Technical Assignment #3

Existing Conditions Evaluation

Photo by Fred Martin

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Anderson, SC

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Mechanical Option

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Executive Summary

This report is a detailed summary of the existing mechanical systems and equipment for the Clemson University Advanced Material Research Laboratory. Major components and equipment used in the system are explained and analyzed. Design objectives and requirements for the project are also listed in order to fully understand the system.

Included in this report are the design and ventilation requirements from ASHRAE Standard 62.1-2004 for the air handling units. The design cooling and heating loads for the major equipment are calculated using Carrier's Hourly Analysis Program. HAP is used to estimate the annual consumption of energy for the AMRL as well.

Basic schematic drawings of the system were created in order to better understand and describe the existing system. Equipment schedules are also found in this report. A description of the mechanical system utilizes the schematic drawings to describe the system. The building is critiqued according to all the information gathered.

Design Objectives and Requirements

Clemson University AMRL is a two-story mixed use building located in Anderson, SC. This 111, 270 sq ft. building houses office space, laboratories, conference rooms, and clean rooms. There are 15 AHU's and 4 MAH's that condition this building. The mechanical system uses an on site boiling and chilling plant to condition air for the AHU's and VAV distribution system. AHU numbers 8, 10, and 11 uses VAV boxes to supply the space. Most of the mechanical equipment is located on the second floor, where there is a small space allocated for this on the first floor. Clemson University ARML, due to its many laboratories, requires a lot of mechanical equipment. In design, they used mostly an entire floor to house the mechanical equipment. With this, the total area of the mechanical space on the second floor is 31,841 sq. ft. After calculating the areas other than the mechanical floor space, such as the draw tower and first floor mechanical room, there is a total of 35, 626 sq. ft. of lost rentable space. Out of 117,000 sq. ft, 30.4 % of this area is given to the mechanical equipment.

The AMRL is served by 19 units, ranging from 1,000 cfm to 20,650 cfm. The amount of minimum outside air to the AHU's varying between 300 to 20,650 cfm. As noted before, the rooms serviced by AHU 8, 10, and 11 uses VAV boxes to control the climate which people occupy.

Clemson AMRL uses two 3,348 MBH gas fired boilers and one 4,094 MBH electric boiler. There are three 750 gpm/266.6 ton chillers and two 1,125 gpm/375 ton cooling towers. The air supplied to the building is from the fifteen AHU's range from 1,000-11,300 cfm and four MAH units ranging from 6,800 to 20,650 cfm.

Outdoor and Indoor Design Conditions

Outdoor Design Conditions:

The 2001 ASHRAE Fundamentals handbook provides weather data in Chapter 27. The system is not designed for any extreme conditions and may not meet indoor air requirements in those situations.

Table 1

Latitude: 34.50
Longitude: 82.72
Elevation: 771 feet

Table 2

Summer Conditions	Design Dry Bulb: 93 °F
Winter Conditions	Design Dry Bulb: 19 °F

Carrier's HAP was used to simulate and model the Clemson AMRL's energy consumption. In order to compute this, weather conditions were properly selected for the buildings site. HAP inputs the correct weather data for the design and simulation city, which was from 2001 ASHRAE Fundamentals Handbook. See Figure 1.

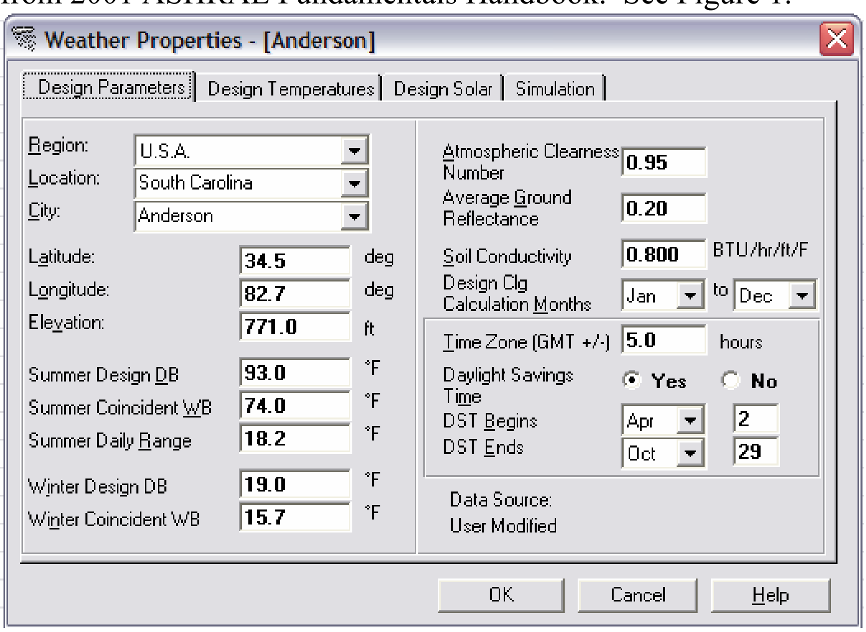


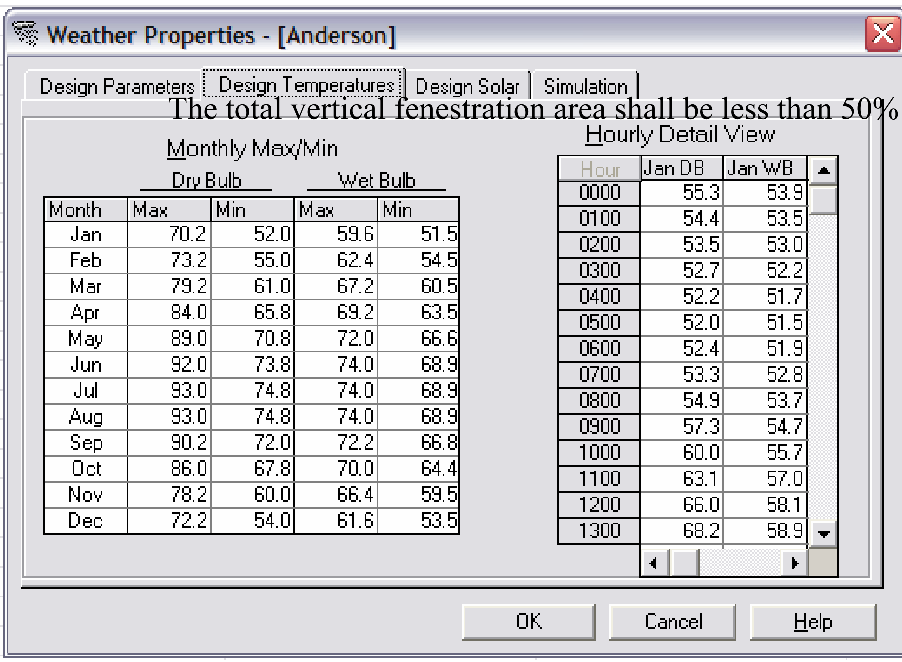
Figure 1—HAP Weather Design Parameters

Indoor Design Conditions:

The following table and figure show the indoor design conditions for the AMRL.

