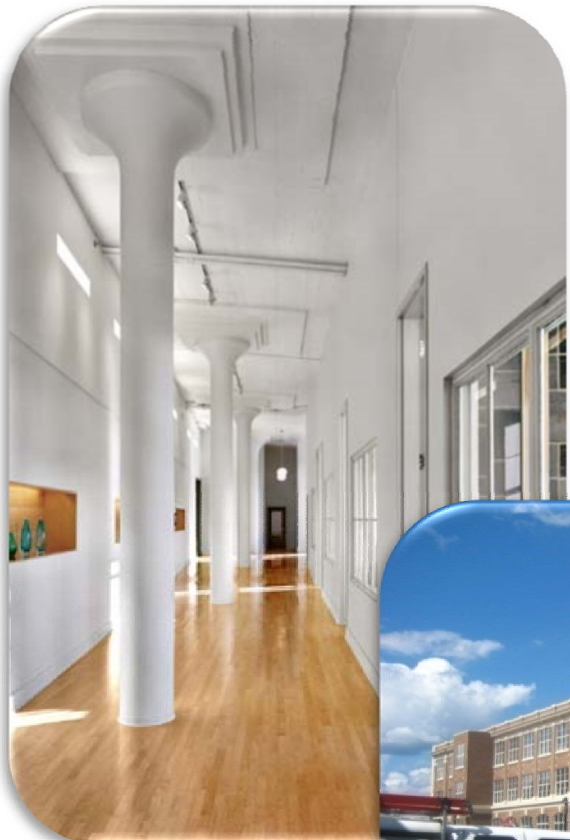
A Sustainable Retrofit Analysis

For the Hershey Press Building
Hershey, PA



AE Senior Thesis
Final Report
Spring 2009

Alyssa Adams | Mechanical Option | April 7, 2009 | Dr. William Bahnfleth

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1.0 Executive Summary

The Hershey Press Building, originally built in 1915, has been renovated to accommodate four tenants including Hershey Entertainment and Resorts offices, Houlihan's restaurant, Jack Gaughen Realty offices, and Devon Seafood Grill restaurant. The facility uses terminal water to air heat pumps to serve a variety of zones and spaces. A boiler plant and fluid cooler is used for heat reject and absorption from the water source heat pump loop. While many of the original building objectives are being met, there is a variety of possible sustainable alternatives that could enrich the system.

The goal for the mechanical retrofit redesign is to study three major areas associated with sustainability, including water efficiency, energy efficiency and indoor environmental quality. Three sustainable alternatives were chosen and will be discussed. These three include a rain water storage application for the cooling tower, the addition of variable frequency drives for the pumps, and a ducted ventilation air supply to all critical spaces.

The rain water storage had a first cost of $157,320.00, and an annual savings of $3,285.00. Therefore, the calculated the payback for this investment was 48 years, not an optimal scenario for implementation.

For the energy efficiency analysis, the option with the cheapest 20-year life cycle cost option, at $77,625, was to originally install the variable frequency drives during the original construction. The next best option for the lowest life cycle cost, at $90,484, is the current state of the building, a pump without a VFD. Finally, the most expensive life cycle cost, at 115,225, is to retrofit a VFD and the required controls into the facility.

The indoor environmental quality option had a total cost for of approximately $236,759.00. The total duration for the install will 26 days, starting June 1, 2009 and ending July 7, 2009. The construction management breadth will provide a detailed cost and schedule analysis of the ducted ventilation supply system.

The second breadth includes an architecture redesign of the building envelope in order for the building to become more energy efficiency, namely replacing the windows. The windows met ASHRAE Standard 90.1-2007, however, ending up using more energy than the existing windows.

The mechanical system was then analyzed for its performance as sustainable building using the US Green Building Council (USGBC) current LEED-NC rating system. The three sustainable retrofits were all able to contribute one point individually, leading to an addition of three LEED points altogether. With 14 definite points and 34 possible, it would only require 24% of the "maybes" to become points for a "Certified" certification to be awarded.

Overall, the study for a sustainable retrofit was an educational experience with unfortunate results. While the proposed options would increase sustainability points for LEED, the options will still come up short in life cycle costs and payback on investment.

2.0 Facility Background

The Hershey Press building is a three story, 75,000 square foot, mixed use facility located in Hershey, Pennsylvania. It stands as a historic monument on the corner of Park and Chocolate Avenue. See Figure 2-1 for site location. Originally built in 1915 as a printing facility, it was renovated in 2005. The renovation called for a complete exterior restoration project with total interior demolition. The goal of the renovation was to return the building to its original 1915 look, while also serving as an office complex. With the town's main amusement attraction, Hershey Park, located directly behind the facility, and an historical museum recently constructed next door, the building stands as a popular eatery and office complex for the town of Hershey and its visitors.

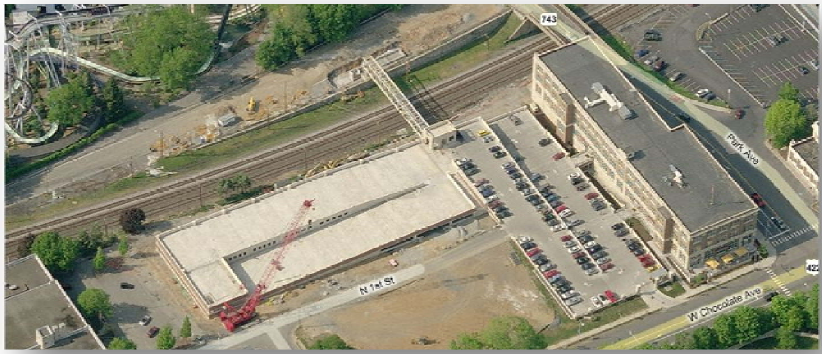

Figure 2-1: Hershey Press Building – Site

2.1 CONSTRUCTION BACKGROUND

The Hershey Press Building was a 24-month construction schedule that included façade restoration and interior renovation of four tenant fit-out spaces. The preconstruction activities, including the design, permitting, and procurement phases, took approximately one year to complete. The demolition phase, marking the beginning of construction, included the removal of hazardous materials, interior demolition and exterior demolition including the removal of large shade panels used to cover the window openings. Afterwards, the construction team began the building facade restoration to the original 1915 design by replacing storefront glass and windows, restoring the roof, and filling in the shade panel areas. Concurrently, teams performed site work, paved parking areas, and began in the interior renovation, including installment of engineering systems and interior finishes.

The cost of the entire restoration and the second and third floor tenant fit-out on the second and third floors was approximately $8 million dollars, completed at the end of 2005. This tenant, Hershey Entertainment & Resorts, is a true Hershey conglomerate owns that many of the attractions located in Hershey, including: Hershey Park, Giant Center, Hershey Arena & Stadium, Zoo America, and many other popular attractions. Call reservation centers, conference rooms, open offices, private offices, and a gym facility are a few spaces located on these floors. The sheik interior design of the office spaces, mixed with local materials and historical columns, give this office facility a high-end, personal look.

The first floor was left unfinished during the original renovation, to accommodate future tenant fit-outs. Those tenants, and their spaces, are shown in Figure 2-2. Houlihan's, a restaurant constructed in 2006, offers indoor and outdoor seating facing Chocolate Avenue. Jack Gaughen Realty, finished in 2007, serves as commercial office space. Devon's Seafood Grille restaurant, which will be finished this spring, will provide up-scale dining.

Figure 2-2: Hershey Press Building - First Floor Tenant Spaces

2.2 ELECTRICAL AND LIGHTING SYSTEM BACKGROUND

The service feeder that enters the Hershey Press building is first step down by an outside transformer. This transformer converts the 12,470 volt underground feeder voltage into a 480Y/277, 3-phase building voltage. This feeder is then drawn through a non-tapered, copper bus main distribution panel, located in the basement electric room. The power from the bus is than distributed to ten 60-500 amp, 480Y/277 volt electric panels and eight 100-350 amp, 208Y/120 volt electric panels. In case of power failure, a gas powered, 250 kW generator can be used for the emergency electrical systems of the building.

The building's lighting is typically generated by direct and indirect T8 lamp fixtures with electronic ballasts. Pendants, wall washers, and sconces are also used for decorative lighting in lobby, restaurant, and conference spaces.

2.3 STRUCTURAL SYSTEM BACKGROUND

The Hershey Press Building has steel reinforced concrete structural system, known as the "Kahn "system, developed early in the twentieth century. The foundation consists of normal weight, cast in place, 16" slab on grade concrete system. The exterior columns, formed around the slab on grade, are spaced 15' on center. The interior columns, "elephant columns", are 20" round in diameter, concentrically expands two feet from the top to a 5'-5" diameter. They are spaced 17' apart from each other, on center. An 11'x11' panel, 5" thick, serves as a header to column and support for the slab above.

Each floor, supported by the interior and exterior columns, was cast in place, normal weight concrete slab. The first floor is a 12-1/2" slab, reinforced by steel rods and tied into place on chairs with wires. Beams spanning 22' have no less than 9" of bearing. Beams were used to provide the vertical shafts, including the elevator shaft and stairwells, at various perimeter areas of the building. The second and third floors have 10" slabs. The roof system, similar to the other floor slabs, was cast in place, normal weight concrete, except with a slight 7/8" per 12" pitch. The slab is 8" thick and supported by columns, varying heights, which are spaced 22' on center.

For the original design of the mechanical system, a list of project objectives was created. By identifying objectives prior to design, enhanced design decisions could be made in order to meet the final requirements. These objectives included:

- Multiple zone temperature control with the ability heat and cool zones simultaneously
- Energy efficiency and life cycle cost optimization
- Simplicity of control and control reliability
- Integration with existing architecture and structural systems

Design objectives were not the only influences during the design development phase. Site factors and other issues played a large role. The site, for example, is surrounded by the building seen in Figure 3-1. Enclosed site logistics, acoustical properties of the site, and centrality of the building as a town monument became factors in the mechanical design.

The office and restaurant parking, located west side of the building, occupies the majority of the free space surrounding the building. With the enclosed historical confined site, any opportunities for setting large mechanical equipment outside on site, an air-cooled chiller example became an impractical choice. Another factor the design would have to balance was the noise factors from the nearby amusement park and the lack of noise generated near the Hershey Museum. Careful consideration needed to be taken when designing the location of mechanical rooms and equipment placement, to neither add noise to the nearby area, nor leave the building open to noise from the nearby rollercoaster.

1. Hershey Press Building
2. Parking Garage
3. Hershey Museum
4. Hershey Park Amusement Resort

Figure 3-1: The Intersection of Chocolate & Park Avenue in Hershey, PA

The south façade, as seen in Figure 3-1, faces Chocolate Avenue, the main artery in the town of Hershey, Pennsylvania. Renovating the façade became a focal point in the downtown revitalization movement. Becoming a monument of change and beauty within the community challenged to project team, especially the mechanical designer, to ensure that the aesthetics of building would not be compromised. In all, the site affected exterior and acoustic decisions made to the building by the entire project team.

The exterior was not the only issue; the interior layout also impacted many design decisions during renovation. Also, additional shaft space was integrated into the architectural scheme to accommodate all three floors, without disturbing the structural concrete integrity. Below, in Table 3-1, is a breakdown by floor of the lost usable space associated with the mechanical system design, including both the mechanical equipment floor space area and the vertical mechanical shaft area. With the current floor plan, the entire mechanical system floor space is located in the basement. This is broken down into 431 square feet of boiler room space and 2,281 of shared mechanical and storage space.

Table 3-1: Breakdown of Lost Useable Space Associated with the Mechanical System

	Mechanical System Floor Space (Sq. Ft)	Vertical Mechanical Shaft Area (Sq. Ft.)	Lost Useable Space (%)
Basement	2712	30	37%
First Floor	0	32	<1%
Second Floor	0	32	<1%
Third Floor	0	32	<1%

3.1 DESIGN CONDITIONS

First, the outdoor and indoor design conditions needed to be decided. McClure company engineers decided upon the following general design conditions:

- Summer outdoor condition: 92°F DB/74°F WB
- Winter outdoor condition: 0°F DB
- Summer indoor condition: 72°F DB, not to exceed 60% relative humidity
- Winter indoor condition: 70°F DB

The design is also based on the climate of Harrisburg, PA, located approximately fifteen miles from Hershey. Harrisburg is located at 40 degrees latitude, 76 degrees longitude, and at an altitude of 335 ft. During the summer, the design summer dry bulb is 91 degrees Fahrenheit, while the wet bulb temperature is 74 degrees Fahrenheit. The winter dry bulb is 11 degrees Fahrenheit. This weather information helps to determine the building energy load required.

This information, along with individual thermal room criterion, was entered in a load simulation program. This process was repeated for all four tenant fit-outs. The program was then able to estimate the design heating and cooling loads of the space. See Table 3-2 below for the calculated values for the entire building and the as-designed values from the original design. Supply air, vent air, cooling loads and heating loads, in terms of area, for both the calculated and as-design, are compared in Table 3-3.

Table 3-2: Calculated and As-Designed Heating and Cooling Mechanical Loads

Hershey Press Building Heating and Cooling Loads				
Occupancy & Floor	Calculated Thermal Loads		As-Designed Thermal Loads	
	Calculated Heating Load (MBH)	Calculated Cooling Load (Tons)	As-Designed Heating Load (MBH)	As-Designed Cooling Load (Tons)
HE&R (partial basement and 2nd & 3rd Floor offices)	471	122	1,845	136
Houlihan's restaurant (1st)	778	86	637	44
Jack Gaughen Realty offices (1st)			454	19
Devon Seafood restaurant (1st)			26	39
Total	1,249	208	2,962	238

One noticeable difference in Table 3-2 is that the heating and cooling loads are greater for the as-designed. During the original design, the calculations for the heat pumps, which will be discussed in greater detail in the next section, were based on the cooling and heating load without ventilation. A summary of this calculation can be seen in Figure 3-2. Ventilation was added to the load afterwards and a heat pump was selected, based on the higher of the two heating and cooling values.

As-Designed Heat Pump Calculations		
Total Vent Load	=	4.45 *Vent Rate *(4.7) (in BTUs)
Total Trace Load	=	Trace Total Load (in BTUs)
Total Design Load	=	Total Vent Load + Total Trace Load (in BTUs)
Sensible Vent Load	=	1.08 *Vent Rate *(80-72) (in BTUs)
Sensible Trace Load	=	Trace Sensible Load (in BTUs)
Sensible Design Load	=	Sensible Vent Load + Sensible Trace Load (in BTUs)

Figure 3-2: As-Designed Heat Pump Sizing Calculations

Each heat pumps heating value is proportional to the cooling value. Therefore, the cooling need is greater than the heating need in all the heat pumps; the heating capacity is oversized based on need. While the entire heating capacity will rarely ever be utilized, it is still represented as a possibility for the as-designed conditions. This would explain the inflated as-designed value. This trait is also represented in Table 3-3, showing the area per MBH required for the building.

Table 3-3: Calculated and As-Designed Airflow Values in Terms of Area

Building Airflow Values in Terms of Area				
	Cooling Load ft^2/ton cooling	Heating Load ft^2/MBH heating	Supply Air cfm/ft^2 supply	Vent Air cfm/ft^2 vent
Calculated	303.0	50.5	1.93	0.30
As-Designed	264.8	21.3	2.09	0.32

Once the required loads are calculated, equipment can be selected. Water-source heat pumps became a logical choice for the designers, because it allowed the Hershey Press Building to take advantage of the large ceiling space, while minimizing the necessary shaft and mechanical space. Also, the heat pumps were sized based on cooling capacity (80°F DB/67°F WB EAT and 90°F EWT) and the heating capacity (70°F DB EAT and 60°F EWT).

3.2 AIR SIDE MECHANICAL SYSTEM

The Hershey Press building's mechanical system utilizes ninety-four terminal air-to-water ceiling-mounted heat pumps are located in the spacious ceiling plenums. Overall, this was an energy-efficient choice, taking advantage of the large 3-8' high plenum spaces. Within these plenums, return air and outside air from energy recovery ventilators are supplied into the plenum. This air is mixed through temperature gradients, and the mixed air is drawn through the heat pump. Once conditioned by the heat pump, the airstream is directly ducted to the spaces by the heat pumps.

Each water source heat pump will be controlled by an individual, 7-day programmable thermostat. The thermostat, provided by the heat pump manufacturer Florida heat pumps, will be mounted in plain view for the offices and in the back of house or the manager's office for the restaurant spaces. Thermostats will be located at ADA compliant wall heights. The heat pumps will maintain a heating dry bulb set point of 70°F and a cooling set point of 72°F during the occupancy schedule of the space.

The ventilation air is supplied by two energy recovery ventilators to each floor plenum from the roof. In order to provide the necessary outside air requirements to all three floors and basement, the ERVs serve as dedicated outside air units for the facility. Exhaust air, providing relief for the ERV's, is ducted from numerous occupied spaces back to the ERV. This exhaust air then flows over silica gel heat exchangers within the ERV to temper the outside air before it is discharged to the plenums.

Both energy recovery ventilators, located on the roof, operate on an occupancy-based schedule. ERV-401, serving the basement, second floor and third floor, runs from 6:00am to 6:00pm. ERV-401, serving the first floor restaurants and office tenant, operates from 6am to 3am. This occupancy can be adjusted.

When the ERV is in use, also known as occupied mode, the heat wheel is disabled when the temperature of outdoor air stream is between 55°F and 70°F. When the ERVs are in unoccupied mode, both the fans and heat wheel are disabled and the dampers are closed. Smoke detection is also installed in the exhaust duct on the unit. This is used to monitor the exhaust air for smoke, in which case would signal and alarm and fire system, while disabling the unit.

Make-up air units and kitchen grease exhausts provide proper ventilation and exhaust of equipment without cross-contaminating the building's plenums' for both restaurant kitchen spaces.

3.3 WATER SIDE MECHANICAL SYSTEM

The water source heat pumps are served by a water source heat pump hydronic loop, tempered by three natural gas boilers and closed-loop fluid cooler tower. This loop serves all floors in a parallel circuit arrangement. The loop serves as a heat rejecter or acceptor for the refrigeration cycle of each unit.

Two pumps circulate the WSHP loop, for redundancy purposes. These pumps operate in a lead/lag fashion. On a weekly basis, the lead and auxiliary pump alternate, in order for equal usage and depreciation to occur. While one pump is acting as lead, it shall run continuously, and at 100% output, for the seven day rotation. There are no variable drives connected to either pump. In event of a lead pump failure, the auxiliary pump will take over and an alarm will sound.

Two plants that temper the loop at the proper temperature required by the heat pumps is the boiler and fluid cooler plant. There are three natural gas boilers that all includes back draft fans and control panels with interlocks. With a total capacity of 414 MBH, 12.4 horsepower, 80 % efficiency and 40 gallons per minute capacity, these boilers are arranged in a parallel loop to serve the water source heat pump loop.

Each boiler will rotate on a lead/lag weekly rotation such the each boiler will lead every third week, much like the heat pump water pumps. All the boiler temperature set points are adjustable through the Sage controller. Each boiler will have an alarm output, indicated to the Sage controller, and can alert facility managers as well as the mechanical service contractor in case a boiler needs to be removed from the control sequence for any reason. In this case, the other boilers will operate as normal.

