacelle, and foundation designs. New developments in the construction of taller structures using better, lightweight materials, and improved turbine design techniques have allowed today's taller turbines to tap better winds at higher elevations for reduced costs. As a result of the improved turbine designs using lighter-weight steel for the tower, smaller, lighter foundations can be used and in turn reducing costs. It is imperative to continue improving the design of the wind turbine in order to harvest better energy and optimize its cost.

Wind turbine towers and foundations must be designed to withstand heavy loads and moments due to extreme wind conditions to prevent failures, as well as other forces that are introduced with alternative site designs. The forces that the tower and foundation must resist are wind loads, ice loads, and the self-weight of the tower. The tower structure must also resist earthquake loads, which can be designed

[4] Singh. *Concrete Construction for Wind Energy Towers* http://www.icjonline.com/views/POV_Wind_energy_tower.pdf (November 2009)

[5] *Wind Energy Fast Facts,* American Wind Energy Association, http://www.awea.org/newsroom/pdf/Fast_Facts.pdf (September 2009).

[6] *Wind Energy Basics,* American Wind Energy Association, http://www.awea.org/newsroom/pdf/Wind_Energy_Basics.pdf (September 2009).

[7] *U.S. Wind Energy Industry Installed Nearly 10,000 MW in 2009,* Energy Efficiency and Renewable Energy http://apps1.eere.energy.gov/news/news_detail.cfm/news_id=15794 (February 2010).

[8] http://www.awea.org/newsroom/pdf/Wind_Energy_Basics.pdf

[9] *U.S. Wind Resource Even Larger than Previously Estimated*, American Wind Energy Association, http://www.awea.org/newsroom/releases/02-18-10_US_Wind_Resource_Larger.html (October 2009).

based on checking resistance in the steel's plastic range.[10] In addition, the soil has to have adequate bearing capacity to resist the loads on the tower and weight of the foundation.

The construction of a wind turbine is limited to specific site guidelines due to social, political, and environmental constraints; therefore there is an alternative need for sites other than land-based turbines, such as offshore applications. Offshore wind turbines are becoming increasingly favored because of the high wind speeds off the coast, and the fact that there is little or no effect in terms of noise because of their distance from the shoreline; however, aesthetics may pose an issue with area residents who feel the turbines adversely affect the natural seascape of an area. Additionally, offshore turbines must harvest more energy to offset increased construction costs due to large underwater support structures and foundations.[11]

The purpose of this project was to design a land-based wind turbine as well as explore designs for offshore options for the energy needs of the chosen site. To begin studying the construction of wind turbines, a suitable site must be chosen based on a given criteria. The effect of loading conditions is evaluated on the wind turbine tower and foundation for its design. This project investigated and drew recommendations on the process of constructing two different wind turbine heights with alternative foundations as well as a cost analysis of the designs.

In addition to the design of the tower and foundation, one of the main deliverables for this project was an integrated spreadsheet, which was developed to effectively suggest a suitable tower and foundation design and the corresponding cost data. The creation of this spreadsheet allowed for the investigation of various design alternatives.

This report will contain an overview of wind energy and the current status of wind turbines as an effective producer of renewable energy, a methodology of how the project was completed, chapters detailing the tower design, foundation design, cost-estimation, and the investigation of offshore wind turbines, followed by a conclusion chapter, which will summarize the key findings and discuss limitations and suggestions for future work related to our research and analysis.

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[10] *Manual of Steel Construction LRFD, 3rd ed* (2001). American Institute of Steel Construction Inc.

[11] Malhotra, Sanjeev. "Design and Construction Considerations for Offshore Wind Turbine Foundations in North America". *Civil Engineering Practice,* Volume 24, Number 1. 2009.

Chapter 2: Background

As energy needs are continuously changing, the structural elements associated with the new energy sources need to be developed. An understanding of all the energy, mechanical, construction, and structural components related to the design, construction, and operation of wind turbines must be evaluated to develop an understanding for the design and management of this project.

Harvesting Wind Energy

Wind energy is defined as the process by which wind is used to generate mechanical power and electricity and is the world's fastest-growing energy source.[12] Figure 1: U.S. Wind Energy ProductionFigure 1 below shows the wind energy capacity, or the amount of energy produced by the United States from 1999 to 2009.[13]

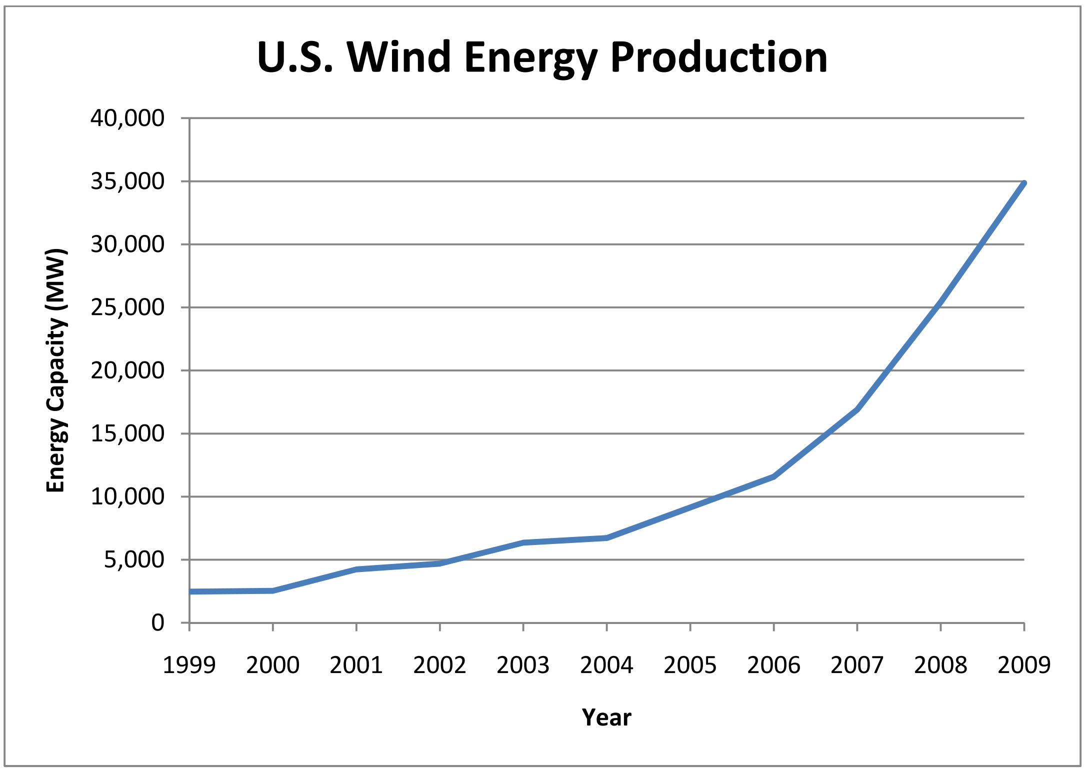

Figure 1: U.S. Wind Energy Production[14]

[12] *US Department of Energy: Energy Efficiency and Renewable Energy*. Wind & Hydropower Technologies Program. www1.eere.energy.gov/windandhydro/wind_technologies.html (October 2009).
[13] *Installed U.S. Capacity and Wind Project Locations.* U.S. Department of Energy. http://www.windpoweringamerica.gov/wind_installed_capacity.asp (January 2010).
[14] http://www.windpoweringamerica.gov/wind_installed_capacity.asp.

From 2007-2009 alone, wind energy production increased 109 percent. It is predicted that wind energy will provide at least 20 percent of the nation's electricity by 2030.[15]

Wind power is nondispatchable, which means the output cannot be controlled by operators and must be used at the time the wind is available; however, as long as a suitable site and design is selected, it serves as a reliable, renewable energy source.[16]

Wind turbines emerged as one of the most efficient ways of converting the kinetic energy in wind into mechanical power, aside from hydroelectric plants from flooding reservoirs and wave power from oceans.[4] Wind turbine consumers have found many ways to use the wind energy harnessed by the turbines. Historically, turbines were used on remote sites that did not have access to the electricity grid, and are still used for that purpose today even though electricity is significantly more widely available.[17] Some homeowners who do have access to the grid have chosen to use turbines to be more environmentally-friendly and save on energy costs. The use of large, utility-sized wind turbines or multiple wind turbines used in conjunction can create bulk energy to help supply electricity to the utility grid for residential, commercial, or industrial use.

Types of Turbines

Wind turbines are classified by the orientation of its axis and power output. The axis can be horizontally or vertically oriented, which have various affects on the design of the overall structure. The power output of the turbine can be selected based on the energy needs of the site and affect the overall size of the turbine.

Orientation of Axis

There are two main designs of wind turbines, the horizontal axis wind turbines (HAWT) and the vertical axis wind turbines (VAWT), both shown below in Figure 2. Horizontal axis wind turbines are more common and widely available. For these reasons and since more information is available on the construction of horizontal axis wind turbines, the HAWT model will be used in this project. Horizontal axis wind turbines usually have two or three tapered fiberglass-reinforced blades which are operated facing into the wind.[18] The turbine unit, which includes the blades, rotor, nacelle, and additional

[15] http://www.awea.org/newsroom/pdf/Wind_Energy_Basics.pdf

[16] *Wind Power*. (2009, October). *Wind Power*. en.wikipedia.org/wiki/Wind_power(2009, October).

[17] Gipe, P. (2004). *Wind Power: Renewable Energy for Home, Farm and Business.* White River Junction, VT: Chelsea Green Publishing Co.

[18] *American Wind Energy Association*, (September 2009), www.awea.org/faq/wwt_basics.html

mechanical equipment, is attached to a tubular steel tower which supports a main rotor shaft and electrical generator at the top. Most horizontal axis wind turbines are equipped with furling and shutdown systems to protect the turbines from damaging high-speed winds. If the wind speeds are too high for the designed critical strength of the blades, a furling system will turn the wind turbine generator rotor away from the direct wind force while still producing maximum output. A shutdown system can be electrical or mechanical and is designed to shut down the generator completely, and the blades are unable to spin.[19]

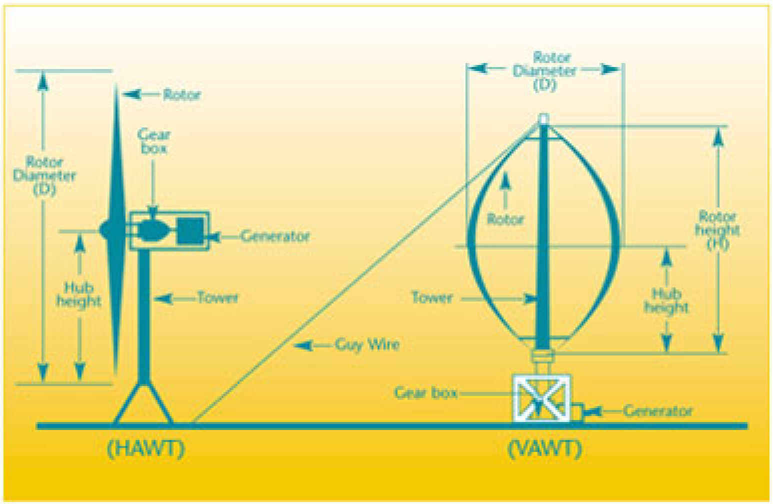

Figure 2: A Comparison of the Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT) Configurations

Source: http://colonizeantarctica.blogspot.com/2008/01/vertical-axis-wind-turbines.html

Power Outputs

Wind turbines are also classified by the amount of power that they can generate, and are directly correlated to the physical size of the turbine (larger wind turbines produce more energy). The three types of turbines in terms of power output levels are utility-, industrial-, and residential-scaled wind turbines. Table 1 displays the average size range and uses for each of the three scales of turbines. Utility-scaled turbines produce the highest amount of energy which is commonly sold back to the grid, while Residential-scaled turbines produce only 2 to 28 percent of the energy of a Utility-scaled wind turbine and are used for single buildings. Industrial-scaled wind turbines lie between the range of a

[19] *Wind Turbine Concepts Defined and Explained.* (Retrieved September 2009) otherpower.com/otherpower_wind_tips.html#tower

Utility- and Residential-scaled turbine, and can either be applied for single buildings or communities or sold to the grid.

Table 1: Wind Turbine Classifications[20]

Scale	Average Output Range	Uses
Utility	900 kW - 2 MW	•Generate bulk energy for sale in power markets •Commonly used in “wind farms”
Industrial	50 kW - 250 kW	•Remote grid production •Reduce consumption of higher cost grid power •May be sold if permitted by state regulations
Residential	400 W to 50 kW	•Remote power •Battery charging •Net-metering type generation

Mechanical Operation

In order to design the tower and foundation of a wind turbine, it is helpful to know the mechanical design and how it works. The force of the wind is applied to the blades of the turbine, which are angled to produce a rotation where the blades convene.[21] The blades are connected to a shaft that also spins along with the rotation of the blades. The mechanical energy that is produced by the revolving shaft is converted to electricity through a generator at the base of the turbine. The equipment at the top of the tower rotates based on the direction of the wind, in which the blades are positioned perpendicular to the wind load to maximize the wind exposed surface area. When the force of the wind exceeds the force for which the turbine was designed, the furling and/or shutdown systems are activated to prevent failure.[22]

Initial Site Assessment

Once an interest for constructing a wind turbine has been shown, a site must be chosen and evaluated based on the optimal conditions for installing a wind turbine, which are outlined in the following

[20] *Global Energy Concepts*. (September 2009), www.powernaturally.org/Programs/Wind/toolkit/9_windturbinetech.pdf
[21] *Wind Turbine Design.* (2009, October Wikipedia, The Free Encyclopedia: en.wikipedia.org/wiki/Wind_turbine_design
[22] *Wind Turbine Concepts* (2009, October).

sections. These steps are necessary to develop a wind turbine to produce the maximum profit return to the investor based on the expected value of the system.

Feasibility and Permitting

The wind turbine process can begin in many different ways. If a person owns a great deal of land, they might investigate how to purchase and install a wind turbine and utilize the electricity on their own property. In order to do this, the property owner would need to have the need for such a great deal of electricity. Another possibility is that a person who owns sufficient land for a turbine can lease their land to a company who would install the turbine and maintain it. In this scenario, the company who owns the turbine would pay the landowner a monthly amount to lease the site. Also, a landowner can be approached by a company who believes their land is valuable and the land owner can either lease the land or can become part owners of the wind turbine. In all of these scenarios, the land is only useful if there is sufficient wind energy available.

Siting

There are several factors that must be considered when choosing an appropriate site for a wind turbine. The factors include:

- Land size
- Wind speeds
- Surrounding landscape and structures
- Social constraints
- Distance between the turbine site and the local power distributer/substation site
- Air zone constraints

There must be a sufficient amount of land for the turbine. Generally, there are specific laws on how much land area must be unoccupied surrounding the wind turbine tower. In Massachusetts, this land area is often defined as "one and a half times the overall blade tip height of the wind turbine from the nearest existing residential or commercial structure and 100 feet from the nearest property line and private or public way"[23].

[23] Massachusetts Division of Energy Resources. *Model Amendment to a Zoning Ordinance or By-law: Allowing Wind Facilities by Special Permit,* (November 2010), http://www.mass.gov/Eoca/docs/doer/renew/model-allow-wind-by-permit.pdf

Another variable that must be considered is the quality of the wind in the area. There must be a significant amount of wind at the site for it to be considered suitable for the use of a turbine. On average, any site with less than an average annual wind speed of 5.8 mph is not considered feasible in New England. The breakeven wind speed varies depending on location of the wind turbine due to the retail value of electricity. In some locations wind speeds of lower than 7.0 mph cannot be considered. [24] Initial wind speed data can be collected using online wind energy databases and local wind maps of the area.

The distance between the wind turbine site and the local power distribution or substation is also a factor to be considered. If this distance is too great, it is not practical to install a wind turbine on the site. This is because the electricity would have to travel such a great distance to be disbursed that it would not be economically beneficial. If there is the need for electricity "behind the grid," however, this is another option for the turbine. This means that if there is a high need of electricity locally where the turbine is being installed, the electricity can go directly to these locations instead of having to travel a great distance to an electricity distribution center.

The use for the electricity must be analyzed and the most economically beneficial option should be chosen. If there are no beneficial options, a different site should be considered.

The limitations on the air zones should be considered next. For example, if there is an airport within a close proximity to the site the Federal Aviation Administration (FAA) may have laws prohibiting or limiting the construction of a very tall object. According to the United States Department of Energy, "Tower heights more than 200 feet, which include most utility-scale wind turbines, require Federal Aviation Lighting and the filing of the FAA form '7460-1 Notice of Proposed Construction or Alteration."[25]

Community Bylaws

After these first initial variables are considered, the next factor that should be researched is the community's decision making process. This is important to the wind turbine process because it is information on the steps that must be taken to obtain project approval. For example, a town may have a wind energy bylaw already created. This bylaw would define all of the rules governing the wind turbine approval and installation process. If such a bylaw does not exist, then one would have to be written and proposed to the local government. This local government could also be run many different ways. There

[24] Brian Kuhn, Email, 1/28/2010
[25] *US Department of Energy*. (2009, May 21).

could be a mayor, or town selectmen that make up a town council, and/or there could be town meetings. Knowing how the local government works is essential to comprehending what steps must be taken to get the wind turbine approved.

In addition to community bylaws, one should analyze the probable community position towards the installation of wind turbines in the area. Many times if a community is opposed to wind turbines, it may postpone the permitting process for years. An example of this is the Cape Wind project off the coast of Cape Cod, Massachusetts. This project has been searching for approval for over five years but the lack of community support has made it almost impossible to get the necessary permits and approvals. Community support of wind turbines makes the entire process much easier. [26]

Site Analysis

Once it is clear that the construction of a wind turbine is possible on a site, much more detailed factors must be analyzed in order to ensure the feasibility of constructing a wind turbine as well as collecting useful data for cost analysis.

Access to a site can often be a major issue. Many times, viable sites for wind turbines are at high altitudes where the wind energy is most profitable. These remote sites can be very hard to access, however. If the access road leading to the site is not large enough, a wider road would need to be created. A report prepared by Global Energy Concepts states that, “Developers look for sites with existing adequate roads that can handle the construction equipment requirements of delivering large turbine and tower components and the specialized crane to erect the turbine…The grade, turning radius, and loading criteria for construction require highly suited road access, or the ability to modify the road to accommodate the criteria.”[9] Depending on the distance to the nearest road, this could be a very costly project and could make the economic benefits of the turbine not sensible. Also, these sites may not even be available for construction purposes. The Global Energy Concepts report goes further to say that, “In New England, many of the higher elevation sites that are attractive for wind energy projects are under conservation easements or are state or federally owned lands that may not allow for wind development…Other windy sites, whether on mountain ridges or shorelines, are highly valued for their recreational or scenic purposes.”[9] This statement suggests that finding sites that are both constructible and not valued for other reasons is very rare.

[26] *Cape Wind,* (February 2010), en.wikipedia.org/wiki/Cape_Wind

In addition, foundation types will be a very important part of the construction process. If the site has a great deal of rocks or is on a rock bed, then rock anchors will need to be considered to stabilize the foundation. If there is no rock, but rather a silt/sand composition, then a larger foundation will need to be constructed to limit the bearing stresses exerted on the soil. This factor can change the initial cost of the turbine by tens of thousands of dollars.

The onsite electrical demand should then be researched more in depth. Electricity bills and finances from the past year could be gathered and analyzed to see just how much electricity could be used locally before the electricity enters the grid. This scenario would be beneficial to a project whose goal is to provide lower cost electricity for people in the local area. If the project's goal is to be as profitable as possible then selling all of the electricity that is generated to the local grid would be the most appropriate. Research on local utility sales ($/kWh) in order to calculate the income from the grid sales would be necessary. Also, the cost of connecting to the local utility (grid) would need to be determined. By completing these steps the cost analysis will be more accurate. In this cost analysis phase all monetary factors must be considered. This includes the basic cost of the construction and materials of the turbine, shipping, installation, electricity sales, government benefits, and maintenance.

The profit made from selling the electricity that is generated could vary exponentially by location. Some locations have high costs of electricity, which makes wind energy more attractive; however they do not have high wind energies. While other areas have high wind energies, but the cost of electricity in that area is low enough that investment in wind turbines is not attractive. For example, Maine has high wind energy but has low cost of electricity, while southern Connecticut has high costs of electricity but little wind energy. Often times wind energy seems most practical when the local price for electricity exceeds 10 to 15 cents/kWh.[27] In addition to revenue from sale and electricity, there are many state and federal incentives available to people who install wind turbines, which be a great source of profit. These should be considered in the cost analysis portion of the project in order to make an accurate assessment of the potential profit.

The earlier research into the winds at the site was a very general investigation of the local winds. While the other factors are being considered, this stage of the process should be developed to give a more detailed and more accurate description of the local winds. For example, previously only the local wind maps of the area would have been analyzed. At this stage in the project, however, the specific wind on

[27] Database of State Incentives for Renewables and Efficiency: http://www.dsireusa.org/, (2009)

the site should be measured for at least one full year to give accurate wind values for each season[28]. The data generated from the in-depth wind analysis will be used to determine more accurately the amount of electricity the wind turbine could generate. This step can be bypassed if a nearby site has been screened for its wind energy. Then the information can be correlated, and this new information would be sufficient for wind energy examination.

In order to obtain a permit for a wind turbine, a feasibility test is often necessary. This test includes many different factors including avian and bat interaction, wildlife/plants/wetlands studies, archaeological and historical reviews, stream crossing and soil disturbance, and local zoning[29]. All of these studies must be done to prove that the turbine will not interfere with the local environment. The feasibility studies add time and cost to the overall construction of a wind turbine, and it is greatly influenced by the public. This part of the process allows the public to learn more about the project and also express their opinions on the construction of the turbine. Public involvement also educates the community about the benefits of wind turbines. This is extremely important in encouraging the societal acceptance of the structures, as well as to the adaption of more wind turbine projects in the future. If the community understands the benefits of wind energy, they are more likely to consider the construction of turbines on their own property.

Social Integration of Wind Turbines

While the technical aspects of wind turbines are a main focus, part of the process of implementing a wind turbine is the social acceptance of the turbines into the areas in which they are being constructed. Studies have been conducted focusing on three main social groups: the public, the community, and the stakeholders. There are different methods used to analyze the factors that influence each individual group.

Typically, researchers will obtain the opinion of the public through surveys and polls related to renewable energy in general as well as wind turbines. In the past, studies have shown that public acceptance does not have a direct correlation between favorable opinions about turbines and the presence of turbines.

Local controversies or issues in the community in which the turbine is being proposed can be looked into to help determine the likelihood of acceptance of wind energy. According to the “Not in My Back Yard”

[28] *Wind Resource Assessment Handbook, AWS Scientific, Inc*. (1997)
[29] National Wind, (September 2009), www.nationalwind.com

theory devised by Maarten Wolsink, “local opposition is often based on distrust, negative reactions to the actors (developers, authorities and energy companies) trying to build the turbines, and the way projects are planned and managed, and not the wind turbines themselves.”[30] Therefore, the “actors” play a large role in whether or not the community will trust these developers or companies to complete the project efficiently.

The stakeholders of the project must also be considered because they are often the policy makers and politicians in the area. Research shows that the financial status of the stakeholders as well as their planning capabilities and past political history can influence their opinions on a large-scale project such as the implementation of a wind turbine.

After the opinions of each group are explored, the most important factors to consider when attempting understanding the reactions of a community to a proposed installation of a wind turbine are:

- The physical and environmental characteristics and potential of the site including facts and figures on how successful a turbine could produce energy at a specific site.
- The individual and collective profile of the community such as their knowledge of wind energy and the demographic (age, gender, nationality, etc).
- The interaction between technology and society.

The most effective way to gather this information is to conduct surveys to establish the current views on wind energy and the past decision-making capabilities of the town and then distribute appropriate information to educate the community and stakeholders about wind energy and the benefits.[31]

Choosing a Turbine Size

The size of a turbine is also considered when establishing a location for the site based on the projected energy needs. The size is determined to be a Utility-, Industrial-, or Residential-scale wind turbine (see Table 1). The manufacturers that produce turbines in the area are researched, and a model of the turbine is chosen based on the size needed to support the site. Economically, it is advised a wind turbine with the largest feasible energy output is chosen for the constraints of the investor and the site because smaller wind turbines are more expensive per kW than larger wind turbines. Regardless of the

[30] *The Social Research on Wind Energy Onshore*, Accessed: January 2010, Wind Energy: The Facts: http://www.wind-energy-the-facts.org/en/environment/chapter-6-social-acceptance-of-wind-energy-and-wind-farms/social-research-on-wind-energy-onshore.html
[31] *The Social Research on Wind Energy Onshore*, Accessed: January 2010

wind turbine size, the controls, electrical connection to grid and maintenance are a much higher proportion of the capital value of the system. Larger wind turbines are more successful in offsetting operating costs because of the larger energy output.

Planning Process of Wind Turbine Installation

There are various stages and people involved in the planning process of determining the feasibility of a wind turbine. This can involve social and political issues including permitting and approval through town meetings. Figure 3 is a flowchart which summarizes the general steps, individuals, and organizations involved in the planning process of the installation of a wind turbine.

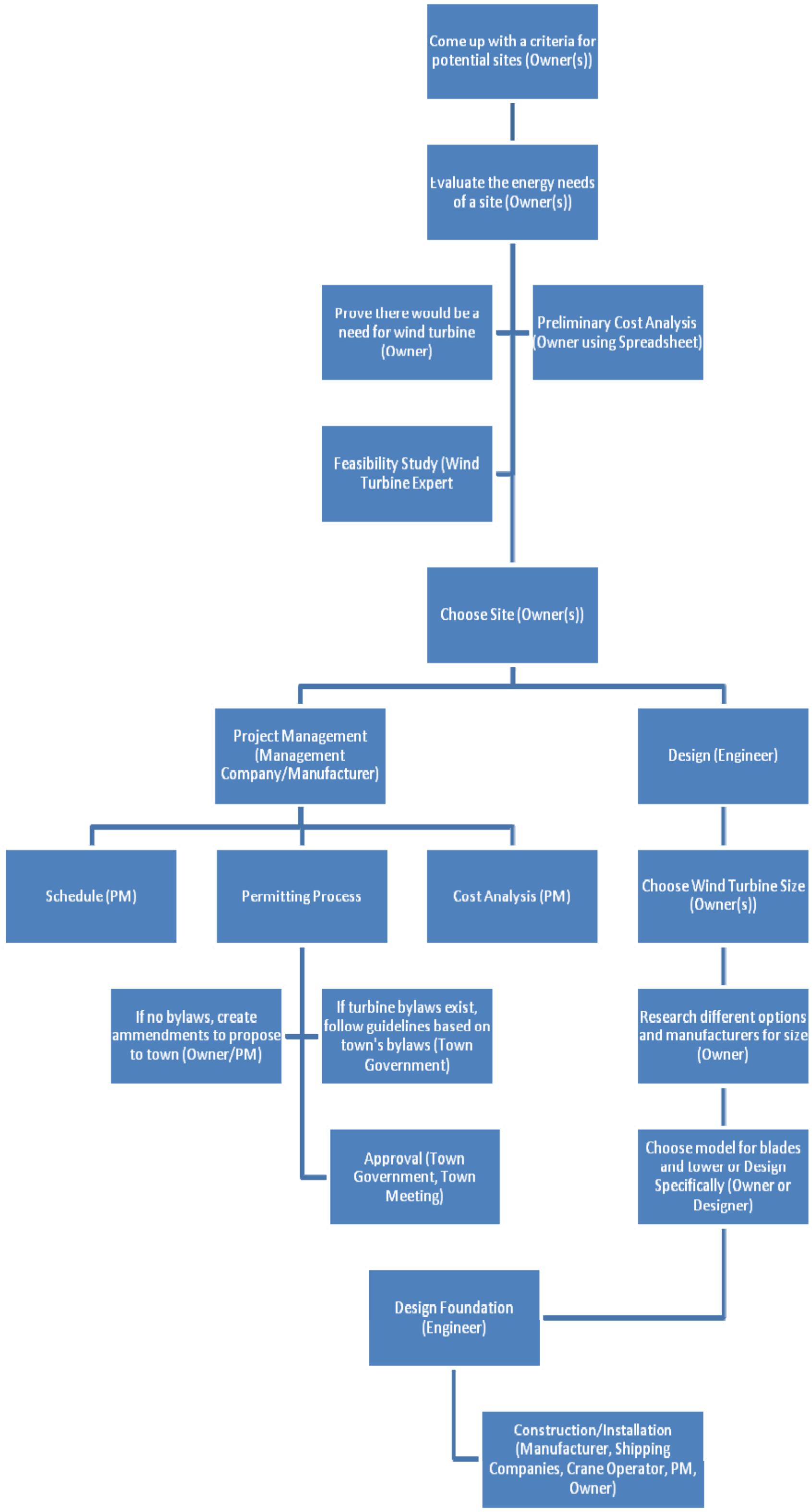

Figure 3: Planning Process of Installing a Wind Turbine

Wind Turbine Design

The structural design of a wind turbine consists of two main parts: its tower and its foundation. The tower design is based primarily on wind and ice loads, loads acting from the rotor, nacelle, blades, and additional equipment at the top of the tower in addition to wind loads acting on the tower. The foundation is designed according to the moment and axial loads resulting from the tower design and the properties of the supporting soil.

Tower

The tower is designed to resist the loads acting on it based on the desired scale of the wind turbine and desired hub height. A taller tower translates to an exponential increase in the amount of wind that is being harvested from the wind turbine because wind speed increases as the harvest height increases. The "increase factor" of the wind speed increases exponentially as the height above a surface increases, as shown in Figure 4.[32] From this graph, one can see that at low heights, the wind speed increases significantly at first, but at higher elevations the rate of increase is much less.

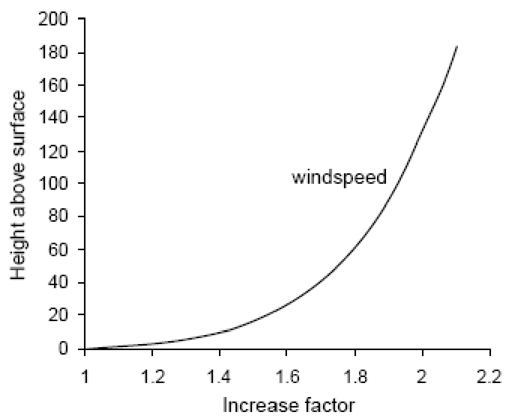

Figure 4: Increase Factor Due to Height of Tower

The wind speed will also vary due to the surrounding area.[4] The increase factor of wind speeds is higher in open areas (such as over a body of water) than in highly vegetated areas (such as wooded or built- up areas). Through years of experience, turbine manufacturers and consultants have recommended that a turbine should be at least 30 feet higher than any object within 300 feet.[33] This rule of thumb is used to avoid rapid changes in wind velocity and direction, or turbulence. The wind speeds must be maximized

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[32] *Energy Effiiciency and Renewable Energy Clearinghouse,* (September 2009), www.greenenergyohio.org

[33] Gipe, P. (2004).

and direction constant at the blades of the turbine in order to maximize the productivity of the wind turbine. A reduction in turbulent winds also reduces the wear and fatigue on the wind turbine.[34]

The most widely used design of a wind turbine tower today is a freestanding, continuously tapered, cylindrical hollow steel monopole.[35] The conical shape is efficient in simultaneously increasing the tower strength and saving materials as well as reducing the exposed profile for wind forces at higher elevations.[36] The tower is constructed in sections from rolled steel at a desired thickness, and is transported on site and bolted and/or welded together to create the massive towers.

The design of a wind turbine tower is dependent on the criteria outline in Table 2. The codes used in conjunction with the design method are also listed. It is the responsibility of the engineer to design the wind turbine tower against local buckling, bending and combined axial and bending failures.

Table 2: Tower Design Criteria

Design Factor	Design Criteria	Design Codes
Dead Load	Consists of the self weight of the tower, the turbine equipment at the top of the tower, and ice loads	Massachusetts Building Code
Wind Load	Wind profile is approximated along small sections of the tower	TIA/EIA-222
Local Buckling	Considers a column's slenderness ration, resist failure due to high axial compressive loads	AISC
Flexural Failure	Resist failure due to high bending moments inducing tensile strength in a cross section that is greater than the yield strength	AISC
Combined Axial and Bending loads	Considers the combined failure due to combined axial and bending loads with a magnification factor on the bending stress, B_2	AISC

[34] Hansen, P. *Modular towers and the quest for stronger wind*, (2010, February 10). http://www.windpowerengineering.com/tag/modular-towers/
[35] Hansen
[36] *Wind Turbine Towers* (19 Sept 2003). Retrieved January 2010 from Danish Wind Industry Association: http://guidedtour.windpower.org/en/tour/wtrb/tower.htm

Foundation

The foundation of a wind turbine is designed for the worst-case loading. The turbine foundation has to resist great loads mainly because of the overturning moment due to wind and must simultaneously resist forces from geotechnical conditions.[37] Reinforced concrete spread footings are most common in design because they are applicable to a wide range of soil strengths, however for some weaker soils a deeper foundation is needed to stabilize the turbine tower.[38] The main components in designing a spread footing are its width, depth, amount of steel reinforcement, and construction requirements.

The essential foundation design criteria are stiffness, strength, stability, differential settlement, durability, and economy. These minimum values for foundations are usually provided by the turbine manufacturers' design specifications. Table 3 below lists the design factor, its design criteria, and any design codes or standards that are used in conjunction with the criteria.[39]

Table 3: Foundation Design Criteria

Design Factor	Criteria	Design Codes/Standards
Strength	Withstand factored loads and fatigue loads	ACI
Stability	Resist excessive translational and rotational movement under extreme loads	ACI
Settlement	Considers soil criteria to ensure adequate bearing capacity	Geotechnical Standards
Durability	Resist environmental damage to concrete and maintain serviceability for the turbine's lifetime	ACI

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[37] Morgan, K., & Ntambakwa, E. (2008, June). Retrieved September 2009, from AWEA Windpower Conference, Houston: www.garradhassan.com/downloads/reports/Wind_Turbine_Foundation_Behavior_and_Design_Considerations.pdf

[38] *Wind Energy Basics,* American Wind Energy Association.

[39] *Installed U.S. Capacity and Wind Project Locations.* U.S. Department of Energy.

Chapter 3: Methodology

When designing a wind turbine, there are different alternatives to the design factors associated with the site that is chosen to build upon. As seen in Table 4 several alternatives of each design component were analyzed to explore the affect of each alternative on the overall design. The first column in Table 4 displays the specific design component, the second column displays alternatives to the design component to consider, and the third column displays what other design factors play into designing that particular part of the turbine.

Table 4: Design Factor Alternatives for Consideration

Design Component	Alternatives to Consider	Design Factors to Consider
Soil Profile	1. Sandy-Gravel 2. Clayey (2000 psf) 3. Rocky (6500 psf)	Strength of Soil
Foundation Type	1. Spread 2. Monopile (Offshore)	Soil Profile, Turbine Size, Number of Blades, Tower Design, Wind Speed, Tower Location
Turbine Size	1. Small Scale 2. Mid-scale 3. Large Scale	Type of Site, Distribution
Number of Blades	1. Two Blades 2. Three Blades	Wind Speed, Tower height
Tower Design	1. Width 2. Height 3. Shape	Wind Speed, Surrounding Terrain, Turbulence
Distribution	1. Behind the Grid 2. Sell to the Grid	Energy needs of the Site

The following flow chart in Design Figure details the process of designing the wind turbine:

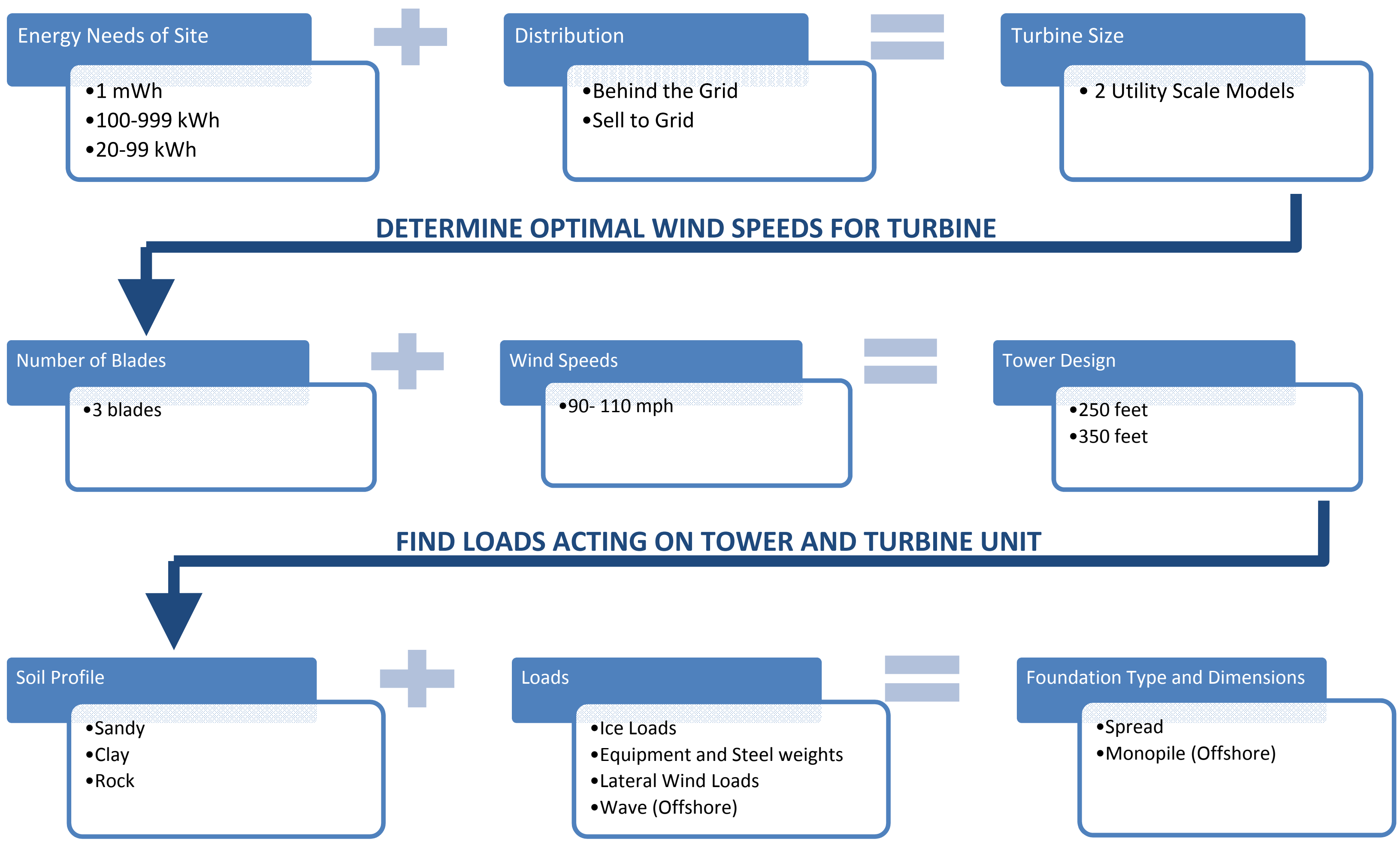

Figure 5: Flow Chart of Wind Turbine Design

Through research and calculations, this project determined how the different alternatives to the design components affected the overall design of the turbine and is discussed in the subsequent sections. The following three sections were outlined: the tower design, foundation design, and the project analysis. Each section was researched individually and eventually was compared with the other two sections.

The individual design sheets for the tower design, foundation design, and project analysis were developed individually throughout the course of this project. When the design sheets were finalized, they were linked together in order to create one completely integrated spreadsheet which produced output sheets that summarized important information regarding Energy Output, Financial Analysis, Foundation Design, and Tower Design. With little knowledge about the specific calculations, a user can use this spreadsheet simply by inputting common information outlined in a user friendly main page and check if their wind turbine project is feasible. The following chapters will elaborate on the methodologies of the tower design, foundation design, and project analysis.

Chapter 4: Tower Design

The tower was designed in accordance with the latest edition of the *Massachusetts State Building Code (780 CMR)* and *AISC Steel Construction Manual*. The material used to design the tower is A36 steel plates, which can be formed and welded in sections to create the tower. Loading conditions on the tower were determined through local wind speed data from *780 CMR*, and dimensions of the tower were later established based on Load and Resistance Factor Design (LRFD). Two tower heights were chosen for design, one at 250 feet and another at 350 feet (standard heights for utility-scale wind turbines).

Loading Conditions

Since there are no regulations specific to loading conditions for wind turbine towers in the *Massachusetts State Building Code*, the tower was modeled per *780 CMR 3108.0* for Radio and Television Towers. It is an industry standard to use this section of the *Building Code* because the shape of a tapered, cylindrical steel radio or television tower is comparable to that of a wind turbine tower.[40]

Section 780 CMR 3108.0 details *Location and Access* (3108.2), *Construction* (3108.3), *Loads* (3108.4), and *Grounding* (3108.5). For structural design purposes, the section that is of most concern is *Loads* and takes into consideration both dead loads and wind loads.

Axial Loads

It is stated in *CMR 3108.4.1* that "towers shall be designed for the dead load plus the ice load in regions where ice formation occurs," which is the case for New England. The dead load components of a wind turbine are summarized in Table 5 below:

Table 5: Axial Load Components

Axial Load Component	Weight	Method/Standard
Equipment at top of tower	400 to 700 kips for utility-scale turbine	Research from existing turbines
Steel Tower	$[V_{steel}\,(ft^3)]*[\gamma_{steel} = 0.490$ k/cf]	Basic geometric principles for determining volumes
Ice	$[V_{ice}\,(ft^3)]*[\gamma_{ice} = 0.056$ k/cf]	ASCE-7-05 Design Formulas

The equipment at the top of the tower includes the rotor, blades, nacelle, and all other mechanical components. The thickness of ice is determined through ASCE-7-05 design equations as follows:

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[40] Lagadimos, F. (2009, December 8).

$$t_d = 2.0 t I_i f_z (K_{zt})^{0.35}$$

where:

the nominal thickness of ice *t* is obtained from the design maps in ASCE-7-05 Chapter 10; ranges from 0.75” to 1” for Massachusetts,

importance factor I_i is 0.8 for category I structures,

$f_z = (\frac{z}{33})^{0.1}$, *z* is the mid-height of the tower section, and

K_{zt} does not apply, assuming no wind speed up.

This design ice thickness is then used in the following equation to obtain the cross-sectional area of ice,

$$A_i = \pi t_d (D_c + t_d)$$

where D_c is the diameter of the tower. The use of design spreadsheets were used to determine the axial loads through repetitive calculations. These dead loads will act vertically downward on the tower and supporting foundation.

Lateral Loads

CMR 3108.4 specifies that the tower “shall be designed to resist wind loads in accordance with *TIA/EIA-222*,” the *Structural Standards for Steel Antenna Towers and Antenna Supporting Structures*. A horizontal wind force was applied on the tower, and a separate horizontal wind force was applied to the equipment at the top of the tower, which was considered a discrete appurtenance. The wind loading along the tower height was defined in 1’ sections to obtain an accurate wind profile and resultant load (due to the varying section height from the ground, and also average section diameter because of the taper).

The horizontal force (F, lbs) applied to each section along the tower height was calculated from the following equation: [41]

$$F = q_Z G_H [C_F A_E + \sum(C_A A_A)] \leq 2 q_Z G_H A_G$$

To use the force equation, the following values were obtained from the provisions of *TIA/EIA-222*:

[41] *TIA/EIA-222 Structural Standard for Antenna Supporting Structures and Antennas* (June 1996). Telecommunications Industry Association.

velocity pressure $q_Z = 0.00256 K_Z V^2$ for wind speed *V* in mi/h,

gust response factor G_H is 1.69 for tubular towers,

force coefficient C_F is 0.59 for tall cantilevered tubular pole structures,

effective projected area of structural components in one face A_E is equal to the tower's height multiplied by its diameter,

$\sum(C_A A_A)$ applies to linear appurtenances (does not apply to wind turbine tower),

and A_g is the gross area of one tower face in ft^2 (for tubular tower, $A_g = diameter \times height$).

For the velocity pressure q_Z, the exposure coefficient $K_Z = [\frac{z}{33}]^{2/7}$ where $1.00 \leq \mathrm{K_Z} \leq 2.58$, *V* (mi/h) is the basic wind speed measured in the fastest mile, and *z* is the height above the average ground level to the midpoint of the section. The basic wind speed was obtained from the *Massachusetts State Building Code (780 CMR)*, where the basic wind speeds are listed for each individual city in Massachusetts in units of 3-second gusts. The wind speed must be converted from 3-second gust to fastest mile using the equation $V_{FM} = V_3 \frac{V_t/3600}{1.53}$. First, the gust duration $t = \left(3600\, {}^{s}/_{mi}\right)/V_3$ was calculated where V_3 = 3-second gust speed in miles/hour. Then, *Vt* was found using the design chart in Figure 6 from ASCE-7-05 by matching t along the x-axis, drawing a vertical line to the durst line, and from there drawing a horizontal line over to the y-axis to find the corresponding $V_t/3600$ sec/hr value to use in the equation.

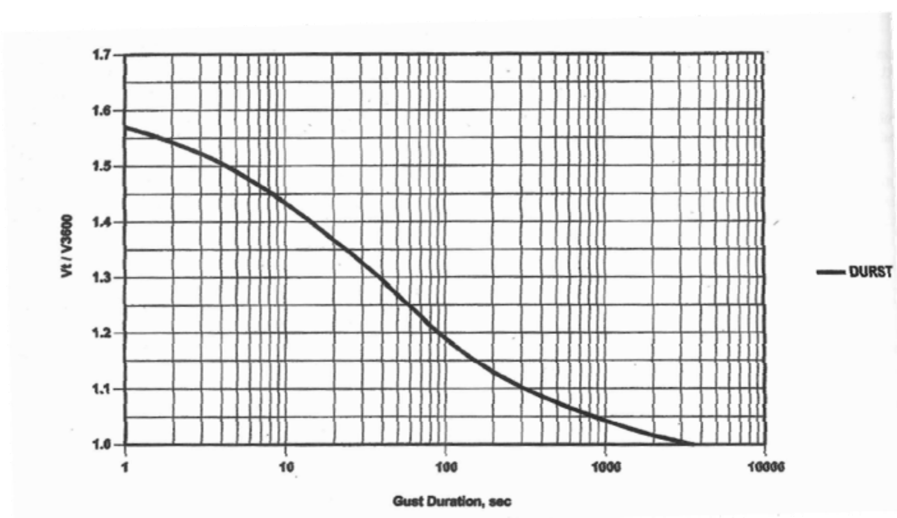


Figure 6: Wind Speed Conversion Table, *Massachusetts State Building Code (780 CMR)*

For instance, the specified 3-second gust speed for Worcester is 100 mph, which corresponds to a wind speed V_t equal to 87 mph. When using a tower height of 250 feet, a constant diameter of 10 feet, and a design wind speed of 87 mph in Worcester, the design wind profile in one foot increments is shown in Figure 7.

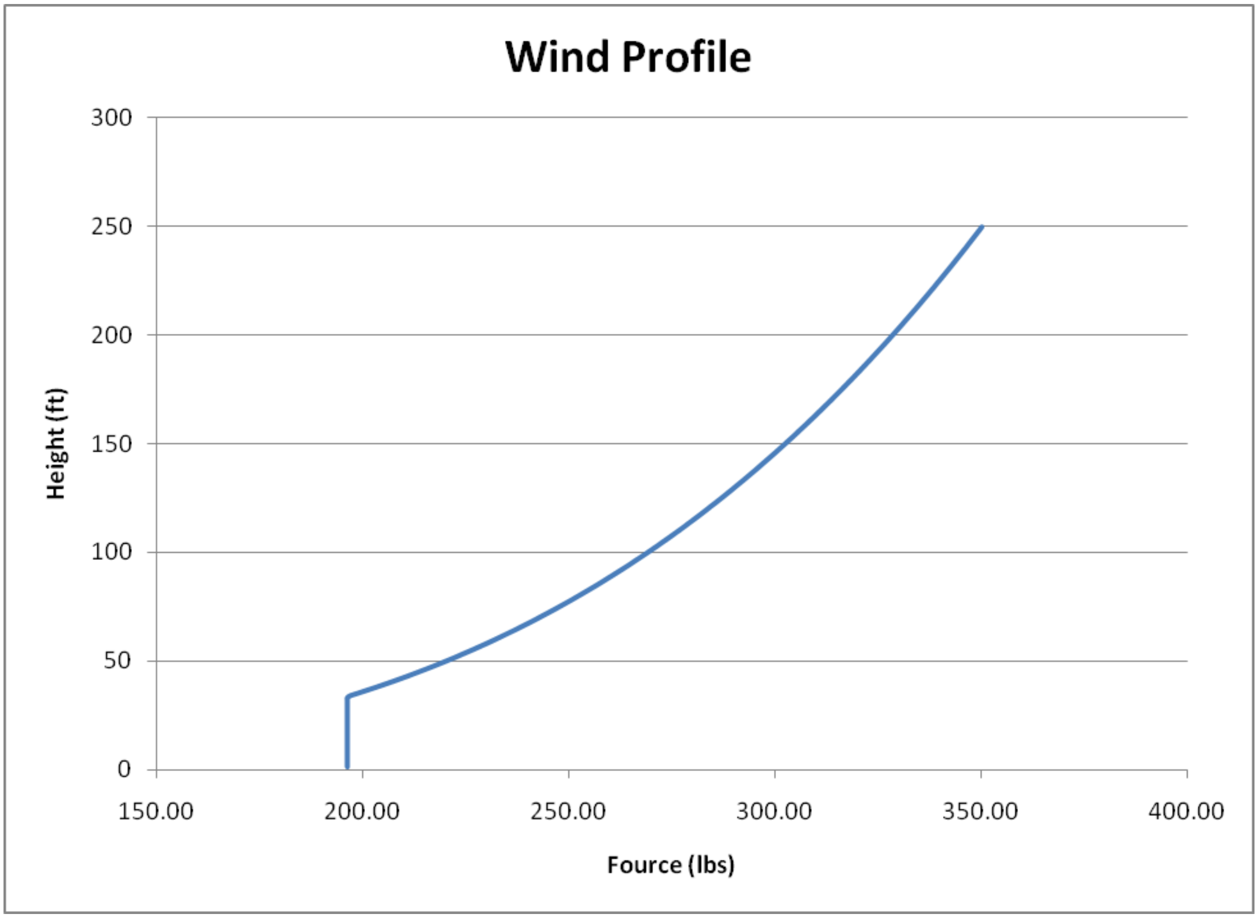


Figure 7: Example Wind Profile Graph

The point force F_c for the discrete appurtenance will act on the center of the hub (normal to the plane of the spinning blades). The design wind load F_C is calculated from the following equation: [42]

$$F_C = q_Z G_H [\sum C_A A_C]$$

where the velocity pressure q_Z and gust response factor G_H uses the same calculations as stated above for the force on the tower and $\sum C_A A_C$ takes into account all elements related to the appertenance (in

[42] *TIA/EIA-222* (June 1996).

this case, the three blades). The force coefficient C_A is equal to 1.2 for the long cylindrical blades and acts on the projected area A_C of the discrete appurtenance.

Load Design Spreadsheet

In order to facilitate the repetitive calculations, a design spreadsheet was created in Microsoft Excel that calculates the axial and lateral forces as well as the moment for each one foot section of the tower. Figure 8 below summarizes the calculations of the axial and lateral loads for every one foot section of the tower for the top and bottom five feet of the tower.

Required Strength

Weight of Equipment:	400	kips
Height of tower	250	ft
Outer Diameter at base	8	ft
Outer Diameter at hub	7	ft
Thickness	0.75	in
Weight of Steel	490	pcf
Town (Massachusetts)	Rutland	
t_{ice}	0.083333333	

Total Design Loads

Axial Load	774.40	kips
Moment Load	6956.00	ft-kips
Total Shear	52.00	kips

Values used to calculate the axial loads (Height through td); Values used to calculate the lateral loads (Diameter through Moment)

Height	*Volume of Steel*	*Weight of Steel*	*Volume of Ice*	*Weight of Ice*	*Fz*	*td*	*Diameter*	*z*	*1≤Kz≤2.58*	*q_z*	*Ag*	*Force*	*Moment*
1	1.56	0.76	2.23	0.12	0.66	0.09	8	0.5	1.00	19.38	8.17	0.1578	0.0789
2	1.56	0.76	2.49	0.14	0.73	0.10	8	1.5	1.00	19.38	8.17	0.1578	0.2367
3	1.56	0.76	2.62	0.15	0.77	0.10	8	2.5	1.00	19.38	8.17	0.1578	0.3945
4	1.56	0.76	2.71	0.15	0.80	0.11	8	3.5	1.00	19.38	8.17	0.1578	0.5522
5	1.56	0.76	2.78	0.16	0.82	0.11	8	4.5	1.00	19.38	8.17	0.1578	0.7100
246	1.36	0.67	3.67	0.21	1.22	0.16	7	245.5	1.77	34.38	7.17	0.2457	60.3461
247	1.36	0.67	3.67	0.21	1.22	0.16	7	246.5	1.78	34.42	7.17	0.2460	60.6622
248	1.36	0.67	3.67	0.21	1.22	0.16	7	247.5	1.78	34.46	7.17	0.2462	60.9786
249	1.36	0.67	3.67	0.21	1.22	0.16	7	248.5	1.78	34.50	7.17	0.2465	61.2954
250	1.36	0.67	3.67	0.21	1.22	0.16	7	249.5	1.78	34.54	7.17	0.2468	

Figure 8: Required Strength Design Sheet

To account for the taper in the tower height, the tower was broken into five sections with an average diameter for that section. The total design loads that are to be used in calculating the available strengths are the sum of the forces acting on each individual one foot sections.

Design for Stresses

Once loading conditions were established, the wind turbine tower was designed using the LRFD approach to design for the tower diameter and the thickness of the shell. The *Manual of Steel Construction LRFD, 3rd ed.* by the American Institute of Steel Construction requires that "all steel structures and structural elements be proportioned so that no strength limit state is exceeded when subjected to all required factored load combinations" by ensuring that the factored loads do not exceed the ultimate strength of the tower:[43]

$$\varphi R \geq \gamma Q$$

In the previous equation, *R* is the resistance of the steel, *Q* is the applied load, φ'_b is a strength reduction factor and γ is a load factor. Table 6 below summarizes the design equations that were used for the design of the wind turbine tower and were based on the *Manual of Steel Construction LRFD, 3rd Edition*[44].

Table 6: Tower Design Equations for Available Strength

Design Component	Design Equation	Description
Axial Strength	$P_u \leq \varphi F_{cr} A_g$	Factored axial loads must not exceed the reduced axial capacity, which is the critical load multiplied by the gross area.
Flexural Strength	$M_u \leq \varphi F_y Z$	Check strength: ultimate flexure must not exceed the steel strength multiplied by its section modulus
	$M_u \leq \varphi \left[\dfrac{0.021E}{\frac{D}{t}F_y} + 1\right] F_y S$	Check local buckling (for non-compact members only): the flexural strength should be greater than the required moment strength, takes slenderness into account
Combined Axial and Flexural Strength	$\dfrac{P_r}{P_c} + B_2 \dfrac{8}{9}\dfrac{M_r}{M_c} \leq 1.0$	Checks that member under combined forces will not fail by taking ratio of required strength to available strength. Moment is multiplied by magnification factor of B_2 that considers lateral stability.
	$\dfrac{P_r}{2P_c} + B_2 \dfrac{8}{9}\dfrac{M_r}{M_c} \leq 1.0$	

The stresses in the tapered tower were analyzed for five different sections to account for the varying cross-sectional geometry. The magnification factor B_2 found in the combined axial and flexural strength equations takes into account the shear loads on the structure lateral deflection of the tower, which was

[43] *Manual of Steel Construction LRFD, 3rd ed (2001).* American Institute of Steel Construction Inc.
[44] *Manual of Steel Construction LRFD, 3rd ed.*

found through using ANSYS, a computer analysis program. The tower was entered as a beam with five separate sections to assume different properties. The results of the ANSYS analysis can be found in Appendix C.

Flexure Strength	
Factored Load	83472.00 in-kips
Reduced Strength	220467.83 in-kips
Yielding Mn	244964.25
Local Buckling	216128.81
Check for Compact section:	
D/t	128.00
λp	56.39
λc	249.72
non-compact	
Flexure Strength:	OK

Combined Loads	
Combined Loading	0.8621 ≤1.0 **OK**
Pu/Pc	0.5133
For Pu/Pc≥0.2	0.8621
For Pu/Pc<0.2	0.6054
Magnification Factors	
B2	1.04
Pnt	774.40
Pe2	22100.00
∑H	52.00
ΔH	6.00
L	3000.00

Figure 9 below shows the checks for the axial, flexural, and combined strength using the design equations listed above.

Available Strength

User Input	
Overall height	250 ft in
Diameter at Base	8 ft in
Shell Thickness	0.75 in
Strength of Steel	36 ksi
Modulus of Elasticity	29000 ksi

Section Properties	
ID	94.50
S	5302.76
Z	6804.56
r	33.68
I	254532.37

Axial Strength	
Factored Load	774.40 kips
Reduced Strength	1508.54 kips
Pn	1774.75
Fcr	7.91
KL/r	178.16
4.71*sqrt(E/Fy)	133.68
Fe	9.02
Fcr for KL/r≤4.71*sqrt(E/Fy)	6.77
Fcr for KL/r>4.71*sqrt(E/Fy)	7.91
Ag	224.43
Check for Compact section:	
D/t	128.00
λp	
λc	88.61
noncompact	
Axial Strength:	OK

Flexure Strength	
Factored Load	83472.00 in-kips
Reduced Strength	220467.83 in-kips
Yielding Mn	244964.25
Local Buckling	216128.81
Check for Compact section:	
D/t	128.00
λp	56.39
λc	249.72
non-compact	
Flexure Strength:	OK

Combined Loads	
Combined Loading	0.8621 ≤1.0 **OK**
Pu/Pc	0.5133
For Pu/Pc≥0.2	0.8621
For Pu/Pc<0.2	0.6054
Magnification Factors	
B2	1.04
Pnt	774.40
Pe2	22100.00
∑H	52.00
ΔH	6.00
L	3000.00

Figure 9: Available Strength Design Sheet

This design sheet allows the user to modify the diameter and shell thickness of the wind turbine tower to determine an acceptable design. The spreadsheet shows the previously calculated required strength, shown in orange, and compares it to the calculated available strength, in blue. If the dimensions entered satisfy the design criteria (required strength does not exceed the available strength), the design is deemed "OK" shown in the yellow boxes. If the dimensions entered do not satisfy the design criteria (required strength exceeds the available strength), the design is deemed "N.G." for no good, and either the thickness of the shell or the diameter must be increased.

Flange Design

The design of the tower flange at the base was also considered in order to effectively attach the tower to its foundation. Since 1 ½" diameter rods were used in the anchor bolt design (see Chapter 5: Foundation Design for equations used to design the connections), the minimum edge distance was based on 12 times the diameter of the rod, which is 7 ½" from the edge, or 15" centered on the flange. The flange width was checked for flexural strength using the equation $M_u \leq \varphi F_y Z$, and also checked for shear in yield and ultimate strength. Finally, the thickness was calculated based on the nominal moment at the outside edge of the tower base using the equation $\geq \sqrt{\frac{6M_u}{\varphi_b F_y}}$, where φ_b is 0.9. Note that the flange design was not included in the design sheets because it is very case-specific based on the anchor bolt design. Supporting calculations can be found in Appendix C.

Design Summary

The designs of the 250 foot tower are as follows. Figure 10 shows the overall tower dimensions, which includes the height, and base and hub dimensions. It also shows the steel tower with reasonably-sized turbine equipment attached. Figure 11 depicts the base detail, including the flange design. The bolt design is also shown, which is later designed in Chapter 5: Foundation Design.

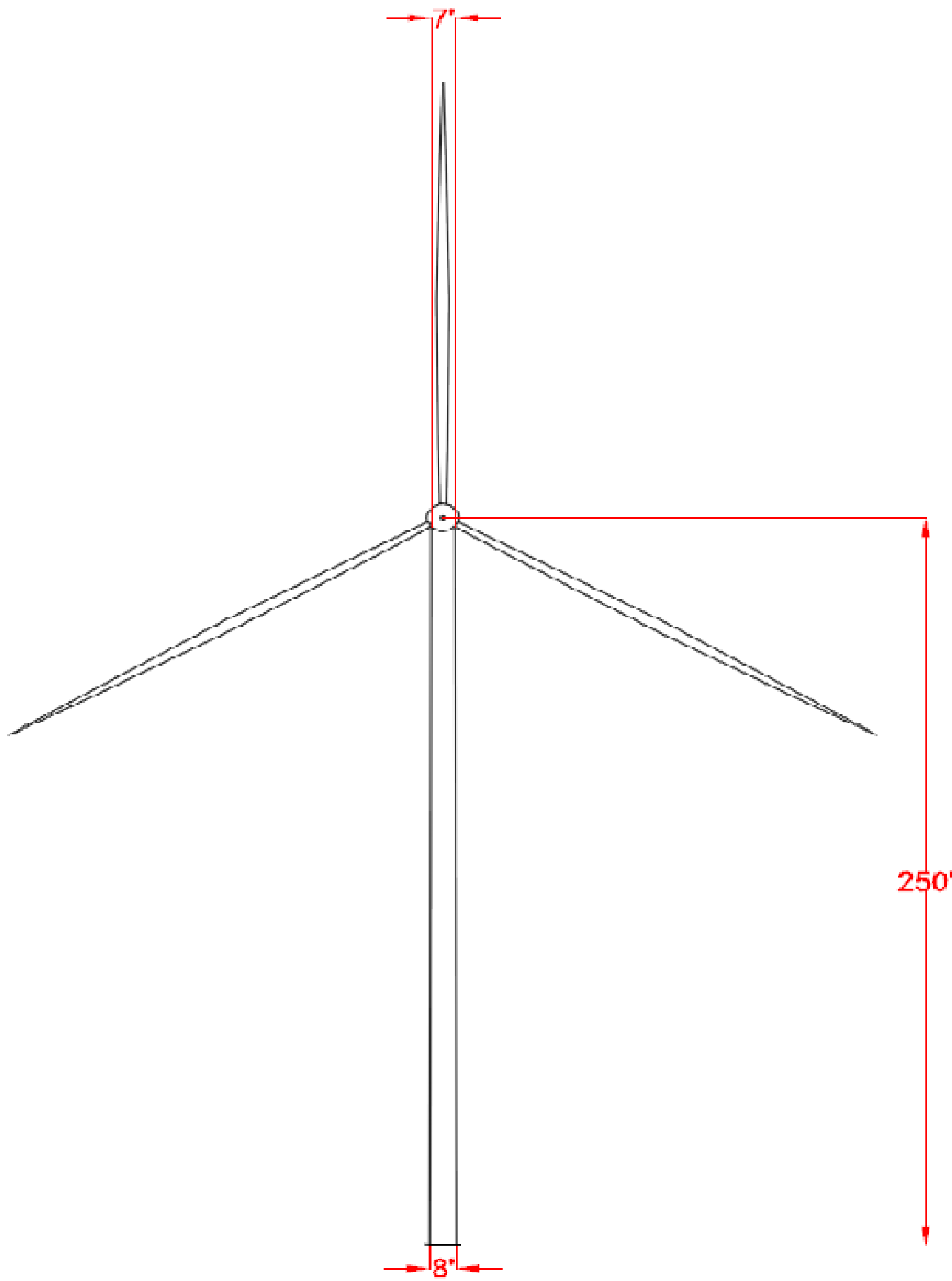


Figure 10: Overall Tower Dimensions

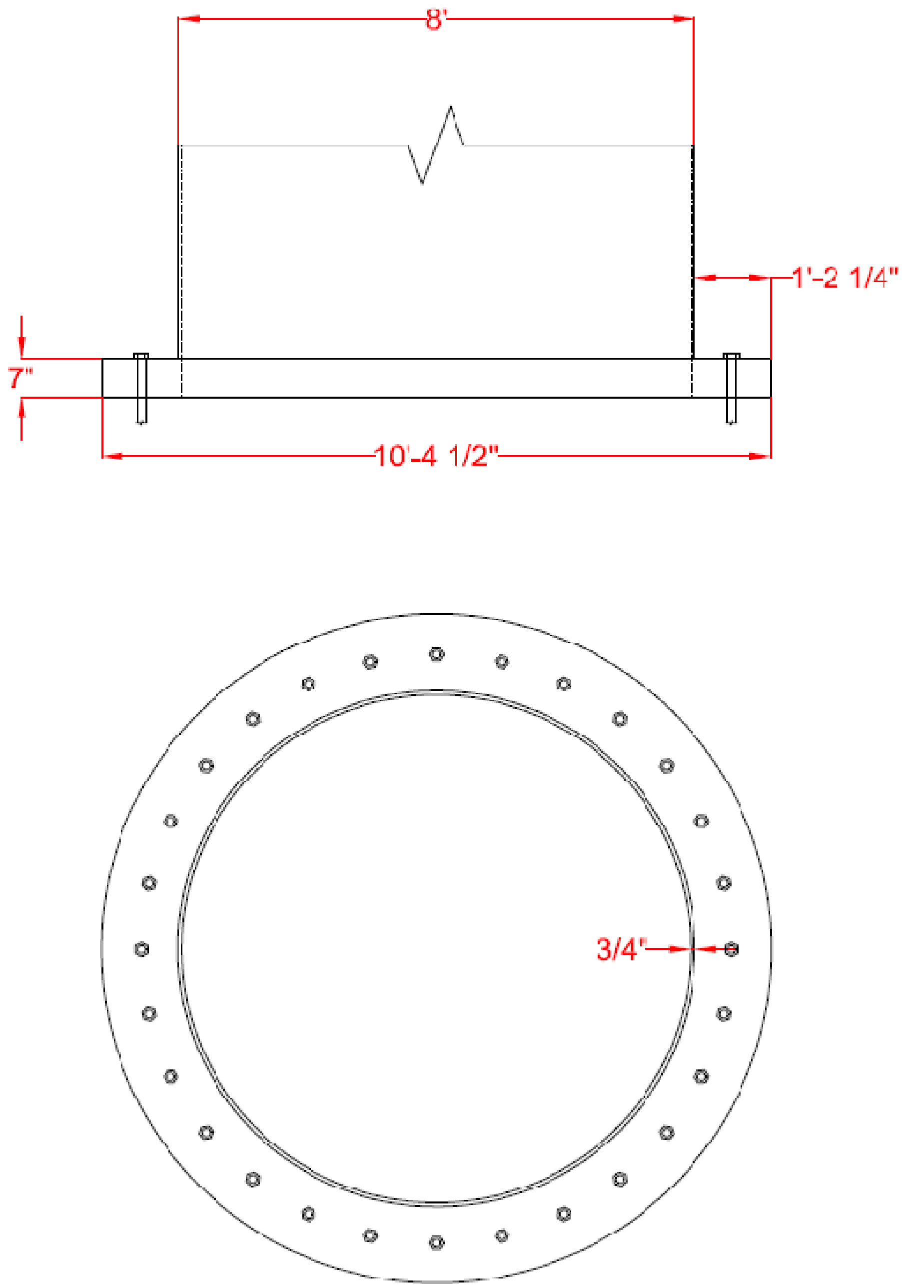


Figure 11: Tower Base Detail

Discussion of Data

The design loads and materials are summarized for a 250 foot and 350 foot tower in the following table.

All supporting calculations can be accessed in Appendix C: Supporting Calculations, including the associating design sheets to compare to the hand calculations. The foundation design and project analysis of the 250 foot and 350 foot towers will also be examined in the appropriate chapters for consistency. Table 7: Tower Design Data for Varying HeightsTable 7 shows the criteria that were used for the varying tower heights.

Table 7: Tower Design Data for Varying Heights

Design Criteria	250' Tower	350' Tower
Diameter at base	8 feet	12 feet
Diameter at hub	7 feet	10 feet
Shell thickness	3/4 in.	3/4 in.
Strength of steel	36 ksi	36 ksi
Modulus of Elasticity	29,000 ksi	29,000 ksi
Total axial load acting at tower base	774.4 kips	1206.9 kips
Total moment acting at tower base	6956.0 ft-kips	21637.7 ft-kips
Total shear load acting at tower base	52.0 kips	115.5 kips

By examining this table, it is important to note that with a tower height increase of 40 percent, the axial load acting at the tower base increases by just over 40%; however the moment on the tower increases by over 200%. Therefore, the design will most likely be governed by the required flexural strength.

In order to determine the effects of different wind speeds on a turbine design, Table 8 was produced for the design data of three different towns in Massachusetts with varying wind speeds and a constant tower height of 250 feet, steel strength of 36 ksi, and modulus of elasticity of 29,000 ksi.

Table 8: Tower Design Data for Varying Windspeeds

Design Criteria	Lee	Belmont	Yarmouth
Design Windspeed (3-sec gust)	90 mph	105 mph	120 mph
Diameter at base	8'-3"	8'-3"	8'-6"
Diameter at hub	7'-6"	7'-6"	7'-6"
Shell thickness	1/2 in.	3/4 in.	3/4 in.
Total axial load acting at tower base	669.7 kips	757.7 kips	748.7 kips
Total moment acting at tower base	5587.9 ft-kips	7878.0 ft-kips	10553.0 ft-kips
Total shear load acting at tower base	41.5 kips	58.5 kips	78.8 kips

The supporting design sheet calculations are referenced in Appendix D. The loads acting on the wind turbine have a minimal increase by increasing the design windspeeds by 15 miles per hour. In turn, there is little change in the design of the tower. However, as noted in the background section, a small increase in windspeed produces an exponential increase in power output and in turn increasing profit.[45]

[45] *Energy Effiiciency and Renewable Energy Clearinghouse,* (September 2009),

Chapter 5: Foundation Design

When designing the foundation of a wind turbine, there are many factors that engineers must take into account including loading and geotechnical conditions. Spread, drilled, and anchored footings can be used for turbine foundations. Spread footings are some of the most common foundation designs for modern turbines.[46] Several different shapes of spread footings are used for turbine foundations including circular, hexagonal, octagonal, and square. Since there are no specific codes for wind turbine foundation design, ACI standards were used in developing the procedure. The textbook, *Reinforced Concrete Design,* was used as a major source for the steps and equations involved in the design process.

The following chapter will explain the procedure used for designing a square spread footing as well as the directions for the use of the spreadsheet to aid in the design process. Hand calculations supporting the spreadsheet can be found in Appendix E. Figure 12 shows the general procedure for designing a square spread footing.

