Senior Thesis

Spring, 2008

330 Fellowship Road

A Liberty Property Group Project

J. Springer Wahl

5th Year Construction Management Student

Professor Riley

Faculty Advisor

J. Springer Wahl

Liberty Property Trust
Liberty Walk at East Gate
330 Fellowship Road

LIBERTY PROPERTY TRUST

JSW225@PSU.EDU
5th Year, Construction Management

PROJECT TEAM

Owner: Liberty Property Trust
GC: Penntex Construction
Architect: Meyer Associates
Engineers: Bala Consulting, Revision Architecture, Taylor-Wiseman.

PROJECT FEATURES

Duration: Spring 2006 - Fall 2007
Size: 4 Stories, 103,700 ft squared
Total Cost:
Building Use: Office, Mixed Tenants
Delivery: Design - Bid - Build

MECHANICAL

AHU's: 4 AHU's, 1 Per Floor
CFM: 27,000 CFM Each
Voltage: 460 Volts, 3 Phase Each
Plumbing: 1 Set per Floor

ARCHITECTURE

LEED: Silver Rating, Poss Gold
Entry: Attractive Lobby, Sculpture in Rear Lobby
Exterior: 50% Brick with windows, 50% Glass on corners and top

STRUCTURE

Foundation: Slab on Grade w/ Pile Caps, 3' Edge footing
Steel: W-Shape Beams
Concrete: Concrete Decks Flrs 2-4
Masonry: Steel backed Bricks

ELECTRICAL, LIGHTING

Lighting: Majority Flourescant with spec Flourescant Highlights in non-Tenant space
Lighting: Tenants to design their own space
Electric: Basic 120 / 277 Volt System

http://www.engr.psu.edu/ae/thesis/portfolios/2008/jsw225

Table of Contents

Executive Summary

Within these pages you will find the research and findings of my 5th year Construction Management Thesis. One of the first pages to be found will be a page acknowledging and thanking all those that helped me to find answers and design new systems.

The second part of this Thesis report is a brief description of the project which the research is based around. 330 Fellowship Road is a 4 story 100,000 square feet core and shell office building in Southern New Jersey.

Following that will be the sections containing the research and innovation. First will be a new Fire Protection Systems method that aims to further steel structural integrity in a fire. Next will be a section that describes how the owner of the building stands to make a lot of money by using government incentives and Solar Panel Systems. Lastly, is a research topic that discusses how to apply the Solar Panel ideas over a quantity of buildings a General Contractor is building, or that a Property Trust company owns. The most important thing to note is a deviation from the second version of the Proposal. The old depth topic research wasn't very interesting, and there wasn't that much money to be saved. With the new depth topic research, the owner stands to save millions of dollars in a single state alone.

Acknowledgements

The first people I'd like to thank are my fellow students. Not only for making the time here immensely enjoyable, but for sharing knowledge and ideas in fields I had not studied. I can only hope that I earned that honor by doing the same for them.

Specifically, I would like to name a few students who helped me directly with my research. First is Maxwell Chien who helped to get my fire protection systems research heading in a viable direction. Next to thank would be William Tang, who helped us to figure out specifics of the equations needed to calculate total heat loss. Professor Bahnfleth then helped me to sum up the vast amount of information I had on the system to a useable and desirable solution. And last to thank for the fire protection research is Professor Hargather who initially pointed me in the correct direction for the beginnings of my research.

For my Solar Power research, I'd like to begin to thank Tom Yost and Kyle Macht who are both members of the PSU Solar Decathlon team. They helped me to start the Solar Panel sizing and placement. Next would be David Kanida who not only helped me to figure out the power properties of solar panels, but some of the government benefits available in purchasing a system.

Next I would like to thank Liberty Property Trust, and specifically Jim Sunday VP and Jenny Schow. They allowed me to use their building for research. They also helped to send me information I needed. I hope my research and work can help benefit them and Liberty Property Trust greatly.

Lastly I'd like to thank my Father, especially for all the money I promise I will pay back in some form or another. But mostly for all the funny stories and life experiences that kept me going both in happiness, and knowledge I had gained.

Project Information

330 Fellowship Road is a part of a four building complex that is Liberty Walk at East Gate in Mount Laurel, New Jersey. Liberty Properties have purchased a corner of a street block containing 3 buildings. Two buildings were demolished and three were built, including 330 Fellowship Road. There are a pair of warehouses behind 330 Fellowship Road that hope to soon purchase and replace. All of the land will be enhanced, including miles of sidewalk for the general public to use.

There were two buildings that needed to be demolished before construction could commence. This helped to earn points in the Leed rating. How extensive of demolition that would be needed is unknown.

This building is a typical shell and core Office Building coming in at a little more than 25,000 square feet per floor, for four floors. The 239ft by 114ft rectangular building has both new and old architectural features, as well as some very interesting ideas. It will be receiving at least Leed Silver rating, with a chance of receiving a Leed Gold rating.

For roughly 3/4 of the front and rear exteriors length wise and for 3 floors up the building has attractive brick with details and raised texture sections. Above the 3/4 lengths and on the 4th floor it switches from brick to sandblasted aluminum, as well as making the windows larger. However, on 1/8 of the front and rear exteriors on the ends, there is no brick or aluminum, but pure spandrel and vision glass from the ground to the top of the 4th floor. A similar effect is produced for the two shorter sides except for a little more than 1/4 the short side length on each end being glass. It has a very elegant entrance lobby, with perhaps an even more interesting back lobby which connects and split the bottom floor down the middle. On the north side of the lobby, there is an atrium which the second floor balcony looks over.

The curtain wall system isn't too complex. Where there are bricks, they shall be laid in front of a structural steel backer wall with a minimum 1" air gap. An exterior vapor barrier as well as a sheathing layer will be placed on the outside of the steel backer wall. The interior face of the panel will be insulated. The glass will be glazed with the frames having a Duraner XL Finish. The vision glass will be 1" thick, with another layer of 1/4" Low-E glass.

The roof will be an energy star roof for Leed Points. It will be a thermoplastic polyolefin (TPO) roof of a reinforced 0.60 mm thickness, on top of 6" rigid insulation. This insulation will be adhered to the metal decking, and not pierced. This system will provide an R value of 30.

Structural

The structural system is a pretty basic or common system. It has a 4" Slab on Grade Foundation, with concrete edge beams around the perimeter of the building. The bottoms of the edge beams need to be a minimum of 3' below grade. Below the interior steel columns are 2' to 4' deep from top of SOG square column footings.

Running up from the foundation are all W12 steel columns, with weights ranging from 45 to 79 with the larger columns being on the interior grid. W18x35's are the most common beam size, being placed where the tenants would lease. Slightly smaller beams are used for the interior third span, being that it is smaller. The girders on the end of the building as well as the interior longitudinal girders are bigger, from sizes W21x50 to W24x84. This description is typical for the two other floors above. For the roof, much smaller beams are used, as well as trusses, with the 28K6 being the most common truss.

Electrical and Lighting

The system is a standard 277 volt / 480Y volt building. The entire building is on a 2000 Amp Service. The Air Handling Units run off of the 480 volt service. Because the tenant space is designed to be self furnished and finished, the electricity service is not finished. There is a 250 KW generator Life Safety Standby in an exterior weather proof casing.

The only finished lighting resides in the two lobbies, and any common areas including elevator lobbies, and a single corridor on the second floor. The majority of the lights in most of the common space are recessed circular fluorescent lamps. The corridor has square 2x2 fluorescent lamps. The sculpture in the rear lobby is backlit by 10 single line fluorescent bulbs.

Mechanical System

There is a specific Air Handling Unit per floor, with the ducts running down the chases to each floor directly down from each AHU. Because the tenant space isn't leased, the final diffusers or finished ducts aren't in place yet. The tenant will place these when it leases the space. The cooling operation runs off of electricity, while the heating coils run off of a gas line in from the street.

Construction Systems

There is a General Contractor from Penntex Construction running the show. I currently do not have the information of what kind of contracts were signed between the owner and GC, and the GC and subcontractors. The building will be LEED Rated, with the most probable rating of Silver. If Liberty Properties works hard enough, they'll receive a Gold rating. Liberty was proud to boast of their support for the GBC and the LEED system, telling the workers that what they are doing will be good for the environment. Liberty hopes that this will result in more productive workers as they take more pride in their work.

Fire Protection Systems

The Fire Protection is a standard system sized for Ordinary Danger Levels. It stems directly off of a 12" water main from the street into the building. The main feeder rises up to each floor and branches off to cover all of the floor area. It is a standard wet system. All of the interior exposed columns have fire proofing sprayed on.

Miscellaneous Systems

The Elevator is an Otis Holed Hydraulic LVM 3500, with a 3500 pound rated capacity each. The telecommunications system is not currently finished, due to the tenant space not being finished. The tenants will run the lines from the electrical rooms to where they want.

Problem Statement – Fire Protection

Breadth Number One

There is no real problem in the current state of Fire Protection Systems. In general, water comes in from the water main, and runs to a Sprinkler Specific water pump. This pump needs to be able to send the correct water pressure to the furthest area from the pump. Basically it needs to adequately supply the point in a far corner of the building. Along the way fluid dynamics rob the flowing water of energy by friction and pressure loss.

In current buildings, the sprinklers go up a central core, or at least up a logical area of the building. From here, the lines are branched off to cover the each story's floor area.

While there is no major problem plaguing this industry, this didn't stop my desire to make it better. On 9/11 the attacks did something that no one had predicted would happen. They blasted off the fire protection material on the columns. With the subsequent fires, this exposed the columns, which had very little heat resistance capability, directly to the fires. It took very little time for the columns to hit failure temperature where the loss of strength became more than the safety factors applied to the loading of the columns.

The solutions to our problems only go as far as our imaginations take us, or as far as our failures have fallen.

