Lucas Ciacco, Mason Elliott, Nicholas Gardner,
Trevor Howard, Christian Tello

MEGN 461 | Thermodynamics II | Dr. Rodriguez

Analysis and Modification of the LockRidge Arena HVAC System During A Worst Case Heat Generation Scenario

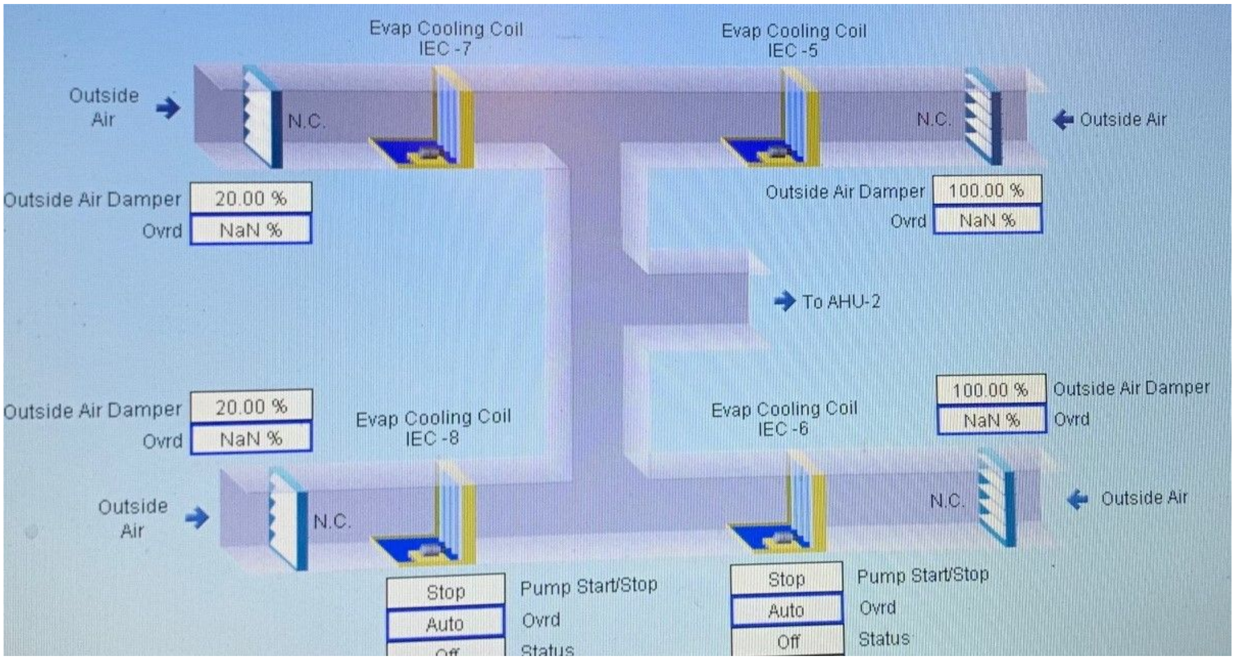
PROBLEM STATEMENT

Our consulting team has been tasked with running an analysis on the HVAC system for the Student Recreation Center on the Colorado School of Mines campus. More specifically, the Lockridge Arena competition gymnasium which currently faces issues with its cooling system. The initial HVAC system that was installed operates using indirect and direct evaporative cooling systems. Evaporative cooling systems work well for cooling the air temperature in a highly efficient manner, but raise the humidity of the air while doing so. Meanwhile, the gymnasium flooring begins to warp when the relative humidity (RH) goes above 40%. To prevent damage to the flooring, the current system must fully shut off and stop cooling the room once the relative humidity goes above 40%. This creates an issue when the outside air is at high temperatures and humidity, and the gym is being used. A potential fix to this problem that has already been evaluated is to connect the main campus chilled water system from Brown Building to the Student Rec Center, and connecting that to a cooling coil within the system, but this solution has proven to not be cost effective enough to implement. Our team has chosen to analyze the option of using a local water chiller to provide cold water to a cooling coil with hopes it will be a more feasible solution to lower the temperature without increasing humidity. Figure 1, seen below shows what we classify as a "worst case" scenario wherein all 2,500 bleacher seats are occupied, and the floor has also been converted to seating adding an additional strain up to 3,500 people. This occurs at lectures, convocation, graduation, and various other school events.

Figure 1: Lockridge Arena Near Full Capacity

BACKGROUND

The student recreation center on the Colorado School of Mines campus runs on an HVAC system that is split into six sections. The HVAC section of the recreation center that regulates the temperature of the Lockridge arena is called AHU-2. This unit starts by pulling outside air into one of four vents. The air passes through dampers that can open and close to regulate the amount of air based on the needs of the system. The incoming air first passes through an indirect evaporative cooling coil (see Figure 2).



Outside Air Damper 20.00 %
Ovrd NaN %

Outside Air Damper 100.00 %
Ovrd NaN %

Outside Air Damper 20.00 %
Ovrd NaN %

Outside Air Damper 100.00 %
Ovrd NaN %

Pump Start/Stop Stop
Ovrd Auto
Status

Pump Start/Stop Stop
Ovrd Auto
Status Off

Figure 2: System diagram of first stage of AHU-2

These are the first components that are able to cool incoming air on a hot day. However, they are not very effective as they can only drop the air temperature by one to two degrees Fahrenheit. The air from the four ducts are then funneled into the air input for the next step. To cool the air even further before it enters the arena, the air passes through an air filter to remove large particulate matter, then through a heating coil (which is turned off in the warmer months), then to a direct evaporative cooler (see Figure 3).

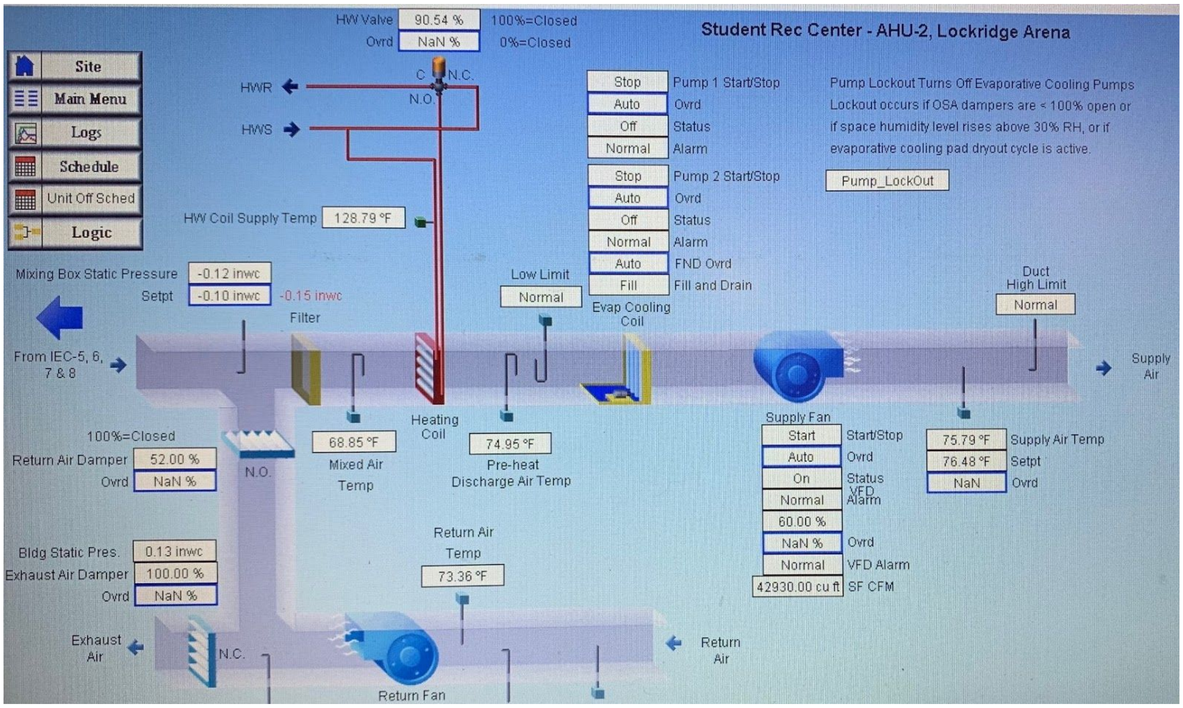


Figure 3: System diagram of second stage of AHU-2

The direct evaporative cooler sprays a fine mist of cool water down to a collection tray. As the air passes through, heat is transferred directly to the water and cools the air even more. Though the direct evaporative cooler results in a cooler air temperature, it also increases the relative humidity inside the arena. Return air from the arena is then brought back to the outside air inlet where it mixes. There is also an exhaust duct that takes some of the air back into the atmosphere.

DESCRIPTION

The facilities department at the Colorado School of Mines has a limited budget and cost-benefit analyses were done prior to the completion of the student recreation center to determine what kind of cooling system would be implemented. Due to humidity considerations, a mechanical cooler (chilled water cooling coil) was selected. The facilities manager has looked into changing the system, and there is space available within AHU-2 (which solely handles the competition gym) as well as room in both the electrical and mechanical rooms to give a chiller a new home.

This report will compare the effectiveness of the current cooling system to that of a new chiller system to help justify the necessity for upgrading the HVAC system for Lockridge Arena. Using computer programs, EES and MathCAD, the two systems will be modeled and arena relative humidity and costs will be discussed to see if purchasing a new system is worth the cost.

CALCULATIONS, ASSUMPTIONS & DISCUSSION:

Evaporative Cooler

This analysis is looking at how effective the current system is at cooling based on how the relative humidity of the air entering the arena is affected. Therefore, it will only be looking at summer time conditions in Golden, CO, because in the winter there is less need for the cooler and most problems the facilities crew face are in the summer.

Assumptions:

- Air from the indirect evaporative coolers (see Figure 1) can be neglected due to the fact they add no relative humidity and only affected the temperature by a few degrees.
- Outside temperatures and humidities are based on reasonable summer conditions in Colorado.
- Return air damper is 100% closed (see Figure 2)
- The heating coil (see Figure 2) can be neglected as the heater is not used in the summer.
- Mass flow rate for the direct evaporative cooler was not given so a reasonable value was given
- Volumetric flow rate of inlet air used in summer was not given, though it was reasonably assumed based on the rate used in winter (42,930 cfm).
- Water temperatures for the direct evaporative cooler are not monitored so they were reasonably assumed.
- Assume the inside set temperature is 65 degrees F in the summer (T_2 in EES)

Below is a simplified illustration based on the above assumptions. State numbers are shown and variables in the following EES calculations correspond accordingly.

