4.0 Air Side Alternatives

A number of alternatives had to be compared to find the best system to serve the air loads for the building. The alternatives presented below offer a number of different approaches that were all considered at some point during the design phase of the final system. This section will first discuss each alternative or idea presented on a conceptual basis. Then the idea will be critically weighed by the three metrics set as the selection criteria: energy consumption, environmental impact, and economics.

4.1 Original Rooftop Unit Design

The originally proposed design for this project used natural gas fired packaged rooftop units. The 13 units use direct expansion to meet the cooling load for the building. It has been said that there is no beating this equipment when it comes to first cost. The first cost for the 13 units is $247,000 bringing the initial cost of the airside to $9.31/sf. The performance data and dimensions for these units can be found in Appendix A.

Equipment	$247,000.00
Fans & Grills	$40,000.00
Controls	$14,000.00
Ductwork	$54,000.00
T & B	$13,000.00
Sales Tax	$29,000.00
Misc	$22,000.00
Total	$419,000.00
Total/sf	$9.31

Table 4.1 – Original Mechanical System First Cost

The total energy consumption for this rooftop unit design is 1,624,031 kWh for one year of operation. Of that energy, 368,172 kWh was electric energy that was consumed by the lighting system. The remaining 1,255,859 kWh represents the amount of energy being consumed by the natural gas fired rooftop units. The table below shows the energy and cost breakdown for the current electric and natural gas rates at the site.

End-Use	Energy Consumption	Unit of Energy	Cost/Unit	Enery Cost/Year	First Cost of System
Lighting	368172	kWh	$0.078	$28,717	N/A
HVAC	4285.0	MMBtu	$14.660	$62,818	$419,000

Table 4.2 – Original Rooftop Unit Design Cost Breakdown

The next factor to consider in this design is the environmental impact of using this system. Shown below are the environmental emissions that will be produced by using these fuels at this site.

Building Emissions lbm				
Fuel	**Particulates/yr**	**SO_2/yr**	**NO_x/yr**	**CO_2/yr**
Coal	166	1929	1119	324728
Natural Gas	0	8	1469	774865
Totals	166	1937	2589	1099593

Table 4.3 – Original Rooftop Design Emissions/yr

4.2 Hydronic System

The focus of this section is to consider the option of using a chilled water system to serve the cooling loads for the building. Both water-cooled and air-cooled chillers were initially explored for this analysis as they both presented benefits. It is assumed that the primary air handling units for these scenarios will be variable air volume (VAV) units. In addition, one constant volume unit will serve the four zones on the north side of the building where the pressure balances become a delicate issue because of the indoor pool and the locker room.

4.2.1 Compressor Selection

The first decision to make regarding the chiller alternative was which compressor would best serve the load. From the initial analysis and provided documents, it can be assumed that the cooling demand is approximately 200 tons for the building. This led to the decision to use either a rotary screw or a reciprocating compressor for the chiller. CoolTools Design Guide offered an excellent comparison of these compressors and their typical loads and first costs as seen in Table 4.4 below.

Compressor Type	**Range (tons)**	**First Cost Range ($/ton)**
Reciprocating	50-230	200-250
Screw	70-400	225-275
Centrifugal	200-2000	180-300
Single-Effect Absorption	100-1700	300-450
Double-Effect Absorption	100-1700	300-550
Engine Driven	100-3000	450-600

Table 4.4 – Compressor Performance and Cost from CoolTools Design Guide

A screw compressor was chosen over a reciprocating one for this design based on the size of the load served, ease of maintenance, more efficient part load performance, and comparable price. Reciprocating compressors in chillers have more moving parts and may need rebuilds. Screw compressors have higher part load efficiency and smoother loading than reciprocating engines. In a screw compressor, there is a sliding valve that modulates where refrigerant is introduced to the screw as opposed to a reciprocating compressor where part load performance is achieved by turning pistons on and off.