Table 3

Indoor Air Requirement	Dry Bulb Temp:	74 °F
	RH:	50%



The total vertical fenestration area shall be less than 50% of the gross wall area. The t

Figure 2—HAP Weather Design Temperatures

Energy Sources and Rates

The Clemson AMRL is serviced by both electricity and natural gas energy. The electric service is provided by Duke Power. The rates can be seen in Figure 3. The natural gas service is provided by Piedmont Natural Gas. The rates can be seen in Figure 4.

RATE:

		Summer Months June 1 – September 30	Winter Months October 1 – May 31
I.	Basic Facilities Charge	$33.54	
II.	Demand Charge		
	A. On-Peak Demand Charge per month		
	For the first 2000 KW of Billing Demand per month	$13.16 per KW	$7.69 per KW
	For the next 3000 KW of Billing Demand per month	$11.67 per KW	$6.40 per KW
	For all over 5000 KW of Billing Demand per month	$ 9.40 per KW	$4.74 per KW
	B. Economy Demand Charge per month	$1.01 per KW	$1.01 per KW
III.	Energy Charge		
	A. All On-Peak Energy per month	4.3937 cents per kWh	4.3937 cents per kWh
	B. All Off-Peak Energy per month	1.7336 cents per kWh	1.7336 cents per kWh

DETERMINATION OF ON-PEAK AND OFF-PEAK HOURS

	Summer Months June 1 – September 30	Winter Months October 1 – May 31
On-Peak Period Hours	1:00 p.m. – 9:00 p.m. Monday – Friday	6:00 a.m. – 1:00 p.m. Monday – Friday
Off-Peak Period Hours	All other weekday hours and all Saturday and Sunday hours.	

Figure 3—Duke Power Costs

Rate Classification	Facility Charge	Units	Rate/Therm November/March	Units	Rate/Therm April/October
	250.00	First 15,000	1.19349	First 15,000	1.12654
Demand (Therm)	1.90	Next 15,000	1.13290	Next 15,000	1.08143
		Next 75,000	1.08558	Next 75,000	1.05278
		Next 165,000	1.04020	Next 165,000	1.02163
		Next 330,000	0.99909	Next 330,000	0.99409
		Over 600,000	0.97052	Over 600,000	0.97052

Figure 4—Piedmont Natural Gas Costs

Cost Factors

There are several factors that could potentially influence the design decisions made with the mechanical system. Initial first cost, operating and maintenance costs, and life cycle are just to name a few. The first initial cost would be a significant factor in system selection.

The following information for system first cost was provided my IDC Architects through the master bid summary. The following break down includes all costs associated with the HVAC installation in dollars. Once the total first cost is calculated, the price per square foot can be determined.

SHV 1003	**HVAC**		**3,024,000**
SHV 1010	heat/cooling equipment	700,000	
SHV 1020	AHU/MAU	300,000	
SHV 1030	reheat coils	110,000	
SHV 1040	dehumidification	100,000	
SHV 1050	exhaust fans	70,000	
SHV 1060	ductwork	400,000	
SHV 1070	piping and supports	520,000	
SHV 1080	pumps	24,000	
SHV 1090	Phoenix Control System	400,000	
SHV 1100	insulation	350,000	
SHV 1200	LEED Commissioning	50,000	

Figure 5—Mechanical System First cost

The price/sf is calculated to be $25.85 based on 117,000 sq. ft.

Site Factors:

The site of the AMRL building is in a off campus industrial park. The only major concern was the orientation of the building to incorporate solar gain and day lighting into the design. With this, IDC had a lot to gain since there were really no restrictions.

