Technical Report 3

Mechanical Systems Existing Conditions

RIVER VUE APARTMENTS, PITTSBURGH, PA

November 16, 2011
Authored by: Laura C. Pica
Adviser: Stephen Treado

Technical Report 3

Mechanical Systems Existing Conditions

Table of Contents

Technical Report 3

Mechanical Systems Existing Conditions

Summary of Tables

Summary of Figures

Executive Summary

Technical Report 3 provides a summary of River Vue Apartment's mechanical system's design requirements, hardware components, system configuration and control logic described thus far through Technical Reports 1 and 2. A review of the Trane TRACE 700 energy model created for energy, emissions, and load analysis, a description of operating characteristics and the building program are also provided.

Figure 1: Exterior View of River Vue Apartments, Photo taken by Laura Pica

River Vue Apartments is a renovation project to turn the Old State Office Building located downtown Pittsburgh, Pennsylvania into a high rise multifamily apartment complex. The site is tightly constrained by neighboring buildings and historic sites and most of the existing structure will remain with the exception of fenestration which will be replaced to lighten the solar gains.

Ventilation is provided by the single make up air handling unit whereas heating and cooling is supplied by heat pumps located in each apartment unit. Loop water serves the heat pumps and a chilled water loop provides water for domestic use. Minimal floor space is lost on each floor due to mechanical equipment and shafts.

Construction spans over a time period of approximately ten months and involves the demolition of all existing interior work, installation of new mechanical, electrical and plumbing systems as well as new finishes, site work, and balconies for units on upper floors. The guaranteed maximum price of $28 million allows little room for energy modeling or energy usage tracking however, LEED Certified status will be achieved through the use of regional and recycled materials, reuse of the project site and detailed management and commissioning of the project from construction through project delivery.

Design

Design Objectives/Requirements

River Vue Apartments is a renovation project to turn the Old State Office Building in downtown Pittsburgh, Pennsylvania into a high-rise apartment complex. The new facility will house repetitive dwelling units on the 2-14th floors with bi-level apartments on the fifteenth and sixteenth floors featuring private balcony spaces. Tenants will enjoy the complex's fitness room, two valet parking garage levels, and retail space located on the first floor. Much of the appeal of this site are the city views and close proximity to river-side walkways and downtown business.

Figure 2: Exterior View of River Vue Apartments 2, Photo taken by Laura Pica

Pittsburgh zoning and building codes were not considered during the project because the existing structure will completely remain and be only updated with cross bracing on the lower two floors. Limited exterior architectural changes include the addition of curved metal panels on the roof, which will mask a new air handling unit with energy recovery and a cooling tower. Apartments on the 15th and 16th floors will be modified to include balconies.

All existing mechanical, plumbing, and electrical will be replaced to allow for new, more efficient systems in accordance with the National Electric Code and the National Plumbing Code. Exterior glazing will be replaced with bronze, operable windows for additional building ventilation and improved heat transfer rates.

LEED Certification is the sustainability goal for this renovation project and that will be met through the use of regional materials, recycled content, low emitting materials and weather proofing. Each apartment unit will have individual temperature controls to promote energy conscious living. A LEED evaluation is provided later in this technical report.

Energy Sources

The United States has several different regions within electricity is generated and distributed. Pittsburgh, Pennsylvania is located in the RFC (Eastern) region which is typically known for producing most of its electricity by burning bituminous and subbituminous coal, since it is the

natural resource most prevalent in that region. Mechanical equipment like the generator and boilers in this building also consume natural gas for operation.

Energy Rates

River Vue Apartments uses Duquesne Light as an electricity provider, Equitable Gas Company for natural gas, and the Pittsburgh Water & Sewer Authority for water. Each company's typical utility rate was used to calculate monthly and annual utility costs, based on usage predicted by a Trane TRACE 700 energy model.

Type of Service	Provider	Rate ($)
Electricity	Duquesne Light	0.0896
Natural Gas	Equitable Gas Company	0.0622
Water	Pittsburgh Water & Sewer Authority	13.7656

Table 1: Utility Rate Structure

Factors Influencing Design

Site

River Vue Apartments is located across Commonwealth Place from the historical Point State Park, where Fort Pitt and Fort Duquesne were constructed in the mid 1700's. Although it is not directly located on this historical site, it must respect the landscape and will be noticed in all views from the park. As noted in the project's Historic Sites Map in the geotechnical report, the project site is located within walking distance to many other historic sites and federal historic areas as well. It is important for the project to not disturb these city landmarks.

As with most urban construction projects, the building footprint utilizes much of the site's area, making for tight spacing for the storage of construction materials and waste. No additional space is available for the addition of a campus utility plant. Deliveries must be highly coordinated to avoid prolonged street closures and noise levels must be observed so nearby businesses and residents are not disturbed.

Cost

Since this project is in the form of a contract plus construction costs and has a guaranteed maximum price, there was little room in the project budget for detailed energy modeling or energy usage tracking after operation of the facility begins. Strict budgeting also constrains the

design team and construction managers to completing the project on time and without additional costs. The project will be financed through the HUD 220 program created by the United States Department of Housing and Urban Development and will require payment of prevailing wage rates, which are listed in the project's contract documents. HUD 220 is a mortgage insurance program for rental housing for urban renewal and concentrated development areas that insures lenders against loss on mortgage defaults.