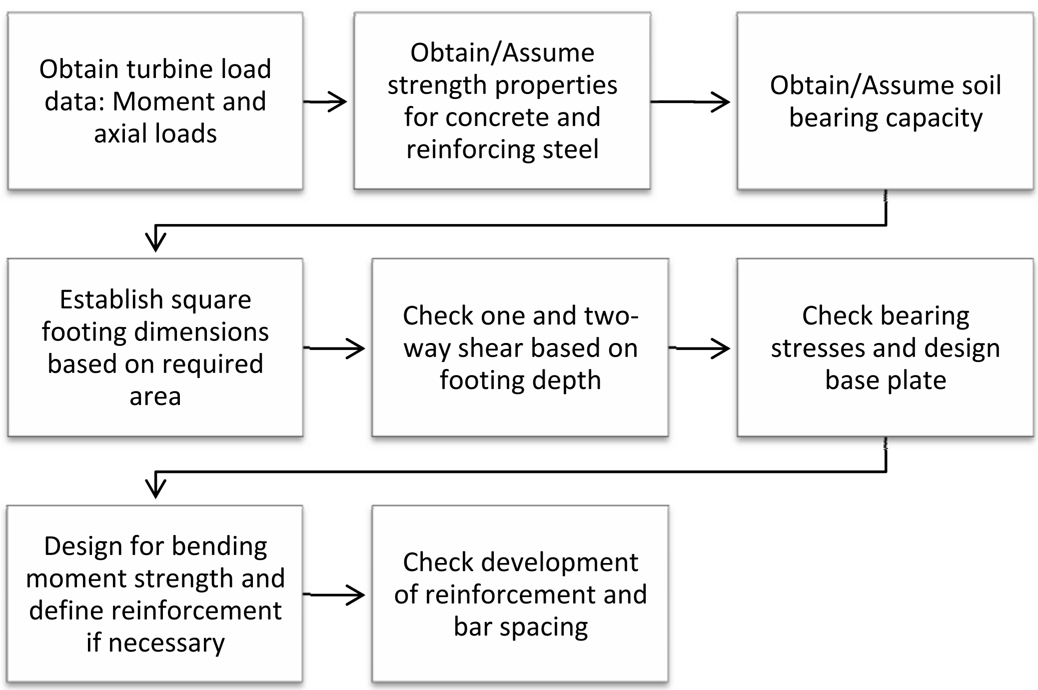


Figure 12: Steps for the Design of a Square Spread Footing

[46] Ischebeck, D.-I. E. (n.d.). *Combination Spread Footing with Micropiles as Foundation for Wind Turbines.* Retrieved November 2009, from www.contechsystems.com/Articles/CSFM.pdf

Footing Dimension Design

The wind turbine foundation can be designed using the data from the analysis of the tower. This information includes the axial load, lateral moment, and the diameter at the base of the tower. Other design factors, such as the bearing capacity of the soil and the concrete strength properties used for the foundation, influence the design and can either be obtained from actual site data or assumed for initial calculations.

After the tower data and the soil and concrete data are established, they can be used to estimate the pressure of the footing and the required area. The pressure of the footing must also be calculated using a trial size for the depth of the footing and an assumed unit weight of concrete. For the purposes of this project, the standard value of 150 pounds per cubic foot was used and the average footing depth for wind turbine spread footing foundations typically do not exceed 6 feet.[47] The axial load of the column and the net pressure of the soil, found by subtracting the pressure of the footing from the allowable soil pressure, are used in the equation below for the required area:

$$required\ A = \frac{Pu}{p_{net}}$$

Where Pu is the factored axial load in kips from the tower load data and p_{net} is the net soil pressure in ksi. Once the required area is calculated, the square root of this number can be used as the trial size for the square footing. Figure 13 below shows depicts the forces acting on the footing.

[47] RAM/STAAD Solution Center. Bentley: *RAM/STAAD Solution Center*. (December 2009), ftp://ftp2.bentley.com/dist/collateral/Web/Building/STAADPro/Wind_Turbine_Footing_Design.pdf

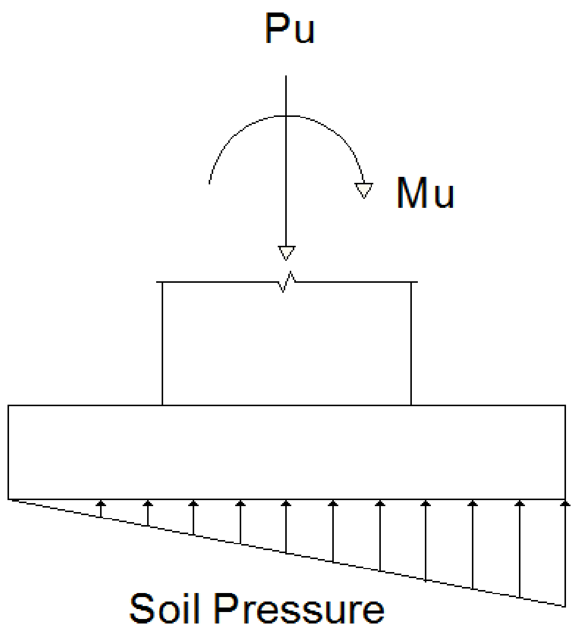


Figure 13: Loading Model and Soil Pressure on Footing

The eccentricity, e, must be calculated in order to determine if the suggested side footing length, B, is adequate by satisfying the following inequality:

$$e = \frac{M_u}{P_u + W_f} \leq \frac{B}{6}$$

Where W_f is the weight of the footing in psf. This check of eccentricity is done to verify that the resultant force on the footing acts within the kern of the cross section and ensures that there are only compressive stresses between the foundation and the soil. In addition, the equivalent soil bearing pressure, q_{equiv}, must be checked to ensure that it is less than the allowable bearing pressure, q_a, using the equations below[48]:

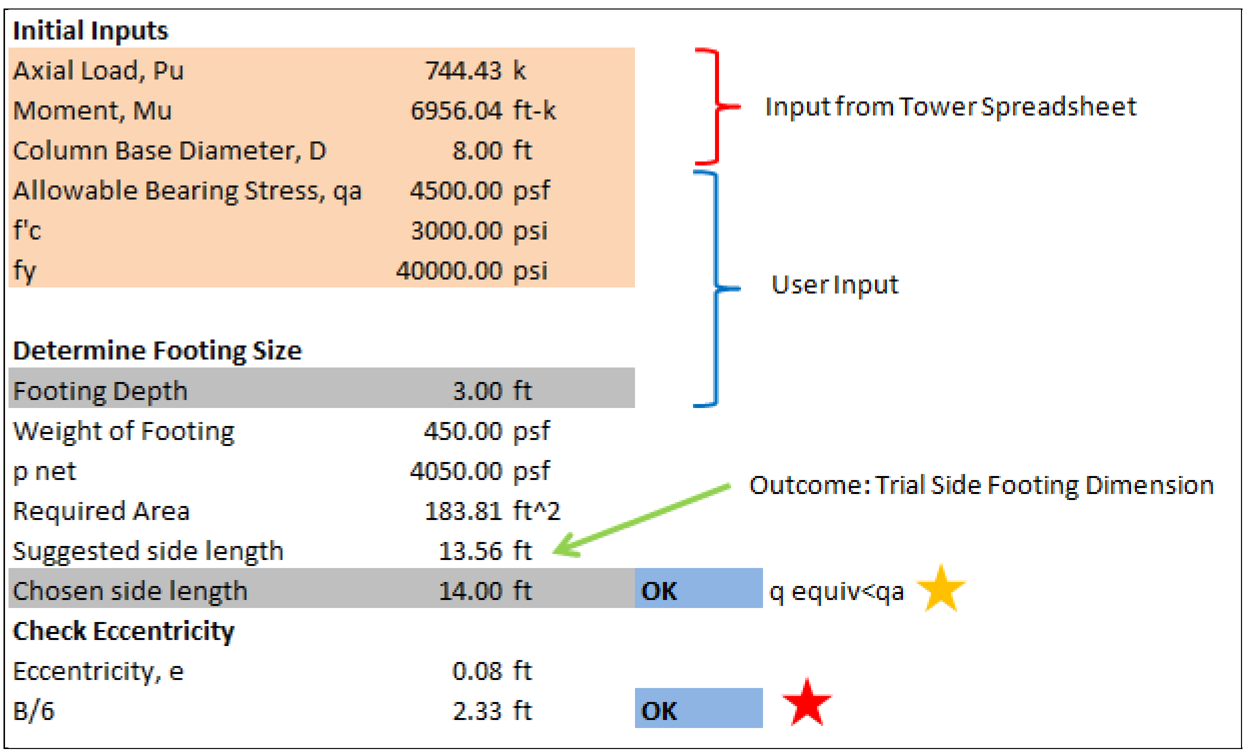
$$q_{equiv} = \frac{P_u + W_f}{B^2} < q_a$$

If the aforementioned conditions are satisfied, then the chosen footing side length is adequate for the bearing capacity of the soil and the resultant is within the middle third of the footing.

[48] Coduto, D. (2001). *Foundation Design: Principles and Practices.*

In the design spreadsheet, the axial load, moment, and column base diameter from the tower design automatically fills in the appropriate cells and the concrete and soil properties are chosen by the user. The user input includes the values for the allowable bearing stress of the soil, q_a, compressive strength of the concrete, f'_c, the yield strength of the concrete, f_y, and trial depth of the footing, B.

In Figure 14, the red bracket shows the auto-fill cells and the blue bracket identifies the user input. The outcome of this section of the spreadsheet, shown by the green arrow, will suggest a side length for the square foundation to the user. For constructability purposes, the value for the side length dimension is rounded up to the nearest foot. The “OK” to the left of the yellow star indicates that the bearing strength of the soil can withstand the axial load and weight of the foundation with the chosen side dimension. The “OK” to the left of the red star indicates that the suggested side length is adequate for eccentricity, meaning that the resultant falls within the middle third of the footing. If the conditions fail, “NG” for “no good” will appear in the check box and a larger footing size must be chosen. It should be noted that the side length is a trial size and may need to be altered later to satisfy other conditions later in the design process.



Initial Inputs			
Axial Load, Pu	744.43	k	
Moment, Mu	6956.04	ft-k	
Column Base Diameter, D	8.00	ft	
Allowable Bearing Stress, qa	4500.00	psf	
f'c	3000.00	psi	
fy	40000.00	psi	
Determine Footing Size			
Footing Depth	3.00	ft	
Weight of Footing	450.00	psf	
p net	4050.00	psf	
Required Area	183.81	ft^2	
Suggested side length	13.56	ft	
Chosen side length	14.00	ft	**OK**
Check Eccentricity			
Eccentricity, e	0.08	ft	
B/6	2.33	ft	**OK**

Figure 14: Footing Dimension Spreadsheet Output and Side Length Checks

Design for Shear Loads

According to ACI standards, foundations must be checked for two modes of shear failure, two-way shear and one-way shear. The footing design of this project does not address footings designed with shear reinforcement to simplify the design for constructability purposes. Therefore, if it was found that the chosen dimensions required shear reinforcement, the depth of the footing was increased.

Two-Way Shear

For two-way shear, an initial footing thickness must be assumed and modifications must be made for bar spacing and bar diameter. The result is used to determine the critical sections for shear. The equation below is used to calculate the two-way shear in the footing:

$$V_u = p_{net} * a_{effective}$$

Where a_{net} is the effective area of the foundation, which accounts for the perimeter of the column, *D*, and calculated effective depth, *d*. Supporting calculations for these values can be found in Appendix E. The critical section for two-way shear in a square footing must be calculated to investigate the adequacy of the footing thickness as shown in Figure 15 the shaded area. The area "D+d" in Figure 15 is the diameter of the base of the column, *D*, plus the diameter of the effective depth, *d*.

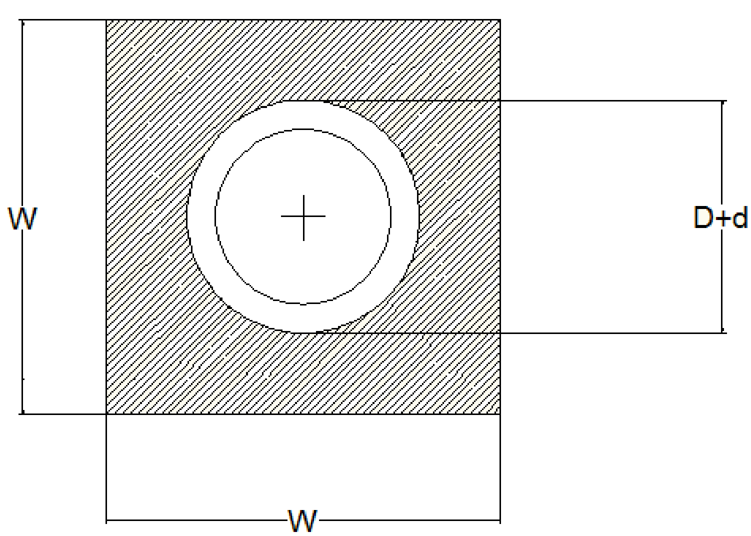


Figure 15: Critical section for two-way shear in square footing

According to ACI-11.12.2.1, when no shear reinforcement is used in the footing, the nominal punching shear strength is V_c. Although the column is circular, ACI code provisions for four-sided critical section were modified and used to compare the perimeter of the critical section, b_0, and the effective depth of the slab, d. ACI-11.12.2.1 states that $\beta_c \leq 2$ and $b_0/d \leq 20$ where β_c is the footing aspect ratio. Since the foundation is square, β_c will be 1, which satisfies the requirement of the ratio of long side to short side of the loaded area. ACI formulas 11-33 through 11-35 below were used to identify the smallest value for V_c.

$$V_c = \left(2 + \frac{4}{\beta_c}\right)\sqrt{f'_c}b_o d \qquad \text{ACI Formula (11-33)}$$

$$V_c = \left(\frac{\alpha_s}{b_o/d} + 2\right)\sqrt{f'_c}b_o d \qquad \text{ACI Formula (11-34)}$$

$$V_c = 4\sqrt{f'_c}b_o d \qquad \text{ACI Formula (11-35)}$$

Where α_s is a provided modifier for two-way shear action, which is assumed to be 40 for an interior column. The smallest value obtained from these three equations was then used to check the allowable two-way shear, φV_c, against the actual shear, V_u , in the equation:

$$\varphi V_c > V_u$$

Where the strength reduction factor, φ, is equal to 0.75. If this equation is satisfied, no shear reinforcement is required for two-way shear.

One-Way Shear

For one-way shear, the actual shear, V_u, is calculated at the critical section located at a distance , d, from the face of the column as shown in Figure 16.

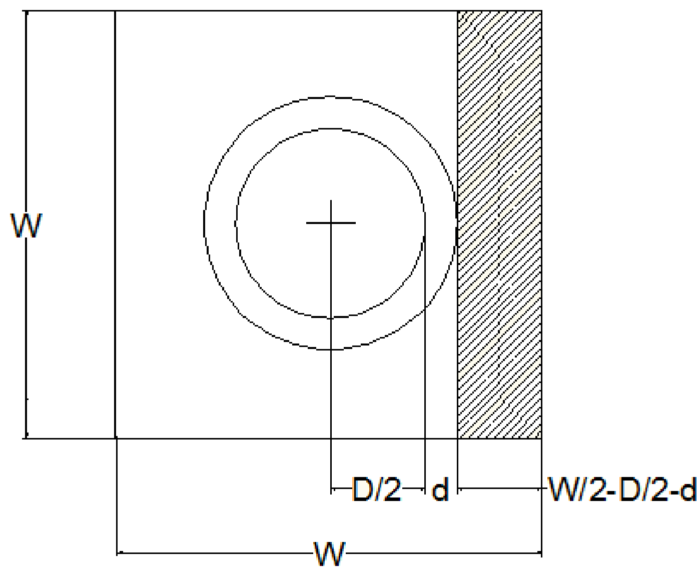


Figure 16: Critical Section for One-Way Shear in a Square Footing

According to ACI-11.12.1.1 and 11.3.1.1, the following equation can be used to calculate the one-way shear capacity, V_c, at the critical section:

$$V_c = 2\sqrt{f'_c}b_w$$

Where b_w is equal to the width of the footing. As with two-way shear, the allowable one-way shear was checked against the actual shear, with Φ equal to 0.75. If the equation is satisfied, then no shear reinforcement is required for one-way shear. Thus, the assumed thickness for the footing would be adequate for shear.

For the portion of the design spreadsheet dealing with shear capacity, the user will have already entered the required information shown in the red bracket in Figure 17. The blue bracket shows the checks which satisfy ACI-11.12.2.1. The outcome of the one and two-way shear test of the spreadsheet informs the user if the depth of the footing is adequate for shear. The blue boxes in the spreadsheet indicated by the green bracket show that when the design requires “No Shear Reinforcement” the check is “OK.” As mentioned previously, if the spreadsheet determines that shear reinforcement is needed, then a greater foundation depth should be chosen until the design is adequate for shear. The intent is to avoid the use of shear reinforcement as a strategy for controlling construction costs. When computing the average d, a 3 -inch cover and a 2-inch bar diameter is assumed as a conservative approach since none of the selected bars will have a diameter greater than 2 inches.

Determine Depth based on Shear				
average d	31.00	in		Assumed or Calculated Values
Vu	793.80	k		
bo	271.01	in		
Bc	1.00	(for squares)		
Alpha s	40.00	(for columns)		
Choose smallest of:				
Vc	2760.92	k		
Vc	3025.75	k		
Vc	1840.61	k		
Governing Vc	1840.61	k		
Check Two-Way Shear				
Bc	1.00		**OK**	Ratio Checks for Four-Sided Critical Section
bo/d	8.74		**OK**	
Shear Capacity (phi c, Vc)	1380.46	k	**OK**	No Shear Reinforcement
Check One-Way Shear				Outcome: Footing Depth Adequate for
Vu	23.63	k		
Vcu	570.51	k		
Phi*Vc	427.88	k	**OK**	No Shear Reinforcement

Figure 17: Design and Checks for Shear Loading in Spreadsheet

Design for Bearing Strength and Base Plate

In accordance with ACI-15.8.2.1, all forces acting at the base of the tower must be transferred into the footing. Since the footing is subject to extreme loading, the column load cannot be transferred by bearing alone. It was determined that a base plate would be the most effective way of transferring the loads from the tower to the foundation.

The design of the base plate requires checks the ultimate capacity of the concrete in bearing against the axial load on the footing due to the column. In order to do this check, the ultimate capacity of the concrete is computed using the equations below:

$$\varphi_c P_p = \varphi_c * 0.85 f'_c A_1 \sqrt{\frac{A_2}{A_1}} \leq \varphi * 1.7 f'_c A_1$$

Where A_1 is the area of the base plate, using an estimated side length greater than the diameter of the column base, but less than the side length of the footing. A_2 is the area of the footing using the trial side length. In the above equation, $\varphi_c * 0.85 f'_c A_1 \sqrt{\frac{A_2}{A_1}}$ the value on the left governs unless it exceeds the upper-bound value given on the right side of the equation. This value is then compared to the ultimate axial load, P_u, obtained from the tower calculations to ensure that the concrete has adequate bearing capacity.

The bearing strength in the base plate must be checked against the combined axial and moment forces transferred by the column to the base plate. The equation below is used to compute the maximum stress that occurs on each end of the bearing plate:

$$f = -\frac{P_u}{A_1} \pm \frac{6M_u}{bd^2}$$

The result of this equation was compared to the ultimate bearing stress on the base plate to unsure that the trial width of the base plate was adequate.

In order to design the thickness of the base plate, the flexural strength of the base plate must be investigated using the moment to right at center of the right flange, M_u, in the equation below:

$$t \geq \sqrt{\frac{6M_u}{\varphi_b F_y}}$$

Where t is the thickness of the flange, φ_b is equal to 0.9, and F_y is the strength of the steel used for the base plate. [49]

In the spreadsheet for the design of the base plate, a trial value for the width of the base plate is entered and checked to ensure that it is larger than the diameter at the base of the column, but smaller than the side length of the footing, as stated earlier. This check is indicated by the green arrow in Figure 18. The yellow star indicates that the concrete has enough bearing capacity to withstand the axial load of the column. The red star shows that the maximum stress that occurs on each end of the bearing plate is less than the bearing capacity. The blue star shows that the chosen value for the plate thickness exceeds the minimum calculated value, t_{min}.

[49] McCormak, Jack C,. *Structural Steel Design*, 4th Ed. Pearson Prentice Hall, 2008.

Design of Baseplate				
Try base plate width	128.00	in	**OK**	Trial Width and Check
Check Bearing Pressure:				
$\Phi_c P_P$	32901.12	>	744.43	**OK**
Φ_c*0.85*f'c*A1*sqrt(A2/A1)	32901.12	k		
1.7*f'c*A1	50135.04	k		
fmax	-0.28	ksi	**OK**	
Mu	256.00	in-k		
tmin	6.89	in		
Choose t	7	in	**OK**	

Figure 18: Base Plate Design Spreadsheet

Design for Bending Moment Strength and Reinforcement

The foundation is subject to large overturning moment forces and therefore must be designed for bending moment strength. The critical section for the bending moment using sample values can be seen in Figure 19 below.

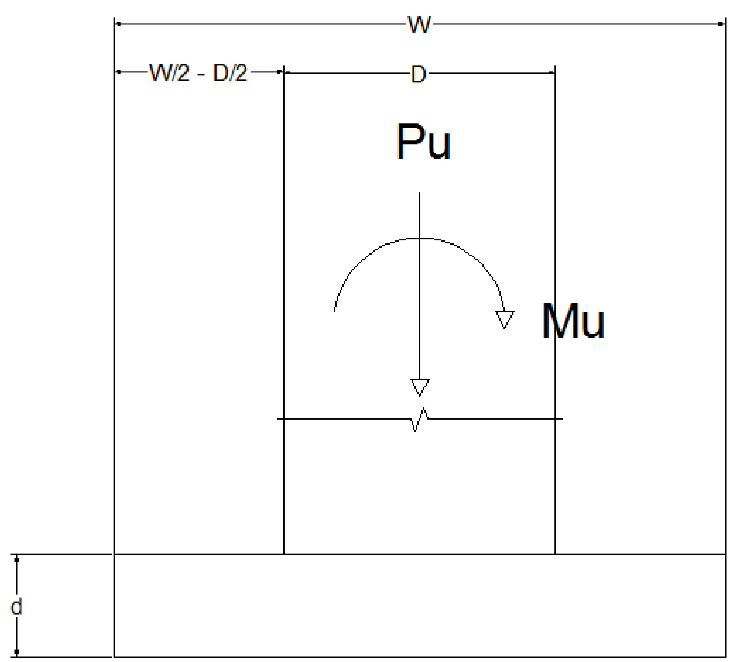


Figure 19: Critical Section for Bending Moment

For the purpose of the project, the bending moment value will be previously determined from the tower design. When the side footing length was selected, the eccentricity was checked to ensure that the loading was within the middle third of the footing. Thus, the dimension of the side of the square footing and the moment value from the tower design will be used along with the footing dimensions and reduction factor to compute the required coefficient of resistance for strength design, R_n, in the equation below:

$$Required\ R_n = \frac{M_u}{\varphi b d^2}$$

Where φ is equal to 0.9. This value is used in the equations for the reinforcement ratio, ρ, to find the required and minimum required area of steel, A_s, as specified by ACI- 10.5.4, for the development of reinforcement for the critical section seen below:

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mR_n}{f_y}}\right)$$

Once the value of ρ is computed, it is necessary to check to ensure that it is less than or equal to 75% of the reinforcement for a balanced condition, p_b, which is calculated in the equation below:

$$p_b = \frac{0.85f'_c}{f_y} * \beta_1 * \left(\frac{87{,}000}{87{,}000 + f_y}\right)$$

Where β_1 is equal to 0.85 for a concrete compressive strength of 3000 psi and the values for f'_c and f_y are taken from the initial assumptions. Once this check is satisfied, the reinforcement ratio can be used to compute the total area of reinforcing steel required and the minimum required area of steel shown below:

$$required\ A_s = \rho b d$$

$$minimum\ required\ A_s = 0.002bd$$

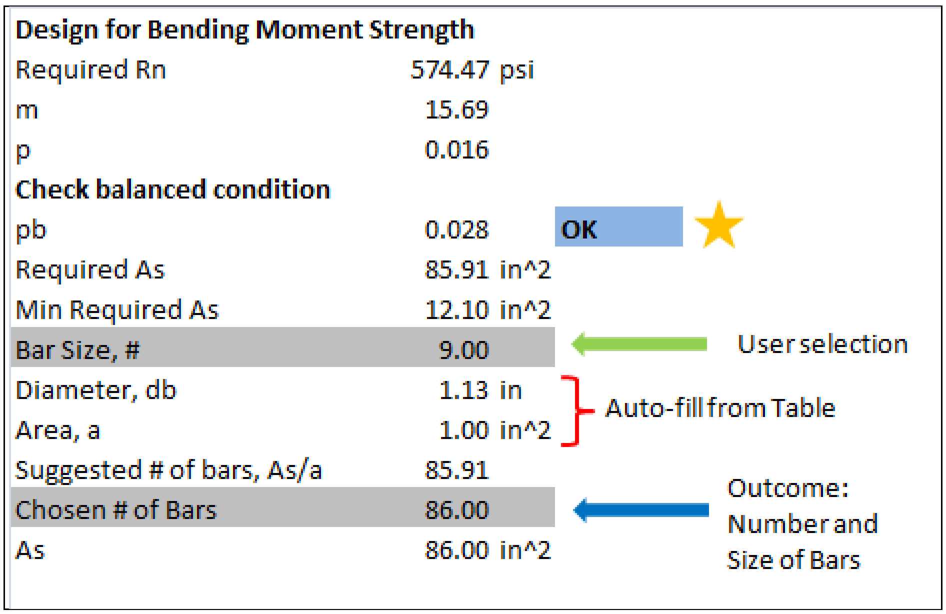
Where m is equal to $f_y / 0.85f'_c$. The result of this equation can be used to choose the number and diameter of bars for reinforcement. In the design spreadsheet, the input values can be chosen by the user based on the computed A_s. The bar sizes can be chosen from Table 9 below.

Table 9: Size, Diameter, and Area of Reinforcing Bars 50

Bar Size	Nominal Diameter (in.)	Bar Area (in^2)
3	0.375	0.11
4	0.5	0.2
5	0.625	0.31
6	0.75	0.44
7	0.875	0.6
8	1	0.79
9	1.128	1
10	1.27	1.27
11	1.41	1.56
14	1.693	2.25
18	2.257	4

[50] *Chu-Kia Wang, C. G. (2007). Reinforced Concrete Design. John Wiley & Sons, Inc.*

As shown in Figure 20, when the user selects a bar size as indicated by the green arrow, the values for the nominal diameter and the area for one bar are auto-filled from Table 9 as shown by the red bracket. The calculated reinforcement ratio will be checked determine if it satisfies the requirement for a balanced condition as indicated by the “OK” to the left of yellow arrow. The outcome of this portion of the spreadsheet, shown by the blue arrow, is that it suggests a number of bars based on the size chosen by the user.



Design for Bending Moment Strength		
Required Rn	574.47 psi	
m	15.69	
p	0.016	
Check balanced condition		
pb	0.028	**OK**
Required As	85.91 in^2	
Min Required As	12.10 in^2	
Bar Size, #	9.00	
Diameter, db	1.13 in	
Area, a	1.00 in^2	
Suggested # of bars, As/a	85.91	
Chosen # of Bars	86.00	
As	86.00 in^2	

Figure 20: Design for Bending Moment Strength in Design Spreadsheet

After the number of bars and the area of steel are selected, the bar spacing and moment values must be checked. The spacing is calculating by dividing the side length of the footing by the number of bars. According to ACI Code provisions, the spacing must be at least 1 in between the bars. The new bar diameter is calculated using the same equation as the initial calculation below:

$$new\ d = d - 3(cover) - \ 1\ bar\ diameter$$

The nominal bending capacity must also be found using the area of steel provided by the bars in the following series of equations:

$$C = 0.85f'_c ba$$

Where C is the compressive stress and a is the depth of the stress block. This equation is set equal to the equation for tension:

$$T = A_s f_y$$

The result is a value for a which is used to compute the nominal bending capacity, φM_n using the equation below:

$$\varphi M_n = \varphi T[new\ d - 0.5a]$$

Where φ is equal to 0.9. This value is compared to the actual moment value , M_u, resulting from the tower calculations. The suggested value of bars does not necessarily result in adequate bending capacity since the values of the required area of steel and the actual area of steel can be very close. Therefore, if "NG" is displayed in the check for the moment capacity, the user must increase the amount of bars used. In addition, the spacing of the bars will automatically default to at least one inch if the calculated value is less than one inch. This means that the side length of the footing may need to be increased or larger bars can be chosen. Although the exact values for the bar spacing are displayed in the spreadsheet, for a more realistic design, the bar spacing would most likely be rounded. Figure 21 shows the checks for bar spacing and adequate bending strength.

Check Bar Spacing			
Calculated bar spacing	1.95	in/bar	**OK**
Actual bar spacing	1.95	in/bar	
New d	31.87	in	
Compressive Strength, C	428.40	a	
Tensile Strength, T	3440.00	k	
a	8.03	in	
Phi Mn	7187.12	ft-k	**OK**

Figure 21: Check for Bending Moment Strength and Bar Spacing

If the chosen reinforcement passes all bending moment strength and bar spacing tests then ACI Formula 12-1 below can be used for the development of reinforcement.

$$L_d = \left(\frac{3}{40} \frac{f_y}{\sqrt{f'_c}} \frac{\psi_t \psi_e \psi_s \lambda}{\left(\frac{c_b + k_{tr}}{d_b} \right)} \right) d_b$$

Where c_b is the smaller of the two values from the following equations:

$$bottom\ and\ side\ cover = 1.5\ (clear) +\ bar\ radius =\ c_b$$

$$one - half\ center - to - center\ spacing = c_b$$

The values for $\psi_e, \psi_{s,}$ $and\ \lambda$ are equal to 1.0 because for the purpose of this project, the bar sizes will typically need to be #7 or larger due to spacing constraints. The value for ψ_t is equal to 1.3 for top bars, which according to ACI-12.2.4 are horizontal reinforcement which greater than 12 inches of concrete below them. Since footings for turbines are deeper than 12 inches, a value of 1.3 can be assumed in the calculations and design spreadsheet. The value k_{tr} is equal to zero if there are no stirrups. The maximum value is 2.5, so if $\frac{c_b}{d_b}$ is greater than that value, then 2.5 must be used. These substitutions simplify the equation to:

$$L_d = \left(\frac{3}{40} \frac{f_y}{\sqrt{f'_c}} \frac{1.3}{\left(\frac{c_b}{d_b}\right)} \right) d_b \qquad \textbf{ACI 12.1}$$

Once this value is computed, it is compared against the actual embedment which is about two inches of cover subtracted from the width of the footing.

As seen in Figure 22 below, the actual embedment must be greater than the development length. In this example the required embedment length is too large resulting in a “NG” message to the left of the yellow star. This check will cause the design spreadsheet to display the “Increase footing width” message underneath the check. This requires that all hand calculations affected by the footing length need to be updated, however, with the spreadsheet, the side length of the footing can be increased until the check is “OK” as long as all of the other requirements in the design spreadsheet remain satisfied.

Development of Reinforcement		
bottom and side cover	2.06 in	
one half c-c spacing	0.98 in	
cb	0.98 in	
Cb/db	0.87	**OK**
Actul Cb/db	0.87	
Ld	92.76 in	
Actual Embedment	70.00 in	**NG**
		Increase footing width

Figure 22: Failed Embedment Length Check

Using the numbers in this example, the footing needed to be increased from 14 feet to 16 feet in order for the embedment length to be adequate as seen in Figure 23. As mentioned above, all other checks were satisfied and the number of bars was adjusted to reflect the increase in footing width.

Chosen side length	16 ft	**OK**	q equiv<qa
Development of Reinforcement			
bottom and side cover	2.064 in		
one half c-c spacing	1.129412 in		
cb	1.129412 in		
Cb/db	1.001252	**OK**	
Actul Cb/db	1.001252		
Ld	80.21764 in		
Actual Embedment	94 in	**OK**	★

Figure 23: Embedment Length Check "OK" After Increase in Footing Width

The final step in the design of the footing is to update the shear calculations using the new value for d, which was updated for the actual spacing and bar diameters. The procedure is the same as before as seen in Figure 24 from the design spreadsheet below with the red bracket signifying the calculated values including the new value for d.

Check Shear with New d			
average d	31.87 in		Assumed or Calculated Values (average d through Governing Vc)
Vu	1036.80 k		
bo	270.13 in		
Bc	1.00 (for squares)		
Alpha s	40.00 (for columns)		
Choose smallest of:			
Vc	2829.44 k		
Vc	3168.71 k		
Vc	1886.30 k		
Governing Vc	1886.30 k		
Check Two-Way Shear			
Bc	1.00	**OK**	Ratio Checks for Four-Sided Critical Section (Bc and bo/d)
bo/d	8.48	**OK**	
Shear Capacity (phi c, Vc)	1414.72 k	**OK**	No Shear Reinforcement
Check One-Way Shear			Outcome: Footing Depth Adequate for
Vu	87.09 k		
Vcu	670.35 k		
Phi*Vc	502.76 k	**OK**	No Shear Reinforcement

Figure 24: Updated Shear Check with New d value

Since the updated shear check is "OK", and no reinforcement is needed, this means that the dimensions, base plate, and reinforcement for the footing are adequate for the given tower including loading and soil conditions.

Foundation Dimensions

Based on the tower axial load, moment, and column base diameter, obtained from the tower design, the footing was designed using the method explained throughout the chapter. Table 10 displays the user input values were used for the soil and concrete conditions for the design examples:

Table 10: Assumed User Input Values for Design Examples

Soil and Concrete Condition	Value Used in Design Examples
Bearing Strength of the Soil, q_a	4500 psf (sandy-gravel)
Compressive Strength of Concrete, f'_c	3000 psi
Yield Strength of Concrete, f_y	40,000 psi

The results of the calculations involving the assumed user input values from Table 10 and the characteristics listed below in Table 11, the following results for the foundation design were produced.

Table 11: Summary of Foundation Design Results for Various Tower Heights

Design Criteria	250' Tower	350' Tower
Diameter at base	8 feet	12 feet
Total axial load acting at tower base	774.4 kips	1206.9 kips
Total moment acting at tower base	6956.0 ft-kips	21637.7 ft-kips
Total shear load acting at tower base	52.0 kips	115.5 kips
Footing Dimensions	16'x16'x3'	24'x24'x6'
Base Plate Dimensions	128"x128"x7"	180"x180"x8"
Reinforcing Steel	85 #9 @ 2.25"	113 #9 @ 2.55"

By observing these results, it can be determined that the 100 foot increase in tower height and consequent increase in axial loads and moment forces resulted in a 350% increase in the area of footing required. It was found that for both tower heights, the embedment length was the governing factor in the width of the footing. The bar size, #9, was kept consistent to show the increase in bars between the two footing sizes, which was 28 bars, and the spacing was increased 0.30 inches. Since the base plate calculation is checked with shear, the designs were similar because the shear strengths of the 250' and 350' towers were similar as seen in Table 11. Hand calculations and the corresponding design sheets for the 250 foot tower can be found in Appendix E.

In addition to the variations in the loads from the tower, three different soil types were investigated using the dimensions and load data from the 250-foot tower. The soil types included clayey soil, sandy-gravel, which was used as an assumed user input value in the previous examples, and rocky soil. The foundation results are summarized in Table 12 below:

Table 12: Summary of Foundation Design Results for Various Soil Types

Design Criteria	Clayey Soil	Sandy-Gravel	Rocky Soil
Diameter at Base	8 feet	8 feet	8 feet
Allowable Bearing Strength[51]	2000 psf	4500 psf	6500 psf
Footing Dimensions	22'x22'x3'	16'x16'x3'	14'x14'x4'
Base Plate Dimensions	128"x128"x7"	128"x128"x7"	128"x128"x7"
Reinforcing Steel	82 # 9 @ 3.22"	85 #9 @ 2.25"	58 #9 2.90"

By observing these results, it can be determined that the changes in the soil type affect both the width and the depth of the foundation. In the clayey soil, the footing width needed to be larger in order to compensate for a loss in bearing capacity in comparison to the assumed user value of 4500psf. When the allowable soil capacity was increased to 6500 psf for rocky soil, the footing width was able to be decreased; however, the depth of the foundation needed to be increased to satisfy the requirements for shear strength. The bar size, #9, was kept consistent to show the fluctuation in the number of bars between the different footing sizes and soil types. The results show that a significant decrease in the number of bars occurred in the rocky soil because of the combination of the increase in the depth and the decrease in the width of the footing. The design spreadsheets for the clayey and rocky soil can be found in Appendix E.

Anchor Bolt Design

Another important aspect of the design of the wind turbine footing and base plate is the anchor design. Since the anchor bolt design very case-specific and dependent on many different factors, it was not included in the design spreadsheet. The sample calculations for the anchor bolt design are referenced in

[51] Pole Barns, (November 2009), www.pole-barn.info/soil-bearing-capacity.html

Appendix G. An anchor bolt design was created for the 250-foot tower in with the characteristics in Table 13:

Table 13: Anchor Bolt Design Tower and Foundation Characteristics

Design Criteria	250' Tower
Diameter at base	8 feet
Total axial load acting at tower base	774.4 kips
Total moment acting at tower base	6956.0 ft-kips
Total shear at tower base	52.0 kips
Footing Dimensions	16'x16'x3'
Base Plate Dimensions	128"x128"x7"
Reinforcing Steel	85 #9 @ 2.25"

There are a large variety of rods available for use as anchor bolts. In the design for the 250-foot tower, the rods used for the anchor bolt design are threaded ASTM A490 rods with a tensile capacity of 119 ksi and a shear capacity of 60 ksi. The rods were designed for tensile strength based on ASCE 7-05 Table 7-2. The bolts were designed in a circular configuration around the base of the tower flange. The bolt strength for combined shear and tension was considered to ensure that the bolts had adequate strength to resist those forces. The final design for the anchor bolts is listed in Table 14. Figure 25 shows the anchor bolt design and dimensions.

Table 14: Anchor Bolt Design for 250' Tower

Anchor Bolt Characteristic	Result
Number and Type of Rods	28 1-½" ASTM 490 rods
Embedment Length	18 "
Edge Distance	7.5"
Spacing	17 1/8"

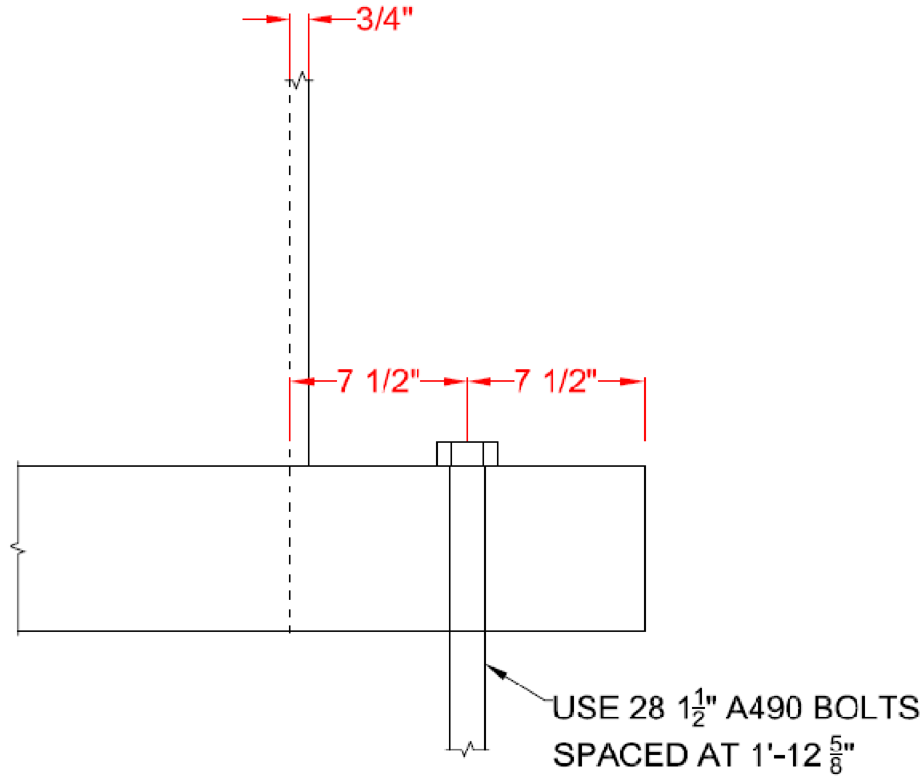


Figure 25: Anchor Bolt Design Detail

AutoCAD Drawings

AutoCAD Drawings were prepared for the design alternative in Table 15. Figure 26 and Figure 27 show the final dimensions for the design criteria.

Table 15: Design Criteria for AutoCAD Drawings

Design Criteria	250' Tower
Diameter at base	8 feet
Total axial load acting at tower base	774.4 kips
Total moment acting at tower base	6956.0 ft-kips
Footing Dimensions	16'x16'x3'
Base Plate Dimensions	128"x128"x7"
Reinforcing Steel	85 #9 @ 2.25"

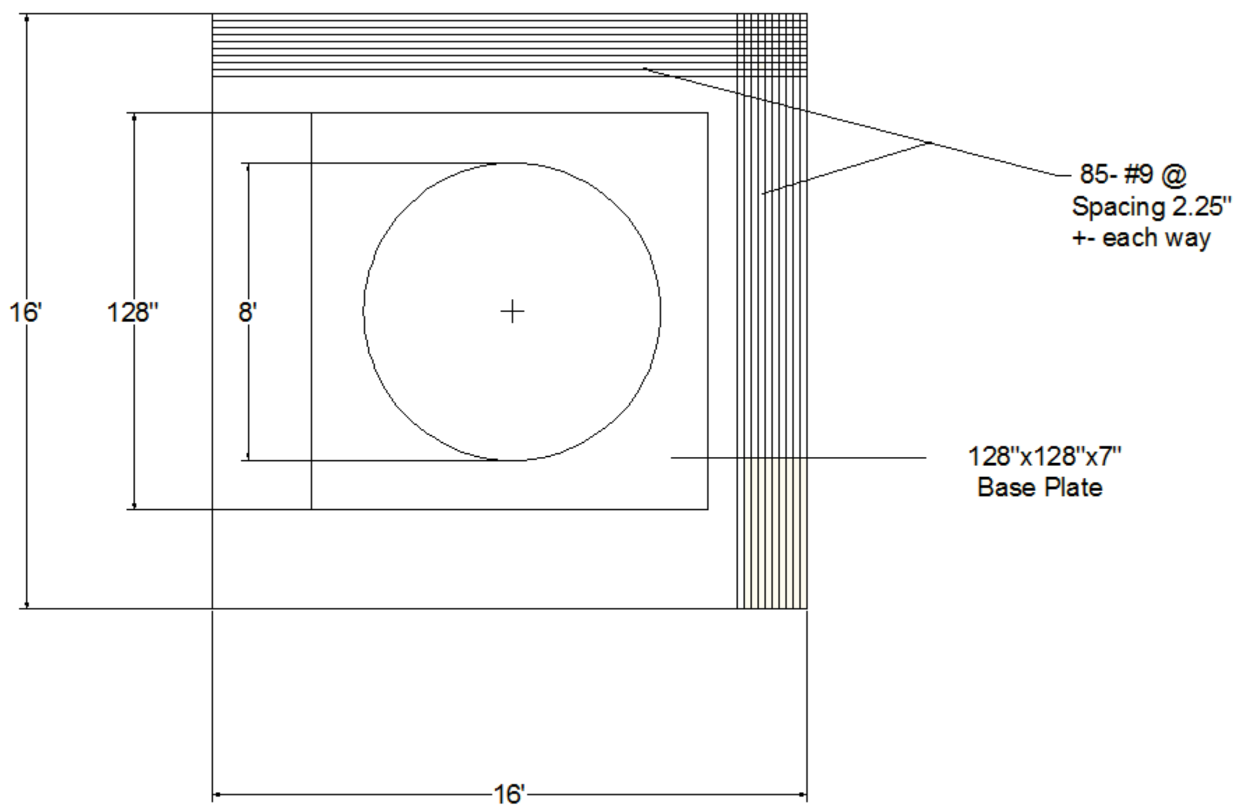


Figure 26: Footing and Base Plate Dimensions with Established Reinforcement (Top View)

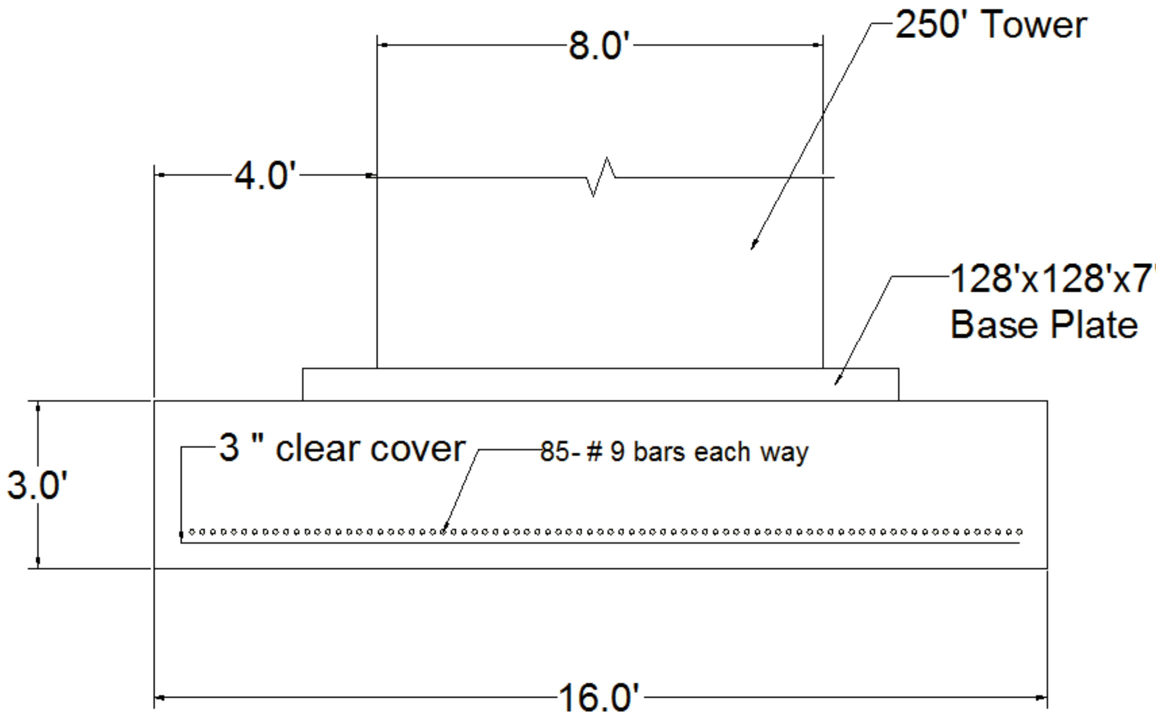


Figure 27: Footing and Base Plate Dimensions with Established Reinforcement (Side View)

Chapter 6: Project Analysis

The economics, energy output, permitting and scheduling all play a big role in the overall understanding of a project. In order to analyze these topics, an Excel spreadsheet was created which uses key information entered by a person involved in the project and calculates various necessary pieces of information needed to analyze many aspects of the project. This spreadsheet can calculate an estimate of the electricity output, the revenue earned, the expenses owed, the overall cash flow, and even the IRR of investing in a wind turbine. These are all important pieces of information for anyone who is researching the benefits of installing a wind turbine. This spreadsheet does many calculations and takes many things into consideration; all of which will be explained in this chapter. While this spreadsheet details the energy output, economic feasibility, and even helps design the tower and foundation, permitting and the overall process of installing a turbine were also researched for this project. These two topics are left out of the spread sheet, but are explained in this report.

Permitting

One of the first steps in the scheduling process is permitting the turbine. The process of obtaining a permit for a wind turbine project varies by state and county according to local laws. This report will focus on the general permitting process in the state of Massachusetts, where the guidelines are well developed. The Massachusetts Division of Energy Resources developed a “model amendment” for all Massachusetts towns which is show in the document “Model Amendment to a Zoning Ordinance or By-law: Allowing Wind Facilities by Special Permit.” This model explains the General Standards and Permitting Application. The permitting application is required to prove that a project is abiding by the general standards outlined in the beginning of the amendment.

In the general standards section of the amendment many topics are addressed. These topics range from insurance to turbine design; and from lighting to environmental impacts. Specifically, the following topics are addressed: Liability Insurance, Site Control, Height, Setbacks, Color, Finish, Lighting, Signage/Advertisement, Utility Connections, Appurtenant Structures, Shadow/Flicker, Noise, Habitat Impact, Facility Maintenance, Removal/Abandonment and Financial Security. Details about each of these topics can be found in the model amendment on The Official Website of the Commonwealth of Massachusetts. Significant details that should be considered are: insurance must be owned for the turbine; the tower must be set back at least 1.5 times the height of the turbine from any nearby inhabited structures, overhead utility lines and public roads; a financial surety is sometimes required of turbine projects in the case that the turbine becomes abandoned and must be removed; and the wind turbine should not adversely affect neighboring properties. An application must be submitted by the project owners in order to prove they are abiding by all of the above standards.

The permit application process is a lengthy step in a wind turbine project. This can last upwards of many years if there is any opposition to the turbine installation. In this application the owner must include several pieces of information regarding their project. Included in this packet must be: General Information, Descriptions of the Property, Operation and Maintenance Plans and Compliance Documents. Each of these sections details a list of necessary documents that must be submitted in order to be considered for a permit.

The General Information section of the permit application is a very simple section. In this section the owner must supply the applicant's name, address, phone number, and signature. They must also provide the name, address, phone number, and signature of any agent who is representing the applicant. Lastly, in this section, documentation is needed to prove that the applicant has a legal right to use the site.

The Description of Property section is a much lengthier section of the application. First a locus map (1:25,000) showing the area within at least two miles of the facility is needed along with the planned wind turbine location. Next, a map of the proposed facility site at the scale of 1"=200' is needed that shows the contour intervals, property lines, existing buildings, roads, tree cover, and proposed ground equipment. Also needed are pictures which show what the structure will look like once it is installed. These pictures "should be representations from populated areas or public ways within a 2 mile radius of the wind facility." Lastly, a landscape plan for the site is needed.

The next section is the Operation and Maintenance Plan. This section requires a plan to maintain all of the access roads and storm water controls on the site. Also, a plan that outlines the procedures for operating and maintaining the wind facility is needed. These procedures are often provided by the manufacturer of wind turbines, so it will be beneficial to have the wind turbine model chosen prior to this permitting step.

The last section needed for the permit application is the Compliance Documents section. In this section, the owner must demonstrate to the town that the project is complying with the general standards outlined earlier. A financial surety must be provided here, as well as proof of liability insurance. A certification must be provided showing that the height of the structure is within the limitations addressed in the General Conditions and if it is not within these limitations that it has been documented that the turbine has permissible reasons to be taller. These reasons that will allow the tower to be taller are "the applicant demonstrates by substantial evidence that such height reflects industry standards for a similarly sited wind facility; such excess height is necessary to prevent financial hardship to the applicant, and the facility satisfies all other criteria for the granting of a special permit under the provisions of this section.[52]" And lastly, documentation regarding existing and maximum project noise levels is necessary to show that the noise is lower than the allowed maximum detailed in the general standards section.

This permitting process, while specific to Massachusetts, is similar across the country and often focuses on the same topics (see other state government websites). It is necessary to obtain a permit for a wind turbine project in order for construction to begin, and it is often this stage which holds up undesirable projects. Permitting is one of the first steps in the process to installing a wind turbine facility and must be taken seriously.

Installation

The next step in the schedule of a wind turbine project is the installation of the turbine. In order for this step to occur, the permitting, cost analysis, and manufacturing of the turbine must all have taken place. The first step of the installation process is clearing the site. This may be a large step if the site has many trees and other vegetation. After this step, the construction of an access road might be necessary, especially where the site is remote and has no existing roads. This road is needed in order to transport the wind turbine to the site, as well as any necessary construction equipment. After these two steps have been completed, the excavation for the foundation can take place. The entire installation of the cast-in-place foundation (and often design) is completed by a separate company who must be hired for the job in advance. The foundation can then be formed and installed. This step can be affected by the weather. Thus, enough time should be allotted for concrete placement and curing. After the foundation is cured the wind turbine can be installed. In order to complete this step a crane is needed to lift the tower segments, nacelle, and blades into place. This step is often done by companies suggested by the manufacturer. Wind speeds should not be excessive during installation of the tower in order to steer clear of all possible problems. Erection in rain or snow conditions also impedes the installation process.

[52] *Massachusetts Division of Energy Resources. (n.d.).* (November 2009), http://www.mass.gov/Eoca/docs/doer/renew/model-allow-wind-by-permit.pdf

Once the turbine is completely installed, it is connected to the local utility and can start generating electricity.

Maintenance

Once the wind turbine has been installed, some maintenance is required to keep it operating. The turbine should be inspected at least once every year; however, twice is recommended. Most turbines will come with a maintenance schedule and procedure when they are purchased from the manufacturer. These procedures detail how the blades, tower, foundation, and mechanics are inspected and maintained. Maintenance cannot be done by the average person. Often times, manufacturers have companies in many areas whom they train in maintenance in order to perform services in their region. The types of companies who perform these services are becoming more popular around the country. It costs, on average, $10,000-$15,000 every year in order to keep a turbine well maintained[53]. This cost is relatively small compared to the cost of repairing a large problem on the turbine. Annual maintenance increases the overall life of the turbine and ensures that it runs smoothly.

Project Analysis Spreadsheet

As previously mentioned a project analysis spreadsheet was created to calculate values that would be needed to analyze the finances and design of the project. This analysis of the finances of the project is crucial to a successful project. Investors depend on this cost analysis when deciding whether or not an investment in the project is beneficial or not. Many different factors must be considered when calculating these final numbers, and often times these factors vary from project to project. It is most beneficial to have a spreadsheet that can be altered according to each different project. Major factors that must be considered are the average wind speed of a site, the size of the wind turbine, the location of the turbine, which influence ice loads and maximum wind forces, and the financing structure of the project.

The four main sections of the spreadsheet are Energy Output, Economic Analysis, Tower Design, and Foundation Design. The document is user friendly and only requires data to be typed into one main "General Information" page as shown in Figure 28. This input information is used in many different equations and eventually important turbine information is summarized in the output reports. Data is also calculated in the input tab of the spreadsheet in order to show the user various pieces of

[53] Kuhn, B. (2009, October 23). Vice President Marketing.

information that can be useful in the design of the project. This information includes checks of different equations that show whether or not design dimensions entered will be adequate.

Project Information	
Project Name	
Street Address	
Town, ZipCode	

Legend
User Input
Auto Fill
Drop Down

Site Information	
Average Wind Speed (m/s):	9
Altitude (m):	150
Average Temperature (°C):	16
Land Costs ($/mo):	$0
Altitude Correction:	0.99
Temperature Correction:	1.00
Land Area (acre):	2
Clear Area or Wooded?:	Clear
Road Needed?:	No
Length of Road Needed (ft):	
Financing Information	
Initial Costs (NPV):	$3,301,449
Down Payment ($):	$3,301,449
Years of Payback (N):	15
Salvage Value (%):	25%
5-Year Escalation Rate:	5%
Initial Investment:	$3,301,449
Coupon Payments:	$200,000
Internal Rate of Return:	5.29%
Grants Received ($):	$100,000
Tower Designed Specific or from Mfgr?:	Designed Specifically
Electricity Information	
Retail Value ($/kWh):	$0.128
Value of RECs ($/kWh):	$0.035
Value of PTCs ($/kWh):	$0.021
Weibull K Factor:	2
Wind Shear Exponent:	
Availability:	0.96
Turbulence Intensity Loss:	0.03
Safety Margin Loss:	0
Electricity Generated/Year (kWh/yr):	2,601,073
Turbine Information	
Turbine Model:	Aeronautica Windpower 47-750
Turbine Cost:	$1,265,000
Rated Power (kW):	750.0
Rotor Diameter (m):	47.0
Swept Area (m²):	1734.9
Tower Height (m):	76.2
Hub Height (m):	77.7
Tower Information	
Town	Worcester
Overall height (ft):	250
Diameter at Base (ft):	8
Diameter at Hub (ft):	7
Shell Thickness (in):	0.75
Strength of Steel (ksi):	36
Modulus of Elasticity (ksi):	29,000
Weight of Steel (lbs/ft³):	490
Weight of Equipment (kip):	400
Axial Strength (Check):	OK
Flexural Strength (Check):	OK
Combined Loading (Check):	OK
Overall Tower Design (Check):	OK
Price of Steel ($/lb):	$0.30
Price of Steel Fabrication ($/lb):	$2.70
Foundation Information	
Allowable Bearing Stress, q_a (psf):	4,500
Compression Strength of Concrete (f'c)(psi):	3,000
Yield Strength of Concrete (fy) (psi):	40,000
Footing Depth (ft):	3
Footing Width (ft):	16.0
Base Plate Width (in):	128
Bar Size, Moment (#):	9
Number of Bars:	85
Bar Spacing (in/bar):	2.26
One-Way Shear Reinforcement Needed?:	No
Two-Way Shear Reinforcement Needed?:	No
Footing Depth (Check):	OK
Reinforcement (Check):	OK
Base Plate Width (Check):	OK
Bearing Pressure (Check):	OK
"t" (Check):	OK
Overall Foundation Design (Check):	OK

Actual Load		<	Design Load	
744.4	ft-k	<	1508.5	ft-k
83472.5	ft-k	<	220467.8	ft-k
0.8	ft-k	<	1.0	ft-k

Figure 28: Sample General Information Page

Energy Output

The electricity output of the wind turbine is the key revenue generator for the project. Because of this, in order to reliably analyze the economics of the project, the electricity output must be predicted using a probabilistic model which account for many different uncertainties in the wind. In order to do this, many different factors must be considered and analyzed. The key to this analysis is the power curve for the specific wind turbine. The power curve depicts the amount of electricity that the given wind turbine can generate at varying wind speeds. Because the energy contained in the wind raises exponentially for every 1 mile per hour increase in wind velocity, the electricity output of the machine also raises exponentially. The manufacturer generally produces these power curves for each of their products and provides these to the general public so that they can show how much electricity their product could produce.

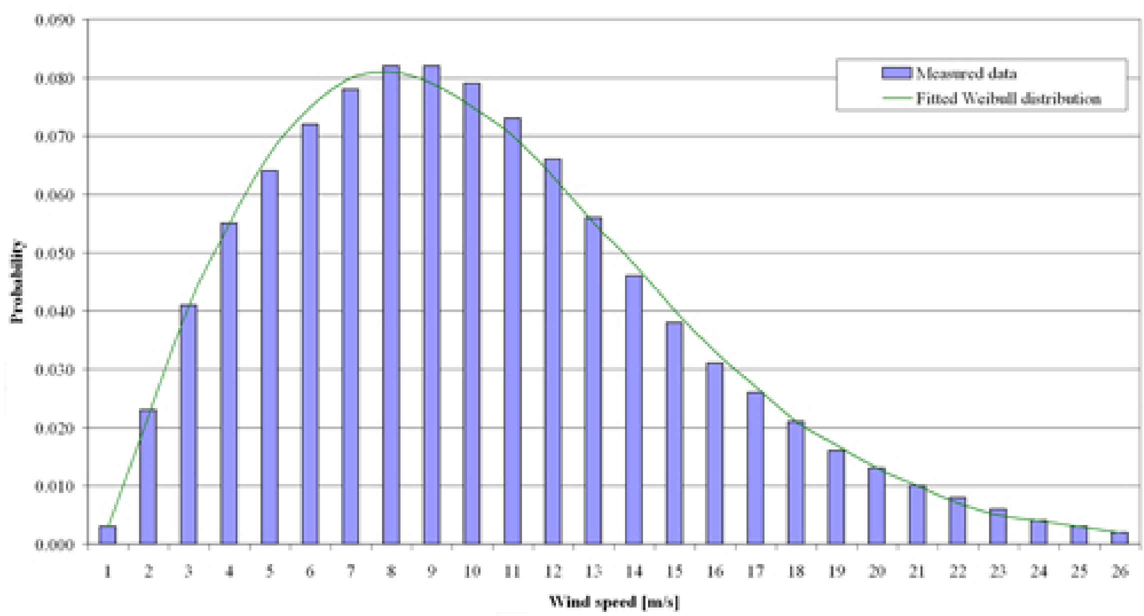


Figure 29: Wind Speed Distribution (www.wind-energy-the-facts.org)

The probability curve above in Figure 29 estimates the amount of time the wind will be blowing at any given wind speed at a specific location. In order to do this, the average wind speed for a site is used and is evaluated using a statistical formula to model the probability density of the distribution of wind speeds. The curve that defines the assumed distribution of wind speeds is generated using a certain factor that is common in the wind energy community. This factor is called the Weibull K factor, and for a curve that is predicting wind speeds the factor is assumed to be 2[54]. This factor defines the shape of the parabola being used as shown in Figure 29. Once this parabola is developed, other factors must be taken into consideration in order to more accurately derive an expected value for the amount of electricity that will be generated by the wind turbine in the specific location.

The altitude and temperature of a site also affect the expected value for the overall electricity the turbine generates. Both of these factors play a direct role in the density of the air in a given area, and the density of the air changes the amount of energy it contains. Equations are used to evaluate the change in energy contained in the wind colliding with the turbine, and these equations are incorporated into the spreadsheet. Often, these factors play a small role in affecting the electricity produced by the machine; however it still must be analyzed to produce results which consider all factors. The equations below are for the altitude and temperature correction in evaluating the energy in the wind coming in contact with the wind turbine:

$$\frac{1.2252 - (0.0001194 \times A)}{1.2252} = x_a$$

A = Altitude (m)

$$\frac{1013250}{2870000 \times (273.15 + T)} \times \frac{1000}{1.2252} = x_t$$

T = Temperature (°C)

The efficiency of the wind turbine is an attractive fact to know. This can be calculated by dividing the power curve energy (kW) for a given wind speed by the energy actually contained in the wind (kW) at that speed. The actual energy contained in the wind is calculated in the equation below. The entirety of this energy cannot be harvested by a wind turbine, and the energy that can be harvested is defined by the power curve of the turbine given by the manufacturer. By comparing these two numbers the efficiency of the turbine (at a given wind speed) is found:

[54] J.V.Seguro, T. (2000). Modern estimation of the parameters of the Weibull wind speed distribution for wind energy analysis. *Journal of Wind Engineering and Industrial Aerodynamics* , 75-84.

$$E_w = \frac{(W_S{}^3 * (1.2252/2) * A_S)}{1000}$$

W_s= Wind Speed (mph)

E_w= Energy in the Wind

A_s= Swept Area of Blades

The times that the wind turbine will not be operating are also considered when analyzing the overall energy output of the machine for an entire year. These outages are usually due to the annual maintenance that must occur for the upkeep of the machines. There are also outages due to extreme wind speeds when the turbine must shut down to prevent damage. These outages usually cause a very small percentage of lost revenue, but are vital to the quality of the estimate for the overall energy output. In order to take these times into consideration, a location is available in the Project Analysis spreadsheet to input the limiting factor that will be used. This factor can be cautious or bold, depending on the owner's approach to risk. If cautious, this number could be as low as 0.7[55], to allow for any possibility of low energy generation from the turbine, which would occur if there was not enough wind, there was a great deal of maintenance needed, and the turbine was not performing to maximum capacity. If bold, this number could be as high as 1.0, assuming that the turbine will always perform as expected for the entire year.

All of these variables are taken into account when calculating the expected value for the overall energy output of a given wind turbine. They are shown in Table 16 to demonstrate how each different wind speed produces a different output, which is summarized in the final section of the page.

[55] (Kuhn, Vice President Marketing, 2009)

Table 16: Sample Energy Output Analysis

Wind Speed Group (m/s)	Gross Wind Power (kW)	Turbine Power Curve	Efficiency (%)	Corrected Turbine Power (kW)	Weibull Freq. Distribution	Turbine Power (kW)	Hours/Year Wind Blows at this	Gross Wind Energy (kWh/yr)	Turbine Avg. Energy Output
1	1.062826	0	0	0.0	0.0318	0.00	279	296	0
2	8.502609	0	0	0.0	0.0606	0.00	531	4515	0
3	28.69631	4	0.1393906	4.2	0.0839	0.35	735	21080	3,100
4	68.02087	24	0.3528329	25.3	0.0998	2.53	875	59497	22,146
5	132.8533	52	0.3914093	54.9	0.1079	5.92	945	125588	51,857
6	229.5704	91	0.3963925	96.0	0.1084	10.41	950	217995	91,159
7	364.5494	152	0.4169531	160.4	0.1025	16.44	898	327316	143,973
8	544.167	234	0.4300151	246.9	0.0919	22.69	805	438155	198,764
9	774.8002	332	0.4284975	350.2	0.0786	27.51	688	533199	241,026
10	1062.826	440	0.4139906	464.2	0.0642	29.80	562	597764	261,064
11	1414.622	540	0.3817275	569.7	0.0503	28.65	441	623261	250,986
12	1836.564	635	0.3457544	669.9	0.0378	25.34	331	608629	221,997
13	2335.029	714	0.3057778	753.2	0.0274	20.61	240	559614	180,518
14	2916.395	740	0.2537379	780.7	0.0190	14.87	167	486490	130,222
15	3587.038	750	0.2090861	791.2	0.0128	10.10	112	401173	88,488
16	4353.336	750	0.1722817	791.2	0.0083	6.53	72	314638	57,184
17	5221.665	750	0.1436324	791.2	0.0051	4.07	45	235207	35,639
18	6198.402	750	0.1209989	791.2	0.0031	2.45	27	167891	21,431
19	7289.924	750	0.1028817	791.2	0.0018	1.42	16	114602	12,438
20	8502.609	750	0.0882082	791.2	0.0010	0.80	9	74903	6,970
					Total	230.48		5911815	2,018,963

Expected production (kWh) in one year

The expected value for the output electricity, measured in kilowatt hours (kWh), is crucial to the cost analysis and decisions about the feasibility of the project. This electricity can be sold, and its revenue accounts for the majority of revenue acquired by the project.

Once all of these factors are taken into consideration, the Project Analysis spreadsheet summarizes all of the important information regarding the estimated Energy Output and displays this information in a user friendly printout page. This page is shown in Figure 30.

Energy Generation

Project Name

Street Address

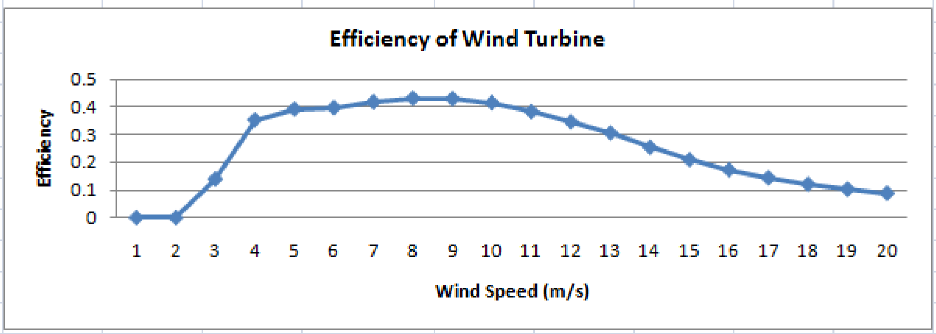
Town, ZipCode

Wind Turbine Model:	*Aeronautica Windpower 47-750*	
Rated Power:	750	kW
Average Wind Speed:	7.5	m/s
Electricity Generated/Year:	1,990,504	kWh/year
Weibull K Factor:	2	

Theoretical Wind Power = $W_{avg}^{3}*(1.2252/2)*(A_{swept}/1000)$

Power Curve for Turbine (Advised Power Generated): Given by Manufacturer

Efficiency = Theoretical Power in Wind/Advised Power Generated



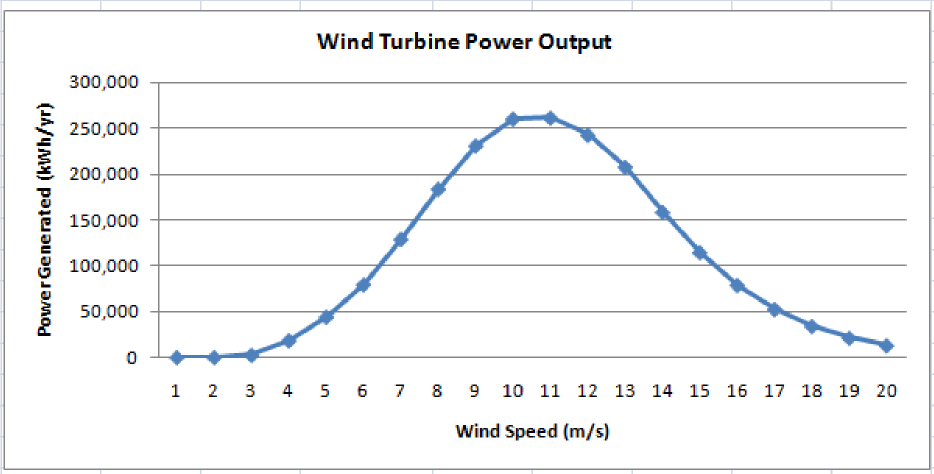


Figure 30: Sample Energy Generation Summary Sheet

Financial Analysis

Installing a wind turbine requires a large, lump sum of money in the beginning of the project. Approximately 70% of the capital that is needed for the project is needed in the first year. This can be seen in the financing information in project analysis spreadsheet. Because of this, the owners of projects must often receive financing from an outside source. It is very rare that an owner can fund the entire project without the use of an outside lender or investor.

There are many ways capital can be obtained in the beginning of a project. The owner can apply for a loan from the bank, similar to a mortgage, and pay back monthly payments on the loan. Another option is to have outside financers invest their money in the project. In order to do this, the owner needs to provide them with the expected return on their investment, and prove to them that the investment is a good financial decision. Similar to investors, the owner could partner with one other person who has a large sum of money and they could receive capital from that individual. This would be similar to a business partnership, and the partner with the large sum of money would see the financial returns quickly.

In order to demonstrate to investors that their investment would be a good economic decision, the owner of a project must analyze the expected revenues versus the expected costs. Various expenditures must be considered when analyzing the expected cost of the entire project. These main factors include feasibility studies, permitting costs, machine costs, installation, maintenance, financing, and insurance. Out of these main costs, feasibility studies, permitting costs, machine costs and installation costs are all required in the very beginning of the project. It is safe to analyze these costs as initial costs to the project; however, the costs of maintenance, financing, and insurance all have more costs due to the fact that they are affected by time value of money because they are needed years later.

Analyzing the finances for a project is a necessary step in order to verify that the project will be financially feasible. In analyzing these finances, many different factors must be considered that can affect the overall revenue of the project. The escalation rate of money, time value of money, internal rate of return, and safety factors all should be analyzed.

