Technical Report 3

Mechanical Systems Existing Conditions

Steelstacks Preforming Arts Center

Bethlehem, Pa

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Executive Summary

Technical Report III is a summary of everything the mechanical system entails in the Steelstacks Performing Arts Center in Bethlehem, PA. It starts with the design objectives and requirements, followed by the site and budget consideration right into cost. After that is described, we can go into the usability consideration in the building such as lost space in the building (mechanical rooms and vertical shafts), as well as available energy sources on the site.

The Steelstacks building is very concerned with thermal comfort and air quality. This is so important because of the nature of the building; the large amount occupants could greatly affect the comfort of the building. Cost was also a great importance for this building, a low first cost as well as manageable yearly cost is essential for the center to be profitable.

The design of the mechanical system is fairly simple with packaged units serving all the major spaces in the building individually. This allows for certain areas of the building to work independently so that certain areas can be conditions based on their current load.

The energy sources that are being used for the systems are gas for the AHU heating loads and electricity for the condensing units and packaged coils. The initial cost of the mechanical equipment is 2.5 million dollars. The yearly cost is a little tougher to estimate because unit prices of energy were not readily available.

LEED played a major role in the design of the Steelstacks building. Many points were given to the land development along with mater and resource usage, but some still applied to the mechanical system of the building.

The systems design has been found to be very adequate in conditioning the building. The thermal loads are met as well as all the ventilation requirements. This building will run very effectively once opened and appears to have low cost for the future.

Mechanical System Overview

Introduction

Steelstacks is a four story, 67,000 square foot performing arts center that is designed to be the signature center for the Artsquest organization. This multi-purpose venue contains two cinemas, a nightclub/café, banquet facilities, a full kitchen along with several concession stands, bars, an open common area and an outdoor patio system. The building north façade is completely glass, which allows for beautiful views of the existing blast furnaces from the former Bethlehem Steel plant. While having a full glass façade enhances the architecture of the building, it greatly alters the mechanical design considerations for the building. With LEED in mind, great measures were gone through to assure that this building was designed efficiently and in a sustainable manner.

Design Objectives and Requirements

The Steelstacks building was designed with a few main objectives in mind. The first of which was to design an energy efficient building that met LEED certification with a very structured budget. As well as achieving some type of LEED certification, the designers also need to meet all ASHRAE Standards that were applicable. From this the building had to meet energy, ventilation, temperature, and humidity requirements. While having these in mind, the design that became the most logical to use was having each major zone of the building to have its own air-handling with energy recovery units on areas which have high occupancy densities.

Site and Budget

The Steelstacks is on a very unique site which affected everything from the architecture to the mechanical systems. It is located on what was previously the Bethlehem Steel plant from the late 1800's till about 2001. In an effort to minimize the economical impact the closing had on the Lehigh Valley, a plan was made to revitalize the south side of Bethlehem. A major redevelopment has ensued with the addition of a casino, hotel, and Museum of Industrial History. The revitalizing continued when the concept of Steelstacks emerged. Along with this performing arts center there are plans for outdoor amphitheater and community centers. In the years to come

this site plans on hosting Musikfest, which is an annual festival held in Bethlehem that brings thousands of visitors from across the country. The site had great affects on the architecture of the building, a slab to roof window is placed on the north wall of the building to give views of the Blast Furnaces, and steel beams are exposed as well mechanical ductwork as homage to the original site.

System Initial Cost

A piece by piece breakdown of the mechanical system cost was not available for use in this project. A cost of 2.5 million dollars is the overall cost of the mechanical system thought. With the building being 67,000 square feet, we get a cost of $38.81 per square foot of building space. The mechanical equipment totals 9.62% of the total building cost.