Rebates/Tax Relief

No rebate or tax relief information was available at the time this report was completed.

Other

Since the building was originally constructed in the 1950's, there are many aspects of construction that do not meet today's current building codes. Most of the construction work occurring throughout the summer of 2011 is asbestos abatement and testing of interior building surfaces for lead paint levels. Although most interior surfaces are being completely demolished, the interior stairwells, which are lined with tile, are under review to determine if the existing materials conform to IBC section 800 requirements for interior finishes.

Fenestration

Each exterior wall has a significant amount of glazing which heavily influences the cooling load of the building, especially during summer months when solar radiation is high. Percentage of glass per floor was tabulated in Technical Report 1 to understand River Vue Apartments' compliance with ASHRAE Standard 90.1 for fenestration. Each floor exceeded the maximum allowance of 40% as seen below:

Level	Glass Area	Wall Area	% Glass	Compliance
G	3992	6336	63.01	N
1	3600	6336	56.82	N
2	3600	6336	56.82	N
3	3600	6336	56.82	N
4	3600	6336	56.82	N
5	3600	6336	56.82	N
6	3600	6336	56.82	N
7	3600	6336	56.82	N
8	3600	6336	56.82	N
9	3600	6336	56.82	N
10	3600	6336	56.82	N
11	3600	6336	56.82	N
12	3600	6336	56.82	N

13	3600	6336	56.82	N
14	3600	6336	56.82	N
15	3600	6336	56.82	N
16	3000	6336	47.35	N
TOTAL	60992	107712	56.63	N

Table 2: Fenestration Analysis

Outdoor Design Conditions

Design day weather conditions for Pennsylvania provided by the ASHRAE Handbook of Fundamentals 2009 are as follows:

- Winter Design Dry Bulb Temperature: 61 degrees F (15 degrees Celsius)
- Summer Design Dry Bulb Coincident Temperature: 88 degrees F (31 degrees Celsius)
- Summer Design Wet Bulb Temperature: 86 degrees F (30 degrees Celsius)
- Mean Daily Range of Temperatures: 11 degrees
- Typical Prevailing Winds: West at 6 mph

Indoor Design Conditions

The single make up air handling unit provides two operational modes, summer and winter, and these design conditions are detailed below. An ASHRAE psychrometric chart was used in Technical Report 1 to specify what relative humidity exists at each state point.

	Winter Months	**Summer Months**
Dry Bulb Temperature (degrees)	78	58
Wet Bulb Temperature (degrees)	54	55
Relative Humidity (percent)	17	82

Table 3: Design Conditions

Loads & Energy

As stated in Technical Report 2, much of the load for this building comes from its occupants, ventilation, infiltration, lighting and mechanical equipment as well as significant solar gains. Tenants will likely be using the most energy early in the morning and later in the evening during dinner hour since this is a residential facility. The mechanical equipment like boilers, pumps, air handling unit and the generator will be in constant use whereas lighting loads and solar gains will vary throughout the day and year.

Ventilation Requirements

The Ventilation Rate Calculation Procedure from ASHRAE Standard 62.1 was used to calculate outdoor ventilation rates for typical spaces inside River Vue Apartments based on space dimensions and occupancy in Technical Report 1. "As Designed" airflow rates were read directly from contract drawings and a comparison was made to determine if spaces within the complex require further attention and potential redesign. The table below summaries these calculations and it can be seen that most occupied spaces do receive enough ventilation air.

Space	ASHRAE Outdoor Airflow (cfm)	As Designed Outdoor Airflow (cfm)	Requires Redesign
Common Corridor	933	5250	
Stairwells	346	3200	
Main Entry Lobby	42	570	
Stair Lobby	81	150	
Elect Equip Room	48	0	YES
Bsmt Machine Room	96	0	YES
Elevator Machine Room	150	0	YES
Boiler Room	96	0	YES
Fire Pump Room	96	0	YES
Generator Room	96	0	YES
Dwelling Units 2nd Floor	1641	11565	
Dwelling Units 3-14	17504	85800	
Dwelling Units 15-16	2217	31070	
Fitness Center	516	500	YES
Retail Sales	365	500	
Parking Garage	2070	0	YES

Table 4: Ventilation Analysis

It was anticipated that mechanical spaces and the parking garage would not receive ventilation and therefore their comparison results are expected however, redesign for minimal ventilation would provide a healthier indoor air quality. Dwelling units on each floor seem to be provided with an extremely large amount of ventilation but it must be noted that the "As Designed" values account for not only ventilation air but also cooling supply air. Detailed comparison information and calculations for ventilation requirements is provided for reference in Appendix A.

Infiltration

Building infiltration occurs when envelopes allow outdoor air to leak in through cracks. Given that the system operates in two primary modes, summer operation and winter operation, the latent and sensible loads due to infiltration differ throughout the year and were calculated separately using the following simple relationships:

$$\textit{Sensible Load: } q_s = 1.10Q(\Delta T)\ (BTU/hr\text{-}sqft)$$

$$\textit{Latent Load: } q_L = 4840Q(\Delta w)(BTU/hr\text{-}sqft)$$

As seen by the equations above, sensible load is a direct result of temperature changes whereas latent load is affected by the humidity ratio (Δw) and moisture content. It makes sense that there is higher sensible load during the winter season because of the large temperature difference between outdoor and indoor air. In the summer operating scheme latent loads dominate due to high moisture content in the outdoor air. Overall, the summer condition sees higher loads.

