Architectural Engineering Final Thesis Report

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April 9, 2010

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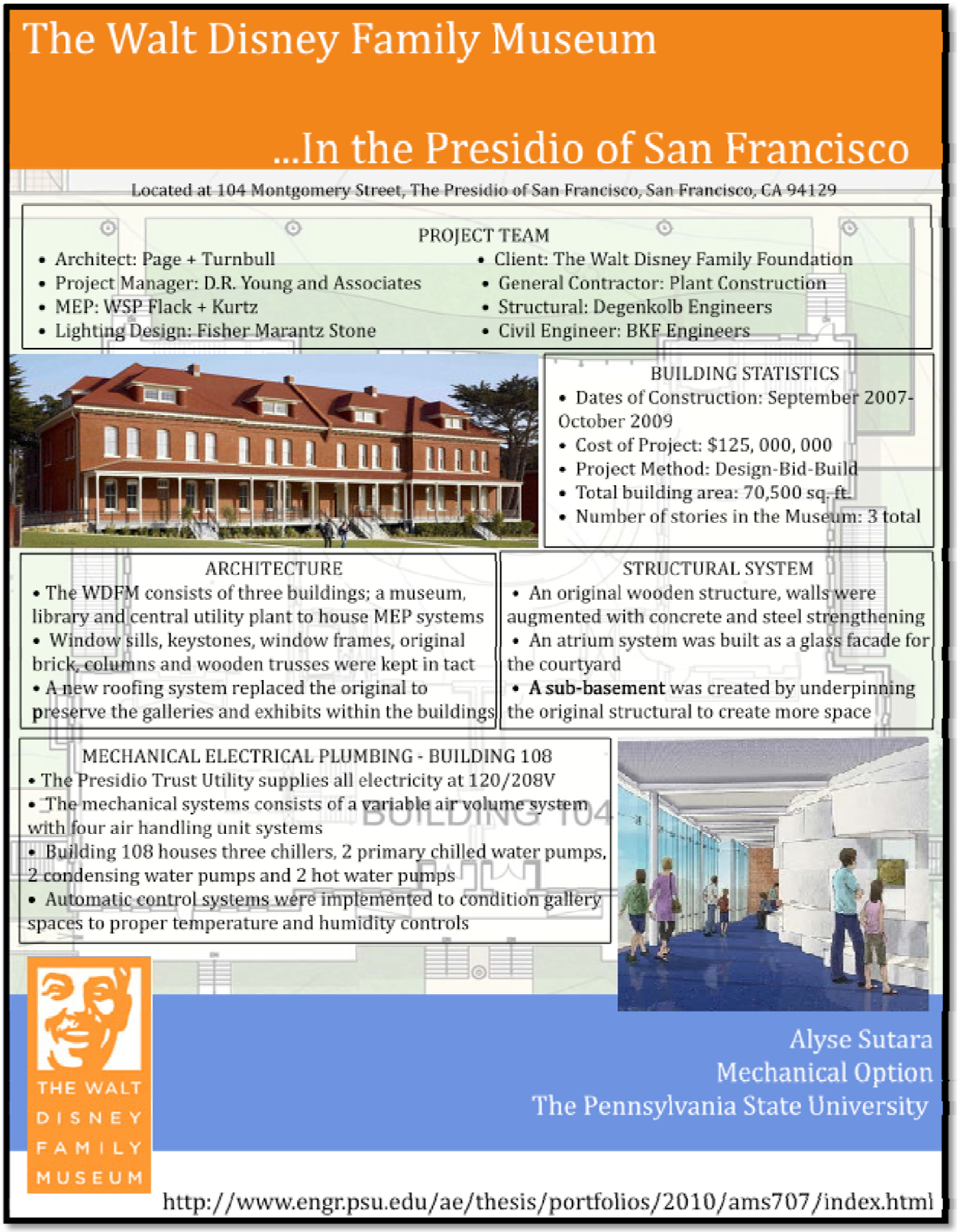
THE WALT DISNEY FAMILY MUSEUM
THE PRESIDIO OF SAN FRANCISCO, CALIFORNIA



The Walt Disney Family Museum

...In the Presidio of San Francisco

Located at 104 Montgomery Street, The Presidio of San Francisco, San Francisco, CA 94129

PROJECT TEAM

- Architect: Page + Turnbull
- Project Manager: D.R. Young and Associates
- MEP: WSP Flack + Kurtz
- Lighting Design: Fisher Marantz Stone
- Client: The Walt Disney Family Foundation
- General Contractor: Plant Construction
- Structural: Degenkolb Engineers
- Civil Engineer: BKF Engineers

BUILDING STATISTICS

- Dates of Construction: September 2007-October 2009
- Cost of Project: $125, 000, 000
- Project Method: Design-Bid-Build
- Total building area: 70,500 sq. ft.
- Number of stories in the Museum: 3 total

ARCHITECTURE

- The WDFM consists of three buildings; a museum, library and central utility plant to house MEP systems
- Window sills, keystones, window frames, original brick, columns and wooden trusses were kept in tact
- A new roofing system replaced the original to preserve the galleries and exhibits within the buildings

STRUCTURAL SYSTEM

- An original wooden structure, walls were augmented with concrete and steel strengthening
- An atrium system was built as a glass facade for the courtyard
- **A sub-basement** was created by underpinning the original structural to create more space

MECHANICAL ELECTRICAL PLUMBING - BUILDING 108

- The Presidio Trust Utility supplies all electricity at 120/208V
- The mechanical systems consists of a variable air volume system with four air handling unit systems
- Building 108 houses three chillers, 2 primary chilled water pumps, 2 condensing water pumps and 2 hot water pumps
- Automatic control systems were implemented to condition gallery spaces to proper temperature and humidity controls

THE WALT DISNEY FAMILY MUSEUM

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http://www.engr.psu.edu/ae/thesis/portfolios/2010/ams707/index.html

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ACKNOWLEDGMENTS

As this senior thesis project has been a very challenging and demand learning experience, it is necessary to thank the people who have made this achievement possible.

First, I would like to thank the Walt Disney Family Foundation for allowing me to use their Museum as the focus of this research. I found the Museum to be an intricate, original idea behind the Disney family's amazing legacy and truly appreciate the opportunity to dissect an equally amazing historical building.

I would also like to thank WSP Flack + Kurtz for my summer internship in San Francisco during 2009. F+K was the WDFM's MEP engineering company and I was able to gain owner permission to study this building. WSP F+K also shipped my drawings and documents across the country from California, which I am very grateful for as well. Thank you so much Todd See, James Gronek, and Yulien Wong.

Also, a special thank you to Page +Turnbull, the WDFM architects and historical preservationists. Sean Fine and Carolyn Kiernat have gone out of their way to provide answers to my questions, emails and provide further information.

Next, I would like to thank the Penn State Architectural Engineering faculty and staff. Without the AE department, I would not have been able to complete this project. Dr. Stephen Treado, my thesis advisor, has guided me through this project on numerous occasions while allowing me to voice my personal thoughts and opinions on this project. Professors Robert Holland and Kevin Parfitt also have done a superb job of guiding another AE class through the thesis process. They have always been very understanding of the hardships and learning experiences we students have endured throughout this year.

Finally, I would like to thank my family and friends for being available throughout this entire process. My mother and father have supported me effortlessly throughout this year as well as my past four. They have always been just a phone call away, to listen, to laugh, to encourage and to say, “Toughen up, you’ll get through it.” Without their love and support, my college life would not have been the amazing journey that it has become. My brother, Aaron, for his wit and sarcasm, for understanding me without question and always being available despite his own busy schedule. My roommate Karen Mowery, San Francisco darling Holly Haber, best friends Caitie Larkin and Patrick Mest, tech squad Joel Boucher and Hermes Frangoudis, as well as my boyfriend David Sivin; without my closest support group, I think I would have lost it long before now.

Thanks guys, I love you all so so much.

THE
WALT DISNEY
FAMILY MUSEUM
AT THE PRESIDIO OF SAN FRANCISCO

Executive Summary

The Walt Disney Family Museum is an example of the fundamental idea of architectural design. A creative initial concept that started with a few small sketches and ideas, placed on paper over time, which later turned into a fully restored, historical renovation project filled with rich history both inside and out.

This final senior design project summarizes the building's past history, renovation process, existing building and corresponding building systems as well as newly implemented engineering technologies meant to provide a solution for previous issues. The key point to keep in mind when reviewing this report is the method in which the building analysis was conducted. The existing conditions were dissected and examined to understand how the building was created to be today's structure. The building was evaluated to find compliance with current standards and codes while individual systems were studied to understand the overall architectural design decisions and processes.

After the existing structure was studied and concluded, the next major portion of research was meant to improve the current systems while keeping in mind time and cost effectiveness. For the WDFM, in particular, the newly implemented design concepts were found to be more passive types of engineering technologies. The Museum's restoration and historical stance would not allow bold or colorful design choices. Modern design ideas would have conflicted with the Museum's military history as well as the style and look of the Presidio's campus.

Therefore, in the Museum's existing engineering systems, the building abides by ASHRAE Standards, IBC Codes and National Historic Landmark Guidelines. Much of the original structure was kept and restored to the original condition, while a sub-basement was added to the structure as well as an infill area on the Western façade to create a "glass cover" for the existing courtyard. The engineering systems were found to be mostly energy efficient while abiding by California Code Title 24. The

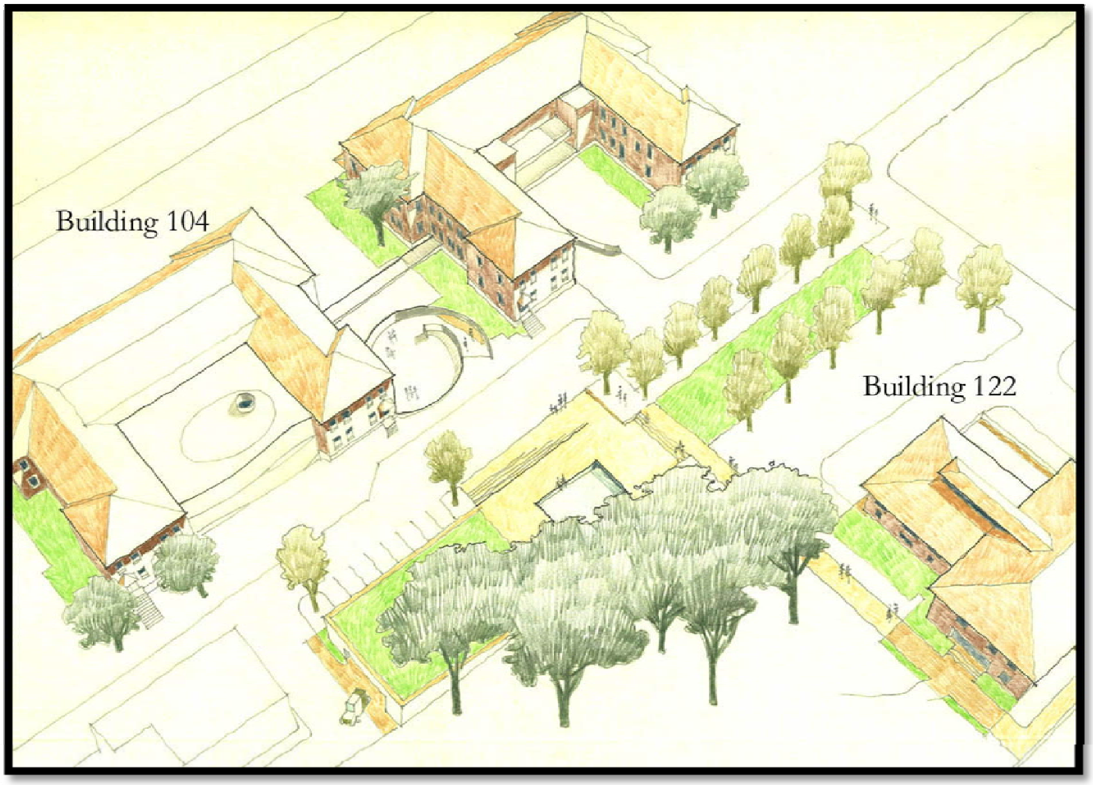
mechanical system has a centralized heating and cooling plant which condenses all of the water systems under one roof: chilled water, hot water and condenser water, while providing service to the Museum and the Archive building. One of the few criticisms found during the existing conditions analysis was the lack of energy harvesting technologies. Today's society is pushing for more energy independence, which can collectively result in ease on the demands placed on energy companies, a decrease in the cost of energy over time as well as energy emissions due to consumption. With this concept in mind, the new system design concepts were created.

After the existing conditions analysis, the building was found to be lacking an environmental consideration. Instead of manually cooling and heating service water for the building, why not use the Earth's natural constant temperatures to condition the service water? Therefore, a geothermal heat pump system, the depth of this study, was implemented in place of the centralized heating and cooling plant, Building 108.

Next, the Museum was found to have a guided path for visitors to view the exhibits and galleries, taking them through the life of Walter Disney as well as his created characters and cartoons. The idea to harvest the movement of the visitors through the Museum came from this guided path. If each visitor walks over certain areas so many times throughout the day, can their force over a certain area be harvested and converted to energy? The answer is yes. The piezoelectric flooring placed strategically throughout the Museum stemmed from this observation.

Finally, while the building itself is mostly efficient, the site and weather surrounding the building was not being used to fuel the buildings daily energy loads. We, as people going from place to place, with daily objectives and lives, often view weather with disdain. For example, try driving in the rain or hail over a long distance, reading a newspaper in high wind conditions while waiting for the bus or even enjoying the afternoon sun without proper protection. However, if weather is viewed as a force of nature, comparable to a mechanical force, this energy can be harvested, possibly stored, for use within the building. The idea for a rainwater collection device stemmed from this idea.

Ultimately, this report will show the study of the Walt Disney Family Museum's existing building as well as the newly designed technologies meant to correspond with the results from the original study. The proposed systems make the building more energy efficient, energy independent as well as environmentally conscious, all while improving and creating a better home for the history of the life of Walter Disney.



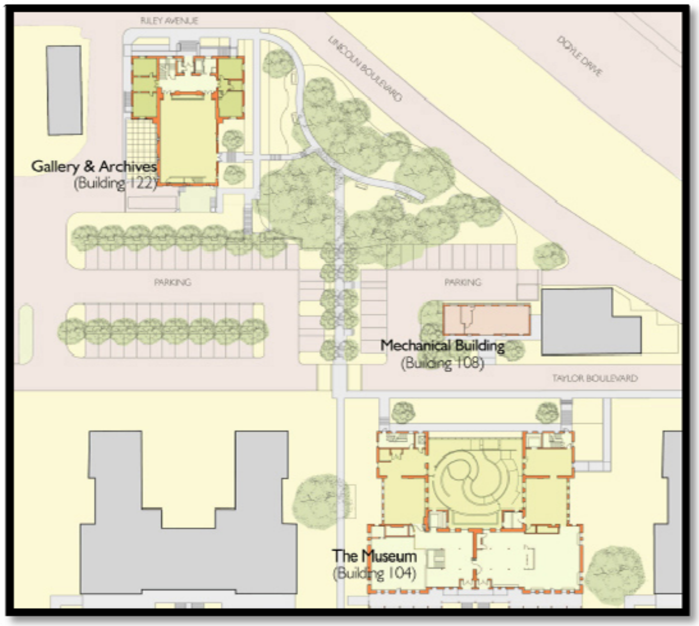
Above, Campus Map, courtesy of Page+Turnbull

The Walt Disney Family Museum
Original Concept and Building History

The Walt Disney Family Museum is historical renovation project located in the Presidio of San Francisco. The original idea behind the Museum came from Walt Disney's daughter, Diane Disney Miller, in order to properly display the life and work of the man behind the magic. The Walt Disney Family Foundation, a non-profit organization established by the Disney family in which Mrs. Miller plays an active role, approached Page and Turnbull, the project architects with the idea in September 2005.

With the Disney family's home located in Northern California, San Francisco was an ideal location for the Museum project. Walt Disney, a veteran of World War I, had an immense amount of respect for the American military and therefore, the Presidio, a former army post for over 200 years, serving the Spanish, Mexican and American armies, made an ideal location for the project.

The Museum, which is also identified as Building 104, occupies former army barracks, which were originally built in 1897, which housed various troops and army purposes until 1994. This building was the ideal home for the Museum, which showcases impressive views of the Golden Gate Bridge as well as the San Francisco Bay and also shares the neighborhood with other famous tenants, such as George Lucas Films.



The WDFM campus layout, locating each of the three buildings. (Right)

The WDFM consists of three buildings within the project. The original design objectives required that spaces be provided for a Museum consisting of galleries, exhibits, offices and a lecture hall. The project also needed a space for art archives, restorations areas and library space as well as all necessary utilities associated with the buildings. Therefore, three buildings were renovated within the campus. Building 104, the Museum building, houses the galleries, displays, lecture halls, learning areas and some offices for the Museum Staff. Building 122, houses the art archives and preservation spaces as well as more offices while Building 108 houses the MEP system.

While the entire space of Building 108, 1,174 ft^2, is dedicated solely to the MEP systems, Building 104 has five (5) levels within the building. Four of the five levels are gallery spaces, exhibits, lecture halls and office space while the sub-basement houses the four air handling units. Therefore, the Museum has 52,090 ft^2 of occupied space, while 7,305 ft^2 dedicated to ductwork and air handling unit space.