Once the heat pump loop water temperature, detected by the temperature indicator/thermometer and sent to the sage controller by the temperature indicator, falls to 64°F, the fluid cooler isolation valve (CV-5) closes. At this point, the systems bypass valve (CV-4) and all three boiler isolation valves (CV-1-3) open. Figure 3-4 shows the control sequences for the fluid cooler, by-pass valve, and boilers.

Table 3-4: Hershey Press Building Boiler Control Sequence of Operation

BOILER OPERATION CONTROL SEQUENCE					
	Fluid cooler	By-Pass Valve	Lead Boiler	1st Lag Boiler	2nd Lag Boiler
60°F	OFF	OPEN	ON	ON	ON
62°F	OFF	OPEN	ON	ON	OFF
64°F	OFF	OPEN	ON	OFF	OFF
66°F	OFF	OPEN	OFF	OFF	OFF

Each valve provides real-time feed of their open/close status. The bypass vale and the fluid cooler valve will never be closed at the same time, according to the sequence. Once the boiler approves the proper flow, 40 gpm, the lead boiler will enable and fire to maintain a discharge temperature above 65°F.

If the water loop temperature continues to drop to this point, to a temperature of 62°F, the first lag boiler shall be enabled and fire to maintain the discharge temperature by internal control modulation. In the scenario, if the first two boilers are unable to meet the proper discharge temperature and the water loop drops to 60°F, the second lag boiler will enable and fire.

Once the temperature begins to rise in the water pump loop, the second lag boiler will disable at 62°F and the first lag boiler will disable at 64°F. The lead boiler will disable at a loop temperature of 66°F, the ambient temperature for the loop, and the loop will bypass the boiler completely.

The second plant utilized to reject heat from the loop is the closed loop fluid cooler. The entering water temperature is 100°F and the leaving water temperature is 90°F, with an entering air temperature of the fluid cooler estimated at 78°F. By utilizing two fifteen horse power pumps, the fluid cooler cools the loop by spraying the loop to release heat, similar to the way a cooling tower works.

Once the 66°F water source heat pump loop rises in temperature to 85°F, the fluid cooler isolation valve (CV-5) will open and all three boiler isolation valves (CV-1-3) and system by-pass valve (CV-4) will close. At this stage, the heat pumps are rejecting heat to the heat pump loop and further heat rejection of the loop is required.

As the temperature of the loop increases to 86°F, the damper to the fluid cooler will open. At 87°F, the spray pump is energized. With proof the damper is open and at 88°F temperature, the first fan motor will turn on. As the temperature rises an additional degree, to 89F, a second fan motor is energized. As the temperature decreases, each temperature increment that powered a certain fluid cooler component will deactivate in the same corresponding manor. See Table 3-5 for a summary of the fluid cooler operation. Remember, the temperature set points can be customized.

Table 3-5: Hershey Press Building Boiler Control Sequence of Operation

FLUID COOLER OPERATION CONTROL SEQUENCE						
	Fluid Cooler (FC)	By-Pass Value	FC Damper	FC Spray Pump	FC Fan Motor 1	FC Fan Motor 2
85°F	ON	CLOSED	OPEN	OFF	OFF	OFF
86°F	ON	CLOSED	OPEN	ON	OFF	OFF
87°F	ON	CLOSED	OPEN	ON	ON	OFF
88°F	ON	CLOSED	OPEN	ON	ON	ON

The fluid cooler has a sump pump heater that will energize once the water temperature falls below 40°F. If the cooler would spring a leak or the water level drops below a certain level, a low water cutout switch will de-energize the heater and sound an alarm.

To simplify the water side system, a schematic can be created. The water source heat pump schematic, located in Figure 3-3, shows the integration of both plants prior to being distributed to the heat pumps. The schematic shows five control valves (CV 001-005) that will divert the flow depending on the temperature of the loop. An expansion tank (ET-001) and an air separator (AS-001) are used to maintain the correct loop water pressure. The boilers (B 001-003) are shown in parallel arrangement as discussed. The closed loop fluid cooler is marked CT-001 on the schematic. A heat pump loop chemical shot feeder is used to disinfect any micro bacterial growth.

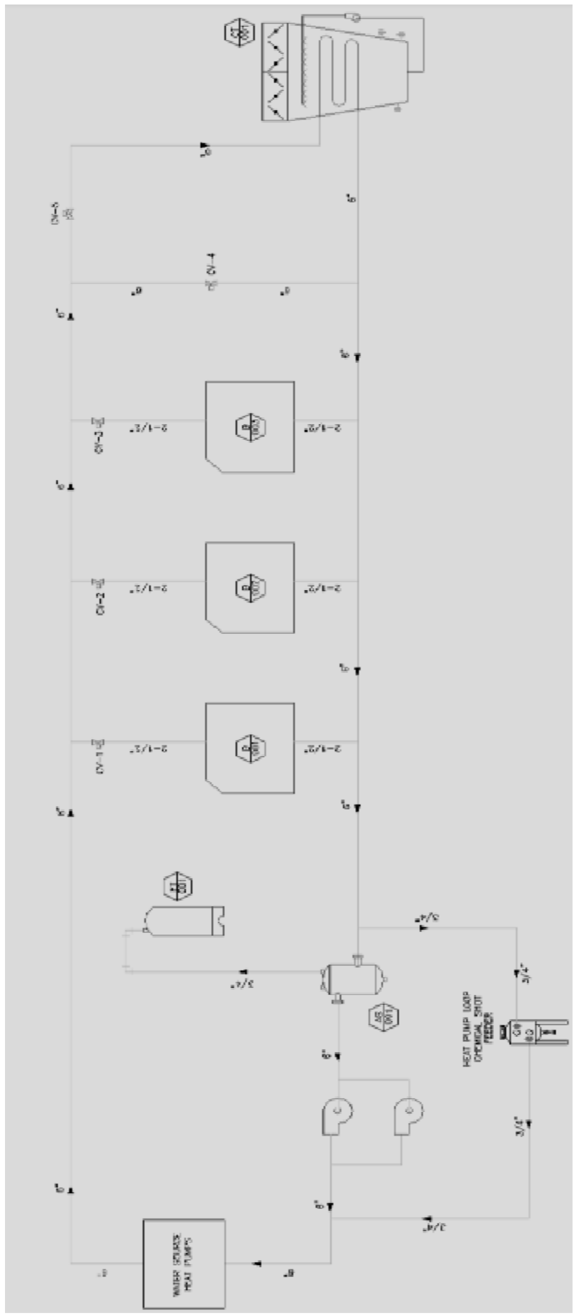

Figure 3-3: Water Source Heat Pump Loop Schematic

This section summarizes the compliance evaluations for the existing mechanical system at the Hershey Press Building. These standards include ASHRAE Standard 62.1-2007 and ASHRAE Standard 90.1-2007.

4.1 ASHRAE Standard 62.1-2004

The designers used ASHRAE 62.1-2007 to calculate the minimum outside air requirements for the spaces. Based on occupancy, population, and area, the minimum ventilation rates were calculated and compared to the original minimum outside air volumetric flow rate found. The results proved that indeed the Hershey Press Building had the proper amount of outside air being distributed to the system.

For the ventilation rate analysis, Energy Recovery Ventilator (ERV-402) was used to compare the minimum outdoor air ventilation that was calculated versus what was designed. The ERV serves the first floor only, which houses 3 major tenants' area. All three of the tenant's mechanical systems were designed and occupied at separate times. Two ducts mains from the ERV above, dedicated to outside air and exhaust air, run parallel to all three spaces, branching out to each to serve the plenums with outside and air and exhaust room directly through ceiling exhaust grilles.

This system, ERV-402, was the most important to analyze because of the diversity of the spaces it serves. The second and the third floor have similar occupancies, office space and conference rooms being occupied from 9-5 on weekdays, thus ERV-1 was sized to meet these criteria. However, the first floor was sized prior to the other two tenant's layouts, it was important to ensure the designer allowed enough ventilation air was leftover after the third design was finished, without knowing who the second and third tenants were going to be. There is also a variety of occupancies with varied times of occupancy, that need to be taken into consideration. The first floor also has more complex exhaust and make-up air systems that had to be examined to ensure there was no cross-contamination of grease exhaust and recirculated air.

For these reasons, it is necessary to calculate the outside air requirements for the first floor, being served by ERV-402, to ensure the ventilation design used to select the ERV was valid.

Table 4-1: Hershey Press Building Standard 62.1-2007 System Final Results

Hershey Press Building ERV-402 ASHRAE Standard 62.1-2007 System Final Results									
Calculated Minimum Ventilation				Minimum Outdoor Air Intake Airflow					
System	Floor Area Served (A_s)	Population Served (P_s)	Primary Supply Airflow Rate (V_{psd})	OA Intake Flow Req'd (V_{ot})	OA Intake Req'd Fraction of Primary SA ($Y = V_{ou}/E_v$)	Ventilation System Efficiency (E_v)	OA per Unit Floor Area (V_{ot}/A_s)	OA per Person (V_{ot}/P_s)	% OA per Design Primary Supply Air (Y_{pd})
ERV-402	20,467	569	40,000	8,298	0.21	0.84	0.41	14.6	21%

Using the minimum ventilation rates taken from Table 1-6 in Standard 62.1-2007, the ventilation rates were calculated. In Table 4-1 above contains the overall system results.

One way of reducing the Z_p value for this zone is to supply more air to the space. While using the *Short-Term Condition* calculation may be another possible way of reducing Z_p, it is not applicable in this case due to the dining room being occupied 12-14 hours a day, thus not being considered short-term.

Although Zone 12, the dining room for Devon Seafood has the maximum value for Z_p, it is important to realize that the rest of the Zp values are close in proximity to one another. In fact, most of the values are in the 10-20% range. This is quite beneficial for our ERV/heat pump system. As discussed in Section 5, the amount of o/a required to each space is critical to the design. If all the spaces has similar outside air fractions, it is much more likely that each zone will receive an even amount of outside air, thus meeting their zone ventilation requirement. In other words, if all the zones are pulling for relative equal amounts of outside air, there is a greater chance that the ventilation requirements will be met.

Some of the zone efficiencies (E_{vz}) are greater than one. This is the case because a few of these spaces are being over ventilated, being supplied more outside air than what is actually required. Having an abundance of ventilation air isn't' necessarily a bad problem to have. Studies have found that over ventilated spaces have occupants that are less lethargic and more productive. The spaces that have efficiencies greater than one, such as conference rooms, offices, and kitchens, will have occupants that will benefit from the additional ventilation.

After the results were calculated, the data calculated for minimum ventilation was compared to the original calculations made by the designer a few years earlier. See Table 4-2 below for the comparison.

Table 4-2: Hershey Press Building Standard 62.1-2007 Compliancy Calculations

Hershey Press Building ERV-402 ASHRAE Standard 62.1-2007 Calculations			
Calculated Minimum Ventilation		As-Designed Minimum Ventilation	
Tenant	Calculated V_{ot} (CFM)	Orignal Min. O/A (CFM)	Meets Std. 62.1-2007?
Lobby	24	25	YES
Houlihan's	2,975	5,760	YES
Devon Seafood Grill	3,261	3,330	YES
Jack Gaughen Realty	752	1,925	YES
Total	7,011	11,040	YES

All of the original outside air calculations from the three tenant spaces met and *exceeded* the Standard 62.1-2007 calculated ventilation requirements. Therefore, all three tenant spaces being served by ERV-402 are Standard 62.1-2007 compliant.

In fact, the original outside air calculated was 65% higher than the found minimum outside air required. It's important to remember that the original designer was very conservative with his calculations for the future tenant spaces. Without knowing the future occupancy type or population, it was necessary to estimate the amount of outside on the high side, to ensure the original system would be able to handle the new tenants without needing to be replaced.

4.2 ASHRAE STANDARD 90.1-2007

According to ASHRAE Standard 90.1, its purpose is to "provide minimum requirements for the energy-efficient design of buildings except low-rise residential buildings". Within the scope of the standard includes new systems and equipment in existing buildings, in which the Hershey Press Building would be considered.

Section 5 – Building Envelope

The Hershey Press Building, located in Hershey, Pennsylvania, is included in the Climate Zone 5A, according Appendix B in the standard.

According to the *Compliance Paths,* Section 5.2.1, the building can be evaluated using the Prescriptive Building Envelope Option since "the vertical fenestration area does not exceed 50% of the gross wall area for each space-conditioning category. With over 200 windows, the 40% of glass area for the entire building is not surprising. See Table 4-3 for the calculation used to determine the total glass percentages.

Table 4-3: Hershey Press Building Roof & Building Envelope Glazing Percentages

Hershey Press Building Roof & Building Envelope Wall/Glass Values			
	SF	Glazing	% Glazing
Roof	24,710	0	0%
Walls	36,900	14675	39.8%

Back during the original construction, a brick encased concrete block facade supported by a concrete structural system, a relatively insulated R-value was established. The roof, walls, floors, and glass can be checked for meeting their energy-efficiency. By calculating the U-values, for the different building envelope elements, it can be checked for meeting 90.1 Building Envelope Requirements in Table 5.5-5.

For the roof, the construction is a 6" Concrete slab roof with 2" ISO insulation and EPDM Single-Ply membrane. The overall roof construction U-value is 0.12 (R-value of 8). The standard requires roof insulation entirely above deck for a non-residential roof to have a maximum assembly U-value of 0.63 (Insulation minimum of R-15). Therefore, the roof of the Press Building meets the Roof Building Envelope Requirements.

For the walls, a U-value of 0.13 (R-Value = 7.86) was found for the Hershey Press Building. See Table 4-4 for the derivation of these values. Since the walls are Nonresidential, mass walls, above grade, the maximum u-value is 0.123 (Minimum R-Value = 7.6). Therefore, the walls of the Hershey Press Building do not meet the Wall Building Envelope Requirements.

Table 4-4: Hershey Press Building Thermal Wall U & R Value Properties

Hershey Press Building Thermal Wall Properties	
Layer	R-Value
Inside Air Film	0.68
5/8" Gypsum Board	0.56
1" Insulation	3.33
12" HW Concrete Block (filled)	2.56
4" Face Brick	0.56
Outside Surface Resistance	0.17
Total R-Value	7.86
Total U-Value	0.13

For the floor, a 6" concrete slab on grade is used. Its overall U-value is 0.53. According to Table 5.5-1, the maximum assembly U-value for an unheated, slab on grade floor is 0.73. According to this value, the Press Building's floor meets the Floor Building Envelope Requirements.

For fenestration elements, the Press Building has double coated ¼" glass picture windows, non operable. The U-value for the windows is 0.29 with a shading coefficient of 0.43. For the standard, it requires fenestration with 30.1-40% vertical glazing of wall for fixed windows to be 0.57 U-value and 0.49 shading coefficient. Therefore, the Press Building windows do meet the window standards for 90.1 due to the high shading coefficient.

See Table 4-5 for a summary of the building envelope requirement compliancy.

Table 4-5: Hershey Press Building – Building Envelope Requirements for Zone 5 Summary

Building Envelope Requirements Summary			
Opaque/Fenestration Elements	Max. U Value Req'd	Actual U-value	Meets Standard?
Roof - Insulation Entirely Above Deck	0.63	0.12	Yes
Walls - Above Grade, Mass	0.12	0.13	No
Floors – Slab on Grade, Unheated	0.73	0.53	Yes
Windows - Vertical Glazing of 30.1-40% of Wall, fixed	0.57 w/maximum SHGC of 0.39	0.29 w/ SHGC of 0.43	No

Section 6 – Heating, Ventilating, and Air Conditioning

In order to meet Section 6.4 *Mandatory Provisions* and Section 6.5 *Prescriptive Paths*, the building must have more than 2 stories and the overall square feet must be greater than 25,000. Since the Press Building has 3-story, 75,000 square foot building, it is included in both these sections.

For starters, the water-source heat pumps must follow the efficiency standards of Table 6.8.1D – *Packaged Terminal and Room Air Conditioners and Heat Pumps.* The minimum efficiency for a replacement packaged terminal heat pumps (PTHP) in cooling is 10.8 EER and for heating is 2.9 EER. The heat pumps installed in the building have a cooling EER of 14.2-14.6 and a heating COP of 4.5-4.6. The installed heat pumps meet the standard.

The boiler, found in Table 6.8.1F of the standard, requires that all Gas-Fired Boilers, greater than 300 MBH, at maximum capacity should have a minimum efficiency of 75%. The three installed boilers meet the standard, each of which has an efficiency of 80%.

In the same regard, the closed loop fluid cooler is considered a type of heat rejection equipment, and Table 6.8.1G of the standard handles the efficiency requirements. Similar to a propeller or axial fan cooling tower, the fluid cooler is required to meet a performance level greater than 20 gallons per minute (gpm) per horse power (hp). The press building's heat pump is 690 gpm and has two 15 hp motors. Therefore, it has a ratio of 23 gpm/hp, thus it does not meet the standard.

The exhaust hoods, vents and ventilators are all equipped with motorized dampers, thus meeting standard 6.4.3.3.2. The maximum leakage for the damper is less than 10 CFM/square foot of damper area.

All ducts that are located in non-conditioned spaces, not including plenums, need to be insulated according to Section 6.4.4.1. The ducts for the press building are insulated in the shafts and on the roof, therefore following the standard's requirements. Also, the entire pipe that is located in critical conditions where condensate is not welcome, needs to be insulated.

Since heat pumps are being utilized, each heat pump will have its own zone controls for re-heating, re-cooling, and/or mixing with conditioned room air. Therefore, the system meets section 6.5.2.1 of the standard. In section 6.5.4.4, the standard asks that each hydronic pump should have a two-position automatic valve interlocked to shut of water flow when the compressor is off. After reviewing the specifications for the heat pumps, it indeed is in line with this standard.

Hydronic (Water Loop) Heat Pump Systems, discussed in section 6.5.2.2.3, requires that the loop have controls that are capable of a 20°F deadband for the supply water temperature, which the Press Building is able to do. Following the code for fluid coolers, the Press Building also has an automatic valve to bypass all but minimal flow pass the cooler.

The ERV-402 is a 7.5 hp for a maximum 9,600 CFM outside area/supply air volume. In other words, it can serve a constant volume of 0.78 hp/1000 CFM. The standard, as stated in Table 6.5.3.1, demands that the fan power shall not exceed 1.2hp/1000 CFM for a constant volume supply air volume less than 20,000 CFM. Therefore, the energy recovery ventilator meets this criterion.

In Section 6.5.6 of the standard, there are specifications that deal specifically with *Energy Recovery*. The system is a perfect candidate for heat recovery since the capacity of the ERV is greater than 5000 CFM (9600 CFM) and has a minimum outside air supply of 70% or greater (100%). Therefore, the silica gel energy wheel is following the 50% energy recovery effectiveness from the recovery of energy from the exhaust/relief air of the system.