Goals

The utmost goal of this was to reroute the sprinkler lines through any building and to use the sprinkler lines themselves as heat sinks on the columns. Instead of running the sprinkler in one giant line up a central core, and then branching off at each floor, I would run the lines up the columns. In the event of a fire, the running water would remove heat from the column, and then run out the sprinkler heads, further extinguishing, quenching or delaying the damaging effects.

But this new system won't come without a price. It was expected that it would cost more, and that the schedule ramifications would be greatly more than the current simple installations.

Resources

1.) Penn State Course IHS 420, Fire Protection Systems.

2.) Michael Hargather, Me 201 Professor

3.) William Bahnfleth, AE Department Professor

4.) Maxwell Chien, AE Undergraduate Student

5.) William Tang, AE Undergraduate Student

6.) Fundamentals of Heat and Mass Transfer, DEWITT, ICROPERA

7.) ASHRAE Standards Water Tables

Process

1.) Size and design the new system

2.) Estimate new system's costs

3.) Estimate old system's costs

4.) Analyze Controlling factors

5.) Set up Thermal Model

6.) Get help to analyze Thermal Model

7.) Conclusions

8.) Further Research

Size and Design

First off, all of the columns are assumed to be W12x79 sized throughout the building. There will be 4 sprinkler pipes which rise up each column. At first, there were several problems with the design of the system. Namely, I had figured on each rising line being dedicated to only one floor. This created a problem where at the top of each sprinkler riser, a complex system of turns, bends and breaks to cover the required floor area for the sprinklers themselves.

This created another problem, however it might not be as bad as the problem stated immediately above. By dedicating a single pipe to each floor, as the pipes break off and end, the column would lose that pipe's cooling capacities as it doesn't follow the column up. This isn't so terrible considering that the bottom floor column piece has the greatest capacity for failure in comparison to the higher floors, however it would create uneven cooling / heating problems on those top floors.

After a little day dreaming in a Thermal Dynamics class, the solution became quite apparent to the complex bends and uneven cooling problems. Instead of having a dedicated line per floor, all the pipes would hit all of the floors. From each pipe at each floor would emanate an "F" shaped layout having roughly 4 sprinkler heads each as seen on Appendix Page 39, General Layout Plan. On Appendix Page 40 is a more detailed look at a single column system. On Appendix Page 41 is a detailed view of the column, the pipes, and the baseplate. On Appendix Pages 42-43 are 3d views of the standard system per floor, and the underslab feeders respectively.

The amount of water in the system is sized hydraulically as per learned in IHS 420 class on Fire Protection. It was assumed that one column's system would be running, and no more. From the building being Ordinary Hazard, roughly 12.5 Gallons per minute would flow through each sprinkler. With the sprinkler lines being sized to be 2", there is very little pressure loss. All told, per "F" shape, there runs 50 Gallons per minute. So a single column with all sprinklers firing will be consuming near 200 Gallons per minute. With losses from pipe travel and pressure losses, the entire Sprinkler Pump will be sized at 250 Gallons per minute.

System Cost Analysis

A detailed breakdown of the costs is located in Appendix Pages 33 and 34. The current system is estimated to cost roughly $450,000 with a square foot cost of $4.18 for the old system. The new system is estimated to cost roughly $610,000 with a square foot cost of $5.59 for the new system. There is an explicit cost difference of $153,439.61, which translates to my new system costing roughly 34% more.

There could be several reasons for the cost disparity. First, there is much more 2" pipe in my new system, but some of the costs are saved up due to the lack of as many 4" sprinkler mains that don't need to be run through the building. In general, there are more connection pieces in the new system, which also drives up the cost.

However, that being said I believe my new system is much more conducive to prefabrication construction practices, especially on some of the larger highrises. Considering highrises further, the repeatability could also help to drive down the price more.

Controlling Factors

The first controlling factor analyzed was the actual loading upon the column. The column including K factors and length is rated for 900 Kips. Through using 1.6L + 1.2D loading for the roof including 20lbs LL, 20lbs Snow, and 20lbs Dead, and using given loadings for interior floors of each beam, the calculated load the bottom column is carrying is 617 Kips.

Dividing this by the 900 Kips rated, it loses the leeway the safety factors grant it at 68.5% strength. Through graphing this is seen on Appendix Page 48 which comes from an 8-value strength vs. temperature chart shown in the Steel Manual, the corresponding temperature to a strength percentage of 68.5 is roughly 980 degrees Fahrenheit. This basically means that when the column heats up to 980 degrees, it will begin to fail assuming that the building is fully loaded.

However, upon conferring with several Mechanical Options like Mr. Chien, Mr. Tang and Professor Bahnfleth, we have decided that the real controlling factor would be the water in the pipes attached to the column flashing over to steam. This is a big problem because not only does the water in the pipes remove heat from the column, but they still act as the fire quenching agent from the sprinkler heads. If the water becomes steam, then the building is doubly in trouble.

Thermal Model

Given that I am very lacking in thermal dynamic capabilities, the model that would be set up needed to be very basic. The basics of it would be the W12x79 Wide Flanged column would be compressed into a pipe with very thick walls.

This pipe is based around being 2" wide. From here, I looked up the area of the W12x79 column, and decided the thickness. The resulting pipe's wall would be roughly 2" thick, making the entire column stand 6" wide as documented on Appendix Page 44.

The water flow in this simulated column will only be 50 GPM to simulate the kind of flow that will exist in the new system. Making the flow higher like to the 200 GPM that will be flowing past the actual column could create fluid dynamics problems in such a small pipe.

Thermal Calculations

The basis of the thermal calculations is a lumped capacitance thermal analysis. The amount of heat the steel can absorb will be equal to the amount of heat given off when it is surrounded by air of a certain temperature multiplied by time. The heat given off by the air is controlled by the convective heat transfer coefficient of the air (the ease of which it gives off energy) multiplied by the surface area of the outside column, then multiplied by the temperature of the air minus the temperature goal of the equation. This first part assumes that no water is flowing. It is a basic calculation to figure out how long the steel will take to get to a failure temperature. This is documented both for 200 degrees water failure and 980 degrees material failure of just the steel alone in Appendix Page 35.

The second calculation is very similar to the first. But in addition to the heat added to the steel from the surrounding temperature, the amount of heat subtracted is also calculated from the flowing water. First, the conductive heat transfer coefficient needs to be calculated from the amount of heat the flowing water can remove, then this is multiplied by the inner surface area of the pipe, and then by the temperature of the water minus the temperature goal of the equation. This is all documented in Appendix Page 35.

The conductive heat transfer coefficient is not so easy to calculate. First I needed to calculate the Prandtl number which deals with heat capacity, the viscosity and the thermal conductivity of water. Then I calculated the Reynolds number, which deals with the mass flow rate, the surface area per unit length of the pipe, and the viscosity. From there, I use the Prandtl number and the Reynolds number to calculate the Nusselt number. Then the conductive heat coefficient can be calculated using that number, the thermal conductivity of water and the diameter of the pipe.

The results of these calculations are documented in Appendix Page 35.

Conclusions

The results were quite astonishing. Given such a high temperature applied to the column, and such a low controlling temperature of the water, I expected minimal time gained, something that wouldn't have been worth the 33% added costs. The column takes 13.9 seconds to reach 200 degrees by itself, and 24.5 seconds to reach the material failure at 980 degrees. The column with the running water will never reach 200 degrees.

The big question is, does it still apply to a non-simplified column? While I have very little thermal background, I believe it does apply. The first thing to consider is that the column is not just a lump of steel. It is a complex shape with fins, and thin sections which could probably be more easily heated. On top of that, it probably would not be heated in a steady state. Meaning that it probably won't be uniformly heated, so some sections of the column will be a different temperature.

However, given all that you also need to remember that there will be 3x more water flow (200 GPM) rushing past the column than the calculated 50 GPM. The only stipulation for this is that the sprinkler pipes would need to get a good thermal bond with the column. Some sort of material would need to be chosen to fill up all of the spaces to the column, possibly including around the pipes as well.

Further Research

This is a very promising system. I am naming it the Springer System. It will need more research done to determine if it truly is a viable system.

First and foremost, this needs to get in the hands of a Mechanical Engineer, or a Mechanical Systems Option AE. From this a more detailed analysis will be able to be performed, either by hand or in some sort of computer program. This would need to be done on a Wide Flange shaped column. Included in that analysis would need to be a temperature gradient drawing of the column. However, given that the 50 degree water would stop the lumped column from heating to 200 degrees, I don't believe that on the W shape that any small piece or any piece large enough would reach the material failure temperature. According to the information taken from the steel manual, the steel starts to lose strength at 750 degrees Fahrenheit.

Past any calculations, I believe it's too risky to put in a building without some sort of mock up test. Given a limited application across the building industry, it could be years or possibly even decades or longer until the off chance that the Springer System's full capabilities are tested. But it would be extremely expensive to just light a bunch of full scale mockups on fire. Professor Hargather was studying how to apply small scale mockups to real world buildings using explosives. I believe that something very similar could be done using my system. If we know how a regular column reacts in a fire, we can set several small different scales of a similar construction, copy the scales and construction and use flowing water, and try to find some factors at which it could be applied to a real world size building.

Solar System Designs

Breadth Number Two

With emerging technologies, a Solar Panel system is becoming an increasingly better choice for businesses and building owners. The increasing efficiencies have driven up the power that is able to be converted from the Sun's energy, at the same time driven down the power it takes to produce a solar panel. These panels take 1 to 4 years to earn back the energy it took to create them, but still have life expectancy of roughly 30 years.

The problems exist with the cost of these solar panels. While over the lifetime of the solar panels they can earn their money back, it is often a difficult expenditure for any owner, as will be described later. However, it is possible to take advantage of government rebates and incentives at a federal, state and local level to decrease the cost of the system to very manageable levels.

