HVAC SYSTEMS STUDY

Muskegon Community College / March.08.13

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I. INTRODUCTION

Muskegon Community College has commissioned GMB Architecture + Engineering to conduct an engineering study to analyze their heating, ventilating and air conditioning (HVAC) systems, in accordance with GMB's Proposal for Engineering Services, dated June 7, 2012. The study addresses the central heating and cooling systems in the Main Building (Areas 'A' through 'G'), the Fine Arts Center and the Stevenson Center, and the central air handling systems in the Main Building, Areas 'A' through 'G'. Investigation of the central heating and cooling systems also takes into account a future 21,000 square foot Science addition. Air handling systems in the Stevenson Center and Fine Arts Center have not been reviewed. The Meijer Library has dedicated heating, cooling and air handling systems, and has also been excluded from this study.

An emphasis has been placed in the following problem areas:

- Inadequate hot water flow in the central heating system.
- General comfort issues and lack of seasonal control in areas served by some dual duct systems.
- Comfort issues in the Area 'C' and 'D' office towers. Specifically, an inability of these areas to warm up during cold weather. The problem is most severe following a very cold weekend.
- The inability to provide 'free cooling' with outside air during late Fall and early Spring in several areas.

Although Muskegon Community College staff indicated that there aren't any known chilled water flow or balancing issues, an overview of the central cooling systems has been done to confirm that any cooling issues aren't caused by chilled water flow deficiencies, and to consider the impact of the future Science addition.

GMB has identified HVAC system deficiencies, has made recommendations for possible improvements, and has developed Opinions of Probable Cost. Our findings are presented in this report. Our primary contact at Muskegon Community College has been Gerald Nyland, Physical Plant Director.

II. APPROACH

We reviewed available drawings, including original drawings of Wings A through G (1965), the Fine Arts Center (1967), the Stevenson Center (1993), the Library/Information Technology Building (2004) and seven remodeling projects. A complete list of reviewed drawings is included in Appendix A. Where necessary to verify the accuracy of drawings, we field-verified installed conditions. Field-verification included all mechanical equipment rooms in Areas A though G and the Fine Arts Center, plus the majority of the equipment served by primary heating pumps in Areas A through G and the Fine Arts Center. An extensive field review of the Boiler Room and central heating system was done. We reviewed Gerald Nyland's "Overview, History and Current Status" document describing the central heating system, and an August 15, 2011 Memo written by Century A&E, describing central heating system problems.

We developed simplified schematic diagrams of the central heating and cooling systems.

We estimated pump heads for the primary heating pumps serving the Main Building and the Fine Arts Center.

We calculated block heating and cooling loads for the areas served by dual duct air handling systems in Areas 'A', 'B', 'C' and 'D'.

We measured floor and window indoor surface temperatures of the Office Tower corridors with an outdoor temperature of 7^{o}F.

III. EXECUTIVE SUMMARY

We identified many problems in the central heating system, the central air handling systems serving Areas 'A' and 'B', and in the construction of the Areas 'C' and 'D' Office Towers. The central heating system and central air handling systems were marginally designed in 1965. Subsequent building additions and remodeling projects have resulted in an inability to heat and cool portions of the building, with the most significant problems being in Areas 'A' and 'C'. Also as the result of building additions and remodeling projects, free cooling with outside air is no longer possible in the Third Floor Nursing Offices and in Third Floor Classrooms 331 and 335, resulting in a lack of cooling in these areas during the late Fall and early Spring. The design deficiencies of the Area 'C' and 'D' office towers have resulted in very cold interior floors and windows, making it extremely difficult to maintain occupant comfort.

We identified corrective measures, and generated a list of Recommendations. Preliminary cost estimates have been developed for budgeting purposes. Corrective measures are described within this study. Total costs for the most critical issues are summarized below:

- Heating system upgrades: $537,300.
- Air handling system upgrades: $253,500.
- Improvements to the building envelope in the Area 'C' and 'D' Office towers: $119,400.
- Correction of free cooling problems: $116,000.

Note that the above list reflects only items A1 through A13 in the recommended heating systems upgrades. Items A1 through A13 are considered the minimum improvements necessary to create a fully functional heating system. The following improvements are also recommended:

- Provide a system filter and filter pump on the central heating system: $7500.
- Replace the heating coil, coil pump and control valve for existing Kitchen Make-Up Air Unit HV-A2, to enable the unit to operate without freezing the coil: $15,000.
- Plan for the replacement of the remaining original (1965 and 1967) mechanical equipment. Although no immediate operational issues exist, the equipment is nearly fifty years old; it will eventually fail. Identification of all remaining original equipment has not been done, and its cost will overlap with some of the above recommendations. Replacement could occur over a single summer, or could be phased over a number of years.

Refer to **Table 2 in Section XI** (pages 19 and 20) for a complete list of recommendations and a cost summary.

IV. GENERAL BUILDING INFORMATION

A. The building consists of three floors, with main entry on the First (upper) Floor, and the Second (intermediate) floor and Third (lower) floor below. The total floor area is approximately 385,200 square feet, including the Main Building, the Fine Arts Center and the Stevenson Center, with a floor-by-floor breakdown as follows:

First Floor:	180,700 square feet
Second Floor:	121,200 square feet
Third Floor:	83,300 square feet

B. Building Area Designations: For the purposes of this study, building area designations are as follows:

1. Areas 'A' through 'G'; the original Main Building, including all areas of the building constructed in 1965-66.
2. The Fine Arts Center, including the Overbrook Theater and all areas of the building constructed in 1967-68.
3. The Stevenson Center for Higher Education, including all areas of the building constructed in 1993-94.

Building area designations are summarized on Sketches No. 1, 2 and 3 (Appendix B).

V. CENTRAL HEATING SYSTEM

A. Existing System

The complex is heated by three natural gas-fired boilers, which were installed in 1996 as part of the Stevenson Center construction. Each boiler is a Weil McLain Model 1388 cast iron boiler with a gas input rating of 4,113,000 BTUs per hour (BTUH), and a gross output rating of 3,270,000 BTUH. The boiler rated efficiency is therefore 79.5 percent (3270/4113).

Each boiler has a dedicated, in-line boiler pump. The boiler pumps are each Bell & Gossett Model PD, Size 037S, rated for 130 gallons per minute (GPM) against a flow resistance of 12 feet of head.

The heating distribution system consists of three primary distribution pumps, each with a dedicated standby pump. One pair of primary pumps serves Areas 'A' through 'G', one pair serves the Fine Arts Center and one pair serves the Stevenson Center. Reference has been made throughout this study to 'common heating piping', meaning piping through which flow from all three sets of primary pumps flows. The distribution pumps serving Areas 'A' through 'G' are Bell & Gossett Model U6C, selected for a flow rate of 675 gpm at 100 feet of head. The distribution pumps serving the Fine Arts Center are Bell & Gossett Series U4A, selected for a flow rate of 140 GPM at 20 feet of head. The distribution pumps serving the Stevenson Center are Bell & Gossett Model 1510, size 4E, selected for a flow rate of 570 GPM at 96 feet of head. The Main Building primary distribution system is divided into a west loop, serving Areas 'A', 'C', 'E' and 'F', and an east loop, serving Areas 'B', 'D' and 'G'. All primary distribution systems are direct return.

Each primary heating pump has a variable frequency drive, and differential pressure sensors are located within the Boiler Room. It is our understanding that variable frequency drives operate at 100 percent speed "most of the time". When observed on a mild (50^{o}F) day, the variable frequency drives serving the Main Building and Fine Arts Center primary heating pumps were each operating at 100 percent, and the Stevenson Building primary heating pump was not operating.

Boilers, boiler pumps and primary distribution pumps are located in the Boiler Room. The heating system has three ASME compression tanks located in the Boiler Room (one connected to the air separator, and two connected to the boilers. Staff has indicated that three other remote compression tanks exist.

Refer to **Sketch 7 in Appendix D** for a simplified schematic diagram of the central heating system.

B. Analysis

The existing boilers have a combined output of 9,810,000 BTUH, for an average of 25.46 BTUH per square foot. This capacity is too low for a building of this era. Single pane windows and poorly insulated building envelopes were common in the 1960's. A central heating plant with an output of approximately 40.0 BTUH per square foot is recommended. The total recommended heating output is therefore approximately 15,400,000 BTUH; an increase of 5,590,000 BTUH.

The central heating system has many flow deficiencies, resulting in an inability to properly heat Areas 'A' and 'B' during very cold weather, a Monday morning warm-up problem in the

Fine Arts Center, along with several other heating problems that have resulted from attempts to compensate for lack of flow in Areas 'A' and 'B' by reducing heating flow elsewhere. As generally accepted design practices, piping is typically sized for a maximum pressure drop of 4 feet per hundred feet of straight pipe, with maximum flow velocities of 10 feet per second in mechanical rooms and 7 feet per second in occupied spaces (due to the desire to limit noise generated by high flow velocity). The installed heating piping greatly exceeds these pressure drop and velocity guidelines in several areas. Flow deficiencies are summarized below:

1. The Main Building primary heating pumps were undersized in 1965. They were sized for 675 GPM, but the sum of the connected heating loads was 818 GPM. Because the heating system was designed with three-way control valves on all air handling unit heating coils and secondary heating loop pumps, no flow diversity occurs. The original primary heating pumps serving Areas 'A' through 'G' should have been selected for 818 GPM. Subsequent renovations have increased the connected load of the Main Building primary distribution pumps to 966 GPM. We recommend that the Main Building primary heating pumps and variable frequency drives be replaced to match the current (and possibly future) load. **Refer to item A9 in the list of recommendations.**

2. The common Boiler Room primary heating piping and air separator were marginally sized in 1965, and have become significantly more undersized as a result of the subsequent remodeling projects. When the Fine Arts Center was added, the connected heating load increased to 958 GPM. Based on the pipe sizing design practices described above, a six inch heating pipe located in a Boiler Room has an approximate peak flow of 800 GPM. When the Stevenson Center was added in 1993-94, the total primary heating system connected load increased to 1385 GPM. The 2001 Science Classroom 151 air handling unit, the 2003 Technology Wing Air Conditioning project (Areas 'F' and 'G'), and the 2008 Student Center remodeling project (Area 'E') increased the primary heating system connected load to 1701 GPM. The undersized 6 inch piping and air separator restrict water flow, and should be increased in size to 10 inch. **Refer to Item A2 in the list of recommendations, and to Sketch 9 in Appendix D**.

   Seven replacement air handling units included in the Technology Wing Air Conditioning project were part of a bid alternate that was not accepted. Future replacement of these units would add 76 GPM to the primary heating system connected load, for a total of 1777 GPM.

3. The 4 inch primary heating system piping in the First Floor ceiling between the Technology Wing (Area 'F') and the north Classrooms in Area 'C' (near the stairwell) is undersized. A 4 inch pipe has an approximate peak flow of 270 GPM. It was marginally sized in 1965 with a connected load of 328 GPM, including all three-way control valves (therefore no flow diversity). The 2001 Science Classroom 151 project increased the connected load to 353 GPM. The 2008 Student Center remodeling project increased the connected load to 440 GPM, with 71 GPM of the 87 GPM flow increase being controlled

by two-way control valves and the remainder by three-way valves. Heating the proposed future Science Classroom addition from the central heating system would increase hot water flow demand by approximately 100 to 200 GPM. With a flow capacity of 270 GPM, a connected load of 440 GPM, and a possible future connected load of 540 to 640 GPM, the 4 inch piping is undersized. We recommend that it be replaced with 6 inch piping. **Refer to Item A5 in the list of recommendations.**

4. The existing boilers are undersized, and the boiler pumps are too small relative to the size of the primary heating distribution pumps. At full load conditions, the sum of the boiler pump flows must be approximately equal the sum of the distribution pump flows. This is not currently the case, with the boiler pump capacities totaling 390 GPM and the distribution pump capacities totaling 1385 GPM (based on current primary distribution pump sizes, not connected loads). As a result, a significant amount of water bypasses the three boilers under peak load conditions, resulting in an inability of the boilers to maintain system hot water supply temperatures equal to the boiler discharge temperature. Refer to **Sketch 8 in Appendix D** for an example based on 190.3 degree boiler discharge temperatures and 140 degree hot water return temperatures. Note that in this example, a boiler discharge temperature of 190.3 degrees yields a hot water supply temperature of only 154.2 degrees, not hot enough to heat the building on a cold winter day. Correctly sizing the primary heating pumps serving the Main Building will increase the primary distribution pump flow, and make the problem worse. Actual flows have not been verified, but the problem is significant; slight variations between design flow and actual flow will not eliminate it. We recommend that a fourth boiler and boiler pump be added. The boiler should be high efficiency, with an input rating of 6,000,000 BTUH. The new boiler pump should have a capacity of 561 GPM. We also recommend that the three existing boiler pumps and their piping be replaced. The three new boiler pumps should be sized for 327 GPM each, and the new piping should be 6 inch size. **Refer to Item A1 in the list of recommendations, and to Sketch 9 in Appendix D**.

5. The primary distribution pumps serving the Fine Arts Center are also undersized. The pumps were sized for 140 GPM at a pump head of only 20 feet. Although majority of the distribution piping is oversized at 5 inches (this was field-verified, as the drawings are unclear), the existing pressure drop through common Boiler Room piping alone is estimated to be nearly 20 feet, and a typical pressure drop through an air handling unit heating coil and control valve is in the range of 20 feet. We estimate the existing pump head to be 40 to 50 feet. The future pump head will depend on the extent to which the undersized common Boiler Room piping is replaced, and on whether the Fine Arts Center air handling units and heating coil control valves are replaced. We recommend that the existing Fine Arts Center primary distribution pumps and variable frequency drives be replaced. Costs have been developed based on new pump capacities of 140 GPM at 40 feet head, and 3 HP motors. **Refer to Item A10 in the list of recommendations.**

6. Water balancing provisions for the primary distribution system are inadequate. Several problems exist:

   a. No balancing provisions exist for the remaining original heating and ventilating units HV-F1 through F5 (located in Area 'F'), and HV-G2 through G4 (located in Area 'G'). Because water flow will follow its path of least resistance, these units create a short circuiting of water, preventing adequate flow to the Nurses Pit Mechanical Room in Area 'A', and to the Snake Pit Mechanical Room in Area 'B'. We recommend that two-way control valves and coil pumps be added to each of the eight remaining heating and ventilating units. **Refer to item A3 in the list of recommendations, and to Sketch 10 in Appendix D.**

   b. Excessive differential pressure exists between the hot water supply and hot water return mains throughout Areas 'B' through 'G' of the Main Building, making flow control very difficult. The Main Building primary heating loop has a total length (including supply and return piping) of approximately 2000 feet, with piping sized at or above flow capacities in many areas. Secondary heating loops and air handling units are connected to the primary hot water supply and return piping throughout the building. Refer to **Sketches 11 and 12 in Appendix D** for simplified schematic diagrams of the Main Building west and east primary piping heating loops, respectively. The secondary piping connections nearest the Boiler Room (in the Tech. Wing) have a very high differential pressure between the primary hot water supply and return piping. The secondary piping connections located furthest from the Boiler Room (in the Nurses Pit Mechanical Rooms on the Lower Level of Area 'A', and the Snake Pit Mechanical Room on the Lower Level of Area 'B') operate with a much smaller differential pressure between the primary hot water supply and return piping. We estimate that a 10 psi differential pressure must exist between the primary hot water supply and return piping in the Nurses Pit and the Snake Pit Mechanical Rooms to generate design flow rates. Air handling units in Areas 'F' and 'G' must operate with a much higher differential pressure between primary hot water supply and return piping (estimated at a maximum of 51.3 psi with current pipe sizing). As a result, control valves nearest the Main Building primary heating pumps must close most of the way to overcome the excess differential pressure available, and are forced to operate over a very small control range. This reduces the ability of the control valves to maintain close control, and results in control valve 'hunting' and instability. **Sketches 11 and 12 in Appendix D** summarize the estimated differential pressures between primary hot water supply and return piping at various equipment connection locations in the Main Building.

