Mechanical Thesis Proposal

Geothermal Gyms and Satisfactory Stages

Altoona Area Junior High School
Altoona, PA

Christopher G. Conrad
Mechanical Option
Faculty Advisor: James D. Freihaut, Ph.D.
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Executive Summary

The Altoona Area Junior High School building is a 292,000 SF, $48 million educational facility with a variety of mixed-use and single-use spaces. The primary HVAC system utilizes a two pipe change-over system for chilled and hot water delivery to air handling units within this network. Large modular AHUs serve the larger spaces of the school, while individual unit ventilators serve the classrooms. Several direct expansion (DX)/gas air handling units also serve the building.

The DX/gas air handling units in the gymnasiums operate independently of the two-pipe changeover system and invite the prospect of improved performance through redesign or replacement. The single-zone systems utilized in these spaces also make it feasible to integrate a more efficient and effective system without major disruption to the rest of the building design. The architectural characteristics of spaces in and around the auditorium area also invite the prospect to improve noted ventilation deficiencies through air delivery based on proximity.

Instead of attempting to change the entire dual-pipe changeover system that serves most of the spaces in the school, it appears to be feasible to change the systems in the athletic wing of the school only to **geothermal heat pumps**. The academic and athletic wings of the school are separated architecturally, reinforcing the possibility of separately-controlled, differing systems in each wing. Of the spaces where a noted deficiency of outdoor air is apparent, the school's stage is one special use area whose air quality requirements are critical. Surrounded by spaces where outdoor air surpluses are noted, it seems logical to **divert the supply of existing air handling units to compensate for the stage's deficiency**.

The primary justification for utilizing a geothermal system in the school's gymnasiums and athletic spaces is to reduce energy and fuel consumption, thus reducing the life cycle costs of the building. The justification for the diversion of outdoor air to the stage area is to improve the air quality and to do so without the need for additional mechanical equipment.

To satisfy breadth study requirements, the effect that any proposed changes on the **structural systems** and **acoustic considerations** will be examined.

1. Existing Systems Summary

The Altoona Area Junior High School is served by several different HVAC systems, selected for their cost and effectiveness. A two-pipe change over chilled water/hot water system serves a majority of the air handlers and classroom unit ventilators in the building. Several prepackaged rooftop units and DX/gas units were also utilized, mainly in the school's athletic areas.

It is important to note that the DX/gas air handling units in the gymnasiums operate independently of the two-pipe changeover system and invite the prospect of improved performance through redesign or replacement. Large occupancy areas such as gymnasiums also present unique design considerations due to their varying requirements for thermal loads, ventilation, and humidity. The single-zone systems utilized in these spaces also make it feasible to integrate a more efficient and effective system without major disruption to the rest of the building design.

Another space within the school where design conditions vary critically based on occupancy is the auditorium/stage area. In the design documentation, these spaces have been separated into two separate zones to accommodate the separate needs of both areas. The architectural characteristics of these spaces invite the prospect to improve noted ventilation deficiencies through air delivery based on proximity. The auditorium area also presents a set of unique acoustic challenges if any redesign of air delivery in these areas were to occur.

2. Considered Alternatives

In order to effectively address the deficiencies and utilize the opportunities for improvement in the design, the areas discussed above will become the focus of the redesign efforts presented in this report.

Spaces directly affected include:

- **Gymnasium 1**
- **Gymnasium 2**
- **Main Athletic Areas**
- **Stage**

Spaces indirectly affected include:

- **Secondary Athletic Areas**
- **Auditorium**
- **Band Room**

Alternative options for redesign in these areas are discussed below. Some alternatives inherently require an entire reconfiguration of the building HVAC system, while others allow for simple implementation which may or may not disrupt the operation of the current overall system.

Radiant Heating/Cooling

Radiant heating/cooling systems are an attractive alternative to the existing DX/gas air handling units that serve the school's gymnasium. Because the floor of both gymnasiums sits atop the concrete slab-on-grade, a piping system sufficient to serve such a radiant system is architecturally feasible. Such a system could easily be integrated into the existing hydronic configuration that serves the dual pipe system in the rest of the building, but would alter the sizing and loading of hydronic components. Institutions where radiant heating systems have been implemented have reported an increase in thermal comfort and a decrease in energy consumption compared to traditional forced-air systems.