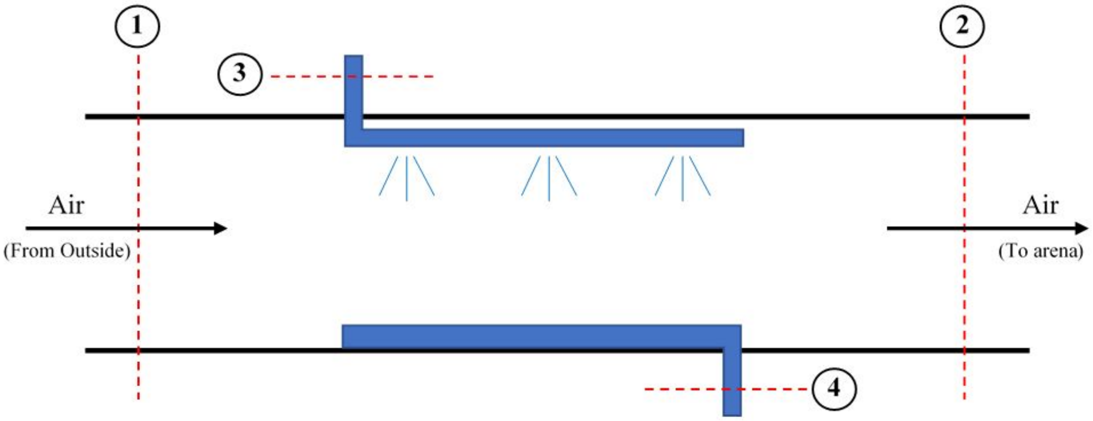


Figure 4: Simplified system illustration used for calculations

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AHU-2 Model with Direct Evaporative Cooling

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STATE INFORMATION AND RELATIVE HUMIDITY AT STATE 2 CALCULATION:

Outside Air -> State 1

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User Defined Variables

$T_1 = \text{ConvertTemp}(F, C, 100)$ *Outside temp in F*

$RH_1 = 0.4$ [-] *Outside Relative Humidity*

$\dot{V}_1 = 45000 \cdot \left| 0.000471947 \cdot \frac{m^3/s}{cfm} \right|$ *Inlet Air Volumetic Flow Rate (assume max capacity)*

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$$P_{atm} = 1 \cdot \left| 101.325 \cdot \frac{kPa}{atm} \right|$$

$density = 0.954$ [kg/m³] *Air Density in Denver, CO*

$$\dot{m}_1 = \dot{V}_1 \cdot density$$

$$Pv_1 = RH_1 \cdot P(water, T = T_1, x = 0)$$

$$hv_1 = h(water, T = T_1, x = 1)$$

$$Pa_1 = P_{atm} - Pv_1$$

$$w_1 = 0.622 \cdot \frac{Pv_1}{Pa_1}$$

$cp = 1.005$ [kJ/kg*C]

$$h_1 = cp \cdot T_1 + w_1 \cdot hv_1$$

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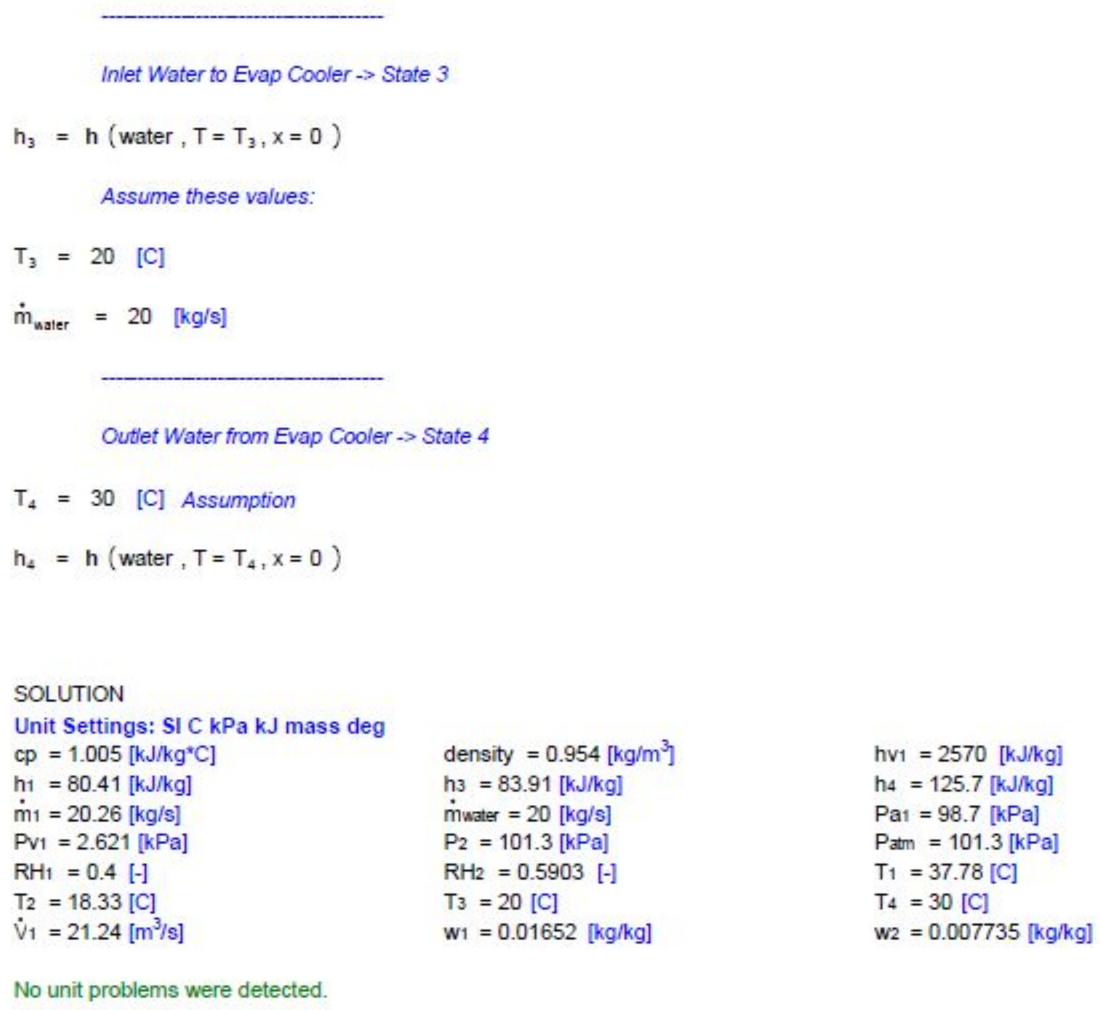
Air to Arena -> State 2

$P_2 = P_{atm}$ *Assume no pressure change across cooler*

$$T_2 = \text{ConvertTemp}(F, C, 65)$$

$$w_2 = \frac{\frac{\dot{m}_{water}}{\dot{m}_1} \cdot (h_3 - h_4) - h_4 \cdot w_1 + h_1 - cp \cdot T_2}{h(water, T = T_2, x = 1) - h_4}$$

$$RH_2 = \frac{w_2 \cdot P_2}{(0.622 + w_2) \cdot P(water, T = T_2, x = 0)}$$



Inlet Water to Evap Cooler -> State 3

$h_3 = h(\text{water}, T = T_3, x = 0)$

Assume these values:

$T_3 = 20$ [C]

$\dot{m}_{water} = 20$ [kg/s]

Outlet Water from Evap Cooler -> State 4

$T_4 = 30$ [C] *Assumption*

$h_4 = h(\text{water}, T = T_4, x = 0)$

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SOLUTION
Unit Settings: SI C kPa kJ mass deg
cp  = 1.005 [kJ/kg*C]      density  = 0.954 [kg/m^3]    hv1  = 2570  [kJ/kg]
h1  = 80.41 [kJ/kg]        h3  = 83.91 [kJ/kg]          h4  = 125.7 [kJ/kg]
ṁ1 = 20.26 [kg/s]          ṁwater = 20 [kg/s]           Pa1  = 98.7 [kPa]
Pv1  = 2.621 [kPa]         P2  = 101.3 [kPa]            Patm  = 101.3 [kPa]
RH1  = 0.4  [-]            RH2  = 0.5903  [-]           T1  = 37.78 [C]
T2  = 18.33 [C]            T3  = 20 [C]                 T4  = 30 [C]
V̇1  = 21.24 [m^3/s]        w1  = 0.01652  [kg/kg]       w2 = 0.007735 [kg/kg]

No unit problems were detected.
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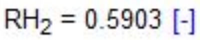
Figure 5: EES Calculations for Evaporative Cooler

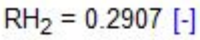
From these calculations, two scenarios were tested. The first scenario is presented in Figure 3: 100 degree F day with 40% relative humidity. The second scenario is an 80 degree F day with 25% humidity. These two scenarios were used to back up the claims by the facilities crew that on normal days, the cooler does a good job, but on hot and humid days, they have to shut it off due to too much humidity inside. The results were as follows:

Scenario 1



$RH_2 = 0.5903$ [-]

Scenario 2



$RH_2 = 0.2907$ [-]

The results show that in order to keep the inside temperature at 65 degrees F, and keeping all else the same, the cooling system fails to keep the relative humidity inside the arena under the comfortable limit of 35-40% in Scenario 1, but succeeds in Scenario 2. These calculations back up the claims that hot, humid days are the worst conditions for the current cooling system and mild, drier days are handled just fine.

Water Chiller & Cold Water Coil

Assumptions:

- Mechanical chiller and chilled water cooling coil will not introduce humidity.
- Gym size will be approximated.
- Lights are LEDs with minimal heat production.
- At RH 40%, DEC and IEC systems turn off. Mechanical cooling system will run alone.

Tc: the temperature the room will be cooled to (based on averages of sensors).

Tc_air: the temperature of the air after it passes through the cooled water coil (assume insulation).

Treturn: the temperature of the air as it exits the room (assuming the room maintains equilibrium in a worst case scenario) .

n: the highest number of people in the gym in a “worst” case scenario i.e. lecture or convocation.

Qp: average/assumed amount of heat generated by a human to a room temp atmosphere.

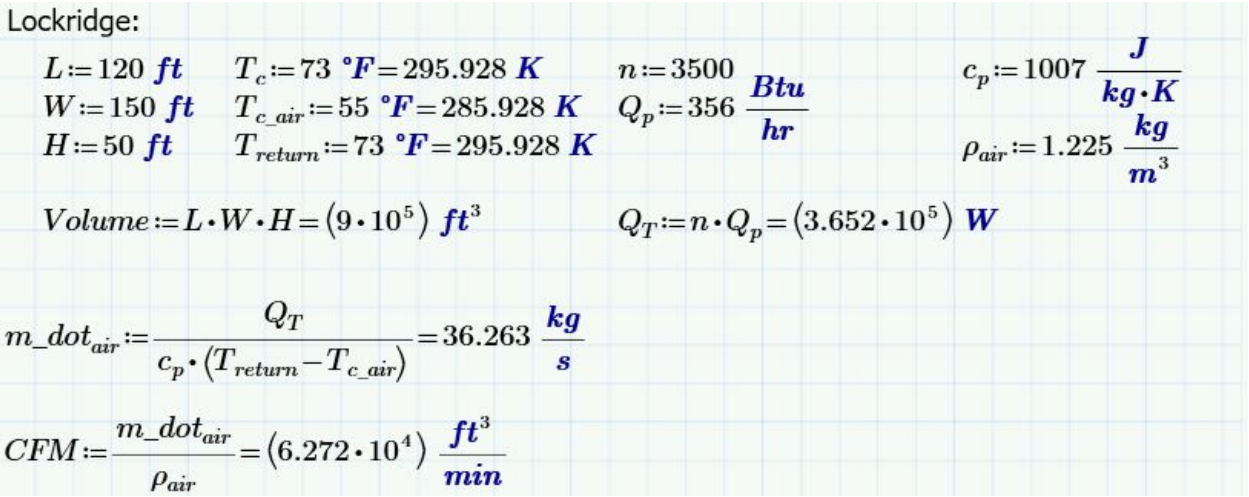
Cp: assumed value to simplify calculations given temperature conditions of room.

P_air: density of air at a given temperature.

QT: total heat generated by all people.

m_dotair: the amount of cold air needed to be supplied to counteract the heat generated by the people in the gym.

CFM: cubic feet per minute of air needed to counteract the heat generated by the people.