Many companies are now starting up solely for the purpose of taking advantage of the government subsidies. These companies would put on a solar panel system on a building at no cost to the owner, and then begin to sell power back to the owner at a better than standard rate. After 15-20 years, the owner assumes control and ownership of the system and can generate their own power.

Goals

The main goal of this research will be to generate a plan and a system for the current owner to immediately use and implement. I will detail the costs of a new system, as well as give quoted schedule estimates. Further, I will show how these systems are financially viable and well worth the initial costs, given the current subsidies market.

Resources

1.) Dsireusa.org Detailing government subsidies

2.) Solar Power in Building Design: The engineer's complete design resource, GEVORKIAN

3.) Sun Power Corporation

4.) Tom Yost, Undergrad AE, Solar Decathlon Member

5.) Kyle Macht, Undergrad AE, Solar Decathlon Member

6.) The Heat Shed, Sun Power Corp dealer

7.) David Kanida, PE, IDA Inc.

Process

1.) Research Weather Data

2.) Pick solar panel

3.) Place solar panels on roof

4.) Calculate power generated

5.) Calculate costs and benefits

6.) Show payback periods with and without benefits

Solar Panel Sizings

The first step I did was to use NASA's meteorological website to find the Insolation from the sun in south New Jersey. The average insolation over a 10 year period per year is 4.35 kWhrs/m^2/day at the optimum angle of 33 degrees. This is the average energy the sun generates per square meter of surface area.

After some brief research on the internet, Sun Power Corporations 305 Watt model was chosen. This panel is roughly 3 feet by 5 feet. After some trigonometry, if the panel was laid with the 5' length on the bottom, it would stand 1.65' tall at the highside, and would need 2.5' behind it for the shadow to clear it. Just to give it more room, each panel and a decent amount of walking room behind it would take up a 5' by 5' horizontal box, as documented in Appendix Page 45. With south being nearly at a 45 degree angle to the building lengthwise, it was very easy to arrange the panels. However, the mechanical roof housing is given some leeway to keep the solar panels that would nearly always be shaded further away. With all of this being taken into consideration, 681 panels could be placed on the roof. This is shown on Appendix Pages 46 and 47.

The size of the panel is 15 square feet. This is 1.39 square meters. This multiplied by the insolation yields about 6.05 kWhrs/day. Sun Power Corp's 305 Watt model is currently the top of the line panel. It has an efficiency of 18.7%. This means that of the 6.05kWhrs/day provided, the panels can only give 1.13kWhrs/day. With Sun Power Corp's top inverter conversion rate of 95%, this gives off 1.074kWhrs/day per panel of AC power, and back into the system.

With 681 panels, this gives off 731.5kWhrs/day for this building. Over a year, the power generated is about 267MWhrs. This is documented on Appendix Page 36, Chart #4.

Government Subsidies

As per the Dsireusa.org website, there are two major subsidies currently active in New Jersey. The first is at the Federal level where 30% of the system's cost can be written off as a tax credit. Combined with this, 30% of the depreciated value can be written off every year as well as a tax credit. This gives a savings of roughly 60% per system, provided the system is still in place. Every year the program gets extended by one year, so it is not a sure thing.

The other major subsidy is from the State of New Jersey. New Jersey is offering $0.20 per kWhr produced. This is very substantial. The estimated value of electricity for 330 Fellowship Road building is about $0.10 per kWhr.

Value of System

The value of this system is very substantial, with and without the government tax credits. This is documented expressly in Appendix Page 37, Chart #7. At an estimated $7.25 per watt cost quoted from The Heat Shed of the 305 system, the total cost of the system is about $1,500,000. The energy generated by the solar panels valued at $0.10 electricity cost plus $0.20 NJ Incentive is worth $80,000 a year. Assuming no inflation or different dollar values over the years, this system will be paid back in about 19 years without any of the Government tax credits. After that, the system will save the owner $900,000 over the remaining 11 years of the estimated 30 year lifespan. This is shown on Appendix Page 37, Chart #6.

The system saves the owner a significant amount more with the Government tax credits. The system with the rebates will cost the owner a total of $600,000 over the 5 year depreciations. Again, assuming no inflation or differing dollar values, this system will be paid back in 7.5 years. The system will save the owner $1,800,000 over the remaining 22.5 year lifespan. This is shown on Appendix Page 37, Chart #6.

Conclusions

As the time goes on, these systems will only become more efficient. Even without the Tax Credits, I believe that this system is worth it to install. $600,000 is a significant amount of money. By the time the solar panels need to be replaced, it should only be cheaper. Not only that, but with the efficiencies climbing, the systems could cost half as much, but still produce twice as much. Using that wild unsubstantiated claim, and assuming no inflation or differing dollar values, the same sized system as shown here could cost $750,000, but produce $160,000 worth of electricity every year.

But if you could guarantee the Government incentives, or act fast enough to ensure you'll receive this year's incentives, there is very little risk in building a system. With a decent amount of money to be gained from building a solar panel system, the only thing you are really risking is whether or not you will earn more by taking advantage of government programs.

Another consideration is that a controlling factor for a smaller company may not be the cost or speed of construction of the systems, but the amount of taxes paid each year. It would do a company no good to claim more in tax credits a year than they pay, especially with the year by year tax credit program extensions.

A decent problem I encountered when picking my solar system is that I accidentally picked the best system out there. While it is nice to show the best that the building can currently host, it has been made apparent that it might not be feasible. With Sun Power Corporation's panels being the best and given their non-infinite production capabilities, the demand for their product is extremely high. As such, Sun Power Corp gets to pick and choose which buildings or projects will house their panels. Unless you are a friend of theirs, or have a really interesting project, you probably won't get to use their panels. If there was more time, the systems would be redesigned to use a more available, but still good set of solar panels.

There was a problem encountered way late in my research of this solar panel system. After talking to the owner of The Heat Shed, I made casual mention of the angle of the solar panels to get the most insolation over the year. They are currently set at 33 degrees. However, the owner of The Heat shed he mentioned that nearly all of the raised angles are 15 degrees. If they are raised any further they will catch too much wind and become a problem to handle. The solar panels will lose 4-5% of the insolation by dropping the angle nearly by half. However, because of the trigonometry involved, this may be able to be reclaimed from having the panels closer together. Unfortunately, there is not enough time to calculate the power lost and then the number of panels gained.

Applying Solar Systems on a Mass Scale

Depth Research

With the money to be gained from purchasing a solar panel system these days, there are very few reasons left for nearly all builders or all owners to invest in a system of some sort. With every passing year the benefits become greater due to the research of the Photovoltaic systems.

Goals

The main goal of my depth research is to convince all new building owners to include a solar panel system with every building capable. Another goal is to convince every property trust company that leases out office spaces that it is profitable to start retrofitting older buildings with new solar systems where the government incentives make it worthy.

Resources

1.) Dsireusa.org Detailing government subsidies

2.) Solar Power in Building Design: The engineer's complete design resource, GEVORKIAN

3.) Sun Power Corporation

4.) Tom Yost, Undergrad AE, Solar Decathlon Member

5.) Kyle Macht, Undergrad AE, Solar Decathlon Member

6.) The Heat Shed, Sun Power Corp dealer

7.) David Kanida, PE, IDA Inc.

Process

1.) Use Second Breadth Topic for Data

2.) Calculate NJ Savings for Liberty Property Trust

3.) Describe Power Purchase Agreements

4.) Design Sample PPA for Liberty Buildings

Liberty Property New Jersey Savings

The savings for just 330 Fellowship Road building with the government tax credits is $1.8 million. This is a significant amount of money. However, there are 69 other Liberty Property Trust buildings in New Jersey. Given that New Jersey has some powerful incentives, combined with the tax credits, there should be no reason to not outfit as many buildings as possible.

For example, over the 70 buildings, the amount of savings (assuming everything above holds true) over the 30 year lifespan of the panels is $126 million. This is making a few assumptions. The first assumption is that all these buildings would magically be built instantly. As per the time quoted to me from The Heat Shed, with the repeatability present with Liberty, it would take roughly 2 weeks to outfit each building. This gives us 26 buildings outfitted a year.

The next major assumption is that each building is roughly the same size as 330 Fellowship Road, or at least has the same amount of useable space to mount solar panels. A rough estimate of 330 Fellowship Road has 680 Panels over about 17,000 square feet. While the building may be bigger or smaller than 330 Fellowships 103,000 square feet over 4 floors, as long as it has 17,000 square feet of roof space it will produce similar amounts of energy.

Downfalls

Unfortunately, given the current efficiency and cost of available Solar Panels, it is not fiscally viable to use Solar Panels given no government incentives. Using the information from the Solar Panel sizing, with only $0.10 per kWhr saved from electricity usage and no tax credits, it would take 56.5 years to cover the costs of the solar power system. With this the owner would lose $700,000 over the course of the 30 years for each building, and then the cost of a new system at the 30 year life span mark, assuming the owner would buy another.

With the tax credit only, and no production incentives, the system would be paid off in 22.5 years, and save the owner $200,000 over the remaining 7.5 years.

But, there are many claims about costs per watt on the horizon that are truly outstanding. For example, a company named Nanosolar claims to be able to make solar panels at $0.99 a watt. These panels aren't really panels either, but super thin plates of conductors mounted on a paper like substance. This could allow the panels to be mounted in more places than just an array on the roof, thus allowing more electricity to be produced.

They claim to be able to give us solar panels at an ultimate of one tenth to one fifth the prices. At one fifth the price, this would make the current system cost roughly $300,000. However, they are currently only producing about half the energy of the most efficient panel which I have quoted above, making the value of energy provided roughly $14,000 with no government incentives. With all of these assumptions, this system could be paid off by itself in 22 years with another $115,000 saved over the remaining 8 years.

Power Purchase Agreements

All of the above was geared to the owner of the building being the one who would place the system. However, a lot of buildings are built by General Contractors. Because of this, if the incentives are right the General Contractors should take advantage of putting into place a Power Purchase Agreement.