The escalation rate of money must be considered when analyzing future costs and revenue. This rate can fluctuate from year to year and a safe estimate of the average for past years may be determined. In this project, it was assumed that a 5-year escalation rate was sufficiently accurate and would be acceptable for the research. This was decided because the escalation rate varies only slightly from year to year, and analyzing the rate every five years gives a balanced rate that accounts for the slight fluctuation from year to year. This escalation rate can then be applied to the annual cost analysis in order to consider how the money in the future is affected.

Time value of money is also a key factor that must be analyzed. The time value of money is the value of money including a given amount of interest earned over a certain period of time. For example, if someone was to invest $1.00 at a 5% interest rate then they would have $1.05 in one year. The value of the $1.00 today and the $1.05 in one year is the same to the investor at T=0, however at T=1 year the investor would rather have $1.05. The interest rate for this investment must be calculated using the present value (the $1.00, or in the wind turbine situation, the initial value of the investment) and also the future value (the $1.05, or in the wind turbine situation, the final amount of money the project is left with).

Another factor that the analyst might want to consider is the safety percentage of the financial investment. This percentage takes into consideration the safety factor in the project's financial analysis. This is to consider the fact that the project may not make as much money as anticipated, because the actual energy output was less than the expected. When doing an analysis, one should make sure that they will definitely have a positive investment and not lose any money. This percentage can be as high or low as the investor wants, it merely depends on how cautious the investor would like to be.

The internal rate of return is a calculated value that is used to show investors how much profit their investment will produce. This value shows the investor the quality (or yield) of their investment. By calculating this number the owner of the project is more likely (or less likely, if the IRR is small) to obtain willing investors. This value must be as accurate as possible in order to eliminate the potential conflicts in the future. The IRR can be calculated using the net present value equation shown in the equation below for net present value. In this equation, the IRR is the "r" value.

$$\mathrm{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0$$

C_n= Net Yield in Year "n"

Many portions of the wind turbine installation process cost money which is not considered in the price of the turbine from the manufacturer. These added expenditures include the foundation, surveying, land clearing, and roadway installation (if necessary). RSMeans is a publisher of reference books that offers construction cost data that can be used to estimate costs of various construction activities. These books were used to estimate the cost of the portions of wind turbine installation process. The cost data was used to estimate the cost/unit of each activity. The foundation is estimated in $/CY, surveying and land clearing is estimated in $/acre, and roadway installation is measured in $/LF. This is integrated into the Project Analysis spreadsheet in such a way that the operator only has to enter the cubic yards of foundation needed (specifically the dimensions of the foundation and the CY is calculated), acreage of land on the site, and the linear feet of roadway needed, and the spreadsheet will calculate and output the costs of each of the activities.

All of the revenues and expenses of the project are analyzed in the Project Analysis spreadsheet. This analysis gives the expected profits of the owner and the investor for various projects. This information is also summarized in an output sheet titled “Economic Analysis” from which the user can easily see important financial information about the project. A sample of this output sheet is shown in Figure 31.

Economic Analysis

Project Name
Street Address
Town, ZipCode

Wind Turbine Model:	*Aeronautica Windpower 47-750*
Turbine Cost (w/ Installation):	*$3,301,449*
Retail Value of Electricity:	*$0.128*
Owner's Profit (20 Year Value):	*$2,787,662*
Investor's Profit (20 Year Value):	*$1,701,122*

Revenue:

Retail Revenue:	**$332,937**
(Electricity $/kWh x kWh Generated per Year)	
REC Revenue:	**$91,038**
(RECs $/kWh x kWh Generated per Year)	
PTC Revenue:	**$54,623**
(PTCs $/kWh x kWh Generated per Year)	
Grant Revenue:	**$100,000**
(Sum of All Grants)	
Total Revenue:	**$578,597**

Expenses:

Turbine Cost:	**$1,725,500**
(Turbine Cost, Shipping, Foundation)	
Pre-Construction:	**$134,990**
(Site Investigation, Legal Work, Permitting)	
Construction:	**$1,405,250**
(Site Upgrades, Electrical Tie-In, Labor)	
Yearly Expenses:	**$91,000**
(O&M, Insurance, Land Leasing)	
Total Expenses:	**$3,265,740**

Financing Structure:

Loan Type:	Investor	**5 Year Escalation Rate:**	5%
Loan Amount:	-$3,301,449	**Break-Even Point (Owner):**	13
Coupon Payment:	$250,000	**Break-Even Point (Investor):**	10
Years of Payback:	10	**Internal Rate of Return:**	4.40%

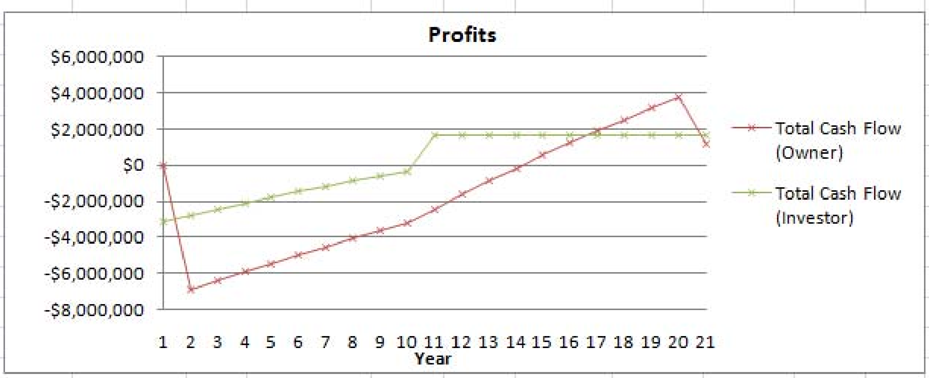


Figure 31: Sample Economic Analysis Summary Sheet

This summary sheet shows the user the financial outcomes based off of the project information they entered into the General Information tab of the Project Analysis spreadsheet. This specific output sheet shows the results of a positive cash flow project, which uses an investor type of investment. In this output sheet the user can reference the break-even point for the investor and the owner, which is given in the number of years it takes for the cash-flow to be positive. It also shows the overall profit of the investor and the owner, in 20-year values (i.e. the future value of their investments). The internal rate of return is given which shows the investor that the investment will (or will not) make money and at what degree they will do so.

Sample Project Analysis

This output sheet gives values for a ten year loan, paying $250,000, on a 750kW Aeronautica Wind Turbine. The tower is designed specifically and the cost of the tower is taken from the cost estimation tab. The break-even point for the investor is year ten, and for the owner it is year 13. This example shows that with these values, both the investor and the owner have positive profits from the project. Table 17 shows financial information for the same 250 foot wind turbine that was designed in Chapters 4 and 5.

Table 17: Summary of Financial Data for 250' Turbine

Wind Turbine Model:	Aeronautica Windpower 47-750
Turbine Cost (w/ Installation):	$3,301,449.24
Retail Value of Electricity:	$0.12
Owner's Profit (20 Year Value):	$1,626,386.20
Investor's Profit (20 Year Value):	$3,692,746.17

Chapter 7: Offshore Turbine

In addition to land-based wind turbines, wind turbines located in the ocean, or offshore wind turbines, have emerged as an efficient source of renewable energy. In comparison to land-based wind turbines, offshore turbines are subject to higher wind speeds and are made in a larger scale. Thus, offshore turbines have the potential to produce more energy in a more efficient manner. This chapter will investigate the implications of an offshore wind turbine including the tower and foundation design, and modifications to the construction and energy delivery process.

Offshore Wind Turbine Background

As indicated throughout this report, a main factor in the feasibility and potential energy production of a wind turbine is the wind speeds in the location of the turbine. For this reason, offshore wind turbines appear to be a promising source of renewable energy for the future due to stronger wind speeds. While the investigation of offshore wind turbines in Europe began in the early 1980's, the design of offshore wind turbines is a relatively new technology to the United States. [56] The reason for this is because the United States has had more success with wind energy on land than European countries due to the climate and geography of the country. However, with increasing energy demands and costs, there has been a recent focus on offshore wind in the United States. At the end of 2008, it was determined that worldwide, there was 120,800 MW of wind generating capacity versus 1,471 MW from European offshore projects.[57] The wind generating capacity from offshore projects is predicted to rise to over 11,000 MW as a result of projects planned throughout Europe, Asia, the United States, and Canada in 2010.[58]

As with land-based wind turbines, there are several characteristics and variables that that need to be investigated when selecting a suitable site for the offshore turbine. The following characteristics should be examined:

- Distance from the shore
- Proximity to power demand sites, local electric companies, local airports
- Interference with telecom installations and line of site from onshore
- Interference with wildlife and avian population

[56] European Wind Energy Association. EWEA. (October 2009), from www.ewea.org
[57] European Wind Energy Association
[58] *OCS Alternative Energy and Alternate Use Programmatic EIS: Information Center.* (n.d.). R(February 2010), Offshore Wind Energy: ocsenergy.anl.gov/index/index.cfm

- Existence of under-sea gas lines and cables
- Impact on existence on shipping routes

In terms of assessing the effects of the surrounding environment on the performance of the wind turbine, the existing wind conditions, the depth to bottom of the ocean, and wave conditions are critical. Additionally, currents, tides, ice loads, and geotechnical properties associated with the sea-floor soil must be taken into consideration. [59]

Offshore towers are typically larger than land-based turbines because of cost implications. The massive and unique loading conditions on an offshore turbine drive the construction and foundation costs.[60] Therefore, larger turbines with greater energy outputs are being produced to offset initial construction expenses.

Offshore Tower Design

The offshore tower design was based on methods used for the land-based turbine design and included additional loads due to the effects of wave, shown in Figure 32.

[59] Malhotra, S. (2009). *Design & Construction Considerations for Offshore Wind Turbine Foundations in North America*. Civil Engineering Practice , 9.
[60] Malhotra, 11

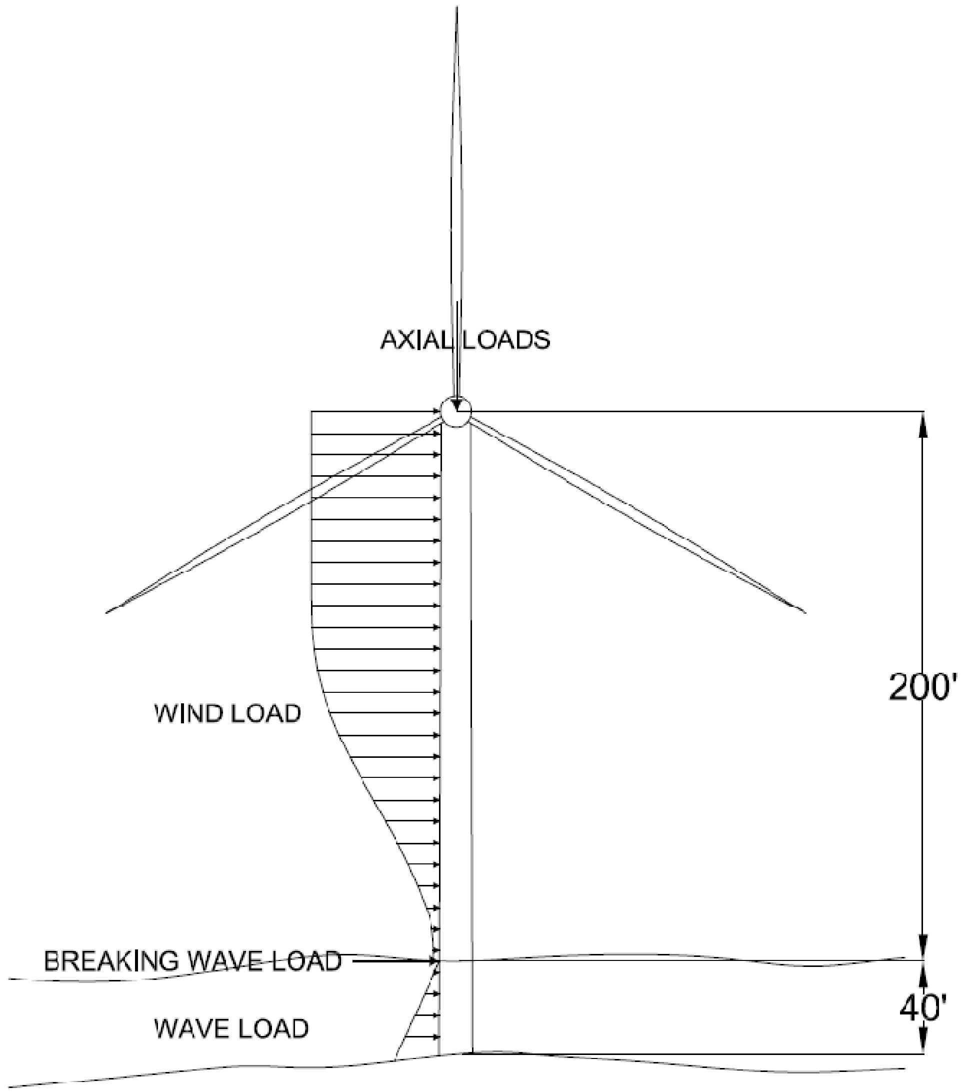


Figure 32: Loads Acting on Tower

The portion of the tower that remains above the sea level is designed with the same axial and lateral loads as a land-based turbine as described in Chapter 4: Tower Design. At sea level, a breaking wave load is introduced as follows:[61]

$$F_D = 0.5\gamma_w C_D D {H_b}^2$$

where

[61] *ASCE-7-05* (2005). American Society of Civil Engineers.

γ_w is the density of sea water, 64 pcf,

C_D is 1.75 for round columns,

D is the diameter of the tower at the sea level height,

and H_b is the water depth times a reduction factor of 0.78.

The hydrodynamic loads below the water surface are calculated by multiplying the water prism, $F_{water} = \frac{1}{2}\gamma_w h^2 D$ by an impact factor of two. In the water prism equations, *h* is the water depth. The forces on a 240 foot tower with 40 feet submerged underwater are summarized in Table 18 and Table 19 below. All supporting calculations and design sheets can be found in Appendix H.

Table 18: Forces Due to Axial Loads

Force	Axial
Equipment	700 kips
Steel	359.2 kips
Ice	47.03 kips

Table 19: Forces Due to Lateral Loads

Force	Moment	Shear
Wind	15370 ft-k	106.7 kips
Breaking Wave	27256 ft-k	681.4 kips
Wave	17066.7 ft-k	1280 kips

The tower was designed for axial, bending, and combined stresses in the same manner as the land-based wind turbine. The design summary data is in Table 20 below.

Table 20: Offshore Turbine Design Data

Design Criteria	240' Tower
Diameter at base	12.5'
Diameter at hub	11'
Shell thickness	1 in.
Strength of steel	36 ksi
Modulus of Elasticity	29,000 ksi
Total axial load acting at tower base	1318.1 kips
Total moment acting at tower base	59693 ft-k
Total shear load acting at tower base	2068.1 kips

Offshore Foundation Design

The design chosen for this tower is the driven steel monopole deep foundation, which is acceptable for depths up to 165 feet.[62] Since the wind turbine is subjected to such excessive lateral forces, the foundation must be designed to resist it. The method used to design the diameter and depth of the foundation was Evan and Duncan's Charts, which is based on the p-y method. The p-y method limits the design in terms of lateral load deflection, which must not exceed ½".[63] In the equations used to calculate the characteristic shear and moment loads, the diameter of the pile is assumed and checked for deflection. The depth of the pile is determined by multiplying its diameter by 35 so that it is considered fixed at its bottom for a correct analysis. The diameter chosen for this design was 12 ½ feet, and the minimum depth of the pile should be 437 ½ feet. All equations and calculations can be found in Appendix H.

Construction of Offshore Wind Turbines

The construction of offshore wind turbines can be summarized in three main phases. First, the transportation phase depends on the type of turbine and supporting structure being used. Most often the pieces of the turbine are transported to barges located at the site of construction. Sometimes pieces can be transported together after they are already assembled (i.e. the nacelle attached to the tower with the rotor also attached), but sometimes the turbine has to be shipped with the pieces separate. The barges at the site are used as a construction platform for the second phase of construction, the erection. The barges are most commonly available, however they lack the stability needed to construct the turbine. An alternative to this platform is a "jack-up" rig which is stable enough platform for

[62] Malhotra, 11
[63] Coduto

installing the nacelle, rotors, and tower as well as for driving the piles needed for the foundation. These jack-up rigs lack the amount of maneuverability needed to install the turbine efficiently. A platform with a good balance of both stability and maneuverability is a “ship-shaped vessel” which carries a rotating crane. The last phase of construction needed for the installation of an offshore turbine is installing electrical wires in order to transport the generated electricity to the main land where it will be used. These wires cannot float in the open ocean because of the change of animal or marine vessel interference. In order to prevent this, the wires can be buried under the sea floor. Many different methods exist for burying these wires; however a method that has shown to be less invasive to the surrounding ocean floor is called “hydro-plowing”. This method uses water to excavate a trench in which the wires can be placed, and this trench is eventually filled with shifting sediment.[64]

[64] Malhotra, S.,14

Chapter 8: Conclusions

The purpose of this project was to design a land-based wind turbine considering various design alternatives and investigate the implications. In-depth research was conducted on wind energy and current design standards of wind turbines. This research contributed to the improved understanding of the main factors that influence the feasibility and potential efficiency of a wind turbine at a given site. This allowed for the initial establishment of suitable conditions for wind turbines. Once these conditions were determined, the group explored the available options for designing the turbine tower and foundation. The background research also provided key information on the social and political aspects involved when a suitable site is found for a turbine in a given community.

In terms of the structural design of the turbine tower, the main factors that were considered were the wind loads, dead loads from the weight of the turbine, ice loads, and lateral loads. Using the *Massachusetts State Building Code (780 CMR)* and *AISC Steel Construction Manual* as main resources for the design equations, it was determined that in terms of height, the tower is governed by the required flexural strength. A computer analysis was conducted using ANSYS, which investigated the deflection of the tower design in order to find the magnification factor of the moment on the tower. By exploring different wind speeds and tower heights, the portion of the project pertaining to the tower design resulted in a better understanding of the relationship between axial loads, moment forces, and varying wind speeds.

The foundation design procedure for the wind turbine was created primarily in reference to ACI code provisions. The foundation was designed considering different design alternatives, such as varying tower heights and soil properties. The implications of these changes were observed from the use of the integrated design spreadsheet, which used the tower data from the tower design process. This portion of the project resulted in the understanding of the checks involved in the design of a foundation including shear, bearing, and bending stresses.

The project analysis not only helped to fulfill the capstone design requirement of investigating the cost-effectiveness of a project, but also tied the construction of a wind turbine back to the initial research about the feasibility. It was important to recognize that the success of a wind turbine is not just based on the site, but also the financial status of the individuals and organizations involved.

The investigation of an offshore wind turbine provided further experience with alternative designs and the implications involved. New forces were introduced and considered, such as dynamic wave forces and breaking wave loads. This section of the report helped to reinforce the idea of how forces and other factors can affect the wind turbine design and helped to identify the advantages of offshore wind.

The integrated spreadsheet was designed with the intention to allow users with less technical experience to explore their options in terms of turbine and foundation sizes and the financial aspects of installing a wind turbine. The spreadsheet can also theoretically eliminate a site based on feasibility and save a community or perspective builder the time and money that may have been spent on a preliminary wind study.

As stated in the background chapter, wind energy and wind turbines are relatively new technologies, and therefore, do not have an abundance of prior research. Therefore, it was difficult to find complete design methods for the turbines. The design processes utilized throughout this project was adapted from several different codes and methods because most of the published information on wind turbines are owned by wind turbine companies. In the future, when more cohesive design methods are available for wind turbine towers and foundations, the integrated spreadsheet could be modified to increase its accuracy.

For future work, it is recommended that additional design alternatives are performed such as the use of ring stiffeners or high strength steel. The consideration of the amount of steel and concrete used in the design could be investigated in order to determine the most cost-efficient design. As a result of the background research, it was found that ring stiffeners could help optimize the design of the tower by decreasing local buckling and allowing for the use of thinner steel for the shell[65]. For the purpose of the integrated spreadsheet, complex design factors, such as ring stiffeners, were not considered, but it may be effective to design them for more specific projects.

In addition, research revealed that other geometries for the footing may be more efficient including circular, octagonal, or hexagonal. It is recommended that once more information is available to investigate the implications of replacing a square foundation with another shape.

[65] Uys, *Optimisation of a Steel Tower for a Wind Turbine Structure,* ScienceDirect, http://www.sciencedirect.com/science (November 2009).

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Appendices

Appendix A: Project Proposal

Project Number: LDA-1004

WIND TURBINE DESIGN AND IMPLEMENTATION

A Proposal for a Major Qualifying Project Report:

Submitted to Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

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Bethany Kuhn

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Julie Marquis

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Hilary Rotatori

Date: October 15, 2009

Approved:

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Professor Leonard D. Albano, Advisor

Table of Contents

Problem Statement

As the demand for more environmentally-friendly energy resources grows, energy providers have recognized the importance of wind power through the development of wind turbines. In fact, wind energy is the only renewable resource that has grown faster than predicted.[1] The construction of a wind turbine is limited to specific site guidelines due to social and special constraints; therefore there is an alternative need for sites other than land-based turbines, such as off-shore and retrofit (on an existing building) turbines. Wind turbines must be designed to withstand heavy loads and moments due to extreme wind condition to prevent failures, as well as other forces that are introduced with alternative site designs.

Objective

The purpose of this project is to design a land-based wind turbine as well as explore designs for off-shore and retrofit options for the energy needs of the chosen site. To begin studying the construction of wind turbines, a suitable site must be chosen based on a given criteria. The effect of wind loads is evaluated on the wind turbine for its design. This project will investigate and draw recommendations on the process of constructing three different wind turbines with different types of foundations.

Scope of Work

This project will be split into two main sections; the first being design and the second being project management. All three group members will contribute to each section of the project. The design section will focus on detailing how a specific wind turbine tower is designed as well as how a foundation should be designed. The project management section will detail the steps that go into scheduling and analyzing the overall cost of the project. These parts contribute to fulfilling the capstone design requirement for the three group members.

Background

Project Management

The Project Management aspect of this process must commence as early as possible in order to have the most efficient decision making process. The main part of this stage is to create an accurate schedule in order to complete the tasks at hand on time. This will help keep the project on track and will set

[1] Singh; Concrete construction for wind energy towers

deadlines for different phases. Project Management will also focus the steps that would be needed to permit a wind turbine project. Later on in the project, the cost will be analyzed throughout all stages of the project to ensure that the project is still financially feasible, as well as a life-cycle cost analysis for long-term use of the turbine.

Design

In order to design the tower and foundation of a wind turbine, it is helpful to know the mechanical design and how it works. The force of the wind is applied to the blades of the turbine, which are angled to produce a rotation where the blades convene.[2] The blades are connected to a shaft that also spins along with the rotation of the blades, which in turns creates energy that is converted through a generator at the base of the turbine. The tower of the turbine rotates (with an axis of rotation perpendicular to the ground) based on the direction of the wind, in which the blades are positioned perpendicular to the wind load to maximize the wind exposed surface area. When the force of the wind exceeds the force at which the turbine was designed for, the blades are positioned parallel to the wind direction in order to reduce the wind exposed surface area and the spinning motion is constricted due to a rotor brake.

Power

The turbine size is determined based on the energy needs of a site. A turbine is generally classified as one of three sizes. Wind turbines can vary in size from small residential turbines to large utility-scale turbines. Table 1 shows the scale, size ranges, and uses for different classifications of wind turbines.

Table 1: Wind Turbine Classifications[3]

Scale	Average Size Range	Uses
Utility	900 kW - 2 MW	•Generate bulk energy for sale in power markets •Commonly used in “wind farms”
Industrial	50 kW - 250 kW	•Remote grid production •Reduce consumption of higher cost grid power •May be sold if permitted by state regulations
Residential	400 W to 50 kW	•Remote power •Battery charging •Net-metering type generation

[2] http://en.wikipedia.org/wiki/Wind_turbine_design
[3] http://www.powernaturally.org/Programs/Wind/toolkit/9_windturbinetech.pdf

Tower

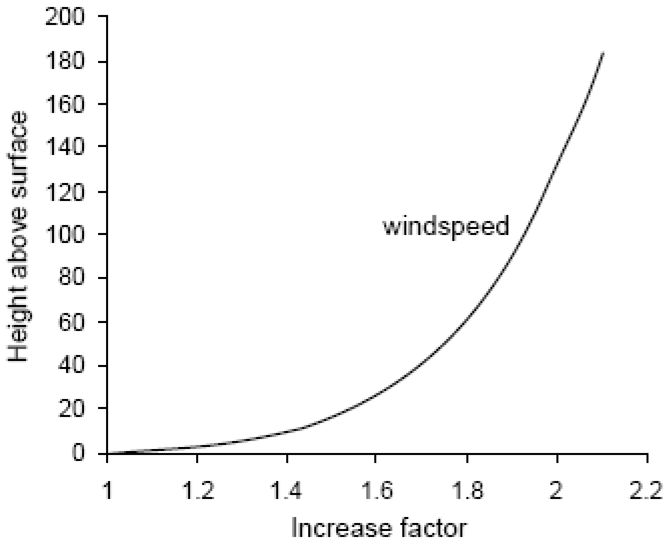


Figure 1: Relationship of Height and Increase factor of Wind

The tower is also an important factor in the design of the wind turbine. The "increase factor" of the wind speed increases exponentially as the height above a surface increases, as shown in Figure 3.[4] From this graph, one can see that at low heights, the wind speed increases significantly at first, but at higher elevations the rate of increase is much less. The wind speed will also vary due to the surrounding area.[4] The increase of wind speeds is higher in open areas (such as over a body of water) than in highly vegetated areas (such as wooded areas). Through years of experience, turbine manufacturers and consultants have recommended that a turbine should be at least 30 feet higher than any object within 300 feet.[5] This rule of thumb is used to avoid rapid changes wind velocity and direction, or turbulence. The wind speeds must be maximized and direction constant at the blades of the turbine in order to maximize the productivity of the wind turbine.

Foundation

The foundation of a wind turbine is designed for the worst-case loading. The turbine foundation has to resist great loads mainly because of the moment due to wind and must simultaneously resist forces and uplift from geotechnical conditions.[6] Reinforced Concrete Spread footings are most common in design because it is applicable to a wide range of soil strengths, however for some weaker soils a deeper foundation is needed to stabilize the turbine tower.[6] The main components in designing a spread footing are its width, depth, amount of steel reinforcement, and construction requirements.

The essential foundation design criteria are stiffness, strength, stability, differential settlement, durability, and economy. These minimum values for foundations are usually provided by the turbine

[4] http://www.greenenergyohio.org/page.cfm?pageId=536 pg 36
[5] http://books.google.com/books?id=1ZKky0XK6IUC&pg=PA270&dq=turbulence+wind+turbine# pg 270
[6] *www.garradhassan.com/.../**Wind_Turbine**_Foundation_Behavior_and_Design_Considerations.pdf*

manufacturers' design specifications. Below lists the design factor, its design criteria, and any design codes or standards that are used in conjunction with the criteria.[12]

Table 2: Foundation Design Criteria

Design Factor	Criteria	Design Codes/Standards
Rotational Stiffness	Acceptable interaction between the flexible concrete footing and the soil supporting it due to rotational forces, allows footing to "give" with applied loads	Arya, et al. and DNV
Strength	Withstand factored loads and fatigue loads	IEC, ACI, FoS
Stability	Resist excessive translational and rotational movement under extreme loads	FoS (Factor of Safety)
Differential Settlement	Considers soil criteria to minimize short-term and long-term differential settlements	Geotechnical Standards
Durability	Resist environmental damage to concrete and maintain serviceability for the turbine's lifetime	ACI

Capstone Design

This project will address the design constraints set by the Accreditation Board for Engineering and Technology (ABET) in order to meet the requirement of capstone design experience for the Major Qualifying Project. As stated by ABET General Criterion 4, "Student must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political."[7] In addition to these constraints, this project will consider the American Association of Civil Engineers (ASCE) Commentary on "Engineering Design."

Economic

One of the more important constraints on large-scale civil engineering projects is economic feasibility. The design of the project should consider the cost of construction and the materials used. In order to ensure that the project is affordable, a cost analysis of alternative designs and materials will be

[7] http://abet.soe.ucsc.edu/design.html

performed to help choose a design. A life-cycle analysis of the final design will also be conducted to determine the economic impact of the turbine once it is in operation.

Environmental

The environmental impacts of projects have been a rising concern in the civil engineering industry in recent years. It is important to protect the land surrounding the construction site and to investigate the affects of the wind turbine on wildlife. This project will address environmental constraints by reviewing all environmental codes and regulations regarding the construction and operation of the turbine. This review will allow the group to compile a list of typical regulations that should be considered before a turbine is constructed.

Sustainability

Sustainability is an important aspect of the design of the wind turbine because the design should be durable as well as economical and environmentally-friendly. This project will address sustainability by considering the maintenance to be done on the turbine in the future. The availability of the materials used will also be taken into account. Also, by using innovative designs such as retrofit turbines (on an existing building), land can be preserved. In addition, a life-cycle cost analysis will be done including an estimation of the "payback" time for the construction of the turbine.

Constructability

The constructability of the project will address feasibility of the design and construction of the turbine. This project will address this constraint by considering ease of construction when choosing building materials, and researching the most practical methods for the construction of a turbine. The group will consider using standard dimensions for the tower height and a standard turbine power so that the turbine could be easily constructed and replicated if successful. In addition, the tower will be constructed using a modular approach to facilitate the construction process and limit the necessary site operations.

Ethical

In order to address the ethical constraints the group will use the principles outlined by the American Society of Civil Engineers (ASCE) Code of Ethics which states, "Engineers uphold and advance the integrity, honor and dignity of the engineering profession by using their knowledge and skill for the enhancement of human welfare and the environment, being honest and impartial and serving with fidelity the public, their employers and clients, striving to increase the competence and prestige of the engineering profession, and supporting the professional and technical societies of their disciplines."[8] This project will consider these principles in all aspects of the design and construction plans including creating a sufficient list of regulations and factors related to the location of the turbine.

Health and Safety

In order to address health and safety considerations a structural analysis of the foundation design materials under different forces will be performed. The research performed on zoning and location restrictions will be considered in the design process to ensure that the turbine is an appropriate distance from its surroundings. In addition, the description of the construction process will include the proper safety precautions to protect laborers and residents in the nearby area.

Social and Political

Since wind energy is a relatively new technology, society has not fully embraced the idea of wind turbines being constructed in their communities. This project will address social and political constraints by considering the permitting process of constructing a wind turbine in a specific community and by researching the people and steps involved. Once these processes are understood, a flow chart of the permitting process and people or organizations are involved will be prepared. In addition, the group will examine case studies in order to determine ways that wind turbines have been successfully integrated into the social aspect of communities in the past.

Methodology

This Major Qualifying Project will focus mainly on the design of a land-based wind turbine, with substantial consideration of how this design would change for off-shore and retrofit wind turbine designs.

Schedule

The project will take place over a period of eight months. During the month of September 2009, the scope of the project will be created and initial research for design and construction components will commence. After the initial research is completed and the proposal is written, the design of a land-based turbine will be derived, considering all design factors. Then, a site that would be suitable for the use of a wind turbine will be selected and a wind turbine will be designed for that particular site. A stress analysis will be performed on the turbine foundation with the aid of computer software to check

[8] http://www.asce.org/inside/codeofethics.cfm

our final design. Finally, the design of the land-based wind turbine will be modified to a suitable design for an off-shore and retrofit wind turbine. During this time the group will create relationship chart that will outline the different factors that go into installing a wind turbine, and how a turbine should be designed based on the different variables. In C term, the group will finalize the report and also finish the capstone design requirement of the project. A detailed timeline can be seen in Figure 2.

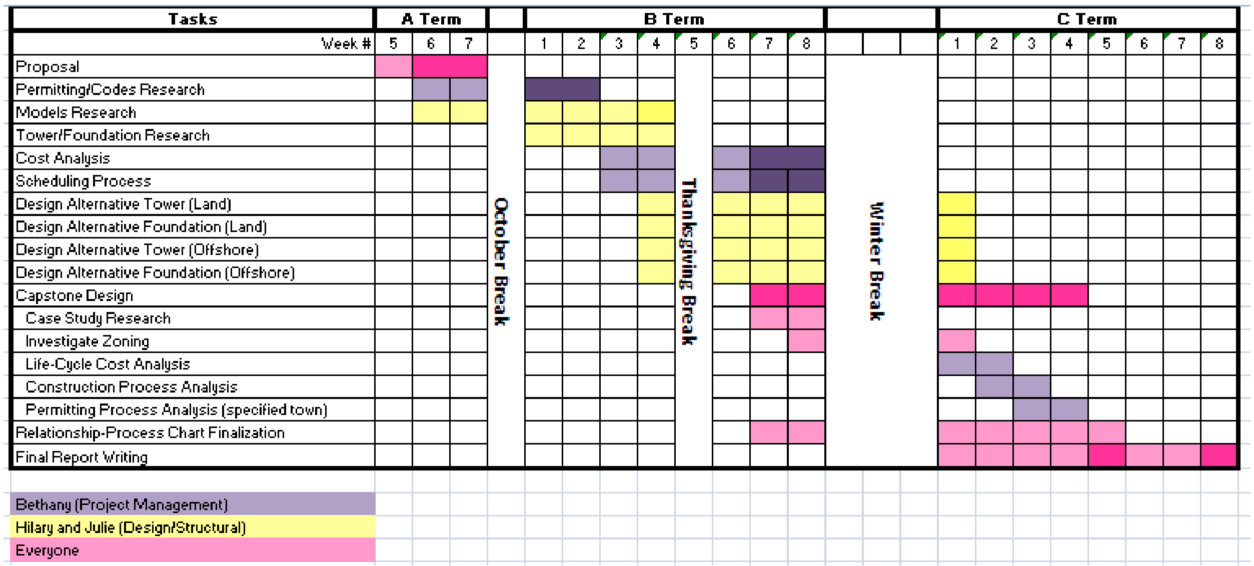


Figure 2: MQP Schedule

Land-Based Wind Turbine Design

When designing a wind turbine, there will be certain design factors associated with the site that is chosen to build upon. This project will examine several different alternatives to the design factors listed below in Table 3. The first column displays the specific design component, the second column displays alternatives to the design component to consider, and the third column displays what other design factors play into designing that particular part of the turbine.

Table 3: Design Factor Alternatives for Consideration

Design Component	Alternatives to Consider	Design Factors to Consider
Soil Profile	1. Sandy 2. Clayey 3. Rock	Strength of Soil
Foundation Type	1. Spread 2. Pile 3. Anchor	Soil Profile, Turbine Size, Number of Blades, Tower Design, Wind Speed
Turbine Size	1. Small Scale 2. Mid-Scale 3. Large Scale	Type of Site, Distribution
Number of Blades	1. Two blades 2. Three blades	Wind Speed, Tower height
Tower Design	Width, height, shape	Wind Speed, Surrounding Terrain, Turbulence
Type of Site	1. Residential 2. Commercial	Zoning, Surrounding Parcels
Wind Speed	1. Class 1-3 2. Class 4-7	Location of Site, Height off the Ground
Distribution	1. Behind the Grid 2. Sell to the Grid	Energy needs of the Site

Through research and calculations, this project will determine how the different alternatives to the design component will affect the overall design of the turbine. A turbine will then be designed for a particular site using the information from this component of the project.

Alternative Turbine Designs

Using the knowledge and experience gained from designing a land-based wind turbine, two alternative turbine designs will be generated: an off-shore wind turbine and a retrofit wind turbine on an existing building. Both cases will have the same basic concepts of designing a land-based turbine; however each design will have different loads applied and different design constraints. The off-shore wind turbine will now have an additional load on the tower from the water current, stronger winds and zero turbulence from the smooth surface of the water, and construction constraints. The retrofit wind turbine will also have stronger winds from being at an increased height (however, more turbulence if surrounding buildings are of comparable heights), and the building will have to be reinforced to handle the force created by the wind turbine. Both designs will be incorporated in this Major Qualifying Project to better understand the differences in design of the wind turbine in different environments.

Deliverables and Conclusions

The final deliverables of this project will include designs for a land-based, offshore, and retrofit wind turbine, along with a design chart identifying different components of designing a wind turbine and how these factors changed based on site conditions. A cost analysis of each design, a list of criteria used to determine potential sites, and a summary of the permitting process to construct a wind turbine will also be determined. Also, a design chart will be created as a reference to assist future turbine designs, in which all of the aforementioned design criteria will be incorporated. The designs will be completed through hand calculations and CAD drawings. The foundation design of the towers will be analyzed in a computer program such as ANSYS. The cost analysis for the land-based, offshore, and retrofit turbines will be completed and will detail the economic return of the entire life-cycle of the turbines. A list of criteria for potential sites will be created in an organized table in order to be referenced for future projects. Also, the steps that must be taken to get a wind turbine approved and permitted will be given in a detailed list. Finally, all of our results will be presented in the form of a Major Qualifying Project Report which will include how all of our deliverables took into account the ABET constraints for capstone design experience.

Appendix B: Interview Notes with Aeronautica Wind Power

Brian Kuhn (Aeronautica), Hilary Rotatori, Julie Marquis, Bethany Kuhn

Friday; October 23, 2009; 8:45AM-10:15AM

1. Aeronautica must send the information they have to a local civil engineer, located near the location where the turbine is being installed, in order to have a foundation designed.
2. Aeronautica can provide us with loading data for the foundation
3. Vestas is a fully integrated design and manufacturing company (as is Norwin)
4. Aeronautica has the design for a 60m tower for the 750kW machine
5. Goal should be to make spreadsheet for wind speeds/tower height (like Norwin has and charges for)
6. Towers are often made of steel
7. Size scales
    a. ~15-99kW: small-scale
    b. 100-999kW: mid-scale
    c. 1MW and up: utility-scale
8. Retrofit is only used for micromachines- not economically feasible
    a. Smaller machines
    b. Higher noise
    c. Rattling/vibrations
9. Clean air vs. Turbulent air
    a. Clean air is located above all other obstacles
    b. Turbulent air has more drag/friction
        i. Located near buildings
        ii. Another reason retrofit doesn't make sense
10. Power in wind is a cubic function of wind speed
11. Offshore turbines are often done close to the shore line with piles driven into the sand/mud. Turbines located further from the coast are often on a floating platform that is anchored to the ground.
    a. This costs twice as much money as land-based designs
12. Process chart can depend on the customer**
    a. Need vs. Desire
    b. Choose the site vs. Verify the site
    c. Design of turbine vs. Selection of turbine
13. Special permitting is often required if a bylaw doesn't exist in a town (not creating a bylaw like we had)
14. Do project management before 'design'
15. Town regulations usually refer to the hub height
16. FAA regulations usually refer to the overall height

17. Rotorsize=wingspan
18. Usually an attorney presents the application for a permit to the town (knows the zoning regulations and such)
19. Foundation Design Contacts
    a. Atlantic Design Engineers, LLC
    b. Patrick and Henderson (CA)
    c. Meridian, SGE (RI), Alteris
20. MTC (Massachusetts Technology Collaborative)
    a. Grants for renewable energy
        i. Money can go towards wind studies or other necessary studies
21. Can cost anywhere between $50,000-$150,000 for permits (even more or less)
    a. Averages $100,000
    b. Studies included in this price
    c. Feasibility studies- actual vs. desktop wind data (eventually actual data is necessary)
        i. Doppler wind provides initial data but a wind tower must be installed for at least 1 year to get real wind data ($30,000-$40,000)
            1. This is often needed to obtain financing for the turbine
        ii. Feasibility (Simon's studies(noise, how it will look (pictures), flicker): $10,000-$20,000
    d. Wind appraisal (first step): $2,000-$3,000
22. Maintenance and Debt Service are the two major costs once the turbine is installed
    a. 7-10 year loans available, often between 8%-9%
    b. O&M (operating and maintenance)
        i. Twice yearly service checkups
        ii. Manufacturers provide maintenance checklists
        iii. $10,000-$15,000/year for maintenance

**Also see notes on Process Flow Chart

Appendix C: Tower Design Sheets and Hand Calculations

Design a 250' wind turbine tower in Rutland, Massachusetts for a 1.5 MW turbine.

TRY: 10' ϕ at base
9' ϕ at hub
0.75" shell thickness.

DETERMINE AXIAL LOADS.

→ Wt. of equipment @ top of tower ~ 400k for 1.5 MW turbine.

→ Wt. of steel: Approximate taper, use 5 - 50' sections to calculate wt. of steel:

$V = 50'[\pi R^2 - \pi r^2]$, where R = outer radius and r = inner radius.
$W = V \cdot \rho_{steel}$

Section 1: 10' ϕ

$V = 50'[\pi(5)^2 - \pi(4.9375)^2] = 97.56\ ft^3$
$W = (97.56\ ft^3)(0.490\ k/ft^3) = 47.8050^k$

Section 2: 9.75' ϕ

$V = 50'[\pi(4.875)^2 - \pi(4.8125)^2] = 95.11\ ft^3$
$W = (95.11\ ft^3)(0.490\ k/ft^3) = 46.6023^k$

Section 3: 9.5' ϕ

$V = 50[\pi(4.75)^2 - \pi(4.6875)^2] = 92.65\ ft^3$
$W = (92.65\ ft^3)(0.490^k/ft^3) = 45.3997^k$

Section 4: 9.25' ϕ

$V = 50[\pi(4.625)^2 - \pi(4.5625)^2] = 90.20\ ft^3$
$W = (90.20\ ft^3)(0.490^k/ft^3) = 44.1971^k$

Section 5: 9' ϕ

$V = 50[\pi(4.5)^2 - \pi(4.4375)^2] = 87.74\ ft^3$
$W = (87.74\ ft^3)(0.490\ k/ft^3) = 42.9944^k$

Total wt. of tower = $\Sigma W = 226.9985^k$.

→ Wt. of ice: Use 5 - 50' sections to approximate taper, so ϕ of tower changes

Using spreadsheet, calculate the cross-sectional area of ice A_i for 1' sections. Sample calculation for z = 249'-250' (z will vary).

ASCE-7-05 Ch. 10 - Ice Loads.

$A_i = \pi t_d (D_c + t_d)$

$t_d = 2.0 t I_i f_z (K_{zt})^{0.35}$

t = nominal ice thickness, 1" in Rutland (0.0833')

$I_i = 0.80$ for category I buildings.

$f_z = \left(\frac{z}{33}\right)^{0.1} = \left(\frac{249.5}{33}\right)^{0.1} = 1.2242$

$K_{zt} = 1$ assuming no wind speed-up.

$t_d = 2.0(0.0833)(0.8)(1)^{0.35} = 0.1632$

$D_c = \phi$ tower $= 9'$

$A_i = \pi(0.1632)(9 + 0.1632) = 4.6989\ ft^2 \times 1'$ section $= V_i = \underline{4.6989 ft^3}$

$W_i = (4.6989\ ft^3)(0.056\ ^k/ft^3) = 0.2631^k$

Repeat for all 1' sections; $\Sigma W_i = 62.8124$ (already factored)

Total Factored DL $= 1.2(400^k) + 1.2(226.9985^k) + 62.8124$
$= \underline{815.21^k}$

DETERMINE LATERAL LOADS - (wind).
TIA/EIA-222

Approximate wind profile by using 1' tower sections. Show example for tower height = 249 - 250'.

$F = q_z G_h [C_F A_e + \Sigma C_A A_A]$ lb $\leq 2 q_z G_H A_G$

$q_z = 0.00256 K_z V^2$ (lb/ft²)

$K_z = \left(\frac{z}{33}\right)^{2/7} = \left(\frac{249.5}{33}\right)^{2/7} = 1.7824$; $1 \leq K_z \leq 2.58$ ✓

V = 100 mph in 3-second gust, convert to fastest mile wind speed

$V_{FM} = V_3 \left[\frac{V_t / 3600}{1.5}\right]$

gust duration $t = (3600\ s/mi)\ V_3 = 3600/(100\ mph) = 36$
using figure ASCE-7-05, $V_t = 1.31$

$V_{FM} = 100\left(\frac{1.31}{1.5}\right) = 87$ mph

$q_z = 0.00256(1.7824)(87)^2 = 34.5378$ lb/ft²

$G_H = 1.69$ for tubular pole structures.

C_F : $D_p = 9' + [2(\text{nominal thickness} = 1''/12)] = 9.1667'$

$C = \sqrt{K_z}\, V D_p = \sqrt{1.7824}\,(87)(9.1667') = 1064.715 > 64$ mph·ft

∴ $C_F = 0.59$ according to TIA/EIA-222 table 1.

$A_F = D_F A_F + D_R A_R R_R$ (ft³)

$D_F A_F \to 0$ (no flat structures).

D_R = 1.0 for wind direction normal to surface

A_R = Projected area of round structural components in one face + t_{ice} = 9.1667'

$R_R = 0.51e^2 + 0.57 \leq 1$

$e = \frac{A_F + A_R}{A_G} = \frac{9.1667}{9.1667} = 1$

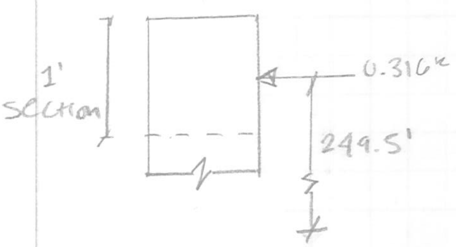
$R_R = 0.51(1)^2 + 0.57 = 1.08$, use $R_R = 1$.

$A_F = 0 + (1)(9.1667')(1) = 9.1667'$

$\Sigma C_A A_A$ does not apply - no linear appertenances.

$F = (34.5378)(1.69)[(0.59)(9.1667')] = 315.57^k = \underline{0.3156^k}$

Determine Moment



$M = F_z = (0.316^k)(249.5') = 78.40$ ft·kips

Repeat for all 1' sections of the tower, sum all moments (see excel spreadsheet

$\Sigma M = M_{max} = \underline{\underline{8827.16}}$ ft·kips; acting at base of tower.

Total Shear = ΣF = $\underline{\underline{65.71^k}}$

CHECK AXIAL STRENGTH:

Try shell thickness = 0.75", F_y = 36 ksi (standard for rolled steel)
E = 29000 ksi

height = 250' × 12" = 3000"
O.D. = 10' = 120"
I.D. = 10' − 0.75"/12' = 118.5"

KL/R:

K = 2.0 for fixed joint @ 1. end.
L = 3000

$$R = \sqrt{\frac{D^2 + d^2}{16}} = \sqrt{\frac{120^2 + 118.5^2}{16}} = 42.16$$

$$KL/R = 2(3000)/42.16 = 142.31$$

Check for compact section:

$D/t = 120/0.75 = 160$

λ_p for compression: N/A
λ_r for compression: $0.11 \frac{E}{F_y} = 0.11 \frac{(29000)}{(36)} = 88.61$

$D/t = 160 > 88.61$, member is noncompact.

$P_n = F_{cr} A_g$

$$\left[KL/R = 142.31\right] \geq \left[4.71 \sqrt{\frac{E}{F_y}} = 4.71 \sqrt{\frac{29000}{36}} = 133.68\right]$$

Use $F_{cr} = 0.877 F_e$

$$F_e = \frac{\pi^2 E}{(KL/R)^2} = \frac{\pi^2 (29000)}{(142.31)^2} = 14.13$$

$F_{cr} = 0.877(14.13) = 12.3948^k$.

$$A_g = \pi R^2 - \pi r^2 = \pi (120/2)^2 - \pi (118.5/2)^2 = 280.98 \text{ in}^2$$

$P_n = (12.3948)(280.98) = 3482.69^k$

$\phi P_n = 0.85(3482.69^k) = 2960^k > P_u = 815.21^k$ ✓ O.K.

CHECK FLEXURAL STRENGTH:
Circular hollow cross-section will yeild in strength + local buckling only; choose highest of 2 values.

1. Yield in strength:

$\gamma M_r \le \phi M_n = \phi M_p = \phi F_y Z$

$Z = \frac{D^3 - d^3}{6} = \frac{120^3 - 118.5^3}{6} = 10665.56$

$F_y = 36$ ksi

$\phi M_n = (0.9)(10665.56 \text{ in}^3)(36 \text{ ksi}) = 34,556.4$ ft kips

2. Yield in Local Buckling
→ check for compact section: if section is compact, then tower will not yield in LB:

$D/t = 160$

λ_p for flexure $= 0.07\frac{E}{F_y} = 0.07\frac{(29000)}{36} = 56.39$

λ_c for flexure $= 0.31\frac{E}{F_y} = 0.31\frac{(29000)}{36} = 249.72$

$[\lambda_p = 56.39] < [D/t = 160] < [\lambda_c = 249.72]$, tower is non-compact (check)

$M_n = \left[\frac{0.021}{(D/t)}\frac{E}{F_y} + 1\right] F_y S = \left[\frac{0.021(29000)}{(160)(36)} + 1\right](36)(8324)$

$M_n = 331,370^k$.

$S = \frac{\pi(D^4 - d^4)}{32D} = \frac{\pi((120)^4 - (118.5)^4)}{32(120)} = 8324 \text{ in}^3$

$\phi M_n = (0.9)(331,370^k) = 298,233^k$

Yield in strength:

$[M_u = 8827 \text{ ft}\cdot k] < [\phi M_n = 34,556.4^k]$ ✓ ok

ASCE-7-05

CHECK FOR COMBINED AXIAL + FLEXURAL LOADS: (Stability).

$$\left[\frac{P_u}{\phi P_n} = \frac{815.21^k}{2960^k} = 0.275\right] \geq 0.2 \text{; use equ. H1 - 1a}$$

$$\frac{P_u}{\phi P_n} + \frac{8}{9} B_2 \left[\frac{M_u}{\phi_b M_n}\right] \leq 1.0$$

where B_2 is magnification factor for stability.

$P_u = 815.21^k$

$\phi P_n = 2960.^k$

$$B_2 = \frac{1}{1 - \frac{\alpha \Sigma P_{nt}}{\Sigma P_{e2}}}$$

$\alpha = 1.00$ for LRFD

$\Sigma P_{nt} = 815.21^k$

$\Sigma P_{e2} = \Sigma R_M \frac{\Sigma HL}{\Delta_H}$ for lateral load resisting systems

$R_m = 0.85$ for moment-frame + combined systems

$\Sigma H = 65.71^k$

$L = 3000''$

$\Delta H = 6''$ from ANSYS analysis.

$$\Sigma P_{e2} = 0.85 \left[\frac{(65.71)(3000)}{6}\right] = 27927^k$$

$$B_2 = \frac{1}{1 - \frac{815.21}{27927}} = 1.0301$$

$M_u = 105932$ in kips

$\phi M_n = 345564$ in kips.

$$\frac{(815.21)}{(2960)} + \frac{8}{9}(1.0301)\frac{(105932)}{(345564)} = 0.5561 \leq 1.0 \quad \text{O.K.}$$

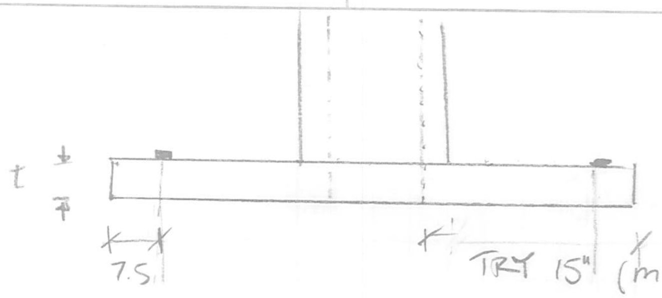
Tower is overdesigned, so use excel spreadsheet to adjust.

FINAL DESIGN: 250' tower, 8' ϕ at base, 7' ϕ at hub, 0.75" thickness.

Resulting loads for baseplate + foundation design:

Axial load: 744.4^k Shear load: 52.03^k

Moment load: 6956.0 ft-k



Assume bolts are prestressed - neglected in design
+ Gussetts for rigidity.

DESIGN FOR FLEXURAL STRENGTH:

$\phi F_B = \phi_B F_y Z_x$

$Z_x = \frac{D^3 - d^3}{6} = \frac{126^3 - 96^3}{6} = 185940 \text{ in}^4$

$\phi F_B = 0.9(36)(185940) = 6\,024\,456$ in-kips $> [M_u = 83472]$ OK.

CHECK SHEAR:

Yield strength:

$\phi V = \phi(0.6 F_y A_g)$

$\phi = 0.9$

$F_y = 36$ ksi

$A_g = \pi R^2 - \pi r^2 = \pi(126)^2 - \pi(96)^2 = 20923.0 \text{ in}^2$

$\phi V = 0.9(0.6)(36)(20923 \text{ in}^2) = 406743^k > [V_u = 52.0^k]$ ✓

Ultimate strength:

$\phi V = \phi(0.6 F_u A_g)$

$\phi = 0.75$

$F_u = 80$ ksi

$A_g = 20923 \text{ in}^2$

$\phi V = 0.75(0.6)(80)(20923) = 753228^k > [V_u = 52.0^k]$ ✓

DESIGN FLANGE THICKNESS.

$t \geq \sqrt{\frac{6 M_u}{\phi_b F_y}}$

$M_u = 256$ ft·k (from Baseplate design).

$\phi_b = 0.9$

$F_y = 0.9$

$t \geq \sqrt{\frac{6(256)}{0.9(36)}} = 6.88" \rightarrow$ use 7"

OR. = 111 in = 9.25'

t = 7"

Weight of Equipment:	400 kips	Axial Load	744.4273105
Height of tower	250 ft	Moment Load	6956.037889
Outer Diameter at base	8 ft	Total Shear	52.03
Outer Diameter at hub	7 ft		
Thickness	0.75 in		
Weight of Steel	490 pcf	t_{ice}	0.083333333
Town (Massachusetts)	Rutland		

Section	Diameter	Height	to	Inner Dia.	OR	IR	Ice Radius
D1	8	0	50	7.875	4	3.9375	4.25
D2	7.75	51	100	7.625	3.875	3.8125	4.125
D3	7.5	101	150	7.375	3.75	3.6875	4
D4	7.25	151	200	7.125	3.625	3.5625	3.875
D5	7	201	250	6.875	3.5	3.4375	3.75

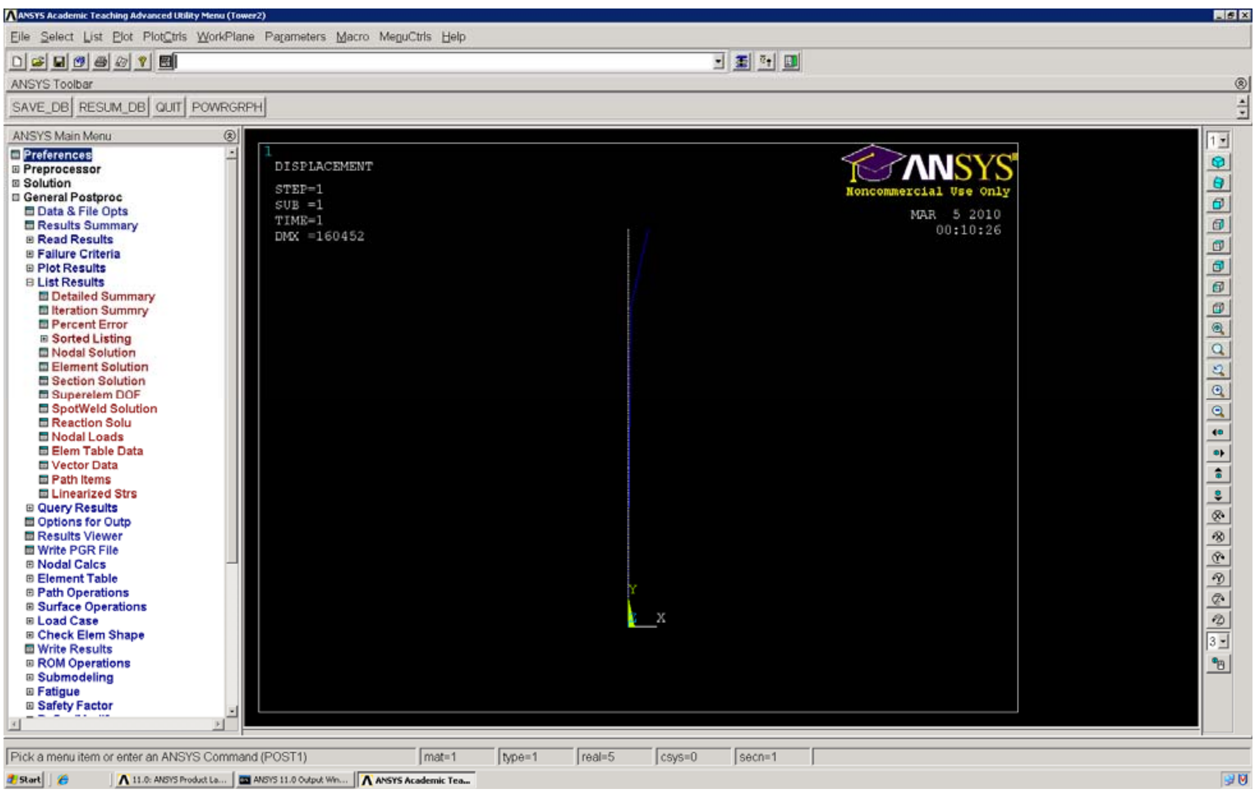
Height	Volume of Steel	Weight of Steel	Volume of Ice	Weight of Ice	Fz	td	D1	D2	D3	D4	D5	Diameter	V(3-s)	V(f.m)	z	Kz calc	1 ≤Kz	1 ≤Kz≤2.58	q z	Gh	Cf	Ar	Ag	e	Ae	Force	Moment
1	1.55852448	0.763676995	2.228225212	0.124780612	0.6577269	0.08769692	8					8	100	87	0.5	0.302086	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	0.07889183
2	1.55852448	0.763676995	2.490105275	0.139445895	0.73410424	0.09788057	8					8	100	87	1.5	0.413476	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	0.23667548
3	1.55852448	0.763676995	2.622271265	0.146847191	0.77257848	0.10301046	8					8	100	87	2.5	0.478449	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	0.39445914
4	1.55852448	0.763676995	2.713184367	0.151938325	0.79901588	0.10653545	8					8	100	87	3.5	0.526729	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	0.5522428
5	1.55852448	0.763676995	2.783165184	0.15585725	0.81935075	0.10924677	8					8	100	87	4.5	0.565941	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	0.71002645
6	1.55852448	0.763676995	2.840354703	0.159059863	0.8359588	0.11146117	8					8	100	87	5.5	0.599337	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	0.86781011
7	1.55852448	0.763676995	2.888871096	0.161776781	0.85004113	0.11333882	8					8	100	87	6.5	0.628637	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	1.02559377
8	1.55852448	0.763676995	2.931098322	0.164141506	0.86229275	0.11497237	8					8	100	87	7.5	0.654872	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	1.18337742
9	1.55852448	0.763676995	2.968545048	0.166238523	0.8731533	0.11642044	8					8	100	87	8.5	0.678715	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	1.34116108
10	1.55852448	0.763676995	3.002228755	0.16812481	0.88291921	0.11772256	8					8	100	87	9.5	0.70063	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	1.49894474
11	1.55852448	0.763676995	3.032869301	0.169840681	0.89180014	0.11890669	8					8	100	87	10.5	0.720953	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	1.65672839
12	1.55852448	0.763676995	3.060995366	0.171415741	0.89995002	0.11999334	8					8	100	87	11.5	0.739938	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	1.81451205
13	1.55852448	0.763676995	3.087007058	0.172872395	0.90748532	0.12099804	8					8	100	87	12.5	0.757778	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	1.97229571
14	1.55852448	0.763676995	3.111214732	0.174228025	0.91449636	0.12193285	8					8	100	87	13.5	0.774625	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	2.13007936
15	1.55852448	0.763676995	3.133864143	0.175496392	0.92105466	0.12280729	8					8	100	87	14.5	0.790603	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	2.28786302
16	1.55852448	0.763676995	3.155153326	0.176688586	0.92721783	0.12362904	8					8	100	87	15.5	0.805812	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	2.44564668
17	1.55852448	0.763676995	3.17524428	0.17781368	0.93303299	0.1244044	8					8	100	87	16.5	0.820335	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	2.60343033
18	1.55852448	0.763676995	3.194271274	0.178879191	0.93853919	0.12513856	8					8	100	87	17.5	0.834243	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	2.76121399
19	1.55852448	0.763676995	3.212346875	0.179891425	0.94376915	0.12583589	8					8	100	87	18.5	0.847594	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	2.91899765
20	1.55852448	0.763676995	3.229566418	0.180855719	0.94875061	0.12650008	8					8	100	87	19.5	0.860439	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	3.0767813
21	1.55852448	0.763676995	3.246011378	0.181776637	0.95350723	0.1271343	8					8	100	87	20.5	0.872822	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	3.23456496
22	1.55852448	0.763676995	3.261751952	0.182658109	0.95805943	0.12774126	8					8	100	87	21.5	0.884781	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	3.39234862
23	1.55852448	0.763676995	3.276849062	0.183503547	0.96242492	0.12832332	8					8	100	87	22.5	0.896348	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	3.55013227
24	1.55852448	0.763676995	3.291355934	0.184315932	0.96661914	0.12888255	8					8	100	87	23.5	0.907554	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	3.70791593
25	1.55852448	0.763676995	3.30531935	0.185097884	0.97065571	0.12942076	8					8	100	87	24.5	0.918425	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	3.86569959
26	1.55852448	0.763676995	3.318780654	0.185851717	0.97454663	0.12993955	8					8	100	87	25.5	0.928982	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	4.02348324
27	1.55852448	0.763676995	3.331776573	0.186579488	0.97830257	0.13044034	8					8	100	87	26.5	0.939249	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	4.1812669
28	1.55852448	0.763676995	3.344339883	0.187283033	0.98193304	0.13092441	8					8	100	87	27.5	0.949242	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	4.33905056
29	1.55852448	0.763676995	3.35649996	0.187963998	0.98544659	0.13139288	8					8	100	87	28.5	0.958978	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	4.49683421
30	1.55852448	0.763676995	3.36828324	0.188623861	0.98885089	0.13184678	8					8	100	87	29.5	0.968474	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	4.65461787
31	1.55852448	0.763676995	3.379713597	0.189263961	0.99215286	0.13228705	8					8	100	87	30.5	0.977743	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	4.81240153
32	1.55852448	0.763676995	3.390812673	0.18988551	0.9953588	0.13271451	8					8	100	87	31.5	0.986797	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	4.97018518
33	1.55852448	0.763676995	3.401600145	0.190489608	0.99847442	0.13312992	8					8	100	87	32.5	0.995647	1	1	19.37664	1.69	0.59	8.166667	8.166667	1	8.166667	0.157784	5.13906541
34	1.55852448	0.763676995	3.412093959	0.191077262	1.00150492	0.13353399	8					8	100	87	33.5	1.004306	1.00430578	1.0043058	19.46007	1.69	0.59	8.166667	8.166667	1	8.166667	0.158463	5.3310235
35	1.55852448	0.763676995	3.42231053	0.19164939	1.00445507	0.13392734	8					8	100	87	34.5	1.012781	1.012781498	1.0127815	19.6243	1.69	0.59	8.166667	8.166667	1	8.166667	0.1598	5.535818
36	1.55852448	0.763676995	3.432264909	0.192206835	1.00732924	0.13431057	8					8	100	87	35.5	1.021084	1.021083506	1.0210835	19.78517	1.69	0.59	8.166667	8.166667	1	8.166667	0.16111	5.74231012
37	1.55852448	0.763676995	3.441970938	0.192750373	1.01013145	0.13468419	8					8	100	87	36.5	1.02922	1.029220112	1.0292201	19.94283	1.69	0.59	8.166667	8.166667	1	8.166667	0.162394	5.95046568
38	1.55852448	0.763676995	3.451441369	0.193280717	1.01286539	0.13504872	8					8	100	87	37.5	1.037199	1.03719901	1.037199	20.09743	1.69	0.59	8.166667	8.166667	1	8.166667	0.163653	6.16025208
39	1.55852448	0.763676995	3.460687983	0.193798527	1.01553449	0.1354046	8					8	100	87	38.5	1.045027	1.045027344	1.0450273	20.24912	1.69	0.59	8.166667	8.166667	1	8.166667	0.164888	6.37163825
40	1.55852448	0.763676995	3.469721683	0.194304414	1.01814191	0.13575225	8					8	100	87	39.5	1.052712	1.052711756	1.0527118	20.39802	1.69	0.59	8.166667	8.166667	1	8.166667	0.166101	6.58459446
41	1.55852448	0.763676995	3.478552582	0.194798945	1.02069058	0.13609208	8					8	100	87	40.5	1.060258	1.06025844	1.0602584	20.54425	1.69	0.59	8.166667	8.166667	1	8.166667	0.167291	6.79909232
42	1.55852448	0.763676995	3.487190077	0.195282644	1.02318324	0.13642443	8					8	100	87	41.5	1.067673	1.067673173	1.0676732	20.68792	1.69	0.59	8.166667	8.166667	1	8.166667	0.168461	7.0151046
43	1.55852448	0.763676995	3.495642915	0.195756003	1.0256224	0.13674965	8					8	100	87	42.5	1.074961	1.074961362	1.0749614	20.82914	1.69	0.59	8.166667	8.166667	1	8.166667	0.169611	7.23260521
44	1.55852448	0.763676995	3.503919254	0.196219478	1.02801046	0.13706806	8					8	100	87	43.5	1.082128	1.082128069	1.0821281	20.96801	1.69	0.59	8.166667	8.166667	1	8.166667	0.170742	7.45156913
45	1.55852448	0.763676995	3.512026715	0.196673496	1.0303496	0.13737995	8					8	100	87	44.5	1.089178	1.089178042	1.089178	21.10461	1.69	0.59	8.166667	8.166667	1	8.166667	0.171854	7.67197231
46	1.55852448	0.763676995	3.519972424	0.197118456	1.03264191	0.13768559	8					8	100	87	45.5	1.096116	1.096115745	1.0961157	21.23904	1.69	0.59	8.166667	8.166667	1	8.166667	0.172949	7.89379163
47	1.55852448	0.763676995	3.527763062	0.197554731	1.03488931	0.13798524	8					8	100	87	46.5	1.102945	1.102945375	1.1029454	21.37138	1.69	0.59	8.166667	8.166667	1	8.166667	0.174027	8.11700483
48	1.55852448	0.763676995	3.535404894	0.197982674	1.03709363	0.13827915	8					8	100	87	47.5	1.109671	1.109670885	1.109671	21.50169	1.69	0.59	8.166667	8.166667	1	8.166667	0.175088	8.34159051
49	1.55852448	0.763676995	3.542903809	0.198402613	1.03925657	0.13856754	8					8	100	87	48.5	1.116296	1.116296006	1.116296	21.63007	1.69	0.59	8.166667	8.166667	1	8.166667	0.176133	8.56752799
50	1.55852448	0.763676995	3.550265347	0.198814859	1.04137974	0.13885063	8					8	100	87	49.5	1.122824	1.122824262	1.1228243	21.75656	1.69	0.59	8.166667	8.166667	1	8.166667	0.177163	8.65934525
51	1.509437095	0.739624177	3.448223361	0.193100508	1.04346466	0.13912862		7.75				7.75	100	87	50.5	1.129259	1.129258983	1.129259	21.88124	1.69	0.59	7.916667	7.916667	1	7.916667	0.172724	8.74715348
52	1.509437095	0.739624177	3.455111026	0.193486217	1.04551274	0.1394017		7.75				7.75	100	87	51.5	1.135603	1.135603321	1.1356033	22.00418	1.69	0.59	7.916667	7.916667	1	7.916667	0.173695	8.96999256
53	1.509437095	0.739624177	3.461879815	0.19386527	1.04752534	0.13967004		7.75				7.75	100	87	52.5	1.14186	1.141860267	1.1418603	22.12542	1.69	0.59	7.916667	7.916667	1	7.916667	0.174652	9.19406869
54	1.509437095	0.739624177	3.468533988	0.194237903	1.04950372	0.13993383		7.75				7.75	100	87	53.5	1.148033	1.148032653	1.1480327	22.24502	1.69	0.59	7.916667	7.916667	1	7.916667	0.175596	9.41936504
55	1.509437095	0.739624177	3.475077575	0.194604344	1.05144911	0.14019321		7.75				7.75	100	87	54.5	1.154123	1.154123172	1.1541232	22.36303	1.69	0.59	7.916667	7.916667	1	7.916667	0.176527	9.64586529
56	1.509437095	0.739624177	3.481514393	0.194964806	1.05336262	0.14044835		7.75				7.75	100	87	55.5	1.160134	1.160134383	1.1601344	22.47951	1.69	0.59	7.916667	7.916667	1	7.916667	0.177447	9.87355367
57	1.509437095	0.739624177	3.487848064	0.195319492	1.05524536	0.14069938		7.75				7.75	100	87	56.5	1.166069	1.166068719	1.1660687	22.59449	1.69	0.59	7.916667	7.916667	1	7.916667	0.178354	10.1024149
58	1.509437095	0.739624177	3.494082022	0.195668593	1.05709834	0.14094645		7.75				7.75	100	87	57.5	1.171928	1.171928499	1.1719285	22.70804	1.69	0.59	7.916667	7.916667	1	7.916667	0.179251	10.332434
59	1.509437095	0.739624177	3.500219533	0.196012294	1.05892254	0.14118967		7.75				7.75	100	87	58.5	1.177716	1.177715932	1.1777159	22.82018	1.69	0.59	7.916667	7.916667	1	7.916667	0.180136	10.5635968
60	1.509437095	0.739624177	3.5062637	0.196350767	1.06071889	0.14142919		7.75				7.75	100	87	59.5	1.183433	1.183433126	1.1834331	22.93096	1.69	0.59	7.916667	7.916667	1	7.916667	0.18101	10.7958892
61	1.509437095	0.739624177	3.512217477	0.196684179	1.06248827	0.1416651		7.75				7.75	100	87	60.5	1.189082	1.189082092	1.1890821	23.04042	1.69	0.59	7.916667	7.916667	1	7.916667	0.181874	11.0292977
62	1.509437095	0.739624177	3.518083677	0.197012686	1.06423152	0.14189754		7.75				7.75	100	87	61.5	1.194665	1.194664752	1.1946648	23.14859	1.69	0.59	7.916667	7.916667	1	7.916667	0.182728	11.263809
63	1.509437095	0.739624177	3.523864982	0.197336439	1.06594944	0.14212659		7.75				7.75	100	87	62.5	1.200183	1.200182944	1.2001829	23.25551	1.69	0.59	7.916667	7.916667	1	7.916667	0.183572	11.4994104
64	1.509437095	0.739624177	3.52956395	0.197655581	1.06764281	0.14235237		7.75				7.75	100	87	63.5	1.205638	1.205638427	1.2056384	23.36122	1.69	0.59	7.916667	7.916667	1	7.916667	0.184407	11.7360893
65	1.509437095	0.739624177	3.535183024	0.197970249	1.06931234	0.14257498		7.75				7.75	100	87	64.5	1.211033	1.211032883	1.2110329	23.46575	1.69	0.59	7.916667	7.916667	1	7.916667	0.185232	11.9738337
66	1.509437095	0.739624177	3.540724537	0.198280574	1.07095873	0.1427945		7.75				7.75	100	87	65.5	1.216368	1.216367926	1.2163679	23.56912	1.69	0.59	7.916667	7.916667	1	7.916667	0.186048	12.2126318
67	1.509437095	0.739624177	3.546190721	0.19858668	1.07258266	0.14301102		7.75				7.75	100	87	66.5	1.221645	1.221645104	1.2216451	23.67138	1.69	0.59	7.916667	7.916667	1	7.916667	0.186855	12.4524721
68	1.509437095	0.739624177	3.551583709	0.198888688	1.07418475	0.14322463		7.75				7.75	100	87	67.5	1.226866	1.226865898	1.2268659	23.77254	1.69	0.59	7.916667	7.916667	1	7.916667	0.187653	12.6933433
69	1.509437095	0.739624177	3.556905545	0.19918671	1.07576563	0.14343542		7.75				7.75	100	87	68.5	1.232032	1.232031735	1.2320317	23.87264	1.69	0.59	7.916667	7.916667	1	7.916667	0.188444	12.9352345
70	1.509437095	0.739624177	3.562158186	0.199480858	1.07732586	0.14364345		7.75				7.75	100	87	69.5	1.237144	1.237143983	1.237144	23.97169	1.69	0.59	7.916667	7.916667	1	7.916667	0.189226	13.1781352
71	1.509437095	0.739624177	3.56734351	0.199771237	1.07886603	0.1438488		7.75				7.75	100	87	70.5	1.242204	1.242203955	1.242204	24.06974	1.69	0.59	7.916667	7.916667	1	7.916667	0.189999	13.4220349
72	1.509437095	0.739624177	3.572463315	0.200057946	1.08038665	0.14405155		7.75				7.75	100	87	71.5	1.247213	1.247212918	1.2472129	24.1668	1.69	0.59	7.916667	7.916667	1	7.916667	0.190766	13.6669234
73	1.509437095	0.739624177	3.57751933	0.200341082	1.08188826	0.14425177		7.75				7.75	100	87	72.5	1.252172	1.252172089	1.2521721	24.26289	1.69	0.59	7.916667	7.916667	1	7.916667	0.191524	13.912791
74	1.509437095	0.739624177	3.582513213	0.20062074	1.08337133	0.14444951		7.75				7.75	100	87	73.5	1.257083	1.257082638	1.2570826	24.35804	1.69	0.59	7.916667	7.916667	1	7.916667	0.192275	14.159628
75	1.509437095	0.739624177	3.587446557	0.200897007	1.08483636	0.14464485		7.75				7.75	100	87	74.5	1.261946	1.261945695	1.2619457	24.45227	1.69	0.59	7.916667	7.916667	1	7.916667	0.193019	14.4074249
76	1.509437095	0.739624177	3.592320896	0.20116997	1.0862838	0.14483784		7.75				7.75	100	87	75.5	1.266762	1.266762348	1.2667623	24.5456	1.69	0.59	7.916667	7.916667	1	7.916667	0.193756	14.6561725
77	1.509437095	0.739624177	3.597137702	0.201439711	1.08771408	0.14502854		7.75				7.75	100	87	76.5	1.271534	1.271533644	1.2715336	24.63805	1.69	0.59	7.916667	7.916667	1	7.916667	0.194486	14.9058619
78	1.509437095	0.739624177	3.601898394	0.20170631	1.08912763	0.14521702		7.75				7.75	100	87	77.5	1.276261	1.276260596	1.2762606	24.72964	1.69	0.59	7.916667	7.916667	1	7.916667	0.195209	15.1564842
79	1.509437095	0.739624177	3.606604337	0.201969843	1.09052486	0.14540332		7.75				7.75	100	87	78.5	1.280944	1.28094418	1.2809442	24.82039	1.69	0.59	7.916667	7.916667	1	7.916667	0.195925	15.4080308
80	1.509437095	0.739624177	3.611256848	0.202230383	1.09190617	0.14558749		7.75				7.75	100	87	79.5	1.285585	1.285585339	1.2855853	24.91032	1.69	0.59	7.916667	7.916667	1	7.916667	0.196635	15.6604934
81	1.509437095	0.739624177	3.615857193	0.202488003	1.09327192	0.14576959		7.75				7.75	100	87	80.5	1.290185	1.290184984	1.290185	24.99945	1.69	0.59	7.916667	7.916667	1	7.916667	0.197338	15.9138636
82	1.509437095	0.739624177	3.620406595	0.202742769	1.09462249	0.14594967		7.75				7.75	100	87	81.5	1.294744	1.294743995	1.294744	25.08779	1.69	0.59	7.916667	7.916667	1	7.916667	0.198036	16.1681335