Finally, it is important to take note that the WDFM campus falls under the category of National Historic Landmark (NHL). A structure labeled as a National Historic Landmark, as stated by the National Park service, has been determined "a nationally significant historic place designated by the Secretary of the Interior because they possess exceptional value or quality in illustrating or interpreting the heritage of the United States." While the Presidio encourages adaptive use of the buildings within the park, the preservation of the original structure, character and landscape must be maintained while abiding by the Secretary of Interiors Standards for Rehabilitation of Historic Properties.

While this historical project required a large amount of research and dedication that required the design team to work within the limits of redeveloping a NHL, the Walt Disney Family Museum contributes to the community of the Presidio and more importantly, reaches its ultimate goal of properly displaying the life and legacy of Walt Disney to the world.

Existing Building Systems Summary

Architecture Summary

As stated previously, the project consists of three buildings, which will house a museum, library and central utility plant to honor the late Walt Disney and family. These three historic buildings will be part of a rehabilitation project within the Presidio of San Francisco, a historic army post turned into a national park. The architects, Page and Turnbull, well known for their architectural design, historic preservation and urban planning, worked with the Presidio to ensure proper guidelines were abided by within the design phases.

Historical Requirements

The Presidio of San Francisco is a federally managed public space with private tenants that make up a small city within this National Park, formal military installation, as well as historic district. The Presidio Trust is a federal corporation that manages all construction and redevelopment within the park. Any project development within the Presidio must comply with Historic Preservation requirements and the Trust must approve all building and occupancy permits.

During construction, much of the building was preserved and reused such as the existing window sills, keystones, window frames, original brick, existing walls, columns, wooden trusses, all depending on the status of deterioration and current conditions.

Building Envelope Summary

The buildings within the Walt Disney Family Foundation Museum campus consist of exterior facades, which are composed of existing, reinforced brick masonry that was cleaned with warm low-pressure water wash to remove biological growth as well as existing stains. Most of the building envelope was kept intact as much as possible in order to preserve the historic structure.

Window support consists of repaired sandstone windowsill and overhead anchored, channeled keystone elements. Window framing consists of existing salvaged steel window frames, which are modified to be compatible with new locking devices in conjunction with the security system. Most windows also have acoustical glazing in areas where needed. All doors were replaced, interior as well as exterior. Exterior doors are hollow metal or wooden depending on location within building.

Construction Methods

Typical administrative requirements were placed upon Plant Construction during the project, such as a formal schedule in a horizontal bar format which was to be approved by the owner. Coordination of the structural and MEP systems were also required. Quality requirements, such as mock-ups, manufacturer's field services and independent lab testing were to be used when necessary.

During the construction process, a difference between the terms repaired, rehabilitation and replace must first be understood. Repair, as per the building specifications, is understood to be a second option where preservation cannot uphold the material or system for mid- to long-term use. The different aspects of the building, if needed, were to be repaired instead of replaced when necessary. During the construction phase, as much of the original materials and structure were to be preserved and protected. Uses of traditional materials and techniques were also encouraged during the construction in order to recreate an older style of building.

During cleaning phases, Plant Construction was asked to aim for achieving 85% clean, instead of 100% clean because as per the specifications, damaged to historic materials occur within the final 15% of cleaning.

A Historic Preservation Architect as well as a Restoration Specialist were both part of the construction phases, which both were required to have numerous years of experience.

Structural System

A new foundation system was laid for the basement theater area as well as HVAC equipment and electrical equipment within Building 104. This foundation was built by underpinning the existing structure, creating concrete columns and brick walls, and finally filling in the walls with shotcrete and rebar. The existing structure was kept intact as possible which consisted of wooden trusses with brick walls. The floors were reconnected and the walls throughout the entire building, like the sub-basement level, were filled with shotcrete and rebar in order to provide additional support. Steel roof deck consists of an acoustical roof deck, non-composite type, and galvanized steel sheet with plan vertical flute faces perforated with holes staggered on center. Other roof decking consists of non-composite steel sheet with a galvanized coating. The roofing was tied into the existing brick walls. Within the center of the building, a two-level ADA compliant ramp was built in order to take the visitor from Disney's past to present. Much discussion and thought was put into this element of the building.

Electrical System

The Presidio Trust supplies electrical service to the Walt Disney Family Museum campus in the form of 160-volt primary, 120/208 volt secondary. In Building 104, the main electrical room and main switchgear is located in the sub-basement in Room 003 that consists of 2,500A, 120/208V, 3-phase, 4-wire. Building

108, the electrical room is found in Room 000 and consists of 2,000A, 120/208V, 3-phase, 4-wire service. Building 122, the electrical room is found in Room 005, 800A, 120/208V, 3-phase, 4-wire electricity.

A generator for the campus is found within Building 108 and provides power to emergency loads. The generator is one radiator cooled, diesel fuel fired standby engine supplying 300kW/375kVA 120/208V, 3-phase, 4-wire electricity and is fueled by 300-gallons of oil fuel which can provide power for loads up to 8-hours.

Emergency power is supplied to emergency/life safety loads and optional loads, which are wired to two automatic transfer switches, found in the generator room of Building 108. Life safety systems consist of exit signs, egress lighting fixtures and fire management systems while optional loads consist of air handling system equipment used to maintain environmental control of the galleries where art storage is located, sump pumps and sewage ejector pumps, building management systems, security systems and telecom systems.

Acoustical Considerations

Acoustical considerations were taken into account for certain areas of the building such as the gallery spaces, learning areas and the lecture hall. Minimum airflow rates were chosen in order to help prevent draft and wind noises throughout the ducts. Within some areas of the buildings, acoustical lining was also placed within the ducts in order to reduce noise.

The Museum's Existing Mechanical System

As the Museum is located in San Francisco, California, design conditions were moderate in terms of design. The following tables display design data from the American Society of Refrigeration and Air Conditioning Engineering as well as general location data collected.

Table 1: General Located Information

Geographical Data: San Francisco, CA	
Location	The Presidio
Latitude	37°
Longitude	122°
Environment	Urban City

Table 2: ASHRAE Design Conditions

Design Conditions as per ASHRAE and Building Requirements		
Seasonal Loads	Dry Bulb Temperature	Wet Bulb Temperature
Cooling Loads (Summer)	75°F (0.4%)	63°F (0.4%)
Heating Loads (Winter)	40°F (99.6%)	-
Indoor Design Conditions	68-70°F (±2°F)	-

Within the Museum's campus, Building 108 houses the central heating and central cooling plant, which supplies hot water, chilled water and condenser water for Building 104 and Building 122. This concept of a central plant was ideal because it allows the major HVAC components to be consolidated into one centralized location for maintenance and repairs without disturbing the visitors or employees within the

Museum. Also within the Museum, sound and vibration was also a sensitive issue, therefore, the central plant eliminates these disturbances as well.

The system consists of a central chilled water plant, heating water plant, condenser water loop as well as distributed air system. The boiler heats hot water for use by the buildings and air handling units and two pumps supply the water. The chiller provides chilled water and condenser water by processing water through the condenser and evaporator, accordingly.

Existing Mechanical System Components within the WDFM

Central Chilled Water Plant

The central chilled water plant consists of three (3) 254 ton maximum capacity, electric powered, water cooled screw chillers. The chillers evaporatively cool the chilled glycol and water mixture to 40°F using R-134A refrigerant. The chilled water is then pumped to the buildings for use by the coils. One primary chilled inline water pump with a 435 GPM capacity pumps the chilled water to Buildings 104 and Building 122 for use, while a secondary chilled water pump with a variable frequency drive as well as a 435 GPM capacity returns the water. Both primary and secondary pumps have additional pumps on standby for use when needed. Pressure gauges, thermometers and flow meters ensure the chilled water is leaving the plant at the right temperature, pressure and velocity for proper use by the buildings.

After the buildings receive the water, the coils chill the air by using the chilled water, that air is supplied to the appropriate spaces. Then, the water is pumped back into the chiller system to reduce the temperature once again for reuse. From the schematic drawings, one can see the chiller evaporatively cools the chilled glycol and water mixture, which is then pumped to the buildings for use by the coils. After the coils chill the air by using the chilled water, that air is supplied to the appropriate spaces. Then, the water is then pumped back into the chiller system to reduce the temperature once again for reuse. This set-up is also applicable for the hot water system except the central piece of equipment is a boiler instead of a chiller.

As shown on the schematic drawing for the cooling tower, the condenser water serves the cooling tower and the condenser portion of the chiller. The screw compressor increases the pressure of the refrigerant and after passing through the condenser, transfers heat to the condenser water. The condenser water then goes through a heat rejection process via the cooling towers and then is pumped back to the condenser portion of the chiller. The chemical feed pumps are used to clean the condenser water in order to prevent mold and other particle build-up. This process is continued while the chillers are in operation to meet the building's demands.

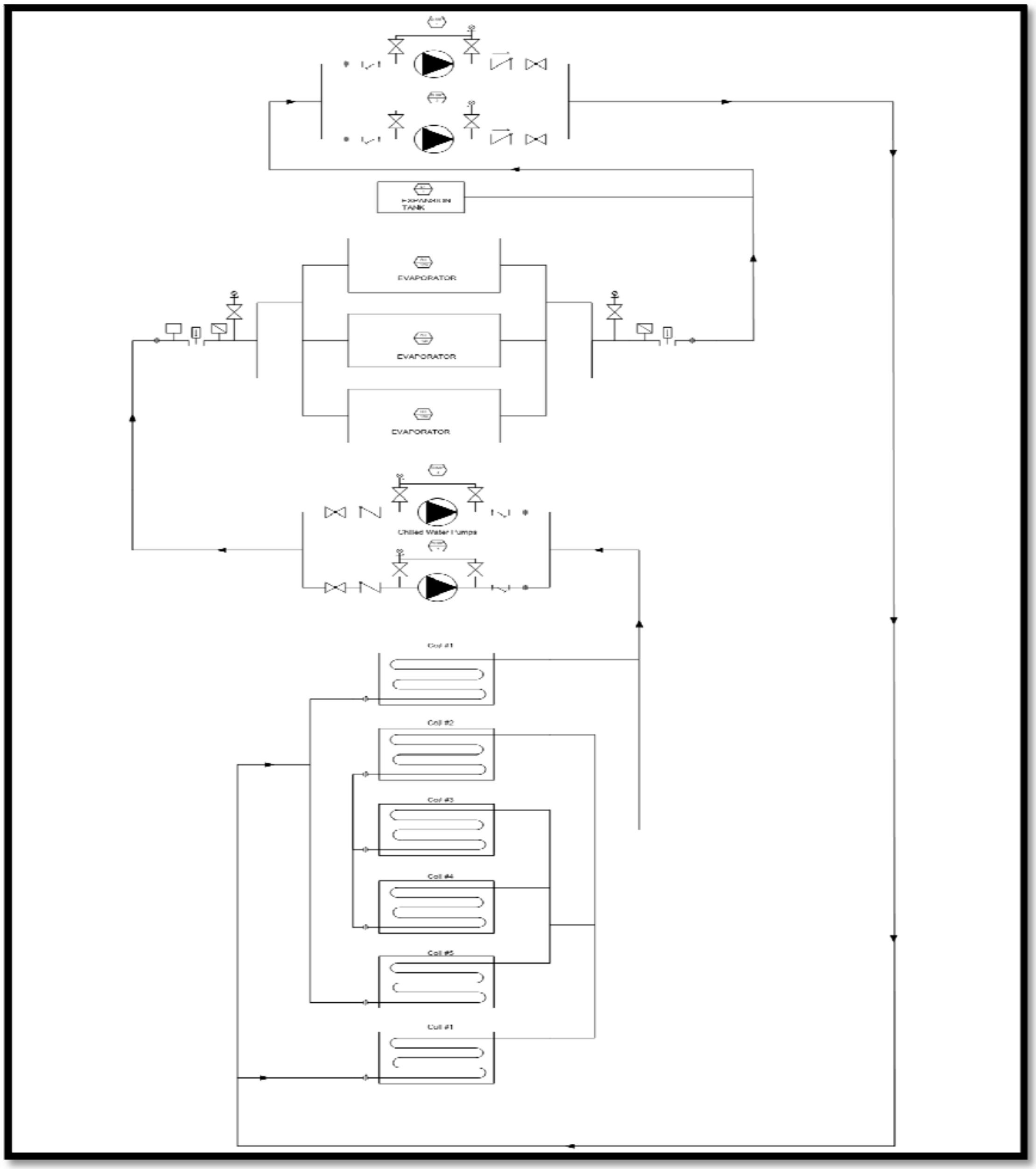


Chart 1: Schematic Drawing of the Chilled Water System within the Museum

Hot Water Plant

To provide hot water to the buildings, two natural gas fueled, condensing type boilers, each with a 860 MBtu output capacity, which provide heating for the system. Water enters the boiler, at 60 GPM and is heated to 170°F which is then pumped to the buildings by an inline, primary hot water pump with a 60 GPM capacity on a variable frequency drive. Both the boiler system and hot water system pump have equal components on standby for use if the building demands are measured necessary. The hot water is then pumped to Building 104 and Building 122 for use by the air distribution systems.

Condenser Water System

In order to process the chilled water in the central chiller plant, a cooling tower uses a heat rejection process to reduce the temperature of the condenser water. The cooling tower, like the chillers, is located in Building 108 and has a total capacity of 260 tons. The process begins with the screw compressor within each of the chillers, which increases the pressure of the refrigerant and after passing through the condenser, transfers heat to the condenser water. The condenser water then goes through a heat rejection process via the cooling towers, which reduce the temperature to 80°F. The flow is measured by a globe value then enters through a check valve before it entering the condenser pump. The water continues through the condenser pump that has a 740 GPM capacity while another pump with the same capacity is on standby and used if necessary. After leaving the pump, the water is measured by a pressure gauge, pressure cock and goes through a "Y" type strainer to filter debris and particles out of the water. Chemical feed pumps are used to clean the condenser water in order to prevent mold and other particle build-up. This process is continued while the chillers are in operation to meet the building's demands.

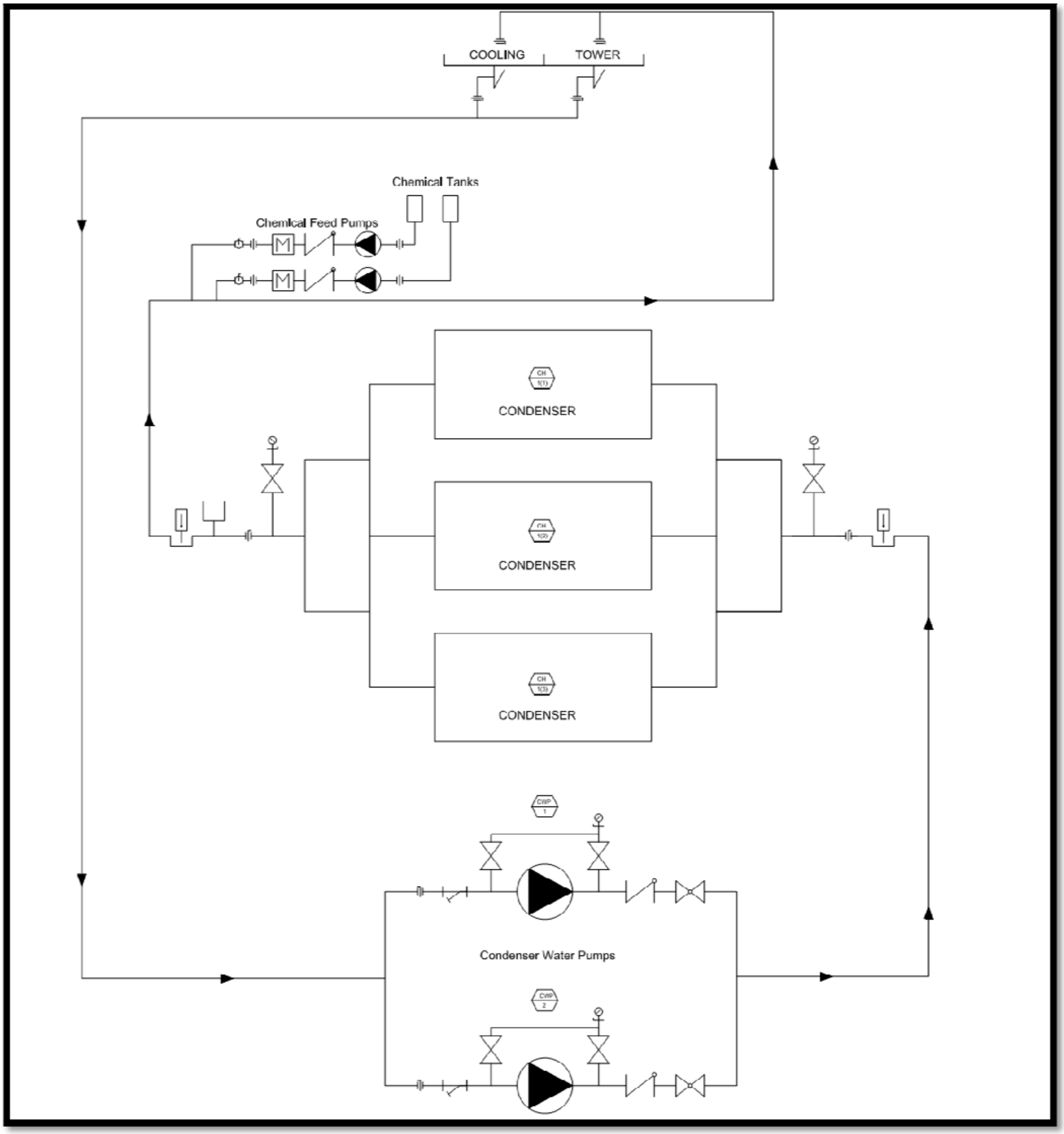


Chart 2: Schematic Drawing of the Condensor Water System within the Museum

Generator

Also located within Building 108, a radiator cooled, diesel fuel fired standby generator provides power to emergency loads. This generator is rated 500kW/625kVA, 120/208V, 3-phase, 4 wire. Emergency power is provided to air handling system equipment used to maintain the environmental control in the gallery and display areas, sump pumps and sewage ejector pumps, fire management system as well as other components of the building.