Lost space

The Steelstacks building is very efficient in placing mechanical spaces. On floors one, two, and three the mechanical lost space is less than 3% on all floors. The lost space on these floors is for small mechanical rooms, or duct chases. The fourth floor houses all of the major mechanical equipment. I have included all the mechanical space outside of the building as well (roof). Normally this would not count as wasted space because it does not count for square footage of the building, but it was decided to be counted because it stored such a large amount of the mechanical equipment. If this were to not be counted the percentage loss would be 1.95%.

Floor	Lost Space(ft^2)	Percentage Loss
1st	290	1.45%
2nd	470	2.57%
3rd	135	0.64%
4th	6205	44.27%
Total	**7100**	**9.68%**

Energy sources

This information was not readily available for this area. The electricity and gas cost below were found using the regional suppliers of energy. Other available energy sources are not know but

can be assumed to be minimal because of the prior use on the site and because the site is still in the infancy stage of development.

Electricity

Electric demand charge	$6.25
Electric Consumption charge	$0.14/kWh

Gas

Consumption charge	S1.25/therm

Design Air conditions

The Steelstacks building is located in Bethlehem, PA. The design outdoor air conditions for Bethlehem, PA were taken from the ASHRAE Fundamental 2005. The coldest weather month is January and the warmest is July. The values obtained are shown below.

ASHRAE Values	Summer Design Cooling- 0.4%	Winter Design Heating- 99.6%
OA Dry Bulb (F)	90.7	6.6
OA Wet Bulb(F)	73.4	-
IA Temperature	75	70
Clearness Number	1	1
Ground Reflectance	0.2	0.2

Equipment Summaries

The Steelstacks building utilizes a fairly simple conditioning system. It consists of six rooftop units (RTUs) that serve almost the entire building. Each of these systems serves a very specific area; this is done so that the building can be controlled according to what type of event is going on. There is also one Air Handling Units (AHU) that serves exclusively the Blast Furnace Room. The Blast Furnace Room is the one of the highlight areas of this building; it is a multipurpose room that can host events from concerts to banquets.

	Supply Air(CFM)	Supply Fan Power(HP)	Exhaust Fan Power (HP)	Enthalpy Wheel Power (HP)	Cooling Coil Cap (MBH)	Gas Fired Cap (MBH)
RTU-1	6800	5	-	-	191.1	199
RTU-2	1650	1	-	1.18	39.9	52.5
RTU-3	3020	2	-	3.62	79.3	126.7
RTU-4	23485	25	-	7.24	457.4	117.5
RTU-5	17500	20	10	10.86	443.3	790
RTU-6	3000	1.5	0.5	-	113.4	126.7
AHU-1	5300	7.5	0	-	291.2	378.8

RTU-1- This unit serves the kitchen area on the third floor and the areas relating to this area such as storage areas.

RTU-2- This unit serves exclusively the Small Cinema on the first floor.

RTU-3- This unit serves the Large Cinema on the first floor

RTU-4- This unit serves the Creative Commons area, this area has portions of it that are two stories high. The Creative Commons is an area for people to gather, it boast views of the blast furnaces as well as sitting areas and places to relax

RTU-5- This unit serves the Musikfest Café that is on the third floor and is two floors high. It also serves the mezzanine level that overlooks the Café. This area will hold concerts and musical events, with the VIP area located on the Mezzanine as well as bar. This area also overlooks the blast furnaces to the north.

RTU-6- This unit is the most diverse unit, it serves most of the remaining space in the building that require conditioned air. Areas include offices, retail areas, corridors, green room, and some storage areas.

AHU-1- This unit is used to condition the Blast Furnace room.

Enthalpy wheel-There is a total of four enthalpy wheels associated with the conditioning systems for the Steelstacks building. The wheels are placed on systems that serve areas with high population density. This is because these areas require a high ventilation rate. So an enthalpy

wheel is can recoup some of the energy that would otherwise be thrown back into the environment.

