

## Mechanical Systems Project Proposal



Straumann USA  
Andover, MA

December 15, 2006

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## **1.0 Executive Summary**

The Straumann USA renovation project featured the replacement of the airside systems of the facility while using the existing heating and cooling central plants of the building. Ten rooftop units serve a variety of spaces including manufacturing areas, offices, an auditorium, and dental operatory suites. The project was designed to comply with the requirements of the Massachusetts State Building Code 780 CMR.

The main goal of the proposed redesign is to take a different approach in designing the mechanical system for the Straumann USA facility while striving to reduce energy consumption. This redesign does not imply that there were flaws in the original design, or that another alternative should have been pursued, it is for educational purposes only.

The proposed mechanical system redesign is to replace the existing VAV system with a combination dedicated outdoor air system (DOAS) with a parallel radiant cooling system. The DOAS system will supply ventilation air and meet any latent loads, while the parallel radiant system will provide any additional sensible cooling needed. The mechanical redesign will also include comparing a direct-fire absorption chiller, with a centrifugal electric chiller to determine which would be the best selection for the central cooling plant.

The electrical breadth proposes to resize any electrical equipment that is effected by the mechanical redesign. The electric requirements of the DOAS air-handlers are less than those of the VAV units. A direct-fire absorption chiller would also reduce the electric requirements for the building resulting in some of the feeders, branch wiring, over current protection devices and panel boards needing resized.

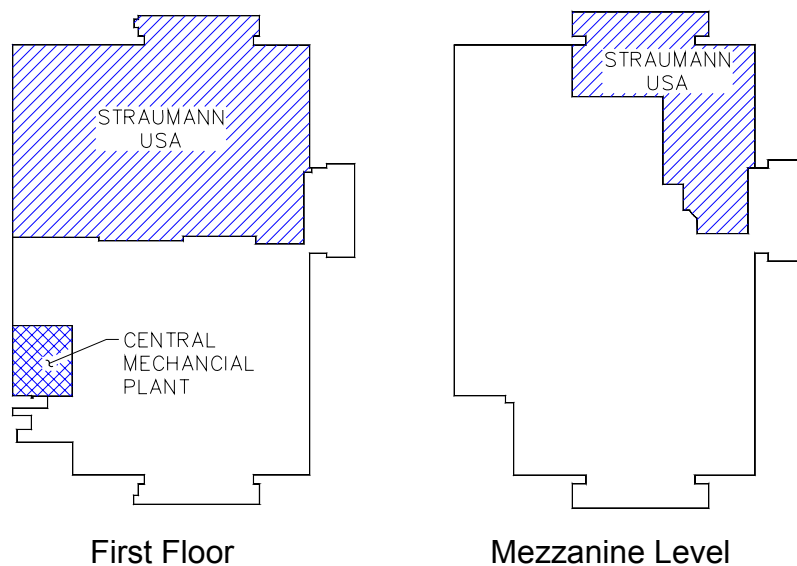
The construction breadth proposes to perform a detailed first cost analysis between the VAV and DOAS systems as well as the two different types of chillers. Impacts on the schedule will also be considered for each system. There will be a significant difference in required materials for the VAV and DOAS systems. The DOAS system will require radiant panels, and more copper piping , while the VAV system uses a larger amount of ductwork and supply diffusers.

In order to carry out the proposed redesigns several methods will be used. Carrier's Hourly Analysis Program (HAP) will be used to calculate loads for the mechanical systems as well as yearly energy costs. For the electrical redesign, the National Electric Code will be used as a reference. Resources such as sales representative quotes, RS Means, and CostWorks will be utilized to calculate initial costs.

Overall, regardless of the final outcomes, the redesigns will be a very valuable educational experience.

## **2.0 Building Background**

The Straumann USA facility is located in Andover Massachusetts. Straumann USA occupies close to half of the 100 Minuteman building. The entire building is 327,000 square feet and is owned by The Brickstone Companies. It is a two-story building with first floor and mezzanine levels. The Straumann facility occupies 153,000 square feet and is separated from the rest of the building by a firewall in order to comply with maximum floor area codes. The areas of the building Straumann USA occupies can be seen below in Figure 2.1.