The generator is also provided with a separate fuel oil tank, which can provide power to emergency loads for 72 hours.

Air Distribution System

Within Building 104, all air supplied to the spaces is conditioned by the four air handling units that are located in the sub-basement of the building. The AHUs condition and circulate air for use throughout the Museum. These units supply air throughout the building upwards throughout the ductwork.

The four AHUs within the Museum provide supply heating and cooling air to the spaces as well as ventilation air on a variable frequency drive which provides air based on the needs of the spaces. These units can supply a maximum of 88,000 cfm of total airflow with the minimum outside airflow totaling 15,800 cfm (Table 3). The air supplied to the spaces ranges from 54°F to 70°F depending on the loads as well as the outdoor air temperatures. AHUs 1, 2,and 3 service the entire Museum building while AHU 4 is dedicated solely to the Lecture Hall space. After the air handling units condition the air needed by the spaces, the supply air is distributed to the spaces through pressure independent modules and VAV boxes.

The air handling units contain coils, which hot water and chilled water flow through in order to cool or heat the air based on the loads within the building. The return air moves throughout the pressure differences within the building, with the negative pressure in the sub-basement pulling the air back through the building. This air is then conditioned with new outside air in order to provide further ventilation through the spaces. An economizer is also located within each of the air handling units so that energy can be conserved based on the outside air conditions versus the re-circulated conditions.

Five fan coil units are also located throughout the building on the basement level and first floor level. These units provide 8,935 cfm to spaces when determined necessary.

The buildings also have exhaust fans located in restrooms, kitchens and also in telecommunications closets.

Table 3: WDFM AHUs in Building 104

Air Handling Units within Building 104		
Air Handling Unit	Total Airflow CFM (Supply Air)	Outside Air CFM (Ventilation Air)
AHU-104-1	28,000	5,200
AHU-104-2	34,000	5,100
AHU-104-3	22,000	3,000
AHU-104-4	4,000	2,500
Totals	88,000	15,800

Energy Load Analysis: Trane Trace Conclusion

In creating an energy model for the Museum, information was gathered about the initial design conditions, located in Table 1. After inputting the location and weather data for the city, the next step in creating an appropriate energy modeling analysis was to define the building materials found within the Museum. These materials are located in Table 4.

Table 4: The Museum's Building Materials

Building Component	Type of Material	U-Value (Btu/hr-ft^2-°F)
Slab	4" LW Concrete	0.2126
Roof	Attic Roof, 6" Insulation	0.048
Wall	Wood-framed, brick façade	0.089
Partition	Drywall	0.388
Windows	¼" Single Pane	0.95
Windows (Infill area)	Insulating Tinted	0.60

The next step in creating the model was to define room areas and room heights, which were calculated by hand from the drawings. Room heights were taken as 10 feet with 2 feet of ceiling spaces. Areas were taken from previous analysis calculated in past projects.

Building lighting and equipment loads are defined by individual space uses. The Museum has higher lighting loads due to the artistic, theater style lighting within the Exhibit Spaces, Media Explosion Areas and Galleries. Also, the Museum does not utilize natural day lighting due to the historical preservation requirements that required the architect to keep as much of the original building, the structure as well as the façade intact. The Lecture Hall in the Basement Level also has high lighting loads as the space requires appropriate lighting for events and is also located in the basement.

These same areas and the Learning Areas also have heavy equipment loads due to interactive displays, movie projects and audio exhibits.

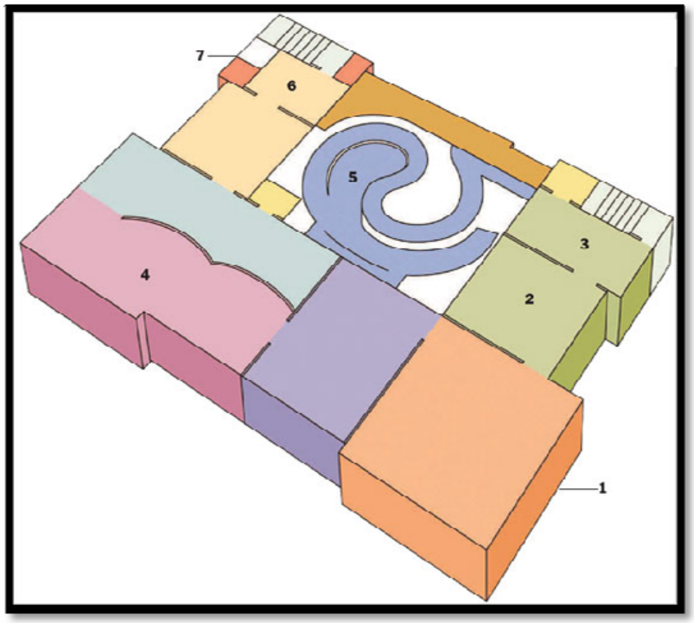
Table 5: Building Electrical Loads in Individual Zones

Building Electrical Loads as Individual Spaces		
Spaces	Lighting (W/ft^2)	Equipment (W/ft^2)
Exhibit Spaces, Media Explosions	6	3
Gallery Spaces	6	3
Lecture Hall	3	1400 W
Learning Areas	1.5	1400 W
General Offices	1.2	0.5
Corridor	1.5	0.0
Bookstore	1.5	0.0
Conference Rooms	1.2	0.0
Lobby	1.5	1.5
Reception	1.5	0.5
Restaurant/Dining	1.5	1.5
Telephone/Data	1.5	350W

Within the next step of building the energy model, occupant loads and necessary outdoor air must be factored into the model as well. In most cases, the occupancy loads were determined using the furniture drawings in order to appropriately calculate loads. For example, in the Learning Areas, 24 desks are located within the room in addition to 2 instructor desks and therefore, 26 people may occupy the area. However, not all of the design occupancy loads were available from the design documents. Therefore, typical people loads and ventilation rates per occupants were taken from the Trane Trace library. The chart below shows values that were inputted in the program when design occupancy loads could not be calculated using the drawings.

Table 6: Design Occupancy and Outside Air Considerations

Designed Occupancy and Outside Air as Individual Spaces		
Spaces	People (ft^2/person)	Outside Air (cfm/person)
Exhibit Spaces, Media Explosions	75	20
Gallery Spaces	75	20
Lecture Hall	125 persons	20
Learning Areas	75	20
General Offices	Varies per office	Operable windows
Corridor	-	0.05 cfm/ft^2
Bookstore	50	15
Conference Rooms	20	20
Lobby	33.3	15
Reception	16.7	15
Restaurant/Dining	15	20
Telephone/Data	143	20



The energy model room inputs were not inputted into the program as exterior zones versus interior zones, however, instead the Museum was broken down into the 9 different gallery zones, learning areas, lecture hall as well as different offices on the attic level. The diagram to the right shows how the galleries were selected (Disregard the numbering). The final energy analysis results are listed in Table 6.

(Above: Gallery Layout; Credit NY Times)

A Trane Trace energy model was created by the original design team and used in calculating loads. Therefore, the results are within range of the design documents.

Table 7: Trane Trace Analysis Result Compared to Design Documents

AHU	Trane Trace Calculations	Design Document Calculations
Cooling Load	159.99 ft^2/ton	138.25 ft^2/ton
Heating Load	18.02 Btuh/ft^2	19.65Btuh/ft^2
Total Supply Air	1.71 cfm/ft^2	2.21 cfm/ft^2
Ventilation Supply Air	0.3365 cfm/ft^2	0.4884 cfm/ft^2
Outside Air Percentage	19.7%	22.1%

Annual Energy Consumption and Operating Cost

Within the Museum, the largest load within the building is the lighting system followed by receptacles. When analyzing the results of the Trane energy load generation, this makes sense because the lighting loads are so large due to the uses within the spaces as well as the lack of natural day lighting incorporated into the building. The Museum, as a protected historical building, was forced to keep as much of the façade and structure in tact as possible, including the original windows. The original wooden widows with 1/4” single pane glass are 1.5’ x 3.5ft’ with a total area of each window equaling 5.5 ft^2.

The loads on the receptacles come from the projectors, interactive displays, audio exhibits and other electronic education tools.

Total heating consumption is very small, totaling only 5.7% of the overall energy consumption within the building each year. Due to the mild weather within San Francisco as well as the heating from the lighting and receptacles, heating loads are much smaller than most other buildings such as office buildings, retail centers, etc.

Total cooling loads equal 6.9% of the building total energy consumption while the Auxiliary loads total 25.8% of the total energy consumption.

Table 8 Yearly Energy Consumption within WDFM

Total Energy Consumption within Building per Year				
Energy Load Type	Electrical Consumption (kWh)	Gas Consumption (kBtu)	Water Consumption (1000 gals)	Percentage of Total Energy
Primary Heating	-	247,947	-	4.8%
Heating Accessories	13,140	-	-	0.9%
Cooling Compressor	83,281	-	-	5.4%
Tower/Condenser Fans	10,093	-	764	0.7%
Condenser Pump	8,035	-	-	0.5%
Cooling Accessories	4,816	-	-	0.3%
Supply Fans	119,160	-	-	7.8%
Pumps	19,455	-	-	1.3%
Base Utilities	256,666	-	-	16.8%
Lighting	628,448	-	-	41.1%
Receptacles	313,984	-	-	20.5%
Totals	1,457,078	247,947	764	100%

Pacific Gas and Electric Utility Company bills the Walt Disney Family Foundation per therm each month. The Museum consumes 2479 therms per year, therefore, it falls under the category of consuming 123.1 therms and up. The Customer Charge per day is the highest amount billed at $2.14936 multiplied by 365 days per year for an amount of $784.52, a Procurement Chare totaling $1,271.08 and a Transportation Charge of $257.93 for a total year cost of $2,313.54.

The Presidio Trust Utility Building provides electricity at a constant cost of $0.141 per kWh. Therefore, the cost of electricity to the Walt Disney Family Museum totals $205, 447.98 each year.

The Presidio Trust also provides water to the Museum at a rate of $2.77 per kgal. Therefore, the total cost of providing water to the system totals $2,116.28

Table 9 Utility Rates from the Presidio Trust Utility Company and PG&E

Utility Rates from the Presidio Trust Utility Billing	
Water Consumption Rate	$2.77 kgal
Electricity Rate	$0.141 kW/h

Gas Rates from Pacific Gas and Energy (G-NR1 Schedule Type)	
Customer Charge (per day)	$2.14936
Procurement Charge (per therm)	$0.51274
Transportation Charge (per therm)	$0.10405
Total Cost per Year	$2313.54

The table below shows a break-down of the cost of each energy load. Once again, the lighting and receptacle loads are the largest energy consumers. When averaged per each month, the cost of lighting for the Museum each month totals $7,384.26 while the cost of receptacles totals $3489.31.

Table 10 Yearly Energy Consumption by Load

Total Energy Consumption within Building per Year				
Energy Load Type	Electrical Consumption Cost	Gas Consumption Cost	Water Consumption Cost	Percentage of Total Energy
Primary Heating	-	$2313.54	-	4.8%
Heating Accessories	$1852.74	-	-	0.9%
Cooling Compressor	$11,742.62	-	-	5.4%
Tower/Condenser Fans	$1,423.11	-	$2,116.28	0.7%
Condenser Pump	$1,132.93	-	-	0.5%
Cooling Accessories	$679.05	-	-	0.3%
Supply Fans	$16,801.56	-	-	7.8%
Pumps	$2743.15	-	-	1.3%
Base Utilities	$36,189.91	-	-	16.8%
Lighting	$88,611.17	-	-	41.1%
Receptacles	$44,271.74	-	-	20.5%
Totals	$205, 447.98	$2,313.54	$2116.28	100%

Conclusion of the Existing Mechanical Systems Analysis

Within the Walt Disney Family Museum campus, the mechanical system provides the appropriate amount of heating and cooling to meet the calculated loads, however, the system lacks environmental efficiency and sustainable design. However, the historical nature of the building as well as the constraints of the Museum's budget have left the system meeting the HVAC needs but lacking green quality. Therefore, with a closer look at the budget costs as well as long-term benefits of a greener mechanical system, the WDFM could have been pursued to agree to a more environmentally friendly design.

The overall construction cost of the system average about $94.00 per square foot while the total cost to install the mechanical system totaled over $2.5 million dollars. The total energy cost each year total $209,877.80 that equals $6.05 per square foot, which seems somewhat high but due to the large loads within the building needed to properly display the exhibits and galleries; however, this number is appropriate. However, if green systems were implemented concerning day lighting as well as renewable energy systems, this operating cost could be reduced. The occupants receive a substantial amount of ventilation air as well as supply air within the Museum. The system has appropriate controls within the variable air volume system (VAV), which senses the need for more air at desired temperatures. Other controls within the building include monitoring of occupants and CO_2 levels that contribute to the HVAC system. The lighting system is also controlled although by occupancy sensor, however, a scheduled lighting system usually overrides the occupant controls.

Therefore, while the system meets basic HVAC needs of the space and the occupants, further consideration should be given to environmental concerns. Green should not be quantified by how much recycling the Museum processes every month, however, energy reduction as well as renewable energy resources that could be implemented in the Museum should define “going green”.

Mechanical Redesign Considerations

Based on the existing system design, the Walt Disney Family Museum redesign was meant to make the building more energy efficient while reducing the yearly energy costs. Therefore, with these initial concepts in mind, a geothermal system was implemented, reducing the system costs over the course of 87 years. While this may be an extended payback period, the system may be eligible for California green system rebates.

Next, the system was redesigned for energy harvesting based on visitors movements throughout the Museum. Therefore, strategically placed piezoelectric flooring, are located at every doorway and on the ramp in the center of the building, capturing the vibrations of the movements of visitors, creating electricity for use within the Museum. This is especially essential for reducing loads within the gallery areas and media displays.

Finally, the site was analyzed for weather harvesting technologies that could be implemented. The site was viewed for wind turbines, solar panels as well as rain water harvesting. Using TMY2 data as well as various other sources of data, research was gathered pertaining to rain fall, wind speeds and number of clear days. Afterwards, the site was analyzed to find the best energy generating weather power. In conclusion, a rain water harvesting system incorporating rain water runoff from the roof as well as designed in order to reduce water loads on utility companies while providing energy independence.

Finally, these systems are very energy efficient, but unfortunately their payback periods are extended periods of time, if not unfeasible. However, with more use of these type of technologies, over time the technologies may be available for reduced costs.

Geothermal System Design

The idea of a geothermal was original meant to eliminate the use of Building 108, the centralized cooled water and heated water plant, while meeting the Museum's energy needs, reducing the cost of energy consumption as well as the annual emissions from the current system. The geothermal initial concept stemmed from the fact that a large portion of the cost of a ground source heat pump system comes from excavating the ground and the bore holes. However, because the WDFM already excavated part of the Museum for the sub-basement, the cost of the geothermal excavation would be reduced.

The system replaces part of the existing mechanical system, while keep the existing 4-Air Handling Units while using Ground Source Heat Pumps found throughout the building.

Vertical Loop System Design

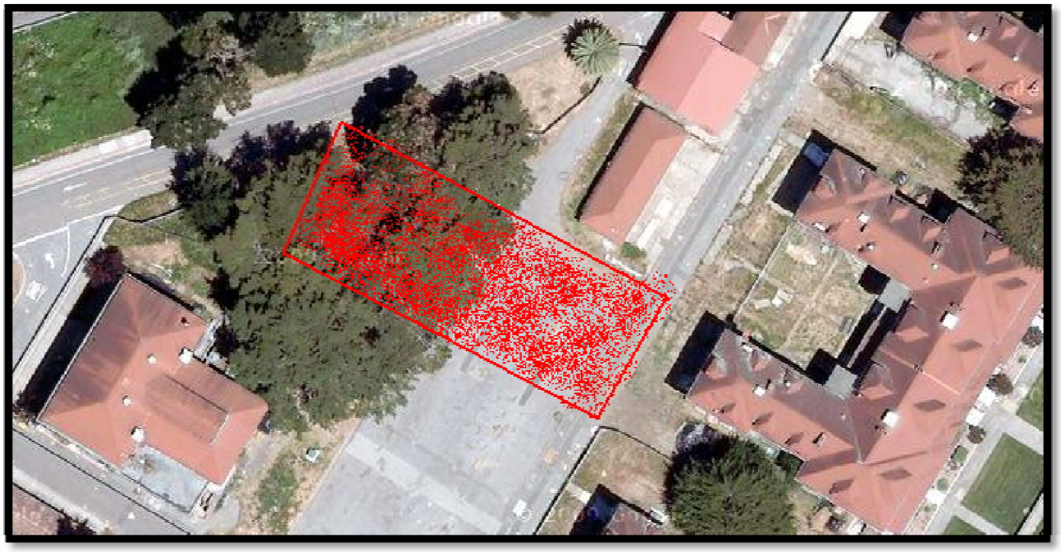
The system uses vertical bore holes for the closed loop system. Initially, the San Francisco Bay seemed close enough to consider using as a thermal sink, however, the water is too far from the building and it also be outside of the scope of the site. Another reason for the use of a vertical looping system is due to the small amount of land available for use. In the image below, the red boxed area in the satellite map below, an area of 150 ft x 175 ft, is used to for the ground piping.