Gymnasiums that have effectively utilized a radiant floor system have done so with much success, even under wooden athletic flooring. The use of a non-forced air system presents the challenge of ventilating the space, but is often solved through the use of heat-recovery ventilation units. Another challenge that is presented by radiant floor systems is the need for cooling. The use of radiant cooling in floors is a relatively new and unexplored territory. Cooled floors also present the challenge of condensation and subsequent mold growth. Based on the current research available, it does not seem feasible to implement radiant floor cooling in the Altoona Junior High School because of the reasons mentioned above. Because an effective and efficient cooling method does not seem possible to implement with a radiant floor system, it is unlikely to feature in a system redesign

3. Proposed Redesign and Coordination

Geothermal System in Gymnasiums/Athletic Spaces

Instead of attempting to change the entire dual-pipe changeover system that serves most of the spaces in the school, it appears to be feasible to change the systems in the athletic wing of the school only to geothermal heat pumps. Most of these spaces are already served by modular DX/gas units which afford the opportunity for replacement without interruption to the rest of the system and the centralized boiler/chiller plant. This is under the assumption that the dual pipe changeover system is both effective and economically justified, both of which are echoed in design and contract documents. Furthermore, the academic and athletic wings of the school are separated architecturally, reinforcing the possibility of separately-controlled, differing systems in each wing.

Diversion of Outdoor Air to Stage Area

Of the spaces where a noted deficiency of outdoor air is apparent, the school’s stage is one special use area whose air quality requirements are critical. Surrounded by spaces where outdoor air surpluses are noted, it seems logical to divert the supply of existing air handling units to compensate for the stage’s deficiency. This appears to be feasible without the replacement of major equipment, as the total available outdoor air delivery in this area of the building is sufficient to meet all of the calculated needs with the existing air handling units. Along with altering the duct configuration in this area of the building, a separate control system could be used to increase system customization and efficiency based on duration and frequency of use.

4. Justification for Proposed Work

The primary justification for utilizing a geothermal system in the school’s gymnasiums and athletic spaces is to reduce energy and fuel consumption, thus reducing the life cycle costs of the building. Bringing a geothermal system into a community where it is not widely used also presents a tremendous opportunity to educate and stimulate interest in this progressive heating and cooling method. The school district can utilize this energy-saving HVAC system to educate citizens and set an example within the community.

Implementing a separate system within the athletic section of the building also allows for an isolation of controls, allowing the geothermal system to operate on a different cycle than the rest of the building’s split-pipe system. This will allow for greater control during times where special events require differing loads on the system.

The justification for the diversion of outdoor air to the stage area is to improve the air quality and to do so without the need for additional mechanical equipment. Just as the thermal loads due to occupancy and theatrical lighting have been considered critical in conditioning the stage space, so should outdoor air requirements, particularly for performers and speakers whose comfort on stage are also critical.

A comparison of minimum outdoor air requirements determined using ASHRAE Standard 62.1 and design values for air handling units serving the stage and adjacent spaces has been provided below in **Table 4-A**.

Table 4-A (OA Requirements for Auditorium-area Spaces)

AHU	Room	Min. OA Design	Min. OA Calculated	Difference
C-2	Stage	200 CFM	1389 CFM	1189 CFM
C-3	Band Room	2305 CFM	1071 CFM	-1234 CFM
D-1	Auditorium	4875 CFM	3573 CFM	-1302 CFM

It appears that where the band room has been over-ventilated by 1234 CFM, the stage has been under-ventilated by 1189 CFM, a difference that is virtually identical. Because the band room is adjacent to the stage, it seems feasible that a reconfiguration of the duct work in this area could allow AHU C-3 to also condition the stage on a variable basis to meet the established outdoor air requirements.

5. Integration

Structural Impact (basis for breadth study)

Because the athletic wing of the school is virtually devoid of hydronic equipment, the implementation of a heat pump system seems further justified. The only equipment that would be replaced would be the existing roof-mount modular DX/gas air handlers, in favor of a lighter, largely underground system. While a higher expense for such a system is probable, the subsequent effect on the structural system is noteworthy. The effects of such an alteration on the structural system, mainly the decrease in dead load for the roof, will be further discussed in a breadth study later during the course of this thesis examination.

Acoustic Impact (basis for breadth study)

A greater amount of air delivery into the stage/auditorium space will undoubtedly alter acoustic considerations. Outlet air velocities and diffuser sizes all have an impact on background noise and sound transmission. A basic acoustic analysis in the auditorium including the impact from additional air delivery will feature in future breadth studies for this project.

6. Preliminary Research Bibliography

ANSI/ASHRAE Standard 62.1-2007. 2007. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers: Atlanta, GA.

ASHRAE, 2005. ASHRAE Handbook: Fundamentals. American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc: Atlanta, GA.

McQuiston, Faye C., et al. 2005. Heating, Ventilating and Air Conditioning: Analysis and Design. John Wiley & Sons: Hoboken, NJ.