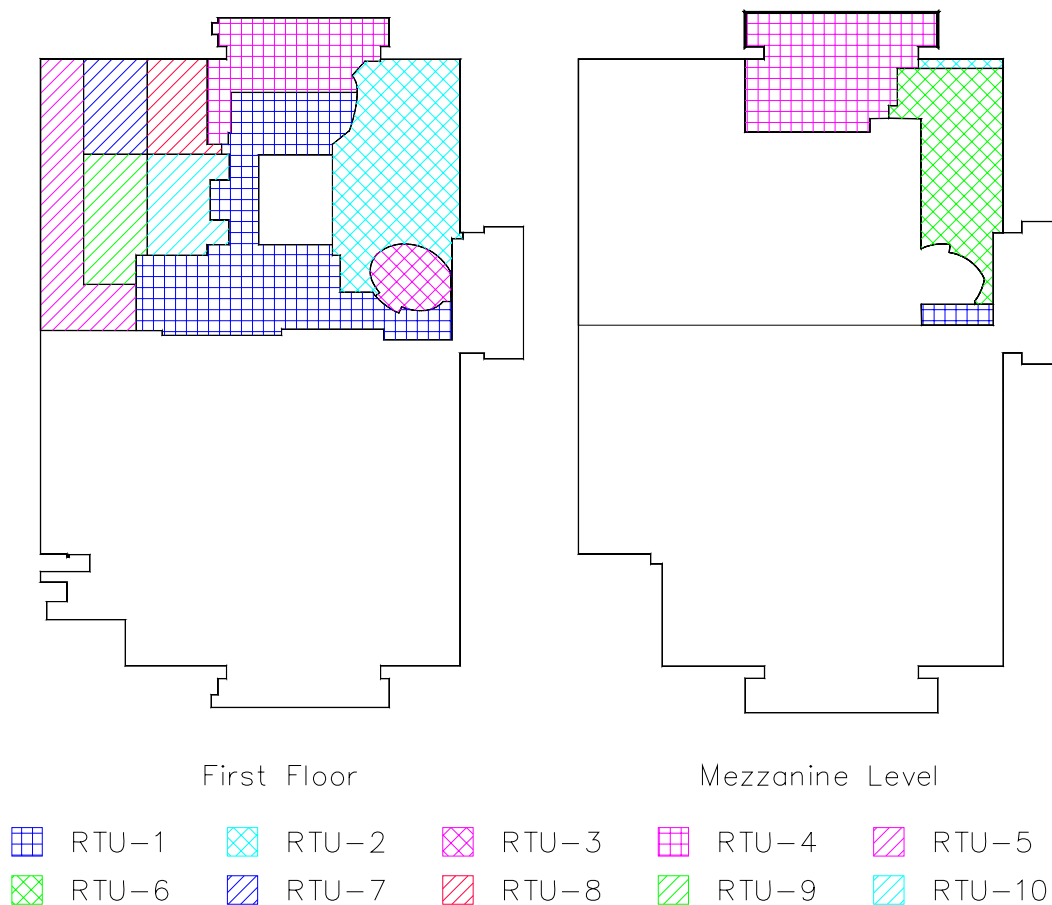
**Figure 2.1 – Straumann USA Occupancy Locations**

The Straumann USA facility includes a variety of spaces. It is largely a combination office and light manufacturing building. However, other unique spaces include a dental operatory suite, a dental training room, and an auditorium seating up to 95 people.

Straumann USA is served by 10 rooftop air handling units. Nine of the units are variable air volume ranging from 21,000 cfm to 33,000 cfm at design conditions and the tenth unit that serves the auditorium area is a 6,400 cfm constant air volume unit. All 10 of the units condition air with a chilled water cooling coil and a steam heating coil. Table 2.1 breaks down the type of areas each rooftop unit serves and lists the size of each unit. Figure 2.2 displays the location of each zone within the building.

