Mechanical

Submitted: Integration Structural Mechanical Electrical Construction

350 Mission St.

ASCE Charles Pankow Foundation Architectural Engineering Student Competition

AEI Team 2-2014

Contents

Narrative

Appendices

Mechanical System Highlights

- BioMethane Fuel Generation
- AquaCELL Blackwater Treatment
- BioMethane-fueled Trigeneration
- Evaporative Radiant Cooling
- 100% Outside Air Throughout

100% Energy Reduction

84% Potable Water Reduction

95% Waste Reduction

99% Emissions Reduction

Drawings

Executive Summary. The Mechanical Systems Team has addressed the challenges facing the design of 350 Mission. This submittal includes an executive summary, introduction, illustrations of how project goals were met, associated analyses, and justifications for design decisions. Additionally, the submittal includes appendices containing supporting documentation of detailed calculations, floor plans, sections, elevations, equipment data and references.

In this report, AEI Team 2 was required to address the integrative and collaborative aspects of the building's design, in addition to addressing sustainability, energy efficiency, immediate building reoccupation and the building budget as it pertains to the design of 350 Mission.

Shaped by the team design principles of ***Performance***, ***Endurance*** and ***Connectivity***, AEI Team 2 formed four mechanical design goals:

1. Achieve **Near-Net Zero Energy**, **Water**, **Waste** and **Emissions**, as per the Integration Narrative
2. Design **mechanical**, **plumbing** and **fire protection** systems which will maintain their performance and integrity after a major design-level earthquake
3. Utilize **Building Information Modeling** software, processes and workflows to ensure the highest level of performance possible
4. Design mechanical systems which **enhance the aesthetic and participative connectivity** of 350 Mission with the surrounding urban ecology

Building services which enable the aforementioned goals were designed and are elaborated upon below:

A. On-site Fuel Creation

- ***Thermophilic Anaerobic Digestion*** of municipal food waste and sewage creates bio-methane at an average rate of 73,300 ft^3 per day—this supplies enough fuel to 350 Mission to enable the building to **achieve Net Zero Energy**

B. On-site Energy Generation

- *A **310 kW Waukesha Internal Combustion (IC) Engine** uses on-site BioMethane to create* electricity, heating hot water, domestic hot water and process hot water

C. Heating and Cooling Plant

- Four **980 gpm Cooling Towers** use the low ambient wet-bulb to generate 67^{F} chilled water for **Radiant Ceiling Panels** and a **Thermal Slab**
- An **85-ton Absorption Chiller** provides chilled water to **100% Outside Air Units** to mitigate latent space loads
- A dedicated **20-ton Water-to-Wastewater Heat Pump** provides chilled water to the restaurant air handler
- Heat recovered from **Jacket Cooling** and **Exhaust Gas** is used for space heating, domestic hot water and maintaining the 135^{F} digester temperature
- A **2,500 MBH Boiler** meets peak heating loads

D. Office Design

- **Chilled Ceilings** provide sensible space cooling
- **100% Outdoor Air Units** remove latent loads and provide demand-controlled fresh air
- **Induction VAV Terminals** contain hot water coils which provide perimeter heat

E. Lobby Design

- A **Thermally-active Slab** provides sensible space heating and cooling
- **100% Outdoor Air Units** remove latent loads and provide demand-controlled fresh air
- Exhaust air from the first five office floors pressurizes the space against stack pressures

F. Restaurant Design

- A **Dedicated 100% Outdoor Air Unit** handles the large sensible and latent loads

G. Water Reclamation System

- An **AquaCELL** treats on-site and municipal blackwater in order to meet non-potable demand

The results of these systems are shown below, illustrating exemplary environmental performance.

ENERGY	WATER	WASTE	EMISSIONS
EUI: -0.02	GAL: 1,169,158	TONS: 321	$TONS_{CO2}$: 25
100% REDUCTION	84% REDUCTION	95% REDUCTION	99% REDUCTION

1. Project Introduction

The AEI Charles Pankow Student Design Competition proposed the challenge of designing a 30-story high-rise building in Downtown San Francisco which addressed the desire to focus on three main areas:

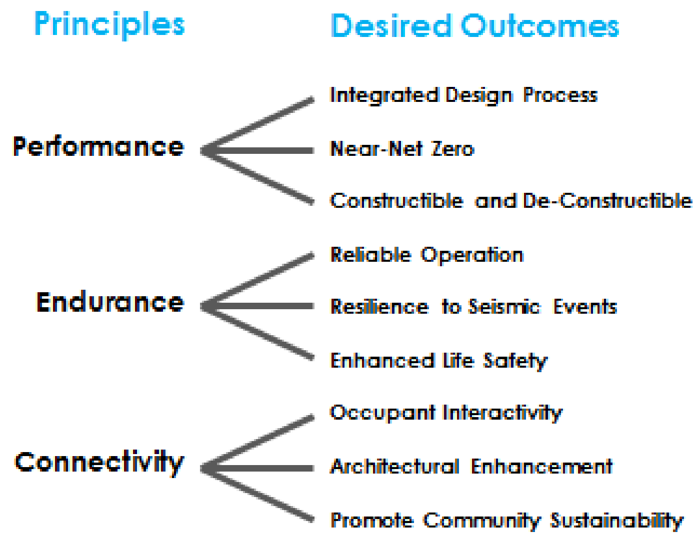
1. Address construction, design and life cycle cost concepts pertaining to a Near-Net Zero building—high levels of sustainability and durability are desired
2. Utilize the existing design as a baseline, and make analytical comparisons with the baseline and alternative options
3. Consider solutions which enable resilience after a design-level seismic event, reducing structural drift to one half of the code-allowed value

The Mechanical Design Team prepared this submission to address the design of 350 Mission. The Submission addresses the design of the building's HVAC systems, heating and cooling plant, energy generation plant, water reclamation system and associated sustainability strategies.

2. Project Scope

While the Mechanical Design Team was focused on designing a building that would operate efficiently while satisfying occupant comfort needs, it was necessary to do in conjunction with all building delivery disciplines in order to figure out how all aspects of the design and construction could be actualized. The Mechanical Design Team was a member of a multi-disciplinary, integrated design team. The Integrated Design Team developed a set of project principles based on the project requirements and owner requests: ***Performance***, ***Endurance*** and ***Connectivity***.

Performance was defined as the way the building performs throughout its lifecycle. ***Endurance*** describes the resilience of the building over time. ***Connectivity*** describes how the building engages and connects with occupants and the surrounding community. These project goals guided all disciplines though the design process, helping them to produce a fully integrated building solution. The graphic below illustrates how the Mechanical Design Team's responsibilities and desired design outcomes were shaped and guided by these integrated project principles.



3. Integration

AEI Team 2 regarded the principle of ***Performance*** to be as one which should be upheld throughout the project's lifecycle—building design and conceptualization included. A high-*performance* design approach was used to design 350 Mission as effectively and efficiently as possible. An integral part of this high-performance design process was the application of BIM software and workflows. The Mechanical Systems Team leveraged BIM software and workflows to foster a real-time, holistic approach to building services design that allowed for spatial and data coordination with all disciplines to allow for the most efficient use of time and resources. The concept for the mechanical system was being constantly revised in conjunction with feedback from the other team disciplines, so an innovative system for tracking both spatial and engineering data through these revisions was developed. In order to ensure that thermal and electrical data, as well as material quantities were properly tracked by the proper disciplines, the Building Information Modeling software Revit was used to create the building systems within 350 Mission.

Because of its ability to populate physical, spatial models with information, Revit became a crucial component in AEI Team 2's workflow. Information-populated components automatically populated equipment and material schedules; these schedules were then exported to a Tracking Spreadsheet in which team-developed Visual Basic macros utilized comparison algorithms to inform the proper disciplines of thermal, electric and material quantity changes. This ensured that all disciplines were informed in real-time without having to introduce potential human error into the inspection process.

4. Context Analysis

Located at the corners of Fremont and Mission Street, 350 Mission will rise 30 stories above street level. The building is primarily comprised of 25 floors of office space; however the project features a double-story lobby, which serves as both the entrance for the building and as a landmark, interactive public space. 350 Mission also contains a restaurant and an underground parking garage.

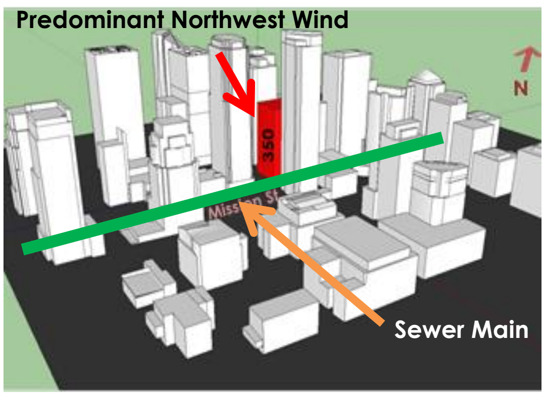


Figure 1. *Graphic illustrating 350 Mission's situation within its surrounding environment*

350 Mission is located in an area which is populated by residential and business traffic. It is sandwiched between office buildings: 45 Fremont, 50 Fremont, and 50 Beale. Furthermore, the Millennium Tower—primarily comprised of residential, culinary and recreation properties—is located across Mission Street from the site. Beyond, the Transbay Tower will be located one block south of 350 Mission. The Transbay Tower will be the tallest building in the city upon completion with a roof height of 920 ft and will feature additional office space.

The building is shaded for a majority of the year, given that it is entrenched among many taller buildings. This location also limits the occurrence of frequent, high-speed winds. Utilities service entrances are located along Mission St. and Front St. and the municipal combined sewer runs along Mission Street towards the Embarcadero.

The basis for performative comparison is based on several factors; a ***Baseline Building*** is defined as follows:

- **Energy:** ASHRAE 90.1 Baseline Building as dictated by the Performance Rating Method
    - **Baseline EUI: 31** kBTUh/SF-yr
    - It should also be noted that the ***Actual HVAC Design*** reduced by 31.5%, achieving an **EUI** of **21** kBTUh/SF-yr
- **Water:** Estimated using the LEED Usage Baseline
    - **Baseline Water: 5,237,100** gal per year
- **Waste:** Estimated using CalRecycle office profiles for solid waste and LEED profiles for water waste
    - **Baseline Waste: 6,754** tons per year
- **Emissions:** Estimated using EPA eGRID and Air Quality Planning emissions profiles for primary energy sources for Baseline Energy Consumption
    - **Baseline Emissions: 2,285** tons per year

5. Design Theory

The Mechanical Design Team of AEI Team 2 sought to create systems through the use of BIM which achieved the discipline goals of achieving Near-Net Zero, withstanding a design-level earthquake, and enhancing connectivity with the surrounding community. The Mechanical Design Team formulated the following design theory which shaped how mechanical systems were conceived and thereby shapes the format of the following narrative:

1. **Reduce Resource Demand**—because there is no *entirely* clean way of consuming resources, the Mechanical Design Team sought to minimize 350 Mission's thermal, electrical and water loads through *passive*, *active* and *participative* means—IES Virtual Environment was used to parametrically model proposed ideas
2. **Produce Resources**—in order to enhance the environment in which it resides, 350 Mission was designed to *draw fuel from the environment in which it resides*
3. **Efficiently Apply Resources**—in an effort to minimize 350 Mission's environmental footprint over the course of the building lifecycle, the most *efficient* and *seismically-resilient* application of the site-generated resources was designed

This design theory created a clear step-by-step roadmap of how to create 350 Mission as a building which is not only efficient, sustainable and seismically-resilient, but as a structure whose presence educates and enriches its community. Below, the aforementioned design process will create the narrative of the systems designed for the competition.

6. Demand Reduction

Maintaining thermal comfort and generating electricity consumes resources. Creating potable water in wastewater treatment facilities requires large quantities of primary energy and building waste also consumes a largely diminishing quantity—*space*. Buildings create a demand for finite resources and, in doing so, release emissions which contribute to environmental degradation.

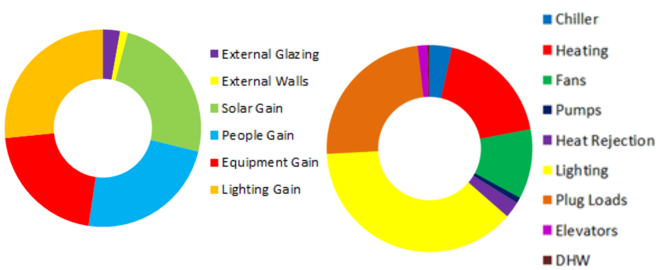


Figure 2. *Graphs showing the load breakdown and major energy end-uses of the baseline model*

The Mechanical Design Team formulated a series of strategies in order to reduce primary energy and environmental resource requirements. Before devising demand reduction methods, AEI Team 2 used IES Virtual Environment to analyze a baseline building to determine the major loads on the building. These analyses were used in order to guide the team towards devising a load reduction strategy. The graphic below illustrates the load breakdown which guided load reduction strategies.

Based on the load and energy studies, the following strategies were developed in order to reduce 350 Mission's need to utilize resources:

- **Optimize the building enclosure**
  - It was desired that the enclosure should allow natural light into the space while minimizing solar gain
- **Reduce water use**
  - Through fixture selection, the demand for potable and non-potable water can be reduced
    - *Appendix T*
- **Collocate refuse facilities**
  - By placing recycling stations near workstations and locating refuse containers in the core of the building it will become more convenient to divert from landfills
    - *Appendix I*
- **Create an energy-efficient workstation**
  - Because the building is primarily office space, an office workstation which minimizes sensible heat gain and electricity usage through task-ambient lighting and a Thin-client Virtual Desktop infrastructure was designed
    - *Electrical Narrative*

In the following sections, the detailed building enclosure optimization process is elaborated upon. For the other Demand Reduction strategies, see the appendices and narratives referenced above.

6.1. Envelope Optimization

The building envelope provides shelter from the exterior environment and is, in a large way, what makes buildings a necessary structure in society. The envelope also consumes no energy during the building's operation, so a high-performing façade can passively reduce energy demand throughout the building lifecycle. It was realized that he building envelope also resides at the intersection of almost every discipline involved in a building's design. AEI Team 2 sought to create an enclosure which enabled 350 Mission to accomplish the following:

- Withstand design-level seismic forces
- Allow for easy and expedient construction
- Create an independent architectural identity within San Francisco
- Enable optimal energy performance throughout the year

For a detailed explanation of how the first two goals were accomplished, refer to the Structural, Construction and Integration Narratives, respectively.

6.1.1 Façade Studies

In addition to creating a façade which engaged the surrounding environment, AEI Team 2 desired to optimize the façade in order to minimize overall energy usage over the course of the year while allowing the building envelope to maintain high levels of seismic resilience during a design-level earthquake.

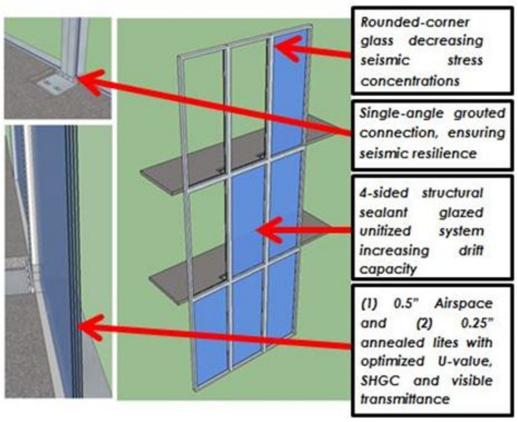


Figure 3. *Graphic showing the different components of the curtain wall facade*

Through collaborating with the Construction Team, Electrical Team and the Structural Design Team, it was decided that an all-glass curtain wall presented constructability, seismic and natural lighting advantages. AEI Team 2 used IES Virtual Environment and DaySim to analyze the thermal energy and lighting energy advantages of three different curtain wall options which met the Movement and Tolerances Requirements specified by the Structural Team, the results of which are shown below. This analysis was carried forward as a part of the ASHRAE 90.1 Performance Rating Method analysis necessary to justify our 350 Mission versus a Baseline Building.

Assembly Type	Assembly U-value [BTU/hr-SF-F]	SHGC	VT
Viracon Triple Pane	0.17	0.25	41%
Solarban 60	0.4	0.39	70%
Guardian 62/27	0.35	0.27	64%

Table 1. *Control and variation parameters analyzed during the facade study*

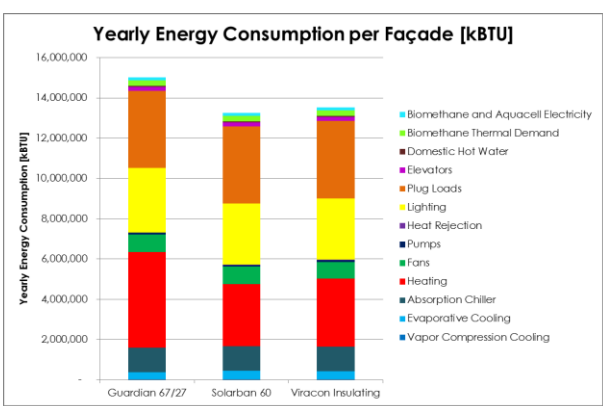


Figure 4. *Graph showing the results of the glazing study; it was clear that Solarban 60 was the best choice*

It can be shown from the IES Virtual Environment and DaySim studies that the ***Solarban 60 Double-pane, Air-filled glazing*** makes the most sense because its lower SHGC allows for higher winter solar gain to reduce heating energy throughout the winter, while only minimally raising cooling energy—this is due to the very efficient cooling strategy discussed in Section 8.2.2.1. Solarban 60 also presented lighting advantages, presenting the highest daylighting performance of the three glazing types. For further details see the Electrical narrative.

6.1.2 Roof Design

Because of the low percentage of the building which is in contact with the roof, thermal insulation was not deemed to be a major design constraint. Acoustical insulation, however, was decided to be the driving consideration for the roof because of the roof-mounted mechanical equipment. **NC 35 was maintained in the office space below** using a roof composed of concrete poured over a metal deck with a layer of insulation to provide the necessary transmission loss. For further explanation of the analysis which led to this decisions, see Appendix R. A roof with a high **Solar Reflective Index of 92** was also selected for the roof to minimize the Urban Heat Island Effect.

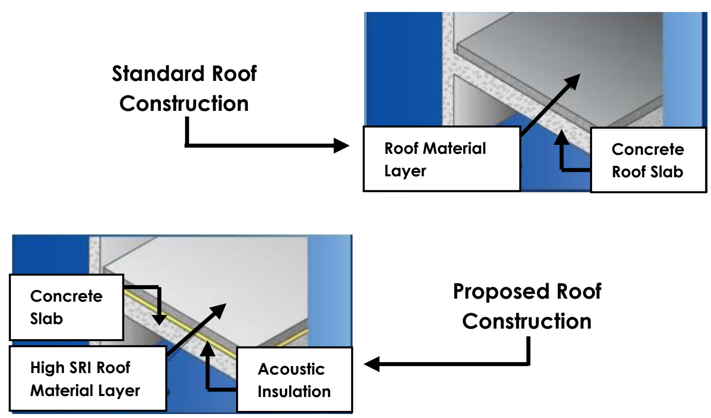


Figure 5. *Graphic illustrating the standard roof construction compared to the proposed roof construction*

Another code requirement of the San Francisco area is the elimination of surface runoff of rainwater. Based on 100 year storm data for San Francisco, four roof drains of 5" diameter were placed in strategic locations along the roof to capture all possible rainfall without little risk of overflowing out onto the roof surface. After harvesting the rainwater, it is stored in a tank near the top of the building that is connected into the plumbing piping system. This rain water is staged to primarily service the top five floors of 350

Mission. In the event that the tank is not sufficiently full, the primary plumbing system is tied into the top five floors in order to meet demand.

6.1.3 Demand Reduction Takeaway

After implementing the strategies mentioned above, it was shown that the **space cooling loads were reduced by 7% and the heating loads were reduced by 8%** relative to the ASHRAE 90.1 Baseline. It was also shown that **potable water demand was reduced by 34%** and **landfill waste was reduced by 95%**. It will become apparent after discussion on Resource Generation methods and Resource Application methods, the extent to which this reduces overall building emissions.

7. Resource Production

As illustrated in the Site Analysis, section 4.0, 350 Mission has minimal access to solar and wind energy. CFD simulations on the surrounding five blocks showed AEI Team 2 that the wind generation potential of the site was inadequate due to the taller surrounding buildings. Initial studies also showed that, based on the shading of surrounding buildings over the course of a Typical Meteorological Year, roof-mounted photovoltaic panels would only produce a theoretical maximum of 81,700 kWh.

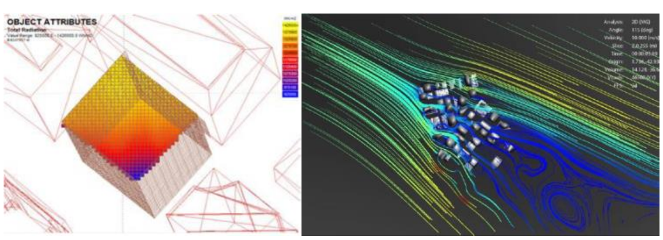


Figure 6. *Graphic showing the results of the site studies, illustrating need for non-conventional energy generation*

Installing PV panels was deemed to be inadequate for our site because of low generation capacity, and because the off-shore manufacturing which makes them economically-competitive has been known to pollute riverine ecologies adjacent to manufacturing facilities.

The Mechanical Design Team then turned to biology in order to examine how energy is transferred within natural processes and it was found that, within ecologies, the waste of one biological process is a source of energy input for another. It was realized that, within the urban ecology of San Francisco, large quantities of sewage and food waste are present and contain a large quantity of embodied energy.

7.1 BioMethane Generation

Generating BioMethane from raw sewage and organic compost is an energy generation method which has had success in the wastewater treatment and solid waste management industries, respectively. There has also recently been a high-rise installation in Osaka, Japan in the Abenobashi Terminal Building. Anaerobic digestion—the process by which methane is created from oxygen-deprived organic matter—is comprised of four phases, Hydrolysis, Acidogenesis, Acetogenesis and Methanogenesis. For an explanation of the process by which BioMethane is generated, see Appendix E.

This BioMethane can be harvested and then stored for use in combustion. During Methanogenesis, either Thermophiles—bacteria which thrive in high heat—or Mesophiles—bacteria which thrive under normal temperatures—break down the organic matter. Thermophilic digestion creates bio-methane at a rate up to three times faster than Mesophilic digestion and is the process used in 350 Mission. This digestion condition requires that the digested solids be maintained between 120 and 135F, creating a consistent thermal load which, as illustrated later, will ensure that the building's combined heat and power system utilizes its fuel efficiently. Another advantage of Thermophilic digestion is that it neutralizes pathogens in the digested solids, rendering the material in the anaerobic digesters harmless and odorless.

It was found that one of the main veins of the city's combined sewer system runs via Mission Street to the Embarcadero. This presents a large wastewater resource to the building because 15,000,000 gallons per day flow through this sewer main, as reported by San Francisco's Wastewater Enterprises Division. Scalping wastewater from municipal sewer systems is a renewable energy scheme becoming increasingly-popular in Australia and is allowed in San Francisco under the condition that a Memorandum of Understanding is signed between the San Francisco Public Utilities Commission and the owner of 350 Mission. The Mechanical Systems Team has decided to deploy it for three main reasons other than the fact that it presents fuel-creation opportunities:

1. Harvesting water from the sewer allows for the reclamation of water resources from the

solids-separated wastewater for non-potable water end-uses in the building
2. Wastewater mining allows 350 Mission to reduce the strain on San Francisco's overtaxed combined sewer system, reducing odor problems downstream at the Embarcadero sewer vents
3. Scalped wastewater, once passed through solids separation, can be used as a heat extraction or rejection source for the water-to-water heat pumps in the building

It was also found that the San Francisco sanitary service provider Recology mandatorily collects compostable food scraps separately from landfill and recycling waste. Recology also provides preprocessed food waste to wastewater treatment plants in the Bay Area free of charge for use in their anaerobic digesters. The Mechanical Design Team intends to engage in a similar arrangement with Recology in order to collect municipal food waste on-site in order to slurry the mixture and use it in the biomethane system.

350 Mission will receive **32 tons of food waste per day** from Recology, which is relatively small compared to the 600 tons per day that Recology collects in San Francisco. It was decided that food waste would be the primary source of fuel generation for the plant because the energy density of food seven times higher than that of sewage; when humans digest food they remove a large quantity of the embodied energy. This means that the quantities, therefore the auxiliary energy overhead, of digesting the food waste is significantly lower than solely digesting sewage.

The Mechanical Design team decided that a hybrid sewage/compost digestion system would be the most worthwhile investment because of the ability to reclaim water from the sewage in addition to being able to reject heat into the solid-separated wastewater, saving cooling tower fan energy.

By **scalping wastewater from the municipal sewer system at a rate of** 1,500 gpm and **collecting compost at a rate of** 32 tons per day, **BioMethane is generated at a rate of** 72,300 ft^3 per day. The mathematical models used to determine methane production quantities were sourced from research journals published by the *Slovenian National Institute of Chemistry*. These models were crucial in determining residence time, space requirements and system output. Because the generated methane volume is largely dependent on residence time, spatial constraints are introduced. These space constraints result in a **residence time of 10 ½ days**, which was selected because of the space requirements of the digestion tanks, gas conditioning equipment and other associated supplementary systems.

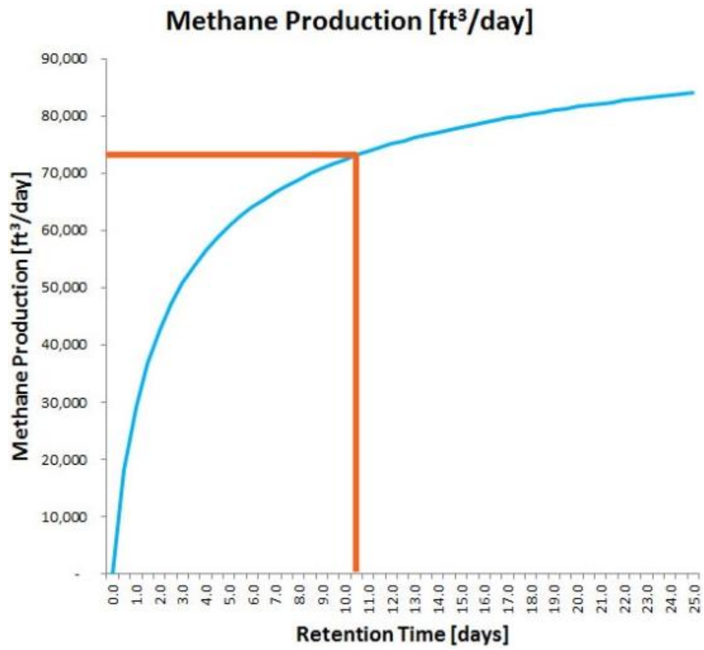


Figure 7. *Graph showing methane production vs. residence time*

Generating fuel on-site allows for the majority of site-utilized energy to be produced without paying for fuel. Typically cogeneration processes require natural gas to be purchased, limiting the economics of the system. After a Life Cycle Economic Analysis, considering fuel price escalation rates as well as projected discount rates, it is shown that the proposed bio-methane cogeneration plant (*including the CHP prime mover*), costing **between $1,147,000 and $2,170,000** will have a total discounted payback period of **2 ¾ to 5 ¼ years** without any grants or government incentives. These figures were calculated according to the sensitivity analysis on the digestion facility costs. For a detailed breakdown of the economics calculations and justifications see Appendix E. It was found that, over the course of a typical year, **2,715,600 kWh of electricity are generated**. This is enough electricity to bring 350 Mission's **EUI to -0.02 kBTU/yr-SF**. Over the course of a 50 Year Life-cycle, the BioMethane System **saves $13,646,200** and **52,100 tons of CO_2** emissions. This total is equivalent to the lifecycle carbon sequestration potential of over **114,300 trees**.

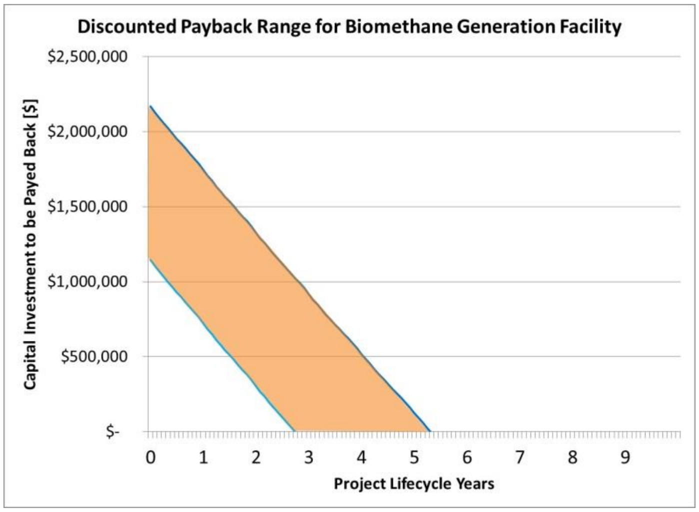


Figure 8. *Graph showing the sensitivity analysis on the power generation system payback*

7.1.1 BioMethane Facility

Because the conversion of food waste and sewage to methane is a crucial component of AEI Team 2's design for 350 Mission, the Mechanical Design Team conceived a design for the BioMethane Plant and constructed it in Revit. This allowed the Mechanical Team to arrange the plant spatially as well as coordinate the outgoing utilities with the rest of the design team. The plant's Revit model is shown below. For a detailed schematic, and further details and views, see Drawing 4.

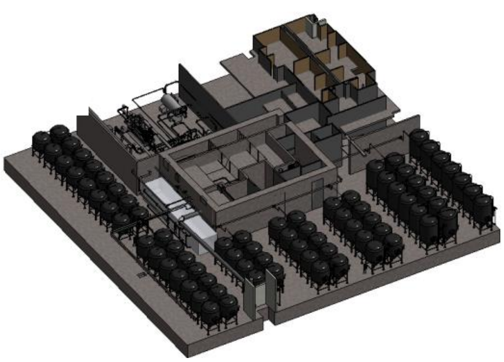


Figure 9. *Isometric view of the modeled BioMethane Facility*

The design of this facility is a result of integrated collaboration. In order to generate renewable heat and electricity on-site, space needed to be made for the fuel generation system, due to the fact that the fourth-level sub-basement had an average floor-to-floor height less than 6'. The Structural Design Team reduced the overall weight of the building's structure in order to reduce loads on the foundation. This allowed the thickness of the Mat Slab to be reduced by 4', enabling the floor-to-floor height to be increased such that the facility would be able to fit in the basement, seismically protecting it from earthquake accelerations.

7.2 Combined Heat and Power

The BioMethane generated from the process discussed above is then combusted in a 310 kW IC Engine (60 Hz at 1800 rpm) in order to generate electricity. The thermal energy generated from jacket cooling water as well as from the exhaust gas is captured and utilized in order to maintain thermophilic temperatures in the anaerobic digesters as well as for heating and absorption cooling.

An IC Engine was selected over alternatives such as microturbines because of higher resilience to H_2S, better part-load efficiency, better load-tracking, lower O&M costs and a better $/kW$_e$, as illustrated by a report published by the EPA.

Though normal Combined Heat and Power (CHP) facilities which purchase natural gas must typically track thermal loads in order to gain an emissions advantage over Separate Heat and Power (SHP) systems, the BioMethane-fueled CHP system designed for 350 Mission is able to justifiably produce electricity at full output constantly due to the characteristics of its fuel source—sewage is anaerobically digested at local wastewater facilities and is either flared or used in CHP processes; the same is true of Recology's compost—landfill gas is typically flared in San Francisco except for the small amount distributed to the CHP-utilizing wastewater plants. Essentially, the fuel *has* to be combusted no matter what, so it is desired that 350 Mission add value to the waste stream by harnessing it for energy.

With that being said, 350 Mission utilizes thermal energy well throughout the year. Studies to analyze the Primary Fuel Utilization Efficiency (PFUE) of 350 Mission's CHP system compared to Separate Heat and Power (SHP) were undertaken under a range of electrical grid and power generation efficiencies in order to obtain the objective performance of the system, though almost all of the primary energy used in 350 Mission was renewably generated on-site. It can be shown below that, for a range of electrical grid performance characteristics, CHP outperforms SHP for all but the lowest thermal loading conditions, assuming the highest performing electrical grid possible; for average grid conditions, CHP outperforms for the entire year, as illustrated below.

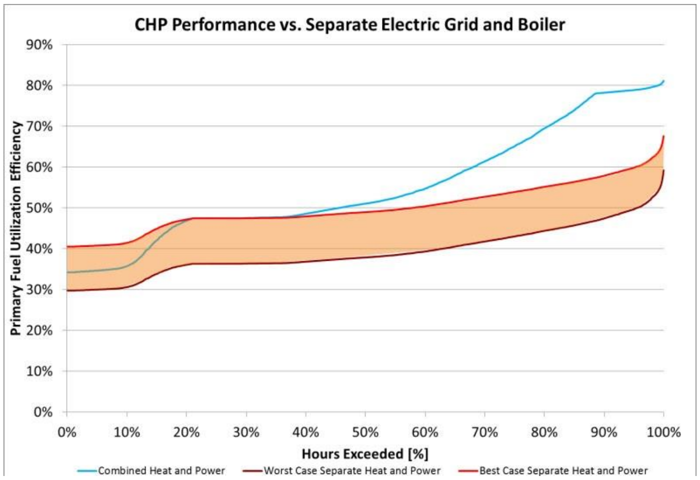


Figure 10. *Graph illustrating the PFUE for 350 Mission's CHP system vs. Grid SHP for varying conditions*

Because of the free fuel, as discussed in Section 7.1, the overall discounted system payback (including the BioMethane generation plant) is between **2 ¾ to 5 ¼ years** without any grants or government incentives. Over the course of the year, **over 2,715,600 kWh** of electricity and **119,000 therms** are produced, **offsetting 350 Mission's grid energy usage of *399 MBTU of natural gas and 924,000 kWh of electricity*.**

7.3 Blackwater Recycling

It was also realized that repurposing greywater and blackwater would reduce the resources required by the municipalities because water intended for non-potable end-uses can then be treated to a lower, less energy-intensive standard than that which typically flows through domestic water pipes. To achieve this, an AquaCELL Blackwater Purification System is utilized in order to generate water for toilet flushing and cooling tower makeup.

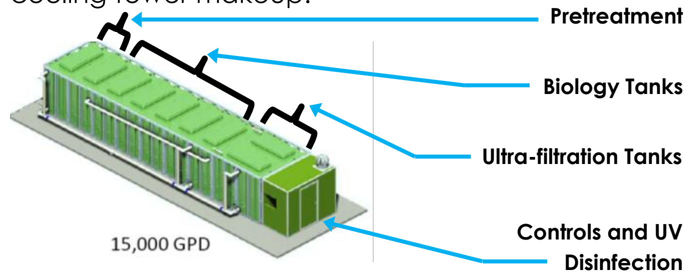


Figure 11. *Illustration of the AquaCELL system designed for 350 Mission*

The **AquaCELL is sized to treat 14,115 gpd at a low 7.3 W/gal**; the module with a 15,000 gpd capacity (*38' x 8' x 7'*) is selected in order to meet this demand. This results in an **84% reduction in municipal potable water use** for a **price of $1,210,000**.

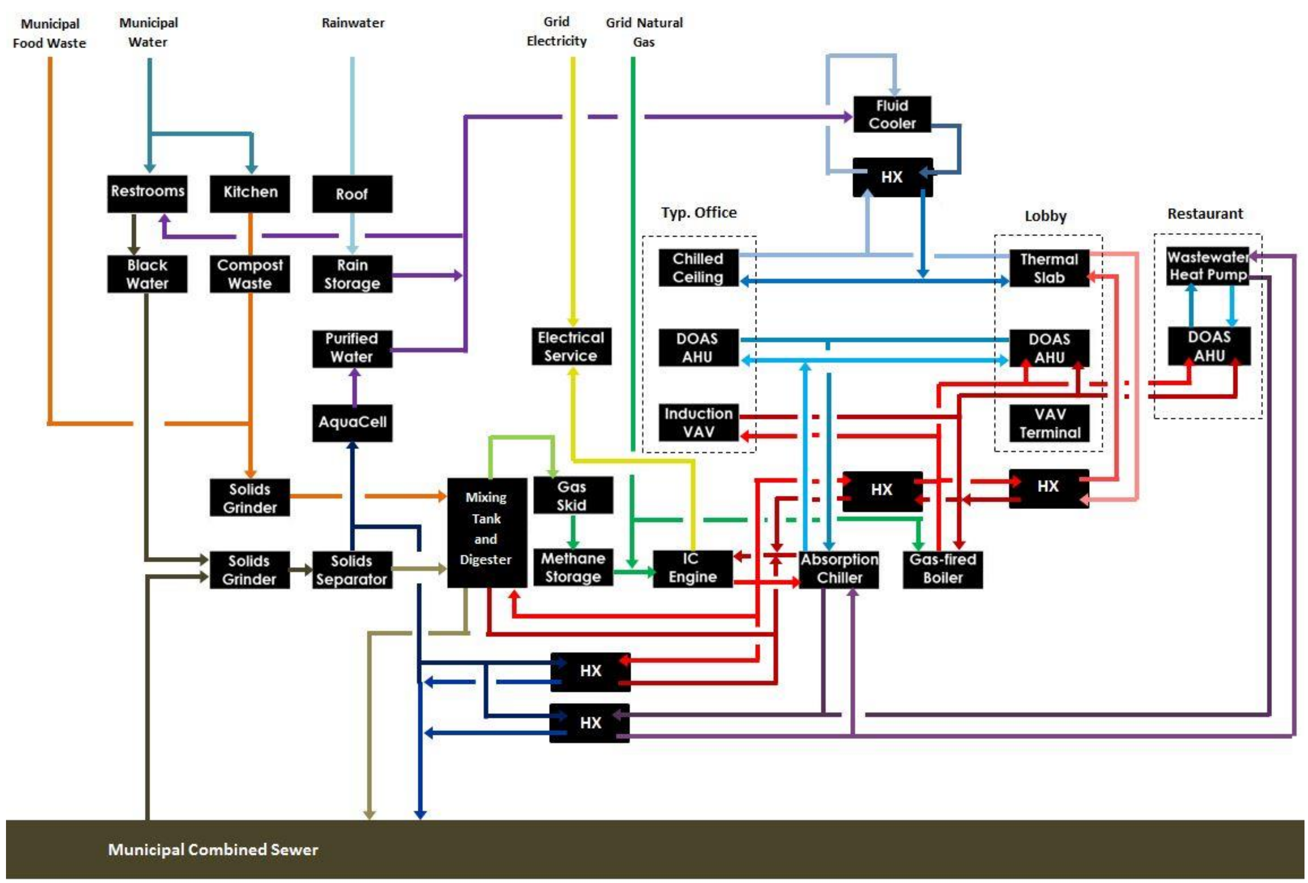


Figure 12. *Overall schematic of the building's mechanical systems*

8. Resource Application

In order to make 350 Mission as resource-efficient as possible, space design schemes which allocated site-generated resources as effectively as possible were used. Load-handling strategies which minimized the need for thermal input beyond that which is produced from bio-methane were employed. Systems and design schemes are divided into **Plant** and **End-use**. The end-uses of the site-generated energy are discussed below and an overall schematic of the design is shown at the bottom of the next page.

8.1 Efficient End-uses

350 Mission's mechanical systems are discussed below in terms of Supply and Demand. The demand side of the mechanical systems for AEI Team 2's 350 Mission includes the detailed design of the building's Upper and Lower Lobby, Restaurant and Typical Office Floor. The design for each space will be discussed in depth below:

Space Design Conditions	Cooling			Heating	
	T_{db} [F]	$RH_{\%}$ [%]	$T_{drift,cooling}$ [F]	T_{db} [F]	$T_{drift,heating}$ [F]
Upper / Lower Lobby	76	55	78	70	68
Restaurant	75	50	77	72	70
Typ. Office Floor	76	55	78	70	68

Table 2. *Table illustrating the space design conditions for the detailed design spaces in the building*

Outdoor Design Conditions		
Summer Dry Bulb	78.0	[F]
Summer Wet Bulb	62.0	[F]
Winter Dry Bulb	37.8	[F]

Table 3. *Table showing the outdoor design conditions for San Francisco*

8.1.1 Upper and Lower Lobby

Because of the architecturally-significant nature of the lobby, great care was taken to protect the integrity of the architect's vision for the space. A key goal of the architect's was to visually and spatially connect 350 Mission with the Transbay Center across the street. In the plans, the corner of the lobby which resides at the corner of Mission and Fremont is open to the air. The space conditioning strategy considers the preservation of the architect's vision for this corner, in addition to the preservation of the aesthetic integrity of the space.

Lobby Peak Load Summary					
Space Sensible	499,946	[BTUh]	Space Heating	197	[MBH]
Space Latent	193,444	[BTUh]	Fresh Air	14,198	[CFM]

Table 4. *Table showing the loads for the lobby space*

8.1.1.1 HVAC Systems

The Mechanical Systems Team realized that space conditioning should not be done through a forced air system due to the fact that potentially-unsteady air movement patterns through the opening could compromise the effectiveness of a forced air system's ability to deliver thermal comfort. AEI Team 2 decided that a thermally-active radiant slab would fit the space conditioning needs of the lobby most effectively. By relying on primarily radiant heat transfer, view-factor becomes the most important heat transfer parameter. This allows for thermal comfort despite potentially-dynamic air conditions at the lobby's open-air entry. By utilizing a hydronic system to provide thermal comfort in the space, the pressurization can be decoupled from the space conditioning system.