The following section, Section 6.5.7, goes into the specification for kitchen hoods. Since the two individual kitchen hoods for Devon Seafood and Houlihan's Restaurant are both larger than 5,000 CFM, the standard requires that the makeup air unit should be sized for at least 60% of the exhaust air volume. The make-up air units for Houlihan's and Devon Seafood are sized for 85% and 94% of the kitchen hood exhausts respectively, thus following the standard.

Section 7 – Service Water Heating

The Hershey Press Building has four domestic hot water heaters to serve the building. Located in the basement, three gas-fired boilers, and one auxiliary boiler, supply heated water to the heat pump loops. All boilers have a 94% thermal efficiency and each having an input varying from 500-540 MBH.

The standard, in Table 7.8, requires the performance of gas storage water heaters, greater than 75 MBG, to have a minimum thermal efficiency of 90%. All of the domestic water heaters meet this standard.

Section 8 – Power

In terms of voltage drop, all feeders shall be sized for a maximum voltage drop of 2% at design load. Also, branch circuits shall be sized for a maximum voltage drop of 3% at design load.

Section 9 – Lighting

The requirements for lighting systems in buildings are discussed in this section. Because the Hershey Press Building has a mixed occupancy, it is necessary to take the most conservative value and apply that to the entire building. For example, according to Table 9.5.1, the maximum lighting power density for a dining-bar lounge/leisure area is 1.3 watts per square foot and for an office building is 1.0 watts per square foot. By using the Building Area Method, I summed the watts per square foot for the entire facility as well as the area. The results were astounding. The building's overall power density is 1.9 watts per square foot, which is extremely high and does not pass code.

The reason the building's lighting power density is so high is due to old fixtures and aesthetically-pleasing lighting plans. The architect was concerned only for the "look" of the lighting, and less concerned with energy conservation. One way to reduce the power density is to determine space by space criteria for lighting density and reduce each space accordingly.

Section 10 – Other Equipment

After comparing Table 10.8 *Minimum Nominal Efficiency for General Purpose Design A and Design B Motors*, it became apparent, after comparing the date to the Press Building's data, that all motors met the criterion.

Overall, six sections of ASHRAE Standard 90.1-2007 were evaluated. The building envelope did not meet all the standards required by this standard, namely the walls and glazing fell short of expectations. In the heating, ventilating and air conditioning section, it meets most of the standards except for the heat rejection equipment, the fluid cooler, needs to be more efficient in order to meet the standard. The service water heating, gas-fired domestic water heaters of the space met the criterion of this section. As did the power requirements in the power section. Section nine, lighting, was one section that the Hershey Press Building failed to meet miserably. The lighting power density for the facility greatly exceeded the maximum allowable, and therefore failed the building's ability to be lighting efficient. In the other equipment section, the press building redeemed itself to an extent, by meeting all the efficiencies in the motor requirements.

5.0 Sustainable Retrofit Introduction

The Hershey Press Building has gone through four extensive design processes and energy analyses for each of the four tenant fit-outs. The mechanical design was chosen based on many factors, including system control in multiple zones, integration of the structural, mechanical and architectural systems, as well as energy efficiency and life cycle cost. While the McClure Company chose an extensive, logical design, there are still some changes that can be made to optimize the system long term. These include strategies to reduce the energy lifecycle cost for the building, improve in the indoor air quality, and make the building more sustainable.

5.1 SUSTAINABLE RETROFIT OBJECTIVES

A sustainable retrofit is an analysis of beneficial changes that could be utilized in a real world application, for all intents and purposes of this report. The Hershey Press Building manager stated that if the sustainable study concluded anything with an optimal payback and substantial energy savings, it could potentially be executed. A main goal for this study is to choose realistic alternatives that future benefits will lead to a need for implementation.

The mechanical retrofit redesign will focus on three major areas associated with sustainability, including water efficiency, energy efficiency and indoor environment quality. In each area, three to six alternatives will be evaluated. With each alternative, key factors will be evaluated in terms of cost and constructability. These factors will need to be addressed and researched, prior to any sustainable alternative suggestions.

Two breadth alternatives will also be analyzed to supplement the mechanical proposal. The first area includes a possible architecture redesign of the building envelope in order for the building to become more energy efficiency. These include improvements to the roof, wall, and windows. The second area will provide a construction management analysis which will include cost and schedule impacts due to alternatives. The mechanical designer and contractor are from the same company, design/build, estimation and installation challenges can be predicted and later evaluated.

5.2 OPTIONS FOR THE WATER EFFICIENCY STUDY

With three million gallons of on-site water used annually on site, water conservation should become a priority. While water is often treated as an infinite resource, possibly due to its inexpensiveness, it is actually not an infinite resource and has been under restrictions a number of times. By reducing the water usage in the Hershey Press Building, a sustainable water system could be initiated.

This section will discuss different options researched for improved water efficiency for the Hershey Press Building. One option for water efficiency was to take treated building water and use it for the exterior landscaping. After close examination of the landscape outdoors, it was quite minimal and would not be a cost effective choice. A second option for water reduction includes implementing water efficiency methods in the building's daily plumbing use. Low to no flow lavatory and sink fixtures could be installed, as well as lavatory and sink fixtures with automatic shut offs. This option was also eliminated, after researching the current plumbing fixtures already were already low flow and had sensors. The final and selected option was to use treated building water for the fluid cooler instead of fresh water. Section 6 will feature this study.

5.3 OPTIONS FOR THE ENERGY EFFICIENCY STUDY

With an estimated two million kWh energy demand usage for electricity annually, it becomes necessary to research alternatives for energy use and reduction. Energy savings can occur by discovering ways to reduce energy usage. Analysis is needed for the chosen solution to guarantee energy savings and rapid payback of the instituted system. Similar to the water efficiency study, multiple options were researched beforehand in order to find the most suitable alternative to investigate. By analyzing the effectiveness and application of all of these ideas, one can determine which should be suggested for implementation. Energy savings and annual payback can then be calculated. This information will then be added to the energy savings of the entire building.

One option to reduce energy usage is to combine the heating for the heat pump loop and domestic water heating requirement. Instead of using dedicated systems for both, the efficient condensing boilers could be used to provide the heating for both. A storage tank for the hot water supply would have to be installed for this system to operate. Also, attention to loop temperatures and dish washing temperatures would have to be investigated. Use of the auxiliary boiler or addition of a boiler may be an end result of this analysis; in order to ensure neither the water loop system or domestic water heating system is compromised.

This option was eventually eliminated because of the boiler range temperatures required for the loop was substantially lower than the temperature range for the domestic hot water. The water source heat pump loop was only required the boiler to heat the loop to 66°F. The domestic water temperature requirement would almost be three times as much. Therefore, combing the systems would not be effective.

A second option to improve energy efficiency for the site is to find ways to improve or reduce the load on the boiler and its gas consumption. One way is to improve the boiler to a variable load or pulse boiler. Another way is to use geothermal system or ground source heat pump to reduce the boiler overall consumption. A third method is to initiate micro turbines for combined heat and power for the mechanical system. While the during the winter months, the mechanical system would use the excess heat to supplement the boilers in the water loop heating requirements, the summer would present a challenge for the excess heat use. Domestic water heating in the summer, however, could be impacted by this heat excess to even further the reduction of boiler requirement during these months.

While this option had many possible alternatives, each alternative seemed to fall short individually. The combined heat and power, along with the micro turbines, posed problems of installation, first cost, and payback for the investment. Changing the boiler was also a failed idea, because the condensing boiler is best suited for lowing hot water temperature requirements. Geothermal systems and ground source heat pumps also fell by the way side due to the enclosed site. A possible idea was to disassemble a rollercoaster fifty feet away, bore wells on the open site, and reassemble the rollercoaster upon completion. This solution is extremely impractical due to the length of the piping required and the disturbance of a railroad that runs between the park and the site.

A third energy reduction option that could be implemented is the use of variable frequency drives on the water loop pumps. This method would require a reconfiguration of controls for all heat pumps as well as on the pump itself; however, it would allow the pump to run on a schedule rather than continuously. The lead and lag pump would still remain on a biweekly usage. A possible energy savings and pay back could be determined for this measure. This option was chosen for the study and can be found in Section 7 of this report.

5.4 OPTIONS FOR THE INDOOR ENVIRONMENTAL QUALITY STUDY

The indoor environment of any building is a major concern for building owners. The tenants deserve spaces that are well ventilated and free from any health deficiencies, like an exposure to contaminants or improper ventilation to spaces.

While overall the ventilation flow rates for the building appears meet ASHRAE Standard 62.1-2007, the distribution of this air through a combined supply/return plenum makes it unclear whether each heat pump will receive the proper amount of outside air for the zone it serves. By developing methods for proper ventilation air distribution, the indoor environmental quality can be optimized.

Similar to the previous two sections, several options were developed and researched in order to find the best solution based on cost, affectability, and health improvements for the facility. Each option is listed below with reasoning why, or why not, the option was chosen. These options range from improved ventilation strategies to air quality improvements.

One option is utilize carbon dioxide monitors. These devices could be installed in high occupancy spaces to manage the amount of ventilation required for each space. Not only would this increase the efficiency of the ventilation system, it would also give the owner a measurement and verification method to ensure proper ventilation of spaces and optimized indoor air quality.

Initially, this method seemed optimal and one could question why it wasn't already in place. However, because of the current design of ventilation air distribution, this option would stop short. An increase to the ventilation air only occurs within the plenum. Without direct ducting the ventilation air, it cannot be guaranteed that the additional ventilation is reaching the desired space.

With the increase of return air circulation into the spaces, filters place in the return air grilles could be used to remove contaminants from the populated spaces. This would improve the cleanliness of the plenum spaces as well as reduce the amount of filtering done at the heat pump level. In turn, this could reduce the amount of filter changes for the heat pumps, which is quite a feat due to the quantity and locations of multiple terminal units.

While in theory, this option seems like a positive initiative, it has one major issue. The pressure drop of a filter place on a return grille would put strain on nearby heat pumps, with a possibility of damaging the internal motors.

A third way to improve the indoor environments air quality is to tackle the kitchen make-up air and exhaust. Since the same plenum is used for all first floor inhabitants, kitchen and dining rooms alike, certain precautions have to take place to ensure the pressurization of the plenum is optimized. It is also necessary to use hoods to exhaust the kitchen spaces of harmful air contaminants.

A possible solution would be to separate the kitchens from the central heat pump system and provide commercial kitchen ventilation system that would solve kitchen comfort problems as well as a dedicated system that will not affect the office and dining systems. A dedicated outdoor air system (DOAS) could be installed to take care of both the conditioning and make-up air required for the system. Load will also be taken from the central heat pump loop and therefore, the conditioning of this load on the loop would be reduced significantly. The control sequence for the DOAS unit and the hoods will need to be highly coordinated in order for the energy efficiency and spatial comfort to be optimized. Further research and calculations will have to take place in order to properly demonstrate the beneficial effects this system could offer.

This option has flaws as well. While a dedicated kitchen unit would solve the kitchen/dining room issue for both restaurants, that would be the only resolution made. The offices and other spaces would still have incomplete ventilation. The kitchen already has a make-up air unit within the space, coordinated to the exhaust fans in order to keep the kitchen pressurized and well ventilated. Although this option was not chosen for the study, the final option will correct the kitchen ventilation contamination issue.

The final option, and the option chosen for more in-depth research, discovers a way to guarantee proper ventilation to all spaces. One way to ensure proper delivery of ventilation air is to directly duct the outside air into all tenant spaces. This method was chosen and is discussed in greater detail in Section 8 of this report.

5.5 SUSTAINABLE RETROFIT SUMMARY

Three sustainable alternatives were chosen and will be discussed. These three include a rain water usage application, the addition of variable frequency drives for the pumps, and ducted ventilation air to all critical spaces. These three studies, although they may seem quite simple, are three highly possible projects the owners of the Hershey Press Building could pursue. The next three sections will discuss how each option was researched, the cost analysis associated with each, and final payback opportunities if implemented.

In order to correctly conduct a water efficiency study, it is important to identify equipment and systems in the building that use the majority of water. During the summer months, the fluid cooler, used for water source heat pump heat rejection, utilizes a fresh water supply for its cooling purposes. An estimated 5,000 gallons is used by the fluid cooler on a typical day in July. A proposed alternative is to use treated building water for the fluid cooler instead of fresh water.

Treated building water could be taken from the following systems:

- Condensate Water Loop: The condensate water from the water source heat pumps could be used to supplement the fluid cooler. A pump would have to purchased and installed in order to supply the water. The condensing boiler condensation, in the winter time especially, could also be used for excess water.
- Grey water: The grey water, including dishwasher water and sink water, could be treated and supplied to the fluid cooler as well. The treatment of this water would be substantial, but between Houlihan's and Devon Seafood kitchens, an annual abundance of grey water should be sufficient.
- Rainwater: By redirecting this water from a drain and into a storage tank, this rainwater could be redirected during times of almost drought conditions. Rain water could be captured from the roof and directed to the basement through roof drains. Once in the basement, water can be directed underground to a large storage tank for later use. A pump would have to be installed to take the water from collection to its desired destination.

Condensate water, through further investigation, was not a logical choice. One reason is because the abundance of condensate is lower than what is required by the fluid cooler. The infrequency of condensate, and low predictability, also causes this option to fall short. Grey water is also another poor choice, especially from the kitchen standpoint. The grey water would have a substantial amount of grease intertwined with the water. Even with the use of a grease interceptor, the water would still be unsuitable for the fluid cooler.

Therefore, rainwater becomes the primary choice. Central Pennsylvania is blessed with a climate that yields an abundance of rain throughout the year. This steady flow, if captured, could serve the Hershey Press Building with more than enough water required for the fluid cooler. The shape of the building is also advantageous for the collection of rain water. While the building is only three floors high, it makes up for the lost vertical space by an elongated horizontal plan with a flat roof, pitched for drainage purposes.

The roof area of this massive structure is approximately 24, 180 square feet, which allows the collection of rain water through seventeen roof drains, arranged around the perimeter of the building, approximately three feet from the parapet. There are sixteen 3" roof drains, with the maximum individual collection area of 2,332 ft^2 and one 4" roof drain has the maximum collection area of 3,256 ft^2. The roof drains are then combined around the perimeters of the roof into 7 branches that penetrate through the building In the basement, all the branches are consolidated into an 8" rain water collection piping with test tees and clean outs. The main drain then ties into an existing 10" roof drain that directs rainwater into an underground storm drain.

One potential pitfall with rainwater is the infrequency of rain throughout the summer months, at the time when the fluid cooler is using the most water. The storage tank will have to size large enough to supply enough water between the days of no precipitation.   The tank will also need to be served by an automatic city water fill in case of low water levels caused by possible drought scenarios. An overflow gauge and relief piping into the storm drain would also be required, in order to prevent overfilling during continual rains and flood scenarios.

The first step for the rainwater collection analysis was to research the amount of rain water that could be collected monthly. The National Weather Service Forecast Office has an online resource that offers a monthly water summary with historical archived data available, based on location. In this case, Harrisburg was representative of Hershey climate. Three years of data were averaged in order to get a relative approximation of typical precipitation index.   Only the months of April through October were used due to cooling towers typical months of requirement for water.

The rainwater measurement was converted into feet and multiplied by the roof area in order to get the volume of water available for capture. This volume of cubic feet was converted into gallons. This value was reduced by 10% to adjust for evaporation and other losses in order to get the final adjusted gallons of rain water during the months April through October. These values can be seen in Table 6-1.

Table 6-1: Total Rainwater Collection in Gallons

	Annual Rainfall (2006-2008)		Maximum Available Rain Water to Capture/Month		Final Adjusted Gallons of Rainwater
	3-Year Average (in)	3- Year Average (ft)	Avg. Rain (ft) * Area (ft) = (ft3)	Total Volume of Rain (gallons)	Adjusted for 10% Evaporation Loss (gallons)
Apr	3.37	0.28	7778	58,218	52,396
May	3.03	0.25	10901	81,595	73,436
Jun	5.80	0.48	5118	38,309	34,478
Jul	4.03	0.34	7113	53,240	47,916
Aug	3.30	0.28	2196	16,440	14,796
Sep	4.60	0.38	13319	99,694	89,724
Oct	3.93	0.33	3849	28,807	25,926

With the amount of rain water that could possibly be collected, it became necessary to compare that value to how much water the cooling tower actually uses during those months. The cooling tower is a BAC Model FXV-641 Closed Loop Fluid Cooler, with approximately 690 gallons per minute of water passing through its system. The cooling tower is sized for 230 tons with a 10 degree change in temperature (delta T).   In order to compute the amount of water the fluid cooler requires per month, it is necessary to find the makeup water evaporation rate. This is the rate at which the water needs to be replenished per hour based on the gallons/ton of water used by the fluid cooler, also known as the makeup water flow rate. The equation used in Figure 6-1 for the evaporation calculation was taken from the manufacturer's literature.

Closed-Loop Fluid Cooler Evaporation Calculation

Evaporation Rate (Gallons/Ton-Hrs)	=	Flow Rate/Ton (gpm/ton)	*Delta T	*.06 constant (min/Hr)
1.8 Gallons/Ton-Hrs	=	3	*10	*0.06

Figure 6-1: Evaporation Rae for the Closed Loop Fluid Cooler Calculation

Next, computer energy modeling software, Trane TRACE, was utilized to find the water required in gallons/month by the fluid cooler. TRACE models the building energy conditions, based on internal and external thermal loads, in order to generate the required amount of conditioning the spaces are required to have in order to maintain certain set points. The loads are translated into energy consumption based on the source. The scope of these calculations includes district hot and/or chilled water, in this case three boilers and a closed loop fluid cooler. Below, Figure 6-2, is the unloading curve for the fluid cooler, as modeled by the program. TRACE is able to calculate the total amount of makeup water required by a fluid cooler.

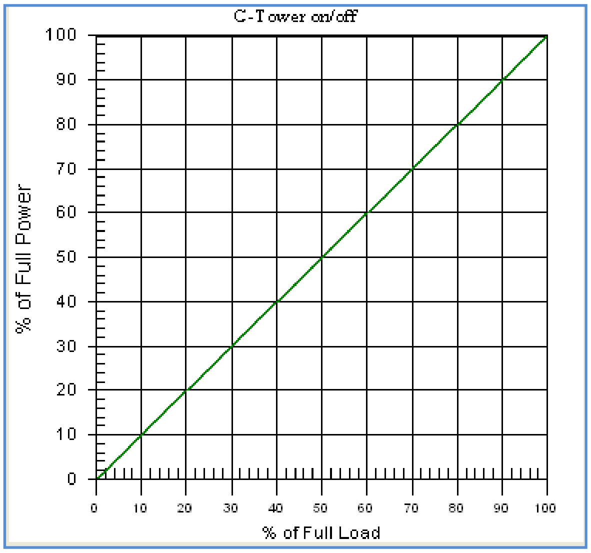

Figure 6-2: Unloading Curve for the Closed Loop Fluid Cooler

With the cooling tower make-up water requirement computed, it can now be compared to rain water gallons. Both of these values are shown, side by side, in Table 6-2. Notice that the cooling tower requirement is about 55% greater than the total gallons of rainwater, on average. This will require additional water to be used to supplement the system. The quantity of rain water (gallons/month) is multiplied by the price per gallon of water to find the overall savings, by month. June is the month with the greatest savings, while May has the least amount of savings.