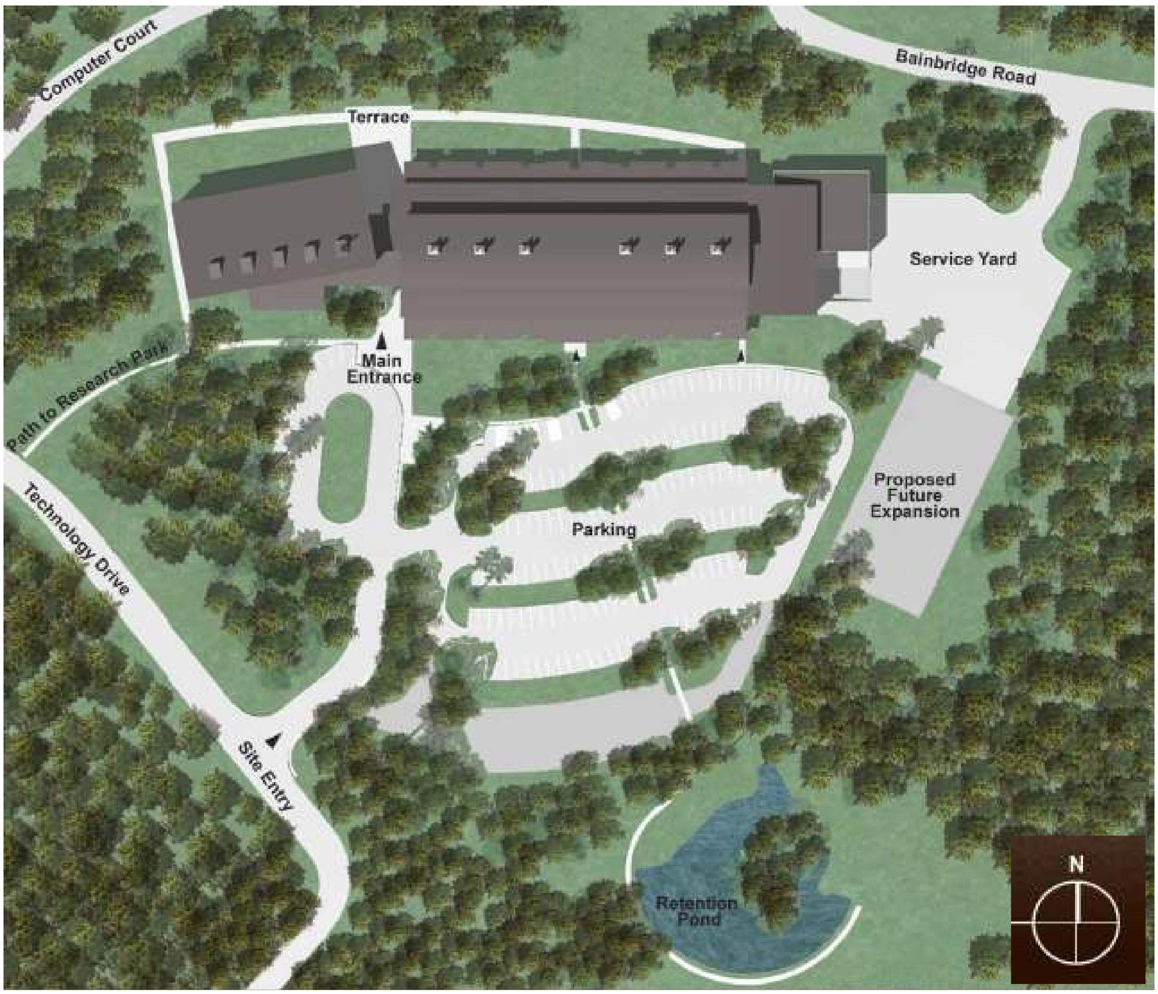


Figure 6—Building Orientation and Foot Print

Being able to incorporate day lighting and solar heat gain, reduces the load on the building tremendously. As seen in figure 7, is an illustration of how the sun can reach the inner parts of the laboratories during summer and winter months along with gaining extra heat from this during the winter months. Orienting the building to have the most glass to the south is one way to benefit from the sun. Another is to take in consideration of the angle of the sun during summer and winter, and while orienting the building to the south, one would be able to take advantage of light entering the building during the day.

Figure 7—Daylight harvesting/solar gain

Design Ventilation Requirements:

At the specified design considerations taken in account for Tech Report One, the AHU's were to have an intake of around ten percent. All units were found to be compliant with ASHRAE Standard 62.1-2004 except AHU-11. It had a required outdoor intake greater than the design OA supply. All other units were over designed.

Design Heating and Cooling Loads:

The design heating and cooling loads were calculated in Tech Report Two. Using Carrier's HAP, I was able to obtain the loads from calculation. The numbers struck me in such a way where I believe that there is an error due to the low numbers. When the simulation was done, I was only able to obtain the peak data, and not the year-round data. This may deal with the low numbers that where achieved. In Table 4, I list the loads recorded from Tech Two. The design load for AHU 12, 13, and 15 were not calculated due to the low number associated with load.

Table 4—Estimated Design Loads from HAP

Estimated Design Loads			
System	Design Load (MBH)	Load (ton)	Design Load (sf/ton)
AHU-1	145.4	12.1	237.7
AHU-2	101.1	8.4	353.3
AHU-3	124.9	10.4	310.4
AHU-4	147.4	12.3	233.8
AHU-5	114.2	9.5	434.5
AHU-6	116.3	9.7	425.6
AHU-7	126.9	10.6	459.2
AHU-8	175.3	14.6	352.5
AHU-9	81.5	6.8	759.4
AHU-10	82.9	6.9	682.8
AHU-11	140.3	11.7	426.9
AHU-12	7.1	0.6	
AHU-13	3.4	0.3	
AHU-14	14	1.2	440.0
AHU-15	6.2	0.5	
MAH-1	391.2	32.6	598.9
MAH-2	413.9	34.5	591.3
MAH-3	417.7	34.8	589.5
MAH-4	389.8	32.5	589.2

Annual Energy Costs

Annual Energy Costs were estimated using Carrier's HAP. Table 4 below illustrates the cost of the AMRL.

Table 4—Calculated Costs

Component	Clemson AMRL ($)
HVAC Components	
Electric	4,241,147
Natural Gas	9,545
HVAC Sub-Total	**4,250,692**
Non-HVAC Components	
Electric	2,047,133
Non-HVAC Sub-Total	**2,047,133**
Grand Total	**6,297,825**

Major Equipment:

Air Handling Units/ Make-Up Air Handling Units

Fifteen air handling units with three of them being VAV's and 4 MAH units serve Clemson AMRL. They provide conditioned air to offices, laboratories, conference areas, and clean rooms. Table 5 shows the operating conditions for the AHU's. The Make-Up Air Handling Units are also shown in table 5. They were needed to condition the additional space since the air exhausted through the fume hoods would need replaced.

Table 5—Air Handling Unit Schedule

			RETURN FAN						
EQUIP NO.	LOCATION ROOM NO.	SERVES	FAN TYPE	MAX R/A CFM	MIN R/A CFM	E.S.P.	T.S.P.	HP	V/PH/HZ
AHU-03-01	A2B200	LAB OFFICES	AF	2,200	2,200	0.75	0.98	1.5	460/3/60
AHU-03-02	A2C200	LAB OFFICES	AF	2,700	2,700	0.75	0.99	1.5	460/3/60
AHU-03-03	A2B200	LAB OFFICES	AF	3,900	3,900	0.75	0.97	2.0	460/3/60
AHU-03-04	A2C200	LAB OFFICES	AF	3,400	3,400	0.75	0.93	1.5	460/3/60
AHU-03-05	A2B200	LASER LABS	AF	2417	0	1.00	1.23	1.5	460/3/60
AHU-03-06	A2C200	LASER LABS	AF	2,677	250	1.00	1.23	1.5	460/3/60
AHU-03-07	A3A300	CU OFFICES (L1)	AF	4,600	4,600	1.00	1.29	5.0	460/3/60
AHU-03-08	A3A300	LOBBY	AF	9,550	9,550	1.00	1.16	7.5	460/3/60
AHU-03-09	A3A300	MICROSCOPY	-	-	-	-	-	-	-
AHU-03-10	A3A300	CU OFFICES (L2)	AF	6,200	6,200	0.75	0.93	5.0	460/3/60
AHU-03-11	A3A300	SCRA OFFICES (L2)	AF	6,550	6,550	0.75	0.93	5.0	460/3/60
AHU-03-12	A2C200	HAZARDOUS MAT	FC	750	550	0.75	0.99	1.0	460/3/60
AHU-03-13	A2B200	CLEANROOM	-	-	-	-	-	-	-
AHU-03-14	A2C200	STM	-	-	-	-	-	-	-
AHU-03-15	A2C200	DRAW TOWER	AF	4,800	4,800	1.00	1.17	3.0	460/3/60
MAH-01-01	A2B200	WET LABS	-	-	-	-	-	-	-
MAH-01-02	A2C200	WET LABS	-	-	-	-	-	-	-
MAH-01-03	A2B200	WET LABS	-	-	-	-	-	-	-
MAH-01-04	A2C200	WET LABS	-	-	-	-	-	-	-

Table 5—continued

EQUIP NO.	ENERGY RECOVERY COIL												
	FLOW GPM	AIR P.D. IWG	WATER P.D. FT	PRE-COOLING					PRE-HEATING				
				EWT	LWT	EAT	LAT	BTUH	EWT	LWT	EAT	LAT	BTUH
AHU-03-01	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-02	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-03	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-04	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-05	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-06	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-07	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-08	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-09	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-10	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-11	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-12	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-13	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-14	-	-	-	-	-	-	-	-	-	-	-	-	-
AHU-03-15	-	-	-	-	-	-	-	-	-	-	-	-	-
MAH-01-01	56.3	0.50	10.00	78.2	86.8	95.0	84.6	221,379	49.3	32.3	10.0	30.5	435,132
MAH-01-02	56.3	0.50	10.00	78.2	86.8	95.0	84.6	231,300	49.3	32.3	10.0	30.5	454,632
MAH-01-03	56.3	0.50	10.00	78.2	86.8	95.0	84.6	234,135	49.3	32.3	10.0	30.5	460,204
MAH-01-04	56.3	0.50	10.00	78.2	86.8	95.0	84.6	217,127	49.3	32.3	10.0	30.5	426,775