Lockridge:

$L := 120\ ft$ $\quad T_c := 73\ °F = 295.928\ K$ $\quad n := 3500$ $\quad c_p := 1007\ \frac{J}{kg \cdot K}$

$W := 150\ ft$ $\quad T_{c\_air} := 55\ °F = 285.928\ K$ $\quad Q_p := 356\ \frac{Btu}{hr}$

$H := 50\ ft$ $\quad T_{return} := 73\ °F = 295.928\ K$ $\quad \rho_{air} := 1.225\ \frac{kg}{m^3}$

$Volume := L \cdot W \cdot H = \left(9 \cdot 10^5\right)\ ft^3$ $\quad Q_T := n \cdot Q_p = \left(3.652 \cdot 10^5\right)\ W$

$$m\_dot_{air} := \frac{Q_T}{c_p \cdot \left(T_{return} - T_{c\_air}\right)} = 36.263\ \frac{kg}{s}$$

$$CFM := \frac{m\_dot_{air}}{\rho_{air}} = \left(6.272 \cdot 10^4\right)\ \frac{ft^3}{min}$$

Figure 6: MathCAD calculations for CFM necessary in worst case scenario

As shown above, in a worst case scenario with 3500 people occupying Lockridge (which was initially rated for 2500), there would need to be a maximum total of 62,720 CFM generated through the supply fan seen in Figure 2. If we were to simply insert the coil into AHU-2 it would be imperative that minimal changes to the rest of the system would be necessary. The maximum CFM necessary is such that the pre-installed supply fan would be capable of fulfilling the needed specifications. It is rated at a maximum of 67,200 CFM, but as the temperature differential increases, the (Treturn - Tc_air) term would increase and the CFM would actually decrease in accordance with the mass flow rate of air equation seen in figure 6. In conducting research on product implementation, the core limiting factor to product selection would be fitting the coil into AHU-2. Modern day coils can support large variances in Propylene Glycol + Water combinations, and the temperature of this mixture as it entered the coil could also be varied and tuned to any parameters since it would be a local system and not dependant on the needs of other facilities on campus. Despite this promising fact however, the fact still stands that there is an issue with stratification of the air, and the further recommendation is made to install fan systems along the ceiling to promote air circulation. Having proven that this type of system would be compatible with fulfilling the design needs of lockridge, further feasibility analysis will need to be done in regard to the logistics of a chillers implementation, whether that be installation to the mechanical or electrical room, and the volume it would need to be rated to depending on the coil size selected.

CONCLUSION

The implementation of a local water chiller and water cooling coil is possible, and the logistical issues posed are not tied into whether it can be done or not. However, the question of whether it will be installed or not would be a matter of cost. We believe that the School of Mines has enough other problems to not need to worry about this one, and would recommend redirecting costs to providing adequate parking solutions for its students. Furthermore, the number of occasions where it is hot, humid, and the arena is heavily occupied are very few each year. This is mostly due to the fact that these hot, humid days occur rarely in Colorado and only occur during the warmer months when a limited number of people are on campus. As a result, the additional costs of adding a local water chiller and cooling coil are likely not worth the small benefit they would provide.

FUTURE INVESTIGATION

At this juncture, exact specifications and cost analysis has not been done on the additional load that would be taken on the lockridge electrical power systems. On top of running power lines to the water chiller, there may be additional installations from the main grid. These costs could potentially be reduced if the electrical room was used, but there may be some issues with space allotment/fitment depending on the exact dimensions available in the mechanical or electrical room. Without a guaranteed space set out for the chiller, there would be the option of mounting it to the roof, but additional vibrational dampers would be needed to ensure there was sufficient noise reduction and further safety analysis would need to be done to ensure the safety of the athletes. There would also need to be installation of a control valve, the coil itself, a pump to circulate the water & propylene glycol mixture, and a controls system to connect the systems programming to that currently in use within the system.

PROBLEMS ENCOUNTERED / REFLECTIONS

Heat Transfer Analysis Issues:
Struggling to find a qualifying CFM value to keep the gym cold. This problem was exacerbated by the fact that the team didn't have extensive heat transfer experience, however the decision was made to create all assumptions as that of a worst case scenario.

ACKNOWLEDGEMENTS

We would like to acknowledge and thank the Mines facilities manager Michael Willy for all the information and database access he granted us. Without his help we would not have been able to get property or equipment information at each stage in the HVAC system.

CITATIONS

[1] http://ergo.human.cornell.edu/studentdownloads/DEA3500notes/Thermal/thcondnotes.html
[2] Thermodynamics: An Interactive Approach, Subrata Bhattacharjee
[3] EES: Engineering Equation Solver

APPENDIX:

[A] M0.02: Mechanical Equipment Schedules
See Attached

[B] M4.02: AHU-2 Airflow and Control Schematic
See Attached

[C] M4.06: Steam / Hot Water Flow, Control, and Piping Schematic
See Attached

ROOFTOP UNIT SCHEDULE

TAG	AREA SERVED	TYPE	SUPPLY FAN SECTION										RETURN FAN SECTION										DIRECT EVAP. COOLING PAD			HEATING COIL								FILTER	VIB	MIN	WT	ELECTRICAL			MFGR	NOTES
			CFM	TSP	ESP	MAX RPM	MAX BHP	MAX HP	DIA	TYPE	ARRANG.	VFD	CFM	TSP	ESP	MAX RPM	MAX BHP	MAX HP	DIA	TYPE	ARRANG.	VFD	THICKNESS	APD"	MIN AREA [FT2]	CFM	EAT	LAT	MBH	APD"	GPM	WPD'	AREA	PRE/FINAL	ISO.	OSA CFM	LBS	V	PH	HZ	MODEL	
AHU-1	GENERAL AREAS	VAV	65,350	5.20	2.00	1000	78.0	100	54	AP	1	Y	64,250	1.60	1.10	800	31.0	40	54	AP	1	Y	12"	0.2	130	13,275	-10	60	806	0.15	42.6	3	130	30/65	INTERNAL SPRING	11,000	76,200	460	3	60	ENERGY LABS CUSTOM	1,3,8
AHU-2	COMPETITION GYM	SINGLE ZONE VAV	67,400	3.90	0.71	1000	64.0	75	54	AP	1	Y	66,495	1.00	0.51	600	20.0	30	60	AP	1	Y	12"	0.2	135	45,000	-10.0	54	2497	0.15	132.0	3	135	30/65	INTERNAL SPRING	3,000/45,000	86,300	460	3	60	ENERGY LABS CUSTOM	1,4,8
AHU-3	RECREATIONAL GYM	SINGLE ZONE CV	11,750	3.8	0.61	1500	11	15	22	AP	1	N									1		12"	0.2	24	11750	59.8	81.9	225	0.15	11.9	3	24	30/65	INTERNAL SPRING	1,500	14,000	460	3	60	ENERGY LABS CUSTOM	2,5,8
AHU-4	NATATORIUM	SINGLE ZONE CV	32,000	4.5	1.0	1500	34	40	36	AP	1	N	32,500	2.4	0.95	900	18	25	44	AP	1	Y	N/A	–	–	32000	66.7	90.7	666	0.15	35.2	3	64	30/65	INTERNAL SPRING	4,500/9,000	55,600	460	3	60	ENERGY LABS CUSTOM	1,2,6
AHU-5	LOCKER ROOMS	CV	4,785	5	1.5	1500	7	10	22	AP	1	N	8,605	2.5	1.3	1800	5	7.5	22	AP	1	N	12"	0.2	10	4785	20	57	154	0.15	8.1	3	10	30/65	INTERNAL SPRING	100%	26,000	460	3	60	ENERGY LABS CUSTOM	2,7,8

GENERAL NOTES:

A. CAPACITIES ARE AT JOB SITE CONDITIONS OF 6,000' ABOVE SL.
B. DIRECT EVAPORATIVE COOLING AREA BASED ON 500 FPM FACE VELOCITY.
C. HEATING COIL PERFORMANCE BASED ON 180°F EWT AND 140°F LWT.
D. HEATING WATER CONTAINS 30% PROPYLENE GLYCOL
E. INDIRECT EVAPORATIVE COOLING UNITS SHALL HAVE A MINIMUM EFFECTIVENESS OF 60% AND INCLUDE ALL CONTROLS MOUNTED IN A NEMA 4 ENCLOSURE.
F. AHUS SHALLHAVE A SINGLE POINT OF POWER CONNECTION FOR ALL ELECTRICAL COMPONENTS.
G. PROVIDE A SLOPED ROOF CURB, MIN. 12" HIGH.
H. SEE M5.03 FOR DETAILS OF AIR-HANDLING UNITS.
I. SEE THE INDIRECT EVAPORATIVE COOLER SCHEDULE FOR IEC UNITS FOR EACH AHU.
J. SEE THE AIR/AIR HEAT EXCHANGER SCHEDULE FOR AHU-4 AND AHU-5.

NOTES:

1. VFD'S UNIT-MOUNTED OUTSIDE THE UNIT WITH COOLING AIR INTO THE ENCLOSURE.
2. STARTERS UNIT-MOUNTED OUTSIDE THE UNIT.
3. COMPONENTS FOR AHU-1 INCLUDE RETURN FAN, ECONOMIZER, BLENDER, FILTER (PRE + 65%), HEATING COIL, INDIRECT EVAP, DIRECT EVAP, SUPPLY FAN.
4. COMPONENTS FOR AHU-2 INCLUDE RETURN FAN, ECONOMIZER, BLENDER, FILTER (PRE + 65%), HEATING COIL, INDIRECT EVAP, DIRECT EVAP, SPACE (ONLY) FOR A CHW COIL, SUPPLY FAN.
5. COMPONENTS FOR AHU-3 INCLUDE ECONOMIZER, BLENDER, FILTER (PRE + 65%), HEATING COIL, INDIRECT EVAP, DIRECT EVAP, SUPPLY FAN.
6. COMPONENTS FOR AHU-4 INCLUDE - EXHAUST SIDE: EXHAUST FAN, FILTER (2" PREFILTER ONLY), AIR/AIR HX; SUPPLY SIDE: ECONOMIZER, BLENDER, FILTER (PRE + 65%), AIR/AIR HX, HEATING COIL, INDIRECT EVAP, SUPPLY FAN.
7. COMPONENTS FOR AHU-5 INCLUDE - EXHAUST SIDE: EXHAUST FAN, FILTER (2" PREFILTER ONLY), AIR/AIR HX; SUPPLY SIDE: FILTER (PRE + 65%), AIR/AIR HX, HEATING COIL, INDIRECT EVAP, DIRECT EVAP, SUPPLY FAN.
8. DESIGN COOLING SUPPLY AIR TEMPERATURE IS 60°F.

AIR/AIR HEAT EXCHANGER SCHEDULE

TAG	PURPOSE	AIRFLOW (CFM)	EAT (°F)	LAT (°F)	PRESSURE DROP (IW)	BYPASS AIRFLOW (CFM)	NOTES
AHU-4	SUPPLY	9,000	-10	34	0.42	32,000	
	EXHAUST	9,500	85	56	0.5		
AHU-5	SUPPLY	4,800	-10	22	0.18	4,800	
	EXHAUST	8,600	75	55	0.45		

GENERAL NOTES:

A PERFORMANCE IS AT SITE CONDITIONS, 6000' ASL.
B UNIT SIZED TO FIT INSIDE AHU, WITH FULL (CENTER) BYPASS.