Rooftop Unit Summary				
	Max CFM	Number of People per Unit	Square Feet Served	Areas Served
RTU-1	33,000	126	27,139	First floor manufacturing support areas and mezzanine level server room
RTU-2	33,000	248	19,968	First floor office and dental operatory areas
RTU-3	6,400	151	3,303	First floor auditorium
RTU-4	33,000	204	20,602	First floor and mezzanine office areas
RTU-5	21,000	81	11,126	First floor manufacturing support areas
RTU-6	21,000	118	17,326	Mezzanine office areas
RTU-7	33,000	20	5,850	Manufacturing area
RTU-8	33,000	20	5,850	Manufacturing area
RTU-9	33,000	20	5,850	Manufacturing area
RTU-10	33,000	20	5,850	Manufacturing area

**Table 2.1 – Spaces Served by Each Rooftop Air Handling Unit**



**Figure 2.2 – Rooftop Air-Handling Unit Zones**

The central plant produces building chilled water and steam for the entire building, not just the Straumann USA facility. Figure 2.1 shows the location of the central plant in the building. The central plant includes three water-cooled electric centrifugal chillers of 750, 500, and 350 tons. Heat is rejected from the condenser water system with two cooling towers of 680 and 750 tons. The system is equipped with a waterside free cooling mode that directly rejects heat from the chilled water loop to the condenser water loop by using a plate heat exchanger. High pressure steam is produced for the building by two 11.7MBH fuel oil or natural gas fired boilers. Steam is then reduced to a lower pressure (15psi) and routed to the heating coils in the rooftop units. A shell and tube heat exchanger uses the steam to heat the building hot water used by the fintube radiators at the perimeter of the building.

Several design considerations were taken into account during the renovation of the Straumann USA facility. Interior spaces were designed to fall within the comfort region of Standard 55.1-2004. The project was also designed to comply with the requirement of the Massachusetts State Building Code 780 CMR. Since the central plant systems were existing several assumptions were made with regard to the supply conditions. Building chilled water was designed assuming the at 7°F  $\Delta T$ . The building hot water system was designed with supply and return temperatures of 228°F and 180°F respectively. The rooftop units were designed with the assumption that 12psi steam would be available for the heating coils.

Exhaust systems were designed for the toilet room at a rate of 75cfm per fixture. Janitors closets would also be exhausted at rate of 6 air changes per hour. The manufacturing area would be equipped with a general exhaust to prevent excessive temperatures. The final area to be provided with exhaust was the loading dock. It was designed with a dedicated exhaust of 6 air changes per hour with the makeup being drawn through the manufacturing area.

### **3.0 Proposal Objectives**

The main goal of this proposal is to take a different approach in the design of the mechanical system for the Straumann USA facility. The design should be one that strives to reduce energy consumption while still considering the effects on the first cost of the project. The redesign of the Straumann USA facility does not imply that there were flaws in the original design, or that another alternative should have been pursued. The redesign is strictly an educational tool required by the Department of Architectural Engineering at The Pennsylvania State University. The redesign demonstrates it is possible to pursue any number of potential designs, and that each one affects other systems of the building as well as the budget and schedule of the project. Any number of requirements including budget, life cycle costs, owner specific requirements, etc. can

affect the final design. Therefore, changing just one requirement, or priority could lead to a completely different design for the building.

## **4.0 Initial Considerations**

There are a large number mechanical systems that could be considered for the redesign of Straumann USA. The first considerations are based on the air side systems, followed the potential for the redesign of the waterside system.

### **Air Side**

The first alternative considered was a dedicated outdoor air system (DOAS). This type of a system only supplies enough ventilation air to meet the requirement of ASHRAE Standard 62.1. One advantage of such a system is smaller air handling can be used since less air needs conditioned. This also means that smaller fans would be required to supply the air to occupied spaces, and smaller fans require less energy. Less plenum space is also required since reduced air flow results in the use of smaller ductwork.