	Summer Condition	Winter Condition
Sensible Load	925,514	1,735,338
Latent Load	2,163,388	381,775
Total	3,088,902	2,117,113

Table 5: Infiltration Loads

Energy Modeling

A comparison between ASHRAE design specifications and the Trane TRACE energy model created for Technical Report 2 is shown in the table below. As previously described,it can be seen that assumptions used for the model were almost always conservative compared to typical design values from ASHRAE for high rise apartment complexes. However, most values

seen in the model are within reason given the knowledge that many simplifications to space loads, construction materials, occupancy and equipment schedules were made in the modeling process.

High Rise Apartment			River Vue Apartments
occupancy sqft/person			*occupancy sqft/person*
Lo	Av	Hi	Model
325	175	100	200
lights watts/sqft			*lights watts/sqft*
Lo	Av	Hi	Model
1	2	4	1
refrigeration sqft/ton			*refrigeration sqft/ton*
Lo	Av	Hi	Model
450	400	350	90
supply air rate (east-south-west) cfm/sqft			*supply air rate (east-south-west) cfm/sqft*
Lo	Av	Hi	Model
0.8	1.2	1.7	0.63
supply air rate (north) cfm/sqft			*supply air rate (north) cfm/sqft*
Lo	Av	Hi	Model
0.5	0.8	1.3	0.63

Table 6: Energy Model Results

Annual Energy Consumption

Annual energy consumption was calculated based on an energy model created with Trane TRACE 700 in the second technical report. A summary of this data is provided below.

Monthly Utility Usage			
Month	Electric (kW)	Gas (therms)	Water (gal)
1	722	36776	16
2	717	35939	13
3	722	26060	17
4	849	15040	104
5	839	4558	263

6	845	1307	411
7	846	46	509
8	844	1717	350
9	839	4782	238
10	842	17417	96
11	749	20845	83
12	726	33222	17
TOTAL	9540	197709	2117

Table 7: Utility Usage

It is important to note that the energy usage calculated with the Trane TRACE 700 energy model only accounts for the HVAC equipment, solar gains, lighting and plug loads. No miscellaneous kitchen appliances or other apartment equipment was included. The loads vary depending on the occupancy schedules outlined in Technical Report 2, where most load occurs during times when occupants are likely to be present. This energy model predicts that most energy consumed at River Vue Apartments will be in the form of natural gas.

System Operation

HVAC flow diagrams are simple graphic representations of the fluid or thermal systems in a building and are used to easily convey how the system works without referring to other plans or elevations.

Water Side

Water is circulated throughout two distinct loops in River Vue Apartments, the first being the chilled water loop, noted by CS and CR on Figure 3. This loop is controlled by two 1024 GPM condensing water pumps in the basement. Water is delivered to each floor for use by small appliances, bathroom faucets, showers, and lavatories and once it is consumed, it is drained through the sanitary sewage piping down to basement level where it is fed into Pittsburgh's sanitary sewer system. Excess water moves to the cooling tower located on the roof where it is then fed down through risers to its starting point.

