Mechanical Tech Report 2

Building and Plant Energy Analysis Report

Altoona Area Junior High School
Altoona, PA

Christopher G. Conrad
Mechanical Option
Faculty Advisor: James D. Freihaut, Ph.D.
October 29, 2007

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Executive Summary

This report analyzes the energy consumed by the Altoona Area Junior High School. The report begins with an assessment of the school's Leadership in Energy and Environmental Design (LEED) aspirations, continues with an examination of its compliance with ASHRAE Standard 90.1-2004, and concludes with a load and energy consumption estimation.

The overall HVAC design in the school features zonal air handling units, classroom unit ventilators, and a network of fan coil units. Because of the size and redundancy of the system, several items have been omitted to lessen the scope of this report. An attempt has been made to represent each type of system present while still providing an accurate overview of the building as a whole.

As determined by the owner and project team, the Altoona Area Junior High School will not be built with LEED aspirations in mind. This is consistent with the evidence presented in this report. Several prerequisite items necessary for awarding have not been fulfilled, nullifying many point-gaining possibilities. The LEED evaluation in this report was completed with verifiable project data and knowledge of the report only, as no record was provided by the designers in this regard.

The examination of the school's compliance with ASHRAE Standard 90.1-2004 provided in this report does not present any major conclusions to be made about the system. As was determined, compliance varies from item to item, indicating that Standard 90.1-2004 may or may not have been used as a design consideration.

The lost rentable space and mechanical system first cost of the building were determined to be relatively low based on a comparison with other similar projects. The low lost rentable space calculation can be attributed to the extensive use of exterior-mounted equipment. The low first cost can be attributed to the goal of the owner to keep initial costs low, thus lowering the overall price tag for the building.

To carry out the load and energy consumption estimation for this building, Carrier's Hourly Analysis Program (HAP) was extensively utilized. The loads calculated for the systems analyzed in the building were determined to be close to those in the design documentation. Where differences occur, it can be speculated that factors of safety had been built into the design by the engineer, although this does not account for the uneven fluctuation of load values.

At the time of writing, a HAP project file for the systems in this building had been created which included full loading conditions for the boiler and chiller plants, despite the lowered scope of the project. As of submittal time, the software had been unable to provide simulation data for any of these systems or any other previous projects created by the author. This indicates an unidentifiable error, as verified by Christopher G. Conrad. The author will act upon further guidance of a faculty advisor to amend this report for re-submittal.

1. LEED Certification Assessment

The US Green Building Council (USGBC) establishes provisions for environmental and health concerns in buildings. These provisions can be utilized to obtain Leadership in Energy and Environmental Design (LEED) certification, a nationally-recognized benchmark for buildings. Currently, buildings are utilizing LEED-NC Version 2.2 as a set of standards by which buildings are rated. The rating system consists of six categories: *Sustainable Sites*, *Water Efficiency*, *Energy and Atmosphere*, *Materials and Resources*, *Indoor Environmental Quality*, and *Innovation and Design Process*. The implementation of the provisions in LEED-NC Version 2.2 can be verified through the use of a project checklist which provides a point total that will determine a building's level of certification. There are four levels of LEED certification:

1. Certified (26-32 points)
2. Silver (33-38 points)
3. Gold (39-51 points)
4. Platinum (52-69 points)

The Altoona Area Junior High School was not designed with aspirations for LEED certification, therefore much of the data used to verify compliance was not recorded. To remain within the scope of this report, special attention was paid to the *Energy and Atmosphere* and *Indoor Environmental Quality* LEED rating categories. Each of these categories has verifiable data that can be used specifically to asses the school's HVAC system.

A full LEED-Registered Project Checklist for the project has been prepared and can be found in **Appendix A**. Applicable and non-applicable items that can be confirmed with verifiable data and knowledge of the project have been marked with "Y" or "N," respectively. Items that could not be confirmed were marked with a "?." As could have been predicted, the Altoona Area Junior High School fell drastically short of LEED certification. Many category prerequisites were not adhered to, thus nullifying related points. If all prerequisites had been followed, the building would have obtained a LEED point rating of 7 based on this evaluation.