While the rainwater cannot completely fill the requirements of the fluid cooler, it can greatly reduce the amount of fresh water required. Not only does this system have the opportunity to save money on water usage, it is also very sustainable system, reusing one of our most important resources.

Table 6-2: Annual Rain Water Data & Cooling Tower Requirement Comparison

	Total Gallons of Rain Water	Cooling Tower Requirement	Additional Water Required	Savings
	in Gallons/month	in Gallons/month	in Gallons/month	$0.0097 / Gal
Apr	52,396	62,000	9,604	$508.24
May	73,436	109,200	35,764	$712.33
Jun	34,478	127,800	93,322	$334.44
Jul	47,916	137,700	89,784	$464.79
Aug	14,796	132,100	117,304	$143.52
Sep	89,724	100,900	11,176	$870.32
Oct	25,926	63,800	37,874	$251.48
Total	**338,672**	**733,500**	**394,828**	**$3,285.12**

Table 6-2 also shows that during the peak months between June and September, the cooling tower uses and average of 125,000 gallons/month, or roughly 31,250 gallons/week. This information becomes important when sizing the underground storage tank. The tank will be sized on the weekly usage of gallons; therefore, a 32,000 gallon storage tank could be used.

While this method of sizing the tank is optimistic and simple at the same time, it should give a rather conservative estimate of a size. Other calculations, including overlaying the dry bulb and wet bulb in order to form an unloading chart to approximate the evaporation rates would have required substantial data. Some of the data required was not available during the time of the study, thus this method was abandoned.

Other factors that affected the tank selection include economic and technical factors. The tank will be placed underground, therefore excavation and connection to the rain water piping must be taken into consideration. Since rock will be an issue, the tank must be durable enough to withstand ground pressures and rigidity of its surroundings. The price of the tank must also be estimated based on size. See Figure 6-3 for calculation of tank size.

Calculations to Size a Rain Water Storage Tank

Volume (ft^3)	=	Pi	*Radius^2 (ft^2)	* Length (ft)
4,278 (32,000 gallons)	=	3.14	*$(5)^2$	* **55**

Figure 6-3: Rain Water Storage Tank Sizing Calculation

Therefore, a tank, estimated to have a ten foot diameter, should be approximately fifty-five feet in length in order to hold 32,000 gallons of rainwater at a time. Using past estimation data, used by McClure Company of other past water collection tanks, an estimate of $90,000.00 for the tank would be sufficient. One-third of that value, $29,700.00, represents the cost of the tank, while the other two-thirds represent the install, excavation and labor estimate. The first cost, $157,320.00, and annual savings, $3,285.00, are then used to calculate the payback for this investment, 48 years, as seen in Table 5-3.

Table 5-3: Payback for an Underground Rain Water Collection System

First Cost	An Savings	Payback (Years)
$157,320.00	$3,285.12	47.9

The payback for this estimate is not optimal. A more reasonable payback, and investment for the owner, would have been somewhere in the area between ten and twenty years. While this payback will not be appealing to the building owner, it would have environmental and sustainable qualities if initiated. If the building was going to any LEED ratings, this would be an excellent way for the Hershey Press Building to earn water efficiency credits.

Once the water is collected in the storage tank, it would have to be pumped to the fluid cooler outside. The fresh water connection and the storm drain/rain water connection are in proximity of one another in the basement. This would alleviate the connections and tie-ins required for this system to work.

Another modification required for this system is a rainwater filter. The rainwater will have a variety of particulates. Although the water from the roof will be relatively cleaned, especially when compared to water from a parking lot, a filter is still required to ensure clean water for the fluid cooler. One solution is a rainwater Vortex filter, similar to Jay R Smith, which has a floating suction line, prior to entrance of rainwater to the tank, which allows particulates to settle. While the recirculation pumps for the fluid cooler will have an inlet strainer, and a chemical injection system is already in place, the Jay R Smith Vortex filter, installed in the tank, will alleviate the existing filtration system. Below, in Figure 6-4, is an illustration of the rainwater Vortex filter.

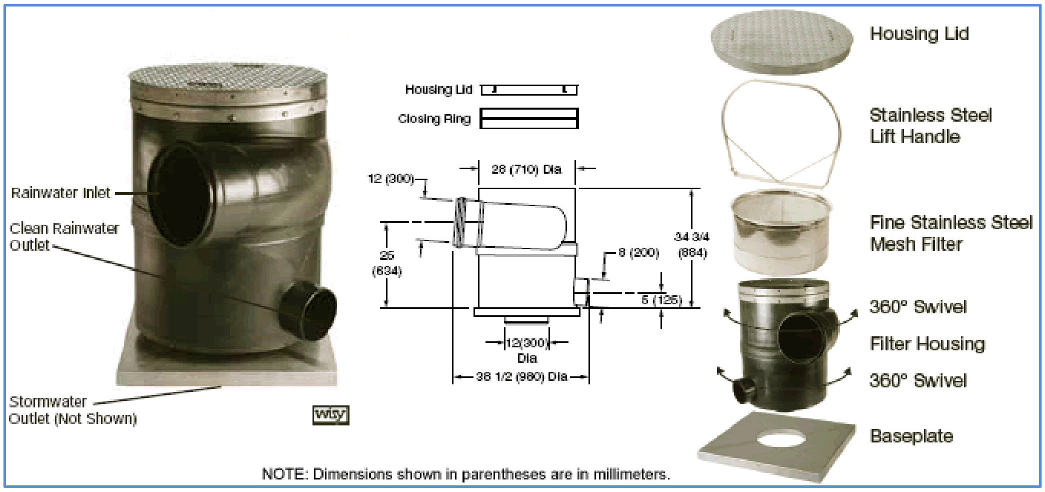

Figure 6-4: Jay R Smith Vortex Rainwater Filter

Overall, I would not recommend the rainwater collection system for cooling tower make-up water as a viable system for installation. While the owner may integrate this system for sustainable reasons, based on the approximate fifty year payback, this retrofit option is awash.

Annually, the Hershey Press Building use approximately 3,006,500 gallons of water. This value was taken from the owner's utility bills for water consumption. With the rainwater collection system, 338,672 gallons of water can be reused, resulting in 11% water savings.

The energy study will focus on the two-pipe heat pump water loop. This loop provides the perfect heat absorption/rejection mechanism necessary for the refrigeration cycle for each heat pump. The loop is kept at a temperature necessary for the loop by a natural gas boiler and fluid cooler. The small pipes are also run through the small vertical shafts between floors. One possible evaluation for improvement is the control sequence between the pumps and the heat pumps. The pumps are utilized at full output continuously. If the pumps could be ramped back by a variable frequency drive while reconfiguring each controller for the heat pump terminal units, an efficient pumping system could be satisfied. This could lead to potential energy cost savings.

While the energy savings may prove that an addition of variable frequency drives (VFDs) would be advantageous, many alterations would need to occur to the system. Ninety-Four heat pumps would also need their controls to be reconfigured, to allow for a variable flow of the heat pump loop. This would involve an addition a strainer and an automatic temperature control valve that would open if the heat pump needs to accept or reject heat from the loop. A schematic of this is shown in Figure 7-1.

This would not be an easy task; the heat pumps would have to be located individually, changed out, and all work would have to be done while the spaces are unoccupied to minimize disruption to tenants. Two variable frequency drives would need to be purchased and installed, one for each pump. Pressure sensors will be utilized to vary the pump speed according to what is required by the loop. For example, if the pressure in the loop increases, that means more heat pump valves are closed, therefore signaling the pump to step down from current state. If the pressure in the loop decreases, more valves to the heat pumps are opening, requiring a greater flow required by the pump to produce.

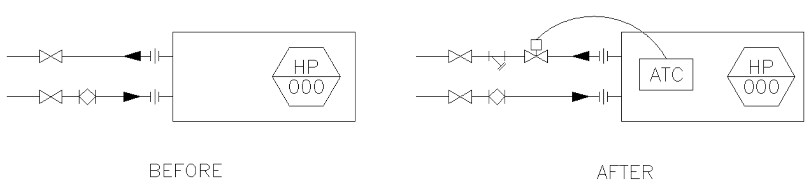

Figure 7-1: Change in Heat Pump Control Configurations

To find if a VFD would be an effective energy saver, an estimate of the current energy consumed daily by a pump is required. Then estimate the amount the pump would be required to operate if not continuous and at what capacity (nearest quarter horsepower). An estimate the cost to reconfigure controls for all heat pumps and heat pump water loop would also need to be completed. Finally, one could calculate the energy savings and payback.

In order to model the energy used by the water source heat pump loop circulating pump, Trane TRACE software is used. This program will simulate the actual load profile and energy consumption of the pump, with and without a variable frequency drive. Currently, the pump is constant volume; hence the pump will always be at 100% full load, independent of building loads. However, when a variable frequency drive is applied to the pump, the load profile will shift to a direct load to power relationship, as seen in Figure 7-2.

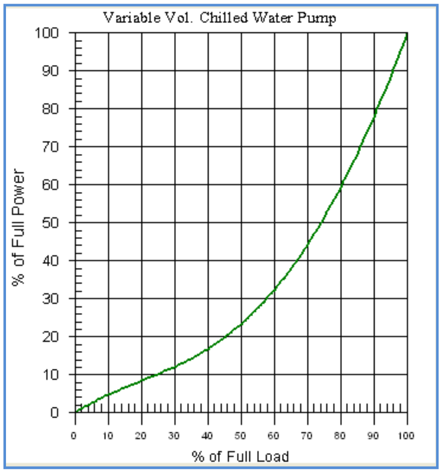

Figure 7-2: Unloading Curve for the WSHP Loop Pump with VFD

The loads were simulated twice, once without the VFD and once with the VFD. Results were documented of total energy consumption, broken down by electric (kWh) and peak (kW) energy consumption by month. See Table 7-1 and Figure 7-3 for a comparison of both pump styles.

Table 7-1: Energy Consumption Comparison of Pump with and without VFD

WSHP Loop Pump - Constant and Variable Volume Energy Consumption Comparison						
		Pump without VFD			**Pump with VFD**	
		kWh	kW		kWh	kW
Jan		11,562.5	18.5		843.4	6.8
Feb		10,341.5	18.5		733.0	6.8
Mar		10,896.5	18.5		792.6	4.0
Apr		10,545.0	18.5		1,018.8	7.4
May		10,896.5	18.5		2,227.2	13.0
Jun		10,545.0	18.5		2,983.7	15.3
Jul		10,896.5	18.5		3,532.4	17.7
Aug		10,896.5	18.5		3,083.5	16.6
Sep		10,545.0	18.5		1,998.5	12.4
Oct		10,896.5	18.5		1,054.0	7.6
Nov		10,545.0	18.5		817.0	5.1
Dec		11,340.5	18.5		780.3	6.1
Total		129,907.0	18.5		19,864.4	17.7

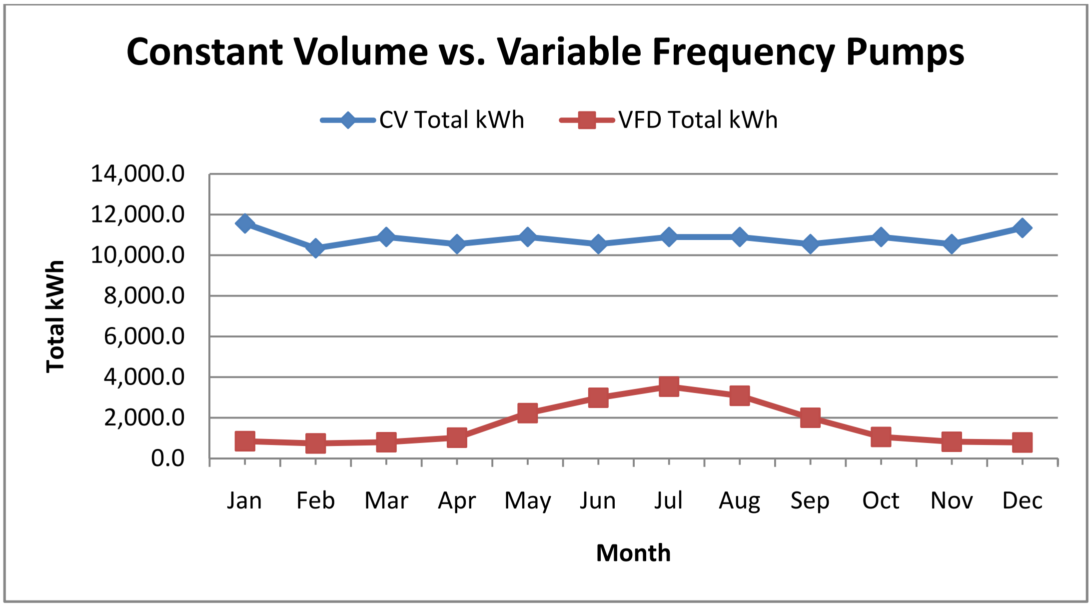

Figure 7-3: Energy Consumption Comparison of Constant Volume vs. Variable Frequency Pumps

A calculation of the reduction of energy consumption (kWh) and difference in peak energy consumption (kW) was found and applied to the rate schedule from the energy provider. Using actual energy bills, the difference in energy consumption was subtracted from current energy consumption to find the savings created by a variable frequency drive. These values were applied to the GS3 rate schedule for greater accuracy. A copy of this schedule can be found in Appendix A. A total savings **of $7,810.41** could be saved annually by installing two VFDs to the existing pumps, as seen in Table 2.

Table 7-2: Annual Savings for a Pump with a Variable Frequency Drive

Annual Savings with a VFD					
	Peak kW Savings with VFD	**kWh Savings with VFD**	**Current Cost of Electricity**	**Proposed Cost of Electricity with VFDs**	**Total Savings with VFD**
Jan	11.7	10,719.1	$13,729.75	$12,986.03	$743.72
Feb	11.7	9,608.5	$13,072.06	$12,390.23	$681.83
Mar	14.5	10,103.9	$14,657.02	$13,912.55	$744.47
Apr	11.1	9,526.2	$14,800.35	$14,130.62	$669.73
May	5.5	8,669.3	$16,939.37	$16,387.45	$551.92
Jun	3.2	7,561.3	$17,595.50	$17,134.10	$461.40
Jul	0.8	7,364.1	$17,879.51	$17,459.12	$420.39
Aug	1.9	7,813.0	$18,503.86	$17,610.22	$893.64
Sep	6.1	8,546.5	$16,380.33	$15,841.18	$539.15
Oct	10.9	9,842.5	$15,272.47	$14,599.68	$672.79
Nov	13.4	9,728.0	$14,245.93	$13,545.79	$700.14
Dec	12.4	10,560.2	$13,618.00	$12,886.77	$731.23
Total	**14.5**	**110,042.6**	**$186,694.15**	**$178,883.74**	**$7,810.41**

With the annual total savings, it is necessary to calculate the cost to install and purchase to VFD's in order to find the payback and life cycle cost of this investment. Two different sets of analyses were observed. The first analysis shows the pack back if the pumps were originally installed with variable frequency drives. The second analysis will show the pay back if the alterations were made today for an addition of variable frequency drives to the system. By comparing these two values, a difference in cost savings will be shown for making the decision early on in the design process.

For both estimates, similar values will be used to characterize the total cost. However, for the retrofit option, it will cost more per heat pump. This is due to the factors of locating the heat pump, pulling away ceiling tiles or access doors, working within a confined space, and paying for additional overtime to union workers so the work does not affect the tenants. The estimates for the initial design and retrofit can be found in Tables 7-3 and 7-4 respectively.

Table 7-3: Estimate of the Variable Frequency Drive Installed Initially

Variable Frequency Drive Cost Estimate - First Design/Install					
Material	**Purchase and Install**		**Quantity**	**Total Cost**	
Heat Pump Controls (per HP)	$	500.00	94	$	47,000.00
Pressure Sensors (per Sensor)	$	500.00	2	$	1,000.00
Variable Frequency Drives (per VFD)	$	1,700.00	2	$	3,400.00
Electric Install	$	3,000.00	1	$	3,000.00
			TOTAL	**$**	**54,400.00**

Table 7-4: Estimate of a Variable Frequency Drive Installed as a Retrofit

Variable Frequency Drive Cost Estimate - Retrofit					
Material	**Purchase and Install**		**Quantity**	**Total Cost**	
Heat Pump Controls (per HP)	$	900.00	94	$	84,600.00
Pressure Sensors (per Sensor)	$	500.00	2	$	1,000.00
Variable Frequency Drives (per VFD)	$	1,700.00	2	$	3,400.00
Electric Install	$	3,000.00	1	$	3,000.00
			TOTAL	**$**	**92,000.00**

With the estimate of the install and cost savings found, a payback can be calculated for both scenarios, as seen in Table 7-5. The payback for the original install is almost twice as quick as the retrofit. Another observation is that both paybacks are relatively in the range that would warrant the installation.

Table 7-5: Payback to Install Two Variable Frequency Drives

Type	First Cost	An Savings	Payback (Years)
First Design/Install	$54,400.00	$7,810.41	8.1
Retrofit	$92,000.00	$7,810.41	13.8

The 20 year lifecycle cost (LCC) of the VFDs purchase and installation can also be analyzed. This will provide evidence why installing VFDs is a practical solution from an economics point of view. Table 7-6 will illustrate the life cycle cost analysis.

Table 7-6: LCC Analysis to Install Two Variable Frequency Drives

Life Cycle Cost Analysis			
	No VFD	**VFD - Original Install**	**VFD - Retrofit**
Initial Capital	$10,000	$64,400	$102,000
Service Life	20	20	20
Annual Op Cost	$6,917	$1,053	$1,053
Maintenance/Repair	$100	$100	$100
Salvage Value	$0	$0	$0
i=6%			
LCC Life Cycle Cost	**$90,484**	**$77,625**	**$115,225**
NPW - Maintenance	$1,147	$1,147	$1,147
NPW - Energy	$79,337	$12,078	$12,078

The table indicates that the cheapest life cycle cost option, at $77,625, was to originally install the variable frequency drives. Next best option for the lowest life cycle cost, at $90,484, is the current state of the building, a pump without a VFD. Finally, the most expensive choice of a 20 year period life cycle cost, at 115,225, is to retrofit a VFD and the required controls into the facility.

While according to the life cycle cost, the retrofit of VFD might not be the best investment, Section 11 will show that an additional LEED point would be awarded for the addition of a VFD.

Energy recovery ventilators provide the indoor environment with fresh, outside air. Using energy recovery ventilators as dedicated outside air units, shafts between floors provide the vertical space necessary for ventilation air to be distributed. An enthalpy wheel also improves the efficiency of keeping the ambient temperature necessary required for the plenum. While both ERVs are being used to serve the spaces with ventilation air, it is difficult to judge whether or not the correct quantities, if any at all, of air is being served to these critical spaces.