83	1.509437095	0.739624177	3.624906233	0.202994749	1.09595823	0.14612776		7.75				7.75	100	87	82.5	1.299263	1.299263223	1.2992632	25.17536	1.69	0.59	7.916667	7.916667	1	7.916667	0.198727	16.4232951
84	1.509437095	0.739624177	3.629357246	0.203244006	1.09727947	0.14630393		7.75				7.75	100	87	83.5	1.303743	1.30374349	1.3037435	25.26217	1.69	0.59	7.916667	7.916667	1	7.916667	0.199412	16.6793408
85	1.509437095	0.739624177	3.633760731	0.203490601	1.09858655	0.14647821		7.75				7.75	100	87	84.5	1.308186	1.308185595	1.3081856	25.34824	1.69	0.59	7.916667	7.916667	1	7.916667	0.200092	16.9362629
86	1.509437095	0.739624177	3.63811775	0.203734594	1.09987978	0.14665064		7.75				7.75	100	87	85.5	1.31259	1.312590307	1.3125903	25.43359	1.69	0.59	7.916667	7.916667	1	7.916667	0.200765	17.194054
87	1.509437095	0.739624177	3.642429329	0.203976042	1.10115947	0.14682126		7.75				7.75	100	87	86.5	1.316958	1.316958373	1.3169584	25.51823	1.69	0.59	7.916667	7.916667	1	7.916667	0.201433	17.4527069
88	1.509437095	0.739624177	3.646696459	0.204215002	1.10242591	0.14699012		7.75				7.75	100	87	87.5	1.321291	1.321290517	1.3212905	25.60217	1.69	0.59	7.916667	7.916667	1	7.916667	0.202096	17.7122145
89	1.509437095	0.739624177	3.650920098	0.204451526	1.10367939	0.14715725		7.75				7.75	100	87	88.5	1.325587	1.325587439	1.3255874	25.68543	1.69	0.59	7.916667	7.916667	1	7.916667	0.202753	17.9725698
90	1.509437095	0.739624177	3.655101175	0.204685666	1.10492019	0.14732269		7.75				7.75	100	87	89.5	1.32985	1.32984982	1.3298498	25.76802	1.69	0.59	7.916667	7.916667	1	7.916667	0.203405	18.2337659
91	1.509437095	0.739624177	3.659240585	0.204917473	1.10614857	0.14748648		7.75				7.75	100	87	90.5	1.334078	1.334078317	1.3340783	25.84996	1.69	0.59	7.916667	7.916667	1	7.916667	0.204052	18.4957961
92	1.509437095	0.739624177	3.6633392	0.205146995	1.1073648	0.14764864		7.75				7.75	100	87	91.5	1.338274	1.338273571	1.3382736	25.93125	1.69	0.59	7.916667	7.916667	1	7.916667	0.204694	18.7586539
93	1.509437095	0.739624177	3.667397859	0.20537428	1.10856913	0.14780922		7.75				7.75	100	87	92.5	1.342436	1.342436201	1.3424362	26.0119	1.69	0.59	7.916667	7.916667	1	7.916667	0.20533	19.0223327
94	1.509437095	0.739624177	3.671417379	0.205599373	1.10976179	0.14796824		7.75				7.75	100	87	93.5	1.346567	1.346566811	1.3465668	26.09194	1.69	0.59	7.916667	7.916667	1	7.916667	0.205962	19.2868263
95	1.509437095	0.739624177	3.675398549	0.205822319	1.11094303	0.14812574		7.75				7.75	100	87	94.5	1.350666	1.350665984	1.350666	26.17137	1.69	0.59	7.916667	7.916667	1	7.916667	0.206589	19.5521284
96	1.509437095	0.739624177	3.679342136	0.20604316	1.11211307	0.14828174		7.75				7.75	100	87	95.5	1.354734	1.35473429	1.3547343	26.2502	1.69	0.59	7.916667	7.916667	1	7.916667	0.207211	19.8182329
97	1.509437095	0.739624177	3.683248882	0.206261937	1.11327213	0.14843628		7.75				7.75	100	87	96.5	1.358772	1.358772279	1.3587723	26.32844	1.69	0.59	7.916667	7.916667	1	7.916667	0.207829	20.0851337
98	1.509437095	0.739624177	3.687119509	0.206478693	1.11442044	0.14858939		7.75				7.75	100	87	97.5	1.36278	1.36278049	1.3627805	26.40611	1.69	0.59	7.916667	7.916667	1	7.916667	0.208442	20.3528251
99	1.509437095	0.739624177	3.690954716	0.206693464	1.11555819	0.14874109		7.75				7.75	100	87	98.5	1.366759	1.366759443	1.3667594	26.48321	1.69	0.59	7.916667	7.916667	1	7.916667	0.209051	20.6213012
100	1.509437095	0.739624177	3.694755182	0.20690629	1.1166856	0.14889141		7.75				7.75	100	87	99.5	1.37071	1.370709645	1.3707096	26.55975	1.69	0.59	7.916667	7.916667	1	7.916667	0.209655	20.5596816
101	1.46034971	0.715571358	3.581465526	0.200562069	1.11780285	0.14904038			7.5			7.5	100	87	100.5	1.374632	1.374631591	1.3746316	26.63574	1.69	0.59	7.666667	7.666667	1	7.666667	0.203615	20.4923557
102	1.46034971	0.715571358	3.585082513	0.200764621	1.11891014	0.14918802			7.5			7.5	100	87	101.5	1.378526	1.378525761	1.3785258	26.7112	1.69	0.59	7.666667	7.666667	1	7.666667	0.204192	20.7546007
103	1.46034971	0.715571358	3.588667704	0.200965391	1.12000766	0.14933435			7.5			7.5	100	87	102.5	1.382393	1.382392622	1.3823926	26.78612	1.69	0.59	7.666667	7.666667	1	7.666667	0.204765	21.0175841
104	1.46034971	0.715571358	3.592221686	0.201164414	1.12109558	0.14947941			7.5			7.5	100	87	103.5	1.386233	1.386232629	1.3862326	26.86053	1.69	0.59	7.666667	7.666667	1	7.666667	0.205334	21.2813007
105	1.46034971	0.715571358	3.595745027	0.201361722	1.12217408	0.14962321			7.5			7.5	100	87	104.5	1.390046	1.390046226	1.3900462	26.93443	1.69	0.59	7.666667	7.666667	1	7.666667	0.205898	21.5457456
106	1.46034971	0.715571358	3.599238282	0.201557344	1.12324334	0.14976578			7.5			7.5	100	87	105.5	1.393834	1.393833844	1.3938338	27.00782	1.69	0.59	7.666667	7.666667	1	7.666667	0.206459	21.8109137
107	1.46034971	0.715571358	3.602701988	0.201751311	1.12430351	0.14990713			7.5			7.5	100	87	106.5	1.397596	1.397595905	1.3975959	27.08071	1.69	0.59	7.666667	7.666667	1	7.666667	0.207017	22.0768002
108	1.46034971	0.715571358	3.606136671	0.201943654	1.12535476	0.1500473			7.5			7.5	100	87	107.5	1.401333	1.401332817	1.4013328	27.15312	1.69	0.59	7.666667	7.666667	1	7.666667	0.20757	22.3434001
109	1.46034971	0.715571358	3.609542839	0.202134399	1.12639725	0.1501863			7.5			7.5	100	87	108.5	1.405045	1.405044981	1.405045	27.22505	1.69	0.59	7.666667	7.666667	1	7.666667	0.20812	22.6107089
110	1.46034971	0.715571358	3.612920989	0.202323575	1.12743112	0.15032415			7.5			7.5	100	87	109.5	1.408733	1.408732787	1.4087328	27.29651	1.69	0.59	7.666667	7.666667	1	7.666667	0.208666	22.8787218
111	1.46034971	0.715571358	3.616271605	0.20251121	1.12845653	0.15046087			7.5			7.5	100	87	110.5	1.412397	1.412396615	1.4123966	27.3675	1.69	0.59	7.666667	7.666667	1	7.666667	0.209209	23.1474342
112	1.46034971	0.715571358	3.619595158	0.202697329	1.12947362	0.15059648			7.5			7.5	100	87	111.5	1.416037	1.416036835	1.4160368	27.43804	1.69	0.59	7.666667	7.666667	1	7.666667	0.209748	23.4168416
113	1.46034971	0.715571358	3.622892105	0.202881958	1.13048254	0.15073101			7.5			7.5	100	87	112.5	1.419654	1.41965381	1.4196538	27.50812	1.69	0.59	7.666667	7.666667	1	7.666667	0.210284	23.6869395
114	1.46034971	0.715571358	3.626162893	0.203065122	1.13148341	0.15086446			7.5			7.5	100	87	113.5	1.423248	1.423247891	1.4232479	27.57776	1.69	0.59	7.666667	7.666667	1	7.666667	0.210816	23.9577236
115	1.46034971	0.715571358	3.629407959	0.203246846	1.13247639	0.15099685			7.5			7.5	100	87	114.5	1.426819	1.426819425	1.4268194	27.64697	1.69	0.59	7.666667	7.666667	1	7.666667	0.211345	24.2291896
116	1.46034971	0.715571358	3.632627725	0.203427153	1.13346158	0.15112821			7.5			7.5	100	87	115.5	1.430369	1.430368748	1.4303687	27.71574	1.69	0.59	7.666667	7.666667	1	7.666667	0.211871	24.5013331
117	1.46034971	0.715571358	3.635822607	0.203606066	1.13443913	0.15125855			7.5			7.5	100	87	116.5	1.433896	1.433896188	1.4338962	27.78409	1.69	0.59	7.666667	7.666667	1	7.666667	0.212394	24.77415
118	1.46034971	0.715571358	3.638993008	0.203783608	1.13540916	0.15138789			7.5			7.5	100	87	117.5	1.437402	1.437402066	1.4374021	27.85202	1.69	0.59	7.666667	7.666667	1	7.666667	0.212913	25.0476362
119	1.46034971	0.715571358	3.64213932	0.203959802	1.13637178	0.15151624			7.5			7.5	100	87	118.5	1.440887	1.440886696	1.4408867	27.91954	1.69	0.59	7.666667	7.666667	1	7.666667	0.213429	25.3217876
120	1.46034971	0.715571358	3.64526193	0.204134668	1.13732712	0.15164362			7.5			7.5	100	87	119.5	1.44435	1.444350385	1.4443504	27.98666	1.69	0.59	7.666667	7.666667	1	7.666667	0.213942	25.5966001
121	1.46034971	0.715571358	3.64836121	0.204308228	1.1382753	0.15177004			7.5			7.5	100	87	120.5	1.447793	1.447793432	1.4477934	28.05337	1.69	0.59	7.666667	7.666667	1	7.666667	0.214452	25.8720699
122	1.46034971	0.715571358	3.651437528	0.204480502	1.13921641	0.15189552			7.5			7.5	100	87	121.5	1.451216	1.451216129	1.4512161	28.11969	1.69	0.59	7.666667	7.666667	1	7.666667	0.214959	26.148193
123	1.46034971	0.715571358	3.654491239	0.204651509	1.14015059	0.15202008			7.5			7.5	100	87	122.5	1.454619	1.454618764	1.4546188	28.18562	1.69	0.59	7.666667	7.666667	1	7.666667	0.215463	26.4249656
124	1.46034971	0.715571358	3.657522693	0.20482127	1.14107792	0.15214372			7.5			7.5	100	87	123.5	1.458002	1.458001615	1.4580016	28.25117	1.69	0.59	7.666667	7.666667	1	7.666667	0.215964	26.7023839
125	1.46034971	0.715571358	3.660532231	0.204989805	1.14199852	0.15226647			7.5			7.5	100	87	124.5	1.461365	1.461364957	1.461365	28.31634	1.69	0.59	7.666667	7.666667	1	7.666667	0.216462	26.9804442
126	1.46034971	0.715571358	3.663520185	0.20515713	1.14291249	0.15238833			7.5			7.5	100	87	125.5	1.464709	1.464709058	1.4647091	28.38114	1.69	0.59	7.666667	7.666667	1	7.666667	0.216958	27.2591428
127	1.46034971	0.715571358	3.66648688	0.205323265	1.14381993	0.15250932			7.5			7.5	100	87	126.5	1.468034	1.46803418	1.4680342	28.44557	1.69	0.59	7.666667	7.666667	1	7.666667	0.21745	27.538476
128	1.46034971	0.715571358	3.669432634	0.205488227	1.14472093	0.15262946			7.5			7.5	100	87	127.5	1.471341	1.471340579	1.4713406	28.50964	1.69	0.59	7.666667	7.666667	1	7.666667	0.21794	27.8184402
129	1.46034971	0.715571358	3.672357756	0.205652034	1.1456156	0.15274875			7.5			7.5	100	87	128.5	1.474629	1.474628506	1.4746285	28.57335	1.69	0.59	7.666667	7.666667	1	7.666667	0.218427	28.099032
130	1.46034971	0.715571358	3.675262551	0.205814703	1.14650402	0.1528672			7.5			7.5	100	87	129.5	1.477898	1.477898208	1.4778982	28.6367	1.69	0.59	7.666667	7.666667	1	7.666667	0.218911	28.3802479
131	1.46034971	0.715571358	3.678147316	0.20597625	1.14738629	0.15298484			7.5			7.5	100	87	130.5	1.48115	1.481149924	1.4811499	28.69971	1.69	0.59	7.666667	7.666667	1	7.666667	0.219393	28.6620843
132	1.46034971	0.715571358	3.681012339	0.206136691	1.1482625	0.15310167			7.5			7.5	100	87	131.5	1.484384	1.48438389	1.4843839	28.76237	1.69	0.59	7.666667	7.666667	1	7.666667	0.219872	28.9445379
133	1.46034971	0.715571358	3.683857906	0.206296043	1.14913273	0.1532177			7.5			7.5	100	87	132.5	1.4876	1.487600337	1.4876003	28.8247	1.69	0.59	7.666667	7.666667	1	7.666667	0.220348	29.2276054
134	1.46034971	0.715571358	3.686684293	0.20645432	1.14999707	0.15333294			7.5			7.5	100	87	133.5	1.490799	1.490799492	1.4907995	28.88669	1.69	0.59	7.666667	7.666667	1	7.666667	0.220822	29.5112834
135	1.46034971	0.715571358	3.689491773	0.206611539	1.1508556	0.15344741			7.5			7.5	100	87	134.5	1.493982	1.493981574	1.4939816	28.94834	1.69	0.59	7.666667	7.666667	1	7.666667	0.221294	29.7955687
136	1.46034971	0.715571358	3.69228061	0.206767714	1.1517084	0.15356112			7.5			7.5	100	87	135.5	1.497147	1.497146803	1.4971468	29.00967	1.69	0.59	7.666667	7.666667	1	7.666667	0.221763	30.080458
137	1.46034971	0.715571358	3.695051065	0.20692286	1.15255556	0.15367408			7.5			7.5	100	87	136.5	1.500295	1.50029539	1.5002954	29.07068	1.69	0.59	7.666667	7.666667	1	7.666667	0.222229	30.3659482
138	1.46034971	0.715571358	3.697803393	0.20707699	1.15339715	0.15378629			7.5			7.5	100	87	137.5	1.503428	1.503427543	1.5034275	29.13137	1.69	0.59	7.666667	7.666667	1	7.666667	0.222693	30.6520361
139	1.46034971	0.715571358	3.700537842	0.207230119	1.15423326	0.15389777			7.5			7.5	100	87	138.5	1.506543	1.506543468	1.5065435	29.19175	1.69	0.59	7.666667	7.666667	1	7.666667	0.223154	30.9387186
140	1.46034971	0.715571358	3.703254658	0.207382261	1.15506394	0.15400853			7.5			7.5	100	87	139.5	1.509643	1.509643364	1.5096434	29.25182	1.69	0.59	7.666667	7.666667	1	7.666667	0.223614	31.2259926
141	1.46034971	0.715571358	3.705954077	0.207533428	1.15588929	0.15411857			7.5			7.5	100	87	140.5	1.512727	1.512727428	1.5127274	29.31157	1.69	0.59	7.666667	7.666667	1	7.666667	0.22407	31.5138552
142	1.46034971	0.715571358	3.708636336	0.207683635	1.15670936	0.15422791			7.5			7.5	100	87	141.5	1.515796	1.515795852	1.5157959	29.37103	1.69	0.59	7.666667	7.666667	1	7.666667	0.224525	31.8023032
143	1.46034971	0.715571358	3.711301663	0.207832893	1.15752423	0.15433656			7.5			7.5	100	87	142.5	1.518849	1.518848826	1.5188488	29.43019	1.69	0.59	7.666667	7.666667	1	7.666667	0.224977	32.0913339
144	1.46034971	0.715571358	3.713950282	0.207981216	1.15833398	0.15444453			7.5			7.5	100	87	143.5	1.521887	1.521886535	1.5218865	29.48905	1.69	0.59	7.666667	7.666667	1	7.666667	0.225427	32.3809441
145	1.46034971	0.715571358	3.716582414	0.208128615	1.15913866	0.15455182			7.5			7.5	100	87	144.5	1.524909	1.524909161	1.5249092	29.54762	1.69	0.59	7.666667	7.666667	1	7.666667	0.225875	32.6711311
146	1.46034971	0.715571358	3.719198275	0.208275103	1.15993834	0.15465845			7.5			7.5	100	87	145.5	1.527917	1.527916882	1.5279169	29.6059	1.69	0.59	7.666667	7.666667	1	7.666667	0.22632	32.9618921
147	1.46034971	0.715571358	3.721798075	0.208420692	1.1607331	0.15476441			7.5			7.5	100	87	146.5	1.53091	1.530909874	1.5309099	29.66389	1.69	0.59	7.666667	7.666667	1	7.666667	0.226764	33.2532241
148	1.46034971	0.715571358	3.724382023	0.208565393	1.16152298	0.15486973			7.5			7.5	100	87	147.5	1.533888	1.533888309	1.5338883	29.7216	1.69	0.59	7.666667	7.666667	1	7.666667	0.227205	33.5451244
149	1.46034971	0.715571358	3.726950321	0.208709218	1.16230807	0.15497441			7.5			7.5	100	87	148.5	1.536852	1.536852354	1.5368524	29.77903	1.69	0.59	7.666667	7.666667	1	7.666667	0.227644	33.8375902
150	1.46034971	0.715571358	3.729503169	0.208852177	1.1630884	0.15507845			7.5			7.5	100	87	149.5	1.539802	1.539802177	1.5398022	29.83619	1.69	0.59	7.666667	7.666667	1	7.666667	0.228081	33.5729911
151	1.411262325	0.691518539	3.610161203	0.202169027	1.16386406	0.15518187				7.25		7.25	100	87	150.5	1.542738	1.54273794	1.5427379	29.89308	1.69	0.59	7.416667	7.416667	1	7.416667	0.221064	33.3016792
152	1.411262325	0.691518539	3.612602991	0.202305767	1.16463509	0.15528468				7.25		7.25	100	87	151.5	1.54566	1.545659802	1.5456598	29.94969	1.69	0.59	7.416667	7.416667	1	7.416667	0.221483	33.5862338
153	1.411262325	0.691518539	3.615030382	0.202441701	1.16540155	0.15538687				7.25		7.25	100	87	152.5	1.548568	1.54856792	1.5485679	30.00604	1.69	0.59	7.416667	7.416667	1	7.416667	0.221899	33.8713251
154	1.411262325	0.691518539	3.617443554	0.202576839	1.1661635	0.15548847				7.25		7.25	100	87	153.5	1.551462	1.551462449	1.5514624	30.06213	1.69	0.59	7.416667	7.416667	1	7.416667	0.222314	34.1569506
155	1.411262325	0.691518539	3.619842683	0.20271119	1.166921	0.15558947				7.25		7.25	100	87	154.5	1.554344	1.55434354	1.5543435	30.11796	1.69	0.59	7.416667	7.416667	1	7.416667	0.222727	34.4431079
156	1.411262325	0.691518539	3.62222794	0.202844765	1.16767409	0.15568988				7.25		7.25	100	87	155.5	1.557211	1.557211342	1.5572113	30.17352	1.69	0.59	7.416667	7.416667	1	7.416667	0.223138	34.7297946
157	1.411262325	0.691518539	3.624599495	0.202977572	1.16842285	0.15578971				7.25		7.25	100	87	156.5	1.560066	1.560066	1.560066	30.22884	1.69	0.59	7.416667	7.416667	1	7.416667	0.223547	35.017008
158	1.411262325	0.691518539	3.626957512	0.203109621	1.1691673	0.15588897				7.25		7.25	100	87	157.5	1.562908	1.562907659	1.5629077	30.2839	1.69	0.59	7.416667	7.416667	1	7.416667	0.223954	35.304746
159	1.411262325	0.691518539	3.629302155	0.203240921	1.16990752	0.15598767				7.25		7.25	100	87	158.5	1.565736	1.56573646	1.5657365	30.33871	1.69	0.59	7.416667	7.416667	1	7.416667	0.22436	35.593006
160	1.411262325	0.691518539	3.631633583	0.203371481	1.17064355	0.15608581				7.25		7.25	100	87	159.5	1.568553	1.568552541	1.5685525	30.39328	1.69	0.59	7.416667	7.416667	1	7.416667	0.224763	35.8817857
161	1.411262325	0.691518539	3.633951952	0.203501309	1.17137543	0.15618339				7.25		7.25	100	87	160.5	1.571356	1.57135604	1.571356	30.4476	1.69	0.59	7.416667	7.416667	1	7.416667	0.225165	36.1710828
162	1.411262325	0.691518539	3.636257416	0.203630415	1.17210322	0.15628043				7.25		7.25	100	87	161.5	1.574147	1.574147089	1.5741471	30.50168	1.69	0.59	7.416667	7.416667	1	7.416667	0.225565	36.4608951
163	1.411262325	0.691518539	3.638550127	0.203758807	1.17282697	0.15637693				7.25		7.25	100	87	162.5	1.576926	1.576925821	1.5769258	30.55552	1.69	0.59	7.416667	7.416667	1	7.416667	0.225963	36.7522201
164	1.411262325	0.691518539	3.640830233	0.203886493	1.17354671	0.1564729				7.25		7.25	100	87	163.5	1.579692	1.579692365	1.5796924	30.60913	1.69	0.59	7.416667	7.416667	1	7.416667	0.226359	37.0420557
165	1.411262325	0.691518539	3.64309788	0.204013481	1.17426251	0.15656833				7.25		7.25	100	87	164.5	1.582447	1.58244685	1.5824468	30.6625	1.69	0.59	7.416667	7.416667	1	7.416667	0.226754	37.3333996
166	1.411262325	0.691518539	3.64535321	0.20413978	1.1749744	0.15666325				7.25		7.25	100	87	165.5	1.585189	1.5851894	1.5851894	30.71564	1.69	0.59	7.416667	7.416667	1	7.416667	0.227147	37.6252497
167	1.411262325	0.691518539	3.647596365	0.204265396	1.17568244	0.15675766				7.25		7.25	100	87	166.5	1.58792	1.587920138	1.5879201	30.76856	1.69	0.59	7.416667	7.416667	1	7.416667	0.227538	37.9176037
168	1.411262325	0.691518539	3.649827484	0.204390339	1.17638665	0.15685155				7.25		7.25	100	87	167.5	1.590639	1.590639187	1.5906392	30.82124	1.69	0.59	7.416667	7.416667	1	7.416667	0.227928	38.2104595
169	1.411262325	0.691518539	3.652046701	0.204514615	1.17708709	0.15694495				7.25		7.25	100	87	168.5	1.593347	1.593346665	1.5933467	30.8737	1.69	0.59	7.416667	7.416667	1	7.416667	0.228316	38.5038149
170	1.411262325	0.691518539	3.65425415	0.204638232	1.1777838	0.15703784				7.25		7.25	100	87	169.5	1.596043	1.596042691	1.5960427	30.92594	1.69	0.59	7.416667	7.416667	1	7.416667	0.228702	38.7976678
171	1.411262325	0.691518539	3.656449964	0.204761198	1.17847682	0.15713024				7.25		7.25	100	87	170.5	1.598727	1.598727379	1.5987274	30.97796	1.69	0.59	7.416667	7.416667	1	7.416667	0.229087	39.0920161
172	1.411262325	0.691518539	3.65863427	0.204883519	1.17916619	0.15722216				7.25		7.25	100	87	171.5	1.601401	1.601400843	1.6014008	31.02977	1.69	0.59	7.416667	7.416667	1	7.416667	0.22947	39.3868578
173	1.411262325	0.691518539	3.660807196	0.205005203	1.17985195	0.15731359				7.25		7.25	100	87	172.5	1.604063	1.604063195	1.6040632	31.08136	1.69	0.59	7.416667	7.416667	1	7.416667	0.229852	39.6821908
174	1.411262325	0.691518539	3.662968866	0.205126257	1.18053415	0.15740455				7.25		7.25	100	87	173.5	1.606715	1.606714546	1.6067145	31.13273	1.69	0.59	7.416667	7.416667	1	7.416667	0.230231	39.9780131

175	1.411262325	0.691518539	3.665119404	0.205246687	1.18121281	0.15749504				7.25		7.25	100	87	174.5	1.609355	1.609355004	1.609355	31.18389	1.69	0.59	7.416667	7.416667	1	7.416667	0.23061	40.2743225
176	1.411262325	0.691518539	3.66725893	0.2053665	1.18188799	0.15758506				7.25		7.25	100	87	175.5	1.611985	1.611984676	1.6119847	31.23485	1.69	0.59	7.416667	7.416667	1	7.416667	0.230987	40.5711173
177	1.411262325	0.691518539	3.669387562	0.205485703	1.18255971	0.15767463				7.25		7.25	100	87	176.5	1.614604	1.614603666	1.6146037	31.28559	1.69	0.59	7.416667	7.416667	1	7.416667	0.231362	40.8683952
178	1.411262325	0.691518539	3.671505418	0.205604303	1.18322801	0.15776373				7.25		7.25	100	87	177.5	1.617212	1.617212079	1.6172121	31.33614	1.69	0.59	7.416667	7.416667	1	7.416667	0.231736	41.1661546
179	1.411262325	0.691518539	3.673612612	0.205722306	1.18389293	0.15785239				7.25		7.25	100	87	178.5	1.61981	1.619810016	1.61981	31.38648	1.69	0.59	7.416667	7.416667	1	7.416667	0.232108	41.4643932
180	1.411262325	0.691518539	3.675709257	0.205839718	1.18455451	0.1579406				7.25		7.25	100	87	179.5	1.622398	1.622397578	1.6223976	31.43661	1.69	0.59	7.416667	7.416667	1	7.416667	0.232479	41.7631094
181	1.411262325	0.691518539	3.677795464	0.205956546	1.18521278	0.15802837				7.25		7.25	100	87	180.5	1.624975	1.624974864	1.6249749	31.48655	1.69	0.59	7.416667	7.416667	1	7.416667	0.232848	42.0623011
182	1.411262325	0.691518539	3.679871343	0.206072795	1.18586778	0.1581157				7.25		7.25	100	87	181.5	1.627542	1.627541971	1.627542	31.53629	1.69	0.59	7.416667	7.416667	1	7.416667	0.233216	42.3619665
183	1.411262325	0.691518539	3.681937002	0.206188472	1.18651954	0.1582026				7.25		7.25	100	87	182.5	1.630099	1.630098995	1.630099	31.58584	1.69	0.59	7.416667	7.416667	1	7.416667	0.233582	42.6621036
184	1.411262325	0.691518539	3.683992545	0.206303583	1.18716809	0.15828908				7.25		7.25	100	87	183.5	1.632646	1.632646031	1.632646	31.63519	1.69	0.59	7.416667	7.416667	1	7.416667	0.233947	42.9627108
185	1.411262325	0.691518539	3.686038079	0.206418132	1.18781346	0.15837513				7.25		7.25	100	87	184.5	1.635183	1.635183171	1.6351832	31.68436	1.69	0.59	7.416667	7.416667	1	7.416667	0.234311	43.2637861
186	1.411262325	0.691518539	3.688073704	0.206532127	1.1884557	0.15846076				7.25		7.25	100	87	185.5	1.637711	1.637710507	1.6377105	31.73333	1.69	0.59	7.416667	7.416667	1	7.416667	0.234673	43.5653277
187	1.411262325	0.691518539	3.690099523	0.206645573	1.18909483	0.15854598				7.25		7.25	100	87	186.5	1.640228	1.640228131	1.6402281	31.78211	1.69	0.59	7.416667	7.416667	1	7.416667	0.235034	43.8673338
188	1.411262325	0.691518539	3.692115634	0.206758476	1.18973088	0.15863078				7.25		7.25	100	87	187.5	1.642736	1.642736131	1.6427361	31.83071	1.69	0.59	7.416667	7.416667	1	7.416667	0.235393	44.1698027
189	1.411262325	0.691518539	3.694122136	0.20687084	1.19036388	0.15871518				7.25		7.25	100	87	188.5	1.645235	1.645234594	1.6452346	31.87912	1.69	0.59	7.416667	7.416667	1	7.416667	0.235751	44.4727325
190	1.411262325	0.691518539	3.696119126	0.206982671	1.19099387	0.15879918				7.25		7.25	100	87	189.5	1.647724	1.647723608	1.6477236	31.92735	1.69	0.59	7.416667	7.416667	1	7.416667	0.236108	44.7761216
191	1.411262325	0.691518539	3.698106697	0.207093975	1.19162088	0.15888278				7.25		7.25	100	87	190.5	1.650203	1.650203257	1.6502033	31.97539	1.69	0.59	7.416667	7.416667	1	7.416667	0.236463	45.0799682
192	1.411262325	0.691518539	3.700084944	0.207204757	1.19224493	0.15896599				7.25		7.25	100	87	191.5	1.652674	1.652673627	1.6526736	32.02326	1.69	0.59	7.416667	7.416667	1	7.416667	0.236817	45.3842706
193	1.411262325	0.691518539	3.702053958	0.207315022	1.19286605	0.15904881				7.25		7.25	100	87	192.5	1.655135	1.655134799	1.6551348	32.07095	1.69	0.59	7.416667	7.416667	1	7.416667	0.23717	45.6890271
194	1.411262325	0.691518539	3.704013831	0.207424775	1.19348428	0.15913124				7.25		7.25	100	87	193.5	1.657587	1.657586855	1.6575869	32.11846	1.69	0.59	7.416667	7.416667	1	7.416667	0.237521	45.994236
195	1.411262325	0.691518539	3.705964652	0.207534021	1.19409964	0.15921329				7.25		7.25	100	87	194.5	1.66003	1.660029877	1.6600299	32.1658	1.69	0.59	7.416667	7.416667	1	7.416667	0.237871	46.2998956
196	1.411262325	0.691518539	3.707906509	0.207642764	1.19471215	0.15929495				7.25		7.25	100	87	195.5	1.662464	1.662463943	1.6624639	32.21297	1.69	0.59	7.416667	7.416667	1	7.416667	0.23822	46.6060043
197	1.411262325	0.691518539	3.709839488	0.207751011	1.19532186	0.15937625				7.25		7.25	100	87	196.5	1.664889	1.664889133	1.6648891	32.25996	1.69	0.59	7.416667	7.416667	1	7.416667	0.238567	46.9125604
198	1.411262325	0.691518539	3.711763675	0.207858766	1.19592878	0.15945717				7.25		7.25	100	87	197.5	1.667306	1.667305522	1.6673055	32.30678	1.69	0.59	7.416667	7.416667	1	7.416667	0.238914	47.2195624
199	1.411262325	0.691518539	3.713679155	0.207966033	1.19653293	0.15953772				7.25		7.25	100	87	198.5	1.669713	1.669713188	1.6697132	32.35343	1.69	0.59	7.416667	7.416667	1	7.416667	0.239259	47.5270085
200	1.411262325	0.691518539	3.71558601	0.208072817	1.19713436	0.15961791				7.25		7.25	100	87	199.5	1.672112	1.672112206	1.6721122	32.39992	1.69	0.59	7.416667	7.416667	1	7.416667	0.239603	47.0274417
201	1.36217494	0.66746572	3.592058007	0.201155248	1.19773308	0.15969774					7	7	100	87	200.5	1.674503	1.67450265	1.6745026	32.44624	1.69	0.59	7.166667	7.166667	1	7.166667	0.231857	46.5204216
202	1.36217494	0.66746572	3.59388544	0.201257585	1.19832911	0.15977722					7	7	100	87	201.5	1.676885	1.676884593	1.6768846	32.49239	1.69	0.59	7.166667	7.166667	1	7.166667	0.232187	46.8187829
203	1.36217494	0.66746572	3.595704769	0.201359467	1.19892249	0.15985633					7	7	100	87	202.5	1.679258	1.679258107	1.6792581	32.53838	1.69	0.59	7.166667	7.166667	1	7.166667	0.232515	47.1175672
204	1.36217494	0.66746572	3.597516068	0.2014609	1.19951324	0.1599351					7	7	100	87	203.5	1.681623	1.681623264	1.6816233	32.58421	1.69	0.59	7.166667	7.166667	1	7.166667	0.232843	47.4167732
205	1.36217494	0.66746572	3.599319413	0.201561887	1.20010139	0.16001352					7	7	100	87	204.5	1.68398	1.683980133	1.6839801	32.62988	1.69	0.59	7.166667	7.166667	1	7.166667	0.233169	47.7163994
206	1.36217494	0.66746572	3.601114878	0.201662433	1.20068695	0.16009159					7	7	100	87	205.5	1.686329	1.686328785	1.6863288	32.67539	1.69	0.59	7.166667	7.166667	1	7.166667	0.233494	48.0164442
207	1.36217494	0.66746572	3.602902534	0.201762542	1.20126995	0.16016933					7	7	100	87	206.5	1.688669	1.688669287	1.6886693	32.72074	1.69	0.59	7.166667	7.166667	1	7.166667	0.233819	48.3169063
208	1.36217494	0.66746572	3.604682453	0.201862217	1.20185041	0.16024672					7	7	100	87	207.5	1.691002	1.691001707	1.6910017	32.76593	1.69	0.59	7.166667	7.166667	1	7.166667	0.234142	48.6177841
209	1.36217494	0.66746572	3.606454707	0.201961464	1.20242836	0.16032378					7	7	100	87	208.5	1.693326	1.693326112	1.6933261	32.81097	1.69	0.59	7.166667	7.166667	1	7.166667	0.234463	48.9190763
210	1.36217494	0.66746572	3.608219364	0.202060284	1.20300383	0.16040051					7	7	100	87	209.5	1.695643	1.695642568	1.6956426	32.85586	1.69	0.59	7.166667	7.166667	1	7.166667	0.234784	49.2207815
211	1.36217494	0.66746572	3.609976493	0.202158684	1.20357682	0.16047691					7	7	100	87	210.5	1.697951	1.697951139	1.6979511	32.90059	1.69	0.59	7.166667	7.166667	1	7.166667	0.235104	49.5228981
212	1.36217494	0.66746572	3.611726162	0.202256665	1.20414737	0.16055298					7	7	100	87	211.5	1.700252	1.70025189	1.7002519	32.94517	1.69	0.59	7.166667	7.166667	1	7.166667	0.235422	49.8254249
213	1.36217494	0.66746572	3.613468438	0.202354233	1.2047155	0.16062873					7	7	100	87	212.5	1.702545	1.702544883	1.7025449	32.9896	1.69	0.59	7.166667	7.166667	1	7.166667	0.23574	50.1283604
214	1.36217494	0.66746572	3.615203385	0.20245139	1.20528123	0.16070416					7	7	100	87	213.5	1.70483	1.704830182	1.7048302	33.03388	1.69	0.59	7.166667	7.166667	1	7.166667	0.236056	50.4317033
215	1.36217494	0.66746572	3.61693107	0.20254814	1.20584458	0.16077928					7	7	100	87	214.5	1.707108	1.707107849	1.7071078	33.07801	1.69	0.59	7.166667	7.166667	1	7.166667	0.236372	50.7354522
216	1.36217494	0.66746572	3.618651557	0.202644487	1.20640557	0.16085408					7	7	100	87	215.5	1.709378	1.709377943	1.7093779	33.122	1.69	0.59	7.166667	7.166667	1	7.166667	0.236686	51.0396058
217	1.36217494	0.66746572	3.620364908	0.202740435	1.20696422	0.16092856					7	7	100	87	216.5	1.711641	1.711640525	1.7116405	33.16584	1.69	0.59	7.166667	7.166667	1	7.166667	0.236999	51.3441627
218	1.36217494	0.66746572	3.622071186	0.202835986	1.20752055	0.16100274					7	7	100	87	217.5	1.713896	1.713895654	1.7138957	33.20954	1.69	0.59	7.166667	7.166667	1	7.166667	0.237311	51.6491215
219	1.36217494	0.66746572	3.623770452	0.202931145	1.20807459	0.16107661					7	7	100	87	218.5	1.716143	1.71614339	1.7161434	33.25309	1.69	0.59	7.166667	7.166667	1	7.166667	0.237623	51.9544811
220	1.36217494	0.66746572	3.625462767	0.203025915	1.20862635	0.16115018					7	7	100	87	219.5	1.718384	1.718383789	1.7183838	33.2965	1.69	0.59	7.166667	7.166667	1	7.166667	0.237933	52.2602399
221	1.36217494	0.66746572	3.627148192	0.203120299	1.20917585	0.16122345					7	7	100	87	220.5	1.720617	1.72061691	1.7206169	33.33977	1.69	0.59	7.166667	7.166667	1	7.166667	0.238242	52.5663968
222	1.36217494	0.66746572	3.628826785	0.2032143	1.20972311	0.16129642					7	7	100	87	221.5	1.722843	1.722842809	1.7228428	33.3829	1.69	0.59	7.166667	7.166667	1	7.166667	0.23855	52.8729505
223	1.36217494	0.66746572	3.630498604	0.203307922	1.21026816	0.16136909					7	7	100	87	222.5	1.725062	1.725061541	1.7250615	33.4259	1.69	0.59	7.166667	7.166667	1	7.166667	0.238858	53.1798997
224	1.36217494	0.66746572	3.632163708	0.203401168	1.210811	0.16144147					7	7	100	87	223.5	1.727273	1.727273162	1.7272732	33.46875	1.69	0.59	7.166667	7.166667	1	7.166667	0.239164	53.4872431
225	1.36217494	0.66746572	3.633822153	0.203494041	1.21135166	0.16151356					7	7	100	87	224.5	1.729478	1.729477726	1.7294777	33.51147	1.69	0.59	7.166667	7.166667	1	7.166667	0.239469	53.7949794
226	1.36217494	0.66746572	3.635473994	0.203586544	1.21189016	0.16158536					7	7	100	87	225.5	1.731675	1.731675286	1.7316753	33.55405	1.69	0.59	7.166667	7.166667	1	7.166667	0.239773	54.1031074
227	1.36217494	0.66746572	3.637119289	0.20367868	1.21242652	0.16165687					7	7	100	87	226.5	1.733866	1.733865897	1.7338659	33.5965	1.69	0.59	7.166667	7.166667	1	7.166667	0.240077	54.4116259
228	1.36217494	0.66746572	3.638758091	0.203770453	1.21296075	0.1617281					7	7	100	87	227.5	1.73605	1.736049611	1.7360496	33.63881	1.69	0.59	7.166667	7.166667	1	7.166667	0.240379	54.7205337
229	1.36217494	0.66746572	3.640390454	0.203861865	1.21349286	0.16179905					7	7	100	87	228.5	1.738226	1.738226479	1.7382265	33.68099	1.69	0.59	7.166667	7.166667	1	7.166667	0.24068	55.0298294
230	1.36217494	0.66746572	3.642016431	0.20395292	1.21402289	0.16186972					7	7	100	87	229.5	1.740397	1.740396552	1.7403966	33.72304	1.69	0.59	7.166667	7.166667	1	7.166667	0.240981	55.3395119
231	1.36217494	0.66746572	3.643636076	0.20404362	1.21455084	0.16194011					7	7	100	87	230.5	1.74256	1.742559882	1.7425599	33.76496	1.69	0.59	7.166667	7.166667	1	7.166667	0.24128	55.64958
232	1.36217494	0.66746572	3.64524944	0.204133969	1.21507674	0.16201023					7	7	100	87	231.5	1.744717	1.744716519	1.7447165	33.80674	1.69	0.59	7.166667	7.166667	1	7.166667	0.241579	55.9600325
233	1.36217494	0.66746572	3.646856575	0.204223968	1.21560059	0.16208008					7	7	100	87	232.5	1.746867	1.746866512	1.7468665	33.8484	1.69	0.59	7.166667	7.166667	1	7.166667	0.241877	56.2708683
234	1.36217494	0.66746572	3.648457531	0.204313622	1.21612242	0.16214966					7	7	100	87	233.5	1.74901	1.749009909	1.7490099	33.88994	1.69	0.59	7.166667	7.166667	1	7.166667	0.242174	56.582086
235	1.36217494	0.66746572	3.650052358	0.204402932	1.21664224	0.16221897					7	7	100	87	234.5	1.751147	1.75114676	1.7511468	33.93134	1.69	0.59	7.166667	7.166667	1	7.166667	0.242469	56.8936846
236	1.36217494	0.66746572	3.651641107	0.204491902	1.21716007	0.16228801					7	7	100	87	235.5	1.753277	1.753277112	1.7532771	33.97262	1.69	0.59	7.166667	7.166667	1	7.166667	0.242764	57.2056629
237	1.36217494	0.66746572	3.653223825	0.204580534	1.21767593	0.16235679					7	7	100	87	236.5	1.755401	1.755401012	1.755401	34.01377	1.69	0.59	7.166667	7.166667	1	7.166667	0.243058	57.5180198
238	1.36217494	0.66746572	3.654800561	0.204668831	1.21818982	0.16242531					7	7	100	87	237.5	1.757519	1.757518507	1.7575185	34.0548	1.69	0.59	7.166667	7.166667	1	7.166667	0.243352	57.8307541
239	1.36217494	0.66746572	3.656371362	0.204756796	1.21870178	0.16249357					7	7	100	87	238.5	1.75963	1.759629643	1.7596296	34.09571	1.69	0.59	7.166667	7.166667	1	7.166667	0.243644	58.1438646
240	1.36217494	0.66746572	3.657936276	0.204844431	1.2192118	0.16256157					7	7	100	87	239.5	1.761734	1.761734466	1.7617345	34.13649	1.69	0.59	7.166667	7.166667	1	7.166667	0.243935	58.4573503
241	1.36217494	0.66746572	3.65949535	0.20493174	1.21971991	0.16262932					7	7	100	87	240.5	1.763833	1.763833021	1.763833	34.17716	1.69	0.59	7.166667	7.166667	1	7.166667	0.244226	58.77121
242	1.36217494	0.66746572	3.661048629	0.205018723	1.22022613	0.16269682					7	7	100	87	241.5	1.765925	1.765925352	1.7659254	34.2177	1.69	0.59	7.166667	7.166667	1	7.166667	0.244516	59.0854427
243	1.36217494	0.66746572	3.662596158	0.205105385	1.22073046	0.16276406					7	7	100	87	242.5	1.768012	1.768011504	1.7680115	34.25812	1.69	0.59	7.166667	7.166667	1	7.166667	0.244805	59.4000471
244	1.36217494	0.66746572	3.664137983	0.205191727	1.22123292	0.16283106					7	7	100	87	243.5	1.770092	1.77009152	1.7700915	34.29843	1.69	0.59	7.166667	7.166667	1	7.166667	0.245093	59.7150223
245	1.36217494	0.66746572	3.665674147	0.205277752	1.22173353	0.1628978					7	7	100	87	244.5	1.772165	1.772165444	1.7721654	34.33861	1.69	0.59	7.166667	7.166667	1	7.166667	0.24538	60.0303671
246	1.36217494	0.66746572	3.667204695	0.205363463	1.2222323	0.16296431					7	7	100	87	245.5	1.774233	1.774233318	1.7742333	34.37868	1.69	0.59	7.166667	7.166667	1	7.166667	0.245666	60.3460804
247	1.36217494	0.66746572	3.66872967	0.205448862	1.22272924	0.16303057					7	7	100	87	246.5	1.776295	1.776295184	1.7762952	34.41863	1.69	0.59	7.166667	7.166667	1	7.166667	0.245952	60.6621612
248	1.36217494	0.66746572	3.670249115	0.20553395	1.22322437	0.16309658					7	7	100	87	247.5	1.778351	1.778351083	1.7783511	34.45847	1.69	0.59	7.166667	7.166667	1	7.166667	0.246236	60.9786085
249	1.36217494	0.66746572	3.671763072	0.205618732	1.22371771	0.16316236					7	7	100	87	248.5	1.780401	1.780401058	1.7804011	34.49819	1.69	0.59	7.166667	7.166667	1	7.166667	0.24652	61.2954211
250	1.36217494	0.66746572	3.673271582	0.205703209	1.22420926	0.1632279					7	7	100	87	249.5	1.782445	1.782445149	1.7824451	34.5378	1.69	0.59	7.166667	7.166667	1	7.166667	0.246803	

ANSYS Analysis for Deflection

```
PRINT U    NODAL SOLUTION PER NODE

 ***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

 LOAD STEP=     1  SUBSTEP=     1
  TIME=    1.0000      LOAD CASE=   0

 THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN THE GLOBAL COORDINATE SYSTEM

   NODE      UX
      1    0.0000
      2 -1.56623
      3  -2.1016
      4  -2.6027
      5  -3.0657
      6  -5.4877

MAXIMUM ABSOLUTE VALUES
NODE          6
VALUE   -5.4877
```



User Input				
Overall height	250	ft =	3000	in
Diameter at Base	8	ft=	96	in
Shell Thickness	0.75	in		
Strength of Steel	36	ksi		
Modulus of Elasticity	29000	ksi		

ID	94.5
S	5302.757785
Z	6804.5625
r	33.67700439
I	254532.3737

Axial Strength	
Factored Load	744.4273105
Factored Strength	1508.537309
Pn	1774.749775
Fcr	7.907897098
KL/r	178.1631148
4.71*sqrt(E/Fy)	133.680683
Fe	9.016986429
Fcr for KL/r≤4.71*sqrt(E/Fy)	6.769799368
Fcr for KL/r>4.71*sqrt(E/Fy)	7.907897098
Ag	224.4275252
Check for Compact section:	
D/t	128
λp	
λc	88.61111111
noncompact	
Axial Strength:	OK

Flexure Strength	
Factored Load	83472.45
Factored Strength	220467.83
Yielding Mn	244964.25
Local Buckling	216128.8075
Check for Compact section:	
D/t	128
λp	56.38888889
λc	249.7222222
non-compact	
Flexure Strength:	OK

Combined Loads			
Combined Loading	0.841748	≤1.0	**OK**
Pu/Pc	0.493476		
For Pu/Pc≥0.2	0.841748		
For Pu/Pc<0.2	0.59501		
Magnification Factors			
B2	1.03484		
Pnt	744.4273		
Pe2	22111.49		
∑H	52.03		
ΔH	6		
L	3000		

Appendix D: Tower Design Alternatives

Weight of Equipment:	400 kips		Axial Load	757.7449302	
Height of tower	250 ft		Moment Load	7878.008784	
Outer Diameter at base	8.25 ft		Total Shear	58.54	
Outer Diameter at hub	7.5 ft				
Thickness	0.75 in				
Weight of Steel	490 pcf		t_{ice}	0.083333333	
Town (Massachusetts)		Belmont			

Section	Diameter	Height	to	Inner Dia.	OR	IR	Ice Radius
D1	8.25	0	50	8.125	4.125	4.0625	4.375
D2	8.0625	51	100	7.9375	4.03125	3.96875	4.28125
D3	7.875	101	150	7.75	3.9375	3.875	4.1875
D4	7.6875	151	200	7.5625	3.84375	3.78125	4.09375
D5	7.5	201	250	7.375	3.75	3.6875	4

Height	*Volume of Steel*	*Weight of Steel*	*Volume of Ice*	*Weight of Ice*	*Fz*	*td*	*D1*	*D2*	*D3*	*D4*	*D5*	*Diameter*	*V(3-s)*	*V(f.m)*	*z*	*Kz calc*	*1 ≤Kz*	*1 ≤Kz≤2.58*	*q z*	*Gh*	*Cf*	*Ar*	*Ag*	*e*	*Ae*	*Force*	*Moment*
1	1.607611866	0.787729814	2.297102212	0.128637724	0.6577269	0.08769692	8.25					8.25	105	90	0.5	0.302086	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	0.08701093
2	1.607611866	0.787729814	2.566980491	0.143750908	0.73410424	0.09788057	8.25					8.25	105	90	1.5	0.413476	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	0.2610328
3	1.607611866	0.787729814	2.703175494	0.151377828	0.77257848	0.10301046	8.25					8.25	105	90	2.5	0.478449	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	0.43505467
4	1.607611866	0.787729814	2.796857114	0.156623998	0.79901588	0.10653545	8.25					8.25	105	90	3.5	0.526729	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	0.60907654
5	1.607611866	0.787729814	2.868967395	0.160662174	0.81935075	0.10924677	8.25					8.25	105	90	4.5	0.565941	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	0.78309841
6	1.607611866	0.787729814	2.927896104	0.163962182	0.8359588	0.11146117	8.25					8.25	105	90	5.5	0.599337	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	0.95712028
7	1.607611866	0.787729814	2.977887196	0.166761683	0.85004113	0.11333882	8.25					8.25	105	90	6.5	0.628637	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	1.13114215
8	1.607611866	0.787729814	3.021397408	0.169198255	0.86229275	0.11497237	8.25					8.25	105	90	7.5	0.654872	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	1.30516402
9	1.607611866	0.787729814	3.059981447	0.171358961	0.8731533	0.11642044	8.25					8.25	105	90	8.5	0.678715	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	1.47918588
10	1.607611866	0.787729814	3.094687838	0.173302519	0.88291921	0.11772256	8.25					8.25	105	90	9.5	0.70063	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	1.65320775
11	1.607611866	0.787729814	3.126258393	0.17507047	0.89180014	0.11890669	8.25					8.25	105	90	10.5	0.720953	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	1.82722962
12	1.607611866	0.787729814	3.155237912	0.176693323	0.89995002	0.11999334	8.25					8.25	105	90	11.5	0.739938	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	2.00125149
13	1.607611866	0.787729814	3.182038698	0.178194167	0.90748532	0.12099804	8.25					8.25	105	90	12.5	0.757778	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	2.17527336
14	1.607611866	0.787729814	3.206980567	0.179590912	0.91449636	0.12193285	8.25					8.25	105	90	13.5	0.774625	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	2.34929523
15	1.607611866	0.787729814	3.230316762	0.180897739	0.92105466	0.12280729	8.25					8.25	105	90	14.5	0.790603	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	2.5233171
16	1.607611866	0.787729814	3.25225135	0.182126076	0.92721783	0.12362904	8.25					8.25	105	90	15.5	0.805812	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	2.69733897
17	1.607611866	0.787729814	3.272951267	0.183285271	0.93303299	0.1244044	8.25					8.25	105	90	16.5	0.820335	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	2.87136084
18	1.607611866	0.787729814	3.292554868	0.184383073	0.93853919	0.12513856	8.25					8.25	105	90	17.5	0.834243	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	3.0453827
19	1.607611866	0.787729814	3.31117815	0.185425976	0.94376915	0.12583589	8.25					8.25	105	90	18.5	0.847594	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	3.21940457
20	1.607611866	0.787729814	3.328919349	0.186419484	0.94875061	0.12650008	8.25					8.25	105	90	19.5	0.860439	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	3.39342644
21	1.607611866	0.787729814	3.345862422	0.187368296	0.95350723	0.1271343	8.25					8.25	105	90	20.5	0.872822	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	3.56744831
22	1.607611866	0.787729814	3.362079701	0.188276463	0.95805943	0.12774126	8.25					8.25	105	90	21.5	0.884781	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	3.74147018
23	1.607611866	0.787729814	3.377633964	0.189147502	0.96242492	0.12832332	8.25					8.25	105	90	22.5	0.896348	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	3.91549205
24	1.607611866	0.787729814	3.392580054	0.189984483	0.96661914	0.12888255	8.25					8.25	105	90	23.5	0.907554	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	4.08951392
25	1.607611866	0.787729814	3.406966178	0.190790106	0.97065571	0.12942076	8.25					8.25	105	90	24.5	0.918425	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	4.26353579
26	1.607611866	0.787729814	3.420834938	0.191566757	0.97454663	0.12993955	8.25					8.25	105	90	25.5	0.928982	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	4.43755765
27	1.607611866	0.787729814	3.434224179	0.192316554	0.97830257	0.13044034	8.25					8.25	105	90	26.5	0.939249	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	4.61157952
28	1.607611866	0.787729814	3.447167671	0.19304139	0.98193304	0.13092441	8.25					8.25	105	90	27.5	0.949242	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	4.78560139
29	1.607611866	0.787729814	3.459695686	0.193742958	0.98544659	0.13139288	8.25					8.25	105	90	28.5	0.958978	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	4.95962326
30	1.607611866	0.787729814	3.471835462	0.194422786	0.98885089	0.13184678	8.25					8.25	105	90	29.5	0.968474	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	5.13364513
31	1.607611866	0.787729814	3.483611602	0.19508225	0.99215286	0.13228705	8.25					8.25	105	90	30.5	0.977743	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	5.307667
32	1.607611866	0.787729814	3.495046403	0.195722599	0.9953588	0.13271451	8.25					8.25	105	90	31.5	0.986797	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	5.48168887
33	1.607611866	0.787729814	3.506160142	0.196344968	0.99847442	0.13312992	8.25					8.25	105	90	32.5	0.995647	1	1	20.736	1.69	0.59	8.416667	8.416667	1	8.416667	0.174022	5.6679493
34	1.607611866	0.787729814	3.516971309	0.196950393	1.00150492	0.13353399	8.25					8.25	105	90	33.5	1.004306	1.00430578	1.0043058	20.82528	1.69	0.59	8.416667	8.416667	1	8.416667	0.174771	5.87966265
35	1.607611866	0.787729814	3.527496819	0.197539822	1.00445507	0.13392734	8.25					8.25	105	90	34.5	1.012781	1.012781498	1.0127815	21.00104	1.69	0.59	8.416667	8.416667	1	8.416667	0.176246	6.10553345
36	1.607611866	0.787729814	3.537752181	0.198114122	1.00732924	0.13431057	8.25					8.25	105	90	35.5	1.021084	1.021083506	1.0210835	21.17319	1.69	0.59	8.416667	8.416667	1	8.416667	0.177691	6.33327659
37	1.607611866	0.787729814	3.547751656	0.198674093	1.01013145	0.13468419	8.25					8.25	105	90	36.5	1.02922	1.029220112	1.0292201	21.34191	1.69	0.59	8.416667	8.416667	1	8.416667	0.179107	6.56285435
38	1.607611866	0.787729814	3.557508385	0.19922047	1.01286539	0.13504872	8.25					8.25	105	90	37.5	1.037199	1.03719901	1.037199	21.50736	1.69	0.59	8.416667	8.416667	1	8.416667	0.180495	6.7942308
39	1.607611866	0.787729814	3.567034506	0.199753932	1.01553449	0.1354046	8.25					8.25	105	90	38.5	1.045027	1.045027344	1.0450273	21.66969	1.69	0.59	8.416667	8.416667	1	8.416667	0.181858	7.02737165
40	1.607611866	0.787729814	3.576341255	0.20027511	1.01814191	0.13575225	8.25					8.25	105	90	39.5	1.052712	1.052711756	1.0527118	21.82903	1.69	0.59	8.416667	8.416667	1	8.416667	0.183195	7.26224413
41	1.607611866	0.787729814	3.58543905	0.200784587	1.02069058	0.13609208	8.25					8.25	105	90	40.5	1.060258	1.06025844	1.0602584	21.98552	1.69	0.59	8.416667	8.416667	1	8.416667	0.184508	7.4988169
42	1.607611866	0.787729814	3.594337575	0.201282904	1.02318324	0.13642443	8.25					8.25	105	90	41.5	1.067673	1.067673173	1.0676732	22.13927	1.69	0.59	8.416667	8.416667	1	8.416667	0.185798	7.73705996
43	1.607611866	0.787729814	3.603045842	0.201770567	1.0256224	0.13674965	8.25					8.25	105	90	42.5	1.074961	1.074961362	1.0749614	22.2904	1.69	0.59	8.416667	8.416667	1	8.416667	0.187067	7.97694452
44	1.607611866	0.787729814	3.611572258	0.202248046	1.02801046	0.13706806	8.25					8.25	105	90	43.5	1.082128	1.082128069	1.0821281	22.43901	1.69	0.59	8.416667	8.416667	1	8.416667	0.188314	8.21844299
45	1.607611866	0.787729814	3.619924673	0.202715782	1.0303496	0.13737995	8.25					8.25	105	90	44.5	1.089178	1.089178042	1.089178	22.5852	1.69	0.59	8.416667	8.416667	1	8.416667	0.189541	8.46152883
46	1.607611866	0.787729814	3.628110432	0.203174184	1.03264191	0.13768559	8.25					8.25	105	90	45.5	1.096116	1.096115745	1.0961157	22.72906	1.69	0.59	8.416667	8.416667	1	8.416667	0.190748	8.70617655
47	1.607611866	0.787729814	3.636136417	0.203623639	1.03488931	0.13798524	8.25					8.25	105	90	46.5	1.102945	1.102945375	1.1029454	22.87068	1.69	0.59	8.416667	8.416667	1	8.416667	0.191937	8.95236161
48	1.607611866	0.787729814	3.644009085	0.204064509	1.03709363	0.13827915	8.25					8.25	105	90	47.5	1.109671	1.109670885	1.1096709	23.01014	1.69	0.59	8.416667	8.416667	1	8.416667	0.193107	9.20006039
49	1.607611866	0.787729814	3.651734503	0.204497132	1.03925657	0.13856754	8.25					8.25	105	90	48.5	1.116296	1.116296006	1.116296	23.14751	1.69	0.59	8.416667	8.416667	1	8.416667	0.19426	9.44925009
50	1.607611866	0.787729814	3.659318378	0.204921829	1.04137974	0.13885063	8.25					8.25	105	90	49.5	1.122824	1.122824262	1.1228243	23.28288	1.69	0.59	8.416667	8.416667	1	8.416667	0.195396	9.59119273
51	1.570796327	0.7696902	3.584812565	0.200749504	1.04346466	0.13912862		8.063				8.0625	105	90	50.5	1.129259	1.129258983	1.129259	23.41631	1.69	0.59	8.229167	8.229167	1	8.229167	0.192138	9.73031186
52	1.570796327	0.7696902	3.591968323	0.201150226	1.04551274	0.1394017		8.063				8.0625	105	90	51.5	1.135603	1.135603321	1.1356033	23.54787	1.69	0.59	8.229167	8.229167	1	8.229167	0.193217	9.9781975
53	1.570796327	0.7696902	3.599000561	0.201544031	1.04752534	0.13967004		8.063				8.0625	105	90	52.5	1.14186	1.141860267	1.1418603	23.67761	1.69	0.59	8.229167	8.229167	1	8.229167	0.194282	10.2274592
54	1.570796327	0.7696902	3.605913704	0.201931167	1.04950372	0.13993383		8.063				8.0625	105	90	53.5	1.148033	1.148032653	1.1480327	23.80561	1.69	0.59	8.229167	8.229167	1	8.229167	0.195332	10.4780783
55	1.570796327	0.7696902	3.612711941	0.202311869	1.05144911	0.14019321		8.063				8.0625	105	90	54.5	1.154123	1.154123172	1.1541232	23.9319	1.69	0.59	8.229167	8.229167	1	8.229167	0.196368	10.7300366
56	1.570796327	0.7696902	3.619399238	0.202686357	1.05336262	0.14044835		8.063				8.0625	105	90	55.5	1.160134	1.160134383	1.1601344	24.05655	1.69	0.59	8.229167	8.229167	1	8.229167	0.197391	10.9833166
57	1.570796327	0.7696902	3.625979358	0.203054844	1.05524536	0.14069938		8.063				8.0625	105	90	56.5	1.166069	1.166068719	1.1660687	24.1796	1.69	0.59	8.229167	8.229167	1	8.229167	0.198401	11.2379013
58	1.570796327	0.7696902	3.632455871	0.203417529	1.05709834	0.14094645		8.063				8.0625	105	90	57.5	1.171928	1.171928499	1.1719285	24.30111	1.69	0.59	8.229167	8.229167	1	8.229167	0.199398	11.493774
59	1.570796327	0.7696902	3.63883217	0.203774601	1.05892254	0.14118967		8.063				8.0625	105	90	58.5	1.177716	1.177715932	1.1777159	24.42112	1.69	0.59	8.229167	8.229167	1	8.229167	0.200383	11.7509189
60	1.570796327	0.7696902	3.645111478	0.204126243	1.06071889	0.14142919		8.063				8.0625	105	90	59.5	1.183433	1.183433126	1.1834331	24.53967	1.69	0.59	8.229167	8.229167	1	8.229167	0.201355	12.0093204
61	1.570796327	0.7696902	3.651296866	0.204472625	1.06248827	0.1416651		8.063				8.0625	105	90	60.5	1.189082	1.189082092	1.1890821	24.65681	1.69	0.59	8.229167	8.229167	1	8.229167	0.202317	12.2689634
62	1.570796327	0.7696902	3.657391257	0.20481391	1.06423152	0.14189754		8.063				8.0625	105	90	61.5	1.194665	1.194664752	1.1946648	24.77257	1.69	0.59	8.229167	8.229167	1	8.229167	0.203266	12.5298332
63	1.570796327	0.7696902	3.663397438	0.205150257	1.06594944	0.14212659		8.063				8.0625	105	90	62.5	1.200183	1.200182944	1.2001829	24.88699	1.69	0.59	8.229167	8.229167	1	8.229167	0.204205	12.7919156
64	1.570796327	0.7696902	3.669318067	0.205481812	1.06764281	0.14235237		8.063				8.0625	105	90	63.5	1.205638	1.205638427	1.2056384	25.00012	1.69	0.59	8.229167	8.229167	1	8.229167	0.205134	13.0551967
65	1.570796327	0.7696902	3.675155682	0.205808718	1.06931234	0.14257498		8.063				8.0625	105	90	64.5	1.211033	1.211032883	1.2110329	25.11198	1.69	0.59	8.229167	8.229167	1	8.229167	0.206051	13.319663
66	1.570796327	0.7696902	3.680912707	0.206131112	1.07095873	0.1427945		8.063				8.0625	105	90	65.5	1.216368	1.216367926	1.2163679	25.22261	1.69	0.59	8.229167	8.229167	1	8.229167	0.206959	13.5853014
67	1.570796327	0.7696902	3.686591462	0.206449122	1.07258266	0.14301102		8.063				8.0625	105	90	66.5	1.221645	1.221645104	1.2216451	25.33203	1.69	0.59	8.229167	8.229167	1	8.229167	0.207857	13.8520991
68	1.570796327	0.7696902	3.692194164	0.206762873	1.07418475	0.14322463		8.063				8.0625	105	90	67.5	1.226866	1.226865898	1.2268659	25.44029	1.69	0.59	8.229167	8.229167	1	8.229167	0.208745	14.1200436
69	1.570796327	0.7696902	3.697722936	0.207072484	1.07576563	0.14343542		8.063				8.0625	105	90	68.5	1.232032	1.232031735	1.2320317	25.54741	1.69	0.59	8.229167	8.229167	1	8.229167	0.209624	14.3891228
70	1.570796327	0.7696902	3.703179812	0.207378069	1.07732586	0.14364345		8.063				8.0625	105	90	69.5	1.237144	1.237143983	1.237144	25.65342	1.69	0.59	8.229167	8.229167	1	8.229167	0.210494	14.6593249
71	1.570796327	0.7696902	3.708566742	0.207679738	1.07886603	0.1438488		8.063				8.0625	105	90	70.5	1.242204	1.242203955	1.242204	25.75834	1.69	0.59	8.229167	8.229167	1	8.229167	0.211355	14.9306383
72	1.570796327	0.7696902	3.713885597	0.207977593	1.08038665	0.14405155		8.063				8.0625	105	90	71.5	1.247213	1.247212918	1.2472129	25.86221	1.69	0.59	8.229167	8.229167	1	8.229167	0.212207	15.2030518
73	1.570796327	0.7696902	3.719138171	0.208271738	1.08188826	0.14425177		8.063				8.0625	105	90	72.5	1.252172	1.252172089	1.2521721	25.96504	1.69	0.59	8.229167	8.229167	1	8.229167	0.213051	15.4765543
74	1.570796327	0.7696902	3.724326189	0.208562267	1.08337133	0.14444951		8.063				8.0625	105	90	73.5	1.257083	1.257082638	1.2570826	26.06687	1.69	0.59	8.229167	8.229167	1	8.229167	0.213887	15.7511351
75	1.570796327	0.7696902	3.729451305	0.208849273	1.08483636	0.14464485		8.063				8.0625	105	90	74.5	1.261946	1.261945695	1.2619457	26.16771	1.69	0.59	8.229167	8.229167	1	8.229167	0.214714	16.0267837
76	1.570796327	0.7696902	3.734515112	0.209132846	1.0862838	0.14483784		8.063				8.0625	105	90	75.5	1.266762	1.266762348	1.2667623	26.26758	1.69	0.59	8.229167	8.229167	1	8.229167	0.215533	16.30349
77	1.570796327	0.7696902	3.739519142	0.209413072	1.08771408	0.14502854		8.063				8.0625	105	90	76.5	1.271534	1.271533644	1.2715336	26.36652	1.69	0.59	8.229167	8.229167	1	8.229167	0.216345	16.5812438
78	1.570796327	0.7696902	3.744464867	0.209690033	1.08912763	0.14521702		8.063				8.0625	105	90	77.5	1.276261	1.276260596	1.2762606	26.46454	1.69	0.59	8.229167	8.229167	1	8.229167	0.21715	16.8600354
79	1.570796327	0.7696902	3.749353708	0.209963808	1.09052486	0.14540332		8.063				8.0625	105	90	78.5	1.280944	1.28094418	1.2809442	26.56166	1.69	0.59	8.229167	8.229167	1	8.229167	0.217946	17.1398553
80	1.570796327	0.7696902	3.754187031	0.210234474	1.09190617	0.14558749		8.063				8.0625	105	90	79.5	1.285585	1.285585339	1.2855853	26.6579	1.69	0.59	8.229167	8.229167	1	8.229167	0.218736	17.420694
81	1.570796327	0.7696902	3.758966153	0.210502105	1.09327192	0.14576959		8.063				8.0625	105	90	80.5	1.290185	1.290184984	1.290185	26.75328	1.69	0.59	8.229167	8.229167	1	8.229167	0.219519	17.7025425
82	1.570796327	0.7696902	3.763692344	0.210766771	1.09462249	0.14594967		8.063				8.0625	105	90	81.5	1.294744	1.294743995	1.294744	26.84781	1.69	0.59	8.229167	8.229167	1	8.229167	0.220294	17.9853916