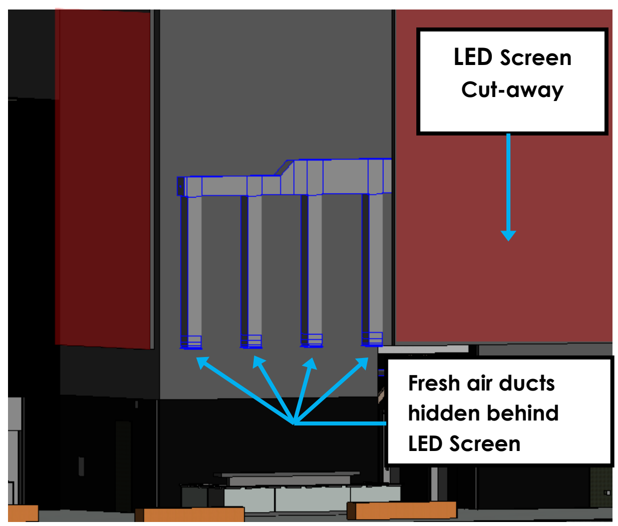


Figure 13. *Graphic showing that HVAC elements are hidden from view in order to preserve the sleek appearance of the lobby*

Cooling Season

The thermal slab chilled water supply will be supplied by roof-mounted heat exchanger-coupled cooling towers at a design temperature of 67F. These fluid coolers will supply High Temperature Chilled Water throughout the cooling season. A typical concern with chilled slabs is that condensation can occur, causing puddles and bacterial growth, however the design for 350 Mission avoids these concerns due to a

10.2^{F} difference between average slab surface temperature and the design dew point.

Thermal Slab Cooling Parameters			
V_{design}	1.5 gpm	ΔT	3.3 F
$T_{CHW,in}$	67.0 F	$T_{avg,surface}$	68.9 F
$T_{CHW,out}$	70.3 F	$Flux_{Cooling}$	14.6 BTUh/SF

Table 5. *Table illustrating slab cooling design conditions*

Heating Season

During the heating season, a plate-and-frame heat exchanger will provide heat transfer between the IC Engine's waste heat hot water loop—the temperature of which (200^{F}) is too hot for radiant floor applications—and the radiant floor's Low Temperature Heating Hot Water (LHHW). The cooling and heating design conditions for the thermal slab are illustrated in Tables 4 and 5, respectively.

Thermal Slab Heating Parameters			
V_{design}	1.5 gpm	ΔT	6.9 F
$T_{HW,in}$	93.0 F	$T_{avg,surface}$	89.0 F
$T_{HW,out}$	86.1 F	$Flux_{Heating}$	37.0 BTUh/SF

Table 6. *Table illustrating the design conditions for the thermal slab heating system*

Lobby Pressurization

Because 350 Mission is a high-rise building, the Mechanical Systems Team recognized that counteracting the stack effect during the cooler months of the year would be important. Winter design conditions result in a maximum **stack pressure differential of -1.23 in wg**, at the lobby level. This pressure difference was recognized to be a large design concern in the lobby space due to the large opening on the southwest corner of the lobby, it was estimated that this pressure difference could allow **up to 7,500 CFM of unfiltered street-level air** into the lobby space, displacing it throughout the upper office levels.

Pressurizing the space in an energy efficient manner became a key focus for the team for the design of this space. Exhaust air from the AHU serving the first five floors is used to pressurize the lobby without having to expend extra thermal energy to condition pressurization air; this is possible because the office levels are Class I spaces and the transfer and recirculation of their air is permitted under Title 24. Pressurization air is supplied alongside the Upper Lobby's ventilation air through a pressurized plenum above the second floor of the lobby as shown below.

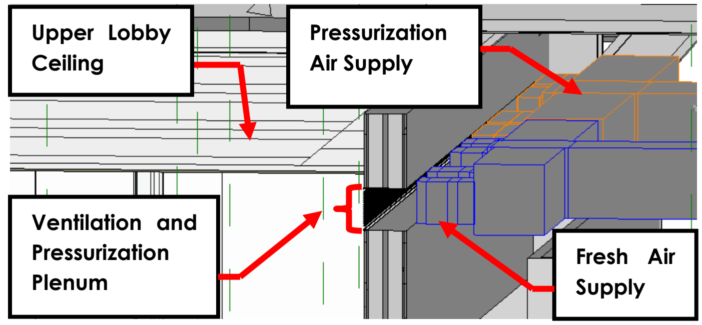


Figure 14. *Picture showing the ventilation air and pressurization air in a plenum **above the restaurant entrance***

The pressurization of the lobby was considered to be very important for the maintenance of good thermal comfort and indoor air quality. Contaminants enter the space and are driven upwards through the building any time that the outdoor temperature drops below the indoor set-point. The mechanical system team desired to avoid street-level infiltration due to the large number of contaminants and pollutants which would enter the space from the buses, cars and other means of transportation present at the Transbay Terminal. CONTAM Multi-zone airflow analysis illustrated that allowing stack infiltration to occur so close to a major transportation hub would increase the *aggregate cancer risk* in 350 Mission by over 30%. The prevention of contaminant migration is done in order to preserve the health of the employees who would be in the lobby for extended periods of time, as well as the health of other occupants throughout the building. Combatting stack infiltration additionally helps to prevent the constant cleaning of lobby surfaces which would be necessary if infiltration was allowed to occur.

8.1.1.2 Plumbing Systems

The main plumbing design element of the lobby space is the electro-chromically glazed interactive restroom. This space educates visitors and passersby on how the sanitary systems of 350 Mission not only contribute to reducing 350 Mission's municipal water use, but function as a part of a self-integrated energy generating system within the building.

8.1.1.3 Design for Resilience and Life Safety

Endurance and operation during a seismic event was an important factor when designing the lobby mechanical systems. The lobby space utilizes a deluge sprinkler system a smoke evacuation system in the case of a fire emergency. The smoke system exhaust system will use the exhaust method outlined in *Section 909.8* of the *California Fire Protection Code*. Smoke is exhausted through a large return at the top of the space which will maintain tenable conditions for 20 minutes while also keeping the smoke at least 10 feet above the highest occupied surface, which is the second story restaurant space. The air that is typically exhausted into the lobby to maintain a positive pressurization will then be used as make-up air in the case of a fire emergency.

8.1.2 Restaurant

350 Mission features a premier destination-style restaurant, the exact details of which are not specified in the competition program. AEI Team 2's Mechanical Design Team opted to treat the restaurant, kitchen and supporting areas as tenant fit-out spaces, providing future occupants with the means to mitigate sensible and latent loads and properly provide exhaust and makeup air.

Restaurant Load Summary					
Space Sensible	169,433	[BTUh]	Space Heating	79	[MBH]
Space Latent	56,017	[BTUh]	Fresh Air	6,862	[CFM]

Table 7. *Table illustrating loads for the Restaurant*

8.1.2.3 HVAC Systems

The restaurant features a dedicated 100% Outside Air Unit which is exclusively supplied by a water-to-wastewater heat pump. This dedicated system was desired because it allows the restaurant to operate on independent hours efficiently. For details on the design of the water-to-wastewater heat pump, refer to Section 8.2.1.3.

The 100% Outside Air Unit supplies the restaurant and supporting spaces in order to mitigate the high latent loads. Because of these latent loads, an all-air space conditioning strategy was desired over using a radiant system. This 100% outside air system was chosen over using a recirculating air handler in order to take advantage of the coolth of San Francisco's climate, which has less enthalpy than recirculation air would have for a majority of the year.

8.1.2.2 Plumbing Systems

The plumbing system for the restaurant will be accounted for in the design for the rest of the system. Cap offs and other extensions are installed within the main riser to allow for the restaurant to tie in as necessary.

8.1.2.3 Design for Resilience and Life Safety

The restaurant space will be designed according to code for fire protection and seismic resiliency once all information is known about the space.

8.1.3 Typical Office Floor

Because the office floors account for over 75% of the total building area, AEI Team 2 realized that energy conservation measures on the office floors would have the largest return for the overall project. An initial load study on the 20th floor—the level which was decided to be our "typical office floor"—illustrated that the majority of the office floor would need year-round cooling, however there would be periods of the year which required perimeter space heating. An energy-efficient scheme in order to achieve our goal of minimizing energy consumption while satisfying both conditions, as discussed in the following sections.

Office Load Floor Summary					
Space Sensible	219,813	[BTUh]	Space Heating	51	[MBH]
Space Latent	19,928	[BTUh]	Fresh Air	3,775	[CFM]
Typical Office AHU Load (Serves 5 Floors)					
Space Sensible	1,099,065	[BTUh]	Space Heating	255	[MBH]
Space Latent	99,638	[BTUh]	Fresh Air	18,877	[CFM]

Table 8. *Table illustrating the loads for the office floor and office air handler*

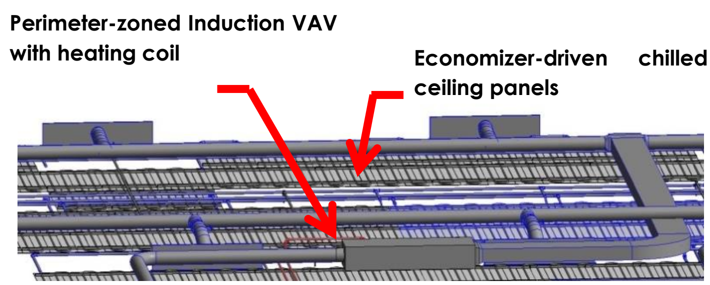


Figure 15. *Picture illustrating the terminal equipment for the simultaneous heating and cooling scheme*

8.1.3.1 HVAC Systems

On each office floor, a 100% Outside Air Unit provides fresh air to occupants while mitigating latent loads. Demand-controlled ventilation air is supplied on a zone-by-zone basis by VAV Induction terminals which are controlled by zone-level CO2 sensors. Perimeter zone terminals have a hot water coil which provides heat in the winter. Chilled ceiling panels mitigate sensible cooling loads and are directly supplied by cooling towers on the roof.

Cooling Season

Because of large sensible loads generated by solar gain, people, computers and the lighting system, an energy efficient cooling strategy was desired in order to mitigate these loads. Chilled ceiling panels were designed in order to be able to deliver both radiative and convective cooling. This option was chosen over a thermally-active chilled slab for the following reasons:

- Chilled slabs are approximately 25x heavier than radiant ceiling panels, introducing unwanted lateral forces into the structure during a design-level earthquake
- Because chilled ceilings are suspended above a space, they can take better advantage of convective heat transfer, affording chilled ceilings 1.7x greater heat flux
- Quality assurance during construction is easier to guarantee because the cooling system isn't embedded in concrete

A radiant cooling system was desired for 350 Mission because of its ability to take advantage of water-side economizer-driven free cooling for San Francisco's cooling season. Extensive cooling tower, plate-and-frame heat exchanger and chilled panel design was used to optimize chilled water ΔT, panel coverage, and cooling tower design conditions in order to allow the system to meet the design-level sensible cooling load, as well as perform at full capacity at 1% Design-day conditions.

On the 20th floor, it was determined that an **87% chilled ceiling coverage** was required in the open office in order to meet the peak cooling load. Though this is higher than typical coverage values, this panel density is a result of designing to **year-round water-side economizer use**. By designing to this condition, the **annual electricity required for radiant panel cooling is reduced by 57%** compared to serving the radiant panels with a centrifugal chiller. Panel design conditions for the 1% Cooling Condition are described in Table 8. It should also be noted that, due to potential acoustical concerns regarding large reflective surfaces, analysis was performed in order to ensure that speech intelligibility would not be negatively affected—an average reverberation time of **0.55** was found in the **250 – 4000 Hz** range, which is below the recommended **0.60 seconds**.

Chilled Ceiling Cooling Parameters			
V_{design}	1.0 gpm	ΔT	3.4 F
$T_{CHW,in}$	67.0 F	$T_{avg,surface}$	69.0 F
$T_{CHW,out}$	70.4 F	$Flux_{Cooling}$	16.2 BTUh/SF

Table 9. *Table illustrating the chilled ceiling design parameters*

Utilizing radiant cooling allows the sensible and latent loads to be decoupled, which, in an office environment in which sensible and latent loads can be fairly non-coincident, presents an advantage. A 100% Outdoor Air System was designed for the office levels. Each AHU serves five floors and has a variable-speed fan supply fan. Several dehumidification strategies were investigated including desiccant dehumidification, run-around coils and wrap-around coils. Run-around coils were decided on for the dehumidification technology because they reduced cooling coil size compared to using desiccant dehumidification. Run-around coils presented an advantage over wrap-around coils because run-around coils allowed the air to be supplied at a cold condition, whereas wrap-around coils return air to a neutral condition. By supplying fresh air at 50^F, mixed to 55^F at terminal units, instead of 62^F, the added cooling capacity of not rejecting heat back into the airstream presented an advantage over wrap-around coils. By supplying air at a colder condition, the overall cooling tower flow rate is reduced by **550 gpm and 500 chilled ceiling panels are avoided throughout the building, saving $100,000 of capital cost**, assuming roughly $200 per panel.

Heating Season

For the colder months of the year, both heating and cooling loads are present. Heat-producing people and equipment present in the core outweigh heat loss, while the perimeter zones see heating loads throughout the morning and evening. This was solved by using the Induction VAV terminals in the core zone to utilize economizer hours, mixing to 55F in the event of lower temperatures. Heating is then isolated to perimeter zones and coolth is not wasted by heating the entire airstream at the AHU.

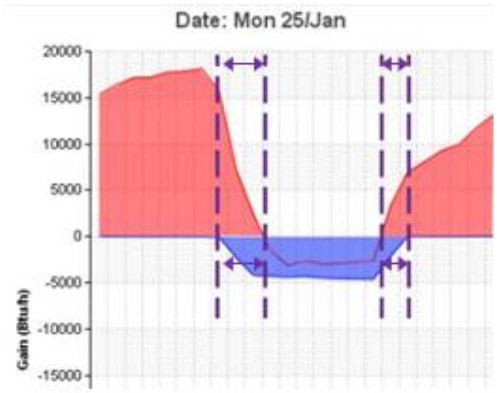


Figure 16. *Daily profile showing the need for simultaneous heating and cooling*

8.1.3.2 Plumbing Systems

The plumbing system for 350 Mission is directly integrated into the central plant and other key functions of the building as a whole. The non-potable demand will be served by the treated blackwater and greywater from the building, sewer and the rainwater tank on the roof. After solid separation occurs, the building wastewater is sent through the AquaCELL and is cleaned, then pumped to the parking garage, lobby, and the first 25 floors of the building. The rooftop rainwater tank will serve the top five floors of the system, with a bypass installed for the black water from the sewer to either service those floors or fill the rainwater tank if there is not enough rainwater to meet the demand of the top five floors. For a detailed plumbing schematic see Drawing 10.

8.1.3.3 Design for Resilience and Life Safety

The office floors of 350 Mission were designed with endurance in mind. Seismically bracing a chilled ceiling system is easier than ensuring seismic resilience for a comparable Underfloor Air system. The panels are also made of lightweight aluminum with copper piping, making them approximately 8x lighter than a UFAD system decreasing the lateral seismic loading experienced during an earthquake.

The fire protection system is an automated sprinkler system designed to activate appropriately when necessary. The system is designed to meet code and is sequenced into three different riser areas. The fire department connection from the street is diverted into main runs which service the parking garage, floors 1-16, and floors 17-30. Each floor has a dedicated sprinkler layout that is serviced from standpipes located in the two stairwells located within the core. Calculations were done to determine the necessary GPM and pressure that each pump must be designed to reach the farthest sprinkler on each floor. See Appendix __ for a more detailed analysis.

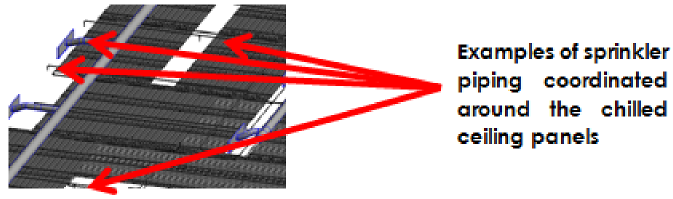


Figure 17. *Picture illustrating the coordination of MEP trades*

The airside system was designed based on the airflow design method. When a fire occurs on a specific floor, that floor is isolated from the others and the air handling unit responsible for that floor will exhaust the smoke through the return duct system and expel it outdoors via a diverting damper. To accompany the smoke evacuation system, a separate riser will supply air to the stairwells to provide a **positive pressurization of 0.15 in wg** to allow occupants to evacuate into the stairwell while simultaneously preventing the smoke from entering the space.

8.2 Efficient Plant

In order to ensure that 350 Mission met its Near-net Zero Goals, the heating and cooling plant of the building was optimized in order to require minimal input to deliver heating and cooling throughout the year. The details of each plant are discussed below:

8.2.1 Cooling Plant

The cooling plant was designed to serve diverse end-uses throughout the building. In order to maximize the efficiency of the cooling system, the cooling plant was divided into High Temperature Chilled Water (HCHW) and Low Temperature Chilled Water (LCHW). In order to generate HCHW and LCHW, a cooling tower system and an absorption cooling system was designed to deliver each commodity to the main spaces within the building, respectively. A water-to-water heat pump is designed to serve the Restaurant.

8.2.1.1 Cooling Tower HCHW System

San Francisco's climate can be characterized by hot/dry and mild/humid and during the ASHRAE 1% Cooling Design Day, the coincident ambient wet-bulb is only 62^F. Because of this climatic characteristic and the fact that chilled ceiling systems can leverage large cooling capacities at high CHW supply temperatures, **(4) Cooling Towers** were designed to supply HCHW to the building's radiant conditioning systems at a set-point of 67^F. Through using cooling towers with VFD fans, the cooling energy required to maintain an adequate set-point is reduced dramatically as the ambient wet-bulb temperature decreases.

Cooling Tower Loading Summary					
Flow per Cell	980	[gpm]	T_{in}	68	[F]
Number of Cells	4	[#]	T_{out}	65	[F]

Table 10. *Table illustrating the design conditions of the cooling towers*

In order to **avoid fouling** throughout the building's radiant panels, a **plate-and-frame heat exchanger** (PFHX) was designed to transfer heat from the cooling tower chilled water to the building's chilled water loop. This roof-mounted PFHX also presented the advantage of isolating the gravity head to height of the cooling tower, instead of the height of the building. This approach was introduced to minimize pumping energy. The cooling tower design conditions are outlined in Table 9. The design conditions, including inlet/outlet conditions, pressure drop, LMTD, passes and more for the PFHX are described in Appendix M.

This cooling strategy was modeled as a Strainer Cycle in IES Virtual Environment in order to compare against a centrifugal chiller. Simulations showed that, despite higher pumping energy due to increased flow rates, the lack of a compressor enabled **savings of 57% over supplying the chilled ceilings and thermal slab with an equivalent centrifugal chiller.**

The acoustics of having four large cooling towers on the roof was also modeled in order to ensure that there were no negative effects on surrounding buildings. The A-weighted sound pressure level 40 feet horizontal from the roof is calculated to be 32 dBA due to the attenuation from the roof parapet.

8.2.1.2 Absorption Chiller LCHW System

Because office buildings contain large numbers of people, large latent loads are present during operating hours. An **85-ton single-effect absorption chiller** was designed to generate 44^F chilled water using the low-grade exhaust and jacket heat from the IC Engine. Double-effect alternatives were explored; however the heat quality was not sufficient to drive the generator of a sufficiently-sized chiller.

Absorption Chiller Loading Summary					
Coincident Coil Loads	81.9	[tons]	T_{CHWR}	54	[F]
Flow Rate$_{LCHW}$	197	[gpm]	T_{CHWS}	44	[F]

Table 11. *Table illustrating the design conditions for the absorption chiller*

On the office floors, a run-around coil brings the on-coil temperature to saturation, rejecting heat into the exhaust air stream. The absorption chiller then cools air down to 50^F and 51.3 Gr/lb, which is mixed at the Induction VAV terminal to 55^F. This handles the design latent load of 19,930 BTUh per office floor. This utilization of CHP waste heat, coupled with maintaining high digester temperatures, ensures a large heat-to-power ratio ($\boldsymbol{\lambda_D}$) which maximizes the efficiency and economic viability of combined heat and power.

The absorption chiller uses the solid-separated wastewater from the biomethane plant as a heat rejection loop before it is re-injected into the municipal sewer. Using wastewater as a heat rejection loop is becoming increasingly popular in Philadelphia and a packaged system by NovaThermal Energy is making its application easier to adopt. For the application in 350 Mission, however this heat rejection method makes even more economic sense because sewer water has already been scalped and filtered by another process in the building—the resource is already present in high volumes. By using solid-separated wastewater as a heat sink, this shares auxiliary energy across multiple end-uses, increasing the overall system efficiency. It should also be noted that San Francisco limits sewer discharge temperatures to 125^F. The chiller's cooling water exit temperature does not exceed 98^F during operation, so after mixing it cannot exceed the limit.

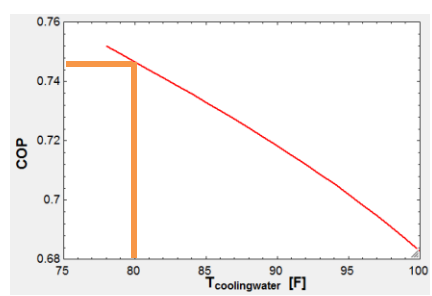


Figure 18. *Graph illustrating COP vs. cooling water inlet temperature for a generator inlet temperature of 200F*

In order to maximize the efficiency of the absorption chiller beyond the rated conditions, a generator water temperature of 200^F and a cooling water temperature of 80F was selected in order to **raise the COP from 0.68 to 0.75**. The condenser water temperature is selected with a 10F safety margin above the lower limit of 70F in order to avoid LiBr crystallization.

8.2.1.3 Water-to-Wastewater Heat Pump

A dedicated **20-ton water-to-wastewater heat pump** is used to provide chilled water to the restaurant's dedicated AHU. It was desired that this system be separate from the rest of the building due to the varying requirements and schedules of restaurant tenants. A dedicated system allows maximum tenant flexibility. The heat pump produces 44F LCHW and rejects heat to the solid-separated wastewater which is not directed to the AquaCELL blackwater reclamation system.

Wastewater Heat Pump Loading Summary					
Coincident Coil Loads	18.2	[tons]	T_{CHWR}	54	[F]
Flow Rate$_{LCHW}$	44	[gpm]	T_{CHWS}	44	[F]

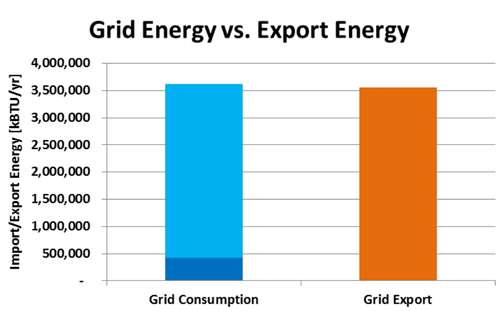
Table 12. *Table illustrating heat pump design conditions*

8.2.2 Heating Plant

The IC Engine which is used to generate electricity for 350 Mission also produces a constant stream of jacket and exhaust heat at a rate of **785** and **570 MBH**, respectively. This is sufficient to meet 91% of heating loads throughout the year, however for 9% of the year a supplemental boiler is required to meet perimeter heating loads. A **2,500 MBH boiler** is designed in order to generate hot water for perimeter heating coils.

8.2 Building Energy Balance

It has been shown, through extensive performance analysis, that 350 Mission is able to export 2,300 more yearly kWh to the grid than is required to operate the building, qualifying it as Net Zero Energy.



9. LEED Results: *PLATINUM*

AEI Team 2's 350 Mission achieved ***88 points***. For a detailed breakdown of which credits were contributed to by the Mechanical Team, see Appendix P.

10. Conclusion

The design for AEI Team 2's 350 Mission was driven by the desire to leverage advanced design tools to create a building which engages with the surrounding urban ecology to enable **Near-net Zero Energy, Water, Waste and Emissions** while creating a quality indoor environment for occupants. BIM allowed the Mechanical Team to create efficient distribution networks, reducing energy consumption while analytical modeling software enabled AEI Team 2 to optimize the holistic energy performance of the building. At the end of the design process, ***350 Mission achieved its Near-net Zero goals***:

ENERGY	WATER	WASTE	EMISSIONS
EUI: -0.02	GAL: 1,169,158	TONS: 321	TONS$_{CO2}$: 25
100% REDUCTION	84% REDUCTION	95% REDUCTION	99% REDUCTION

It was only through careful analysis, and continuous interdisciplinary collaboration, that the proposed solution was possible. Through cross-disciplinary, integrated design decisions, the basement structure and foundation was able to be modified in order to create space for the **BioMethane Plant** and **AquaCELL**. This **allowed large quantities of thermal and electric energy to be created**, shaping the design of the **heating** and **absorption cooling system**. It was also through interdisciplinary collaboration that an **optimized façade** which enhanced construction, structural, electrical and thermal performance, reduced space heat gains such that a **completely compressor-less space cooling system** was possible for 350 Mission.

Through all of these decisions, 350 Mission exists as an **environmentally-beneficial structure**—the building absorbs and treats waste streams in order to **produce 2,715,600 kWh** and **119,000 therms** on-site per year while **recycling 1,680,000 gallons of water** on-site. 350 Mission saves over 52,830 **tons of CO_2**, 85,148,815 **kWh**, 4,463,600 **therms**, 296,333,500 **gallons of potable water** and 25,500 **tons of landfill waste** over its **50-year lifecycle**. Through interacting with the community of San Francisco, 350 Mission is able to be designed not only as an architectural landmark, but as a *precedent-setting example of holistic sustainability*.

Appendix A – References

Codes & Handbooks

Title 24, Part 4 – *2010 California Mechanical Code* (CMC, 2010)

Title 24, Part 5 – *2010 California Plumbing Code* (CPC, 2010)

Title 24, Part 6 – *2010 California Energy Code* (CEC, 2010)

Title 24, Part 9 – *2010 California Fire Code* (CFC, 2010)

Title 24, Part 11 – *2010 California Green Building Code* (CGBC, 2010)

ASHRAE – *2013 Handbook of Fundamentals* (ASHRAE, 2013)

ASHRAE –*2012 HVAC Systems and Equipment* (ASHRAE, 2012)

ASHRAE – *2011 HVAC Applications* (ASHRAE, 2011)

ASHRAE – *Standard 55* (Standard 55, 2010)

ASHRAE – *Standard 62.1* (Standard 62.1, 2010)

ASHRAE – *Standard 90.1* (Standard 90.1, 2010)

ASHRAE – *Standard 189.1* (Standard 189.1, 2009)

Computer Programs

Acoustic Information Model 2013 (Dynasonics)

AutoCAD 2014 (Autodesk)

CONTAM 3.1 2013 (National Institute of Standards and Technology)

Engineering Equation Solver 2013 (F-Chart Software)

Excel 2010 (Microsoft)

Revit 2014 (Autodesk)

SketchUp 2013 (Trimble)

SPC HPD 2013 (S&P Coil Products Limited)

Thermal Heat Transfer Selection Software 2013 (ESP Thermal)

Virtual Environment 2013 (Integrated Environmental Solutions)

Update 2013 (SPX Cooling Technologies)

Report Images

Figure 5: Image of lightweight concrete acoustic roof: Courtesy of the AIA

Figure 12: Image of AquaCELL modular units: Courtesy of Mark Meredith

Additional Resources

U.S Environmental Protection Agency Combined Heat and Power Partnership (2008). "Catalog of Combined Heat and Power Technologies (CHP)" – p. 7 Comparison Graph (CHP, 2008)

Rushing A.S., Kneifel J.D. and Lippiatt B.C. (2013). "Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis." National Insitute of Standards and Technology, US Department of Commerce. < http://dx.doi.org/10.6028/NIST.IR.85-3273-28> (EnergyPrice, 2013)

"Average Energy Prices, San Francisco – Oakland - San Jose - December 2013." 14-104-SAN, Bureau of Labor and Statistics, U.S Department of Labor. < http://www.bls.gov/ro9/> (Average Energy, 2013).

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Mumma, S.A., Conroy, C.L. (2001). "Ceiling Radiant Cooling Panels as a Viable Distributed Parallel Sensible Cooling Technology with Dedicated Outdoor Air Systems". ASHRAE Transactions, AT-01-7-5. Atlanta, GA.

Leonardo Academy, (2011). "Guide to Calculating Emissions Including Emission Factors and Energy Prices". Technical white paper. <http://www.cleanerandgreener.org/download/Leonardo%20Academy%20C&G%20Emission%20Factors%20and%20Energy%20Prices.pdf>

Appendix B – Site Orientation

Climatic Design Considerations. Before the design of mechanical, plumbing and energy-creation systems could begin, a thorough understanding of San Francisco's climate had to be obtained. The following conclusions were made:

- ASHRAE 4C Climate—Mixed Marine environment
- Koppen-Geiger Csb Climate—Mediterranean
  - Dry summers
  - Wet winters
- Significant solar radiation due to mid-range latitude
- Rainfall characteristics of dry-temperate climate
- Primarily westerly winds
- HDD (64.4) = 3644.3
- CDD (50.0) = 2337.7

These observations shaped the development of building services and associated energy generation concepts.

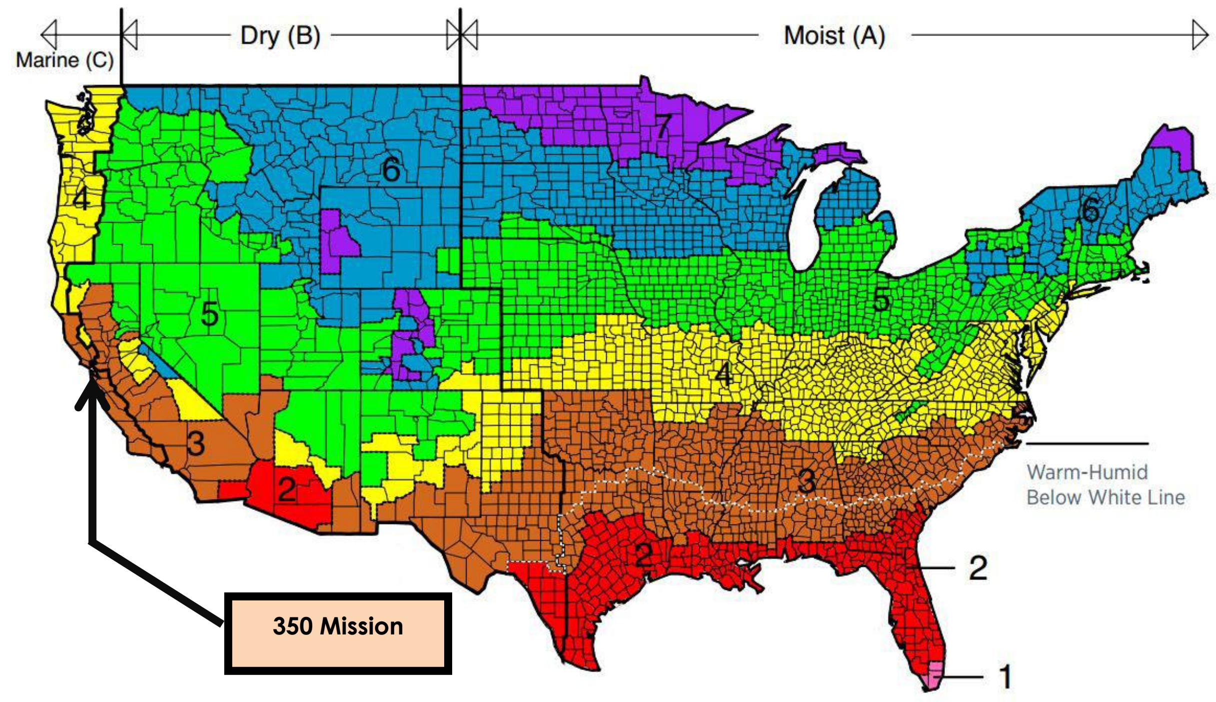


Figure 1. D.O.E. Climate map of the United States

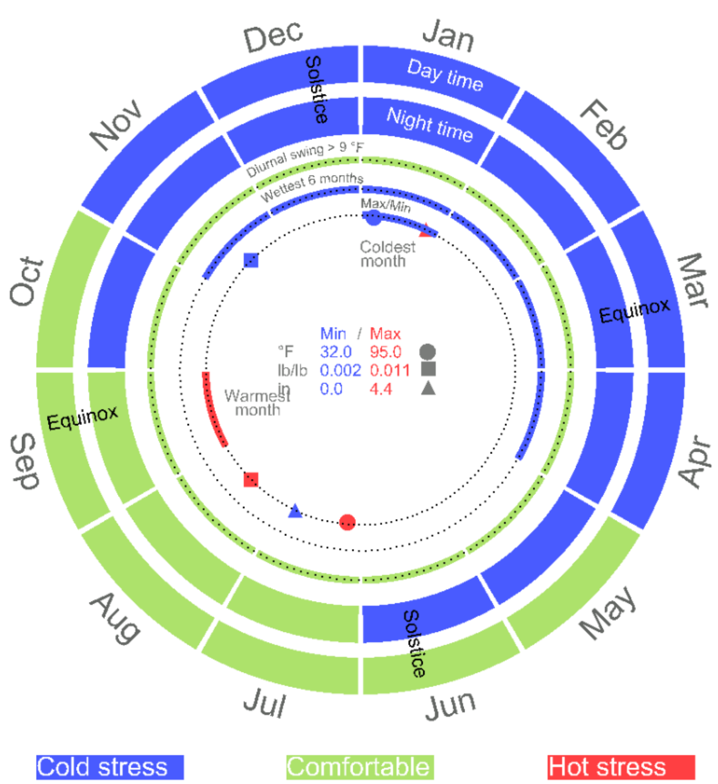


Figure 2. IES Virtual Environment climate analysis summarizing San Francisco's yearly weather conditions. Daytime and nightime conditions are shown, as are minimums, maximums and precipitation data

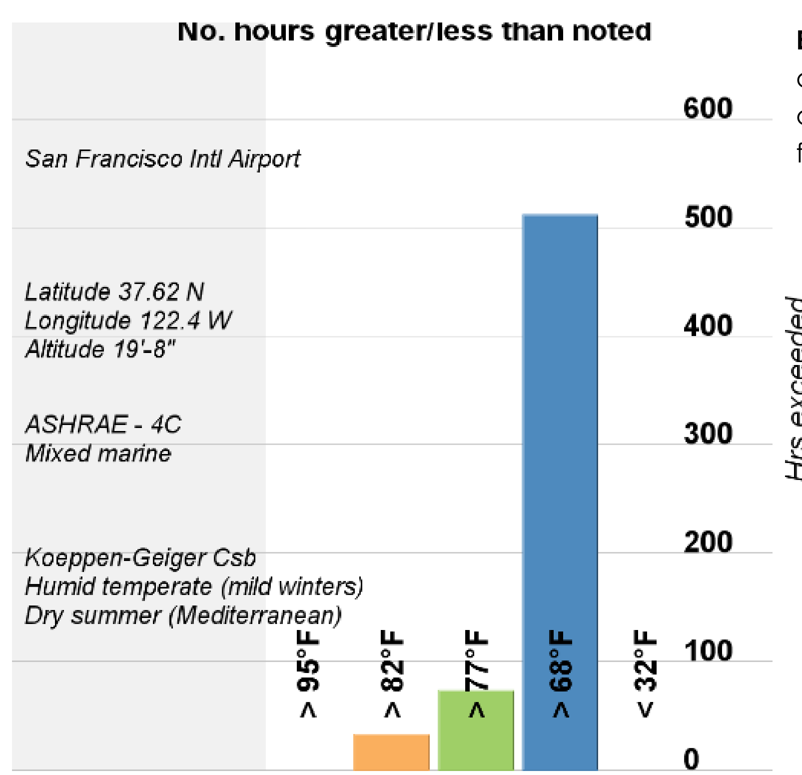
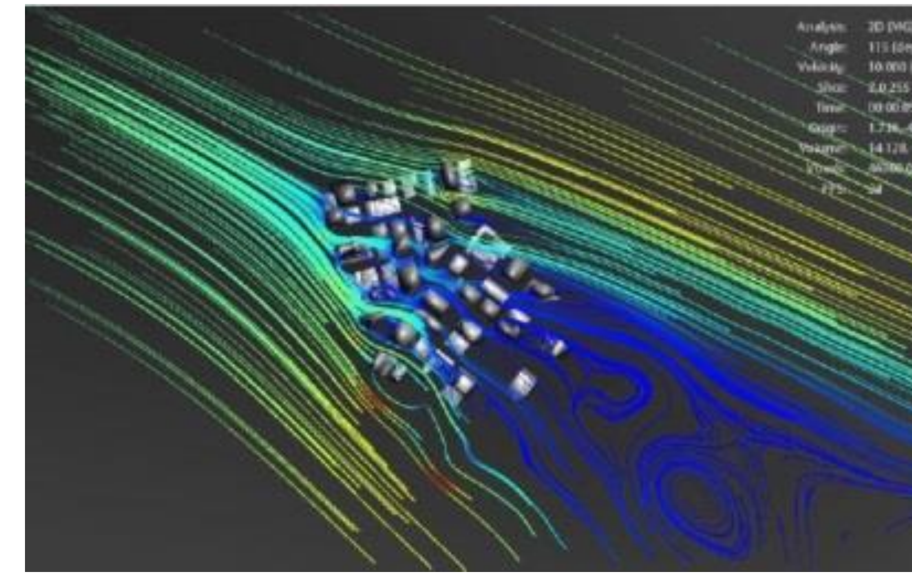


Figure 3. IES Virtual Environment climate analysis showing minimal extreme ambient heat gain

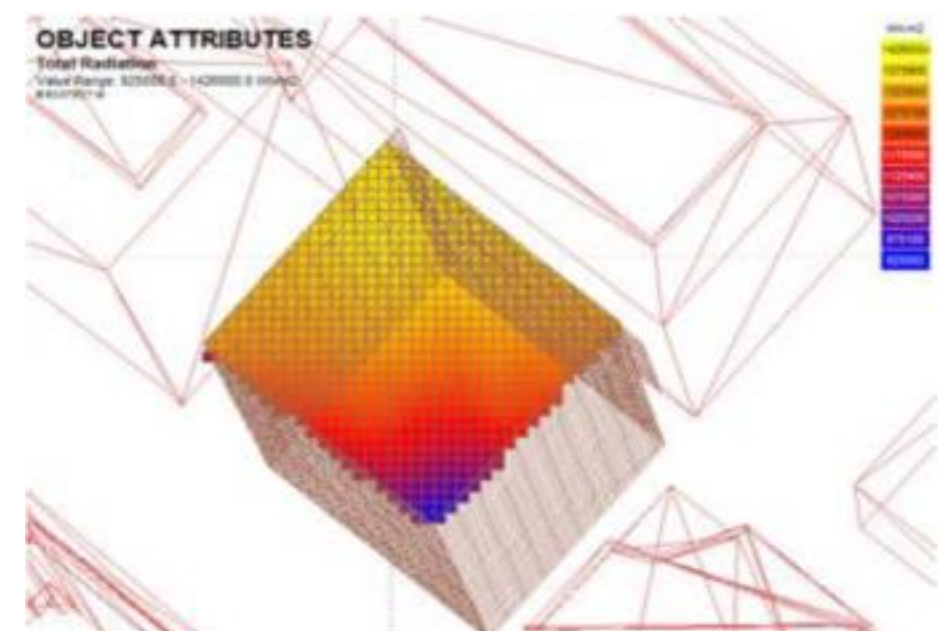
Bioclimatic Analysis. After analyzing yearly temperature, solar and precipitation conditions, the following strategies were devised:

- Minimize solar gain
- Utilize evaporative cooling strategies
- Reduce urban heat island effect
- Utilize adjustable solar shading to maximize comfort
- Create perimeter and core zones due to differing heating and cooling requirements during winter



Power Generation Assessment. In order to assess the potential for using Building-integrated Wind Turbines, Large Eddy CFD simulations were used to analyze predominant wind directions. It was found, due to the dense urban environment, usable wind would not consistently reach 350 Mission. Wind turbines were discarded as an energy-generation strategy.

Below, a solar study is shown. It was determined that a minimal amount of solar energy (81,700 kWh per year) could be generated relative to the electricity demand of the site. This solution was also discarded.