For example, say the GC instituted a Power Purchase Agreement over a lease period of 20 years in the prime conditions of New Jersey. Using the information calculated in Breadth 2, the GC can make a million dollars over 20 years before transferring ownership to the building owner. The GC can make more if the PPA lease lasts longer. With developments promised for the future, a lifespan for solar cells of 40 years may be possible, thus increasing the time useable for a PPA.

However, the prime conditions may not exist elsewhere like they do in NJ. Assuming that the federal tax credits are in place, a GC could hope to make $200,000 over the course of 30 years. This itself may not be worth the investment given the short term risk that the tax credits may be revoked every year. But if the GC can clear the 5 year risk, then it should be attempted.

Conclusions

With the current state of affairs of Photovoltaic cells and systems, it is a difficult decision whether or not to invest in some instances. In 10 years with the new technologies it may be much easier to choose.

For a property holdings company like Liberty Property Trust, there are a few instances where they should install a solar system. The first and most obvious instance is when both the tax credit system and a local production incentive exist. With this, same assumptions standing, a company could make $1.8 million in straight savings. With no tax credits, the company could save $800,000. With no production incentive, but a tax credit present, the property trust company stands to save $200,000 which is still a significant amount. With no benefits however, the companies stand to lose a lot of money currently by investing in a system.

It is a little bit different for a General Contractor, but not by much. Given all the incentives, it is still clearly worth it for the GC to place a PPA on the table. With just a 20 year lease, they stand to make a million dollars or more in profit. However with no tax credits available, a GC stands to only make $97,000 in profit over 20 years. This might be difficult to achieve, given that very few states have strong production incentives. But it may be worth the endeavor if the GC can rig several buildings in advantageous states every year. $100,000 could be worth a lot over many buildings. Considering the opposite with a production incentive present, but no tax credits, the payback period is 19 years. While it is possible to extend the lease to 25 years, it wouldn't be attractive to a client for them to assume control on the remaining 5 years of the panels' lives. However, if the GC can convince the client, they would stand to make $500,000 per building. With no benefits at all, it is not viable to set up a PPA.

In a University environment much like Penn State, a lot of the same plans apply from the property trusts. However, this is contingent on Penn State paying federal taxes. With the lack of production incentives in Pennsylvania, without the federal taxes being paid, a solar panel system on the buildings would not be worth it. But with the great fundraising abilities of PSU, they may be able to supplement the tax credit loss (assuming that it is a loss) with donations from Alumni. Instead of applying the systems to the buildings, they could be placed in unused fields that PSU does own.

Final Conclusions

After much research and deliberation I cannot be unbiased when I recommend my new Fire Protection System. Of course it seems like it is the greatest thing ever to me. It should increase structural safety and prevent any collapse due to temperature loading. But is the extra cost estimated at 30-40% more worth something that rarely ever happens? Even with a bias, I think it needs to be scale modeled to determine actual effects.

As for the solar systems, given the right conditions there is no fiscal reason that any building owner should not follow the plan set out in this thesis. The same applies to most current buildings in the planning stages or not too far along in the building process. The propensity to profit with something so easy to do should make all companies consider adding these to their projects.

Appendices, Calculations, and Charts

Old System Estimate						
		Materials	Labor	Equipment	Total	Tot O+P
2" Pipe	L.F.	$7.90	$11.55		$19.45	$24.31
	9681	$76,479.90	$111,815.55		$188,295.45	$235,369.31
4" Pipe	L.F.	$23.50	$20.57		$44.07	$55.09
	1956	$45,966.00	$40,234.92		$86,200.92	$107,751.15
2" 90 Elbow	Each	$34.50	$41.25		$75.75	$94.69
	167	$5,761.50	$6,888.75		$12,650.25	$15,812.81
2" T's	Each	$42.50	$67.10		$109.60	$137.00
	45	$1,912.50	$3,019.50		$4,932.00	$6,165.00
2"-4" T's	Each	$134.00	$74.25		$208.25	$260.31
	31	$4,154.00	$2,301.75		$6,455.75	$8,069.69
2"-4" t's	Each	$134.00	$74.25		$208.25	$260.31
	72	$9,648.00	$5,346.00		$14,994.00	$18,742.50
4" T	Each	$272.00	$184.80		$456.80	$571.00
	7	$1,904.00	$1,293.60		$3,197.60	$3,997.00
4" 90 Elbow	Each	$197.00	$123.20		$320.20	$400.25
	16	$3,152.00	$1,971.20		$5,123.20	$6,404.00
Reg Sprinklers	Each	$6.40	$25.85		$32.25	$40.31
	886	$5,670.40	$22,903.10		$28,573.50	$35,716.88
Dry Sprink	Each	$79.50	$29.15		$108.65	$135.81
	18	$1,431.00	$524.70		$1,955.70	$2,444.63
Hidd Sprink	Each	$30.00	$45.65		$75.65	$94.56
	147	$4,410.00	$6,710.55		$11,120.55	$13,900.69
Brass Sprink	Each	$15.00	$25.85		$40.85	$51.06
	19	$285.00	$491.15		$776.15	$970.19
Sum		$160,774.30	$203,500.77		$364,275.07	$455,343.84
Cost per SqFt.		$1.48	$1.87		$3.34	$4.18

Chart #1 – Old Fire Protection System Estimate

New System Estimate							
		Materials	Labor	Equipment	Total	Tot O+P
2" Pipe	L.F.	$7.90	$11.55		$19.45	$24.31
	14748	$116,509.20	$170,339.40		$286,848.60	$358,560.75
4" Pipe	L.F.	$23.50	$20.57		$44.07	$55.09
	1208	$28,388.00	$24,848.56		$53,236.56	$66,545.70
2" 90 Elbow	Each	$34.50	$41.25		$75.75	$94.69
	306	$10,557.00	$12,622.50		$23,179.50	$28,974.38
2" 45's	Each	$40.00	$41.25		$81.25	$101.56
	128	$5,120.00	$5,280.00		$10,400.00	$13,000.00
2" T's	Each	$42.50	$67.10		$109.60	$137.00
	528	$22,440.00	$35,428.80		$57,868.80	$72,336.00
2"-4" T's	Each	$134.00	$74.25		$208.25	$260.31
	74	$9,916.00	$5,494.50		$15,410.50	$19,263.13
4" T	Each	$272.00	$184.80		$456.80	$571.00
	5	$1,360.00	$924.00		$2,284.00	$2,855.00
4" 90 Elbow	Each	$197.00	$123.20		$320.20	$400.25
	2	$394.00	$246.40		$640.40	$800.50
Reg Sprinklers	Each	$6.40	$25.85		$32.25	$40.31
	1056	$6,758.40	$27,297.60		$34,056.00	$42,570.00
4"-2" 90 Elbow	Each	203	184.8		$387.80	$484.75
	8	$1,624.00	$1,478.40		$3,102.40	$3,878.00
Sum		$203,066.60	$283,960.16		$487,026.76	$608,783.45
Cost per SqFt.		$1.86	$2.61		$4.47	$5.59

Chart #2 – New Fire Protection System Estimate

Fire Protection System	Springer's System			
Steel Alone	**m*c*T=h(st)*A(st)*t*(Tamb-T)**			
Calculated for time				
Steel And Flowing Water	**m*c*T=h(st)*A(st)*t*(Tamb-T)+U*t*(Twat-T)**			
Variable Definitions	Variables	Equations	Value	Unit
Mass of Steel	m		790	lbs
Specific Heat of Steel	c		0.105569	Btu/lb*F
Time Dependent Temp	T		200	Fahrenheit
Temp of Fire	Tamb		2000	Fahrenheit
Heat Transf Water to Steel	U	h(p)*A(p)	39892.6	Btu*ft^2/lb*F
Air Conv. Heat Transfer	h(st)		0.04242	Btu/lb*F
Outside Surface Area	A(st)		15.71	Square Feet
Nusselt Number	Nud	0.23*Red^(4/5)*Pr^(.4)	3779.265	
Prandtl Number	Pr	Cp(wat)*Mu(wat)/K(wat)	9.43791	
Reynolds Number	Red	4*M(dot)/(Pi*D*Mu(wat))	60556.59	
Heat Transf Coeff, Water	h(p)	Nud*K(wat)/D(pipe)	7598.59	Btu/lb*F
Inside area of Pipe	A(p)		5.25	Square Feet
Mass Flow Rate	M(dot)		6.96	lbs/s
Viscosity of Water	Mu(wat)		3.161	lbm/ft*hr
Diameter of Pipe	D		0.17	Feet
Heat Capacity of Water	Cp(wat)		1.00052	Btu/lb*F
Thermal Cond. Of Water	K(wat)		0.3351	Btu/s*ft*F
Viscosity of Water	Mu(wat)		0.000878	lbm/ft*s
Temperature of Water	T(wat)		50	Fahrenheit
Steel Failure Temp	Tfail		980	Fahrenheit

Calculations for time	Seconds
Steel Alone Time to 200 Fahr	13.90510076
Steel Alone Time to 980 Fahr	24.53841311
Steel and Water Time to 200 Fahr	-0.00278803
Negative Means it will never reach Temp.	