PUMP SCHEDULE

TAG	PURPOSE	TYPE	GPM	FEET HEAD	RPM	ELECTRICAL				EFF	VFD	MANUFACTURER AND MODEL	NOTES
						HP	V	PH	HZ				
HWP-1	HEATING WATER	BASE MNTD.	294	72	1750	10	460	3	60		N	B & G SERIES 1510-2.5BB	1
HWP-2	HEATING WATER	BASE MNTD.	294	72	1750	10	460	3	60		N	B & G SERIES 1510-2.5BB	1

NOTES:

1. PUMPED FLUID IS 30% P.G.
2.

HEAT EXCHANGER SCHEDULE

TAG	PURPOSE	WATER SIDE					STEAM SIDE		MBH	WT	MANUFACTURER & MODEL	NOTES
		GPM	EWT F	LWT F	FT WPD	FLUID	PSIG	PPH		LBS.		
HX-1	HEATING WATER	310	142	180	1.3	30% PG	2.0	5747	5586		B & G SU14-7-4	2
HX-2	HEATING WATER	310	142	180	1.3	30% PG	2.0	5747	5586		B & G SU14-7-4	2

GENERAL NOTES:

A. HX-1 AND 2 ARE EACH SIZED FOR THE PEAK HEATING LOAD FOR THE BUILDING.
B. TUBESIDE FOULING FACTOR OF .00025 FOR HX-1/2 AND .001 FOR HX-3 AND 4.
C. MINIMUM NOZZLE CONNECTION SIZE SHALL MATCH PIPING SIZE.

NOTES:

1. ADMIRALTY BRASS TUBES, CAST BRASS HEAD, STEEL SHELL.
2. COPPER TUBES, CAST IRON HEAD, STEEL SHELL.

INDIRECT EVAPORATIVE COOLING UNIT SCHEDULE

TAG	AHU No.	NOMINAL CFM	FANS (QTY) HP	PUMP HP	MANUFACTURER AND MODEL NUMBER	NOTES
IEC-1	AHU-1	11,000	(2) 3/4	3/4	ENERGY LABS, I-110-48	
IEC-2	AHU-1	22,000	(2)1-1/2	3/4	ENERGY LABS, I-220-48	
IEC-3	AHU-1	11,000	(2) 3/4	3/4	ENERGY LABS, I-110-48	
IEC-4	AHU-1	22,000	(2)1-1/2	3/4	ENERGY LABS, I-220-48	
IEC-5	AHU-2	12,000	(2) 3/4	3/4	ENERGY LABS, I-120-48	
IEC-6	AHU-2	22,000	(2)1-1/2	3/4	ENERGY LABS, I-220-48	
IEC-7	AHU-2	12,000	(2) 3/4	3/4	ENERGY LABS, I-120-48	
IEC-8	AHU-2	22,000	(2)1-1/2	3/4	ENERGY LABS, I-220-48	
IEC-9	AHU-3	6,000	(1) 3/4	1/2	ENERGY LABS, I-60-36	
IEC-10	AHU-3	6,000	(1) 3/4	1/2	ENERGY LABS ,I-60-36	
IEC-11	AHU-4	16,000	(2) 1.0	3/4	ENERGY LABS, I-160-48	
IEC-12	AHU-4	16,000	(2) 1.0	3/4	ENERGY LABS, I-160-48	
IEC-13	AHU-5	6,000	(1) 3/4	1/2	ENERGY LABS ,I-60-36	

GENERAL NOTES:

1 ALL MOTORS ARE 460V/3-PHASE.
2 UNITS ARE PRE-WIRED WITH ALL REQUIRED ELECTRICAL COMPONENTS (SEE SPEC.)
3 400 FPM MAX. FACE VELOCITY OF PRIMARY AIRFLOW ACROSS HX, 60% MIN. EFFECTIVENESS.

GRILLE/REGISTER/DIFFUSER SCHEDULE

TAG	PURPOSE	TYPE	MOUNTING	PATTERN	NC (MAX)	ACCESSORIES	MANUFACTURER AND MODEL	NOTES
A	SUPPLY	DIFFUSER	LAY-IN	4-WAY	25		TITUS TMS	1
B	SUPPLY	DIFFUSER	SURFACE	4-WAY	25	OBD	TITUS TMS	1
C	RETURN/EXHST	GRILLE	LAY-IN/SUR	-	-		TITUS PAR	1,4
D	RETURN/EXHST	REGISTER	SURFACE	-	30		TITUS 50F	
E	RETURN/EXHST	GRILLE	SURFACE	-	25	OBD	TITUS 350FL	
F	SUPPLY	REGISTER	SURFACE	DBL DEFL	25	OBD	TITUS 272RS	
G	SUPPLY	DRUM LOUVER	DIRECT	DBL DEFL	30	OBD	TITUS DL	3
H	SUPPLY	GRILLE	DIRECT	DBL DEFL	25	ASD	TITUS S300FS	3
I	RETURN/EXHST	GRILLE	SURFACE	-	25		TITUS 63FL	
J	SUPPLY/RETURN	LINEAR DIFFUSER	SURFACE	-	25	OBD	TITUS CT-540	2
K	SUPPLY	PLENUM SLOT	SURFACE	-	25		TITUS TBD-30	5,6
L	SUPPLY	DIFFUSER	DIRECT	-	25		TITUS TMRA-AA	
M	SUPPLY	DIFFUSER	LAY-IN	-	25		TITUS TDC	5
N	RETURN/EXHST	GRILLE	SURFACE	-	25		TITUS 350ZFL	

GENERAL NOTES:

A. ASSUMES 10 Db ROOM ABSORPTION
B. RETURNS AND TG'S SHALL NOT HAVE OBD'S

NOTES:

1. 24x24 MODULE TYPICAL
2. 4" NOMINAL DUCT SIZE, 1/4" BARS, 0 DEFLECTION, 1/2" SPACING
3. SEE TAGS ON DRAWING FOR <QTY, DEFLECTION ANGLE, DOWN ANGLE
4. INSTALL SOUND BOOT IN ALL AREAS EXCLUDING CORRIDORS AND CIRCULATION AREAS
5. SEE DWGS FOR DISCHARGE PATTERN
6. 2 SLOT, 3/4" SLOT WIDTH

FAN SCHEDULE

TAG	SERVICE	TYPE	CFM	ESP	RPM	VFD	ELECTRICAL				WT.	DRIVE	MANUF. & MODEL	NOTES
							HP	V	PH	HZ	LBS.	TYPE		
EF-1	RECREATION GYM	DOWNBLAST VENTILA	6,000	0.25	1,079	Y	1.5	460	3	60	200	B	COOK ACE 210C 8B	1
EF-2	RECREATION GYM	DOWNBLAST VENTILA	6,000	0.25	1079	Y	1.5	460	3	60	200	B	COOK ACE 210C 8B	1
EF-3	SANITIZER ROOM	UPBLAST VENTILATOR	100	0.2	903	N	1/8	120	1	60	28	D	COOK ACRU 90R15DH	1, 2, 3
EF-4	NW RESTROOMS	DOWNBLAST VENTILA	875	0.5	1260	N	1/3	120	1	60	55	B	COOK ACE 120C 2B	1, 3
EF-5	NE RESTROOMS	DOWNBLAST VENTILA	950	0.5	1295	N	1/3	120	1	60	55	B	COOK ACE 120C 2B	1, 3
EF-6	CONCESSION HOOD	UPBLAST VENTILATOR	1,750	0.5	1188	N	1/3	120	1	60	70	B	COOK ACRU 150R 4B	1, 3
EF-7	PH BUFFER ROOM	UPBLAST VENTILATOR	100	0.2	903	N	1/8	120	1	60	28	D	COOK ACRU 90R15DH	1, 2, 3

GENERAL NOTES:

A. ALL WELDED CONSTRUCTION WITH DRAIN PLUG AND VIB. ISOLATION BASE.
B. MOTOR HP AT DESIGN CONDITIONS SHALL NOT BE LESS THAN 125% OF BHP.
C. STATIC PRESSURES SHOWN ARE AT SITE CONDITIONS, 5800' ASL.

NOTES:

1 14" HIGH ROOF CURB
2 SPEED CONTROL
3 ISOLATION DAMPER WITH ACTUATOR, (OPENS WHEN FAN IS STARTED).

MISCELLANEOUS EQUIPMENT

TAG	PURPOSE OR TYPE	DESCRIPTION	NOTES
AS-1	HW AIR SEPARATER	BELL AND GOSSET, RL-5, 5"	
CDP-1, 2	STEAM CONDENSATE PUMP	SPIRAX-SARCO, PIVOTROL MODEL PTC, 10,000 PPH PER PUMP, 3" X 2" SIZE, 50 PSIG STEAM MOTIVE PRESSURE, 15 PSIG BACK PRESSURE.	
CRAC-1	DATA ROOM COOLING UNIT	LIEBERT 1.5 TON MINI MATE 2, CEILING MOUNTED, AIR COOLED, SPLIT SYSTEM, 12,000 BTUH SENSIBLE, 72F/50% RH, 105F AMBIENT, 6000' ASL; EVAPORATOR (INDOORS) 208V/1-PHASE, 1.4 FLA, 1.8 WSA, 15 OPD; CONDENSER (ON ROOF), 208V/1-PHASE, 11.4 FLA, 13.9 WSA, 20 OPD	
CRAC-2	DATA ROOM COOLING UNIT	LIEBERT 3 TON MINI MATE 2, CEILING MOUNTED, AIR COOLED, SPLIT SYSTEM, 24,000 BTUH SENSIBLE, 72F/50% RH, 105F AMBIENT, 6000' ASL; EVAPORATOR (INDOORS) 208V/1-PHASE, 2.8 FLA, 3.5 WSA, 15 OPD; CONDENSER (ON ROOF), 2460V/3-PHASE, 7.4 FLA, 8.8 WSA, 15 OPD	
EXPT-1	HW EXPANSION TANK	AMTROL, EXTROL MODEL 300-L, 42 GALLON MINIMUM ACCEPTANCE VOLUME, DIAPHRAGM TANK, 66.4 GALLON MINIMUM TANK VOLUME, ASME CONSTRUCTION, VERTICAL TANK, WITH VIEW PORT	
GF-1	HW GLYCOL FEEDER	SEE SPEC. SECTION 15145, SAGE INDUSTRIES, 50 GALLON TANK	
LV-1		LOUVER, RUSKIN MODEL ELF-375, 4" DEEP, EXTRUDED ALUMINUM BLADES AND FRAME, ANODIZED FINISH, COLOR BY ARCHITECT, INSECT SCREEN ON INSIDE WITH REMOVABLE FORMED ALUMINUM CHANNEL FRAME, SIZE ON PLANS.	
SPR-1	STEAM PRV	LESLIE, MODEL GPKP, 3" SIZE, 80 PSIG INLET PRESSURE, 15 PSIG OUTLET PRESSURE, 6900 PPH.	
SPR-2	STEAM PRV	LESLIE, MODEL GPKP, 2" SIZE, 80 PSIG INLET PRESSURE, 15 PSIG OUTLET PRESSURE, 3500 PPH.	
SPR-3	STEAM PRV	ARMSTRONG MODEL GD-45, 80 PSIG INLET PRESSURE, 7 - 50 PSIG ADJUSTABLE OUTLET PRESSURE, 50 PPH, 1/2" SIZE.	
SPRV-1	STEAM RELIEF VALVE	LESLIE, FIGURE 31, MODEL BC0041PMD, 4" X P X 6", 25 PSIG RELIEF SETTING, SIZED FOR SPR-1.	