Appendix C – Loads and Heating/Cooling Plant

Typical Office Floors

Zone Name	Cooling Season: DOAS: Outside Air	Cooling Season: DOAS: Cooling Coil Load Contribution	Cooling Season: Space Conditions: Peak Latent Load	Peak Sensible Load	Supply Air Latent Capacity	Supply Air Sensible Capacity	Cooling Season: Chilled Ceiling: Sensible Load	Number of Panels	Heating Season: DOAS: Outside Air	Supplemental Induced Heating Airflow	Total Terminal Unit Flow	Heating Season: Space Conditions: Peak Sensible Heating Load	Coincident Supply Air Sensible Cooling Capacity	Heating Season: Terminal Unit: HTW Coil Load
	[CFM]	[BTUh]	[BTUh]	[BTUh]	[BTUh]	[BTUh]	[BTUh]	[#]	[CFM]	[CFM]	[CFM]	[BTUh]	[BTUh]	[BTUh]
Office Perim. West	486	10,719	4,960	39,883	8,541	14,175	25,708	33	486	119	605	17,648	-	35,949
Office Core West	257	5,660	4,495	14,662	4,510	7,485	7,177	9	257	-	257	-	7,485	-
Corridor West	40	891	-	1,234	710	1,178	56	-	40	-	40	-	1,178	-
Office Perim. South	486	10,719	4,960	46,216	8,541	14,175	32,041	36	486	83	569	16,600	-	33,815
Office Core South	257	5,660	4,495	12,541	4,510	7,485	5,057	6	257	-	257	-	7,485	-
Corridor South	40	891	-	1,237	710	1,178	59	-	40	-	40	-	1,178	-
Meeting Area 1	355	7,837	4,030	15,573	6,244	10,364	5,209	6	355	-	355	-	10,364	-
Meeting Area 2	99	2,181	1,550	10,574	1,738	2,885	7,689	9	99	-	99	-	2,885	-
Meeting Area 3	136	3,002	1,705	10,965	2,392	3,970	6,994	9	136	-	136	-	3,970	-
Corridor Central	47	1,032	-	4,370	822	1,365	3,005	4	47	-	47	-	1,365	-
Lounge Perimeter	362	7,992	3,615	22,039	6,368	10,570	11,469	13	362	-	362	10,405	-	21,531
Lounge Core	133	2,933	2,143	12,256	2,337	3,878	8,378	11	133	-	133	-	3,878	-
Pantry	60	1,326	969	2,048	1,056	1,753	295	-	60	-	60	-	1,753	-
Lobby	621	13,690	10,950	14,497	10,908	18,104	-	-	621	-	621	-	18,104	-
Misc. Room	263	5,793	4,379	12,712	4,616	7,661	5,051	6	263	-	263	1,909	-	15,606
Stairwell East	28	628	-	-	500	830	-	-	28	-	28	-	830	-
Stairwell West	28	628	-	-	500	830	-	-	28	-	28	-	830	-
Restrooms	36	791	-	8,633	630	1,046	7,587	10	36	-	36	-	1,046	-
Server Room	4	86	-	2,000	69	114	1,886	2	4	-	4	-	114	-
Fan Room	36	791	-	7,548	630	1,046	6,502	8	36	123	159	4,628	-	9,427
Coincident Peak Totals:	1,559	34,382	19,928	219,813	27,395	45,468	174,345	164			3,898	51,190	25,798	116,328

Upper and Lower Lobby

Zone Name	Cooling Season: DOAS: Outside Air	Cooling Season: DOAS: Cooling Coil Load Contribution	Cooling Season: Space Conditions: Peak Latent Load	Peak Sensible Load	Supply Air Latent Capacity	Supply Air Sensible Capacity	Cooling Season: Thermal Slab: Sensible Load	Slab Capacity Needed	Heating Season: DOAS: Outside Air	Heating Coil Load	Heating Season: Space Conditions: Peak Sensible Heating Load	Heating Season: Supplemental Heat: Coincident Supply Air Sensible Cooling Capacity	Heating Season: Thermal Slab: Slab Capcacity Needed
	[CFM]	[BTUh]	[BTUh]	[BTUh]	[BTUh]	[BTUh]	[BTUh]	[BTUh/SF]	[CFM]	[BTUh]	[BTUh]	[BTUh]	[BTUh/SF]
Open Lobby Entry	7,398	133,158	130,470	271,640	129,971	215,715	55,925	13	7,398	223,705	107,146	-	25
Retail East	1,193	21,475	1,866	43,807	20,961	34,790	9,017	14	1,193	36,079	22,530	-	36
Retail West	112	2,024	1,116	2,953	1,975	3,279	-	-	112	3,400	3,130	-	8
Fire Command Room	16	285	-	-	278	462	-	-	16	479	-	-	-
Gas Meter Room	6	110	-	-	107	177	-	-	6	184	-	-	-
Elevator Lobby	675	12,155	11,910	14,051	11,864	19,692	-	-	675	20,421	4,060	-	10
Public Restroom	980	17,640	-	30,615	17,218	28,577	2,038	14	980	29,635	17,582	12,200	36
Exit Passageway	31	551	-	843	538	893	-	-	31	926	6,304	-	20
Upper Lobby	3,687	66,364	59,370	136,037	64,775	107,509	28,528	14	3,687	111,491	36,433	-	18
Stairwell East	50	899	-	-	877	1,456	-	-	50	1,510	-	-	-
Stairwell West	50	899	-	-	877	1,456	-	-	50	1,510	-	-	-
Coincident Peak Totals:	14,198	255,559	204,732	499,946	249,443	414,005	95,507		14,198	429,339	197,185	12,200	

Restaurant

Zone Name	Cooling Season: DOAS: Outside Air	Cooling Season: DOAS: Cooling Coil Load Contribution	Cooling Season: Space Conditions: Peak Latent Load	Peak Sensible Load	Supply Air Latent Capacity	Supply Air Sensible Capacity	Heating Season: DOAS: Outside Air	Heating Coil Load	Heating Season: Space Conditions: Peak Sensible Heating Load
	[CFM]	[BTUh]	[BTUh]	[BTUh]	[BTUh]	[BTUh]	[CFM]	[BTUh]	[BTUh]
Dining Area	4,717	84,899	35,422	126,762	46,570	127,349	4,717	280,167	64,278
Kitchen	2,082	37,467	20,595	36,822	20,552	56,201	2,082	123,642	15,159
Men's Restroom	5	98	-	2,453	54	147	5	165	-
Women's Restroom	5	98	-	2,461	54	147	5	165	-
Corridor	53	952	-	935	522	1,428	53	1,599	-
Coincident Peak Totals:	6,862	123,515	56,017	169,433	67,752	185,272	6,862	405,739	79,437

Equipment Schedules

Absorption Chiller Schedule

Name	Location	Chilled Water: Flow Rate	T_{CHWS}	T_{CHWR}	$Q_{evaporator}$	Cooling Water: Flow Rate	T_{CWS}	T_{CWR}	$Q_{cooling}$	Generator Water: Flow Rate	T_{HWS}	T_{HWR}	$Q_{generator}$
		[gpm]	[F]	[F]	[BTUh]	[gpm]	[F]	[F]	[BTUh]	[gpm]	[F]	[F]	[BTUh]
ACH - 1	B4 - Basement	197	44	54	(982,800)	374	80	92	2,244,000	87	200	170	(1,310,000)

Supplemental Boiler Schedule

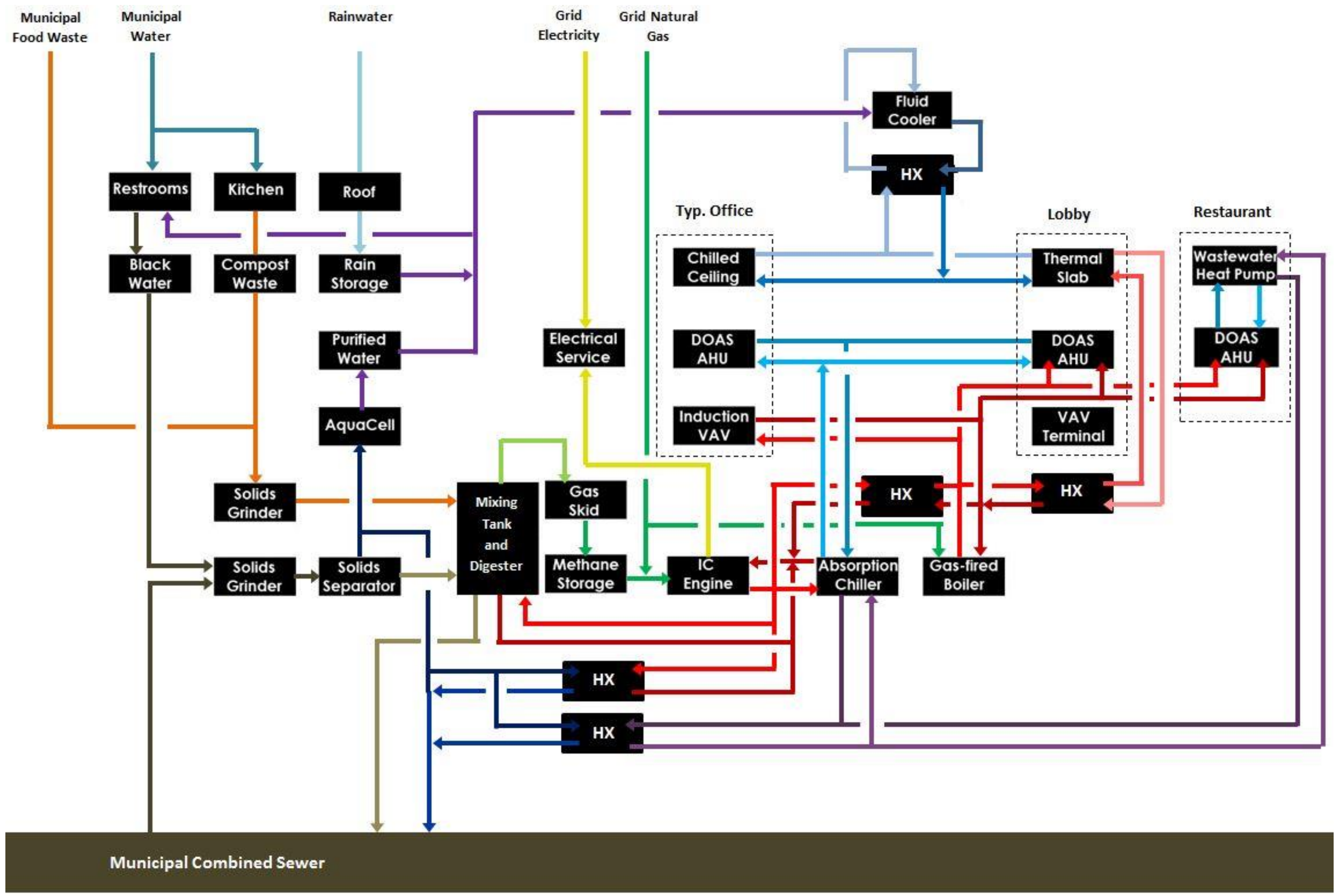
Name	Location	Heat Output: Water Flow Rate	T_{HWS}	T_{HWR}	Q_{boiler}	Fuel Input: Flow Rate	LHV
		[gpm]	[F]	[F]	[BTUh]	[CFM]	[BTU/ft^3]
SB - 1	B4 - Basement	148	160	130	2,220,000	521	80

Wastewater Heat Pump Schedule

Name	Location	Power Consumption	Chilled Water: Flow Rate	T_{CHWS}	T_{CHWR}	$Q_{evaporator}$	Condenser Water: Flow Rate	T_{CWS}	T_{CWR}	$Q_{cooling}$
		[kW]	[gpm]	[F]	[F]	[BTUh]	[gpm]	[F]	[F]	[BTUh]
HP - 1	3rd Floor Mech Room	14	47	44	54	(236,600)	50	80	91	282,500

In order to ensure high performance for 350 Mission, specific components within the mechanical system were designed in-depth. The absorption chiller was modeled with Engineering Equation Solver in order to optimize the design conditions, and the boiler and heat pump generator and condensing water temperatures were designed to match temperatures, respectively. The schedules above reflect the design decisions made for each piece of equipment. All equipment ΔTs are matched in order to ensure good overall system thermodynamics.

Appendix D – Energy, Water, Waste and Emissions



ENERGY

EUI: -0.02

100% REDUCTION

WATER

GAL: 1,169,158

84% REDUCTION

WASTE

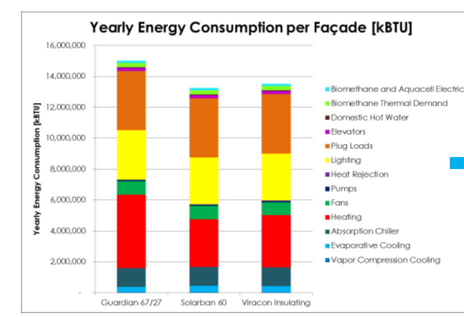
TONS: 321

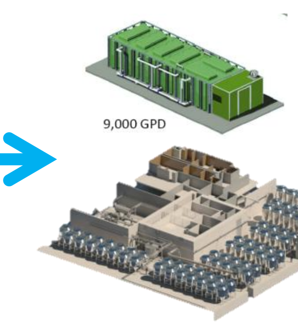
95% REDUCTION

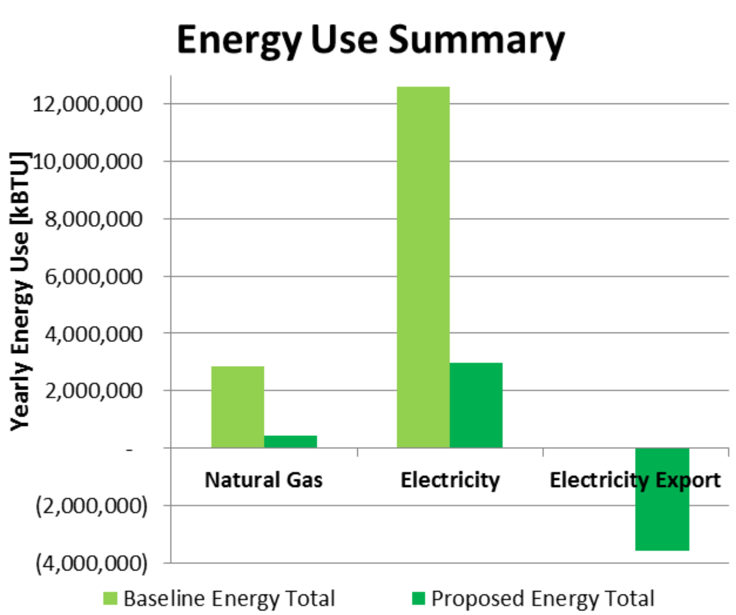
EMISSIONS

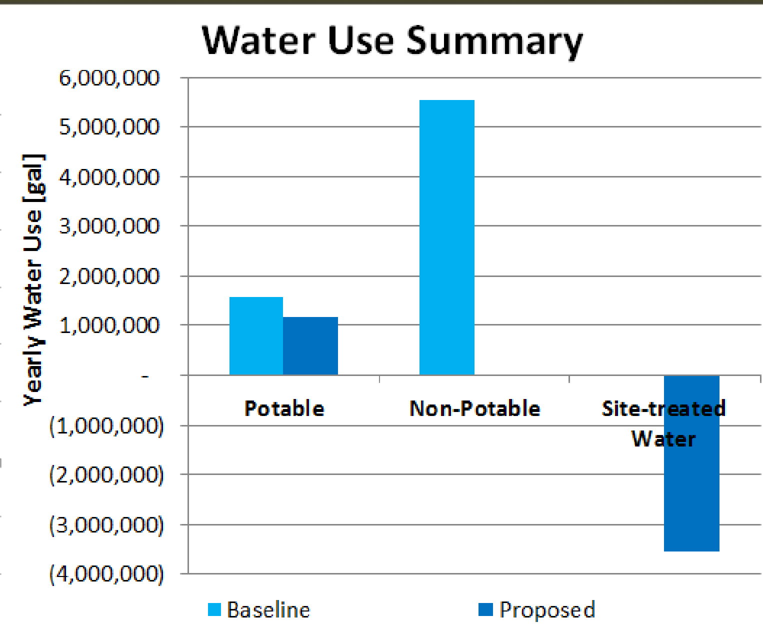
TONS$_{CO2}$: 25

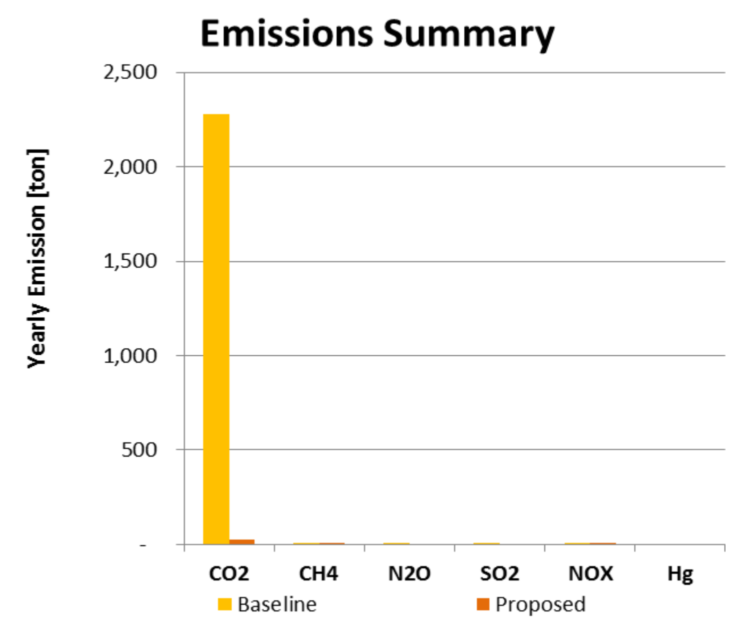
99% REDUCTION

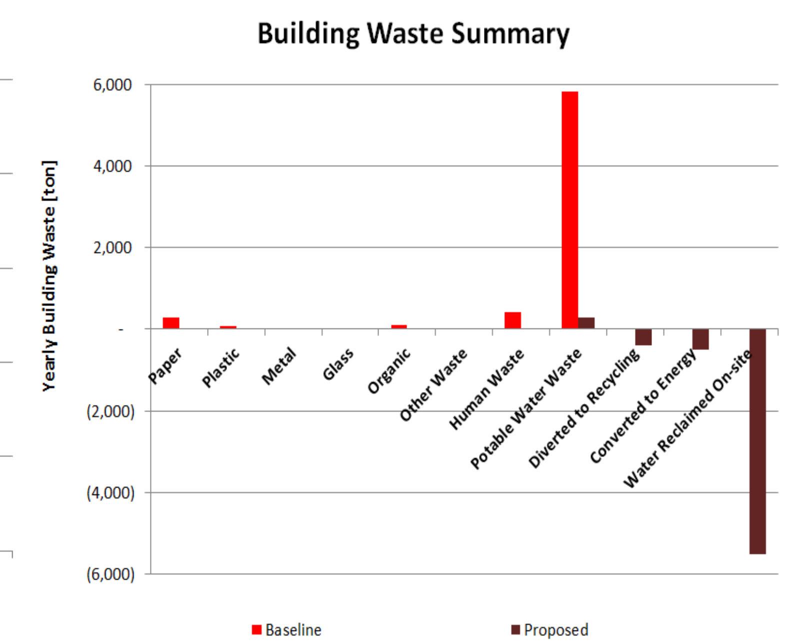












Appendix E – BioMethane Plant

Municipal Food Waste Rate		Organic Sludge Mass Flow	
8,500	[gpd]	113.4	[g/s]
Building Food Waste Rate		Organic Sludge Volume Flow	
52	[gpd]	0.11	[L/s]
Building Sewage Rate		Sewage Solids Accumulation	
300	[gpd]	2,863	[gpd]
Wastewater Flow Rate		CH4 Mass Branching Ratio	
1,500	[gpm]	0.35	[m3 CH4/kg]
VOS Concentration		COD of Mixed Food Waste	
300	[mg/L]	252,000	[mg/L]
VOS Mass Flow		COD of Human Feces	
28.4	[g/s]	37,211	[mg/L]

Methane Generation Process

Hydrolysis: carbohydrates, fats and proteins are converted to sugars, fatty acids and amino acids, respectively

Acidogenesis: hydrolysis byproducts are transformed into carbonic acids, alcohols, hydrogen, carbon dioxide and ammonia

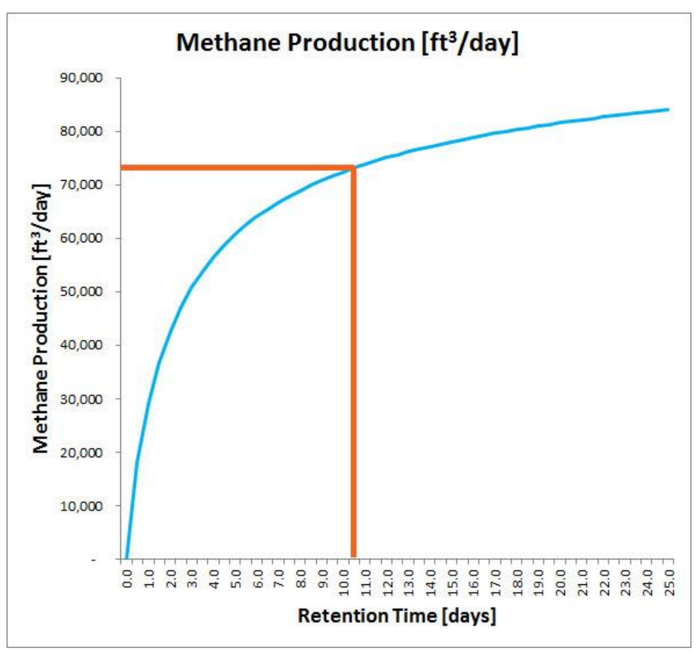
Aceteogenesis: byproducts of acidogenesis are converted to hydrogen, acetic acid and carbon dioxide

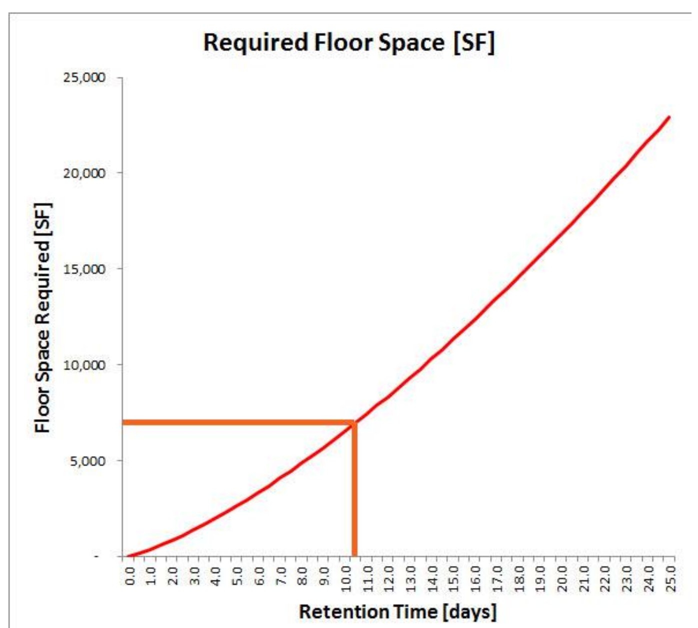
Methanogenesis: aceteogenesis byproducts are converted to methane and carbon dioxide

Production Model Variables

Q_{CH4}: Methane production
Q_w: Influent flow rate
S_{T0}: Original concentration of volatile solids
S_{Te}: Final concentration of volatile solids
M: Mass branching ratio
$\eta_{digestion}$: Digestion efficiency
S': Normalized solids concentration
k: Reaction constant
n: Reaction order
t: Standardized retention time
X_v/X_w: Average mixed concentration

Retention Time [days]	Avg. Norm. Conc. [--]	Digestion Efficiency [%]	Methane Production [ft3/day]	Biogas Production [ft3/day]		Tank Volume [gal]	Tank Volume [ft3]	Number of Tanks [#]	Required Space [SF]
0.0	1.000	0%	-	-		-	-	-	-
0.5	0.908	17%	17,925	27,577		6,289	841	4	89
1.0	0.841	27%	29,032	44,665		13,569	1,814	9	191
(...etc...)									
8.0	0.518	65%	68,883	105,974		176,233	23,559	123	2,485
8.5	0.508	66%	69,859	107,475		191,001	25,533	133	2,693
9.0	0.498	67%	70,761	108,863		206,109	27,553	144	2,906
9.5	0.489	68%	71,599	110,152		221,547	29,617	154	3,124
10.0	0.481	68%	72,379	111,352		237,307	31,723	165	3,346
10.5	0.473	69%	73,109	112,475		253,381	33,872	176	3,572





BioMethane Production Model *(Procedure from Slovenian National Inst. Of Chemistry)*

Step 1: Define needed equation to find methane volume

$$Q_{CH_4} = Q_w(S_{T0} - S_{Te})M \Longrightarrow Q_{CH_4} = (\eta_{digestion})Q_w M S_{T0}$$

Step 2: Define digestion efficiency based on normalized VSS concentration per particulate influent

$$\eta_{digestion} = \frac{(S_{T0} - S_{Te})}{S_{T0}} = \frac{(S'(t=0) - S'(t))}{S'(t=0)} = \frac{(1 - S')}{1}$$

Step 3: Normalize VSS concentration

$$S' = \frac{S}{S_0}$$

Step 4: Model VSS decay rate as a function of kinetic reaction order ($n = 3$) and reaction constant (k)

$$\frac{\partial S'}{\partial t} = -k \cdot (S')^n$$

Step 5: Define normalized concentration based on remaining VSS per particulate influent; Thermophilic digestion constants are defined as ($k' = 0.449$) and ($c_1 = 1$)

$$S' = \frac{1}{\sqrt{c_1 + 2k' \cdot t}}$$

Step 6: Define standard residence time based on digester flow, volume and average remaining VSS concentration

$$t = \frac{V X_v}{Q_w X_w}$$

Step 7: Define average remaining VSS concentration

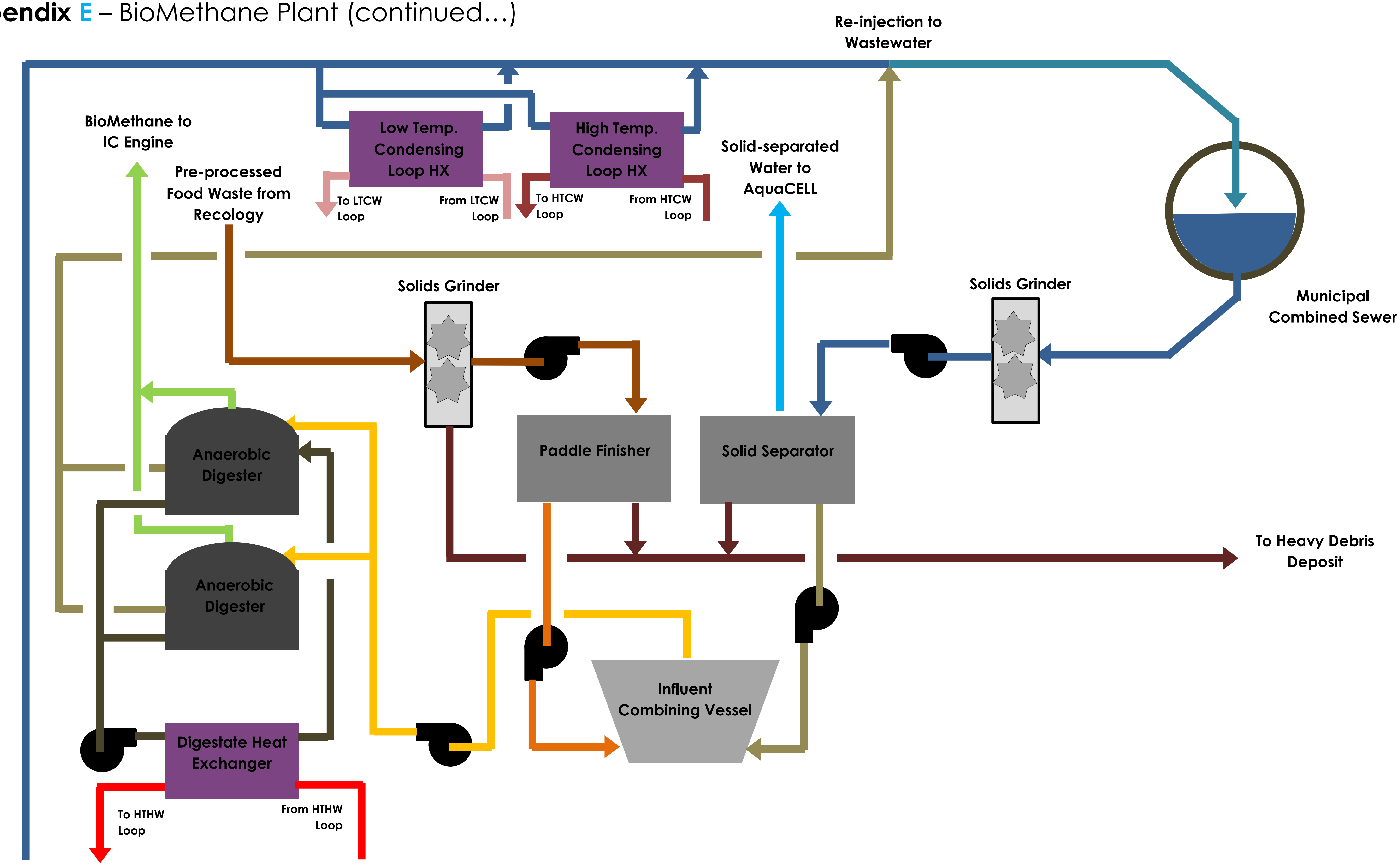
$$\left(\frac{X_v}{X_w}\right) = \frac{1}{t}\int_0^t \frac{1}{\sqrt{c_1 + 2k' \cdot t}}$$

Step 8: Combine terms to find methane production based on tank volume, standard residence time, influent mass branching ratio and influent Chemical Oxygen Demand

$$Q_{CH_4} = \left(\frac{V}{t^2}\int_0^t \frac{1}{\sqrt{c_1 + 2k' \cdot t}}\right)\left(1 - \frac{1}{\sqrt{c_1 + 2k' \cdot t}}\right) M S_{T0}$$

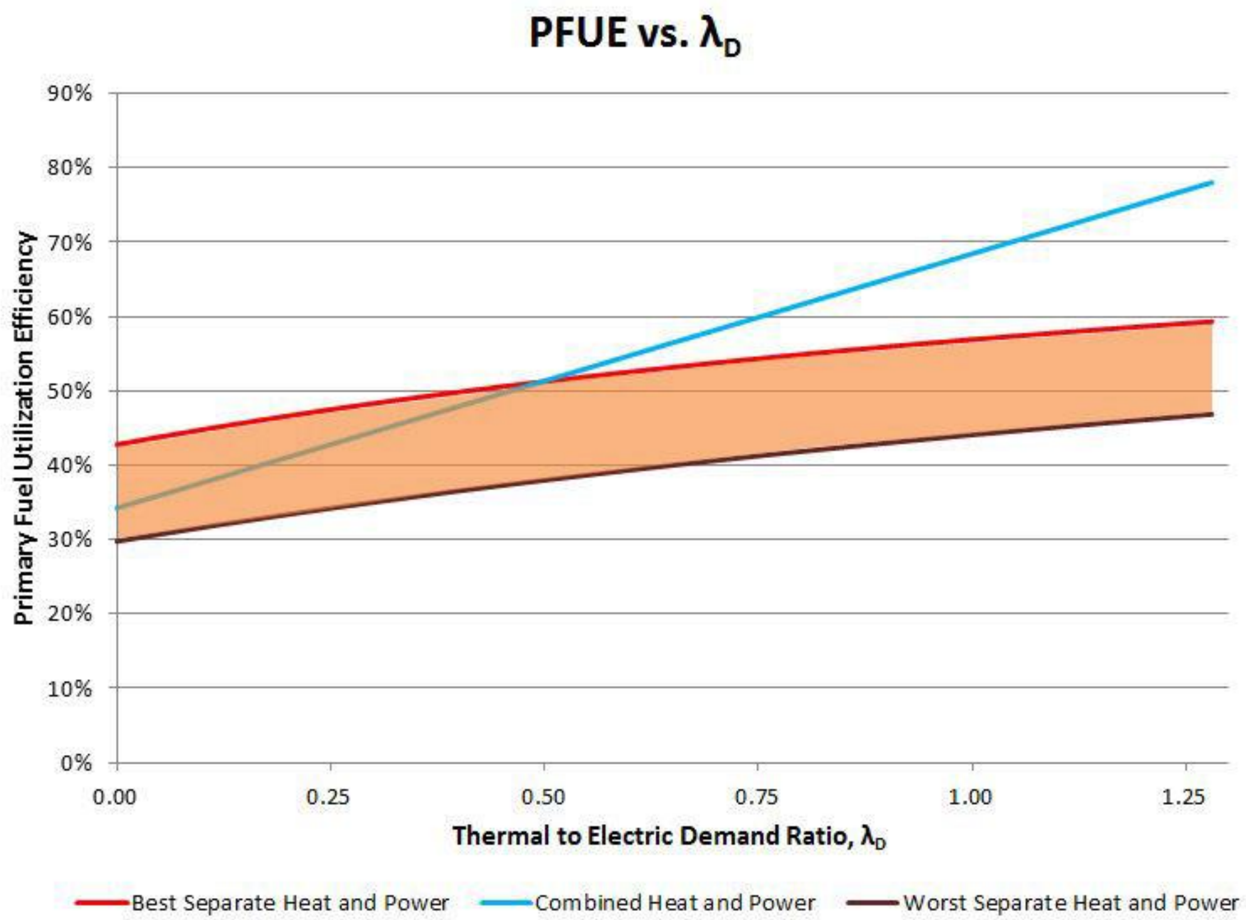
Step 9: Set spatial constraints and analyze influent characteristics and quantities

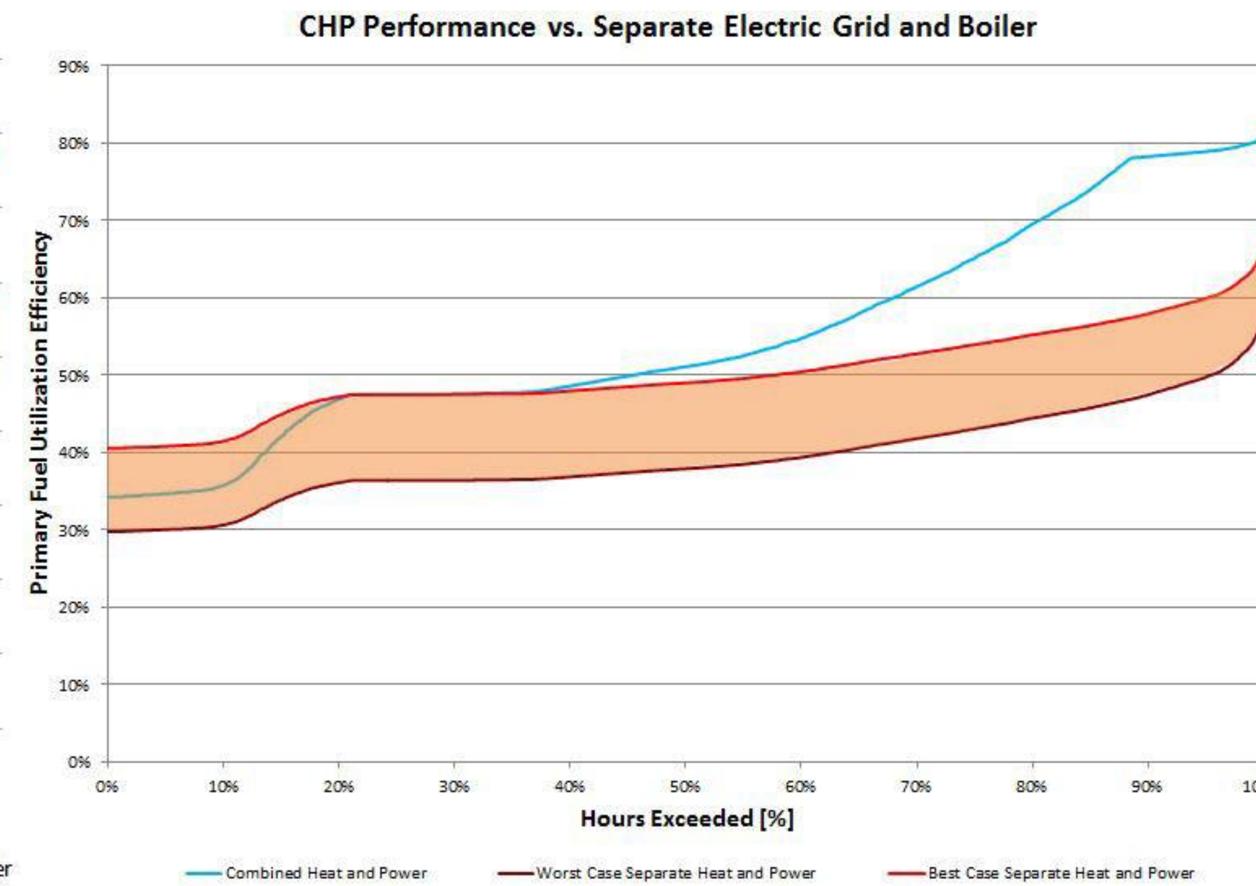
Appendix E – BioMethane Plant (continued…)



Appendix F – CHP Calculations

Waukesha IC Engine		
Biomethane Flow Rate	4,649	[ft^3/hr]
Usable Electricity	**310**	[kW]
Usable Jacket Heat	**785**	[kBTUh]
Exhaust Heat Output	877	[kBTUh]
HX Effectiveness	65%	
Usable Exhaust Heat	**570**	[kBTUh]
Electrical Efficiency	34.2%	
Overall Efficiency	**78.0%**	





Performance Sensitivity Analysis of 310 kW IC Engine. Though 350 Mission generates fuel on-site, the Mechanical Design Team wanted to assess the performance of its Combined Heat and Power system design compared to a separate electrical grid and boiler for the purposes of system performance validation. This analysis is conducted to ensure that on-site CHP is a good match for 350 Mission's resource utilization profile. It is shown in the above analyses that, for 60 – 100% of the year, depending on the characteristics of San Francisco's electrical grid, on-site CHP is objectively a more effective use of resources.