Table 5—continued

EQUIP NO.	PREHEAT COIL							
	BTUH	EWT	LWT	FLOW GPM	AIR P.D. IWG	WATER P.D. FT	EAT	LAT
AHU-03-01	27,539	200.0	160.0	1.4	0.11	0.11	45.5	51.8
AHU-03-02	23,924	200.0	160.0	1.2	0.13	0.47	48.4	53.3
AHU-03-03	5,213	200.0	160.0	0.3	0.10	0.50	52.9	53.7
AHU-03-04	14,372	200.0	160.0	0.7	0.09	7.32	51.1	53.6
AHU-03-05	282,871	200.0	160.0	14.1	0.11	11.49	15.2	56.6
AHU-03-06	228,633	200.0	160.0	11.4	0.11	11.06	18.0	54.3
AHU-03-07	-	-	-	-	-	-	65.6	65.6
AHU-03-08	-	-	-	-	-	-	64.6	64.6
AHU-03-09	-	-	-	-	-	-	53.8	53.8
AHU-03-10	-	-	-	-	-	-	63.8	63.8
AHU-03-11	-	-	-	-	-	-	65.8	65.8
AHU-03-12	108,977	200.0	160.0	5.4	0.26	0.29	25.0	57.4
AHU-03-13	19,906	200.0	160.0	1.0	0.18	0.09	33.3	44.8
AHU-03-14	-	-	-	-	-	-	53.6	53.6
AHU-03-15	-	-	-	-	-	-	54.0	54.0
MAH-01-01	1,006,270	200.0	160.0	50.3	0.10	3.71	10.0	57.5
MAH-01-02	1,051,365	200.0	160.0	52.6	0.11	4.04	10.0	57.5
MAH-01-03	1,064,249	200.0	160.0	53.2	0.11	4.15	10.0	57.5
MAH-01-04	986,943	200.0	160.0	49.3	0.09	3.57	10.0	57.5

Table 5—continued

EQUIP NO.	COOLING COIL										
	SENS BTUH	TOTAL BTUH	EWT	LWT	FLOW GPM	AIR P.D. IWG	WATER P.D. FT	EAT DB	EAT WB	LAT DB	LAT WB
AHU-03-01	134,626	198,774	42.0	54.0	33.1	0.59	12.60	82.3	67.6	51.8	51.6
AHU-03-02	140,427	204,576	42.0	54.0	34.1	0.69	13.26	81.0	66.7	53.3	52.3
AHU-03-03	149,566	213,810	42.0	54.0	35.6	0.65	4.57	79.1	65.4	53.7	53.3
AHU-03-04	140,515	204,730	42.0	54.0	34.1	0.56	4.22	79.7	65.8	53.6	53.4
AHU-03-05	280,136	440,141	42.0	54.0	73.4	0.81	15.09	92.3	74.2	56.6	56.6
AHU-03-06	254,388	417,829	42.0	54.0	69.6	0.82	15.43	93.8	74.9	54.3	54.3
AHU-03-07	104,840	120,074	42.0	54.0	20.0	0.44	3.91	76.7	62.3	55.8	53.8
AHU-03-08	255,109	295,020	42.0	54.0	49.2	0.61	4.96	76.2	62.2	55.6	53.4
AHU-03-09	365,695	504,221	42.0	54.0	84.0	1.41	7.75	76.5	62.9	47.7	47.6
AHU-03-10	155,555	190,597	42.0	54.0	31.8	0.44	5.78	77.2	63.0	55.0	53.0
AHU-03-11	161,977	184,473	42.0	54.0	30.7	0.45	5.47	75.9	61.8	55.2	53.0
AHU-03-12	120,096	181,087	42.0	54.0	30.2	0.83	10.28	90.3	72.9	57.4	57.3
AHU-03-13	71,790	119,775	41.0	57.0	15.0	1.17	6.34	87.0	70.5	44.8	44.7
AHU-03-14	23,731	36,022	42.0	54.0	6.0	0.28	8.93	81.5	66.7	48.0	47.9
AHU-03-15	201,585	269,604	42.0	54.0	44.9	0.72	14.71	77.4	64.3	51.7	51.3
MAH-01-01	812,280	1,443,094	42.0	54.0	240.5	0.97	11.02	94.4	75.2	57.5	54.7
MAH-01-02	848,924	1,508,053	42.0	54.0	251.3	1.16	17.78	94.4	75.2	57.5	54.7
MAH-01-03	846,944	1,513,754	42.0	54.0	252.3	1.07	12.01	94.4	75.2	57.5	54.9
MAH-01-04	785,010	1,403,964	42.0	54.0	234.0	0.91	10.49	94.4	75.2	57.5	54.9

Table 5—continued

EQUIP NO.	SUPPLY FAN					
	(4) FAN TYPE	DESIGN S/A CFM	E.S.P.	T.S.P.	HP	O/A CFM
AHU-03-01	AF	4,000	1.25	3.54	7.5	1,800
AHU-03-02	AF	4,500	1.25	3.69	7.5	1,800
AHU-03-03	AF	5,700	1.25	3.68	10.0	1,800
AHU-03-04	AF	5,200	1.25	3.49	7.5	1,800
AHU-03-05	AF	6,300	1.25	5.80	10.0	6,300
AHU-03-06	AF	5,800	1.25	5.82	10.0	5,550
AHU-03-07	AF	5,000	1.75	3.90	7.5	400
AHU-03-08	AF	10,600	1.75	3.94	15.0	1,050
AHU-03-09	AF	11,300	1.75	6.54	20.0	3,350
AHU-03-10	AF	7,000	1.75	3.79	10.0	800
AHU-03-11	AF	7,100	1.75	3.82	10.0	550
AHU-03-12	FC	3,100	1.00	3.77	5.0	2,550
AHU-03-13	AF	1,600	1.00	1.35	3.0	1,100
AHU-03-14	AF	1,000	2.00	5.01	3.0	300
AHU-03-15	AF	6,800	1.50	3.80	10.0	2,000
MAH-01-01	AF	19,525	2.00	4.24	25.0	19,525
MAH-01-02	AF	20,400	2.00	4.49	25.0	20,400
MAH-01-03	AF	20,650	2.00	4.42	25.0	20,650
MAH-01-04	AF	19,150	2.00	4.15	25.0	19,150

Cooling Towers

There are two 375 ton, 1,125 gpm cooling towers located on site. The cooling towers provide condenser water for the 15 AHU's. Below in Table 6, the operating conditions and additional information is provided.