NOTES:

1. SEE DRAWINGS FOR SIZES.

SOUND ATTENUATOR SCHEDULE

TAG	DYNAMIC INSERTION LOSS (dB) @ LISTED FREQ.(HZ)								LENGTH	FACE SIZE	FACE VELOCITY [FPM]	MAX. P.D. [IWC]	MANUFACTURER AND MODEL	NOTES
	63	125	250	500	1000	2000	4000	8000						
SA-1S	17	23	41	51	50	28	21	16	10'	see plans	+1000	0.25	IAC-LFM	1
SA-1R	20	25	43	52	51	27	22	17	10'	see plans	-1000	0.25	IAC-LFM	1
SA-2S	10	20	35	45	50	48	45	34	7'	see plans	+1000	0.23	IAC-S	
SA-2R	6	8	14	23	27	20	14	8	3'	see plans	-2000	0.40	IAC-MS	2
SA-3S	15	16	31	41	38	22	16	14	7'	see plans	+1000	0.23	IAC-LFM	2
SA-3R	12	15	27	31	30	17	14	13	5'	see plans	-1000	0.20	IAC-LFM	2
SA-4S	10	20	35	45	50	48	45	34	7'	see plans	+1000	0.23	IAC-S	
SA-4R	15	19	33	43	39	21	17	15	7'	see plans	-1000	0.23	IAC-LFM	
SA-5S	15	16	31	41	38	22	16	14	7'	see plans	+1000	0.23	IAC-LFM	
SA-5R	12	15	27	31	30	17	14	13	5'	see plans	-1000	0.20	IAC-LFM	

GENERAL NOTES:

A. DYNAMIC INSERTION LOSS IS IN Db
B. DYNAMIC INSERTION LOSS IS BASED ON FACE VELOCITY LISTED
C. MAX. PRESSURE LOSS (P.D.) IS RATED AT FACE VELOCITY LISTED.
D. NEGATIVE VELOCITY INDICATES SOUND OPPOSITE FLOW

NOTES:

1. ELBOW-TYPE CONFIGURATION
2. TWO UNITS REQUIRED

VARIABLE AIR VOLUME UNIT SCHEDULE

TAG	MAX. CFM	INLET SIZE	OUTLET SIZE	APD IN.	VIB. ISO.	DISCHARGE SOUND POWER							RADIATED SOUND POWER							SOUND ATTENUATOR	MANUFACTURER & MODEL	NOTES
						125	250	500	1K	2K	4K	ROOM NC	125	250	500	1K	2K	4K	ROOM NC			
A	180	4"	12"x8"	0.00	NONE	74	68	69	69	69	58	35	69	63	59	56	60	64	35	NONE	TITUS ESV	
B	400	6"	12"x8"	0.0	NONE	76	70	74	92	81	66	35	69	63	59	56	60	64	35	NONE	TITUS ESV	
C	720	8"	12"x10"	0.0	NONE	77	71	72	71	71	61	35	69	63	59	56	60	64	35	NONE	TITUS ESV	
D	1120	10"	14"x12"	0.2	NONE	77	71	72	71	70	60	35	69	63	59	56	60	64	35	NONE	TITUS ESV	
E	1600	12"	16"x16"	0.2	NONE	79	73	74	73	72	62	35	69	63	59	56	60	64	35	NONE	TITUS ESV	
F	2400	14"	20"x18"	0.2	NONE	79	73	74	73	72	62	35	69	63	59	56	60	64	35	NONE	TITUS ESV	
G	3200	16"	24"x18"	0.2	NONE	79	73	74	73	72	62	35	69	63	59	56	60	64	35	NONE	TITUS ESV	

GENERAL NOTES:

A. SEE HVAC PLANS FOR COOLING MAX/MIN CFM AND HEATING CFM FOR EACH BOX.
B. SEE PIPING PLANS FOR BOXES WHICH REQUIRE HEATING COILS. HEATING GPM LISTED ON PLANS.
C. HEATING COIL PERFORMANCE BASED ON 30% PG SOLUTION, 180F EWT, 150F LWT AT LISTED HEATING CFM.
D. NC LEVELS ARE REFERENCE ONLY
F. PERFORMANCE IS AT JOBSITE ELEVATION, 6000' ASL.
G. CONNECTING DUCT SIZES SHALL BE THE SAME SIZE AS THE BOX INLET/OUTLET SIZES, UNLESS NOTED OTHERWISE ON THE DRAWINGS.
F. PERFORMANCE IS AT JOBSITE ELEVATION, 6000' ASL.

CABINET/UNIT HEATER SCHEDULE

TAG	LOCATION	TYPE	HTG BTUH	GPM	WPD'	CFM	RPM	ELECTRICAL				MANUFACTURER & MODEL	NOTES
								HP	V	PH	HZ		
CUH-1	VESTIBULE 100	RECESS. CLNG. MNTD.	13524	1.0	3.0	350		0.25	120	1	60	VULCAN RC-04	
CUH-2	VESTIBULE 100	RECESS. CLNG. MNTD.	13524	1.0	3.0	350		0.25	120	1	60	VULCAN RC-04	
CUH-3	VESTIBULE 100A	RECESS. CLNG. MNTD.	14810	1.0	3.0	370		0.25	120	1	60	VULCAN RC-04	
CUH-4	VESTIBULE 101	RECESS. CLNG. MNTD.	9000	0.6	3.0	225		0.25	120	1	60	VULCAN RC-03	
CUH-5	STAIR 3	FLOOR MOUNTED	37075	2.6	3.0	925		0.25	120	1	60	VULCAN F-10	
CUH-6	VESTIBULE 240	RECESS. CLNG. MNTD.	12300	0.9	3.0	305		0.25	120	1	60	VULCAN RC-04	
CUH-7	VESTIBULE 240	RECESS. CLNG. MNTD.	12300	0.9	3.0	305		0.25	120	1	60	VULCAN RC-04	
UH-1	RECEIVING 144	CEILING HUNG	9000	0.6	3.0	500		0.25	120	1	60	VULCAN HV-118A	
UH-2	RECEIVING 144	CEILING HUNG	9000	0.6	3.0	500		0.25	120	1	60	VULCAN HV-118A	

GENERAL NOTES:

A. HEATING CAPACITIES BASED ON 180 DEGREE EWT, 150 DEGREE LWT, 60 DEGREE EAT.
B. CAPACITIES ARE AT SITE CONDITIONS, 6000' ASL
C. 30% PROPYLENE GLYCOL

NOTES:

1. PROVIDE UNIT WITH WALL MOUNTED THERMOSTAT
2. PROVIDE UNIT WITH DOWN DISCHARGE ADJUSTABLE LOUVER.
3. PROVIDE UNIT WITH INTEGRAL THERMOSTAT.

COIL SCHEDULE

TAG	SIZE (FINNED WIDTH X FINNED HEIGHT)	CFM	MBH	EAT DEG F	LAT DEG F	GPM	APD IN.	WPD FT.	MANUFACTURER & MODEL	NOTES
RHC-107A	14" x 12"	610	11975	60	82.6	0.8	0.1	3	Trane	
RHC-107	10" x 12"	450	6242	60	76.0	0.4	0.1	3	Trane	
RHC-109	16" x 12"	815	11305	60	76.0	0.8	0.1	3	Trane	
RHC-109D	8" x 6"	200	2774	60	76.0	0.2	0.1	3	Trane	
RHC-107D	7" x 9"	250	6373	60	89.4	0.4	0.1	3	Trane	
RHC-132	6" x 6"	95	1318	60	76.0	0.1	0.1	3	Trane	
RHC-130	10" x 9"	425	5895	60	76.0	0.4	0.1	3	Trane	
RHC-128	8" x 12"	410	5687	60	76.0	0.4	0.1	3	Trane	
RHC-134	10" x 6"	240	3329	60	76.0	0.2	0.1	3	Trane	
RHC-135	6" x 6"	145	2011	60	76.0	0.1	0.1	3	Trane	
RHC-120	10" x 12"	460	7216	60	78.1	0.5	0.1	3	Trane	
RHC-121	10" x 12"	445	8548	60	82.2	0.6	0.1	3	Trane	
RHC-126	6" x 6"	90	1248	60	76.0	0.1	0.1	3	Trane	
RHC-127	6" x 6"	150	2658	60	80.4	0.2	0.1	3	Trane	

GENERAL NOTES:

A. HEATING CAPACITIES BASED ON 180 DEGREE EWT, 150 DEGREE LWT, 30% PROPYLENE GLYCOL
B. CAPACITIES ARE AT SITE CONDITIONS, 6000' ASL..
C. PROVIDE COILS WITH SLIP AND DRIVE DUCT CONNECTIONS.
D. INSTALL AN 8"x8" ACCESS DOOR UPSTREAM OF EACH RHC.

NOTES:

1.

SINK COMBS DETHLEFS

A Professional Corporation for Architecture
475 Lincoln Street, Suite 100
Denver, Colorado 80203
303 308 0200
FAX 308 0222

CIVIL ENGINEER: MARTIN/MARTIN
LANDSCAPE ARCHITECT: studio INSITE LLC.
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ACOUSTICAL: WJHW

ENGINEERS CONSULTANTS
RMH GROUP

The RMH Group, Inc.
12600 West Colfax Avenue
Lakewood, Colorado 80215
Phone (303) 239-0909
Fax (303) 235-0218
RMH Job Number: 18946

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Issues/Revisions:	Date:
SCHEMATIC DESIGN	02/21/05
DESIGN DEVELOPMENT	05/16/05
BID PKG. 1 SITE AND FND.	07/08/05
GMP	08/05/05
100% CD'S	09/02/05
FINAL CD'S	09/23/05
ADDENDA 1-4	10/14/05
ADDENDA 5	10/21/05
REVISIONS 6	11/30/05
COB-6	12/12/05
COB-7 C7	12/23/05

COLORADO SCHOOL OF MINES
STUDENT RECREATION CENTER
GOLDEN, COLORADO

SCD Project No.: 0422

MECHANICAL EQUIPMENT SCHEDULES

Drawn by: CMT
Checked by: REP

M0.02

AHU–2 SEQUENCE OF OPERATION

A. GENERAL: AHU–2 SERVES ONLY A SINGLE ZONE. IT HAS A VARIABLE–FLOW SUPPLY FAN, WHICH MODULATES ITS SPEED TO CONTROL SPACE TEMPERATURE. THE UNIT HAS A MIXED–AIR ECONOMIZER, HEATING COIL, INDIRECT EVAPORATIVE COOLING MODULES AND A DIRECT EVAPORATIVE COOLING PAD. THE RETURN FAN IS ALSO A VARIABLE FLOW FAN.

B. THE UNIT SHALL BE OPERATED ON AN OCCUPANCY MODE SCHEDULE (OCCUPIED–UNOCCUPIED), WHICH SHALL BE DETERMINED THROUGH A USER–ADJUSTABLE, GRAPHICAL, SEVEN–DAY SCHEDULE WITH AN ADDITIONAL HOLIDAY SCHEDULE. THE START TIME SHALL BE ADJUSTED BY AN OPTIMUM–START ROUTINE SUCH THAT THE UNIT IS STARTED AT THE LATEST POSSIBLE TIME TO ALLOW THE SPACE TEMPERATURES TO BE AT THE OCCUPIED SETPOINT AT THE TIME OF OCCUPANCY. INITIALLY THE UNIT SHALL BE CONFIGURED TO OPERATE CONTINUOUSLY IN THE OCCUPIED MODE.