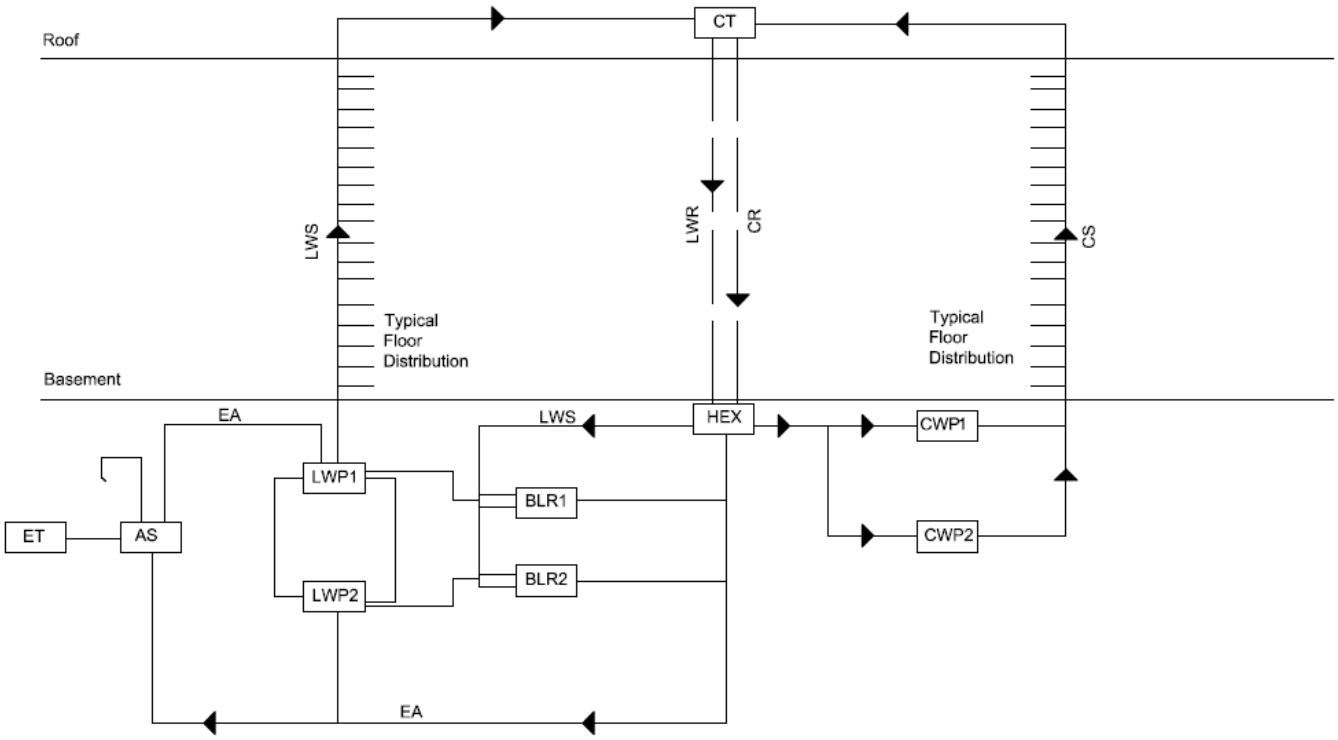


Figure 3: Water Flow Diagram

The second loop water system is heated by two natural gas fired boilers and circulated by two corresponding loop water pumps, also located in the basement. Loop water is circulated to each apartment unit and fed into individual heat pumps that condition the spaces. Water source heat pumps can facilitate heating in one zone and cooling in another at the same time making it an attractive option for a high-rise residential complex where solar gains and occupancy fluctuate throughout the day. The cooling tower and boilers act as a heat rejector and heat supplements during extreme weather conditions. A diagram of the building's repetitive heat pumps is shown in Appendix B for reference.

Loop water piping follows the chilled water piping through the same risers when it is returned to the basement. It is then moved through the plate and frame heat exchanger which transfers unwanted heat from the chilled water return stream to the loop water supply stream, conserving energy and freeing the boilers from a heavy load.

Air Side

A single make-up air handling unit sitting on the roof of River Vue Apartments, shaded by curved aluminum panels, incorporates outdoor air into the return air stream to supply air to the apartment units. As these air streams are mixed, they pass through an enthalpy wheel in the air

handling unit where latent and sensible energy from the return air is transferred to the supply stream. This preheats the air in the winter and cools it in the summer, allowing the heat pumps to run less often. Two separate exhaust risers exist to evacuate exhaust air from stacked trash and mechanical rooms on each typical floor, as seen in Figure 4.

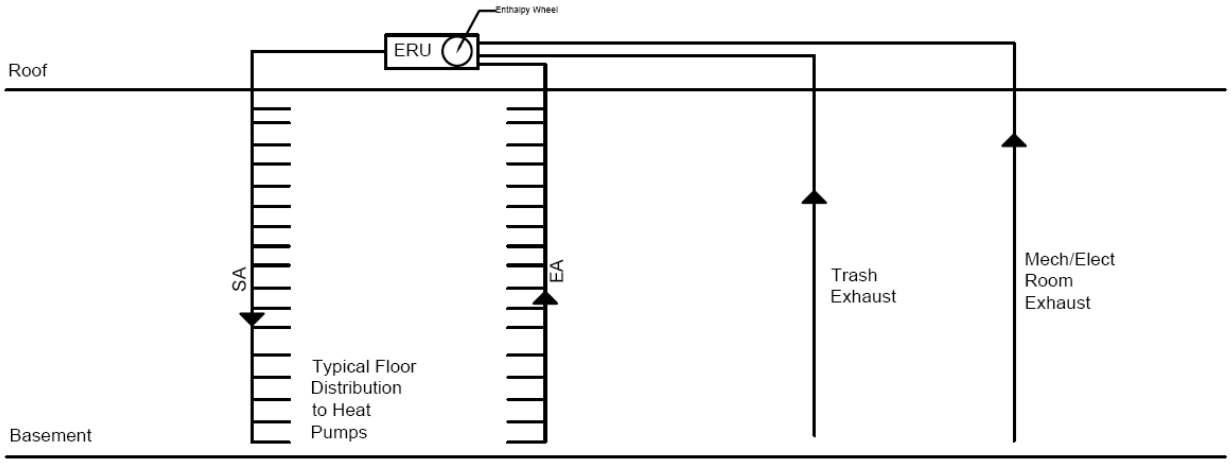


Figure 4: Air Flow Diagram

Control Logic

As described in Technical Report 1, there is a direct-digital control system with 48 hour battery backup prescribed for River Vue Apartments which will act to automatically control temperature, control valves, dampers and their operators, interface equipment and accessories for the make-up air unit, ventilation systems, unit heaters, and plumbing equipment. The sequence of operation for control of the equipment is described explicitly in the contract document specification section 0230993.

Equipment

Due to the simplicity of the complex, River Vue Apartments is served by only one 26,300 CFM air handling unit with an energy recovery wheel located on the roof serving two supply risers and two exhaust risers located in the north-east corner of the building. Two 200 GPM boilers and a 1024 GPM plate heat exchanger are located in the basement mechanical space and a 350 ton cooling tower located behind stainless steel curved panels on the roof serve the plumbing system's risers.The building can be divided into several simple zones requiring ventilation and

conditioned air from the air handling unit, including residential apartment units, corridors, lobby/retail space, and the parking garage. Much of the building's ventilation will be provided by operable windows in the façade. Fire protection will be supplied through sprinklers on each floor, which will be new to the building in the current renovation project. A full mechanical equipment schedule is listed in Appendix A.