Table 6—Cooling Tower Schedule

EQUIP NO.	LOCATION ROOM NO.	CAPACITY TONS	FLOW GPM	E W T F	L W T FDB	L W T FWB	FAN MOTOR HP	BASIN HEATER QTY	BASIN HEATER KW/EA	V/PH/HZ	BASIS OF DESIGN
CT-14-01	EQUIPMENT YARD	375	1,125	95.0	85.0	78.0	15	2	12	460/3/60	MARLEY NC8305FL-2
CT-14-02	EQUIPMENT YARD	375	1,125	95.0	85.0	78.0	15	2	12	460/3/60	MARLEY NC8305FL-2

Chillers

There are three 266.6 ton, 750 gpm chillers located at the AMRL. The chillers are explained in Table 7 along with some additional information.

Table 7—Chiller Schedule

EQUIP NO.	LOCATION ROOM NO.	NOMINAL CAPACITY TONS	CONDENSER FLOW GPM	CONDENSER W P D FT H_20	CONDENSER E W T F	CONDENSER L W T F	EVAPORATOR FLOW GPM	EVAPORATOR W P D FT H_20	EVAPORATOR E W T F	EVAPORATOR L W T F	KW/TON	V/PH/HZ	BASIS OF DESIGN
CH-11-01	A1D116	266.6	750	9.6	85.0	95.1	531	9.3	54.0	42.0	0.633	460/3/60	TRANE RTHC
CH-11-02	A1D116	266.6	750	9.6	85.0	95.1	531	9.3	54.0	42.0	0.633	460/3/60	TRANE RTHC
CH-11-03	A1D116	266.6	750	9.6	85.0	95.1	531	9.3	54.0	42.0	0.633	460/3/60	TRANE RTHC
CH-40-01	EQUIPMENT YARD	50	-	-	-	-	100	7.2	54.0	42.0	1.205	460/3/60	TRANE CGAF

Boilers

There are two 3,348 MBH gas fired boilers and one 4,094 MBH electric boiler located at Clemson's AMRL. Below in table 8, they are further explained.

Table 8—Boiler Schedule

EQUIP NO.	LOCATION ROOM NO.	CAPACITY INPUT MBH	CAPACITY OUTPUT MBH	BoHP	FUEL	MAX FLOW GPM	E W T F	L W T F	BLOWER MOTOR HP	BURNER V/PH/HZ	BASIS OF DESIGN
BLR-15-01	A1D116	4,200	3,348	100	NG	167	160	200	1.5	208/3/60	HURST SERIES 400
BLR-15-02	A1D116	4,200	3,348	100	NG	167	160	200	1.5	208/3/60	HURST SERIES 400
BLR-15-03	A1D116	1,200 KW	4,094	122	ELEC	205	160	200	1,444 A	480/3/60	PRECISION HW30D-1200D

Energy Recovery Coil

Clemson's AMRL uses three energy recovery coils. They provide cooling for the condenser water loop from the cooling towers and heat for the hot water loop from the boilers. Below, table 9 illustrates more information.

Table 9—Energy Recovery Coil Schedule

ENERGY RECOVERY COIL SCHEDULE																		
									PRE-COOLING					PRE-HEATING				
EQUIP NO.	LOCATION ROOM NO.	DESIGN AIR FLOW CFM	MAX AIR FLOW CFM	MAX VELOCITY FPM	MAX AIR P.D. IWG	WATER FLOW GPM	ROWS QTY	WATER P.D. FT	EWT	LWT	EAT	LAT	BTUH	EWT	LWT	EAT	LAT	BTUH
ERC-20-01	A3B300	35,000	44,500	1,000	1.25	75.0	8	15.0	86.82	78.24	72.0	80.0	302,281	32.26	49.3	72.0	56.35	594,309
ERC-20-02	A3B300	35,000	44,500	1,000	1.25	75.0	8	15.0	86.82	78.24	72.0	80.0	302,281	32.26	49.3	72.0	56.35	594,309
ERC-20-03	A3C300	35,000	44,500	1,000	1.25	75.0	8	15.0	86.82	78.24	72.0	80.0	302,281	32.26	49.3	72.0	56.35	594,309

Variable Air Volume Boxes

The conditioned air from AHU 8, 10, and 11 is ducted to several variable air volume (VAV) boxes, which are located in the ceiling plenum. They are selected in ranges of cfm. There are also different gpm amounts for the hot water reheat coils to each of the VAV boxes. Below in Table 10, the operating conditions are shown along with some other additional information.

Table 10—Variable Air Volume Box Schedule

EQUIP NO.	LOCATION ROOM NO.	AHU No.	SERVES	HW HEATING BTUH	EWT F	LWT F	FLOW GPM	MAX S/A CFM	MIN S/A CFM	EAT F	SAT F	COIL LAT F
VVR-06-04	A1A103	AHU-8	LOBBY (SOUTH)	34,220	200.0	160.0	1.7	2,250	1,125	55.6	83.6	83.6
VVR-06-05	A1A107	AHU-8	LOBBY (SOUTH)	45,005	200.0	160.0	2.3	1,500	750	55.6	110.9	110.9
VVR-06-06	A1A134	AHU-8	ELEC/TELE	4,551	200.0	160.0	0.2	550	275	55.6	70.9	70.9
VVR-06-07	A2A253	AHU-10	BREAK/COPY/STOR	6,415	200.0	160.0	0.3	630	315	55.0	73.8	73.8
VVR-06-08	A2A229	AHU-10	CORRIDOR	8,628	200.0	160.0	0.4	750	375	55.0	76.2	76.2
VVR-06-09	A2A243	AHU-10	ELEC/TELE	4,523	200.0	160.0	0.2	525	263	55.0	70.9	70.9
VVR-06-10	A2A223	AHU-11	RECEPT/WAITING	4,553	200.0	160.0	0.2	470	235	55.2	73.1	73.1
VVR-06-11	A2A221	AHU-11	OPEN AREA/CORRIDOR	6,018	200.0	160.0	0.3	620	310	55.2	73.1	73.1
VVR-06-12	A2A202	AHU-11	LOBBY/RESTROOMS	8,391	200.0	160.0	0.4	800	400	55.2	74.5	74.5
VVR-06-13	A2A222	AHU-11	CONFERENCE ROOM	7,770	200.0	160.0	0.4	850	425	55.2	72.0	72.0
VVR-06-14	A2A221	AHU-11	STOR/OPEN OFFICE	11,249	200.0	160.0	0.6	1,210	605	55.2	72.3	72.3
VVR-06-15	A2A219	AHU-11	REPRO/SERVER	2,051	200.0	160.0	0.1	200	100	55.2	74.1	74.1
VVR-06-16	A2A218	AHU-11	CONFERENCE ROOM	2,646	200.0	160.0	0.1	290	145	55.2	72.0	72.0
VVR-06-17	A2A224	AHU-11	DIRECTOR ASST	1,623	200.0	160.0	0.1	150	75	55.2	75.1	75.1
VVR-06-18	A2A230	AHU-11	ADMIN	1,623	200.0	160.0	0.1	150	75	55.2	75.1	75.1
VVR-06-19	A2A233	AHU-11	ADMIN ASST	1,623	200.0	160.0	0.1	150	75	55.2	75.1	75.1
VVR-06-20	A2A250	AHU-11	INDIVIDUAL OFFICE	1,623	200.0	160.0	0.1	150	75	55.2	75.1	75.1
VVR-06-21	A2A249	AHU-11	INDIVIDUAL OFFICE	1,623	200.0	160.0	0.1	150	75	55.2	75.1	75.1

Pumps

There are several different types of pumps which service the AMRL. Table 11 below shows what pumps serve what areas of the building.