The excessive differential pressure between the Main Building hot water supply and return piping mains can be corrected in one of two ways:

i. Limit flows by adding automatic flow control valves to each branch main. Automatic flow control valves are spring-operated devices that limit maximum flow over a specific differential pressure range.

ii. Control differential pressure between the primary hot water supply and return branch mains directly. Measure differential pressure between supply and return piping in each branch main, and modulate a control valve to maintain constant differential pressure between hot water supply and hot water return piping.

Either option is valid, with the first option having a lower initial cost, and the second option resulting in slightly more accurate control. Due to the lower initial cost, we recommend that automatic flow control valves be installed at ten locations in the Main Building primary heating system. **Refer to item A4 in the list of recommendations.**

c. The majority of the heating control valves on the Main Building primary heating system are three-way type. With three-way valves, hot water flows at a constant volume at all times. Hot water not needed to satisfy a load bypasses the load, but is still required at the pump. Two-way control valves do not have bypasses. When load demand is low, pump water flow is reduced. The use of two-way control valves results in a pumping system diversity and reduces peak pump demand. We recommend that all of the existing 1965 and 1967 three-way control valves serving air handling units in the Main Building and Fine Arts Center be replaced with two-way control valves. Provide a new coil pump and a new pipe rig at each location. **Sketch 10 in Appendix D** indicates the required piping detail. **Refer to item A7 in the list of recommendations, and to Sketch 9 in Appendix D.**

d. Similarly, newer air handling units AHU-11 and AHU-12 in the Area 'G' Technology Wing were installed with three-way control valves. We recommend that they be replaced with two-way control valves, and that the pipe rigs be revised per **Sketch 10 in Appendix D**. **Refer also to item A8 in the list of recommendations.**

e. Several "wild legs" exist in the Stevenson Center heating system. A wild leg is a means by which flow may increase in an unrestricted manner when control system two-way valves begin to close. Four of the wild legs consist of heating piping loops with manual balancing valves located above corridor ceilings at the ends at the ends of branch heating pipes. The heating pipes serve terminal heating units having two-way control valves. Wild legs also exist at eleven cabinet unit heaters and the one unit heater, which have no control valves. In this system, wild legs are not necessary to maintain minimum pump variable frequency drive set point (typically 20 percent) during times of low heating system demand, since over half of the connected heating loads in the Stevenson Center have three-way control valves. The wild legs located at the ends of the branch mains were presumably installed to keep piping loops warm during times of low heating system demand, enabling terminal heating units to respond quickly on a call for heat. During times of peak heating demand, water flows through the wild legs, increasing pumping energy slightly and contributing to flow problems in other areas.

We recommend that the “wild legs” in the Stevenson Center heating system be eliminated by closing the four manual balancing valves located in the Second Floor and Third Floor ceilings, and adding automatic flow control valves to each of the eleven cabinet heaters and to the unit heater. **Refer to item A12 in the list of recommendations.**

7. It is common practice to locate differential pressure sensors in the most remote mechanical equipment room on a heating system. This enables direct sensing of the “worst case” flow requirement. We recommend relocating the three differential pressure sensors controlling primary heating distribution pump variable frequency drives from the Boiler Room to remote Mechanical Rooms. The new locations would be the Nurses Pit Mechanical Room, the Third Floor Fine Arts Center Mechanical Room, and to the Stevenson First Floor (south) Mechanical Room to control the Main Building, the Fine Arts Center and the Stevenson primary heating pumps, respectively. **Refer to item A11 in the list of recommendations**

8. The heating system has too many compression tanks, and in too many different locations. Compression tanks in a heating system limit operating pressure when water temperature increases, and provide a control point to ensure that system pressures remain above atmospheric pressure regardless of whether pumps are running. Tanks are typically located at the lowest pressure and highest temperature point in the system, between the boiler discharge and the distribution pump inlets. Hydronic heating and cooling systems should have a single pressure control point.

   We recommend that compression tanks not located in the Boiler Room be removed, and that the three Boiler Room compression tanks be connected to the heating system in a single location. A determination must be made when the heating system is re-filled as to whether additional compression tank capacity is required. An allowance of $7,500 has been included as **item A6 in the list of recommendations**.

9. A fan coil unit located in the ceiling of Exam Room 305 has been tied into the heating system incorrectly. The heating piping serving the fan coil unit has been connected to the primary hot water supply and return piping upstream of the secondary heating pump located in the Nurses Pit Mechanical Room, and should have been connected downstream of the secondary pump. We recommend that this piping be corrected. **Refer to item A13 in the list of recommendations**.

10. When piping is disturbed, as it will be when portions of the heating system are drained, modified, flushed and re-filled, scale and sediment from the inner pipe surfaces can be dislodged and may plug strainers, control valves and coils. The addition of a heating system filter and filter pump will minimize the likelihood of problems resulting from construction, will keep the piping system clean in the future, and are recommended. **Refer to item A14 in the list of recommendations**.

11. The heating coil in Kitchen makeup air unit HV-A2, located in the Nurses Pit Mechanical Room, has frozen several times in recent years. To prevent the coil from freezing again, and to free up heating hot water flow for adjacent air handling unit AHU-A1, the unit is currently not running. The unit's outside air damper has been closed, with a minimum amount of hot water flow circulating through the unit heating coil to prevent it from freezing.

    We recommend that the existing heating coil be removed, and that a new heating coil, coil pump and control valve be added to existing Kitchen Make-Up Air Unit HV-A2, to enable the unit to operate reliably. **Refer to the piping detail on Sketch 10, and to item A15 in the list of recommendations** .

12. According to Muskegon Community College staff, overheating occurs on the First Floor due to the radiation of heat from heating piping in the Spring and Fall. The addition of a high efficiency boiler will make possible the reduction of heating water temperatures in the Spring and Fall from 160^{o}F-180^{o}F to 100^{o}F-120^{o}F, and may solve or minimize the problem.

VI. CENTRAL COOLING SYSTEMS

A. Existing Systems

Muskegon Community College has four separate central cooling systems, with chiller locations and service areas as follows:

1. A chiller located in the Boiler Room serves the Stevenson Center and Area 'F' and 'G' of the Technology Wing. The Boiler Room chiller has a nominal capacity of 300 tons.
2. A chiller located in the Nurses Pit Mechanical Room serves air handling units AHU-A1, AHU-B1 and AHU-E1, and all miscellaneous cooling loads in Areas 'A', 'C' and 'D'. The Nurses Pit chiller has a nominal capacity of 180 tons.
3. A chiller located in the Fine Arts Center Third Floor Mechanical Room serves the Fine Arts Center and Area 'D'. The Fine Arts Center chiller has a nominal capacity of 300 tons.
4. A second chiller located in the Nurses Pit Mechanical Room serves the Library (not analyzed).

All chillers except the Library chiller are Trane RTA-series water-cooled, rotary screw type, with dedicated cooling towers.

B. Analysis

1. Boiler Room Chiller

With a chilled water supply temperature of 45°F and a condensing temperature of 95°F (standard operating conditions), the chiller has a net capacity of approximately 283 tons. The chiller initially served only the Stevenson Center, and had a connected load of 242 tons. The 2003 Technology Wing air conditioning project added 51.6 tons of connected load, increasing the connected cooling load to 293.6 tons. As part of the 2003 Technology Wing air conditioning project, piping provisions were made for an additional 86.9 tons of future connected load. Refer to **Sketch 13 in Appendix E** for a simplified Schematic Diagram. Diversity exists in the cooling loads, therefore the peak chiller load is often much less than the sum of the connected loads. Should Muskegon Community College decide to add future cooling load to the Technology Wing, actual chiller loading on a peak design day should be monitored to verify available chiller capacity.

The Boiler Room chiller condenser pumps are Bell & Gossett Model 1510, Size 5BC, with 7 inch pump impellers and 10 HP motors. The pumps were designed for a capacity of 900 GPM with a pump head of only 20 feet. The actual pumps can generate 900 GPM flow with 25 feet of head. Because the condenser water system is an 'open' system (water flows from the cooling tower nozzles to the tower basin), static lift (the vertical distance between the spray nozzles and the water in the tower basin) must be added to the pump head. Piping between the cooling tower and the condenser pump inlets was sized at only 6 inches, resulting in a design flow velocity of 10 feet per second. This pipe size is marginal. According to staff, the Boiler Room chiller has experience head pressure problems, consistent with problems that may occur due to low condenser water flow.

We recommend that the Boiler Room condenser pump suction and discharge pressures be measured (cooling tower pumps were not operating throughout the course of this study). A determination can then be made regarding the need to increase the diameter of the existing water pump impellers, and to replace the existing six inch piping between the cooling tower basin and the condenser water pump inlets with eight inch piping. We do not recommend increasing the condenser pump capacity without replacing the piping, due to pump cavitation concerns. The existing 10 HP condenser pump motors appear adequately sized to accept a modest increase in pump impeller size.

2. Nurses Pit Chiller

The Nurses Pit chiller has a net capacity of approximately 170 tons at standard operating conditions. We estimate the connected cooling load to be 281.9 tons. The Nurses Pit chiller is overloaded, and does not have spare capacity to serve the future Science Classroom addition. Refer to **Sketch 14 in Appendix E** for a simplified Schematic Diagram.

The Nurses Pit chiller has two chilled water pumps, both of which must operate to satisfy system flow requirements.

3. Fine Arts Center Chiller

   The Fine Arts Center chiller has a net capacity of approximately 283 tons at standard operating conditions. We estimate the connected load to be 294.1tons. Refer to **Sketch 15 in Appendix E** for a simplified Schematic Diagram.

VII. AIR HANDLING SYSTEMS

A. Existing Systems

1. Area 'A', the Office Tower in Area 'C' and the Area 'C' Planetarium are served by original dual duct air handling system AHU-A1, located in the Nurses Pit Mechanical Room. The original AHU-A1 system was designed for a maximum of 35,860 cubic feet per minute (CFM) supply air to the cold deck, and a maximum of 18,000 CFM supply air to the hot deck. Revisions to the AHU-A1 duct distribution system were made during the 1987 Bookstore Addition, and during the2007 Student Center Renovations. Although the 2007 drawings indicate that the AHU-A1 supply fan was to be re-balanced to 40,450 CFM, the sum of the dual duct box air flows is only 37,300 CFM. The original cooling coil leaving air temperature was 60.0^{o}F, and the original heating coil leaving air temperature was 120.0^{o}F. With a hot deck temperature of 120^{o}F, and an assumed winter cold deck temperature of 70^{o}F, the system has been designed for a peak winter supply air temperature of 95^{o}F.

2. Area 'B' and the Office Tower in Area 'D' are served by original dual duct air handling system AHU-B1, located in the Nurses Pit Mechanical Room. The original AHU-B1 system was designed for a maximum of 39,450 CFM supply air to the cold deck, and a maximum of 20,000 CFM supply air to the hot deck. Revisions to the AHU-B1 duct distribution system were made during the 2007 Student Center Renovations, resulting in a reduction to 37,450 CFM supply air to the cold deck. The original cooling coil leaving air temperature was 60.0^{o}F, and the original heating coil leaving air temperature was 120.0^{o}F. With a hot deck temperature of 120^{o}F, and an assumed winter cold deck temperature of 70^{o}F, the system has been designed for a peak winter supply air temperature of 95^{o}F.

3. Refer to **Sketches 4, 5 and 6 in Appendix C** for air handling unit service areas.

4. The air handling unit AHU-A1 and AHU-B1 cooling coils were each selected for cooling coil entering air temperatures of 83.5^{o}F dry bulb, 69.0^{o}F wet bulb, and cooling coil leaving air temperatures of 60^{o}F dry bulb, 58^{o}F wet bulb. At the original design air quantities, the total cooling capacities of AHU-A1 and AHU-B1 were 1291 MBH (107.6 tons) and 1420 MBH 118.3 tons), respectively. Subsequent renovations have revised air handling unit supply air quantities, resulting in cooling capacities of 111.9 tons and 112.3 tons for AHU-A1 and AHU-B1, respectively.

5. The original hot deck design temperature for AHU-A1 and AHU-B1 was 120^{o}F. Based on original hot deck design air quantities of 18,000 CFM and 20,000 CFM for AHU-A1 and AHU-B1, respectively, the original heating supply air temperature was approximately 95^{o}F.
6. The original cooling coils and heating coils are still in use.
7. The area served by AHU-A1 is 32,000 square feet, resulting in a current average of 1.17 CFM per square foot during cooling operation. The area served by AHU-B1 is 24,600 square feet, resulting in an average of 1.52 CFM per square foot during cooling operation.
8. Classrooms in Areas ‘A’, ‘B’, ‘C’ and ‘D’ are served by unit ventilators.
9. Area ‘E’ is served by a variable air volume (VAV) system installed as part of the 2007 Student Center Renovations. The supply air quantity is 22,000 CFM, with a cooling coil leaving air temperature of 54.0^{o}F.

B. Analysis

Based on GMB’s cooling load calculations, and based on the original AHU-A1 and AHU-B1 design supply air temperature of 60^{o}F, the First and Second Floors in Area ‘A’, the First Floor in Area ‘B’ and the Planetarium have inadequate sensible cooling capacities. Cooling air flow requirements are determined by Sensible Heat Gains to the space, including building envelope gains, solar gains, and internal heat generated by occupants, lights and equipment, and by the temperature difference between supply air and room air (typically 75^{o}F during the cooling season). Refer to *Trace 700* Heating and Cooling Load Calculations in Appendix E. Refer specifically to the “Space Sensible Btu/h” under CLG SPACE PEAK on Room Checksums in the *Trace 700* output.

Table 1 – Main Building Airflow and Cooling Summaries in Appendix C includes an area-by-area breakdown of existing square footages, supply air quantities, design cooling capacities and calculated cooling capacities.

AHU-A1 and AHU-B1 air flows cannot be increased. The original systems were marginally sized, and AHU-A1 has been made worse as the result of the 1987 Bookstore Addition and the 2007 Student Center Renovations. The cold deck supply air mains are currently sized for 3300 to 3400 feet per minute (FPM) velocity in the Mechanical Rooms (fairly common for dual duct systems designed in the 1960’s and 1970’s). Cooling coil face velocities are currently sized for 600 to 650 FPM face velocity; 500 FPM is a typical design standard, with air pressure drop and moisture carryover being concerns at higher face velocities. The outside air intakes have been sized at 2200 to 2300 FPM when the systems are in economizer mode (free cooling with outside air).