Using the University of Alabama's GCHPCalc, as well as Gaia Geothermal GLD software, the ground temperature in California was found to be a constant 62˚F degree temperature range for use within a vertical piping system. The GCHPCalc program asks for the daily peak heat gains and losses, found in the following table as well as the number of heating hours per year and cooling hours per year.

Table 11 **Daily Heating Gains and Losses**

Daily Heating Gains: Cooling Hours 740.0	
8AM-Noon	708.0 kBtu/hr
Noon-4PM	835.4 kBtu/hr
4PM-8PM	595.3 kBtu/hr

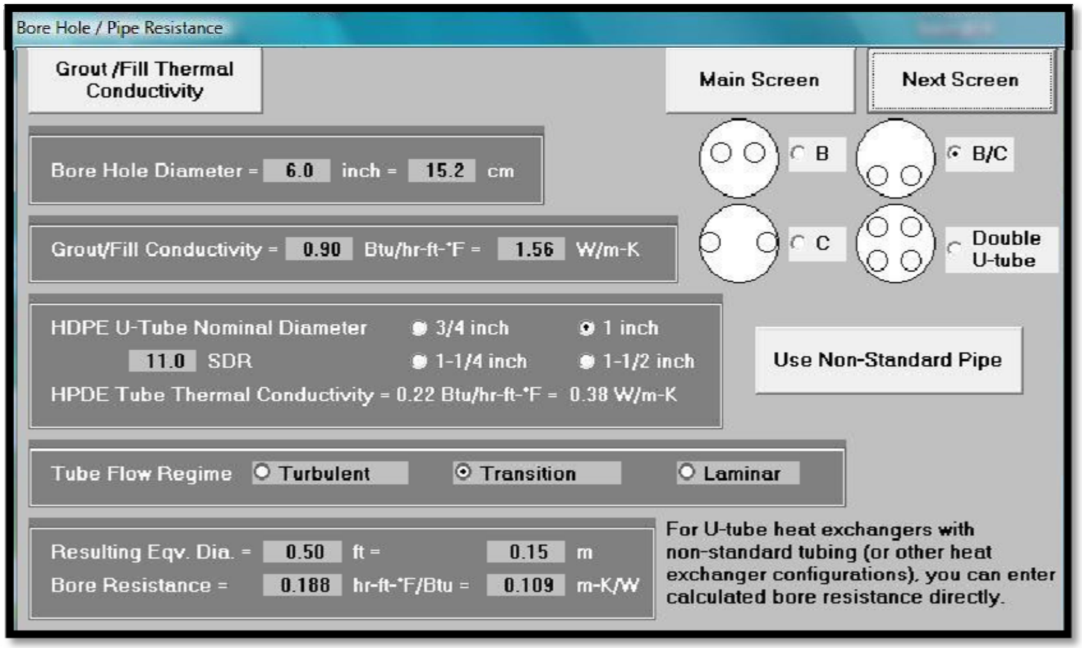
Daily Heating Losses: Heating Hours 493.0	
8AM-Noon	346.8 kBtu/hr
Noon-4PM	461.2 kBtu/hr
4PM-8PM	317.0 kBtu/hr



(Above) Satellite view of the WDFM Campus with geothermal proposed location.

Research and Methodology

Using GCHPCalc, the ground properties were found; the ground temperature of 62˚F, thermal conductivity of the ground was found to be 1.2 Btu/Hr-ft-˚F, while the thermal diffusivity totals 0.8 ft^2/day. This is generalized data for San Francisco, CA as a ground study was performed but, I could not obtain the data of that survey. After the ground properties were entered according to the building's location, the piping system properties were selected. The borehole diameter was entered as 6.0 inches, the grout/fill conductivity was 0.9 Btu/Hr-ft-˚F, while the flow was selected as transition. These properties were selected based upon the ground heat conductivity.



Bore Hole Diameter = 6.0 inch = 15.2 cm

Grout/Fill Conductivity = 0.90 Btu/hr-ft-°F = 1.56 W/m-K

○ B ● B/C ○ C ○ Double U-tube

HDPE U-Tube Nominal Diameter ○ 3/4 inch ● 1 inch ○ 1-1/4 inch ○ 1-1/2 inch

11.0 SDR

HPDE Tube Thermal Conductivity = 0.22 Btu/hr-ft-°F = 0.38 W/m-K

Tube Flow Regime ○ Turbulent ● Transition ○ Laminar

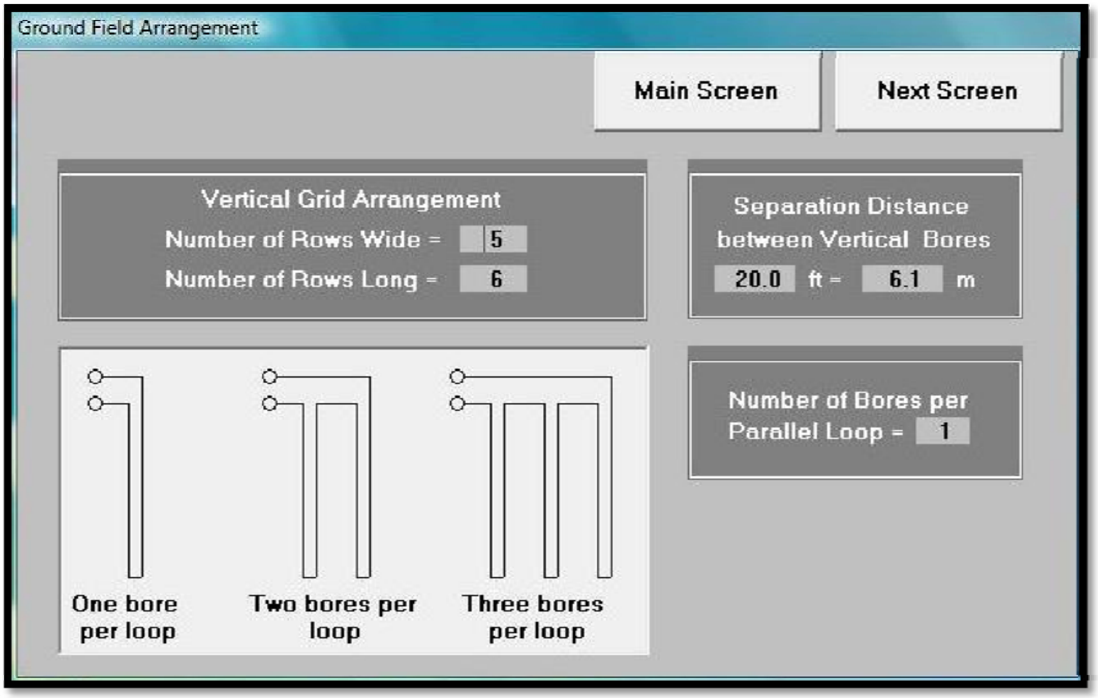
Resulting Eqv. Dia. = 0.50 ft = 0.15 m

Bore Resistance = 0.188 hr-ft-°F/Btu = 0.109 m-K/W

For U-tube heat exchangers with non-standard tubing (or other heat exchanger configurations), you can enter calculated bore resistance directly.

(Above) Ground information in GCHPCalc.

Then, with the loop layout selected as a vertical looping system, the separation between vertical bores was selected as 20 feet and the number of bores per parallel loop as 1. The vertical grid arrangement was found to be 5 rows wide by 6 rows long, at a spacing of 20 feet between bores, the piping system fits within the selected area. Therefore, the site area that the geothermal system will use totals approximately 100 feet x 125 feet, within the designated area allowed for the geothermal system.



Ground Field Arrangement

Vertical Grid Arrangement

Number of Rows Wide = 5

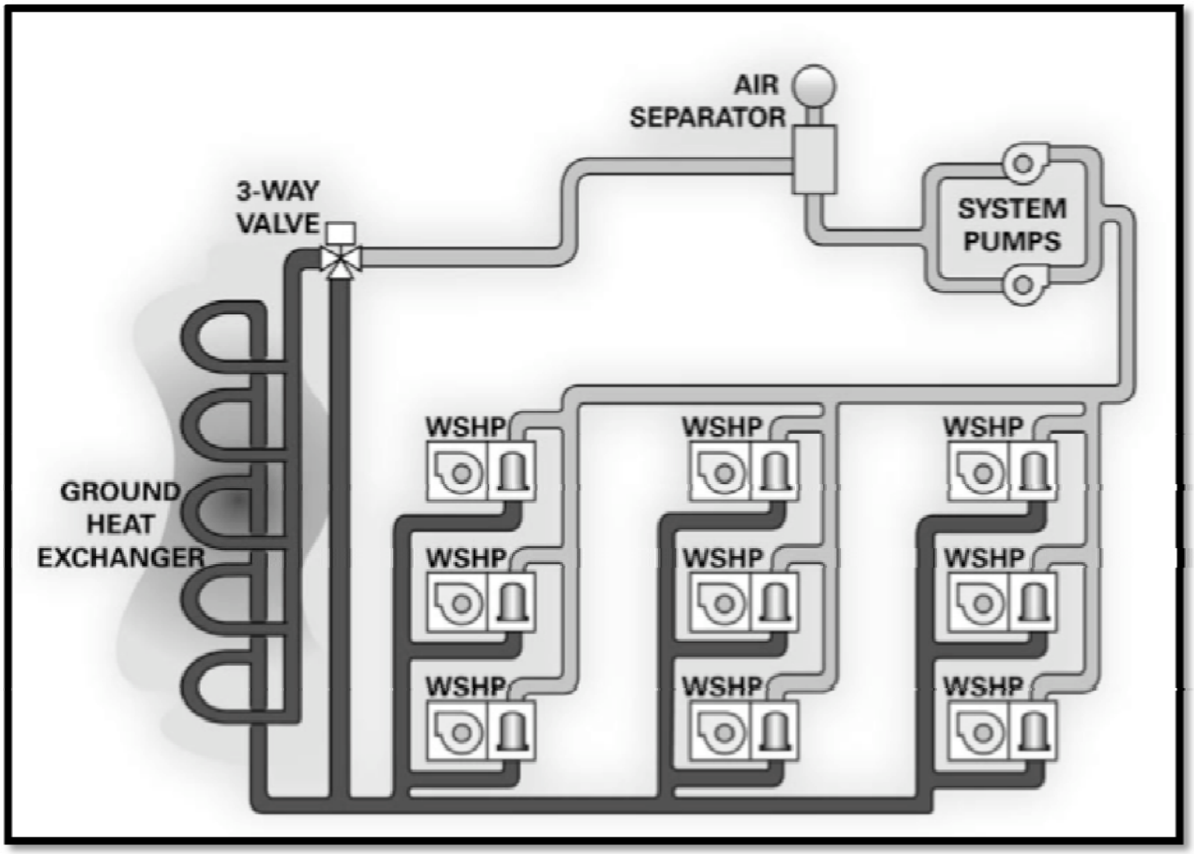
Number of Rows Long = 6

Separation Distance between Vertical Bores

20.0 ft = 6.1 m

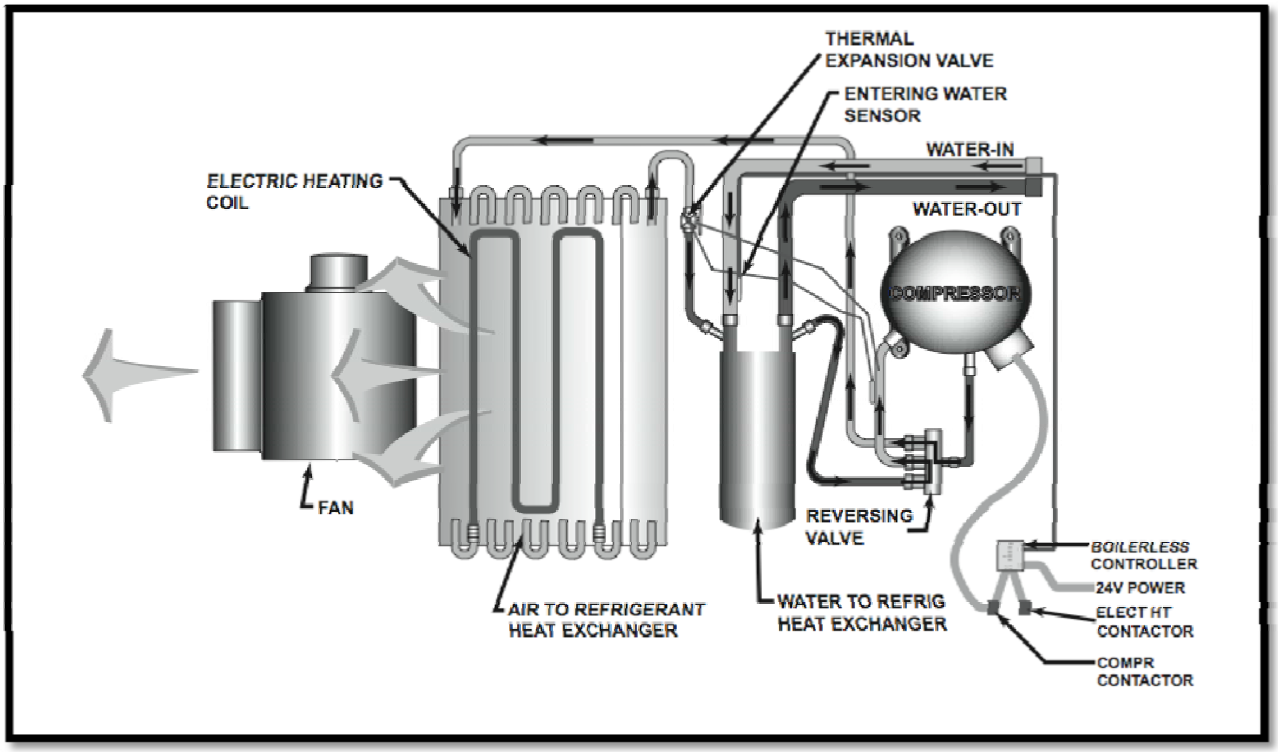
Number of Bores per Parallel Loop = 1

Next, the cost of the system was estimated. The program has estimated the cost of the system at $22, 836, 300 for the cost of excavation, piping costs, refrigeration, and labor. However, this number may vary by at least 10%, since the site was already being excavated due to the sub-basement installation.



Heat Pump Selection

The heat pumps were selected as Trane's Axiom™ Vertical Water-Source Heat Pumps, GEV – R-410A, for this geothermal system. This system, having a ground temperature of 62 degrees, makes the systems boiler obsolete, however, in extreme cases, if the loop temperature falls below 60°F, the Trane Axiom™ heat pumps have an electric heat option, locking out the compressor in order to restore water temperatures about 60°F.



The heat pumps will also utilize a centralized piping system versus a distributed piping system to pump water to each of the water-source heat pumps. The advantages of this option versus the later will be less equipment installed, therefore, less maintenance and servicing. Therefore, once the heat pumps were selected, the buildings loads were incorporated into specifically selecting the number of heat pumps and locations within the building. Pumping data and sizing data are located in the appendix section.

Table 12 **Heat Pump and Sizing in Museum**

Head Pump Location and Size in Building				
Floor	Number of Pumps	Pump Number	Maximum CFM Output Cooling	Cooling (tons)
Ground	4	GEV- E - 012 – 3 ton each	26,400	12
First Floor	4	GEV- E - 012 - 3 ton each	26,400	12
Second	4	GEV- E - 012 - 3 ton each	26,400	12

Floor				
Attic	4	GEV- E - 006 – 1 ton	22,600	4
Total	12	-	101,800	40

The ground floor, first and second floor have the largest loads due to the lecture hall, projection equipment, lighting, media displays and galleries. The following table shows the heat pumps service to the corresponding galleries.

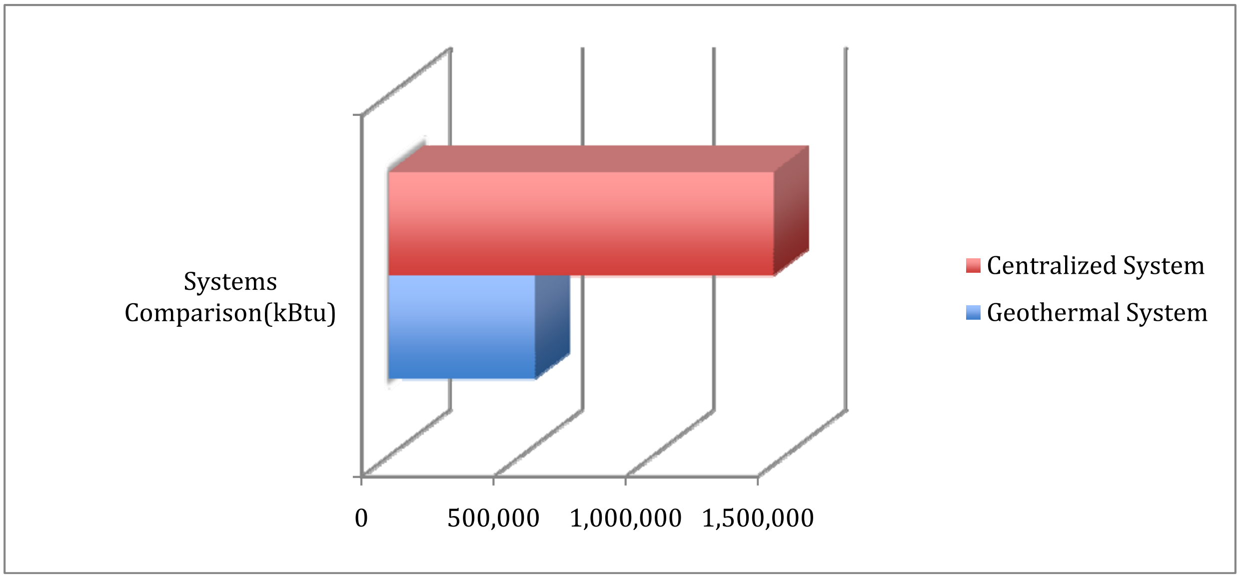
Table 13 Galleries and Entrance Areas Pumps

WDFM Galleries/Entrance Areas Serviced	
Pump Number	Areas Serviced
First Floor, Pump GEV-E-012-1A/B	Gallery 10A
	Gallery 10B
	Museum Store
	Coffee Shop
First Floor, Pump GEV-E-012-1C/D	Gallery 1C
	Gallery 1A/1B
	Pre-Show
	Ticketing
Second Floor, Pump GEV-E-012-2A/B	Gallery 2A
	Gallery 2B
	Gallery 3
	Gallery 4
	Gallery 8
	Gallery 9
Second Floor, Pump GEV-E-012-2C/D	Gallery 7A
	Gallery 7B
	Gallery 6

	Gallery 5
	Gallery 9

Next, using Trane Trace 700, the yearly energy loads were analyzed using the newly implemented equipment, while based upon the number of heat pumps installed, the geothermal system costs and the reduction in energy, the system has significantly reduced energy costs. Therefore, the system costs of the older system was **$2,573,664** while the new cost of the geothermal system totals $22, 836, 300 plus the costs of heat pumps, $100,480, totaling **$22,936,780.** However, this system will save the building energy per year, offsetting the initial cost difference of **$20,363,116.**

The geothermal system significantly reduces energy consumption per year based on the ground constant temperature, reducing the need for heating and cooling. Therefore, based on the Trace analysis, the following table shows the difference in energy consumption.