83	1.570796327	0.7696902	3.76836683	0.211028542	1.09595823	0.14612776	8.063				8.0625	105	90	82.5	1.299263	1.299263223	1.2992632	26.94152	1.69	0.59	8.229167	8.229167	1	8.229167	0.221063	18.2692328
84	1.570796327	0.7696902	3.772990792	0.211287484	1.09727947	0.14630393	8.063				8.0625	105	90	83.5	1.303743	1.30374349	1.3037435	27.03443	1.69	0.59	8.229167	8.229167	1	8.229167	0.221826	18.5540573
85	1.570796327	0.7696902	3.777565374	0.211543661	1.09858655	0.14647821	8.063				8.0625	105	90	84.5	1.308186	1.308185595	1.3081856	27.12654	1.69	0.59	8.229167	8.229167	1	8.229167	0.222581	18.8398568
86	1.570796327	0.7696902	3.782091677	0.211797134	1.09987978	0.14665064	8.063				8.0625	105	90	85.5	1.31259	1.312590307	1.3125903	27.21787	1.69	0.59	8.229167	8.229167	1	8.229167	0.223331	19.1266231
87	1.570796327	0.7696902	3.786570766	0.212047963	1.10115947	0.14682126	8.063				8.0625	105	90	86.5	1.316958	1.316958373	1.3169584	27.30845	1.69	0.59	8.229167	8.229167	1	8.229167	0.224074	19.4143479
88	1.570796327	0.7696902	3.791003673	0.212296206	1.10242591	0.14699012	8.063				8.0625	105	90	87.5	1.321291	1.321290517	1.3212905	27.39828	1.69	0.59	8.229167	8.229167	1	8.229167	0.224811	19.7030235
89	1.570796327	0.7696902	3.795391393	0.212541918	1.10367939	0.14715725	8.063				8.0625	105	90	88.5	1.325587	1.325587439	1.3255874	27.48738	1.69	0.59	8.229167	8.229167	1	8.229167	0.225542	19.9926421
90	1.570796327	0.7696902	3.799734889	0.212785154	1.10492019	0.14732269	8.063				8.0625	105	90	89.5	1.32985	1.32984982	1.3298498	27.57577	1.69	0.59	8.229167	8.229167	1	8.229167	0.226267	20.283196
91	1.570796327	0.7696902	3.804035095	0.213025965	1.10614857	0.14748648	8.063				8.0625	105	90	90.5	1.334078	1.334078317	1.3340783	27.66345	1.69	0.59	8.229167	8.229167	1	8.229167	0.226987	20.5746778
92	1.570796327	0.7696902	3.808292913	0.213264403	1.1073648	0.14764864	8.063				8.0625	105	90	91.5	1.338274	1.338273571	1.3382736	27.75044	1.69	0.59	8.229167	8.229167	1	8.229167	0.227701	20.8670801
93	1.570796327	0.7696902	3.812509218	0.213500516	1.10856913	0.14780922	8.063				8.0625	105	90	92.5	1.342436	1.342436201	1.3424362	27.83676	1.69	0.59	8.229167	8.229167	1	8.229167	0.228409	21.1603958
94	1.570796327	0.7696902	3.816684857	0.213734352	1.10976179	0.14796824	8.063				8.0625	105	90	93.5	1.346567	1.346566811	1.3465668	27.92241	1.69	0.59	8.229167	8.229167	1	8.229167	0.229112	21.4546178
95	1.570796327	0.7696902	3.820820651	0.213965956	1.11094303	0.14812574	8.063				8.0625	105	90	94.5	1.350666	1.350665984	1.350666	28.00741	1.69	0.59	8.229167	8.229167	1	8.229167	0.229809	21.7497392
96	1.570796327	0.7696902	3.824917396	0.214195374	1.11211307	0.14828174	8.063				8.0625	105	90	95.5	1.354734	1.35473429	1.3547343	28.09177	1.69	0.59	8.229167	8.229167	1	8.229167	0.230501	22.0457531
97	1.570796327	0.7696902	3.828975864	0.214422648	1.11327213	0.14843628	8.063				8.0625	105	90	96.5	1.358772	1.358772279	1.3587723	28.1755	1.69	0.59	8.229167	8.229167	1	8.229167	0.231189	22.342653
98	1.570796327	0.7696902	3.832996803	0.214647821	1.11442044	0.14858939	8.063				8.0625	105	90	97.5	1.36278	1.36278049	1.3627805	28.25862	1.69	0.59	8.229167	8.229167	1	8.229167	0.23187	22.6404322
99	1.570796327	0.7696902	3.836980942	0.21487093	1.11555819	0.14874109	8.063				8.0625	105	90	98.5	1.366759	1.366759443	1.3667594	28.34112	1.69	0.59	8.229167	8.229167	1	8.229167	0.232547	22.9390843
100	1.570796327	0.7696902	3.840928985	0.215092023	1.1166856	0.14889141	8.063				8.0625	105	90	99.5	1.37071	1.370709645	1.3707096	28.42304	1.69	0.59	8.229167	8.229167	1	8.229167	0.23322	22.9730378
101	1.533980788	0.751650586	3.757049587	0.210394777	1.11780285	0.14904038		7.875			7.875	105	90	100.5	1.374632	1.374631591	1.3746316	28.50436	1.69	0.59	8.041667	8.041667	1	8.041667	0.228558	23.0026508
102	1.533980788	0.751650586	3.760840507	0.210607068	1.11891014	0.14918802		7.875			7.875	105	90	101.5	1.378526	1.378525761	1.3785258	28.58511	1.69	0.59	8.041667	8.041667	1	8.041667	0.229205	23.2970205
103	1.533980788	0.751650586	3.764598096	0.210817493	1.12000766	0.14933435		7.875			7.875	105	90	102.5	1.382393	1.382392622	1.3823926	28.66529	1.69	0.59	8.041667	8.041667	1	8.041667	0.229848	23.5922191
104	1.533980788	0.751650586	3.768322968	0.211026086	1.12109558	0.14947941		7.875			7.875	105	90	103.5	1.386233	1.386232629	1.3862326	28.74492	1.69	0.59	8.041667	8.041667	1	8.041667	0.230487	23.8882408
105	1.533980788	0.751650586	3.77201572	0.21123288	1.12217408	0.14962321		7.875			7.875	105	90	104.5	1.390046	1.390046226	1.3900462	28.824	1.69	0.59	8.041667	8.041667	1	8.041667	0.231121	24.1850799
106	1.533980788	0.751650586	3.775676933	0.211437908	1.12324334	0.14976578		7.875			7.875	105	90	105.5	1.393834	1.393833844	1.3938338	28.90254	1.69	0.59	8.041667	8.041667	1	8.041667	0.231751	24.4827309
107	1.533980788	0.751650586	3.779307171	0.211641202	1.12430351	0.14990713		7.875			7.875	105	90	106.5	1.397596	1.397595905	1.3975959	28.98055	1.69	0.59	8.041667	8.041667	1	8.041667	0.232376	24.7811882
108	1.533980788	0.751650586	3.782906983	0.211842791	1.12535476	0.1500473		7.875			7.875	105	90	107.5	1.401333	1.401332817	1.4013328	29.05804	1.69	0.59	8.041667	8.041667	1	8.041667	0.232997	25.0804464
109	1.533980788	0.751650586	3.786476904	0.212042707	1.12639725	0.1501863		7.875			7.875	105	90	108.5	1.405045	1.405044981	1.405045	29.13501	1.69	0.59	8.041667	8.041667	1	8.041667	0.233615	25.3805003
110	1.533980788	0.751650586	3.790017455	0.212240977	1.12743112	0.15032415		7.875			7.875	105	90	109.5	1.408733	1.408732787	1.4087328	29.21148	1.69	0.59	8.041667	8.041667	1	8.041667	0.234228	25.6813445
111	1.533980788	0.751650586	3.793529142	0.212437632	1.12845653	0.15046087		7.875			7.875	105	90	110.5	1.412397	1.412396615	1.4123966	29.28746	1.69	0.59	8.041667	8.041667	1	8.041667	0.234837	25.9829739
112	1.533980788	0.751650586	3.797012459	0.212632698	1.12947362	0.15059648		7.875			7.875	105	90	111.5	1.416037	1.416036835	1.4160368	29.36294	1.69	0.59	8.041667	8.041667	1	8.041667	0.235442	26.2853835
113	1.533980788	0.751650586	3.800467886	0.212826202	1.13048254	0.15073101		7.875			7.875	105	90	112.5	1.419654	1.41965381	1.4196538	29.43794	1.69	0.59	8.041667	8.041667	1	8.041667	0.236044	26.5885682
114	1.533980788	0.751650586	3.803895892	0.21301817	1.13148341	0.15086446		7.875			7.875	105	90	113.5	1.423248	1.423247891	1.4232479	29.51247	1.69	0.59	8.041667	8.041667	1	8.041667	0.236641	26.8925231
115	1.533980788	0.751650586	3.807296933	0.213208628	1.13247639	0.15099685		7.875			7.875	105	90	114.5	1.426819	1.426819425	1.4268194	29.58653	1.69	0.59	8.041667	8.041667	1	8.041667	0.237235	27.1972434
116	1.533980788	0.751650586	3.810671454	0.213397601	1.13346158	0.15112821		7.875			7.875	105	90	115.5	1.430369	1.430368748	1.4303687	29.66013	1.69	0.59	8.041667	8.041667	1	8.041667	0.237825	27.5027243
117	1.533980788	0.751650586	3.814019889	0.213585114	1.13443913	0.15125855		7.875			7.875	105	90	116.5	1.433896	1.433896188	1.4338962	29.73327	1.69	0.59	8.041667	8.041667	1	8.041667	0.238412	27.808961
118	1.533980788	0.751650586	3.817342661	0.213771189	1.13540916	0.15138789		7.875			7.875	105	90	117.5	1.437402	1.437402066	1.4374021	29.80597	1.69	0.59	8.041667	8.041667	1	8.041667	0.238995	28.115949
119	1.533980788	0.751650586	3.820640183	0.21395585	1.13637178	0.15151624		7.875			7.875	105	90	118.5	1.440887	1.440886696	1.4408867	29.87823	1.69	0.59	8.041667	8.041667	1	8.041667	0.239574	28.4236836
120	1.533980788	0.751650586	3.823912857	0.21413912	1.13732712	0.15164362		7.875			7.875	105	90	119.5	1.44435	1.444350385	1.4443504	29.95005	1.69	0.59	8.041667	8.041667	1	8.041667	0.24015	28.7321605
121	1.533980788	0.751650586	3.827161076	0.21432102	1.1382753	0.15177004		7.875			7.875	105	90	120.5	1.447793	1.447793432	1.4477934	30.02144	1.69	0.59	8.041667	8.041667	1	8.041667	0.240722	29.0413751
122	1.533980788	0.751650586	3.830385223	0.214501573	1.13921641	0.15189552		7.875			7.875	105	90	121.5	1.451216	1.451216129	1.4512161	30.09242	1.69	0.59	8.041667	8.041667	1	8.041667	0.241291	29.351323
123	1.533980788	0.751650586	3.833585674	0.214680798	1.14015059	0.15202008		7.875			7.875	105	90	122.5	1.454619	1.454618764	1.4546188	30.16297	1.69	0.59	8.041667	8.041667	1	8.041667	0.241857	29.662
124	1.533980788	0.751650586	3.836762794	0.214858716	1.14107792	0.15214372		7.875			7.875	105	90	123.5	1.458002	1.458001615	1.4580016	30.23312	1.69	0.59	8.041667	8.041667	1	8.041667	0.24242	29.9734018
125	1.533980788	0.751650586	3.839916939	0.215035349	1.14199852	0.15226647		7.875			7.875	105	90	124.5	1.461365	1.461364957	1.461365	30.30286	1.69	0.59	8.041667	8.041667	1	8.041667	0.242979	30.2855242
126	1.533980788	0.751650586	3.843048459	0.215210714	1.14291249	0.15238833		7.875			7.875	105	90	125.5	1.464709	1.464709058	1.4647091	30.37221	1.69	0.59	8.041667	8.041667	1	8.041667	0.243535	30.5983631
127	1.533980788	0.751650586	3.846157694	0.215384831	1.14381993	0.15250932		7.875			7.875	105	90	126.5	1.468034	1.46803418	1.4680342	30.44116	1.69	0.59	8.041667	8.041667	1	8.041667	0.244088	30.9119144
128	1.533980788	0.751650586	3.849244977	0.215557719	1.14472093	0.15262946		7.875			7.875	105	90	127.5	1.471341	1.471340579	1.4713406	30.50972	1.69	0.59	8.041667	8.041667	1	8.041667	0.244637	31.226174
129	1.533980788	0.751650586	3.852310634	0.215729395	1.1456156	0.15274875		7.875			7.875	105	90	128.5	1.474629	1.474628506	1.4746285	30.5779	1.69	0.59	8.041667	8.041667	1	8.041667	0.245184	31.5411381
130	1.533980788	0.751650586	3.855354982	0.215899879	1.14650402	0.1528672		7.875			7.875	105	90	129.5	1.477898	1.477898208	1.4778982	30.6457	1.69	0.59	8.041667	8.041667	1	8.041667	0.245728	31.8568026
131	1.533980788	0.751650586	3.858378333	0.216069187	1.14738629	0.15298484		7.875			7.875	105	90	130.5	1.48115	1.481149924	1.4811499	30.71312	1.69	0.59	8.041667	8.041667	1	8.041667	0.246268	32.1731637
132	1.533980788	0.751650586	3.861380991	0.216237335	1.1482625	0.15310167		7.875			7.875	105	90	131.5	1.484384	1.48438389	1.4843839	30.78018	1.69	0.59	8.041667	8.041667	1	8.041667	0.246806	32.4902177
133	1.533980788	0.751650586	3.864363253	0.216404342	1.14913273	0.1532177		7.875			7.875	105	90	132.5	1.4876	1.487600337	1.4876003	30.84688	1.69	0.59	8.041667	8.041667	1	8.041667	0.247341	32.8079606
134	1.533980788	0.751650586	3.86732541	0.216570223	1.14999707	0.15333294		7.875			7.875	105	90	133.5	1.490799	1.490799492	1.4907995	30.91322	1.69	0.59	8.041667	8.041667	1	8.041667	0.247873	33.126389
135	1.533980788	0.751650586	3.870267747	0.216734994	1.1508556	0.15344741		7.875			7.875	105	90	134.5	1.493982	1.493981574	1.4939816	30.9792	1.69	0.59	8.041667	8.041667	1	8.041667	0.248402	33.4454989
136	1.533980788	0.751650586	3.873190543	0.21689867	1.1517084	0.15356112		7.875			7.875	105	90	135.5	1.497147	1.497146803	1.4971468	31.04484	1.69	0.59	8.041667	8.041667	1	8.041667	0.248928	33.7652869
137	1.533980788	0.751650586	3.87609407	0.217061268	1.15255556	0.15367408		7.875			7.875	105	90	136.5	1.500295	1.50029539	1.5002954	31.11013	1.69	0.59	8.041667	8.041667	1	8.041667	0.249452	34.0857494
138	1.533980788	0.751650586	3.878978594	0.217222801	1.15339715	0.15378629		7.875			7.875	105	90	137.5	1.503428	1.503427543	1.5034275	31.17507	1.69	0.59	8.041667	8.041667	1	8.041667	0.249973	34.4068828
139	1.533980788	0.751650586	3.881844378	0.217383285	1.15423326	0.15389777		7.875			7.875	105	90	138.5	1.506543	1.506543468	1.5065435	31.23969	1.69	0.59	8.041667	8.041667	1	8.041667	0.250491	34.7286836
140	1.533980788	0.751650586	3.884691677	0.217542734	1.15506394	0.15400853		7.875			7.875	105	90	139.5	1.509643	1.509643364	1.5096434	31.30396	1.69	0.59	8.041667	8.041667	1	8.041667	0.251006	35.0511485
141	1.533980788	0.751650586	3.887520742	0.217701162	1.15588929	0.15411857		7.875			7.875	105	90	140.5	1.512727	1.512727428	1.5127274	31.36792	1.69	0.59	8.041667	8.041667	1	8.041667	0.251519	35.3742739
142	1.533980788	0.751650586	3.890331817	0.217858582	1.15670936	0.15422791		7.875			7.875	105	90	141.5	1.515796	1.515795852	1.5157959	31.43154	1.69	0.59	8.041667	8.041667	1	8.041667	0.252029	35.6980566
143	1.533980788	0.751650586	3.893125144	0.218015008	1.15752423	0.15433656		7.875			7.875	105	90	142.5	1.518849	1.518848826	1.5188488	31.49485	1.69	0.59	8.041667	8.041667	1	8.041667	0.252537	36.0224932
144	1.533980788	0.751650586	3.895900958	0.218170454	1.15833398	0.15444453		7.875			7.875	105	90	143.5	1.521887	1.521886535	1.5218865	31.55784	1.69	0.59	8.041667	8.041667	1	8.041667	0.253042	36.3475805
145	1.533980788	0.751650586	3.898659489	0.218324931	1.15913866	0.15455182		7.875			7.875	105	90	144.5	1.524909	1.524909161	1.5249092	31.62052	1.69	0.59	8.041667	8.041667	1	8.041667	0.253544	36.6733152
146	1.533980788	0.751650586	3.901400964	0.218478454	1.15993834	0.15465845		7.875			7.875	105	90	145.5	1.527917	1.527916882	1.5279169	31.68288	1.69	0.59	8.041667	8.041667	1	8.041667	0.254044	36.999694
147	1.533980788	0.751650586	3.904125604	0.218631034	1.1607331	0.15476441		7.875			7.875	105	90	146.5	1.53091	1.530909874	1.5309099	31.74495	1.69	0.59	8.041667	8.041667	1	8.041667	0.254542	37.3267139
148	1.533980788	0.751650586	3.906833627	0.218782683	1.16152298	0.15486973		7.875			7.875	105	90	147.5	1.533888	1.533888309	1.5338883	31.80671	1.69	0.59	8.041667	8.041667	1	8.041667	0.255037	37.6543718
149	1.533980788	0.751650586	3.909525245	0.218933414	1.16230807	0.15497441		7.875			7.875	105	90	148.5	1.536852	1.536852354	1.5368524	31.86817	1.69	0.59	8.041667	8.041667	1	8.041667	0.25553	37.9826644
150	1.533980788	0.751650586	3.912200668	0.219083237	1.1630884	0.15507845		7.875			7.875	105	90	149.5	1.539802	1.539802177	1.5398022	31.92934	1.69	0.59	8.041667	8.041667	1	8.041667	0.25602	37.8640278
151	1.497165249	0.733610972	3.823450431	0.214113224	1.16386406	0.15518187			7.688		7.6875	105	90	150.5	1.542738	1.54273794	1.5427379	31.99021	1.69	0.59	7.854167	7.854167	1	7.854167	0.250528	37.7401827
152	1.497165249	0.733610972	3.826033518	0.214257877	1.16463509	0.15528468			7.688		7.6875	105	90	151.5	1.54566	1.545659802	1.5456598	32.0508	1.69	0.59	7.854167	7.854167	1	7.854167	0.251002	38.0626632
153	1.497165249	0.733610972	3.82860137	0.214401677	1.16540155	0.15538687			7.688		7.6875	105	90	152.5	1.548568	1.54856792	1.5485679	32.1111	1.69	0.59	7.854167	7.854167	1	7.854167	0.251475	38.385752
154	1.497165249	0.733610972	3.831154177	0.214544634	1.1661635	0.15548847			7.688		7.6875	105	90	153.5	1.551462	1.551462449	1.5514624	32.17113	1.69	0.59	7.854167	7.854167	1	7.854167	0.251945	38.7094462
155	1.497165249	0.733610972	3.833692125	0.214686759	1.166921	0.15558947			7.688		7.6875	105	90	154.5	1.554344	1.55434354	1.5543435	32.23087	1.69	0.59	7.854167	7.854167	1	7.854167	0.252412	39.033743
156	1.497165249	0.733610972	3.836215395	0.214828062	1.16767409	0.15568988			7.688		7.6875	105	90	155.5	1.557211	1.557211342	1.5572113	32.29033	1.69	0.59	7.854167	7.854167	1	7.854167	0.252878	39.3586397
157	1.497165249	0.733610972	3.838724165	0.214968553	1.16842285	0.15578971			7.688		7.6875	105	90	156.5	1.560066	1.560066	1.560066	32.34953	1.69	0.59	7.854167	7.854167	1	7.854167	0.253342	39.6841335
158	1.497165249	0.733610972	3.841218612	0.215108242	1.1691673	0.15588897			7.688		7.6875	105	90	157.5	1.562908	1.562907659	1.5629077	32.40845	1.69	0.59	7.854167	7.854167	1	7.854167	0.253803	40.0102216
159	1.497165249	0.733610972	3.843698906	0.215247139	1.16990752	0.15598767			7.688		7.6875	105	90	158.5	1.565736	1.56573646	1.5657365	32.46711	1.69	0.59	7.854167	7.854167	1	7.854167	0.254263	40.3369014
160	1.497165249	0.733610972	3.846165217	0.215385252	1.17064355	0.15608581			7.688		7.6875	105	90	159.5	1.568553	1.568552541	1.5685525	32.52551	1.69	0.59	7.854167	7.854167	1	7.854167	0.25472	40.6641701
161	1.497165249	0.733610972	3.848617711	0.215522592	1.17137543	0.15618339			7.688		7.6875	105	90	160.5	1.571356	1.57135604	1.571356	32.58364	1.69	0.59	7.854167	7.854167	1	7.854167	0.255175	40.9920253
162	1.497165249	0.733610972	3.85105655	0.215659167	1.17210322	0.15628043			7.688		7.6875	105	90	161.5	1.574147	1.574147089	1.5741471	32.64151	1.69	0.59	7.854167	7.854167	1	7.854167	0.255628	41.3204642
163	1.497165249	0.733610972	3.853481894	0.215794986	1.17282697	0.15637693			7.688		7.6875	105	90	162.5	1.576926	1.576925821	1.5769258	32.69913	1.69	0.59	7.854167	7.854167	1	7.854167	0.25608	41.6494842
164	1.497165249	0.733610972	3.855893901	0.215930058	1.17354671	0.1564729			7.688		7.6875	105	90	163.5	1.579692	1.579692365	1.5796924	32.7565	1.69	0.59	7.854167	7.854167	1	7.854167	0.256529	41.9790829
165	1.497165249	0.733610972	3.858292724	0.216064393	1.17426251	0.15656833			7.688		7.6875	105	90	164.5	1.582447	1.58244685	1.5824468	32.81362	1.69	0.59	7.854167	7.854167	1	7.854167	0.256976	42.3092576
166	1.497165249	0.733610972	3.860678516	0.216197997	1.1749744	0.15666325			7.688		7.6875	105	90	165.5	1.585189	1.5851894	1.5851894	32.87049	1.69	0.59	7.854167	7.854167	1	7.854167	0.257422	42.640006
167	1.497165249	0.733610972	3.863051425	0.21633088	1.17568244	0.15675766			7.688		7.6875	105	90	166.5	1.58792	1.587920138	1.5879201	32.92711	1.69	0.59	7.854167	7.854167	1	7.854167	0.257865	42.9713254
168	1.497165249	0.733610972	3.865411597	0.216463049	1.17638665	0.15685155			7.688		7.6875	105	90	167.5	1.590639	1.590639187	1.5906392	32.98349	1.69	0.59	7.854167	7.854167	1	7.854167	0.258307	43.3032135
169	1.497165249	0.733610972	3.867759176	0.216594514	1.17708709	0.15694495			7.688		7.6875	105	90	168.5	1.593347	1.593346665	1.5933467	33.03964	1.69	0.59	7.854167	7.854167	1	7.854167	0.258746	43.6356678
170	1.497165249	0.733610972	3.870094305	0.216725281	1.1777838	0.15703784			7.688		7.6875	105	90	169.5	1.596043	1.596042691	1.5960427	33.09554	1.69	0.59	7.854167	7.854167	1	7.854167	0.259184	43.9686859
171	1.497165249	0.733610972	3.872417121	0.216855359	1.17847682	0.15713024			7.688		7.6875	105	90	170.5	1.598727	1.598727379	1.5987274	33.15121	1.69	0.59	7.854167	7.854167	1	7.854167	0.25962	44.3022655
172	1.497165249	0.733610972	3.874727761	0.216984755	1.17916619	0.15722216			7.688		7.6875	105	90	171.5	1.601401	1.601400843	1.6014008	33.20665	1.69	0.59	7.854167	7.854167	1	7.854167	0.260054	44.6364042
173	1.497165249	0.733610972	3.877026359	0.217113476	1.17985195	0.15731359			7.688		7.6875	105	90	172.5	1.604063	1.604063195	1.6040632	33.26185	1.69	0.59	7.854167	7.854167	1	7.854167	0.260487	44.9710996
174	1.497165249	0.733610972	3.879313049	0.217241531	1.18053415	0.15740455			7.688		7.6875	105	90	173.5	1.606715	1.606714546	1.6067145	33.31683	1.69	0.59	7.854167	7.854167	1	7.854167	0.260917	45.3063496

175	1.497165249	0.733610972	3.881587958	0.217368926	1.18121281	0.15749504				7.688		7.6875	105	90	174.5	1.609355	1.609355004	1.609355	33.37159	1.69	0.59	7.854167	7.854167	1	7.854167	0.261346	45.6421517
176	1.497165249	0.733610972	3.883851216	0.217495668	1.18188799	0.15758506				7.688		7.6875	105	90	175.5	1.611985	1.611984676	1.6119847	33.42611	1.69	0.59	7.854167	7.854167	1	7.854167	0.261773	45.9785037
177	1.497165249	0.733610972	3.886102947	0.217621765	1.18255971	0.15767463				7.688		7.6875	105	90	176.5	1.614604	1.614603666	1.6146037	33.48042	1.69	0.59	7.854167	7.854167	1	7.854167	0.262198	46.3154034
178	1.497165249	0.733610972	3.888343276	0.217747223	1.18322801	0.15776373				7.688		7.6875	105	90	177.5	1.617212	1.617212079	1.6172121	33.53451	1.69	0.59	7.854167	7.854167	1	7.854167	0.262622	46.6528485
179	1.497165249	0.733610972	3.890572323	0.21787205	1.18389293	0.15785239				7.688		7.6875	105	90	178.5	1.61981	1.619810016	1.61981	33.58838	1.69	0.59	7.854167	7.854167	1	7.854167	0.263044	46.990837
180	1.497165249	0.733610972	3.892790209	0.217996252	1.18455451	0.1579406				7.688		7.6875	105	90	179.5	1.622398	1.622397578	1.6223976	33.64204	1.69	0.59	7.854167	7.854167	1	7.854167	0.263464	47.3293665
181	1.497165249	0.733610972	3.894997051	0.218119835	1.18521278	0.15802837				7.688		7.6875	105	90	180.5	1.624975	1.624974864	1.6249749	33.69548	1.69	0.59	7.854167	7.854167	1	7.854167	0.263882	47.668435
182	1.497165249	0.733610972	3.897192964	0.218242806	1.18586778	0.1581157				7.688		7.6875	105	90	181.5	1.627542	1.627541971	1.627542	33.74871	1.69	0.59	7.854167	7.854167	1	7.854167	0.264299	48.0080402
183	1.497165249	0.733610972	3.899378063	0.218365172	1.18651954	0.1582026				7.688		7.6875	105	90	182.5	1.630099	1.630098995	1.630099	33.80173	1.69	0.59	7.854167	7.854167	1	7.854167	0.264715	48.3481802
184	1.497165249	0.733610972	3.90155246	0.218486938	1.18716809	0.15828908				7.688		7.6875	105	90	183.5	1.632646	1.632646031	1.632646	33.85455	1.69	0.59	7.854167	7.854167	1	7.854167	0.265128	48.6888528
185	1.497165249	0.733610972	3.903716265	0.218608111	1.18781346	0.15837513				7.688		7.6875	105	90	184.5	1.635183	1.635183171	1.6351832	33.90716	1.69	0.59	7.854167	7.854167	1	7.854167	0.26554	49.0300559
186	1.497165249	0.733610972	3.905869586	0.218728697	1.1884557	0.15846076				7.688		7.6875	105	90	185.5	1.637711	1.637710507	1.6377105	33.95957	1.69	0.59	7.854167	7.854167	1	7.854167	0.265951	49.3717875
187	1.497165249	0.733610972	3.908012531	0.218848702	1.18909483	0.15854598				7.688		7.6875	105	90	186.5	1.640228	1.640228131	1.6402281	34.01177	1.69	0.59	7.854167	7.854167	1	7.854167	0.266359	49.7140455
188	1.497165249	0.733610972	3.910145205	0.218968131	1.18973088	0.15863078				7.688		7.6875	105	90	187.5	1.642736	1.642736131	1.6427361	34.06378	1.69	0.59	7.854167	7.854167	1	7.854167	0.266767	50.0568279
189	1.497165249	0.733610972	3.912267712	0.219086992	1.19036388	0.15871518				7.688		7.6875	105	90	188.5	1.645235	1.645234594	1.6452346	34.11558	1.69	0.59	7.854167	7.854167	1	7.854167	0.267172	50.4001328
190	1.497165249	0.733610972	3.914380153	0.219205289	1.19099387	0.15879918				7.688		7.6875	105	90	189.5	1.647724	1.647723608	1.6477236	34.1672	1.69	0.59	7.854167	7.854167	1	7.854167	0.267577	50.7439581
191	1.497165249	0.733610972	3.916482628	0.219323027	1.19162088	0.15888278				7.688		7.6875	105	90	190.5	1.650203	1.650203257	1.6502033	34.21861	1.69	0.59	7.854167	7.854167	1	7.854167	0.267979	51.0883019
192	1.497165249	0.733610972	3.918575238	0.219440213	1.19224493	0.15896599				7.688		7.6875	105	90	191.5	1.652674	1.652673627	1.6526736	34.26984	1.69	0.59	7.854167	7.854167	1	7.854167	0.26838	51.4331622
193	1.497165249	0.733610972	3.92065808	0.219556852	1.19286605	0.15904881				7.688		7.6875	105	90	192.5	1.655135	1.655134799	1.6551348	34.32088	1.69	0.59	7.854167	7.854167	1	7.854167	0.26878	51.7785371
194	1.497165249	0.733610972	3.922731249	0.21967295	1.19348428	0.15913124				7.688		7.6875	105	90	193.5	1.657587	1.657586855	1.6575869	34.37172	1.69	0.59	7.854167	7.854167	1	7.854167	0.269178	52.1244248
195	1.497165249	0.733610972	3.92479484	0.219788511	1.19409964	0.15921329				7.688		7.6875	105	90	194.5	1.66003	1.660029877	1.6600299	34.42238	1.69	0.59	7.854167	7.854167	1	7.854167	0.269575	52.4708232
196	1.497165249	0.733610972	3.926848946	0.219903541	1.19471215	0.15929495				7.688		7.6875	105	90	195.5	1.662464	1.662463943	1.6624639	34.47285	1.69	0.59	7.854167	7.854167	1	7.854167	0.26997	52.8177306
197	1.497165249	0.733610972	3.92889366	0.220018045	1.19532186	0.15937625				7.688		7.6875	105	90	196.5	1.664889	1.664889133	1.6648891	34.52314	1.69	0.59	7.854167	7.854167	1	7.854167	0.270364	53.165145
198	1.497165249	0.733610972	3.93092907	0.220132028	1.19592878	0.15945717				7.688		7.6875	105	90	197.5	1.667306	1.667305522	1.6673055	34.57325	1.69	0.59	7.854167	7.854167	1	7.854167	0.270757	53.5130647
199	1.497165249	0.733610972	3.932955268	0.220245495	1.19653293	0.15953772				7.688		7.6875	105	90	198.5	1.669713	1.669713188	1.6697132	34.62317	1.69	0.59	7.854167	7.854167	1	7.854167	0.271148	53.8614878
200	1.497165249	0.733610972	3.93497234	0.220358451	1.19713436	0.15961791				7.688		7.6875	105	90	199.5	1.672112	1.672112206	1.6721122	34.67292	1.69	0.59	7.854167	7.854167	1	7.854167	0.271537	53.5623358
201	1.46034971	0.715571358	3.842910637	0.215202996	1.19773308	0.15969774					7.5	7.5	105	90	200.5	1.674503	1.67450265	1.6745026	34.72249	1.69	0.59	7.666667	7.666667	1	7.666667	0.265434	53.2573474
202	1.46034971	0.715571358	3.844862903	0.215312323	1.19832911	0.15977722					7.5	7.5	105	90	201.5	1.676885	1.676884593	1.6768846	34.77188	1.69	0.59	7.666667	7.666667	1	7.666667	0.265811	53.5989163
203	1.46034971	0.715571358	3.846806509	0.215421164	1.19892249	0.15985633					7.5	7.5	105	90	202.5	1.679258	1.679258107	1.6792581	34.8211	1.69	0.59	7.666667	7.666667	1	7.666667	0.266188	53.9409696
204	1.46034971	0.715571358	3.848741534	0.215529526	1.19951324	0.1599351					7.5	7.5	105	90	203.5	1.681623	1.681623264	1.6816233	34.87014	1.69	0.59	7.666667	7.666667	1	7.666667	0.266562	54.2835056
205	1.46034971	0.715571358	3.85066806	0.215637411	1.20010139	0.16001352					7.5	7.5	105	90	204.5	1.68398	1.683980133	1.6839801	34.91901	1.69	0.59	7.666667	7.666667	1	7.666667	0.266936	54.6265225
206	1.46034971	0.715571358	3.852586163	0.215744825	1.20068695	0.16009159					7.5	7.5	105	90	205.5	1.686329	1.686328785	1.6863288	34.96771	1.69	0.59	7.666667	7.666667	1	7.666667	0.267308	54.9700188
207	1.46034971	0.715571358	3.854495923	0.215851772	1.20126995	0.16016933					7.5	7.5	105	90	206.5	1.688669	1.688669287	1.6886693	35.01625	1.69	0.59	7.666667	7.666667	1	7.666667	0.267679	55.3139927
208	1.46034971	0.715571358	3.856397415	0.215958255	1.20185041	0.16024672					7.5	7.5	105	90	207.5	1.691002	1.691001707	1.6910017	35.06461	1.69	0.59	7.666667	7.666667	1	7.666667	0.268049	55.6584427
209	1.46034971	0.715571358	3.858290714	0.21606428	1.20242836	0.16032378					7.5	7.5	105	90	208.5	1.693326	1.693326112	1.6933261	35.11281	1.69	0.59	7.666667	7.666667	1	7.666667	0.268418	56.003367
210	1.46034971	0.715571358	3.860175896	0.21616985	1.20300383	0.16040051					7.5	7.5	105	90	209.5	1.695643	1.695642568	1.6956426	35.16084	1.69	0.59	7.666667	7.666667	1	7.666667	0.268785	56.348764
211	1.46034971	0.715571358	3.862053033	0.21627497	1.20357682	0.16047691					7.5	7.5	105	90	210.5	1.697951	1.697951139	1.6979511	35.20871	1.69	0.59	7.666667	7.666667	1	7.666667	0.269151	56.6946321
212	1.46034971	0.715571358	3.863922199	0.216379643	1.20414737	0.16055298					7.5	7.5	105	90	211.5	1.700252	1.70025189	1.7002519	35.25642	1.69	0.59	7.666667	7.666667	1	7.666667	0.269515	57.0409698
213	1.46034971	0.715571358	3.865783463	0.216483874	1.2047155	0.16062873					7.5	7.5	105	90	212.5	1.702545	1.702544883	1.7025449	35.30397	1.69	0.59	7.666667	7.666667	1	7.666667	0.269879	57.3877754
214	1.46034971	0.715571358	3.867636896	0.216587666	1.20528123	0.16070416					7.5	7.5	105	90	213.5	1.70483	1.704830182	1.7048302	35.35136	1.69	0.59	7.666667	7.666667	1	7.666667	0.270241	57.7350474
215	1.46034971	0.715571358	3.869482569	0.216691024	1.20584458	0.16077928					7.5	7.5	105	90	214.5	1.707108	1.707107849	1.7071078	35.39859	1.69	0.59	7.666667	7.666667	1	7.666667	0.270602	58.0827841
216	1.46034971	0.715571358	3.871320548	0.216793951	1.20640557	0.16085408					7.5	7.5	105	90	215.5	1.709378	1.709377943	1.7093779	35.44566	1.69	0.59	7.666667	7.666667	1	7.666667	0.270962	58.4309842
217	1.46034971	0.715571358	3.873150903	0.216896451	1.20696422	0.16092856					7.5	7.5	105	90	216.5	1.711641	1.711640525	1.7116405	35.49258	1.69	0.59	7.666667	7.666667	1	7.666667	0.271321	58.7796459
218	1.46034971	0.715571358	3.874973699	0.216998527	1.20752055	0.16100274					7.5	7.5	105	90	217.5	1.713896	1.713895654	1.7138957	35.53934	1.69	0.59	7.666667	7.666667	1	7.666667	0.271678	59.1287678
219	1.46034971	0.715571358	3.876789003	0.217100184	1.20807459	0.16107661					7.5	7.5	105	90	218.5	1.716143	1.71614339	1.7161434	35.58595	1.69	0.59	7.666667	7.666667	1	7.666667	0.272034	59.4783485
220	1.46034971	0.715571358	3.878596878	0.217201425	1.20862635	0.16115018					7.5	7.5	105	90	219.5	1.718384	1.718383789	1.7183838	35.63241	1.69	0.59	7.666667	7.666667	1	7.666667	0.27239	59.8283863
221	1.46034971	0.715571358	3.88039739	0.217302254	1.20917585	0.16122345					7.5	7.5	105	90	220.5	1.720617	1.72061691	1.7206169	35.67871	1.69	0.59	7.666667	7.666667	1	7.666667	0.272744	60.1788798
222	1.46034971	0.715571358	3.882190602	0.217402674	1.20972311	0.16129642					7.5	7.5	105	90	221.5	1.722843	1.722842809	1.7228428	35.72487	1.69	0.59	7.666667	7.666667	1	7.666667	0.273096	60.5298275
223	1.46034971	0.715571358	3.883976575	0.217502688	1.21026816	0.16136909					7.5	7.5	105	90	222.5	1.725062	1.725061541	1.7250615	35.77088	1.69	0.59	7.666667	7.666667	1	7.666667	0.273448	60.881228
224	1.46034971	0.715571358	3.885755371	0.217602301	1.210811	0.16144147					7.5	7.5	105	90	223.5	1.727273	1.727273162	1.7272732	35.81674	1.69	0.59	7.666667	7.666667	1	7.666667	0.273799	61.2330798
225	1.46034971	0.715571358	3.887527052	0.217701515	1.21135166	0.16151356					7.5	7.5	105	90	224.5	1.729478	1.729477726	1.7294777	35.86245	1.69	0.59	7.666667	7.666667	1	7.666667	0.274148	61.5853814
226	1.46034971	0.715571358	3.889291677	0.217800334	1.21189016	0.16158536					7.5	7.5	105	90	225.5	1.731675	1.731675286	1.7316753	35.90802	1.69	0.59	7.666667	7.666667	1	7.666667	0.274496	61.9381315
227	1.46034971	0.715571358	3.891049305	0.217898761	1.21242652	0.16165687					7.5	7.5	105	90	226.5	1.733866	1.733865897	1.7338659	35.95344	1.69	0.59	7.666667	7.666667	1	7.666667	0.274844	62.2913285
228	1.46034971	0.715571358	3.892799995	0.2179968	1.21296075	0.1617281					7.5	7.5	105	90	227.5	1.73605	1.736049611	1.7360496	35.99872	1.69	0.59	7.666667	7.666667	1	7.666667	0.27519	62.6449712
229	1.46034971	0.715571358	3.894543804	0.218094453	1.21349286	0.16179905					7.5	7.5	105	90	228.5	1.738226	1.738226479	1.7382265	36.04386	1.69	0.59	7.666667	7.666667	1	7.666667	0.275535	62.9990581
230	1.46034971	0.715571358	3.89628079	0.218191724	1.21402289	0.16186972					7.5	7.5	105	90	229.5	1.740397	1.740396552	1.7403966	36.08886	1.69	0.59	7.666667	7.666667	1	7.666667	0.275879	63.3535877
231	1.46034971	0.715571358	3.898011009	0.218288617	1.21455084	0.16194011					7.5	7.5	105	90	230.5	1.74256	1.742559882	1.7425599	36.13372	1.69	0.59	7.666667	7.666667	1	7.666667	0.276222	63.7085588
232	1.46034971	0.715571358	3.899734516	0.218385133	1.21507674	0.16201023					7.5	7.5	105	90	231.5	1.744717	1.744716519	1.7447165	36.17844	1.69	0.59	7.666667	7.666667	1	7.666667	0.276564	64.06397
233	1.46034971	0.715571358	3.901451367	0.218481277	1.21560059	0.16208008					7.5	7.5	105	90	232.5	1.746867	1.746866512	1.7468665	36.22302	1.69	0.59	7.666667	7.666667	1	7.666667	0.276904	64.4198199
234	1.46034971	0.715571358	3.903161615	0.21857705	1.21612242	0.16214966					7.5	7.5	105	90	233.5	1.74901	1.749009909	1.7490099	36.26747	1.69	0.59	7.666667	7.666667	1	7.666667	0.277244	64.7761071
235	1.46034971	0.715571358	3.904865314	0.218672458	1.21664224	0.16221897					7.5	7.5	105	90	234.5	1.751147	1.75114676	1.7511468	36.31178	1.69	0.59	7.666667	7.666667	1	7.666667	0.277583	65.1328303
236	1.46034971	0.715571358	3.906562516	0.218767501	1.21716007	0.16228801					7.5	7.5	105	90	235.5	1.753277	1.753277112	1.7532771	36.35595	1.69	0.59	7.666667	7.666667	1	7.666667	0.277921	65.4899883
237	1.46034971	0.715571358	3.908253275	0.218862183	1.21767593	0.16235679					7.5	7.5	105	90	236.5	1.755401	1.755401012	1.755401	36.4	1.69	0.59	7.666667	7.666667	1	7.666667	0.278257	65.8475796
238	1.46034971	0.715571358	3.909937641	0.218956508	1.21818982	0.16242531					7.5	7.5	105	90	237.5	1.757519	1.757518507	1.7575185	36.4439	1.69	0.59	7.666667	7.666667	1	7.666667	0.278593	66.2056029
239	1.46034971	0.715571358	3.911615666	0.219050477	1.21870178	0.16249357					7.5	7.5	105	90	238.5	1.75963	1.759629643	1.7596296	36.48768	1.69	0.59	7.666667	7.666667	1	7.666667	0.278928	66.5640571
240	1.46034971	0.715571358	3.913287399	0.219144094	1.2192118	0.16256157					7.5	7.5	105	90	239.5	1.761734	1.761734466	1.7617345	36.53133	1.69	0.59	7.666667	7.666667	1	7.666667	0.279261	66.9229407
241	1.46034971	0.715571358	3.914952891	0.219237362	1.21971991	0.16262932					7.5	7.5	105	90	240.5	1.763833	1.763833021	1.763833	36.57484	1.69	0.59	7.666667	7.666667	1	7.666667	0.279594	67.2822525
242	1.46034971	0.715571358	3.916612191	0.219330283	1.22022613	0.16269682					7.5	7.5	105	90	241.5	1.765925	1.765925352	1.7659254	36.61823	1.69	0.59	7.666667	7.666667	1	7.666667	0.279926	67.6419912
243	1.46034971	0.715571358	3.918265347	0.219422859	1.22073046	0.16276406					7.5	7.5	105	90	242.5	1.768012	1.768011504	1.7680115	36.66149	1.69	0.59	7.666667	7.666667	1	7.666667	0.280256	68.0021556
244	1.46034971	0.715571358	3.919912407	0.219515095	1.22123292	0.16283106					7.5	7.5	105	90	243.5	1.770092	1.77009152	1.7700915	36.70462	1.69	0.59	7.666667	7.666667	1	7.666667	0.280586	68.3627443
245	1.46034971	0.715571358	3.921553419	0.219606991	1.22173353	0.1628978					7.5	7.5	105	90	244.5	1.772165	1.772165444	1.7721654	36.74762	1.69	0.59	7.666667	7.666667	1	7.666667	0.280915	68.7237563
246	1.46034971	0.715571358	3.923188429	0.219698552	1.2222323	0.16296431					7.5	7.5	105	90	245.5	1.774233	1.774233318	1.7742333	36.7905	1.69	0.59	7.666667	7.666667	1	7.666667	0.281243	69.0851901
247	1.46034971	0.715571358	3.924817484	0.219789779	1.22272924	0.16303057					7.5	7.5	105	90	246.5	1.776295	1.776295184	1.7762952	36.83326	1.69	0.59	7.666667	7.666667	1	7.666667	0.281569	69.4470446
248	1.46034971	0.715571358	3.926440629	0.219880675	1.22322437	0.16309658					7.5	7.5	105	90	247.5	1.778351	1.778351083	1.7783511	36.87589	1.69	0.59	7.666667	7.666667	1	7.666667	0.281895	69.8093187
249	1.46034971	0.715571358	3.92805791	0.219971243	1.22371771	0.16316236					7.5	7.5	105	90	248.5	1.780401	1.780401058	1.7804011	36.9184	1.69	0.59	7.666667	7.666667	1	7.666667	0.28222	70.1720109
250	1.46034971	0.715571358	3.929669371	0.220061485	1.22420926	0.1632279					7.5	7.5	105	90	249.5	1.782445	1.782445149	1.7824451	36.96078	1.69	0.59	7.666667	7.666667	1	7.666667	0.282544	

User Input				
Overall height	250	ft =	3000	in
Diameter at Base	8.25	ft=	99	in
Shell Thickness	0.75	in		
Strength of Steel	36	ksi		
Modulus of Elasticity	29000	ksi		

ID	97.5
S	5643.375308
Z	7239.9375
r	34.73763269
I	279347.0777

Axial Strength	
Factored Load	757.7449302
Factored Strength	1655.606644
Pn	1947.772522
Fcr	8.413845629
KL/r	172.7233417
4.71*sqrt(E/Fy)	133.680683
Fe	9.593894674
Fcr for KL/r≤4.71*sqrt(E/Fy)	7.485413811
Fcr for KL/r>4.71*sqrt(E/Fy)	8.413845629
Ag	231.4961087
Check for Compact section:	
D/t	132
λp	
λc	88.61111111
noncompact	
Axial Strength:	OK

Flexure Strength	
Factored Load	94536.11
Factored Strength	234573.98
Yielding Mn	260637.75
Local Buckling	229197.9926
Check for Compact section:	
D/t	132
λp	56.38888889
λc	249.7222222
non-compact	
Flexure Strength:	OK

Combined Loads			
Combined Loading	0.827171	≤1.0	**OK**
Pu/Pc	0.457684		
For Pu/Pc≥0.2	0.827171		
For Pu/Pc<0.2	0.598329		
Magnification Factors			
B2	1.031415		
Pnt	757.7449		
Pe2	24878.07		
∑H	58.54		
ΔH	6		
L	3000		

Weight of Equipment:	400 kips	Axial Load	669.7351275
Height of tower	250 ft	Moment Load	5587.946162
Outer Diameter at base	8.25 ft	Total Shear	41.52
Outer Diameter at hub	7.5 ft		
Thickness	0.50 in		
Weight of Steel	490 pcf	t_{ice}	0.0625
Town (Massachusetts)	Lee		

Section	Diameter	Height	to	Inner Dia.	OR	IR	Ice Radius
D1	8.25	0	50	8.166666667	4.125	4.083333	4.375
D2	8.0625	51	100	7.979166667	4.03125	3.989583	4.28125
D3	7.875	101	150	7.791666667	3.9375	3.895833	4.1875
D4	7.6875	151	200	7.604166667	3.84375	3.802083	4.09375
D5	7.5	201	250	7.416666667	3.75	3.708333	4

Height	Volume of Steel	Weight of Steel	Volume of Ice	Weight of Ice	Fz	td	D1	D2	D3	D4	D5	Diameter	V(3-s)	V(f.m)	z	Kz calc	1 ≤Kz	1 ≤Kz≤2.58	q_z	Gh	Cf	Ar	Ag	e	Ae	Force	Moment
1	1.074468321	0.526489477	1.718296433	0.0962246	0.6577269	0.06577269	8.25					8.25	90	76	0.5	0.302086	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	0.06173916
2	1.074468321	0.526489477	1.919591926	0.107497148	0.73410424	0.07341042	8.25					8.25	90	76	1.5	0.413476	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	0.18521747
3	1.074468321	0.526489477	2.021131134	0.113183343	0.77257848	0.07725785	8.25					8.25	90	76	2.5	0.478449	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	0.30869578
4	1.074468321	0.526489477	2.09095725	0.117093606	0.79901588	0.07990159	8.25					8.25	90	76	3.5	0.526729	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	0.43217409
5	1.074468321	0.526489477	2.144695335	0.120102939	0.81935075	0.08193508	8.25					8.25	90	76	4.5	0.565941	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	0.5556524
6	1.074468321	0.526489477	2.188603977	0.122561823	0.8359588	0.08359588	8.25					8.25	90	76	5.5	0.599337	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	0.67913071
7	1.074468321	0.526489477	2.225848662	0.124647525	0.85004113	0.08500411	8.25					8.25	90	76	6.5	0.628637	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	0.80260902
8	1.074468321	0.526489477	2.258261631	0.126462651	0.86229275	0.08622927	8.25					8.25	90	76	7.5	0.654872	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	0.92608734
9	1.074468321	0.526489477	2.287002286	0.128072128	0.8731533	0.08731533	8.25					8.25	90	76	8.5	0.678715	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	1.04956565
10	1.074468321	0.526489477	2.312852489	0.129519739	0.88291921	0.08829192	8.25					8.25	90	76	9.5	0.70063	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	1.17304396
11	1.074468321	0.526489477	2.336365354	0.13083646	0.89180014	0.08918001	8.25					8.25	90	76	10.5	0.720953	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	1.29652227
12	1.074468321	0.526489477	2.357947076	0.132045036	0.89995002	0.089995	8.25					8.25	90	76	11.5	0.739938	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	1.42000058
13	1.074468321	0.526489477	2.377905042	0.133162682	0.90748532	0.09074853	8.25					8.25	90	76	12.5	0.757778	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	1.54347889
14	1.074468321	0.526489477	2.396477675	0.13420275	0.91449636	0.09144964	8.25					8.25	90	76	13.5	0.774625	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	1.6669572
15	1.074468321	0.526489477	2.413853758	0.13517581	0.92105466	0.09210547	8.25					8.25	90	76	14.5	0.790603	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	1.79043552
16	1.074468321	0.526489477	2.430185411	0.136090383	0.92721783	0.09272178	8.25					8.25	90	76	15.5	0.805812	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	1.91391383
17	1.074468321	0.526489477	2.445597066	0.136953436	0.93303299	0.0933033	8.25					8.25	90	76	16.5	0.820335	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	2.03739214
18	1.074468321	0.526489477	2.460191851	0.137770744	0.93853919	0.09385392	8.25					8.25	90	76	17.5	0.834243	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	2.16087045
19	1.074468321	0.526489477	2.474056221	0.138547148	0.94376915	0.09437692	8.25					8.25	90	76	18.5	0.847594	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	2.28434876
20	1.074468321	0.526489477	2.487263396	0.13928675	0.94875061	0.09487506	8.25					8.25	90	76	19.5	0.860439	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	2.40782707
21	1.074468321	0.526489477	2.499875947	0.139993053	0.95350723	0.09535072	8.25					8.25	90	76	20.5	0.872822	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	2.53130538
22	1.074468321	0.526489477	2.511947781	0.140669076	0.95805943	0.09580594	8.25					8.25	90	76	21.5	0.884781	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	2.6547837
23	1.074468321	0.526489477	2.523525683	0.141317438	0.96242492	0.09624249	8.25					8.25	90	76	22.5	0.896348	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	2.77826201
24	1.074468321	0.526489477	2.534650524	0.141940429	0.96661914	0.09666191	8.25					8.25	90	76	23.5	0.907554	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	2.90174032
25	1.074468321	0.526489477	2.545358226	0.142540061	0.97065571	0.09706557	8.25					8.25	90	76	24.5	0.918425	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	3.02521863
26	1.074468321	0.526489477	2.555680538	0.14311811	0.97454663	0.09745466	8.25					8.25	90	76	25.5	0.928982	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	3.14869694
27	1.074468321	0.526489477	2.565645658	0.143676157	0.97830257	0.09783026	8.25					8.25	90	76	26.5	0.939249	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	3.27217525
28	1.074468321	0.526489477	2.575278753	0.14421561	0.98193304	0.0981933	8.25					8.25	90	76	27.5	0.949242	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	3.39565356
29	1.074468321	0.526489477	2.584602377	0.144737733	0.98544659	0.09854466	8.25					8.25	90	76	28.5	0.958978	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	3.51913188
30	1.074468321	0.526489477	2.593636826	0.145243662	0.98885089	0.09888509	8.25					8.25	90	76	29.5	0.968474	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	3.64261019
31	1.074468321	0.526489477	2.602400431	0.145734424	0.99215286	0.09921529	8.25					8.25	90	76	30.5	0.977743	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	3.7660885
32	1.074468321	0.526489477	2.610909806	0.146210949	0.9953588	0.09953588	8.25					8.25	90	76	31.5	0.986797	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	3.88956681
33	1.074468321	0.526489477	2.619180058	0.146674083	0.99847442	0.09984744	8.25					8.25	90	76	32.5	0.995647	1	1	14.78656	1.69	0.59	8.375	8.375	1	8.375	0.123478	4.02172907
34	1.074468321	0.526489477	2.627224964	0.147124598	1.00150492	0.10015049	8.25					8.25	90	76	33.5	1.004306	1.00430578	1.0043058	14.85023	1.69	0.59	8.375	8.375	1	8.375	0.12401	4.17195161
35	1.074468321	0.526489477	2.635057124	0.147563199	1.00445507	0.10044551	8.25					8.25	90	76	34.5	1.012781	1.012781498	1.0127815	14.97555	1.69	0.59	8.375	8.375	1	8.375	0.125057	4.33221966
36	1.074468321	0.526489477	2.642688094	0.147990533	1.00732924	0.10073292	8.25					8.25	90	76	35.5	1.021084	1.021083506	1.0210835	15.09831	1.69	0.59	8.375	8.375	1	8.375	0.126082	4.49381623
37	1.074468321	0.526489477	2.650128499	0.148407196	1.01013145	0.10101314	8.25					8.25	90	76	36.5	1.02922	1.029220112	1.0292201	15.21862	1.69	0.59	8.375	8.375	1	8.375	0.127086	4.65671458
38	1.074468321	0.526489477	2.657388128	0.148813735	1.01286539	0.10128654	8.25					8.25	90	76	37.5	1.037199	1.03719901	1.037199	15.33661	1.69	0.59	8.375	8.375	1	8.375	0.128072	4.82088919
39	1.074468321	0.526489477	2.664476024	0.149210657	1.01553449	0.10155345	8.25					8.25	90	76	38.5	1.045027	1.045027344	1.0450273	15.45236	1.69	0.59	8.375	8.375	1	8.375	0.129038	4.98631575
40	1.074468321	0.526489477	2.671400556	0.149598431	1.01814191	0.10181419	8.25					8.25	90	76	39.5	1.052712	1.052711756	1.0527118	15.56599	1.69	0.59	8.375	8.375	1	8.375	0.129987	5.15297099
41	1.074468321	0.526489477	2.678169486	0.149977491	1.02069058	0.10206906	8.25					8.25	90	76	40.5	1.060258	1.06025844	1.0602584	15.67758	1.69	0.59	8.375	8.375	1	8.375	0.130919	5.32083269
42	1.074468321	0.526489477	2.684790029	0.150348242	1.02318324	0.10231832	8.25					8.25	90	76	41.5	1.067673	1.067673173	1.0676732	15.78721	1.69	0.59	8.375	8.375	1	8.375	0.131834	5.48987955
43	1.074468321	0.526489477	2.691268897	0.150711058	1.0256224	0.10256224	8.25					8.25	90	76	42.5	1.074961	1.074961362	1.0749614	15.89498	1.69	0.59	8.375	8.375	1	8.375	0.132734	5.66009115
44	1.074468321	0.526489477	2.697612352	0.151066292	1.02801046	0.10280105	8.25					8.25	90	76	43.5	1.082128	1.082128069	1.0821281	16.00095	1.69	0.59	8.375	8.375	1	8.375	0.133619	5.83144791
45	1.074468321	0.526489477	2.703826243	0.15141427	1.0303496	0.10303496	8.25					8.25	90	76	44.5	1.089178	1.089178042	1.089178	16.1052	1.69	0.59	8.375	8.375	1	8.375	0.13449	6.003931
46	1.074468321	0.526489477	2.70991604	0.151755298	1.03264191	0.10326419	8.25					8.25	90	76	45.5	1.096116	1.096115745	1.0961157	16.20778	1.69	0.59	8.375	8.375	1	8.375	0.135347	6.17752232
47	1.074468321	0.526489477	2.71588687	0.152089665	1.03488931	0.10348893	8.25					8.25	90	76	46.5	1.102945	1.102945375	1.1029454	16.30877	1.69	0.59	8.375	8.375	1	8.375	0.13619	6.35220448
48	1.074468321	0.526489477	2.721743542	0.152417638	1.03709363	0.10370936	8.25					8.25	90	76	47.5	1.109671	1.109670885	1.1096709	16.40822	1.69	0.59	8.375	8.375	1	8.375	0.13702	6.52796071
49	1.074468321	0.526489477	2.727490576	0.152739472	1.03925657	0.10392566	8.25					8.25	90	76	48.5	1.116296	1.116296006	1.116296	16.50618	1.69	0.59	8.375	8.375	1	8.375	0.137838	6.70477483
50	1.074468321	0.526489477	2.733132222	0.153055404	1.04137974	0.10413797	8.25					8.25	90	76	49.5	1.122824	1.122824262	1.1228243	16.60271	1.69	0.59	8.375	8.375	1	8.375	0.138644	6.80510734
51	1.049924628	0.514463068	2.677207343	0.149923611	1.04346466	0.10434647		8.063				8.0625	90	76	50.5	1.129259	1.129258983	1.129259	16.69786	1.69	0.59	8.1875	8.1875	1	8.1875	0.136317	6.90342133
52	1.049924628	0.514463068	2.682529359	0.150221644	1.04551274	0.10455127		8.063				8.0625	90	76	51.5	1.135603	1.135603321	1.1356033	16.79167	1.69	0.59	8.1875	8.1875	1	8.1875	0.137083	7.07929021
53	1.049924628	0.514463068	2.687759424	0.150514528	1.04752534	0.10475253		8.063				8.0625	90	76	52.5	1.14186	1.141860267	1.1418603	16.88419	1.69	0.59	8.1875	8.1875	1	8.1875	0.137838	7.25613539
54	1.049924628	0.514463068	2.692900836	0.150802447	1.04950372	0.10495037		8.063				8.0625	90	76	53.5	1.148033	1.148032653	1.1480327	16.97545	1.69	0.59	8.1875	8.1875	1	8.1875	0.138583	7.43394358
55	1.049924628	0.514463068	2.697956713	0.151085576	1.05144911	0.10514491		8.063				8.0625	90	76	54.5	1.154123	1.154123172	1.1541232	17.06551	1.69	0.59	8.1875	8.1875	1	8.1875	0.139319	7.61270193
56	1.049924628	0.514463068	2.702930009	0.151364081	1.05336262	0.10533626		8.063				8.0625	90	76	55.5	1.160134	1.160134383	1.1601344	17.1544	1.69	0.59	8.1875	8.1875	1	8.1875	0.140044	7.79239796
57	1.049924628	0.514463068	2.707823526	0.151638117	1.05524536	0.10552454		8.063				8.0625	90	76	56.5	1.166069	1.166068719	1.1660687	17.24215	1.69	0.59	8.1875	8.1875	1	8.1875	0.140761	7.97301961
58	1.049924628	0.514463068	2.712639922	0.151907836	1.05709834	0.10570983		8.063				8.0625	90	76	57.5	1.171928	1.171928499	1.1719285	17.32879	1.69	0.59	8.1875	8.1875	1	8.1875	0.141468	8.15455516
59	1.049924628	0.514463068	2.717381724	0.152173377	1.05892254	0.10589225		8.063				8.0625	90	76	58.5	1.177716	1.177715932	1.1777159	17.41437	1.69	0.59	8.1875	8.1875	1	8.1875	0.142167	8.33699326
60	1.049924628	0.514463068	2.722051332	0.152434875	1.06071889	0.10607189		8.063				8.0625	90	76	59.5	1.183433	1.183433126	1.1834331	17.4989	1.69	0.59	8.1875	8.1875	1	8.1875	0.142857	8.52032287
61	1.049924628	0.514463068	2.726651032	0.152692458	1.06248827	0.10624883		8.063				8.0625	90	76	60.5	1.189082	1.189082092	1.1890821	17.58243	1.69	0.59	8.1875	8.1875	1	8.1875	0.143539	8.7045333
62	1.049924628	0.514463068	2.731183002	0.152946248	1.06423152	0.10642315		8.063				8.0625	90	76	61.5	1.194665	1.194664752	1.1946648	17.66498	1.69	0.59	8.1875	8.1875	1	8.1875	0.144213	8.88961413
63	1.049924628	0.514463068	2.735649315	0.153196362	1.06594944	0.10659494		8.063				8.0625	90	76	62.5	1.200183	1.200182944	1.2001829	17.74658	1.69	0.59	8.1875	8.1875	1	8.1875	0.144879	9.07555526
64	1.049924628	0.514463068	2.740051952	0.153442909	1.06764281	0.10676428		8.063				8.0625	90	76	63.5	1.205638	1.205638427	1.2056384	17.82724	1.69	0.59	8.1875	8.1875	1	8.1875	0.145537	9.26234683
65	1.049924628	0.514463068	2.744392802	0.153685997	1.06931234	0.10693123		8.063				8.0625	90	76	64.5	1.211033	1.211032883	1.2110329	17.90701	1.69	0.59	8.1875	8.1875	1	8.1875	0.146188	9.44997929
66	1.049924628	0.514463068	2.748673671	0.153925726	1.07095873	0.10709587		8.063				8.0625	90	76	65.5	1.216368	1.216367926	1.2163679	17.9859	1.69	0.59	8.1875	8.1875	1	8.1875	0.146832	9.63844332
67	1.049924628	0.514463068	2.752896285	0.154162192	1.07258266	0.10725827		8.063				8.0625	90	76	66.5	1.221645	1.221645104	1.2216451	18.06393	1.69	0.59	8.1875	8.1875	1	8.1875	0.14747	9.82772984
68	1.049924628	0.514463068	2.757062294	0.154395488	1.07418475	0.10741848		8.063				8.0625	90	76	67.5	1.226866	1.226865898	1.2268659	18.14113	1.69	0.59	8.1875	8.1875	1	8.1875	0.1481	10.01783
69	1.049924628	0.514463068	2.761173281	0.154625704	1.07576563	0.10757656		8.063				8.0625	90	76	68.5	1.232032	1.232031735	1.2320317	18.21751	1.69	0.59	8.1875	8.1875	1	8.1875	0.148723	10.2087352
70	1.049924628	0.514463068	2.765230759	0.154852923	1.07732586	0.10773259		8.063				8.0625	90	76	69.5	1.237144	1.237143983	1.237144	18.2931	1.69	0.59	8.1875	8.1875	1	8.1875	0.14934	10.4004371
71	1.049924628	0.514463068	2.769236181	0.155077226	1.07886603	0.1078866		8.063				8.0625	90	76	70.5	1.242204	1.242203955	1.242204	18.36792	1.69	0.59	8.1875	8.1875	1	8.1875	0.149951	10.5929274
72	1.049924628	0.514463068	2.773190938	0.155298693	1.08038665	0.10803867		8.063				8.0625	90	76	71.5	1.247213	1.247212918	1.2472129	18.44199	1.69	0.59	8.1875	8.1875	1	8.1875	0.150556	10.7861981
73	1.049924628	0.514463068	2.777096368	0.155517397	1.08188826	0.10818883		8.063				8.0625	90	76	72.5	1.252172	1.252172089	1.2521721	18.51532	1.69	0.59	8.1875	8.1875	1	8.1875	0.151155	10.9802416
74	1.049924628	0.514463068	2.780953752	0.15573341	1.08337133	0.10833713		8.063				8.0625	90	76	73.5	1.257083	1.257082638	1.2570826	18.58793	1.69	0.59	8.1875	8.1875	1	8.1875	0.151747	11.17505
75	1.049924628	0.514463068	2.784764325	0.155946802	1.08483636	0.10848364		8.063				8.0625	90	76	74.5	1.261946	1.261945695	1.2619457	18.65984	1.69	0.59	8.1875	8.1875	1	8.1875	0.152334	11.3706161
76	1.049924628	0.514463068	2.788529272	0.156157639	1.0862838	0.10862838		8.063				8.0625	90	76	75.5	1.266762	1.266762348	1.2667623	18.73106	1.69	0.59	8.1875	8.1875	1	8.1875	0.152916	11.5669325
77	1.049924628	0.514463068	2.792249732	0.156365985	1.08771408	0.10877141		8.063				8.0625	90	76	76.5	1.271534	1.271533644	1.2715336	18.80161	1.69	0.59	8.1875	8.1875	1	8.1875	0.153492	11.7639921
78	1.049924628	0.514463068	2.795926804	0.156571901	1.08912763	0.10891276		8.063				8.0625	90	76	77.5	1.276261	1.276260596	1.2762606	18.8715	1.69	0.59	8.1875	8.1875	1	8.1875	0.154062	11.9617881
79	1.049924628	0.514463068	2.799561542	0.156775446	1.09052486	0.10905249		8.063				8.0625	90	76	78.5	1.280944	1.28094418	1.2809442	18.94076	1.69	0.59	8.1875	8.1875	1	8.1875	0.154628	12.1603135
80	1.049924628	0.514463068	2.803154965	0.156976678	1.09190617	0.10919062		8.063				8.0625	90	76	79.5	1.285585	1.285585339	1.2855853	19.00938	1.69	0.59	8.1875	8.1875	1	8.1875	0.155188	12.3595618
81	1.049924628	0.514463068	2.806708054	0.157175651	1.09327192	0.10932719		8.063				8.0625	90	76	80.5	1.290185	1.290184984	1.290185	19.0774	1.69	0.59	8.1875	8.1875	1	8.1875	0.155743	12.5595265
82	1.049924628	0.514463068	2.810221754	0.157372418	1.09462249	0.10946225		8.063				8.0625	90	76	81.5	1.294744	1.294743995	1.294744	19.14481	1.69	0.59	8.1875	8.1875	1	8.1875	0.156294	12.7602011