2. ASHRAE Standard 90.1-2004 Compliance

Building Envelope

Section 5 of ASHRAE Standard 90.1-2004 provides requirements for the building envelope. The standard defines three separate space-conditioning categories: *nonresidential conditioned*, *residential conditioned* and *semiheated*. The Altoona Area Junior High School falls under the *nonresidential conditioned* space category. As per the standard, the climate zone for the building was determined to be *5A*.

The building meets the parameters to be analyzed under the *Prescriptive Building Envelope Option* compliance path because its fenestration area satisfies the provisions established under the standard. The building envelope requirements for climate zone 5 are broken down into *opaque elements* and *fenestration*, both of which break down into elements further discussed in this section:

Opaque Elements
This includes roofs, walls above grade and slab-on grade floors for this project. The nonresidential opaque elements section establishes its guidelines by providing an *Assembly Maximum U-Value* and an *Insulation Minimum R-Value* for each element. A summary of these requirements in comparison with the data approximated from the design documentation is provided below in **Table 2-A**. As shown, the roofing and flooring demonstrated compliance, while the walls did not.

Table 2-A (Opaque Elements Compliance Summary)				
Element	**Description**	**Design R-Value**	**Min. R-Value**	**Compliance**
Roof	*Insulation Entirely Above Deck*	R-15.3	R-15	Yes
Above-Grade Walls	*Mass*	R-7	R-7.6	No
SOG Floor	*Unheated*	NR	NR	Yes

Fenestration

This includes vertical glazing percentage for this project. The guidelines in this section are determined by *Assembly Maximum U-Values* based on the operability of the windows. A summary comparison between design and required minimum values is provided below in **Table 2-B**. The windows selected did not have a U-Value high enough to comply with the standard.

Table 2-B (Fenestration Compliance Summary)				
% Vert. Glazing	**Operability**	**Design U-Value**	**Max. U-Value**	**Compliance**
0-10%	*Operable*	0.59	0.67	No

HVAC Systems

Section 6 of ASHRAE Standard 90.1-2004 provides requirements for minimum HVAC equipment efficiency. Because the size of the building is greater than 25,000 SF, the *Simplified Approach Option* listed in the standard could not be utilized. The analysis for this building was therefore carried out under the *Mandatory Provisions* guidelines. A performance evaluation of the building's boilers and chillers was documented and is provided below in **Tables 2-C** and **2-D**. The equipment analyzed was found not to be in compliance with Section 6 of the standard.

Table 2-C (Boiler Efficiency)					
Mark	**Input MBH**	**Output MBH**	**% Eff.**	**% Min.**	**Compliance**
B-1	4763	3322	69.7	80	No
B-2	4763	3322	69.7	80	No

Table 2-D (Chiller Efficiency)							
Mark	**Power In. (kW)**	**Cooling (kW)**	**COP**	**COP_{min}**	**NLPV**	**$NLPV_{min}$**	**Compliance**
ACC-1	224.4	782.9	3.49	5.9	6.15	6.29	No
ACC-2	224.4	782.9	3.49	5.9	6.15	6.29	No

Service Water Heating

Section 7 of ASHRAE Standard 90.1-2004 provides requirements for water heating equipment. The *Mandatory Provisions* guidelines were again followed in carrying out the analysis. As is consistent with the provisions in Section 7 and documented in **Table 2-C**, a minimum efficiency of 80% is required to meet the standard. The efficiency of the hot water supply boilers in the building's system was determined to be 69.7% using the design data, demonstrating that it does not comply with Section 7 of the standard.

Power

Section 8 of ASHRAE Standard 90.1-2004 provides requirements for power distribution systems. The *Mandatory Provisions* section mandates voltage drop requirements for feeders and branch circuits. The building's project manual requires that feeder conductors and branch circuit conductors be sized for a maximum voltage drop of 2% and 3%, respectively, which is in compliance with the standard.

Lighting

Section 9 of ASHRAE Standard 90.1-2004 provides requirements for lighting power density. The *Building Area Method* was utilized to estimate lighting power allowance. A summary of this estimation is provided below in **Table 2-E**. It is important to note that because of the building's size only estimated power densities for each type of space are used. As estimated, only the lighting systems in the gymnasium and auditorium spaces comply with the standard.