System Conclusion

The new geothermal system consumes 553,610 kBtus per year while the older system consumes 1,457,078 kBtus per year. Therefore, at $2.763/therm for gas prices, the cost of the new system's energy consumption totals **$152,962.44** per year, while the older system cost **$397,782.94** per year, a reduction of $244,820.50 years. Therefore, the payback period for this new system will be 83.17 years, therefore, making this systems change feasible if the Museum is looking to stay in long-term operation.

Electrical Breadth: Piezoelectric Flooring

Piezoelectricity is electricity conducted in certain materials, specifically crystals and ceramics, caused by vibrations or stresses within the materials. This technology was first discovered in the mid-1800 and were first used practically during World War 1, with the application of sonar. The vibration of sound within the ocean returned as an echo, thus allowing piezoelectrics to detect the movement of the returning sound waves.

Today, piezoelectric flooring is being widely researched as a form of sustainable building materials. One of the most major uses of piezoelectric flooring is found in nightclubs all over the world, especially throughout Europe. Club Watt in Rotterdam, Netherlands and Club4Climate in the United Kingdom both have permanent flooring installed while Bahla, Brazil is rented flooring for their Carnival in February. KLUBBERS Day in Madrid, Spain is also renting piezoelectric flooring for their event in March.

Furthermore, piezoelectric flooring is gaining more support with the installation of flooring within the Yaesu North Gate within Toyko, Japan's subway station. With 400,000 people using the subway system in Toyko every day, taking advantage of the vibrations from people's footstep is an ideal situation in which to harvest electricity. Yoshiaki Takuya, a planner within Soundpower Corporation, a company that produces piezoelectric floor panels says, "An average person, weighing 60 kg, will generate only 0.1 watt in the single second required to take two steps across the tile. But when they are covering a large area of floor space and thousands of people are stepping or jumping on them, then we can generate significant amounts of power."

Soundpower Corporation also installed panels in Fujisawa, Japan, within the town's city hall. Club Watt in Rotterdam, Netherlands installed 270 ft^2 of this flooring for \$257,000 which totals about \$950/ft^2

WDFM Analysis: Methodology and Building Layout

Within the Walt Disney Family Museum, flooring will be installed through each of the doorways that each visitor passes through while touring the Museum as well as the center ramp, located within Gallery 9, Blue Sky Exhibit. The Museum has a very specific path for visitors to pass through while viewing the exhibits, which makes the installation of flooring in these areas ideal.

Each doorway within the Museum ranges from 3-5 feet in width while the ramp in the Blue Sky Exhibit is 5 feet in width. However, the appropriate area for the flooring to be installed is approximated to be the middle half of the walkway, leaving a quarter of the area open on each side. For example, the Blue Sky Exhibit ramp will have flooring installed in the middle of the ramp, covering 2.5' of flooring, leaving 1.25' on each side without panels. This assumption was made in order to reduce costs of the flooring as people generally walk in the middle of a walkway; or to the sides of the middle if using both sides of the walkway.

The following chart shows the sizes of the doorways as well as the sizes of the ramp with floor area assigned to piezoelectric panels.

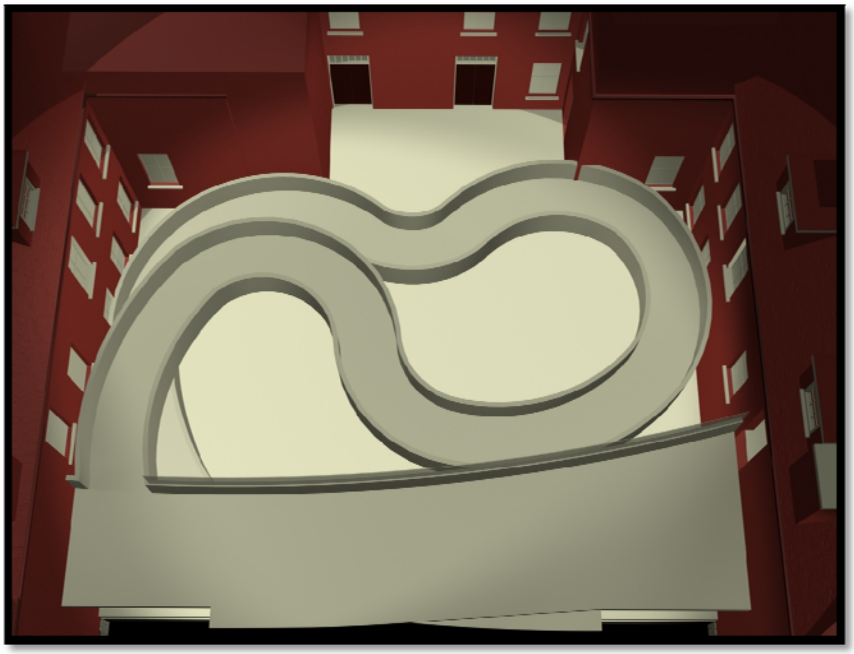
Table 13 **Piezoelectric Flooring and Locations**

Walt Disney Family Museum's Piezoelectric Flooring and Locations			
Door Number	Width of doorway	Flooring width	Total area of Piezoelectrics
A110.1	6'-0"	3'-0"	9
A112	4'-6"	2'-3"	6.75
A114.2	5'-4"	2'-8"	8
A114.1	4-6"	2'-3"	6.75
A212	4-0"	2'-0"	6
A212.1	5'-3"	2'-7 1/2"	7.875
A210	5'-0"	2-6"	7.5
Opening	7'-0"	3'-6"	10.5
A208	7'-0"	3'-6"	10.5
A205	5'-10 1/2"	2'-11"	8.75
A202	6'-0"	3'-0"	9
A202.1	6'-8 1/2	3'-4"	10
Opening	4'-0"	2'-0"	6
Ramp	5'-0"	2'-6"	7.5
A117.4	5'-0 3/4"	2'-6"	7.5
A105	10-1"	5'-0"	15
A105	6'-4"	3'-2"	9.5
106	6'-0"	3'-0"	9
Total Flooring Area for all doors and entryways			155.125 ft^2

Table 10: Piezoelectric Flooring Ramp Area

WDFM Ramp Piezoelectric Flooring			
Ramp	Length	Wide	Total Ramp Floor Area
Total	174.5'	3'	523.5

The ramp area of the building is a major component of the piezoelectric flooring electricity generation. This area is the heart of the Museum in which all visitors must walk through to experience most of the Museum. The path in which the flooring placed follows to Museum's path, which shows the birth to present day of Walter Disney, the man behind the Walt Disney Company.



(Above) Rendering of the WDFM Ramp in center of the Museum.

Credit: Page + Turnbull.

Table 11: Total Piezoelectric Flooring Areas

Total Amount of Piezoelectric Flooring		
Ramp	Doorways	Total Area of Piezoelectrics
523.5	155.125	678.625

After the areas in the Museum where flooring where be located were calculated, the number of occupants was calculated based on the egress diagams. Originally, the WDFM was contacted directly and asked for this information in order to provide a more exact number for the analysis. However, the Museum declined to provide this information after much discussion due to financial reasons.

Table 12: Egress Diagrams for WDFM

Egress Diagrams in the WDFM: Number of Occupants		
Floor Level	Location	People
First	North	292
First	South	720
Second	North	303
Second	South	464
Total Number of People in Building		1779

Therefore, after determining the maximum number of people visiting the Museum, the weight for the average American body was determined. Based on company specifications for the average Japanese person, as well as information provided by a CDC study in 2002, a 135 lb person can produced minimum, 0.1 W per every 2 footsteps. From the CDC study, the average American man weighs 191 pounds while the average American woman weighs 164.3 pounds. Assuming that an equal amount of men and women visit the Museum, the average visitor weighs 177.65 pounds. The following equation converts the average American weight of 177.65 and the number of visitors to the 135 pounds per Japanese person:

Equation 1: Visitor Weight in Museum

$$[(\text{Number of Museum visitors}) \times (177.65\ \text{lbs})/(135\ \text{lbs})] \times (0.1\ \text{W}) = \text{Output watts}$$

The equation also defines the number of watts based on number of visitors and their weights.

Finally, the next table shows the wattage output based on the number of occupants varying from full occupancy to only 10% occupancy. Therefore, the total electrical output for the flooring can vary from 1, 783 W to 17, 829 W, showing the more visitors to the Museum, the greater the output.

Table 13: Wattage Output based on Percentage of Visitors

WDFM Visitor Occupancy and Wattage Output				
Percentage of Occupancy	**Total Weight**	**Number of Visitors at 135 lbs**	**Number of 3' spans in Museum**	**Watt Output**
100	316,039.3	2,341.0	76.16	17,829.30
90	284,435.4	2,106.9	76.16	16,046.371
80	252,831.4	1,872.8	76.16	14,263.44
70	221,227.5	1,638.7	76.16	12480.51

60	189,623.6	1,404.6	76.16	10,697.58
50	158,019.6	1,170.5	76.16	8,914.65
40	126,415.7	936.4	76.16	7,131.72
30	94,811.80	702.3	76.16	5,348.79
20	63,207.87	468.2	76.16	3,565.86
10	31,603.93	234.1	76.16	1,782.93

Cost Reduction and Energy Generated

Each square foot of piezoelectric flooring can range from \$900/ft^2 to \$1600/ft^2. Therefore, using Face Internation piezoelectrics, a square foot of flooring equals approximately **\$1501.45**. At a maximum output of 17,829.3W, the cost per W equals **\$57.15/W**, which is well above the **\$0.141/kWh** rate provided by the Pacific Gas and Electric Company. However, the total cost of the system will equal **\$1,018,923.74**, if the maximum amount of energy is produced each year, 5509.25 kW/year at \$0.141/kWh, the system's payback period will total **1,311.7 years**, make this implementation unfeasible.

Conclusion

While the system's payback period totals 1,311.7 years, many companies are starting to look towards piezoelectrics as a mean to reduced energy consumption in buildings by harvesting human movement. Therefore, this technology has the potential to decrease in cost over the next few years. In conclusion, this technology should be kept in consideration for future years to come.

Landscape Redesign and Weather Analysis Breadth

Within this breadth, a weather analysis was first executed, analyzing rainfall, wind as well as solar energy for the most abundance source of energy generated from a natural element. This breadth was designed to also redesign the parts of landscape architecture in order to make the site more sustainable while harvesting energy from natural resources. Taken from the World Commission on Environment and Development's (the Brundtland Commission) paper 'Our Common Future', "Sustainable development is…development that meets the needs of today's generation without compromising the ability of future generations to meet their needs." This is an important statement to keep in mind while reviewing this breadth. The Walt Disney Family Museum is already a sustainable project because of the redevelopment of a historical building within the Presidio. However, if harvesting natural weather energy can further reduce energy consumption by the Museum, thus furthering its energy independence.

Furthermore, sustainable urban development consists of three factors: society, environment and economy. The WDFM meets all three of these criteria. The project furthers the education of the society, redeveloped an existing building and creating revenue while this breadth focuses on the environment portion of the project.

This analysis uses weather data from the Typical Meterological Year, version 2 as well as BinMaker® Pro and ASHRAE Design Conditions. The following sections are broken into three different categories: Wind, Rain and Solar, the most abundant found to be rainwater harvesting which will allow the Museum to be completely independent from any water company.

Wind Harvesting

Wind turbines have quickly become one of the more sustainable forms of harvesting energy. Produced in a number of sizes and power output, these devices can produce anywhere from 25 to 750 kW based on rotor diameter (blade circular path). These numbers are based on data from the Danish Wind Energy Association and the American Wind Energy Association, which base these numbers on a 33 mph wind speed. 33 mph is found to be the optimal rate at which a turbine can produce energy. The following table shows the sizes and output power.

Table 14 Turbine Rotor Sizes and Outputs: Sources DWEA and AWEA

Typical Wind Turbine Size: Rotor Size and Maximum Energy Output	
Rotor Diameter (Meters)	Power Output (kW)
10	25
17	100
27	225
33	300
40	500
44	600
48	750
54	1000
64	1500
72	2000
80	2500

In San Francisco, the average yearly wind speed was found to be 10.6 mph, by the National Climate Data Center. The highest winds occur during the summer while the lowest winds occur during the wind months, which correlate to the highest building energy loads, also during the summer months.

Figure 3 San Francisco Monthly Wind Speeds: Source NCDC

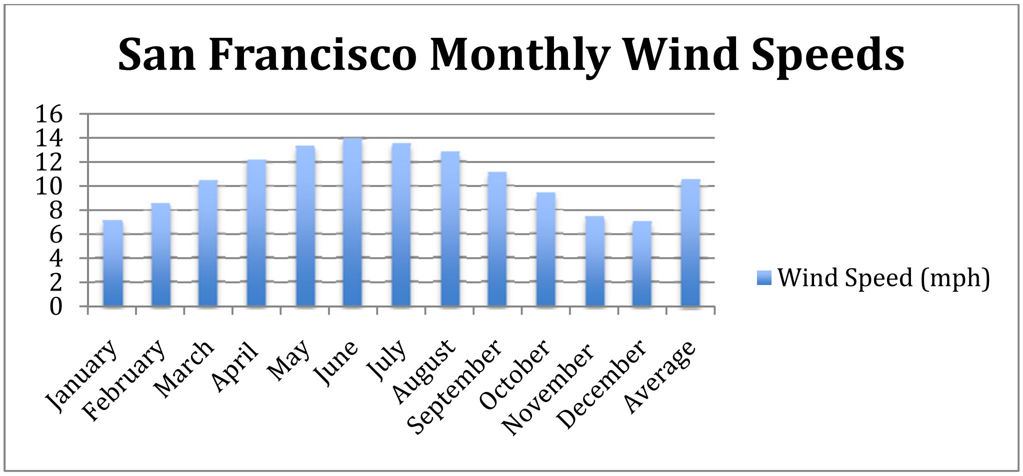
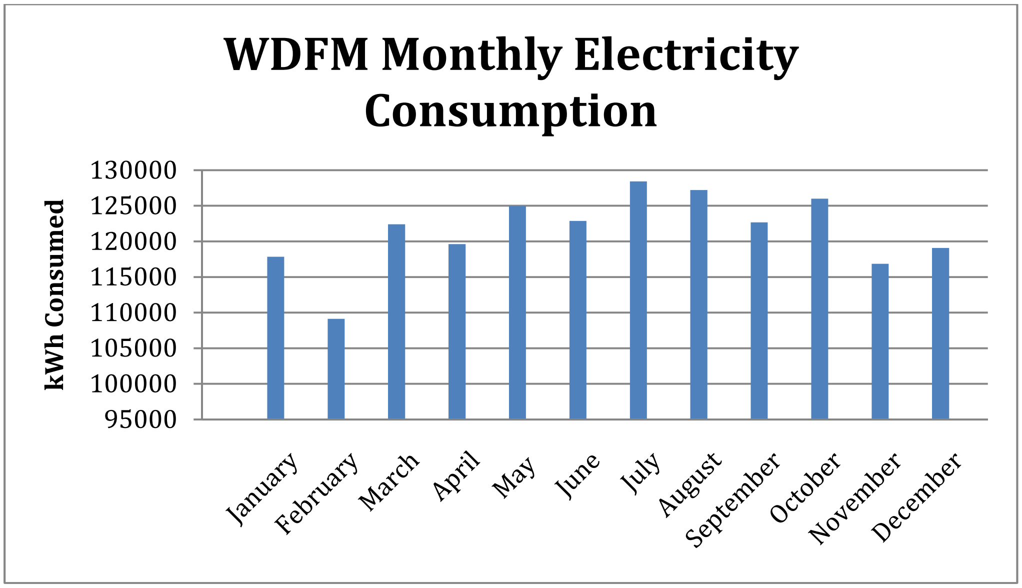


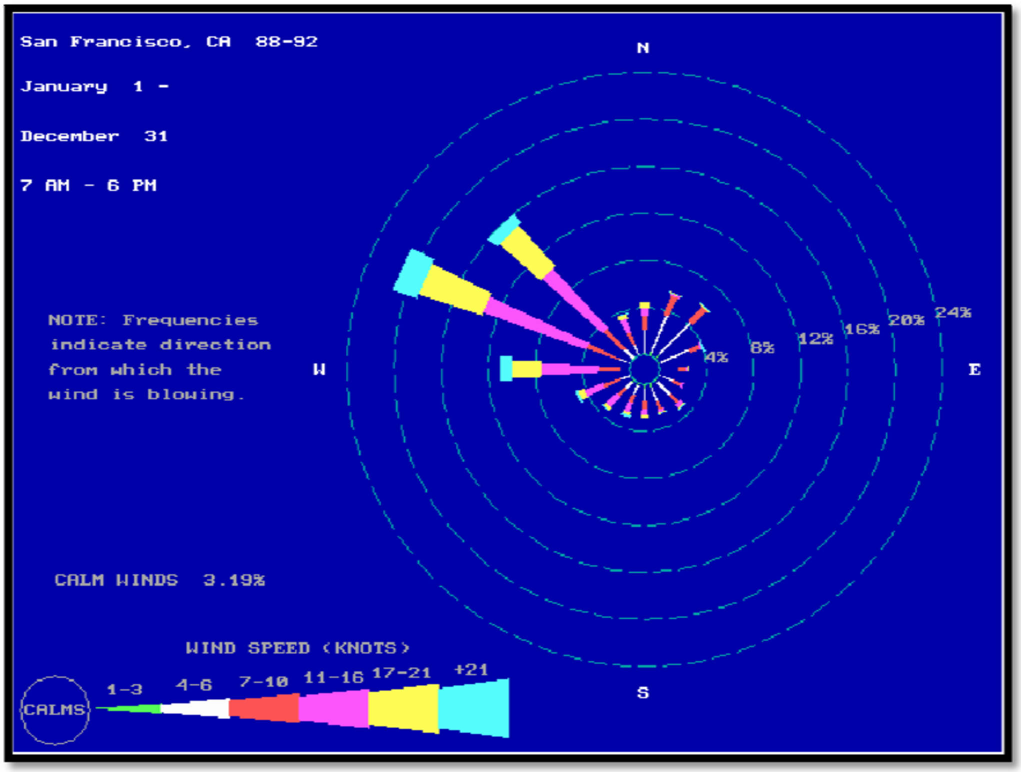
Figure 4 WDFM Monthly Electricity Consumption



However, while the wind speeds could generate energy need within the summer months, the average wind speed in San Francisco falls far below what is needed to generate wind energy.