The natural gas boilers are located on the fourth floor of the building in the mechanical room. It is a Lochinvar Intelli-Fin system with 89.9% steady state combustion efficiency. This boiler provides hot water to AHU-1, which is the indoor only indoor unit (all others are roof top packaged units boilers included). In addition to the supplying this one air handling unit it also provides hot water to the terminal unit hot water re-heat boxes located in the smaller rooms throughout the building.(offices, green rooms ect.)

Unit	Total Gas (MBH)	Net Output (MBH)	GPM	Temperature
B-1	1000	880	90	180

Pumps play a minor role in the Steelstacks building but it is still an important role. Their role is limited because of the rooftop units being packaged units that have a condenser and a boiler in it. The only area that requires pumped fluid to it is the AHU-1 which serves the Blast furnace room and is not a roof top unit and terminal re-heat boxes located in few rooms.

Description	Capacity(GPM)	Head	HP	RPM
Primary Heating	57	15	1/2	1150
Secondary Heating	100	40	2	1750
AHU-1 Freeze Protection	5	10	1/3	1750

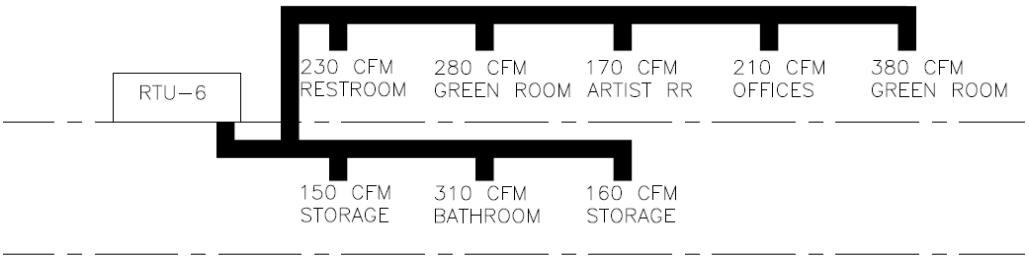
System Operations

Air Side

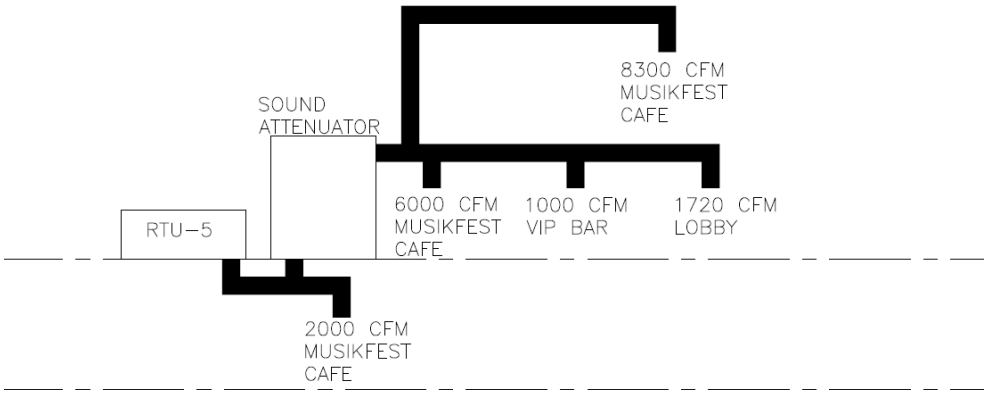
The air system in the Steelstacks building is very simple. As previously stated each zone is independently served by an appropriately sized and configured unit. Certain units contain energy recovery units if there is high occupancy. The systems are variable speed drive motors, so they can supply appropriate levels to cooling and heating to the rooms. Each unit has economizer

settings that will adjust the outside air damper to different levels depending on the outside and indoor air conditions, as well as the occupancy levels.

Below are schematics of two of the 7 total conditioning units. These are the only one really necessary to show because all other units serve just one area such a cinema.