Below are the equations used to analyze the Combined Heat and Power (CHP) system compared to Separate Heat and Power (SHP):

$$PFUE_{CHP} = \frac{\dot{q}_d + \dot{e}^-{}_d}{\dot{q}_{fuel} + \begin{cases} \left(\frac{\dot{q}_d - \dot{q}_{cap}}{\eta_b}\right) if\ \dot{q}_d > \dot{q}_{cap} \\ 0\ if\ \dot{q}_d \le \dot{q}_{cap} \end{cases} + \begin{cases} \left(\frac{\dot{e}^-{}_d - \dot{e}^-{}_{cap}}{\eta_{gen} \cdot \eta_{trans,dist}}\right) if\ \dot{e}^-{}_d > \dot{e}^-{}_{cap} \\ 0\ if\ \dot{q}_d \le \dot{q}_{cap} \end{cases}}$$

$$PFUE_{SHP} = \frac{\dot{q}_d + \dot{e}^-{}_d}{\left(\frac{\dot{q}_d}{\eta_b}\right) + \left(\frac{\dot{e}^-{}_d}{\eta_{gen} \cdot \eta_{trans,dist}}\right)}$$

Figure 2. *310 kW Waukesha IC Engine used in 350 Mission*

For periods where there is little thermal demand, a dedicated cooling tower on the roof of 350 Mission will exhaust heat from the engine's jacket water loop, lubrication oil and intercooler in order to keep the engine at appropriate operating conditions. This heat exchanger is coupled to the wastewater return loop and rejects heat at the following design conditions:

Design Flow: 74 gpm_{hot} and 108 gpm_{cold}

LMTD: 99.9^F

T_{F1}: 200.0^F

T_{F2}: 95.0^F

T_{F3}: 75.0^F

T_{F4}: 170.0^F

Appendix G – Power Generation Economic Analysis

Below is an example of the economics calculations to determine the payback rates of the combined BioDigestion Plant and Internal Combustion Engine. Detailed load analysis was performed in order to determine the monthly breakdown of site-generated thermal and electrical energy, grid electricity, grid natural gas and site-exported electricity. These totals were applied to PG&E's electricity purchase and avoided cost rates as well their natural gas purchase rates. They were also applied to the EPA's estimated energy escalation rates and discount rates in order to find the simple and discounted payback for the proposed systems. Sensitivity analysis was performed based on the highest and lowest capital investment potential for the digestion system—the most expensive option is illustrated below:

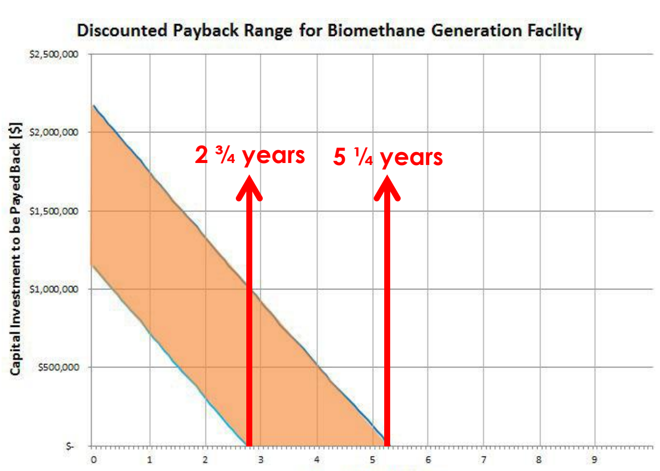
Year	Month	Capital	Operations and Maintainence	Un-escalated Savings and Income		Un-escalated Cost			Escalation Rate		Escalated Savings and Income		Escalated Cost		
				Electricity Savings	Electric Sales	Electric	Natural Gas	Total	Electric	Natural Gas	Electricity Savings	Electric Sales	Electric	Natural Gas	Total
0	0	$ 2,170,000													
1	1	$ -	$ 4,526	$ 35,568.59	$ 4,462.41	$ 14,822.37	$ 2,107.83	$ 16,930.20	1.00	1.00	$ 35,568.59	$ 4,462.41	$ 14,822.37	$ 2,107.83	$ 16,930.20
1	2	$ -	$ 4,526	$ 32,204.10	$ 3,878.32	$ 14,267.96	$ 413.78	$ 14,681.74	1.00	1.00	$ 32,204.10	$ 3,878.32	$ 14,267.96	$ 413.78	$ 14,681.74
1	3	$ -	$ 4,526	$ 36,070.35	$ 4,314.84	$ 16,385.26	$ 536.81	$ 16,922.07	1.00	1.00	$ 36,070.35	$ 4,314.84	$ 16,385.26	$ 536.81	$ 16,922.07
1	4	$ -	$ 4,526	$ 34,704.82	$ 4,235.06	$ 15,959.31	$ 82.16	$ 16,041.47	1.00	1.00	$ 34,704.82	$ 4,235.06	$ 15,959.31	$ 82.16	$ 16,041.47
1	5	$ -	$ 4,526	$ 35,117.19	$ 4,575.12	$ 15,455.69	$ 2.20	$ 15,457.89	1.00	1.00	$ 35,117.19	$ 4,575.12	$ 15,455.69	$ 2.20	$ 15,457.89
1	6	$ -	$ 4,526	$ 34,552.17	$ 4,300.01	$ 16,457.55	$ 0.88	$ 16,458.43	1.00	1.00	$ 34,552.17	$ 4,300.01	$ 16,457.55	$ 0.88	$ 16,458.43
1	7	$ -	$ 4,526	$ 35,545.58	$ 4,469.18	$ 16,789.87	$ -	$ 16,789.87	1.00	1.00	$ 35,545.58	$ 4,469.18	$ 16,789.87	$ -	$ 16,789.87
1	8	$ -	$ 4,526	$ 35,378.06	$ 4,518.46	$ 16,746.83	$ -	$ 16,746.83	1.00	1.00	$ 35,378.06	$ 4,518.46	$ 16,746.83	$ -	$ 16,746.83
1	9	$ -	$ 4,526	$ 34,378.87	$ 4,330.92	$ 16,931.31	$ -	$ 16,931.31	1.00	1.00	$ 34,378.87	$ 4,330.92	$ 16,931.31	$ -	$ 16,931.31
1	10	$ -	$ 4,526	$ 34,966.99	$ 4,639.35	$ 15,489.40	$ -	$ 15,489.40	1.00	1.00	$ 34,966.99	$ 4,639.35	$ 15,489.40	$ -	$ 15,489.40
1	11	$ -	$ 4,526	$ 34,731.15	$ 4,227.31	$ 15,791.36	$ 143.51	$ 15,934.87	1.00	1.00	$ 34,731.15	$ 4,227.31	$ 15,791.36	$ 143.51	$ 15,934.87
1	12	$ -	$ 4,526	$ 36,334.59	$ 4,237.12	$ 16,283.70	$ 1,588.20	$ 17,871.90	1.00	1.00	$ 36,334.59	$ 4,237.12	$ 16,283.70	$ 1,588.20	$ 17,871.90

Month	Un-escalated Baseline		Escalated Baseline		Payback Analysis					
	Electric Total	Natural Gas Total	Electric Total	Natural Gas Total	Baseline	Proposed	Simple Payback	Simple Savings Accumulation	Discounted Payback	Discounted Savings Accumulation
0					$ -	$ 2,170,000				
1	$ 45,928.55	$ 11,236.05	$ 45,928.55	$ 11,236.05	$57,164.60	$ 16,993.79	$ 40,170.81	$ 40,170.81	$ 40,093.96	$ 40,093.96
2	$ 42,593.74	$ 6,929.75	$ 42,593.74	$ 6,929.75	$49,523.49	$ 15,329.42	$ 34,194.07	$ 74,364.88	$ 34,063.37	$ 74,157.33
3	$ 48,140.77	$ 7,852.47	$ 48,140.77	$ 7,852.47	$55,993.24	$ 17,133.23	$ 38,860.01	$ 113,224.89	$ 38,637.42	$ 112,794.75
4	$ 46,429.07	$ 5,619.40	$ 46,429.07	$ 5,619.40	$52,048.47	$ 16,332.41	$ 35,716.06	$ 148,940.95	$ 35,443.54	$ 148,238.29
5	$ 45,997.76	$ 4,129.09	$ 45,997.76	$ 4,129.09	$50,126.85	$ 15,408.77	$ 34,718.08	$ 183,659.03	$ 34,387.27	$ 182,625.56
6	$ 46,709.71	$ 3,686.67	$ 46,709.71	$ 3,686.67	$50,396.38	$ 16,684.42	$ 33,711.96	$ 217,370.99	$ 33,326.86	$ 215,952.42
7	$ 47,866.27	$ 3,102.05	$ 47,866.27	$ 3,102.05	$50,968.32	$ 16,846.69	$ 34,121.63	$ 251,492.62	$ 33,667.32	$ 249,619.75
8	$ 47,606.43	$ 3,166.52	$ 47,606.43	$ 3,166.52	$50,772.95	$ 16,754.37	$ 34,018.58	$ 285,511.20	$ 33,501.43	$ 283,121.18
9	$ 46,979.26	$ 3,013.12	$ 46,979.26	$ 3,013.12	$49,992.38	$ 17,126.39	$ 32,865.99	$ 318,377.19	$ 32,304.45	$ 315,425.62
10	$ 45,817.04	$ 3,767.58	$ 45,817.04	$ 3,767.58	$49,584.62	$ 15,376.05	$ 34,208.57	$ 352,585.76	$ 33,559.76	$ 348,985.39
11	$ 46,295.20	$ 5,963.48	$ 46,295.20	$ 5,963.48	$52,258.68	$ 16,233.56	$ 36,025.12	$ 388,610.88	$ 35,274.25	$ 384,259.64
12	$ 48,381.17	$ 10,956.94	$ 48,381.17	$ 10,956.94	$59,338.11	$ 18,160.78	$ 41,177.33	$ 429,788.21	$ 40,241.95	$ 424,501.59

(…etc…)

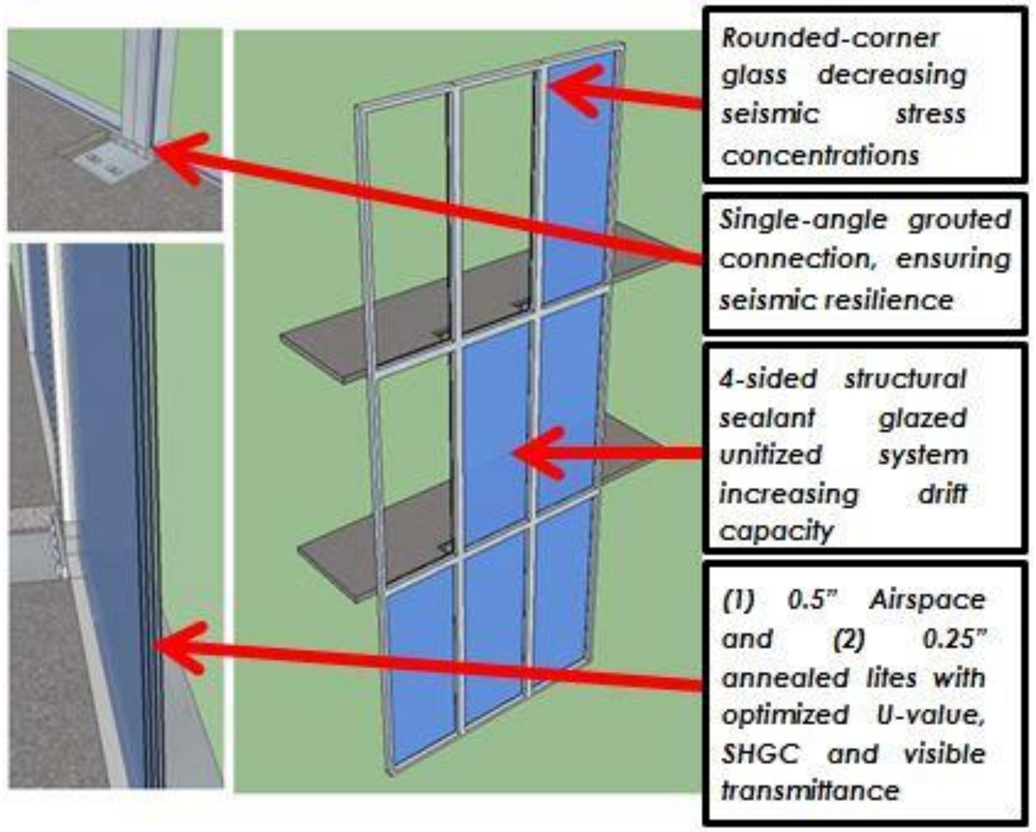
Year	Month	Capital	Operations and Maintainence	Electricity Savings	Electric Sales	Electric	Natural Gas	Total	Escalation Electric	Escalation Natural Gas	Escalated Electricity Savings	Escalated Electric Sales	Escalated Electric	Escalated Natural Gas	Escalated Total
5	49	$ -	$ 4,526	$ 35,568.59	$ 4,462.41	$ 14,822.37	$ 2,107.83	$ 16,930.20	0.97	0.92	$ 34,501.53	$ 4,328.54	$ 14,377.70	$ 1,939.20	$ 16,316.90
5	50	$ -	$ 4,526	$ 32,204.10	$ 3,878.32	$ 14,267.96	$ 413.78	$ 14,681.74	0.97	0.92	$ 31,237.98	$ 3,761.97	$ 13,839.92	$ 380.68	$ 14,220.60
5	51	$ -	$ 4,526	$ 36,070.35	$ 4,314.84	$ 16,385.26	$ 536.81	$ 16,922.07	0.97	0.92	$ 34,988.24	$ 4,185.39	$ 15,893.70	$ 493.87	$ 16,387.57
5	52	$ -	$ 4,526	$ 34,704.82	$ 4,235.06	$ 15,959.31	$ 82.16	$ 16,041.47	0.97	0.92	$ 33,663.68	$ 4,108.01	$ 15,480.53	$ 75.59	$ 15,556.12
5	53	$ -	$ 4,526	$ 35,117.19	$ 4,575.12	$ 15,455.69	$ 2.20	$ 15,457.89	0.97	0.92	$ 34,063.67	$ 4,437.87	$ 14,992.02	$ 2.02	$ 14,994.04
5	54	$ -	$ 4,526	$ 34,552.17	$ 4,300.01	$ 16,457.55	$ 0.88	$ 16,458.43	0.97	0.92	$ 33,515.60	$ 4,171.01	$ 15,963.82	$ 0.81	$ 15,964.63
5	55	$ -	$ 4,526	$ 35,545.58	$ 4,469.18	$ 16,789.87	$ -	$ 16,789.87	0.97	0.92	$ 34,479.21	$ 4,335.10	$ 16,286.17	$ -	$ 16,286.17
5	56	$ -	$ 4,526	$ 35,378.06	$ 4,518.46	$ 16,746.83	$ -	$ 16,746.83	0.97	0.92	$ 34,316.72	$ 4,382.91	$ 16,244.43	$ -	$ 16,244.43
5	57	$ -	$ 4,526	$ 34,378.87	$ 4,330.92	$ 16,931.31	$ -	$ 16,931.31	0.97	0.92	$ 33,347.50	$ 4,200.99	$ 16,423.37	$ -	$ 16,423.37
5	58	$ -	$ 4,526	$ 34,966.99	$ 4,639.35	$ 15,489.40	$ -	$ 15,489.40	0.97	0.92	$ 33,917.98	$ 4,500.17	$ 15,024.72	$ -	$ 15,024.72
5	59	$ -	$ 4,526	$ 34,731.15	$ 4,227.31	$ 15,791.36	$ 143.51	$ 15,934.87	0.97	0.92	$ 33,689.22	$ 4,100.49	$ 15,317.62	$ 132.03	$ 15,449.65
5	60	$ -	$ 4,526	$ 36,334.59	$ 4,237.12	$ 16,283.70	$ 1,588.20	$ 17,871.90	0.97	0.92	$ 35,244.55	$ 4,110.01	$ 15,795.19	$ 1,461.14	$ 17,256.33
6	61	$ -	$ 4,526	$ 35,568.59	$ 4,462.41	$ 14,822.37	$ 2,107.83	$ 16,930.20	0.96	0.93	$ 34,145.85	$ 4,283.91	$ 14,229.48	$ 1,960.28	$ 16,189.76
6	62	$ -	$ 4,526	$ 32,204.10	$ 3,878.32	$ 14,267.96	$ 413.78	$ 14,681.74	0.96	0.93	$ 30,915.94	$ 3,723.19	$ 13,697.24	$ 384.82	$ 14,082.06
6	63	$ -	$ 4,526	$ 36,070.35	$ 4,314.84	$ 16,385.26	$ 536.81	$ 16,922.07	0.96	0.93	$ 34,627.54	$ 4,142.25	$ 15,729.85	$ 499.23	$ 16,229.08
6	64	$ -	$ 4,526	$ 34,704.82	$ 4,235.06	$ 15,959.31	$ 82.16	$ 16,041.47	0.96	0.93	$ 33,316.63	$ 4,065.66	$ 15,320.94	$ 76.41	$ 15,397.35
6	65	$ -	$ 4,526	$ 35,117.19	$ 4,575.12	$ 15,455.69	$ 2.20	$ 15,457.89	0.96	0.93	$ 33,712.50	$ 4,392.12	$ 14,837.46	$ 2.05	$ 14,839.51
6	66	$ -	$ 4,526	$ 34,552.17	$ 4,300.01	$ 16,457.55	$ 0.88	$ 16,458.43	0.96	0.93	$ 33,170.08	$ 4,128.01	$ 15,799.25	$ 0.82	$ 15,800.07
6	67	$ -	$ 4,526	$ 35,545.58	$ 4,469.18	$ 16,789.87	$ -	$ 16,789.87	0.96	0.93	$ 34,123.76	$ 4,290.41	$ 16,118.28	$ -	$ 16,118.28
6	68	$ -	$ 4,526	$ 35,378.06	$ 4,518.46	$ 16,746.83	$ -	$ 16,746.83	0.96	0.93	$ 33,962.94	$ 4,337.72	$ 16,076.96	$ -	$ 16,076.96
6	69	$ -	$ 4,526	$ 34,378.87	$ 4,330.92	$ 16,931.31	$ -	$ 16,931.31	0.96	0.93	$ 33,003.72	$ 4,157.68	$ 16,254.06	$ -	$ 16,254.06
6	70	$ -	$ 4,526	$ 34,966.99	$ 4,639.35	$ 15,489.40	$ -	$ 15,489.40	0.96	0.93	$ 33,568.31	$ 4,453.78	$ 14,869.82	$ -	$ 14,869.82
6	71	$ -	$ 4,526	$ 34,731.15	$ 4,227.31	$ 15,791.36	$ 143.51	$ 15,934.87	0.96	0.93	$ 33,341.90	$ 4,058.22	$ 15,159.71	$ 133.46	$ 15,293.17
6	72	$ -	$ 4,526	$ 36,334.59	$ 4,237.12	$ 16,283.70	$ 1,588.20	$ 17,871.90	0.96	0.93	$ 34,881.21	$ 4,067.64	$ 15,632.35	$ 1,477.03	$ 17,109.38

Month	Un-escalated Baseline Electric Total	Un-escalated Baseline Natural Gas Total	Escalated Baseline Electric Total	Escalated Baseline Natural Gas Total	Baseline	Proposed	Simple Payback	Simple Savings Accumulation	Discounted Payback	Discounted Savings Accumulation
49	$ 45,928.55	$ 11,236.05	$ 44,550.69	$ 10,337.17	$57,164.60	$ 16,514.36	$ 40,650.24	$ 1,771,669.78	$ 37,009.62	$ 1,689,187.98
50	$ 42,593.74	$ 6,929.75	$ 41,315.93	$ 6,375.37	$49,523.49	$ 14,984.63	$ 34,538.86	$ 1,806,208.64	$ 31,385.42	$ 1,720,573.40
51	$ 48,140.77	$ 7,852.47	$ 46,696.55	$ 7,224.27	$55,993.24	$ 16,728.17	$ 39,265.07	$ 1,845,473.71	$ 35,611.86	$ 1,756,185.26
52	$ 46,429.07	$ 5,619.40	$ 45,036.20	$ 5,169.85	$52,048.47	$ 15,974.11	$ 36,074.36	$ 1,881,548.07	$ 32,655.43	$ 1,788,840.69
53	$ 45,997.76	$ 4,129.09	$ 44,617.83	$ 3,798.76	$50,126.85	$ 15,082.18	$ 35,044.67	$ 1,916,592.74	$ 31,662.64	$ 1,820,503.34
54	$ 46,709.71	$ 3,686.67	$ 45,308.42	$ 3,391.74	$50,396.38	$ 16,319.62	$ 34,076.76	$ 1,950,669.50	$ 30,729.24	$ 1,851,232.57
55	$ 47,866.27	$ 3,102.05	$ 46,430.28	$ 2,853.89	$50,968.32	$ 16,477.07	$ 34,491.25	$ 1,985,160.75	$ 31,043.51	$ 1,882,276.09
56	$ 47,606.43	$ 3,166.52	$ 46,178.24	$ 2,913.20	$50,772.95	$ 16,387.52	$ 34,385.43	$ 2,019,546.18	$ 30,889.07	$ 1,913,165.16
57	$ 46,979.26	$ 3,013.12	$ 45,569.88	$ 2,772.07	$49,992.38	$ 16,748.38	$ 33,244.00	$ 2,052,790.18	$ 29,806.57	$ 1,942,971.73
58	$ 45,817.04	$ 3,767.58	$ 44,442.53	$ 3,466.17	$49,584.62	$ 15,050.55	$ 34,534.07	$ 2,087,324.26	$ 30,904.02	$ 1,973,875.75
59	$ 46,295.20	$ 5,963.48	$ 44,906.34	$ 5,486.40	$52,258.68	$ 15,875.16	$ 36,383.52	$ 2,123,707.78	$ 32,496.78	$ 2,006,372.52
60	$ 48,381.17	$ 10,956.94	$ 46,929.73	$ 10,080.38	$59,338.11	$ 17,672.33	$ 41,665.78	$ 2,165,373.56	$ 37,143.56	$ 2,043,516.08
61	$ 45,928.55	$ 11,236.05	$ 44,091.41	$ 10,449.53	$57,164.60	$ 16,431.84	$ 40,732.76	$ 2,206,106.32	$ 36,242.33	$ 2,079,758.41
62	$ 42,593.74	$ 6,929.75	$ 40,889.99	$ 6,444.67	$49,523.49	$ 14,884.87	$ 34,638.62	$ 2,240,744.94	$ 30,761.06	$ 2,110,519.47
63	$ 48,140.77	$ 7,852.47	$ 46,215.14	$ 7,302.80	$55,993.24	$ 16,612.84	$ 39,380.40	$ 2,280,125.34	$ 34,905.13	$ 2,145,424.60
64	$ 46,429.07	$ 5,619.40	$ 44,571.91	$ 5,226.04	$52,048.47	$ 15,857.69	$ 36,190.78	$ 2,316,316.12	$ 32,016.62	$ 2,177,441.23
65	$ 45,997.76	$ 4,129.09	$ 44,157.85	$ 3,840.05	$50,126.85	$ 14,973.39	$ 35,153.46	$ 2,351,469.58	$ 31,039.45	$ 2,208,480.67
66	$ 46,709.71	$ 3,686.67	$ 44,841.32	$ 3,428.60	$50,396.38	$ 16,198.06	$ 34,198.32	$ 2,385,667.90	$ 30,138.33	$ 2,238,619.00
67	$ 47,866.27	$ 3,102.05	$ 45,951.62	$ 2,884.91	$50,968.32	$ 16,353.86	$ 34,614.46	$ 2,420,282.36	$ 30,446.70	$ 2,269,065.70
68	$ 47,606.43	$ 3,166.52	$ 45,702.17	$ 2,944.86	$50,772.95	$ 16,265.24	$ 34,507.71	$ 2,454,790.08	$ 30,294.75	$ 2,299,360.45
69	$ 46,979.26	$ 3,013.12	$ 45,100.09	$ 2,802.20	$49,992.38	$ 16,622.37	$ 33,370.01	$ 2,488,160.08	$ 29,239.89	$ 2,328,600.34
70	$ 45,817.04	$ 3,767.58	$ 43,984.36	$ 3,503.85	$49,584.62	$ 14,942.05	$ 34,642.57	$ 2,522,802.65	$ 30,296.89	$ 2,358,897.23
71	$ 46,295.20	$ 5,963.48	$ 44,443.39	$ 5,546.04	$52,258.68	$ 15,760.95	$ 36,497.73	$ 2,559,300.38	$ 31,858.27	$ 2,390,755.50
72	$ 48,381.17	$ 10,956.94	$ 46,445.92	$ 10,189.95	$59,338.11	$ 17,567.74	$ 41,770.37	$ 2,601,070.75	$ 36,390.92	$ 2,427,146.42



Payback Analysis Conclusions. The figure on the left illustrates that, based on the sensitivity analysis, the BioDigestion Facility and Internal Combustion will have a discounted payback between 2 ¾ and 5 ¼ years. Though the project was presented to infer that budget would not be a major constraint in the pursuit of high-performance design, it is shown by this study that Near-net Zero Energy can be achieved in an economically-feasible, codifiable manner.

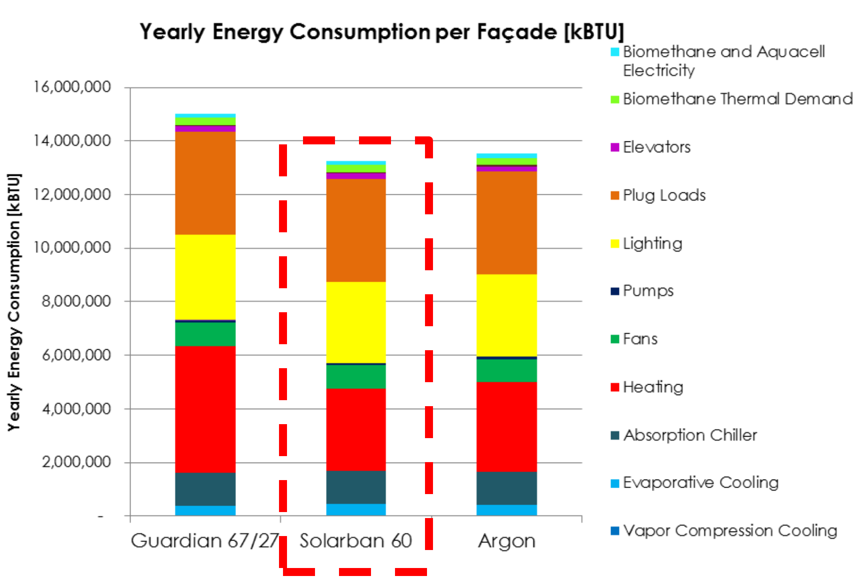
Appendix H – Façade Optimization Study and Demand Reduction

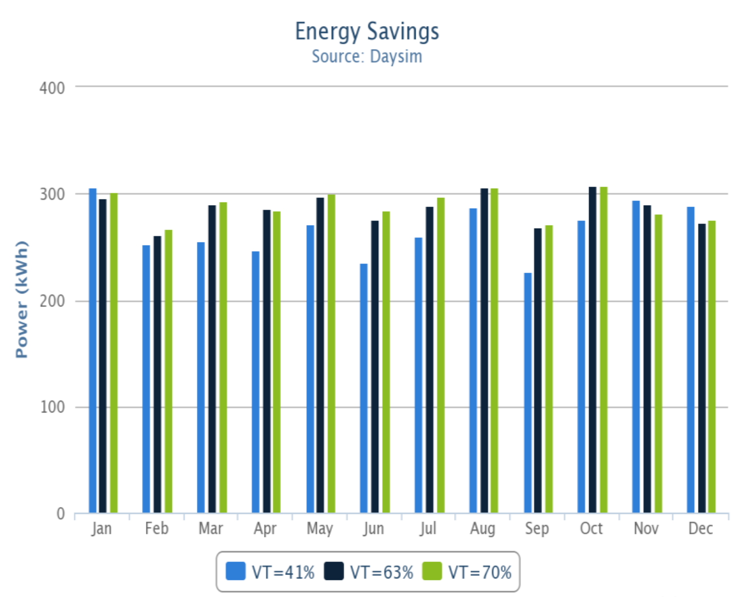


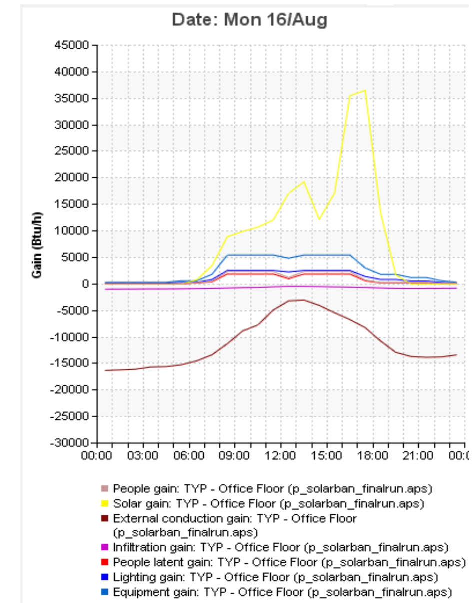
Façade Optimization Preface

It was realized that there would be tradeoffs between thermal energy (conduction and radiative gains/losses) and electrical energy (daylight harvesting and associated dimming) for different glazing characteristics. Because of San Francisco's climate, glass which allows the building to reject heat was desired in order to provide a heat sink for internal space gains. It was also desired to find the balance between allowing heat into the space during colder days of the year and preventing solar gain during the cooling season. Three different glazing types were studied to analyze these interactions.

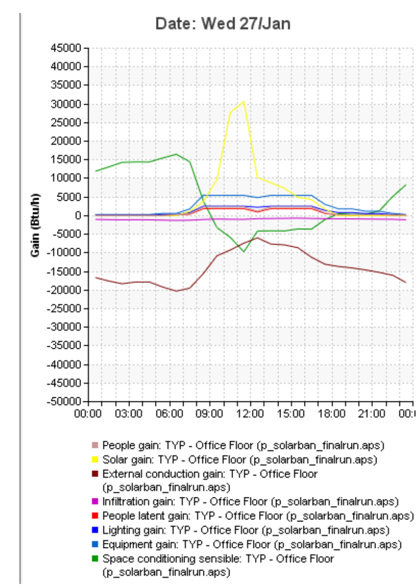
Assembly Type	Assembly U-value [BTU/hr-SF-F]	SHGC	VT
Viracon Triple Pane	0.17	0.25	41%
Solarban 60	0.4	0.39	70%
Guardian 62/27	0.35	0.27	64%







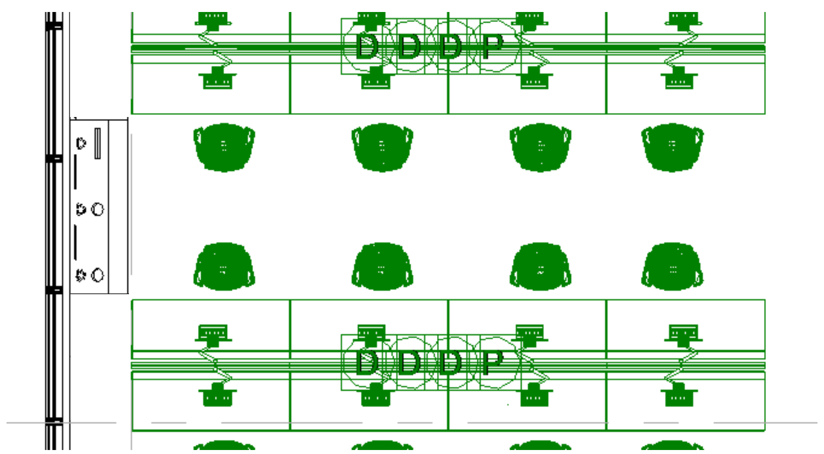
This graph shows a typical day in August during which the façade allows heat to be exhausted through the envelope, offsetting the internal and solar gain throughout a large portion of the day.



This figure shows the large amount of solar gain maintaining a relatively low cooling load, rather than a heating load, during a day in January. This condition is typical of days in the heating season and the higher levels of solar gain allowed by the Solarban glass compared to the other types enables the large reduction of heating energy to make it the most resource-efficient glazing type.

Landfill Demand Reduction

Because people aren't inherently wasteful, they just seek out the most convenient option, the Mechanical Design Team sought to make recycling and composting the most convenient option relative to sending waste to a landfill. Refuse facilities are located at the end of each workstation and landfill receptacles are centrally located in the core. The recycling station is shown below:



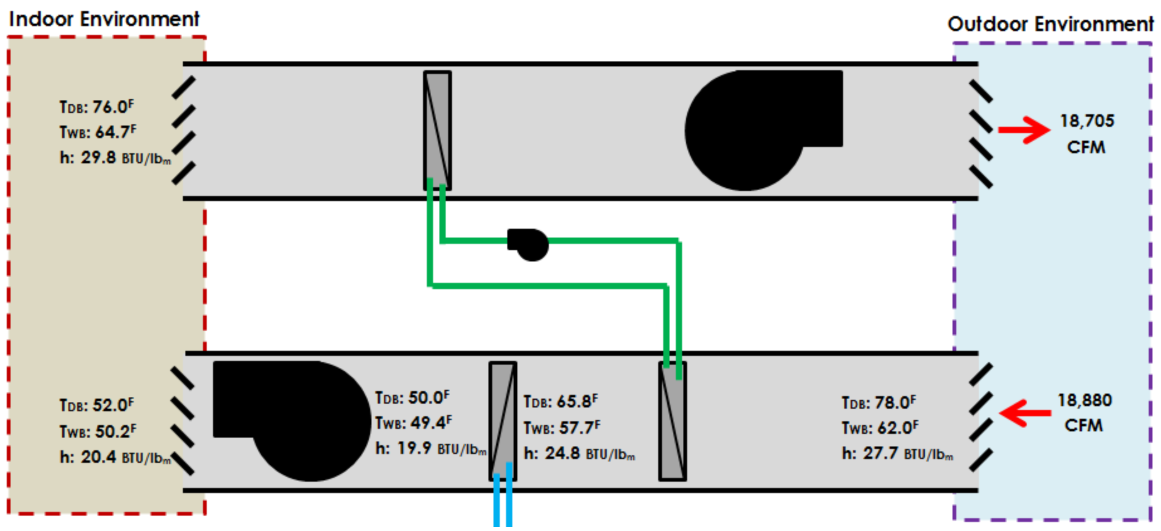
Energy Efficient Workstation

In order to drastically reduce electrical energy consumption, it was recommended that the office floors be designed with *Knoll Antenna Workspace* systems furniture. These systems furniture modules feature The Lighting Quotient's Tambient (task/ambient) workstation lighting. The Tambient lighting system enables photosensor dimming of the uplight and vacancy sensor switching of the downlight. This system contributed to a 41% yearly electricity savings for the photosensor-controlled uplight. For further details, refer to the Electrical narrative.

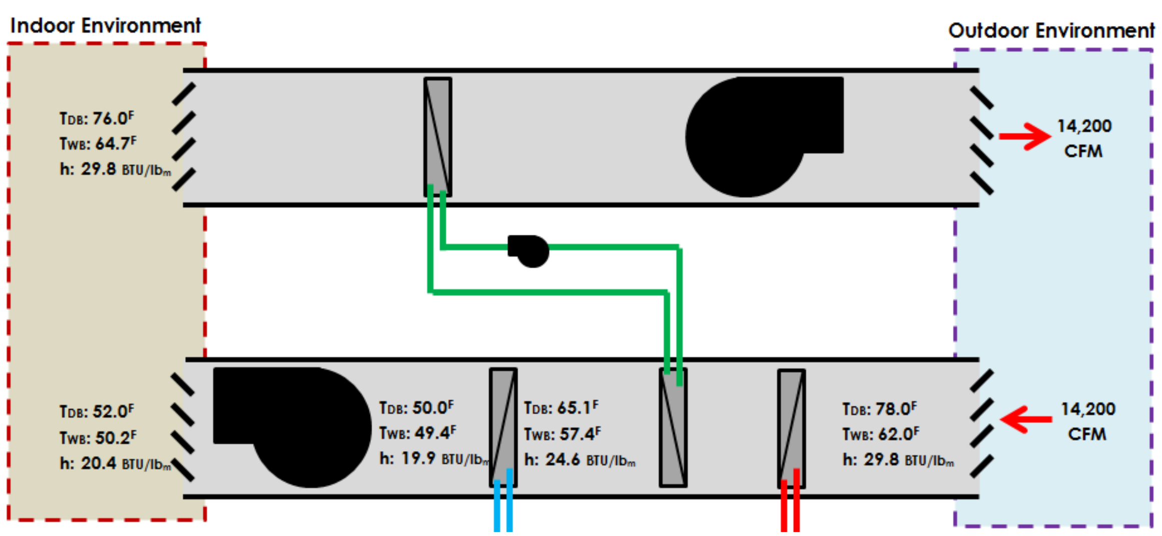
These workstations also feature a thin-client virtual desktop computing infrastructure. In its essence, the CPU is removed from the physical workstation and displaced to a server room in the building. This reduces electrical consumption because of usage diversity and removes heat loads from the office space. This system uses 37% less electricity than a standard computing infrastructure. For further details, see the Electrical narrative.

Appendix I – Air Handling Unit Details

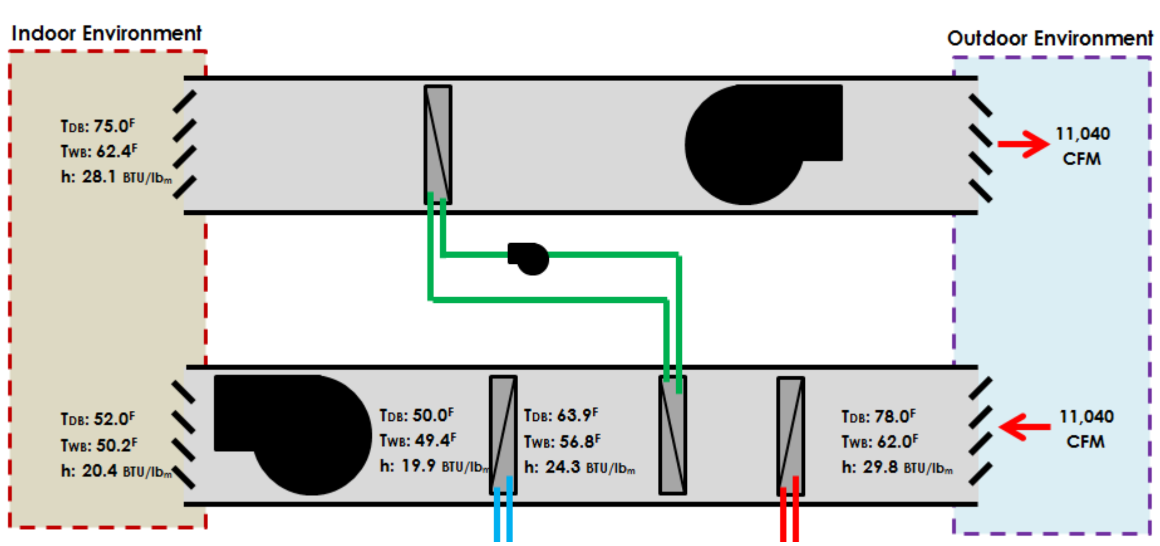
DOAS 3 → 7



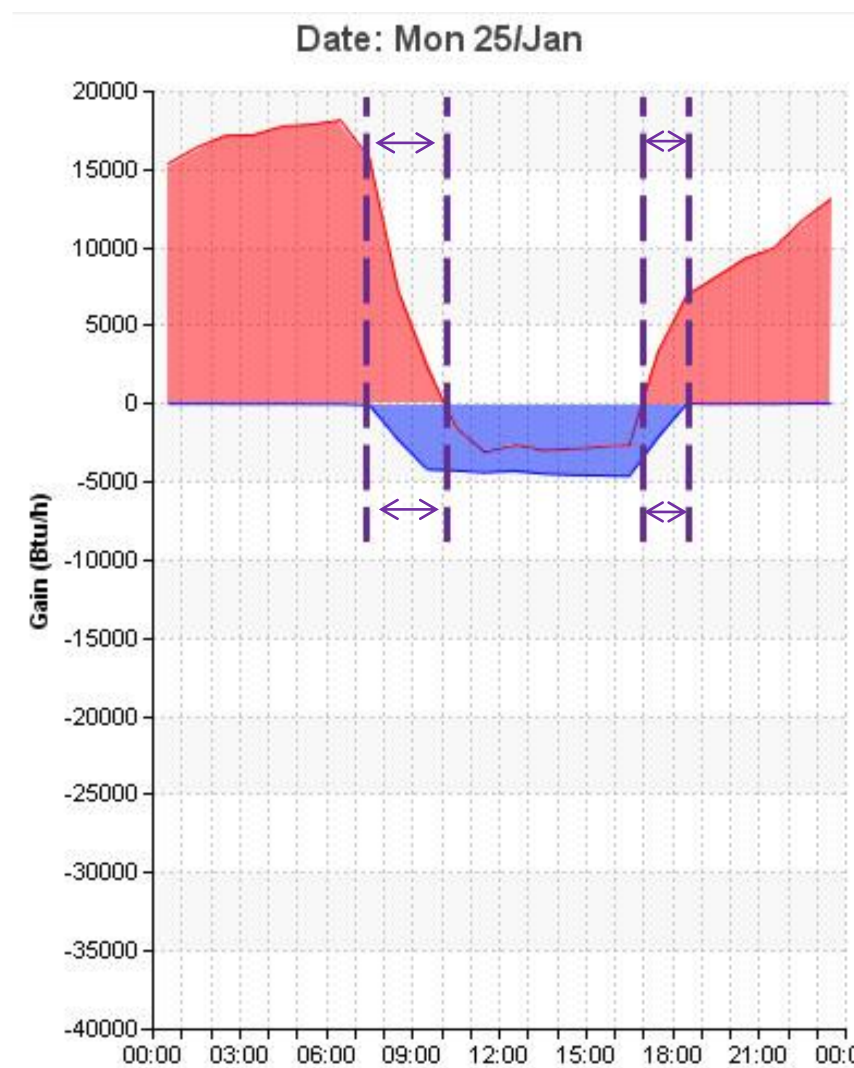
DOAS - 2



DOAS - 1



AHU Name	Zone Served	Title 24 Rqd. Outside Air [CFM]	Supply Air [CFM]	Summer OA [F]	Summer On-coil [F]	Summer Off-coil [F]	Summer SA [F]	Summer Design Load [ton]	Winter OA [F]	Winter On-coil [F]	Winter Off-coil [F]	Winter SA [F]	Winter Design Load [kBTUh]
DOAS - 1	Lobby and Basement	14,200	14,200	78.0DB 62.0WB	65.1DB 57.4WB	50.0DB 49.4WB	52.0DB 50.2WB	25.0	40.0DB	40.0DB	93.0DB	95.0DB	813
DOAS - 2	Office Floors 5 - 9	18,880	18,880	78.0DB 62.0WB	65.8DB 57.7WB	50.0DB 49.4WB	52.0DB 50.2WB	34.7	In order to take advantage of simultaneous heating and cooling in the perimeter and office zones, heating is done at perimeter Induction VAV Terminals, while core zones mix air to 55F for economizer cooling; Graph below illustrates example of dual conditions; ducts are insulated to prevent condensation before mixing ro heating				
DOAS - 3	Office Floors 10 - 15	18,880	18,880	78.0DB 62.0WB	65.8DB 57.7WB	50.0DB 49.4WB	52.0DB 50.2WB	34.7					
DOAS - 4	Office Floors 16 - 20	18,880	18,880	78.0DB 62.0WB	65.8DB 57.7WB	50.0DB 49.4WB	52.0DB 50.2WB	34.7					
DOAS - 5	Office Floors 21 - 25	18,880	18,880	78.0DB 62.0WB	65.8DB 57.7WB	50.0DB 49.4WB	52.0DB 50.2WB	34.7					
AHU - 1	Restaurant	11,040	11,040	78.0DB 62.0WB	63.9DB 56.8WB	50.0DB 49.4 WB	52.0DB 50.2WB	18.2	40.0DB	53.6DB	93.0DB	95.0DB	470
							Peak Coincident Absorption Chiller Load:	82					
							Peak Coincident Heat Pump Load:	18					



Demand Controlled Ventilation

It should be noted that, according to Title 24, the fresh air requirements needs to satisfy the values calculated above, however, due to the use of demand-controlled ventilation (DCV), monitoring for a CO2 concentration of 1,100 ppm, the actual required fresh air is significantly less than the code-required value. By modeling the ventilation system as DCV in IES Virtual Environment, it was shown that the *coincident* cooling load on the absorption chiller is 74 tons.

Simultaneous Heating and Cooling Strategy

The graph on the left, taken from the 20th Floor of the IES model for 350 Mission, shows the sensible cooling load for the West Perimeter Zone (red) and the West Core Zone (blue). It should be noted that negative values indicate that energy needs to be removed (cooling) and positive values indicate that energy needs to be added (heating). This illustrates that, during some hours of the day, adjacent zones without impermeable barriers can have differing conditioning requirements, validating the need for the simultaneous heating and cooling strategy discussed in the table above. Utilizing economizer cooling in the core allows only the air in the perimeter zones to be heated, reducing energy waste.