Table 11—Pump Schedule

EQUIP NO.	LOCATION ROOM NO.	SERVICE	FLOW GPM	T.D.H. FT. H20	MOTOR HP	MOTOR RPM
PMP-11-01	A1D116	PRIMARY CHILLED WATER PUMP	500	30	10	1,750
PMP-11-02	A1D116	PRIMARY CHILLED WATER PUMP	500	30	10	1,750
PMP-11-03	A1D116	PRIMARY CHILLED WATER PUMP	500	30	10	1,750
PMP-40-01	A1D116	PRIMARY PROCESS CHILLED WATER PUMP	100	30	2	1,750
PMP-12-01	A1D116	SECONDARY CHILLED WATER PUMP	1600	75	40	1,750
PMP-12-02	A1D116	SECONDARY CHILLED WATER PUMP	1600	75	40	1,750
PMP-14-01	A1D116	CONDENSER WATER PUMP	750	40	15	1,750
PMP-14-02	A1D116	CONDENSER WATER PUMP	750	40	15	1,750
PMP-14-03	A1D116	CONDENSER WATER PUMP	750	40	15	1,750
PMP-15-01	A1D116	PRIMARY HOT WATER PUMP	160	30	3	1,750
PMP-15-02	A1D116	PRIMARY HOT WATER PUMP	160	30	3	1,750
PMP-15-03	A1D116	PRIMARY HOT WATER PUMP	205	30	5	1,750
PMP-15-04	A1D116	BOILER RECIRC PUMP	16	30	3/4	1,750
PMP-15-05	A1D116	BOILER RECIRC PUMP	16	30	3/4	1,750
PMP-15-06	A1D116	BOILER RECIRC PUMP	20	30	3/4	1,750
PMP-03-01	A2B200	PREHEAT COIL RECIRC PUMP	1.4	25	1/2	1,750
PMP-03-02	A2C200	PREHEAT COIL RECIRC PUMP	1.2	25	1/2	1,750
PMP-03-03	A2B200	PREHEAT COIL RECIRC PUMP	0.3	25	1/2	1,750
PMP-03-04	A2C200	PREHEAT COIL RECIRC PUMP	0.7	25	1/2	1,750
PMP-03-05	A2B200	PREHEAT COIL RECIRC PUMP	11.6	25	1/2	1,750
PMP-03-06	A2C200	PREHEAT COIL RECIRC PUMP	11.4	25	1/2	1,750
PMP-03-12	A2C200	PREHEAT COIL RECIRC PUMP	5.4	25	1/2	1,750
PMP-03-13	A2B200	PREHEAT COIL RECIRC PUMP	1.0	25	1/2	1,750
PMP-01-01	A2B200	PREHEAT COIL RECIRC PUMP	50	25	1/2	1,750
PMP-01-02	A2C200	PREHEAT COIL RECIRC PUMP	53	25	1/2	1,750
PMP-01-03	A2B200	PREHEAT COIL RECIRC PUMP	53	25	1/2	1,750
PMP-01-04	A2C200	PREHEAT COIL RECIRC PUMP	49	25	1/2	1,750
PMP-16-01	A1D116	SECONDARY HOT WATER PUMP	480	75	15	1,750
PMP-16-02	A1D116	SECONDARY HOT WATER PUMP	480	75	15	1,750
PMP-20-01	A3B300	ENERGY RECOVERY WATER PUMP	225	60	7.5	1,750
PMP-41-01	A1D116	SECONDARY PROCESS CHILLED WATER PUMP	120	90	7.5	1,750
PMP-41-02	A1D116	SECONDARY PROCESS CHILLED WATER PUMP	120	90	7.5	1,750
PMP-42-01	A1A103	TERTIARY PROCESS CHILLED WATER PUMP	30	15	1/2	1,750

Basic System Operation:

Clemson's AMRL consists of both air-side and water-side mechanical equipment and systems. The air-side consists of AHU's, MAH's, and VAV boxes. An example of the air-side schematic is shown in Figure 8. The water-side operation consists of a hot water system and a condenser water system. The hot water system is shown in Figure 9 and the condenser water system is shown in Figure 10.