83	1.049924628	0.514463068	2.813696977	0.157567031	1.09595823	0.10959582		8.063				8.0625	90	76	82.5	1.299263	1.299263223	1.2992632	19.21163	1.69	0.59	8.1875	8.1875	1	8.1875	0.156839	12.9615796
84	1.049924628	0.514463068	2.817134603	0.157759538	1.09727947	0.10972795		8.063				8.0625	90	76	83.5	1.303743	1.30374349	1.3037435	19.27788	1.69	0.59	8.1875	8.1875	1	8.1875	0.15738	13.1636557
85	1.049924628	0.514463068	2.820535483	0.157949987	1.09858655	0.10985865		8.063				8.0625	90	76	84.5	1.308186	1.308185595	1.3081856	19.34356	1.69	0.59	8.1875	8.1875	1	8.1875	0.157916	13.3664236
86	1.049924628	0.514463068	2.823900437	0.158138424	1.09987978	0.10998798		8.063				8.0625	90	76	85.5	1.31259	1.312590307	1.3125903	19.4087	1.69	0.59	8.1875	8.1875	1	8.1875	0.158448	13.5698773
87	1.049924628	0.514463068	2.827230258	0.158324894	1.10115947	0.11011595		8.063				8.0625	90	76	86.5	1.316958	1.316958373	1.3169584	19.47328	1.69	0.59	8.1875	8.1875	1	8.1875	0.158975	13.7740111
88	1.049924628	0.514463068	2.830525714	0.15850944	1.10242591	0.11024259		8.063				8.0625	90	76	87.5	1.321291	1.321290517	1.3212905	19.53734	1.69	0.59	8.1875	8.1875	1	8.1875	0.159498	13.9788195
89	1.049924628	0.514463068	2.833787545	0.158692103	1.10367939	0.11036794		8.063				8.0625	90	76	88.5	1.325587	1.325587439	1.3255874	19.60088	1.69	0.59	8.1875	8.1875	1	8.1875	0.160017	14.1842968
90	1.049924628	0.514463068	2.83701647	0.158872922	1.10492019	0.11049202		8.063				8.0625	90	76	89.5	1.32985	1.32984982	1.3298498	19.6639	1.69	0.59	8.1875	8.1875	1	8.1875	0.160531	14.3904378
91	1.049924628	0.514463068	2.840213182	0.159051938	1.10614857	0.11061486		8.063				8.0625	90	76	90.5	1.334078	1.334078317	1.3340783	19.72643	1.69	0.59	8.1875	8.1875	1	8.1875	0.161042	14.5972371
92	1.049924628	0.514463068	2.843378354	0.159229188	1.1073648	0.11073648		8.063				8.0625	90	76	91.5	1.338274	1.338273571	1.3382736	19.78846	1.69	0.59	8.1875	8.1875	1	8.1875	0.161548	14.8046895
93	1.049924628	0.514463068	2.846512636	0.159404708	1.10856913	0.11085691		8.063				8.0625	90	76	92.5	1.342436	1.342436201	1.3424362	19.85001	1.69	0.59	8.1875	8.1875	1	8.1875	0.162051	15.0127899
94	1.049924628	0.514463068	2.849616659	0.159578533	1.10976179	0.11097618		8.063				8.0625	90	76	93.5	1.346567	1.346566811	1.3465668	19.91109	1.69	0.59	8.1875	8.1875	1	8.1875	0.162549	15.2215333
95	1.049924628	0.514463068	2.852691034	0.159750698	1.11094303	0.1110943		8.063				8.0625	90	76	94.5	1.350666	1.350665984	1.350666	19.9717	1.69	0.59	8.1875	8.1875	1	8.1875	0.163044	15.4309148
96	1.049924628	0.514463068	2.855736355	0.159921236	1.11211307	0.11121131		8.063				8.0625	90	76	95.5	1.354734	1.35473429	1.3547343	20.03186	1.69	0.59	8.1875	8.1875	1	8.1875	0.163535	15.6409296
97	1.049924628	0.514463068	2.858753195	0.160090179	1.11327213	0.11132721		8.063				8.0625	90	76	96.5	1.358772	1.358772279	1.3587723	20.09157	1.69	0.59	8.1875	8.1875	1	8.1875	0.164023	15.8515728
98	1.049924628	0.514463068	2.861742112	0.160257558	1.11442044	0.11144204		8.063				8.0625	90	76	97.5	1.36278	1.36278049	1.3627805	20.15084	1.69	0.59	8.1875	8.1875	1	8.1875	0.164507	16.06284
99	1.049924628	0.514463068	2.864703646	0.160423404	1.11555819	0.11155582		8.063				8.0625	90	76	98.5	1.366759	1.366759443	1.3667594	20.20967	1.69	0.59	8.1875	8.1875	1	8.1875	0.164987	16.2747265
100	1.049924628	0.514463068	2.867638324	0.160587746	1.1166856	0.11166856		8.063				8.0625	90	76	99.5	1.37071	1.370709645	1.3707096	20.26808	1.69	0.59	8.1875	8.1875	1	8.1875	0.165464	16.2978568
101	1.025380936	0.502436658	2.804702632	0.157063347	1.11780285	0.11178028			7.875			7.875	90	76	100.5	1.374632	1.374631591	1.3746316	20.32607	1.69	0.59	8	8	1	8	0.162137	16.3178889
102	1.025380936	0.502436658	2.807519887	0.157221114	1.11891014	0.11189101			7.875			7.875	90	76	101.5	1.378526	1.378525761	1.3785258	20.38365	1.69	0.59	8	8	1	8	0.162596	16.5267123
103	1.025380936	0.502436658	2.810312346	0.157377491	1.12000766	0.11200077			7.875			7.875	90	76	102.5	1.382393	1.382392622	1.3823926	20.44083	1.69	0.59	8	8	1	8	0.163052	16.7361237
104	1.025380936	0.502436658	2.813080468	0.157532506	1.12109558	0.11210956			7.875			7.875	90	76	103.5	1.386233	1.386232629	1.3862326	20.49761	1.69	0.59	8	8	1	8	0.163505	16.9461191
105	1.025380936	0.502436658	2.815824697	0.157686183	1.12217408	0.11221741			7.875			7.875	90	76	104.5	1.390046	1.390046226	1.3900462	20.554	1.69	0.59	8	8	1	8	0.163955	17.1566943
106	1.025380936	0.502436658	2.818545464	0.157838546	1.12324334	0.11232433			7.875			7.875	90	76	105.5	1.393834	1.393833844	1.3938338	20.61001	1.69	0.59	8	8	1	8	0.164402	17.3678454
107	1.025380936	0.502436658	2.82124319	0.157989619	1.12430351	0.11243035			7.875			7.875	90	76	106.5	1.397596	1.397595905	1.3975959	20.66564	1.69	0.59	8	8	1	8	0.164846	17.5795685
108	1.025380936	0.502436658	2.823918283	0.158139424	1.12535476	0.11253548			7.875			7.875	90	76	107.5	1.401333	1.401332817	1.4013328	20.72089	1.69	0.59	8	8	1	8	0.165286	17.7918598
109	1.025380936	0.502436658	2.826571142	0.158287984	1.12639725	0.11263972			7.875			7.875	90	76	108.5	1.405045	1.405044981	1.405045	20.77578	1.69	0.59	8	8	1	8	0.165724	18.0047155
110	1.025380936	0.502436658	2.829202154	0.158435321	1.12743112	0.11274311			7.875			7.875	90	76	109.5	1.408733	1.408732787	1.4087328	20.83031	1.69	0.59	8	8	1	8	0.166159	18.2181319
111	1.025380936	0.502436658	2.831811695	0.158581455	1.12845653	0.11284565			7.875			7.875	90	76	110.5	1.412397	1.412396615	1.4123966	20.88449	1.69	0.59	8	8	1	8	0.166591	18.4321053
112	1.025380936	0.502436658	2.834400134	0.158726407	1.12947362	0.11294736			7.875			7.875	90	76	111.5	1.416037	1.416036835	1.4160368	20.93831	1.69	0.59	8	8	1	8	0.167021	18.6466321
113	1.025380936	0.502436658	2.836967827	0.158870198	1.13048254	0.11304825			7.875			7.875	90	76	112.5	1.419654	1.41965381	1.4196538	20.9918	1.69	0.59	8	8	1	8	0.167447	18.8617088
114	1.025380936	0.502436658	2.839515123	0.159012847	1.13148341	0.11314834			7.875			7.875	90	76	113.5	1.423248	1.423247891	1.4232479	21.04494	1.69	0.59	8	8	1	8	0.167871	19.0773319
115	1.025380936	0.502436658	2.842042362	0.159154372	1.13247639	0.11324764			7.875			7.875	90	76	114.5	1.426819	1.426819425	1.4268194	21.09775	1.69	0.59	8	8	1	8	0.168293	19.2934979
116	1.025380936	0.502436658	2.844549876	0.159294793	1.13346158	0.11334616			7.875			7.875	90	76	115.5	1.430369	1.430368748	1.4303687	21.15023	1.69	0.59	8	8	1	8	0.168711	19.5102035
117	1.025380936	0.502436658	2.847037986	0.159434127	1.13443913	0.11344391			7.875			7.875	90	76	116.5	1.433896	1.433896188	1.4338962	21.20239	1.69	0.59	8	8	1	8	0.169127	19.7274453
118	1.025380936	0.502436658	2.849507007	0.159572392	1.13540916	0.11354092			7.875			7.875	90	76	117.5	1.437402	1.437402066	1.4374021	21.25423	1.69	0.59	8	8	1	8	0.169541	19.94522
119	1.025380936	0.502436658	2.851957247	0.159709606	1.13637178	0.11363718			7.875			7.875	90	76	118.5	1.440887	1.440886696	1.4408867	21.30576	1.69	0.59	8	8	1	8	0.169952	20.1635245
120	1.025380936	0.502436658	2.854389006	0.159845784	1.13732712	0.11373271			7.875			7.875	90	76	119.5	1.44435	1.444350385	1.4443504	21.35697	1.69	0.59	8	8	1	8	0.17036	20.3823554
121	1.025380936	0.502436658	2.856802575	0.159980944	1.1382753	0.11382753			7.875			7.875	90	76	120.5	1.447793	1.447793432	1.4477934	21.40788	1.69	0.59	8	8	1	8	0.170766	20.6017096
122	1.025380936	0.502436658	2.859198241	0.160115101	1.13921641	0.11392164			7.875			7.875	90	76	121.5	1.451216	1.451216129	1.4512161	21.45849	1.69	0.59	8	8	1	8	0.17117	20.8215841
123	1.025380936	0.502436658	2.861576281	0.160248272	1.14015059	0.11401506			7.875			7.875	90	76	122.5	1.454619	1.454618764	1.4546188	21.50881	1.69	0.59	8	8	1	8	0.171571	21.0419758
124	1.025380936	0.502436658	2.863936967	0.16038047	1.14107792	0.11410779			7.875			7.875	90	76	123.5	1.458002	1.458001615	1.4580016	21.55883	1.69	0.59	8	8	1	8	0.17197	21.2628816
125	1.025380936	0.502436658	2.866280566	0.160511712	1.14199852	0.11419985			7.875			7.875	90	76	124.5	1.461365	1.461364957	1.461365	21.60856	1.69	0.59	8	8	1	8	0.172367	21.4842987
126	1.025380936	0.502436658	2.868607337	0.160642011	1.14291249	0.11429125			7.875			7.875	90	76	125.5	1.464709	1.464709058	1.4647091	21.65801	1.69	0.59	8	8	1	8	0.172762	21.7062239
127	1.025380936	0.502436658	2.870917533	0.160771382	1.14381993	0.11438199			7.875			7.875	90	76	126.5	1.468034	1.46803418	1.4680342	21.70718	1.69	0.59	8	8	1	8	0.173154	21.9286546
128	1.025380936	0.502436658	2.873211403	0.160899839	1.14472093	0.11447209			7.875			7.875	90	76	127.5	1.471341	1.471340579	1.4713406	21.75607	1.69	0.59	8	8	1	8	0.173544	22.1515878
129	1.025380936	0.502436658	2.875489187	0.161027394	1.1456156	0.11456156			7.875			7.875	90	76	128.5	1.474629	1.474628506	1.4746285	21.80468	1.69	0.59	8	8	1	8	0.173932	22.3750206
130	1.025380936	0.502436658	2.877751124	0.161154063	1.14650402	0.1146504			7.875			7.875	90	76	129.5	1.477898	1.477898208	1.4778982	21.85303	1.69	0.59	8	8	1	8	0.174317	22.5989504
131	1.025380936	0.502436658	2.879997443	0.161279857	1.14738629	0.11473863			7.875			7.875	90	76	130.5	1.48115	1.481149924	1.4811499	21.90111	1.69	0.59	8	8	1	8	0.174701	22.8233744
132	1.025380936	0.502436658	2.882228373	0.16140479	1.1482625	0.11482625			7.875			7.875	90	76	131.5	1.484384	1.48438389	1.4843839	21.94893	1.69	0.59	8	8	1	8	0.175082	23.0482898
133	1.025380936	0.502436658	2.884444133	0.161528871	1.14913273	0.11491327			7.875			7.875	90	76	132.5	1.4876	1.487600337	1.4876003	21.99649	1.69	0.59	8	8	1	8	0.175462	23.273694
134	1.025380936	0.502436658	2.886644941	0.161652117	1.14999707	0.11499971			7.875			7.875	90	76	133.5	1.490799	1.490799492	1.4907995	22.0438	1.69	0.59	8	8	1	8	0.175839	23.4995844
135	1.025380936	0.502436658	2.888831008	0.161774536	1.1508556	0.11508556			7.875			7.875	90	76	134.5	1.493982	1.493981574	1.4939816	22.09085	1.69	0.59	8	8	1	8	0.176214	23.7259584
136	1.025380936	0.502436658	2.891002541	0.161896142	1.1517084	0.11517084			7.875			7.875	90	76	135.5	1.497147	1.497146803	1.4971468	22.13765	1.69	0.59	8	8	1	8	0.176588	23.9528133
137	1.025380936	0.502436658	2.893159744	0.162016946	1.15255556	0.11525556			7.875			7.875	90	76	136.5	1.500295	1.50029539	1.5002954	22.18421	1.69	0.59	8	8	1	8	0.176959	24.1801467
138	1.025380936	0.502436658	2.895302815	0.162136958	1.15339715	0.11533972			7.875			7.875	90	76	137.5	1.503428	1.503427543	1.5034275	22.23052	1.69	0.59	8	8	1	8	0.177328	24.4079561
139	1.025380936	0.502436658	2.897431948	0.162256189	1.15423326	0.11542333			7.875			7.875	90	76	138.5	1.506543	1.506543468	1.5065435	22.2766	1.69	0.59	8	8	1	8	0.177696	24.6362389
140	1.025380936	0.502436658	2.899547334	0.162374651	1.15506394	0.11550639			7.875			7.875	90	76	139.5	1.509643	1.509643364	1.5096434	22.32243	1.69	0.59	8	8	1	8	0.178062	24.8649928
141	1.025380936	0.502436658	2.901649159	0.162492353	1.15588929	0.11558893			7.875			7.875	90	76	140.5	1.512727	1.512727428	1.5127274	22.36803	1.69	0.59	8	8	1	8	0.178425	25.0942153
142	1.025380936	0.502436658	2.903737605	0.162609306	1.15670936	0.11567094			7.875			7.875	90	76	141.5	1.515796	1.515795852	1.5157959	22.41341	1.69	0.59	8	8	1	8	0.178787	25.3239041
143	1.025380936	0.502436658	2.905812852	0.16272552	1.15752423	0.11575242			7.875			7.875	90	76	142.5	1.518849	1.518848826	1.5188488	22.45855	1.69	0.59	8	8	1	8	0.179147	25.5540567
144	1.025380936	0.502436658	2.907875075	0.162841004	1.15833398	0.1158334			7.875			7.875	90	76	143.5	1.521887	1.521886535	1.5218865	22.50347	1.69	0.59	8	8	1	8	0.179506	25.7846709
145	1.025380936	0.502436658	2.909924445	0.162955769	1.15913866	0.11591387			7.875			7.875	90	76	144.5	1.524909	1.524909161	1.5249092	22.54816	1.69	0.59	8	8	1	8	0.179862	26.0157443
146	1.025380936	0.502436658	2.91196113	0.163069823	1.15993834	0.11599383			7.875			7.875	90	76	145.5	1.527917	1.527916882	1.5279169	22.59263	1.69	0.59	8	8	1	8	0.180217	26.2472748
147	1.025380936	0.502436658	2.913985297	0.163183177	1.1607331	0.11607331			7.875			7.875	90	76	146.5	1.53091	1.530909874	1.5309099	22.63689	1.69	0.59	8	8	1	8	0.18057	26.47926
148	1.025380936	0.502436658	2.915997105	0.163295838	1.16152298	0.1161523			7.875			7.875	90	76	147.5	1.533888	1.533888309	1.5338883	22.68093	1.69	0.59	8	8	1	8	0.180921	26.7116977
149	1.025380936	0.502436658	2.917996714	0.163407816	1.16230807	0.11623081			7.875			7.875	90	76	148.5	1.536852	1.536852354	1.5368524	22.72476	1.69	0.59	8	8	1	8	0.181271	26.9445858
150	1.025380936	0.502436658	2.919984278	0.16351912	1.1630884	0.11630884			7.875			7.875	90	76	149.5	1.539802	1.539802177	1.5398022	22.76838	1.69	0.59	8	8	1	8	0.181619	26.8587724
151	1.000837243	0.490410249	2.8534027	0.159790551	1.16386406	0.11638641				7.688		7.6875	90	76	150.5	1.542738	1.54273794	1.5427379	22.81179	1.69	0.59	7.8125	7.8125	1	7.8125	0.1777	26.7692425
152	1.000837243	0.490410249	2.855321214	0.159897988	1.16463509	0.11646351				7.688		7.6875	90	76	151.5	1.54566	1.545659802	1.5456598	22.85499	1.69	0.59	7.8125	7.8125	1	7.8125	0.178037	26.997979
153	1.000837243	0.490410249	2.857228401	0.16000479	1.16540155	0.11654015				7.688		7.6875	90	76	152.5	1.548568	1.54856792	1.5485679	22.89799	1.69	0.59	7.8125	7.8125	1	7.8125	0.178372	27.227147
154	1.000837243	0.490410249	2.859124403	0.160110967	1.1661635	0.11661635				7.688		7.6875	90	76	153.5	1.551462	1.551462449	1.5514624	22.94079	1.69	0.59	7.8125	7.8125	1	7.8125	0.178705	27.4567444
155	1.000837243	0.490410249	2.861009356	0.160216524	1.166921	0.1166921				7.688		7.6875	90	76	154.5	1.554344	1.55434354	1.5543435	22.98339	1.69	0.59	7.8125	7.8125	1	7.8125	0.179037	27.6867693
156	1.000837243	0.490410249	2.862883397	0.16032147	1.16767409	0.11676741				7.688		7.6875	90	76	155.5	1.557211	1.557211342	1.5572113	23.0258	1.69	0.59	7.8125	7.8125	1	7.8125	0.179367	27.9172196
157	1.000837243	0.490410249	2.864746658	0.160425813	1.16842285	0.11684228				7.688		7.6875	90	76	156.5	1.560066	1.560066	1.560066	23.06801	1.69	0.59	7.8125	7.8125	1	7.8125	0.179696	28.1480935
158	1.000837243	0.490410249	2.866599269	0.160529559	1.1691673	0.11691673				7.688		7.6875	90	76	157.5	1.562908	1.562907659	1.5629077	23.11003	1.69	0.59	7.8125	7.8125	1	7.8125	0.180024	28.3793889
159	1.000837243	0.490410249	2.868441358	0.160632716	1.16990752	0.11699075				7.688		7.6875	90	76	158.5	1.565736	1.56573646	1.5657365	23.15186	1.69	0.59	7.8125	7.8125	1	7.8125	0.180349	28.611104
160	1.000837243	0.490410249	2.870273051	0.160735291	1.17064355	0.11706435				7.688		7.6875	90	76	159.5	1.568553	1.568552541	1.5685525	23.1935	1.69	0.59	7.8125	7.8125	1	7.8125	0.180674	28.8432369
161	1.000837243	0.490410249	2.872094472	0.16083729	1.17137543	0.11713754				7.688		7.6875	90	76	160.5	1.571356	1.57135604	1.571356	23.23495	1.69	0.59	7.8125	7.8125	1	7.8125	0.180997	29.0757857
162	1.000837243	0.490410249	2.873905741	0.160938721	1.17210322	0.11721032				7.688		7.6875	90	76	161.5	1.574147	1.574147089	1.5741471	23.27622	1.69	0.59	7.8125	7.8125	1	7.8125	0.181318	29.3087485
163	1.000837243	0.490410249	2.875706977	0.161039591	1.17282697	0.1172827				7.688		7.6875	90	76	162.5	1.576926	1.576925821	1.5769258	23.31731	1.69	0.59	7.8125	7.8125	1	7.8125	0.181638	29.5421236
164	1.000837243	0.490410249	2.877498296	0.161139905	1.17354671	0.11735467				7.688		7.6875	90	76	163.5	1.579692	1.579692365	1.5796924	23.35822	1.69	0.59	7.8125	7.8125	1	7.8125	0.181957	29.7759091
165	1.000837243	0.490410249	2.879279815	0.16123967	1.17426251	0.11742625				7.688		7.6875	90	76	164.5	1.582447	1.58244685	1.5824468	23.39895	1.69	0.59	7.8125	7.8125	1	7.8125	0.182274	30.0101032
166	1.000837243	0.490410249	2.881051646	0.161338892	1.1749744	0.11749744				7.688		7.6875	90	76	165.5	1.585189	1.5851894	1.5851894	23.4395	1.69	0.59	7.8125	7.8125	1	7.8125	0.18259	30.2447041
167	1.000837243	0.490410249	2.882813898	0.161437578	1.17568244	0.11756824				7.688		7.6875	90	76	166.5	1.58792	1.587920138	1.5879201	23.47988	1.69	0.59	7.8125	7.8125	1	7.8125	0.182905	30.4797101
168	1.000837243	0.490410249	2.884566682	0.161535734	1.17638665	0.11763866				7.688		7.6875	90	76	167.5	1.590639	1.590639187	1.5906392	23.52008	1.69	0.59	7.8125	7.8125	1	7.8125	0.183218	30.7151195
169	1.000837243	0.490410249	2.886310104	0.161633366	1.17708709	0.11770871				7.688		7.6875	90	76	168.5	1.593347	1.593346665	1.5933467	23.56012	1.69	0.59	7.8125	7.8125	1	7.8125	0.18353	30.9509305
170	1.000837243	0.490410249	2.888044269	0.161730479	1.1777838	0.11777838				7.688		7.6875	90	76	169.5	1.596043	1.596042691	1.5960427	23.59998	1.69	0.59	7.8125	7.8125	1	7.8125	0.18384	31.1871414
171	1.000837243	0.490410249	2.889769281	0.16182708	1.17847682	0.11784768				7.688		7.6875	90	76	170.5	1.598727	1.598727379	1.5987274	23.63968	1.69	0.59	7.8125	7.8125	1	7.8125	0.184149	31.4237506
172	1.000837243	0.490410249	2.891485241	0.161923174	1.17916619	0.11791662				7.688		7.6875	90	76	171.5	1.601401	1.601400843	1.6014008	23.67921	1.69	0.59	7.8125	7.8125	1	7.8125	0.184457	31.6607563
173	1.000837243	0.490410249	2.893192249	0.162018766	1.17985195	0.1179852				7.688		7.6875	90	76	172.5	1.604063	1.604063195	1.6040632	23.71858	1.69	0.59	7.8125	7.8125	1	7.8125	0.184764	31.8981569
174	1.000837243	0.490410249	2.894890404	0.162113863	1.18053415	0.11805341				7.688		7.6875	90	76	173.5	1.606715	1.606714546	1.6067145	23.75778	1.69	0.59	7.8125	7.8125	1	7.8125	0.185069	32.1359509

175	1.000837243	0.490410249	2.896579801	0.162208469	1.18121281	0.11812128				7.688		7.6875	90	76	174.5	1.609355	1.609355004	1.609355	23.79682	1.69	0.59	7.8125	7.8125	1	7.8125	0.185374	32.3741365
176	1.000837243	0.490410249	2.898260536	0.16230259	1.18188799	0.1181888				7.688		7.6875	90	76	175.5	1.611985	1.611984676	1.6119847	23.83571	1.69	0.59	7.8125	7.8125	1	7.8125	0.185676	32.6127121
177	1.000837243	0.490410249	2.899932703	0.162396231	1.18255971	0.11825597				7.688		7.6875	90	76	176.5	1.614604	1.614603666	1.6146037	23.87443	1.69	0.59	7.8125	7.8125	1	7.8125	0.185978	32.8516762
178	1.000837243	0.490410249	2.901596393	0.162489398	1.18322801	0.1183228				7.688		7.6875	90	76	177.5	1.617212	1.617212079	1.6172121	23.913	1.69	0.59	7.8125	7.8125	1	7.8125	0.186279	33.0910273
179	1.000837243	0.490410249	2.903251696	0.162582095	1.18389293	0.11838929				7.688		7.6875	90	76	178.5	1.61981	1.619810016	1.61981	23.95142	1.69	0.59	7.8125	7.8125	1	7.8125	0.186578	33.3307636
180	1.000837243	0.490410249	2.904898701	0.162674327	1.18455451	0.11845545				7.688		7.6875	90	76	179.5	1.622398	1.622397578	1.6223976	23.98968	1.69	0.59	7.8125	7.8125	1	7.8125	0.186876	33.5708838
181	1.000837243	0.490410249	2.906537497	0.1627661	1.18521278	0.11852128				7.688		7.6875	90	76	180.5	1.624975	1.624974864	1.6249749	24.02779	1.69	0.59	7.8125	7.8125	1	7.8125	0.187173	33.8113862
182	1.000837243	0.490410249	2.908168168	0.162857417	1.18586778	0.11858678				7.688		7.6875	90	76	181.5	1.627542	1.627541971	1.627542	24.06575	1.69	0.59	7.8125	7.8125	1	7.8125	0.187468	34.0522694
183	1.000837243	0.490410249	2.909790801	0.162948285	1.18651954	0.11865195				7.688		7.6875	90	76	182.5	1.630099	1.630098995	1.630099	24.10356	1.69	0.59	7.8125	7.8125	1	7.8125	0.187763	34.2935319
184	1.000837243	0.490410249	2.911405477	0.163038707	1.18716809	0.11871681				7.688		7.6875	90	76	183.5	1.632646	1.632646031	1.632646	24.14122	1.69	0.59	7.8125	7.8125	1	7.8125	0.188056	34.5351721
185	1.000837243	0.490410249	2.91301228	0.163128688	1.18781346	0.11878135				7.688		7.6875	90	76	184.5	1.635183	1.635183171	1.6351832	24.17873	1.69	0.59	7.8125	7.8125	1	7.8125	0.188349	34.7771887
186	1.000837243	0.490410249	2.914611289	0.163218232	1.1884557	0.11884557				7.688		7.6875	90	76	185.5	1.637711	1.637710507	1.6377105	24.2161	1.69	0.59	7.8125	7.8125	1	7.8125	0.18864	35.0195801
187	1.000837243	0.490410249	2.916202585	0.163307345	1.18909483	0.11890948				7.688		7.6875	90	76	186.5	1.640228	1.640228131	1.6402281	24.25333	1.69	0.59	7.8125	7.8125	1	7.8125	0.18893	35.2623449
188	1.000837243	0.490410249	2.917786246	0.16339603	1.18973088	0.11897309				7.688		7.6875	90	76	187.5	1.642736	1.642736131	1.6427361	24.29042	1.69	0.59	7.8125	7.8125	1	7.8125	0.189219	35.5054816
189	1.000837243	0.490410249	2.919362349	0.163484292	1.19036388	0.11903639				7.688		7.6875	90	76	188.5	1.645235	1.645234594	1.6452346	24.32736	1.69	0.59	7.8125	7.8125	1	7.8125	0.189506	35.748989
190	1.000837243	0.490410249	2.920930969	0.163572134	1.19099387	0.11909939				7.688		7.6875	90	76	189.5	1.647724	1.647723608	1.6477236	24.36416	1.69	0.59	7.8125	7.8125	1	7.8125	0.189793	35.9928654
191	1.000837243	0.490410249	2.922492182	0.163659562	1.19162088	0.11916209				7.688		7.6875	90	76	190.5	1.650203	1.650203257	1.6502033	24.40083	1.69	0.59	7.8125	7.8125	1	7.8125	0.190079	36.2371097
192	1.000837243	0.490410249	2.924046061	0.163746579	1.19224493	0.11922449				7.688		7.6875	90	76	191.5	1.652674	1.652673627	1.6526736	24.43736	1.69	0.59	7.8125	7.8125	1	7.8125	0.190363	36.4817203
193	1.000837243	0.490410249	2.925592678	0.16383319	1.19286605	0.11928661				7.688		7.6875	90	76	192.5	1.655135	1.655134799	1.6551348	24.47375	1.69	0.59	7.8125	7.8125	1	7.8125	0.190647	36.7266959
194	1.000837243	0.490410249	2.927132105	0.163919398	1.19348428	0.11934843				7.688		7.6875	90	76	193.5	1.657587	1.657586855	1.6575869	24.51001	1.69	0.59	7.8125	7.8125	1	7.8125	0.190929	36.9720352
195	1.000837243	0.490410249	2.928664413	0.164005207	1.19409964	0.11940996				7.688		7.6875	90	76	194.5	1.66003	1.660029877	1.6600299	24.54613	1.69	0.59	7.8125	7.8125	1	7.8125	0.191211	37.2177369
196	1.000837243	0.490410249	2.93018967	0.164090622	1.19471215	0.11947122				7.688		7.6875	90	76	195.5	1.662464	1.662463943	1.6624639	24.58212	1.69	0.59	7.8125	7.8125	1	7.8125	0.191491	37.4637995
197	1.000837243	0.490410249	2.931707945	0.164175645	1.19532186	0.11953219				7.688		7.6875	90	76	196.5	1.664889	1.664889133	1.6648891	24.61798	1.69	0.59	7.8125	7.8125	1	7.8125	0.19177	37.7102217
198	1.000837243	0.490410249	2.933219305	0.164260281	1.19592878	0.11959288				7.688		7.6875	90	76	197.5	1.667306	1.667305522	1.6673055	24.65371	1.69	0.59	7.8125	7.8125	1	7.8125	0.192049	37.9570024
199	1.000837243	0.490410249	2.934723817	0.164344534	1.19653293	0.11965329				7.688		7.6875	90	76	198.5	1.669713	1.669713188	1.6697132	24.68931	1.69	0.59	7.8125	7.8125	1	7.8125	0.192326	38.2041401
200	1.000837243	0.490410249	2.936221545	0.164428407	1.19713436	0.11971344				7.688		7.6875	90	76	199.5	1.672112	1.672112206	1.6721122	24.72479	1.69	0.59	7.8125	7.8125	1	7.8125	0.192602	37.9894989
201	0.97629355	0.47838384	2.867160253	0.160560974	1.19773308	0.11977331					7.5	7.5	90	76	200.5	1.674503	1.67450265	1.6745026	24.76013	1.69	0.59	7.625	7.625	1	7.625	0.188249	37.770694
202	0.97629355	0.47838384	2.868609497	0.160642132	1.19832911	0.11983291					7.5	7.5	90	76	201.5	1.676885	1.676884593	1.6768846	24.79535	1.69	0.59	7.625	7.625	1	7.625	0.188516	38.0129384
203	0.97629355	0.47838384	2.870052305	0.160722929	1.19892249	0.11989225					7.5	7.5	90	76	202.5	1.679258	1.679258107	1.6792581	24.83045	1.69	0.59	7.625	7.625	1	7.625	0.188783	38.2555263
204	0.97629355	0.47838384	2.871488737	0.160803369	1.19951324	0.11995132					7.5	7.5	90	76	203.5	1.681623	1.681623264	1.6816233	24.86542	1.69	0.59	7.625	7.625	1	7.625	0.189049	38.4984565
205	0.97629355	0.47838384	2.872918852	0.160883456	1.20010139	0.12001014					7.5	7.5	90	76	204.5	1.68398	1.683980133	1.6839801	24.90027	1.69	0.59	7.625	7.625	1	7.625	0.189314	38.7417279
206	0.97629355	0.47838384	2.874342708	0.160963192	1.20068695	0.12006869					7.5	7.5	90	76	205.5	1.686329	1.686328785	1.6863288	24.935	1.69	0.59	7.625	7.625	1	7.625	0.189578	38.9853393
207	0.97629355	0.47838384	2.875760363	0.16104258	1.20126995	0.12012699					7.5	7.5	90	76	206.5	1.688669	1.688669287	1.6886693	24.96961	1.69	0.59	7.625	7.625	1	7.625	0.189841	39.2292893
208	0.97629355	0.47838384	2.877171875	0.161121625	1.20185041	0.12018504					7.5	7.5	90	76	207.5	1.691002	1.691001707	1.6910017	25.0041	1.69	0.59	7.625	7.625	1	7.625	0.190103	39.473577
209	0.97629355	0.47838384	2.878577298	0.161200329	1.20242836	0.12024284					7.5	7.5	90	76	208.5	1.693326	1.693326112	1.6933261	25.03847	1.69	0.59	7.625	7.625	1	7.625	0.190365	39.7182011
210	0.97629355	0.47838384	2.879976689	0.161278695	1.20300383	0.12030038					7.5	7.5	90	76	209.5	1.695643	1.695642568	1.6956426	25.07272	1.69	0.59	7.625	7.625	1	7.625	0.190625	39.9631604
211	0.97629355	0.47838384	2.881370101	0.161356726	1.20357682	0.12035768					7.5	7.5	90	76	210.5	1.697951	1.697951139	1.6979511	25.10686	1.69	0.59	7.625	7.625	1	7.625	0.190885	40.2084539
212	0.97629355	0.47838384	2.882757589	0.161434425	1.20414737	0.12041474					7.5	7.5	90	76	211.5	1.700252	1.70025189	1.7002519	25.14088	1.69	0.59	7.625	7.625	1	7.625	0.191143	40.4540804
213	0.97629355	0.47838384	2.884139206	0.161511796	1.2047155	0.12047155					7.5	7.5	90	76	212.5	1.702545	1.702544883	1.7025449	25.17478	1.69	0.59	7.625	7.625	1	7.625	0.191401	40.7000387
214	0.97629355	0.47838384	2.885515004	0.16158884	1.20528123	0.12052812					7.5	7.5	90	76	213.5	1.70483	1.704830182	1.7048302	25.20857	1.69	0.59	7.625	7.625	1	7.625	0.191658	40.9463278
215	0.97629355	0.47838384	2.886885034	0.161665562	1.20584458	0.12058446					7.5	7.5	90	76	214.5	1.707108	1.707107849	1.7071078	25.24225	1.69	0.59	7.625	7.625	1	7.625	0.191914	41.1929465
216	0.97629355	0.47838384	2.888249347	0.161741963	1.20640557	0.12064056					7.5	7.5	90	76	215.5	1.709378	1.709377943	1.7093779	25.27582	1.69	0.59	7.625	7.625	1	7.625	0.192169	41.4398938
217	0.97629355	0.47838384	2.889607995	0.161818048	1.20696422	0.12069642					7.5	7.5	90	76	216.5	1.711641	1.711640525	1.7116405	25.30928	1.69	0.59	7.625	7.625	1	7.625	0.192424	41.6871685
218	0.97629355	0.47838384	2.890961025	0.161893817	1.20752055	0.12075206					7.5	7.5	90	76	217.5	1.713896	1.713895654	1.7138957	25.34262	1.69	0.59	7.625	7.625	1	7.625	0.192677	41.9347696
219	0.97629355	0.47838384	2.892308488	0.161969275	1.20807459	0.12080746					7.5	7.5	90	76	218.5	1.716143	1.71614339	1.7161434	25.37586	1.69	0.59	7.625	7.625	1	7.625	0.19293	42.182696
220	0.97629355	0.47838384	2.893650431	0.162044424	1.20862635	0.12086264					7.5	7.5	90	76	219.5	1.718384	1.718383789	1.7183838	25.40899	1.69	0.59	7.625	7.625	1	7.625	0.193182	42.4309467
221	0.97629355	0.47838384	2.894986902	0.162119267	1.20917585	0.12091759					7.5	7.5	90	76	220.5	1.720617	1.72061691	1.7206169	25.44201	1.69	0.59	7.625	7.625	1	7.625	0.193433	42.6795205
222	0.97629355	0.47838384	2.896317948	0.162193805	1.20972311	0.12097231					7.5	7.5	90	76	221.5	1.722843	1.722842809	1.7228428	25.47492	1.69	0.59	7.625	7.625	1	7.625	0.193683	42.9284165
223	0.97629355	0.47838384	2.897643615	0.162268042	1.21026816	0.12102682					7.5	7.5	90	76	222.5	1.725062	1.725061541	1.7250615	25.50773	1.69	0.59	7.625	7.625	1	7.625	0.193932	43.1776335
224	0.97629355	0.47838384	2.89896395	0.162341981	1.210811	0.1210811					7.5	7.5	90	76	223.5	1.727273	1.727273162	1.7272732	25.54043	1.69	0.59	7.625	7.625	1	7.625	0.194181	43.4271707
225	0.97629355	0.47838384	2.900278996	0.162415624	1.21135166	0.12113517					7.5	7.5	90	76	224.5	1.729478	1.729477726	1.7294777	25.57303	1.69	0.59	7.625	7.625	1	7.625	0.194429	43.6770268
226	0.97629355	0.47838384	2.9015888	0.162488973	1.21189016	0.12118902					7.5	7.5	90	76	225.5	1.731675	1.731675286	1.7316753	25.60552	1.69	0.59	7.625	7.625	1	7.625	0.194676	43.9272011
227	0.97629355	0.47838384	2.902893404	0.162562031	1.21242652	0.12124265					7.5	7.5	90	76	226.5	1.733866	1.733865897	1.7338659	25.63791	1.69	0.59	7.625	7.625	1	7.625	0.194922	44.1776923
228	0.97629355	0.47838384	2.904192853	0.1626348	1.21296075	0.12129607					7.5	7.5	90	76	227.5	1.73605	1.736049611	1.7360496	25.6702	1.69	0.59	7.625	7.625	1	7.625	0.195168	44.4284995
229	0.97629355	0.47838384	2.905487189	0.162707283	1.21349286	0.12134929					7.5	7.5	90	76	228.5	1.738226	1.738226479	1.7382265	25.70239	1.69	0.59	7.625	7.625	1	7.625	0.195412	44.6796218
230	0.97629355	0.47838384	2.906776455	0.162779481	1.21402289	0.12140229					7.5	7.5	90	76	229.5	1.740397	1.740396552	1.7403966	25.73448	1.69	0.59	7.625	7.625	1	7.625	0.195656	44.9310581
231	0.97629355	0.47838384	2.908060693	0.162851399	1.21455084	0.12145508					7.5	7.5	90	76	230.5	1.74256	1.742559882	1.7425599	25.76647	1.69	0.59	7.625	7.625	1	7.625	0.1959	45.1828075
232	0.97629355	0.47838384	2.909339943	0.162923037	1.21507674	0.12150767					7.5	7.5	90	76	231.5	1.744717	1.744716519	1.7447165	25.79836	1.69	0.59	7.625	7.625	1	7.625	0.196142	45.434869
233	0.97629355	0.47838384	2.910614246	0.162994398	1.21560059	0.12156006					7.5	7.5	90	76	232.5	1.746867	1.746866512	1.7468665	25.83015	1.69	0.59	7.625	7.625	1	7.625	0.196384	45.6872417
234	0.97629355	0.47838384	2.911883644	0.163065484	1.21612242	0.12161224					7.5	7.5	90	76	233.5	1.74901	1.749009909	1.7490099	25.86184	1.69	0.59	7.625	7.625	1	7.625	0.196625	45.9399245
235	0.97629355	0.47838384	2.913148175	0.163136298	1.21664224	0.12166422					7.5	7.5	90	76	234.5	1.751147	1.75114676	1.7511468	25.89344	1.69	0.59	7.625	7.625	1	7.625	0.196865	46.1929165
236	0.97629355	0.47838384	2.914407879	0.163206841	1.21716007	0.12171601					7.5	7.5	90	76	235.5	1.753277	1.753277112	1.7532771	25.92494	1.69	0.59	7.625	7.625	1	7.625	0.197104	46.4462168
237	0.97629355	0.47838384	2.915662795	0.163277117	1.21767593	0.12176759					7.5	7.5	90	76	236.5	1.755401	1.755401012	1.755401	25.95634	1.69	0.59	7.625	7.625	1	7.625	0.197343	46.6998245
238	0.97629355	0.47838384	2.916912961	0.163347126	1.21818982	0.12181898					7.5	7.5	90	76	237.5	1.757519	1.757518507	1.7575185	25.98765	1.69	0.59	7.625	7.625	1	7.625	0.197581	46.9537386
239	0.97629355	0.47838384	2.918158415	0.163416871	1.21870178	0.12187018					7.5	7.5	90	76	238.5	1.75963	1.759629643	1.7596296	26.01887	1.69	0.59	7.625	7.625	1	7.625	0.197819	47.2079582
240	0.97629355	0.47838384	2.919399194	0.163486355	1.2192118	0.12192118					7.5	7.5	90	76	239.5	1.761734	1.761734466	1.7617345	26.04999	1.69	0.59	7.625	7.625	1	7.625	0.198055	47.4624823
241	0.97629355	0.47838384	2.920635336	0.163555579	1.21971991	0.12197199					7.5	7.5	90	76	240.5	1.763833	1.763833021	1.763833	26.08102	1.69	0.59	7.625	7.625	1	7.625	0.198291	47.7173102
242	0.97629355	0.47838384	2.921866876	0.163624545	1.22022613	0.12202261					7.5	7.5	90	76	241.5	1.765925	1.765925352	1.7659254	26.11196	1.69	0.59	7.625	7.625	1	7.625	0.198526	47.9724408
243	0.97629355	0.47838384	2.923093852	0.163693256	1.22073046	0.12207305					7.5	7.5	90	76	242.5	1.768012	1.768011504	1.7680115	26.14281	1.69	0.59	7.625	7.625	1	7.625	0.198761	48.2278733
244	0.97629355	0.47838384	2.924316298	0.163761713	1.22123292	0.12212329					7.5	7.5	90	76	243.5	1.770092	1.77009152	1.7700915	26.17356	1.69	0.59	7.625	7.625	1	7.625	0.198995	48.4836069
245	0.97629355	0.47838384	2.92553425	0.163829918	1.22173353	0.12217335					7.5	7.5	90	76	244.5	1.772165	1.772165444	1.7721654	26.20423	1.69	0.59	7.625	7.625	1	7.625	0.199228	48.7396405
246	0.97629355	0.47838384	2.926747742	0.163897874	1.2222323	0.12222323					7.5	7.5	90	76	245.5	1.774233	1.774233318	1.7742333	26.23481	1.69	0.59	7.625	7.625	1	7.625	0.19946	48.9959733
247	0.97629355	0.47838384	2.92795681	0.163965581	1.22272924	0.12227292					7.5	7.5	90	76	246.5	1.776295	1.776295184	1.7762952	26.2653	1.69	0.59	7.625	7.625	1	7.625	0.199692	49.2526045
248	0.97629355	0.47838384	2.929161486	0.164033043	1.22322437	0.12232244					7.5	7.5	90	76	247.5	1.778351	1.778351083	1.7783511	26.29569	1.69	0.59	7.625	7.625	1	7.625	0.199923	49.5095332
249	0.97629355	0.47838384	2.930361806	0.164100261	1.22371771	0.12237177					7.5	7.5	90	76	248.5	1.780401	1.780401058	1.7804011	26.32601	1.69	0.59	7.625	7.625	1	7.625	0.200154	49.7667586
250	0.97629355	0.47838384	2.931557801	0.164167237	1.22420926	0.12242093					7.5	7.5	90	76	249.5	1.782445	1.782445149	1.7824451	26.35623	1.69	0.59	7.625	7.625	1	7.625	0.200383	

User Input				
Overall height	250	ft =	3000	in
Diameter at Base	8.25	ft=	99	in
Shell Thickness	0.5	in		
Strength of Steel	36	ksi		
Modulus of Elasticity	29000	ksi		

ID	98
S	3790.919594
Z	4851.166667
r	34.82545764
I	187650.5199

Axial Strength	
Factored Load	669.7351275
Factored Strength	1112.14855
Pn	1308.410059
Fcr	8.456443794
KL/r	172.2877575
4.71*sqrt(E/Fy)	133.680683
Fe	9.642467267
Fcr for KL/r≤4.71*sqrt(E/Fy)	7.544869482
Fcr for KL/r>4.71*sqrt(E/Fy)	8.456443794
Ag	154.7234382
Check for Compact section:	
D/t	198
λp	
λc	88.61111111
noncompact	
Axial Strength:	OK

Flexure Strength	
Factored Load	67055.35
Factored Strength	157177.80
Yielding Mn	174642
Local Buckling	148133.055
Check for Compact section:	
D/t	198
λp	56.38888889
λc	249.7222222
non-compact	
Flexure Strength:	OK

Combined Loads			
Combined Loading	0.996377	≤1.0	**OK**
Pu/Pc	0.602199		
For Pu/Pc≥0.2	0.996377		
For Pu/Pc<0.2	0.695277		
Magnification Factors			
B2	1.039447		
Pnt	669.7351		
Pe2	17647.76		
∑H	41.52		
ΔH	6		
L	3000		

Weight of Equipment:	400	kips	Axial Load	748.6849367	
Height of tower	250	ft	Moment Load	10552.98717	
Outer Diameter at base	8.5	ft	Total Shear	78.83	
Outer Diameter at hub	7.5	ft			
Thickness	0.75	in			
Weight of Steel	490	pcf	t_{ice}	0.0625	
Town (Massachusetts)	Yarmouth				

Section	Diameter	Height	to	Inner Dia.	OR	IR	Ice Radius
D1	8.5	0	50	8.375	4.25	4.1875	4.5
D2	8.25	51	100	8.125	4.125	4.0625	4.375
D3	8	101	150	7.875	4	3.9375	4.25
D4	7.75	151	200	7.625	3.875	3.8125	4.125
D5	7.5	201	250	7.375	3.75	3.6875	4

Height	*Volume of Steel*	*Weight of Steel*	*Volume of Ice*	*Weight of Ice*	*Fz*	*td*	*D1*	*D2*	*D3*	*D4*	*D5*	*Diameter*	*V(3-s)*	*V(f.m)*	*z*	*Kz calc*	*1 ≤Kz*	*1 ≤Kz≤2.58*	*q_z*	*Gh*	*Cf*	*Ar*	*Ag*	*e*	*Ae*	*Force*	*Moment*
1	1.656699251	0.811782633	1.769954184	0.099117434	0.6577269	0.06577269	8.5					8.5	120	104	0.5	0.302086	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	0.11906235
2	1.656699251	0.811782633	1.977248338	0.110725907	0.73410424	0.07341042	8.5					8.5	120	104	1.5	0.413476	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	0.35718706
3	1.656699251	0.811782633	2.081809306	0.116581321	0.77257848	0.07725785	8.5					8.5	120	104	2.5	0.478449	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	0.59531177
4	1.656699251	0.811782633	2.15371181	0.120607861	0.79901588	0.07990159	8.5					8.5	120	104	3.5	0.526729	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	0.83343648
5	1.656699251	0.811782633	2.209046993	0.123706632	0.81935075	0.08193508	8.5					8.5	120	104	4.5	0.565941	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	1.07156119
6	1.656699251	0.811782633	2.254260028	0.126238562	0.8359588	0.08359588	8.5					8.5	120	104	5.5	0.599337	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	1.3096859
7	1.656699251	0.811782633	2.292610737	0.128386201	0.85004113	0.08500411	8.5					8.5	120	104	6.5	0.628637	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	1.54781061
8	1.656699251	0.811782633	2.325985945	0.130255213	0.86229275	0.08622927	8.5					8.5	120	104	7.5	0.654872	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	1.78593532
9	1.656699251	0.811782633	2.355579586	0.131912457	0.8731533	0.08731533	8.5					8.5	120	104	8.5	0.678715	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	2.02406003
10	1.656699251	0.811782633	2.382196801	0.133403021	0.88291921	0.08829192	8.5					8.5	120	104	9.5	0.70063	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	2.26218474
11	1.656699251	0.811782633	2.406407173	0.134758802	0.89180014	0.08918001	8.5					8.5	120	104	10.5	0.720953	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	2.50030945
12	1.656699251	0.811782633	2.428628985	0.136003223	0.89995002	0.089995	8.5					8.5	120	104	11.5	0.739938	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	2.73843416
13	1.656699251	0.811782633	2.449178772	0.137154011	0.90748532	0.09074853	8.5					8.5	120	104	12.5	0.757778	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	2.97655887
14	1.656699251	0.811782633	2.468302051	0.138224915	0.91449636	0.09144964	8.5					8.5	120	104	13.5	0.774625	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	3.21468358
15	1.656699251	0.811782633	2.486193222	0.13922682	0.92105466	0.09210547	8.5					8.5	120	104	14.5	0.790603	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	3.45280829
16	1.656699251	0.811782633	2.503008929	0.1401685	0.92721783	0.09272178	8.5					8.5	120	104	15.5	0.805812	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	3.690933
17	1.656699251	0.811782633	2.518877306	0.141057129	0.93303299	0.0933033	8.5					8.5	120	104	16.5	0.820335	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	3.92905771
18	1.656699251	0.811782633	2.533904546	0.141898655	0.93853919	0.09385392	8.5					8.5	120	104	17.5	0.834243	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	4.16718242
19	1.656699251	0.811782633	2.548179677	0.142698062	0.94376915	0.09437692	8.5					8.5	120	104	18.5	0.847594	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	4.40530713
20	1.656699251	0.811782633	2.561778095	0.143459573	0.94875061	0.09487506	8.5					8.5	120	104	19.5	0.860439	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	4.64343184
21	1.656699251	0.811782633	2.57476423	0.144186797	0.95350723	0.09535072	8.5					8.5	120	104	20.5	0.872822	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	4.88155655
22	1.656699251	0.811782633	2.587193593	0.144882841	0.95805943	0.09580594	8.5					8.5	120	104	21.5	0.884781	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	5.11968126
23	1.656699251	0.811782633	2.599114359	0.145550404	0.96242492	0.09624249	8.5					8.5	120	104	22.5	0.896348	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	5.35780597
24	1.656699251	0.811782633	2.610568614	0.146191842	0.96661914	0.09666191	8.5					8.5	120	104	23.5	0.907554	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	5.59593068
25	1.656699251	0.811782633	2.621593348	0.146809227	0.97065571	0.09706557	8.5					8.5	120	104	24.5	0.918425	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	5.83405539
26	1.656699251	0.811782633	2.632221251	0.14740439	0.97454663	0.09745466	8.5					8.5	120	104	25.5	0.928982	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	6.0721801
27	1.656699251	0.811782633	2.642481362	0.147978956	0.97830257	0.09783026	8.5					8.5	120	104	26.5	0.939249	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	6.31030481
28	1.656699251	0.811782633	2.652399594	0.148534377	0.98193304	0.0981933	8.5					8.5	120	104	27.5	0.949242	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	6.54842952
29	1.656699251	0.811782633	2.661999171	0.149071954	0.98544659	0.09854466	8.5					8.5	120	104	28.5	0.958978	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	6.78655423
30	1.656699251	0.811782633	2.671300993	0.149592856	0.98885089	0.09888509	8.5					8.5	120	104	29.5	0.968474	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	7.02467894
31	1.656699251	0.811782633	2.680323935	0.15009814	0.99215286	0.09921529	8.5					8.5	120	104	30.5	0.977743	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	7.26280365
32	1.656699251	0.811782633	2.689085104	0.150588766	0.9953588	0.09953588	8.5					8.5	120	104	31.5	0.986797	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	7.50092836
33	1.656699251	0.811782633	2.697600056	0.151065603	0.99847442	0.09984744	8.5					8.5	120	104	32.5	0.995647	1	1	27.68896	1.69	0.59	8.625	8.625	1	8.625	0.238125	7.75579984
34	1.656699251	0.811782633	2.705882976	0.151529447	1.00150492	0.10015049	8.5					8.5	120	104	33.5	1.004306	1.00430578	1.0043058	27.80818	1.69	0.59	8.625	8.625	1	8.625	0.23915	8.0455001
35	1.656699251	0.811782633	2.713946841	0.151981023	1.00445507	0.10044551	8.5					8.5	120	104	34.5	1.012781	1.012781498	1.0127815	28.04287	1.69	0.59	8.625	8.625	1	8.625	0.241168	8.35457286
36	1.656699251	0.811782633	2.721803548	0.152420999	1.00732924	0.10073292	8.5					8.5	120	104	35.5	1.021084	1.021083506	1.0210835	28.27274	1.69	0.59	8.625	8.625	1	8.625	0.243145	8.66620765
37	1.656699251	0.811782633	2.729464037	0.152849986	1.01013145	0.10101314	8.5					8.5	120	104	36.5	1.02922	1.029220112	1.0292201	28.49803	1.69	0.59	8.625	8.625	1	8.625	0.245083	8.98035287
38	1.656699251	0.811782633	2.73693839	0.15326855	1.01286539	0.10128654	8.5					8.5	120	104	37.5	1.037199	1.03719901	1.037199	28.71896	1.69	0.59	8.625	8.625	1	8.625	0.246983	9.29695934
39	1.656699251	0.811782633	2.744235916	0.153677211	1.01553449	0.10155345	8.5					8.5	120	104	38.5	1.045027	1.045027344	1.0450273	28.93572	1.69	0.59	8.625	8.625	1	8.625	0.248847	9.61598014
40	1.656699251	0.811782633	2.751365234	0.154076453	1.01814191	0.10181419	8.5					8.5	120	104	39.5	1.052712	1.052711756	1.0527118	29.14849	1.69	0.59	8.625	8.625	1	8.625	0.250677	9.93737045
41	1.656699251	0.811782633	2.758334337	0.154466723	1.02069058	0.10206906	8.5					8.5	120	104	40.5	1.060258	1.06025844	1.0602584	29.35745	1.69	0.59	8.625	8.625	1	8.625	0.252474	10.2610874
42	1.656699251	0.811782633	2.765150652	0.154848437	1.02318324	0.10231832	8.5					8.5	120	104	41.5	1.067673	1.067673173	1.0676732	29.56276	1.69	0.59	8.625	8.625	1	8.625	0.254239	10.5870898
43	1.656699251	0.811782633	2.771821092	0.155221981	1.0256224	0.10256224	8.5					8.5	120	104	42.5	1.074961	1.074961362	1.0749614	29.76456	1.69	0.59	8.625	8.625	1	8.625	0.255975	10.9153385
44	1.656699251	0.811782633	2.778352104	0.155587718	1.02801046	0.10280105	8.5					8.5	120	104	43.5	1.082128	1.082128069	1.0821281	29.963	1.69	0.59	8.625	8.625	1	8.625	0.257681	11.2457955
45	1.656699251	0.811782633	2.784749711	0.155945984	1.0303496	0.10303496	8.5					8.5	120	104	44.5	1.089178	1.089178042	1.089178	30.15821	1.69	0.59	8.625	8.625	1	8.625	0.25936	11.5784247
46	1.656699251	0.811782633	2.791019546	0.156297095	1.03264191	0.10326419	8.5					8.5	120	104	45.5	1.096116	1.096115745	1.0961157	30.35031	1.69	0.59	8.625	8.625	1	8.625	0.261012	11.913191
47	1.656699251	0.811782633	2.797166886	0.156641346	1.03488931	0.10348893	8.5					8.5	120	104	46.5	1.102945	1.102945375	1.1029454	30.53941	1.69	0.59	8.625	8.625	1	8.625	0.262639	12.250061
48	1.656699251	0.811782633	2.803196686	0.156979014	1.03709363	0.10370936	8.5					8.5	120	104	47.5	1.109671	1.109670885	1.1096709	30.72563	1.69	0.59	8.625	8.625	1	8.625	0.26424	12.5890023
49	1.656699251	0.811782633	2.809113596	0.157310361	1.03925657	0.10392566	8.5					8.5	120	104	48.5	1.116296	1.116296006	1.116296	30.90908	1.69	0.59	8.625	8.625	1	8.625	0.265818	12.9299838
50	1.656699251	0.811782633	2.814921996	0.157635632	1.04137974	0.10413797	8.5					8.5	120	104	49.5	1.122824	1.122824262	1.1228243	31.08984	1.69	0.59	8.625	8.625	1	8.625	0.267372	13.079416
51	1.607611866	0.787729814	2.738672485	0.153365659	1.04346466	0.10434647		8.25				8.25	120	104	50.5	1.129259	1.129258983	1.129259	31.26801	1.69	0.59	8.375	8.375	1	8.375	0.26111	13.2232247
52	1.607611866	0.787729814	2.744115143	0.153670448	1.04551274	0.10455127		8.25				8.25	120	104	51.5	1.135603	1.135603321	1.1356033	31.44367	1.69	0.59	8.375	8.375	1	8.375	0.262577	13.5600944
53	1.607611866	0.787729814	2.74946376	0.153969971	1.04752534	0.10475253		8.25				8.25	120	104	52.5	1.14186	1.141860267	1.1418603	31.61692	1.69	0.59	8.375	8.375	1	8.375	0.264024	13.8988342
54	1.607611866	0.787729814	2.754721709	0.154264416	1.04950372	0.10495037		8.25				8.25	120	104	53.5	1.148033	1.148032653	1.1480327	31.78783	1.69	0.59	8.375	8.375	1	8.375	0.265451	14.2394186
55	1.607611866	0.787729814	2.759892178	0.154553962	1.05144911	0.10514491		8.25				8.25	120	104	54.5	1.154123	1.154123172	1.1541232	31.95647	1.69	0.59	8.375	8.375	1	8.375	0.266859	14.581823
56	1.607611866	0.787729814	2.764978189	0.154838779	1.05336262	0.10533626		8.25				8.25	120	104	55.5	1.160134	1.160134383	1.1601344	32.12291	1.69	0.59	8.375	8.375	1	8.375	0.268249	14.9260235
57	1.607611866	0.787729814	2.769982609	0.155119026	1.05524536	0.10552454		8.25				8.25	120	104	56.5	1.166069	1.166068719	1.1660687	32.28723	1.69	0.59	8.375	8.375	1	8.375	0.269621	15.271997
58	1.607611866	0.787729814	2.774908154	0.155394857	1.05709834	0.10570983		8.25				8.25	120	104	57.5	1.171928	1.171928499	1.1719285	32.44948	1.69	0.59	8.375	8.375	1	8.375	0.270976	15.619721
59	1.607611866	0.787729814	2.77975741	0.155666415	1.05892254	0.10589225		8.25				8.25	120	104	58.5	1.177716	1.177715932	1.1777159	32.60973	1.69	0.59	8.375	8.375	1	8.375	0.272314	15.9691738
60	1.607611866	0.787729814	2.784532832	0.155933839	1.06071889	0.10607189		8.25				8.25	120	104	59.5	1.183433	1.183433126	1.1834331	32.76803	1.69	0.59	8.375	8.375	1	8.375	0.273636	16.3203343
61	1.607611866	0.787729814	2.789236757	0.156197258	1.06248827	0.10624883		8.25				8.25	120	104	60.5	1.189082	1.189082092	1.1890821	32.92445	1.69	0.59	8.375	8.375	1	8.375	0.274943	16.6731819
62	1.607611866	0.787729814	2.793871413	0.156456799	1.06423152	0.10642315		8.25				8.25	120	104	61.5	1.194665	1.194664752	1.1946648	33.07902	1.69	0.59	8.375	8.375	1	8.375	0.276233	17.0276967
63	1.607611866	0.787729814	2.79843892	0.15671258	1.06594944	0.10659494		8.25				8.25	120	104	62.5	1.200183	1.200182944	1.2001829	33.23182	1.69	0.59	8.375	8.375	1	8.375	0.277509	17.3838595
64	1.607611866	0.787729814	2.802941304	0.156964713	1.06764281	0.10676428		8.25				8.25	120	104	63.5	1.205638	1.205638427	1.2056384	33.38287	1.69	0.59	8.375	8.375	1	8.375	0.278771	17.7416512
65	1.607611866	0.787729814	2.807380498	0.157213308	1.06931234	0.10693123		8.25				8.25	120	104	64.5	1.211033	1.211032883	1.2110329	33.53224	1.69	0.59	8.375	8.375	1	8.375	0.280018	18.1010536
66	1.607611866	0.787729814	2.811758348	0.157458467	1.07095873	0.10709587		8.25				8.25	120	104	65.5	1.216368	1.216367926	1.2163679	33.67996	1.69	0.59	8.375	8.375	1	8.375	0.281252	18.4620488
67	1.607611866	0.787729814	2.816076618	0.157700291	1.07258266	0.10725827		8.25				8.25	120	104	66.5	1.221645	1.221645104	1.2216451	33.82608	1.69	0.59	8.375	8.375	1	8.375	0.282472	18.8246195
68	1.607611866	0.787729814	2.820336999	0.157938872	1.07418475	0.10741848		8.25				8.25	120	104	67.5	1.226866	1.226865898	1.2268659	33.97064	1.69	0.59	8.375	8.375	1	8.375	0.283679	19.1887487
69	1.607611866	0.787729814	2.824541107	0.158174302	1.07576563	0.10757656		8.25				8.25	120	104	68.5	1.232032	1.232031735	1.2320317	34.11368	1.69	0.59	8.375	8.375	1	8.375	0.284874	19.5544199
70	1.607611866	0.787729814	2.828690491	0.158406667	1.07732586	0.10773259		8.25				8.25	120	104	69.5	1.237144	1.237143983	1.237144	34.25523	1.69	0.59	8.375	8.375	1	8.375	0.286056	19.9216171
71	1.607611866	0.787729814	2.832786636	0.158636052	1.07886603	0.1078866		8.25				8.25	120	104	70.5	1.242204	1.242203955	1.242204	34.39534	1.69	0.59	8.375	8.375	1	8.375	0.287226	20.2903245
72	1.607611866	0.787729814	2.836830965	0.158862534	1.08038665	0.10803867		8.25				8.25	120	104	71.5	1.247213	1.247212918	1.2472129	34.53403	1.69	0.59	8.375	8.375	1	8.375	0.288384	20.6605268
73	1.607611866	0.787729814	2.840824846	0.159086191	1.08188826	0.10818883		8.25				8.25	120	104	72.5	1.252172	1.252172089	1.2521721	34.67134	1.69	0.59	8.375	8.375	1	8.375	0.28953	21.0322091
74	1.607611866	0.787729814	2.844769592	0.159307097	1.08337133	0.10833713		8.25				8.25	120	104	73.5	1.257083	1.257082638	1.2570826	34.80731	1.69	0.59	8.375	8.375	1	8.375	0.290666	21.4053569
75	1.607611866	0.787729814	2.848666462	0.159525322	1.08483636	0.10848364		8.25				8.25	120	104	74.5	1.261946	1.261945695	1.2619457	34.94196	1.69	0.59	8.375	8.375	1	8.375	0.29179	21.7799558
76	1.607611866	0.787729814	2.852516669	0.159740933	1.0862838	0.10862838		8.25				8.25	120	104	75.5	1.266762	1.266762348	1.2667623	35.07533	1.69	0.59	8.375	8.375	1	8.375	0.292904	22.1559919
77	1.607611866	0.787729814	2.85632138	0.159953997	1.08771408	0.10877141		8.25				8.25	120	104	76.5	1.271534	1.271533644	1.2715336	35.20744	1.69	0.59	8.375	8.375	1	8.375	0.294007	22.5334517
78	1.607611866	0.787729814	2.860081717	0.160164576	1.08912763	0.10891276		8.25				8.25	120	104	77.5	1.276261	1.276260596	1.2762606	35.33833	1.69	0.59	8.375	8.375	1	8.375	0.2951	22.9123218
79	1.607611866	0.787729814	2.863798759	0.160372731	1.09052486	0.10905249		8.25				8.25	120	104	78.5	1.280944	1.28094418	1.2809442	35.46801	1.69	0.59	8.375	8.375	1	8.375	0.296183	23.2925892
80	1.607611866	0.787729814	2.867473548	0.160578519	1.09190617	0.10919062		8.25				8.25	120	104	79.5	1.285585	1.285585339	1.2855853	35.59652	1.69	0.59	8.375	8.375	1	8.375	0.297256	23.6742413
81	1.607611866	0.787729814	2.871107086	0.160781997	1.09327192	0.10932719		8.25				8.25	120	104	80.5	1.290185	1.290184984	1.290185	35.72388	1.69	0.59	8.375	8.375	1	8.375	0.29832	24.0572655
82	1.607611866	0.787729814	2.874700341	0.160983219	1.09462249	0.10946225		8.25				8.25	120	104	81.5	1.294744	1.294743995	1.294744	35.85011	1.69	0.59	8.375	8.375	1	8.375	0.299374	24.4416497