Why is that? The ERV is directly ducted to each floor vertically, and one the duct reaches the plenum space for each floor, ductworks is ran horizontally from the main duct to extents of the plenum space. Through the horizontal ventilation duct, key tap off points, typically spaced approximately fifty feet apart, serve different locations of plenum. Once the air is blown into the open plenum, the ventilations air mixes with the return air that flow through the grilles in the ceiling through negative pressurized plenum. Hypothetically, the two streams are mixed and are drawn through the heat pumps. While it becomes hard to prove if the actual adequate ventilation is being delivered to each space, there are other ways to ensure proper ventilation distribution.

One way is to institute ductwork directly from the ERV ductwork into each heat pump supply. This would increase the amount of sheet metal used on the project as well as labor. Another method would be to install separate diffusers in each room for ventilation and direct duct ventilation air directly into each room. While this method would require separate outside air conditioning methods and additional materials and labor, it would prevent any disturbances and changes to the current system.

The direct duct method from the ERV was chosen. It became more important to direct duct the spaces then to rely on the balancing small volumes of ventilation air into the air steams supplied by the heat pumps. Greater control of ventilation volumes and duct design, the direct duct method proves to be the most beneficial choice to improving the entire building's indoor environmental quality.

Special standards have to be followed for ventilation ductwork. The ductwork used has to be galvanized, 24-gauge sheet metal with a lock-forming quality that meets ASTM A527 G90 galvanized sheet steel recommendations. The pressure classification for ventilation and makeup air ductwork is +/- 2 inches water column. This requirement ensures the structure of the ductwork will not be compromised by pressurization. Ventilation ductwork also has an insulation requirement. The insulation must be 1-1/2"-flexible glass fiber blanket w/ reinforced foil-scrim-kraft facing. The insulation density should be approximately 3/4 pounds per cubic foot.

The first step in designing direct duct ventilation is to find the requirement ventilation air for each space in the entire building. Using ASHRAE Standard 62.1-2007, the required ventilation air was found for each room on all three floors. Next, by hand, diffusers were drawn onto the floor plan in a logical location, and the ventilation requirement was printed next to each diffuser. Hand methods became a logical choice, due to the flexibility and versatility of the design method.

The next step was to take in the existing ventilation ductwork, which currently supplies the plenum, and connect it to the room ventilation diffusers. A clearer representation of this is seen in Figure 8-1. On the left is the existing condition of the ERV ductwork dumping air directly into the plenum. The figure on the right, however, shows the ductwork supplying a diffuser directly in the space. This was repeated for all the spaces.

This task became a balancing act, ensuring the existing ductwork was not supplying more air than it could handle at certain locations of the run. The connection ductwork was sized based on 1000 feet per minute velocity. Flex duct was kept under a length of eight feet, to air on the conservative side when considering pressure drop and proper reach.

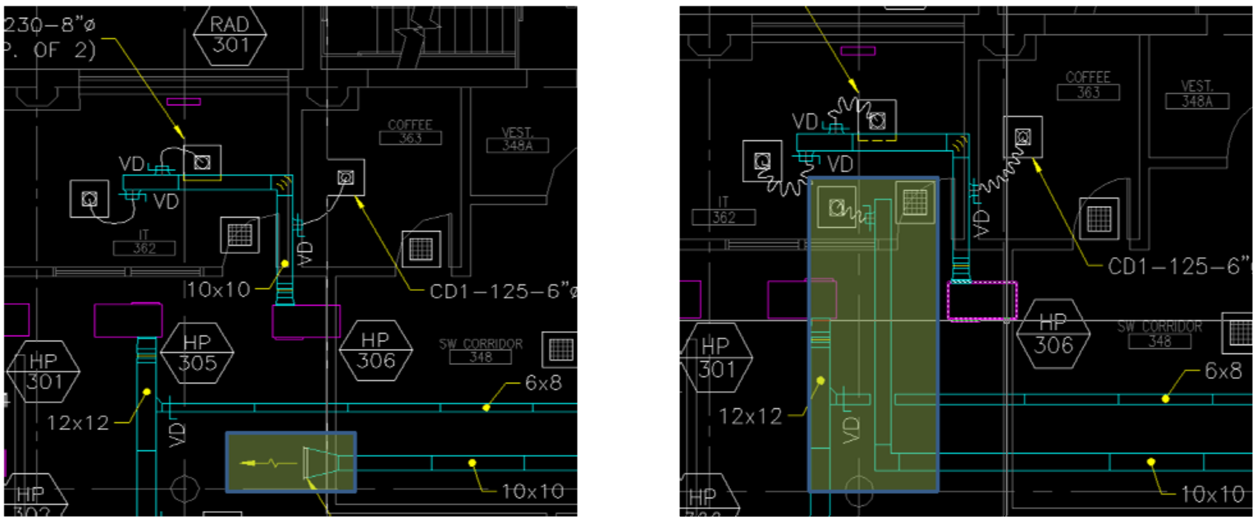

Figure 8-1: Plenum Ventilation (Left) Changed to Direct Duct Ventilation (Right)

The ductwork was also stripped off by hand using an architectural scale. The sizes and lengths of ductwork were recorded. Diffusers, volume dancers, and flex duct length and sizes were also documented. A massive compilation of all four tenant spaces was taken. Ductwork was divided into round and square, as well as flex duct.

Overall, the total cost for direct duct ventilation would be approximately $236,759.00. The total duration for the install will 26 days, starting June 1, 2009 and ending July 7, 2009. For a detailed estimate for cost and schedule of this undertaking, see the construction management breadth section of this report, section 10.

The total cost for the option is quite expensive, especially since there is no real payback for this investment except the health and well being of tenants. However, if this option was implemented for sustainable reasons, LEED points could be awarded.

For the construction management study, the indoor environmental quality option was used: the addition of ventilation ductwork to the mechanical design. This study most advantageous to building occupants from a health standpoint, as it would guarantee ventilation to all spaces. By creating a cost estimate and schedule for this option, a true design/build process could be imitated. The owner could also get a clear grasp on what this option would entail if pursued.

The cost estimate for materials utilized past McClure Company projects to predict material values. The labor costs were also created using labor rates of union contractors in the Harrisburg region, Local 520. The duration and crew sizes for labor, found for the compilation of a construction schedule, were estimated by McClure Company construction managers, familiar with projects similar to this.

The first step, as discussed in the last section, was to design and strip-off the required duct work additions to the system. Sheet metal is estimated in terms of area. In order to find the square feet of sheet metal required for rectangular duct, the perimeter of the ductwork had to be multiplied by the total length of that size. Table 9-1 shows the total area of sheet metal required for the rectangular duct. Round duct sheet metal was estimated in the same way, with the perimeter being the diameter multiplied by pi. Table 9-2 shows the round duct work sheet metal requirement.

Table 9-1: Rectangular Ductwork Take-Off

Rectangular Duct Estimate			
Width	**Height**	**Length**	**Sheet Metal (SF)**
6	8	1,226	2,861
6	10	16	43
8	8	99	264
8	10	143	428
10	10	63	210
10	12	4	15
12	12	99	396
12	16	31	145
12	26	3	19
14	14	109	509
22	22	43	315
24	24	20	160
		Total	**5,363**

Also found in Table 9-2 is the flex duct and diffuser requirements for all four tenant spaces. The table is broken down by size; this will ensure a more accurate take-off. The flex duct is measured by linear feet, and in most cases, is distributed by manufacturers in 8-10 foot sections. The quantity of flex duct will also be important when it is time to create a schedule. This is because flex duct material is estimated by linear feet while the labor for installation is estimated by piece.

Table 9-2: Round Ductwork, Flex and Diffuser Take-Off

Diffuser, Flex, and Round Duct Estimate			
Radius	Diffusers	Flex (ft)	Sheet Metal (SF)
6	130	852	372
8	20	105	48
10	14	61	21
12	7	33	16
Total	**171**	**1,051**	**457**

With the take-off complete, a cost estimate for material and labor could be calculated, as seen in Table 9-3. Each component of the installation is identified by its quantity and unit of measurement. Material and labor values had to be researched and a total cost per unit could be identified. By multiplying the quantity by the unit price and overall total for each component of the design can be estimated. The total material and labor for the ventilation duct addition is $177,021.00.

Table 9-3: Direct Duct Material and Labor Cost Estimate

Cost Estimate of Materials and Labor						
Component	**Unit**	**Quantity**	**Material**	**Labor**	**Total/Unit**	**Total**
Diffusers	PIECE	171	$100.00	$75.00	$175.00	$29,925.00
Flex Duct	FT	1051	$1.50	$37.50	$39.00*	$7,989.00
Rectangular Sheet Metal	SF	5363	$2.25	$20.00	$22.25	$119,326.75
Round Sheet Metal	SF	457	$2.25	$20.00	$22.25	$10,168.25
Insulation, 1-1/2"	SF	5820			$1.65	$9,603.00
					Total	**$177,012.00**
*Flex duct will cost $37.50 per 8' maximum of flex to install.						

While this number is representative of the labor and material required for the project, it does not take in to account many other costs associated with this option. Table 9-4 has the total estimate for the ventilation duct addition, incorporating a variety of other costs. Testing, adjusting and balancing, costing 4% of the total final cost, will ensure they system has the correct, designed airflows. Warranty is representative of the diffuser costs to ensure no premature rusting or other defections will inhibit the look or functionality. General conditions, such as permits, licenses, work protection and other costs not directly related to the design, must also be accounted for financially. Overhead and profit, usually found to be between 10-15% of the total cost, will be used to supplement the contractor for their work. Contingency, approximately 4% of the total cost is added into the budget to prepare for “acts of God”. Potential problems, outside of the control of contractor, are covered by this budgeted number in order for the contractor to be safe from being financially held responsible. Lighting damage, water damage, and earthquakes are a few examples of types of natural acts this budgeted cost will be able to cover.

Table 9-4: Total Estimate for Ventilation Duct Addition

ESTIMATE FOR DIRECT DUCT VENTILATION		
Description	Cost	% Total Budget
Sheet Metal	$129,495	54.7%
Flex Duct	$7,989	3.4%
Diffuser	$29,925	12.6%
Insulation	$9,603	4.1%
Testing, Adjusting, Balancing	$20,000	8.4%
Warranty	$898	0.4%
General Conditions	$5,937	2.5%
Overhead & Mark-up	$16,308	6.9%
Profit	$6,605	2.8%
Subtotal Sell Price	$226,759	95.8%
Contingency	$10,000	4.2%
Recommended Cost	**$236,759**	**100.0%**

The recommended cost for the ductwork addition, with the inclusion with all direct and indirect costs of construction, is approximately **$236,759**. The estimate of indirect costs, such as contingency and general conditions, is more of an art, than a science. A great number of assumption and "feel" values are used to get as close as possible to the actual cost of this option. Conservative numbers are typically used for estimates, unless there the bid is competitive or the risk of going over recommended cost is minimal.

Table 9-5: Duration and Crew Schedule

Crew and Duration Schedule								
	Sheet Metal			Flex and Diffusers				
	Sheet Metal (linear feet)	Sheet Metal Crew (people)	Sheet Metal (days)	Flex (Pieces)	Flex Crew (people)	Diffusers (pieces)	Diffuser Crew (people)	Flex/Diffuser (days)
Houlihan's	192	8	**2**	19	1	19	1	**2**
Jack Gaughen	205	8	**2**	22	1	22	1	**3**
Devon Seafood	240	8	**3**	11	1	11	1	**1**
HE&R - 2nd Floor	797	8	**9**	61	1	61	1	**8**
HE&R - 3rd Floor	695	8	**8**	58	1	58	1	**7**

With the cost estimate in place, a schedule can also be put together for the owner. The schedule is broken down into two different activities. The first activity is labeled sheet metal and includes the hanging, fastening and connection of all ductwork. The second activity, flex and diffusers, will connect ductwork, with flex duct, to diffusers, positioned in the ceiling tiles of the spaces. In order to estimate sheet metal installation durations, linear feet of sheet metal must be known, regardless of size. In this case, the take-off already supplied this number. The sheet metal crew, 2 crews of 4 people, will equate to 8 people for each tenant space. The days can then be determined based on this information. For flex and diffusers, pieces of required installments are used to estimate the total days for completion. Table 9-5 has the number of days per floor and tenant required for the ventilation duct installation.

Since the building will be occupied during this retrofit, construction crews will have work during the evening hours. These hours are represented in Table 9-6. The owner and contractor will also have to figure out a site storage area for materials during the duration of construction. The location most likely to be used will be in the basement. Another request by the contractor, and hopefully agreed upon by the owner, is the ceiling tiles to remain removed during on-going tasks and overlaps between sequences. This will be for the office spaces only. Restaurant tenants, due to food regulations and aesthetics, will be more stringent about the replacement of ceiling tiles after each day of construction. Tiles for the office spaces may be allowed to be left, neatly stacked, in a corner of the office space.

Table 9-6: Hours for Construction and Occupancy

Hours of Occupancy and Construction		
	Hours of Occupancy	Hours of Construction
Houlihan's	11am-11pm	2am-10am
Jack Gaughen	7am-6pm	6pm-2am
Devon Seafood	11am-12pm	2am-10am
HE&R - 2nd Floor	7am-6pm	6pm-2am
HE&R - 3rd Floor	7am-6pm	6pm-2am

With the durations found for each floor and tenants ventilation duct addition, a schedule can be prepared. The schedule will begin with mobilization, allowing for both sequence crews to become accustomed to site and set up materials in their respective lay down locations. June 1, 2009 was arbitrarily chosen for the start date of this activity. The construction will begin on the third floor and will be divided into sections based on numeric column lines, evenly dividing the floor into four different areas. The work will begin between column lines 1-4 and then wrap around down to the second floor, beginning in the air directly below the fourth section of the third floor. A stairwell, between column line 11 and 12 can be utilized to mobilize equipment between floors. All other equipment will need to use the elevator, located between column lines 9 and 10.

Microsoft Project was used to construct a construction management schedule for the project. The durations, as well as the start and finish dates for both activities, is shown in the construction schedule located in Figure 9-1. A visual schedule is also shown, with activities represented by rectangular boxes, spanning the dates in which the activity will be going on. The second crew will make up two days in the process, and will end three days after all the sheet metal is set. While some of the activities on the schedule look as if they are spanning the weekend, work is only being down two of the days, Monday and Friday.

Sheet metal, the first sequence crew, is lagged 5 days by the second sequence flex duct/diffusers crew. This will ensure that both crews will have enough time between sequences to prevent overlapping and piggy backing on similar activity areas. The total duration for this project will take **26 days**.

Hershey Press Building Mechanical Addition

Task Name	Duration	Start	Finish
Ventilation Ductwork Addition	**26 days**	**Mon 6/1/09**	**Mon 7/6/09**
Mobilization	1 day	Mon 6/1/09	Mon 6/1/09
Sheet Metal	**24 days**	**Tue 6/2/09**	**Fri 7/3/09**
3rd Floor CL1-4	2 days	Tue 6/2/09	Wed 6/3/09
3rd Floor CL 4-7	2 days	Thu 6/4/09	Fri 6/5/09
3rd Floor CL 7-11	2 days	Mon 6/8/09	Tue 6/9/09
3rd Floor CL 11-15	2 days	Wed 6/10/09	Thu 6/11/09
2nd Floor CL11-15	2 days	Fri 6/12/09	Mon 6/15/09
2nd Floor CL 7-11	2 days	Tue 6/16/09	Wed 6/17/09
2nd Floor CL 4-7	2 days	Thu 6/18/09	Fri 6/19/09
2nd Floor CL 1-4	3 days	Mon 6/22/09	Wed 6/24/09
1st Floor Houlihan's	2 days	Thu 6/25/09	Fri 6/26/09
1st Floor Jack Gaughen Realty	2 days	Mon 6/29/09	Tue 6/30/09
1st Floor Devon Seafood	3 days	Wed 7/1/09	Fri 7/3/09
Flex Duct/Diffusers	**21 days**	**Mon 6/8/09**	**Mon 7/6/09**
3rd Floor CL1-4	2 days	Mon 6/8/09	Tue 6/9/09
3rd Floor CL 4-7	2 days	Wed 6/10/09	Thu 6/11/09
3rd Floor CL 7-11	1 day	Fri 6/12/09	Fri 6/12/09
3rd Floor CL 11-15	2 days	Mon 6/15/09	Tue 6/16/09
2nd Floor CL11-15	2 days	Wed 6/17/09	Thu 6/18/09
2nd Floor CL 7-11	2 days	Fri 6/19/09	Mon 6/22/09
2nd Floor CL 4-7	2 days	Tue 6/23/09	Wed 6/24/09
2nd Floor CL 1-4	2 days	Thu 6/25/09	Fri 6/26/09
1st Floor Houlihan's	2 days	Mon 6/29/09	Tue 6/30/09
1st Floor Jack Gaughen Realty	3 days	Wed 7/1/09	Fri 7/3/09
1st Floor Devon Seafood	1 day	Mon 7/6/09	Mon 7/6/09

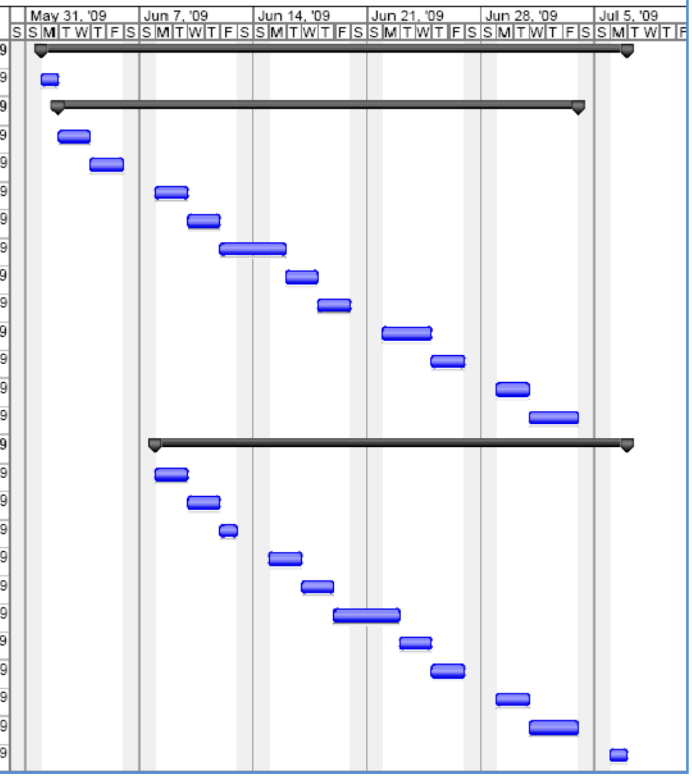

Figure 9-1: Construction Schedule

Overall, this breadth study will give the owner a fairly accurate look of the cost and schedule for installing ventilation ductwork to the existing system. While the cost and time of this project, along with the usual pressures of construction on a building owner, may seem intimidating, the implementation of this option would be highly beneficial.

For the architectural breadth, several options were considered. The main goal was to find a way to improve the energy efficiency was an architectural improvement to provide a better exterior building envelope. Improvement of glass, wall, and roof are three possibilities for a more efficient thermal, moisture, and air barrier. Alternatives to consider include: improved u-value glass replacement, white roof installation, overhang installments, increased insulation, and many more.