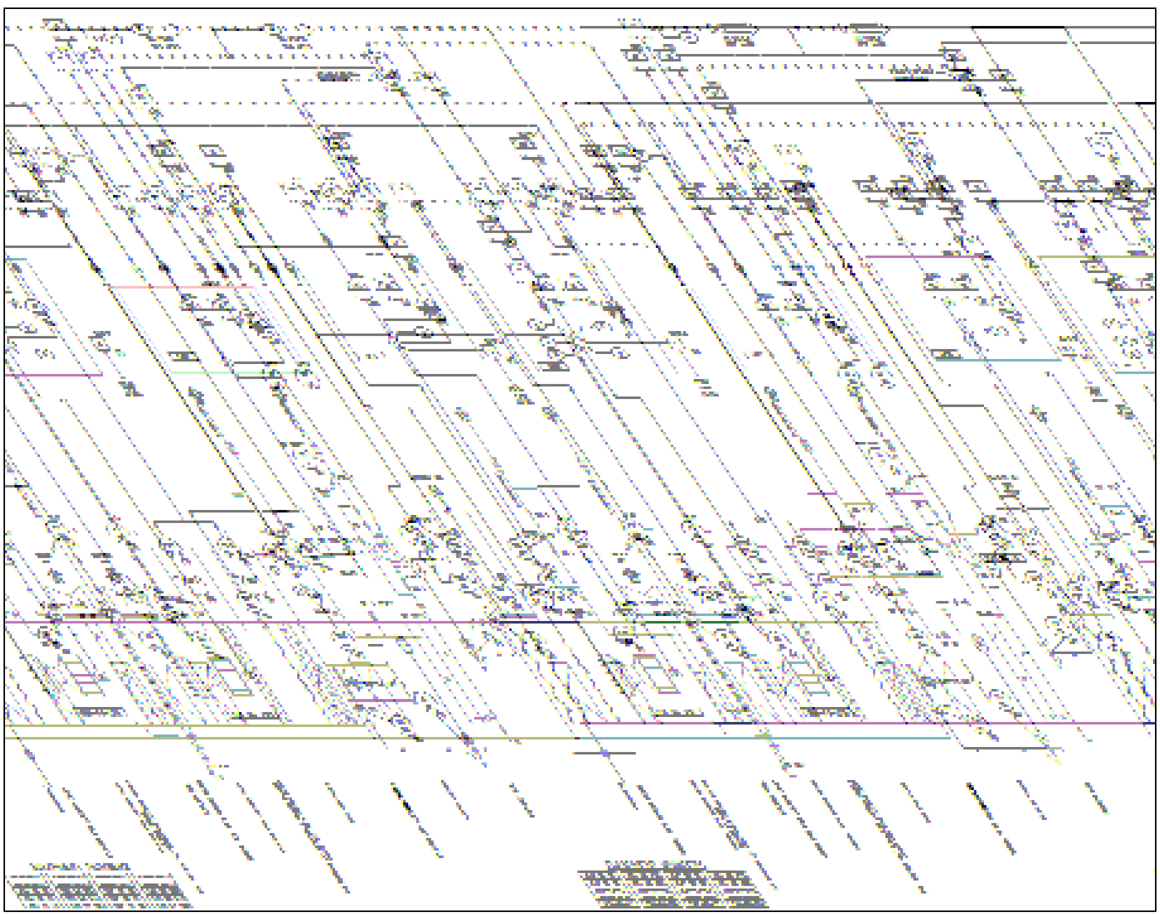


Figure 8—Air-side schematic for a sample of 4 AHU's

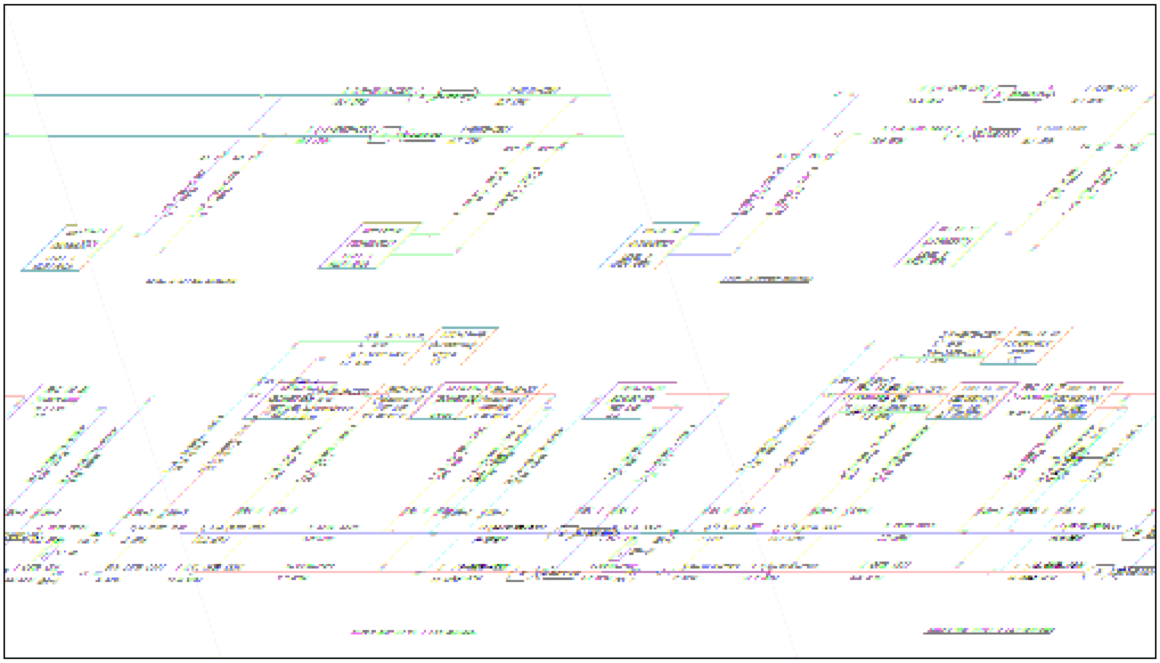


Figure 9—Sample of Hot Water Schematic

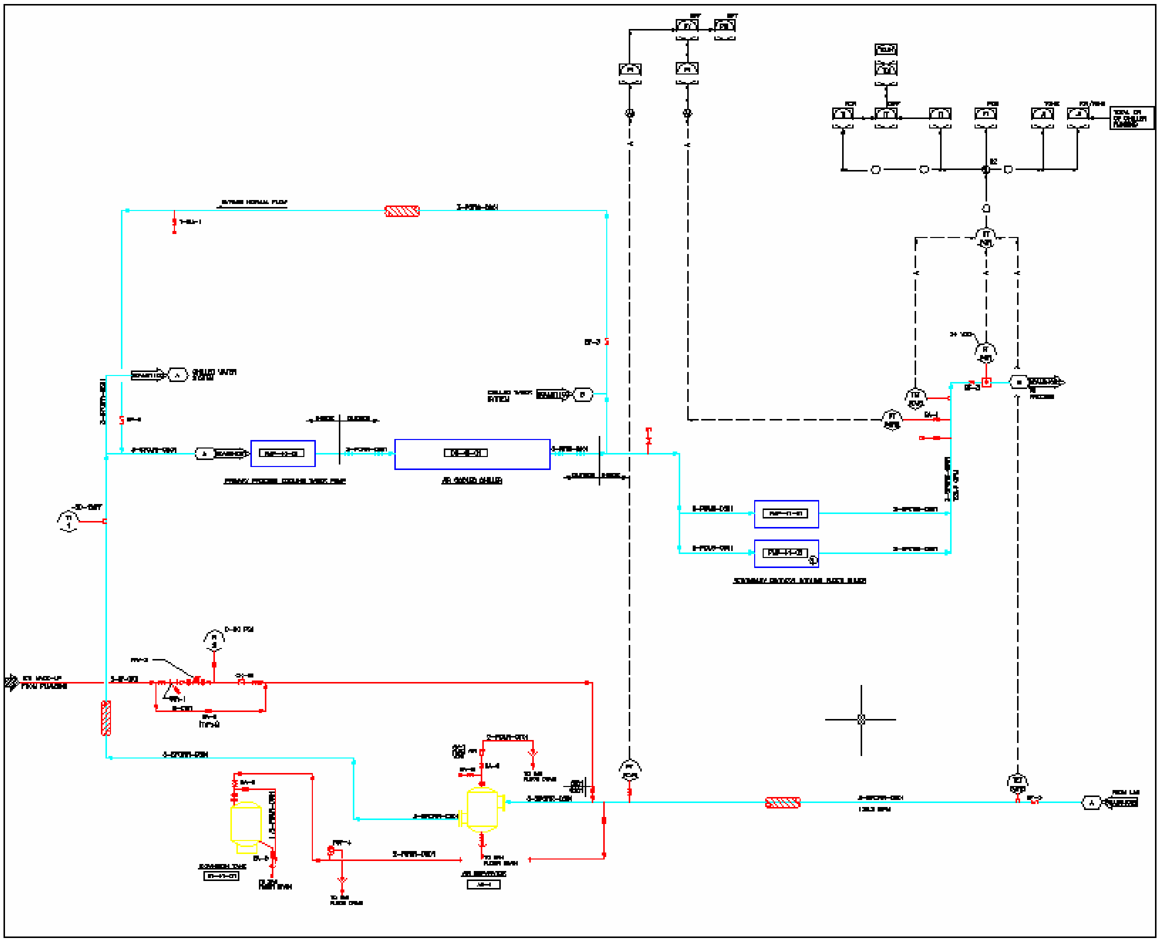


Figure 10—Sample of Condenser Water Schematic

The following two figures, Figure 11 and 12, show how the system is supplied from a section point of view. This allows one to gain a better understanding of the mechanical system setup at the AMRL.

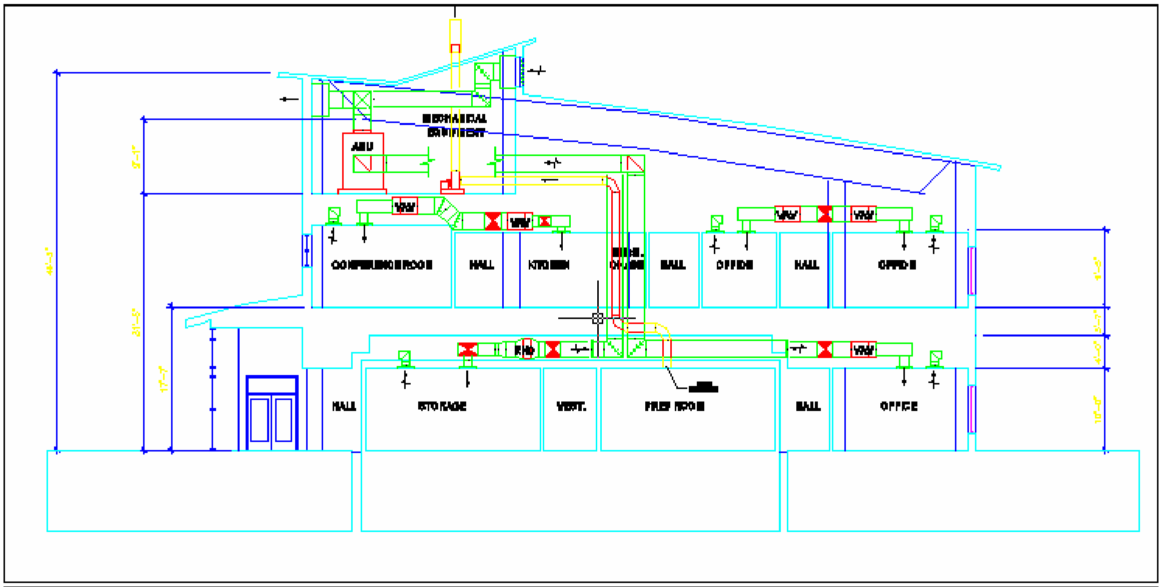


Figure 11—Section view of mechanical system

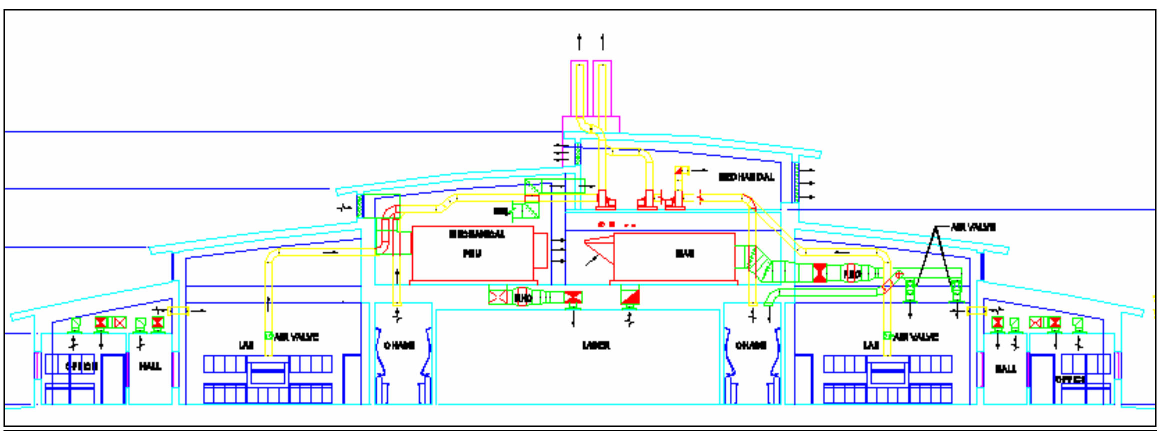


Figure 12—Section view of mechanical system

System Critique:

The mechanical system at Clemson University's AMRL could be considered satisfactory. The chosen systems seem to be adequate in design. Others, namely the oversized AHU's could be reevaluated and redesigned. Some other forms of design could be incorporated to bring down energy costs in the building. First cost was a factor in selecting a design, but not only that, since Clemson would be the tenant, long term costs were also incorporated.