Several options have been considered to enable air handling units AHU-A1 and AHU-B1 to satisfy their calculated cooling loads:

1. Increase the cooling capacity of air handling units AHU-A1 and AHU-B1 by decreasing the air handling unit supply air temperatures from 60°F to 55°F. Reducing the supply air temperatures to 55°F would increase the cooling coil capacities sufficiently to meet peak cooling demand in the Planetarium, and nearly enough (99.0 percent) to meet peak cooling demand in the First Floor in Area 'B'. The First and Second Floors in Area 'A' would still be at less than 100 percent cooling capacity (80.9 percent and 95.6 percent, respectively). The right hand column in **Table 1** indicates the sensible cooling capacity available to each area with a reduction in supply air temperature to 55°F. We considered two options to reduce the AHU-A1 and AHU-B1 supply air temperatures.

    a. Reduce the chilled water supply temperature. Manufacturer's data on the existing American Standard air handling units is not available. We modeled the cooling coils based on the existing face areas, and based on the original performance requirements. According to our model, a chilled water supply temperature of 37°F would be required to reduce the supply air temperature in each air handling unit from 60°F to 55°F. Operating at a 37°F chilled water temperature isn't an option with the existing chillers.

    b. Replace the air handling unit cooling coils. We estimate that new cooling coils could generate air handling unit supply air temperatures of 55°F with a chilled water supply temperature of 42°F. We also estimate that larger cooling coils would increase the static pressure on the supply fan by approximately 0.2 inches, reducing fan capacity slightly. The larger cooling coils would increase the connected load to the Nurses Pit chiller by approximately 30 tons. Reducing the chilled water temperature from 45°F to 42°F would reduce chiller capacity by approximately five percent.

    We recommend decreasing the air handling unit AHU-A1 and AHU-B1 supply air temperatures. This includes replacing the air handling unit cooling coils and reducing the chilled water supply temperature from 45°F to 42°F. It will result in a slight increase in connected chiller loads, and a slight reduction in chiller and supply fan capacities. **Refer to items B3 and B4 in the list of recommendations.**

2. Even with a reduced supply air temperature, air handling system AHU-A1 has insufficient cooling capacity on the first floor. Multiple renovations and building additions have added too much cooling load to the system. We recommend shedding some of the cooling load by reducing the area served by AHU-A1. Several options have been considered:

    a. Reduce the loads on air handling system AHU-A1 by providing a new air handling unit dedicated to the Area 'C' office tower. This would reduce the supply air quantity to the air handling system by 8200 CFM. The new air handling unit would use chilled water for cooling, and hot water for heating. The resultant AHU-A1 maximum supply air duct velocity would be approximately 2600 FPM, the cooling coil face velocity would be 470 to 500 FPM, and the outside air intake velocity would be approximately 1860 FPM (still very high). Existing chiller loads would not be reduced. A functional option for the locations of new air handling unit appears to be the roof of the South Classrooms in Area ‘C’. The building structural has not been checked for its ability to support a new unit. The sensitive campus aesthetics are another important consideration.

b. Reduce the loads on air handling unit AHU-A1 by providing a new packaged rooftop air conditioning units dedicated to the Area ‘C’ office tower. Packaged rooftop units are not compatible with dual duct systems. The air handling system would therefore have to be converted to a variable air volume (VAV) system, with hot water reheat coils. VAV reheat terminals would replace existing dual duct boxes on a one-for-one basis, and the existing dual duct hot duct would be abandoned in the First Floor ceiling. We anticipate that a substantial amount of the existing ductwork could be re-used. This option would reduce the connected cooling load on the Nurses Pit chiller by approximately 25 tons.

c. Reduce the load on air handling unit AHU-A1 by providing new ground water heat pump units dedicated to the Area ‘C’ office tower. A constant source of ground water is available through de-watering of the building footings at the far south end of the Nurses Pit Mechanical Room. Opportunity exists to incorporate the use of ground water as a heat source and as a heat sink in a ground source heat pump system. Any use of ground water in an HVAC system is predicated on it being sufficiently clean and non-corrosive. It is our understanding that the pumped ground water is naturally sand-filtered, and that its use may be feasible. An insulated water storage tank would be required in the Mechanical Room, to provide a constant source of water as sump pumps cycle, and possibly to de-couple the ground water from the heat pump heat exchangers. Refer to **Sketch 16 in Appendix F** for a simplified ground water heat pump system schematic diagram. Heat pump units would replace existing dual duct units on a one-for-one basis, and the existing dual duct hot duct would be abandoned in the First Floor ceiling. New return air ductwork from the offices would be re-routed to the heat pump inlets, and the existing supply air ducts from the Area ‘C’ south offices would be re-used to provide minimum outside air to the heat pump units. A new roof-mounted air intake hood would be provided on the Area ‘C’ south office roof. This option would reduce the connected cooling load on the Nurses Pit chiller by approximately 25 tons.

d. Reduce the loads on air handling unit AHU-A1 by providing a new packaged rooftop air conditioning unit dedicated to the Gerber Lounge (First Floor, Area ‘A’). The Gerber Lounge currently has a supply air quantity of 4200 CFM, and the ductwork layout lends itself to the removal of two dual duct boxes and the addition of a 12-

1/2 ton packaged rooftop unit. The building structural has not been checked for its ability to support new unit; a 12-1/2 ton unit weighs approximately 2000 pounds. Hot water heating coils would be added to the existing ductwork, with heating piping connected to the existing secondary heating piping loop originating in the Nurses Pit Mechanical Room.

We recommend that the load Reduce the load on air handling unit AHU-A1 by providing new ground water heat pump units dedicated to the Area 'C' office tower, and by providing a new packaged rooftop air conditioning unit dedicated to the Gerber Lounge. **Refer to items B1 and B2 in the list of recommendations.**

Dual duct system supply air temperatures are currently controlled manually, based on outside temperature and on 'hot' and 'cold' complaints from occupants. Automatic control cannot occur because operating the existing boilers during early Spring and late Fall results in overheating of the First Floor. The existing Weil-McLain boilers require a minimum return water temperature of 140°F to prevent boiler damage due to flue gas condensation, and therefore cannot supply low temperature heating water.

We recommend that the control of dual duct air handling units cold deck temperatures be done automatically through the building automation system. Affected units will include AHU-A1 and AHU-B1, plus unit AC-1 in the Fine Arts Center. Control the cold deck temperature to 55°F (possibly lower for AHU-A1), unless reset upward through the BAS when no dual duct boxes are calling for full cooling. To avoid over-cooling spaces, boiler heat must be available from early Fall through late Spring. The addition of a high efficiency boiler will make possible the circulation of low temperature heating water (100°F to 120°F) in the early Fall and late Spring. **Refer to item B5 in the list of recommendations**.

Air handling system AHU-E1, serving Area 'E', has been adequately sized and there are no known problems. Area 'E' has average air flows (based on the sums of VAV box peak airflows, and not including diversity) of 1.0 CFM per square foot on the Second Floor, and 1.26 CFM per square foot on the Third Floor. With a peak supply air flow of 22,000 CFM and VAV boxes with a total air flow of 23,565 CFM, the airflow diversity is 0.93. The air handling unit serves 21,155 square feet, and the cooling coil has a capacity of 75.9 tons, for an average of 279 square feet per ton. No improvements are recommended.

VIII. BUILDING ENVELOPE IN THE AREA 'C' AND 'D' OFFICE TOWERS

A. Existing Conditions

Comfort in the Area 'C' and 'D' office towers has been very difficult to maintain. The floor and window surfaces are cold in the winter, and the windows leak cold air. The windows are single-pane. According to Muskegon Community College staff, cold air infiltrates to within the interior building walls in some locations.

Floors are concrete, with a ventilated soffit below the Second Floors. The soffits below the Second Floors are insulated, but ventilation grilles allow cold air into the soffits and negate the value of the insulation. Heating water piping and sanitary piping are located within the soffits. According to Muskegon Community College staff, some pipe freezing within the soffits has occurred.

B. Analysis

Although the Area 'C' and 'D' office towers were designed with adequate supply air from systems AHU-A1 and AHU-B1, it is unlikely that design air quantities are being delivered to the spaces. Actual air flows have not been verified. Supply air and return air duct branches serving the offices towers are each 200 feet long, and ductwork is undersized. Supply air ductwork has a design pressure drop of 0.34 inches per hundred feet, and a design velocity of 2600 FPM. Return air ductwork has a design pressure drop of 0.14 inches per hundred feet, and a design velocity of 1750 FPM.

We measured interior window and floor surface temperatures at an outside temperature of 7^{o}F. The temperature of the inside surface of the windows was between 43.5^{o}F and 45^{o}F (center of glass), with window mullion temperatures between 47^{o}F and 50^{o}F. The temperature of the floors was measured to be 46.5^{o}F to 61^{o}F in carpeted areas (with the colder temperature measured near a corner). The temperature on the underside of the concrete floor (within the soffit) was measured to be 30^{o}F to 31^{o}F.

It is unlikely that occupant comfort can be achieved unless the surface temperatures of floors and windows are increased. We recommend that the existing single glazing in the Office Towers be replaced with double glazing to increase interior surface temperatures, reduce cold air infiltration and reduce heat loss and solar heat gain. **Refer to item C2 in the list of recommendations.**

We also recommend that the existing blanket insulation be removed from the soffits, soffit vents be removed and all cold air short circuits within the soffits be identified and sealed. We recommend that two inches of spray-applied cavity wall insulation be applied to the 'plenum' sides of the soffits. A closed-cell foam product applied at the soffits will provide a vapor barrier at the soffits, maintain a warmer floor temperature and protect piping within the soffits from freezing. We anticipate that substantial cutting and patching of the soffits will be required to accommodate this work. **Refer to item C1 in the list of recommendations.**

IX. FREE COOLING WITH OUTSIDE AIR

A. Existing Conditions

Mechanical cooling is available through the chillers from early Spring through mid- Fall, with the chiller startup and shut-down dates determined by weather trends. When mechanical cooling is not available, cooling occurs through 'free cooling' with the use of cool outdoor air when required. Free cooling is available in all air conditioned spaces served by the chillers, with the following exceptions:

1. The Third Floor Nursing Offices are served by fan coil units located above the ceilings. When designed as part of the 2007 Student Center Renovations, no provisions for free cooling were included. The college has since added outside air ventilation louvers and ductwork to slightly improve the conditions, but not sufficiently to enable free cooling.
2. When the Library addition was built, provisions for free cooling in Third Floor Classrooms 331 and 335 were eliminated.
3. Comfort cannot be maintained in the early Spring and late Fall in these spaces without the re-introduction of free cooling. We recommend that the existing fan coil units in the Third Floor Nursing Offices be replaced with ground water heat pump units, and that the building de-watering sump pumps be used to provide a ground water source. A water storage tank would be required in the Nurses Pit Mechanical Room, to provide a constant source of water as sump pumps cycle, and possibly to de-couple the ground water from the heat pump heat exchangers. Re-use the existing outside air louvers, supplementing as necessary to provide minimum ventilation air to the heat pump units. **Refer to Sketch 16 in Appendix F**. The heat pump units would be capable of providing heat or cooling year-round, without operating the central chillers. **Refer to item D1 in the list of recommendations.**
4. We recommend that the existing under-window unit ventilators in Classrooms 331 and 335 be replaced with vertical unit ventilators, that an outside air louver be added above the ceiling in Classroom 339 (at the existing areaway) and that outside air ductwork be routed between the new outside air louver and the new vertical unit ventilators. **Refer to item D2 in the list of recommendations.**

X. REPLACEMENT OF OLD EQUIPMENT

The oldest (1965 and 1967) mechanical equipment is nearly 50 years old, and should be considered for phased replacement to prevent a future crisis. Remaining original equipment includes, but may not be limited to:

A. Air handling units in the Nurses Pit, the Snake Pit and the Fine Arts Center Mechanical Rooms. Individual heating coil, cooling coil and fan replacements could also be considered, re-using the existing air handling unit housings.

B. Return air fans.

C. Primary heating pumps in the Boiler Room.

D. Secondary heating pumps in the Main Building Mechanical Rooms, and in the ‘Attic’ areas above the corridor ceilings in the Area ‘C’ and ‘D’ office towers, including their dedicated control valves.

E. Heating coil pumps and control valves.

F. Air handling unit cooling coil control valves.

XI. RECOMMENDATIONS AND COSTS

Recommended measures are and their associated costs are listed in Table 2 below. These costs have been developed for preliminary budgeting purposes only, and are listed in order of priority under each category.

Table 2 - Opinion of Probable Costs

Item	Item	Costs	Reference
	HEATING SYSTEM UPGRADES		
A1	Add a new 6,000,000 BTUH high efficiency boiler and a new boiler pump. Replace the three existing boiler pumps and piping to increase pump capacities.	$170,000	Page 6, Para. 4
A2	Increase the main heating piping in the Boiler Room from 6 inch to 10 inch size. Provide a new 10 inch air separator.	$51,000	Page 5, Para. 2
A3	Add 2-way control valves and coil pumps to the existing 1965 heating and ventilating units in the Technology Wing.	$60,000	Page 7, Para. 6.a
A4	Add automatic flow control valves to each of ten hot water supply branch mains in the Main Building.	$25,000	Page 7, Para. 6.b
A5	Replace 4" hot water supply and return piping between the Area 'F' Technology Wing and the Area 'C' stairwell with 6" piping.	$48,000	Page 5, Para. 3
A6	Remove compression tanks not located in the Boiler Room. Add compression tanks in the Boiler Room.	$7500	Page 9, Para. 8
A7	Replace all existing 1965 and 1967 three-way heating control valves serving air handling units with two-way control valves.	$90,000	Page 8, Para. c
A8	Replace all existing 3-way control valves serving AHU-11 and AHU-12 in Area 'G' with 2-way control valves.	$10,000	Page 8, Para. d
A9	Replace the Main Building primary heating pumps and variable frequency drives.	$46,000	Page 5, Para. 1
A10	Replace the Fine Arts Center primary heating pumps and variable frequency drives.	$21,000	Page 6, Para. 5
A11	Relocate differential pressure sensors serving primary heating pumps.	$4500	Page 9, Para. 7
A11	Eliminate ‘wild legs’ in the Stevenson Center heating system to limit overall system flow and to provide greater system flow diversity.	$3600	Page 8, Para. e
A13	Revise heating piping serving the fan coil unit located in Exam Room305.	$700	Page 9, Para. 9
	Sub-Total (Minimum for a fully functional heating system)	**$537,300**	
A14	Add a filter and a filter pump to the central heating system.	$7500	Page 10, Para. 10
A15	Provide a new heating coil, coil pump and control valve for Kitchen make-up air unit HV-A2.	$15,000	Page 10, Para. 11
	Sub-Total (Miscellaneous heating items)	**$22,500**	
	Total for Heating System Upgrades	**$559,800**	

Table 2 - Opinion of Probably Costs (Cont.)