C. OCCUPIED MODE:

1. THE SUPPLY FAN SHALL BE ENERGIZED. THE FAN SPEED SHALL BE SLOWLY RAMPED FROM ZERO TO AN INITIAL 50% VALUE WHEN THE SUPPLY FAN IS STARTED, WITH THE OUTSIDE AIR DAMPER CLOSED AND THE RETURN AIR DAMPER FULLY OPEN UNTIL THE FAN REACHES ITS INITIAL OPERATING SPEED (ALLOW 2–MINUTES MIN.). THE AIR HANDLER SUPPLY FAN SPEED SHALL MODULATE BETWEEN ITS MINIMUM AND MAXIMUM CFM SETTINGS WITH A PI CONTROL LOOP TO MAINTAIN THE SPACE TEMPERATURE SETPOINT OF 75°F (ADJ.) IN COOLING MODE AND 70°F IN HEATING MODE. THE FAN AIRFLOW RATE (CFM) SHALL BE MEASURED BY THE FAN–INLET FLOW METER. THE SPACE TEMPERATURE READING SHALL BE DETERMINED BY AVERAGING THE READINGS OF ALL TEMPERATURE SENSORS IN THE SPACE. THE FAN SPEED CONTROL LOOP SHALL BE TUNED TO BE SLOW–ACTING, TO MINIMIZE FLUCTUATIONS IN FAN SPEED.

SUPPLY AIR FLOW LIMITS	CFM VALUE
MAXIMUM	AS NOTED ON AHU SCHEDULE
MINIMUM	20% OF MAX. VALUE

2. WHENEVER THE SUPPLY FAN IS ENERGIZED, AFTER A 20–SECOND (ADJUSTABLE) TIME DELAY, THE RETURN FAN SHALL BE ENERGIZED. THE RETURN FAN SPEED SHALL MODULATE TO MAINTAIN THE RETURN AIR PLENUM PRESSURE SETPOINT OF 0.15" W.G. (ADJUSTABLE) REFERENCED TO OUTSIDE AIR.

3. THE EXHAUST AIR DAMPER SHALL MODULATE TO MAINTAIN THE SPACE STATIC PRESSURE SETPOINT OF 0.05" W.G. (ADJUSTABLE) REFERENCED TO OUTSIDE AIR.

4. IN COOLING MODE, DISCHARGE AIR TEMPERATURE SETPOINT SHALL BE RESET BASED UPON OUTDOOR AIR TEMPERATURE ACCORDING TO THE FOLLOWING RESET SCHEDULE:

DISCHARGE AIR TEMPERATURE SETPOINT	OUTDOOR TEMPERATURE
55°F	> 70°F
65°F	< 30°F

ALL PARAMETERS SHALL BE INDEPENDENTLY ADJUSTABLE.

5. THE MINIMUM OA DAMPER SECTION SHALL BE OPEN TO ITS MINIMUM POSITION (SET IN CONJUNCTION WITH THE BALANCE CONTRACTOR AT THE MIN. SCHEDULED OA CFM), OR GREATER, AT ALL TIMES (EXCEPT DURING THE STARTUP PERIOD) TO MAINTAIN MINIMUM OUTSIDE AIR FLOW.

A. WHEN THE MINIMUM OA DAMPER SECTION IS AT ITS MINIMUM POSITION, IT SHALL BE OPENED FURTHER IF ANY CO2 SENSOR RECORDS A READING OF 700 PPM OR HIGHER. THE MINIMUM DAMPER POSITION SHALL BE OPENED GRADUALLY UNTIL THE CO2 READING DECREASES BELOW A READING OF 500 PPM. IN DECREASING THE CO2 LEVEL IN THE BUILDING AT A TIME WHEN THE OA DAMPER SHOULD BE AT ITS MINIMUM POSITION FOR MAINTAINING MAT SETPOINT, DO NOT OPEN THE MINIMUM OA DAMPER (AND OTHER OA DAMPER SECTIONS AS NEEDED) BEYOND THE MINIMUM OA MAXIMUM POSITION SETTING (SET IN CONJUNCTION WITH THE BALANCE CONTRACTOR AT THE MAX. SCHEDULED MIN. OA CFM).

B. IF THE MIN. OA DAMPER (AND OTHER OA DAMPER SECTIONS AS NEEDED) HAS BEEN OPENED TO ITS MAXIMUM POSITION SETTING AND THE CO2 LEVELS HAVE STILL NOT DROPPED BELOW 500 PPM, SLOWLY RAMP UP THE FAN SPEED UNTIL THE CO2 LEVELS REACH THE DESIRED LEVEL. STEP UP THE FAN SPEED IN INCREMENTS OF 3% (ON A 0–100% SCALE), WITH A TIME DELAY OF 5–MINUTES BETWEEN CHANGES. DO NOT EXCEED A SA FLOW OF 45,000 CFM IN THIS CONDITION, AS MEASURED BY THE SF FLOW MEASUREMENT STATION. ONCE THE CO2 LEVEL STAYS BELOW 500 PPM FOR 15–MINUTES OR LONGER, STEP THE FAN SPEED DOWN IN SIMILAR INCREMENTS UNTIL THE NORMAL OPERATING POINT IS REACHED.

C. DON'T START OPENING THE OTHER OA DAMPERS UNTIL THE MINIMUM OA DAMPER IS FULLY OPEN.

6. IN COOLING MODE, THE MIXED AIR DAMPERS, DIRECT EVAPORATIVE COOLER (DEC), AND INDIRECT EVAPORATIVE COOLER (IEC) SHALL MODULATE IN SEQUENCE TO MAINTAIN DISCHARGE AIR TEMPERATURE SETPOINT. PROVIDE DEADBAND BETWEEN HEATING AND COOLING.

7. MIXED AIR TEMPERATURE CONTROL. WHEN THE OUTSIDE AIR ECONOMIZER IS USED FOR COOLING, THE RETURN AIR AND OA DAMPERS SHALL MODULATE IN UNISON TO MAINTAIN A MIXED AIR TEMPERATURE SETPOINT. THE MAT SETPOINT SHALL BE RESET THROUGH A CASCADE ACTION BASED ON DAT SETPOINT. A SEPARATE PI MODULE SHALL CONTROL THE MA DAMPERS, WITH MAT AS AN INPUT. THE SETPOINT FOR THIS PI MODULE SHALL ORIGINATE FROM THE DAT CONTROL PI MODULE. THE MAT SETPOINT SHALL BE SCALED LINEARLY AS THE DAT CONTROL PI MODULE VARIES FROM MINIMUM TO MAXIMUM. AS ADDITIONAL OA IS CALLED FOR, THE MINIMUM OA DAMPER SHALL BE HELD IN ITS FULL–OPEN POSITION AND THE OTHER OA DAMPERS SHALL BE MODULATED WITH A COMMON SIGNAL.

8. HEATING MODE SHALL BE ACTIVATED WHENEVER THE SPACE TEMPERATURE FALLS BELOW THE SPACE HEATING SETPOINT AND THE IEC AND DEC MODULES ARE OFF, AND THE MIXED AIR DAMPERS ARE AT MINIMUM POSITION (EXCEPT AS OVERRIDDEN BY THE CO2 CONTROLS), AND THE FAN IS AT MINIMUM SPEED (EXCEPT AS OVERRIDDEN BY CO2 CONTROLS).

A. SET THE FAN SPEED TO MAINTAIN 25,000 CFM.

B. RAISE THE DAT SETPOINT IN 3°F INCREMENTS ABOVE THE CURRENT COOLING MODE SETPOINT UNTIL THE HEATING SPACE TEMPERATURE SETPOINT IS REACHED, WITH A 5–MINUTE TIME DELAY BETWEEN CHANGES. LOWER THE DAT SETPOINT IN SIMILAR INCREMENTS, WITH A 5–MINUTE TIME DELAY, AS NEEDED TO MAINTAIN THE SPACE TEMPERATURE SETPOINT.

C. WHEN THE DAT SETPOINT IS LOWERED TO A VALUE LESS THAN THE CURRENT COOLING SETPOINT FOR A PERIOD OF 30–MINUTES OR LONGER, SWITCH BACK TO COOLING MODE.

8. NOT USED

9. DIRECT EVAPORATIVE COOLER (DEC) SECTION:

A. STAGE THE EVAPORATIVE COOLER PUMPS TO MAINTAIN THE DAT SETPOINT. MINIMUM OF 15–MINUTES (ADJ.) BETWEEN STARTING AND STOPPING A STAGE. STAGE 1 – 1–FOOT SECTIONS OF PAD ACTIVATED, STAGE 2 – 2–FOOT SECTIONS OF PAD ACTIVATED (1–FOOT SECTIONS OFF), STAGE 3 – ENTIRE PAD ACTIVATED. WHEN GOING FROM STAGE 1 TO STAGE 2, TURN OFF STAGE 1 FOR 10–MINUTES (ADJ) BEFORE ACTIVATING STAGE 2, TO GIVE TIME FOR THE STAGE 1 PAD TO DRY OUT. WHEN GOING FROM STAGE 2 TO STAGE 1, TURN OFF STAGE 2 FOR 10–MINUTES (ADJ) BEFORE ACTIVATING STAGE 1, TO GIVE TIME FOR THE STAGE 2 PAD TO DRY OUT.

B. THE EVAPORATIVE COOLER SHALL OPERATE CONTINUOUSLY AS LONG AS THERE IS A CALL FOR COOLING, EXCEPT WHEN THERE IS A HIGH HUMIDITY LEVEL IN THE BUILDING. THE OUTDOOR AIR DAMPER SHALL BE FULLY OPEN WHENEVER THE EVAPORATIVE COOLER IS IN USE.

C. THE EVAPORATIVE COOLER SUMP SHALL DRAIN WHEN THE OUTSIDE AIR TEMPERATURE DROPS BELOW 40°F (ADJUSTABLE) FOR 2 HOURS (ADJUSTABLE). THE EVAPORATIVE COOLER SUMP SHALL FILL ONLY WHEN THE OUTSIDE AIR TEMPERATURE EXCEEDS 55°F AND THE SPRAY PUMP IS CALLED FOR ON A CALL FOR COOLING. PROVIDE AN ADJUSTABLE TIME DELAY BETWEEN THE FILL AND PUMP–ON SIGNALS TO ALLOW THE SUMP TO FILL (IF THE SUMP HAS BEEN FILLED PREVIOUSLY AND NOT DRAINED, THE TIME DELAY DOES NOT NEED TO OCCUR). PROGRAM A WEEKLY SUMP DRAINAGE CYCLE TO COINCIDE WITH THE EVAPORATIVE COOLER PAD DRY–OUT PERIOD ON SUNDAY MORNING. DRAIN THE SUMP ONLY IF IT HAS NOT BEEN DRAINED IN THE PRECEDING FOUR DAYS.

D. THE EVAPORATIVE COOLER SPRAY PUMP SHALL HAVE SOFTWARE INTERLOCKS TO PERMIT OPERATION ONLY WHEN THE SA FAN IS RUNNING, THE SUMP HAS BEEN FILLED, AND THE OA DAMPER IS OPEN 100%. THERE SHALL BE MINIMUM ON AND OFF TIMERS FOR THE PUMP (INDEPENDENTLY ADJUSTABLE) TO PREVENT SHORT CYCLING. THERE SHALL BE A DAILY DRY–OUT CYCLE OF 60 MINUTES (ADJUSTABLE) DURING WHICH TIME THE EVAPORATIVE COOLER PUMPIS DE–ENERGIZED. THIS DRY–OUT SHALL OCCUR DAILY BETWEEN 5 A.M. AND 6 A.M. (ADJUSTABLE) IF THE EVAPORATIVE COOLER HAS NOT BEEN OFF FOR AT LEAST ONE HOUR DURING THE PREVIOUS 24 HOURS.