While a DOAS system supplies ventilation air to the building, it does not completely condition the building. A second parallel system must be installed in order to meet the cooling and/or heating needs of the building. Several parallel systems could be used with a DOAS system.

The first parallel system consideration was a radiant panel system. As the name states, this type of system uses ceiling tiles supplied with chilled or hot water to radiantly cool or heat a space. The ceiling tiles come in a variety of sizes and can be incorporated into just about any drop ceiling grid of a building.

A chilled beam system was a second consideration for the parallel system. Chilled beams are also installed in the ceiling and use chilled and hot water to cool or heat the air of the building. The chilled beam actually uses the natural buoyancy of air to aid in the conditioning of spaces. As warm air rises to the ceiling, it enters the chilled beam, passes over the conditioning coil where it is cooled, and through buoyancy falls back down in the occupied space. A second type of chilled beam can also incorporate the ventilation air diffuser into the same unit. In such an application, the ventilation air actually aids in pulling air across the coils for conditioning.

Yet another parallel system that could be implemented is an underfloor air distribution (UFAD) system. Such a system would provide conditioned air to occupied spaces through a pressurized supply air plenum located under a raised floor. While this type of system has the possibility of reducing fan costs since the supply air plenum is has a

lower pressure drop than ductwork, several concerns area associated with such a design. If a floor is not properly sealed and installed, more air can actually leak into the space through the joints of the floor tiles than the actual diffusers. Some individuals have also raised concerns with indoor air quality issues since anything that lands on the floor has the potential of falling through the diffusers directly into the supply air plenum and possibly contaminating the supply air stream.

#### Waterside

During the initial design for Straumann USA, the redesign of the central chilled and hot water plants was considered. However, based on costs, it was removed from the project. If the central chilled water plant was redesigned, in addition to simply replacing the electric centrifugal chillers with an updated model, direct fire absorption chillers could be considered. Natural gas is available on site and could be utilized for cooling as well as heating. At this time it is not know if any incentives or rebates are offered for using natural gas during the summer months for cooling, but if they are, direct fire chillers could be a way to save on yearly operating costs.

## **5.0 Proposed Mechanical Redesign**

Upon carefully considering all the options and combination of options available for Straumann USA the following proposal will be the focus of the semester long redesign. The results be presented to the Architectural Engineering Department in mid April 2006.

#### Scope

The scope of the redesign will include the airside and waterside components of the mechanical system. The effects on the electrical system as well as the impact on the initial costs and construction schedule will also be considered.

The airside mechanical redesign will focus on the implementation of DOAS ventilation system with a parallel radiant cooling system. Currently, one of the largest contributors to mechanical costs of the building are fans. The fans from the ten air-handling units account for about 30% of the yearly mechanical electrical energy consumed. By implementing a DOAS system, the size of air-handling units will decrease along with the size of the fans and ultimately the amount of required energy for the units will also be reduced. In order to prevent condensation problems from occurring in the building, the size of the DOAS air-handling units will probably be increased slightly to ensure the latent load is also met by the air system. An energy recovery system will also be implemented with each of the DOAS units to help reduce energy costs. The energy recovery could include a desiccant wheel, enthalpy wheel, sensible wheel, or a combination of two wheels.



As stated earlier, at the start of the Straumann Renovation, the chilled water plant was considered for an update but was later removed. The waterside redesign of the mechanical system will explore whether a direct-fire absorption chiller or electric centrifugal chiller would be the best replacement selection. This will allow for the direct-fire absorption chillers to be compared to a electric centrifugal chiller with both airside systems, DOAS and VAV.

#### Justification

Reducing energy consumption is a major goal of the redesign. Implementing a DOAS system should certainly accomplish this since fan energy which is the largest component of the annual mechanical costs will be reduced. The direct-fire absorption chiller certainly will reduce electric consumption, however, whether or not the overall energy consumption will be reduced will be determined by the redesign. Changes in initial cost will certainly have to be carefully analyzed to determine if the potential cost savings of the redesigned systems offset any increased initial costs. Regardless of the outcome, the redesign will provide a very valuable learning experience.