Item	Item	Costs	Reference
	AIR HANDLING SYSTEM UPGRADES		
B1	Reduce the load on air handling systems AHU-A1 by providing new ground water heat pump units dedicated to the Area ‘C’ Office Tower.	$156,000	Page 15, Para. c
B2	Reduce the load on air handling system AHU-A1 by providing a new packaged rooftop air conditioning unit dedicated to the First Floor Gerber Lounge.	$30,000	Page 15, Para. d
B3	Reduce the chilled water supply temperature of the Nurses Pit and Fine Arts Center chillers to 42^{o}F.	0	Page 14, Para. 1
B4	Replace the air handling unit AHU-A1 and AHU-B1 cooling coils with new 8-row cooling coils.	$60,000	Page 14, Para. 1
B5	Control the cold deck temperature of three dual duct systems automatically through the building automation system. Provide low temperature hot water heat for control of hot deck temperature from early Spring through late Fall. Note that Item No. 2 under “Heating System Upgrades” must also be implemented for this item to work.	$7500	Page 16
	Total for Air Handling System Upgrades	**$253,500**	
	IMPROVEMENTS TO THE BUILDING ENVELOPE IN THE AREA ‘C’ AND ‘D’ OFFICE TOWERS		
C1	Revise existing Office Tower soffits.	$56,000	Page 17, Para. B
C2	Replace existing single glazing with double glazing in office areas.	$63,400	Page 17, Para. B
	Total for Building Envelope Upgrades	**$119,400**	
	UPGRADES TO ALLOW FREE COOLING WITH OUTSIDE AIR		
D1	Replace the existing fan coil units in the Nursing Offices with ground water heat pump units.	$86,000	Page 18, Para. 3
D2	Replace existing unit ventilators in Classrooms 331 and 335 with vertical unit ventilators. Provide a new outside air louver and outside air ductwork.	$30,000	Page 18, Para. 4
	Total for free cooling upgrades	**$116,000**	
	GRAND TOTAL	**$1,048,700**	

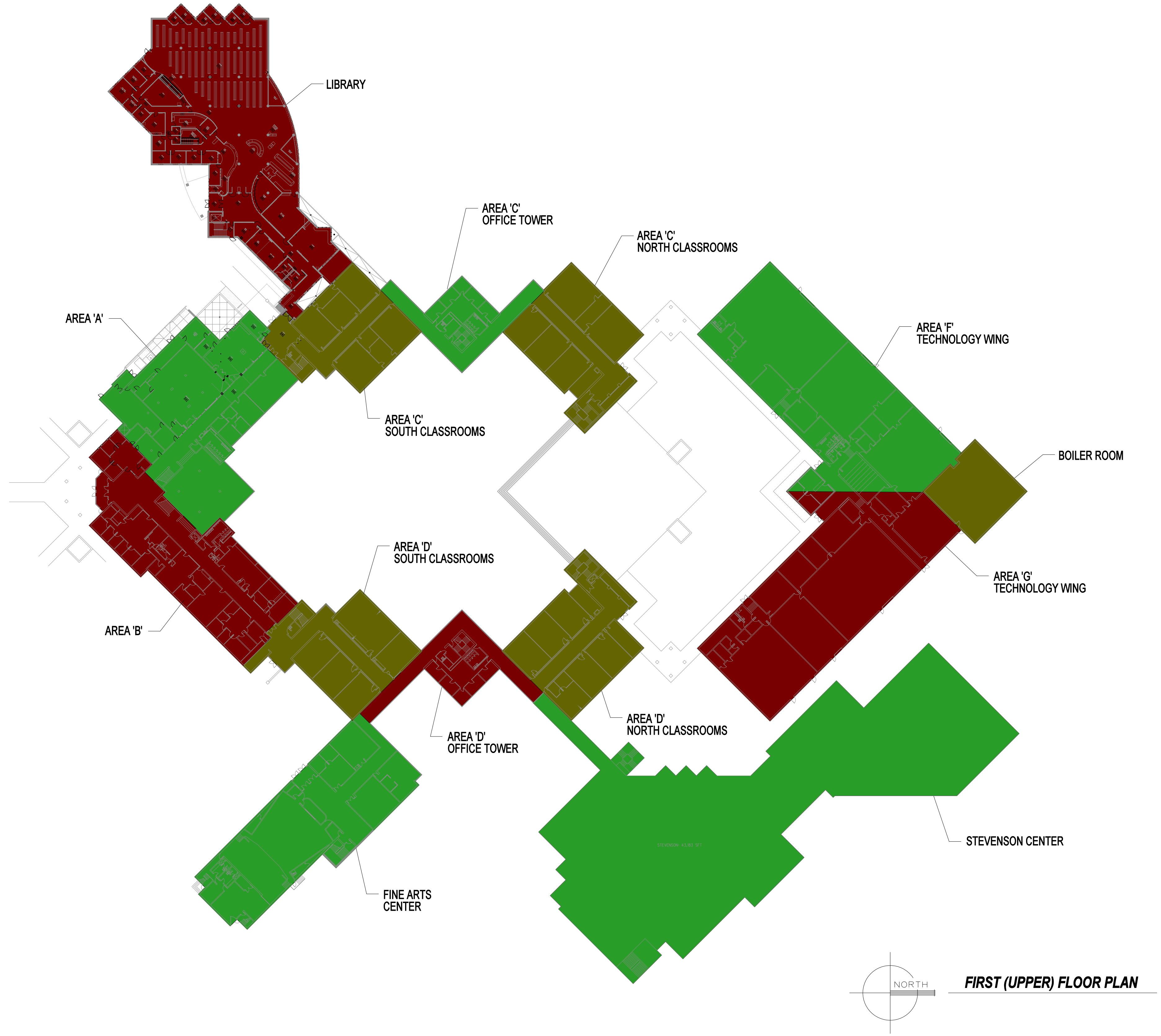
APPENDIX A

LIST OF AVAILABLE DRAWINGS

DRAWING DATE	PROJECT DESCRIPTION	ARCHITECT/ENGINEER
	Original Construction	
5/3/1965	Original Main Building Construction	Alden B. Dow Associates, Inc. Architects
6/7/1967	Fine Arts Center Addition	Alden B. Dow Associates, Inc. Architects
5/19/1993	Stevenson Center Addition	Beta Design Group
11/1/2004	Library/Library Technology Building Addition	Hooker-DeJong
	Renovations and Minor Additions	
6/14/1985	D.O.E. Cycle XI Energy Conservation Measures	Hoyem Basso Associates
6/4/1987	Bookstore and Facility Addition	Dow Howell Gilmore Associates, Inc.
11/16/2000	2000 Unit ‘D’ Classroom Air Conditioning Project	Tower Pinkster Titus
7/17/2001	Fume Hood Revisions – Room 151	Hooker-DeJong
2/20/2002	2002 Unit ‘C’ Classroom Air Conditioning Project	Rhoades Engineering
2/21/2003	Technology Wing Air Conditioning Project	Tower Pinkster Titus
12/24/2007	Student Center Renovations	Tower Pinkster Titus

APPENDIX B

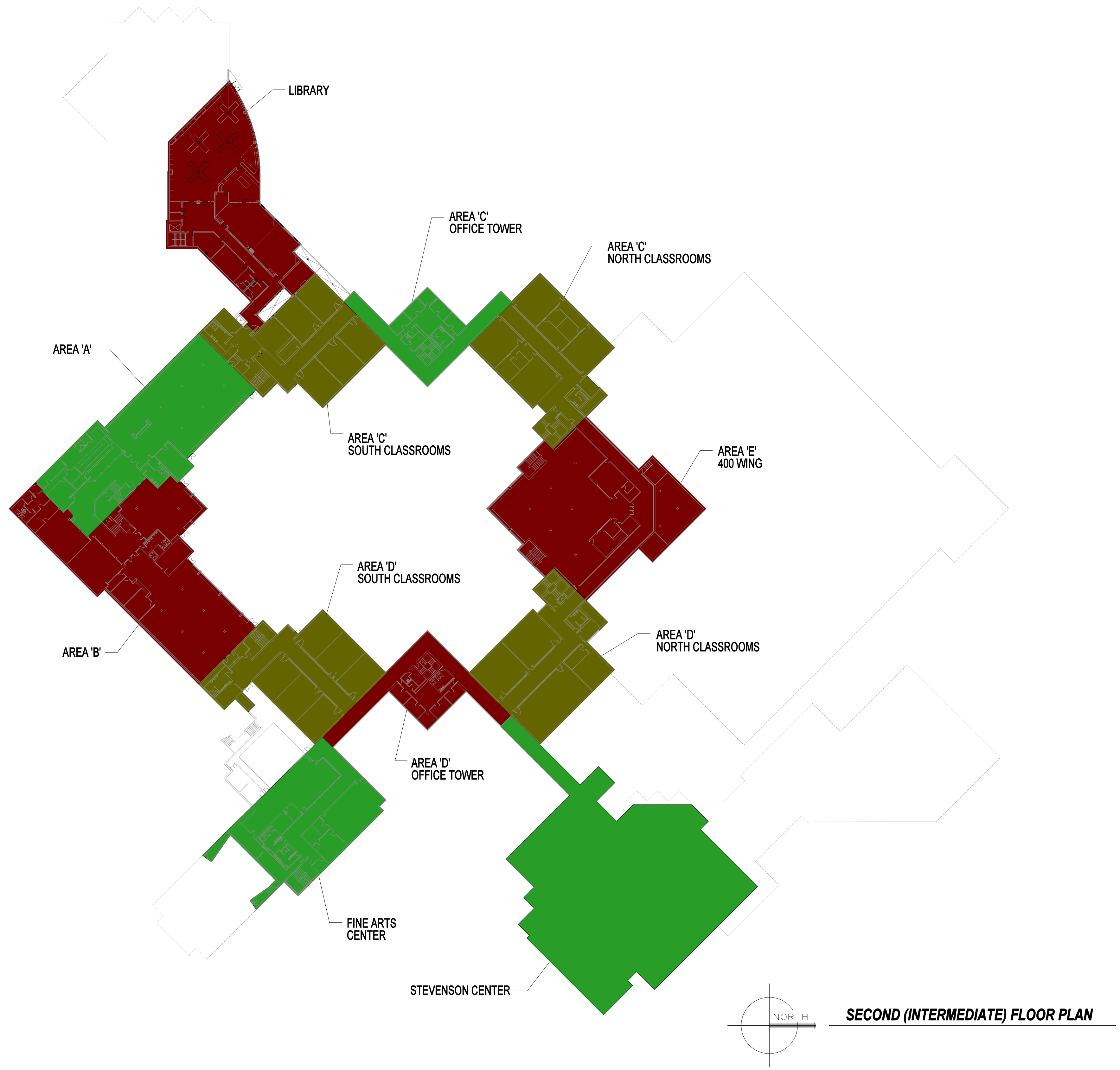
BUILDING AREA DESIGNATIONS



FIRST (UPPER) FLOOR PLAN

AREA DESIGNATIONS / FIRST (UPPER) FLOOR PLAN

HVAC SYSTEM STUDY
Muskegon Community College



SECOND (INTERMEDIATE) FLOOR PLAN

AREA DESIGNATIONS / SECOND (INTERMEDIATE) FLOOR PLAN

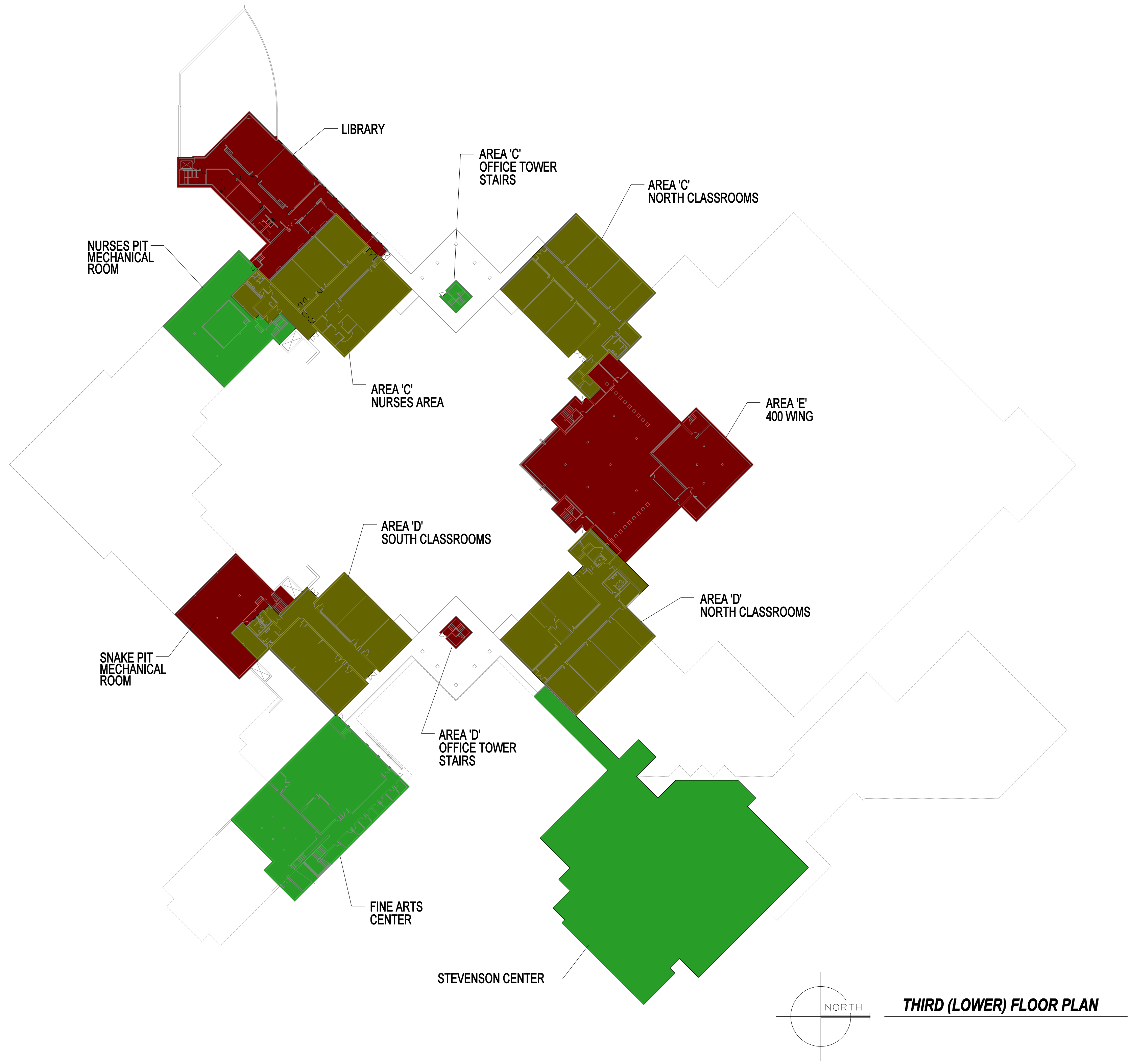
NOT TO SCALE / APPENDIX B / **SKETCH # 002**

03.08.2013

HVAC SYSTEM STUDY

Muskegon Community College

GMBae ARCHITECTURE + ENGINEERING



THIRD (LOWER) FLOOR PLAN

AREA DESIGNATIONS / THIRD (LOWER) FLOOR PLAN

APPENDIX C

AIR HANDLING SYSTEMS

Air Handling Unit AHU-A1	Area (SFT) Served	Supply Air CFM (Design)	CFM per SFT (Design)	Design Space Sensible Cooling Capacity (BTUH, based on 60.0ºF S.A. Temp.)	Calculated Space Sensible Cooling Load (BTUH)	Space Sensible Cooling Capacity (BTUH, based on 55.0ºF S.A. Temp.)
First Floor Area 'A'	18,460	13,885	0.75	224,937	401,251	299,916
First Floor Planetarium	546	800	1.47	12,960	16,381	17,280
First Floor Area 'C'	1896	4100	2.16	66,420	51,379	88,560
First Floor Totals	20,902	18,785	0.90	304,317	469,011	405,756
Second Floor Area 'A'	9,175	14,415	1.57	233,523	223,350	311,364
Second Floor Area 'C'	1896	4100	2.16	66,420	41,253	88,560
Second Floor Totals	11,071	18,515	1.67	299,943	264,603	399,924
AHU-A1 Totals	31,973	37,300	1.17	604,260	733,614	805,680

Air Handling Unit AHU-B1	Area (SFT) Served	Supply Air CFM (Design)	CFM per SFT (Design)			
First Floor Area 'B'	10,420	10,750	1.03	174,150	234,504	232,200
First Floor Area 'D'	1896	4100	2.16	66,420	53,887	88,560
First Floor Totals	12,316	14,850	1.21	240,570	288,391	320,760
Second Floor Area 'B'	10,361	18,500	1.79	299,700	177,208	399,600
Second Floor Area 'D'	1896	4100	2.16	66,420	45,143	88,560
Second Floor Totals	12,257	22,600	1.84	366,120	222,351	488,160
AHU-B1 Totals	24,573	37,450	1.52	606,690	510,742	808,920