Overhangs were eliminated, due to the architectural authenticity the building owners were striving for. White roof also became a sustainable choice, but was not that cost effective in the long run. Increased insulation wasn't considered since the structure and brick already had good insulating effectiveness. With the building façade engrossed over 50% of glass, window replacements became a study worth researching.

10.1 REPLACEMENT WINDOW INFORMATION

As discussed in Section 4, the existing windows did not meet ASHRAE Standard 90.1-2007. Therefore, it became a goal to choose a window that did. MI Windows and Doors, a local manufacturer with the corporate headquarters in Gratz, PA, had a suitable replacement. Their CertainTeed 7800 series is a light commercial replacement window. The window has tempered 3/16th glass with LOE and argon for an improved thermal rating. As seen in Table 10-1, the window meets the ASHRAE Standard 90.1-2007 requirements.

Table 10-1: ASHRAE Standard 90.1-2007 Window Comparison

ASHRAE Standard 90.1-2007 Window Requirement Summary			
Opaque/Fenestration Elements	Max. U Value Required	Actual U-value	Meets Standard?
Existing Windows Vertical Glazing of 30.1-40% of Wall, fixed	0.57 w/maximum SHGC of 0.39	0.29 w/ SHGC of 0.43	No
Proposed Windows Vertical Glazing of 30.1-40% of Wall, fixed	0.57 w/maximum SHGC of 0.39	0.37 w/SHCG of 0.35	Yes

To recreate the window, a 2x2 grid would have to be created in order to mimic the existing windows. Other modifications to frames and sizes would have to be customized to meet the building's large window requirements. Located in Appendix B are the eight different kinds of window elevations that would need to be manufactured for the building. Appendix C also contains sections cuts to show how the pieces of window frame are connected out in the field. Both elevations and sections are useful for the architects and general contractors on site, to convey information from the window engineer to the people who are installing it.

10.2 REPLACEMENT WINDOW INSTALLATION INSTRUCTIONS

The entire window replacement will occur while the building continues to be occupied by the tenants. Therefore, the contractors will need to replace the windows during the evenings and weekends, after hours of the office and restaurant spaces.

The first step is to carefully remove the existing window in place. These windows can be recycled, and possible LEED points could be awarded. Once the window is removed, all that should be left is an open space within the building envelope.

The contractor will then run a heavy bead of sealant or on the flange around the full perimeter of the window. Next, the installer will set the window into the opening, while the sealant oozes out between the window flange and wall. While stabilizing the window, the installer will run #10 screws through the nailing flange and into façade, trying to maintain keep the sill level.

The contractor then starts to fasten the window, beginning at the middle of the sill and working his way out towards the jambs, continuing to make sure the sill stays level. He needs to ensure that he is fastening the window, at the jambs and head, every 18" on center. Next, the installer will use a backer rod around the window perimeter while applying another sealant.

It is important to note that all mullions must be caulked on the interior, exterior, and the top and bottom edges to prevent vapor and moisture from translating into the space. The installer are must plug and seal all unused anchor holes. He shall also seal over all anchor screws on frame sills. Another important step is to caulk fins of the window to the opening by using an acrylic, butyl, or silicone base sealant. Lastly, the installer must seal all seams and joints in nailing fins at all corners of windows during installation.

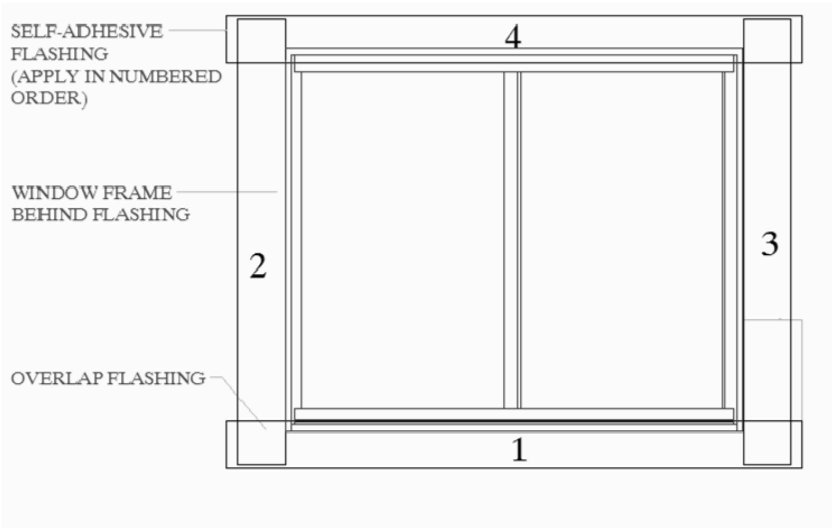

Figure 10-1: Replacement Window Self-Adhesive Flashing Detail

The Hershey Press Buildings window has self- adhesive flashing that is required to be on all window units with nailing flanges. Apply as shown in Figure 10-1, a detail of the replacement window self-adhesive instructions.

10.3 REPLACEMENT WINDOW ENERGY STUDY

The final step to warrant the idea of a window replacement is to an energy study. This study will show the affects of the window change on the HVAC system. Trane TRACE software was used to model the current building, with current windows, to find the energy consumption required by the HVAC equipment. Next, the model was changed to reflect the replacement window values and the energy simulation was re-calculated. The results of this study for both the existing and replacement windows are shown in Table 10-2.

Table 10-2: HVAC Energy Based On Windows Comparison

Window Energy Consumption Comparison		
	Existing	Replacement
Demand kW	565	577
Cons. kWh	2,014,881	213,0788
HVAC Cost	$185,934	$194,269

While the replacement window beat the base case requirement for ASHRAE Standard 90.1-2007, the window was still not able to mimic the current thermal qualities of the existing glass. The energy costs for the HVAC equipment increased with the replacement windows.

The cost for the chose windows is also fairly costly, at $512,774.00. See Appendix D for the manufacturer's entire cost estimate for the required material.

It is safe to say that this energy study did not pose any good results. While the shading coefficient was better than the current windows, while exceeding the base care requirements of ASHRAE Standard 90.1-2007, the u-value had the most effect of the loads. Therefore, when choosing a glass replacement for future energy studies, it becomes imperative to always choose a window with a better u-value.

11.0 Sustainable Impacts to LEED

The Hershey Press Building's mechanical system can be evaluated using US Green Building Council (USGBC) current LEED-NC rating system. The three sustainable retrofit studies can also be incorporated. The LEED rating system is broken down into six sections including:

- Sustainable Sites
- Water Efficiency
- Energy & Atmosphere
- Materials & Resources
- Indoor Environment Quality
- Innovation & Design Process

Not every section is related to the mechanical systems; these include Sustainable Sites, Materials & Resources, and Innovation & Design process. The other three sections are closely related. Broken down by the three sections below, an evaluation of Hershey's Press Building currently as well as a comparison to another base building will be evaluated. The final LEED-NC worksheet can be found in Appendix E, with a numerical list of the possible points that could possibly be awarded to the Hershey Press Building and its mechanical system.

11.1 Water Efficiency

During the renovation in 2005, no immediate impacts were made towards water efficiency. The site itself has minimal landscaping, none of which seen a reduction in water efficient landscaping was made. The wastewater also has no significant use. The water reductions within the plumbing system are significant, through efficient fixtures. However, they are not substantial enough to be awarded a point in this area. The rainwater collection system, if implemented, results in an 11% water reduction, as seen in Section 5. This will not be enough of a reduction to receive a point. However, an "Innovative Wastewater Technologies" credit will more than likely be awarded for the rainwater collection system design.

11.2 Energy and Atmosphere

One of the prerequisites, commissioning, was performed by the mechanical contractor. The Hershey Press Building, analyzed an ASHRAE 90.1-2007 Standard base building (System 3 – Packaged Rooftop Air-Conditioner with Fossil Fuel Furnace), also found in Section 4 of this report. With the inclusion of VFDs, the facility is 21.7% more efficient than the base scenario, awarding the building 6 LEED points, as seen in Table 11-1. That is an increase of energy cost savings from 17.2%, found without the VFDs, which currently gives the building 5 LEED points. On-site renewable energy, 3rd party commissioning, and green power were areas in which no points were award. The lack of refrigerants within the mechanical system coupled with the measurement and verification performed, each earned the Press Building additional points.

Table 11-1: Hershey Press Building Comparison to ASHRAE 90.1-2007 Base Building

Hershey Press Building LEED Analysis ASHRAE Standard 90.1-2007 Base Building Comparison					
Direction	Cooling (BTUs)	Cooling (Tons)	Heating (BTUs)	Original Electric Consumption (kWh)	Electric Consumption w/VFD (kWh)
Base - North	2,436,359	259	4,089,000	2,445,111	2,445,111
Base - East	2,262,883	240	4,125,300	2,265,074	2,265,074
Base - South	2,434,750	259	4,472,100	2,595,119	2,595,119
Base - West	2,250,988	242	4,453,600	2,423,715	2,423,715
Base Average	2,346,245	250	4,285,000	2,432,255	2,432,255.0
Actual	2,037,029	208	777,648	2,014,881	1,904,838
			Energy Cost Savings	17.2%	**21.7%**

11.3 Indoor Environmental Quality

The ventilation was over estimated compared to ASHRAE Standard 62.1-2007; therefore, qualified for Credit 2 for Increased Ventilation. Other indoor environmental quality points the Press Building received include the controllability of systems, thermal comfort design and verification. The eighth credit, Daylight & Views, did not apply since only 52% of the spaces had exterior windows within them.

With the addition of the ventilation direct duct option, an additional could be awarded for “Outdoor Air Delivery Monitoring”.

11.4 Summary

While many of sections do not relate directly to mechanical, further research would need to occur in order to accurately fill in the check list. While the construction occurred without the LEED mentality, an addition of more points is highly unlikely. If the Press Building would undergo another renovation in the future, it would only take a few alterations to certify the building.

After all sections were carefully reviewed for possible applications to this 1915 building, the final credits for each section could be tallied. Below, in Table 3-8, shows the LEED-NCv2.2 Certification Checklist summary.

The three sustainable retrofits were all able to contribute one point individually, leading to an addition of three LEED points altogether. Notice, that there are 14 definite points and 34 possible. If only 24% of the maybes are indeed points, a “Certified” Certification could be awarded for a minimum of 26 points and valid proof and paperwork. The next level of certification, silver, could be awarded if 44% of the maybes become points.

Table 3-8: Hershey Press Building LEED-NCv2.2- Certification Checklist Summary

Hershey Press Building LEED Analysis Certification Checklist Summary							
	Sustainable Sites	Water Efficiency	Energy and Atmosphere	Materials and Resources	Indoor Environment Quality	LEED Innovation Credits	Total
Yes	0	1	8	0	5	0	14
Maybe	14	0	0	10	5	5	34
No	0	4	5	3	5	0	17
Total	14	5	13	13	15	5	65

Overall, to become certified in LEED, it is necessary to start with that decision in mind and work towards that goal. For future renovations, the Hershey Press Building would have a great start, with 14 points, towards a LEED certification.

12.0 Conclusion and Recommendations

The sustainable retrofit of the Hershey Press Building mechanical system met many of the goals and design criteria put forth prior to investigation. The mechanical retrofit redesign studied three major areas associated with sustainability, including water efficiency, energy efficiency and indoor environmental quality. These three options include a rain water storage application for the cooling tower, the addition of variable frequency drives for the pumps, and a ducted ventilation air supply to all critical spaces.

The rain water storage had a first cost of $157,320.00, and an annual savings of $3,285.00. Therefore, the calculated the payback for this investment was 48 years, not an optimal scenario for implementation. Therefore, this sustainable would not be recommended unless the owner wants to find a way to earn a LEED credit for “Innovative Wastewater Technologies”.

For the energy efficiency analysis, variable frequency drives were looked at for implementation. Three options were looked at. The first was the installment of VFDs during the original construction. This option with the cheapest 20-year life cycle cost option, at $77,625. The second option was to leave the building the way it was, with a constant volume pump. This option had the second lowest life cycle cost, at $90,484. Finally, the most expensive life cycle cost, at 115,225, was the option of trying to present day retrofit a VFD and install the required controls into the facility. While the investment payback seemed to better for present day retrofit from the current conditions, the life cycle cost (LCC) analysis is a much better forecast for the investment. The VFD installation option would not be a recommended, since the life cycle cost of the system would be more expensive than the system they already have.

The indoor environmental quality option proposed to direct duct the ventilation supply air to all spaces requiring ventilation air based on ASHRAE Standard 62.1-2007. Coupled with the construction management breadth, a detailed cost and schedule analysis of the ducted ventilation supply system was constructed. The total duration for this install will 26 days, starting June 1, 2009 and ending July 7, 2009. Although this proposal has a total cost of approximately $236,759.00, the overall benefits from the system for the tenants would be worth the cost. This system should be recommended if the owner is interested in gaining a LEED point for “Outdoor Air Delivery Monitoring” and also improving the current indoor environment air quality.

The second breadth included an architecture redesign of the building envelope in order for the building to become more energy efficiency. Windows were chosen for their ability to exceed ASHRAE Standard 90.1-2007 base case scenario. However, the windows ended up using more energy for the mechanical equipment to make up for the poorly insulated u-value of the windows.

The mechanical system was then analyzed for its performance as sustainable building using the US Green Building Council (USGBC) current LEED-NC rating system. The three sustainable retrofits were all able to contribute one point individually, leading to an addition of three LEED points altogether. With 14 definite points and 34 possible, it would only require 24% of the “maybes” to become points for a “Certified” certification to be awarded.

13.0 References

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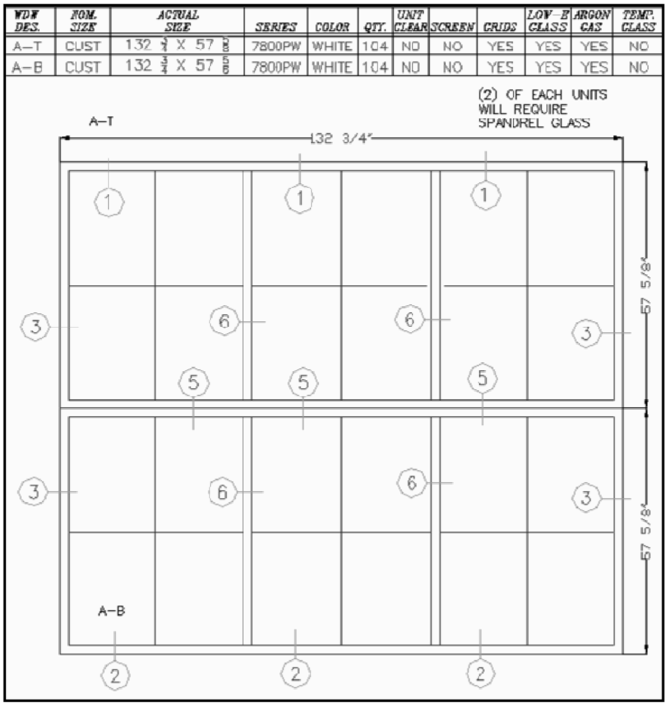
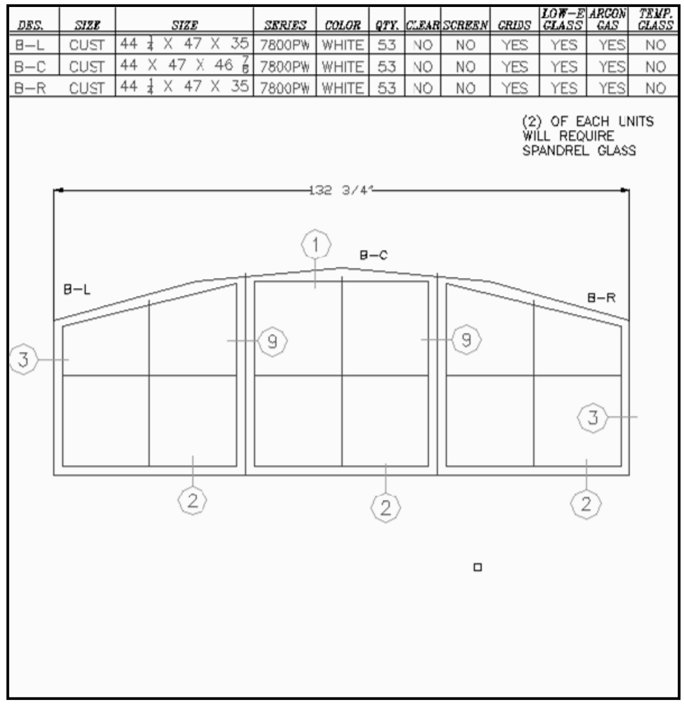
Appendix A – GS3 Rate Schedule

