Mechanical Tech Report 3

Mechanical Systems Existing Conditions Evaluation

Altoona Area Junior High School
Altoona, PA

Christopher G. Conrad
Mechanical Option
Faculty Advisor: James D. Freihaut, Ph.D.
December 3, 2007

Table of Contents

Executive Summary

The purpose of this report is to provide an evaluation of the existing conditions present in the HVAC systems used in the Altoona Area Junior High School. The primary 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 control logic for this system, as specified in the design documentation has been reported. A schematic diagram for the two pipe system has also been provided.

The design objectives for the system include having a low first cost, as well as simplification of the system. Analytically, the systems meet the needs of the building for the most part, and where deficiencies have been found, they have been discussed. Design conditions as well as a comparison of load and ventilation calculations have been provided.

A critique of the system has been carried out which evaluates the systems to be adequate and logical. The discrepancies found during the ventilation assessment could be a cause for concern, especially in highly-occupied areas where ventilation is critical. This is a likely starting point for any future research based on the analysis of this report.

1. System 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. This dual pipe change over system and its condensing units will serve as the primary focus of this report, with emphasis also on main prepackaged and DX units. Schedules have been provided in **Appendix A** that list the characteristics and design conditions for this equipment.

The equipment schedules include seven DX/gas air handling units, six CW/HW air handling units, and three CW/HW air handling units that also feature a DX coil. Note that a schedule of condensing units has been provided for each system utilizing direct expansion. Boiler and Chiller data is also provided.

Due to the building's size, it would be too tedious to list each space and the system by which it is served. Instead, **Table 1-A**, provided below, makes a listing of the types of spaces in the building and by which type of system these spaces are generally served.

Table 1-A (Building System Summary Organized by Type)

Unit	Space
DX/gas AHUs	Gymnasiums/Athletics
CW/HW AHUs	Library/Auditorium/Cafeteria
VAV Box System	Office Suite
Individual Unit Ventilators	Classrooms/Lounges

The Two-Pipe Change Over System

The obvious characteristic of this system is that only two sets of pipes (one for supply and one for return) serve the units in the building. Chilled water is provided by two 225-ton air-cooled chillers and hot water is provided by two 3,322-MBH natural gas boilers. A three-way mixing valve provides a controlled mixture of return and supply water. Change-over valves control the operation of the system based on seasonal requirements. The chilled water supply temperature is 45°F and the hot water supply temperature is 180°F. Chilled water is returned at 55°F, while hot water is returned at 160°F. It is assumed that these temperatures constitute the EWT and LWT for equipment utilizing the two-pipe system, and have been omitted from the schedules in **Appendix A**. This is consistent with the design data. A simplified schematic of this system has been provided in **Appendix B**. It is worthy to note, while omitted from the schematic, air-separating and water treatment equipment is utilized on the return loop of the system.

Control Logic

The junior high school utilizes a fully-integrated Building Automation System (BAS) which incorporates direct digital control (DDC) for energy management, equipment monitoring and control, and open-communication with subsystems. This includes an operator terminal with a graphic representation of the system provided to the maintenance personnel. One set of controls is mandated by the design documents for air handling units, pumps, chillers, boilers, and cooling towers.

Other control systems included in the building:

Hydronic piping – control valves, temperature sensors, flow switches and meters

Refrigerant piping – pressure and temperature sensors
Duct work – dampers, air-flow stations, terminal unit controls

Thermostats, duct pressure sensors, and variable frequency drives are also included.

Secondary Systems

Secondary HVAC systems include the use of fan coil units, hydronic heating units, electric wall heaters, and radiant ceiling panel heaters. A VAV box system is also utilized in the school's office suite. It is also worthy to note that the school features advanced ventilation systems, particularly in kitchens, science laboratories, and technical education shops. Although these elements are not featured within the primary focus of this report, their contribution to the energy consumption of the building is significant.