Chart #3 – New System Thermal Calculations

Solar Panel Value Calculations		
		Units
Insolation per Day	6.05	kWhrs/panel/day
Efficiency	18.7	Percent
Total used Insolation	1.13135	kWhrs/panel/day
Inverter Efficiency	95	Percent
AC Given per Panel	1.0747825	kWhrs/panel/day
Number of Panels	681	Number
Power Given Total	731.9268825	kWhrs/day
Power Given Yearly	267153.3121	kWhrs
Value of NJ Subs.	$0.20	Dollars / kWhr
Value of Electricity	$0.10	Dollars Estimated
Value of Electr Year	$80,145.99	Dollars

Chart #4 – Solar Power Calculations

Cost of System		
		Units
Number of Panels	681	Number
Watts per Panel	305	Watts
Cost per Watt	$7.25	Dollars
Total Cost	$1,505,861.25	Dollars

Chart #5 – Solar Cost Calculations

Tax Value of System					
30% Writeoff	$451,758.38	Dollars	System Value		
30% of DDB Year 0	$225,879.19	Dollars	Value at 0 Years	$752,930.63	Dollars
30% of DDB Year 1	$112,939.59	Dollars	Value at 1 Years	$376,465.31	Dollars
30% of DDB Year 2	$56,469.80	Dollars	Value at 2 Years	$188,232.66	Dollars
30% of DDB Year 3	$28,234.90	Dollars	Value at 3 Years	$94,116.33	Dollars
30% of DDB Year 4	$14,117.45	Dollars	Value at 4 Years	$47,058.16	Dollars
30% of DDB Year 5	$14,117.45	Dollars	Value at 5 Years	$47,058.16	Dollars
Sum of Writeoffs	$903,516.75				
Percentage	60.00%				

Chart #6 – Tax values of System

Payoffs			
No Gov't Writeoff		Gov't Writeoff	
Cost	$1,505,861.25	Cost	$602,344.50
Electricity Generated	$80,145.99	Electricity Gen'd	$80,145.99
Years til Payback	18.79	Years til Payback	7.52
Value over 30 year	$898,518.56	Value over 30 Yrs	$1,802,035.31

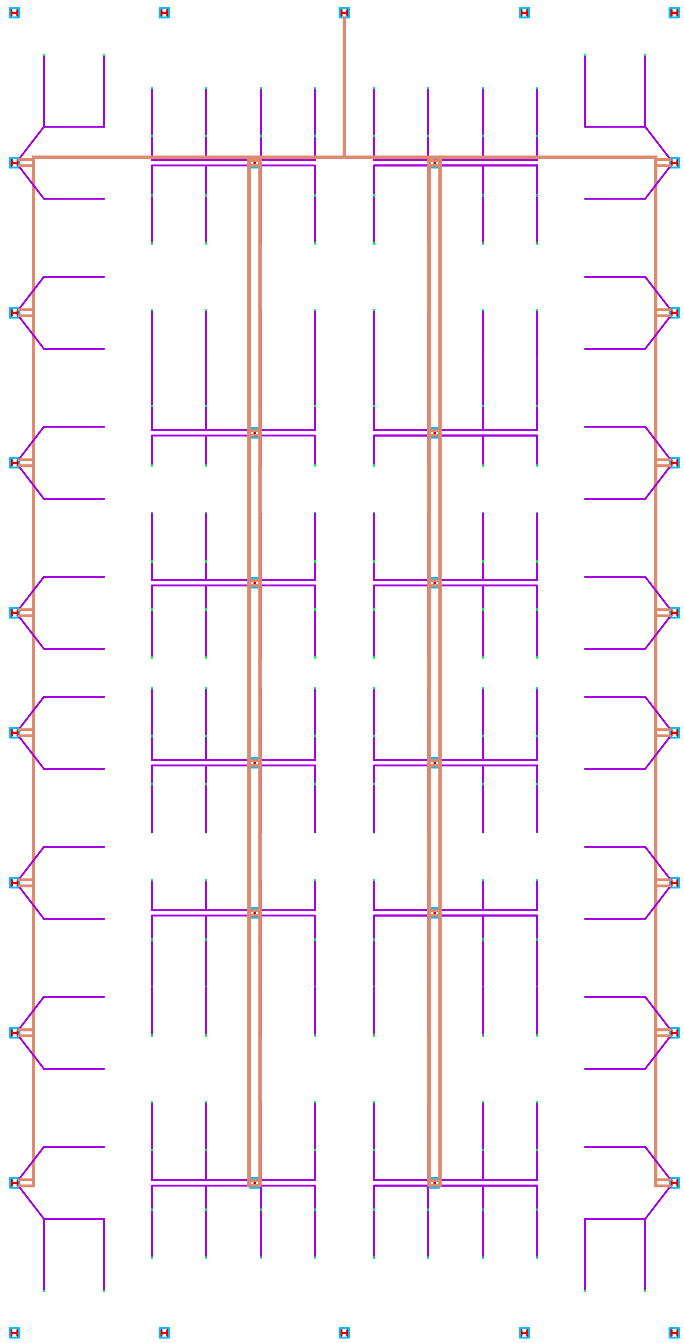
Chart #7 – Benefit Paybacks

Value over Entire System			
Number of LPG Buildings in NJ	70		
30 Year Value w/o writeoff	$62,896,299.13	30 Year Value w/ writeoff	$126,142,471.63
$ Saved / year est.	$2,096,543.30	$ Saved / year est.	$4,204,749.05
Systems built / year	26		
NJ Solar Powered in?	3 Years		

Chart #8 – New Jersey Estimated Values

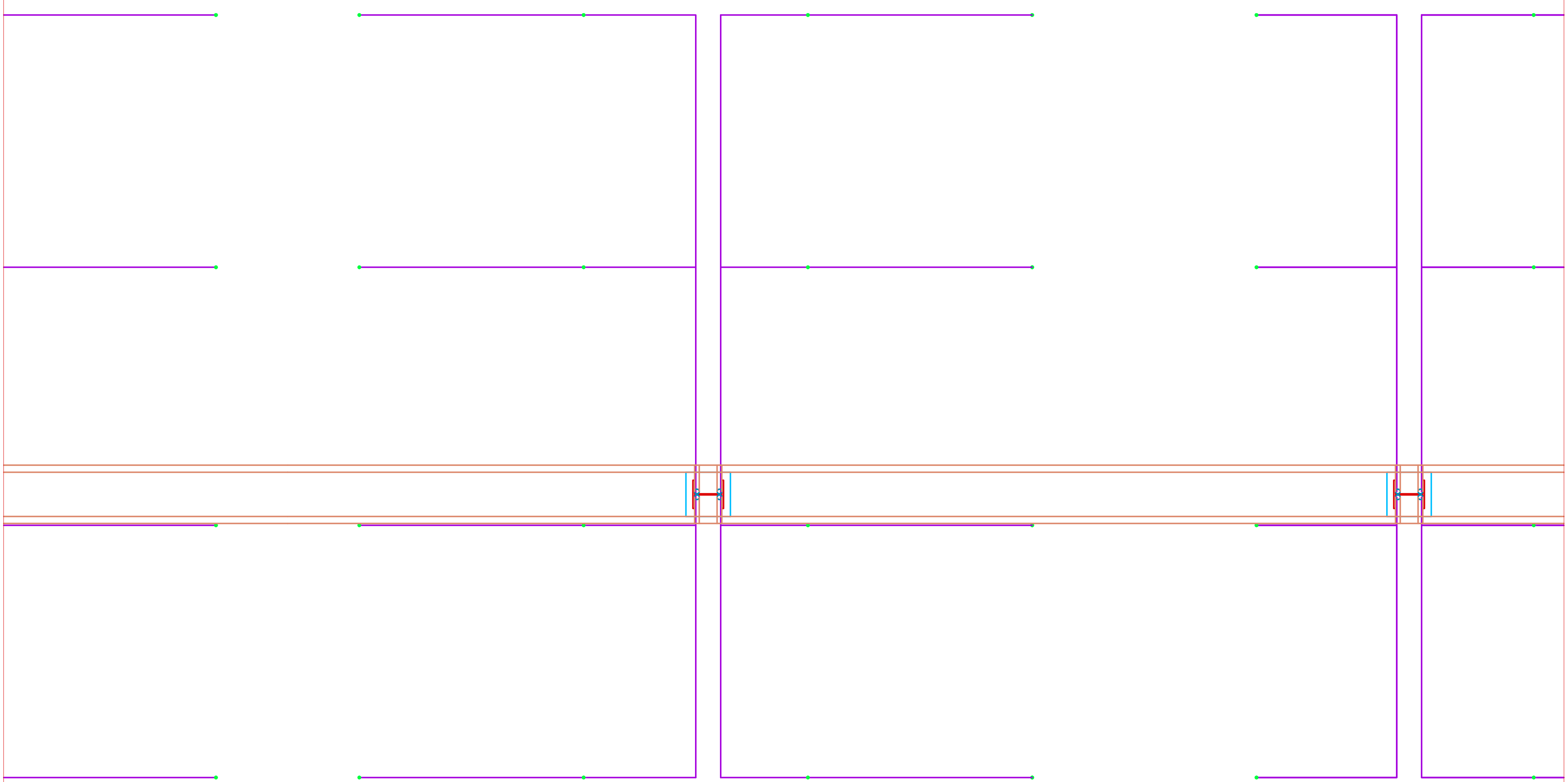
Value without Benefits			
No Tax Credit	Power @$0.10	Tax Credit	Power @$0.10
Value of Electr. Gen'd	$26,715.33	Value of Electr.	$26,715.33
Years to pay off	56.36693171	Years to pay off	22.54677268
Value over 30 Years	-$704,401.31	Value over 30 Yrs.	$199,115.44