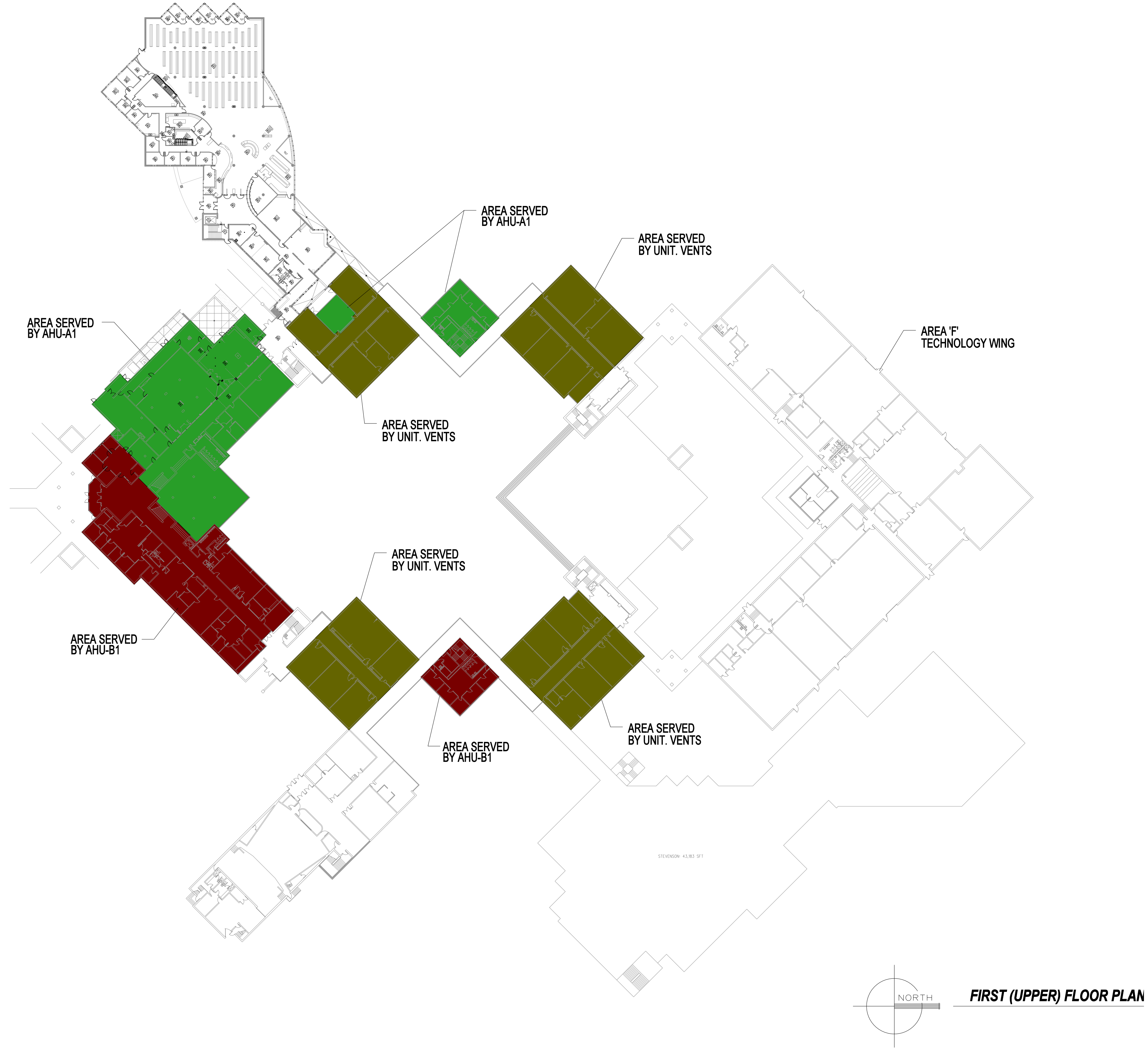
Air Handling Unit AHU-E1	Area (SFT) Served	Supply Air CFM (Design)	CFM per SFT (Design)
Second Floor Area 'E'	11,776	11,740	1.00
Third Floor Area 'E'	9379	11,825	1.26
AHU-E1 Totals	21,155	23,565	1.11

TABLE 1

MAIN BUILDING AIRFLOW AND COOLING SUMMARIES

HVAC SYSTEM STUDY
Muskegon Community College

GMB ae ARCHITECTURE + ENGINEERING



AIR HANDLING UNIT SERVICE / FIRST (UPPER) FLOOR PLAN

HVAC SYSTEM STUDY

Muskegon Community College

GMB ae ARCHITECTURE + ENGINEERING

SECOND (INTERMEDIATE) FLOOR PLAN

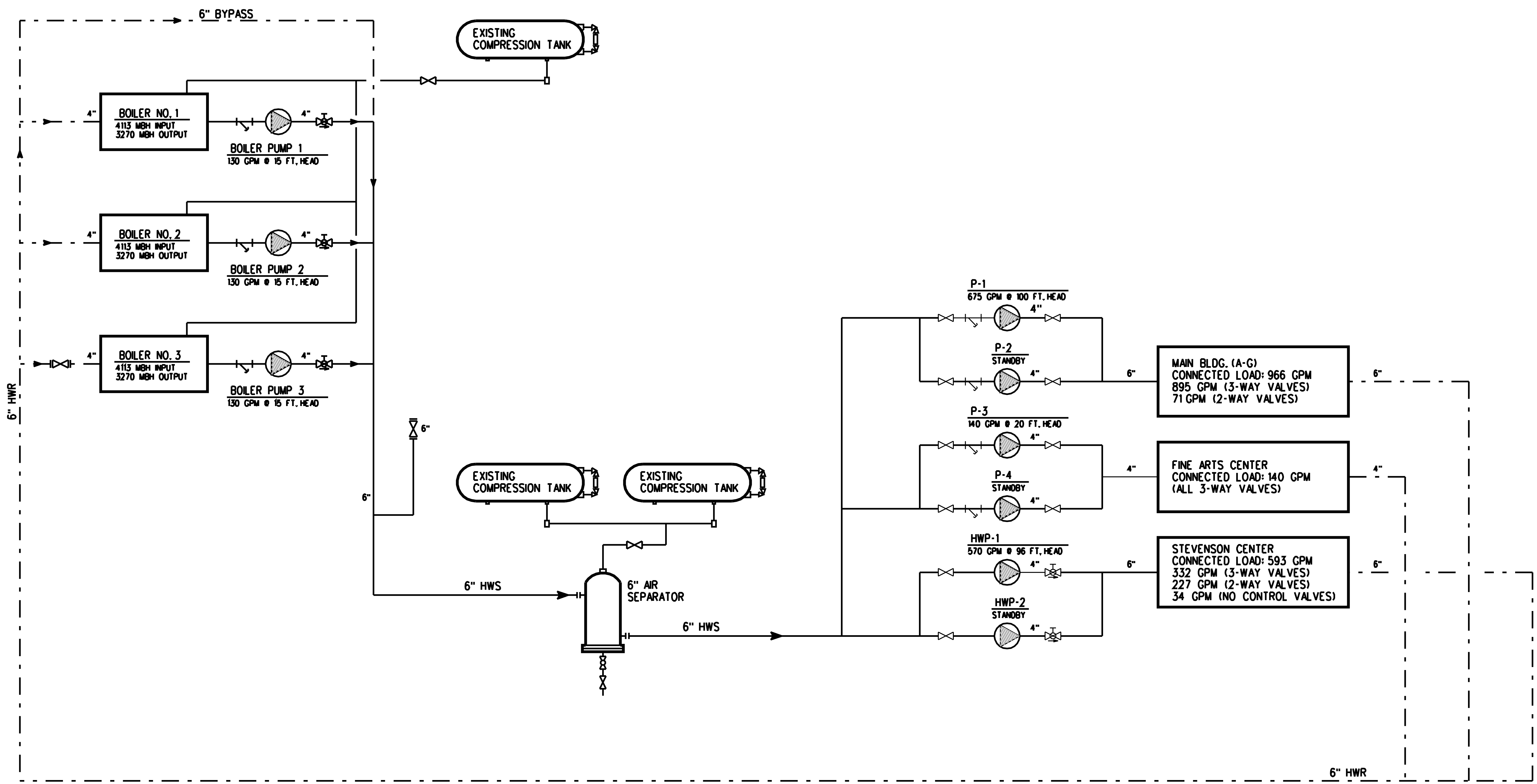
AIR HANDLING UNIT SERVICE / SECOND (INTERMEDIATE) FLOOR PLAN

GMBae
ARCHITECTURE + ENGINEERING

AIR HANDLING UNIT SERVICE / THIRD (LOWER) FLOOR PLAN

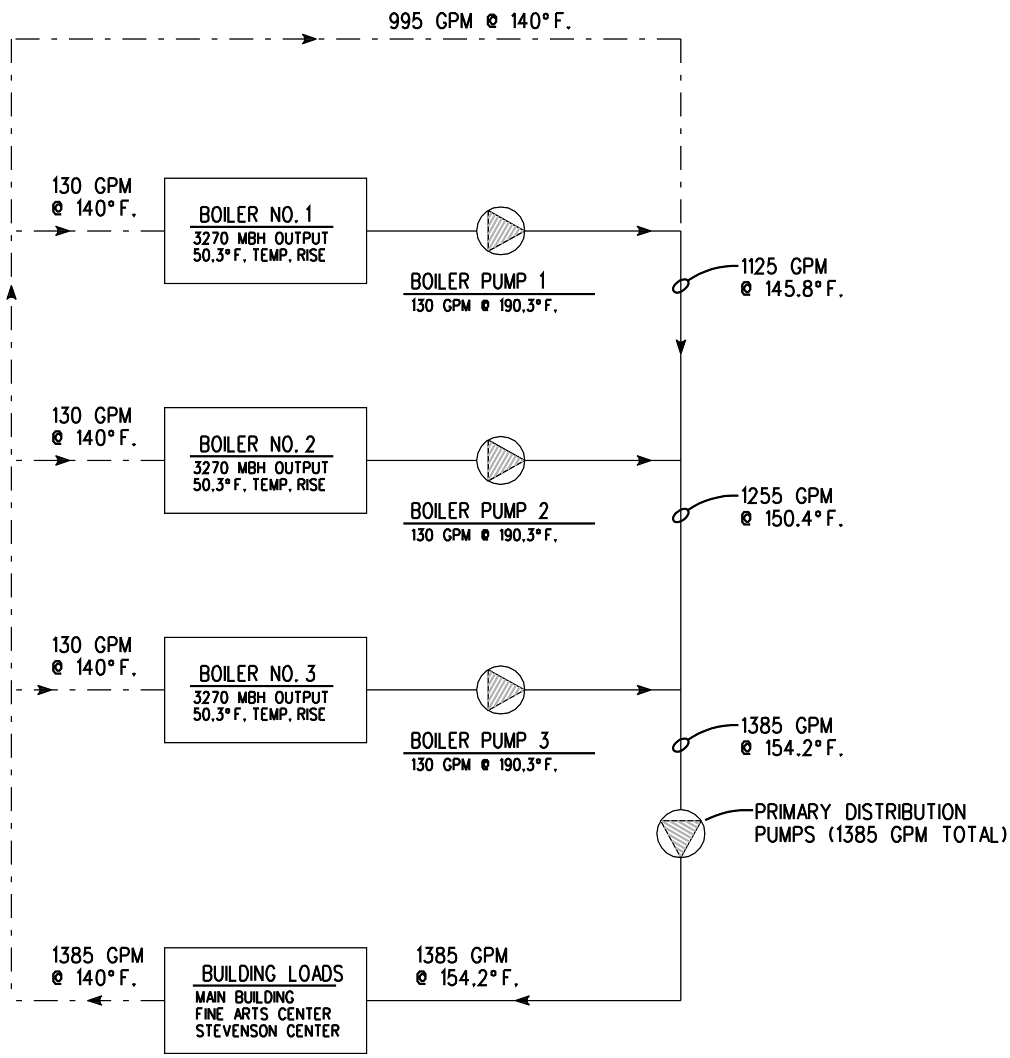
APPENDIX D

HEATING SYSTEM SCHEMATIC DIAGRAMS



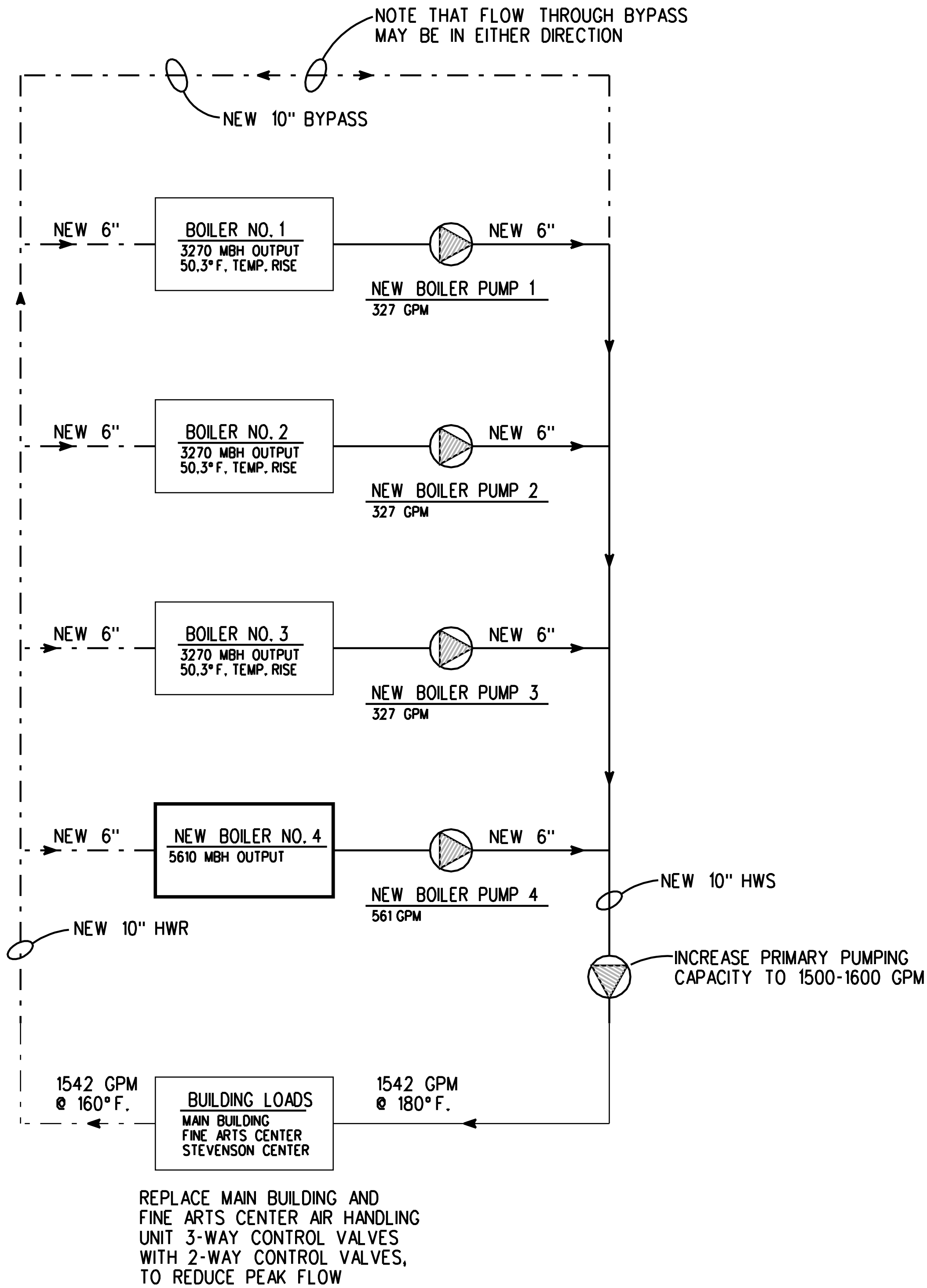
HEATING SYSTEM SCHEMATIC (EXISTING)