Lost Usable Space

A floor-by-floor breakdown of lost usable space was done to understand how much floor space is consumed due to mechanical equipment and vertical shafts. The basement and roof had the most floor area lost to mechanical equipment since major equipment rooms are located on those floors. Every typical apartment floor has a loss of about 5.5% due to shafts and a small mechanical room near each elevator lobby. The building as a whole has a loss of 6.5% with an average of 6.21% of floor space per floor. A detailed breakdown of lost usable floor space is provided in Appendix C.

Costs

River Vue Apartments renovation project has a guaranteed maximum price of $28,248,910 which, with a total building area of 297,000 square feet, equates to approximately $95 per square foot. A complete breakdown of project costs is provided in the figure below.

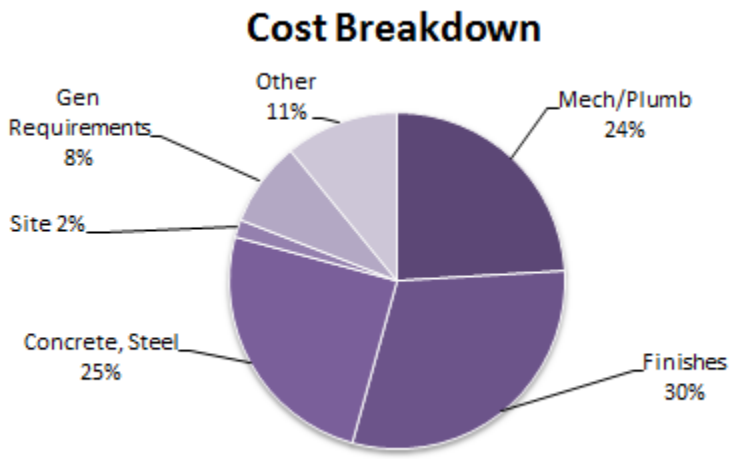


Figure 5: Project Cost Breakdown

The mechanical, plumbing, and fire protection systems equate to approximately 24 percent of the total construction cost. It makes sense that the percentage is relatively high because most of the work being performed through the renovation is to replace mechanical, electrical, and plumbing services as well as install all new finishes throughout the building.

Meter Data or Utility Bills

As noted in Technical Report 2, no operational data or current utility bills were available for River Vue Apartments. The costs associated with a commercial office building do not correspond to those of a residential facility since the building function is different, therefore old operational data would not be directly applicable given the future residential application of the facility. Since the project has an initial substantial completion date of April 2012, operational data may become available later in the development of this senior thesis. If this is the case, data will be provided at that time as a supplement to this report.

The energy analysis produced in Technical Report 2 detailed the expected monthly utility consumption and predicted an annual operational cost of nearly $153,000 for electricity, natural gas and water for the large mechanical equipment. This equates to roughly $0.57 per square foot.

Sustainability

In today's energy-conscious world, building labeling for sustainability has become one of the biggest trends in new construction and large-scale renovation projects. A major leader in this field is the United States Green Building Council, (USGBC) which publishes guidelines for ranking buildings' sustainable design, construction, and operation.

Figure 6: USGBC logo. Image courtesy: http://ecosalon.com/wp-content/uploads/Leed-Logo.jpg

LEED-NC Green Building Rating System for New Construction and Major Renovations, Version 2.2 was used as a benchmark for the renovation of River Vue Apartments. This method evaluates site selection and use, water efficiency, energy use, materials and resources as well as indoor environmental quality and innovative design.

Type of Certification	Points Range
Certified	26-32
Silver	33-38
Gold	39-51
Platinum	52-69

Table 8: LEED Certifications

The project scored 31 out of a possible 69 points, categorizing the building as LEED Certified. Most points came from repurposing the site and building, using regional and low-emitting materials, and managing the construction process with recycling and commissioning. There was a lack of points associated with lighting control, ventilation, materials reuse, renewable energy and energy monitoring. A complete breakdown of the LEED scorecard is provided in Appendix D for reference.

System Evaluation & Conclusions

Technical report 3 was used to perform a complete system evaluation, including the design of systems, construction and operating costs, mechanical space requirements and sustainability. River Vue apartments has sixteen floors, each approximately sixteen thousand square feet in area and a loss of over 6% of the square footage to mechanical space and shafts per floor. With a guaranteed maximum price of $28 million, the project equates to $95/square foot in construction costs and$0.57/square foot for operation of the large mechanical equipment.

River Vue Apartments has an exceedingly large amount of fenestration on each exterior wall which accounts for its significant solar gains throughout the year. Because of this, it does not comply with ASHRAE Standard 90.1.

The single make up air handling unit provides 26,300 cfm supply air to the complex, which barely meets the requirement of 26,293 cfm prescribed by ASHRAE Standard 62.1 (as seen in Technical Report 1). An enthalpy wheel in the make-up air unit allows for the transfer of latent and sensible energy and the reduction of wasted heat. A loop water system provides recirculated water for heat pumps within each apartment unit for heating. This type of system is well suited for residential apartment complexes like River Vue Apartments and requires little maintenance except for the replacement of filters in the air handling unit.