Chart #9 – Risk Values of Government Benefits

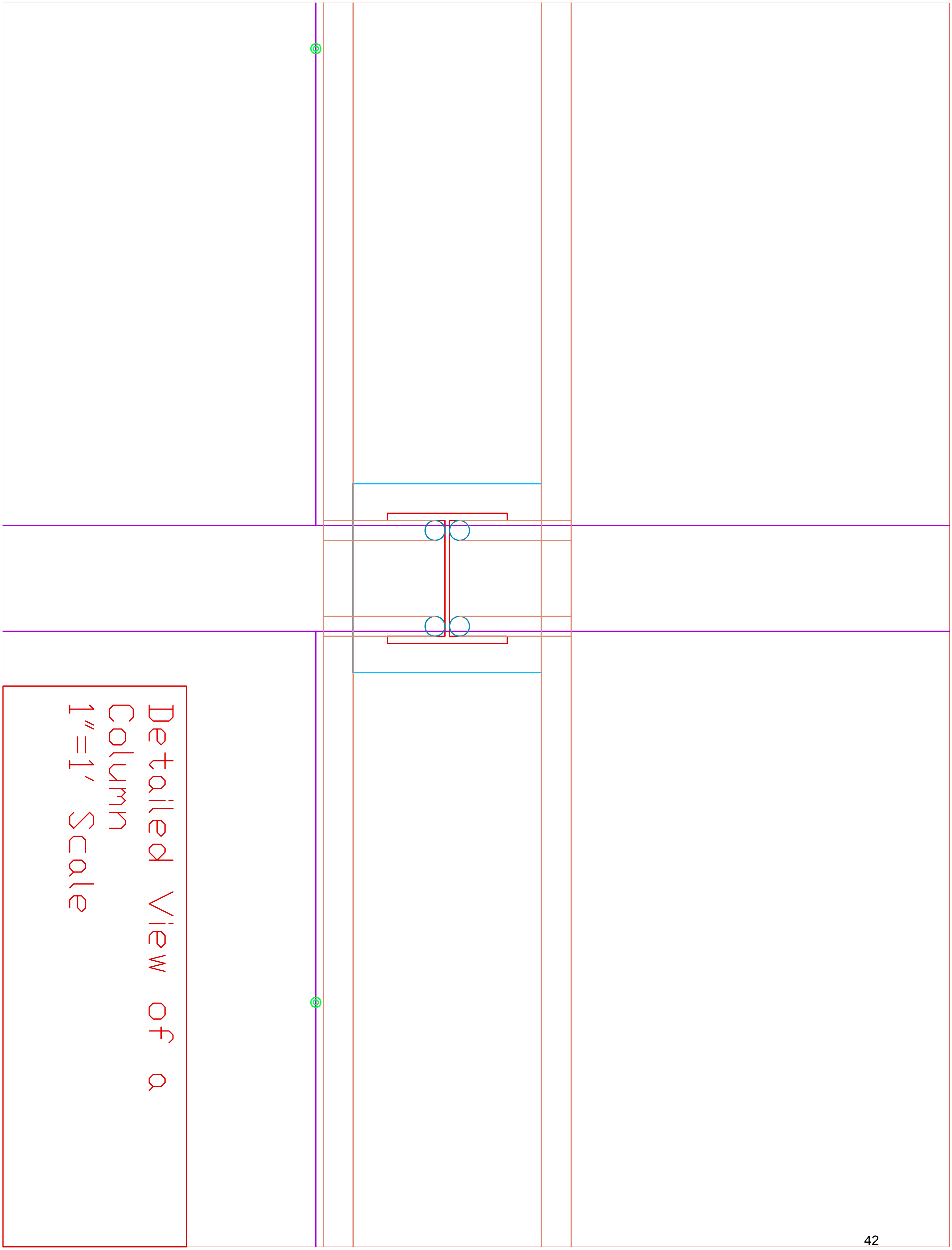


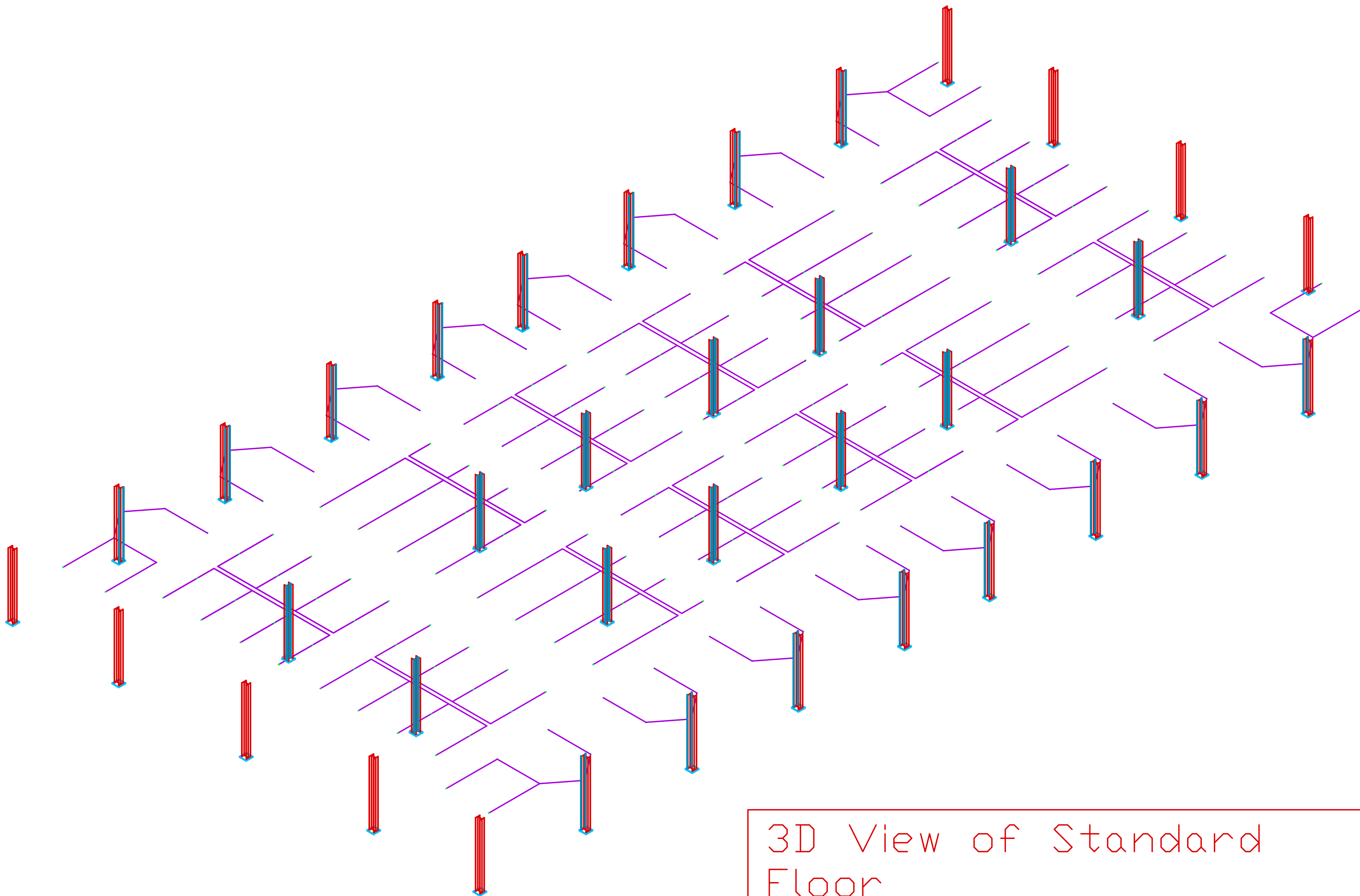
General Layout Plan

$\frac{1}{32}$"=1' Scale

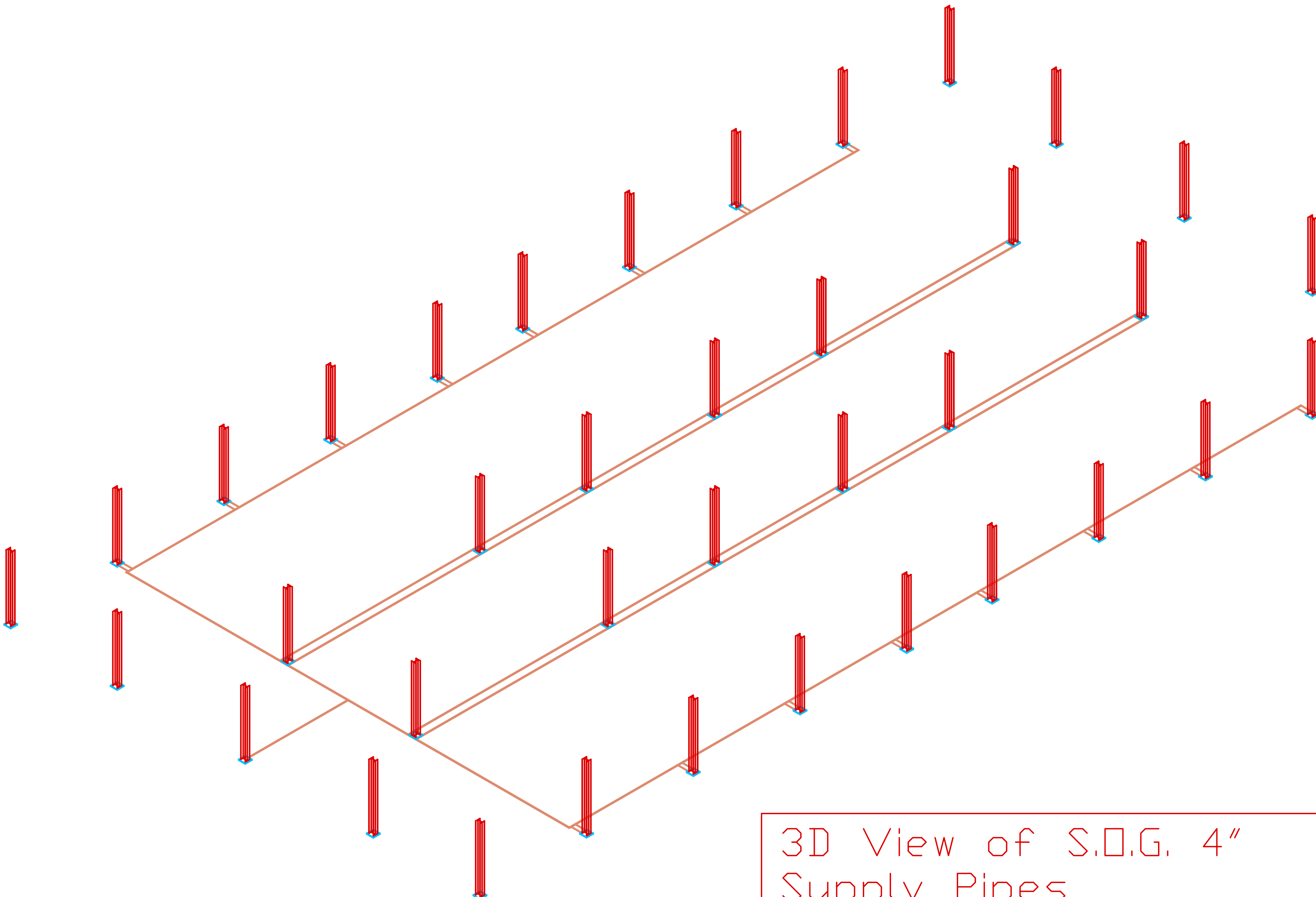


Detailed View of Standard Columns
$\frac{3}{32}$"=1' Scale

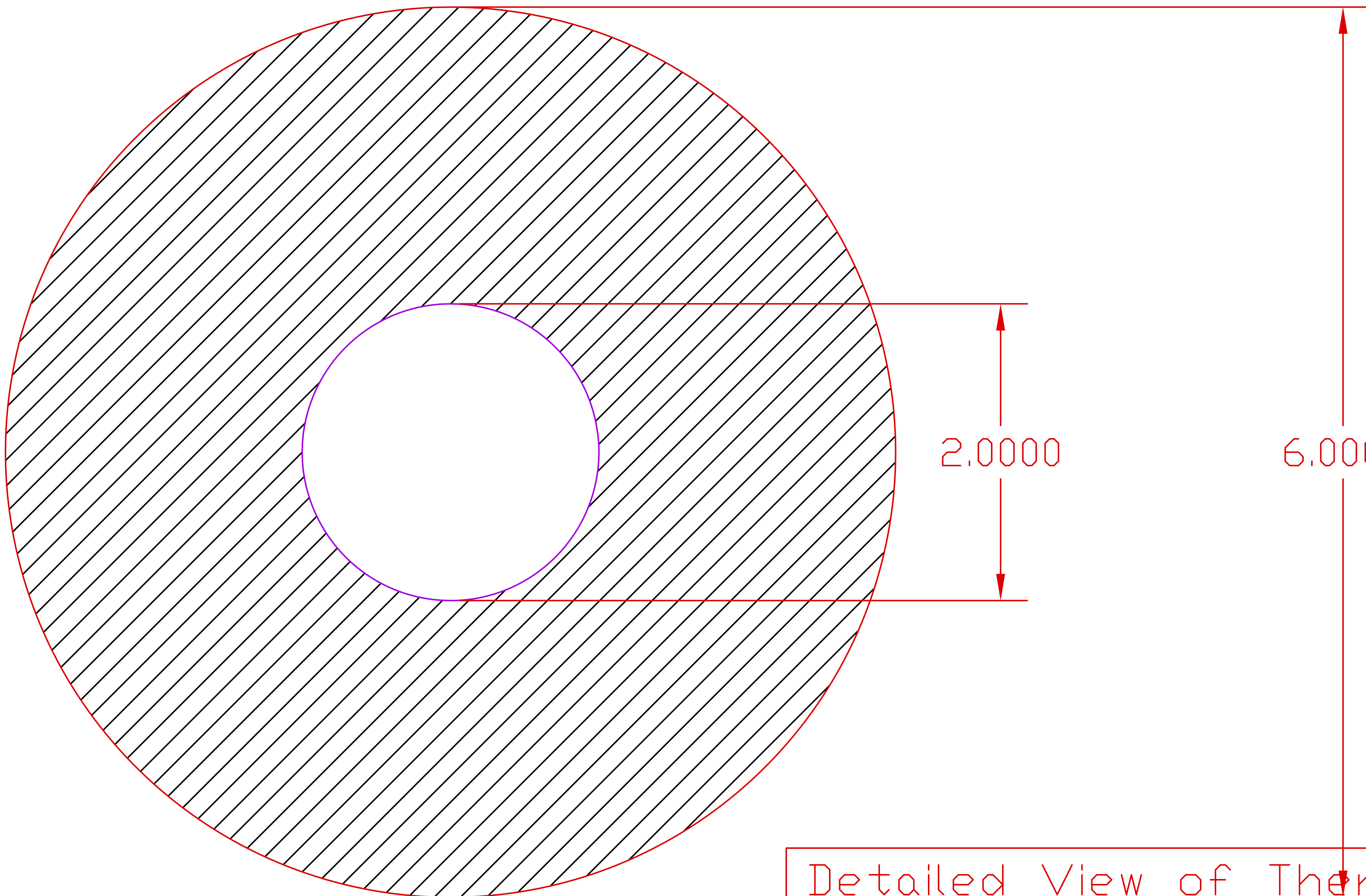

Detailed View of a