#### Coordination and Integration

Both the airside and waterside systems will need to be analyzed for potential coordination and integration issues. Since the project was a renovation, the redesigned systems will need to work within any constraints of the original project.

The airside systems should not pose any large issues. The Straumann portion of the building was completely gutted before new construction took place. The air-handling units were located on the roof, and since the DOAS units will be smaller, neither location nor weight should be an issue for the redesign of the airside system.

The chillers may pose the greatest difficulty to integrate into the existing building. The current mechanical room is quite crowded with existing equipment. Direct-fire absorption chillers are typically larger than electric centrifugal chillers. Final selection of the units may be constrained by space limitations.

Location and size of equipment will not be the only impact the redesign has on the building. Other systems will certainly be effected. Impacts of the redesign on the electrical system, initial costs, and schedule impacts will be discussed in section 6.0 Proposed Breadth Topics.

## **6.0 Proposed Breath Topics**

### Electrical Breadth

The proposed mechanical redesigns could have serious impacts on the electrical design for the project. Since the air-handlers will be reduced in size, the power requirements will also be reduced. The removal of the VAV boxes with the VAV system will also reduce power requirements. Potentially removing electric chillers will also remove a large load from the building. Based on the proposed mechanical changes, the electrical system will be evaluated and wire sizes, feeders, conduits, panels, and over current protection devices will to be resized to reflect the mechanical system changes.

### Construction Breadth

The implementation of both the mechanical and electrical redesigns will have significant changes to the construction costs. A detailed cost estimate for the differences between the original design and redesign is proposed, along with an assessment of how the schedule would be impacted. When the DOAS system is implemented, smaller air-handling units will cost less but adding energy recovery will certainly add initial costs to the project. Another significant impact on cost will be the addition of radiant panels along with copper piping while reducing the amount of ductwork necessary. All changes to the central plant would be additional first costs. However, the cost of replacing the plant with similar electric chillers can be compared to the redesigned direct-fire absorption chillers.

The change in initial costs can then be compared to any energy savings calculated in the mechanical system redesign to determine what type of payback period the owner could expect.

## **7.0 Proposed Methods**

The mechanical redesign will be the main focus of the 2007 spring semester. Loads for the DOAS system proposed for Straumann USA will be calculated with Carrier's Hourly Analysis Program (HAP). The load for the portions of the building Straumann does not occupy will also have to be entered into HAP to find the full load of the building in order to size the new chillers. Once the chillers are selected, operation characteristics will also be placed in HAP to determine the yearly energy costs of the redesigned systems.

After the equipment is selected for the DOAS system, the power requirements for Straumann can be analyzed. Any panels, feeders, branch circuiting, and over current protection devices can be resized as necessary using the National Electric Code.

Once all changes for the redesign are complete, a first cost estimate of all mechanical and electrical changes can be compiled. All major pieces of equipment will need to be priced, if possible by sale representatives or through RS Means Books and the CostWorks. The previous methods will also be used to calculate the costs for piping, radiant panels, ductwork, and any electrical equipment.

Throughout the semester problems or setbacks may arise. As they do, each one will be carefully considered, and implications will be discussed with a faculty consultant as necessary.

## **8.0 Preliminary Research**

ASHRAE Handbook - 2005 Fundamentals. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. Atlanta, GA. 2005.

ASHRAE Handbook – 2004 HVAC Systems and Equipment. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. Atlanta, GA. 2004.

ASHRAE Handbook – 2003 HVAC Applications. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. Atlanta, GA. 2005.

Penn State DOAS-Radiant Website: [www.doas-radiant.psu.edu](http://www.doas-radiant.psu.edu)

Sterling Commercial Hydronic Website: [http://www.sterlingheat.com/html/radiant\\_heating.htm](http://www.sterlingheat.com/html/radiant_heating.htm)

## **9.0 References**

Kaufman, Kevin. Mechanical Technical Report 1 – ASHRAE Standard 62.1 Ventilation Compliance Evaluation. 5 October 2006.