ARCHITECTURE + ENGINEERING

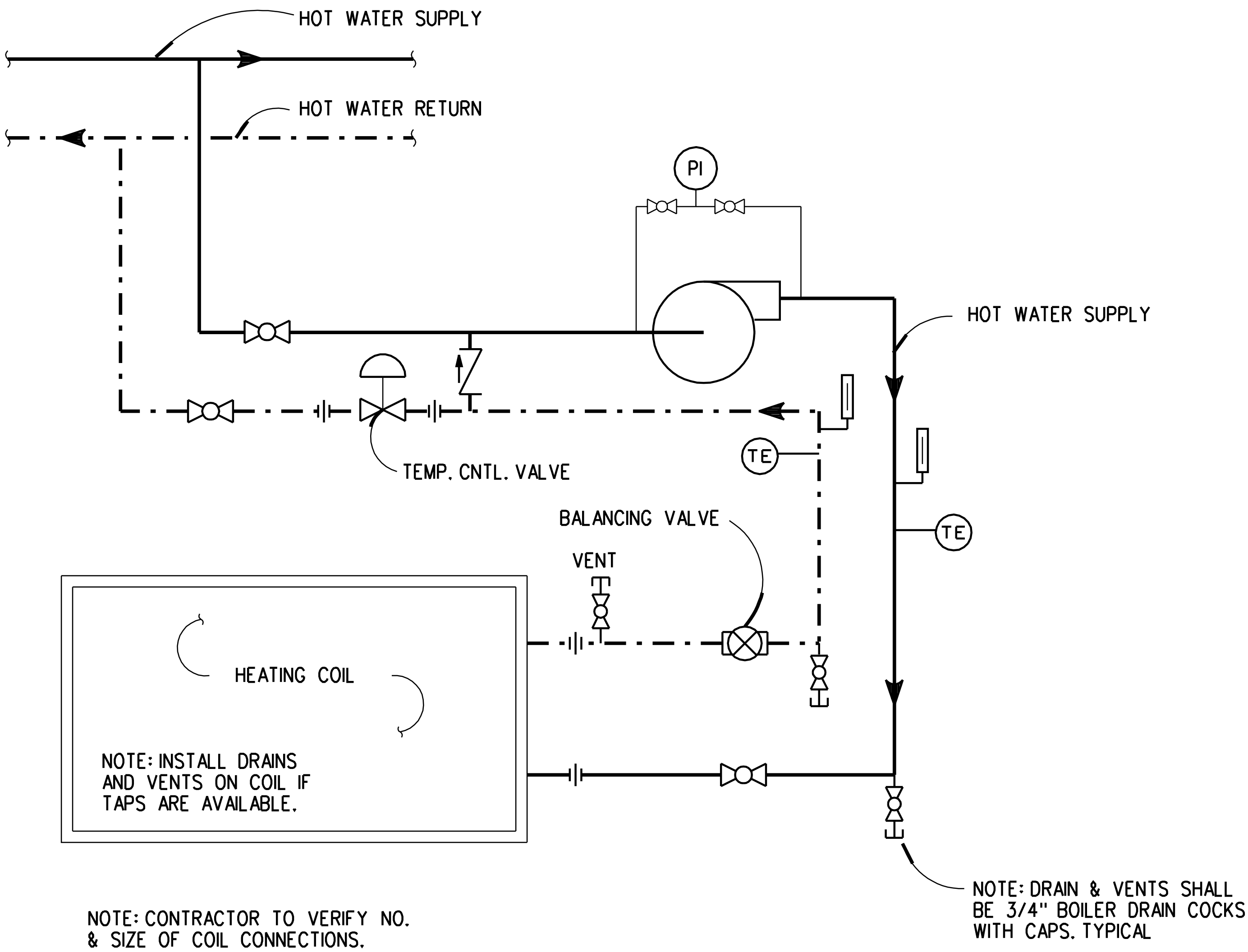


HEATING SYSTEM TEMPERATURE ANALYSIS (EXISTING)

GMBae
ARCHITECTURE + ENGINEERING



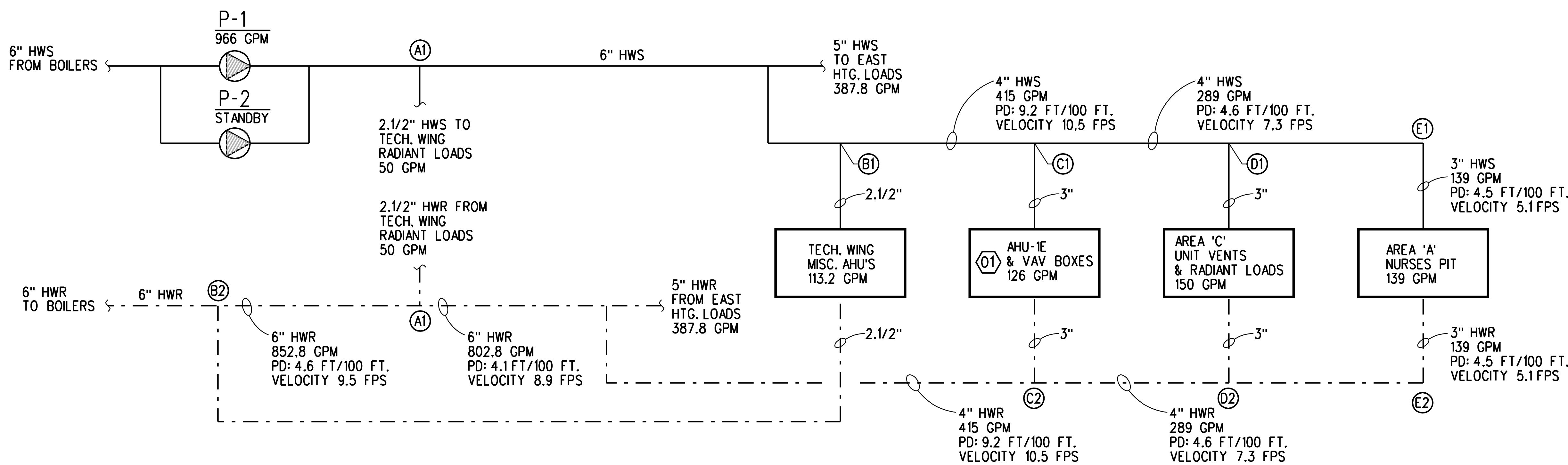
HEATING SYSTEM TEMPERATURE ANALYSIS (PROPOSED)



TYPICAL PUMPED HEATING COIL PIPING (2-WAY)

N.T.S.

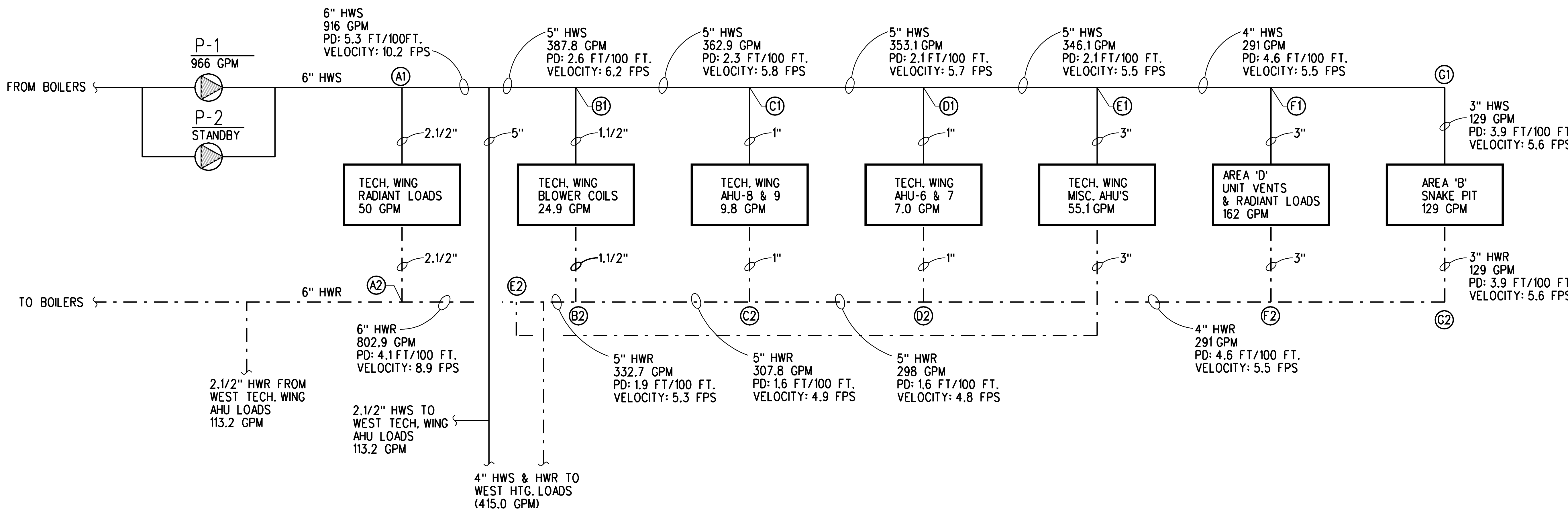
GMBae ARCHITECTURE + ENGINEERING



(01) VAV BOXES (TOTALLING 71.0 GPM) HAVE 2-WAY CONTROL VALVES.

PIPING SYSTEM DIFFERENTIAL PRESSURE (PSI)			
NODE	HWS	HWR	DIFFERENTIAL
(A)	81.0	29.6	51.3
(B)	75.4	28.9	46.5
(C)	69.6	37.5	32.1
(D)	60.7	40.4	20.3
(E)	58.6	48.6	10.0

MAIN (WEST) PRIMARY HEATING LOOP

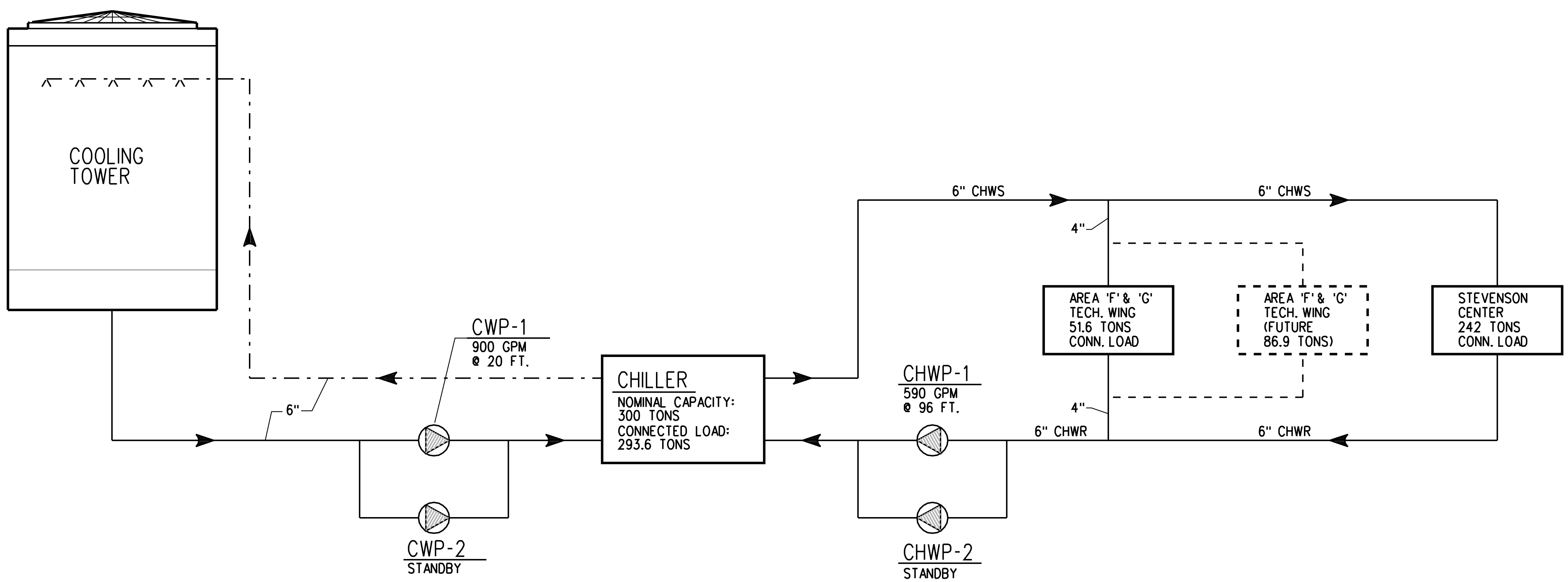


PIPING SYSTEM DIFFERENTIAL PRESSURE (PSI)			
NODE	HWS	HWR	DIFFERENTIAL
(A)	81.0	29.6	51.3
(B)	79.8	30.5	49.3
(C)	79.0	31.0	48.3
(D)	78.3	31.6	46.7
(E)	77.9	30.1	47.8
(F)	72.2	38.1	34.1
(G)	66.1	44.2	21.9

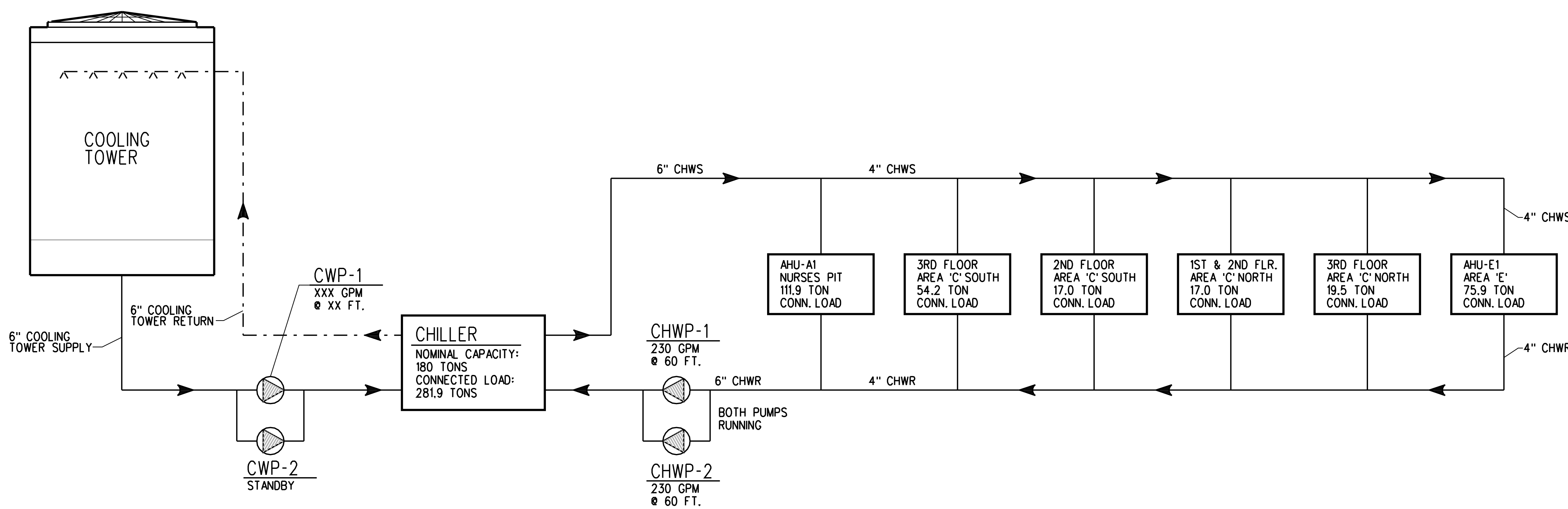
MAIN BUILDING (EAST) PRIMARY HEATING LOOP