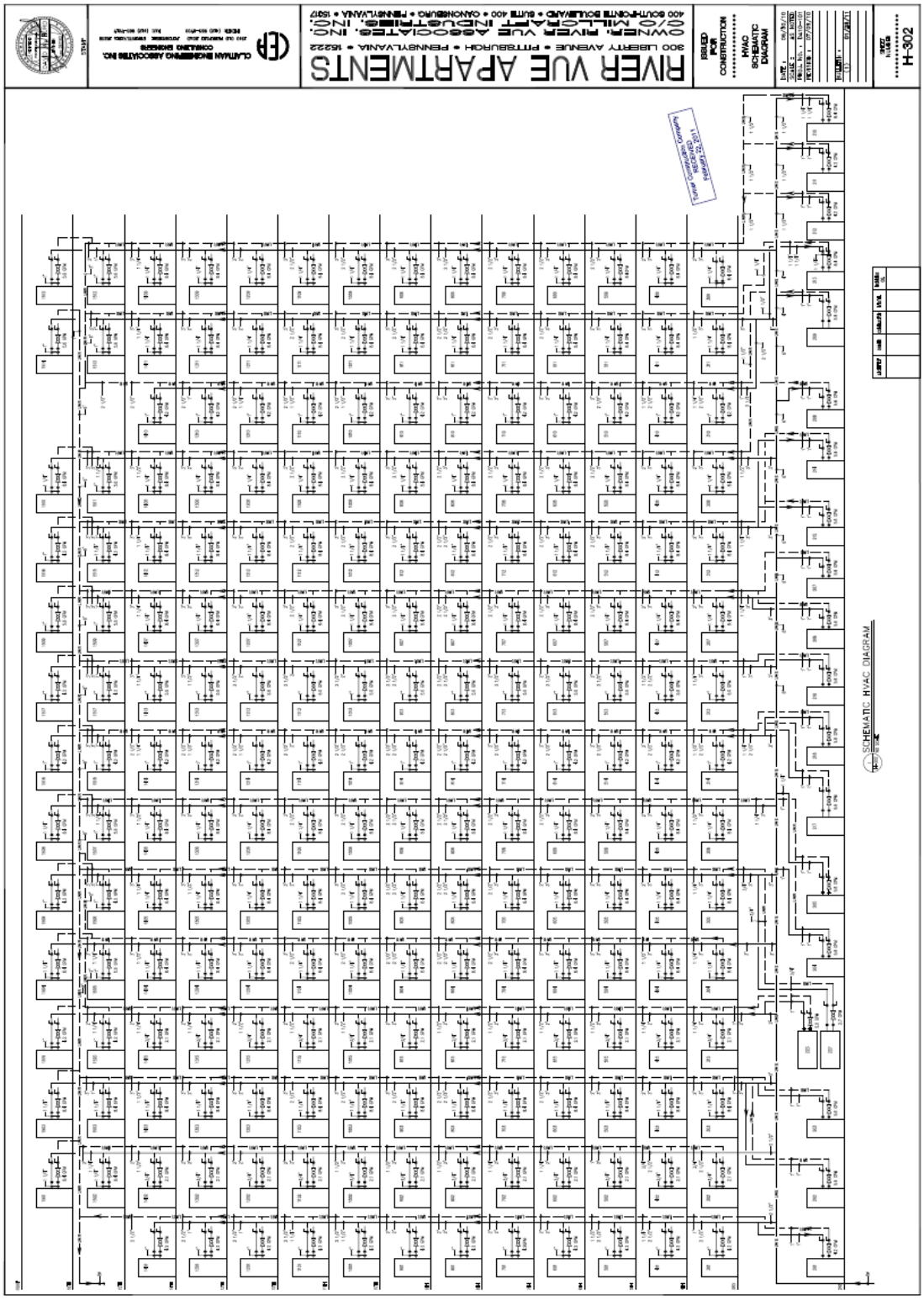
As noted in Technical Report 2, indoor environmental air quality may be low due to the low amount of ventilation provided to each unit. There is no engineered natural ventilation system however; new operable windows are being installed for occupant-controlled ventilation.

There are areas for improvement in this building renovation project that could yield significant savings in energy and renovation costs including changes to fenestration, ventilation air, energy storage, lighting, and added thermal massing. The construction schedule and site logistics could also be considered. River Vue Apartments is located at a prominent corner in downtown Pittsburgh and will remain the staple of the “Golden Triangle” for years to come, making this renovation of high importance.