The system will use a large amount of energy, especially electric to condition the spaces. Although IDC met all design requirements except for AHU-11, it would have been possible to make a more energy efficient system given different circumstances. Incorporating heat pumps, since location is ok for such design, would be one way of making this system more energy efficient. During the proposal stage of thesis, I plan on focusing on a more energy efficient system, as opposed to up front cost and time. With this in mind, I plan on improving an already well-designed system with key ideas in mind, without sacrificing air quality issues.

References

2001 ASHRAE Handbook—Fundamentals. Inch-Pound Edition
ASHRAE, Inc. Atlanta, GA. 2001.

Anderson, David. *Technical Assignment #1: ASHRAE Standard 62.1-2004 Ventilation Compliance Evaluation Report.* October 5, 2006.

Anderson, David. *Technical Assignment #2: Building and Plant Energy Analysis Report.* October 27, 2006.

ANSI/ASHRAE/IESNA Standard 90.1-2004—Energy Standard for Buildings Except Low-Rise Residential Buildings. ASHRAE, Inc. Atlanta, GA. 2004.

ANSI/ASHRAE Standard 62.1-2004—Ventilation for Acceptable Indoor Air Quality. ASHRAE, Inc. Atlanta, GA. 2004

Hourly Analysis Program v.4.20a. Carrier Corporation. 2004