Schematic 1-RTU-6 air distribution layout



Schematic 2-RTU-5 air distribution layout

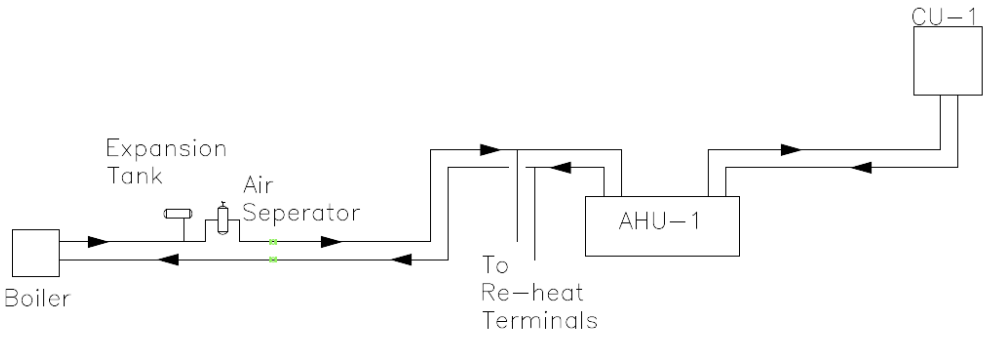
Water side

Once again this is a very straightforward system. Due to the fact that every system is independently run, the system has little built in redundancy and therefore is rather simple in nature. The packaged units are run completely self sustained, so the only unit that requires chilled and hot water from an outside source is air handling unit supplying air to the Blast furnace rooms as well as the terminal re-heat boxes. This unit is inside for two main reason, the first

being that the mecahincal space on the roof was not big enough to house it. Also the duct length required to go from the rooftop mechanical space to the blast furnace room is great.

The chilled water comes from and outside condensing unit which serves exclusively this air handler. These condensers along with all of the other components of the Mechanical system are system controlled either on-site or they can be remotely altered. This allow for altercations and real-time viewing of how the system is operating. This allows for on the fly changes that can greatly reduce the amount of energy use in the building.

Also there are a few condensing units that are considered part of a mini-split system. This system supplies the same rooms that have the terminal reheat boxes. There are a total of three condensing units for this system ranging in size from 6.2 tons to 16.6 tons. Since this system is a packaged unit again, all the heat exchanging is done internally and cold water is run from these units directly to their corresponding AC unit.



Schematic 3- AHU-1 water layout

Relevant Data from Previous Reports

Technical Reports I & II both provided information that is relevant to this report. The areas that crossover are areas that directly correlate to ASHRAE 62.1 and 90.1 and some Building Load Analysis.

Ventilation Requirements

The Steelstacks building has many diverse areas of usage within the building. This required an area specific ventilation calculation. The procedure described in ASHRAE 62.1 was performed to gain an understanding on each zone ventilation requirements. The varieties of different zones included in the building were cinemas, multipurpose, cafeteria, offices.

A total of 6 zones were checked for compliance with the minimum airflow rates. The maximum Z_p values come from zones that seemed to have a very high occupancy rates. These values could be estimated a little high due to using ASHRAE standards for occupancy rather than what the designers used because they probably have a better understanding of what the room will be used for.

Below in the graph I have summarized the minimum air flow requirements set forth by ASHRAE, it can be seen that even with the minor mishaps in calculating the zones with high occupancy all the units seem to be working in compliance of the 62.1. The one zone that is not in compliance is the kitchen, this can be rationalized by the lack of knowledge I have into the specifications of all the cooking equipment and the desired airflows for these areas.