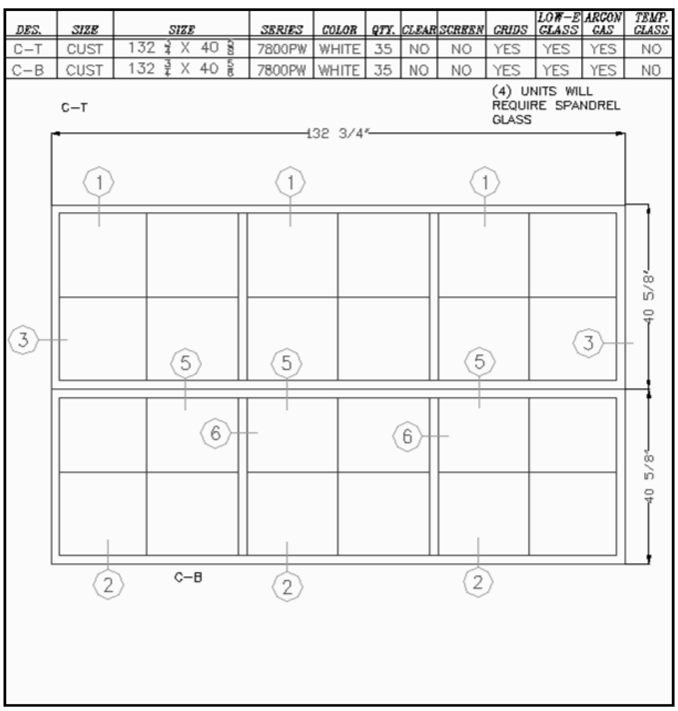
Date:		GS3 Rate, Prices 2008						
	Customer : Hershey Press Building							
	Billing Period Ending :	January						
	Actual Demand :	415 KW		EDI/IDI		0 KW		
	Kilowatt Hours :	153,208 KWH		Base:		0 KWH		
	Billing Demand:	415 KW		EDI/IDI?: N				
	Hours of Use:	n/a					Shopping Customer	
		DISTRIBUTION						
$4.380	/KW for all KW of demand				415 kW		$1,817.70	(A)
(1)	($0.00040) for the first 200 KWH for each Kw of demand							
	200	x	415	=		83,000		
	Cost=	($0.00040)	x	83,000		KWH =	($33.20)	(B)
			Remaining KWH =	70,208				
(2)	($0.00040) for the next 200 KWH for each Kw of demand							
	200	x	415	=		83,000		
		($0.00040)	x	70,208		KWH =	($28.08)	(C)
			Remaining KWH =	0				
(3)	($0.00040) for all additional							
		($0.00040)	x	0		KWH =	$0.00	(D)
					Total KWH Cost (B+C+D) =		($61.28)	(E)
					Distribution Total (A+E) =		$1,756.42	(F)
		TRANSMISSION						
$0.000	per kW for all kW of demand				0.000 x	415	$0.00	(G)
	$0.00507 for all kWh							
(1)								
	$0.00507 /kWh			0.00507	x	153,208 =	$776.76	(H)
					Transmission Total (G+H) =		$776.76	(I)
		ENERGY & CAPACITY						
	Capacity supplied by PPL Electric Utilities:			100% x	415	= 415.0	kW	
	Energy supplied by PPL Electric Utilities:			100% x	153,208	= 153,208	kWh	
$4.461	/kW for all capacity purchased from PPL:				4.461 x	415 =	$1,851.32	(J)
(1)	$0.04940 for the first 200 kWh for each kW of capacity							
	200	x	415	=		83,000		
	Cost=	$0.04940	x	83,000		KWH =	$4,100.20	(K)
			Remaining KWH =	70,208				
(2)	$0.03760 for the next 200 kWh for each kW of capacity							
	200	x	415	=		70,208		
		$0.03760	x	70,208		KWH =	$2,639.82	(L)
			Remaining KWH =	0				
(3)	$0.03593 for all additional							
		$0.03593	x	0		KWH =	$0.00	(M)
					Total KWH Cost (K+L+M) =		$6,740.02	(N)
					Energy & Capacity Total (J+N) =		$8,591.34	(O)
		COMPETITIVE TRANSITION CHARGE						
$0.000	/KW for all KW of demand						$0.00	(P)
(1)	$0.00207 for the first 200 KWH for each Kw of demand							
	200	x	415	=		83,000		
	Cost=	$0.00207	x	83,000		KWH =	$171.81	(Q)
			Remaining KWH =	70,208				
(2)	$0.00162 for the next 200 KWH for each Kw of demand							
	200	x	415	=		70,208		
		$0.00162	x	70,208		KWH =	$113.74	(R)
			Remaining KWH =	0				
(3)	$0.00156 for all additional							
		$0.00156	x	0		KWH =	$0.00	(S)
					Total KWH Cost (Q+R+S) =		$285.55	(T)
					Competitive Transition Charge Total (P+T)		$285.55	(U)
		INTANGIBLE TRANSITION CHARGE						
$0.000	/KW for all KW of demand						$0.00	(V)
(1)	$0.01089 for the first 200 KWH for each Kw of demand							
	200	x	415	=		83,000		
	Cost=	$0.01089	x	83,000		KWH =	$903.87	(W)
			Remaining KWH =	70,208				
(2)	$0.00852 for the next 200 KWH for each Kw of demand							
	200	x	415	=		70,208		
		$0.00852	x	70,208		KWH =	$598.17	(X)
			Remaining KWH =	0				
(3)	$0.00818 for all additional							
		$0.00818	x	0		KWH =	$0.00	(Y)
					Total KWH Cost (W+X+Y) =		$1,502.04	(Z)
					Intangible Transition Charge Total (V+Z)		$1,502.04	(AA)
Time of Day Meter Charge				T.O.D. ?:	N	(Y/N)	$0.00	(BB)
EDI/IDI Credits								
					Total EDI/IDI Credits =		$0.00	(CC)
State Tax Adjustment Surcharge(STAS): Distribution (F+Z)				x		0.336%	$5.90	(DD)
State Tax Adjustment Surcharge(STAS): (G+M+S+Y+AA)				x		0.310%	$34.58	(EE)
					Pre-tax Total (F+I+O+U+AA+BB+CC+DD+EE) =		$12,952.59	(FF)
					Average Cost per KWH =		$0.0845	
PA Sales Tax				0.00%	Exempt			
					(FF x [6% x (100% - Exemption %)]) =		$777.16	(GG)
					Total Bill (FF + GG) =		$13,729.75	
	Average Price to Compare* =	$0.0896		per kWh	Average Cost per KWH =		$0.0896	



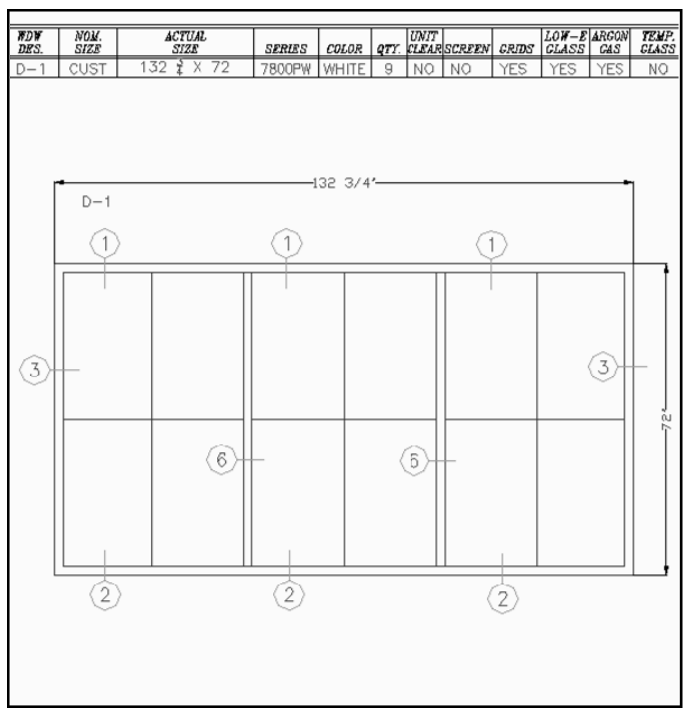
Window Type A



Window Type B

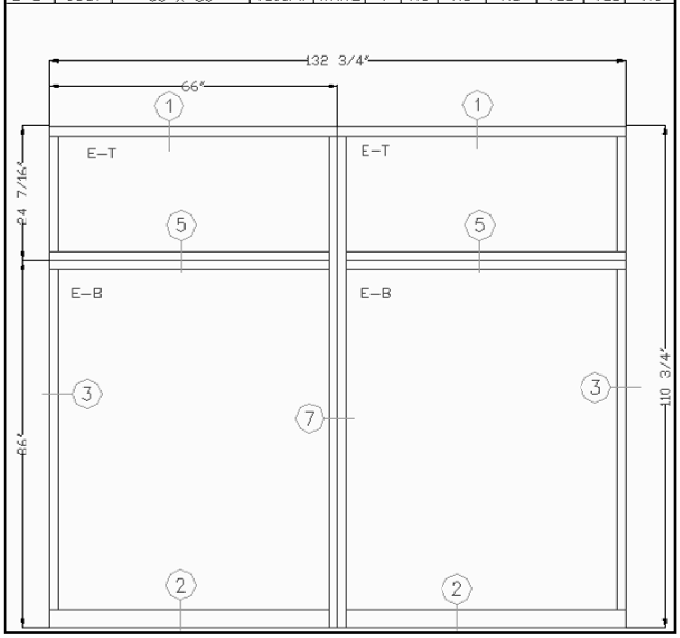


Window Type C



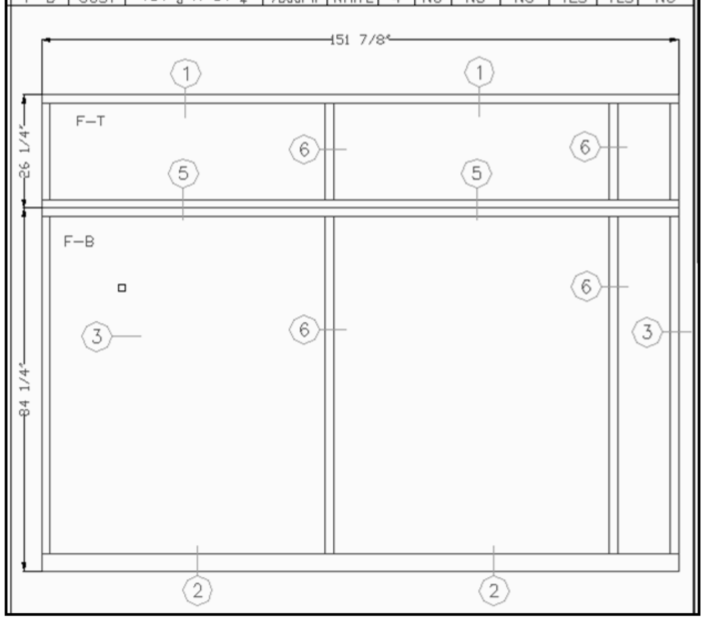
Window Type D

DES.	SIZE	SIZE	SERIES	COLOR	QTY.	CLEAR	SCREEN	GRIDS	LOW-E GLASS	ARGON GAS	TEMP. GLASS
E-T	CUST	66 X 24 7/16	7800PW	WHITE	4	NO	NO	NO	YES	YES	NO
E-B	CUST	66 X 86	7800PW	WHITE	4	NO	NO	NO	YES	YES	NO



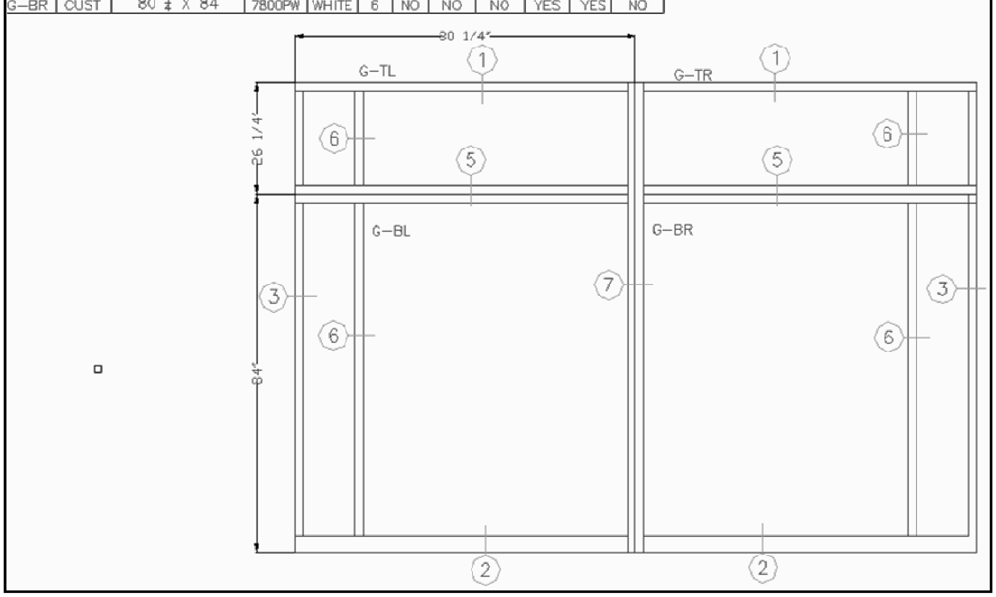
Window Type E

DES.	SIZE	SIZE	SERIES	COLOR	QTY.	CLEAR	SCREEN	GRIDS	LOW-E GLASS	ARGON GAS	TEMP. GLASS
F-T	CUST	151 7/8 X 26 7/16	7800PW	WHITE	4	NO	NO	NO	YES	YES	NO
F-B	CUST	151 7/8 X 84 1/4	7800PW	WHITE	4	NO	NO	NO	YES	YES	NO



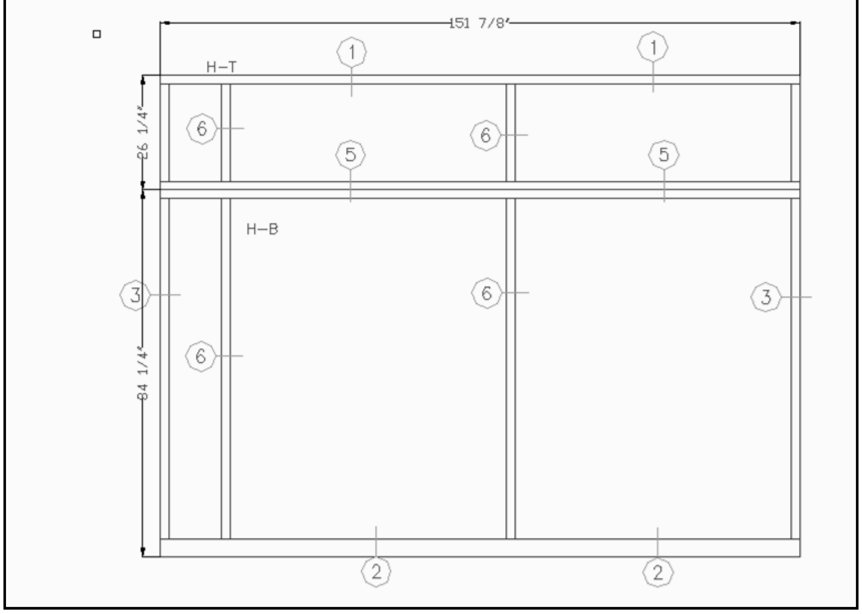
Window Type F

WDW DES.	NOM. SIZE	ACTUAL SIZE	SERIES	COLOR	QTY.	UNIT CLEAR	SCREEN	GRIDS	LOW-E GLASS	ARGON GAS	TEMP. GLASS
G-TL	CUST	80 1/4 X 26 1/4	7800PW	WHITE	6	NO	NO	NO	YES	YES	NO
G-TR	CUST	80 1/4 X 26 1/4	7800PW	WHITE	6	NO	NO	NO	YES	YES	NO
G-BL	CUST	80 1/4 X 84	7800PW	WHITE	6	NO	NO	NO	YES	YES	NO
G-BR	CUST	80 1/4 X 84	7800PW	WHITE	6	NO	NO	NO	YES	YES	NO

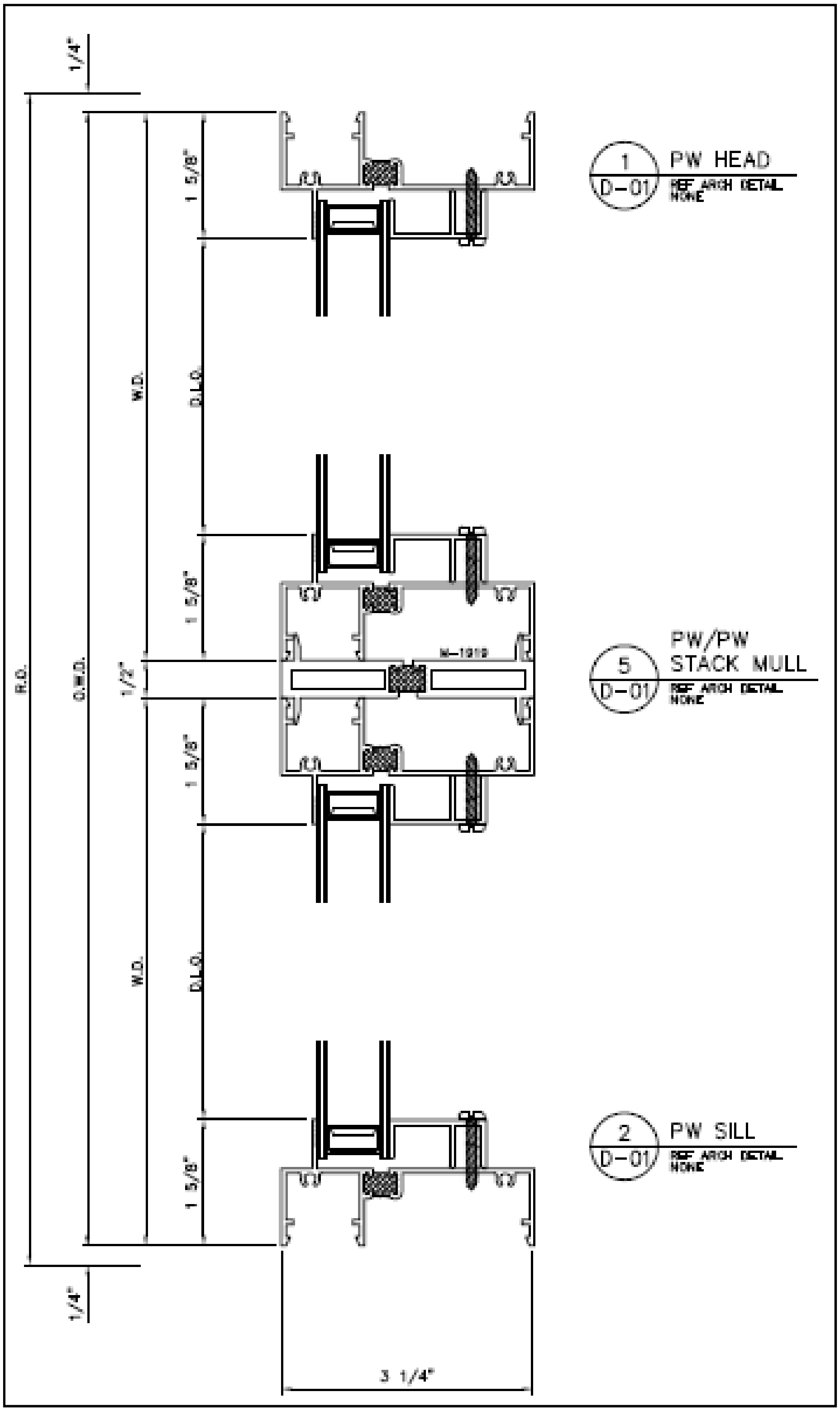


Window Type G

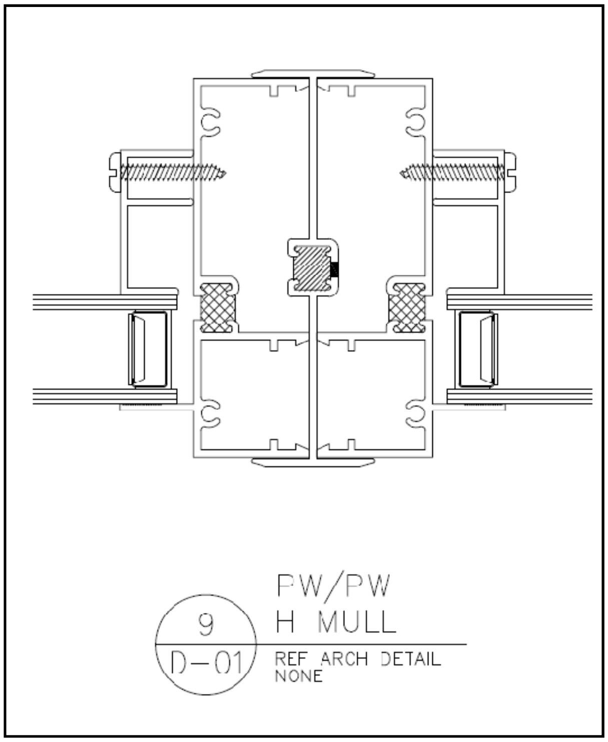
DES.	SIZE	SIZE	SERIES	COLOR	QTY.	CLEAR	SCREEN	GRIDS	LOW-E GLASS	ARGON GAS	TEMP. GLASS
H-T	CUST	151 $\frac{7}{8}$ X 26 $\frac{7}{16}$	7800PW	WHITE	4	NO	NO	NO	YES	YES	NO
H-B	CUST	151 $\frac{7}{8}$ X 84 $\frac{1}{4}$	7800PW	WHITE	4	NO	NO	NO	YES	YES	NO