APPENDIX E

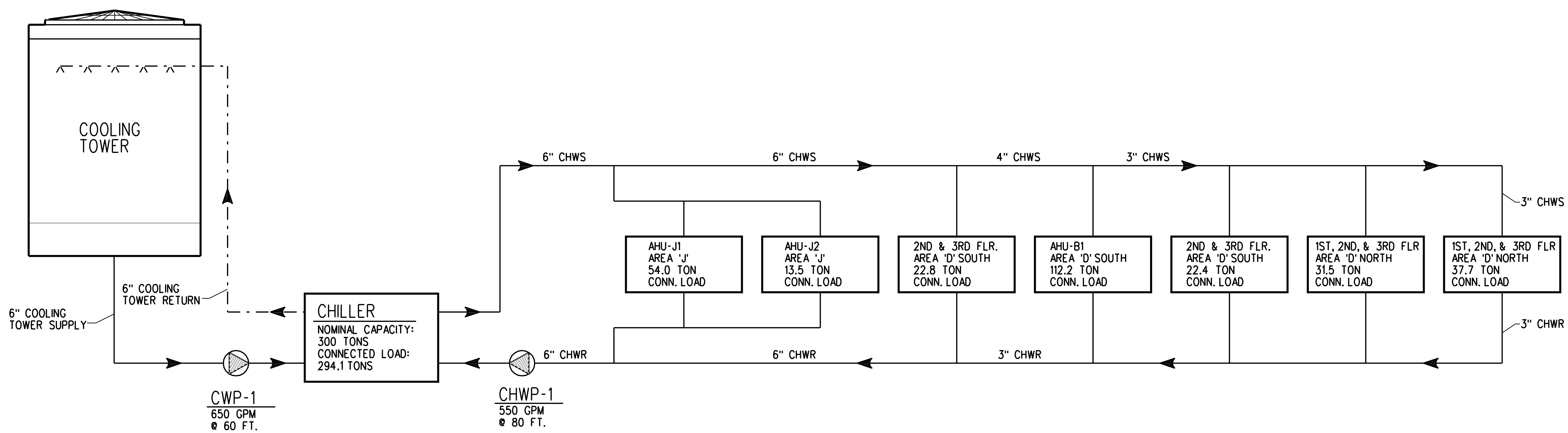
CHILLED WATER SYSTEM SCHEMATIC DIAGRAMS



CHILLED WATER SYSTEM SCHEMATIC (BOILER ROOM CHILLER)



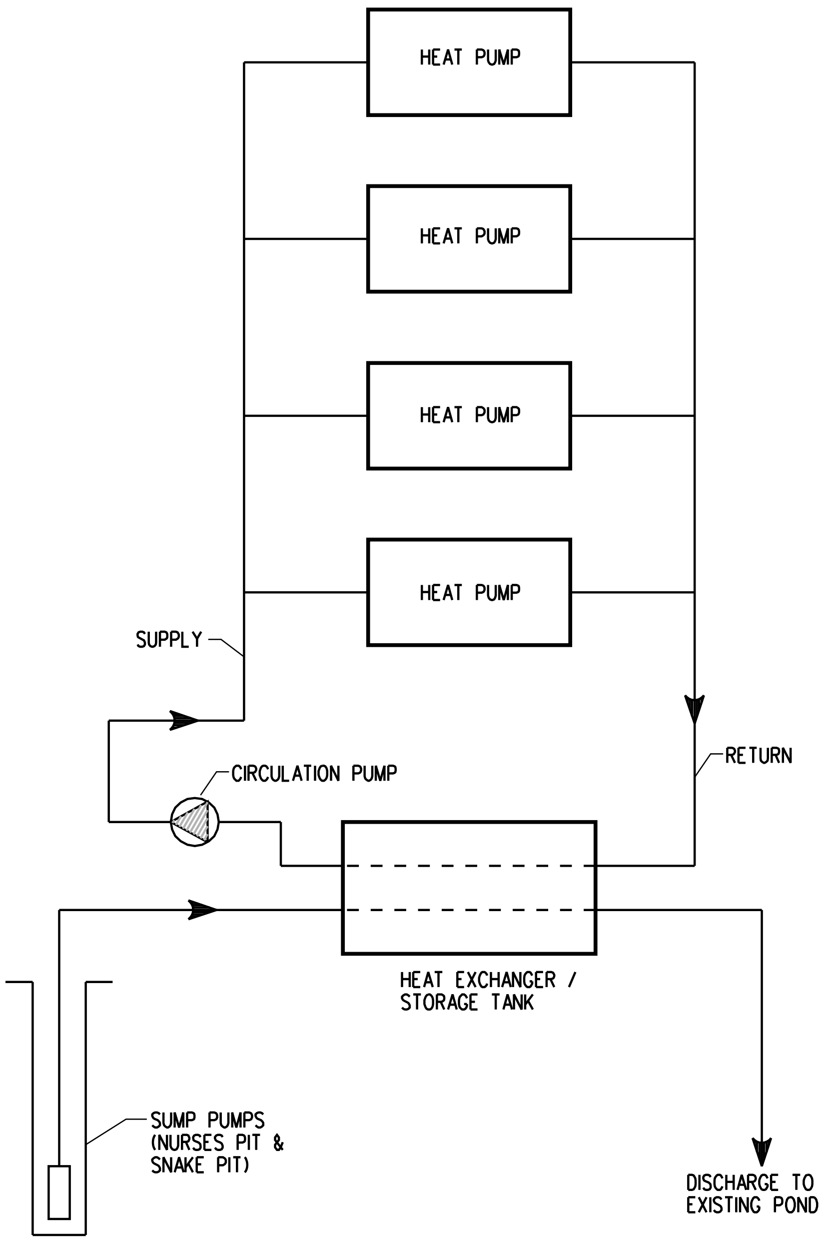
CHILLED WATER SYSTEM SCHEMATIC (NURSES PIT CHILLER)



CHILLED WATER SYSTEM SCHEMATIC (FINE ARTS CHILLER)

APPENDIX F

GROUND WATER HEAT PUMP SCHEMATIC DIAGRAM



GROUND WATER HEAT PUMP SYSTEM SCHEMATIC

APPENDIX G

TRACE 700 HEATING AND COOLING LOAD CALCULATIONS

(AIR HANDLING SYSTEMS A1 AND B1)

Location	**Muskegon, MI**
Building owner	**Muskegon Community College**
Program user	**Travis S**
Company	**GMB A+E**
Comments	**GMB Project 5-2501**

By	**GMB ARCHITECTS-ENGINEERS**
Dataset name	**C:\Users\TravisS\Documents\TRACE 700 Projects\5-2501 Muskegon CC\TRACE.TRC**

Calculation time	**01:00 PM on 03/01/2013**	
TRACE® 700 version	**6.2.9**	
Location	**Muskegon, Michigan**	
Latitude	**43.0**	**deg**
Longitude	**86.0**	**deg**
Time Zone	**5**	
Elevation	**627**	**ft**
Barometric pressure	**29.2**	**in. Hg**
Air density	**0.0742**	**lb/cu ft**
Air specific heat	**0.2444**	**Btu/lb·°F**
Density-specific heat product	**1.0886**	**Btu/h·cfm·°F**
Latent heat factor	**4,791.9**	**Btu·min/h·cu ft**
Enthalpy factor	**4.4534**	**lb·min/hr·cu ft**
Summer design dry bulb	**86**	**°F**
Summer design wet bulb	**73**	**°F**
Winter design dry bulb	**0**	**°F**
Summer clearness number	**1.00**	
Winter clearness number	**1.00**	
Summer ground reflectance	**0.20**	
Winter ground reflectance	**0.20**	
Carbon Dioxide Level	**400**	**ppm**
Design simulation period	**January - December**	
Cooling load methodology	**TETD-TA1**	
Heating load methodology	**UATD**	

TRACE 700
comprehensive building analysis software from Trane

ARCHITECTURE + ENGINEERING

COOLING COIL PEAK / CLG SPACE PEAK

Peaked at Time: Mo/Hr: 7 / 16 — CLG Space Peak Mo/Hr: 7 / 16

Outside Air: OADB/WB/HR: 86 / 72 / 99 — CLG Space Peak OADB: 86

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	148,534	0	148,534	17	148,534	21
Glass Solar	29,865	0	29,865	3	29,865	4
Glass/Door Cond	5,648	0	5,648	1	5,648	1
Wall Cond	19,493	0	19,493	2	19,493	3
Partition/Door	0		0	0	0	0
Floor	1,041		1,041	0	1,041	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	14,131		14,131	2	4,736	1
Sub Total ==>	218,712	0	218,712	25	209,317	29
Internal Loads						
Lights	218,248	0	218,248	25	218,248	31
People	340,835	0	340,835	38	177,650	25
Misc	109,124	0	109,124	12	109,124	15
Sub Total ==>	668,207	0	668,207	75	505,022	71
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	886,918	0	886,919	100.00	714,338	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design

OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-128,845	-128,845	23.56
Glass Solar	0	0	0.00
Glass/Door Cond	-40,883	-40,883	7.47
Wall Cond	-99,238	-99,238	18.14
Partition/Door	0	0	0.00
Floor	-35,295	-35,295	6.45
Adjacent Floor	0	0	0
Infiltration	-31,304	-31,304	5.72
Sub Total ==>	-335,564	-335,564	61.35
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-46,364	-46,364	8.48
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-165,066	30.18
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-381,928	-546,994	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	32,810	14,034
Terminal	32,810	14,034
Main Fan	32,810	14,034
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	411	411
MinStop/Rh	10,109	10,109
Return	33,221	14,445
Exhaust	411	411
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	1.03	0.44
cfm/ton	443.92	
ft²/ton	432.59	
Btu/hr·ft²	27.74	-17.11
No. People	672	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	73.9	886.9	714.3	32,810	75.0	62.3	65.8	55.0	53.0	58.1
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	73.9	886.9								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	31,973		
Part	0		
Int Door	0		
ExFlr	2,211		
Roof	20,902	0	0
Wall	9,173	588	6
Ext Door	42	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-381.9	14,034	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-165.1	10,109	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-547.0			

TRACE 700 HEATING AND COOLING LOAD CALCULATIONS (AIR HANDLING SYSTEMS A1 AND B1)

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 17; Outside Air: OADB/WB/HR: 84 / 71 / 94

CLG Space Peak — Mo/Hr: 7 / 17; OADB: 84

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	129,389	0	129,389	29	129,389	32
Glass Solar	15,379	0	15,379	3	15,379	4
Glass/Door Cond	1,711	0	1,711	0	1,711	0
Wall Cond	10,259	0	10,259	2	10,259	3
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	156,739	0	156,739	35	156,739	39
Internal Loads						
Lights	126,008	0	126,008	28	126,008	31
People	99,900	0	99,900	22	55,500	14
Misc	63,004	0	63,004	14	63,004	16
Sub Total ==>	288,912	0	288,912	65	244,512	61
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	445,651	0	445,651	100.00	401,251	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-113,792	-113,792	41.12
Glass Solar	0	0	0.00
Glass/Door Cond	-13,062	-13,062	4.72
Wall Cond	-50,763	-50,763	18.35
Partition/Door	0	0	0.00
Floor	-8,810	-8,810	3.18
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-186,427	-186,427	67.37
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-90,284	32.63
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-186,427	-276,711	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	18,430	6,850
Terminal	18,430	6,850
Main Fan	18,430	6,850
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	5,529	5,529
Return	18,430	6,850
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	1.00	0.37
cfm/ton	496.26	
ft²/ton	497.07	
Btu/hr·ft²	24.14	-14.99
No. People	222	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	37.1	445.7	401.3	18,430	75.0	62.3	65.8	55.0	54.0	62.3
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	37.1	445.7								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	18,460		
Part	0		
Int Door	0		
ExFlr	210		
Roof	18,460	0	0
Wall	4,573	182	4
Ext Door	42	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-186.4	6,850	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-90.3	5,529	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-276.7			

TRACE 700 HEATING AND COOLING LOAD CALCULATIONS (AIR HANDLING SYSTEMS A1 AND B1)

HVAC SYSTEM STUDY

Muskegon Community College

ARCHITECTURE + ENGINEERING

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 17; Outside Air: OADB/WB/HR: 84 / 71 / 94

CLG Space Peak — Mo/Hr: 7 / 18; OADB: 82

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	86,325	0	86,325	15	79,943	16
Glass Solar	45,612	0	45,612	8	51,211	10
Glass/Door Cond	6,089	0	6,089	1	5,273	1
Wall Cond	20,125	0	20,125	3	22,615	5
Partition/Door	0		0	0	0	0
Floor	1,627		1,627	0	2,084	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	13,309		13,309	2	3,260	1
Sub Total ==>	173,087	0	173,087	30	164,386	33
Internal Loads						
Lights	167,735	0	167,735	29	167,735	34
People	151,883	0	151,883	26	84,379	17
Misc	83,868	0	83,868	15	83,868	17
Sub Total ==>	403,486	0	403,486	70	335,982	67
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	576,573	0	576,573	100.00	500,368	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-75,919	-75,919	18.44
Glass Solar	0	0	0.00
Glass/Door Cond	-46,489	-46,489	11.29
Wall Cond	-92,405	-92,405	22.45
Partition/Door	0	0	0.00
Floor	-30,280	-30,280	7.36
Adjacent Floor	0	0	0
Infiltration	-31,304	-31,304	7.60
Sub Total ==>	-276,396	-276,396	67.15
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-20,323	-20,323	4.94
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-114,921	27.92
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-296,718	-411,640	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	22,982	10,903
Terminal	22,982	10,903
Main Fan	22,982	10,903
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	411	411
MinStop/Rh	7,038	7,038
Return	23,393	11,314
Exhaust	411	411
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	0.94	0.44
cfm/ton	478.32	
ft²/ton	511.43	
Btu/hr·ft²	23.46	-16.75
No. People	338	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter DB/WB/HR °F	Enter DB/WB/HR gr/lb	Leave DB/WB/HR °F	Leave DB/WB/HR °F	Leave DB/WB/HR gr/lb
Main Clg	48.1	576.6	499.9	22,962	75.0	61.4	61.4	55.0	52.5	56.5
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	48.1	576.6								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	24,573		
Part	0		
Int Door	0		
ExFlr	2,099		
Roof	12,316	0	0
Wall	8,637	644	7
Ext Door	168	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-296.7	10,903	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-114.9	7,038	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-411.6			

TRACE 700 HEATING AND COOLING LOAD CALCULATIONS (AIR HANDLING SYSTEMS A1 AND B1)