ASHRAE 62.1 Calculations

	Zone floor Area (**Az**)	Zone Population (**Pz**)	Outdoor Airflow rate required per Person (**Rp**) (cfm/person)	Outdoor Airflow Rate Required per Unit Area (**Ra**) (cfm/sqft)	Occupant Density (#/1000 sqft)	OA Rate (cfm per person)	Class		(Rp)*(Pz) =	(Ra)*(Az) =	breathing zone outdoor airflow (**Vbz**)	As Designed (Drawing Data)	Comparison
Common Corridor	15540	0	N/A	0.06	N/A	N/A	1		0	932.4	932.4	5250	463%
Stair wells	5760	0	N/A	0.06	N/A	N/A	1		0	345.6	345.6	3200	826%
Main Entry Lobby	375	3.75	5	0.06	10	11	1		18.75	22.5	41.25	570	1282%
Stair Lobby	260	13	5	0.06	50	6	1		65	15.6	80.6	150	86%
Elect Equip Room	800	0	N/A	0.06	N/A	N/A	1		0	48	48	0	-100%
Bsmt Mech Room	800	0	N/A	0.12	N/A	N/A	1		0	96	96	0	-100%
Elevator Machine Room	1250	0	N/A	0.12	N/A	N/A	1		0	150	150	0	-100%
Boiler Room	800	0	N/A	0.12	N/A	N/A	1		0	96	96	0	-100%
Fire Pump Room	800	0	N/A	0.12	N/A	N/A	1		0	96	96	0	-100%
Generator Room	800	0	N/A	0.12	N/A	N/A	1		0	96	96	0	-100%
Dwelling Units 2nd floor	14917.5	149.175	5	0.06	10	11	1		745.875	895.05	1640.925	11565	605%
Dwelling Units 3-14 floors	159120	1591.2	5	0.06	10	11	1		7956	9547.2	17503.2	85800	390%
Dwelling Units 15-16 floors	20150	201.5	5	0.06	10	11	1		1007.5	1209	2216.5	31070	1302%
Fitness Center	600	24	20	0.06	40	22	2		480	36	516	500	-3%
Retail Sales	1568	23.52	7.5	0.12	15	16	2		176.4	188.16	364.56	500	37%
Parking Garage	34500		7.5	0.06	100	8	1		0	2070	2070	0	-100%
	258041								10450	15844	26293	138605	427%

Appendix B – Mechanical Riser Diagram



Appendix C– Mechanical Equipment Schedule

Mark	Equipment	Capacity
ERU-1	Make Up Air Handling Unit	864000 BTU/hr
A/C-100	Heat Pump	73000 BTU/hr
A/C-103	Heat Pump	5000 BTU/hr
A/C-223	Heat Pump	12900 BTU/hr
A/C-227	Heat Pump	11600 BTU/hr
A/C-1	Heat Pump	8800 BTU/hr
A/C-2	Heat Pump	1900 BTU/hr
A/C-3	Heat Pump	18100 BTU/hr
A/C-4	Heat Pump	23600 BTU/hr
A/C-5	Heat Pump	34700 BTU/hr
HE-1	Heat Exchanger	1024 GPM
BOILER-1	Boiler	1750 RPM
BOILER-2	Boiler	1750 RPM
CT	Axial Propeller Cooling Tower	350 tons
SF-A	Supply Fan	13800 cfm
SF-B	Supply Fan	11000 cfm
EF-B19-A	Exhaust Fan	15000 cfm
EF-B19-B	Exhaust Fan	15000 cfm
EF-114-A	Exhaust Fan	15000 cfm
EF-114-B	Exhaust Fan	15000 cfm
EF-1700-A	Exhaust Fan	4600 cfm
EF-1700-B	Exhaust Fan	3000 cfm
EF-B20	Exhaust Fan	10000 cfm
EF-B21	Exhaust Fan	30000 cfm
EF-1600-A	Exhaust Fan	150 cfm
EF-1600-B	Exhaust Fan	200 cfm
SF-1600-A	Supply Fan	16000 cfm
SF-1600-B	Supply Fan	31000 cfm

A	Electric Heater	4800 W
B	Electric Heater	375 W
C	Electric Heater	4800 W
D	Electric Heater	5000 W
E	Electric Heater	15000 W
F	Electric Heater	18700 W
G	Electric Heater	2500 W
H	Electric Heater	5000 W
CWP-1	Condesing Water Pump	1024 GPM
CWP-2	Condesing Water Pump	1024 GPM
LWP-1	Loop Water Pump	1030 GPM
LWP-2	Loop Water Pump	1030 GPM
AS-1	Air Separator	1030 GPM

Appendix D– Lost Usable Floor Space Calculations

Floor	Room	Room Area	Total Floor Area	% Wasted Space
Basement	Boiler	1344		
	Electrical	900		
	Mechanical	1120		
	Elevator	320		
	Fire Pump	720		
	Generator	624		
TOTAL		5028	26260	19.15%
1st	Elevator	440		
	Mechanical	240		
	Trash/Freight	200		
	Fire Dept	200		
TOTAL		1080	26760	4.04%
2nd	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	26148	3.37%
3rd	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	16100	5.47%
4th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	16100	5.47%
5th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	16100	5.47%
6th	Elevator	440		
	Trash/Freight	200		

	Mechanical	240		
TOTAL		880	16100	5.47%
7th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	16100	5.47%
8th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	16100	5.47%
9th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	16100	5.47%
10th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	16100	5.47%
11th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	16100	5.47%
12th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	16100	5.47%
13th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
TOTAL		880	16100	5.47%
14th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		

TOTAL		880	16100	5.47%
15th	Elevator	440		
	Trash/Freight	200		
	Mechanical	240		
		880	16100	5.47%
16th	Elevator	440		
	Mechanical	240		
		680	16100	4.22%
17th	Mechanical	1600		
		1600	16100	9.94%
TOTAL		20708	320668	6.46%