Table 2-E (Lighting Power Allowance)			
Space	**Estimated Power Density (W/ft^2)**	**Max. Power Density (W/ft2)**	**Compliance**
Gymnasium	1.0	1.1	Yes
Cafeteria	1.5	1.4	No
Library	1.5	1.3	No
Office	1.5	1.0	No
Classroom	1.5	1.2	No
Theater	1.5	1.6	Yes

Motors

Section 10 of ASHRAE Standard 90.1-2004 provides requirements for minimum motor efficiency based on horsepower and speed. Data used to determine efficiency was taken directly from the design documents. Interpolation between table values has been carried out, where necessary. Because of their small size (<1 HP), exhaust fans were not analyzed in this segment of the report. **Tables 2-F** and **2-G** show motor efficiencies for pumps and AHU fans, respectively, and are provided below. As shown, about half of the analyzed motors were in compliance with Section 10 of the standard, while the other half were not.

Table 2-F (Pump Efficiency)					
Motor	**HP**	**BHP**	**% Eff.**	**% Min.**	**Compliance**
P-1	60	50.8	84.7	93.6	No
P-2	60	50.8	84.7	93.6	No

Table 2-G (AHU Fan Efficiency)					
Motor	**HP**	**BHP**	**% Eff.**	**% Min.**	**Compliance**
A-1	7.5	6.1	81.3	89.5	No
A-2	7.5	6.1	81.3	89.5	No
A-3	3	2.2	73.3	87.5	No
A-4	3	2.2	73.3	87.5	No
A-5	10	8.2	82	89.5	No
A-6	1.5	1.4	93.3	84	Yes
A-7	5	3.4	68	87.5	No
B-1	3	2.9	96.7	87.5	Yes
C-1	3	2.5	83.3	87.5	No
C-2	1.5	1.4	93.3	84	Yes
C-3	3	2.9	96.7	87.5	Yes
C-4	2	1.9	95	84	Yes
C-5	2	1.9	95	84	Yes
C-6	5	4.7	94	87.5	Yes
D-1	5	4.9	98	87.5	Yes
D-2	1	0.95	95	82.5	Yes

3. Lost Rentable Space

The rentable space occupied by HVAC equipment in the Altoona Area Junior High School consists of physical floor area and vertical shaft area. The spaces have been listed by building section and are provided below in **Table 3-A**. Only spaces physically occupied by HVAC equipment have been considered in the calculation, ignoring spaces listed in the design documents as *mechanical storage*. A considerable amount of HVAC equipment was mounted on the outside of the building, contributing to the relatively low number generated for the total lost square footage. It is worthy to note that building section D had no lost rentable space because this area houses an auditorium and library, where special acoustic considerations required isolated, roof-top equipment mounting.

Table 3-A (Rentable Space Lost by HVAC System)	
Building Section	**Lost Area (SF)**
A	2067
B	996
C	1975
D	0
Total:	5038
% of Whole Building:	1.72%

4. Mechanical System First Cost

The mechanical system first cost was based upon the base bid of the HVAC contractor, with the owner choosing not to add any alternates to the contract. This amount includes labor and

equipment costs for HVAC work only. Plumbing and fire protection systems were not included. **Table 4-A**, provided below, lists both the total and per SF mechanical system first cost. The figures generated were based on a total building size of 292,066 SF.

Table 4-A (Mech. System First Cost)	
Total	$4,127,000
Per SF	$14.13/ft^2

5. Energy Utilization Data

At the time of writing, the Altoona Area Junior High School had still been under construction. Meter data and utility bills were therefore unable to be obtained. An estimate of the energy utilization data for electric and fossil fuel consumption has been prepared and is further detailed in **Section 6** of this report.

6. Design Load Estimation

Carrier's Hourly Analysis Program (HAP) was utilized in the estimation of the cooling load for the Altoona Area Junior High School. Air supply rates, lights/equipment loads, and occupancy were taken from the design documents. Latent and sensible loads from various sources were considered in this calculation. These sources include internal lighting, occupant, and equipment loads and external infiltration loads. Lighting and occupancy schedules have been provided in **Figures B.1** and **B.2** of **Appendix B**.

A summary of the load estimation is provided below in **Table 6-A**. It is important to note that the scope of this analysis has been lessened due to the redundancy of the overall system. An attempt has been made to represent each type of space served within the building. Air handling units have been designated "AHU" on the table, while individual unit ventilators have been designated "UV."