2. Design Objectives and Requirements

Generally, the HVAC objectives for the building have been met. The use of a two pipe change over system accomplishes the goals of the owner to lower system first cost and have a system that is easy to maintain and control. As will be demonstrated in Section 3, design loads and ventilation requirements for system components were found to be relatively close to those calculated. The advantages and disadvantages of the system are further discussed in Section 4.

3. Design Conditions

The design conditions for Altoona, PA have been prepared for a HAP energy simulation and are provided below in **Figure 3-A**.

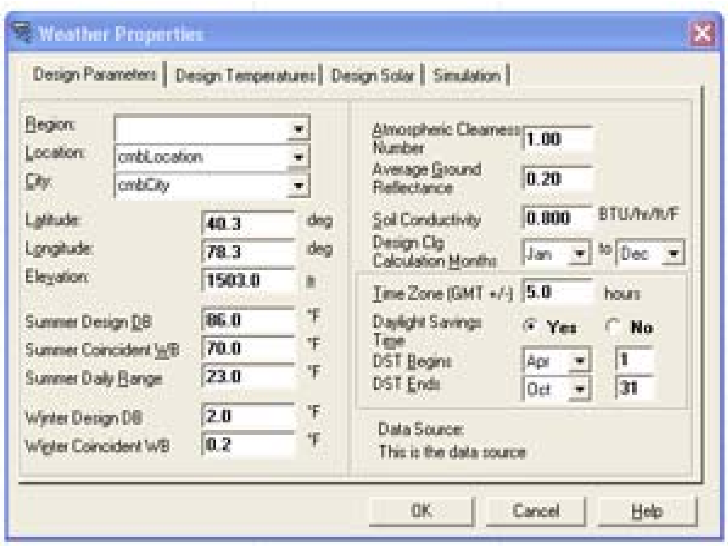

Figure 3-A Design Conditions for Altoona, PA

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.

Ventilation Requirements

The ventilation requirements for the building have been calculated and compared to design values in **Table 3-A**, provided below. Note that, as in previous technical reports for this building, only a sampling of the unit ventilators have been provided for analysis.

Table 3-A (Actual and Calculated OA Requirement Comparison)

System	Min. OA Actual	Min. OA Calculated	Difference
AHU A-1	3875	4333	458
AHU A-2	3875	4333	458
AHU A-3	1440	1524	84
AHU A-4	1440	1524	84
AHU A-7	1040	1288	248
AHU C-1	1300	954	-346
AHU C-2	200	1389	1189
AHU C-3	2305	1071	-1234
AHU C-4	2700	3081	381
AHU C-5	2700	2991	291
AHU B-1	1400	738	-662
AHU D-1	4875	3573	-1302
AHU D-2	375	403	28
UV-109	100	119	19
UV-102	375	613	238
UV-232	375	373	-2
UV-218	375	365	-10
UV-313	375	444	69
UV-408	375	389	14
UV-214	375	417	42
UV-301	375	405	30
UV-324	375	365	-10
UV-320	375	396	21
UV-233	240	211	-29
UV-104	375	420	45
UV-434	375	422	47

Load Requirements

The cooling loads calculated as part of the energy simulation are provided below in **Table 3-B**.

Table 3-B (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

Air Flow Requirements

A summary of the supply air flow rates, as prepared for the energy simulation is provided below in **Table 3-C**.

Table 3-C (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

4. System Critique

As is consistent with most of the research conducted for this project, the HVAC systems selected for this building seem to make an effort towards a simple and low first-cost overall system. The use of a dual pipe change over system appears to be a logical choice for the building needs and certainly was the best first-cost option satisfying the requirements of the owner. The drawbacks inherent of a two pipe system, as opposed to a four pipe system, result in lower controllability of the systems, as there are only two operating modes (cooling or heating). This can often sacrifice the thermal comfort of the occupant, particularly in central Pennsylvania, where weather can be unpredictable. With the amount of electronic equipment and secondary electric heating, it can be assumed that the cooling operating mode will be in use longer than expected. The occupancy times and dates for the school building seem to support this assumption.