E. PUMPS SHALL BE INTERLOCKED WITH SUMP LEVEL SWITCHES TO DE–ENERGIZE THE PUMPS WHEN THE SUMP WATER LEVEL IS LOW.

F. THE SPRAY PUMPS SHALL BE DEACTIVATED DURING COOLING MODE WHEN HIGH HUMIDITY LEVELS ARE DETECTED IN THE BUILDING. IF THE RA HUMIDITY SENSOR DETECTS HUMIDITY LEVELS OVER 60% RH (ADJ.) FOR A PERIOD OF AT LEAST 30 MINUTES (ADJ.), THE PUMPS SHALL BE SWITCHED OFF. THE PUMPS SHALL BE REACTIVATED WHEN THE HUMIDITY LEVEL DROPS 10% RH (ADJ.) BELOW THE HIGH–LIMIT RH SETPOINT FOR A CONTINUOUS PERIOD OF 60 MINUTES (ADJ.).

G. THERE ARE TIMES WHEN THE EVAPORATIVE COOLER WILL COOL THE AIR BELOW THE DAT SETPOINT. THIS WILL OCCUR DURING PERIODS WHEN THE DRY–BULB TEMPERATURE IS ABOVE 55°F AND THE WET–BULB TEMPERATURE IS BELOW 50°F. UNDER THESE CONDITIONS, ALLOW THE DAT TO GO DOWN TO 50°F, THEN SHUTDOWN THE PUMP. CYCLE THE UNIT BACK ON, WHEN THE DAT RISES ABOVE ITS SETPOINT. LOCKOUT THE HEATING COIL VALVE SO HEATING AND COOLING DO NOT OCCUR SIMULTANEOUSLY.

10. INDIRECT EVAPORATIVE COOLER (IEC) MODULES:

A. IEC MODULES SHALL BE STAGED ON IF THE DEC ALONE IS NOT ABLE TO MAINTAIN THE DAT SETPOINT. NORMALLY, BOTH THE DEC AND IEC MODULES WILL OPERATE TOGETHER; HOWEVER, IF THE SPACE HUMIDITY EXCEEDS THE RANGE GIVEN ABOVE, THE IEC MODULES WILL BE OPERATING ALONE. THE IEC MODULES HAVE INTERNAL CONTROLS FOR ACTIVATING ITS FANS AND PUMP. THE DDC CONTROLS THE FILL/DRAIN CYCLE AND ACTIVATION OF THE UNIT. NEVER ACTIVATE THE UNIT IF IT HAS BEEN COMMANDED TO DRAIN. THE OUTDOOR AIR DAMPER FOR A MODULE SHALL BE FULLY OPEN WHENEVER THE IEC IS IN USE.

B. THE EVAPORATIVE COOLER SUMP FOR EACH MODULE SHALL DRAIN WHEN THE OUTSIDE AIR TEMPERATURE DROPS BELOW 40°F (ADJUSTABLE) FOR 2 HOURS (ADJUSTABLE) AND IMMEDIATELY IF THE OAT DROPS BELOW 35°F. THE EVAPORATIVE COOLER SUMP SHALL FILL ONLY WHEN THE OUTSIDE AIR TEMPERATURE EXCEEDS 55°F AND THE IEC IS CALLED FOR ON A CALL FOR COOLING. PROVIDE A 15–MINUTE ADJUSTABLE TIME DELAY BETWEEN THE FILL AND UNIT ACTIVATION SIGNALS TO ALLOW THE SUMP TO FILL (IF THE SUMP HAS BEEN FILLED PREVIOUSLY AND NOT DRAINED, THE TIME DELAY DOES NOT NEED TO OCCUR). PROGRAM A WEEKLY SUMP DRAINAGE CYCLE FOR WATER QUALITY CONTROL ON SUNDAY MORNING STARTING AT 5AM. ALLOW FOR A 10–MINUTE (ADJ.) DRAIN PERIOD, WHICH WILL RESULT IN A PARTIAL DRAINAGE OF THE SUMP TO CONSERVE WATER. DRAIN THE SUMP ONLY IF IT HAS NOT BEEN DRAINED IN THE PRECEDING FOUR DAYS. COORDINATE THE DRAIN CYCLE SO ONLY ONE IEC MODULE DRAINS AT A TIME FOR A GIVEN AHU.

C. THE IEC MODULES SHALL HAVE SOFTWARE INTERLOCKS TO PERMIT OPERATION ONLY WHEN THE SA FAN IS RUNNING, THE SUMP HAS BEEN FILLED, AND THE OA DAMPER IS OPEN 100%. THERE SHALL BE MINIMUM ON AND OFF TIMERS FOR THE MODULES (INDEPENDENTLY ADJUSTABLE) TO PREVENT SHORT CYCLING.

D. PUMPS SHALL BE INTERLOCKED WITH INTERNAL SUMP LEVEL SWITCHES TO DE–ENERGIZE THE PUMPS WHEN THE SUMP WATER LEVEL IS LOW.

E. THE IEC MODULES SHALL BE STAGED ON AND OFF AS NEEDED TO MAINTAIN THE DAT. PROVIDE MINIMUM OFF AND ON TIMERS FOR EACH MODULE, SET AT 15–MINUTES (ADJ). DON'T BRING ON ANOTHER MODULE WHILE THE LAST STAGE ACTIVATED IS IN A TIME–OUT PERIOD. SETUP THE MODULES IN A LEAD/LAG CONFIGURATION. THE LEAD DESIGNATION SHALL BE ROTATED TO THE NEXT MODULE IN LINE AFTER ACCUMULATING 100–HOURS OF OPERATING TIME.

D. UNOCCUPIED MODE:

1. THE SUPPLY AND RETURN FANS SHALL BE DE–ENERGIZED. OUTDOOR AIR DAMPERS AND EXHAUST DAMPERS SHALL BE CLOSED.

2. THE HEATING COIL VALVE SHALL CYCLE TO MAINTAIN MIXED–AIR TEMPERATURE OF 45°F (ADJUSTABLE).

3. WHEN THE COLDEST SPACE TEMPERATURE DROPS BELOW THE UNOCCUPIED SETPOINT (60°F, ADJ.) THE UNIT SHALL ENERGIZE WITH THE OUTDOOR AND EXHAUST DAMPERS CLOSED AND SHALL OPERATE UNTIL THE COLDEST SPACE IS 5°F ABOVE THE UNOCCUPIED SETPOINT. LIMIT THE NUMBER OF FAN STARTS TO THREE (3) PER HOUR.

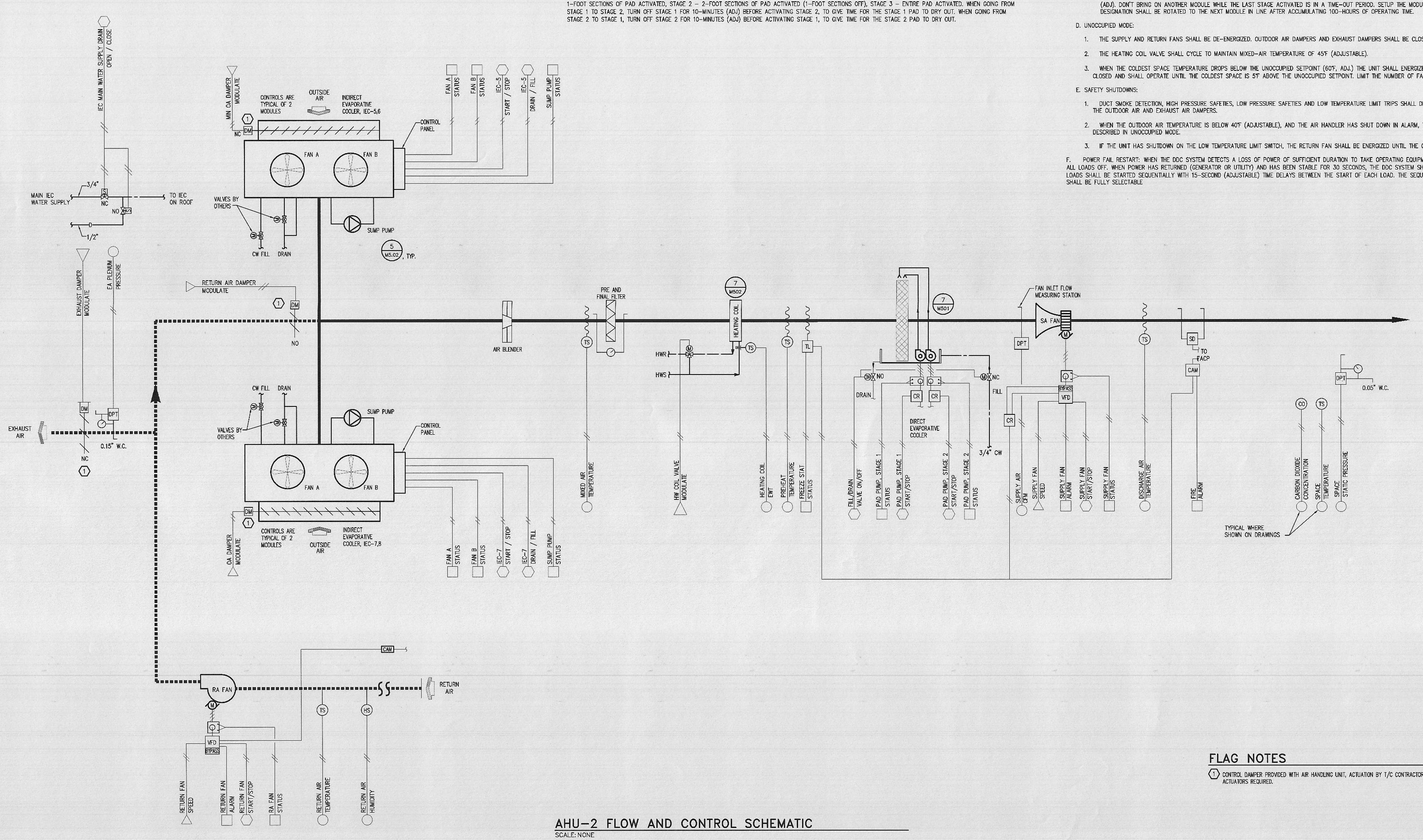
E. SAFETY SHUTDOWNS:

1. DUCT SMOKE DETECTION, HIGH PRESSURE SAFETIES, LOW PRESSURE SAFETIES AND LOW TEMPERATURE LIMIT TRIPS SHALL DE–ENERGIZE THE AIR–HANDLING UNIT AND CLOSE THE OUTDOOR AIR AND EXHAUST AIR DAMPERS.

2. WHEN THE OUTDOOR AIR TEMPERATURE IS BELOW 40°F (ADJUSTABLE), AND THE AIR HANDLER HAS SHUT DOWN IN ALARM, THE HEATING COIL VALVE SHALL CYCLE AS DESCRIBED IN UNOCCUPIED MODE.

3. IF THE UNIT HAS SHUTDOWN ON THE LOW TEMPERATURE LIMIT SWITCH, THE RETURN FAN SHALL BE ENERGIZED UNTIL THE CONDITION HAS BEEN RESOLVED.

F. POWER FAIL RESTART: WHEN THE DDC SYSTEM DETECTS A LOSS OF POWER OF SUFFICIENT DURATION TO TAKE OPERATING EQUIPMENT OFF–LINE, THE SYSTEM SHALL COMMAND ALL LOADS OFF. WHEN POWER HAS RETURNED (GENERATOR OR UTILITY) AND HAS BEEN STABLE FOR 30 SECONDS, THE DDC SYSTEM SHALL BEGIN TO RESTART THE BUILDING SYSTEMS. LOADS SHALL BE STARTED SEQUENTIALLY WITH 15–SECOND (ADJUSTABLE) TIME DELAYS BETWEEN THE START OF EACH LOAD. THE SEQUENCE AND TIME INTERVAL OF RESTARTING LOADS SHALL BE FULLY SELECTABLE



AHU–2 FLOW AND CONTROL SCHEMATIC

SCALE: NONE

FLAG NOTES

① CONTROL DAMPER PROVIDED WITH AIR HANDLING UNIT, ACTUATION BY T/C CONTRACTOR. MULTIPLE ACTUATORS REQUIRED.