Not only does wind speed need to be considered, wind direction also needs to be analyzed. In San Francisco, the wind was found to come prevalently from the North West direction, which would be an ideal location for wind turbines. However, the site lacks the necessary amount of open space needed for the turbines and the Museum implementing this technology would also jeopardize its historical look, which is consists with the Presidio.

Figure 4 San Francisco Wind Rose, Source US EPA



In conclusion, wind energy harvesting is not an option for the Walt Disney Family Museum based on size of the open area within the site, wind speeds as well as landscape aesthetics and NHL guidelines.

Solar Panels

California is known to be one of the sunniest states in the continental United States, with the largest amount of clear days. The number of clear days in a city is based on the amount of sky coverage and clearness index, which in California, the number of clear days in major cities ranges from 146-201, with San Francisco falling right in the middle of this range at 162. The following table, from the Western Region Climate Center, shows the monthly number of clear days in the city.

Table 14 Number of Clear Days in San Francisco, CA, Source WRCC

Month	Clear Days
January	9
February	8
March	10
April	11
May	14
June	16
July	21
August	19
September	18
October	16
November	11
December	9
Total days	162

Therefore, with an abundance of clear days and sunlight, San Francisco would generally be an ideal candidate for solar energy harvesting.

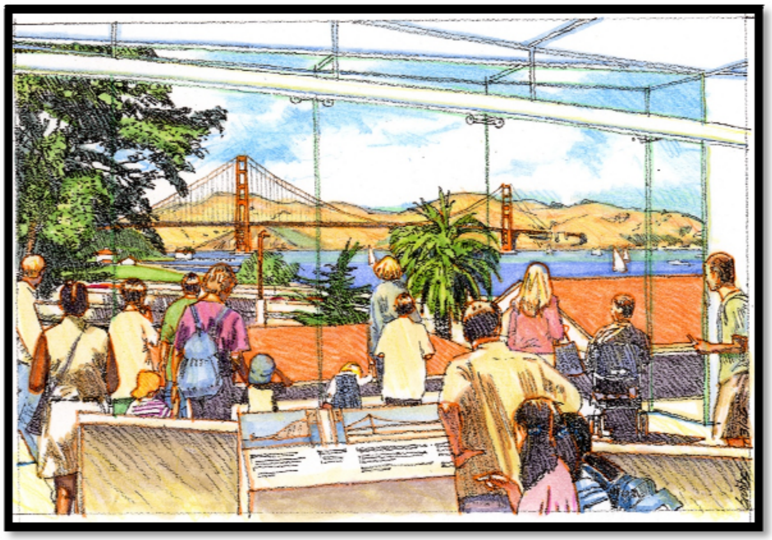
Also, in California, the California Public Utilities Commission (CPUC), provides tax incentives for use of photovoltaic solar panels on buildings in California which are electrical distribution utility company customers, which Pacific Gas and Electrical Company qualifies for. Therefore, if the Museum were to install PVCs, they would most likely qualify for a tax rebate on top of electrical energy savings.

However, as the Museum is a National Historic Landmark, the original façade and look of the building must be preserved. In conclusion, solar panels will not be used to harvest energy due to the high-tech, modernized look of the panels which do not fit in with the historical, military feel of the Presidio.

Rainwater Collection

The State of California has historically had problems with water shortages and water rationing during the summers. Therefore, to conserve water and help reduce the water loads on utility companies, a rainwater analysis was performed on the City of San Francisco. The following table shows the monthly rainfall in San Francisco with the annual amount of rainfall totaling 20.4 inches per year.

Within the site, the Western façade of the Museum overviews the San Francisco bridge. However, in front of this building side is an open space, which measures 120 feet in length by 25 feet in width. This area is about the only large amount of open space within the site, which can be optimized by building a 80 foot by 10 foot calm reflecting pool.



(Left) Sketch of the San Francisco Golden Gate Bridge view from inside the Museum. Courtesy of Page+Turbull.

Rainwater Data, Water Storage and Distribution Methods

The reflecting pool will increase the aesthetic view of the San Francisco Bridge while doubling as an 800 ft^2 rainwater collection area. The last column of this table shows the amount of rainwater that the reflecting pool will collect about 10,173 gallons of water per year.

Table 15 Design Rainwater Collection Pool Values

Month	Rainfall each month (Inches)	Volume (ft^3)	Gallons of rainwater
January	4.4	293.3333333	2194.133333
February	3	200	1496
March	3.1	206.6666667	1545.866667
April	1.3	86.66666667	648.2666667
May	0.4	26.66666667	199.4666667
June	0.2	13.33333333	99.73333333
July	0	0	0
August	0.1	6.666666667	49.86666667
September	0.3	20	149.6
October	1.1	73.33333333	548.5333333
November	2.9	193.3333333	1446.133333
December	3.6	240	1795.2
Totals	20.4	1360	10,172.8

Furthermore, after finding the amount of water the reflecting pool will collect, the roof was analyzed a larger collecting area, which is a common method of harvesting rainwater. Therefore, the roofing area was measured to be about 13,034 ft^2, without the infill area included. The infill area was not included because is at a lower level than the rest of the roof and has its own individual draining system.

However, 13,034 ft^2 of roofing will collect approximately 165,740 gallons of water. This water could be incorporated as part of the rainwater harvesting system, however, the problem of storing this water for long-term use arose.

The rainwater will be stored in Xerxes fiberglass water collection tanks, which can help to achieve LEED points. Therefore, if the roof is included as a collection device, three different storage tanks will be necessary for storage, two 50,000-gallon tanks and a 25,000-gallon tank. If the roof is excluded, or only a portion of the roof is collected, a 10,000-gallon tank will be necessary to store water from the reflecting pool. The problem with storing the water for later use does not deal with the costs of the tanks, however, the problem lies within the size of the storage tanks. A 50,000-gallon storage tank has a 12-foot diameter and 68.1 ft length, which requires 7701.93 ft^3 of space. If the entire roof area is collected, the three tanks will require 19, 139.41 ft^3 of spacing underground. While this result may be feasible, the site is needs space for the geothermal system, which will ultimately result in a crammed site. This could lead to problems with maintenance and repair issues.

The water will be stored in the Xerxes fiberglass water collection tank and pumped into the buildings water lines when the tank is filled. This will allow the building to store the water during most of the winter months for use during the spring and potentially summer. This water will be used for toilet flushing and potentially sink use as well if a UV disinfectant system is used. The water also has potential to be used for drinking water, however, the tank will need to abide by the NFS Joint Committee for Drinking Water Treatment, which would need further research.

Water Reduction and Cost Savings

The reflecting pool will be approximately 2 feet high, with the top of the sides of the pool doubling as benches for Museum visitors. From the Masonry Advisory Council, Masonry Cost Guide, the 7 5/8" x 3 5/8" x 11 5/8" hollow clay units, CMU block, will cost $20.8/SF. Therefore, reflecting pools total cost, 400ft^2 will cost $8,320 for the walls, with an estimated additional 25% for waterproofing, piping as well as man-hours, totaling about **$10, 400**.

Furthermore, a representative from the Xerxes Tank Company, quoted the tank, freight and pipe risers costing approximately $2/gallon storage, totaling **$20,000.** If the roofing area is incorporated into the collection and distribution system, the cost per gallon reduces to $1.05- $1.15 per gallon, resulting in a tank cost of **$184,708 to $202,300.**

In conclusion, this system has the potential to save 175,912.8 gallons of water per year. The savings in water, at $2.77/kgal, will result in an annual savings of $487.27/year. Therefore, the total costs of the tanks and reflecting pool total **$195,108**, in which the payback period will be **400.4 years**. However, the State of California may offer tax rebate incentives to further this green technology.

Conclusion

In conclusion, the reflecting pool will be used to harvest rainwater while doubling as an aesthetic feature. However, as the payback period is an extremely long duration of time, owners may want to reconsider, or offset costs by viewing the additional LEED Credits as savings as well. This is a passive engineering solution in the sense that it will reduce water consumption without disturbing the sites historical, architectural look.

Final Systems Existing and Newly Designed Summary

The Walt Disney Family Museum's existing campus has rehabilitated an abandon military campus and turned it into a mini-Disney World in order to display the life and achievements of Walt Disney. The three buildings within the campus each serve their own purpose to successfully bring this colorful world together as one grandiose display. Building 122 serves as an archiving and art storage facility, Building 108 serves as a central heating and cooling service water plant, while Building 104 houses the Museum. The Museum consists of lecture halls, gallery displays, learning areas and offices.

The existing building systems abide by current codes such as the National Historic Landmark Guidelines, International Building Codes and corresponding building systems codes. The systems within the buildings were analyzed and found to be somewhat energy efficient. However, further research proved that the existing systems could be improved.

Therefore, a geothermal system, also known as a ground source heat pump was designed for use in the building. This system proved to reduce energy consumption, but unfortunately had higher initial costs. The systems payback period equals 87 years, a larger period of time but worthwhile for long term users.

Next, one breadth, a piezoelectric flooring system was analyzed for use within the building. This type of technology is very new in the architectural engineering field but it is being noticed as an emerging technology which will ultimately lead to reductions in material costs.

Finally, a site analysis and landscaping redesign was conducted. Three different weather forces were researched and a rainwater harvesting technology was selected to be implemented into the Museum's landscape design.

While the Museum's newly designed technologies save energy, the payback periods for these technologies are out of a feasible design duration. A possible solution for this financial problem is to look towards government funded tax rebates for green technologies or cost reducing incentives from independent utilities.

In conclusion, while green technologies are not the most economical choice, they do pay back the costs over a period of time while saving energy and reducing emissions, an ideal choice for our future.

APPENDIX A TRANE HEAT PUMP SELECTION

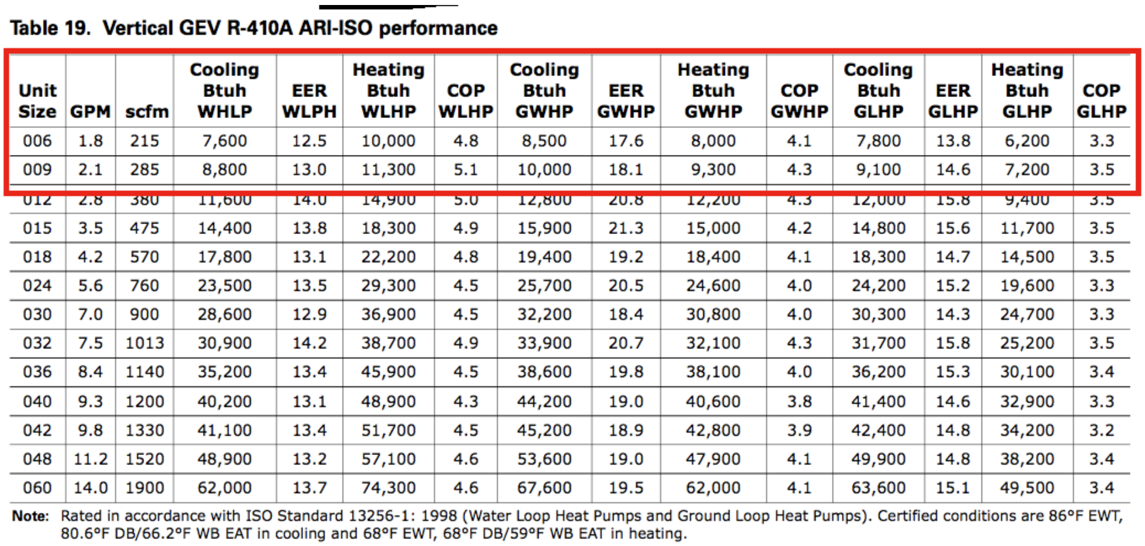


Table 19. Vertical GEV R-410A ARI-ISO performance

Unit Size	GPM	scfm	Cooling Btuh WHLP	EER WLPH	Heating Btuh WLHP	COP WLHP	Cooling Btuh GWHP	EER GWHP	Heating Btuh GWHP	COP GWHP	Cooling Btuh GLHP	EER GLHP	Heating Btuh GLHP	COP GLHP
006	1.8	215	7,600	12.5	10,000	4.8	8,500	17.6	8,000	4.1	7,800	13.8	6,200	3.3
009	2.1	285	8,800	13.0	11,300	5.1	10,000	18.1	9,300	4.3	9,100	14.6	7,200	3.5
012	2.8	380	11,600	14.0	14,900	5.0	12,800	20.8	12,200	4.3	12,000	15.8	9,400	3.5
015	3.5	475	14,400	13.8	18,300	4.9	15,900	21.3	15,000	4.2	14,800	15.6	11,700	3.5
018	4.2	570	17,800	13.1	22,200	4.8	19,400	19.2	18,400	4.1	18,300	14.7	14,500	3.5
024	5.6	760	23,500	13.5	29,300	4.5	25,700	20.5	24,600	4.0	24,200	15.2	19,600	3.3
030	7.0	900	28,600	12.9	36,900	4.5	32,200	18.4	30,800	4.0	30,300	14.3	24,700	3.3
032	7.5	1013	30,900	14.2	38,700	4.9	33,900	20.7	32,100	4.3	31,700	15.8	25,200	3.5
036	8.4	1140	35,200	13.4	45,900	4.5	38,600	19.8	38,100	4.0	36,200	15.3	30,100	3.4
040	9.3	1200	40,200	13.1	48,900	4.3	44,200	19.0	40,600	3.8	41,400	14.6	32,900	3.3
042	9.8	1330	41,100	13.4	51,700	4.5	45,200	18.9	42,800	3.9	42,400	14.8	34,200	3.2
048	11.2	1520	48,900	13.2	57,100	4.6	53,600	19.0	47,900	4.1	49,900	14.8	38,200	3.4
060	14.0	1900	62,000	13.7	74,300	4.6	67,600	19.5	62,000	4.1	63,600	15.1	49,500	3.4

Note: Rated in accordance with ISO Standard 13256-1: 1998 (Water Loop Heat Pumps and Ground Loop Heat Pumps). Certified conditions are 86°F EWT, 80.6°F DB/66.2°F WB EAT in cooling and 68°F EWT, 68°F DB/59°F WB EAT in heating.