Column
1"=1' Scale



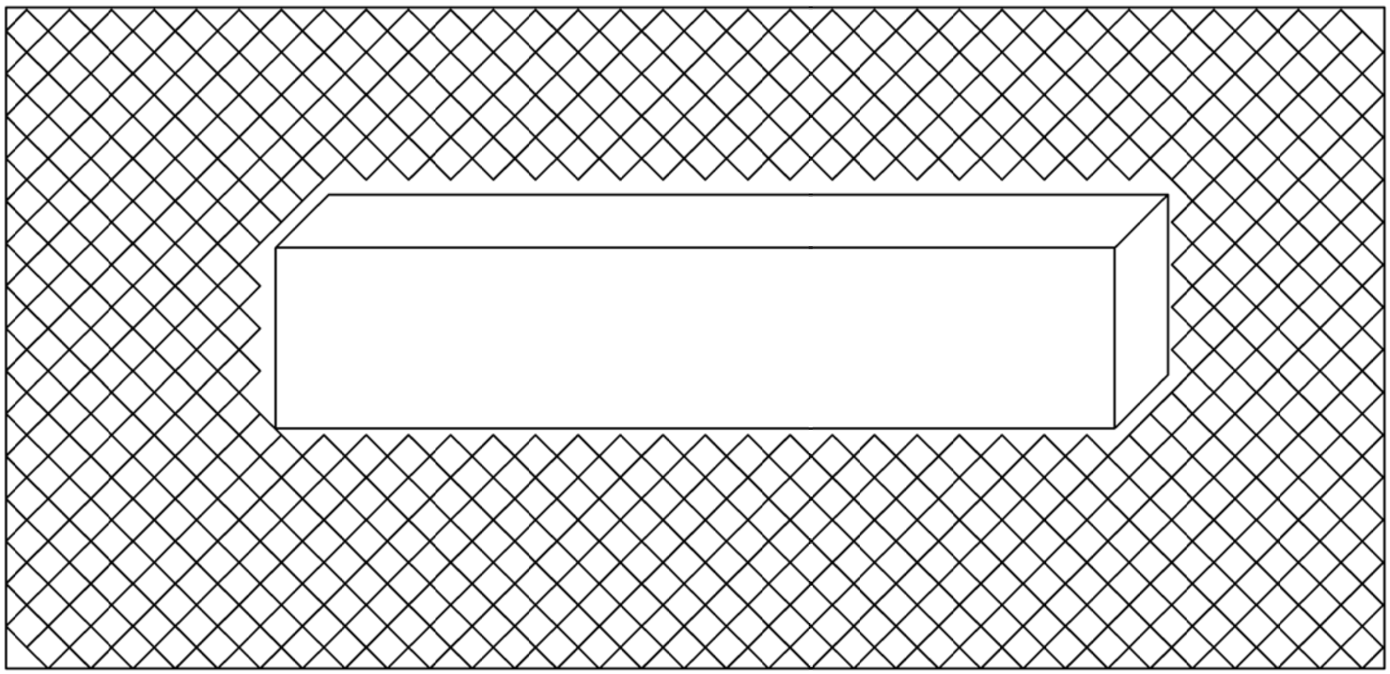
3D View of Standard Floor



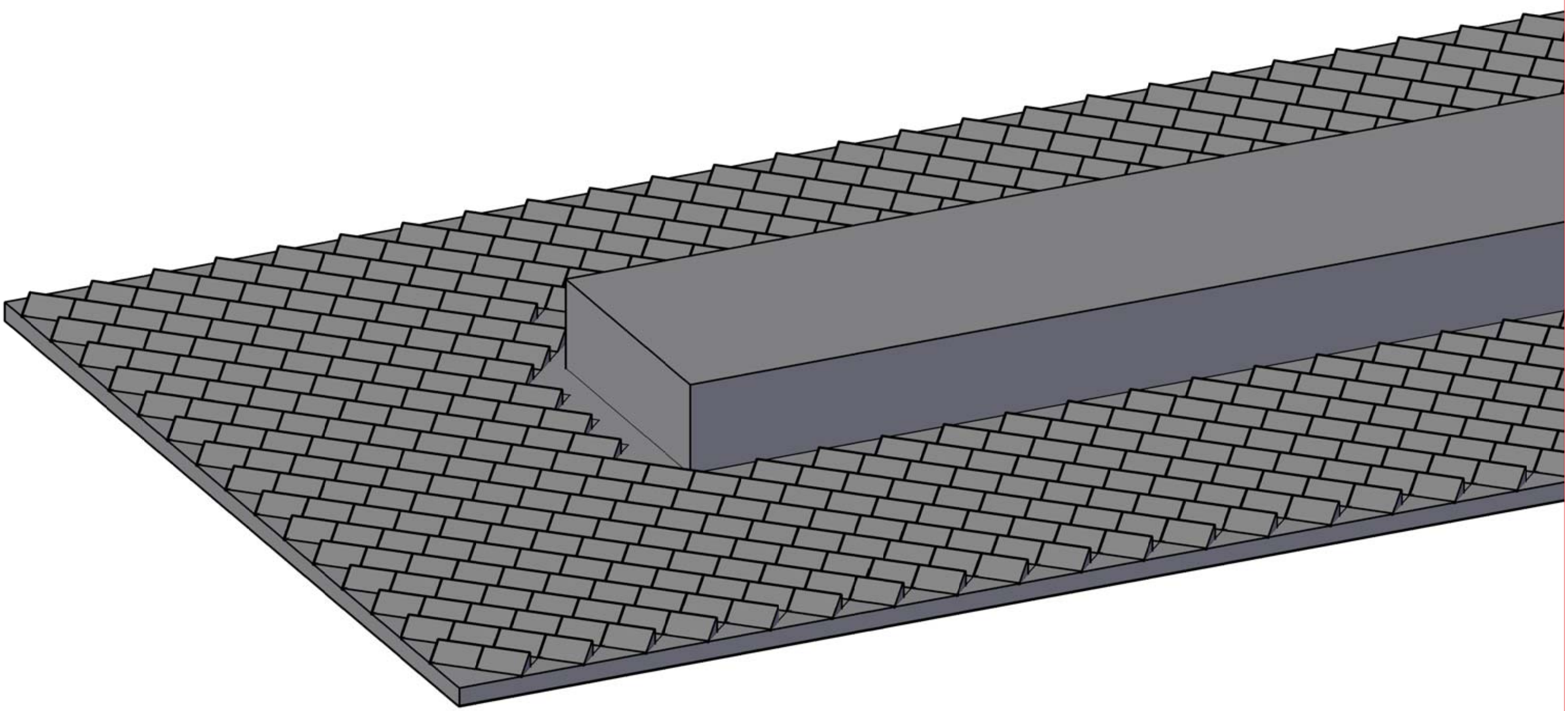
3D View of S.D.G. 4"
Supply Pipes



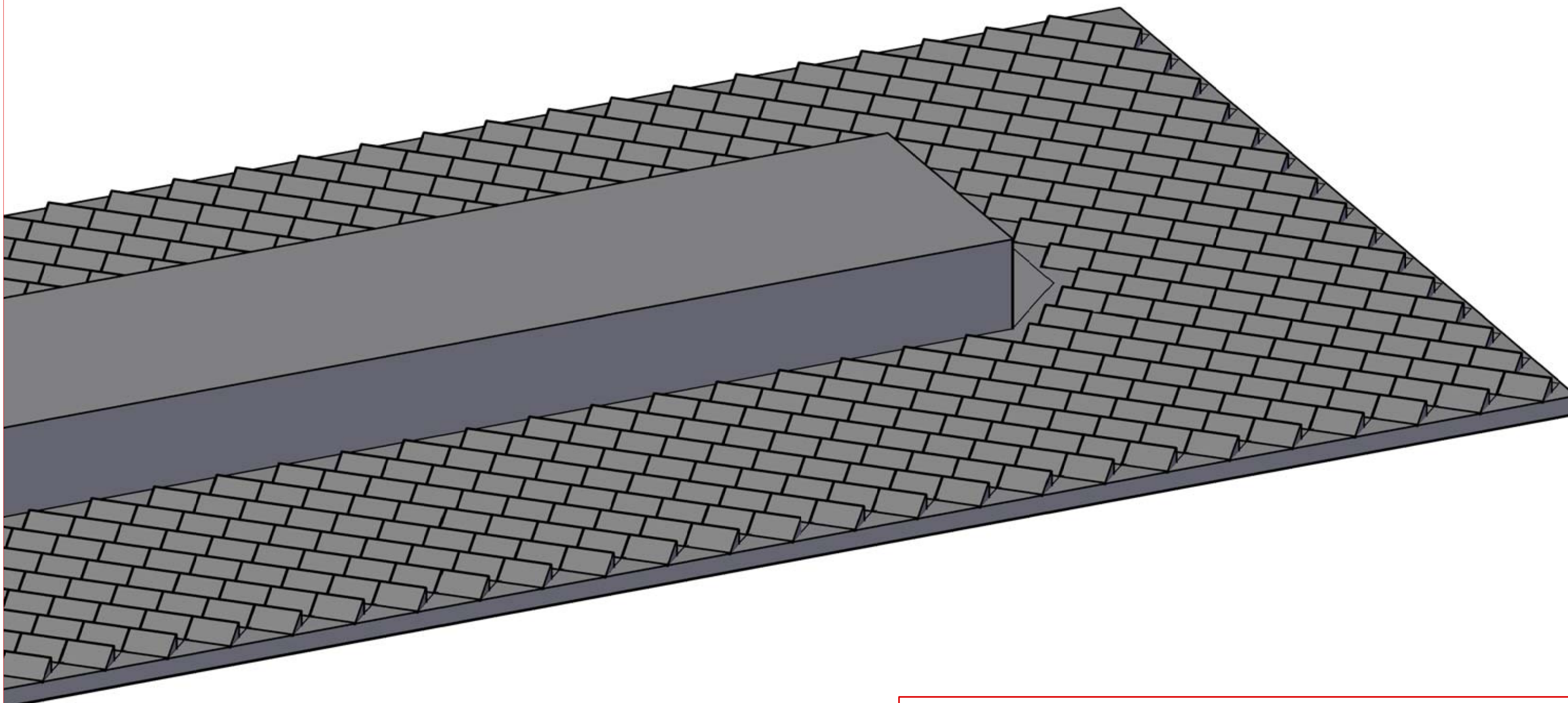
Detailed View of Thermal
Model
6"=1' Scale



Outline of Building, Solar Shadow and Panel Placement $\frac{1}{32}$"=1' Scale