Kaufman, Kevin. Mechanical Technical Report 2 – Building and Plant Energy Analysis Report. 27 October 2006.

Kaufman, Kevin. Mechanical Technical Report 3 – Mechanical Systems Existing Conditions Evaluation. 21 November 2006.

Straumann USA - Plans and Schedules. Construction Document Set. May 28, 2004

## **10.0 Tentative Schedule**

The following is a proposed schedule of work for the Spring 2007 redesign of Straumann USA. The schedule is tentative and is subject to change as adjustments are necessary throughout the semester.

# January 2007

January 2007							February 2007						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
7	8	9	10	11	12	13	4	5	6	7	8	9	10
14	15	16	17	18	19	20	11	12	13	14	15	16	17
21	22	23	24	25	26	27	18	19	20	21	22	23	24
28	29	30	31				25	26	27	28			

Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
January 1, 2007	2	3	4	5	6
					7
8	9	10	11	12	13
					14
15	16	17	18	19	20
	Start of Classes	Model 1st Floor Non-Straumann Spaces in HAP			
					21
					Model 1st Floor Non-Straumann S
22	23	24	25	26	27
	Model Mezzanine Non-Straumann Spaces in HAP				ASHRAE Winter Meeting
					28
					ASHRAE Winter Meeting
29	30	31			
ASHRAE Winter Meeting	Model Straumann DOAS System				

# February 2007

February 2007							March 2007						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
				1	2	3					1	2	3
4	5	6	7	8	9	10	4	5	6	7	8	9	10
11	12	13	14	15	16	17	11	12	13	14	15	16	17
18	19	20	21	22	23	24	18	19	20	21	22	23	24
25	26	27	28				25	26	27	28	29	30	31

Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
			February 1	2	3
			Model Straumann DOAS System in HAP		
					4
					Model Straumann DOAS System in
5	6	7	8	9	10
Model Straumann DOAS System in	Select DOAS Equipment				
					11
					Select DOAS Equipment
12	13	14	15	16	17
Select DOAS Equipment	Model and Select Direct Fire Absorption Chiller				
					18
					Model and Select Direct Fire Absor
19	20	21	22	23	24
Life Cycle Cost Comparisions of DOAS/VAV and Electric/Absorption Chillers (excluding breadth work)					
					25
					Life Cycle Cost Comparisions of D
26	27	28			
Electric Breadth (resize any panels, wire sizes, conduits, overcurrent protection devices)					

# March 2007

March 2007							April 2007						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
				1	2	3	1	2	3	4	5	6	7
4	5	6	7	8	9	10	8	9	10	11	12	13	14
11	12	13	14	15	16	17	15	16	17	18	19	20	21
18	19	20	21	22	23	24	22	23	24	25	26	27	28
25	26	27	28	29	30	31	29	30					

Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
			March 1	2	3
			Electric Breadth (resize any panels, wire sizes, conduits, overcurrent protection devices)		
					4
					Electric Breadth (resize any panels)
					5
5	6	7	8	9	10
Electric Breadth (resize any panels)	Construction Breadth (Electrical Estimating)			Spring Break	
					11
					Spring Break
					12
					13
					14
					15
					16
					17
					Spring Break
					18
					Spring Break
					19
					20
					21
					22
					23
					24
					Construction Breadth (Mechanical Estimating)
					25
					Construction Breadth (Mechanical)
					26
					27
					28
					29
					30
					31
					Construction Breadth (Mechanical Estimating)
					Final Analysis/Wrap Up

# April 2007

April 2007						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

May 2007						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
					April 1 Final Analysis/Wrap Up
2	3	4	5	6	7
Final Analysis/Wrap Up					
					8 Final Analysis/Wrap Up
9	10	11	12	13	14
Final Analysis/Wrap Up		Prepare Presentation			
			Final Report Due		15 Prepare Presentation
16	17	18	19	20	21
Presentations					22
23	24	25	26	27	28
					29
30					