Appendix J – Ventilation Calculations and Exhaust Calculations

Ventilation Calculations

Office Floors 5 - 30

Zone Name	Zone Type	People	Area	People OA Rate	Area OA Rate	Breathing Zone OA	Ez	Delivered OA	Meets LEED 30%	Space Latent Load	Latent Load Handled	% Load Handled	Sensible Capacity Added
		[#]	[SF]	[CFM]	[CFM]	[CFM]	[%]	[CFM]	[Y/N]	[BTUh]	[BTUh]	[%]	[BTUh]
Office Perim. West	Office	32	1,963	5.0	0.06	278	100%	486	Y	4,960	(8,541)	172%	14,175
Office Core West	Office	29	874	5.0	0.06	197	100%	257	Y	4,495	(4,510)	100%	7,485
Corridor West	Corridor	-	518	-	0.06	31	100%	40	Y	-	(710)		1,178
Office Perim. South	Office	32	1,963	5.0	0.06	278	100%	486	Y	4,960	(8,541)	172%	14,175
Office Core South	Office	29	874	5.0	0.06	197	100%	257	Y	4,495	(4,510)	100%	7,485
Corridor South	Corridor	-	518	-	0.06	31	100%	40	Y	-	(710)		1,178
Meeting Area 1	Meeting Room	26	654	5.0	0.06	169	100%	355	Y	4,030	(6,244)	155%	10,364
Meeting Area 2	Meeting Room	10	435	5.0	0.06	76	100%	99	Y	1,550	(1,738)	112%	2,885
Meeting Area 3	Meeting Room	11	829	5.0	0.06	105	100%	136	Y	1,705	(2,392)	140%	3,970
Corridor Central	Corridor	-	600	-	0.06	36	100%	47	Y	-	(822)		1,365
Lounge Perimeter	Lounge	23	933	5.0	0.06	173	100%	362	Y	3,615	(6,368)	176%	10,570
Lounge Core	Lounge	14	553	5.0	0.06	102	100%	133	Y	2,143	(2,337)	109%	3,878
Pantry	Lounge	6	250	5.0	0.06	46	100%	60	Y	969	(1,056)	109%	1,753
Lobby	Lobby	55	365	5.0	0.06	296	100%	621	Y	10,950	(10,908)	100%	18,104
Misc. Room	Meeting Room	28	565	5.0	0.06	175	100%	263	Y	4,379	(4,616)	105%	7,661
Stairwell East	Corridor	-	365	-	0.06	22	100%	28	Y	-	(500)		830
Stairwell West	Corridor	-	365	-	0.06	22	100%	28	Y	-	(500)		830
Restrooms	Restroom	-	460	-	0.06	28	100%	36	Y	-	(630)		1,046
Server Room	Electrical Room	-	50	-	0.06	3	100%	4	Y	-	(69)		114
Fan Room	Mechanical Room	-	460	-	0.06	28	100%	36	Y	-	(630)		1,046
Totals						2,293		3,775		48,251	(66,332)		110,092

Upper and Lower Lower Lobby

Zone Name	Zone Type	People	Area	People OA Rate	Area OA Rate	Breathing Zone OA	Ez	Delivered OA	Meets LEED 30%	Space Latent Load	Latent Load Handled	% Load Handled	Sensible Capacity Added
		[#]	[SF]	[CFM]	[CFM]	[CFM]	[%]	[CFM]	[Y/N]	[BTUh]	[BTUh]	[%]	[BTUh]
Open Lobby Entry	Lobby	652	4,349	5.0	0.06	3,523	100%	7,398	Y	130,470	(129,971)	100%	215,715
Retail East	Retail	9	622	7.5	0.12	145	100%	1,193	Y	1,866	(20,961)	1123%	34,790
Retail West	Retail	6	372	7.5	0.12	86	100%	112	Y	1,116	(1,975)	177%	3,279
Fire Command Room	Mechanical Room	-	203	-	0.06	12	100%	16	Y	-	(278)		462
Gas Meter Room	Mechanical Room	-	78	-	0.06	5	100%	6	Y	-	(107)		177
Elevator Lobby	Lobby	60	397	5.0	0.06	322	100%	675	Y	11,910	(11,864)	100%	19,692
Public Restroom	Restroom	-	150	-	0.06	9	100%	980	Y	-	(17,218)		28,577
Exit Passageway	Corridor	-	319	-	0.06	19	100%	31	Y	-	(538)		893
Upper Lobby	Lobby	297	1,979	5.0	0.06	1,603	100%	3,687	Y	59,370	(64,775)	109%	107,509
Stairwell East	Corridor	-	640	-	0.06	38	100%	50	Y	-	(877)		1,456
Stairwell West	Corridor	-	640	-	0.06	38	100%	50	Y	-	(877)		1,456
Totals						5,800		14,198		204,732	(249,443)		414,005

Restaurant

Zone Name	Zone Type	People	Area	People OA Rate	Area OA Rate	Breathing Zone OA	Ez	Delivered OA	Meets LEED 30%	Space Latent Load	Latent Load Handled	% Load Handled	Sensible Capacity Added
		[#]	[SF]	[CFM]	[CFM]	[CFM]	[%]	[CFM]	[Y/N]	[BTUh]	[BTUh]	[%]	[BTUh]
Dining Area	Restaurant	339	4,848	7.5	0.18	3,418	100%	9,416	Y	93,324	(92,971)	100%	75,254
Kitchen	Kitchen	8	1,680	-	0.70	1,176	100%	1,529	Y	10,250	(15,095)	147%	12,218
Men's Restroom	Restroom	-	70	-	0.06	4	100%	5	Y	-	(54)		44
Women's Restroom	Restroom	-	70	-	0.06	4	100%	5	Y	-	(54)		44
Corridor	Corridor	-	678	-	0.06	41	100%	53	Y	-	(522)		423
Totals						4,643		11,009		103,574	(108,696)		87,982

Ventilation Calculation Procedure for 100% OA Systems– Title 24

$$V_{bz} = R_p P_z + R_a A_z$$

$$V_{oz} = V_{bz}/E_z$$

$$V_{ot} = \sum_{all\ zones} V_{oz}$$

Exhaust Calculations

Office Floors 5 - 30

Zone Name	Zone Type	Area Exhaust Rate	Unit Exhaust Rate	Zone Area	Zone Units	Total Exhaust
		[CFM/SF]	[CFM/unit]	[SF]	[#]	[CFM]
Men's Bathroom	Public Restroom	-	50	-	4	200
Women's Bathroom	Public Restroom	-	50	-	4	200
Pantry	Kitchenette	0.30	-	158	-	47
Copy Room 1	Copy / Print Room	0.50	-	90	-	45
Copy Room 2	Copy / Print Room	0.50	-	107	-	54
				Total Exhaust per Floor		546
				Number of Floors		25
				Total Office Exhaust		13,648

Upper and Lower Lobby

Zone Name	Zone Type	Area Exhaust Rate	Unit Exhaust Rate	Zone Area	Zone Units	Total Exhaust
		[CFM/SF]	[CFM/unit]	[SF]	[#]	[CFM]
Restaurant Kitchen	Commercial Kitchen	0.70	-	1,090	-	763
Lobby Interactive Toilet	Private Restroom	-	25	-	1	25
Restaurant Men's Toilet	Private Restroom	-	25	-	1	25
Restaurant Women's Toilet	Private Restroom	-	25	-	1	25
Storage Closet	Storage Closet	1.50	-	-	-	-
				Total Exhaust		838

Underground Parking Garage

Zone Name	Zone Type	Area Exhaust Rate	Unit Exhaust Rate	Zone Area	Zone Units	Total Exhaust
		[CFM/SF]	[CFM/unit]	[SF]	[#]	[CFM]
Parking Garage - 01	Parking Garage	0.75	-	6,884	-	5,163
Parking Garage - B1	Parking Garage	0.75	-	11,547	-	8,660
Parking Garage - B2	Parking Garage	0.75	-	15,126	-	11,345
Parking Garage - B3	Parking Garage	0.75	-	15,126	-	11,345
Men's Locker Room	Locker Room	0.50	-	270	-	135
Women's Locker Room	Locker Room	0.50	-	250	-	125
Men's Restroom	Public Restroom	-	50	-	3	150
Women's Restroom	Public Restroom	-	50	-	3	150
				Total Exhaust		37,072

Bio-methane Facility

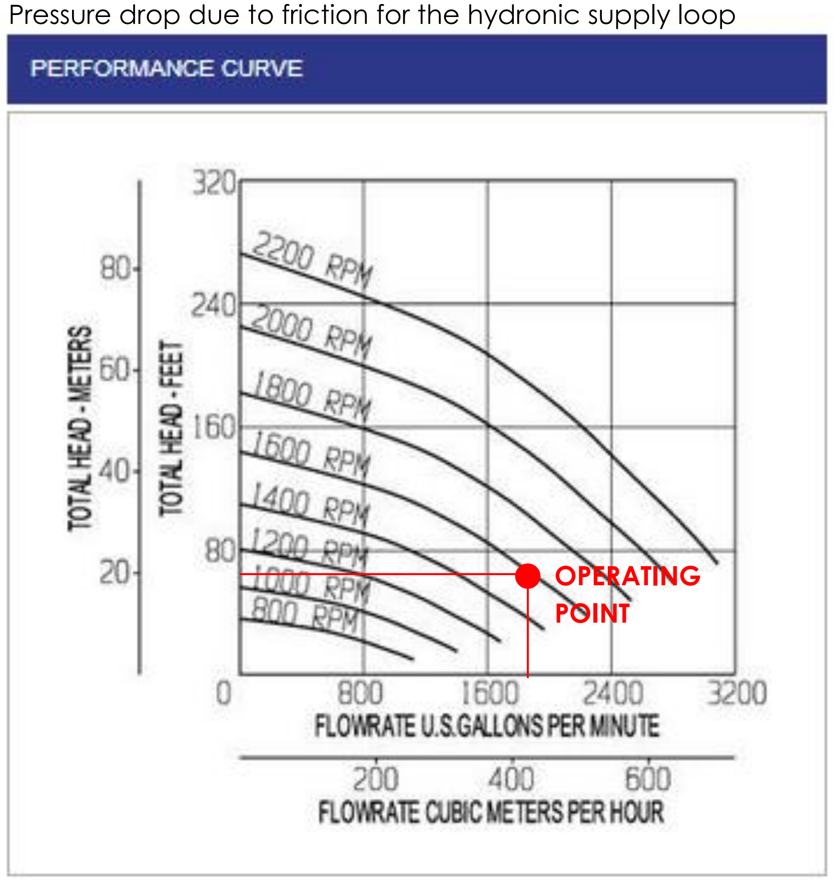
Zone Name	Zone Type	Zone Area	Average Zone Height	Zone Volume	Zone Airflow	Zone Airflow
		[SF]	[ft]	[CF]	[ACH]	[CFM]
Tank Room	Fuel Production	9,530.00	11	104,830	20	34,943
Finishing Room	Fuel Production	700.00	11	7,700	20	2,567
				Total Exhaust		37,510

Appendix K – Fan and Pump Calculations / Sizing

To determine the selection of the fan and pump equipment, pressure drop calculations had to be performed in order to make sure the pumps or fans could overcome the largest pressure drop. Due to the nature of the system being a closed loop, only losses due to friction would need to be determined. For the hydronic pumping, 3 pumps are used in parallel to operate at an N+1 condition.

Type of Transport	Length	Number of Panels Served	Pipe Characteristic	GPM	Diameter	Cross Sectional Area	Volumetric Flow Rate	Velocity	Re	Friction Factor	Pressure Drop
-	[m]	-	[in]	[GPM]	[m]	[m^2]	m^3/s	[m/s]	-	-	[psi]
Straight Run	1.3462	165	4	165	0.1016	0.0081073	0.010412	1.284	129956	0.01710	0.02705
Elbow	-	165	4	165	0.1016	0.0081073	0.010412	1.284	-	0.20000	0.02387
Straight Run	4.2926	165	4	165	0.1016	0.0081073	0.010412	1.284	129956	0.01710	0.08627
Elbow	-	165	4	165	0.1016	0.0081073	0.010412	1.284	-	0.20000	0.02387
Branch	-	165	4	165	0.1016	0.0081073	0.010412	1.284	-	2.00000	0.23872
Straight Run	0.635	108	4	108	0.1016	0.0081073	0.006815	0.841	85062	0.12458	0.03983
Branch	-	108	4	108	0.1016	0.0081073	0.006815	0.841	-	2.00000	0.10228
(…etc…)											
Branch	-	17	3	17	0.0762	0.0045604	0.001073	0.235	-	2.00000	0.00801
Straight Run	2.8448	6	3	6	0.0762	0.0045604	0.000379	0.083	6301	0.10520	0.00196
Branch	-	6	3	6	0.0762	0.0045604	0.000379	0.083	-	2.00000	0.00100
Total Pressure (ft H_2O)											8.42494

Pressure drop due to friction for the hydronic supply loop



STANDARD CENTRIFUGAL SERIES

SC64S12

Pump Specification Data

Manufacturer: Pioneer

13 BISW

Wheel Diameter = 13½ in.
Outlet Area = 1.05 ft.²
Tip Speed = 3.53 x RPM
Maximum BHP = (RPM/1997)³

Minimum Starting HP = ¼
Maximum RPM Class I = 2971
Maximum RPM Class II = 3875
Maximum RPM Class III = 4150

Maximum Open Motor Frame Size

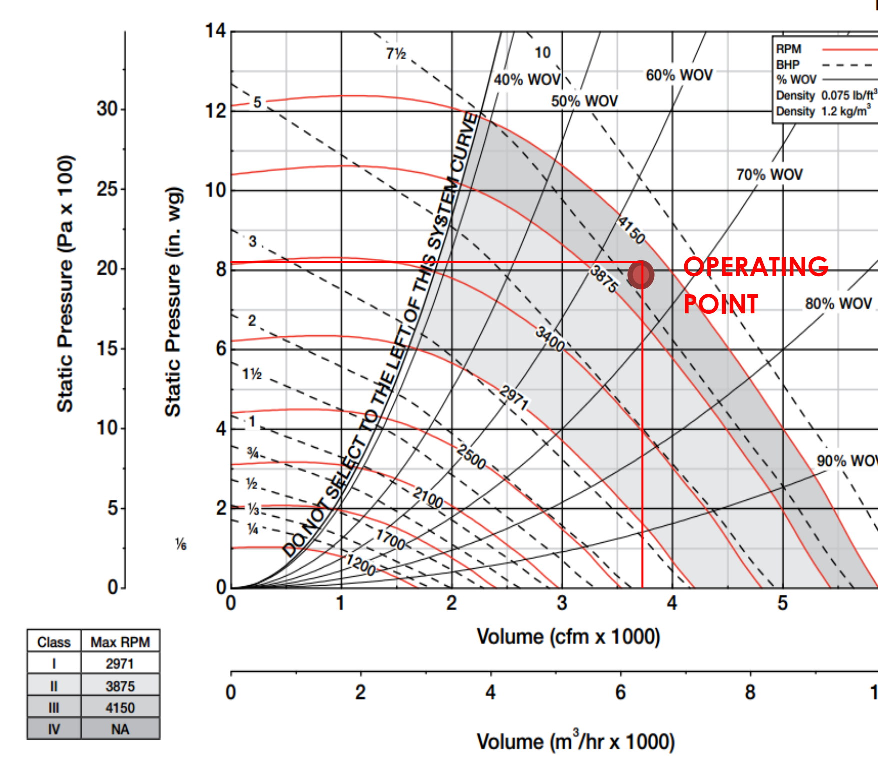
Class	I	II	III
Arr. 9	184T	184T	145T
Arr. 10	184T	213T	NA

CFM	OV	STATIC PRESSURE (in. wg) 2.50		3.00		3.50		4.00		4.50		5.00		5.50		6.00		6.50		7.00	
		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
1500	1428	2030	0.96	2180	1.16	2318	1.36	2451	1.58	2584	1.82	2709	2.07								
1680	1600	2092	1.08	2235	1.29	2373	1.51	2501	1.73	2622	1.97	2741	2.21	2861	2.48	2975	2.76	3084	3.04		
1860	1771	2164	1.22	2300	1.44	2428	1.67	2556	1.91	2677	2.15	2791	2.40	2900	2.66	3006	2.93	3116	3.22	3221	3.52
2040	1942	2237	1.38	2372	1.61	2497	1.85	2614	2.10	2732	2.35	2846	2.62	2954	2.89	3058	3.16	3158	3.44	3254	3.73
2220	2114	2320	1.55	2445	1.79	2568	2.05	2684	2.31	2794	2.57	2902	2.85	3010	3.13	3113	3.42	3212	3.71	3308	4.01
2400	2285	2410	1.75	2526	2.00	2642	2.26	2757	2.54	2865	2.82	2969	3.10	3068	3.39	3169	3.69	3268	4.00	3363	4.31
2580	2457	2502	1.96	2615	2.23	2722	2.50	2830	2.79	2938	3.08	3040	3.38	3139	3.68	3233	3.99	3324	4.30	3419	4.63
2760	2628	2595	2.20	2706	2.48	2812	2.77	2911	3.06	3011	3.36	3113	3.68	3211	4.00	3304	4.32	3394	4.64	3482	4.98
2940	2800	2693	2.46	2799	2.75	2902	3.06	3001	3.36	3094	3.67	3187	3.99	3283	4.33	3376	4.67	3466	5.01	3553	5.35
3120	2971	2793	2.74	2895	3.05	2995	3.37	3091	3.69	3183	4.02	3272	4.35	3357	4.68	3450	5.03	3539	5.39	3625	5.75
3300	3142	2894	3.05	2994	3.37	3089	3.71	3183	4.04	3274	4.38	3361	4.73	3445	5.08	3526	5.43	3612	5.80	3697	6.17
3480	3314	2998	3.38	3094	3.72	3187	4.07	3276	4.42	3366	4.78	3452	5.14	3535	5.50	3615	5.87	3692	6.24	3771	6.62
3660	3485	3104	3.74	3196	4.10	3287	4.46	3374	4.83	3459	5.20	3544	5.58	3626	5.95	3705	6.34	3781	6.72	3856	7.11
3840	3657	3211	4.14	3301	4.51	3388	4.89	3474	5.27	3556	5.65	3637	6.04	3717	6.44	3796	6.83	3871	7.23	3945	7.64
4020	3828	3319	4.56	3406	4.95	3491	5.34	3574	5.74	3655	6.14	3733	6.54	3810	6.95	3887	7.36	3962	7.78	4035	8.19
4200	4000	3428	5.01	3513	5.42	3596	5.83	3675	6.24	3755	6.66	3832	7.07	3907	7.50	3980	7.92	4054	8.35	4126	8.79

Duct Run Location	Length [ft]	Pressure Drop [in wg]
Main Duct Run	28.75	0.24242
90° Elbow	30	0.25296
Main Duct Run	82.17	0.69283
90° Elbow	30	0.25296
Main Duct Run	51.08	0.43073
Tee Branch	-	0.19157
Induction Unit Run	6.32	0.17024
90° Elbow	30	0.80808
Induction Unit Run	4.21	0.11340
Induction Unit	-	0.70000
Branch Duct	2.7	0.00083
Elbow	30	0.00924
Branch Duct	18.5	0.00554
Tee Branch	-	0.19157
Exterior Branch	50.03	0.02880
90° Elbow	30.43	0.01753
Exterior Branch	8.32	0.00479
Total		4.11350

Pressure drop due to friction for the Air Handling Supply Duct Run

13 BISW



Fan Specification Data
Manufacturer: GREENHECK

Appendix L – Radiant Ceiling and Slab Calculations

Radiant Ceiling Panel Parameters

Material Properties			Panel Properties		
Overall U-value	4	[BTU/h/ft2/F]	Tube Diameter	0.5	[in]
Conductivity	118	[BTU/h/ft/F]	Tube Spacing	6	[in]
Volume Flow Rate	1	[gpm]	Fin Thickness	0.125	[in]
Entering Cooling T	67	[F]	Panel Area	48	[ft2]
Cooling Cp	1.000	[BTU/lbm/R]	Panel Perimeter	32	[ft]

Panel Heat Flux Calculation

Season	Heat Transfer Type	Panel Temp. [F]	AUST [F]	Air Temp. [F]	Panel Area [ft2]	Panel Perimeter [ft]	Equivalent Diameter [ft]	Heat Flux [BTU/h/ft2]
Cooling	Radiative	69.23	80.10	-	-	-	-	(9.95)
	Convective	69.23	-	78.00	48.00	32.00	6.00	(6.26)
							Total:	(16.21)

The radiant ceiling panels were modeled using a procedure from ASHRAE as well as Conroy and Mumma (2001). Their system design equations were used in order to configure the chilled ceiling for the office floor to match the performance characteristics of the plate-and-frame heat exchanger and cooling towers which serve the panels. Design parameters were modified in order to meet space requirements in the Typical Office Floors as well as to ensure cooling loads are met during Design Day cooling loads. IES Virtual Environment was used to analyze room surface temperatures for the purpose of finding the Average Unconditioned Surface Temperatures (AUST). Tube spacing and diameters were determined by looking up typical radiant panel geometries.

Panel Average Temperature

Season	Panel Assembly	Overall Heat Transfer Coefficient [BTU/h/ft2/F]	Panel Area [ft2]	Volume Flow Rate [gpm]	Mass Flow Rate [lbm/h]	Water Specific Heat [BTU/lbm-F]	Entering Water Temp. [F]	Leaving Water Temp. [F]	ΔT [F]	Air Temp. [F]	Heat Removal Factor	Panel Temp. [F]
Cooling		4	48.00	1.00	500.4	1.000	67.0	70.4	3.4	78.0	0.80	69.2

Thermally-active Slab Parameters

Material Properties		
Overall U-value	0.24	[BTU/h/ft2/F]
Conductivity	1.04	[BTU/h/ft/F]
Volume Flow Rate	1.5	[gpm]
Volume Flow Rate	1.5	[gpm]
Entering Cooling T	67	[F]
Entering Heating T	93	[F]
Cooling Cp	1.000	[BTU/lbm/R]
Heating Cp	0.998	[BTU/lbm/R]

Slab Properties		
Tube Diameter	0.5	[in]
Tube Spacing	6	[in]
Topping Thickness	2	[in]
Slab Zone Area	1125	[ft2]
Slab Zone Perimeter	180	[ft]

Radiant Slab Design Equations

General Heat Flux Equations

$$\dot{q}_r = 0.15 \times 10^{-8}\left[\left(t_{p,mean}\right)^4 - (AUST)^4\right]$$

$$\dot{q}_c = 0.31\left(t_{p,mean} - t_a\right)^{0.31}\left(t_{p,mean} - t_a\right)$$

Mean Panel Temperature

$$t_{p,mean} = t_{f,in} + \left\{\frac{\dot{m}C_p\left(t_{f,out} - t_{f,in}\right)}{AF_R U}\right\}(1 - F_R)$$

Panel Heat Removal Factor

$$F_R = \frac{\dot{m}C_p\left(t_{f,out} - t_{f,in}\right)}{\{A[-U(t_{f,in} - t_a)]\}}$$

Design Equations (cont.)

Leaving Water Temperature

$$t_{f,out} = t_a + \left(t_{f,in} - t_a\right)e^{\frac{-UAF'}{\dot{m}C_p}}$$

Panel Efficiency Factor

$$F' \cong \frac{[D + (w - D)F]}{w}$$

Fin Effectiveness

$$F = \frac{tanh\left[\frac{1}{2}\sqrt{\frac{U_o}{k\delta}}(w - D)\right]}{\frac{1}{2}\sqrt{\frac{U_o}{k\delta}}(w - D)}$$

The thermally-active slab was modeled using a procedure from ASHRAE and Conroy and Mumma (2001). The slab is designed with extra cooling capacity in the event that large numbers of people gather for an event in the lobby. ASHRAE's three-part article series on Thermally-active Slabs (Nall, 2013) was used as a starting point for the design of the chilled and heated slab.

Slab Heat Flux Calculation

Season	Heat Transfer Type	Panel Temp. [F]	AUST [F]	Air Temp. [F]	Panel Area [ft2]	Panel Perimeter [ft]	Equivalent Diameter [ft]	Heat Flux [BTU/h/ft2]
Cooling	Radiative	68.93	82.60	-	-	-	-	(12.58)
	Convectiv	68.93	-	78.00	1,125.00	180.00	25.00	(2.05)
							Total:	(14.63)
Heating	Radiative	88.95	66.50	-	-	-	-	20.92
	Convectiv	88.95	-	70.00	1,125.00	180.00	25.00	16.13
							Total:	37.04

Slab Average Temperature

Season	Panel Assembly	Overall Heat Transfer Coefficient [BTU/h/ft2/F]	Panel Area [ft2]	Volume Flow Rate [gpm]	Mass Flow Rate [lbm/h]	Water Specific Heat	Entering Water Temp. [F]	Leaving Water Temp. [F]	ΔT [F]	Air Temp. [F]	Heat Removal Factor	Panel Temp. [F]
Cooling		0.24	1,125.00	1.50	750.6	1.000	67.0	70.3	3.3	78.0	0.82	68.9
Heating		0.24	1,125.00	1.50	750.6	0.998	93.0	86.1	6.9	70.0	0.82	89.0

Appendix M – Cooling Towers / Heat Exchangers

Radiant Panel Chilled Water Tower

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1800 rpm
Product	NC Steel	Fan Motor Capacity per cell	30.00 BHp
Model	NC8403SLN4	Fan Motor Output per cell	30.00 BHp
Cells	4	Fan Motor Output total	120.00 BHp
CTI Certified	No	Air Flow per cell	104900 cfm
Fan	7.000 ft, 8 Blades	Air Flow total	419700 cfm
Fan Speed	473 rpm, 10402 fpm	Static Lift	12.234 ft
Fans per cell	1	Distribution Head Loss	0.000 ft
		ASHRAE 90.1 Performance	45.7 gpm/Hp

Model Group: Quiet Fan (L)
Sound Pressure Level: 81 dBA (Single Cell), 5.000 ft from Air Inlet Face. See sound report for details.

Conditions

Tower Water Flow	3917 gpm	Air Density In	0.07386 lb/ft³
Hot Water Temperature	68.00 °F	Air Density Out	0.07477 lb/ft³
Range	3.00 °F	Humidity Ratio In	0.00905
Cold Water Temperature	65.00 °F	Humidity Ratio Out	0.01389
Approach	3.00 °F	Wet-Bulb Temp. Out	66.29 °F
Wet-Bulb Temperature	62.00 °F	Estimated Evaporation	18 gpm
Relative Humidity	50.0 %	Total Heat Rejection	5875100 Btu/h
Capacity	95.0 %		

- This selection is within tolerance but does not satisfy your design conditions.
- The performance for this selection is not guaranteed because the approach is less than 5 °F.
- This selection is not CTI Certified because: the range is less than 4 °F, the approach is less than 5 °F.

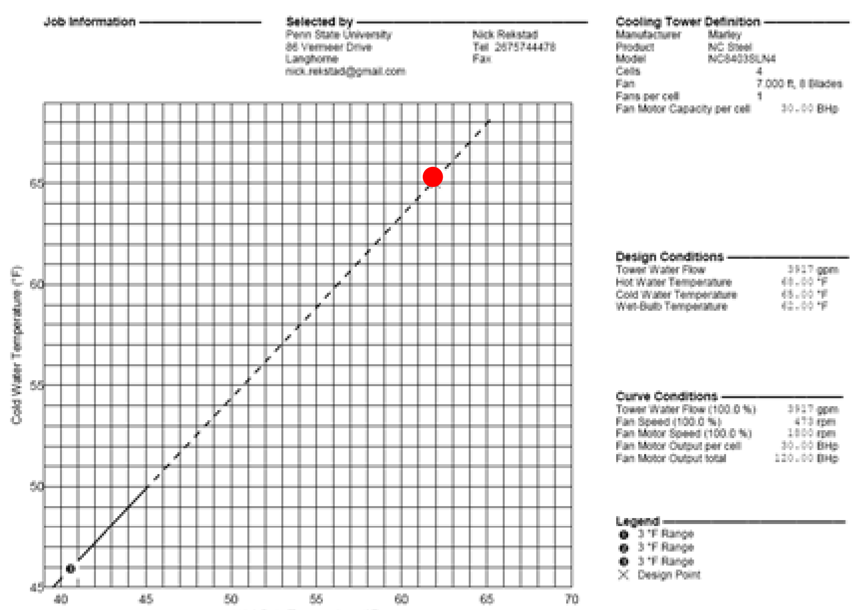
Weights & Dimensions

	Per Cell	Total
Shipping Weight	7440 lb	29770 lb
Heaviest Section	7440 lb	
Max Operating Weight	16770 lb	67090 lb
Width	18.170 ft	18.170 ft
Length	8.400 ft	34.462 ft
Height	11.939 ft	

Minimum Enclosure Clearance

Clearance required on air inlet sides of tower without altering performance. Assumes no air from below tower.

Solid Wall	13.480 ft
50 % Open Wall	10.358 ft



The tower was sized to match the ΔT of the radiant panels at the desired flow conditions for the minimum pumping energy throughout the year. The tower was selected with a Variable Speed Fan Motor so that, as the wet bulb drops below design conditions, the electricity usage decreases drastically. During winter operation, the tower is able to operate almost exclusively off of the spray

Cooling Tower Water Use Calculation Methodology

$$Makeup = E + D + B$$

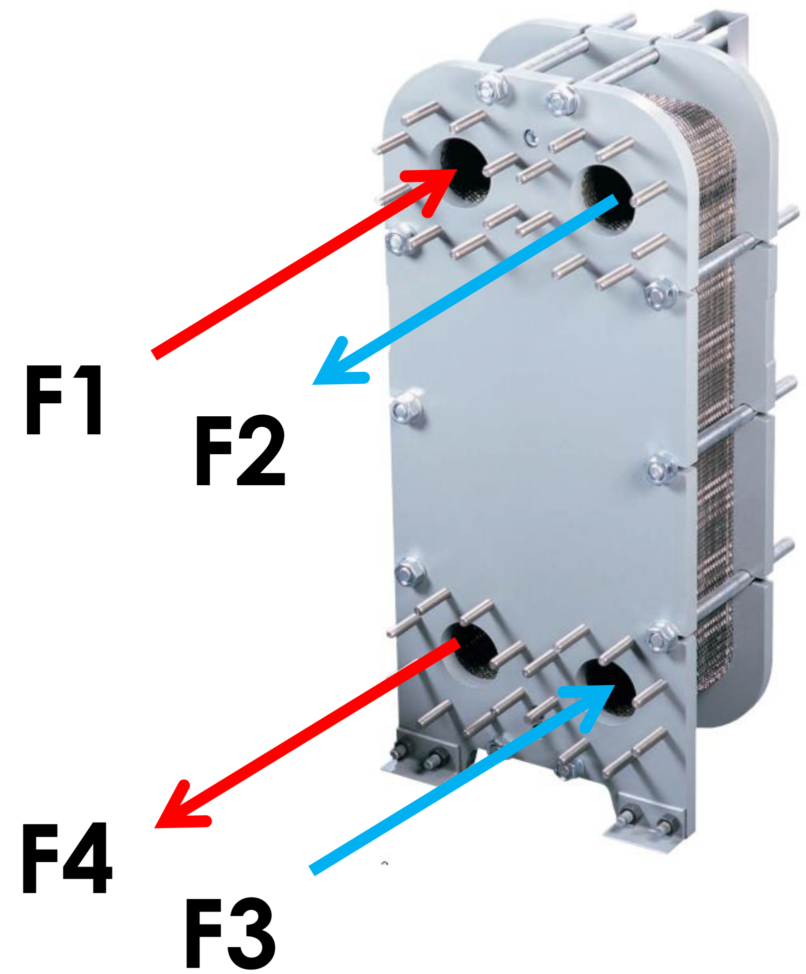
$$E = 1\%\ of\ flow\ per\ 12F\ range$$

$$D = 0.2\%\ of\ flow$$

$$B = \frac{E-(N-1)D}{(N-1)}$$

$$N = \frac{X_c}{X_w} = 1 + \frac{E}{(D+0.005)}$$

It was found that 17.6 gpm of makeup needed to be supplied to the four cooling towers, resulting in the AquaCELL needing to recycle 7,400 gallons per day for the cooling towers



Radiant Panel Chilled Water Tower Heat Exchanger

Parameter	Value	Units
Hot Side Flow	3917	gpm
Cold Side Flow	3917	gpm
Pressure Drop	9.7	psig
LMTD	2.0	F
F1	70.0	F
F2	68.0	F
F3	65.0	F
F4	67.0	F

IC Engine Heat Rejection Heat Exchanger to Wastewater Loop

Parameter	Value	Units
Hot Side Flow	74	gpm
Cold Side Flow	108	gpm
Pressure Drop	8.1	psig
LMTD	99.9	F
F1	200.0	F
F2	95.0	F
F3	75.0	F
F4	170.0	F

IC Engine Waste Heat to High Temperature Hot Water Loop

Parameter	Value	Units
Hot Side Flow	74	gpm
Cold Side Flow	73	gpm
Pressure Drop	6.9	psig
LMTD	40.0	F
F1	200.0	F
F2	160.0	F
F3	130.0	F
F4	170.0	F

Abs. Chiller Heat Rejection Heat Exchanger to Wastewater Loop

Parameter	Value	Units
Hot Side Flow	374	gpm
Cold Side Flow	373	gpm
Pressure Drop	9.3	psig
LMTD	5.0	F
F1	92.0	F
F2	87.0	F
F3	75.0	F
F4	80.0	F

Appendix N – 50-year Life Cycle Analysis

Life Cycle Economic Analysis		
Baseline	**Proposed**	**Simple Savings**
$ -	$ 682,000	
$57,164.60	$ 16,993.79	$ 40,170.81
$49,523.49	$ 15,329.42	$ 34,194.07
$55,993.24	$ 17,133.23	$ 38,860.01
$52,048.47	$ 16,332.41	$ 35,716.06
$50,126.85	$ 15,408.77	$ 34,718.08
$50,396.38	$ 16,684.42	$ 33,711.96
$50,968.32	$ 16,846.69	$ 34,121.63
$50,772.95	$ 16,754.37	$ 34,018.58
$49,992.38	$ 17,126.39	$ 32,865.99
$49,584.62	$ 15,376.05	$ 34,208.57
$52,258.68	$ 16,233.56	$ 36,025.12
$59,338.11	$ 18,160.78	$ 41,177.33

Economics were considered from Year 1 through Year 80 using fuel escalation factors

$67,868.38	$ 19,054.09	$ 48,814.29
$56,552.99	$ 15,984.55	$ 40,568.45
$63,955.01	$ 17,940.89	$ 46,014.12
$58,105.44	$ 16,752.33	$ 41,353.11
$54,933.93	$ 15,737.01	$ 39,196.91
$54,857.61	$ 17,049.88	$ 37,807.73
$54,979.01	$ 17,216.31	$ 37,762.70
$54,829.35	$ 17,121.22	$ 37,708.13
$53,902.65	$ 17,504.40	$ 36,398.25
$54,086.22	$ 15,701.55	$ 38,384.67
$58,597.22	$ 16,699.59	$ 41,897.63
$69,883.81	$ 19,840.38	$ 50,043.42

$$\text{NPV} = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

t = time of the cash flow

i = discount rate

R_t = net cash flow at time *t*

BioMethane System Savings

$13,646,200 over **50-year LifeCycle**

85,148,815 kWh are *off the grid*

4,463,600 therms stay *underground*

CO_2 *reduced* by **52,100 tons**

114,300

TREES

910

CAR LIFETIMES

AquaCELL System Savings

296,333,500 gallons *of potable water*

Saved over **730 tons** of **CO_2**

1,600

TREES

15

CAR LIFETIMES

Appendix O – LEED Points achieved by Mechanical Design Team

LEED 2009 for New Construction and Major Renovations

Project Checklist

350 Mission

2/1/14

Y	?	N		Sustainable Sites	Possible Points: 26
21					
Y			Prereq 1	Construction Activity Pollution Prevention	
1			Credit 1	Site Selection	1
5			Credit 2	Development Density and Community Connectivity	5
		X	Credit 3	Brownfield Redevelopment	1
6			Credit 4.1	Alternative Transportation—Public Transportation Access	6
1			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Roon	1
3			Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Ve	3
			Credit 4.4	Alternative Transportation—Parking Capacity	2
		X	Credit 5.1	Site Development—Protect or Restore Habitat	1
		X	Credit 5.2	Site Development—Maximize Open Space	1
1			Credit 6.1	Stormwater Design—Quantity Control	1
1			Credit 6.2	Stormwater Design—Quality Control	1
1			Credit 7.1	Heat Island Effect—Non-roof	1
1			Credit 7.2	Heat Island Effect—Roof	1
1			Credit 8	Light Pollution Reduction	1

Storm water is collected in a collection tank that prevents surface runoff and provides a non-potable water source for the building

To reduce the urban heat island effect, the roof is coated in a white reflective material with an SRI of 92

Y	?	N		Water Efficiency	Possible Points: 10
10					
Y			Prereq 1	Water Use Reduction—20% Reduction	
4			Credit 1	Water Efficient Landscaping	2 to 4
2			Credit 2	Innovative Wastewater Technologies	2
4			Credit 3	Water Use Reduction	2 to 4

Storm water collection, AquaCELL black water remediation, and reuse of building wastewater in the BioMethane plant all play a role in water efficiency

Y	?	N		Energy and Atmosphere	Possible Points: 35
33					
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
19			Credit 1	Optimize Energy Performance	1 to 19
7			Credit 2	On-Site Renewable Energy	1 to 7
2			Credit 3	Enhanced Commissioning	2
			Credit 4	Enhanced Refrigerant Management	2
3			Credit 5	Measurement and Verification	3
2			Credit 6	Green Power	2

Reaching an EUI of -0.02 with onsite generated renewable biomethane fossil fuel maximizes on site renewable energy usage and optimizes energy performance while protecting the environment by reducing carbon emissions significantly

Y	?	N		Materials and Resources	Possible Points: 14
5					
Y			Prereq 1	Storage and Collection of Recyclables	
		X	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
		X	Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Element	1
2			Credit 2	Construction Waste Management	1 to 2
			Credit 3	Materials Reuse	1 to 2

Y	?	N		Materials and Resources, Continued	
1			Credit 4	Recycled Content	1 to 2
2			Credit 5	Regional Materials	1 to 2
		X	Credit 6	Rapidly Renewable Materials	1
		X	Credit 7	Certified Wood	1

Y	?	N		Indoor Environmental Quality	Possible Points: 15
12					
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
1			Credit 1	Outdoor Air Delivery Monitoring	1
1			Credit 2	Increased Ventilation	1
1			Credit 3.1	Construction IAQ Management Plan—During Construction	1
1			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
1			Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
1			Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
1			Credit 4.3	Low-Emitting Materials—Flooring Systems	1
		X	Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Product	1
1			Credit 5	Indoor Chemical and Pollutant Source Control	1
1			Credit 6.1	Controllability of Systems—Lighting	1
		X	Credit 6.2	Controllability of Systems—Thermal Comfort	1
1			Credit 7.1	Thermal Comfort—Design	1
1			Credit 7.2	Thermal Comfort—Verification	1
		X	Credit 8.1	Daylight and Views—Daylight	1
1			Credit 8.2	Daylight and Views—Views	1

100% Outside Air is supplied at a capacity of *at least* 130% the code-required value. Along with increased outdoor air, low emitting materials were used to further increase IAQ standards.

All space conditioning systems are capable of meeting ASHRAE Standard 55 values for summer and winter thermal comfort. Additionally, a survey and monitoring system will be implemented to ensure delivery of expected thermal comfort.

Y	?	N		Innovation and Design Process	Possible Points: 6
4					
1			Credit 1.1	Pilot Credit: Cooling Tower Water Use	1
1			Credit 1.2	Pilot Credit: Sustainable Wastewater Management	1
1			Credit 1.3	Pilot Credit: Occupant Engagement	1
1			Credit 1.4	Innovation in Design: Biomethane Generation	1
		X	Credit 1.5		1
		X	Credit 2	LEED Accredited Professional	1

Y	?	N		Regional Priority Credits	Possible Points: 4
3					
1			Credit 1.1	Regional Priority: On-site Renewable Energy	1
1			Credit 1.2	Regional Priority: Innovative Wastewater Technologies	1
1			Credit 1.3	Regional Priority: Water Use Reduction	1
		X	Credit 1.4		1

Y	?	N	Total	Possible Points: 110
88				

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

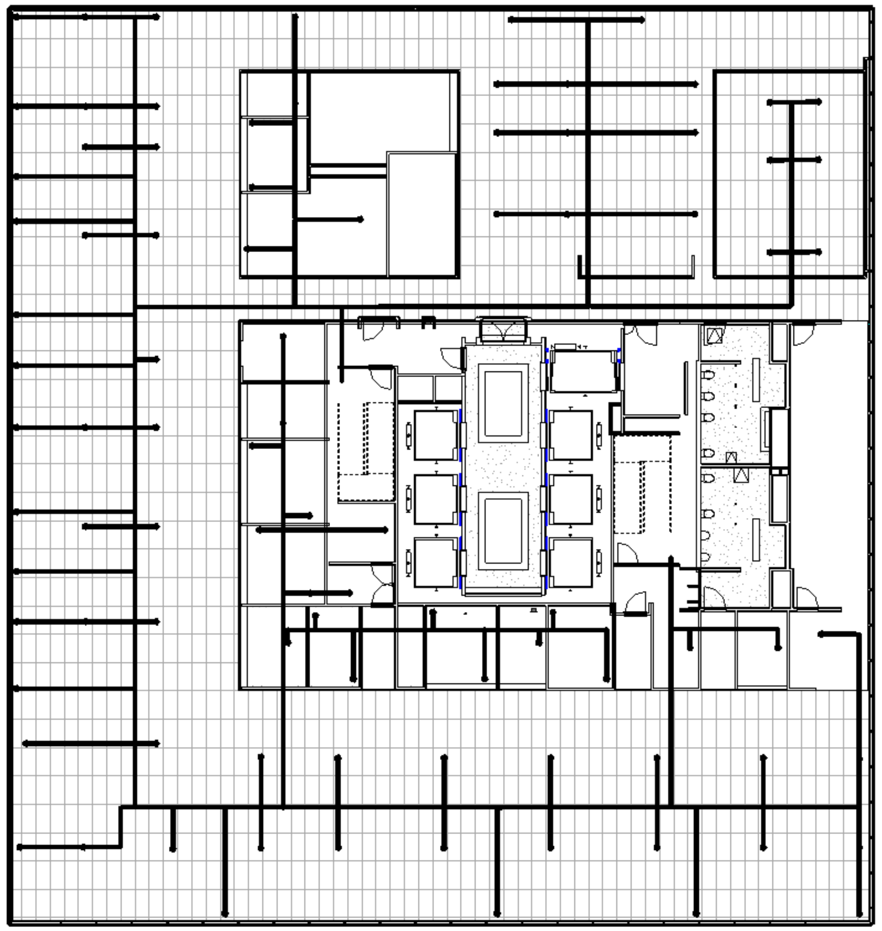
Many systems and processes are innovative in 350 Mission due to the need to meet Net-zero Energy, Water, Waste and Emissions. On-site fuel generation via anaerobic digestion as well as Connective engagements in the lobby. The AquaCELL system also provides makeup water for the cooling towers, in order to reduce the strain on the municipal water grid.