4.2.2 Water-Cooled Chiller

This alternative includes a rotary screw chiller for refrigerant compression and a cooling tower to reject heat to the outdoors. The chiller used for this energy simulation is a helical rotary chiller made by Trane. The actual chiller selected for analysis is the RTHD model with 200 tons of cooling capacity. The chiller was modeled to perform at 0.66 kW/ton. The cooling tower was then selected for the application. The condenser water flow from the chiller and the outdoor air wet bulb temperatures were used to select a Marley cooling tower for the system. The condenser water flow is 935 gpm for this example. The cut sheets for the chiller and the cooling tower used in this configuration can be found in Appendix C.

This alternative is very conventional and energy efficient, but unfortunately it requires more maintenance and more equipment than the initial design. LA Fitness is a relatively small building; as a retail client, the owners may not be interested in a system that will require more maintenance than it has to have if other alternatives are available. In addition to the extra maintenance of the cooling tower itself, there is also the need to treat the water for the tower, and maintain the associated pumps.

First cost and annual energy data were gathered for this chiller and they are shown below in Table 4.5. The yearly energy cost for this alternative is $2942 more than that of the original design, and the first cost is $14,345 higher. It should be noted that this option does consume 412,777 kWh less on site energy for one year of operation. However, the annual energy savings for this scenario did not translate into operation cost savings because this chiller plant is driven by electricity and the original alternative is driven by natural gas. This difference in fuel rates is an important factor for this location.

End-Use	Energy Consumption	Unit of Energy	Cost/Unit	Enery Cost/Year	First Cost of System
HVAC	843084.0	kWh	$0.078	$65,761	$433,345
Original Design	4285.0	MMBtu	$14.660	$62,818	$419,000
Differential	-412777.7	kWh	N/A	$2,942	$14,345

Table 4.5 – Water-cooled Chiller Associated Energy & Cost Breakdown

The resulting emissions from this alternative (Table 4.6) show that the water-cooled chiller is more harmful to the environment than the original design in every pollutant category discussed excepting CO_2. The reasoning behind this increase of emissions stems from the use of electricity to run the chillers.

Building Emissions lbm				
Fuel	**Particulates/yr**	**SO_2/yr**	**NO_x/yr**	**CO_2/yr**
Coal	546	6347	3682	1068328
Natural Gas	0	0	0	0
Totals	546	6347	3682	1068328
Differential	380	4410	1094	-31267

Table 4.6 – Water-cooled Chiller Associated Emissions/yr

4.2.3 Air-Cooled Chiller

Another alternative for heat rejection is the use of an air-cooled chiller. This option is being evaluated because there is less associated maintenance and first cost for this configuration of equipment. It should first be noted that air-cooled chillers themselves are less efficient than water-cooled chillers. However, air-cooled chillers do have relatively good part load performance. CoolTools Design Guide for chillers reports that as ambient air temperature decreases, the COP of an air-cooled chiller improves considerably; these improvements are only relative to the same chiller's full load performance.

The air-cooled chiller used for this analysis is made by Trane. A 200 ton RTAC model was used for analysis and found to perform at a rate of 1.22 kW/ton from the manufacturer's data which can be found in Appendix D. The first cost of this system is $8,990 more than the original design. The simulation showed that this configuration will save the building 237,482 kWh over a one year time period when compared to the original design. However, there are no resulting savings from the annual purchase of fuel for this equipment. This equipment will cost the owner $16,615 more to run the equipment for the first year. There is no financial benefit to the owner for selecting this equipment. The associated cost figures can be seen in relation to the original design in Table 4.7 on the following page.

End-Use	Energy Consumption	Unit of Energy	Cost/Unit	Enery Cost/Year	First Cost of System
HVAC	1018379.0	kWh	$0.078	$79,434	$427,990
Original Design	4285.0	MMBtu	$14.660	$62,818	$419,000
Differential	-237482.7	kWh	NA	$16,615	$8,990

Table 4.7 – Air-cooled Chiller Associated Energy & Cost Breakdown

The building emissions associated with operating this equipment can be seen below in Table 4.8. There is no environmental benefit to operating this equipment because it is more harmful to the environment than the natural gas fired rooftop units.