AVERAGE FOR BUILDING:	6.21%

Appendix E – LEED Scorecard & Rating System

LEED-NC Green Building Rating System for New Construction & Major Renovations, Version 2.2			
		Possible Points	River Vue Apartments
Sustainable Sites			
Prereq 1	Construction Activity Pollution Prevention		YES
Credit 1	Site Selection	1	1
Credit 2	Development Density & Community Connectivity	1	1
Credit 3	Brownfield Redevelopment	1	
Credit 4.1	Alternative Transportation - Public Transportation Access	1	1
Credit 4.2	Alternative Transportation - Bicycle Storage & Changing Rooms	1	
Credit 4.3	Alternative Transportation - Low Emitting & Fuel Efficient Vehicles	1	
Credit 4.4	Alternative Transportation - Parking Capacity	1	
Credit 5.1	Site Development - Protect or Restore Habitat	1	1
Credit 5.2	Site Development - Maximize Open Space	1	
Credit 6.1	Stormwate Design - Quantity Control	1	1
Credit 6.2	Stormwater Design - Quality Control	1	
Credit 7.1	Heat Island Effect - Non-Roof	1	1
Credit 7.2	Heat Island Effect - Roof	1	
Credit 8	Light Pollution Reduction	1	
Water Efficiency			
Credit 1.1	Water Efficient Landscaping, Reduce by 50%	1	
Credit 1.2	Water Efficient Landscaping, No Potable Use or No Irrigation	1	1
Credit 2	Innovative Wastewater Technologies	1	1
Credit 3.1	Water Use Reduction by 20%	1	
Credit 3.2	Water Use Reduction by 30%	1	
Energy & Atmosphere			
Prereq 1	Fundamental Commissioning of the Building Energy Systems		YES
Prereq 2	Minimum Energy Performance		YES
Prereq 3	Fundamental Refrigerant Management		YES
Credit 1	Optimize Energy Performance	10	5
Credit 2	On-Site Renewable Energy	3	
Credit 3	Enhanced Commissioning	1	1
Credit 4	Enhanced Refrigerant Management	1	1
Credit 5	Measurement & Verification	1	
Credit 6	Green Power	1	
Materials & Resources			
Prereq 1	Storage & Collection of Recyclables		YES
Credit 1.1	Building Reuse, Maintain 75% of Existing Walls, Floors, & Roof	1	1

Credit 1.2	Building Reuse, Maintain 95% of Existing Walls, Floors, & Roof	1	1
Credit 1.3	Building Reuse, Maintain 50% of Interior Non-Structural Elements	1	
Credit 2.1	Construction Waste Management, Divert 50% from Disposal	1	1
Credit 2.2	Construction Waste Management, Divert 75% from Disposal	1	
Credit 3.1	Materials Reuse of 5%	1	
Credit 3.2	Materials Reuse of 10%	1	
Credit 4.1	Recycled Content, 10% (post-consumer + 1/2 pre-consumer)	1	1
Credit 4.2	Recycled Content, 20% (post-consumer + 1/2 pre-consumer)	1	
Credit 5.1	Regional Materials, 10% Extracted, Processed & Manufactured Regionally	1	1
Credit 5.2	Regional Materials, 20% Extracted, Processed & Manufactured Regionally	1	
Credit 6	Rapidly Renewable Materials	1	
Credit 7	Certified Wood	1	1
Indoor Environmental Quality			
Prereq 1	Minimum IAQ Performance		YES
Prereq 2	Environmental Tobacco Smoke (ETS) Control		YES
Credit 1	Outdoor Air Delivery Monitoring	1	1
Credit 2	Increased Ventilation	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 & Sealants	1	1
Credit 4.2	Low-Emitting Materials, Paints & Coatings	1	1
Credit 4.3	Low-Emitting Materials, Carpet Systems	1	1
Credit 4.4	Low-Emitting Materials, Composite Wood &Agrifiber Products	1	
Credit 5	Indoor Chemical & Pollutant Source Control	1	
Credit 6.1	Controllability of Systems, Lighting	1	
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	
Credit 8.1	Daylight & Views, Daylight 75% of Spaces	1	1
Credit 8.2	Daylight & Views, Views for 90% of Spaces	1	1
Innovation & Design Process			
Credit 1.1	Innovation in Design	1	
Credit 1.2	Innovation in Design	1	
Credit 1.3	Innovation in Design	1	
Credit 1.4	Innovation in Design	1	
Credit 2	LEED Accredited Professional	1	
TOTAL		69	31

References

- River Vue Apartments Contract Drawings and Specifications
- ANSI/ASHRAE (2007), Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA, 2007.
- ANSI/ASHRAE (2007), Standard 90.1-2007, Energy Standard for Buildings Except Low-Rise Residential Buildings. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA, 2007
- ASHRAE (2009), 2009 ASHRAE Handbook of Fundamentals
- http://www.puco.ohio.gov/puco/index.cfm/apples-to-apples/columbia-gas-of-ohio-apples-to-apples-chart/
- http://inflationdata.com/Inflation/images/charts/Annual_Inflation/annual_inflation_chart.htm
- "Source Energy and Emission Factors for Energy Use in Buildings." M. Deru and P. Torcellini. National Renewable Energy Laboratory. June 2007.
- Information on HUD 220 Program: http://www.hud.gov/offices/hsg/mfh/progdesc/renturbanhsg220.cfm

Acknowledgements

Thank you to the following people:

- Kevin Ludwick, project engineer from Turner Construction Company for providing necessary building data and contract documents.
- My adviser, Stephen Treado, for his help in editing my reports and providing professional consulting
- My friends and family for their continued support throughout my senior year.