Appendix P – Life Safety / Resiliency

Fire Suppression Systems. One of the main design goals of 350 Mission was near immediate occupancy after a seismic or other catastrophic event. A main component of this goal is the installation of fire suppression system that can operate throughout the duration of the event.

Three different fire pumps serve different areas of the building to minimize pressure reduction and reach each floor as efficiently as possible.

Pump	Floors Served	Total GPM	Total Pressure	Required Pump Pressure
Fire Pump 1	1 Through 16	900	132	174
Fire Pump 2	17 Through 25	900	219	261
Fire Pump 3	B4 Through B1	975	22	64



Typical office floor plan sprinkler layout. There are two standpipes located in the stairwells that service the main loop, with branches covering both the interior offices and the open office plans.

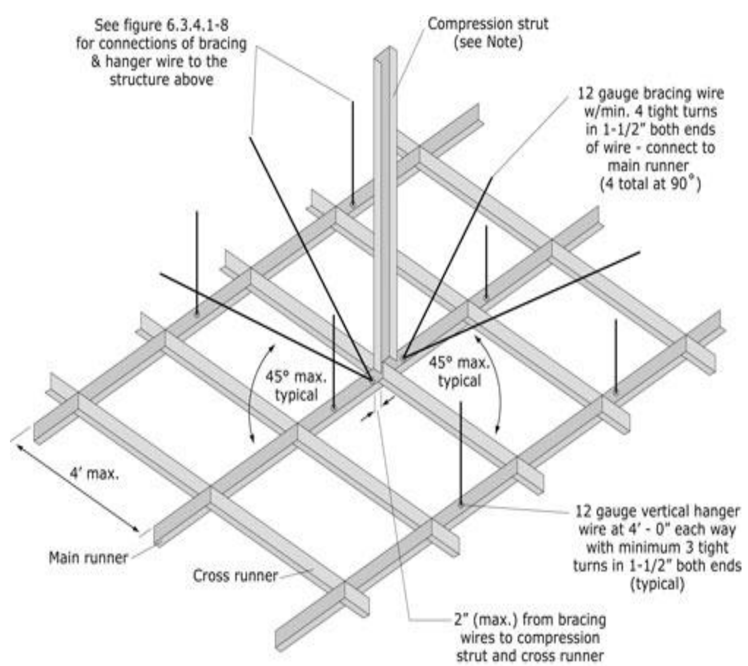
With the office classified as a light hazard area, the sprinklers were laid out to meet the code requirements for that type of occupancy.

- Two standpipes service the building (one in each stairwell) with GPM's of 500 and 250 each.
- Sprinklers are allowed to be placed no closer than 6 ft. and no farther than 15 ft.
- Sprinklers must be at maximum 7'6" away from a wall and no closer than 4"

Stairwell Pressurization. During a fire alarm event, it is necessary to evacuate occupants through the stairwells as the elevators will be out of order. In order to make sure the stairwell is an appropriate area of refuge from smoke and other hazards, air will be provided to positively pressurize the space.

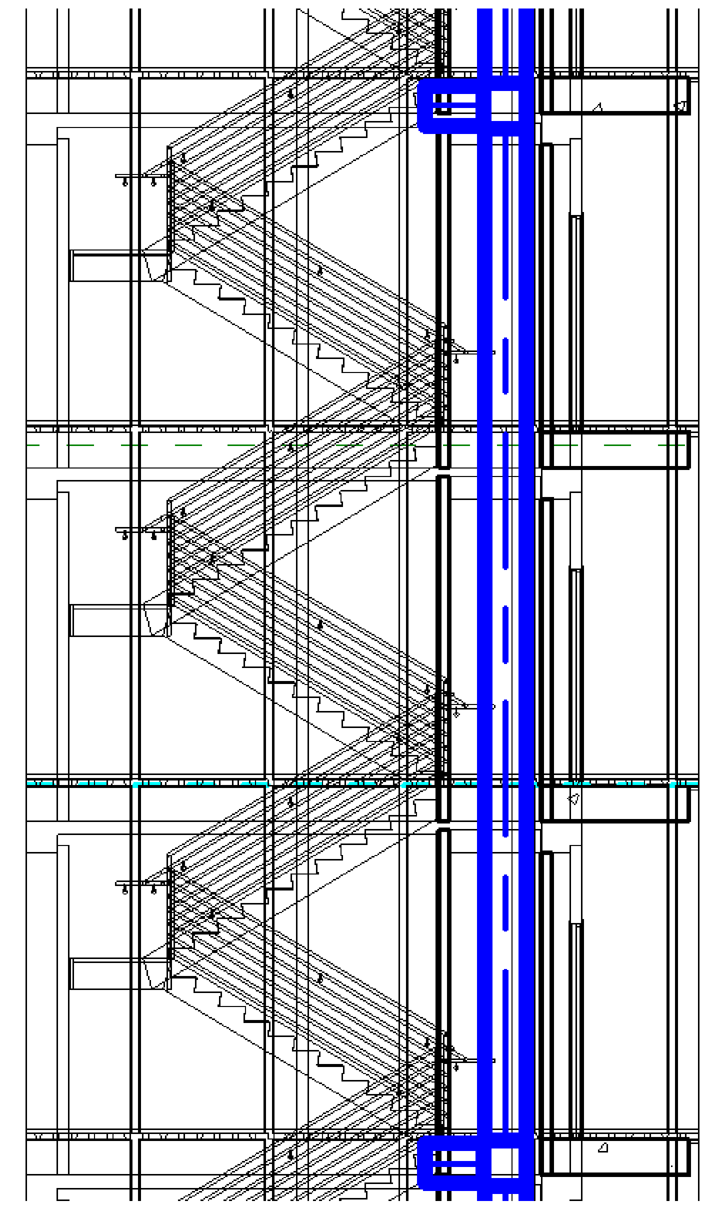
A duct chase will extend up the shaft located next to the stairwell, and during a fire event every third floor will have a damper that will open, allowing air into the stairwell to provide a pressure differential of 0.15 in wg. This will provide enough pressure so that when the door to the stairwell remains open as people are exiting, the smoke will be contained within the office floor space. This pressure differential is not great enough however to prevent occupants from easily opening the door.

Seismic Bracing of Mechanical System Components. Another key design component of operation during events is properly seismically bracing mechanical components such as radiant panels, ductwork and piping. These components will be engaged to the structural framing with seismically appropriate techniques and bracing.



Note: Compression strut shall not replace hanger wire. Compression strut consists of a steel section attached to main runner with 2 - #12 sheet metal screws and to structure with 2 - #12 screws to wood or 1/4" min. expansion anchor to structure. Size of strut is dependent on distance between ceiling and structure ($l/r \leq 200$). A 1" diameter conduit can be used for up to 6', a 1-5/8" X 1-1/4" metal stud can be used for up to 10'

Typical bracing for a suspended ceiling system with acoustical tiling or other appropriately sized panels such as the radiant paneling system. The central piece is attached to the structure to prevent excessive movement of the radiant panels.



Schematic showing the duct riser with the supply every three floors to provide the necessary pressurization in the case of a fire event.

Appendix Q– Acoustics

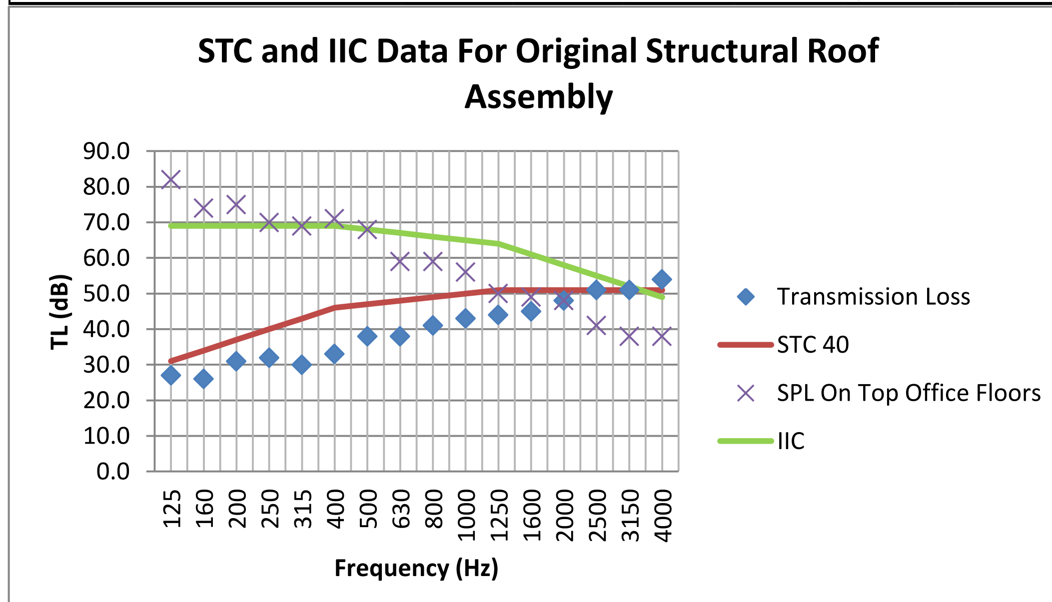
Cooling Tower Noise Reduction Considerations. Once cooling towers were selected as rooftop equipment for 350 Mission, acoustical considerations were considered for excessive sound power levels in key locations.

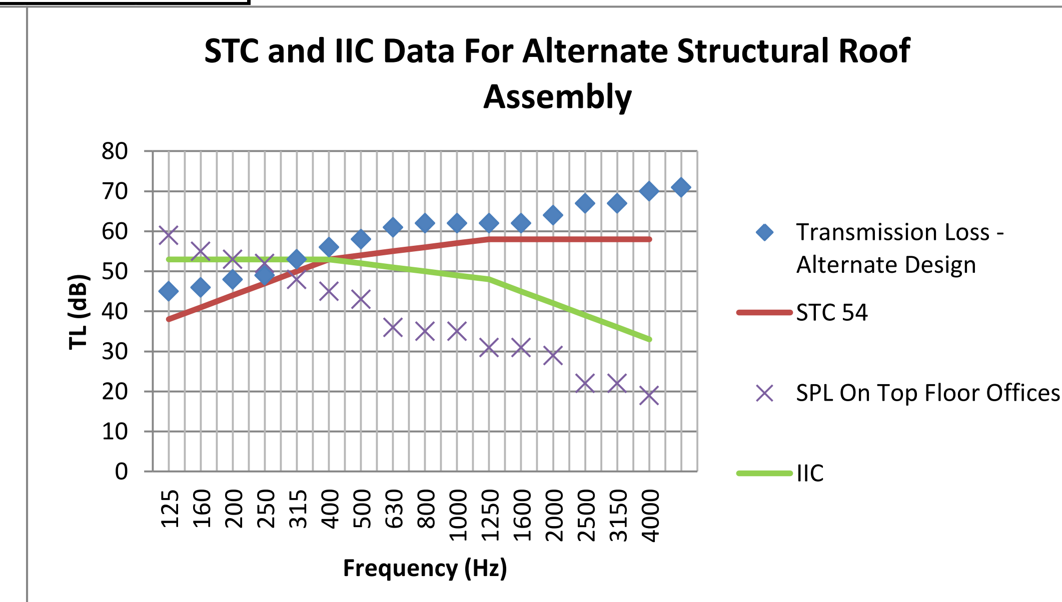
- SPL Barrier Calculation reduction to adjacent buildings assuming the parapet acts as a "barrier"
- Rating of the Roof Assembly
    - IIC
    - NC Rating of Offices Directly Below the Towers

Roof	Top Floor	Sound Class data	
Cooling Towers	Office	STC	IIC
Original Design - slab on metal decking		40	43
Alternate Design - slab on metal decking with 3" mineral wool insulation		54	59

Sound Pressure Level without a Barrier								
Octave Band f_{center} (Hz)	63	125	250	500	1000	2000	4000	8000
L_P at Measured Distance (dB)	104	101	101	97	93	89	86	80
Attenuation due to Distance (dB)	-17.9239	-17.9239	-17.9239	-17.9239	-17.9239	-17.9239	-17.9239	-17.92393
Total L_P (dB)	86.0761	83.0761	83.0761	79.0761	75.0761	71.0761	68.0761	62.0761
A Weighting	-26.2	-16.1	-8.6	-3.2	0	1.2	1	1.1
Total L_P (dBA)	60	67	74	76	75	72	69	63
Overall Sound Pressure Level (dBA)	**81**							
* All dB and dBA values were measured or calculated based on a reference of 20 μPa								

Sound Pressure Level with a Barrier								
Octave Band f_{center} (Hz)	63	125	250	500	1000	2000	4000	8000
L_P at Measured Distance (dB)	56	61	64	66	65	61	59	58
Attenuation due to Distance (dB)	-17.92	-17.92	-17.92	-17.92	-17.92	-17.92	-17.92	-17.92
N	1.192	2.366	4.732	9.463	18.927	37.853	75.706	151.412
Attenuation due to the Barrier (dB)	13.8	16.7	19.7	20.0	20.0	20.0	20.0	20.0
Total L_P (dB)	24.3	26.3	26.3	28.1	27.1	23.1	21.1	20.1
A Weighting	-26.2	-16.1	-8.6	-3.2	0	1.2	1	1.1
Total L_P (dBA)	-2	10	18	25	27	24	22	21
Overall Sound Pressure Level (dBA)	**32**							
* All dB and dBA values were measured or calculated based on a reference of 20 μPa								

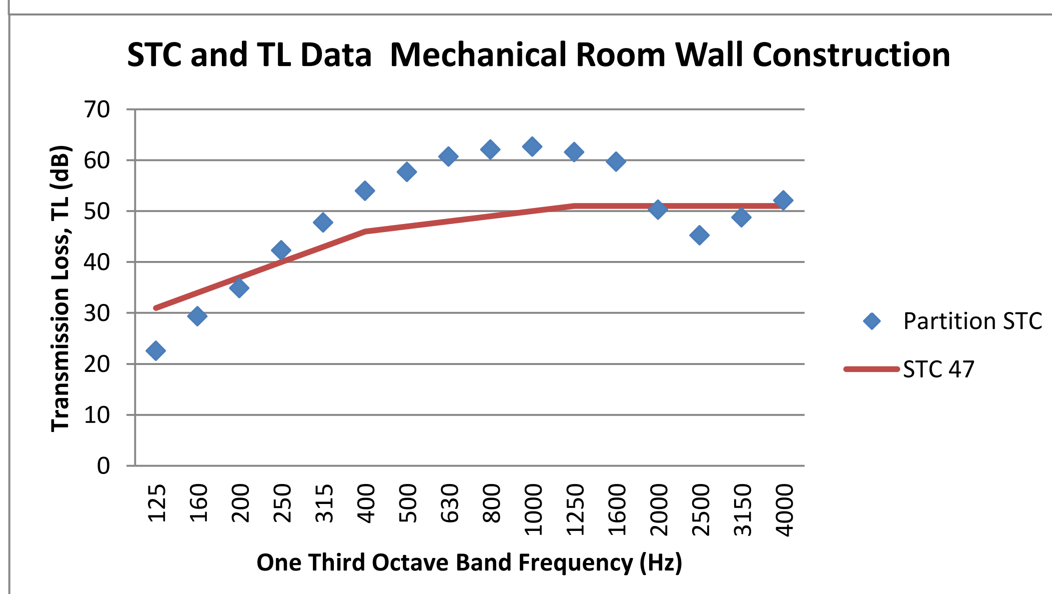


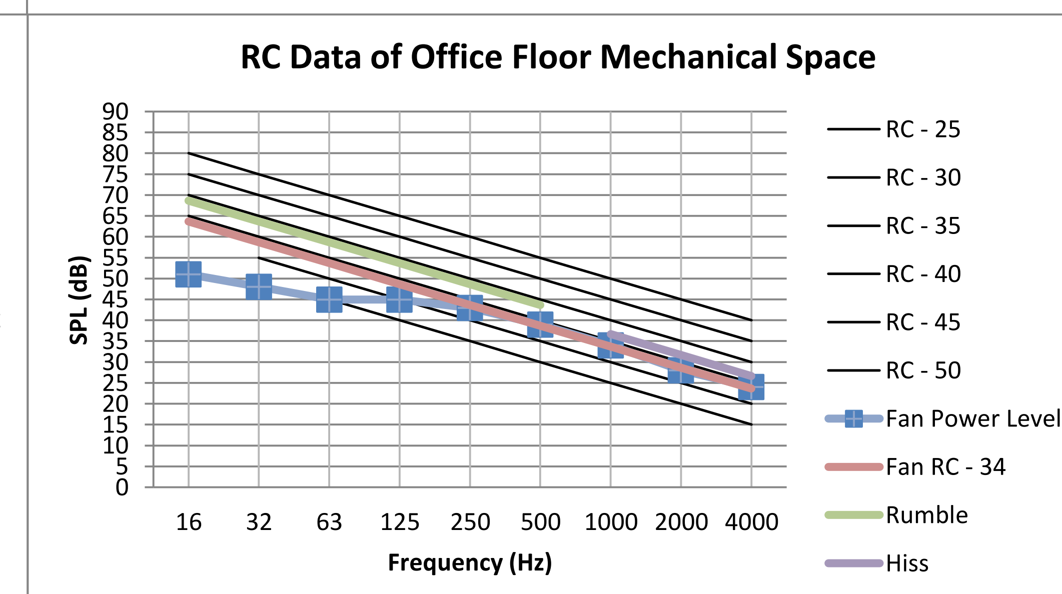


Mechanical Fan Noise Reduction Considerations. One main acoustical consideration was confirming that the mechanical room would not cause excessive background noise in the adjacent occupied spaces. This was confirmed with multiple analyses.

- STC data for a typical gypsum partition assembly
- NC and RC Ratings of the adjacent occupied spaces to confirm low background noise levels.

Rating	Recommended Range for Office spaces from ANSI Standards	Calculated Values
STC	> 45	47
NC	30 - 40	39
RC	30 - 40	34





Open Office Space Reverberation Time. With 87% of the exposed ceiling of the open office area covered with radiant panels, the mechanical design team considered the acoustical side effects of removing a large amount of acoustical ceiling tiles. A reverberation time analysis was done to assess whether the panels would cause excessive noise problems in the open area.

Reverberation Time						
Frequency (Hz)	125	250	500	1000	2000	4000
Calculated RT (s)	**0.89**	**0.82**	**0.72**	**0.54**	**0.43**	**0.24**

Appendix R – IAQ

Excess Risk Factors. Due to the large opening to the ambient environment in the lobby space, an air quality analysis was done to determine the effect of the downtown environment on the occupants of the lobby.

Excess Cancer Risk is a way of determining a person's increase in risk of contracting a severe disease (such as cancer) based on the type and concentration of contaminants that they are exposed to.

Contaminant	Unit Risk Factor $m^3/\mu g$	Molecular Weight (kg/kmol)
Benzene	0.00002650	78.1
Carbon Tetrachloride	0.00009440	153.8
Chloroform	0.00011200	119.4
Formaldehyde	0.00001600	30
Perchloroethylene	0.00000393	166
Styrene	0.00000243	104.2
Component	**Emission Rate**	**Annual pollution emitted**
Hydrocarbons	2.80 grams/mile (1.75 g/Km)	77.1 pounds (35.0 kg)
Carbon Monoxide	20.9 grams/mile (13.06 g/Km)	575 pounds (261 kg)
NO_x	1.39 grams/mile (0.87 g/Km)	38.2 pounds (17.3 kg)
Carbon Dioxide - Green house gas	0.916 pounds per mile (258 g/km)	11,450 pounds (5,190 kg)

The contaminants listed above are just six of the major risk contaminants and their ambient concentrations in the San Francisco Area. There are many more contaminants that can be added to the list.

The unit risk factor is determining by assuming that someone is exposed to a contaminant 8 hours a day every day. Due to this assumption, excess risk is typically overestimated.

The emissions listed below the contaminants are averaged values of what a typical mid-sized car produces when in operation.

The summation of the six main pollutants assumes almost a 0.1% increase in the chance to get cancer. Multiplying that solution by an estimated lobby population of 500 persons per day gives a 41% chance that someone's risk for cancer has increased.

Contaminant	Contaminant Level (ppb)	Contaminant lvl (µg/m3)	Excess Lifetime Cancer Risk	Aggregate Risk
	San Francisco	San Francisco	San Francisco	San Francisco
Benzene	18	58.44	0.00154877	6.707710189
Carbon Tetrachloride	3	19.18	0.00181078	7.842498818
Chloroform	10	49.64	0.00555954	24.07837794
Formaldehyde	20	24.94	0.00039911	1.728526772
Perchloroethylene	5	34.51	0.00013561	0.587320987
Styrene	5	21.66	0.00005263	0.22795487
Total			**0.00950644**	**41.17238957**

Mass Balance. A basic mass balance study was performed on the lobby space to determine steady state concentrations of specific contaminants as well as 8 hour time weighted averages.

Step 1: Determine appropriate differential mass balance equation

$$\frac{VdC}{dt} = PQ_{IN}C_{OA} - Q_{OUT}C + S(t) - L(t)$$

Step 2: Determine Steady State Concentration

If $C = C_{SS}$ then $\frac{VdC}{dt} = 0$ therefore $C_{SS} = [PQ_{IN}C_{OA} + S(t) - L(t)]/Q_{OUT}$

Step 3: Integrate for the time weighted solution

$$C(t) = C_{ss} - (C_{ss} - C(0))e^{-\left(\frac{Q}{V}\right)t}$$

Contaminant	Ambient Contaminant Level (ppb)	Ambient Contaminant lvl (µg/m3)	Steady State Concentration (µg/m3)	Steady State Concentration (ppb)
Ozone	30	59.87	59.87	30.00
$PM_{2.5}$	-	60.00	60.00	-
Carbon Monxide	5	5.82	64.01	54.99
Carbon Dioxide	200000	365846.89	366281.18	*200.24
NO_x	25	47.81	76.74	40.13

* The concentration of CO_2 is in ppm, not ppb.

Due to the size of the lobby space, the 8 hour weighted time average concentration does not vary much from the steady state concentration.

Multiple assumptions were used to derive the steady state concentration

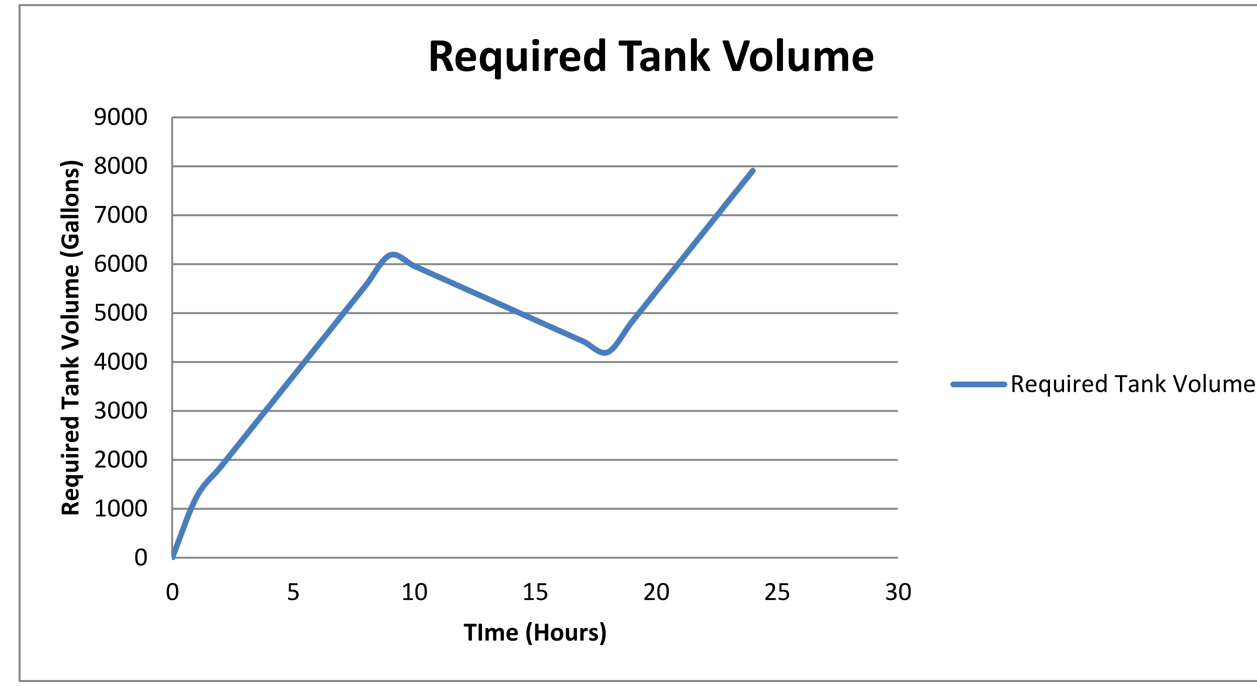
- The ambient concentrations were determined from the EPA's AQI index
- The source variable, S(t) was calculated assuming 10 cars pass by a minute for 5 seconds each and travel a total distance of 1/10 of a mile.

Appendix S – Plumbing, Rain Water and Water Fixture Reduction Calculations

Water Reduction Strategies. Due to the size of 350 Mission, water efficient fixtures were installed to greatly reduce the potable and non-potable water demand as well as aid the progression towards the goal of a net – zero sustainable building. Total yearly reduction in **non – potable** water demand was 1.9 Million Gallons, a 54% reduction. **Potable** demand was reduced by 393,000 gallons, a 78% reduction. Overall, the **building water demand** was reduced by 45.5% a 2.4 Million Gallon Reduction.

350 Mission Water Use										
Fixture	Flow Rate (gpm or gpf)	Fixtures per Floor	Number of Fixtures	Number of People		Uses per Day		Total Daily Demand	Total Monthly Demand	Total Yearly Demand
				Male	Female	Male	Female	[gal]	[gal]	[gal]
Toilets	1.6	8	200	1525.0	1525.0	1	3	9,760	209,142.86	2,449,760
Showers	2.5	0.2	5	1525.0	1525.0	1	1	125	2,678.57	31,375
Faucets	0.5	4	100	1525.0	1525.0	2.5	2.5	3,813	81,696.43	956,938
Drinking Fountain	0.75	1	25	1525.0	1525.0	1	1	2,288	49,017.86	574,163
Urinals	1.60	8	200	1525.0	1525.0	2	0	4,880	104,571.43	1,224,880
Cooling Towers	17.6	--	--	--	--	--	--	7,405	158,683.50	1,858,713
Total Annual								**28,270**	**605,791**	**7,095,828**
Total Non-Potable Annual								**22,045**	**472,398**	**5,533,353**
Total Potable Annual								**6,225**	**133,393**	**1,562,475**
Indoor Water Use Fixtures (Reductions)										
Fixture	Flow Rate (gpm or gpf)	Fixtures per Floor	Number of Fixtures	Number of People		Uses per Day		Total Daily Demand	Total Monthly Demand	Total Yearly Demand
				Male	Female	Male	Female	[gal]	[gal]	[gal]
Toilets	1.1	8	200	1525.0	1525.0	1	3	6,710	143,785.71	1,684,210.00
Showers	1.66	0.2	5	1525.0	1525.0	1	1	83	1,778.57	20,833.00
Faucets	0.4	4	100	1525.0	1525.0	2.5	2.5	3,050	65,357.14	765,550.00
Drinking Fountain	0.5	1	25	1525.0	1525.0	1	1	1,525	32,678.57	382,775.00
Urinals	0.00	8	200	1525.0	1525.0	2	0	-	-	-
Cooling Towers	17.6	--	--	--	--	--	--	7,405	158,683.50	1,858,713
Total Annual								**18,773**	**402,284**	**4,712,081**
Total Non-Potable Annual								**14,115**	**302,469**	**3,542,923**
Total Potable Annual								**4,658**	**99,814**	**1,169,158**

Savings	Daily	Monthly	Yearly	Percentage Reduction
Total Non-Potable	7,930	169,929	1,990,430	36%
Total Potable	1,567	33,579	393,317	84%



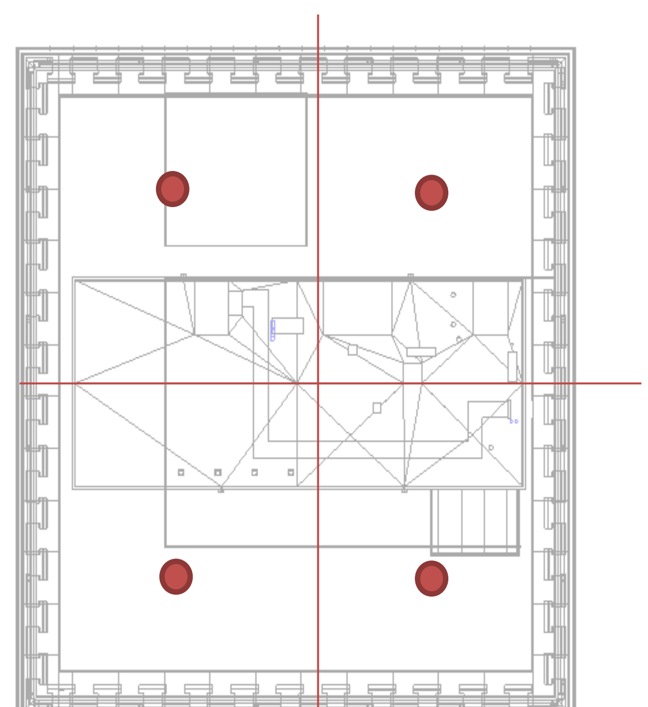
Required Tank Volume based on demand vs. 100 yr storm

Notes for the Water Reduction Table

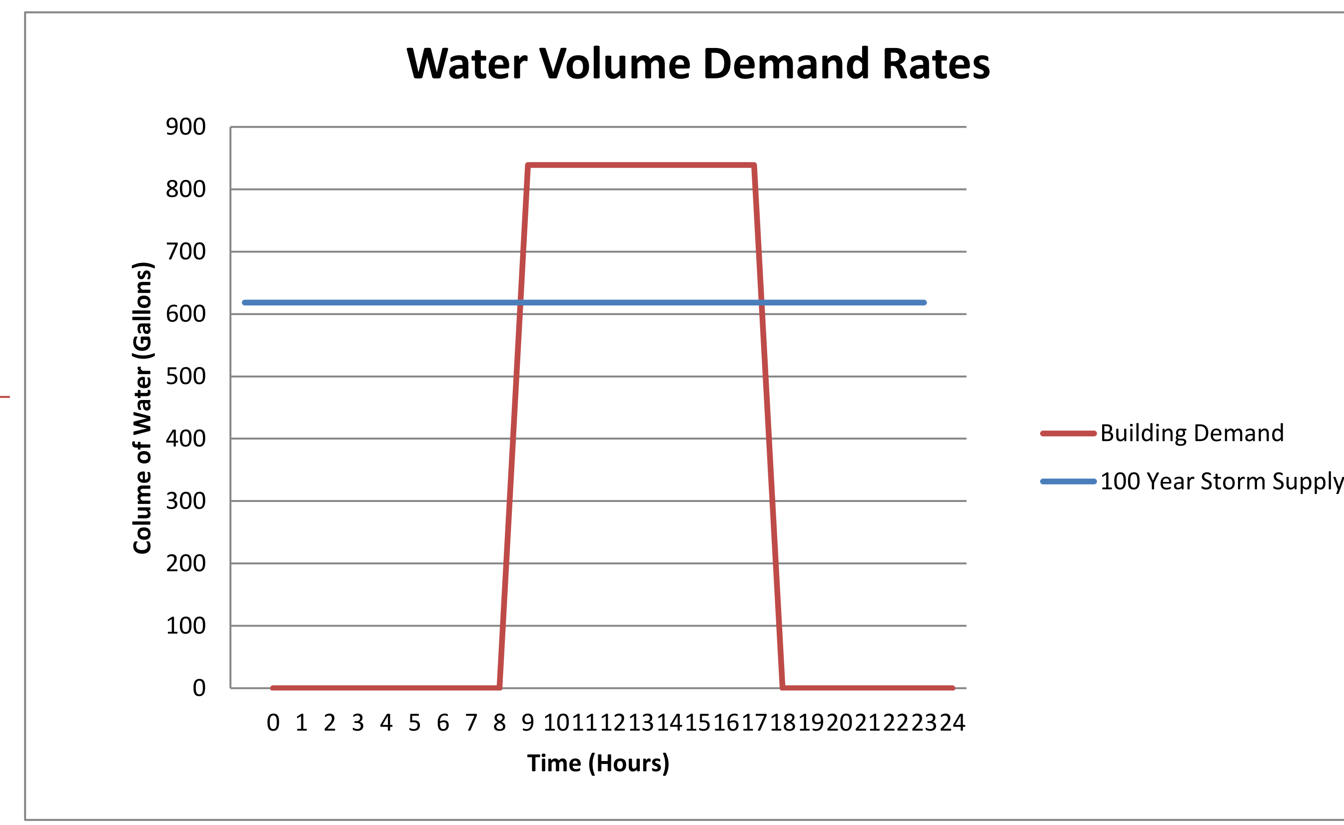
- All flow rates for fixtures were determined either by the 2010 California Plumbing Code or industry practice.
- The occupancy of the building was estimated as 50% women and 50% men, with the uses per day determined by industry best practice
- The total daily demand for each type of fixture was calculated by Daily Demand=Occupants*Uses Per Day*Flow Rate

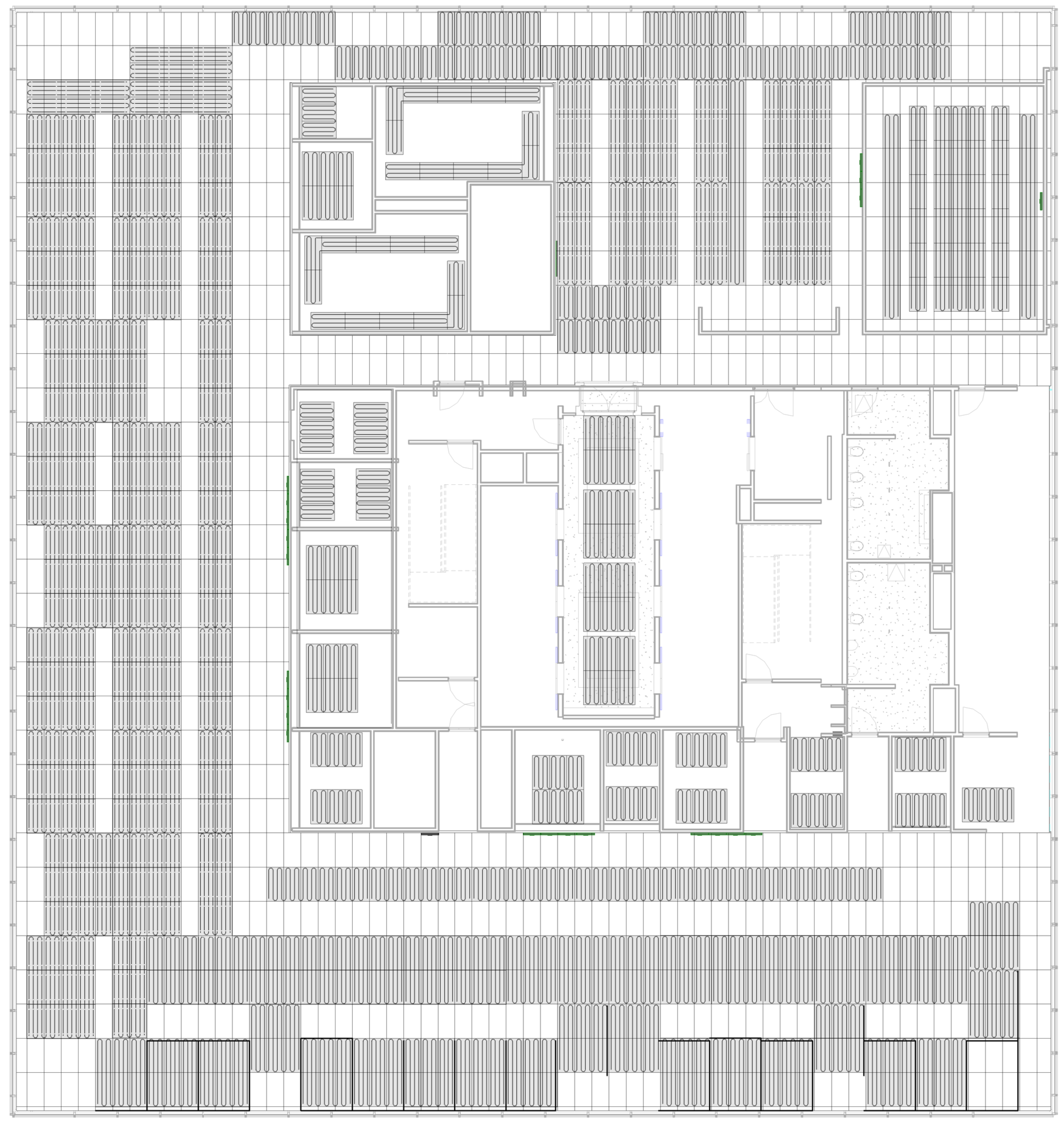
Rainwater Collection and Utilization. Code requires that no surface runoff occur within building properties in San Francisco. To further reduce the non - potable demand, a rooftop rainwater collection system was utilized to provide non potable demand to the upper floors of 350 Mission. The roof was divided into four quadrants, with a storm drain placed in the center of each quadrant. The rain water tank was sized based on a 100 yr storm that occurred for 24 hours continuously. Incorporating that rainfall data with the demand data of the building, a tank size of 5968 Gallons was determined by integrating under the summation of the two curves in the graph on the right.