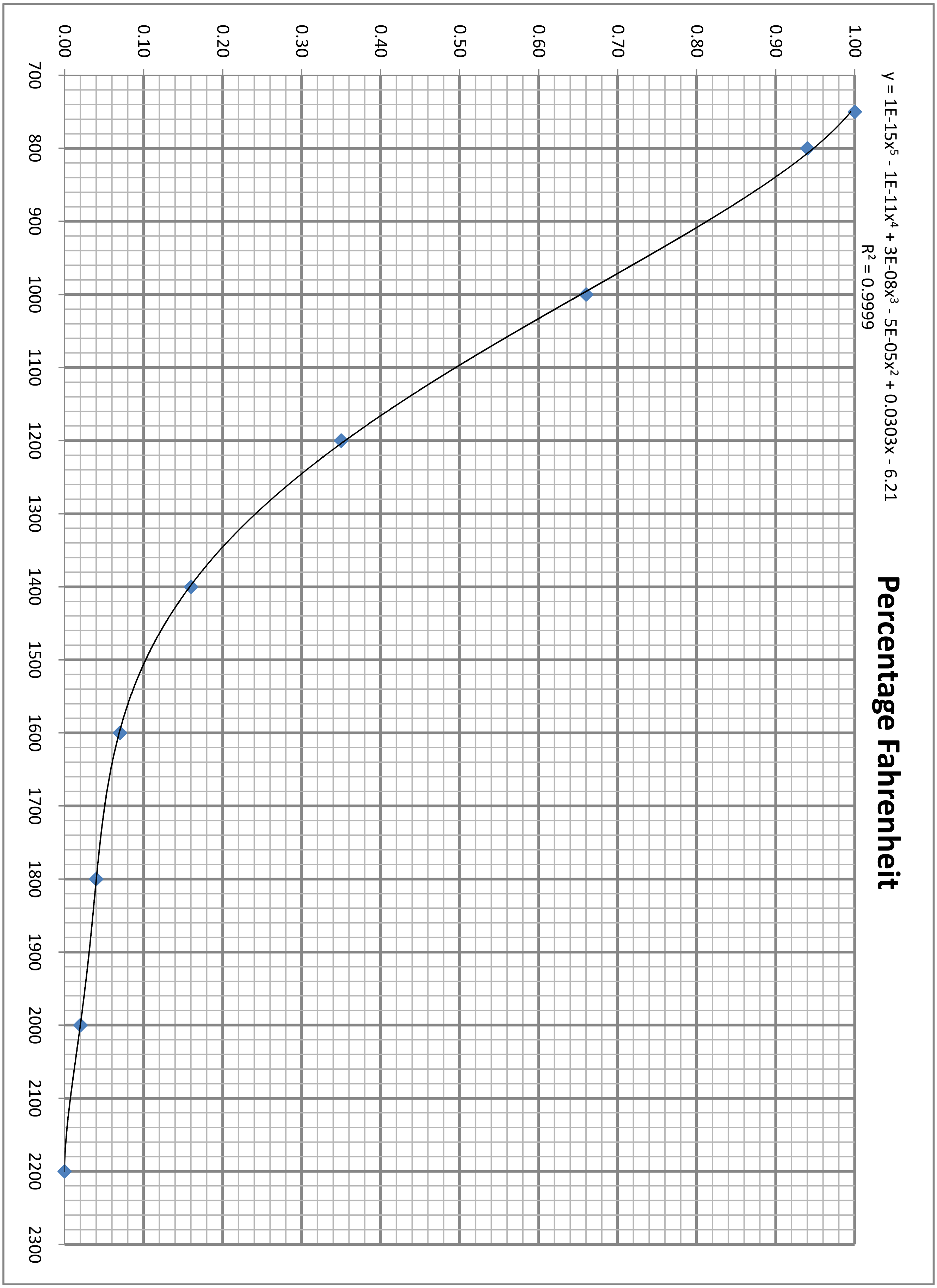


3D Representation of
Panel Placement
$\frac{1}{16}$″=1′ Scale



3D Representation of Panel Placement

$\frac{1}{16}$″=1′ Scale


Percentage Fahrenheit
y = 1E-15x5 - 1E-11x4 + 3E-08x3 - 5E-05x2 + 0.0303x - 6.21
R2 = 0.9999
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300