83	1.607611866	0.787729814	2.878254245	0.161182238	1.09595823	0.10959582		8.25				8.25	120	104	82.5	1.299263	1.299263223	1.2992632	35.97525	1.69	0.59	8.375	8.375	1	8.375	0.300419	24.827382
84	1.607611866	0.787729814	2.881769699	0.161379103	1.09727947	0.10972795		8.25				8.25	120	104	83.5	1.303743	1.30374349	1.3037435	36.0993	1.69	0.59	8.375	8.375	1	8.375	0.301455	25.2144507
85	1.607611866	0.787729814	2.885247572	0.161573864	1.09858655	0.10985865		8.25				8.25	120	104	84.5	1.308186	1.308185595	1.3081856	36.2223	1.69	0.59	8.375	8.375	1	8.375	0.302482	25.6028443
86	1.607611866	0.787729814	2.888688703	0.161766567	1.09987978	0.10998798		8.25				8.25	120	104	85.5	1.31259	1.312590307	1.3125903	36.34426	1.69	0.59	8.375	8.375	1	8.375	0.3035	25.9925517
87	1.607611866	0.787729814	2.892093905	0.161957259	1.10115947	0.11011595		8.25				8.25	120	104	86.5	1.316958	1.316958373	1.3169584	36.46521	1.69	0.59	8.375	8.375	1	8.375	0.30451	26.3835618
88	1.607611866	0.787729814	2.89546396	0.162145982	1.10242591	0.11024259		8.25				8.25	120	104	87.5	1.321291	1.321290517	1.3212905	36.58516	1.69	0.59	8.375	8.375	1	8.375	0.305512	26.775864
89	1.607611866	0.787729814	2.898799628	0.162332779	1.10367939	0.11036794		8.25				8.25	120	104	88.5	1.325587	1.325587439	1.3255874	36.70414	1.69	0.59	8.375	8.375	1	8.375	0.306506	27.1694476
90	1.607611866	0.787729814	2.902101642	0.162517692	1.10492019	0.11049202		8.25				8.25	120	104	89.5	1.32985	1.32984982	1.3298498	36.82216	1.69	0.59	8.375	8.375	1	8.375	0.307491	27.5643023
91	1.607611866	0.787729814	2.905370712	0.16270076	1.10614857	0.11061486		8.25				8.25	120	104	90.5	1.334078	1.334078317	1.3340783	36.93924	1.69	0.59	8.375	8.375	1	8.375	0.308469	27.960418
92	1.607611866	0.787729814	2.908607525	0.162882021	1.1073648	0.11073648		8.25				8.25	120	104	91.5	1.338274	1.338273571	1.3382736	37.0554	1.69	0.59	8.375	8.375	1	8.375	0.309439	28.3577846
93	1.607611866	0.787729814	2.911812747	0.163061514	1.10856913	0.11085691		8.25				8.25	120	104	92.5	1.342436	1.342436201	1.3424362	37.17066	1.69	0.59	8.375	8.375	1	8.375	0.310402	28.7563926
94	1.607611866	0.787729814	2.914987024	0.163239273	1.10976179	0.11097618		8.25				8.25	120	104	93.5	1.346567	1.346566811	1.3465668	37.28503	1.69	0.59	8.375	8.375	1	8.375	0.311357	29.1562321
95	1.607611866	0.787729814	2.91813098	0.163415335	1.11094303	0.1110943		8.25				8.25	120	104	94.5	1.350666	1.350665984	1.350666	37.39854	1.69	0.59	8.375	8.375	1	8.375	0.312304	29.5572939
96	1.607611866	0.787729814	2.921245222	0.163589732	1.11211307	0.11121131		8.25				8.25	120	104	95.5	1.354734	1.35473429	1.3547343	37.51118	1.69	0.59	8.375	8.375	1	8.375	0.313245	29.9595687
97	1.607611866	0.787729814	2.924330336	0.163762499	1.11327213	0.11132721		8.25				8.25	120	104	96.5	1.358772	1.358772279	1.3587723	37.62299	1.69	0.59	8.375	8.375	1	8.375	0.314179	30.3630474
98	1.607611866	0.787729814	2.927386894	0.163933666	1.11442044	0.11144204		8.25				8.25	120	104	97.5	1.36278	1.36278049	1.3627805	37.73397	1.69	0.59	8.375	8.375	1	8.375	0.315106	30.7677211
99	1.607611866	0.787729814	2.930415448	0.164103265	1.11555819	0.1115582		8.25				8.25	120	104	98.5	1.366759	1.366759443	1.3667594	37.84415	1.69	0.59	8.375	8.375	1	8.375	0.316026	31.1735811
100	1.607611866	0.787729814	2.933416535	0.164271326	1.1166856	0.11166856		8.25				8.25	120	104	99.5	1.37071	1.370709645	1.3707096	37.95352	1.69	0.59	8.375	8.375	1	8.375	0.316939	31.1078033
101	1.55852448	0.763676995	2.848598648	0.159521524	1.11780285	0.11178028			8			8	120	104	100.5	1.374632	1.374631591	1.3746316	38.06212	1.69	0.59	8.125	8.125	1	8.125	0.308358	31.0339351
102	1.55852448	0.763676995	2.851459385	0.159681726	1.11891014	0.11189101			8			8	120	104	101.5	1.378526	1.378525761	1.3785258	38.16994	1.69	0.59	8.125	8.125	1	8.125	0.309231	31.4310829
103	1.55852448	0.763676995	2.854294944	0.159840517	1.12000766	0.11200077			8			8	120	104	102.5	1.382393	1.382392622	1.3823926	38.27701	1.69	0.59	8.125	8.125	1	8.125	0.310099	31.8293489
104	1.55852448	0.763676995	2.857105789	0.159997924	1.12109558	0.11210956			8			8	120	104	103.5	1.386233	1.386232629	1.3862326	38.38334	1.69	0.59	8.125	8.125	1	8.125	0.31096	32.2287254
105	1.55852448	0.763676995	2.85989237	0.160153973	1.12217408	0.11221741			8			8	120	104	104.5	1.390046	1.390046226	1.3900462	38.48893	1.69	0.59	8.125	8.125	1	8.125	0.311816	32.6292047
106	1.55852448	0.763676995	2.862655126	0.160308687	1.12324334	0.11232433			8			8	120	104	105.5	1.393834	1.393833844	1.3938338	38.59381	1.69	0.59	8.125	8.125	1	8.125	0.312665	33.0307794
107	1.55852448	0.763676995	2.865394485	0.160462091	1.12430351	0.11243035			8			8	120	104	106.5	1.397596	1.397595905	1.3975959	38.69798	1.69	0.59	8.125	8.125	1	8.125	0.313509	33.4334419
108	1.55852448	0.763676995	2.868110861	0.160614208	1.12535476	0.11253548			8			8	120	104	107.5	1.401333	1.401332817	1.4013328	38.80145	1.69	0.59	8.125	8.125	1	8.125	0.314348	33.8371849
109	1.55852448	0.763676995	2.870804658	0.160765061	1.12639725	0.11263972			8			8	120	104	108.5	1.405045	1.405044981	1.405045	38.90423	1.69	0.59	8.125	8.125	1	8.125	0.31518	34.2420014
110	1.55852448	0.763676995	2.87347627	0.160914671	1.12743112	0.11274311			8			8	120	104	109.5	1.408733	1.408732787	1.4087328	39.00635	1.69	0.59	8.125	8.125	1	8.125	0.316007	34.6478842
111	1.55852448	0.763676995	2.876126079	0.16106306	1.12845653	0.11284565			8			8	120	104	110.5	1.412397	1.412396615	1.4123966	39.10779	1.69	0.59	8.125	8.125	1	8.125	0.316829	35.0548263
112	1.55852448	0.763676995	2.878754459	0.16121025	1.12947362	0.11294736			8			8	120	104	111.5	1.416037	1.416036835	1.4160368	39.20859	1.69	0.59	8.125	8.125	1	8.125	0.317646	35.462821
113	1.55852448	0.763676995	2.881361772	0.161356259	1.13048254	0.11304825			8			8	120	104	112.5	1.419654	1.41965381	1.4196538	39.30874	1.69	0.59	8.125	8.125	1	8.125	0.318457	35.8718614
114	1.55852448	0.763676995	2.883948373	0.161501109	1.13148341	0.11314834			8			8	120	104	113.5	1.423248	1.423247891	1.4232479	39.40825	1.69	0.59	8.125	8.125	1	8.125	0.319264	36.281941
115	1.55852448	0.763676995	2.886514606	0.161644818	1.13247639	0.11324764			8			8	120	104	114.5	1.426819	1.426819425	1.4268194	39.50715	1.69	0.59	8.125	8.125	1	8.125	0.320065	36.6930531
116	1.55852448	0.763676995	2.889060808	0.161787405	1.13346158	0.11334616			8			8	120	104	115.5	1.430369	1.430368748	1.4303687	39.60542	1.69	0.59	8.125	8.125	1	8.125	0.320861	37.1051914
117	1.55852448	0.763676995	2.891587306	0.161928889	1.13443913	0.11344391			8			8	120	104	116.5	1.433896	1.433896188	1.4338962	39.70309	1.69	0.59	8.125	8.125	1	8.125	0.321652	37.5183495
118	1.55852448	0.763676995	2.894094421	0.162069288	1.13540916	0.11354092			8			8	120	104	117.5	1.437402	1.437402066	1.4374021	39.80017	1.69	0.59	8.125	8.125	1	8.125	0.322439	37.9325212
119	1.55852448	0.763676995	2.896582463	0.162208618	1.13637178	0.11363718			8			8	120	104	118.5	1.440887	1.440886696	1.4408867	39.89665	1.69	0.59	8.125	8.125	1	8.125	0.32322	38.3477002
120	1.55852448	0.763676995	2.899051738	0.162346897	1.13732712	0.11373271			8			8	120	104	119.5	1.44435	1.444350385	1.4443504	39.99256	1.69	0.59	8.125	8.125	1	8.125	0.323997	38.7638805
121	1.55852448	0.763676995	2.901502542	0.162484142	1.1382753	0.11382753			8			8	120	104	120.5	1.447793	1.447793432	1.4477934	40.08789	1.69	0.59	8.125	8.125	1	8.125	0.32477	39.1810561
122	1.55852448	0.763676995	2.903935165	0.162620369	1.13921641	0.11392164			8			8	120	104	121.5	1.451216	1.451216129	1.4512161	40.18267	1.69	0.59	8.125	8.125	1	8.125	0.325537	39.5992211
123	1.55852448	0.763676995	2.90634989	0.162755594	1.14015059	0.11401506			8			8	120	104	122.5	1.454619	1.454618764	1.4546188	40.27688	1.69	0.59	8.125	8.125	1	8.125	0.326301	40.0183698
124	1.55852448	0.763676995	2.908746993	0.162889832	1.14107792	0.11410779			8			8	120	104	123.5	1.458002	1.458001615	1.4580016	40.37055	1.69	0.59	8.125	8.125	1	8.125	0.327059	40.4384963
125	1.55852448	0.763676995	2.911126743	0.163023098	1.14199852	0.11419985			8			8	120	104	124.5	1.461365	1.461364957	1.461365	40.46368	1.69	0.59	8.125	8.125	1	8.125	0.327814	40.859595
126	1.55852448	0.763676995	2.913489406	0.163155407	1.14291249	0.11429125			8			8	120	104	125.5	1.464709	1.464709058	1.4647091	40.55627	1.69	0.59	8.125	8.125	1	8.125	0.328564	41.2816603
127	1.55852448	0.763676995	2.915835237	0.163286773	1.14381993	0.11438199			8			8	120	104	126.5	1.468034	1.46803418	1.4680342	40.64834	1.69	0.59	8.125	8.125	1	8.125	0.32931	41.7046868
128	1.55852448	0.763676995	2.918164489	0.163417211	1.14472093	0.11447209			8			8	120	104	127.5	1.471341	1.471340579	1.4713406	40.73989	1.69	0.59	8.125	8.125	1	8.125	0.330052	42.1286689
129	1.55852448	0.763676995	2.920477407	0.163546735	1.1456156	0.11456156			8			8	120	104	128.5	1.474629	1.474628506	1.4746285	40.83093	1.69	0.59	8.125	8.125	1	8.125	0.330789	42.5536014
130	1.55852448	0.763676995	2.922774231	0.163675357	1.14650402	0.1146504			8			8	120	104	129.5	1.477898	1.477898208	1.4778982	40.92146	1.69	0.59	8.125	8.125	1	8.125	0.331523	42.979479
131	1.55852448	0.763676995	2.925055198	0.163803091	1.14738629	0.11473863			8			8	120	104	130.5	1.48115	1.481149924	1.4811499	41.0115	1.69	0.59	8.125	8.125	1	8.125	0.332252	43.4062963
132	1.55852448	0.763676995	2.927320536	0.16392995	1.1482625	0.11482625			8			8	120	104	131.5	1.484384	1.48438389	1.4843839	41.10105	1.69	0.59	8.125	8.125	1	8.125	0.332978	43.8340484
133	1.55852448	0.763676995	2.92957047	0.164055946	1.14913273	0.11491327			8			8	120	104	132.5	1.4876	1.487600337	1.4876003	41.19011	1.69	0.59	8.125	8.125	1	8.125	0.333699	44.2627301
134	1.55852448	0.763676995	2.93180522	0.164181092	1.14999707	0.11499971			8			8	120	104	133.5	1.490799	1.490799492	1.4907995	41.27869	1.69	0.59	8.125	8.125	1	8.125	0.334417	44.6923364
135	1.55852448	0.763676995	2.934025001	0.1643054	1.1508556	0.11508556			8			8	120	104	134.5	1.493982	1.493981574	1.4939816	41.3668	1.69	0.59	8.125	8.125	1	8.125	0.335131	45.1228623
136	1.55852448	0.763676995	2.936230024	0.164428881	1.1517084	0.11517084			8			8	120	104	135.5	1.497147	1.497146803	1.4971468	41.45444	1.69	0.59	8.125	8.125	1	8.125	0.335841	45.5543031
137	1.55852448	0.763676995	2.938420495	0.164551548	1.15255556	0.11525556			8			8	120	104	136.5	1.500295	1.50029539	1.5002954	41.54162	1.69	0.59	8.125	8.125	1	8.125	0.336547	45.9866537
138	1.55852448	0.763676995	2.940596615	0.16467341	1.15339715	0.11533972			8			8	120	104	137.5	1.503428	1.503427543	1.5034275	41.62835	1.69	0.59	8.125	8.125	1	8.125	0.337249	46.4199096
139	1.55852448	0.763676995	2.942758582	0.164794481	1.15423326	0.11542333			8			8	120	104	138.5	1.506543	1.506543468	1.5065435	41.71462	1.69	0.59	8.125	8.125	1	8.125	0.337948	46.8540659
140	1.55852448	0.763676995	2.944906589	0.164914769	1.15506394	0.11550639			8			8	120	104	139.5	1.509643	1.509643364	1.5096434	41.80045	1.69	0.59	8.125	8.125	1	8.125	0.338644	47.2891181
141	1.55852448	0.763676995	2.947040825	0.165034286	1.15588929	0.11558893			8			8	120	104	140.5	1.512727	1.512727428	1.5127274	41.88585	1.69	0.59	8.125	8.125	1	8.125	0.339336	47.7250615
142	1.55852448	0.763676995	2.949161476	0.165153043	1.15670936	0.11567094			8			8	120	104	141.5	1.515796	1.515795852	1.5157959	41.97081	1.69	0.59	8.125	8.125	1	8.125	0.340024	48.1618916
143	1.55852448	0.763676995	2.951268723	0.165271048	1.15752423	0.11575242			8			8	120	104	142.5	1.518849	1.518848826	1.5188488	42.05534	1.69	0.59	8.125	8.125	1	8.125	0.340709	48.599604
144	1.55852448	0.763676995	2.953362744	0.165388314	1.15833398	0.1158334			8			8	120	104	143.5	1.521887	1.521886535	1.5218865	42.13946	1.69	0.59	8.125	8.125	1	8.125	0.34139	49.0381942
145	1.55852448	0.763676995	2.955443714	0.165504848	1.15913866	0.11591387			8			8	120	104	144.5	1.524909	1.524909161	1.5249092	42.22315	1.69	0.59	8.125	8.125	1	8.125	0.342068	49.4776578
146	1.55852448	0.763676995	2.957511803	0.165620661	1.15993834	0.11599383			8			8	120	104	145.5	1.527917	1.527916882	1.5279169	42.30643	1.69	0.59	8.125	8.125	1	8.125	0.342743	49.9179906
147	1.55852448	0.763676995	2.959567179	0.165735762	1.1607331	0.11607331			8			8	120	104	146.5	1.53091	1.530909874	1.5309099	42.3893	1.69	0.59	8.125	8.125	1	8.125	0.343414	50.3591882
148	1.55852448	0.763676995	2.961610006	0.16585016	1.16152298	0.1161523			8			8	120	104	147.5	1.533888	1.533888309	1.5338883	42.47177	1.69	0.59	8.125	8.125	1	8.125	0.344082	50.8012464
149	1.55852448	0.763676995	2.963640444	0.165963865	1.16230807	0.11623081			8			8	120	104	148.5	1.536852	1.536852354	1.5368524	42.55384	1.69	0.59	8.125	8.125	1	8.125	0.344747	51.2441612
150	1.55852448	0.763676995	2.965658653	0.166076885	1.1630884	0.11630884			8			8	120	104	149.5	1.539802	1.539802177	1.5398022	42.63552	1.69	0.59	8.125	8.125	1	8.125	0.345409	50.8910855
151	1.509437095	0.739624177	2.876255117	0.161070287	1.16386406	0.11638641				7.75		7.75	120	104	150.5	1.542738	1.54273794	1.5427379	42.71681	1.69	0.59	7.875	7.875	1	7.875	0.335419	50.5284654
152	1.509437095	0.739624177	2.87818877	0.161178571	1.16463509	0.11646351				7.75		7.75	120	104	151.5	1.54566	1.545659802	1.5456598	42.79771	1.69	0.59	7.875	7.875	1	7.875	0.336055	50.9602185
153	1.509437095	0.739624177	2.880111007	0.161286216	1.16540155	0.11654015				7.75		7.75	120	104	152.5	1.548568	1.54856792	1.5485679	42.87824	1.69	0.59	7.875	7.875	1	7.875	0.336687	51.3927861
154	1.509437095	0.739624177	2.88202197	0.16139323	1.1661635	0.11661635				7.75		7.75	120	104	153.5	1.551462	1.551462449	1.5514624	42.95838	1.69	0.59	7.875	7.875	1	7.875	0.337316	51.8261643
155	1.509437095	0.739624177	2.883921796	0.161499621	1.166921	0.1166921				7.75		7.75	120	104	154.5	1.554344	1.55434354	1.5543435	43.03816	1.69	0.59	7.875	7.875	1	7.875	0.337943	52.2603493
156	1.509437095	0.739624177	2.885810624	0.161605395	1.16767409	0.11676741				7.75		7.75	120	104	155.5	1.557211	1.557211342	1.5572113	43.11756	1.69	0.59	7.875	7.875	1	7.875	0.338566	52.6953374
157	1.509437095	0.739624177	2.887688587	0.161710561	1.16842285	0.11684228				7.75		7.75	120	104	156.5	1.560066	1.560066	1.560066	43.19661	1.69	0.59	7.875	7.875	1	7.875	0.339187	53.1311249
158	1.509437095	0.739624177	2.889555815	0.161815126	1.1691673	0.11691673				7.75		7.75	120	104	157.5	1.562908	1.562907659	1.5629077	43.27529	1.69	0.59	7.875	7.875	1	7.875	0.339805	53.5677082
159	1.509437095	0.739624177	2.891412439	0.161919097	1.16990752	0.11699075				7.75		7.75	120	104	158.5	1.565736	1.56573646	1.5657365	43.35361	1.69	0.59	7.875	7.875	1	7.875	0.34042	54.0050836
160	1.509437095	0.739624177	2.893258584	0.162022481	1.17064355	0.11706435				7.75		7.75	120	104	159.5	1.568553	1.568552541	1.5685525	43.43159	1.69	0.59	7.875	7.875	1	7.875	0.341032	54.4432476
161	1.509437095	0.739624177	2.895094375	0.162125285	1.17137543	0.11713754				7.75		7.75	120	104	160.5	1.571356	1.57135604	1.571356	43.50921	1.69	0.59	7.875	7.875	1	7.875	0.341641	54.8821966
162	1.509437095	0.739624177	2.896919933	0.162227516	1.17210322	0.11721032				7.75		7.75	120	104	161.5	1.574147	1.574147089	1.5741471	43.5865	1.69	0.59	7.875	7.875	1	7.875	0.342248	55.3219272
163	1.509437095	0.739624177	2.89873538	0.162329181	1.17282697	0.1172827				7.75		7.75	120	104	162.5	1.576926	1.576925821	1.5769258	43.66344	1.69	0.59	7.875	7.875	1	7.875	0.342852	55.7624359
164	1.509437095	0.739624177	2.900540832	0.162430287	1.17354671	0.11735467				7.75		7.75	120	104	163.5	1.579692	1.579692365	1.5796924	43.74004	1.69	0.59	7.875	7.875	1	7.875	0.343454	56.2037192
165	1.509437095	0.739624177	2.902336406	0.162530839	1.17426251	0.11742625				7.75		7.75	120	104	164.5	1.582447	1.58244685	1.5824468	43.81631	1.69	0.59	7.875	7.875	1	7.875	0.344053	56.6457739
166	1.509437095	0.739624177	2.904122214	0.16263084	1.1749744	0.1174974				7.75		7.75	120	104	165.5	1.585189	1.5851894	1.5851894	43.89225	1.69	0.59	7.875	7.875	1	7.875	0.344649	57.0885965
167	1.509437095	0.739624177	2.905898369	0.162730309	1.17568244	0.11756824				7.75		7.75	120	104	166.5	1.58792	1.587920138	1.5879201	43.96786	1.69	0.59	7.875	7.875	1	7.875	0.345243	57.5321837
168	1.509437095	0.739624177	2.90766498	0.162829239	1.17638665	0.11763866				7.75		7.75	120	104	167.5	1.590639	1.590639187	1.5906392	44.04314	1.69	0.59	7.875	7.875	1	7.875	0.345834	57.9765322
169	1.509437095	0.739624177	2.909422155	0.162927641	1.17708709	0.11770871				7.75		7.75	120	104	168.5	1.593347	1.593346665	1.5933467	44.11811	1.69	0.59	7.875	7.875	1	7.875	0.346423	58.4216389
170	1.509437095	0.739624177	2.91117	0.16302552	1.1777838	0.11777838				7.75		7.75	120	104	169.5	1.596043	1.596042691	1.5960427	44.19276	1.69	0.59	7.875	7.875	1	7.875	0.347009	58.8675004
171	1.509437095	0.739624177	2.912908619	0.163122883	1.17847682	0.11784768				7.75		7.75	120	104	170.5	1.598727	1.598727379	1.5987274	44.2671	1.69	0.59	7.875	7.875	1	7.875	0.347592	59.3141136
172	1.509437095	0.739624177	2.914638115	0.163219734	1.17916619	0.11791662				7.75		7.75	120	104	171.5	1.601401	1.601400843	1.6014008	44.34112	1.69	0.59	7.875	7.875	1	7.875	0.348174	59.7614754
173	1.509437095	0.739624177	2.916358588	0.163316081	1.17985195	0.1179852				7.75		7.75	120	104	172.5	1.604063	1.604063195	1.6040632	44.41484	1.69	0.59	7.875	7.875	1	7.875	0.348753	60.2095826
174	1.509437095	0.739624177	2.918070138	0.163411928	1.18053415	0.11805341				7.75		7.75	120	104	173.5	1.606715	1.606714546	1.6067145	44.48825	1.69	0.59	7.875	7.875	1	7.875	0.349329	60.6584321

175	1.509437095	0.739624177	2.919772861	0.16350728	1.18121281	0.11812128				7.75		7.75	120	104	174.5	1.609355	1.609355004	1.609355	44.56137	1.69	0.59	7.875	7.875	1	7.875	0.349903	61.108021
176	1.509437095	0.739624177	2.921466853	0.163602144	1.18188799	0.1181888				7.75		7.75	120	104	175.5	1.611985	1.611984676	1.6119847	44.63418	1.69	0.59	7.875	7.875	1	7.875	0.350475	61.5583461
177	1.509437095	0.739624177	2.923152208	0.163696524	1.18255971	0.11825597				7.75		7.75	120	104	176.5	1.614604	1.614603666	1.6146037	44.7067	1.69	0.59	7.875	7.875	1	7.875	0.351044	62.0094044
178	1.509437095	0.739624177	2.92482902	0.163790425	1.18322801	0.1183228				7.75		7.75	120	104	177.5	1.617212	1.617212079	1.6172121	44.77892	1.69	0.59	7.875	7.875	1	7.875	0.351611	62.4611931
179	1.509437095	0.739624177	2.926497379	0.163883853	1.18389293	0.11838929				7.75		7.75	120	104	178.5	1.61981	1.619810016	1.61981	44.85085	1.69	0.59	7.875	7.875	1	7.875	0.352176	62.9137091
180	1.509437095	0.739624177	2.928157375	0.163976813	1.18455451	0.11845545				7.75		7.75	120	104	179.5	1.622398	1.622397578	1.6223976	44.9225	1.69	0.59	7.875	7.875	1	7.875	0.352739	63.3669495
181	1.509437095	0.739624177	2.929809095	0.164069309	1.18521278	0.11852128				7.75		7.75	120	104	180.5	1.624975	1.624974864	1.6249749	44.99386	1.69	0.59	7.875	7.875	1	7.875	0.353299	63.8209116
182	1.509437095	0.739624177	2.931452628	0.164161347	1.18586778	0.11858678				7.75		7.75	120	104	181.5	1.627542	1.627541971	1.627542	45.06494	1.69	0.59	7.875	7.875	1	7.875	0.353857	64.2755923
183	1.509437095	0.739624177	2.933088057	0.164252931	1.18651954	0.11865195				7.75		7.75	120	104	182.5	1.630099	1.630098995	1.630099	45.13575	1.69	0.59	7.875	7.875	1	7.875	0.354413	64.7309889
184	1.509437095	0.739624177	2.934715468	0.164344066	1.18716809	0.11871681				7.75		7.75	120	104	183.5	1.632646	1.632646031	1.632646	45.20627	1.69	0.59	7.875	7.875	1	7.875	0.354967	65.1870985
185	1.509437095	0.739624177	2.936334943	0.164434757	1.18781346	0.11878135				7.75		7.75	120	104	184.5	1.635183	1.635183171	1.6351832	45.27652	1.69	0.59	7.875	7.875	1	7.875	0.355519	65.6439185
186	1.509437095	0.739624177	2.937946562	0.164525007	1.1884557	0.11884557				7.75		7.75	120	104	185.5	1.637711	1.637710507	1.6377105	45.3465	1.69	0.59	7.875	7.875	1	7.875	0.356068	66.101446
187	1.509437095	0.739624177	2.939550408	0.164614823	1.18909483	0.11890948				7.75		7.75	120	104	186.5	1.640228	1.640228131	1.6402281	45.41621	1.69	0.59	7.875	7.875	1	7.875	0.356615	66.5596784
188	1.509437095	0.739624177	2.941146557	0.164704207	1.18973088	0.11897309				7.75		7.75	120	104	187.5	1.642736	1.642736131	1.6427361	45.48566	1.69	0.59	7.875	7.875	1	7.875	0.357161	67.0186128
189	1.509437095	0.739624177	2.942735089	0.164793165	1.19036388	0.11903639				7.75		7.75	120	104	188.5	1.645235	1.645234594	1.6452346	45.55483	1.69	0.59	7.875	7.875	1	7.875	0.357704	67.4782467
190	1.509437095	0.739624177	2.944316079	0.1648817	1.19099387	0.11909939				7.75		7.75	120	104	189.5	1.647724	1.647723608	1.6477236	45.62375	1.69	0.59	7.875	7.875	1	7.875	0.358245	67.9385774
191	1.509437095	0.739624177	2.945889603	0.164969818	1.19162088	0.11916209				7.75		7.75	120	104	190.5	1.650203	1.650203257	1.6502033	45.69241	1.69	0.59	7.875	7.875	1	7.875	0.358784	68.3996023
192	1.509437095	0.739624177	2.947455735	0.165057521	1.19224493	0.11922449				7.75		7.75	120	104	191.5	1.652674	1.652673627	1.6526736	45.76081	1.69	0.59	7.875	7.875	1	7.875	0.359321	68.8613188
193	1.509437095	0.739624177	2.949014548	0.165144815	1.19286605	0.11928661				7.75		7.75	120	104	192.5	1.655135	1.655134799	1.6551348	45.82896	1.69	0.59	7.875	7.875	1	7.875	0.359856	69.3237242
194	1.509437095	0.739624177	2.950566114	0.165231702	1.19348428	0.11934843				7.75		7.75	120	104	193.5	1.657587	1.657586855	1.6575869	45.89686	1.69	0.59	7.875	7.875	1	7.875	0.36039	69.786816
195	1.509437095	0.739624177	2.952110504	0.165318188	1.19409964	0.11940996				7.75		7.75	120	104	194.5	1.66003	1.660029877	1.6600299	45.9645	1.69	0.59	7.875	7.875	1	7.875	0.360921	70.2505918
196	1.509437095	0.739624177	2.953647788	0.165404276	1.19471215	0.11947122				7.75		7.75	120	104	195.5	1.662464	1.662463943	1.6624639	46.0319	1.69	0.59	7.875	7.875	1	7.875	0.36145	70.7150489
197	1.509437095	0.739624177	2.955178035	0.16548997	1.19532186	0.11953219				7.75		7.75	120	104	196.5	1.664889	1.664889133	1.6648891	46.09905	1.69	0.59	7.875	7.875	1	7.875	0.361977	71.180185
198	1.509437095	0.739624177	2.956701312	0.165575273	1.19592878	0.11959288				7.75		7.75	120	104	197.5	1.667306	1.667305522	1.6673055	46.16596	1.69	0.59	7.875	7.875	1	7.875	0.362503	71.6459974
199	1.509437095	0.739624177	2.958217686	0.16566019	1.19653293	0.11965329				7.75		7.75	120	104	198.5	1.669713	1.669713188	1.6697132	46.23262	1.69	0.59	7.875	7.875	1	7.875	0.363026	72.1124839
200	1.509437095	0.739624177	2.959727224	0.165744725	1.19713436	0.11971344				7.75		7.75	120	104	199.5	1.672112	1.672112206	1.6721122	46.29905	1.69	0.59	7.875	7.875	1	7.875	0.363548	71.4257987
201	1.46034971	0.715571358	2.867160253	0.160560974	1.19773308	0.11977331					7.5	7.5	120	104	200.5	1.674503	1.67450265	1.6745026	46.36524	1.69	0.59	7.625	7.625	1	7.625	0.35251	70.7285017
202	1.46034971	0.715571358	2.868609497	0.160642132	1.19832911	0.11983291					7.5	7.5	120	104	201.5	1.676885	1.676884593	1.6768846	46.43119	1.69	0.59	7.625	7.625	1	7.625	0.353011	71.1821228
203	1.46034971	0.715571358	2.870052305	0.160722929	1.19892249	0.11989225					7.5	7.5	120	104	202.5	1.679258	1.679258107	1.6792581	46.49691	1.69	0.59	7.625	7.625	1	7.625	0.353511	71.6363872
204	1.46034971	0.715571358	2.871488737	0.160803369	1.19951324	0.11995132					7.5	7.5	120	104	203.5	1.681623	1.681623264	1.6816233	46.5624	1.69	0.59	7.625	7.625	1	7.625	0.354009	72.0912926
205	1.46034971	0.715571358	2.872918852	0.160883456	1.20010139	0.12001014					7.5	7.5	120	104	204.5	1.68398	1.683980133	1.6839801	46.62766	1.69	0.59	7.625	7.625	1	7.625	0.354505	72.5468368
206	1.46034971	0.715571358	2.874342708	0.160963192	1.20068695	0.12006869					7.5	7.5	120	104	205.5	1.686329	1.686328785	1.6863288	46.69269	1.69	0.59	7.625	7.625	1	7.625	0.354999	73.0030176
207	1.46034971	0.715571358	2.875760363	0.16104258	1.20126995	0.12012699					7.5	7.5	120	104	206.5	1.688669	1.688669287	1.6886693	46.7575	1.69	0.59	7.625	7.625	1	7.625	0.355492	73.4598327
208	1.46034971	0.715571358	2.877171875	0.161121625	1.20185041	0.12018504					7.5	7.5	120	104	207.5	1.691002	1.691001707	1.6910017	46.82208	1.69	0.59	7.625	7.625	1	7.625	0.355983	73.9172799
209	1.46034971	0.715571358	2.878577298	0.161200329	1.20242836	0.12024284					7.5	7.5	120	104	208.5	1.693326	1.693326112	1.6933261	46.88644	1.69	0.59	7.625	7.625	1	7.625	0.356472	74.3753572
210	1.46034971	0.715571358	2.879976689	0.161278695	1.20300383	0.12030038					7.5	7.5	120	104	209.5	1.695643	1.695642568	1.6956426	46.95058	1.69	0.59	7.625	7.625	1	7.625	0.35696	74.8340622
211	1.46034971	0.715571358	2.881370101	0.161356726	1.20357682	0.12035768					7.5	7.5	120	104	210.5	1.697951	1.697951139	1.6979511	47.0145	1.69	0.59	7.625	7.625	1	7.625	0.357446	75.2933929
212	1.46034971	0.715571358	2.882757589	0.161434425	1.20414737	0.12041474					7.5	7.5	120	104	211.5	1.700252	1.70025189	1.7002519	47.07821	1.69	0.59	7.625	7.625	1	7.625	0.35793	75.7533472
213	1.46034971	0.715571358	2.884139206	0.161511796	1.2047155	0.12047155					7.5	7.5	120	104	212.5	1.702545	1.702544883	1.7025449	47.1417	1.69	0.59	7.625	7.625	1	7.625	0.358413	76.2139229
214	1.46034971	0.715571358	2.885515004	0.16158884	1.20528123	0.12052812					7.5	7.5	120	104	213.5	1.70483	1.704830182	1.7048302	47.20497	1.69	0.59	7.625	7.625	1	7.625	0.358894	76.675118
215	1.46034971	0.715571358	2.886885034	0.161665562	1.20584458	0.12058446					7.5	7.5	120	104	214.5	1.707108	1.707107849	1.7071078	47.26804	1.69	0.59	7.625	7.625	1	7.625	0.359374	77.1369303
216	1.46034971	0.715571358	2.888249347	0.161741963	1.20640557	0.12064056					7.5	7.5	120	104	215.5	1.709378	1.709377943	1.7093779	47.3309	1.69	0.59	7.625	7.625	1	7.625	0.359851	77.5993579
217	1.46034971	0.715571358	2.889607995	0.161818048	1.20696422	0.12069642					7.5	7.5	120	104	216.5	1.711641	1.711640525	1.7116405	47.39355	1.69	0.59	7.625	7.625	1	7.625	0.360328	78.0623987
218	1.46034971	0.715571358	2.890961025	0.161893817	1.20752055	0.12075206					7.5	7.5	120	104	217.5	1.713896	1.713895654	1.7138957	47.45599	1.69	0.59	7.625	7.625	1	7.625	0.360803	78.5260506
219	1.46034971	0.715571358	2.892308488	0.161969275	1.20807459	0.12080746					7.5	7.5	120	104	218.5	1.716143	1.71614339	1.7161434	47.51823	1.69	0.59	7.625	7.625	1	7.625	0.361276	78.9903117
220	1.46034971	0.715571358	2.893650431	0.162044424	1.20862635	0.12086264					7.5	7.5	120	104	219.5	1.718384	1.718383789	1.7183838	47.58026	1.69	0.59	7.625	7.625	1	7.625	0.361747	79.4551799
221	1.46034971	0.715571358	2.894986902	0.162119267	1.20917585	0.12091759					7.5	7.5	120	104	220.5	1.720617	1.72061691	1.7206169	47.64209	1.69	0.59	7.625	7.625	1	7.625	0.362217	79.9206533
222	1.46034971	0.715571358	2.896317948	0.162193805	1.20972311	0.12097231					7.5	7.5	120	104	221.5	1.722843	1.722842809	1.7228428	47.70373	1.69	0.59	7.625	7.625	1	7.625	0.362686	80.38673
223	1.46034971	0.715571358	2.897643615	0.162268042	1.21026816	0.12102682					7.5	7.5	120	104	222.5	1.725062	1.725061541	1.7250615	47.76516	1.69	0.59	7.625	7.625	1	7.625	0.363153	80.8534079
224	1.46034971	0.715571358	2.89896395	0.162341981	1.210811	0.1210811					7.5	7.5	120	104	223.5	1.727273	1.727273162	1.7272732	47.8264	1.69	0.59	7.625	7.625	1	7.625	0.363619	81.3206852
225	1.46034971	0.715571358	2.900278996	0.162415624	1.21135166	0.12113517					7.5	7.5	120	104	224.5	1.729478	1.729477726	1.7294777	47.88744	1.69	0.59	7.625	7.625	1	7.625	0.364083	81.78856
226	1.46034971	0.715571358	2.9015888	0.162488973	1.21189016	0.12118902					7.5	7.5	120	104	225.5	1.731675	1.731675286	1.7316753	47.94829	1.69	0.59	7.625	7.625	1	7.625	0.364545	82.2570302
227	1.46034971	0.715571358	2.902893404	0.162562031	1.21242652	0.12124265					7.5	7.5	120	104	226.5	1.733866	1.733865897	1.7338659	48.00894	1.69	0.59	7.625	7.625	1	7.625	0.365007	82.7260941
228	1.46034971	0.715571358	2.904192853	0.1626348	1.21296075	0.12129607					7.5	7.5	120	104	227.5	1.73605	1.736049611	1.7360496	48.06941	1.69	0.59	7.625	7.625	1	7.625	0.365466	83.1957498
229	1.46034971	0.715571358	2.905487189	0.162707283	1.21349286	0.12134929					7.5	7.5	120	104	228.5	1.738226	1.738226479	1.7382265	48.12968	1.69	0.59	7.625	7.625	1	7.625	0.365925	83.6659954
230	1.46034971	0.715571358	2.906776455	0.162779481	1.21402289	0.12140229					7.5	7.5	120	104	229.5	1.740397	1.740396552	1.7403966	48.18977	1.69	0.59	7.625	7.625	1	7.625	0.366381	84.1368291
231	1.46034971	0.715571358	2.908060693	0.162851399	1.21455084	0.12145508					7.5	7.5	120	104	230.5	1.74256	1.742559882	1.7425599	48.24967	1.69	0.59	7.625	7.625	1	7.625	0.366837	84.608249
232	1.46034971	0.715571358	2.909339943	0.162923037	1.21507674	0.12150767					7.5	7.5	120	104	231.5	1.744717	1.744716519	1.7447165	48.30939	1.69	0.59	7.625	7.625	1	7.625	0.367291	85.0802534
233	1.46034971	0.715571358	2.910614246	0.162994398	1.21560059	0.12156006					7.5	7.5	120	104	232.5	1.746867	1.746866512	1.7468665	48.36892	1.69	0.59	7.625	7.625	1	7.625	0.367743	85.5528403
234	1.46034971	0.715571358	2.911883644	0.163065484	1.21612242	0.12161224					7.5	7.5	120	104	233.5	1.74901	1.749009909	1.7490099	48.42827	1.69	0.59	7.625	7.625	1	7.625	0.368195	86.0260081
235	1.46034971	0.715571358	2.913148175	0.163136298	1.21664224	0.12166422					7.5	7.5	120	104	234.5	1.751147	1.75114676	1.7511468	48.48743	1.69	0.59	7.625	7.625	1	7.625	0.368644	86.499755
236	1.46034971	0.715571358	2.914407879	0.163206841	1.21716007	0.12171601					7.5	7.5	120	104	235.5	1.753277	1.753277112	1.7532771	48.54642	1.69	0.59	7.625	7.625	1	7.625	0.369093	86.9740791
237	1.46034971	0.715571358	2.915662795	0.163277117	1.21767593	0.12176759					7.5	7.5	120	104	236.5	1.755401	1.755401012	1.755401	48.60523	1.69	0.59	7.625	7.625	1	7.625	0.36954	87.4489788
238	1.46034971	0.715571358	2.916912961	0.163347126	1.21818982	0.12181898					7.5	7.5	120	104	237.5	1.757519	1.757518507	1.7575185	48.66386	1.69	0.59	7.625	7.625	1	7.625	0.369986	87.9244523
239	1.46034971	0.715571358	2.918158415	0.163416871	1.21870178	0.12187018					7.5	7.5	120	104	238.5	1.75963	1.759629643	1.7596296	48.72231	1.69	0.59	7.625	7.625	1	7.625	0.37043	88.4004978
240	1.46034971	0.715571358	2.919399194	0.163486355	1.2192118	0.12192118					7.5	7.5	120	104	239.5	1.761734	1.761734466	1.7617345	48.7806	1.69	0.59	7.625	7.625	1	7.625	0.370873	88.8771137
241	1.46034971	0.715571358	2.920635336	0.163555579	1.21971991	0.12197199					7.5	7.5	120	104	240.5	1.763833	1.763833021	1.763833	48.8387	1.69	0.59	7.625	7.625	1	7.625	0.371315	89.3542983
242	1.46034971	0.715571358	2.921866876	0.163624545	1.22022613	0.12202261					7.5	7.5	120	104	241.5	1.765925	1.765925352	1.7659254	48.89664	1.69	0.59	7.625	7.625	1	7.625	0.371756	89.8320499
243	1.46034971	0.715571358	2.923093852	0.163693256	1.22073046	0.12207305					7.5	7.5	120	104	242.5	1.768012	1.768011504	1.7680115	48.9544	1.69	0.59	7.625	7.625	1	7.625	0.372195	90.3103667
244	1.46034971	0.715571358	2.924316298	0.163761713	1.22123292	0.12212329					7.5	7.5	120	104	243.5	1.770092	1.77009152	1.7700915	49.01199	1.69	0.59	7.625	7.625	1	7.625	0.372633	90.7892472
245	1.46034971	0.715571358	2.92553425	0.163829918	1.22173353	0.12217335					7.5	7.5	120	104	244.5	1.772165	1.772165444	1.7721654	49.06942	1.69	0.59	7.625	7.625	1	7.625	0.373069	91.2686896
246	1.46034971	0.715571358	2.926747742	0.163897874	1.2222323	0.12222323					7.5	7.5	120	104	245.5	1.774233	1.774233318	1.7742333	49.12668	1.69	0.59	7.625	7.625	1	7.625	0.373505	91.7486924
247	1.46034971	0.715571358	2.92795681	0.163965581	1.22272924	0.12227292					7.5	7.5	120	104	246.5	1.776295	1.776295184	1.7762952	49.18377	1.69	0.59	7.625	7.625	1	7.625	0.373939	92.2292539
248	1.46034971	0.715571358	2.929161486	0.164033043	1.22322437	0.12232244					7.5	7.5	120	104	247.5	1.778351	1.778351083	1.7783511	49.24069	1.69	0.59	7.625	7.625	1	7.625	0.374371	92.7103724
249	1.46034971	0.715571358	2.930361806	0.164100261	1.22371771	0.12237177					7.5	7.5	120	104	248.5	1.780401	1.780401058	1.7804011	49.29745	1.69	0.59	7.625	7.625	1	7.625	0.374803	93.1920465
250	1.46034971	0.715571358	2.931557801	0.164167237	1.22420926	0.12242093					7.5	7.5	120	104	249.5	1.782445	1.782445149	1.7824451	49.35405	1.69	0.59	7.625	7.625	1	7.625	0.375233	

User Input				
Overall height	250	ft =	3000	in
Diameter at Base	8.5	ft=	102	in
Shell Thickness	0.75	in		
Strength of Steel	36	ksi		
Modulus of Elasticity	29000	ksi		

ID	100.5
S	5994.595697
Z	7688.8125
r	35.79826288
I	305724.3805

Axial Strength	
Factored Load	748.6849367
Factored Strength	1811.937034
Pn	2131.690628
Fcr	8.935482487
KL/r	167.6058981
4.71*sqrt(E/Fy)	133.680683
Fe	10.18869155
Fcr for KL/r≤4.71*sqrt(E/Fy)	8.204172194
Fcr for KL/r>4.71*sqrt(E/Fy)	8.935482487
Ag	238.5646921
Check for Compact section:	
D/t	136
λp	
λc	88.61111111
noncompact	
Axial Strength:	OK

Flexure Strength	
Factored Load	126635.85
Factored Strength	249117.53
Yielding Mn	276797.25
Local Buckling	242648.892
Check for Compact section:	
D/t	136
λp	56.38888889
λc	249.7222222
non-compact	
Flexure Strength:	OK

Combined Loads			
Combined Loading	0.875381	≤1.0	**OK**
Pu/Pc	0.413196		
For Pu/Pc≥0.2	0.875381		
For Pu/Pc<0.2	0.668783		
Magnification Factors			
B2	1.022859		
Pnt	748.6849		
Pe2	33501.45		
∑H	78.83		
ΔH	6		
L	3000		

Appendix E: Foundation Design Sheets and Hand Calculations

Design of a Square Spead Footing

$P_u = 744.43\,k$ $M_u = 6956.04\,ft\text{-}k$

column Base Diameter, D = 8 ft

$q_{allowable} = 4500\,psf$

$f'_c = 3000\,psi$

$f_y = 40{,}000\,psi$

a) Estimate footing pressure

→ check $q_{equiv} \le q_a$

$q_{equiv} = \frac{P + W_f}{B^2} = \frac{774.43^k + 88.2^k}{14^2}$

$q_{equiv} = 4400\,psf$

$4400\,psf \le q_a = 4500\,psf$ OK

Assume 3 ft footing ∴ 450 psf

$P_{net} = 4500 - 450 = 4050\,psf$

required A $= \frac{DL}{p_{net}} = \frac{744.13^k}{4.05\,ksf} = 183.81\,ft^2$

$\sqrt{183.81} = 13.56\,ft$ → use 14 ft

$W_f = 450\,lb/ft^2 \times 14^2$

$W_f = 88.2^k$

b) check eccentricity

$e = \frac{M_u}{P_u + W_f} = \frac{6956.04}{774.43 + (14' \times 450)} = 0.078\,ft$

$B/6 = \frac{14}{6} = 2.33\,ft$ $e < B/6$ OK

c) Determine depth based on shear

avg d = 36 − 3 (cover) − 2 (conserv. bardiameter) = 31 in

$V_u = p_{net} \times area = 4.05\,ksf\,(14^2) = 793.8\,k$

$b_o \Rightarrow 2\pi r = 25.13\,ft - 31/12 = 271\,in$ ACI (11-33)

$V_c = \left(2 + \frac{4}{1}\right)\sqrt{f'_c}\,b_o d = (2+4)\sqrt{3000}\,(271'')(31'')\frac{1}{1000}$

$V_c = 2760.92^k$

$V_c = \left(\frac{\alpha_s}{b_o/d} + 2\right)\left(\sqrt{f'_c}\right) b_o d = \left(\frac{40}{271/31} + 2\right)\sqrt{3000}\,(271'' \times 31'')\frac{1}{1000}$

$\alpha_s = 40$ for column

$V_c = 3025.75^k$

$V_c = 4\sqrt{f'_c}\,b_o d = 4\sqrt{3000}\,(271'' \times 31'')\frac{1}{1000}$

$V_c = 1840.61^k$ * smallest governs

Two Way Shear

$B_C = \frac{14'}{14'} = 1 \leq 2$ OK $\quad b_o/d = 271''/31'' = 8.74 < 20$ OK

$\phi V_c = (0.75)(1840.61) = 1380.46 > V_u = 793.8^K$

OK

one way shear

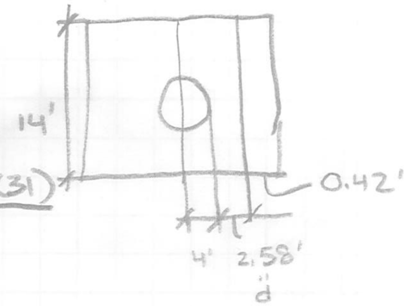
$V_u = 4.05(0.42)(14')$

$V_u = 23.6^K$

ACI-11.12.1.1 and 11.3.1.1

$V_c = 2\sqrt{f'_c}\,b_w d = \frac{2\sqrt{3000}(14)(12)(31)}{1000}$

$V_{cu} = 570.51^K$



$\phi V_c = 0.75(570.51^K) = 427.88^K > V_u = 23.6^K$

OK

*No shear reinforcement needed.

Bearing Strength

Design of baseplate

cont. Next page

DESIGN OF BASEPLATE – try 128" x 128"

CHECK BEARING PRESSURE:

$$\phi_c P_p = \phi_c\, 0.85 f'_c A_1 \sqrt{\frac{A_2}{A_1}} \le \phi 1.7 f'_c A_1 \quad > P_u = 774.4^k$$

$\phi_c = 0.60$

$f'_c = 3\,ksi$

A_1 = Area of baseplate, try 128" x 128", $A = 16384\,in^2$

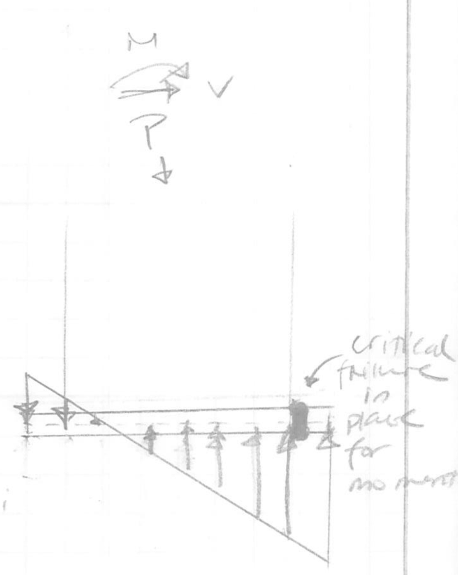
A_2 = Area of concrete footing = 36864 in^2

$$[\phi_c P_p = (0.60)0.85(3\,ksi)(16384\,in^2)\sqrt{\frac{36864}{16384}} = 37601.2^k \le$$

$$[(0.6)1.7(3\,ksi)(16384) = 50135^k\,]$$

use $[\phi_c P_p = 37601^k] > [P_u = 774.4^k]$ OK

CHECK OVERTURNING MOMENT:



$$f_{max} \le \phi_c P_p / A_1$$

$$f = -\frac{P_u}{A_1} \pm \frac{6 M_u}{bd^2}$$

$P_u = 774.4^k$

$A_1 = 16384\,in^2$

$M_u = 6956$ ft-kips · 12" = 83472 in-kips

$b = d = 128"$

$$f = \frac{-774.4^k}{16384\,in^2} \mp \frac{6(83472)}{128^3} = \begin{cases} -0.286\,ksi \\ 0.192\,ksi \end{cases}$$

$[f_{max} = 0.286\,ksi] \le [\phi_c P_p / A_1 = 2.15\,ksi]$ ✓ OK

DESIGN THICKNESS.

$m = 0.5(N - 0.8d)$

$m = 0.5(128 - 0.8(96)) = 25.6"$

$n' = 0.25d$

$n' = 0.25(96) = 24"$

$$\lambda = \frac{2\sqrt{X}}{1+\sqrt{1-X}} \le 1$$

$$X = \frac{P_u}{\phi_c P_p} = \frac{774.4^k}{32521^k} = 0.022$$

$$\lambda = \frac{2\sqrt{0.02}}{1+\sqrt{1-0.02}} = 0.15 \le 1$$

$\lambda n' = 3.51"$

$t_{min} = l\sqrt{\dfrac{2P_u}{0.9 F_y N^2}}$

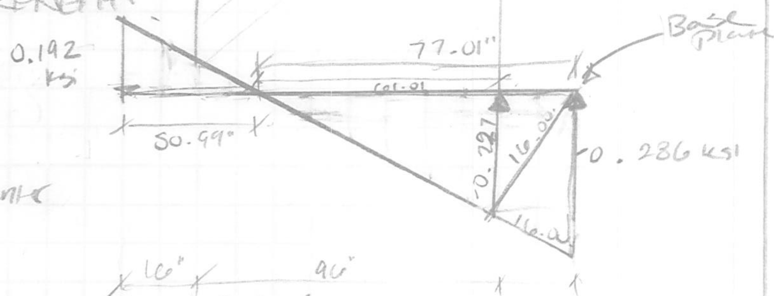
$l = \max(m, \lambda n')$; $l = 25.6"$
$P_u = 774.4^k$
$F_y = 36$ ksi
$N = 128"$

$\dfrac{0.192}{x} = \dfrac{0.482}{128}$ $x = 50.99"$

$t_{min} = 25.6\sqrt{\dfrac{2(774.4^k)}{0.9(36\text{ ksi})(128")^2}} = 1.36"$, Try $t = 1.5"$

CHECK FOR FLEXURAL STRENGTH:

$t \geq \sqrt{\dfrac{6M_u}{\phi_b F_y}}$



M_u = Moment to right @ center of right flange

$= (16.00)\left(\dfrac{16"}{3}\right) + (16.00)\left(\dfrac{2}{3} \cdot 16.00\right) = 256$ ft-k

$\dfrac{77.01"}{-0.286} = \dfrac{61.01"}{x}$

$\phi_b = 0.9$
$F_y = 36$ ksi.

$t \geq \sqrt{\dfrac{6(256)}{0.9(36)}} = 6.88" \rightarrow$ use $\underline{7"}$

Final design: $\underline{128" \times 128" \times 7"}$

Design for Bending Moment Strength

Required $R_n = \frac{M_u}{\phi b d^2} = \frac{6956.04\,(12{,}000)}{(0.9)(168'')(31^2)} = 574.47\,psi$

Section 3.8 eqn. (3.8.5) Wang, Salmon

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2mR_n}{f_y}}\right) \qquad m = \frac{40000}{0.85(3000)} = 15.7$$

$$\rho = \frac{1}{15.7}\left(1-\sqrt{1-\frac{2(15.7)(574.4)}{40{,}000}}\right) = 0.015$$

required $A_s = \rho b d = 0.0075\,(168)(31) = 85.91\,in^2$

min required $A_s = 0.002\,(168)(36) = 12.10\,in^2$

Bar size try #9

Try 86 #9 $\quad A_s = 86\,in^2$

Check bar spacing

↳ $\frac{168}{86} = 1.95\,in$ OK ✓

Check for balanced cond.

$\beta_1 = 0.85$ for $f'_c = 3000\,psi$

$$\rho_b = \frac{0.85 \cdot 3000}{40{,}000}(0.85)\left(\frac{87{,}000}{87{,}000+f_y}\right)$$

$\rho_b = 0.037$

$\rho = \le 0.75\rho_b$

$\rho \le 0.75\,(0.037)$

$0.02 \le 0.028$ ✓

OK

New $d = 36 - 3 - 1.13\,in = 31.87\,in$

(↑ d_b)

$C = 0.85 f'_c b a = 0.85\,(3)(14)(12)a = 428.4\,a$

$T = A_s f_y = 86(40) = 3440^K$

$a = 8.03\,in$

$\phi M_n = 0.9\,(3440)\left([31.87 - 0.5(8.03)]\frac{1}{12}\right)$

$\phi M_n = 7186.6'^K > \phi\, 6956.04\,ft\text{-}K$

OK

Development of reinforcement

bottom + side cover:

$1.5 + \frac{1.13}{2} = 2.06\,in$

↑ clear spacing $\qquad$ ↑ $d_b/2$

one half center to center spacing

$1.95''/2 = 0.98\text{ in} \leftarrow c_b$ smaller

$c_b = 0.98\text{in}$. No stirrups $K_{tr} = 0$

ACI 12-1 $$L_d = \left(\frac{3}{40} \frac{f_y}{\sqrt{f'c}} \frac{\psi_t \psi_e \psi_s \lambda}{\left(\frac{c_b + K_{tr}}{d_b}\right)} \right) d_b =$$

$$\frac{c_b + K_{tr}}{d_b} = \frac{0.98 + 0}{1.13} = 0.867 < 2.5 \text{ max}$$ OK

$$L_d = \frac{3}{40} \frac{40{,}000}{\sqrt{3000}} \frac{1 \times 1 \times 1 \times 1}{0.867} = 71.35 \text{ in}$$

actual embedment $= (14' - 8')\frac{12''}{1'} - 2\text{in} = 34 \text{ in} < L_d$

(2 in ↑ cover)

NO good

Try increasing side length to 16'

Recheck

$\rightarrow q_{equiv} = \frac{774.40 + (450 \times 16 \times 16)}{16} = 3475$ psf < q_a OK

check eccentricity:

$$e = \frac{M_u}{P_u + w_f} = \frac{6956.04}{744.43 \times (16^2 \times 450)} = 0.06 \text{ ft}$$

$B/6 = 16/6 = 2.67\text{ft}$ $\quad e < B/6$ OK

Determine depth based on shear:

avg $d = 36 - 3\text{(cover)} - 2\text{(conser. } d_b) = 31 \text{in}$

$V_u = p_{net} \times \text{area} = 4.05\text{ksf}(16^2) = 1036.8^k$

$b_o \Rightarrow 2\pi r = 25.13 \text{ ft} - 31/12 = 271 \text{ in}$

$$V_c = (2 + 4)\sqrt{3000}(271)(31)\frac{1}{1000} = 2760.92^k$$

$$V_c = \left(\frac{40}{271/31} + 2\right)\sqrt{3000}(271'' \times 31'')\frac{1}{1000} = 3025.75^k$$

$$V_c = 4\sqrt{f'c}\, b_o d = 4\sqrt{3000}(271'' \times 31'')\frac{1}{1000}$$

$V_c = 1840.61^k$ *smallest governs

Two-way shear (same)

$\beta_c = 1 \leq 2$ OK $\quad b_o/d = 271''/31'' = 8.74 < 20^k$ OK

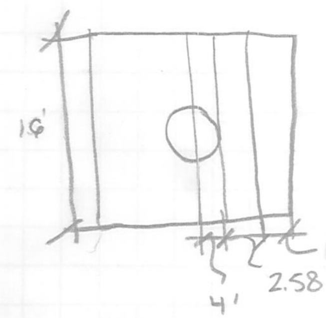
$\phi V_c = (0.75)(1840.61) = 1380.46^k > V_u = 793.8^k$

OK

Check one-way shear

$V_u = 4.05(1.42)(16') = 92^k$

$V_c = \dfrac{2\sqrt{3000}(16)(12)(31)}{1000}$



$V_{cu} = 652^k$

$\phi V_{cu} = 0.75(652^k) = 489.1^k$ OK

* No shear reinforcement

Design of Baseplate → same

Design of Bending Moment Strength

Required $R_n = \dfrac{6956.04(12000)}{(0.9)(192)(31^2)} = 502.7$ psi

check balanced cond.

$m = 15.7$ (same)

$0.75\rho_b = 0.028$

$\rho = \dfrac{1}{15.7}\left(1 - \sqrt{1 - \dfrac{2(15.7)(502.6)}{40{,}000}}\right) = 0.0141 < 0.028$ ✓

OK

Required $A_s = \rho b d = (0.0141)(192)(31) = 84.12$ in²

Min reqd $A_s = 0.002(192)(36) = 13.824$ in²

Try #9 bars → 85 ⇒ $A_s = 85$ in²

Check bar spacing

$\dfrac{192 \text{ in}}{85 \text{ bars}} = 2.26$ in/bar $> d_b$ = OK

New $d = 36 - 3 - 1.13 = 31.87$ in

$C = 0.85 f'_c b a = 0.85(3)(16)(12)a = 489.6a$

$T = A_s F_y = 85(40) = 3400^k$

$a = 6.94$ in

$\phi M_n = 0.9\ (3400)(\ 31.87 - 0.5\ (6.94)]\ \frac{1}{12}$

$\phi M_n = 7242^{\text{ lk}} > 6956.04^{\text{ lk}}$

OK

Development of reinforcement

bottom + side cover $= 1.5 + \frac{1.13}{2} = 2.06$ in

$1/2$ c+oc spacing $= 2.26/2 = 1.13$ in ← cb b/c smaller

$C_b = 1.06$ No stirrups $K_{tr} = 0$

↓

C_b/d_b

↳ $\frac{1.13}{1.13} = 1$

$$L_d = \left(\frac{3}{40}\ \frac{40{,}000}{\sqrt{3000}}\ \frac{1 \times 1 \times 1.3 \times 1}{1.0}\right) 1.13 = 80.5 \text{ in}$$

Actual embedment: $(16-8)(12''/1') - 2$in (cover)

$= 94$in $> L_d$

OK

Check shear w/ new d

$d = 31.87$ in

$V_u = 1036.8^k$ $\quad b_o = 2\pi r - d_b$

$= 2\pi(4) - 31.87''/12''/1' = 270.13$ in

$v_c = (2 + \frac{4}{1})\sqrt{f'_c}\, b_o d = (2+4)(\sqrt{3000})(270.13 \times 31.87)\frac{1}{1000}$

$V_c = 2829.2^k$

$V_c = \left(\frac{\alpha_s}{b_o/d} + 2\right)(\sqrt{f'_c})\, b_o d = \left(\frac{40}{270.13/31.87} + 2\right)(\sqrt{3000})(270.13 \times 31.87)\frac{1}{1000}$

$V_c = 3168.35^k$

$V_c = 4\sqrt{3000}\,(270.13 \times 31.87)\frac{1}{1000}$

$V_c = 1886.2^k$ * smallest governs

Two-way shear

$B_c = \frac{16'}{16'} = 1 \leq 2$ OK $b_o/d = 270.13/31.87 = 8.5'' < 20''$

$\phi V_c = (0.75)(1886.3) = 1414.65^k > V_u = 1036.8^k$ OK

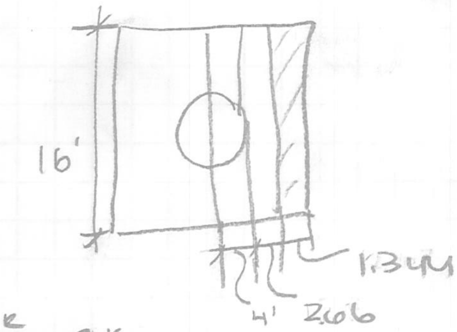
Oneway shear

$V_u = 4.05(1.349)(16') = 87.09^k$

$V_c = \frac{2\sqrt{3000}(16)(12)(31.87)}{1000}$

$V_c = 670.3^k$

$\phi V_c = 0.75(670.3) = 502.76^k$ OK



*No shear reinforcement needed

Design complete.

use 16' × 16' × 3' concrete footing with 85 #9 @≈ 2 1/4" spacing

250' Tower

Initial Inputs				
Axial Load, Pu	744.43	k		
Moment, Mu	6956.04	ft-k		
Column Base Diameter, D	8.00	ft		
Allowable Bearing Stress, qa	4500.00	psf		
f'c	3000.00	psi		
fy	40000.00	psi		
Determine Footing Size				
Footing Depth	3.00	ft		
Weight of Footing	450.00	psf		
p net	4050.00	psf		
Required Area	183.81	ft^2		
Suggested side length	13.56	ft		
Chosen side length	16.00	ft	**OK**	q equiv<qa
Check Eccentricity				
Eccentricity, e	0.06	ft		
B/6	2.67	ft	**OK**	
Determine Depth based on Shear				
average d	31.00	in		
Vu	1036.80	k		
bo	271.01	in		
Bc	1.00	(for squares)		
Alpha s	40.00	(for columns)		
Choose smallest of:				
Vc	2760.92	k		
Vc	3025.75	k		
Vc	1840.61	k		
Governing Vc	1840.61	k		
Check Two-Way Shear				
Bc	1.00		**OK**	
bo/d	8.74		**OK**	
Shear Capacity (phi c, Vc)	1380.46	k	**OK**	No Shear Reinforcement
Check One-Way Shear				
Vu	91.80	k		
Vcu	652.01	k		
Phi*Vc	489.01	k	**OK**	No Shear Reinforcement

Design of Baseplate

Try base plate width	128.00	in	**OK**
Check Bearing Pressure:			
$\Phi_C P_P$	37601.28	>	744.43 **OK**
Φ_C*0.85*f'c*A1*sqrt(A2/A1)	37601.28	k	
1.7*f'c*A1	50135.04	k	
fmax	-0.28	ksi	**OK**
Mu	256.00	in-k	
tmin	6.89	in	
Choose t	7	in	**OK**

Design for Bending Moment Strength

Required Rn	502.66	psi	
m	15.69		
p	0.014		
Check balanced condition			
pb	0.028		**OK**
Required As	84.12	in^2	
Min Required As	13.82	in^2	
Bar Size, #	9.00		
Diameter, db	1.13	in	
Area, a	1.00	in^2	
Suggested # of bars, As/a	84.12		
Chosen # of Bars	85.00		
As	85.00	in^2	
Check Bar Spacing			
Calculated bar spacing	2.26	in/bar	**OK**
Actual bar spacing	2.26	in/bar	
New d	31.87	in	
Compressive Strength, C	489.60	a	
Tensile Strength, T	3400.00	k	
a	6.94	in	
Phi Mn	7241.94	ft-k	**OK**

Development of Reinforcement

bottom and side cover	2.06	in	
one half c-c spacing	1.13	in	
cb	1.13	in	
Cb/db	1.00		**OK**
Actul Cb/db	1.00		

Ld	80.22	in		
Actual Embedment	94.00	in	**OK**	
Check Shear with New d				
average d	31.87	in		
Vu	1036.80	k		
bo	270.13	in		
Bc	1.00	(for squares)		
Alpha s	40.00	(for columns)		
Choose smallest of:				
Vc	2829.44	k		
Vc	3168.71	k		
Vc	1886.30	k		
Governing Vc	1886.30	k		
Check Two-Way Shear				
Bc	1.00		**OK**	
bo/d	8.48		**OK**	
Shear Capacity (phi c, Vc)	1414.72	k	**OK**	No Shear Reinforcement
Check One-Way Shear				
Vu	87.09	k		
Vcu	670.35	k		
Phi*Vc	502.76	k	**OK**	No Shear Reinforcement

Appendix F: Foundation Design Alternatives

350' Tower

Initial Inputs

Axial Load, Pu	1026.88	k		
Moment, Mu	21637.72	ft-k		
Column Base Diameter, D	12.00	ft		
Allowable Bearing Stress, qa	4500.00	psf		
f'c	3000.00	psi		
fy	40000.00	psi		
Determine Footing Size				
Footing Depth	6.00	ft		
Weight of Footing	900.00	psf		
p net	3600.00	psf		
Required Area	285.24	ft^2		
Suggested side length	16.89	ft		
Chosen side length	24.00	ft	**OK**	q equiv<qa
Check Eccentricity				
Eccentricity, e	0.04	ft		
B/6	4.00	ft	**OK**	
Determine Depth based on Shear				
average d	67.00	in		
Vu	2073.60	k		
bo	386.01	in		
Bc	1.00	(for squares)		
Alpha s	40.00	(for columns)		
Choose smallest of:				
Vc	8499.33	k		
Vc	12668.02	k		
Vc	5666.22	k		
Governing Vc	5666.22	k		
Check Two-Way Shear				
Bc	1.00		**OK**	
bo/d	5.76		**OK**	
Shear Capacity (phi c, Vc)	4249.67	k	**OK**	No Shear Reinforcement
Check One-Way Shear				
Vu	36.00	k		
Vcu	2113.77	k		
Phi*Vc	1585.33	k	**OK**	No Shear Reinforcement

Design of Baseplate

Try base plate width	180.00	in	OK		
Check Bearing Pressure:					
$\Phi_C P_P$	79315.20	>		1026.88	OK
Φ_C*0.85*f'c*A1*sqrt(A2/A1)	79315.20	k			
1.7*f'c*A1	99144.00	k			
fmax	-0.30	ksi	OK		
Mu	324.01	in-k			
tmin	7.75	in			
Choose t	8	in	OK		

Design for Bending Moment Strength

Required Rn	223.16	psi	
m	15.69		
p	0.006		
Check balanced condition			
pb	0.028		OK
Required As	112.82	in^2	
Min Required As	41.47	in^2	
Bar Size, #	9.00		
Diameter, db	1.13	in	
Area, a	1.00	in^2	
Suggested # of bars, As/a	112.82		
Chosen # of Bars	113.00		
As	113.00	in^2	
Check Bar Spacing			
Calculated bar spacing	2.55	in/bar	OK
Actual bar spacing	2.55	in/bar	
New d	67.87	in	
Compressive Strength, C	734.40	a	
Tensile Strength, T	4520.00	k	
a	6.15	in	
Phi Mn	21965.39	ft-k	OK

Development of Reinforcement

bottom and side cover	2.06	in	
one half c-c spacing	1.27	in	
cb	1.27	in	
Cb/db	1.13		OK
Actul Cb/db	1.13		
Ld	71.09	in	
Actual Embedment	142.00	in	OK

Check Shear with New d				
average d	67.87	in		
Vu	2073.60	k		
bo	385.14	in		
Bc	1.00	(for squares)		
Alpha s	40.00	(for columns)		
Choose smallest of:				
Vc	8590.50	k		
Vc	12956.07	k		
Vc	5727.00	k		
Governing Vc	5727.00	k		
Check Two-Way Shear				
Bc	1.00		**OK**	
bo/d	5.67		**OK**	
Shear Capacity (phi c, Vc)	4295.25	k	**OK**	No Shear Reinforcement
Check One-Way Shear				
Vu	29.72	k		
Vcu	2141.28	k		
Phi*Vc	1605.96	k	**OK**	No Shear Reinforcement

250' Tower with Clayey Soil

Initial Inputs				
Axial Load, Pu	744.43	k		
Moment, Mu	6956.04	ft-k		
Column Base Diameter, D	8.00	ft		
Allowable Bearing Stress, qa	2000.00	psf		
f'c	3000.00	psi		
fy	40000.00	psi		
Determine Footing Size				
Footing Depth	3.00	ft		
Weight of Footing	450.00	psf		
p net	1550.00	psf		
Required Area	480.28	ft^2		
Suggested side length	21.92	ft		
Chosen side length	22.00	ft	**OK**	q equiv<qa
Check Eccentricity				
Eccentricity, e	0.03	ft		
B/6	3.67	ft	**OK**	
Determine Depth based on Shear				
average d	31.00	in		
Vu	750.20	k		
bo	271.01	in		
Bc	1.00	(for squares)		
Alpha s	40.00	(for columns)		
Choose smallest of:				
Vc	2760.92	k		
Vc	3025.75	k		
Vc	1840.61	k		
Governing Vc	1840.61	k		
Check Two-Way Shear				
Bc	1.00		**OK**	
bo/d	8.74		**OK**	
Shear Capacity (phi c, Vc)	1380.46	k	**OK**	No Shear Reinforcement
Check One-Way Shear				
Vu	150.61	k		
Vcu	896.51	k		
Phi*Vc	672.38	k	**OK**	No Shear Reinforcement

Design of Baseplate

Try base plate width	128.00	in	**OK**
Check Bearing Pressure:			
$\Phi_C P_P$	50135.04	>	744.4 3 **OK**
Φ_C*0.85*f'c*A1*sqrt(A2/A1)	51701.76	k	
1.7*f'c*A1	50135.04	k	
fmax	-0.28	ksi	**OK**
Mu	256.00	in-k	
tmin	6.89	in	
Choose t	7	in	**OK**

Design for Bending Moment Strength

Required Rn	365.57	psi	
m	15.69		
p	0.010		
Check balanced condition			
pb	0.028		**OK**
Required As	81.10	in^2	
Min Required As	19.01	in^2	
Bar Size, #	9.00		
Diameter, db	1.13	in	
Area, a	1.00	in^2	
Suggested # of bars, As/a	81.10		
Chosen # of Bars	82.00		
As	82.00	in^2	
Check Bar Spacing			
Calculated bar spacing	3.22	in/bar	**OK**
Actual bar spacing	3.22	in/bar	
New d	31.87	in	
Compressive Strength, C	673.20	a	
Tensile Strength, T	3280.00	k	
a	4.87	in	
Phi Mn	7241.23	ft-k	**OK**

Development of Reinforcement

bottom and side cover	2.06	in	
one half c-c spacing	1.61	in	
cb	1.61	in	
Cb/db	1.43		**OK**
Actul Cb/db	1.43		

Ld	56.28	in		
Actual Embedment	166.00	in	**OK**	
Check Shear with New d				
average d	31.87	in		
Vu	750.20	k		
bo	270.13	in		
Bc	1.00	(for squares)		
Alpha s	40.00	(for columns)		
Choose smallest of:				
Vc	2829.44	k		
Vc	3168.71	k		
Vc	1886.30	k		
Governing Vc	1886.30	k		
Check Two-Way Shear				
Bc	1.00		**OK**	
bo/d	8.48		**OK**	
Shear Capacity (phi c, Vc)	1414.72	k	**OK**	No Shear Reinforcement
Check One-Way Shear				
Vu	148.13	k		
Vcu	921.73	k		
Phi*Vc	691.30	k	**OK**	No Shear Reinforcement

250' Tower with Rocky Soil

Initial Inputs				
Axial Load, Pu	744.43	k		
Moment, Mu	6956.04	ft-k		
Column Base Diameter, D	8.00	ft		
Allowable Bearing Stress, qa	6500.00	psf		
f'c	3000.00	psi		
fy	40000.00	psi		
Determine Footing Size				
Footing Depth	4.00	ft		
Weight of Footing	600.00	psf		
p net	5900.00	psf		
Required Area	126.17	ft^2		
Suggested side length	11.23	ft		
Chosen side length	14.00	ft	**OK**	q equiv<qa
Check Eccentricity				
Eccentricity, e	0.06	ft		
B/6	2.33	ft	**OK**	
Determine Depth based on Shear				
average d	43.00	in		
Vu	1156.40	k		
bo	259.01	in		
Bc	1.00	(for squares)		
Alpha s	40.00	(for columns)		
Choose smallest of:				
Vc	3660.08	k		
Vc	5270.98	k		
Vc	2440.05	k		
Governing Vc	2440.05	k		
Check Two-Way Shear				
Bc	1.00		**OK**	
bo/d	6.02		**OK**	
Shear Capacity (phi c, Vc)	1830.04	k	**OK**	No Shear Reinforcement
Check One-Way Shear				
Vu	-48.18	k		
Vcu	791.35	k		
Phi*Vc	593.51	k	**OK**	No Shear Reinforcement

Design of Baseplate

Try base plate width	128.00	in	**OK**

Check Bearing Pressure:

$\Phi_C P_P$	32901.12	>	744.4 3	**OK**
Φ_C*0.85*f'c*A1*sqrt(A2/A1)	32901.12	k		
1.7*f'c*A1	50135.04	k		
fmax	-0.28	ksi	**OK**	
Mu	256.00	in-k		
tmin	6.89	in		
Choose t	7	in	**OK**	

Design for Bending Moment Strength

Required Rn	298.58	psi	
m	15.69		
p	0.008		
Check balanced condition			
pb	0.028		**OK**
Required As	57.51	in^2	
Min Required As	16.13	in^2	
Bar Size, #	9.00		
Diameter, db	1.13	in	
Area, a	1.00	in^2	
Suggested # of bars, As/a	57.51		
Chosen # of Bars	58.00		
As	58.00	in^2	
Check Bar Spacing			
Calculated bar spacing	2.90	in/bar	**OK**
Actual bar spacing	2.90	in/bar	
New d	43.87	in	
Compressive Strength, C	428.40	a	
Tensile Strength, T	2320.00	k	
a	5.42	in	
Phi Mn	7162.58	ft-k	**OK**

Development of Reinforcement

bottom and side cover	2.06	in	
one half c-c spacing	1.45	in	
cb	1.45	in	
Cb/db	1.28		**OK**
Actul Cb/db	1.28		

Ld	62.56	in		
Actual Embedment	70.00	in	**OK**	
Check Shear with New d				
average d	43.87	in		
Vu	1156.40	k		
bo	258.13	in		
Bc	1.00	(for squares)		
Alpha s	40.00	(for columns)		
Choose smallest of:				
Vc	3721.73	k		
Vc	5457.50	k		
Vc	2481.16	k		
Governing Vc	2481.16	k		
Check Two-Way Shear				
Bc	1.00		**OK**	
bo/d	5.88		**OK**	
Shear Capacity (phi c, Vc)	1860.87	k	**OK**	No Shear Reinforcement
Check One-Way Shear				
Vu	-54.19	k		
Vcu	807.40	k		
Phi*Vc	605.55	k	**OK**	No Shear Reinforcement

Appendix G: Anchor Bolt Design

DESIGN OF ANCHOR BOLTS:

Use standard steel rods, cut to length and threaded + ASTM A490 rods. Tensile capacity = 119 ksi; shear capacity = 60 ksi

Try 20 - $1\frac{1}{2}$" rods.

Minimum Embedment depth: 12(d) = 12(1.5") = 18"

Minimum Edge distance: Max of 5(d) = 5(1.5") = 7.5"; 4"

Design for tensile strength: (ASCE-7-05 Table 7-2)

$$T_u = \frac{P_u}{n} - \frac{M_x d_i A_b}{I_x}$$

$P_u = 774.4^k$
$n = 20$
$A_b = 1.77 \text{ in}^2$
$M_x = 6956.0$ ft - kips
$d_i = \phi_{Tower}/2$ + min edge dist; $d_i = 96/2 + 7.5" = 55.5"$

$$I_x = \sum_{i=1}^{n} A_b d_i^2$$

$A_b = 1.77$; d_i (varies - found dist. using AutoCad.)

$I_x = 1.77[55.5^2 + 2(52.78^2) + 2(44.90^2) + 2(32.62^2) + 2(17.15^2)$
$I_x = 27260 \text{ in}^4$

$$T_u = \frac{774.4^k}{20} - \frac{(6956 \text{ ft-kip})(12")(55.5")(1.77 \text{ in}^2)}{27260} = 262.1 \text{ ksi tension}$$

Find ϕR_n for combined shear + tension:

$\phi R_n = \phi F'_{nt} A_b$

$$F'_{nt} = 1.3 F_{nt} - \frac{F_{nt}}{\phi F_{nv}} f_v \le F_{nt}$$

Table J3.2 {
$F_{nt} = 113$ ksi
$F_{nv} = 75$ ksi $\phi = 0.75$
}

$$f_v = \frac{V_u}{nA_b} = \frac{52.0^k}{(20)(1.77)} =$$

$f_v = 1.469$ ksi

$$F'_{nt} = 1.3(113) - \frac{(113)}{(0.75)(75)} \times 1.469 \text{ ksi}$$

$F'_{nt} = 143.9$ ksi $\not\le$ [$F_{nt} = 113$ ksi]; use $F'_{nt} = 113$ ksi.

$\phi R_n = (0.75)(113\text{ ksi})(1.77) = 150\text{ ksi}$

* Shear stress is minimal, therefore neglected when checking for combined shear + tensile stress.

$\phi R_n \geq T_u$

$[\phi R_n = 150\text{ ksi}] \ngeq [T_u = 261.1\text{ ksi}]$ NG.