7. Tools and Methods

The addition of a geothermal heat pump system to the Altoona Junior High School building would have a serious impact on scheduling, material needs, and initial cost. Because holes in the ground (many of which could exceed hundreds of feet) will need to be drilled to accommodate the HDPE piping into the ground reservoir, this will have an immense impact on the building's construction. The above ground space required to accommodate pumps and fan units will be minimal, and in comparison with the relatively low amount of space currently occupied by mechanical systems in the building, should not pose a problem. **Table 7-A**, provided below, provides a summary of the lost rentable space due to HVAC systems throughout the building.

Table 7-A (Rentable Space Lost by HVAC System)

Building Phase	Lost Area (SF)
A	2067
B	996
C	1975
D	0
Total:	5038
% of Whole Building:	1.72%

Because the building is being constructed in separate phases, this should also accommodate the preparation for the geothermal system without interruption to the rest of the project, depending on the chosen location for ground wells. The athletic facility is considered to fall under one such phase definition and is convenient for grouping all related projects within that facility. Note that the largest amount of rentable space has been lost in Building Phase A, the section of the building that houses athletic facilities.

Appendix A

Draft Work Plan for Spring 2008

January 2008

Sun	Mon	Tue	Wed	Thu	Fri	Sat
		1 **New Year's Day**	2	3	4	5
6	7	8	9	10	11	12
13	14 **Classes Begin** Update existing documents/ research	15 Update existing documents/ research	16 Update existing documents/ research	17 Update existing documents/ research	18 Update existing documents/ research	19 **ASHRAE Winter Meeting**
20	21 **Martin Luther King Day** **ASHRAE Winter Meeting**	22 **ASHRAE Winter Meeting**	23 **ASHRAE Winter Meeting**	24 Organize data for comparison	25 Organize data for comparison	26
27	28 Model geothermal system	29 Model geothermal system	30 Model geothermal system	31 Model geothermal system		

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February 2008

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4 Obtain geothermal cost and performance information	5 Obtain geothermal cost and performance information	6 Obtain geothermal cost and performance information	7 Examine ventilation solutions	8 Examine ventilation solutions	9
10	11 Coordinate with rest of project	12 Coordinate with rest of project	13 Organize results	14 Organize results	15 Organize results	16
17	18 **Washington's Birthday**	19 Discuss findings with faculty advisor	20 Discuss findings with faculty advisor	21 Make noted improvements/ adjustments	22 Make noted improvements/ adjustments	23
24	25 Make noted improvements/ adjustments	26 Compile finalized model	27 Compile finalized model	28 Compile finalized model	29 Compile finalized model	1

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March 2008

Sun	Mon	Tue	Wed	Thu	Fri	Sat
2	3 Structural analysis breadth work	4 Structural analysis breadth work	5 Structural analysis breadth work	6 Structural analysis breadth work	7 Structural analysis breadth work	8
9	10 **Spring Break**	11 **Spring Break**	12 **Spring Break**	13 **Spring Break**	14 **Spring Break**	15
16	17 Acoustic analysis breadth work	18 Acoustic analysis breadth work	19 Acoustic analysis breadth work	20 Acoustic analysis breadth work	21 Acoustic analysis breadth work	22
23	24 Work on final report/ presentation preparation	25 Work on final report/ presentation preparation	26 Work on final report/ presentation preparation	27 Work on final report/ presentation preparation	28 Work on final report/ presentation preparation	29
30	31 Work on final report/ presentation					

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April 2008

Sun	Mon	Tue	Wed	Thu	Fri	Sat
		1 Work on final report/ presentation	2 Work on final report/ presentation	3 Work on final report/ presentation	4 Work on final report/ presentation	5
6	7 Refine visuals/data for presentation	8 Refine visuals/data for presentation	9 Rehearse presentation	10 Rehearse presentation	11	12
13	14 **Thesis Presentations**	15 **Thesis Presentations**	16 **Thesis Presentations**	17 **Thesis Presentations**	18 **Thesis Presentations**	19
20	21 Finish course work	22 Finish course work	23 Finish course work	24 Finish course work	25 Finish course work	26
27	28 Finish course work	29 Finish course work	30 Finish course work			

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May 2008

Sun	Mon	Tue	Wed	Thu	Fri	Sat
				1 Finish course work	2 **Classes End** **Senior Awards Banquet**	3
4	5 **Final Exams**	6 **Final Exams**	7 **Final Exams**	8 **Final Exams**	9 **Final Exams**	10
11	12	13	14	15	16 **Commence-ment**	17 **Commence-ment**
18 **Commence-ment**	19	20	21	22	23	24
25	26 **Memorial Day**	27	28	29	30	31