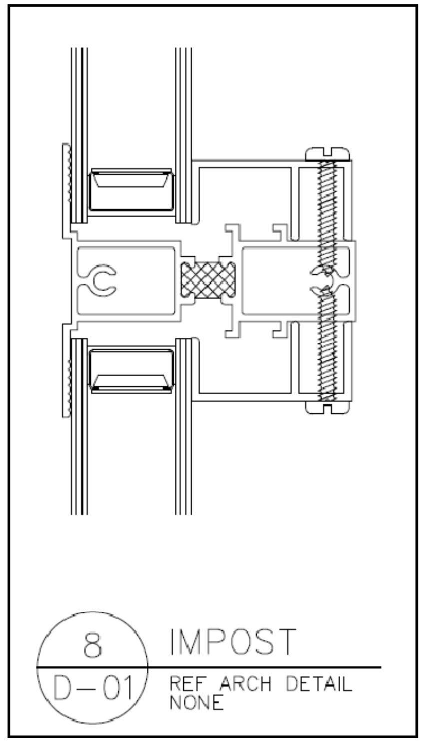
Window Type H



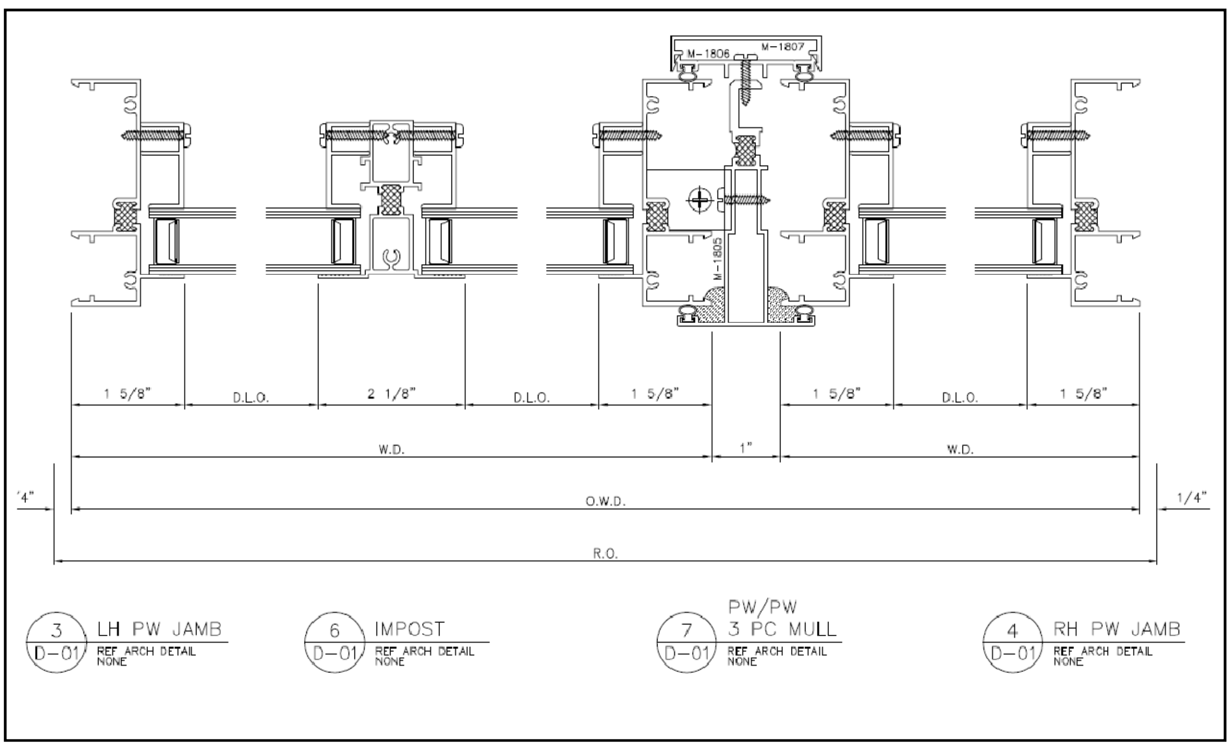
Window Type D Picture Window Stack with Head, Sill and Mullions



Horizontal Mullion for Window Type H



Impost for Window Type H



Impost, Jambs, and Mullions for Left and Right Picture Windows Type D

MI Windows and Doors
* Q U O T E Q U O T E Q U O T E *
Warehouse: 106 - Hegins, PA

Quote # 222227
1 of 6
04/01/09

300000-001

ACCOUNTS PAYABLE
CASH SALES

MI-WD GRATZ
760 W MARKET STREET
GRATZ PA 17030

MI Route: 98 PO# FOLLOW UP JMC 19
Order Type: Standard Terms: CASH SALE Rep#1101 Load Dt:

Item	Ord (** Quantities **)	Shp	B/O	Description	Unit	Extended
001	4			7800PW ALUM DH PICTURE WDW as entered: 132 3/4 X 57 5/8 id: 132 3/4 X 57 5/8 EX WDW,BLACK SPCR,3PNL,WH,FINLESS,CLR,1/4" BL ACK SPANDREL,INS,DSB,FLD-STK TO BE STACKED OVER PW	1701.23	6804.92
002	204			7800PW ALUM DH PICTURE WDW as entered: 132 3/4 X 57 5/8 id: 132 3/4 X 57 5/8 EX WDW,BLACK SPCR,3PNL,WH,FINLESS,5/8"FLAT,CL R,SEE DRAWING,INS,LOE,ARG,DSB,FLD-STK TO BE STACKED ABOVE PW	950.73	193948.92
003	104			7800 ALUM DH SLIDER as entered: 132 3/4 id: 132 3/4 (7800HC),PARTS,EX SZ,M-1919 STK MULL,WH,FINLE SS,INS	45.22	4702.88
004	102			7500SP ALUM SPECIALTY WDW as entered: 44 1/4 X 47 X 35 id: 44 1/4 X 47 X 35 N,EX WDW,HALF ARCH,LT&RT,BLACK SPCR,WH,FINLES S,5/8 FLAT,4LITE-LITE,INS,LOE,DSB,ARGON FACTORY STACK OVER PW'S FLANKERS FOR TRIPLE UNIT	1314.38	134066.76
005	51			7500SP ALUM SPECIALTY WDW as entered: 44 1/8 X 47 X 46 7/8 id: 44 X 47 X 46 7/8 N,EX WDW,ARCH,BLACK SPCR,WH,FINLESS,5/8 FLAT, 4LITE-LITE,INS,LOE,DSB,ARGON,FLD-STK CENTER UNIT OF TRIPLE FIELD STACK ABOVE PW'S	762.55	38890.05
006	2			7500SP ALUM SPECIALTY WDW as entered: 44 1/4 X 47 X 35	1978.89	3957.78

CONTINUED

MI Windows and Doors
* Q U O T E Q U O T E Q U O T E *
Warehouse: 106 - Hegins, PA

Quote # 222227
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300000-001

ACCOUNTS PAYABLE
CASH SALES

MI-WD GRATZ
760 W MARKET STREET
GRATZ PA 17030

MI Route: 98 PO# FOLLOW UP JMC 19
Order Type: Standard Terms: CASH SALE Rep#1101 Load Dt:

Item	** Quantities ** Ord	Shp	B/O	Description	Unit	Extended
				id: 44 1/4 X 47 X 35 EX WDW,HALF ARCH,LT&RT,BLACK SPCR,WH,FINLESS, INS,DSB FLANKERS FOR TRIPLE UNIT BLACK SPANDREL		
007	2			7500SP ALUM SPECIALTY WDW as entered: 44 1/8 X 47 X 46 7/8 id: 44 1/8 X 47 X 46 7/8 TRIP,FLD MULL,EX WDW,ARCH,BLACK SPCR,WH,FINLE SS,INS,DSB CENTER UNIT FOR TRIPLE BLACK SPANDREL GLASS	1282.55	2565.10
008	104			7800 ALUM DH SLIDER as entered: 47 id: 47 (7800HC),PARTS,EX SZ,CM-085,WH,FINLESS,INS	7.05	733.20
009	68			7800PW ALUM DH PICTURE WDW as entered: 132 3/4 X 40 5/8 id: 132 3/4 X 40 5/8 EX WDW,BLACK SPCR,3PNL,WH,FINLESS,5/8"FLAT,CL R,SEE DRAWING,INS,LOE,ARG,DSB FIELD STACK ABOVE PW S	762.72	51864.96
010	2			7800PW ALUM DH PICTURE WDW as entered: 132 3/4 X 40 5/8 id: 132 3/4 X 40 5/8 EX WDW,BLACK SPCR,3PNL,WH,FINLESS,CLR,1/4" BL ACK SPANDREL,INS,DSB,FLD-STK FIELD STACK ABOVE PW'S	1284.46	2568.92
011	35			7800 ALUM DH SLIDER as entered: 132 3/4 id: 132 3/4 (7800HC),PARTS,EX SZ,M-1919 STK MULL,WH,FINLE	45.22	1582.70

CONTINUED

MI Windows and Doors
* Q U O T E Q U O T E Q U O T E *
Warehouse: 106 - Hegins, PA

Quote # 222227
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04/01/09

300000-001

ACCOUNTS PAYABLE
CASH SALES

MI-WD GRATZ
760 W MARKET STREET
GRATZ PA 17030

MI Route: 98 PO# FOLLOW UP JMC 19
Order Type: Standard Terms: CASH SALE Rep#1101 Load Dt:

Item	Ord	Shp	B/O	Description	Unit	Extended
				SS,INS		
012	9			7800PW ALUM DH PICTURE WDW as entered: 132 3/4 X 72 id: 132 3/4 X 72 EX WDW,BLACK SPCR,3PNL,WH,FINLESS,5/8"FLAT,CLR,SEE DRAWING,INS,LOE,ARG,DSB	1105.55	9949.95
013	2			7800PW ALUM DH PICTURE WDW as entered: 66 X 24 7/16 id: 66 X 24 7/16 EX WDW,BLACK SPCR,WH,FINLESS,CLR,INS,LOE,ARG,DSB FIELD MULL SIDE BY SIDE	321.48	642.96
014	2			7800PW ALUM DH PICTURE WDW as entered: 66 X 86 id: 66 X 86 EX WDW,BLACK SPCR,WH,FINLESS,CLR,INS,LOE,ARG,FULL TMP,DSB,FLD-STK MULL SIDE BY SIDE	684.24	1368.48
016	1			7800 ALUM DH SLIDER as entered: 66 id: 66 (7800HC),PARTS,EX WDW,M-1919 STK MULL,WH,FINLESS,INS	22.44	22.44
017	1			7500 ALUMINUM DH as entered: 110 3/4 id: 110 3/4 MULLIONS,M-1805,EX SZ,WH,FINLESS,INS	68.82	68.82
018	1			7500 ALUMINUM DH as entered: 110 3/4 id: 110 3/4 MULLIONS,M-1806,EX SZ,WH,FINLESS,INS	15.54	15.54

CONTINUED

MI Windows and Doors
* Q U O T E   Q U O T E   Q U O T E *
Warehouse: 106 - Hegins, PA

Quote # 222227
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300000-001

ACCOUNTS PAYABLE
CASH SALES

MI-WD GRATZ
760 W MARKET STREET
GRATZ PA 17030

MI   Route: 98   PO# FOLLOW UP   JMC 19
Order Type: Standard   Terms: CASH SALE   Rep#1101   Load Dt:

Item	Ord	Shp	B/O	Description	Unit	Extended
019	1			7500 ALUMINUM DH as entered: 110 3/4 id: 110 3/4 MULLIONS,M-1807,EX SZ,WH,FINLESS,INS	14.43	14.43
020	2			7800PW ALUM DH PICTURE WDW as entered: 151 7/8 X 26 7/16 id: 151 7/8 X 26 7/16 EX WDW,BLACK SPCR,3PNL,WH,FINLESS,CLR,INS,LOE ,ARG,DSB,FLD-STK FIELD STACK OVER PW'S	682.35	1364.70
021	2			7800PW ALUM DH PICTURE WDW as entered: 151 7/8 X 84 1/4 id: 151 7/8 X 84 1/4 EX WDW,BLACK SPCR,3PNL,WH,FINLESS,CLR,INS,LOE ,ARG,DSB,FLD-STK FIELD STACK BELOW PW	1398.01	2796.02
022	12			7800PW ALUM DH PICTURE WDW as entered: 80 1/4 X 26 1/4 id: 80 1/4 X 26 1/4 EX WDW,BLACK SPCR,2PNL,WH,FINLESS,CLR,INS,LOE ,ARG,DSB	404.13	4849.56
023	12			7800PW ALUM DH PICTURE WDW as entered: 80 1/4 X 84 id: 80 1/4 X 84 EX WDW,BLACK SPCR,2PNL,WH,FINLESS,CLR,INS,LOE ,ARG,DSB	834.84	10018.08
024	12			7500 ALUMINUM DH as entered: 80 1/4 id: 80 1/4 MULLIONS,M-1919,EX SZ,WH,FINLESS,INS	72.44	869.28
025	6			7500 ALUMINUM DH as entered: 110 3/4	68.82	412.92

CONTINUED

MI Windows and Doors
* Q U O T E   Q U O T E   Q U O T E *
Warehouse: 106 - Hegins, PA

Quote # 222227
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300000-001

ACCOUNTS PAYABLE
CASH SALES

MI-WD GRATZ
760 W MARKET STREET
GRATZ PA 17030

MI Route: 98 PO# FOLLOW UP JMC 19
Order Type: Standard Terms: CASH SALE Rep#1101 Load Dt:

** Quantities ** Item	Ord	Shp	B/O	Description		Unit	Extended
				id: 110 3/4 MULLIONS,M-1805,EX SZ,WH,FINLESS,INS			
026	6			7500 as entered: 110 3/4 id: 110 3/4 MULLIONS,M-1806,EX SZ,WH,FINLESS,INS	ALUMINUM DH	15.54	93.24
027	6			7500 as entered: 110 3/4 id: 110 3/4 MULLIONS,M-1807,EX SZ,WH,FINLESS,INS	ALUMINUM DH	14.43	86.58
028	2			7800PW as entered: 151 7/8 X 26 7/16 id: 151 7/8 X 26 7/16 EX WDW,BLACK SPCR,3PNL,WH,FINLESS,CLR,INS,LOE ,ARG,DSB,FLD-STK STACK ABOVE PW'S	ALUM DH PICTURE WDW	682.35	1364.70
029	2			7800PW as entered: 151 7/8 X 84 1/4 id: 151 7/8 X 84 1/4 EX WDW,BLACK SPCR,3PNL,WH,FINLESS,CLR,INS,LOE ,ARG,DSB,FLD-STK STACK BELOW PW'S	ALUM DH PICTURE WDW	1398.01	2796.02
030	2			7500 as entered: 151 7/8 id: 151 7/8 MULLIONS,M-1919,EX SZ,WH,FINLESS,INS	ALUMINUM DH	102.48	204.96
031	50			SPCHG MATERIAL COST,SUB SILL - 151 7/8 SUB SILL - 151 7/8	SPECIAL CHARGES	102.48	5124.00

** Quantities ** Item	Ord	Shp	B/O	Description	Unit	Extended
					Goods Total:	483748.87
					Sales Tax:	29024.93
					Order Total:	512773.80

LEED-NC

LEED-NC Version 2.2 Registered Project Checklist
Hershey Press Building
27 West Chocolate Avenue, Hershey PA 17033

Yes	?	No			
	14		**Sustainable Sites**		**14** Points
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
	1		Credit 1	**Site Selection**	1
	1		Credit 2	**Development Density & Community Connectivity**	1
	1		Credit 3	**Brownfield Redevelopment**	1
	1		Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
	1		Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
	1		Credit 4.3	**Alternative Transportation**, Low-Emitting and Fuel-Efficient Vehicles	1
	1		Credit 4.4	**Alternative Transportation**, Parking Capacity	1
	1		Credit 5.1	**Site Development,** Protect of Restore Habitat	1
	1		Credit 5.2	**Site Development,** Maximize Open Space	1
	1		Credit 6.1	**Stormwater Design,** Quantity Control	1
	1		Credit 6.2	**Stormwater Design,** Quality Control	1
	1		Credit 7.1	**Heat Island Effect,** Non-Roof	1
	1		Credit 7.2	**Heat Island Effect,** Roof	1
	1		Credit 8	**Light Pollution Reduction**	1
Yes	**?**	**No**			
1		4	**Water Efficiency**		**5** Points
		1	Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
		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**, 20% Reduction	1
		1	Credit 3.2	**Water Use Reduction**, 30% Reduction	1
Yes	**?**	**No**			
8		5	**Energy & Atmosphere**		**17** Points
Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required
6			Credit 1	**Optimize Energy Performance**	1 to 10
		3	Credit 2	**On-Site Renewable Energy**	1 to 3
		1	Credit 3	**Enhanced Commissioning**	1
1			Credit 4	**Enhanced Refrigerant Management**	1
1			Credit 5	**Measurement & Verification**	1
		1	Credit 6	**Green Power**	1

continued...

Yes	?	No			
	10	3		**Materials & Resources**	**13** Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
		1	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
		1	Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roof	1
		1	Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1
	1		Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
	1		Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
	1		Credit 3.1	**Materials Reuse**, 5%	1
	1		Credit 3.2	**Materials Reuse**,10%	1
	1		Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
	1		Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
	1		Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regic	1
	1		Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regic	1
	1		Credit 6	**Rapidly Renewable Materials**	1
	1		Credit 7	**Certified Wood**	1

Yes	?	No			
5	5	5		**Indoor Environmental Quality**	**15** Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
1			Credit 1	**Outdoor Air Delivery Monitoring**	1
1			Credit 2	**Increased Ventilation**	1
		1	Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
		1	Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
	1		Credit 4.1	**Low-Emitting Materials**, Adhesives & 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
	1		Credit 5	**Indoor Chemical & Pollutant Source Control**	1
		1	Credit 6.1	**Controllability of Systems**, Lighting	1
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
		1	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
		1	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes	?	No			
	5			**Innovation & Design Process**	**5** Points
	1		Credit 1.1	**Innovation in Design**: Provide Specific Title	1
	1		Credit 1.2	**Innovation in Design**: Provide Specific Title	1
	1		Credit 1.3	**Innovation in Design**: Provide Specific Title	1
	1		Credit 1.4	**Innovation in Design**: Provide Specific Title	1
	1		Credit 2	**LEED® Accredited Professional**	1

Yes	?	No		
14	34	17	**Project Totals** (pre-certification estimates)	**69** Points

Certified 26-32 points **Silver** 33-38 points **Gold** 39-51 points **Platinum** 52-69 points