Unit	Designed Max CFM	Designed Min OA	ASHRAE 62.1 Min OA	Compliance
RTU-1	6800	660	1630	NO
RTU-2	1575	1575	1428	YES
RTU-3	3050	2955	2752	YES
RTU-4	23485	5175	3699	YES
RTU-5	17500	10670	4171	YES
RTU-6	3000	660	421	YES
AHU-1	5300	3630	1854	YES

Heating and Cooling Loads

Trace 700 Version 6.2 was used to simulate building block load conditions for the Steelstacks building. Trace was chosen over the other software packages due to the ease of use as well as the familiarity with the program. Each zone was modeled with their appropriate system for

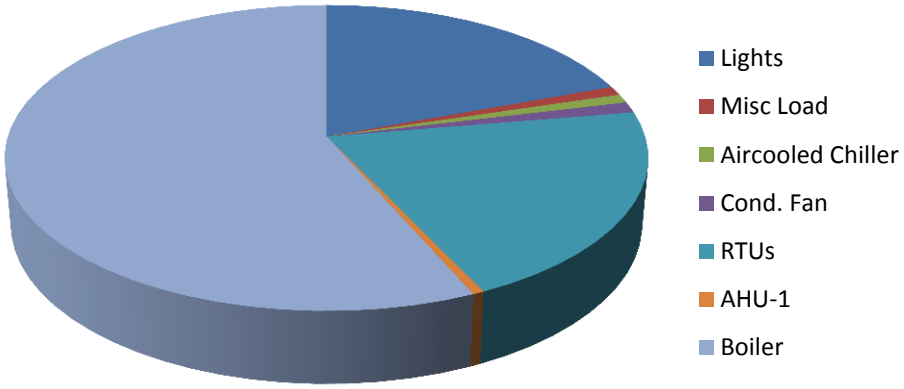
heating, cooling, and supply air. These results were then compared to the designed values and appropriate rational was inferred to why there were such inconsistencies. After an initial run of the software I had great differences in cooling and heating loads in the areas of with the greatest amount of occupancy. I realized that I had greatly overestimated the amount of people that would be in the zones and did and appropriate correction on this. After the corrections were made I got a much more accurate reading on the heating and cooling levels of the Steelstacks building.

	Heating Load (MBH)		Cooling Load (tons)		Supply Air cfm/sf	
	Modeled	Designed	Modeled	Designed	Modeled	Designed
RTU-1	314	199	22.9	17.8	3858	6800
RTU-2	79	52.5	11.4	4.9	1582	1650
RTU-3	131	126.7	12.6	9.71	1927	3050
RTU-4	875	117.5	53.1	55	13111	23485
RTU-5	355	790	51.7	51.47	16564	17500
RTU-6	32	126.7	1.7	11.9	423	3000
AHU-1	157	378.8	23.4	24.25	9862	5300
Total	1943	1791.2	176.8	175.03	47327	60785
Percent Difference	7.8		1.0		28.4	

Annual Energy Use

All of the equipment efficiencies and sizes were taken from the design drawing and the energy consumptions were calculated and reported below.

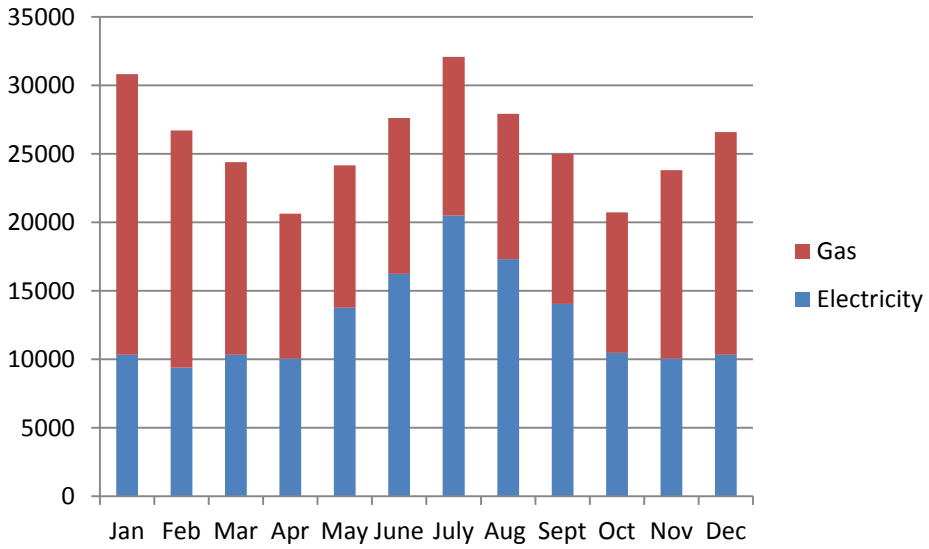
Equipment	Utility	Unit	Total
Lights	Electric	kWh	373086
	Peak	kW	42.6
Misc. Loads	Electric	kWh	17955
	Peak	kW	2.1
Air-cooled Chiller	Electric	kWh	17805
	Peak	kW	156.9
Cond. Fan	Electric	kWh	21806
	Peak	kW	17.1
RTU-1	Electric	kWh	32766
	Peak	kW	3.7
RTU-2	Electric	kWh	6553
	Peak	kW	0.8
RTU-3	Electric	kWh	13107
	Peak	kW	1.5
RTU-4	Electric	kWh	163831
	Peak	kW	18.7
RTU-5	Electric	kWh	131065
	Peak	kW	15
RTU-6	Electric	kWh	49149
	Peak	kW	5.6
AHU-1	Electric	kWh	9830
	Peak	kW	1.1
Boiler	Gas	therms	3698
	Peak	therms/Hr	2.8