SINK COMBS DETHLEFS

A Professional Corporation for Architecture
475 Lincoln Street,
Suite 100
Denver, Colorado 80203
303 308 0200
FAX 308 0222

CIVIL ENGINEER:
MARTIN/MARTIN

LANDSCAPE ARCHITECT:
studio INSITE LLC.

STRUCTURAL ENGINEER:
MARTIN/MARTIN

MECHANICAL ENGINEER:
THE RMH GROUP, INC.

ELECTRICAL ENGINEER:
ME ENGINEERS

POOL CONSULTANT:
COUNSILMAN HUNSAKER

ACOUSTICAL:
WJHW

ENGINEERS
CONSULTANTS
RMH GROUP

The RMH Group, Inc.
12600 West Colfax Avenue
Lakewood, Colorado 80215
Phone (303) 239–0909
Fax (303) 235–0218
RMH Job Number: 16946

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Issues/Revisions:	Date:
SCHEMATIC DESIGN	02/21/05
DESIGN DEVELOPMENT	05/16/05
BID PKG. 1 SITE AND FND.	07/08/05
GMP	08/05/05
100% CD'S	09/02/05
FINAL CD'S	09/23/05
ADDENDA △1–△4	10/14/05
ADDENDA △5	10/21/05
REVISIONS △6	11/30/05
COB–6	12/12/05
COB–7 △C7	12/23/05

COLORADO SCHOOL OF MINES
STUDENT RECREATION CENTER
GOLDEN, COLORADO

SCD Project No.: 0422

AHU-2
AIRFLOW AND
CONTROL SCHEMATIC

Drawn by: CMT
Checked by: REP

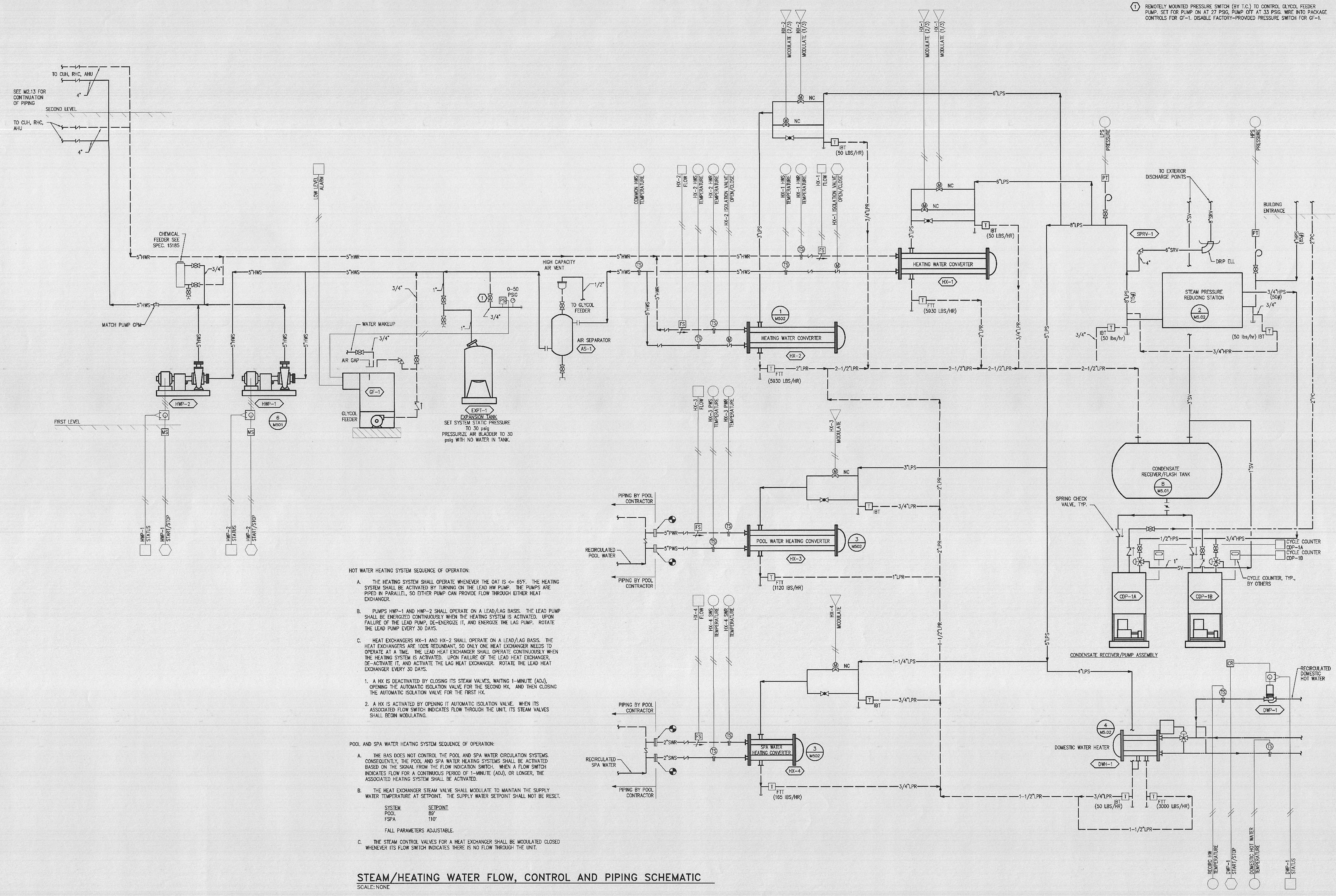
M4.02

SHEET NOTES:

1. SEE DETAIL 1 ON M5.03 FOR STEAM TRAP PIPING.
2. SEE PLANS AND REFERENCED DETAILS FOR ADDITIONAL SIZES AND OTHER PIPING INFORMATION.
3. LISTED STEAM TRAP LOADS ARE DESIGN VALUES WITHOUT SAFETY FACTORS, UNLESS NOTED OTHERWISE.
4. SEE TYPICAL DETAILS ON M5.01 FOR CUH, UH, AND RHC PIPING.

KEY NOTES:

① REMOTELY MOUNTED PRESSURE SWITCH (BY T.C.) TO CONTROL GLYCOL FEEDER PUMP. SET FOR PUMP ON AT 27 PSIG, PUMP OFF AT 33 PSIG. WIRE INTO PACKAGE CONTROLS FOR GF-1. DISABLE FACTORY-PROVIDED PRESSURE SWITCH FOR GF-1.



HOT WATER HEATING SYSTEM SEQUENCE OF OPERATION:

A. THE HEATING SYSTEM SHALL OPERATE WHENEVER THE OAT IS <= 65°F. THE HEATING SYSTEM SHALL BE ACTIVATED BY TURNING ON THE LEAD HW PUMP. THE PUMPS ARE PIPED IN PARALLEL, SO EITHER PUMP CAN PROVIDE FLOW THROUGH EITHER HEAT EXCHANGER.

B. PUMPS HWP-1 AND HWP-2 SHALL OPERATE ON A LEAD/LAG BASIS. THE LEAD PUMP SHALL BE ENERGIZED CONTINUOUSLY WHEN THE HEATING SYSTEM IS ACTIVATED. UPON FAILURE OF THE LEAD PUMP, DE-ENERGIZE IT, AND ENERGIZE THE LAG PUMP. ROTATE THE LEAD PUMP EVERY 30 DAYS.

C. HEAT EXCHANGERS HX-1 AND HX-2 SHALL OPERATE ON A LEAD/LAG BASIS. THE HEAT EXCHANGERS ARE 100% REDUNDANT, SO ONLY ONE HEAT EXCHANGER NEEDS TO OPERATE AT A TIME. THE LEAD HEAT EXCHANGER SHALL OPERATE CONTINUOUSLY WHEN THE HEATING SYSTEM IS ACTIVATED. UPON FAILURE OF THE LEAD HEAT EXCHANGER, DE-ACTIVATE IT, AND ACTIVATE THE LAG HEAT EXCHANGER. ROTATE THE LEAD HEAT EXCHANGER EVERY 30 DAYS.

1. A HX IS DEACTIVATED BY CLOSING ITS STEAM VALVES, WAITING 1-MINUTE (ADJ), OPENING THE AUTOMATIC ISOLATION VALVE FOR THE SECOND HX, AND THEN CLOSING THE AUTOMATIC ISOLATION VALVE FOR THE FIRST HX.

2. A HX IS ACTIVATED BY OPENING IT AUTOMATIC ISOLATION VALVE. WHEN ITS ASSOCIATED FLOW SWITCH INDICATES FLOW THROUGH THE UNIT, ITS STEAM VALVES SHALL BEGIN MODULATING.

POOL AND SPA WATER HEATING SYSTEM SEQUENCE OF OPERATION:

A. THE BAS DOES NOT CONTROL THE POOL AND SPA WATER CIRCULATION SYSTEMS. CONSEQUENTLY, THE POOL AND SPA WATER HEATING SYSTEMS SHALL BE ACTIVATED BASED ON THE SIGNAL FROM THE FLOW INDICATION SWITCH. WHEN A FLOW SWITCH INDICATES FLOW FOR A CONTINUOUS PERIOD OF 1-MINUTE (ADJ), OR LONGER, THE ASSOCIATED HEATING SYSTEM SHALL BE ACTIVATED.

B. THE HEAT EXCHANGER STEAM VALVE SHALL MODULATE TO MAINTAIN THE SUPPLY WATER TEMPERATURE AT SETPOINT. THE SUPPLY WATER SETPOINT SHALL NOT BE RESET.

SYSTEM	SETPOINT
POOL	89°
FSPA	110°

FALL PARAMETERS ADJUSTABLE.

C. THE STEAM CONTROL VALVES FOR A HEAT EXCHANGER SHALL BE MODULATED CLOSED WHENEVER ITS FLOW SWITCH INDICATES THERE IS NO FLOW THROUGH THE UNIT.

STEAM/HEATING WATER FLOW, CONTROL AND PIPING SCHEMATIC

SCALE: NONE

SINK COMBS DETHLEFS

A Professional Corporation for Architecture
475 Lincoln Street,
Suite 100
Denver, Colorado 80203
303 308 0200
FAX 308 0222

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ENGINEERS
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The RMH Group, Inc.
12600 West Colfax Avenue
Lakewood, Colorado 80215
Phone (303) 239-0909
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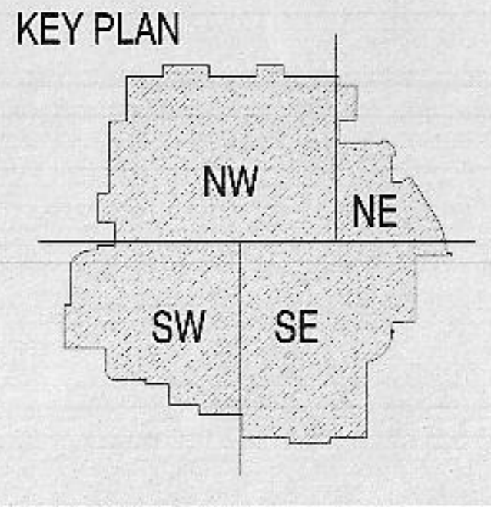
KEY PLAN



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STEAM / HOT WATER FLOW, CONTROL, AND PIPING SCHEMATIC

Drawn by: CMT
Checked by: REP

M4.06