Table 6-A (Cooling Load Comparison)			
System	**Area Served**	**Calculated Load (MBH)**	**Design Load (MBH)**
AHU A-1	Gym 1	302.2	306.3
AHU A-2	Gym 1	302.4	306.3
AHU A-3	Gym 2	135.4	122.6
AHU A-4	Gym 2	135.5	122.6
AHU A-7	Fitness	156.7	122
AHU B-1	Admin.	123.8	123.8
AHU C-1	Library	119.6	125.9
AHU C-2	Stage	66.3	69.8
AHU C-3	Band Room	193.2	183.5
AHU C-4	Cafeteria	170.4	180.3
AHU C-5	Cafeteria	170.4	180.3
AHU D-1	Auditorium	343	361.1
AHU D-2	Library Classroom	55	50.3
UV-102	Tech. Ed. Classroom	33.3	31.9
UV-232	Foreign Lang. Classroom	28.5	28.2

UV-218	Business Ed. Classroom	40.3	40.1
UV-313	Special Ed. Classroom	36.7	33.4
UV-408	Soc. Studies Classroom	30.3	29.6
UV-214	FCS Classroom	32.6	30.3
UV-301	Math Classroom	30.4	31.7
UV-324	English Classroom	33.7	28.5
UV-320	Reading Classroom	27.1	24.4
UV-233	Faculty Lounge	34.4	34.9
UV-104	Music Classroom	27.7	24.2
UV-434	Science Classroom	30.6	30.8

A summary of the supply air flow rates has been prepared and is provided below in **Table 6-B**.

Table 6-B (Supply Air Flow Comparison)

System	Area Served	Computed Total Supply Air (CFM)	Design Total Supply Air (CFM)
AHU A-1	Gym 1	7789.5	7400
AHU A-2	Gym 1	7789.5	7400
AHU A-3	Gym 2	3368.4	3200
AHU A-4	Gym 2	3368.4	3200
AHU A-7	Fitness	3842.1	3650
AHU B-1	Admin.	3160	3160
AHU C-1	Library	3578.9	3400
AHU C-2	Stage	2631.6	2500
AHU C-3	Band Room	4189.5	4410
AHU C-4	Cafeteria	4000	3780
AHU C-5	Cafeteria	4000	3780
AHU D-1	Auditorium	8421.1	8000
AHU D-2	Library Classroom	1371.6	1500
UV-102	Tech. Ed. Classroom	1198	1250
UV-232	Foreign Lang. Classroom	989.5	1000
UV-218	Business Ed. Classroom	1492.1	1500
UV-313	Special Ed. Classroom	1139.1	1250
UV-408	Soc. Studies Classroom	976.8	1000
UV-214	FCS Classroom	928.2	1000
UV-301	Math Classroom	1043.1	1000
UV-324	English Classroom	845.5	1000
UV-320	Reading Classroom	675.7	750
UV-233	Faculty Lounge	1519.8	1500
UV-104	Music Classroom	656	750
UV-434	Science Classroom	1005.5	1000

7. Annual Energy Consumption and Operating Costs

[Incomplete as of 10/29/07]

Appendix A
LEED Project Checklist

LEED-NC Version 2.2 Registered Project Checklist
Altoona Area Junior High School
Altoona, PA

Yes	?	No			
4	2	**8**	**Sustainable Sites**		**14** Points
	?		Prereq 1	**Construction Activity Pollution Prevention**	Required
Y			Credit 1	**Site Selection**	1
Y			Credit 2	**Development Density & Community Connectivity**	1
		N	Credit 3	**Brownfield Redevelopment**	1
Y			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
		N	Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
		N	Credit 4.3	**Alternative Transportation**, Low-Emitting and Fuel-Efficient Vehicles	1
		N	Credit 4.4	**Alternative Transportation**, Parking Capacity	1
		N	Credit 5.1	**Site Development,** Protect of Restore Habitat	1
Y			Credit 5.2	**Site Development,** Maximize Open Space	1
	?		Credit 6.1	**Stormwater Design,** Quantity Control	1
		N	Credit 6.2	**Stormwater Design,** Quality Control	1
		N	Credit 7.1	**Heat Island Effect,** Non-Roof	1
		N	Credit 7.2	**Heat Island Effect,** Roof	1
	?		Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
0	0	**5**	**Water Efficiency**		**5** Points
		N	Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
		N	Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
		N	Credit 2	**Innovative Wastewater Technologies**	1
		N	Credit 3.1	**Water Use Reduction**, 20% Reduction	1
		N	Credit 3.2	**Water Use Reduction**, 30% Reduction	1