This pie chart above was done by converting all of the values to the same units. From this comparison it is very apparent that the boiler and the fans for each of the units are the main

areas for energy consumption.

From this model the total energy cost was calculated. The total energy cost per year was $310,327, and $4.63/ft^2 which seems to be on the high side, the energy rates could be a little off, but I am not immediately sure for this error. Below is a graph of the cost for both electricity and gas for each month during the year.



LEED Analysis for the Mechanical System

The Leadership in Energy and Environmental Design was created by the United States Green Building Council in order to promote sustainable design for both owners and design team. Points are awarded on a scale of how much the improvement will reduce energy consumptions or be friendlier to the environment. Steelstacks was designed with LEED in mind, but due to the ever changing construction and schedule of the building the designer and owner are reluctant to release anything because nothing is set in stone yet. The section will go over the two main areas of LEED that relate to mechanical systems; Energy and Atmosphere (EA) and Indoor Environmental Quality (IEQ).

Energy and Atmosphere

EA Prerequisite 1: Fundamentals of Commissioning and Building Energy Systems-Achieved

This is to make sure the building is installed and operated as designed. The Steelstacks building is not finished construction yet but plans are in place to make sure this system is running appropriately.

EA Prerequisite 2: Minimum Energy Performance-Achieved

This is to establish minimum levels of energy efficiency throughout the building. This building was designed with LEED as a goal, so his was definitely looked at.

EA Prerequisite 3: Fundamental Refrigerant Management-Achieved

Zero use of chlorofluorocarbons (CFCs) refrigerants was used in this building.

EA Credit 1: Optimize Energy Performance-3 Points

These are points given for the amount of energy saved in the designed building over the baseline building. The major factors in this were the windows, the SHGC of the windows that were installed were much lower than the minimum required in ASHRAE 90.1. Other small differences factored in to make a energy reduction of 16% which achieves 3 Points

EA Credit 2: On-site Renewable Energy

This is to promote the use on-site energy use. There is a possibility for the addition of a solar panel array on the roof of the building, but as of right now it is being put on hold due to cost.

EA Credit 3: Enhanced Commissioning

As of right now in the construction process this is not applicable. The commissioning is semi-ongoing and the detail of it is unknown, so it is unclear if this will be achieved.

EA Credit 4: Enhanced Refrigerant Management-2 Points

Reduce the total refrigerant impact. A calculation is associated with this credit and any

value less the 100 receives 2 points. The Steelstacks building had a very low value (35) for this due to the mechanical design and received the points

EA Credit 5: Measurement and Verification

The building is still under constructions so this is not yet known if this credit will be sought after.