The obvious drawback of a low first-cost system is that life cycle costs will inevitably be higher. Further research must be conducted to see which systems would be logical to serve the building and how these systems would influence the life cycle costs of operating the system.

Improvements are needed mainly in the delivery of outdoor air in certain spaces throughout the building. The gymnasium and auditorium spaces are of primary concern because they are the areas of the highest possible occupancy.

Practical measures such as acoustic isolation and serviceability seem to be under control, but this does not limit the need for further understanding in areas where these measures are critical.

Appendix A
Equipment Schedules

Schedule A.1 (DX/Gas Air Handling Units)								
Mark	Total CFM	Min. O.A. CFM	Cooling (DX)			Heating (Gas)		
			MBH	EAT	LAT	MBH	EAT	LAT
AHU A-1	7400	3875	306.3	82.3	55	560	35.3	100
AHU A-2	7400	3875	306.3	82.3	55	560	35.3	100
AHU A-3	3200	1440	122.6	81.1	55	200	40.5	100
AHU A-4	3200	1440	122.6	81.1	55	200	40.5	100
AHU A-5	13150	1500	378.5	76.6	55	560	63.8	100
AHU A-6	2250	1475	102.7	84.2	55	200	27	100
AHU A-7	3650	1040	122	79	55	200	51.5	100

Schedule A.2 (CW/HW Air Handling Units)										
Mark	Total CFM	Min. O.A. CFM	Cooling (chilled water)				Heating (hot water)			
			GPM	MBH	EAT	LAT	GPM	MBH	EAT	LAT
AHU C-1	3400	1300	25.1	125.9	80.4	54.5	18.1	181	45.7	95
AHU C-2	2500	200	15.5	69.8	76.1	54.5	11.1	110.7	54	95
AHU C-3	4410	2305	36.6	183.5	82.3	54.5	19.5	194.8	54.1	95
AHU C-4	3780	2700	35.9	180.3	85	54.5	16.7	167.4	54	95
AHU C-5	3780	2700	35.9	180.3	85	54.5	16.7	167.4	54	95
AHU C-6	5500	550	34.6	150.4	76.3	54.5	16.5	164.5	67.3	95

Schedule A.3 (CW/HW Air Handling Units with DX Coil)													
Mark	Total CFM	Min O.A. CFM	Cooling (chilled water)				Heating (hot water)				Cooling (DX)		
			GPM	MBH	EAT	LAT	GPM	MBH	EAT	LAT	MBH	EAT	LAT
AHU B-1	3160	1400	24.4	123.8	81.2	54.5	19.3	192.8	38.5	95	123.8	81.2	55
AHU D-1	8000	4875	72	631.1	83.5	54.5	34.4	343.9	55.2	95	361.1	83.5	55
AHU D-2	1500	375	10.1	50.3	78.5	54.5	7.1	70.5	51.5	95	50.3	78.5	55

Schedule A.4 (Gas Boilers)				
Mark	Input MBH	Output MBH	HP	LWT
B-1	4763	3322	114.1	180°F
B-2	4763	3322	114.1	180°F

Schedule A.5 (Air-cooled Chillers)			
Mark	Capacity	Flow GPM	LWT
ACC-1	225 tons	526.3	45°F
ACC-2	225 tons	526.3	45°F

Schedule A.6 (Air-cooled Condensing Units)		
Mark	**Capacity (MBH)**	**Corresponding AHU**
ACCU A-1	42	AHU A-1
ACCU A-2	300	AHU A-2
ACCU A-3	300	AHU A-3
ACCU A-4	126	AHU A-4
ACCU A-5	126	AHU A-5
ACCU A-6	360	AHU A-6
ACCU A-7	126	AHU A-7
ACCU B-1	126	AHU B-1
ACCU D-1	360	AHU D-1
ACCU D-2	60	AHU D-2

Appendix B
System Schematics