Size of Conductors, Leaders and Storm Drains		
Roof Plan Width	123	ft.
Roof Plan Length	123	ft.
Roof Slope	0	in./ft.
Storm Requirement	100	yr storm
Rainfall Intensity (100 yr storm)	3.70	in./hr.
Drainable Area (100 yr storm)	330.00	sq. ft
Plan Area	15129.00	sq. ft
Design Area	15129.00	sq. ft.
Minimum Number of Roof Drains	4	
Maximum Roof Area Served By Each Roof Drain	3782.25	sq. ft
Roof Drain	**5**	**in.**



Plan view of the roof, showing the location of the storm drains within each quadrant



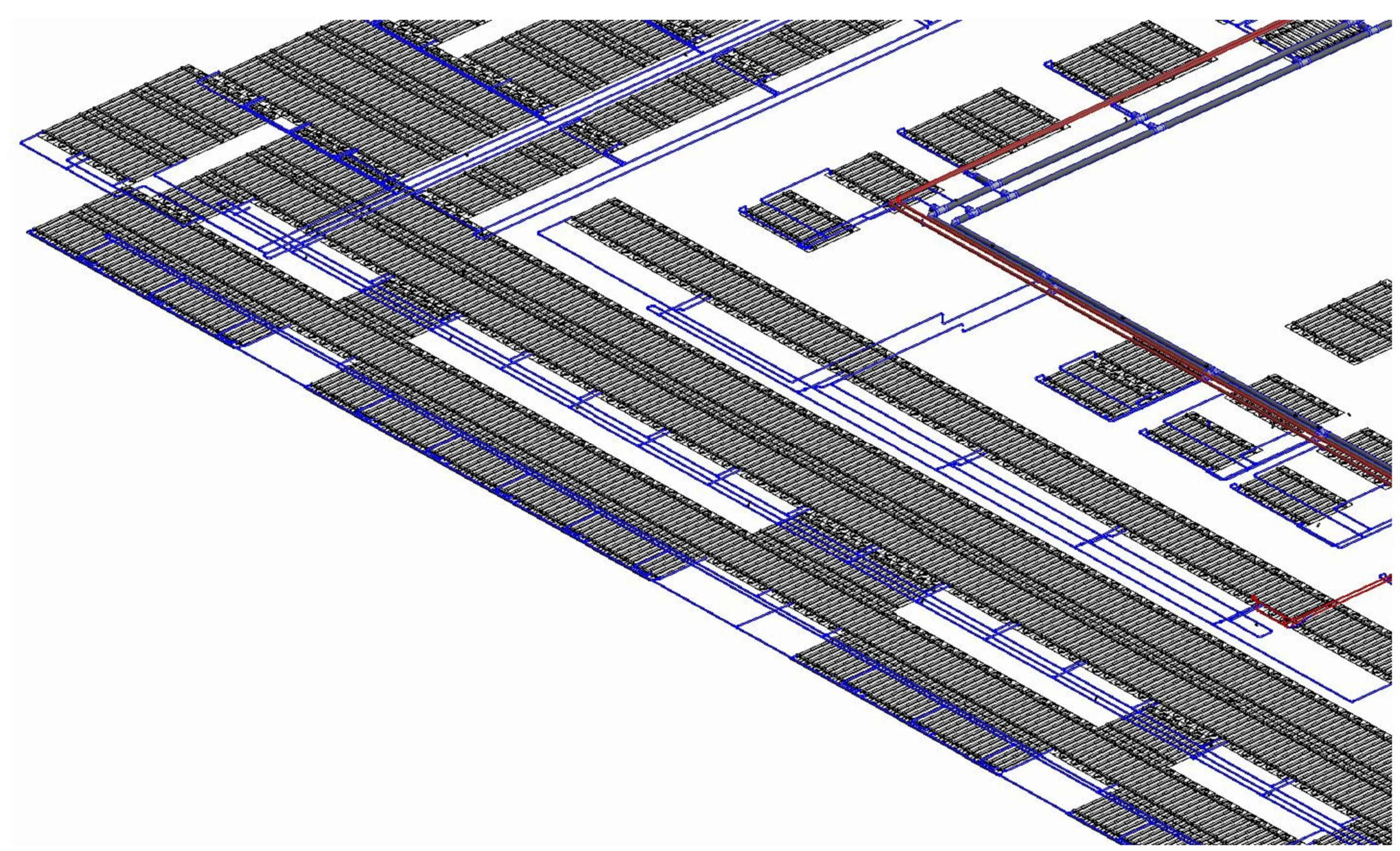


1 RADIANT PANEL SYSTEM LAYOUT
1/8" = 1'-0"

2 HYDRONIC CHILLED WATER AND HOT WATER
1/8" = 1'-0"

DRAWING NOTES:
A. 4" Ø CHW AND CHWR MAIN (REVERSE RETURN)
B. 1 1/2" Ø HWS AND HWR MAIN (REVERSE RETURN)
C. (147) RADIANT PANELS MODULES OPERATE AT A WATER SETPOINT OF 67° F SERVED FROM 3/4" Ø CHWS
D. (6) INDIVUDUAL PANELS OF DIMENSION 2' X 4' ARE COMBINED IN SPECIFIC GEOMETRIC MODULES TO MEET THE SPACE CONDITIONING REQUIREMENTS AS WELL AS AESTHETICALLY CONFORM WITH THE CEILING GRID
E. (4) PERIMETER VAV INDUCTION UNITS SERVED FROM 1/2" Ø HWS

RIGHT. 3D ISOMETRIC VIEW OF THE SOUTH OPEN OFFICE AND INTERIOR OFFICE ZONES AND THE RADIANT PANEL PLACEMENT WITH THE PIPING SYSTEM

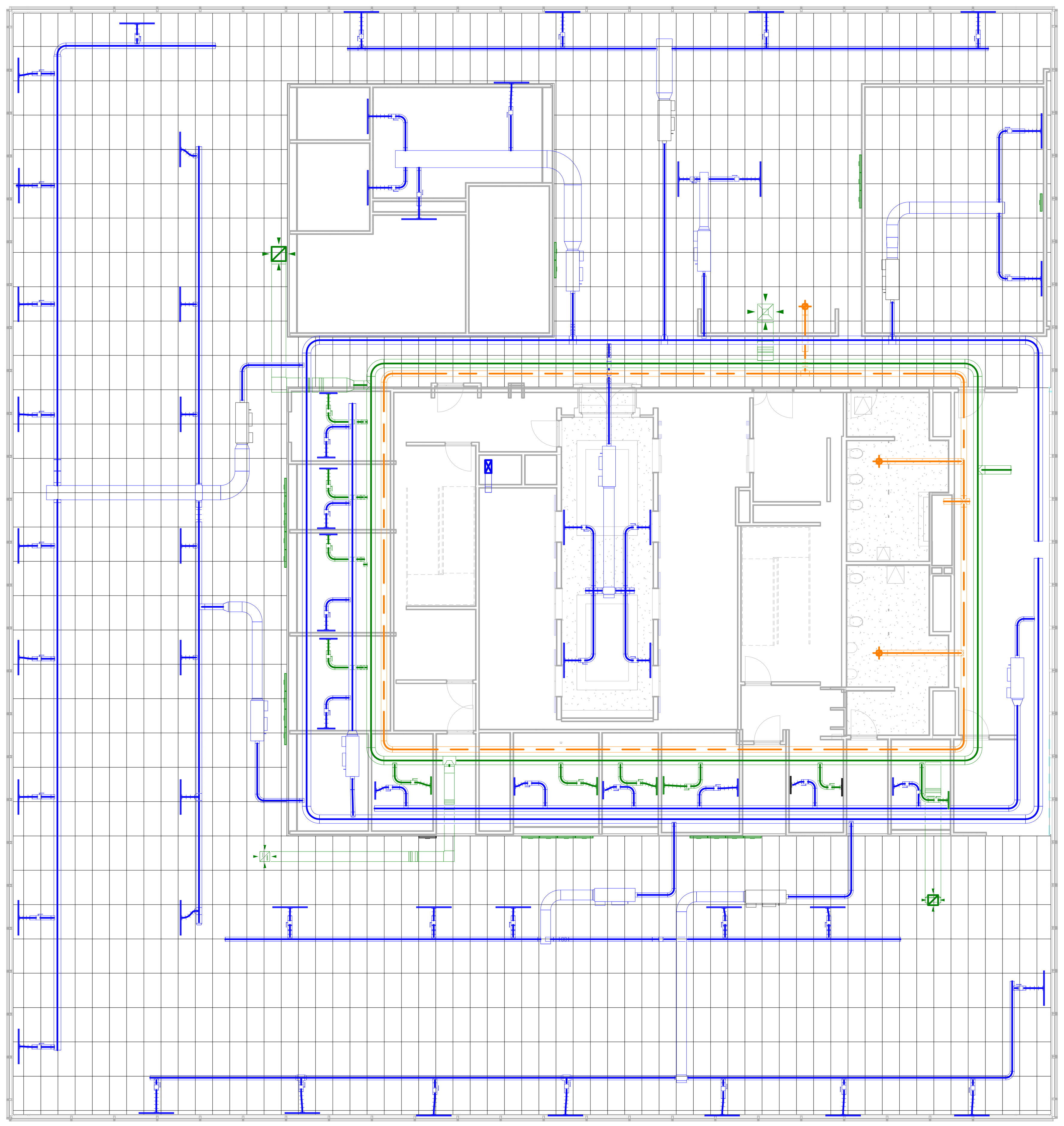


PROJECT
AEI STUDENT COMPETITION
350 Mission Street, San Francisco, CA

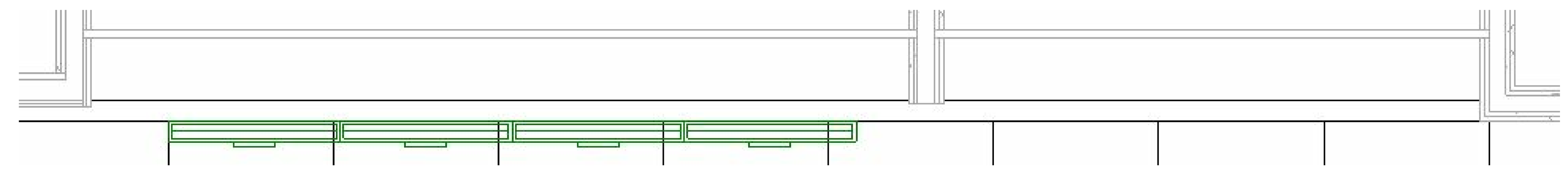
PURPOSE
ASCE | STUDENT COMPETITION
AEI 2 - 2014

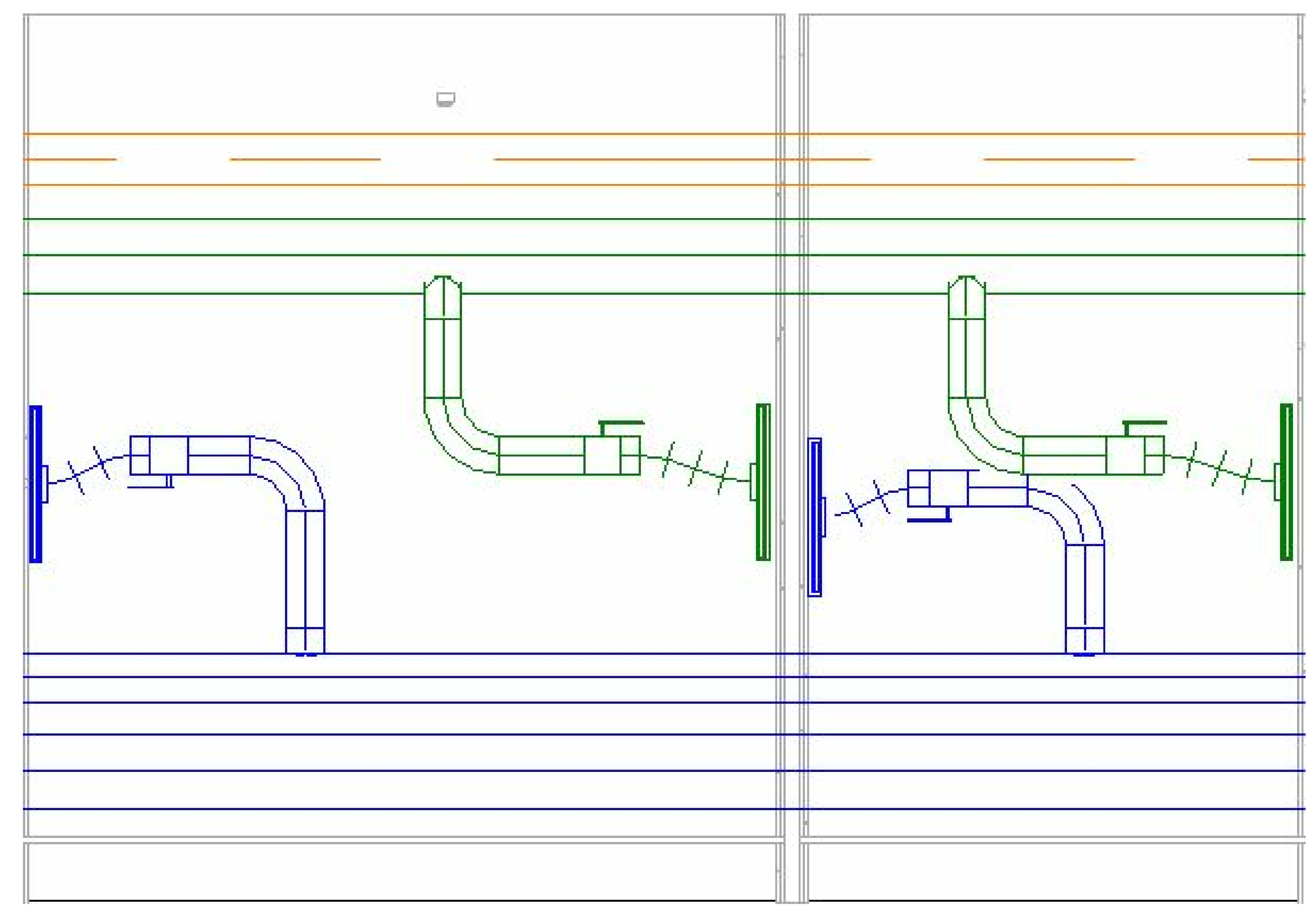
DRAWING TITLE
MECHANICAL - OFFICE FLOOR HYDRONIC PLAN

SCALE: 1/8" = 1'-0"
JOB NUMBER: 350 MISSION
DATE: 02/17/2014
DRAWN BY: AEI 2
SHEET NUMBER: M1

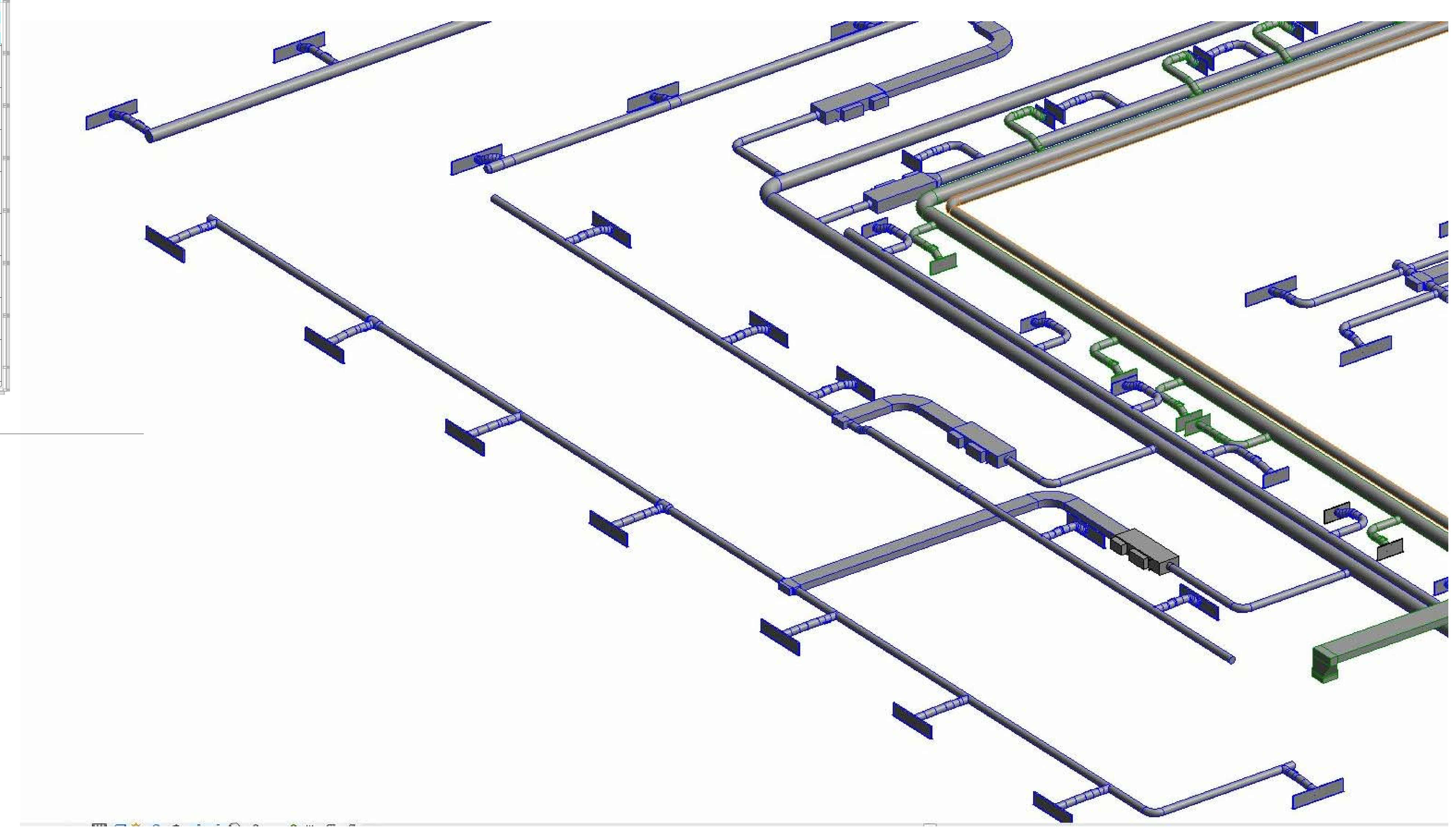


1 AIR SIDE OFFICE PLAN
1/8" = 1'-0"





ABOVE. ENLARGED VIEW OF LINEAR DIFFUSERS USED AS PLENUM RETURNS FOR THE VAV INDUCTION UNITS
LEFT. TYPICAL OFFICE FLOOR LAYOUT, SHOWING THE ELIMINATION OF FLANKING PATHS AND OTHER ACOUSTICAL CONCERNS.
BELOW. 3D ISOMETRIC VIEW OF THE AIRSIDE SYSTEM FOR THE SOUTH OPEN OFFICE ZONES AND THE SOUTH INTERIOR OFFICES



DRAWING NOTES:
A. (56) LINEAR DIFFUSERS SERVE BOTH THE OPEN OFFICE AND CORE SPACES
B. 14 Ø SUPPLY MAIN
C. 14 Ø RETURN MAIN
D. (1) DOAS AIR HANLDING UNIT LOCATED EVERY FIVE FLOORS
E. 3775 CFM SUPPLIED PER FLOOR
F. (8) VAV INDUCTION UNITS, (4) PERIMETER UNITS SERVICED WITH HOT WATER SUPPLY.
G. BATHROOMS AND PANTRY AREA EXHAUSTED
H. IN ORDER TO TAKE ADVANTAGE OF SIMULTANEOUS HEATING AND COOLING IN THE PERIMETER AND OFFICE ZONES, HEATING IS DONE AT PERIMETER INDUCTION VAV TERMINALS, WHILE CORE ZONES MIX AIR TO 55 °F FOR ECONOMIZER COOLING

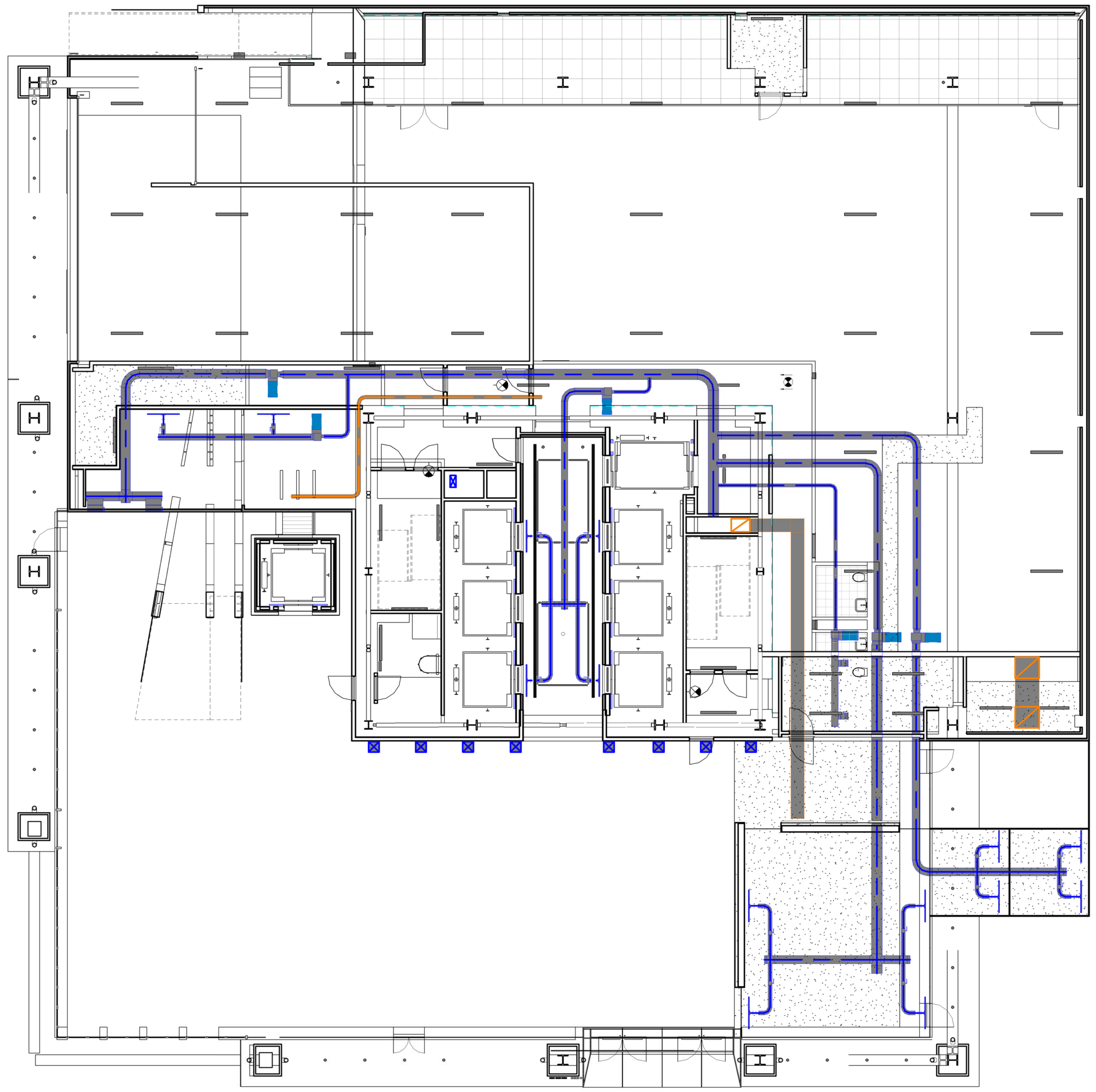
DRAWING NOTES:
A. OFFICE LINEAR DIFFUSERS LAID OUT FOR ACOUSTICAL CONSIDERATIONS
B. DUCT RUNS LAID OUT TO PREVENT FLANKING PATHS FOR SOUND TO TRAVEL BACK INTO OFFICE OFFICES
C. FLEX DUCT AIDS WITH COORDINATION AND WITH ACOUSTIC PROPERTIES
D. LINEAR DIFFUSERS LOCATED ALONG WALLS AT SPECIFIC LOCATIONS AID IN RETURNING AIR TO THE PLENUM SPACE FOR THE VAV INDUCTION UNITS

PROJECT
AEI STUDENT COMPETITION
350 Mission Street, San Francisco, CA

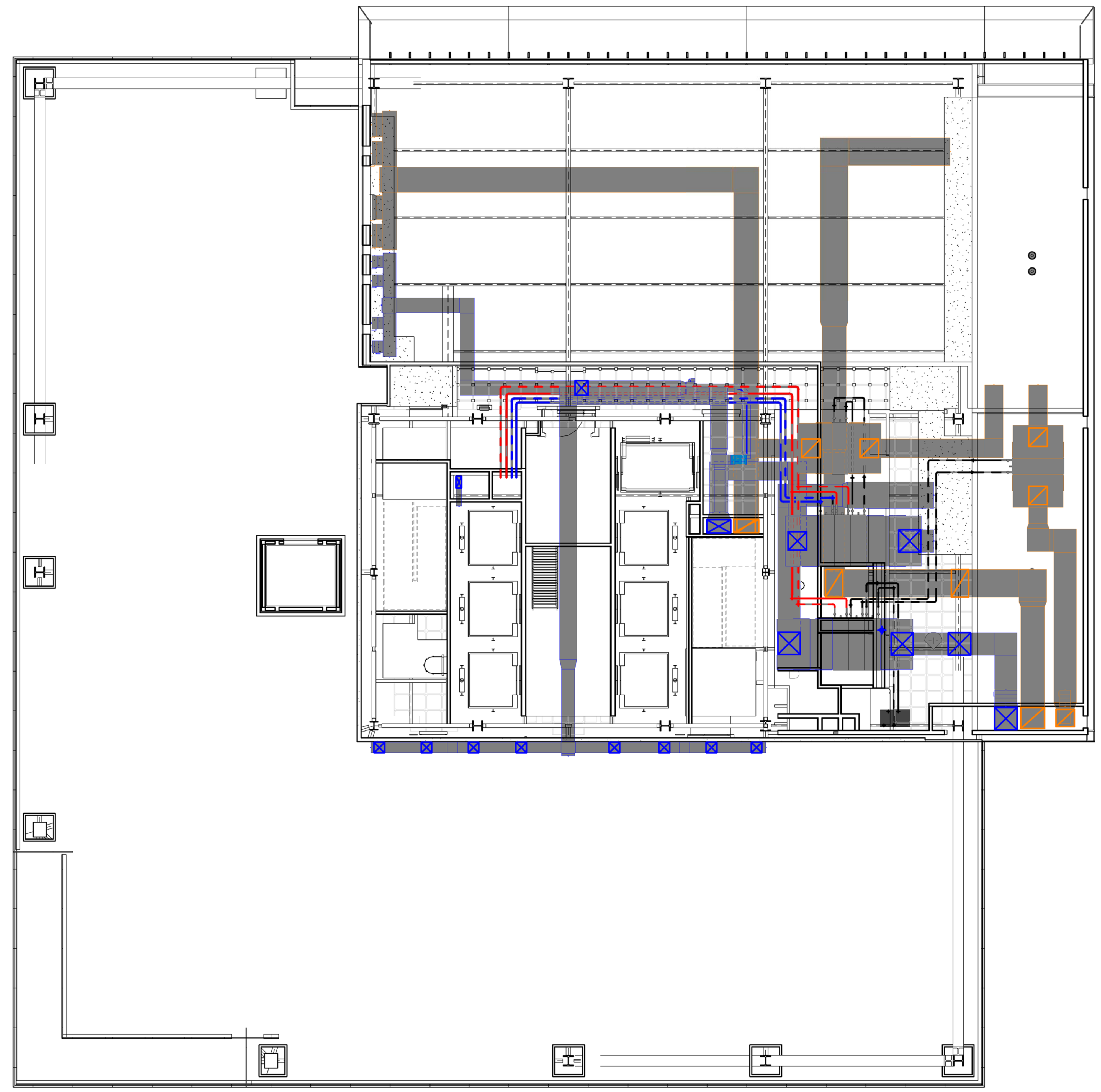
PURPOSE
ASCE STUDENT COMPETITION
AEI 2 - 2014

DRAWING TITLE
MECHANICAL - OFFICE FLOOR PLAN AIR SIDE PLAN

SCALE: 1/8" = 1'-0"
JOB NUMBER: 350 MISSION
DATE: 02/17/2014
DRAWN BY: AEI TEAM 2
SHEET NUMBER: M2



1 01 - Lobby
1/8" = 1'-0"



2 02 - Upper Lobby
1/8" = 1'-0"

DRAWING NOTES:

A. VENTILATION AIR ARRANGED TO BE UNOBTRUSIVE TO PRESERVE THE ARCHITECTURE OF THE SPACE

B. LOBBY SPACE IS ZONED SEPARATELY FROM THE RETAIL AND ELEVATOR SPACES.

C. FIRE COMMAND CENTER DUCTS HAVE FIRE DAMPERS AS SPECIFICED BY THE CALIFORNIA FIRE CODE

DRAWING NOTES:

A. TO MAINTAIN A BALANCE WITH THE OPEN CORNER TO AMBIENT CONDITIONS, PRESSURIZATION AIR IS SUPPLIED VIA THE LOWER OFFICE FLOORS

B. 14200 CFM SUPPLIED TO THE LOBBY TO MAINTAIN IAQ AND VENTILATION STANDARDS

C. RESTAURANT TENTATIVELY DESIGNED FOR 11040 CFM BASED ON INITIAL LOAD ACCOUNTING

PROJECT

AEI STUDENT COMPETITION
350 Mission Street, San Francisco, CA

PURPOSE

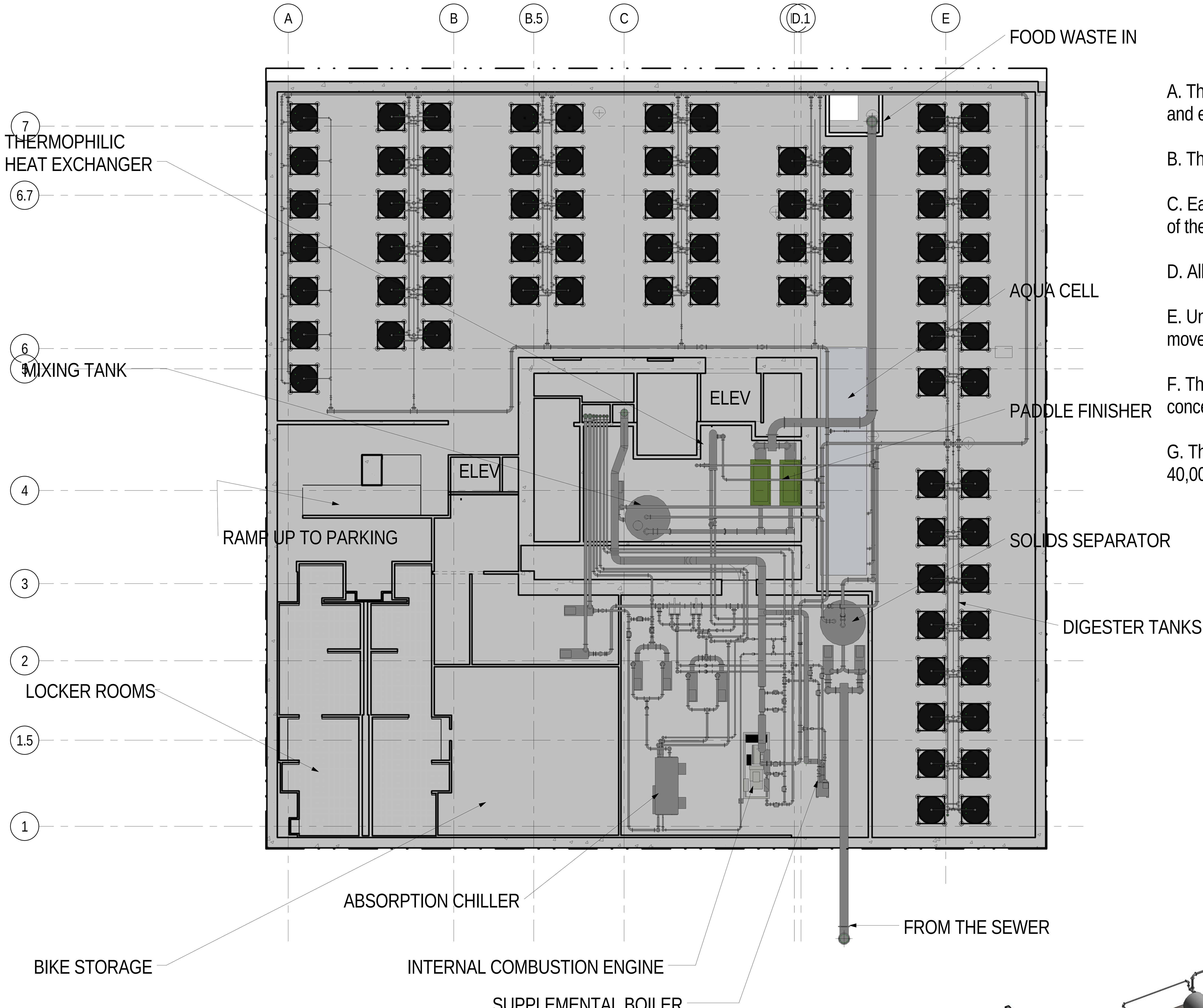
ASCE | STUDENT COMPETITION

AEI 2 - 2014

DRAWING TITLE

MECHANICAL - LOBBY AIR SIDE PLAN

SCALE:	1/8" = 1'-0"
JOB NUMBER:	350 MISSION
DATE:	02/17/2014
DRAWN BY:	TEAM 2
SHEET NUMBER:	M3



1 M4 MECHANICAL - BASEMENT LEVEL B4
1" = 10'-0"

A. The BioMethane Plant is designed to create 73,000 cubic feet of methane per day, supplying thermal and electric energy to the building

B. The plant contains 77 tanks which are 25,000 gal each

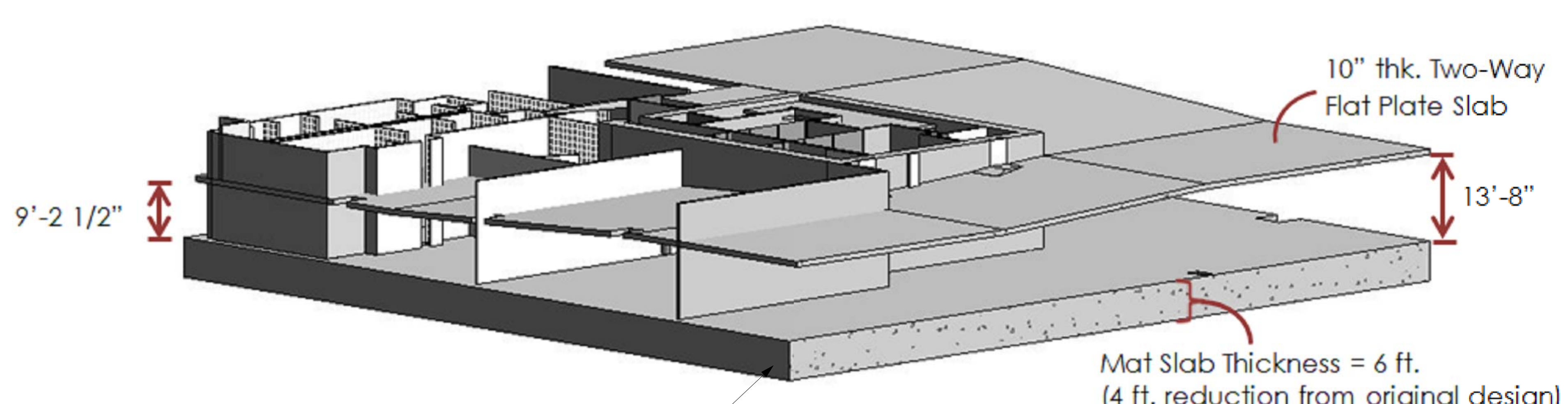
C. Each row in between each tank is designed such that the tanks are able to be removed and carried out of the service elevator for off-site maintainence

D. All pipes are located high enough for the code-required 7' 6" clearance

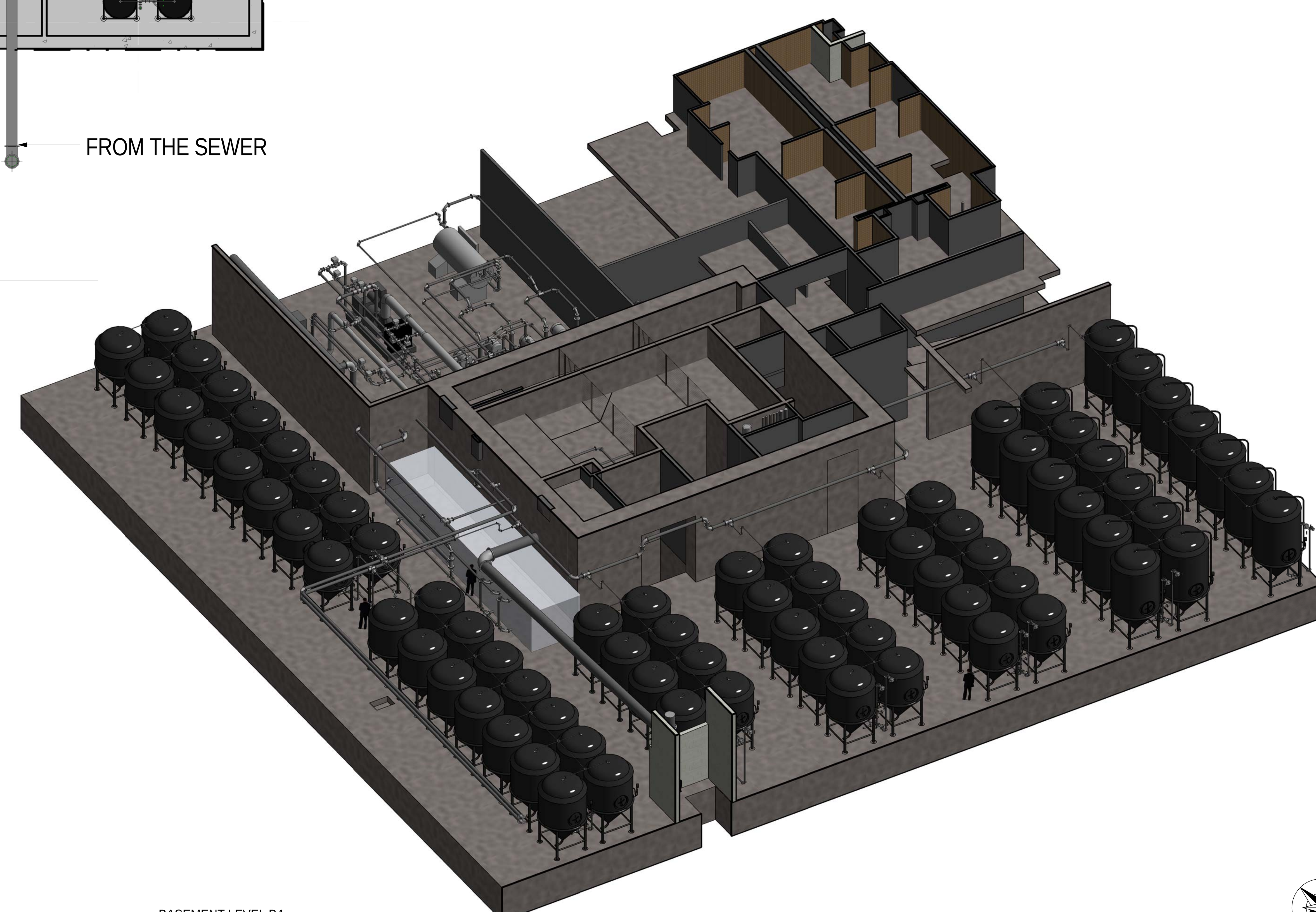
E. Un-pumped pipes such as the food waste and sewage pipes are sloped in order to allow for gravity to move the transport medium

F. The basement exhaust system is capable of removing 37,500 CFM of air in order to keep the methane concentration below 1,000 ppm

G. The exhaust fans have an alarm relay which ramps up capacity in the event that methane levels reach 40,000 ppm in order to avoid reaching the lower limit of methane's flammability range (50,000 ppm)