EA Credit 6: Green Power

This credit is to encourage the use of grid-source, renewable energy technologies on a net zero pollution basis. Steelstacks does not plan to buy green energy.

Indoor Environmental Quality

IEQ Prerequisite 1: Minimum Indoor Air Quality Performance-Achieved

This sets minimum indoor air quality performance to enhance indoor air quality in buildings. The Steelstacks meets and exceeds Sections 4 through 7 of ASHRAE 62.1-2007, Ventilation for Acceptable Indoor Air Quality.

IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control-Achieved

To prevent or minimize the building occupants and surfaces to exposure of indoor tobacco smoke. The Steelstacks building is a non-smoking building so this achieved.

IEQ Credit 1: Outdoor Air Delivery Method-1 Point

This is to provide capacity for ventilation system monitoring to help promote occupant comfort. CO_2 sensors will be installed in the highly populated spaces in the building to allow for proper ventilation.

IEQ Credit 2: Increased Ventilation

This credit is to provide additional outdoor air ventilation to improve indoor air quality. This could be done at the Steelstacks building. The building has the option of running on 100% outdoor air, and has the control system to accompany this idea. But for now this will not be implemented because of energy consumption.

IEQ Credit 6.1: Controllability of Systems-Lighting-1 Point

This credit is to provide that a high level of lighting control by individual occupants or groups of multi-occupant spaces. The lighting system is very diverse at the Steelstacks, because it has to provide lighting for a variety of events from comedians to rock bands to formal gatherings. All of which can be adjusted to suite the occupant.

IEQ Credit 6.2: controllability of Systems- Thermal Comfort-1 Point

This is intended to provide a high level of thermal comfort system control by individual of groups in multi-occupant spaces. The Steelstacks provides exactly this, it has thermostats in all of the offices and green rooms, as well as having numerous sensors in the larger spaces to allow for regional heating and cooling.

IEQ Credit 7.1: Thermal Comfort-Design-1Point

This is to provide a comfortable thermal environment that promotes occupant productivity and well-being. The Steelstacks meets ASHRAE Standards 55-2004 so this credit is achieved.

IEQ Credit 7.2: Thermal Comfort-Verification

This credit is to provide for the assessment of building occupant thermal comfort over time. The owner of the building will decide if there will be verification on this if the building is going for a LEED certification. This will be decided at the end of construction.

Water Efficiency

WE Prerequisite 1: Water Use Reduction-Achieved

This is to increase water efficiency within buildings to reduce the burden o municipal water supply and wastewater systems. Many different ideas were implemented to achieve this credit of at least a 20% aggregate reduction in the baseline building.

WE Credit 3: Water Use Reduction-2 Points

This credit is to further increase water efficiency within the building to reduce the burden on municipal water supply. The Steelstacks building will have at the minimal a 30%

reduction in water over the baseline building which will achieve at least 2 points.

Overall Evaluation

The system chosen to condition the Steelstacks building is a very convention system used very effectively for this use. This type of system has been used in similar buildings for many years and has proven to be adequate.

The construction cost of the mechanical system is about 9% of the building total cost. This is a somewhat low value for this type of building. This can be attributed to the ease of access to the rooftop units as well as most of the ductwork is left exposed which leaves for easier installation.

The operating cost of the Steelstacks Building is somewhat high; this could be for a couple of things. The calculated cost of operating the building was $\$4.63/ft^2$ annually. The use of the building leads to high cost, because of late night activities which call for lots of lighting as well as condition of the air in coldest parts of the day. Another reason the calculated cost could be high is the validity of cost of energy. The cost was estimated from researched values and is not exact to this specific building.

One finding that deemed itself to be very interesting was the amount of sensors placed throughout the inside and outside of the building. These were then sent to the main control system to evaluated different criteria so that the building would run most efficiently. Sensors capacity ranged from temperature to CO_2, to humidity.

Resources

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