Try 24 - $1\frac{1}{2}$" rods. (for 2-way symmetry)

$$T_u = \frac{P_u}{n} - \frac{M_x d_i A_b}{I_x}$$

$P_u = 774.4^k$
$n = 24$
$A_b = 1.77$
$M_x = 6956.0$ ft-kips
$d_i = 55.5$
$I_x = 32712\text{ in}^4$

$$T_u = \frac{774.4^k}{24} - \frac{(6956)(12)(55.5)(1.77\text{ in}^2)}{32712} = 218^k > \phi R_n;\ \text{N.G.}$$

Try 28 - $1\frac{1}{2}$" rods

$$T_u = \frac{P_u}{n} - \frac{M_x d_i A_b}{I_x}$$

$P_u = 774.4$
$n = 28$
$A = 1.77$
$M_x = 6956.0$ ft-kips
$d_i = 55.5"$
$I_x = 70877\text{ in}^4$

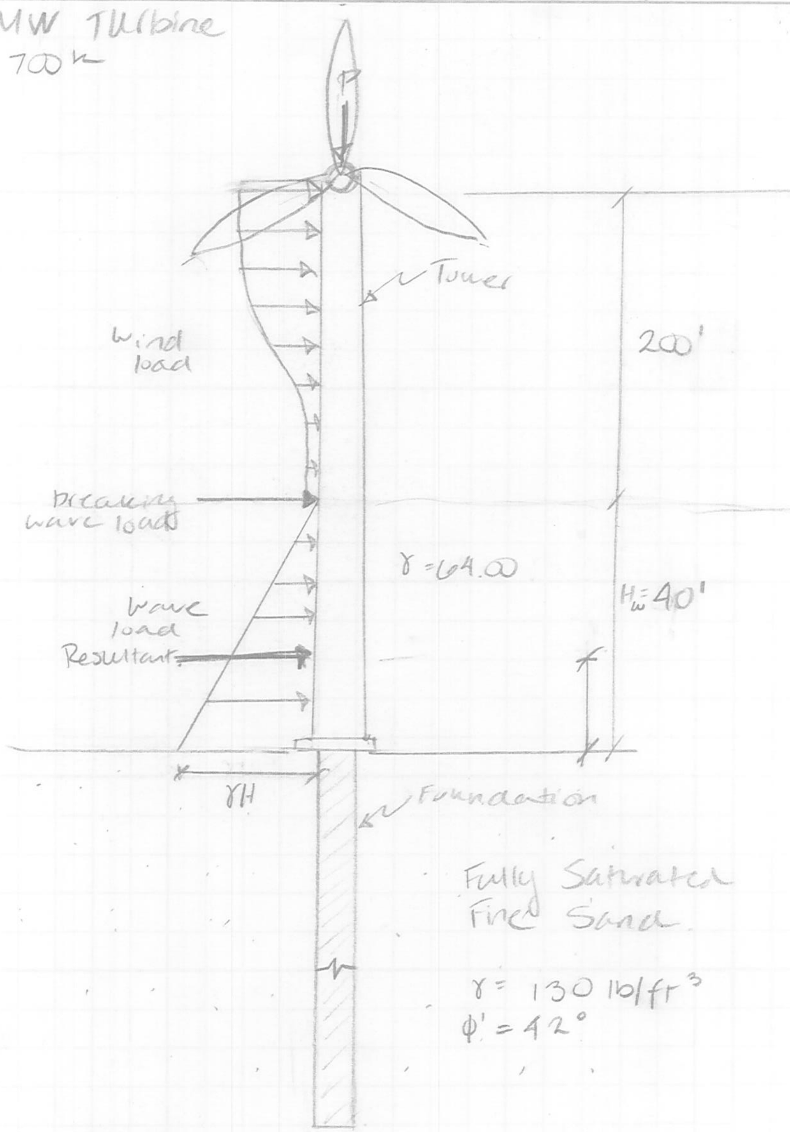
$$T_u = \frac{774.4}{24} - \frac{(6956)(12)(55.5)(1.77)}{70876.53} = 83^k \leq [\phi R_n = 150\text{ ksi}]\ \text{OK}$$

Final design:

28 $1\frac{1}{2}$" rods
Embedment length = 18"
Edge distance = 7.5"
Spacing ~ 1'-5-1/8"

Appendix H: Offshore Wind Turbine Design Sheets and Hand Calculations

Use 3-MW Turbine
$P_{equipment} = 700^k$



TOWER DESIGN (with use of tower design spreadsheet for determining loads.)

TRY: 12.5' φ at base
11' φ at hub
1.00" shell thickness.

DETERMINE AXIAL LOADS.

→ Wt. of equipment @ top of tower ~ 700^k for 3.0 MW Turbine.

→ Wt of steel: = 359.2^k (see excel spreadsheet for multiple calcs of section wt.)

→ wt of ice = 47.03^k (see excel spreadsheet)
*only accounts for portion of tower above sea level

Total Factored $DL = 1.2(700^k) + 1.2(359.2) + 47.03^k$

$= 1318.1^k$

DETERMINE LATERAL LOADS

→ Wind loads for portion of tower above sea level: (see excel sheet for calculations).

$F_{wind} = 106.7\ k$

$M_{wind} = 15370.2\ ft\text{-}k$

$V_{fastest\ mile} = 110\ ft/s$

→ Breaking wave load: (ASCE 7-05 5.4.4)

$F_D = 0.5\ \gamma_w\ C_D\ D H_b^2$

$\gamma_w = 0.064\ kip/ft^3$

$C_D = 1.75$ for round columns

D = Column diameter = 12.5'

$H_b = 0.78\ d_s = 0.78 \times 40' = 31.2'$

$F_D = 0.5(0.064)(1.75)(12.5)(31.2)^2 = 681.4^k$

$M_D = (681.4)(40') = 27256$ ft-kips

→ Water pressure (ASCE 7-05 5.4.3); hydrodynamic power.

$F_{water} = [I\ \frac{1}{2}\ \gamma h^2\ d]$

$I = 2.0$

$\gamma = 0.064\ kip/ft^3$

$h = 40'$

$d = 12.5'$

$F_{water} = (2)\frac{1}{2}(0.064)(40)^2(12.5) = 1280^k$

$M_{water} = (1280^k)\frac{1}{3}(40') = 17066.7$ ft kips

Total Lateral Shear $= 106.7^k + 681.4^k + 1280^k = \underline{2068.1^k}$

Total Moment acting @ base $= 15370.2 + 27256 + 17066.7$

$= \underline{59693.2\ ft\text{-}kips}$

CHECK AXIAL STRENGTH:

height = 240' = 2880"
O.D. = 12.5' = 150"
I.D. = 150 − 2(1") = 148"

$F_y = 36$ ksi
$E = 29000$ ksi

KL/R

$K = 2.0$
$L = 2880$

$$R = \sqrt{\frac{D^2 + d^2}{16}} = \sqrt{\frac{150^2 + 148^2}{16}} = 52.68$$

$$KL/R = \frac{2(2880)}{52.68} = 109.4$$

Check for compact section:

$D/t = 150/1 = 150$

λ_p for compression: N/A
λ_r for compression = 88.61

$D/t = 150 > 88.61$; member is noncompact.

$P_n = F_{cr} A_g$

$$[KL/R = 109.4] \le \left[4.71\sqrt{\frac{E}{F_y}} = 133.68\right]$$

Use $F_{cr} = 0.658^{F_y/F_e} \times F_y$

$$F_e = \frac{\pi^2 E}{(KL/R)^2} = \frac{\pi^2(29000)}{109.4} = 23.94^k$$

$$F_{cr} = 0.658^{(36/23.9)}(36) = 14.20^k$$

$$A_g = \pi R^2 - \pi r^2 = \pi(150/2)^2 - \pi(148/2)^2 = 468.1 \text{ in}^2$$

$$P_n = (14.20^k)(468.1^k) = 8980.8^k$$

$$\phi_c P_n = 0.85(8980.8^k) = 7633^k > [P_u = 1318.1^k]$$ ✓ OK

CHECK FLEXURAL STRENGTH:

1. Yield in strength:

$\gamma M_r \le \phi M_n = \phi M_p = \phi F_y Z$

$Z = \frac{D^3 - d^3}{6} = \frac{150^3 - 148^3}{6} = 22201.33 in^3$

$F_y = 36$ ksi

$\phi M_n = (0.9)(22201.3)(36) = 719323$ in-kips

2. Yield in Local Buckling:
→ Check for compact section.

$D/t = 150$

λ_p for flexure = 56.39
λ_c for flexure = 249.72

$[\lambda_p = 56.34] < [D/t = 150] < [\lambda_c = 249.72]$, tower is non-compact

$M_n = \left[\frac{0.021}{D/t}\frac{E}{F_y} + 1\right] F_y S = \left[\frac{0.021(29000)}{(150)(36 \text{ ksi})} + 1\right](36)(17321.2)$

$M_n = 693886$ ft-kips.

$S = \frac{\pi(D^4 - d^4)}{32D} = \frac{\pi((150)^4 - (148)^4)}{32(150)} \approx 17321.2$

$\phi M_n = (0.9)(693886) = 624497$ in-kips

Yield in strength:

$[M_n = 716318.4 \text{ in-kip}] \le [\phi M_n = 719323.2 \text{ in-kips}]$ ✓ OK

CHECK FOR COMBINED AXIAL + FLEXURAL LOADS.

$\left[\frac{P_u}{\phi P_n} = \frac{1318.1}{7633.6} = 0.175 \right] \leq 0.2$; use equ. H1-1b.

$$\frac{P_u}{2\phi P_n} + \frac{8}{9} B_2 \left[\frac{M_u}{\phi_b M_n} \right] \leq 1.0$$

$P_u = 1318.1$
$\phi P_n = 7633.6$

$$B_2 = \frac{1}{1 - \frac{\alpha \Sigma P_{nt}}{\Sigma P_{e2}}}$$

$\alpha = 1.00$ for LRFD
ΣP_{nt} 1318.1

$$\Sigma P_{e2} = \Sigma R_M \frac{\Sigma HL}{\Delta_H}$$

$R_M = 0.85$ for moment-frame + combined systems

$\Sigma H = 2068$ k

$L = 2880$"

$\Delta H = 6$" from ANSYS Analysis.

$$\Sigma P_{e2} = \frac{0.85(12068)(2880)}{6} = 843795 \text{ k}$$

$$B_2 = \frac{1}{1 - \frac{(1)(1318)}{(843795)}} = 1.002$$

$M_u = 716318.4$ in-kips

$\phi M_n = 719323.2$ in-kips

$$\frac{1318^k}{7633^k} + \frac{8}{9}(1.002)\frac{716318.4}{719323.2} = 0.9729 \leq 1.0 \quad \text{OK}$$

FINAL TOWER DESIGN:

height: 240'
ϕ_{base}: 12.5'
ϕ_{hub}: 11.0'
thickness - 1"

FOUNDATION DESIGN

Since there are large moment loads acting on tower, foundation will be designed for lateral load capacity for shear + moment forces using the p-y method (Coduto 601).

Acceptable lateral deflection = 0.50"

Try B = 12.5'

DESIGN FOR SHEAR LOAD VS. LATERAL DEFLECTION.

$$V_c = \lambda B^2 E R_I \left(\frac{\sigma_p}{E R_I}\right)^m (\epsilon_{50})^n$$

λ = 1.0 for sand
B = 12.5'*12" = 150
E = 29,000 ksi
R_I = 1.00 for solid circular cross-section
σ_p = $2 C_{p\phi}\, \gamma\, B \tan^2(45 + \phi'/2)$

$C_{p\phi} = \phi'/10 = 42°/10 = 4.2$
γ = 130 lb/ft³ = 7.58 e-5 k/ft³
B = 138"
ϕ' = 42°

σ_p = 2(4.2)(7.58 e-5) tan²(45° + 42/2) = 0.4432
m = 0.57 for shear
n = -0.22 for shear.
ϵ_{50} = 0.002 for sand.

$$V_c = (1.0)(150)^2(29000)(1)\left(\frac{0.4432}{29000}\right)^{0.57}(0.002)^{-0.22}$$

V_c = 17113897 k

$$\frac{V}{V_c} = \frac{2068^k}{17113897^k} = 0.000121$$

Using Evans + Duncan Shear load vs. lateral deflection for sand;

$\frac{y_t}{B}$ = 0.0015 ; B = 150" ∴ y_t = (150)(0.0015)
y_t = 0.225" < 0.50" OK.

DESIGN FOR MOMENT LOAD VS. LATERAL DEFLECTION.

$$M_c = \lambda B^3 E R_I \left(\frac{\sigma_p}{E R_I}\right)^m (\epsilon_{50})^n$$

Same values as shown above, except:

m = 0.46 for moment
n = -0.15 for moment.

$M_c = (1.0)(150'')^3(29000)(1)\left(\frac{0.4432}{29000}\right)^{0.46}(0.002)^{-0.15}$

$M_c = 1514433063$ ft · kips

$\frac{M}{M_c} = \frac{59693.2 \text{ ft·kip}}{1514433063 \text{ ft·kip}} = 0.00004$

Using Evans + Duncan Moment load vs. lateral deflection for Sand;

$\frac{y_t}{B} = 0.0003$; B = 150" : $y_t = (150)(0.0003)$
$y_t = 0.045'' < 0.50''$ OK.

DESIGN FOR MAXIMUM MOMENT FROM SHEAR LOADS

$\frac{V}{V_c} = 0.000121$

Using Evans + Duncan shear load vs. maximum moment for sand:

$\frac{M_{max}}{M_c} = 0.0001$; $M_{max} = 0.0001(M_c) = M_{max} = 0.0001(1514433063)$
$M_{max} = 151443$ ft·k > $M_u = 59693$ ft·k
✓OK.

Depth = 20 · ϕ = 20(12.5) = 250'

Weight of Equipment:	700	kips		Axial Load	1318.058907
Height of tower	240	ft		Moment Load	59693.2003
Outer Diameter at base	12.5	ft		Total Shear	2068.12
Outer Diameter at hub	11	ft			
Thickness	1.00	in			
Weight of Steel	490	pcf		t_{ice}	0.0625

Diameter	Height	to	Inner Dia.	OR	IR	Ice Radius
12.5	0	48	12.33333333	6.25	6.166667	6.5
12.125	49	96	11.95833333	6.0625	5.979167	6.3125
11.75	97	144	11.58333333	5.875	5.791667	6.125
11.375	145	192	11.20833333	5.6875	5.604167	5.9375
11	193	240	10.83333333	5.5	5.416667	5.75

			359.1887601		47.03239526																					106.7167	15370.2136
Load	Height	Volume of Steel	Weight of Steel	Volume of Ice	Weight of Ice	Fz	td	D1	D2	D3	D4	D5	Diameter	V(f.m)	z	Kz calc	1 ≤Kz	1 ≤Kz≤2.58	q_z	Gh	Cf	Ar	Ag	e	Ae	Force	Moment
Wave	1	3.250675732	1.592831109					12.5					12.5														
Wave	2	3.250675732	1.592831109					12.5					12.5														
Wave	3	3.250675732	1.592831109					12.5					12.5														
Wave	4	3.250675732	1.592831109					12.5					12.5														
Wave	5	3.250675732	1.592831109					12.5					12.5														
Wave	6	3.250675732	1.592831109					12.5					12.5														
Wave	7	3.250675732	1.592831109					12.5					12.5														
Wave	8	3.250675732	1.592831109					12.5					12.5														
Wave	9	3.250675732	1.592831109					12.5					12.5														
Wave	10	3.250675732	1.592831109					12.5					12.5														
Wave	11	3.250675732	1.592831109					12.5					12.5														
Wave	12	3.250675732	1.592831109					12.5					12.5														
Wave	13	3.250675732	1.592831109					12.5					12.5														
Wave	14	3.250675732	1.592831109					12.5					12.5														
Wave	15	3.250675732	1.592831109					12.5					12.5														
Wave	16	3.250675732	1.592831109					12.5					12.5														
Wave	17	3.250675732	1.592831109					12.5					12.5														
Wave	18	3.250675732	1.592831109					12.5					12.5														
Wave	19	3.250675732	1.592831109					12.5					12.5														
Wave	20	3.250675732	1.592831109					12.5					12.5														
Wave	21	3.250675732	1.592831109					12.5					12.5														
Wave	22	3.250675732	1.592831109					12.5					12.5														
Wave	23	3.250675732	1.592831109					12.5					12.5														
Wave	24	3.250675732	1.592831109					12.5					12.5														
Wave	25	3.250675732	1.592831109					12.5					12.5														
Wave	26	3.250675732	1.592831109					12.5					12.5														
Wave	27	3.250675732	1.592831109					12.5					12.5														
Wave	28	3.250675732	1.592831109					12.5					12.5														
Wave	29	3.250675732	1.592831109					12.5					12.5														
Wave	30	3.250675732	1.592831109					12.5					12.5														
Wave	31	3.250675732	1.592831109					12.5					12.5														
Wave	32	3.250675732	1.592831109					12.5					12.5														
Wave	33	3.250675732	1.592831109					12.5					12.5														
Wave	34	3.250675732	1.592831109					12.5					12.5														
Wave	35	3.250675732	1.592831109					12.5					12.5														
Wave	36	3.250675732	1.592831109					12.5					12.5														
Wave	37	3.250675732	1.592831109					12.5					12.5														
Wave	38	3.250675732	1.592831109					12.5					12.5														
Wave	39	3.250675732	1.592831109					12.5					12.5														
Wave	40	3.250675732	1.592831109					12.5					12.5														
Wind	41	3.250675732	1.592831109	2.596478187	0.145402778	0.6577269	0.06577269	12.5					12.5	110	0.5	0.302086	1	1	30.976	1.69	0.59	12.625	12.625	1	12.625	0.389938	0.20376506
Wind	42	3.250675732	1.592831109	4.050920626	0.226851555	1.02318324	0.10231832	12.5					12.5	110	41.5	1.067673	1.067673173	1.0676732	33.07224	1.69	0.59	12.625	12.625	1	12.625	0.416326	17.3367455
Wind	43	3.250675732	1.592831109	4.060656216	0.227396748	1.0256224	0.10256224	12.5					12.5	110	42.5	1.074961	1.074961362	1.0749614	33.298	1.69	0.59	12.625	12.625	1	12.625	0.419168	17.8742646
Wind	44	3.250675732	1.592831109	4.070188142	0.227930536	1.02801046	0.10280105	12.5					12.5	110	43.5	1.082128	1.082128069	1.0821281	33.52	1.69	0.59	12.625	12.625	1	12.625	0.421963	18.4154
Wind	45	3.250675732	1.592831109	4.079525205	0.228453412	1.0303496	0.10303496	12.5					12.5	110	44.5	1.089178	1.089178042	1.089178	33.73838	1.69	0.59	12.625	12.625	1	12.625	0.424712	18.9600924
Wind	46	3.250675732	1.592831109	4.088675637	0.228965836	1.03264191	0.10326419	12.5					12.5	110	45.5	1.096116	1.096115745	1.0961157	33.95328	1.69	0.59	12.625	12.625	1	12.625	0.427417	19.5082845
Wind	47	3.250675732	1.592831109	4.097647149	0.22946824	1.03488931	0.10348893	12.5					12.5	110	46.5	1.102945	1.102945375	1.1029454	34.16484	1.69	0.59	12.625	12.625	1	12.625	0.43008	20.0599214
Wind	48	3.250675732	1.592831109	4.106446978	0.229961031	1.03709363	0.10370936	12.5					12.5	110	47.5	1.109671	1.109670885	1.1096709	34.37317	1.69	0.59	12.625	12.625	1	12.625	0.432703	20.306802
Wind	49	3.152500961	1.544725471	3.992647391	0.223588254	1.03925657	0.10392566		12.13				12.125	110	48.5	1.116296	1.116296006	1.116296	34.57839	1.69	0.59	12.25	12.25	1	12.25	0.422357	20.5444092
Wind	50	3.152500961	1.544725471	4.000873716	0.224048928	1.04137974	0.10413797		12.13				12.125	110	49.5	1.122824	1.122824262	1.1228243	34.7806	1.69	0.59	12.25	12.25	1	12.25	0.424827	21.0893872
Wind	51	3.152500961	1.544725471	4.008952085	0.224501317	1.04346466	0.10434647		12.13				12.125	110	50.5	1.129259	1.129258983	1.129259	34.97993	1.69	0.59	12.25	12.25	1	12.25	0.427261	21.637513
Wind	52	3.152500961	1.544725471	4.01688801	0.224945729	1.04551274	0.10455127		12.13				12.125	110	51.5	1.135603	1.135603321	1.1356033	35.17645	1.69	0.59	12.25	12.25	1	12.25	0.429662	22.1887418
Wind	53	3.152500961	1.544725471	4.024686698	0.225382455	1.04752534	0.10475253		12.13				12.125	110	52.5	1.14186	1.141860267	1.1418603	35.37026	1.69	0.59	12.25	12.25	1	12.25	0.432029	22.7430308
Wind	54	3.152500961	1.544725471	4.03235307	0.225811772	1.04950372	0.10495037		12.13				12.125	110	53.5	1.148033	1.148032653	1.1480327	35.56146	1.69	0.59	12.25	12.25	1	12.25	0.434365	23.3003381
Wind	55	3.152500961	1.544725471	4.039891783	0.22623394	1.05144911	0.10514491		12.13				12.125	110	54.5	1.154123	1.154123172	1.1541232	35.75012	1.69	0.59	12.25	12.25	1	12.25	0.436669	23.8606234
Wind	56	3.152500961	1.544725471	4.047307248	0.226649206	1.05336262	0.10533626		12.13				12.125	110	55.5	1.160134	1.160134383	1.1601344	35.93632	1.69	0.59	12.25	12.25	1	12.25	0.438943	24.4238478
Wind	57	3.152500961	1.544725471	4.054603647	0.227057804	1.05524536	0.10552454		12.13				12.125	110	56.5	1.166069	1.166068719	1.1660687	36.12014	1.69	0.59	12.25	12.25	1	12.25	0.441189	24.9899734
Wind	58	3.152500961	1.544725471	4.06178495	0.227459957	1.05709834	0.10570983		12.13				12.125	110	57.5	1.171928	1.171928499	1.1719285	36.30166	1.69	0.59	12.25	12.25	1	12.25	0.443406	25.5589634
Wind	59	3.152500961	1.544725471	4.068854928	0.227855876	1.05892254	0.10589225		12.13				12.125	110	58.5	1.177716	1.177715932	1.1777159	36.48093	1.69	0.59	12.25	12.25	1	12.25	0.445595	26.1307823
Wind	60	3.152500961	1.544725471	4.075817166	0.228245761	1.06071889	0.10607189		12.13				12.125	110	59.5	1.183433	1.183433126	1.1834331	36.65802	1.69	0.59	12.25	12.25	1	12.25	0.447759	26.7053955
Wind	61	3.152500961	1.544725471	4.082675076	0.228629804	1.06248827	0.10624883		12.13				12.125	110	60.5	1.189082	1.189082092	1.1890821	36.83301	1.69	0.59	12.25	12.25	1	12.25	0.449896	27.2827694
Wind	62	3.152500961	1.544725471	4.089431909	0.229008187	1.06423152	0.10642315		12.13				12.125	110	61.5	1.194665	1.194664752	1.1946648	37.00594	1.69	0.59	12.25	12.25	1	12.25	0.452008	27.8628715
Wind	63	3.152500961	1.544725471	4.096090761	0.229381083	1.06594944	0.10659494		12.13				12.125	110	62.5	1.200183	1.200182944	1.2001829	37.17687	1.69	0.59	12.25	12.25	1	12.25	0.454096	28.44567
Wind	64	3.152500961	1.544725471	4.102654589	0.229748657	1.06764281	0.10676428		12.13				12.125	110	63.5	1.205638	1.205638427	1.2056384	37.34586	1.69	0.59	12.25	12.25	1	12.25	0.45616	29.031134
Wind	65	3.152500961	1.544725471	4.109126214	0.230111068	1.06931234	0.10693123		12.13				12.125	110	64.5	1.211033	1.211032883	1.2110329	37.51295	1.69	0.59	12.25	12.25	1	12.25	0.458201	29.6192337
Wind	66	3.152500961	1.544725471	4.11550833	0.230468466	1.07095873	0.10709587		12.13				12.125	110	65.5	1.216368	1.216367926	1.2163679	37.67821	1.69	0.59	12.25	12.25	1	12.25	0.46022	30.2099398
Wind	67	3.152500961	1.544725471	4.121803515	0.230820997	1.07258266	0.10725827		12.13				12.125	110	66.5	1.221645	1.221645104	1.2216451	37.84168	1.69	0.59	12.25	12.25	1	12.25	0.462216	30.8032238
Wind	68	3.152500961	1.544725471	4.128014233	0.231168797	1.07418475	0.10741848		12.13				12.125	110	67.5	1.226866	1.226865898	1.2268659	38.0034	1.69	0.59	12.25	12.25	1	12.25	0.464192	31.399058
Wind	69	3.152500961	1.544725471	4.134142845	0.231511999	1.07576563	0.10757656		12.13				12.125	110	68.5	1.232032	1.232031735	1.2320317	38.16342	1.69	0.59	12.25	12.25	1	12.25	0.466146	31.9974156
Wind	70	3.152500961	1.544725471	4.140191612	0.23185073	1.07732586	0.10773259		12.13				12.125	110	69.5	1.237144	1.237143983	1.237144	38.32177	1.69	0.59	12.25	12.25	1	12.25	0.46808	32.59827
Wind	71	3.152500961	1.544725471	4.1461627	0.232185111	1.07886603	0.1078866		12.13				12.125	110	70.5	1.242204	1.242203955	1.242204	38.47851	1.69	0.59	12.25	12.25	1	12.25	0.469995	33.2015957
Wind	72	3.152500961	1.544725471	4.152058189	0.232515259	1.08038665	0.10803867		12.13				12.125	110	71.5	1.247213	1.247212918	1.2472129	38.63367	1.69	0.59	12.25	12.25	1	12.25	0.47189	33.8073676
Wind	73	3.152500961	1.544725471	4.157880073	0.232841284	1.08188826	0.10818883		12.13				12.125	110	72.5	1.252172	1.252172089	1.2521721	38.78728	1.69	0.59	12.25	12.25	1	12.25	0.473766	34.4155612
Wind	74	3.152500961	1.544725471	4.163630268	0.233163295	1.08337133	0.10833713		12.13				12.125	110	73.5	1.257083	1.257082638	1.2570826	38.93939	1.69	0.59	12.25	12.25	1	12.25	0.475624	35.0261528
Wind	75	3.152500961	1.544725471	4.169310615	0.233481394	1.08483636	0.10848364		12.13				12.125	110	74.5	1.261946	1.261945695	1.2619457	39.09003	1.69	0.59	12.25	12.25	1	12.25	0.477464	35.6391189
Wind	76	3.152500961	1.544725471	4.174922882	0.233795681	1.0862838	0.10862838		12.13				12.125	110	75.5	1.266762	1.266762348	1.2667623	39.23923	1.69	0.59	12.25	12.25	1	12.25	0.479287	36.2544368
Wind	77	3.152500961	1.544725471	4.180468771	0.234106251	1.08771408	0.10877141		12.13				12.125	110	76.5	1.271534	1.271533644	1.2715336	39.38703	1.69	0.59	12.25	12.25	1	12.25	0.481092	36.8720842
Wind	78	3.152500961	1.544725471	4.185949921	0.234413196	1.08912763	0.10891276		12.13				12.125	110	77.5	1.276261	1.276260596	1.2762606	39.53345	1.69	0.59	12.25	12.25	1	12.25	0.48288	37.4920394
Wind	79	3.152500961	1.544725471	4.191367907	0.234716603	1.09052486	0.10905249		12.13				12.125	110	78.5	1.280944	1.28094418	1.2809442	39.67853	1.69	0.59	12.25	12.25	1	12.25	0.484652	38.1142811
Wind	80	3.152500961	1.544725471	4.19672425	0.235016558	1.09190617	0.10919062		12.13				12.125	110	79.5	1.285585	1.285585339	1.2855853	39.82229	1.69	0.59	12.25	12.25	1	12.25	0.486408	38.7387885
Wind	81	3.152500961	1.544725471	4.202020412	0.235313143	1.09327192	0.10932719		12.13				12.125	110	80.5	1.290185	1.290184984	1.290185	39.96477	1.69	0.59	12.25	12.25	1	12.25	0.488149	39.3655412
Wind	82	3.152500961	1.544725471	4.207257805	0.235606437	1.09462249	0.10946225		12.13				12.125	110	81.5	1.294744	1.294743995	1.294744	40.10599	1.69	0.59	12.25	12.25	1	12.25	0.489874	39.9945193

Wind		83	3.152500961	1.544725471	4.212437791	0.235896516	1.09595823	0.10959582		12.13				12.125	110	82.5	1.299263	1.299263223	1.2992632	40.24598	1.69	0.59	12.25	12.25	1	12.25	0.491583	40.6257032
Wind		84	3.152500961	1.544725471	4.217561683	0.236183454	1.09727947	0.10972795		12.13				12.125	110	83.5	1.303743	1.30374349	1.3037435	40.38476	1.69	0.59	12.25	12.25	1	12.25	0.493279	41.259074
Wind		85	3.152500961	1.544725471	4.222630751	0.236467322	1.09858655	0.10985865		12.13				12.125	110	84.5	1.308186	1.308185595	1.3081856	40.52236	1.69	0.59	12.25	12.25	1	12.25	0.494959	41.8946127
Wind		86	3.152500961	1.544725471	4.227646218	0.236748188	1.09987978	0.10998798		12.13				12.125	110	85.5	1.31259	1.312590307	1.3125903	40.6588	1.69	0.59	12.25	12.25	1	12.25	0.496626	42.5323012
Wind		87	3.152500961	1.544725471	4.23260927	0.237026119	1.10115947	0.11011595		12.13				12.125	110	86.5	1.316958	1.316958373	1.3169584	40.7941	1.69	0.59	12.25	12.25	1	12.25	0.498279	43.1721215
Wind		88	3.152500961	1.544725471	4.23752105	0.237301179	1.10242591	0.11024259		12.13				12.125	110	87.5	1.321291	1.321290517	1.3212905	40.9283	1.69	0.59	12.25	12.25	1	12.25	0.499918	43.8140559
Wind		89	3.152500961	1.544725471	4.242382666	0.237573429	1.10367939	0.11036794		12.13				12.125	110	88.5	1.325587	1.325587439	1.3255874	41.0614	1.69	0.59	12.25	12.25	1	12.25	0.501543	44.4580872
Wind		90	3.152500961	1.544725471	4.247195188	0.237842931	1.10492019	0.11049202		12.13				12.125	110	89.5	1.32985	1.32984982	1.3298498	41.19343	1.69	0.59	12.25	12.25	1	12.25	0.503156	45.1041984
Wind		91	3.152500961	1.544725471	4.251959653	0.238109741	1.10614857	0.11061486		12.13				12.125	110	90.5	1.334078	1.334078317	1.3340783	41.32441	1.69	0.59	12.25	12.25	1	12.25	0.504756	45.752373
Wind		92	3.152500961	1.544725471	4.256677062	0.238373915	1.1073648	0.11073648		12.13				12.125	110	91.5	1.338274	1.338273571	1.3382736	41.45436	1.69	0.59	12.25	12.25	1	12.25	0.506343	46.4025946
Wind		93	3.152500961	1.544725471	4.261348389	0.23863551	1.10856913	0.11085691		12.13				12.125	110	92.5	1.342436	1.342436201	1.3424362	41.5833	1.69	0.59	12.25	12.25	1	12.25	0.507918	47.0548473
Wind		94	3.152500961	1.544725471	4.265974574	0.238894576	1.10976179	0.11097618		12.13				12.125	110	93.5	1.346567	1.346566811	1.3465668	41.71125	1.69	0.59	12.25	12.25	1	12.25	0.509481	47.7091154
Wind		95	3.152500961	1.544725471	4.270556529	0.239151166	1.11094303	0.1110943		12.13				12.125	110	94.5	1.350666	1.350665984	1.350666	41.83823	1.69	0.59	12.25	12.25	1	12.25	0.511032	48.3653834
Wind		96	3.152500961	1.544725471	4.275095139	0.239405328	1.11211307	0.11121131		12.13				12.125	110	95.5	1.354734	1.35473429	1.3547343	41.96425	1.69	0.59	12.25	12.25	1	12.25	0.512571	48.2708484
Wind		97	3.054326191	1.496619834	4.148436978	0.232312471	1.11327213	0.11132721			11.75			11.75	110	96.5	1.358772	1.358772279	1.3587723	42.08933	1.69	0.59	11.875	11.875	1	11.875	0.498361	48.1629247
Wind		98	3.054326191	1.496619834	4.152756163	0.232554345	1.11442044	0.11144204			11.75			11.75	110	97.5	1.36278	1.36278049	1.3627805	42.21349	1.69	0.59	11.875	11.875	1	11.875	0.499831	48.8048323
Wind		99	3.054326191	1.496619834	4.157035743	0.232794002	1.11555819	0.11155582			11.75			11.75	110	98.5	1.366759	1.366759443	1.3667594	42.33674	1.69	0.59	11.875	11.875	1	11.875	0.501291	49.4486215
Wind		100	3.054326191	1.496619834	4.161276478	0.233031483	1.1166856	0.11166856			11.75			11.75	110	99.5	1.37071	1.370709645	1.3707096	42.4591	1.69	0.59	11.875	11.875	1	11.875	0.50274	50.0942787
Wind		101	3.054326191	1.496619834	4.165479105	0.23326683	1.11780285	0.11178028			11.75			11.75	110	100.5	1.374632	1.374631591	1.3746316	42.58059	1.69	0.59	11.875	11.875	1	11.875	0.504178	50.7417906
Wind		102	3.054326191	1.496619834	4.16964434	0.233500083	1.11891014	0.11189101			11.75			11.75	110	101.5	1.378526	1.378525761	1.3785258	42.70121	1.69	0.59	11.875	11.875	1	11.875	0.505606	51.3911438
Wind		103	3.054326191	1.496619834	4.173772882	0.233731281	1.12000766	0.11200077			11.75			11.75	110	102.5	1.382393	1.382392622	1.3823926	42.82099	1.69	0.59	11.875	11.875	1	11.875	0.507025	52.0423255
Wind		104	3.054326191	1.496619834	4.177865405	0.233960463	1.12109558	0.11210956			11.75			11.75	110	103.5	1.386233	1.386232629	1.3862326	42.93994	1.69	0.59	11.875	11.875	1	11.875	0.508433	52.6953229
Wind		105	3.054326191	1.496619834	4.181922568	0.234187664	1.12217408	0.11221741			11.75			11.75	110	104.5	1.390046	1.390046226	1.3900462	43.05807	1.69	0.59	11.875	11.875	1	11.875	0.509832	53.3501235
Wind		106	3.054326191	1.496619834	4.18594501	0.234412921	1.12324334	0.11232433			11.75			11.75	110	105.5	1.393834	1.393833844	1.3938338	43.1754	1.69	0.59	11.875	11.875	1	11.875	0.511221	54.006715
Wind		107	3.054326191	1.496619834	4.189933354	0.234636268	1.12430351	0.11243035			11.75			11.75	110	106.5	1.397596	1.397595905	1.3975959	43.29193	1.69	0.59	11.875	11.875	1	11.875	0.512601	54.6650851
Wind		108	3.054326191	1.496619834	4.193888204	0.234857739	1.12535476	0.11253548			11.75			11.75	110	107.5	1.401333	1.401332817	1.4013328	43.40769	1.69	0.59	11.875	11.875	1	11.875	0.513971	55.325222
Wind		109	3.054326191	1.496619834	4.19781015	0.235077368	1.12639725	0.11263972			11.75			11.75	110	108.5	1.405045	1.405044981	1.405045	43.52267	1.69	0.59	11.875	11.875	1	11.875	0.515333	55.987114
Wind		110	3.054326191	1.496619834	4.201699766	0.235295187	1.12743112	0.11274311			11.75			11.75	110	109.5	1.408733	1.408732787	1.4087328	43.63691	1.69	0.59	11.875	11.875	1	11.875	0.516686	56.6507494
Wind		111	3.054326191	1.496619834	4.205557608	0.235511226	1.12845653	0.11284565			11.75			11.75	110	110.5	1.412397	1.412396615	1.4123966	43.7504	1.69	0.59	11.875	11.875	1	11.875	0.518029	57.316117
Wind		112	3.054326191	1.496619834	4.209384222	0.235725516	1.12947362	0.11294736			11.75			11.75	110	111.5	1.416037	1.416036835	1.4160368	43.86316	1.69	0.59	11.875	11.875	1	11.875	0.519364	57.9832054
Wind		113	3.054326191	1.496619834	4.213180135	0.235938088	1.13048254	0.11304825			11.75			11.75	110	112.5	1.419654	1.41965381	1.4196538	43.9752	1.69	0.59	11.875	11.875	1	11.875	0.520691	58.6520038
Wind		114	3.054326191	1.496619834	4.216945866	0.236148968	1.13148341	0.11314834			11.75			11.75	110	113.5	1.423248	1.423247891	1.4232479	44.08653	1.69	0.59	11.875	11.875	1	11.875	0.522009	59.3225011
Wind		115	3.054326191	1.496619834	4.220681915	0.236358187	1.13247639	0.11324764			11.75			11.75	110	114.5	1.426819	1.426819425	1.4268194	44.19716	1.69	0.59	11.875	11.875	1	11.875	0.523319	59.9946868
Wind		116	3.054326191	1.496619834	4.224388775	0.236565771	1.13346158	0.11334616			11.75			11.75	110	115.5	1.430369	1.430368748	1.4303687	44.3071	1.69	0.59	11.875	11.875	1	11.875	0.524621	60.6685502
Wind		117	3.054326191	1.496619834	4.228066921	0.236771748	1.13443913	0.11344391			11.75			11.75	110	116.5	1.433896	1.433896188	1.4338962	44.41637	1.69	0.59	11.875	11.875	1	11.875	0.525915	61.3440811
Wind		118	3.054326191	1.496619834	4.231716821	0.236976142	1.13540916	0.11354092			11.75			11.75	110	117.5	1.437402	1.437402066	1.4374021	44.52497	1.69	0.59	11.875	11.875	1	11.875	0.527201	62.0212692
Wind		119	3.054326191	1.496619834	4.235338929	0.23717898	1.13637178	0.11363718			11.75			11.75	110	118.5	1.440887	1.440886696	1.4408867	44.63291	1.69	0.59	11.875	11.875	1	11.875	0.528479	62.7001043
Wind		120	3.054326191	1.496619834	4.238933689	0.237380287	1.13732712	0.11373271			11.75			11.75	110	119.5	1.44435	1.444350385	1.4443504	44.7402	1.69	0.59	11.875	11.875	1	11.875	0.529749	63.3805766
Wind		121	3.054326191	1.496619834	4.242501533	0.237580086	1.1382753	0.11382753			11.75			11.75	110	120.5	1.447793	1.447793432	1.4477934	44.84685	1.69	0.59	11.875	11.875	1	11.875	0.531012	64.0626764
Wind		122	3.054326191	1.496619834	4.246042884	0.237778401	1.13921641	0.11392164			11.75			11.75	110	121.5	1.451216	1.451216129	1.4512161	44.95287	1.69	0.59	11.875	11.875	1	11.875	0.532267	64.7463938
Wind		123	3.054326191	1.496619834	4.249558154	0.237975257	1.14015059	0.11401506			11.75			11.75	110	122.5	1.454619	1.454618764	1.4546188	45.05827	1.69	0.59	11.875	11.875	1	11.875	0.533515	65.4317195
Wind		124	3.054326191	1.496619834	4.253047746	0.238170674	1.14107792	0.11410779			11.75			11.75	110	123.5	1.458002	1.458001615	1.4580016	45.16306	1.69	0.59	11.875	11.875	1	11.875	0.534756	66.118644
Wind		125	3.054326191	1.496619834	4.256512054	0.238364675	1.14199852	0.11419985			11.75			11.75	110	124.5	1.461365	1.461364957	1.461365	45.26724	1.69	0.59	11.875	11.875	1	11.875	0.53599	66.8071581
Wind		126	3.054326191	1.496619834	4.259951461	0.238557282	1.14291249	0.11429125			11.75			11.75	110	125.5	1.464709	1.464709058	1.4647091	45.37083	1.69	0.59	11.875	11.875	1	11.875	0.537216	67.4972527
Wind		127	3.054326191	1.496619834	4.263366343	0.238748515	1.14381993	0.11438199			11.75			11.75	110	126.5	1.468034	1.46803418	1.4680342	45.47383	1.69	0.59	11.875	11.875	1	11.875	0.538436	68.1889188
Wind		128	3.054326191	1.496619834	4.266757066	0.238938396	1.14472093	0.11447209			11.75			11.75	110	127.5	1.471341	1.471340579	1.4713406	45.57625	1.69	0.59	11.875	11.875	1	11.875	0.539648	68.8821474
Wind		129	3.054326191	1.496619834	4.270123989	0.239126943	1.1456156	0.11456156			11.75			11.75	110	128.5	1.474629	1.474628506	1.4746285	45.67809	1.69	0.59	11.875	11.875	1	11.875	0.540854	69.5769299
Wind		130	3.054326191	1.496619834	4.273467462	0.239314178	1.14650402	0.1146504			11.75			11.75	110	129.5	1.477898	1.477898208	1.4778982	45.77937	1.69	0.59	11.875	11.875	1	11.875	0.542054	70.2732576
Wind		131	3.054326191	1.496619834	4.276787828	0.239500118	1.14738629	0.11473863			11.75			11.75	110	130.5	1.48115	1.481149924	1.4811499	45.8801	1.69	0.59	11.875	11.875	1	11.875	0.543246	70.971122
Wind		132	3.054326191	1.496619834	4.280085422	0.239684784	1.1482625	0.11482625			11.75			11.75	110	131.5	1.484384	1.48438389	1.4843839	45.98028	1.69	0.59	11.875	11.875	1	11.875	0.544432	71.6705147
Wind		133	3.054326191	1.496619834	4.283360571	0.239868192	1.14913273	0.11491327			11.75			11.75	110	132.5	1.4876	1.487600337	1.4876003	46.07991	1.69	0.59	11.875	11.875	1	11.875	0.545612	72.3714273
Wind		134	3.054326191	1.496619834	4.286613596	0.240050361	1.14999707	0.11499971			11.75			11.75	110	133.5	1.490799	1.490799492	1.4907995	46.17901	1.69	0.59	11.875	11.875	1	11.875	0.546785	73.0738517
Wind		135	3.054326191	1.496619834	4.289844811	0.240231309	1.1508556	0.11508556			11.75			11.75	110	134.5	1.493982	1.493981574	1.4939816	46.27757	1.69	0.59	11.875	11.875	1	11.875	0.547952	73.7777797
Wind		136	3.054326191	1.496619834	4.293054521	0.240411053	1.1517084	0.11517084			11.75			11.75	110	135.5	1.497147	1.497146803	1.4971468	46.37562	1.69	0.59	11.875	11.875	1	11.875	0.549113	74.4832035
Wind		137	3.054326191	1.496619834	4.296243029	0.24058961	1.15255556	0.11525556			11.75			11.75	110	136.5	1.500295	1.50029539	1.5002954	46.47315	1.69	0.59	11.875	11.875	1	11.875	0.550268	75.190115
Wind		138	3.054326191	1.496619834	4.299410626	0.240766995	1.15339715	0.11533972			11.75			11.75	110	137.5	1.503428	1.503427543	1.5034275	46.57017	1.69	0.59	11.875	11.875	1	11.875	0.551417	75.8985066
Wind		139	3.054326191	1.496619834	4.302557602	0.240943226	1.15423326	0.11542333			11.75			11.75	110	138.5	1.506543	1.506543468	1.5065435	46.66669	1.69	0.59	11.875	11.875	1	11.875	0.55256	76.6083705
Wind		140	3.054326191	1.496619834	4.305684238	0.241118317	1.15506394	0.11550639			11.75			11.75	110	139.5	1.509643	1.509643364	1.5096434	46.76271	1.69	0.59	11.875	11.875	1	11.875	0.553697	77.3196991
Wind		141	3.054326191	1.496619834	4.308790809	0.241292285	1.15588929	0.11558893			11.75			11.75	110	140.5	1.512727	1.512727428	1.5127274	46.85824	1.69	0.59	11.875	11.875	1	11.875	0.554828	78.0324849
Wind		142	3.054326191	1.496619834	4.311877587	0.241465145	1.15670936	0.11567094			11.75			11.75	110	141.5	1.515796	1.515795852	1.5157959	46.95329	1.69	0.59	11.875	11.875	1	11.875	0.555953	78.7467206
Wind		143	3.054326191	1.496619834	4.314944835	0.241636911	1.15752423	0.11575242			11.75			11.75	110	142.5	1.518849	1.518848826	1.5188488	47.04786	1.69	0.59	11.875	11.875	1	11.875	0.557073	79.4623987
Wind		144	3.054326191	1.496619834	4.317992813	0.241807598	1.15833398	0.1158334			11.75			11.75	110	143.5	1.521887	1.521886535	1.5218865	47.14196	1.69	0.59	11.875	11.875	1	11.875	0.558187	78.9107935
Wind		145	2.956151421	1.448514196	4.184463969	0.234329982	1.15913866	0.11591387				11.38		11.375	110	144.5	1.524909	1.524909161	1.5249092	47.23559	1.69	0.59	11.5	11.5	1	11.5	0.541634	78.3433783
Wind		146	2.956151421	1.448514196	4.187379954	0.234493277	1.15993834	0.11599383				11.38		11.375	110	145.5	1.527917	1.527916882	1.5279169	47.32875	1.69	0.59	11.5	11.5	1	11.5	0.542702	79.0406052
Wind		147	2.956151421	1.448514196	4.190277997	0.234655568	1.1607331	0.11607331				11.38		11.375	110	146.5	1.53091	1.530909874	1.5309099	47.42146	1.69	0.59	11.5	11.5	1	11.5	0.543765	79.7392016
Wind		148	2.956151421	1.448514196	4.193158331	0.234816867	1.16152298	0.1161523				11.38		11.375	110	147.5	1.533888	1.533888309	1.5338883	47.51372	1.69	0.59	11.5	11.5	1	11.5	0.544823	80.4391607
Wind		149	2.956151421	1.448514196	4.196021181	0.234977186	1.16230807	0.11623081				11.38		11.375	110	148.5	1.536852	1.536852354	1.5368524	47.60554	1.69	0.59	11.5	11.5	1	11.5	0.545876	81.140476
Wind		150	2.956151421	1.448514196	4.198866772	0.235136539	1.1630884	0.11630884				11.38		11.375	110	149.5	1.539802	1.539802177	1.5398022	47.69691	1.69	0.59	11.5	11.5	1	11.5	0.546924	81.8431408
Wind		151	2.956151421	1.448514196	4.201695321	0.235294938	1.16386406	0.11638641				11.38		11.375	110	150.5	1.542738	1.54273794	1.5427379	47.78785	1.69	0.59	11.5	11.5	1	11.5	0.547967	82.5471489
Wind		152	2.956151421	1.448514196	4.204507043	0.235452394	1.16463509	0.11646351				11.38		11.375	110	151.5	1.54566	1.545659802	1.5456598	47.87836	1.69	0.59	11.5	11.5	1	11.5	0.549004	83.2524937
Wind		153	2.956151421	1.448514196	4.207302148	0.23560892	1.16540155	0.11654015				11.38		11.375	110	152.5	1.548568	1.54856792	1.5485679	47.96844	1.69	0.59	11.5	11.5	1	11.5	0.550037	83.9591691
Wind		154	2.956151421	1.448514196	4.210080842	0.235764527	1.1661635	0.11661635				11.38		11.375	110	153.5	1.551462	1.551462449	1.5514624	48.0581	1.69	0.59	11.5	11.5	1	11.5	0.551065	84.6671687
Wind		155	2.956151421	1.448514196	4.212843328	0.235919226	1.166921	0.1166921				11.38		11.375	110	154.5	1.554344	1.55434354	1.5543435	48.14735	1.69	0.59	11.5	11.5	1	11.5	0.552089	85.3764864
Wind		156	2.956151421	1.448514196	4.215589804	0.236073029	1.16767409	0.11676741				11.38		11.375	110	155.5	1.557211	1.557211342	1.5572113	48.23618	1.69	0.59	11.5	11.5	1	11.5	0.553107	86.0871161
Wind		157	2.956151421	1.448514196	4.218320465	0.236225946	1.16842285	0.11684228				11.38		11.375	110	156.5	1.560066	1.560066	1.560066	48.3246	1.69	0.59	11.5	11.5	1	11.5	0.554121	86.7990517
Wind		158	2.956151421	1.448514196	4.221035503	0.236377988	1.1691673	0.11691673				11.38		11.375	110	157.5	1.562908	1.562907659	1.5629077	48.41263	1.69	0.59	11.5	11.5	1	11.5	0.555131	87.5122874
Wind		159	2.956151421	1.448514196	4.223735104	0.236529166	1.16990752	0.11699075				11.38		11.375	110	158.5	1.565736	1.56573646	1.5657365	48.50025	1.69	0.59	11.5	11.5	1	11.5	0.556135	88.2268172
Wind		160	2.956151421	1.448514196	4.226419455	0.236679489	1.17064355	0.11706435				11.38		11.375	110	159.5	1.568553	1.568552541	1.5685525	48.58748	1.69	0.59	11.5	11.5	1	11.5	0.557136	88.9426352
Wind		161	2.956151421	1.448514196	4.229088734	0.236828969	1.17137543	0.11713754				11.38		11.375	110	160.5	1.571356	1.57135604	1.571356	48.67432	1.69	0.59	11.5	11.5	1	11.5	0.558131	89.6597358
Wind		162	2.956151421	1.448514196	4.231743121	0.236977615	1.17210322	0.11721032				11.38		11.375	110	161.5	1.574147	1.574147089	1.5741471	48.76078	1.69	0.59	11.5	11.5	1	11.5	0.559123	90.3781132
Wind		163	2.956151421	1.448514196	4.23438279	0.237125436	1.17282697	0.1172827				11.38		11.375	110	162.5	1.576926	1.576925821	1.5769258	48.84685	1.69	0.59	11.5	11.5	1	11.5	0.56011	91.0977617
Wind		164	2.956151421	1.448514196	4.237007911	0.237272443	1.17354671	0.11735467				11.38		11.375	110	163.5	1.579692	1.579692365	1.5796924	48.93255	1.69	0.59	11.5	11.5	1	11.5	0.561092	91.8186758
Wind		165	2.956151421	1.448514196	4.239618655	0.237418645	1.17426251	0.11742625				11.38		11.375	110	164.5	1.582447	1.58244685	1.5824468	49.01787	1.69	0.59	11.5	11.5	1	11.5	0.562071	92.54085
Wind		166	2.956151421	1.448514196	4.242215185	0.23756405	1.1749744	0.11749744				11.38		11.375	110	165.5	1.585189	1.5851894	1.5851894	49.10283	1.69	0.59	11.5	11.5	1	11.5	0.563045	93.2642787
Wind		167	2.956151421	1.448514196	4.244797665	0.237708669	1.17568244	0.11756824				11.38		11.375	110	166.5	1.58792	1.587920138	1.5879201	49.18741	1.69	0.59	11.5	11.5	1	11.5	0.564015	93.9889565
Wind		168	2.956151421	1.448514196	4.247366255	0.23785251	1.17638665	0.11763866				11.38		11.375	110	167.5	1.590639	1.590639187	1.5906392	49.27164	1.69	0.59	11.5	11.5	1	11.5	0.564981	94.7148781
Wind		169	2.956151421	1.448514196	4.249921111	0.237995582	1.17708709	0.11770871				11.38		11.375	110	168.5	1.593347	1.593346665	1.5933467	49.35551	1.69	0.59	11.5	11.5	1	11.5	0.565942	95.4420382
Wind		170	2.956151421	1.448514196	4.252462388	0.238137894	1.1777838	0.11777838				11.38		11.375	110	169.5	1.596043	1.596042691	1.5960427	49.43902	1.69	0.59	11.5	11.5	1	11.5	0.5669	96.1704316
Wind		171	2.956151421	1.448514196	4.254990237	0.238279453	1.17847682	0.11784768				11.38		11.375	110	170.5	1.598727	1.598727379	1.5987274	49.52218	1.69	0.59	11.5	11.5	1	11.5	0.567853	96.9000529
Wind		172	2.956151421	1.448514196	4.257504808	0.238420269	1.17916619	0.11791662				11.38		11.375	110	171.5	1.601401	1.601400843	1.6014008	49.60499	1.69	0.59	11.5	11.5	1	11.5	0.568803	97.6308972
Wind		173	2.956151421	1.448514196	4.260006247	0.23856035	1.17985195	0.1179852				11.38		11.375	110	172.5	1.604063	1.604063195	1.6040632	49.68746	1.69	0.59	11.5	11.5	1	11.5	0.569749	98.3629593
Wind		174	2.956151421	1.448514196	4.262494697	0.238699703	1.18053415	0.11805341				11.38		11.375	110	173.5	1.606715	1.606714546	1.6067145	49.76959	1.69	0.59	11.5	11.5	1	11.5	0.57069	99.0962341

Wind	175	2.956151421	1.448514196	4.264970302	0.238838337	1.18121281	0.11812128				11.38		11.375	110	174.5	1.609355	1.609355004	1.609355	49.85138	1.69	0.59	11.5	11.5	1	11.5	0.571628	99.8307166
Wind	176	2.956151421	1.448514196	4.267433201	0.238976259	1.18188799	0.1181888				11.38		11.375	110	175.5	1.611985	1.611984676	1.6119847	49.93284	1.69	0.59	11.5	11.5	1	11.5	0.572562	100.566402
Wind	177	2.956151421	1.448514196	4.269883529	0.239113478	1.18255971	0.11825597				11.38		11.375	110	176.5	1.614604	1.614603666	1.6146037	50.01396	1.69	0.59	11.5	11.5	1	11.5	0.573493	101.303285
Wind	178	2.956151421	1.448514196	4.272321423	0.23925	1.18322801	0.1183228				11.38		11.375	110	177.5	1.617212	1.617212079	1.6172121	50.09476	1.69	0.59	11.5	11.5	1	11.5	0.574419	102.041362
Wind	179	2.956151421	1.448514196	4.274747015	0.239385833	1.18389293	0.11838929				11.38		11.375	110	178.5	1.61981	1.619810016	1.61981	50.17524	1.69	0.59	11.5	11.5	1	11.5	0.575342	102.780626
Wind	180	2.956151421	1.448514196	4.277160435	0.239520984	1.18455451	0.11845545				11.38		11.375	110	179.5	1.622398	1.622397578	1.6223976	50.25539	1.69	0.59	11.5	11.5	1	11.5	0.576261	103.521074
Wind	181	2.956151421	1.448514196	4.279561812	0.239655461	1.18521278	0.11852128				11.38		11.375	110	180.5	1.624975	1.624974864	1.6249749	50.33522	1.69	0.59	11.5	11.5	1	11.5	0.577176	104.262701
Wind	182	2.956151421	1.448514196	4.281951272	0.239789271	1.18586778	0.11858678				11.38		11.375	110	181.5	1.627542	1.627541971	1.627542	50.41474	1.69	0.59	11.5	11.5	1	11.5	0.578088	105.005502
Wind	183	2.956151421	1.448514196	4.28432894	0.239922421	1.18651954	0.11865195				11.38		11.375	110	182.5	1.630099	1.630098995	1.630099	50.49395	1.69	0.59	11.5	11.5	1	11.5	0.578996	105.749473
Wind	184	2.956151421	1.448514196	4.286694937	0.240054916	1.18716809	0.11871681				11.38		11.375	110	183.5	1.632646	1.632646031	1.632646	50.57284	1.69	0.59	11.5	11.5	1	11.5	0.579901	106.494608
Wind	185	2.956151421	1.448514196	4.289049384	0.240186766	1.18781346	0.11878135				11.38		11.375	110	184.5	1.635183	1.635183171	1.6351832	50.65143	1.69	0.59	11.5	11.5	1	11.5	0.580802	107.240904
Wind	186	2.956151421	1.448514196	4.291392401	0.240317974	1.1884557	0.11884557				11.38		11.375	110	185.5	1.637711	1.637710507	1.6377105	50.72972	1.69	0.59	11.5	11.5	1	11.5	0.5817	107.988356
Wind	187	2.956151421	1.448514196	4.293724102	0.24044855	1.18909483	0.11890948				11.38		11.375	110	186.5	1.640228	1.640228131	1.6402281	50.80771	1.69	0.59	11.5	11.5	1	11.5	0.582594	108.736959
Wind	188	2.956151421	1.448514196	4.296044604	0.240578498	1.18973088	0.11897309				11.38		11.375	110	187.5	1.642736	1.642736131	1.6427361	50.88539	1.69	0.59	11.5	11.5	1	11.5	0.583485	109.48671
Wind	189	2.956151421	1.448514196	4.29835402	0.240707825	1.19036388	0.11903639				11.38		11.375	110	188.5	1.645235	1.645234594	1.6452346	50.96279	1.69	0.59	11.5	11.5	1	11.5	0.584372	110.237603
Wind	190	2.956151421	1.448514196	4.30065246	0.240836538	1.19099387	0.11909939				11.38		11.375	110	189.5	1.647724	1.647723608	1.6477236	51.03989	1.69	0.59	11.5	11.5	1	11.5	0.585257	110.989634
Wind	191	2.956151421	1.448514196	4.302940035	0.240964642	1.19162088	0.11916209				11.38		11.375	110	190.5	1.650203	1.650203257	1.6502033	51.1167	1.69	0.59	11.5	11.5	1	11.5	0.586137	111.742799
Wind	192	2.956151421	1.448514196	4.305216852	0.241092144	1.19224493	0.11922449				11.38		11.375	110	191.5	1.652674	1.652673627	1.6526736	51.19322	1.69	0.59	11.5	11.5	1	11.5	0.587015	110.659941
Wind	193	2.85797665	1.400408559	4.166951797	0.233349301	1.19286605	0.11928661					11	11	110	192.5	1.655135	1.655134799	1.6551348	51.26946	1.69	0.59	11.125	11.125	1	11.125	0.568719	109.559498
Wind	194	2.85797665	1.400408559	4.169134584	0.233471537	1.19348428	0.11934843					11	11	110	193.5	1.657587	1.657586855	1.6575869	51.34541	1.69	0.59	11.125	11.125	1	11.125	0.569561	110.291371
Wind	195	2.85797665	1.400408559	4.171307266	0.233593207	1.19409964	0.11940996					11	11	110	194.5	1.66003	1.660029877	1.6600299	51.42109	1.69	0.59	11.125	11.125	1	11.125	0.570401	111.024324
Wind	196	2.85797665	1.400408559	4.17346994	0.233714317	1.19471215	0.11947122					11	11	110	195.5	1.662464	1.662463943	1.6624639	51.49648	1.69	0.59	11.125	11.125	1	11.125	0.571237	111.758354
Wind	197	2.85797665	1.400408559	4.175622705	0.233834871	1.19532186	0.11953219					11	11	110	196.5	1.664889	1.664889133	1.6648891	51.57161	1.69	0.59	11.125	11.125	1	11.125	0.57207	112.493456
Wind	198	2.85797665	1.400408559	4.177765656	0.233954877	1.19592878	0.11959288					11	11	110	197.5	1.667306	1.667305522	1.6673055	51.64646	1.69	0.59	11.125	11.125	1	11.125	0.572901	113.229628
Wind	199	2.85797665	1.400408559	4.179898887	0.234074338	1.19653293	0.11965329					11	11	110	198.5	1.669713	1.669713188	1.6697132	51.72104	1.69	0.59	11.125	11.125	1	11.125	0.573728	113.966865
Wind	200	2.85797665	1.400408559	4.18202249	0.234193259	1.19713436	0.11971344					11	11	110	199.5	1.672112	1.672112206	1.6721122	51.79535	1.69	0.59	11.125	11.125	1	11.125	0.574552	114.705164
Wind	201	2.85797665	1.400408559	4.184136556	0.234311647	1.19773308	0.11977331					11	11	110	200.5	1.674503	1.67450265	1.6745026	51.86939	1.69	0.59	11.125	11.125	1	11.125	0.575374	115.44452
Wind	202	2.85797665	1.400408559	4.186241177	0.234429506	1.19832911	0.11983291					11	11	110	201.5	1.676885	1.676884593	1.6768846	51.94318	1.69	0.59	11.125	11.125	1	11.125	0.576192	116.184929
Wind	203	2.85797665	1.400408559	4.188336441	0.234546841	1.19892249	0.11989225					11	11	110	202.5	1.679258	1.679258107	1.6792581	52.0167	1.69	0.59	11.125	11.125	1	11.125	0.577008	116.926389
Wind	204	2.85797665	1.400408559	4.190422435	0.234663656	1.19951324	0.11995132					11	11	110	203.5	1.681623	1.681623264	1.6816233	52.08996	1.69	0.59	11.125	11.125	1	11.125	0.57782	117.668895
Wind	205	2.85797665	1.400408559	4.192499246	0.234779958	1.20010139	0.12001014					11	11	110	204.5	1.68398	1.683980133	1.6839801	52.16297	1.69	0.59	11.125	11.125	1	11.125	0.57863	118.412444
Wind	206	2.85797665	1.400408559	4.194566958	0.23489575	1.20068695	0.12006869					11	11	110	205.5	1.686329	1.686328785	1.6863288	52.23572	1.69	0.59	11.125	11.125	1	11.125	0.579437	119.157032
Wind	207	2.85797665	1.400408559	4.196625656	0.235011037	1.20126995	0.12012699					11	11	110	206.5	1.688669	1.688669287	1.6886693	52.30822	1.69	0.59	11.125	11.125	1	11.125	0.580241	119.902655
Wind	208	2.85797665	1.400408559	4.198675422	0.235125824	1.20185041	0.12018504					11	11	110	207.5	1.691002	1.691001707	1.6910017	52.38047	1.69	0.59	11.125	11.125	1	11.125	0.581043	120.649309
Wind	209	2.85797665	1.400408559	4.200716337	0.235240115	1.20242836	0.12024284					11	11	110	208.5	1.693326	1.693326112	1.6933261	52.45247	1.69	0.59	11.125	11.125	1	11.125	0.581841	121.396993
Wind	210	2.85797665	1.400408559	4.202748483	0.235353915	1.20300383	0.12030038					11	11	110	209.5	1.695643	1.695642568	1.6956426	52.52422	1.69	0.59	11.125	11.125	1	11.125	0.582637	122.1457
Wind	211	2.85797665	1.400408559	4.204771938	0.235467229	1.20357682	0.12035768					11	11	110	210.5	1.697951	1.697951139	1.6979511	52.59573	1.69	0.59	11.125	11.125	1	11.125	0.583431	122.895429
Wind	212	2.85797665	1.400408559	4.20678678	0.23558006	1.20414737	0.12041474					11	11	110	211.5	1.700252	1.70025189	1.7002519	52.667	1.69	0.59	11.125	11.125	1	11.125	0.584221	123.646176
Wind	213	2.85797665	1.400408559	4.208793088	0.235692413	1.2047155	0.12047155					11	11	110	212.5	1.702545	1.702544883	1.7025449	52.73803	1.69	0.59	11.125	11.125	1	11.125	0.585009	124.397937
Wind	214	2.85797665	1.400408559	4.210790936	0.235804292	1.20528123	0.12052812					11	11	110	213.5	1.70483	1.704830182	1.7048302	52.80882	1.69	0.59	11.125	11.125	1	11.125	0.585794	125.15071
Wind	215	2.85797665	1.400408559	4.2127804	0.235915702	1.20584458	0.12058446					11	11	110	214.5	1.707108	1.707107849	1.7071078	52.87937	1.69	0.59	11.125	11.125	1	11.125	0.586577	125.904489
Wind	216	2.85797665	1.400408559	4.214761553	0.236026647	1.20640557	0.12064056					11	11	110	215.5	1.709378	1.709377943	1.7093779	52.94969	1.69	0.59	11.125	11.125	1	11.125	0.587357	126.659273
Wind	217	2.85797665	1.400408559	4.21673447	0.23613713	1.20696422	0.12069642					11	11	110	216.5	1.711641	1.711640525	1.7116405	53.01978	1.69	0.59	11.125	11.125	1	11.125	0.588134	127.415058
Wind	218	2.85797665	1.400408559	4.218699222	0.236247156	1.20752055	0.12075206					11	11	110	217.5	1.713896	1.713895654	1.7138957	53.08963	1.69	0.59	11.125	11.125	1	11.125	0.588909	128.17184
Wind	219	2.85797665	1.400408559	4.220655879	0.236356729	1.20807459	0.12080746					11	11	110	218.5	1.716143	1.71614339	1.7161434	53.15926	1.69	0.59	11.125	11.125	1	11.125	0.589682	128.929616
Wind	220	2.85797665	1.400408559	4.222604513	0.236465853	1.20862635	0.12086264					11	11	110	219.5	1.718384	1.718383789	1.7183838	53.22866	1.69	0.59	11.125	11.125	1	11.125	0.590452	129.688384
Wind	221	2.85797665	1.400408559	4.224545192	0.236574531	1.20917585	0.12091759					11	11	110	220.5	1.720617	1.72061691	1.7206169	53.29783	1.69	0.59	11.125	11.125	1	11.125	0.591219	130.448139
Wind	222	2.85797665	1.400408559	4.226477986	0.236682767	1.20972311	0.12097231					11	11	110	221.5	1.722843	1.722842809	1.7228428	53.36678	1.69	0.59	11.125	11.125	1	11.125	0.591984	131.208879
Wind	223	2.85797665	1.400408559	4.22840296	0.236790566	1.21026816	0.12102682					11	11	110	222.5	1.725062	1.725061541	1.7250615	53.43551	1.69	0.59	11.125	11.125	1	11.125	0.592746	131.970601
Wind	224	2.85797665	1.400408559	4.230320183	0.23689793	1.210811	0.1210811					11	11	110	223.5	1.727273	1.727273162	1.7272732	53.50401	1.69	0.59	11.125	11.125	1	11.125	0.593506	132.7333
Wind	225	2.85797665	1.400408559	4.232229718	0.237004864	1.21135166	0.12113517					11	11	110	224.5	1.729478	1.729477726	1.7294777	53.5723	1.69	0.59	11.125	11.125	1	11.125	0.594263	133.496975
Wind	226	2.85797665	1.400408559	4.234131633	0.237111371	1.21189016	0.12118902					11	11	110	225.5	1.731675	1.731675286	1.7316753	53.64037	1.69	0.59	11.125	11.125	1	11.125	0.595019	134.261622
Wind	227	2.85797665	1.400408559	4.236025989	0.237217455	1.21242652	0.12124265					11	11	110	226.5	1.733866	1.733865897	1.7338659	53.70823	1.69	0.59	11.125	11.125	1	11.125	0.595771	135.027238
Wind	228	2.85797665	1.400408559	4.237912851	0.23732312	1.21296075	0.12129607					11	11	110	227.5	1.73605	1.736049611	1.7360496	53.77587	1.69	0.59	11.125	11.125	1	11.125	0.596522	135.793819
Wind	229	2.85797665	1.400408559	4.239792282	0.237428368	1.21349286	0.12134929					11	11	110	228.5	1.738226	1.738226479	1.7382265	53.8433	1.69	0.59	11.125	11.125	1	11.125	0.59727	136.561364
Wind	230	2.85797665	1.400408559	4.241664342	0.237533203	1.21402289	0.12140229					11	11	110	229.5	1.740397	1.740396552	1.7403966	53.91052	1.69	0.59	11.125	11.125	1	11.125	0.598015	137.329868
Wind	231	2.85797665	1.400408559	4.243529092	0.237637629	1.21455084	0.12145508					11	11	110	230.5	1.74256	1.742559882	1.7425599	53.97753	1.69	0.59	11.125	11.125	1	11.125	0.598759	138.09933
Wind	232	2.85797665	1.400408559	4.245386593	0.237741649	1.21507674	0.12150767					11	11	110	231.5	1.744717	1.744716519	1.7447165	54.04434	1.69	0.59	11.125	11.125	1	11.125	0.5995	138.869745
Wind	233	2.85797665	1.400408559	4.247236904	0.237845267	1.21560059	0.12156006					11	11	110	232.5	1.746867	1.746866512	1.7468665	54.11094	1.69	0.59	11.125	11.125	1	11.125	0.600238	139.641111
Wind	234	2.85797665	1.400408559	4.249080083	0.237948485	1.21612242	0.12161224					11	11	110	233.5	1.74901	1.749009909	1.7490099	54.17733	1.69	0.59	11.125	11.125	1	11.125	0.600975	140.413425
Wind	235	2.85797665	1.400408559	4.250916189	0.238051307	1.21664224	0.12166422					11	11	110	234.5	1.751147	1.75114676	1.7511468	54.24352	1.69	0.59	11.125	11.125	1	11.125	0.601709	141.186685
Wind	236	2.85797665	1.400408559	4.252745278	0.238153736	1.21716007	0.12171601					11	11	110	235.5	1.753277	1.753277112	1.7532771	54.30951	1.69	0.59	11.125	11.125	1	11.125	0.602441	141.960886
Wind	237	2.85797665	1.400408559	4.254567407	0.238255775	1.21767593	0.12176759					11	11	110	236.5	1.755401	1.755401012	1.755401	54.3753	1.69	0.59	11.125	11.125	1	11.125	0.603171	142.736027
Wind	238	2.85797665	1.400408559	4.256382632	0.238357427	1.21818982	0.12181898					11	11	110	237.5	1.757519	1.757518507	1.7575185	54.44089	1.69	0.59	11.125	11.125	1	11.125	0.603899	143.512105
Wind	239	2.85797665	1.400408559	4.258191007	0.238458696	1.21870178	0.12187018					11	11	110	238.5	1.75963	1.759629643	1.7596296	54.50629	1.69	0.59	11.125	11.125	1	11.125	0.604624	144.289116
Wind	240	2.85797665	1.400408559	4.259992588	0.238559585	1.2192118	0.12192118					11	11	110	239.5	1.761734	1.761734466	1.7617345	54.57149	1.69	0.59	11.125	11.125	1	11.125	0.605347	

Breaking Wave

681.408 27256.32

Water pressure

1280 17066.66667

User Input				
Overall height	240	ft =	2880	in
Diameter at Base	12.5	ft=	150	in
Shell Thickness	1	in		
Strength of Steel	36	ksi		
Modulus of Elasticity	29000	ksi		

ID	148
S	17321.16062
Z	22201.33333
r	52.68064161
I	1299087.047

Axial Strength	
Factored Load	1318.058907
Factored Strength	7633.644538
Pn	8980.75828
Fcr	19.18566541
KL/r	109.3380761
4.71*sqrt(E/Fy)	133.680683
Fe	23.94165422
Fcr for KL/r≤4.71*sqrt(E/Fy)	19.18566541
Fcr for KL/r>4.71*sqrt(E/Fy)	20.99683075
Ag	468.0973054
Check for Compact section:	
D/t	150
λp	
λc	88.61111111
noncompact	
Axial Strength:	OK

Flexure Strength	
Factored Load	716318.40
Factored Strength	719323.20
Yielding Mn	799248
Local Buckling	693885.6946
Check for Compact section:	
D/t	150
λp	56.38888889
λc	249.7222222
non-compact	
Flexure Strength:	OK

Combined Loads				
Combined Loading	0.972893	≤1.0	**OK**	
Pu/Pc	0.172664			
For Pu/Pc≥0.2	1.059225			
For Pu/Pc<0.2	0.972893	624497.1		
Magnification Factors				
B2	1.001565			
Pnt	1318.059			
Pe2	843794.86			
∑H	2068.12			
ΔH	6			
L	2880			