Yes	?	No			
0	2	15	**Energy & Atmosphere**		**17** Points
		N	Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
		N	Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required
	?		Credit 1	**Optimize Energy Performance**	1 to 10
		N	Credit 2	**On-Site Renewable Energy**	1 to 3
		N	Credit 3	**Enhanced Commissioning**	1
	?		Credit 4	**Enhanced Refrigerant Management**	1
		N	Credit 5	**Measurement & Verification**	1
		N	Credit 6	**Green Power**	1

continued…

Yes	?	No			
0	10	3	**Materials & Resources**		**13** Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
		N	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
		N	Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roof	1
		N	Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1
	?		Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
	?		Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
	?		Credit 3.1	**Materials Reuse**, 5%	1
	?		Credit 3.2	**Materials Reuse**,10%	1
	?		Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
	?		Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
	?		Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regionally	1
	?		Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regionally	1
	?		Credit 6	**Rapidly Renewable Materials**	1
	?		Credit 7	**Certified Wood**	1

Yes	?	No			
2	5	8	**Indoor Environmental Quality**		**15** Points
		N	Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
		N	Credit 1	**Outdoor Air Delivery Monitoring**	1
		N	Credit 2	**Increased Ventilation**	1

		N	Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
		N	Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
	?		Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
	?		Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
		N	Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
	?		Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
Y			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
		N	Credit 6.1	**Controllability of Systems**, Lighting	1
		N	Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
	?		Credit 7.1	**Thermal Comfort**, Design	1
		N	Credit 7.2	**Thermal Comfort**, Verification	1
Y			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
	?		Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes	?	No		
1	0	4	**Innovation & Design Process**	**5** Points

		N	Credit 1.1	**Innovation in Design**: Provide Specific Title	1
		N	Credit 1.2	**Innovation in Design**: Provide Specific Title	1
		N	Credit 1.3	**Innovation in Design**: Provide Specific Title	1
		N	Credit 1.4	**Innovation in Design**: Provide Specific Title	1
Y			Credit 2	**LEED® Accredited Professional**	1

Yes	?	No		
7	19	43	**Project Totals (pre-certification estimates)**	**69** Points

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

Appendix B
Load Schedules

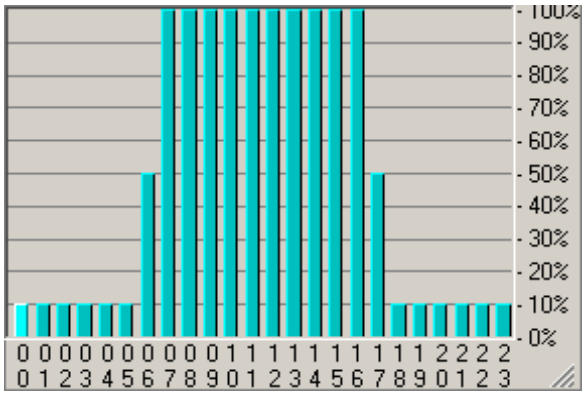

Figure B.1 (Lighting Schedule)

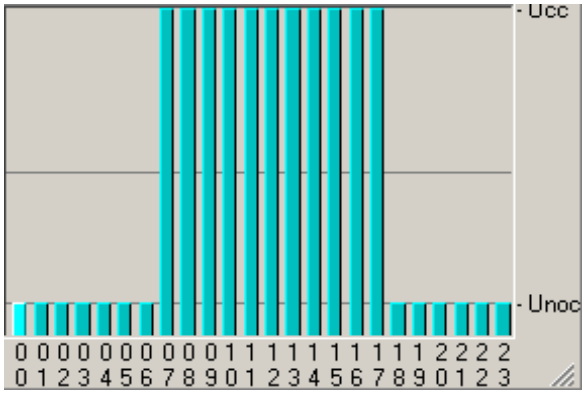

Figure B.2 (Occupancy Schedule)