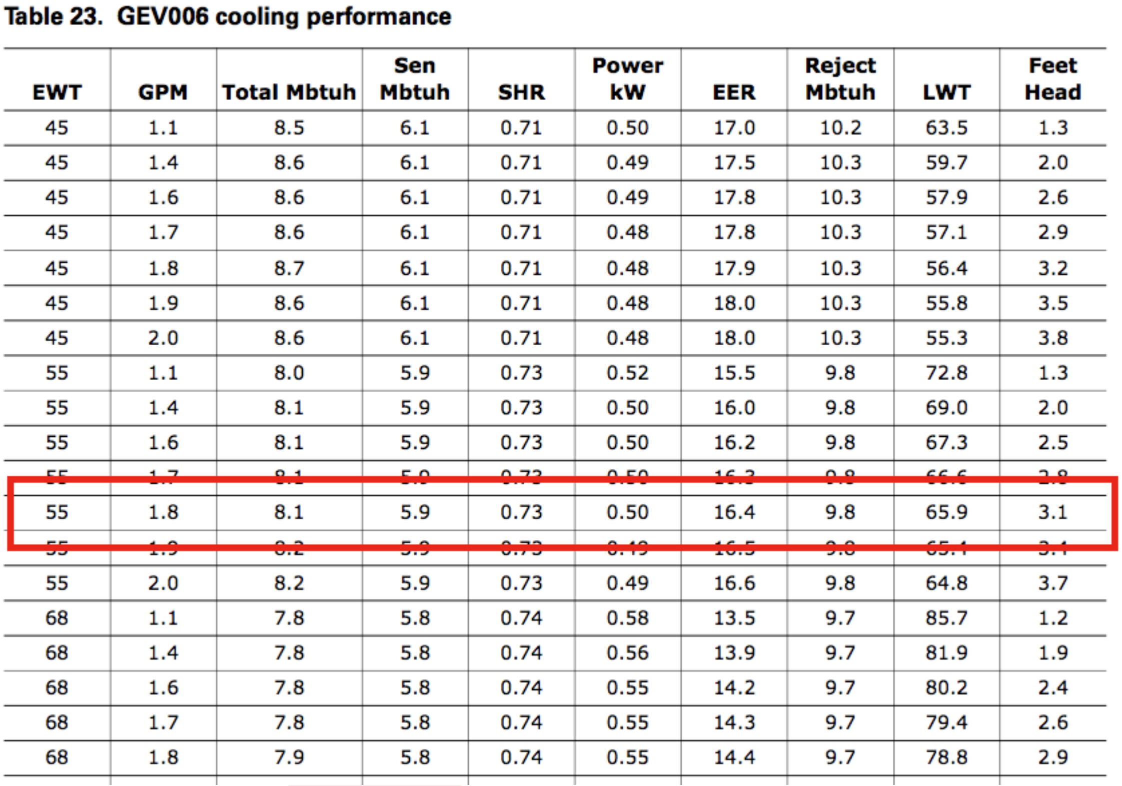
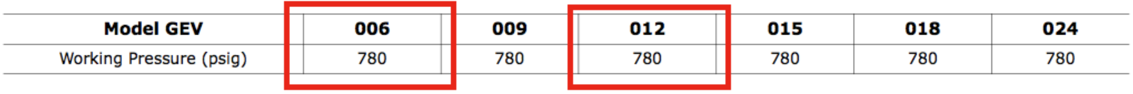


Table 23. GEV006 cooling performance

EWT	GPM	Total Mbtuh	Sen Mbtuh	SHR	Power kW	EER	Reject Mbtuh	LWT	Feet Head
45	1.1	8.5	6.1	0.71	0.50	17.0	10.2	63.5	1.3
45	1.4	8.6	6.1	0.71	0.49	17.5	10.3	59.7	2.0
45	1.6	8.6	6.1	0.71	0.49	17.8	10.3	57.9	2.6
45	1.7	8.6	6.1	0.71	0.48	17.8	10.3	57.1	2.9
45	1.8	8.7	6.1	0.71	0.48	17.9	10.3	56.4	3.2
45	1.9	8.6	6.1	0.71	0.48	18.0	10.3	55.8	3.5
45	2.0	8.6	6.1	0.71	0.48	18.0	10.3	55.3	3.8
55	1.1	8.0	5.9	0.73	0.52	15.5	9.8	72.8	1.3
55	1.4	8.1	5.9	0.73	0.50	16.0	9.8	69.0	2.0
55	1.6	8.1	5.9	0.73	0.50	16.2	9.8	67.3	2.5
55	1.7	8.1	5.9	0.73	0.50	16.3	9.8	66.6	2.8
55	1.8	8.1	5.9	0.73	0.50	16.4	9.8	65.9	3.1
55	1.9	8.2	5.9	0.73	0.49	16.5	9.8	65.4	3.4
55	2.0	8.2	5.9	0.73	0.49	16.6	9.8	64.8	3.7
68	1.1	7.8	5.8	0.74	0.58	13.5	9.7	85.7	1.2
68	1.4	7.8	5.8	0.74	0.56	13.9	9.7	81.9	1.9
68	1.6	7.8	5.8	0.74	0.55	14.2	9.7	80.2	2.4
68	1.7	7.8	5.8	0.74	0.55	14.3	9.7	79.4	2.6
68	1.8	7.9	5.8	0.74	0.55	14.4	9.7	78.8	2.9



Model GEV	006	009	012	015	018	024
Working Pressure (psig)	780	780	780	780	780	780

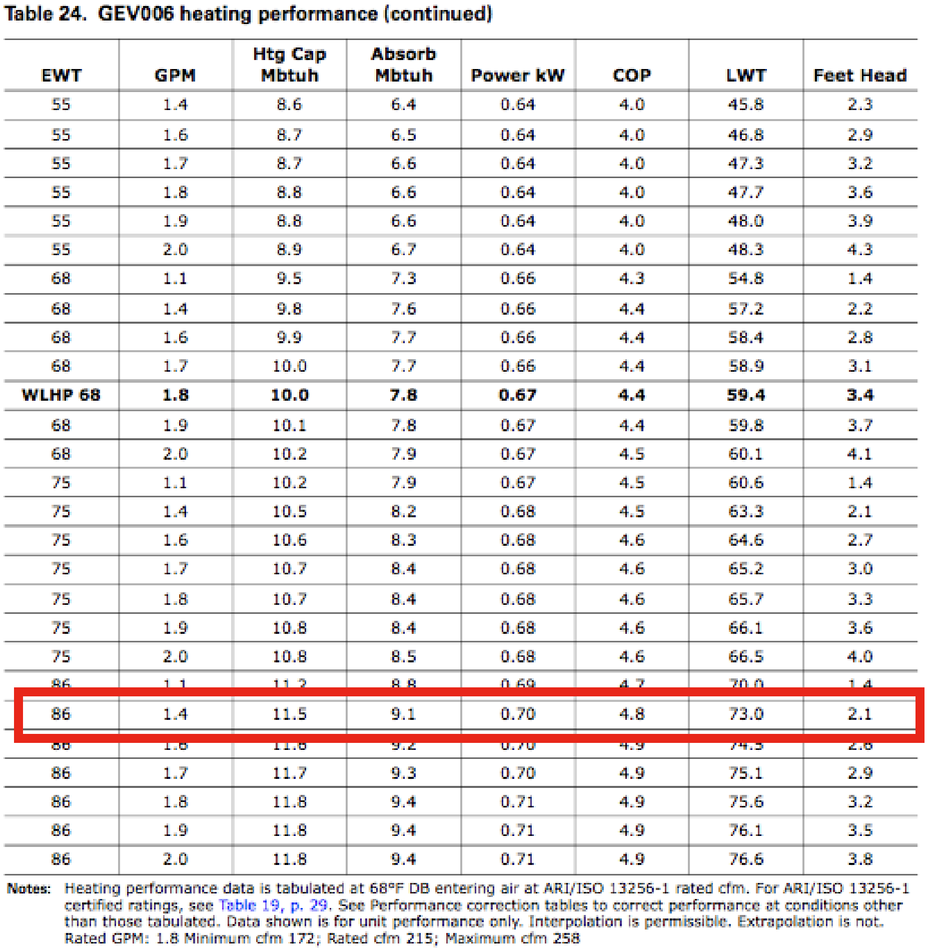
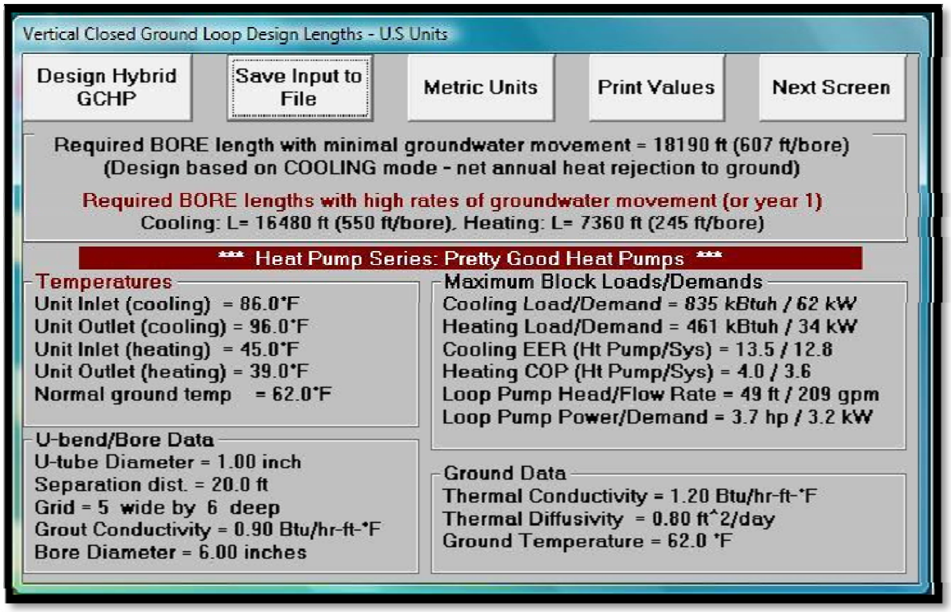


Table 24. GEV006 heating performance (continued)

EWT	GPM	Htg Cap Mbtuh	Absorb Mbtuh	Power kW	COP	LWT	Feet Head
55	1.4	8.6	6.4	0.64	4.0	45.8	2.3
55	1.6	8.7	6.5	0.64	4.0	46.8	2.9
55	1.7	8.7	6.6	0.64	4.0	47.3	3.2
55	1.8	8.8	6.6	0.64	4.0	47.7	3.6
55	1.9	8.8	6.6	0.64	4.0	48.0	3.9
55	2.0	8.9	6.7	0.64	4.0	48.3	4.3
68	1.1	9.5	7.3	0.66	4.3	54.8	1.4
68	1.4	9.8	7.6	0.66	4.4	57.2	2.2
68	1.6	9.9	7.7	0.66	4.4	58.4	2.8
68	1.7	10.0	7.7	0.66	4.4	58.9	3.1
WLHP 68	**1.8**	**10.0**	**7.8**	**0.67**	**4.4**	**59.4**	**3.4**
68	1.9	10.1	7.8	0.67	4.4	59.8	3.7
68	2.0	10.2	7.9	0.67	4.5	60.1	4.1
75	1.1	10.2	7.9	0.67	4.5	60.6	1.4
75	1.4	10.5	8.2	0.68	4.5	63.3	2.1
75	1.6	10.6	8.3	0.68	4.6	64.6	2.7
75	1.7	10.7	8.4	0.68	4.6	65.2	3.0
75	1.8	10.7	8.4	0.68	4.6	65.7	3.3
75	1.9	10.8	8.4	0.68	4.6	66.1	3.6
75	2.0	10.8	8.5	0.68	4.6	66.5	4.0
86	1.1	11.2	8.8	0.69	4.7	70.0	1.4
86	1.4	11.5	9.1	0.70	4.8	73.0	2.1
86	1.6	11.6	9.2	0.70	4.9	74.5	2.6
86	1.7	11.7	9.3	0.70	4.9	75.1	2.9
86	1.8	11.8	9.4	0.71	4.9	75.6	3.2
86	1.9	11.8	9.4	0.71	4.9	76.1	3.5
86	2.0	11.8	9.4	0.71	4.9	76.6	3.8

Notes: Heating performance data is tabulated at 68°F DB entering air at ARI/ISO 13256-1 rated cfm. For ARI/ISO 13256-1 certified ratings, see Table 19, p. 29. See Performance correction tables to correct performance at conditions other than those tabulated. Data shown is for unit performance only. Interpolation is permissible. Extrapolation is not.
Rated GPM: 1.8 Minimum cfm 172; Rated cfm 215; Maximum cfm 258



Required BORE length with minimal groundwater movement = 18190 ft (607 ft/bore)
(Design based on COOLING mode - net annual heat rejection to ground)

Required BORE lengths with high rates of groundwater movement (or year 1)
Cooling: L= 16480 ft (550 ft/bore), Heating: L= 7360 ft (245 ft/bore)

*** Heat Pump Series: Pretty Good Heat Pumps ***

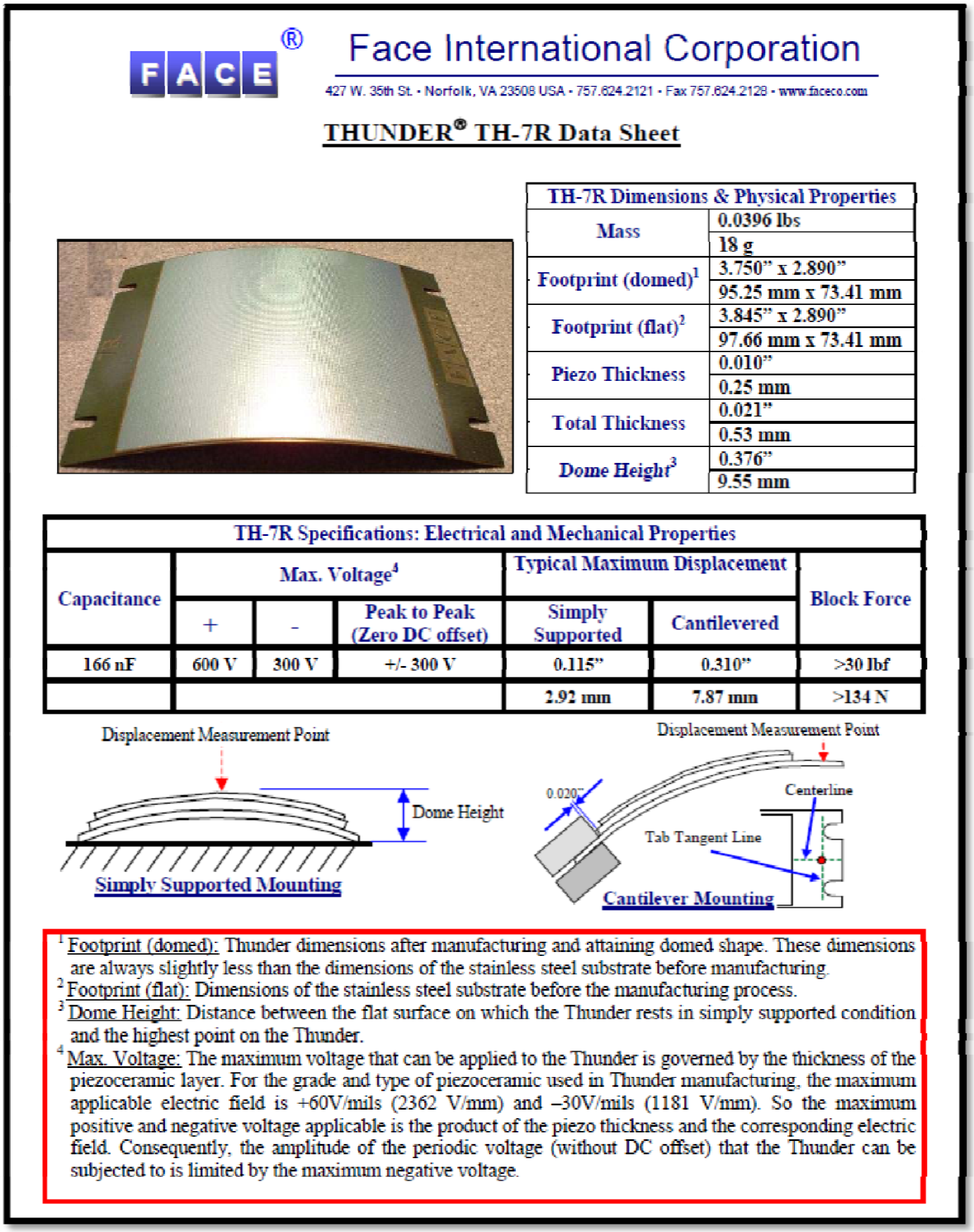
Temperatures
Unit Inlet (cooling) = 86.0°F
Unit Outlet (cooling) = 96.0°F
Unit Inlet (heating) = 45.0°F
Unit Outlet (heating) = 39.0°F
Normal ground temp = 62.0°F

Maximum Block Loads/Demands
Cooling Load/Demand = 835 kBtuh / 62 kW
Heating Load/Demand = 461 kBtuh / 34 kW
Cooling EER (Ht Pump/Sys) = 13.5 / 12.8
Heating COP (Ht Pump/Sys) = 4.0 / 3.6
Loop Pump Head/Flow Rate = 49 ft / 209 gpm
Loop Pump Power/Demand = 3.7 hp / 3.2 kW

U-bend/Bore Data
U-tube Diameter = 1.00 inch
Separation dist. = 20.0 ft
Grid = 5 wide by 6 deep
Grout Conductivity = 0.90 Btu/hr-ft-°F
Bore Diameter = 6.00 inches

Ground Data
Thermal Conductivity = 1.20 Btu/hr-ft-°F
Thermal Diffusivity = 0.80 ft^2/day
Ground Temperature = 62.0 °F

APPENDIX B PIEZOELECTRIC FLOORING SPECS



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THUNDER® TH-7R Data Sheet

TH-7R Dimensions & Physical Properties	
Mass	0.0396 lbs
	18 g
Footprint (domed)[1]	3.750" x 2.890"
	95.25 mm x 73.41 mm
Footprint (flat)[2]	3.845" x 2.890"
	97.66 mm x 73.41 mm
Piezo Thickness	0.010"
	0.25 mm
Total Thickness	0.021"
	0.53 mm
Dome Height[3]	0.376"
	9.55 mm