Building Emissions lbm				
Fuel	**Particulates/yr**	**SO_2/yr**	**NO_x/yr**	**CO_2/yr**
Coal	625	7266	4215	1222938
Natural Gas	0	0	0	0
Totals	625	7266	4215	1222938
Differential	459	5329	1627	123344

Table 4.8 – Air-cooled Chiller Associated Emissions/yr

4.2.4 Discussion of Chillers

These two hydronic design alternatives are being eliminated from further analysis and from the final selection. The three criteria used for selection are economics, energy reduction, and emissions. The simulation of the water-cooled and the air-cooled chillers for this site each resulted in higher annual operating fuel costs. Both chiller options were also found to have higher first costs when compared to the rooftop unit configuration. This is the reason why the units failed to meet the economic criteria. However, special attention must be paid when analyzing the energy consumption criteria. It appears that these units consume less energy on a yearly basis than the rooftop units did. While it is true that the units do consume less on-site energy over the course of a year, it is important to remember that electricity must be produced at the expense of burning other fossil fuels such as coal before it is delivered to the site. This process is estimated to be approximately 35% efficient. The criteria of energy reduction was established as a means of reducing the fossil fuel energy consumed, regardless of what value is consumed at the site by the end-user. The final design criteria focuses on the reduction of building emissions which is tied back to the overall energy consumption criteria. The simulation proves that these two options are more harmful to the environment in this category as well. It is for these reasons that these chilled water systems are being dismissed at this point in the analysis.

4.3 Building Combined Heat and Power

Combined heat and power (CHP), also referred to as cogeneration, is a technology which uses a prime mover such as a natural gas fired reciprocating engine or turbine to create on-site electricity and uses the waste exhaust heat from that process as a fuel to meet thermal load requirements of the building. Often, these systems will use the hot exhaust stream and a heat exchanger to meet the heating demands. In order to meet the cooling loads for the building an absorption chiller also has to be introduced into the system.

An initial feasibility check for the site showed that there was potential for combined heat and power generation on site. A good measure for feasibility of these systems is the spark spread. The spark spread is defined as the difference in price of alternative fuels per million Btu. This spark spread calculation below compares the price of grid purchased electricity to the price of purchased natural gas per MMBtu of energy.

Spark Spread Analysis:
Assuming 1 ft^3 of natural gas has 1030 Btu of energy:

Rate as of July 2005:

Electricity:	$0.078/kWh	➔ $22.86/MMBtu
Natural Gas:	$8.43/1000 ft^3	➔ $8.18/MMBtu
Spark Spread:		**$14.68/MMBtu**

Table 4.9 – Spark Spread Calculation for July 2005 Rates

The rule of thumb for cogeneration design states that if the spark spread is greater than $12/MMBtu, the site has potential for significant energy cost savings. With this knowledge in mind, an analysis for the site ensued. It was decided that for this analysis an absorption chiller would be necessary to meet the cooling loads.

As time passed, the price of oil increased. The price of natural gas consequently increased as well. The spark spread had to be calculated again to adjust for the change in rates.

Rate as of December 2005:

Electricity:	$0.08/kWh	➔ $23.45/MMBtu
Natural Gas:	$14.92/1000$ft^3$	➔ $14.48/MMBtu
Spark Spread:		**$8.67/MMBtu**

Table 4.10 – Spark Spread Calculation for December 2005 Rates

Cogeneration was eliminated as an option for a number of reasons. The feasibility of a reasonable payback period diminished as oil prices continued to influence the natural gas rates in Texas. This design option would need to include a natural gas fired reciprocating engine to generate electricity and an absorption chiller that would be fueled from the exhaust stream to create cooling as well as air handling units to serve the zones. The maintenance, acoustics, first cost, and long payback period were the final factors that terminated further analysis into this technology for this project; however, the initial analysis, modeling, and calculations provided an excellent opportunity for the designer to explore this technology at great length.