ISOMETRIC VIEW ILLUSTRATING
THE ADDITIONAL VOLUME GAINED
BY INCREASING THE FLOOR-TO-CEILING
HEIGHT



2 M4 BASEMENT LEVEL B4
ISOMETRIC

PROJECT

AEI STUDENT COMPETITION
350 Mission Street, San Fransisco, CA

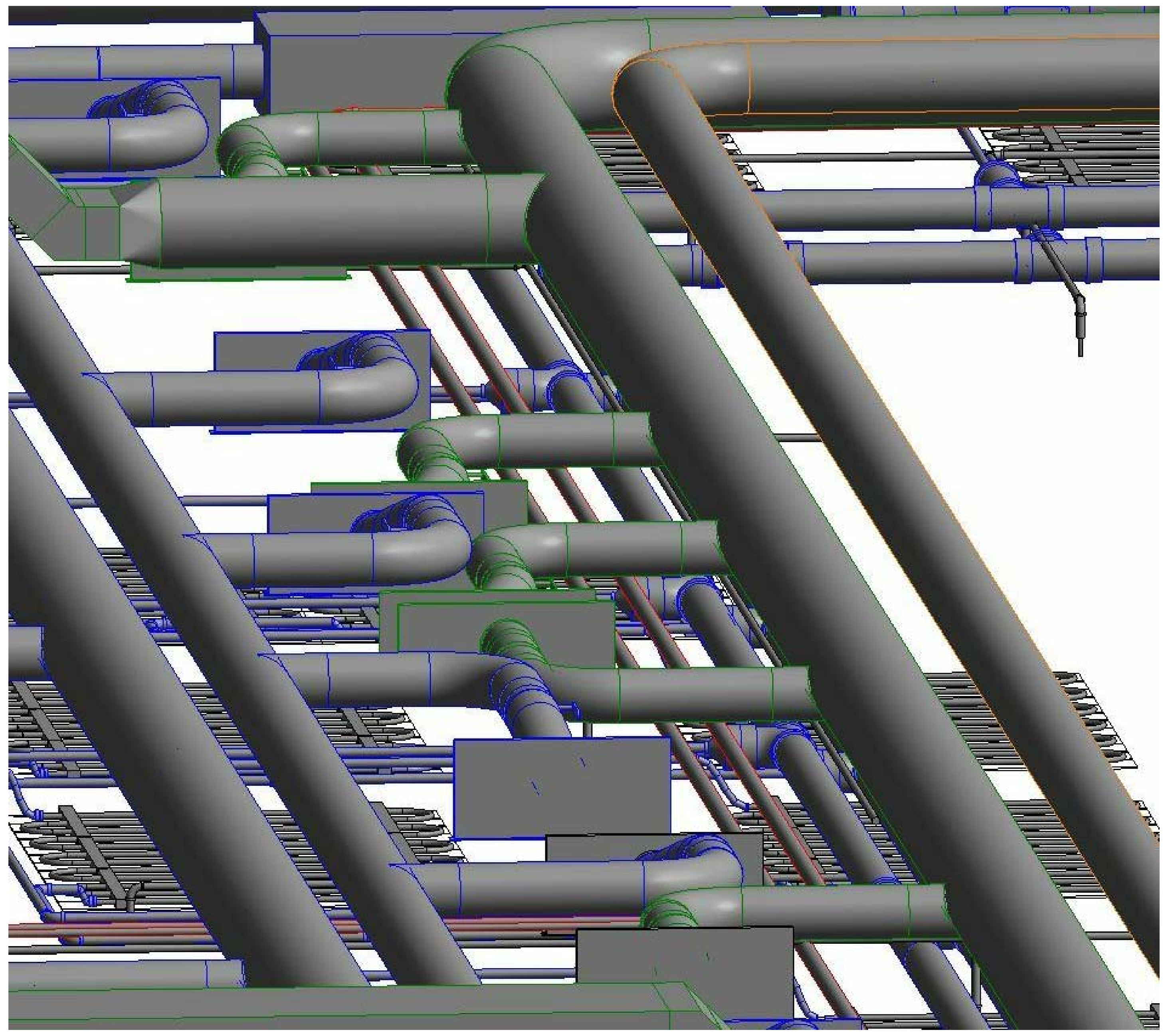
PURPOSE

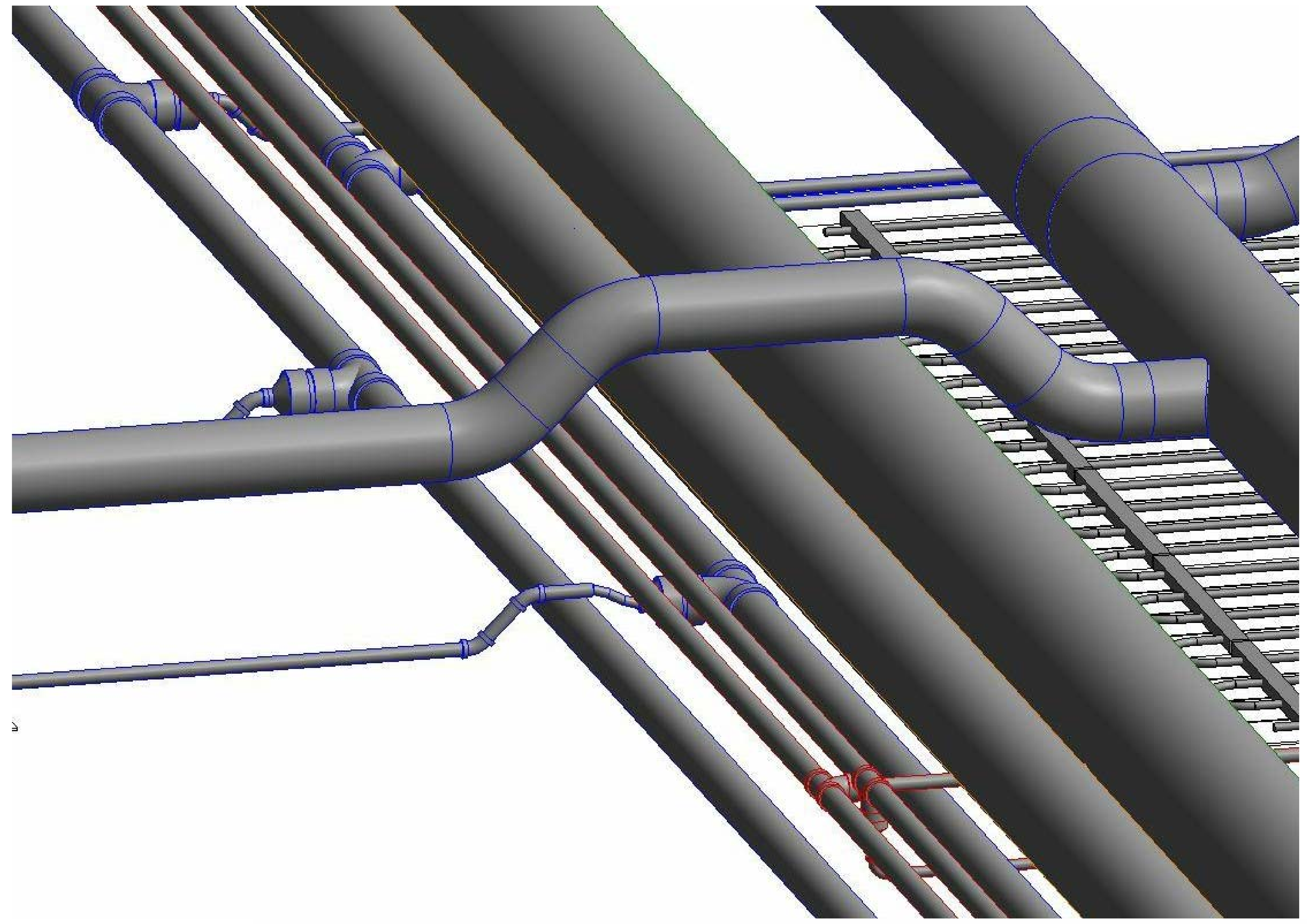
ASCE | STUDENT COMPETITION
AEI 2 - 2014

DRAWING TITLE

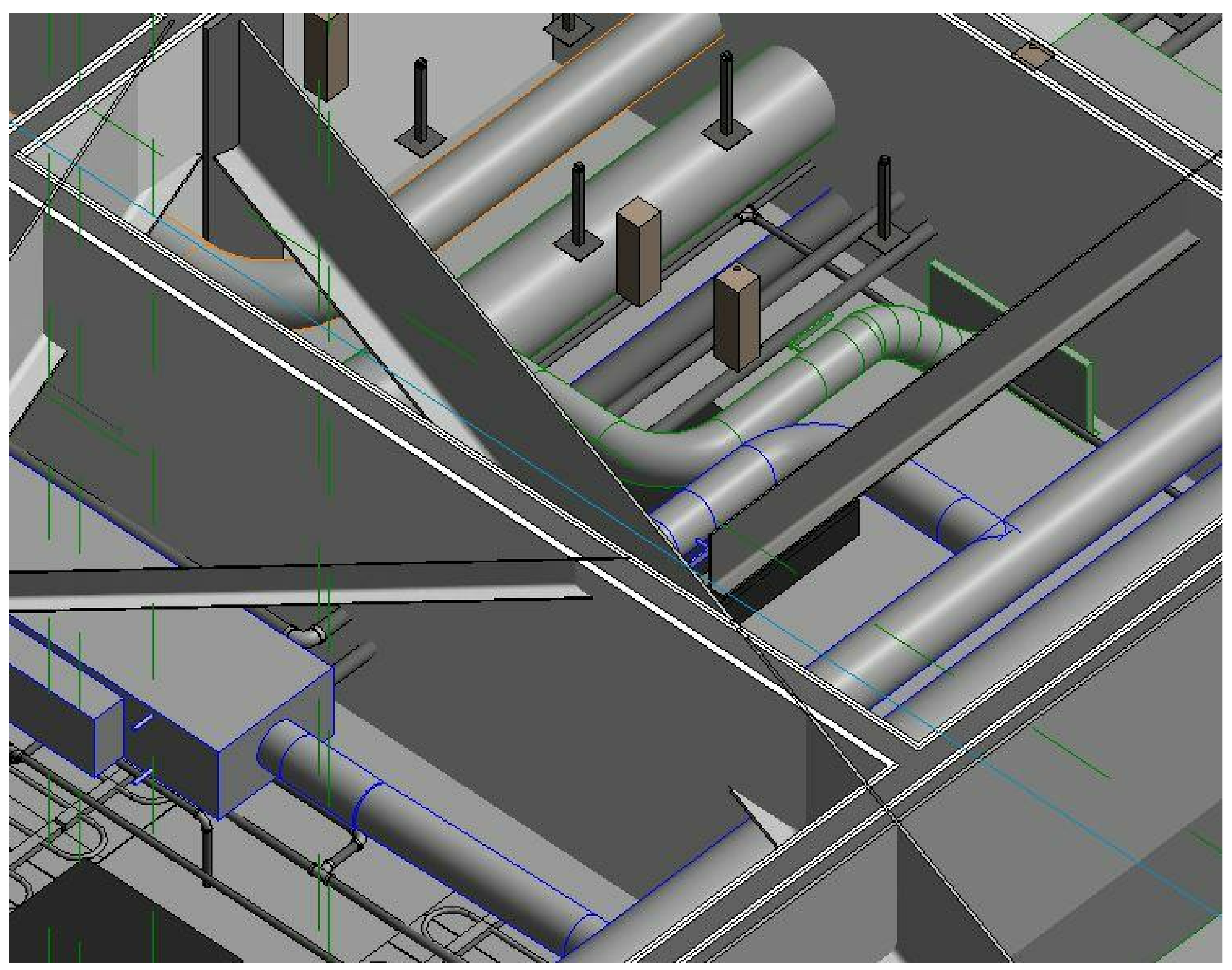
MECHANICAL -
BIOMETHANE
PLANT

SCALE:	1" = 10'-0"
JOB NUMBER:	350 MISSION
DATE:	02/17/2014
DRAWN BY:	AEI 2 - 2014
SHEET NUMBER:	M4

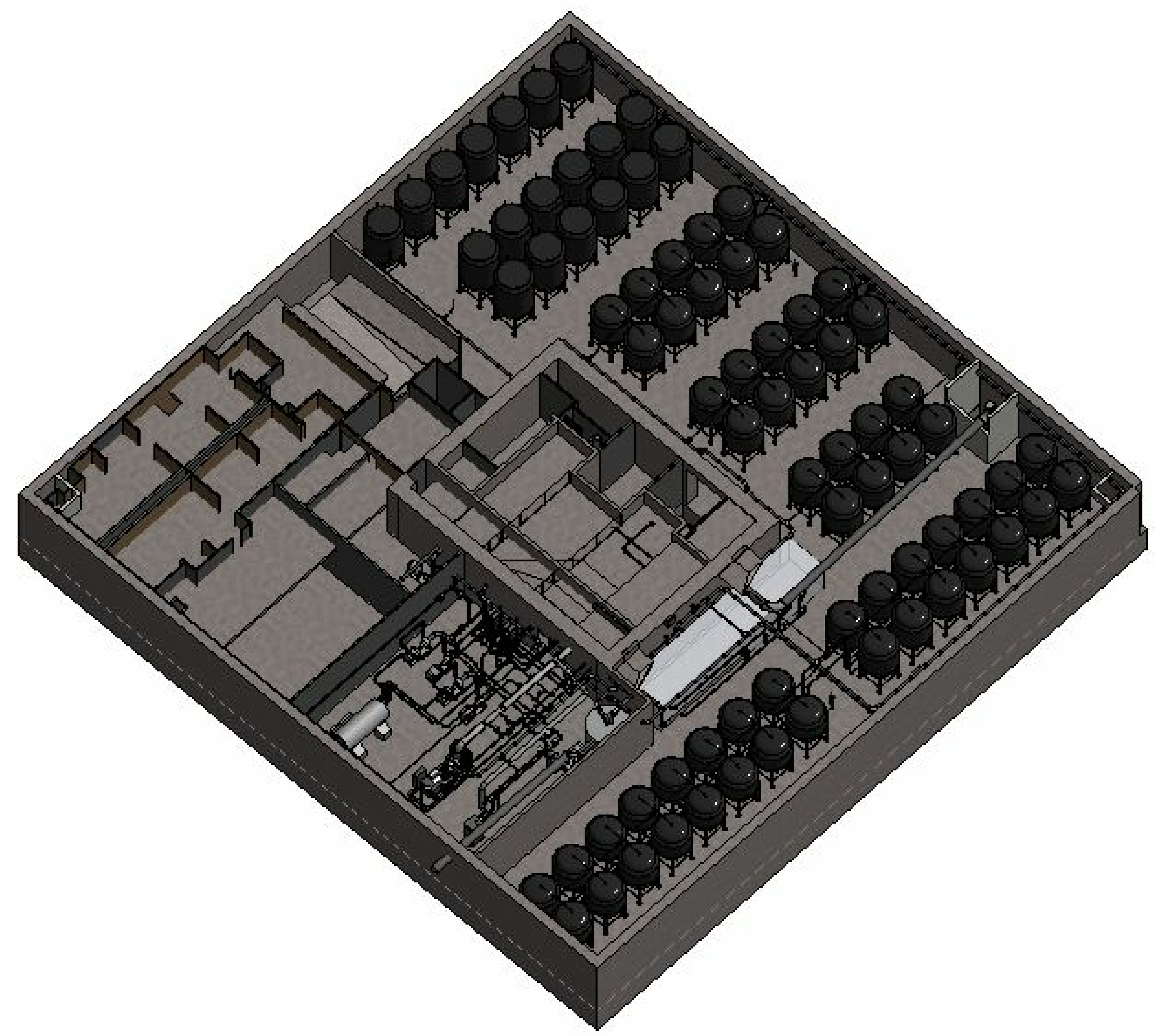




DRAWING NOTES:
A. MEP CLASH DETECTION WAS AN INTEGRAL COLLABORATION AREA WHEN DESIGNING THE OFFICE FLOOR
B. PIPING, DUCTWORK STRUCTURAL FRAMING AND LIGHTING/ELECTRICAL EQUIPMENT WERE THE MAIN ITEMS THAT WERE DETAILED COORDINATION EFFORTS.



DRAWING NOTES:
A. MANY AREAS LOCATED NEAR THE CORE REQUIRED COORDINATION AROUND STRUCTURAL BRACING ELEMENTS



DRAWING NOTES:
A. THE BIOMETHANE PLANT WAS A LARGE DESIGN UNDERTAKING. MANY DIFFERENT DESIGN CHOICES ACROSS THE DISCIPLINES WERE DECIDED UPON TO CREATE THE SPACE AND PIPING NETWORK NECESSARY TO ALLOW THE PLANT TO FUNCTION.

PROJECT
AEI STUDENT COMPETITION
350 Mission Street, San Francisco, CA

PURPOSE
ASCE | STUDENT COMPETITION
AEI 2 - 2014

DRAWING TITLE
MECHANICAL - MEP COORDINATION

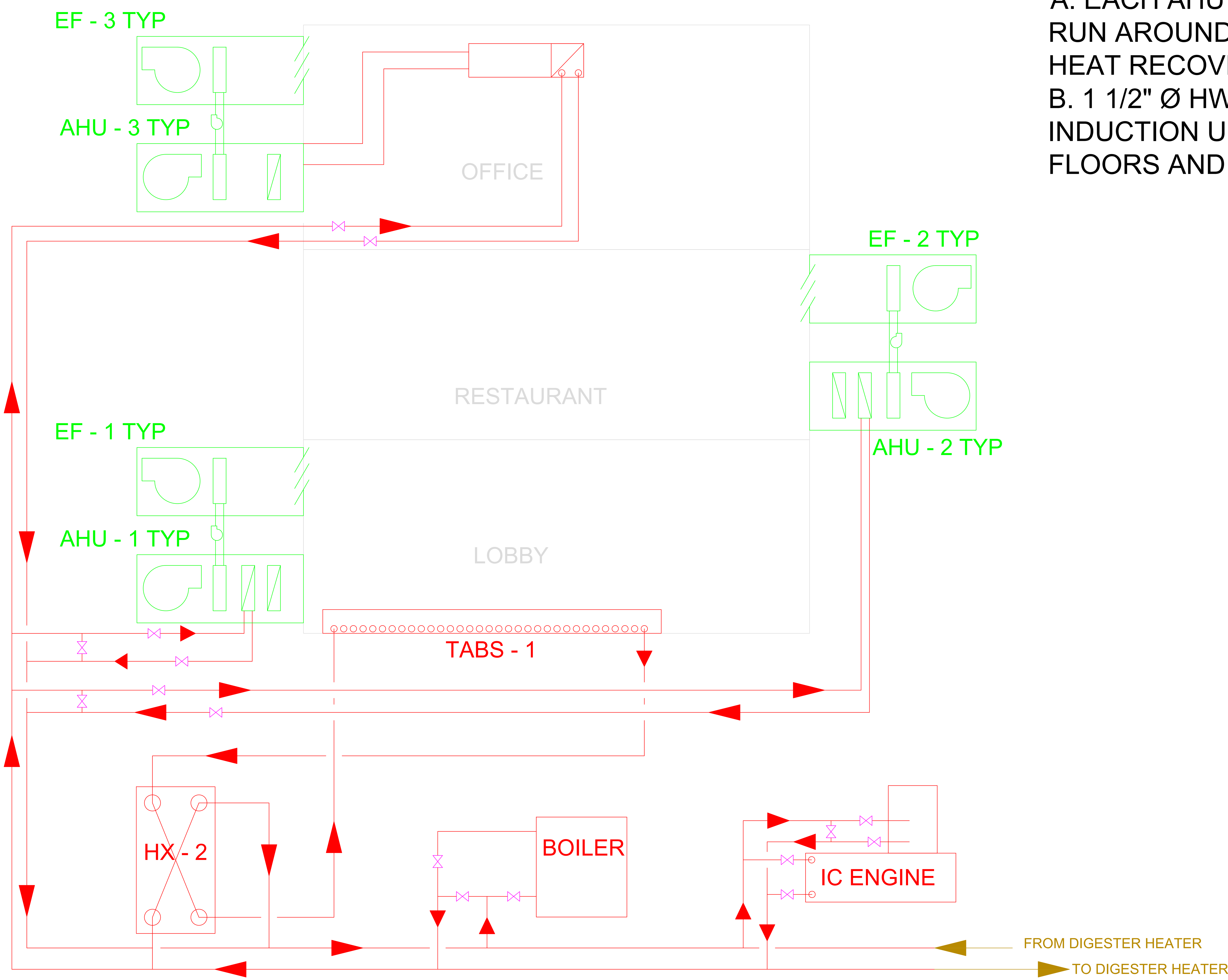
SCALE:

JOB NUMBER: 350 MISSION

DATE: 02/17/2014

DRAWN BY: TEAM 2

SHEET NUMBER:
M5



DRAWING NOTES:

A. EACH AHU IS DESIGNED WITH A RUN AROUND COIL TO MAXIMIZE HEAT RECOVERY

B. 1 1/2" Ø HW LOOP SERVES THE INDUCTION UNITS IN THE OFFICE FLOORS AND AHU'S

PROJECT

AEI STUDENT COMPETITION
350 Mission Street, San Francisco, CA

PURPOSE

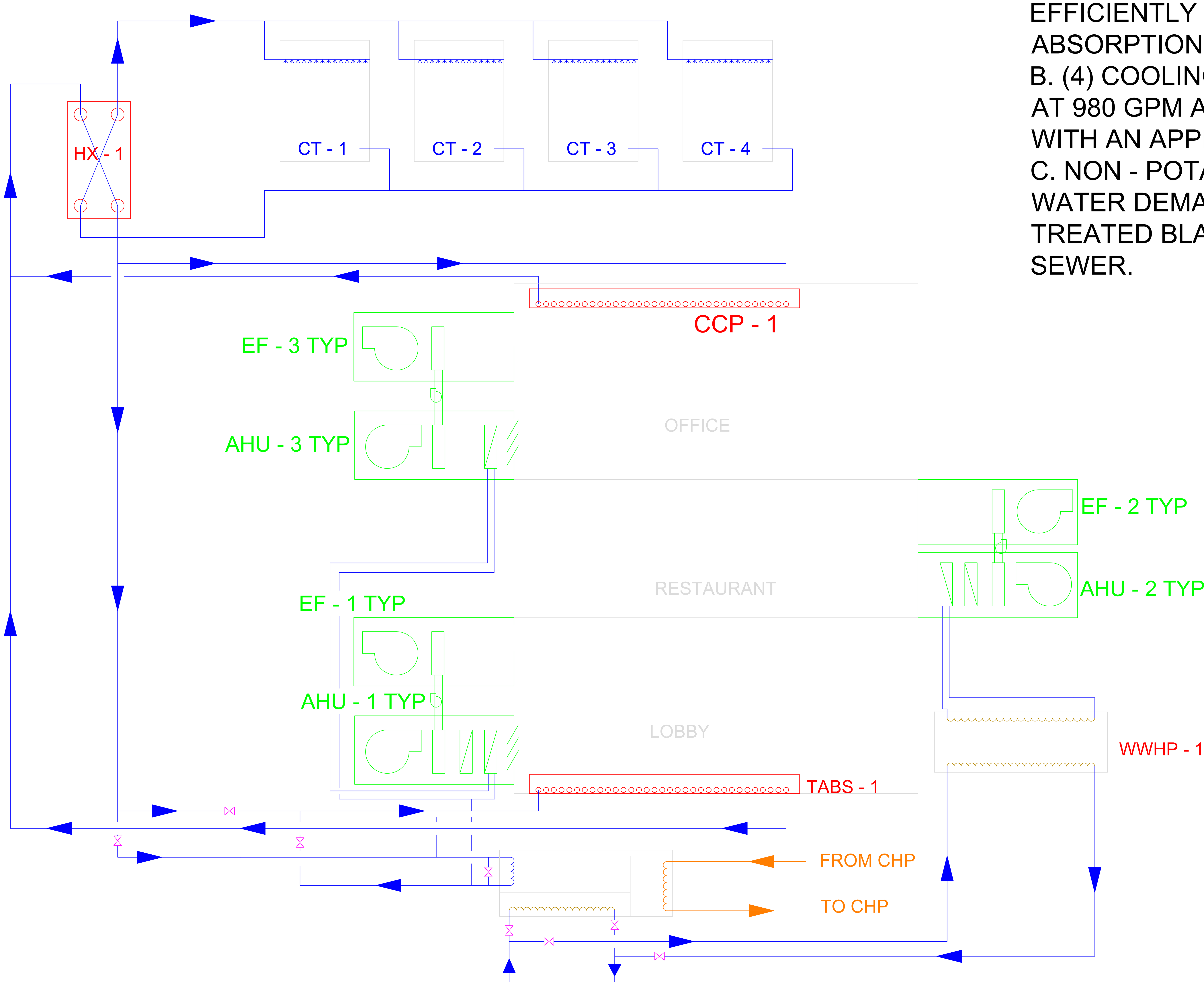
ASCE STUDENT COMPETITION

AEI 2 - 2014

DRAWING TITLE

HW SCHEMATIC

SCALE:	N/A
JOB NUMBER:	350 MISSION
DATE:	02/17/2014
DRAWN BY:	AEI 2 - 2014
SHEET NUMBER:	M6



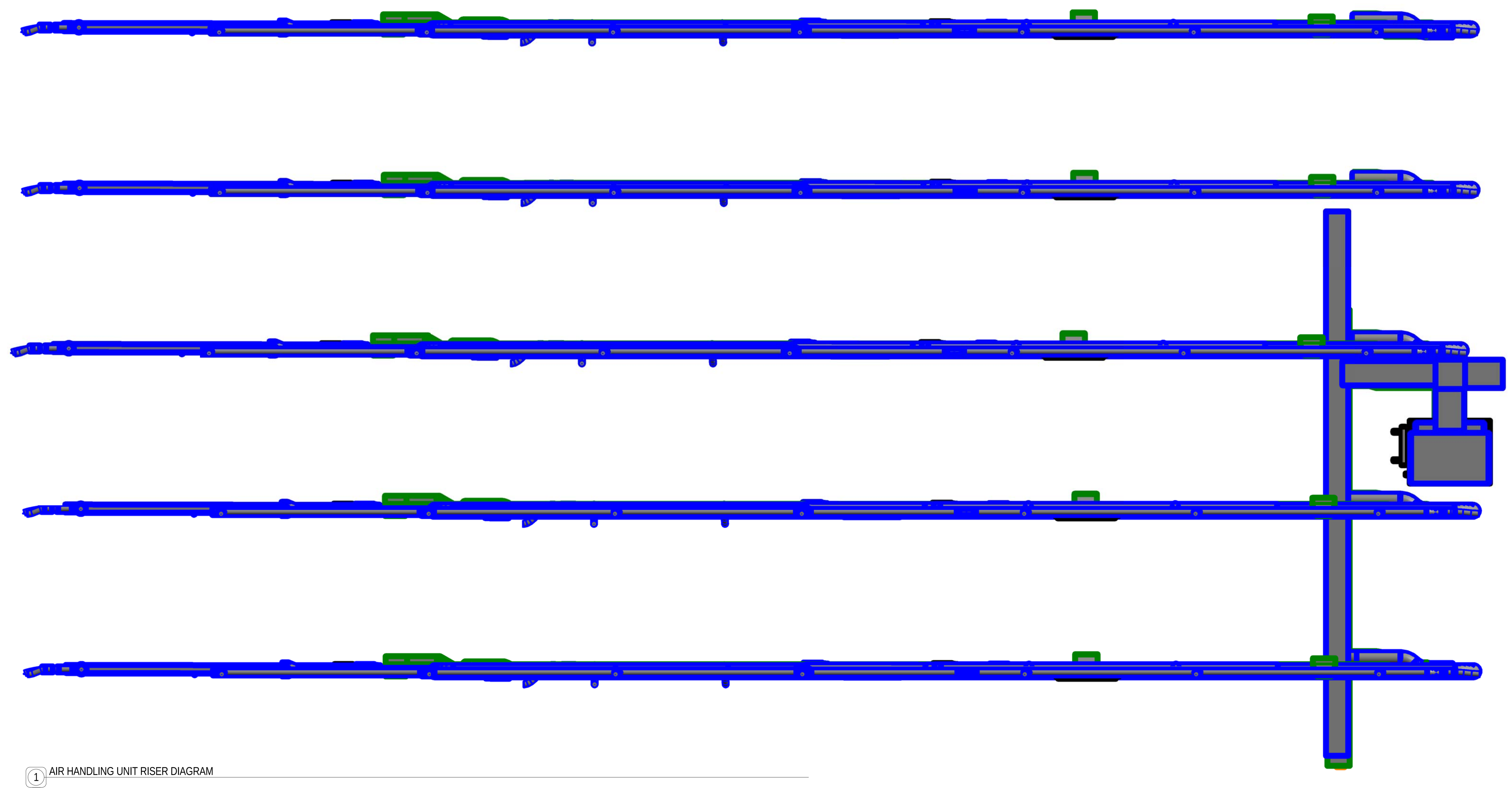
DRAWING NOTES:
A. RADIANT PANELS OPERATING ON EVAPORATIVE COOLING ALLOW COOLING TOWERS TO OPERATE EFFICIENTLY ALONGSIDE AN ABSORPTION CHILLER
B. (4) COOLING TOWERS OPERATE AT 980 GPM AND A RANGE OF 3°F WITH AN APPROACH OF 65 °F
C. NON - POTABLE AND HYDRONIC WATER DEMAND IS MET BY THE TREATED BLACKWATER FROM THE SEWER.

PROJECT
AEI STUDENT COMPETITION
350 Mission Street, San Francisco, CA

PURPOSE
ASCE STUDENT COMPETITION
AEI 2 - 2014

DRAWING TITLE
CHW SCHEMATIC

SCALE:	N/A
JOB NUMBER:	350 MISSION
DATE:	02/17/2014
DRAWN BY:	AEI 2 - 2014
SHEET NUMBER:	M7



1 AIR HANDLING UNIT RISER DIAGRAM

DRAWING NOTES:

A. 18875 CFM DOAS AIR HANDLING UNIT SERVES 5 TYPICAL OFFICE FLOORS REQUIRING 3775 CGM EACH

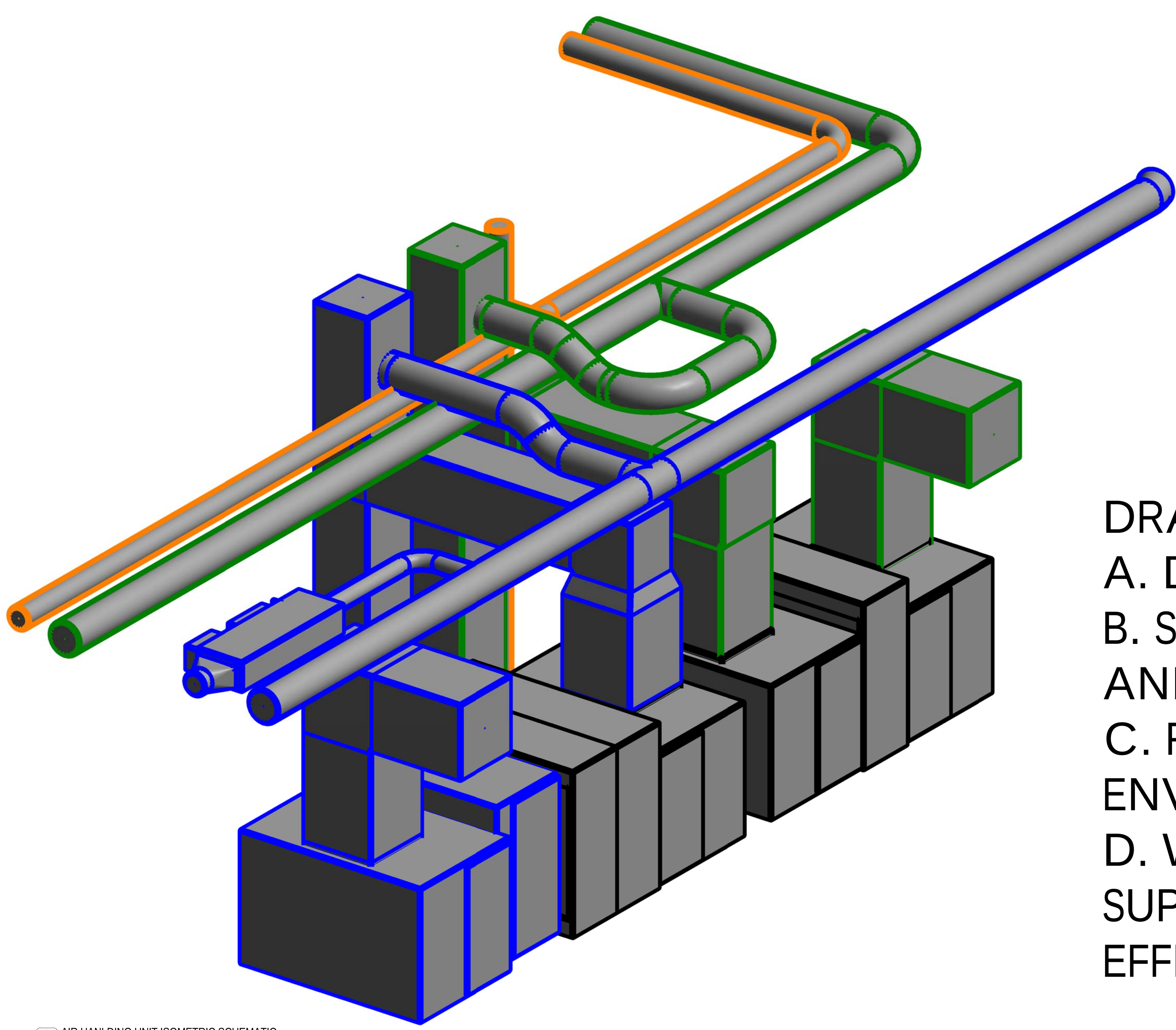
B. 24" X 22" SA MAIN

C. 24" X 22" RA MAIN

D. EACH UNIT SUPPLIES LINEAR DIFFUSERS ON EACH FLOOR THAT OA TO THE PERIMETER AND CORE ZONES

ABOVE. 3D AXIAL VIEW OF A TYPICAL 5 FLOOR SETUP WITH AN AIRHANDLING LOCATED ON THE CENTRAL FLOOR OF THE 5 FLOOR ARRANGEMENT

LEFT. 3D ISOMETRIC OF THE AIR HANDLING UNIT CONNECTING TO THE RISERS AND THE DUCT SYSTEMS ON A TYPICAL FLOOR



2 AIR HANDLING UNIT ISOMETRIC SCHEMATIC

DRAWING NOTES:

A. DOAS UNIT HAS TWO SEPARATE SECTIONS

B. SUPPLY SECTION TAKES IN OA AND HAS A FILTER AND COILS TO CONDITION THE AIR.

C. RETURN SECTION EXHAUSTS THE AIR TO THE ENVIRONMENT

D. WRAP AROUND COIL TRANSFERS HEAT BETWEEN THE SUPPLY AND RETURN SECTIONS TO MAXIMIZE ENERGY EFFICIENCY

PROJECT

AEI STUDENT COMPETITION
350 Mission Street, San Francisco, CA

PURPOSE

ASCE | STUDENT COMPETITION

AEI 2 - 2014

DRAWING TITLE

MECHANICAL - AIR HANDLING UNIT DISTRIBUTION

SCALE:

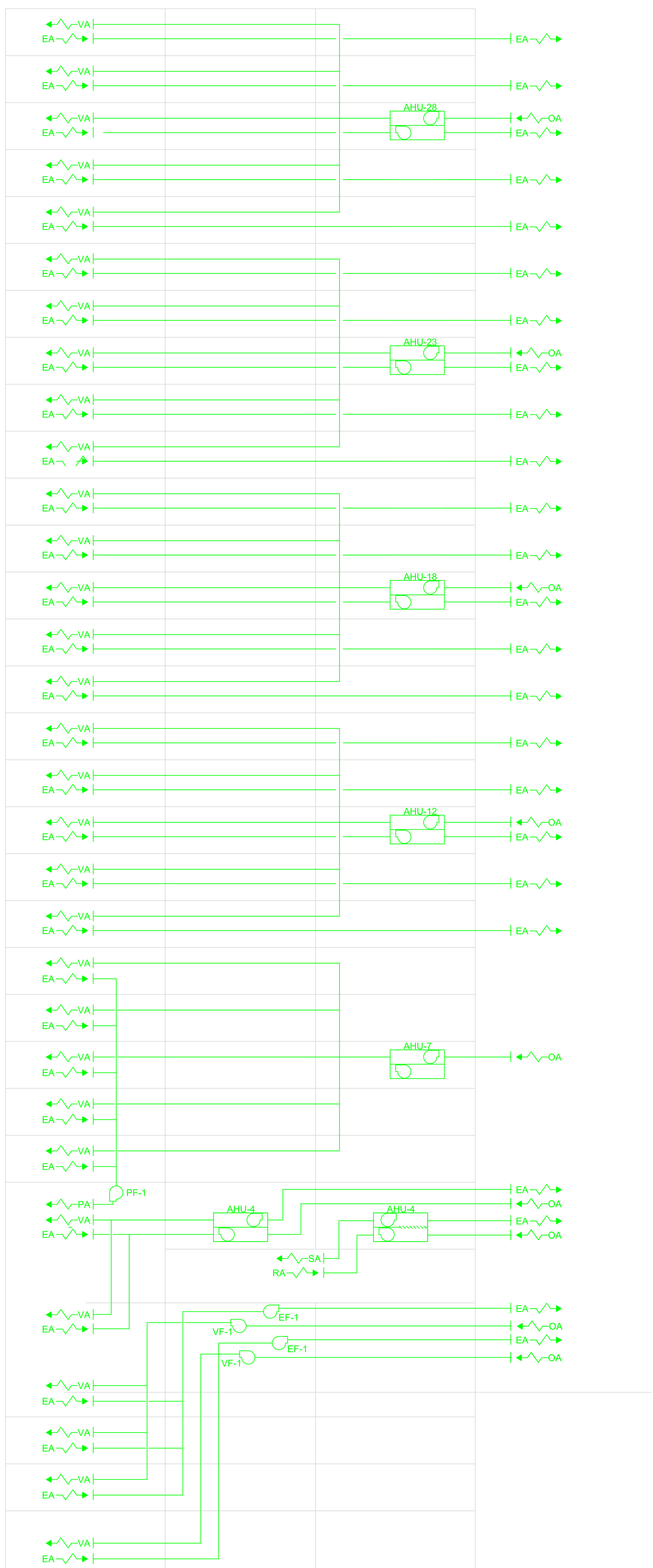
JOB NUMBER: 350 MISSION

DATE: 02/17/2014

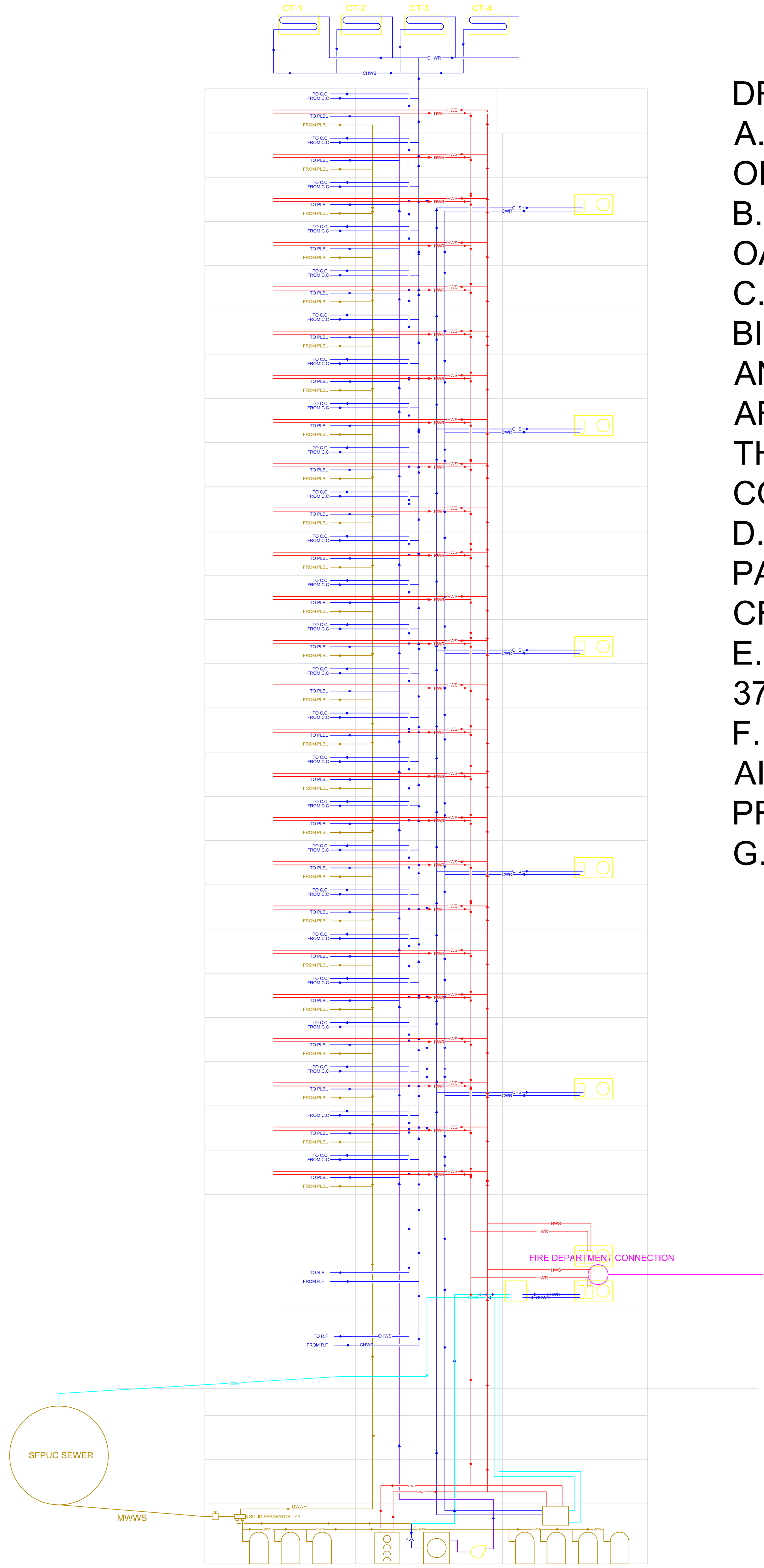
DRAWN BY: AEI 2 - 2014

SHEET NUMBER:

M8



AIR RISER



MECHANICAL WATER RISER

DRAWING NOTES:

A. 1 AHU SERVES FIVE TYPICAL OFFICE FLOORS
B. DOAS UNITS ALLOW FOR 100% OA
C.THE PARKING GARAGE, BIOMETHANE PLANT, RESTAURANT AND OTHER APPRORIATE AREAS ARE EXHAUSTED ACCORDING TO THE CALIFORNIA MECHANICAL CODE
D. THE BIOMETHANE PLANT AND PARKING GARAGE REQUIRE 14200 CFM OF SA
E. THE OFFICE FLOORS REQUIRE 3775 CFM OF SA PER FLOOR
F. THE FIRST OFFICE AHU RETURNS AIR TO THE LOBBY TO AID IN THE PRESSURIZATION OF THE SPACE
G. 15" Ø CHW MAIN RISER

PROJECT

AEI STUDENT COMPETITION
350 Mission Street, San Francisco, CA

PURPOSE

AEI 2 - 2014

DRAWING TITLE

AIRSIDE AND HYDRONIC RISERS

SCALE: N/A

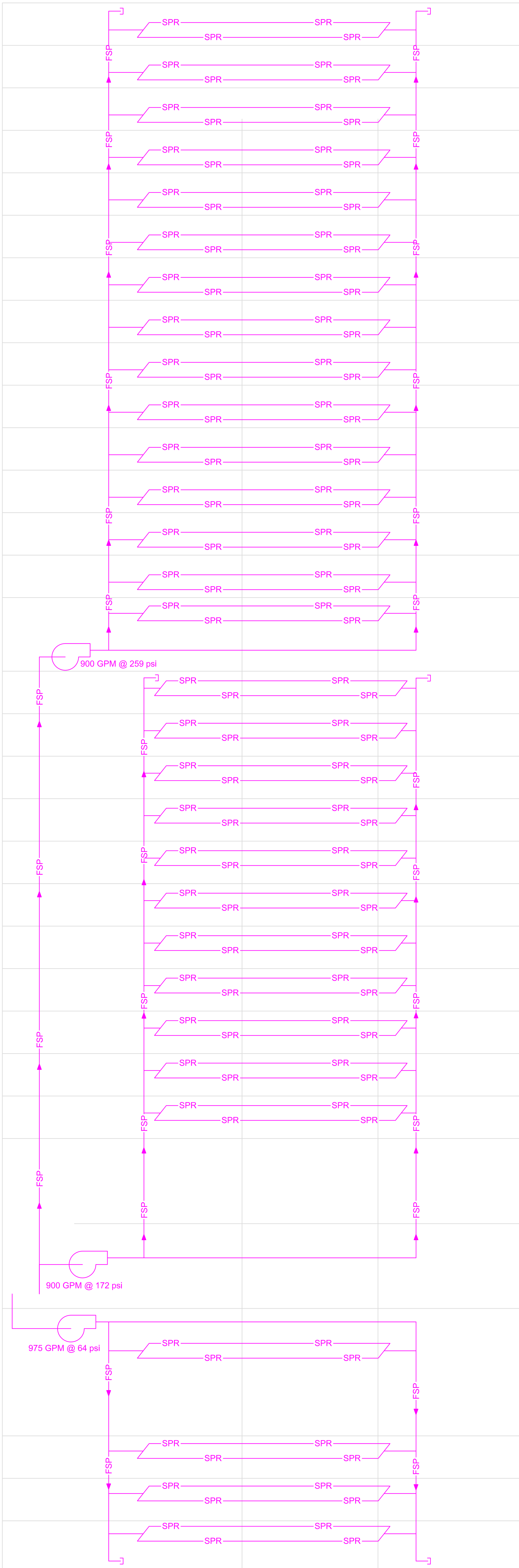
JOB NUMBER: 350 MISSION

DATE: 02/17/2014

DRAWN BY: AEI 2 - 2014

SHEET NUMBER:

M9



FIRE SUPPRESSION WATER RISER

PLUMBING/SANITARY RISER

DRAWING NOTES:

A. 3 FIRE PUMPS SERVICE DIFFERENT AREAS OF THE BUILDING, EACH RATED AT A DIFFERENT GPM AND PSI AS NECESSARY

B. AUTOMATIC SPRINKLER SYSTEMS ARE INSTALLED ON EACH FLOOR

C. 6" Ø MAIN PLUMBING RISER SERVES EACH FLOOR, A SANITARY AND VENT LINE BRINGS THE WASTE BACK TO THE BIOMETHANE PLANT TO BE PROCESSED

D. OFFICE FLOOR STANDPIPES 8" Ø, PARKING GARAGE 10" Ø

E. (4) 5" ROOF DRAINS COLLECT SURFACE RUNOFF AND STORE IN A RAINWATER COLLECTION TANK TO BE USED FOR NON-POTABLE PURPOSES.

PROJECT

AEI STUDENT COMPETITION
350 Mission Street, San Francisco, CA

PURPOSE

ASCE STUDENT COMPETITION

AEI 2 - 2014

DRAWING TITLE

FIRE PROTECTION AND PLUMBING RISER DIAGRAMS

SCALE: N/A

JOB NUMBER: 350 MISSION

DATE: 02/17/2014

DRAWN BY: AEI 2 - 2014

SHEET NUMBER:

M10