TH-7R Specifications: Electrical and Mechanical Properties

Capacitance	Max. Voltage[4]			Typical Maximum Displacement		Block Force
	+	-	Peak to Peak (Zero DC offset)	Simply Supported	Cantilevered	
166 nF	600 V	300 V	+/- 300 V	0.115"	0.310"	>30 lbf
				2.92 mm	7.87 mm	>134 N

Simply Supported Mounting

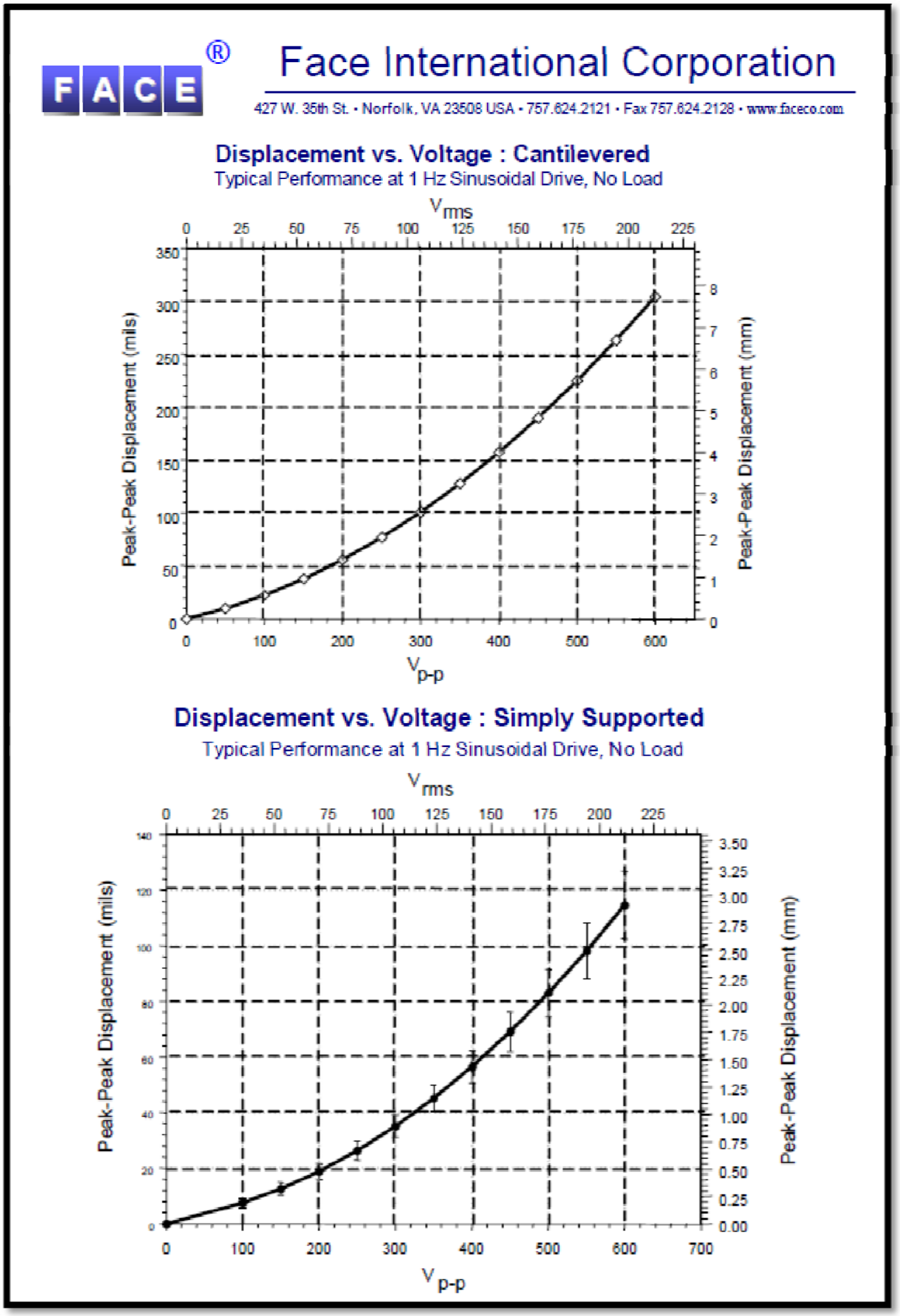
Cantilever Mounting

[1] Footprint (domed): Thunder dimensions after manufacturing and attaining domed shape. These dimensions are always slightly less than the dimensions of the stainless steel substrate before manufacturing.

[2] Footprint (flat): Dimensions of the stainless steel substrate before the manufacturing process.

[3] Dome Height: Distance between the flat surface on which the Thunder rests in simply supported condition and the highest point on the Thunder.

[4] Max. Voltage: The maximum voltage that can be applied to the Thunder is governed by the thickness of the piezoceramic layer. For the grade and type of piezoceramic used in Thunder manufacturing, the maximum applicable electric field is +60V/mils (2362 V/mm) and –30V/mils (1181 V/mm). So the maximum positive and negative voltage applicable is the product of the piezo thickness and the corresponding electric field. Consequently, the amplitude of the periodic voltage (without DC offset) that the Thunder can be subjected to is limited by the maximum negative voltage.



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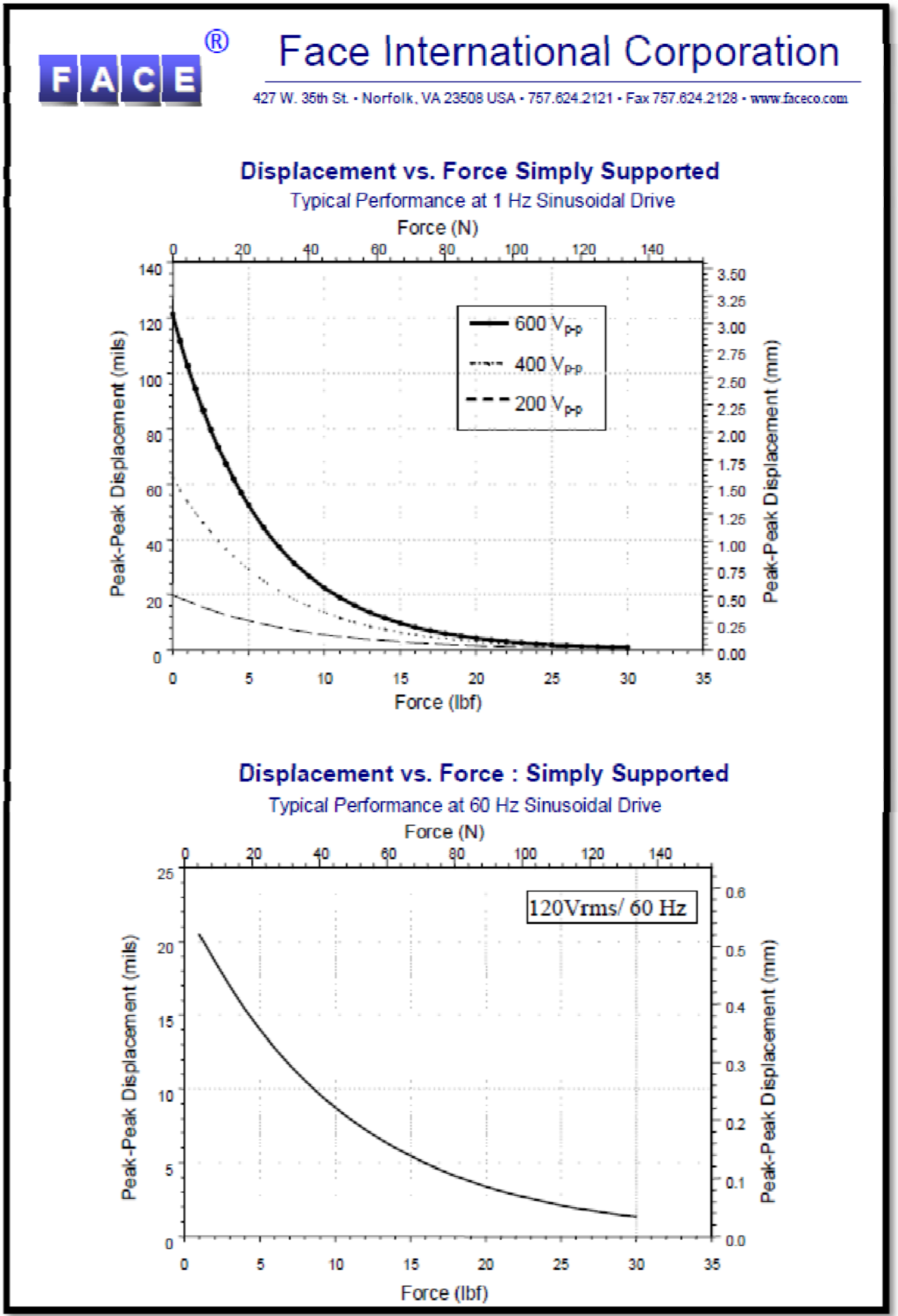
Displacement vs. Voltage : Cantilevered

Typical Performance at 1 Hz Sinusoidal Drive, No Load

Displacement vs. Voltage : Simply Supported

Typical Performance at 1 Hz Sinusoidal Drive, No Load



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Displacement vs. Force Simply Supported

Typical Performance at 1 Hz Sinusoidal Drive

Displacement vs. Force : Simply Supported

Typical Performance at 60 Hz Sinusoidal Drive

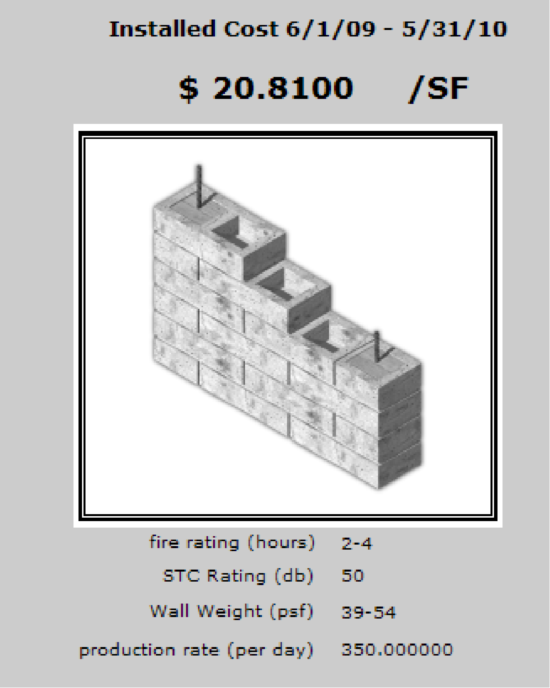
TH-7R

THUNDER TH-7R PHYSICAL PROPERTIES					
Mass	Footprint (domed)	Footprint (flat)	Piezo-layer Thickness	Total Thickness	Dome Height
0.0396 lbs	3.750" x 2.890"	3.845" x 2.890"	0.010"	0.021"	0.376"
18 g	95.25 mm x 73.41 mm	97.66 mm x 73.41 mm	0.25 mm	0.53 mm	9.55 mm

TH-7R DATA SHEET

$ 113.00

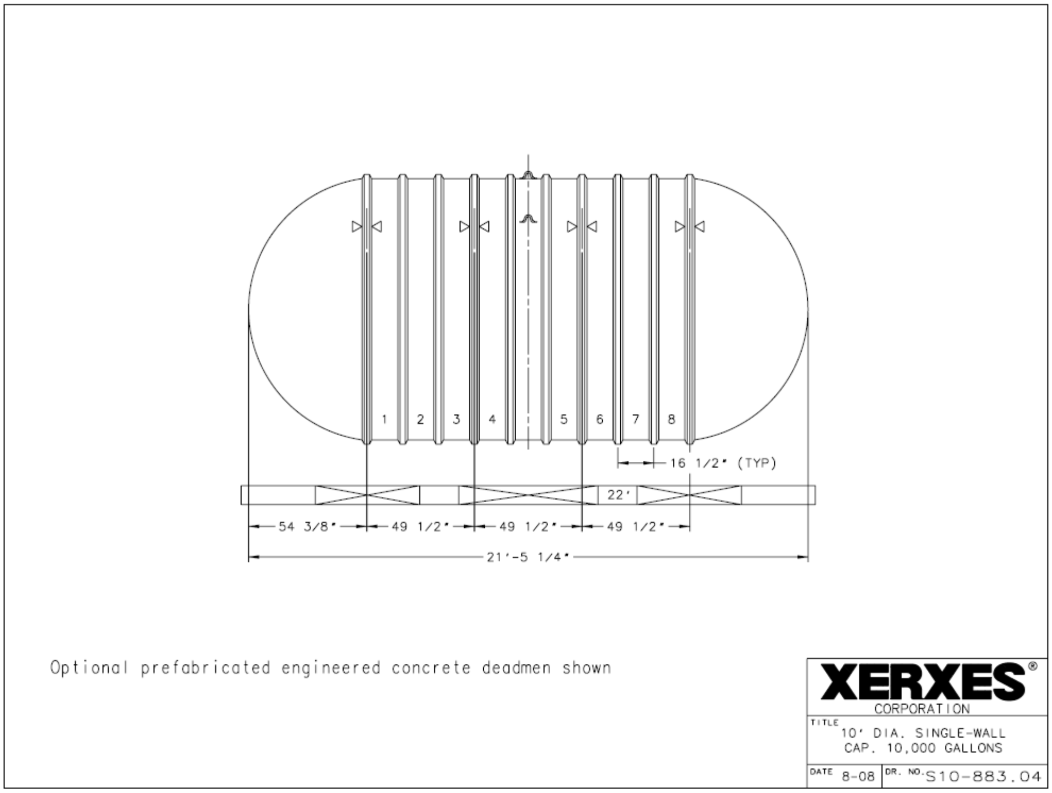
APPENDIX C RAIN HARVESTING SYSTEM



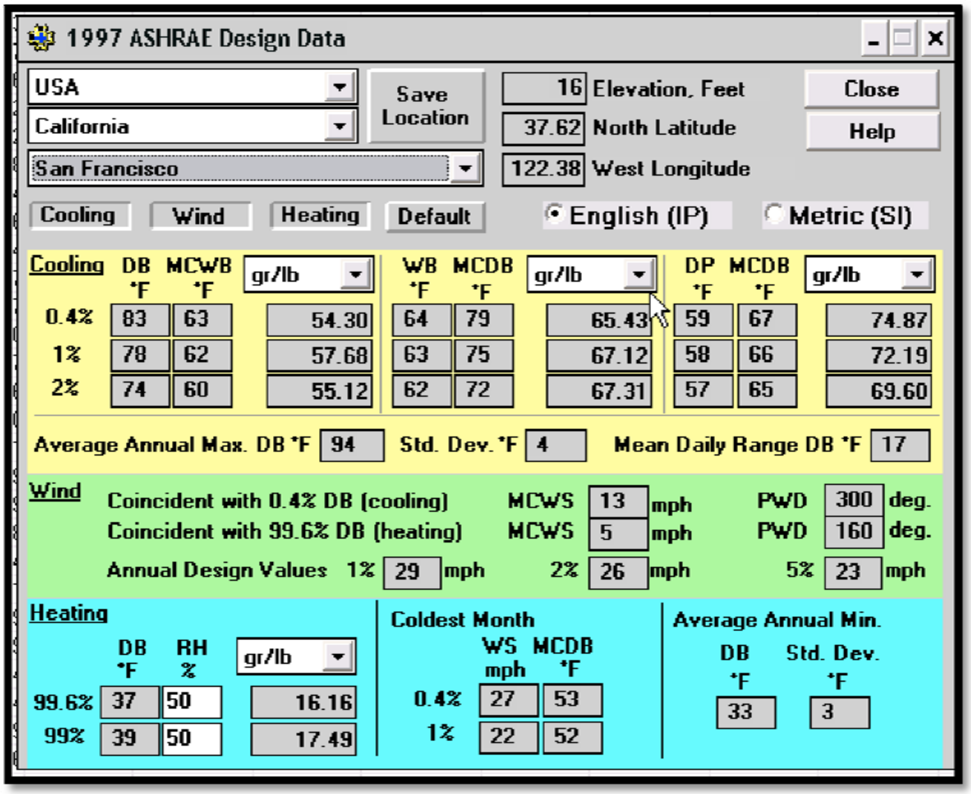
Installed Cost 6/1/09 - 5/31/10

$ 20.8100 /SF

fire rating (hours)	2-4
STC Rating (db)	50
Wall Weight (psf)	39-54
production rate (per day)	350.000000



Optional prefabricated engineered concrete deadmen shown



USA
California
San Francisco

16 Elevation, Feet
37.62 North Latitude
122.38 West Longitude

● English (IP) ○ Metric (SI)

Cooling

	DB °F	MCWB °F	gr/lb	WB °F	MCDB °F	gr/lb	DP °F	MCDB °F	gr/lb
0.4%	83	63	54.30	64	79	65.43	59	67	74.87
1%	78	62	57.68	63	75	67.12	58	66	72.19
2%	74	60	55.12	62	72	67.31	57	65	69.60

Average Annual Max. DB °F 94 Std. Dev. °F 4 Mean Daily Range DB °F 17

Wind

Coincident with 0.4% DB (cooling) MCWS 13 mph PWD 300 deg.
Coincident with 99.6% DB (heating) MCWS 5 mph PWD 160 deg.
Annual Design Values 1% 29 mph 2% 26 mph 5% 23 mph

Heating

	DB °F	RH %	gr/lb
99.6%	37	50	16.16
99%	39	50	17.49

Coldest Month

	WS mph	MCDB °F
0.4%	27	53
1%	22	52

Average Annual Min.

DB °F	Std. Dev. °F
33	3