HVAC SYSTEM STUDY

Muskegon Community College

GMBae ARCHITECTURE + ENGINEERING

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 86 / 72 / 101

Clg Space Peak — Mo/Hr: 7 / 15; OADB: 86

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	70,521	0	70,521	28	70,521	30
Glass Solar	21,979	0	21,979	9	21,979	9
Glass/Door Cond	3,104	0	3,104	1	3,104	1
Wall Cond	6,210	0	6,210	2	6,210	3
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	101,813	0	101,813	40	101,813	43
Internal Loads						
Lights	71,127	0	71,127	28	71,127	30
People	46,800	0	46,800	18	26,000	11
Misc	35,563	0	35,563	14	35,563	15
Sub Total ==>	153,490	0	153,490	60	132,690	57
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	255,304	0	255,304	100.00	234,504	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-64,232	-64,232	36.23
Glass Solar	0	0	0.00
Glass/Door Cond	-23,244	-23,244	13.11
Wall Cond	-37,069	-37,069	20.91
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-124,545	-124,545	70.24
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-52,766	29.76
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-124,545	-177,311	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	10,771	4,576
Terminal	10,771	4,576
Main Fan	10,771	4,576
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	3,231	3,231
Return	10,771	4,576
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	1.03	0.44
cfm/ton	506.27	
ft²/ton	489.77	
Btu/hr·ft²	24.50	-17.02
No. People	104	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	21.3	255.3	234.5	10,771	75.0	61.4	61.4	55.0	53.1	58.5
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	21.3	255.3								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	10,420		
Part	0		
Int Door	0		
ExFlr	0		
Roof	10,420	0	0
Wall	3,529	322	9
Ext Door	84	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-124.5	4,576	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-52.8	3,231	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-177.3			

TRACE 700 **HEATING AND COOLING LOAD CALCULATIONS (AIR HANDLING SYSTEMS A1 AND B1)**

GMBae ARCHITECTURE + ENGINEERING

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 86 / 72 / 101

CLG Space Peak — Mo/Hr: 7 / 14; OADB: 86

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	12,832	0	12,832	21	11,459	22
Glass Solar	7,285	0	7,285	12	9,663	19
Glass/Door Cond	1,129	0	1,129	2	982	2
Wall Cond	2,794	0	2,794	5	2,311	4
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	8,052		8,052	13	2,550	5
Sub Total ==>	32,092	0	32,092	53	26,966	52
Internal Loads						
Lights	12,942	0	12,942	21	12,942	25
People	9,000	0	9,000	15	5,000	10
Misc	6,471	0	6,471	11	6,471	13
Sub Total ==>	28,413	0	28,413	47	24,413	48
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	60,505	0	60,505	100.00	51,379	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-11,687	-11,687	19.04
Glass Solar	0	0	0.00
Glass/Door Cond	-8,485	-8,485	13.82
Wall Cond	-12,811	-12,811	20.86
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-16,856	-16,856	27.45
Sub Total ==>	-49,839	-49,839	81.17
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-11,560	18.83
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-49,839	-61,399	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	2,360	1,831
Terminal	2,360	1,831
Main Fan	2,360	1,831
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	221	221
MinStop/Rh	708	708
Return	2,581	2,053
Exhaust	221	221
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	1.24	0.97
cfm/ton	468.04	
ft²/ton	376.04	
Btu/hr·ft²	31.91	-32.38
No. People	20	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	5.0	60.5	51.2	2,349	75.0	62.3	65.8	55.0	53.4	60.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.0	60.5								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,896		
Part	0		
Int Door	0		
ExFlr	0		
Roof	1,896	0	0
Wall	1,232	124	10
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-49.8	1,831	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-11.6	708	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-61.4			

TRACE 700 HEATING AND COOLING LOAD CALCULATIONS (AIR HANDLING SYSTEMS A1 AND B1)

HVAC SYSTEM STUDY

Muskegon Community College

GMBae ARCHITECTURE + ENGINEERING

COOLING COIL PEAK / CLG SPACE PEAK

Peaked at Time: Mo/Hr: 7 / 16 — CLG Space Peak Mo/Hr: 7 / 17

Outside Air: OADB/WB/HR: 86 / 72 / 99 — CLG Space Peak OADB: 84

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	13,465	0	13,465	22	13,289	25
Glass Solar	11,136	0	11,136	18	11,437	21
Glass/Door Cond	1,164	0	1,164	2	1,108	2
Wall Cond	2,661	0	2,661	4	3,088	6
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	8,273		8,273	13	2,237	4
Sub Total ==>	36,700	0	36,700	59	31,159	58
Internal Loads						
Lights	12,942	0	12,942	21	12,942	24
People	5,966	0	5,966	10	3,315	6
Misc	6,471	0	6,471	10	6,471	12
Sub Total ==>	25,380	0	25,380	41	22,728	42
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	62,079	0	62,079	100.00	53,887	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design

OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-11,687	-11,687	18.86
Glass Solar	0	0	0.00
Glass/Door Cond	-8,485	-8,485	13.69
Wall Cond	-12,811	-12,811	20.67
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-16,856	-16,856	27.20
Sub Total ==>	-49,839	-49,839	80.43
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-12,125	19.57
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-49,839	-61,963	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	2,475	1,831
Terminal	2,475	1,831
Main Fan	2,475	1,831
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	221	221
MinStop/Rh	743	743
Return	2,696	2,053
Exhaust	221	221
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	1.31	0.97
cfm/ton	478.43	
ft²/ton	366.50	
Btu/hr·ft²	32.74	-32.68
No. People	13	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	5.2	62.1	53.7	2,467	75.0	61.4	61.4	55.0	52.5	56.4
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.2	62.1								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,896		
Part	0		
Int Door	0		
ExFlr	0		
Roof	1,896	0	0
Wall	1,232	124	10
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-49.8	1,831	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-12.1	743	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-62.0			

TRACE 700 HEATING AND COOLING LOAD CALCULATIONS (AIR HANDLING SYSTEMS A1 AND B1)

HVAC SYSTEM STUDY

Muskegon Community College

GMBae ARCHITECTURE + ENGINEERING

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 16; Outside Air: OADB/WB/HR: 86 / 72 / 99	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	CLG Space Peak (Mo/Hr: 7 / 16; OADB: 86) Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	3,965	0	3,965	18	3,965	24
Glass Solar	0	0	0	0	0	0
Glass/Door Cond	0	0	0	0	0	0
Wall Cond	0	0	0	0	0	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	3,965	0	3,965	18	3,965	24
Internal Loads						
Lights	3,727	0	3,727	17	3,727	23
People	12,285	0	12,285	56	6,825	42
Misc	1,864	0	1,864	9	1,864	11
Sub Total ==>	17,876	0	17,876	82	12,416	76
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	21,841	0	21,841	100.00	16,381	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-3,366	-3,366	34.24
Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-3,366	-3,366	34.24
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-2,777	-2,777	28.26
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-3,686	37.50
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-6,143	-9,829	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	752	226
Terminal	752	226
Main Fan	752	226
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	226	226
Return	752	226
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	1.38	0.41
cfm/ton	413.38	
ft²/ton	299.99	
Btu/hr·ft²	40.00	-18.00
No. People	27	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	1.8	21.8	16.4	752	75.0	62.3	65.8	55.0	52.2	55.2
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1.8	21.8								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	546		
Part	0		
Int Door	0		
ExFlr	0		
Roof	546	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-6.1	226	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-3.7	226	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-9.8			

TRACE 700 HEATING AND COOLING LOAD CALCULATIONS (AIR HANDLING SYSTEMS A1 AND B1)

HVAC SYSTEM STUDY

Muskegon Community College

ARCHITECTURE + ENGINEERING

COOLING COIL PEAK / CLG SPACE PEAK

Peaked at Time: Mo/Hr: 7 / 10 — CLG Space Peak Mo/Hr: 7 / 10

Outside Air: OADB/WB/HR: 76 / 66 / 81 — CLG Space Peak OADB: 76

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	21,146	0	21,146	6	21,146	9
Glass/Door Cond	-109	0	-109	0	-109	0
Wall Cond	3,046	0	3,046	1	3,046	1
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	24,082	0	24,082	7	24,082	11
Internal Loads						
Lights	62,629	0	62,629	19	62,629	28
People	210,650	0	210,650	64	105,325	47
Misc	31,314	0	31,314	10	31,314	14
Sub Total ==>	304,593	0	304,593	93	199,268	89
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	328,675	0	328,675	100.00	223,350	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design

OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-10,850	-10,850	8.10
Wall Cond	-24,888	-24,888	18.57
Partition/Door	0	0	0.00
Floor	-4,431	-4,431	3.31
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-40,170	-40,170	29.98
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-43,586	-43,586	32.52
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-50,254	37.50
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-83,756	-134,010	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	10,259	3,078
Terminal	10,259	3,078
Main Fan	10,259	3,078
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	3,078	3,078
Return	10,259	3,078
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	1.12	0.34
cfm/ton	374.55	
ft²/ton	334.98	
Btu/hr·ft²	35.82	-14.61
No. People	383	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	27.4	328.7	223.4	10,259	75.0	62.3	65.8	55.0	51.1	50.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	27.4	328.7								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	9,175		
Part	0		
Int Door	0		
ExFlr	105		
Roof	0	0	0
Wall	2,311	158	7
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-83.8	3,078	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-50.3	3,078	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-134.0			

TRACE 700 HEATING AND COOLING LOAD CALCULATIONS (AIR HANDLING SYSTEMS A1 AND B1)

HVAC SYSTEM STUDY

Muskegon Community College

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 19; Outside Air: OADB/WB/HR: 80 / 67 / 83

CLG Space Peak — Mo/Hr: 7 / 19; OADB: 80

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	10,191	0	10,191	5	10,191	6
Glass/Door Cond	521	0	521	0	521	0
Wall Cond	8,660	0	8,660	4	8,660	5
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	19,372	0	19,372	9	19,372	11
Internal Loads						
Lights	70,724	0	70,724	32	70,724	40
People	93,150	0	93,150	43	51,750	29
Misc	35,362	0	35,362	16	35,362	20
Sub Total ==>	199,236	0	199,236	91	157,836	89
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	218,608	0	218,608	100.00	177,208	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-6,274	-6,274	5.90
Wall Cond	-31,749	-31,749	29.86
Partition/Door	0	0	0.00
Floor	-8,109	-8,109	7.63
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-46,133	-46,133	43.39
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-20,323	-20,323	19.11
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-39,873	37.50
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-66,455	-106,329	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	8,139	2,442
Terminal	8,139	2,442
Main Fan	8,139	2,442
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	2,442	2,442
Return	8,139	2,442
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	0.79	0.24
cfm/ton	446.79	
ft²/ton	568.74	
Btu/hr·ft²	21.10	-10.26
No. People	207	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter °F	Enter gr/lb	Leave DB/WB/HR °F	Leave °F	Leave gr/lb
Main Clg	18.2	218.6	177.2	8,139	75.0	61.4	61.4	55.0	51.9	54.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	18.2	218.6								

AREAS

	Gross Total	Glass ft²	(%)
Floor	10,361		
Part	0		
Int Door	0		
ExFlr	193		
Roof	0	0	0
Wall	2,821	74	3
Ext Door	84	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-66.5	2,442	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-39.9	2,442	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-106.3			

TRACE 700 HEATING AND COOLING LOAD CALCULATIONS (AIR HANDLING SYSTEMS A1 AND B1)

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 12; Outside Air: OADB/WB/HR: 82 / 69 / 87

CLG Space Peak — Mo/Hr: 7 / 12; OADB: 82

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	14,942	0	14,942	31	14,942	36
Glass/Door Cond	469	0	469	1	469	1
Wall Cond	1,271	0	1,271	3	1,271	3
Partition/Door	0		0	0	0	0
Floor	-1,264		-1,264	-3	-1,264	-3
Adjacent Floor	0	0	0	0	0	0
Infiltration	4,144		4,144	9	1,422	3
Sub Total ==>	19,562	0	19,562	41	16,840	41
Internal Loads						
Lights	12,942	0	12,942	27	12,942	31
People	9,000	0	9,000	19	5,000	12
Misc	6,471	0	6,471	13	6,471	16
Sub Total ==>	28,413	0	28,413	59	24,413	59
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	47,975	0	47,975	100.00	41,253	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-8,485	-8,485	13.04
Wall Cond	-10,776	-10,776	16.57
Partition/Door	0	0	0.00
Floor	-22,054	-22,054	33.91
Adjacent Floor	0	0	0.00
Infiltration	-14,448	-14,448	22.21
Sub Total ==>	-55,763	-55,763	85.73
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-9,282	14.27
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-55,763	-65,045	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	1,895	2,049
Terminal	1,895	2,049
Main Fan	1,895	2,049
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	190	190
MinStop/Rh	568	568
Return	2,084	2,239
Exhaust	190	190
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	1.00	1.08
cfm/ton	473.95	
ft²/ton	474.25	
Btu/hr·ft²	25.30	-34.31
No. People	20	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter DB/WB/HR °F	Enter DB/WB/HR gr/lb	Leave DB/WB/HR °F	Leave DB/WB/HR °F	Leave DB/WB/HR gr/lb
Main Clg	4.0	48.0	41.3	1,895	75.0	62.3	65.8	55.0	53.6	60.6
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.0	48.0								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,896		
Part	0		
Int Door	0		
ExFlr	1,896		
Roof	0	0	0
Wall	1,056	124	12
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-55.8	2,049	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-9.3	568	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-65.0			

	COOLING COIL PEAK				CLG SPACE PEAK	
	Peaked at Time: Mo/Hr: 7 / 18				Mo/Hr: 7 / 19	
	Outside Air: OADB/WB/HR: 82 / 69 / 90				OADB: 80	
	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	15,487	0	15,487	30	16,127	36
Glass/Door Cond	964	0	964	2	752	2
Wall Cond	1,772	0	1,772	3	2,150	5
Partition/Door	0		0	0	0	0
Floor	2,084		2,084	4	2,376	5
Adjacent Floor	0	0	0	0	0	0
Infiltration	5,222		5,222	10	1,009	2
Sub Total ==>	25,529	0	25,529	50	22,416	50
Internal Loads						
Lights	12,942	0	12,942	25	12,942	29
People	5,966	0	5,966	12	3,315	7
Misc	6,471	0	6,471	13	6,471	14
Sub Total ==>	25,380	0	25,380	50	22,728	50
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	50,909	0	50,909	100.00	45,143	100.00

	HEATING COIL PEAK		
	Mo/Hr: Heating Design		
	OADB: 0		
	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-8,485	-8,485	12.85
Wall Cond	-10,776	-10,776	16.32
Partition/Door	0	0	0.00
Floor	-22,170	-22,170	33.57
Adjacent Floor	0	0	0.00
Infiltration	-14,448	-14,448	21.88
Sub Total ==>	-55,879	-55,879	84.62
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-10,157	15.38
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-55,879	-66,037	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	95.0
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	2,073	2,053
Terminal	2,073	2,053
Main Fan	2,073	2,053
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	190	190
MinStop/Rh	622	622
Return	2,263	2,243
Exhaust	190	190
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	1.09	1.08
cfm/ton	488.75	
ft²/ton	446.92	
Btu/hr·ft²	26.85	-34.83
No. People	13	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	4.2	50.9	44.5	2,046	75.0	61.4	61.4	55.0	52.6	56.8
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.2	50.9								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,896		
Part	0		
Int Door	0		
ExFlr	1,906		
Roof	0	0	0
Wall	1,056	124	12
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-55.9	2,053	70.0	95.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-10.2	622	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-66.0			

TRACE 700 HEATING AND COOLING LOAD CALCULATIONS (AIR HANDLING SYSTEMS A1 AND B1)